The Water Report™

Water Rights, Water Quality & Water Solutions in the West

In This Issue:

Upcoming Stories:

Municipal Water: Sources & Storage

Watershed Restoration

Watershed Projects Prioritizing

& More!

MANAGED AQUIFER RECHARGE

MAR AS A MECHANISM TO ADVANCE WATER POLICY GOALS: A PERSPECTIVE

by Sharon B. Megdal, Ph.D.
Director, University of Arizona Water Resources Research Center (Tucson, AZ)

Introduction

The imbalance between water supply and demand is of growing concern globally. Rarely a day goes by without news about the dwindling surface water supplies, with the Colorado River as the poster child. Coverage of approaches to addressing the supply/demand imbalance is broad, with strategies including augmentation, reuse, market mechanisms, and conservation. The dialogue involves not only diminishing surface water supplies but also the increasing role of, and threats to, groundwater — which accounts for 99% of Earth's liquid freshwater (UNESCO World Water Assessment Programme 2022, *see* References, below). Not coincidentally, heightened dialogue on groundwater has coincided with World Water Day's 2022 theme: "Groundwater — Making the Invisible Visible" and the annual *United Nations World Water Development Report* with the same moniker. Next August, the annual Stockholm World Water Week has the theme of "Seeing the Unseen: The Value of Water." Next December, the 2022 UN-Water Summit on Groundwater will continue 2022's global focus on groundwater.

A key component of discussions regarding groundwater, including conjunctive management of groundwater and surface water, is **m**anaged **a**quifer **r**echarge ("MAR" — sometimes referred to as artificial recharge). MAR is increasingly being recognized as an important mechanism for addressing water quantity and/or water quality concerns. The 2021 compendium *Managing Aquifer Recharge - A Showcase for Resilience and Sustainability* (2021 Compendium) defines MAR as "intentionally replenishing aquifers to stabilize water storage and improve water quality" (Zheng, Ross et al. 2021, 16). Alternatively, Australia's National Guidelines for Managed Aquifer Recharge define MAR as "the purposeful recharge of water to aquifers for subsequent recovery or environmental benefit. It is not a method for waste disposal" (Natural Resources Management Ministerial Council, et al. 2009, 1). MAR "…can be done in a myriad of ways that respect other uses of water or harness otherwise wasted water. The enthusiasm for MAR schemes and their popularity and success are enhanced by significant auxiliary benefits such as in protecting against seawater intrusion, improving environmental flows, banking water for drought relief and purifying water through natural processes" (Zheng, Ross et al. 2021, 16). As noted by Dillon et al. in the editorial paper for the volume, *Managed Aquifer Recharge for Water Resilience*: "Managed aquifer recharge…is part of the palette of solutions to water shortage, water security, water quality decline, falling water tables, and endangered groundwater-dependent ecosystems. It can be the most economic, most benign, most resilient, and most socially acceptable solution, but frequently has not been implemented due to lack of awareness, inadequate knowledge of aquifers, immature perception of risk, and incomplete policies for integrated water management, including linking MAR with demand management. MAR can achieve much towards solving the myriad local water problems that have collectively been termed 'the global water crisis'" (Dillon, Fernández Escalante et al. 2020, 12).

Managed Aquifer Recharge

Policy Aspects

Growing along with the stresses on groundwater and surface water systems is the increasing interest in learning about MAR practices. As someone who has worked on policy aspects of MAR for about 30 years, I jump at the chance to share information on the role MAR can play in furthering water policy goals, with the hope that the information and insights shared are useful to others working on MAR. It is with this objective that I offer this perspective article, the content of which is based on several recent contributions to the MAR dialogue. In addition to contributing to the World Water Development Report and the two compendia cited above, I have recently participated in three conferences/workshops that have explored technical aspects (i.e., the how) of MAR, along with policy aspects (i.e., the why). At the March 2022 "International Conference on Water Resources Management and Sustainability: Solutions for Arid Regions," held in Dubai, The United Arab Emirates, I delivered a keynote opening lecture, "Managed Aquifer Recharge in Semi-Arid Regions." At the April 2022 11th installment of the triennial "International Symposium of Managed Aquifer Recharge" (ISMAR), held in Long Beach, California, I organized the first-ever ISMAR workshop on governance and policy aspects of MAR. This workshop featured experts from the US and abroad who informed participants on how sound MAR governance and regulatory frameworks can facilitate meeting jurisdictional water management goals. I also organized a conference plenary panel on "MAR in Action." Finally, at the May 2022 workshop on "The Future of Managed Aquifer Recharge in the United States" (convened by two boards of the National Academies of Science, Engineering, and Medicine) my contribution considered the regulatory framework for MAR.

Regulatory Frameworks

After providing a brief overview of MAR work globally, this article focuses on Arizona as a case study. After addressing Arizona's regulatory framework and successes, the article concludes with consideration of some outstanding issues.

MAR Information Resources

SOME CONTEXT AND A GLOBAL OVERVIEW

Context

Context is important to understanding "on-the-ground" water policy and management. Of course, the water cycle, the scale and jurisdictional features of the geographic setting, and location of water demands and supplies are key determinants. Societal values and the legal framework, including the degree of (de)centralization of decision-making, are key factors as well. Increasingly, the interconnected nature of water challenges with other problems — such as climate change, poverty, and geopolitics — necessitates working intensely over time on a solutions pathway. Indeed, the problems (often termed "wicked water problems") rarely have quick or easy solutions (Beutler 2021). Understanding how MAR can be part of the suite of strategies addressing the problems has been aided by the publication of international volumes of MAR case studies.

Recharge

Recharge is the process of adding water to an aquifer. Recharge happens naturally from precipitation and streamflow, incidentally after various human uses (such as irrigation uses or leaks in water lines), and intentionally through facilities or projects that are developed for the purpose of adding water to an aquifer. It is this last type of recharge that is considered managed aquifer recharge. Since 2001, The International Association of Hydrologeologists (IAH) has hosted a Commission of scientific experts focused on "Managing Aquifer Recharge." According to IAH's website, the MAR Commission aims to expand water resources and improve water quality in ways that are appropriate, environmentally sustainable, technically viable, economical, and socially desirable. It will do this by encouraging development and adoption of improved practices for MAR.

The MAR Commission fulfills its mission by:

- Increasing awareness of MAR among IAH members and the greater groundwater community
- Facilitating international exchange of information between members
- Disseminating results of research and practical experience
- Informing policy development that enables benefits of MAR to be realized
- Facilitating members to conceive, undertake, and deliver joint projects of international value

(International Association of Hydrogeologists website).

Over time, IAH MAR Commission members have dutifully furthered these objectives through global collaborations, including those related to conferences and publications. Numerous compilations of papers have emerged, with two recent, freely available volumes providing excellent overviews of MAR in action globally. *Managed Aquifer Recharge for Water Resilience* includes 23 papers based on content of the 10th edition of ISMAR, held in May 2019 in Madrid, Spain (Dillon, Fernández Escalante et al. 2021). The editorial paper for the volume categorizes the papers based on stated goals of the projects, which could be multiple. Thirteen papers covered projects to improve water security (quantity), with an equal number of papers focused on water quality. Only three discussed improving the environment, and nine were about assessing MAR opportunities. Though not a complete or necessarily representative sampling of types of projects presented at the ISMAR10 conference, these papers draw from experiences in at least 16 distinct geographic areas and illustrate a wide range of management objectives.

The Water Report
(ISSN 1946-116X)
is published monthly by
Envirotech Publications, Inc.
260 North Polk Street,
Eugene, OR 97402

Editors: David Light
David Moon

Phone
541/ 517-5608
Fax
541/ 683-8279
email
TheWaterReport@yahoo.com
website:
www.TheWaterReport.com

Subscription Rates:
$299 per year
Multiple & Electronic
Subscription Rates Available

Postmaster: Please send
address corrections to
The Water Report
260 North Polk Street
Eugene, OR 97402

Managed Aquifer Recharge

A collaboration of the IAH MAR Commission with the UNESCO Intergovernmental Hydrological Programme and the Groundwater Solutions Initiative for Policy and Practice (GRIPP) resulted in the aforementioned 2021 Compendium. This collection of 28 case studies represents 21 different countries. Notably, the USA and India are most represented, each with four case studies.

Adapting Solutions

Comments from the 2021 Compendium's Executive Summary indicate the purposes of the volume:

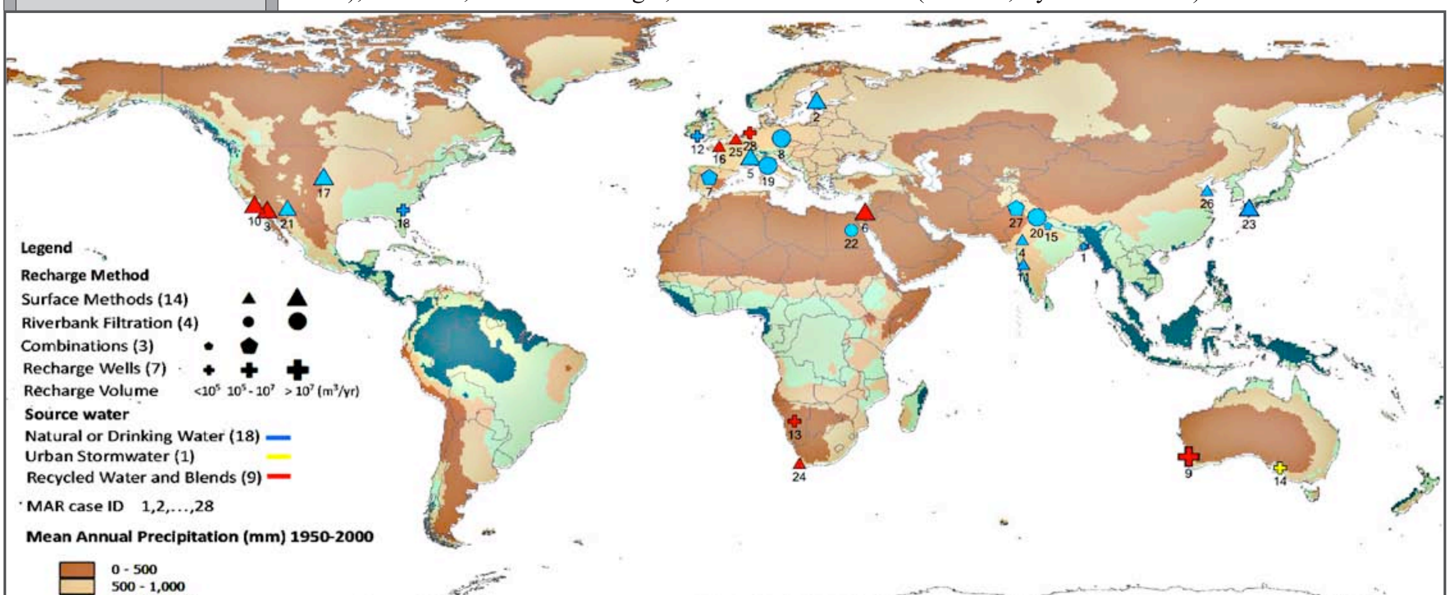
> This book offers hope. It puts on a pedestal 28 real-life examples where, at village to state level, people have collaborated concertedly to manage their water resources to improve quantity and quality of supplies, while buffering against drought and emergencies. The cases show that precedent is no prerequisite, and are offered to help inspire leaders, and assure followers that people at ground level who develop an understanding of their groundwater can adapt and design workable solutions to sustainably meet their needs. (page 14)

Case Studies

The **locator map below** is adapted from the 2021 Compendium. The map shows that the 28 case studies are predominantly located in more arid regions of the world, where water quantity issues are often coupled with water quality concerns, such as is the case with seawater intrusion. Though it is beyond the scope of this article to provide a detailed summary of the case studies, a webinar featuring an overview by lead editor Yan Zheng, summaries of the four case studies from the USA (Arizona, California, Nebraska, and South Carolina), along with the single Mexican case study, can be accessed at: https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/WWD-MAR-Combined-2.pdf.

Negative Lessons

Sharing both positive and negative lessons learned has value, especially for those embarking on MAR. At the Dubai conference, a questioner asked if the written compendia shared problems encountered with MAR projects, explaining that he was working on developing some water projects where developers would benefit from hearing about project performance that did not meet expectations. Articles and project write-ups often do include discussion of challenges, whether they be technical (clogging of basins or injection wells), financial, institutional-legal, or stakeholder related (Bouwer, Pyne et al. 2008).



Adapted from: *Managing Aquifer Recharge - A Showcase for Resilience and Sustainability* (2021)

Arizona MAR

The Regulatory Context

Permits: 1) Facility 2) Storage 3) Recovery

Arizona's 1980 Groundwater Management Act established groundwater regulation in areas of the state designated as Active Management Areas. Mid-1980s legislation introduced a legal framework for recharge and recovery, which was updated in 1994. The statutory framework for managed aquifer recharge is titled "Underground Water Storage, Savings and Replenishment Program." In fact, MAR is not a term officially used by the Arizona Department of Water Resources, the agency charged with implementing and enforcing the Groundwater Management Act. Written on extensively, the statutory framework includes three types of permits: facility; storage; and recovery (Megdal 2012 and Megdal, Dillon, et al. 2014). There are two categories of facilities: 1) **u**nderground **s**torage **f**acility (USF); and 2) **g**roundwater **s**avings **f**acility (GSF).

Recharge Types

USFs are where what may be called "direct" recharge occurs and include constructed infiltration basins and injection wells. GSFs are where what could be considered "indirect" recharge occurs: a water source (surface water or effluent) is used in place of groundwater that would have been used, thereby "recharging" the aquifer through the non-use of groundwater. A GSF is most often an irrigating entity, but can also be an industrial water user, such as a mine. GSF's have different permitting requirements (Arizona Department of Water Resources 2022).

Managed Aquifer Recharge

“Managed Recharge”

Interestingly, there is a third type of USF which is called a “managed recharge” USF. Managed recharge is when a natural streambed is used for recharge. I have always had a problem with this nomenclature, not because of its similarity to what is commonly referred to as MAR but because these facilities are not required to have the operational management required of constructed infiltration basins. Though permitted, with recharge carefully measured, these streambed facilities are closer to “unmanaged” from an operational point of view.

Facility Permit

A facility permit, whether for a USF or for a GSF, is typically held by the facility operator. The facility permit establishes the permitted volume and operating and monitoring requirements. Water quality requirements vary by the water source for recharge, with the Arizona Department of Environmental Quality review required for storage of Colorado River water delivered through the Central Arizona project, but an aquifer protection permit required if effluent is to be stored at the facility (Arizona Department of Water Resources 2019).

Storage Permit

Storage permits, on the other hand, are applied for by those intending to store water at a facility. Multiple entities can hold a storage permit for a given facility; the permitted volume gives the holder of the permit the potential opportunity to store up to the permitted amount at the facility. The totality of permitted storage volume at a facility may exceed the annual permitted capacity of the facility. However, the amount of actual storage each year may not exceed the facility’s annual permitted volume. Stored water accounting, which is carefully done annually, depends on any evapotranspiration deductions and the timing of recovery.

Recovery Permit

A recovery well permit must be issued in order to recover stored water. Permitting considerations differ depending on whether the recovery well is within or outside of the stored water’s area of hydrologic impact. If stored water is recovered in the same calendar year in which it was stored, the water use is considered “Annual Water Storage and Recovery” and there is no “cut” to the aquifer. If stored water remains as of December 31 of the year in which the water was stored, a five percent cut to the aquifer is typically assessed before a **l**ong-**t**erm **s**torage **c**redit (LTSC) is accrued. Recovered water bears the legal character of the stored water, regardless of where it is recovered. LTSCs likely represent the most

Marketable Asset

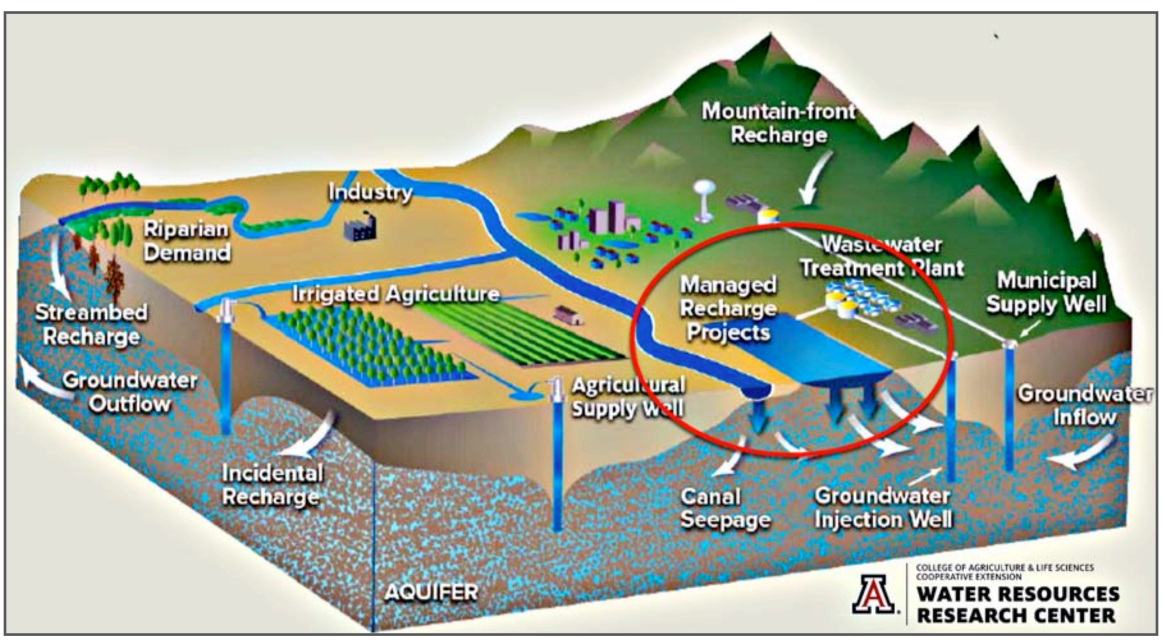
marketable water asset in Arizona. They can easily be bought and sold, provided the associated water recovery occurs in the same Active Management Area as the storage (Bernat, Megdal et al. 2020).

Predictability

Though seemingly complicated, key to Arizona’s regulatory framework is the predictability it provides once permits are issued. It is clear who is responsible for operating recharge facilities, which may be different than those storing the water and gaining the credits for the stored water. It is clear who has annual reporting responsibilities for which actions. And it is clear who has legal right to recover the stored water. Knowing who is doing what MAR-related activities when and where is critical to the utilization of MAR as a water management mechanism. Whether or not the details of the Arizona framework are transferrable to other jurisdictions, the principles of clarity, predictability, and reporting are important elements to

Required Principles

incorporate. As with any activity, the rules of engagement are of critical importance. Of course, I should acknowledge that having the hydrologic conditions conducive to storage and recovery and the water source(s) for storage are absolutely fundamental prerequisites of a successful MAR effort!



Managed Aquifer Recharge

CAP Water

Under Utilization

Uneven Access

Groundwater Replenishment

Colorado River Utilization (Banking)

MAR to Arizona's Rescue

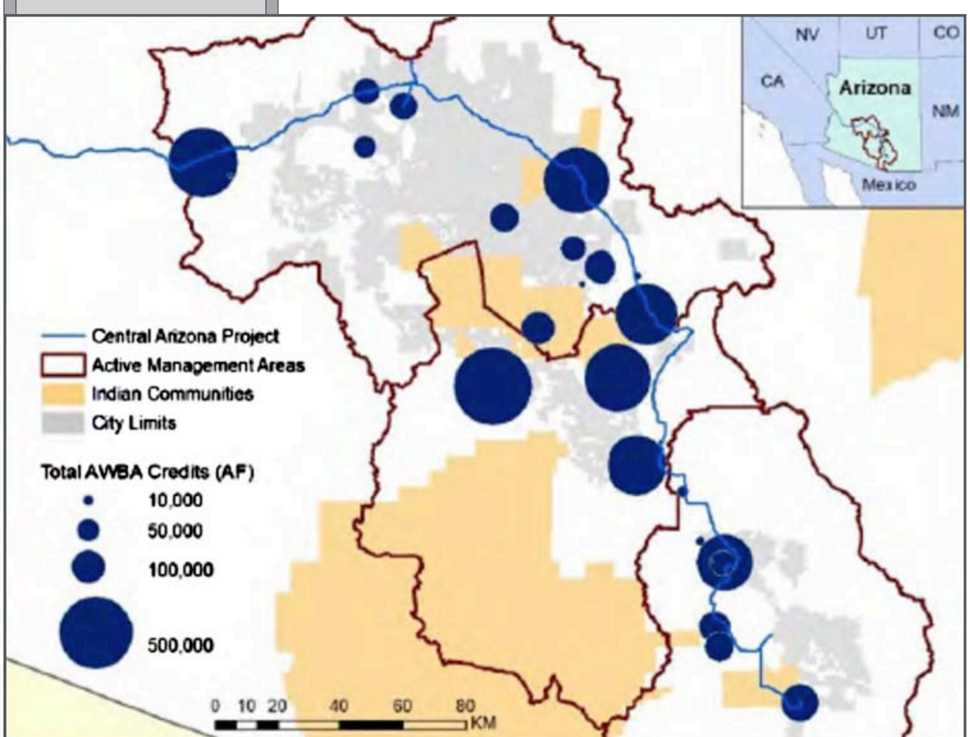
It is hard to believe that about 30 years ago, Arizona was flush with Colorado River water. Following some very wet years, the Central Arizona Project (CAP) canal was nearing completion. Utilization of water delivered through the CAP canal, known as CAP water, was well below annual entitlements. The problem was significant underutilization of CAP water relative to available water, as opposed to the significant shortage of Colorado River water currently being experienced. In the first half of the 1990s, dialogues, debates, and actions ensued on: what to do about this underutilization; the economic implications of completion of the canal, including the unaffordability of CAP water for farmers; and the infrastructure and community fiasco that occurred when Tucson Water replaced half of all its heretofore groundwater water deliveries with treated CAP water (Megdal and Forrest 2015) (McGuire and Pearthree 2020). In Nevada and California, as in Arizona, water demand was only expected to grow. Use of Arizona's regulatory framework for MAR was a key component to addressing several challenges. The following briefly summarizes how MAR assisted in addressing some key water challenges.

Challenge 1: Uneven Access to CAP Water for Central Arizona Builders and Developers

The 1980 Groundwater Management Act required an assured water supply program in order to curtail development's dependence on mined (over-drafted) groundwater. CAP water was key to Central Arizona's switch to renewable supplies. However, some did not have access to CAP water because they were "not there" when CAP water allocations were distributed and/or they were too far from the CAP canal, making access to the water cost-prohibitive. The development community, which was essential to codification of assured water supply rules, required accommodation. That accommodation came in the form of legislative establishment of the Central Arizona Groundwater Replenishment District (CAGRD) in 1993, two years before the formal codification of the Assured Water Supply Rules. The CAGRD allows the MAR framework to be used for replenishment of groundwater pumped to serve new development (Avery, Consoli et al. 2007) (Ferris and Porter 2019). Later discussion summarizes some outstanding issues related to the CAGRD.

Challenge 2: Underutilization of Arizona's Entitled to Colorado River Water

The Governor's Central Arizona Project Advisory Committee was the successor to a Department of Water Resources Task Force on underutilization of CAP water. A key 1995 recommendation of the committee was legislative establishment of the Arizona Water Banking Authority (AWBA). Authorized by the Arizona Legislature in 1996, the AWBA was to make use of recharge to assist with meeting groundwater management goals, enhancing the reliability (firming) of Colorado River water entitlements of certain priorities, and supporting settlement of Indian Water Rights. The agency began operating in 1997. Based on multiple funding sources, partnerships, and federal approval that storing water was a "beneficial use" of Colorado River water, the AWBA through 2019 stored almost 4.3 **m**illion **a**cre **f**eet (MAF) of Long-term Storage Credits, with almost 3.7 MAF on behalf of intrastate entities and over .6 MAF for interstate purposes involving Nevada (Arizona Water Banking Authority). The AWBA, along with others, has stored large quantities of water at GSFs, where the cost per acre-foot of storage is lower than that associated with USFs. The main cost is that associated with buying down the cost of the surface water used in place of groundwater for the agricultural partner. Almost 55% of AWBA's LTSCs emanated from GSF storage. This large amount of storage, and that of others who have partnered with GSF operators, helped



Adapted from *Managing Aquifer Recharge - A Showcase for Resilience and Sustainability* (2021)

Arizona Water Banking Authority Storage Locations

Managed Aquifer Recharge

Storage Benefits

address in a substantial way the problem of CAP water affordability for agricultural use. However, GSF storage by the AWBA occurs only if CAP water is available to the AWBA. Colorado River shortage conditions have eliminated the availability of CAP water for AWBA storage. Of key importance is that the millions of acre-feet of LTSCs are available for when Colorado River shortage conditions deteriorate enough to trigger recovery of the stored water. In fact, AWBA storage is one of the reasons central Arizona cities and towns holding CAP contracts for Municipal & Industrial priority water are not panicking. The deposits into the AWBA are there, underground.

Public Concerns

Storage & Recovery

Blended Water

Long-Term Storage

Challenge 3: Tucson's Problem with Public Acceptance of Direct Delivery of Treated CAP Water

Direct delivery of treated CAP water resulted in some instances of cloudy tap water and the bursting of some homeowners' pipes. Public resistance to direct delivery of treated CAP water became fierce. Public confidence in Tucson Water, the utility serving 80 percent of Tucson metropolitan area residents, sank. In 1995, City of Tucson residents took things into their own hands by passing an initiative limiting the utility's ability to utilize Tucson's first large-scale surface water treatment plant. Tucson had previously relied on pumping groundwater for meeting potable water demands and, responding to the public pressure, Tucson Water moved to an all-recharge plan for CAP water utilization. Tucson Water made use of the aquifer below Avra Valley farmland it had purchased several years earlier (for the groundwater rights) to develop a large-scale storage and recovery system. Rather than utilizing the treatment plant it had built and operated for a short time, CAP water would be delivered to large spreading basins. There, after reaching the water table hundreds of feet below, the soil-aquifer-treated surface water would blend in situ with very good quality groundwater. A system of recovery wells would be built in the same area to transport the water back to the point at which they had intended to deliver the conventionally treated CAP water. This blended water met the quality requirements established by citizen action and, most importantly, met with public acceptance. Deployment of the Avra Valley system of storage and recovery has enabled Tucson Water to use the region's basin-fill aquifers for not only annual delivery of CAP water but for storage for the long-term. Tucson is now drought-ready with about five years of water demand in storage and pumping capacity in place.

These summaries provide key, but by no means the only, examples of how the MAR framework has helped Arizona address some key water challenges. Arizona's regulatory framework for MAR has been there for water managers to utilize. However, some concerns exist and some issues have not been addressed. As noted above, many water problems do not have quickly identified, implementable solutions.

Flexibility

Extinguishment

Outstanding Issues

Arizona's MAR regulatory framework includes quite a bit of flexibility in the location of storage and/or recovery, *provided* the various permit conditions are met and storage and recovery occur within the same Active Management Area (AMA). The stored water associated with an LTSC can be recovered anywhere in the same AMA as the storage, so long as the well is permitted for recovery. There is also the opportunity to purchase a LTSC for extinguishment, when, for example, the CAGRD must replenish, after the fact, what is reported as excess groundwater pumping. Then, no active recovery is required because the water pumping already occurred. Instead, the LTSC is extinguished; that it, it is taken off the books. The regulatory framework provides other opportunities. For example, it has been used voluntarily via intergovernmental agreement with Arizona by the sovereign Gila River Indian Community (GRIC) to further GRIC's achieving its water priorities (Hauter and Mock 2021). But flexibility can be a two-edged sword. The following are some outstanding issues related to Arizona's use of MAR to meet water policy objectives. I caution the reader against being discouraged by the following discussion. Wicked water problems require continuous attention.

Hydro-Disconnect

Groundwater Depletion

Outstanding Issue 1: The Hydrologic Disconnect Between Pumping and Storage

The flexibility in location of recovery can be advantageous when recovery outside the area of hydrologic impact is desired. Often the hydrologic disconnect between pumping/recovery and the storage is not desirable. Arizona's assured water supply program allows localized drawdown of aquifers, and there are questions about what happens when depth to water gets too large for pumping to be economic. This long-recognized issue has been difficult to address. A committee of the Governor's Water Augmentation, Innovation, and Conservation Council (Governor's Council) defined the Hydrologic Disconnect problem in 2021 as the following: "The storage and recovery of water supplies in hydrologically disconnected areas within AMAs has the potential to create or worsen localized groundwater depletion. Similar issues may arise in the context of hydrologically disconnected pumping and replenishment to meet requirements of the Assured Water Supply Program" (Governors Water Augmentation Innovation and Conservation Council Post-2025 AMA Committee 2021). Due to the

Managed Aquifer Recharge

Safe Yield

Replenishment Obligations

Recovery Planning

Shortage Triggers (M&I)

Recoverability Issue

Groundwater Irrigation Rights v. Storage Rights

long-standing dependence on the current framework and the lack of agreed-upon approaches for reducing the disconnect, addressing the undesirable implications of localized aquifer drawdown has been elusive.

<u>Outstanding Issue 2: The Implications of the Popularity of the CAGRD for Meeting the Assured Water Supply Program's Requirement that Groundwater Use be Consistent with the AMA Management Goal</u>

A key aspect of the 1980 Groundwater Management Act was specification of management goals for the Active Management Areas. The CAGRD operates in Central Arizona for the benefit of the Phoenix, Pinal, and Tucson AMAs. Safe-yield —the attempt to balance groundwater withdrawals with natural and artificial recharge — is the statutorily defined goal for the Phoenix and Tucson AMAs, with 2025 specified as the year for meeting the goal. The Pinal AMA statutory management goals allow for groundwater overdraft to preserve the agricultural economy as well as preserve groundwater for future non-agricultural use. In all three AMAs, membership in the CAGRD has been robust and the CAGRD has future replenishment obligations that exceed the CAGRD's current claims on water supplies for replenishment. The committee of the Governor's Council that considered the hydrologic disconnect also formulated an Issue Brief on the CAGRD. That agreement on the issue statement was not possible is indicative of how challenging it will be to come up with any modifications as to how the CAGRD functions, especially any proposals to limit membership. Even without expansion of the replenishment obligation due to membership growth, concerns exist about the supplies available for replenishment to the CAGRD, including questions regarding the projections for replenishment water availability and costs. The fundamental disagreement of parties as to the extent to which the dependence on and growth of the CAGRD is a problem renders agreeing on any solutions nearly impossible.

<u>Outstanding Issue 3: Recovery, Including Multiple Straws in the Aquifer</u>

Due to the temporal disconnect between storage and recovery, especially recovery of water stored by the Arizona Water Banking Authority, regional recovery planning initially took a back seat to other recharge matters, such as getting facilities built. It was argued that it did not make a lot of sense to develop a detailed recovery plan when that plan could well be outdated before recovery was envisioned. Last decade, the AWBA, the Arizona Department of Water Resources, and the Central Arizona Project collaborated on an 81-page recharge plan (Arizona Water Banking Authority, Arizona Department of Water Resources et al. 2014). In 2021, the agencies issued a 199-page updated joint plan (Arizona Water Banking Authority, Arizona Department of Water Resources et al. 2021). Recovery planning is necessarily complex. The complexities of the institutional interrelationships are clearly beyond the scope of this perspective article. What is noteworthy is that the recovery plan's importance grows larger with each month of declining water levels in Colorado River's two large storage reservoirs — Lake Powell for the Upper Basin and Lake Mead for the Lower Basin. Declines in the water levels of Lake Mead have become so severe that a Tier 3 shortage — once considered not very likely prior to the 2026 expiration of the US Bureau of Reclamation's "*2007 Colorado River Interim Guidelines for Low Basin Shortages and Coordinate Operations for Lake Powell and Lake Mead*" — is becoming more probable as early as 2024. According to the 2007 Guidelines, a Tier 3 shortage would trigger cutbacks of CAP water deliveries to holders of Municipal & Industrial (M&I) Priority, those for whom the AWBA has been storing water. With the Lower Basin Drought Contingency Plan overlay to the 2007 Guidelines, M&I priority water deliveries are expected to be cut modestly under a Tier 2b shortage (Arizona Water Banking Authority 2021, 30) (United States of America, Colorado, et al. 2019).

Simultaneously, Arizona Department of Water Resources groundwater modeling for the Pinal AMA has called into question the recoverability of some amount of long-term storage credits accrued through GSF storage, something I must admit I do not fully understand. With a LTSC comes the right to recover that water. Regardless, this is an important point related to expectations regarding recovery of water stored at groundwater savings facilities. The area of hydrologic impact for a GSF is the boundary of the facility. For a farmer or irrigation district, that means the lands where farming occurs. Though groundwater was saved by the water storage, and there is a holder of the LTSC by the partner who provided the surface water to the farming entity, the farming entity never gave up its grandfathered irrigation right — i.e., its right to pump groundwater. As Tier 1 shortage cutbacks reduce surface water availability to Pinal AMA farmers, those not fallowing their fields are returning to groundwater pumping. Their grandfather irrigation rights to pump groundwater exist in perpetuity. So long as their pumping adheres to groundwater regulations in terms of annual quantities, conservation requirements, and depth to groundwater restrictions, they can pump indefinitely. While economic considerations or quality considerations might intervene at any time, the point is that they continue to have the right to have a "straw" in the aquifer — at the same time there may be intentions to recover water pursuant to long-term storage credits held in the Pinal AMA. This is an outstanding issue.

Conclusion

This perspective article is designed to provide a glimpse of the role of MAR globally and for Arizona. Though not comprehensive — even for Arizona — I have provided examples of how the Arizona water community has been innovative and forward-looking in its approach to MAR. Conjunctive management of Colorado River water delivered through the Central Arizona Project has occurred in a state where surface water law and groundwater law are disconnected (administratively). Members of the Arizona water community have worked in partnership with those within and outside its jurisdictional boundaries to use the storage capacity of Arizona aquifers to the benefit of many.

Groundwater is a finite and invisible resource. Surface water availability is being adversely impacted by the changing climate. The One Water concept, where all water sources are considered when planning future water use, is highly relevant as the Colorado River Basin and other regions grapple with addressing the imbalance between demand and supply. We need all hands on deck and all contributing to understanding the potential role of the various tools in the toolbox. Though the use of the tools will depend on the individual circumstances, I hope that this perspective article on managed aquifer recharge as a mechanism to further water policy goals is helpful.

For Additional Information:
Sharon Megdal, University of Arizona, 520/ 621-9591or smegdal@arizona.edu

Acknowledgements and Disclaimer.
I thank Garland Speight for assistance in preparing the citations and references and a colleague for review comments. I am responsible for all views and information presented, including any errors or omissions.

Gila River Indian Community MAR 5 at Ceremonial Opening, March 2019 | **MAR 5 Recharge Project: October 2021** Photos by Sharon Megdal

Sharon B. Megdal, Ph.D. is Director of the University of Arizona Water Resources Research Center, Professor of Environmental Science, C.W. & Modene Neely Endowed Professor, and Distinguished Outreach Professor. Through her work she aims to bridge the academic, practitioner, and civil society communities through research, education, and engagement. Sharon has been working on recharge matters since she headed a regional water augmentation authority in the early 1990s. In addition to numerous publications, her managed aquifer recharge contributions include working to establish multiple recharge projects in Pima County, Arizona. During her entire 12-year service as an elected board member of the Central Arizona Project (2009-2020), she served on the Board's CAGRD and Underground Storage Committee, elected by her peers to chair the committee for her last five years on the Board. I am grateful for these opportunities and for the opportunity to work with the wonderful, dedicated collaborators who make up the MAR community.

Managed Aquifer Recharge

References

Arizona Department of Water Resources (2019). "*Underground Storage Facility Permit Application Guide*" Phoenix, Arizona Department of Water Resources, https://new.azwater.gov/sites/default/files/media/USF%20Permit%20Application%20Guide%2001-2019.pdf

Arizona Department of Water Resources (2022). "*Recharge Permit Applications, Forms and Guides*" Retrieved June 3, 2022, from https://new.azwater.gov/recharge/applications

Arizona Water Banking Authority. "*Water Bank Storage Facilities*" Retrieved June 3, 2022, from https://waterbank.az.gov/storage-facilities

Arizona Water Banking Authority (2021). Annual Report 2020. Phoenix, Arizona Water Banking Authority: 30. https://waterbank.az.gov/sites/default/files/AWBA_2020_Annual_Report.pdf

Arizona Water Banking Authority, Arizona Department of Water Resources and Central Arizona Project (2014). "*Recovery of Water Stored by the Arizona Water Banking Authority*" https://waterbank.az.gov/sites/default/files/media/Joint_RecoveryPlan04-14-14withsignedpreface_0.pdf

Arizona Water Banking Authority, Arizona Department of Water Resources and Central Arizona Project (2021). "*2021 Update: Recovery of Water Stored by the Arizona Water Banking Authority*" https://new.azwater.gov/sites/default/files/media/2021_Update_Joint_Recovery_Plan.pdf

Avery, C., C. Consoli, R. Glennon and S. Megdal (2007). "*Good Intentions, Unintended Consequences: The Central Arizona Groundwater Replenishment District*" Arizona Law Review 49(2): 339-359. https://arizonalawreview.org/pdf/49-2/49arizlrev339.pdf

Bernat, R. F. A., S. B. Megdal and S. Eden (2020). "*Long-Term Storage Credits: Analyzing Market-Based Transactions to Achieve Arizona Water Policy Objectives*" Water 12(2): 568. www.mdpi.com/2073-4441/12/2/568

Beutler, L. (2021). "*Wicked Is a Special Kind of Problem: What It Is and What to Do about It*" Water Resources IMPACT 23(1): 9-11.www.awra.org/Members/Publications/IMPACT_Archive_NonMembers.aspx

Bouwer, H., R. D. G. Pyne, J. Brown, D. S. Germain, T. M. Morris, C. J. Brown, P. Dillon and M. J. Rycus (2008). "*Design, Operation, and Maintenance for Sustainable Underground Storage Facilities*" Denver. AWWA Research Foundation, American Water Works Association, IWA Publishing. https://websites.pmc.ucsc.edu/~afisher/post/MAR_Papers/Bouwer2009_DesignSustainMAR.pdf

Dillon, P., E. Fernández Escalante, S. B. Megdal and G. Massmann (2020). "*Managed Aquifer Recharge for Water Resilience*" Water 12(7): 1846. https://www.mdpi.com/2073-4441/12/7/1846

Dillon, P., E. Fernández Escalante, S. Megdal and G. Massmann (2021). "*Managed Aquifer Recharge for Water Resilience*" Basel, MDPI. www.mdpi.com/books/pdfview/book/3558

Ferris, K. and S. Porter (2019). "*The Elusive Concept of an Assured Water Supply: The Role of CAGRD and Replenishment*" Tempe. https://morrisoninstitute.asu.edu/sites/default/files/kyl_center_elusive_concept_101619.docx.pdf

Governors Water Augmentation Innovation and Conservation Council Post-2025 AMA Committee (2021). Executive Summary and Issue Briefs. Phoenix, Arizona Department of Water Resources. https://new.azwater.gov/sites/default/files/Post-2025_ActiveManagementAreas_IssueBrief_UpdatedVersion_March52021.pdf

Hauter, J. and P. Mock (2021). "*Tribal MAR Project: The Gila River Indian Community's Managed Aquifer Recharge Program*" The Water Report #206: 1-4. http://thewaterreport.com/Issues%20205%20to%20208.html

International Association of Hydrogeologists. "*IAH Commission on Managing Aquifer Recharge: About the Commission*" Retrieved June 3, 2022, from https://recharge.iah.org/about-the-commission

McGuire, M. J. and M. S. Pearthree (2020). "*Tucson Water Turnaround: Crisis to Success*" Denver, American Water Works Association. https://doi.org/10.12999/AWWA.20844.20

Megdal, S. B. (2012). "*Arizona Groundwater Management*" The Water Report #104: 9-15. https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/AZgroundwater-management.pdf

Megdal, S. B., P. Dillon and K. Seasholes (2014). "*Water Banks: Using Managed Aquifer Recharge to Meet Water Policy Objectives*" Water 6(6): 1500-1514. https://www.mdpi.com/2073-4441/6/6/1500

Megdal, S. B. and A. Forrest (2015). "*How a Drought-Resilient Water Delivery System Rose Out of the Desert: The Case of Tucson Water*" Journal AWWA 107(9): 46-52. https://awwa.onlinelibrary.wiley.com/doi/abs/10.5942/jawwa.2015.107.0136 https://doi.org/10.5942/jawwa.2015.107.0136

Natural Resources Management Ministerial Council, Environment Protection and Heritage Council and National Health and Medical Research Council (2009). "*Australian Guidelines for Water Recycling: Managed Aquifer Recharge*" 1. www.waterquality.gov.au/sites/default/files/documents/water-recycling-guidelines-mar-24.pdf

UNESCO World Water Assessment Programme (2022). *The United Nations World Water Development Report 2022: Groundwater: Making the Invisible Visible*. Paris. www.unwater.org/publications/un-world-water-development-report-2022/

United States of America, Colorado, New Mexico, Utah, Wyoming, Arizona, The Metropolitan Water District of Southern California, Coachella Valley Water District, Palo Verde Irrigation District, City of Needles, Colorado Commission of Nevada and S. N. W. Authority (2019). "*Agreement Concerning Colorado River Drought Contingency Management and Operations*" https://www.usbr.gov/dcp/finaldocs.html

Zheng, Y., A. Ross, K. G. Villholth and P. Dillon (2021). "*Managing Aquifer Recharge: A Showcase for Resilience and Sustainability*" Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000379962.locale=en

