Groundwater Recharge for Water Security: The Arizona Water Bank, Arizona

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ABSTRACT The Arizona Water Banking Authority (AWBA) was established in 1996 to make full use of Arizona's Colorado River entitlement. It aims to address groundwater depletion in central Arizona and to protect Colorado River water users against future shortages due to interannual variability in water availability. Each year, the AWBA pays the costs to deliver any of the state's unused entitlement to Colorado River water into central and southern Arizona and to store that water underground. The AWBA stores water on behalf of Central Arizona Project municipal subcontractors, other mainstream municipal Colorado River water rights holders, and tribal entities. Through its interstate banking agreements, the AWBA can also store water on behalf of the states of Nevada and California. Water stored by the AWBA is accounted for using Arizona's statutorily created system of long-term storage credits (LTSCs), which allow future pumping of stored water within the same hydrologic basin. During shortage conditions in the Lower Basin of the Colorado River, the AWBA will distribute the LTSCs, enabling recipients to pump groundwater that otherwise would not be permitted. In this way, the AWBA serves as a unique insurance mechanism against shortages for users of Colorado River water in Arizona and the Lower Basin. To date, the AWBA's focus has been on storage, yet in the coming years, its activities will shift to recovery, and it will need to confront additional challenges associated with matching supplies with demands and limitations on water available for recharge. **KEYWORDS** managed aquifer recharge, groundwater banking, Arizona, water security

INTRODUCTION

The Arizona Water Banking Authority (AWBA) was established in 1996 to make full use of Arizona's Colorado River entitlement. It aims to address groundwater depletion in central Arizona and to protect Colorado River water users in central Arizona against future shortages and interannual variability in water availability [1]. Each year, the AWBA pays the costs to deliver any of the state's unused entitlement to Colorado River water into central and southern Arizona and to store that water underground. The AWBA has also been used to fulfill obligations to Indian tribes incurred through the settlement of water rights claims, to assist both California and Nevada through interstate water banking, and to support Arizona's implementation of its Colorado Basin drought contingency plan (DCP) [1, 2].

The AWBA is an example of how managed aquifer recharge (MAR) can be conducted by a state-level institution to secure supplies for a broad range of water users. Arizona's system exemplifies the importance of tracking and accounting for recharge, particularly given the large geographic expanse and volumetric scale of recharge conducted by the AWBA. The expanding mission of the AWBA also serves as a lesson as to how, once operational, recharge projects can be used to provide not only physical but also social and political benefits beyond those initially conceptualized when designing the project.

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OVERVIEW

Location	Arizona
Groundwater challenges	Groundwater depletion
Motivating factors	Store Arizona's unused Colorado River water to firm existing contracts and subcontracts for Colorado River municipal users, meet state obligations in settlement of Indian water rights claims, and assist Nevada and California through interstate groundwater banking
Project goal	Develop a drought reserve
Recharge method	Direct injection, infiltration, in-lieu
Water source	Lower Basin Colorado River Water
Key actor(s)	Arizona Water Banking Authority, Arizona Department of Water Resources, Central Arizona Water Conservation District, Indian, municipal and industrial holders of long-term subcontracts for Colorado River water in central Arizona and mainstream communities
Challenges	Technical—infrastructure for recovery, water quality of recovered water
Milestones	1980—Arizona passes the Groundwater Management Act, setting up a regulatory and permitting system for groundwater in the most populated areas of the state; 1986 and 1994—Arizona passed the Underground Water Storage and Recovery and the Underground Water Storage and Replenishment Acts, allowing for groundwater recharge and creating a long-term storage credit tracking system; 1996—Creation of the Arizona Water Banking Authority; 1999—The role of the Arizona Water Banking Authority expanded to include interstate banking and allow recharge using effluent; 2004—Arizona Water Settlements Act requires AWBA to conduct water banking on behalf of certain tribal communities in Arizona; 2019—Colorado Drought Contingency Plan allows exchange of long-term storage credits across active management area boundaries
Current status	Fully implemented
Cost	US$45–US$400/AF

CASE EXAMINATION

Methods

This case study forms part of the journal's special collection entitled "Institutional Dimensions of Groundwater Recharge." The collection examines empirical examples of MAR from across the United States to provide insights on the institutional structures and motivations of MAR implementation. An in-depth description of the special collection and its objectives, along with a discussion of the wider context of groundwater management concerns that MAR aims to address, is included in Miller et al. [3]. Each of the case studies in the collection examines a different physical and institutional design for MAR. Case studies were developed through an analysis of documents and expert interviews. Documents reviewed include reports from governmental agencies implementing the MAR projects, permits and reports from regulatory agencies, state laws and regulations, academic literature and technical reports, and news articles. Interviews were conducted with key individuals involved in the development of each project, including government officials, regulators, and project implementers.

Local Background

Groundwater use in central Arizona increased in the 20th century, as cotton acreage boomed and cities grew after World War II. Rates of groundwater withdrawal quickly exceeded natural recharge, leading to a severe overdraft problem in central Arizona. To address this problem and to support growth, in 1973, with the support of the federal government, Arizona began the construction of the Central Arizona Project (CAP) [4], which was completed in 1993. This 326-mile aqueduct conveys Colorado River water to central and southern Arizona [4]. Although CAP water supports many water users, it does not reach all water users; therefore, groundwater

pumping continued. Further, even with the CAP, Arizona was not diverting all 2.8 million acre-feet of Colorado River water allocated to it annually under the law that apportioned flows in the lower Colorado between Arizona, California, and Nevada.[1] Meanwhile, California was regularly exceeding its entitlement to the Colorado River. Concerns about how this dynamic of interstate water use would affect Arizona's future access to Colorado River water led to an interest in storing Arizona's unused entitlement to Colorado River water underground [6].

Groundwater Storage and Recovery in Arizona

In an effort to address groundwater overdraft, in 1980, the Arizona Legislature passed its Groundwater Management Act. This Act established the Arizona Department of Water Resources (ADWR) and designated five regions in the state as active management areas (AMAs) for groundwater and mandated a system of groundwater rights and permits, among other requirements.[2] Following this, two laws—the 1986 Underground Water Storage and Recovery Act and the 1994 Underground Water Storage and Replenishment Act—were passed that supported aquifer recharge. These legislative acts included provisions for underground storage and set up a system for tracking and accounting for water through long-term storage credits (LTSCs) [8]. LTSCs are created when a recharging entity stores water in an aquifer within an AMA. LTSCs grant a right to withdraw groundwater within the AMA in which it was stored, at a later date. LTSCs can be used by recharging entities or sold or transferred by those same entities to other water users.

The AWBA

The AWBA was created by the Arizona Legislature to support the long-term reliability of water for central Arizona. The AWBA was tasked with storing Arizona's Colorado River supplies that would otherwise go unused. To do so, the AWBA can accrue or buy LTSCs, which it holds on behalf of the state and will distribute during shortage conditions. In this manner, the ABWA serves as a form of drought insurance for water users in the state.

During shortage conditions in the Lower Colorado River basin, Colorado River water is allocated according to priority. Because CAP water deliveries hold junior priority in the Lower Basin, shortages of Colorado River water will significantly impact CAP subcontractors,[3] tribes with contracts for Colorado River water delivered through the CAP, as well as other junior priority Colorado River water users. When shortages in the availability of CAP water affect entities[4] for which the AWBA has an obligation to store supplies, the AWBA will distribute LTSCs to those entities. For the distribution of LTSCs to subcontractors to occur, the CAP must make a credit request to the AWBA detailing which delivery obligations it is unable to meet. The AWBA will then review the CAP's request and determine how to distribute credits.[5] Entities receiving a distribution of LTSCs from the AWBA can then exchange the LTSCs for groundwater, in essence substituting an entitlement to pump groundwater for the surface water deliveries they will not receive as a result of decreased deliveries [10].

In 1999, the Arizona legislature expanded the role of the AWBA, allowing it to perform groundwater banking services not only for the state of Arizona but also across a broader set of participants including Tribes and other Lower Colorado River basin states. These revisions also granted the AWBA permission to store effluent if all excess CAP water has been stored (personal communication, AWBA, April 30, 2019) [1]. Interstate banking allows the AWBA to serve as a key component in the management strategy of all three Lower Colorado River basin states. Via the AWBA, California and Nevada can

1. Waters in the Lower Colorado Basin were apportioned between states in the Boulder Canyon Project Act of 1928. See [5].

2. Under Arizona's Groundwater Management Act, five regions (Phoenix, Pinal, Tucson, Prescott, and Santa Cruz) of the state are designated as active management areas (AMAs). These regions, which encompass the major urban and agricultural centers of the state, are governed by groundwater management plans and are subject to more stringent groundwater regulations than other portions of the state. See [7].

3. Under the Boulder Canyon Project Act of 1928, all users of Colorado River water in the Lower Colorado River basin are required to have a water delivery contract with the U.S. Bureau of Reclamation (USBR). The Central Arizona Project (CAP) holds a contract with the USBR for part of Arizona's entitlement to the Colorado River. Water users who receive CAP water are considered subcontractors, as they hold contracts with the CAP, which then has a contract with the USBR. See https://www.usbr.gov/lc/region/g4000/wtrcontracts.html and [9].

4. The AWBA is tasked with shoring supplies for on-river municipal long-term Colorado River contract holders, CAP municipal and industrial subcontract holders, and certain Arizona Indian tribes with rights to Colorado River supplies.

5. With some exceptions, AWBA has the discretion to determine when and how to distribute or distinguish LTSCs (ARS_§45-2457(D)). LTSCs obtained using funds from ad valorem taxes are required by statute to be used within the county paying the tax. Further, LTSCs obtained for interstate banking or tribal water rights settlements must be dedicated to those respective uses. See [8].

store their excess Colorado River water in Arizona. When those states need to recover that water, an exchange occurs. The LTSCs held by those states will be distributed by the AWBA to water users in Arizona who will substitute stored groundwater for the surface water deliveries they would receive. Instead, those surface water deliveries will be sent to the exchanging state. Although the AWBA has agreements to conduct water banking on behalf of both California and Nevada, currently only Nevada actively contracts with the AWBA for water storage (personal communication, AWBA, April 30, 2019).

The AWBA has also become an integral part of several Indian water settlements in central and southern Arizona. In 2004, Congress enacted the Arizona Water Settlements Act[6] (AWSA), which allocated 46% of the state's CAP supplies to tribal communities in Arizona. The AWSA also required the state of Arizona to "firm" 15,000 acre-feet per year for tribal communities by having the AWBA accrue LTSCs on behalf of those communities.[7] During shortage, those LTSCs will be distributed to tribal communities, allowing them to substitute groundwater in place of the CAP surface water supplies they will not receive due to the shortage conditions. To date, approximately 150,000 acre-feet of LTSCs have been accrued by the AWBA on behalf of the Gila River Indian Community in central Arizona. In addition, the AWBA will be required to firm up to 3,750 acre-feet per year for the benefit of the White Mountain Apache Tribe in northeastern Arizona when the Tribe's settlement becomes fully effective.

The AWBA's newest role is in support of Arizona's DCP,[8] which forms part of a coordinated effort by the seven states in the Colorado River Basin to protect water elevations in Lake Mead. Low water levels in Lake Mead lead to reductions in the availability of CAP water. As described above, the AWBA serves to firm supplies for CAP contractors and subcontractors through the accrual of LTSCs and distribution of them when there are substantial reductions in the availability of CAP water. Under the DCP, Arizona agreed to reduce the amount of Colorado River water delivered to it above and beyond the reductions contemplated in the Bureau of Reclamation's 2007 Interim Guidelines for Lower Basin Shortages [11]. In the event of a shortage declaration, CAP water available to farmers in Pinal County will be the first to be reduced. This anticipated impact was politically untenable in Arizona's state legislature. As a compromise, to ensure continued water availability for the farmers, various subcontractors agreed to deliver a portion of their subcontract water normally stored in facilities in the Phoenix and Tucson AMAs to the in-lieu storage facilities of CAP agricultural districts in Pinal County during the duration of the DCP. The subcontractors accrue LTSCs in the Pinal AMA for these deliveries. As LTSCs can only be used in the AMA in which they are created, LTSCs in the Pinal AMA are of no worth to subcontractors in the Phoenix and Tucson AMAs. As a means for those subcontractors not to forgo the benefit of recoverable LTSCs, the AWBA agreed to exchange the LTSCs created by the additional deliveries to the Pinal AMA for LTSCs held by the AWBA in the Phoenix and Tucson AMAs. The effect is to enable the delivery of water to CAP agricultural contractors in the Pinal AMA who would otherwise experience shortage while keeping the subcontractors whole. Without the AWBA facilitating this exchange, it is very possible Arizona would not have participated in the DCP.

Recharge

The AWBA creates LTSCs when water is directly recharged into an aquifer and when surface water supplies substitute for water that would have been pumped from the aquifer. Water is stored in one of 84 direct recharge and 16 in-lieu recharge facilities that have been permitted across the state [12, 13]. These facilities are located primarily in the southern portion of the state (figure 1), with approximately 70% of storage capacity located in the Phoenix AMA and 20% in the Tucson AMA.[9] Recharge (and storage) thus occurs in multiple groundwater basins and subbasins, not all of which are hydrogeologically connected.

Direct recharge occurs through state-permitted underground storage facilities (USFs).[10] There are three recognized forms of USFs under state law: (1) *managed USFs* refers to direct recharge by percolation through a stream

6. P.L.108-451, 108th Congress.

7. Generally, "firm yield" refers to the amount of water that can be expected in most circumstances, including drought conditions.

8. For additional information on the AWBA and the drought contingency plan, see https://waterbank.az.gov/about-us/drought-contingency-plan.

9. For information on storage capacity, see https://waterbank.az.gov/water-storage.

10. For complete information on all active USFs, see the ADWR's website at http://www.azwater.gov/querycenter/query.aspx?qrysessionid=4BF6C620A82B9838E0534C00000A47B1.

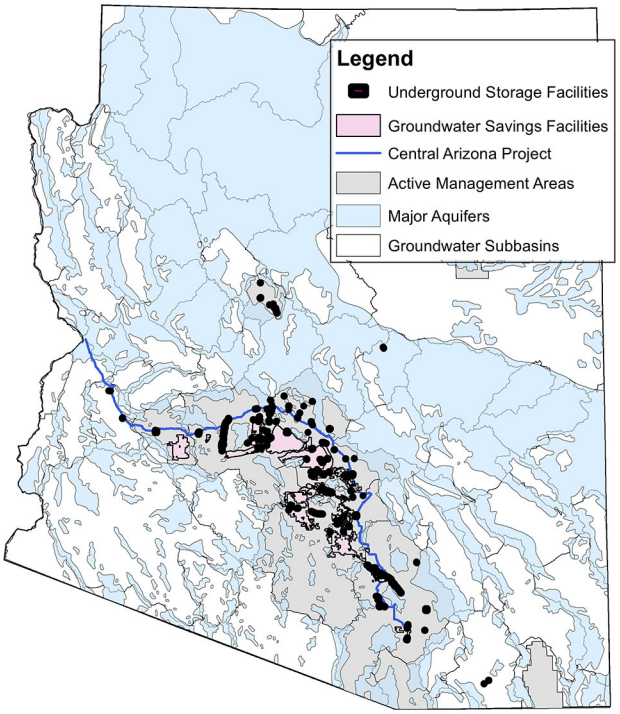

FIGURE 1. Location of underground storage facilities and groundwater savings facilities recharge facilities in Arizona. Source: Map created using GIS files from http://gisdata-azwater.opendata.arcgis.com/.

channel, (2) *infiltration basins* refers to recharge via percolation of water through a large manmade basin, and (3) *injection recharge* refers to recharge through an injection well into the aquifer [14]. USFs are owned and operated by municipal and third-party entities. To establish a USF, entities must obtain a permit from ADWR. The USF permitting process[11] includes an initial US$2,000 application fee and an application that includes a description of facility characteristics, an analysis of unreasonable harm and hydrologic feasibility, a monitoring plan, the proving of technical and financial capability, and the establishment of legal access [15]. In order to store water in a permitted USF, an individual must pay an initial US$1,000 fee and complete a permit application.[12] This application includes information on the USF chosen for storage, a pre-decision hearing, and a site evaluation [16].

In-lieu recharge occurs through groundwater savings facilities (GSFs).[13] These facilities are irrigation districts that utilize Colorado River water, effluent, and other surface water instead of pumping groundwater to which they are legally entitled under the 1980 Groundwater Management Act [12]. Creation of a GSF requires an application, an initial US$1,000 payment, and a pre-decision hearing and site visit by AWBA [16].[14] Funding for the operation of USFs and GSFs is the responsibility of their respective owners, who generally obtain that funding through the aforementioned user permits and user fees [17].

Accounting

Water recharged through both direct and in-lieu recharge is tracked through LTSCs [18]. As described above, the LTSC system predates the AWBA and includes underground storage conducted by other entities in the state for other purposes. The rules for creating and using LTSCs are uniform across all entities.

For each acre-foot of water stored via direct recharge in a USF, the user receives an equivalent LTSC minus a 5% deduction, known as "a cut to the aquifer." This deduction is intended to support a net gain to the aquifer [8]. The deduction applies uniformly to all water stored in USFs and does not reflect an estimate of expected losses within the system as it is not based on hydrogeologic testing or modeling of aquifer properties and groundwater flows at specific facilities. For each acre-foot of water stored via in-lieu recharge, written confirmation to ADWR that the recipient will reduce groundwater withdrawals by an amount equivalent to the LTSCs received is needed [19]. ADWR charges a US$2.50 per acre-foot fee when an LTSC is used by its holder to withdraw groundwater from a USF. LTSCs are permanently retired upon recovery of the water.

Holders of LTSCs are entitled to grant, gift, sell, lease, or exchange those credits [20], and there is a thriving market for recharge of water and subsequent sale of LTSCs in central Arizona. In order for the transfer of LTSCs to occur, the seller must first complete and submit an application to ADWR, accompanied by a US$250

11. For more information on the permitting process of a USF, the application checklist for USF permitting can be found on the ADWR website, under "apply for an underground storage facility permit."

12. For more information on the permitting process to store water in a USF, the application to do so can be found on the ADWR website under "apply for a water storage permit." See https://new.azwater.gov/recharge/applications.

13. For complete information on all active GSFs, see the ADWR's website (http://www.azwater.gov/querycenter/query.aspx?qrysessionid=4C8820B502DD32F9E0534C00000A01DC).

14. For more information on the permitting process of a GSF, the application for a GSF permit can be found on the ADWR website, under "apply for a groundwater savings facility permit."

fee.[15] Included within this application is pertinent information about the buyer and seller, such as LTSC account numbers and groundwater rights numbers [21]. Holders of an LTSC are entitled to sell LTSCs at any price, and the cost to purchase an LTSC has fluctuated over the past 10 years between US$45 and US$400 per acre-foot. The fluctuation of this cost is primarily due to variations in LTSC supply availability in any given year (personal communication, AWBA, April 30, 2019).[16]

The AWBA obtains LTSCs through (1) purchase of a specified volume of water from a storing entity, (2) placement of water in a USF for at least 1 year, (3) utilization of a GSF for in-lieu recharge, or (4) transfer among storage and recovery entities. The AWBA will only purchase LTSCs on behalf of the state at a price that is less than or equal to the cost to the AWBA to store CAP water at the time of purchase (personal communication, AWBA, April 30, 2019).[17] Although the AWBA can purchase LTSCs, it is not authorized to sell its LTSCs and can only distribute them in accordance with its statutory mission.

Recovery

Water stored by the AWBA will be recovered when, in response to shortages, LTSCs held by the AWBA are distributed. This water will be recovered in one of three ways. Through direct recovery, the water will be pumped from the ground and returned to the CAP for distribution. Through indirect recovery, water will be pumped from the ground and delivered to CAP customers using infrastructure other than the CAP. Finally, through exchange, water is not actually pumped, rather a CAP contractor who performs annual storage and recovery voluntarily reduces that storage in exchange for AWBA credits already stored at a specified storage facility.

Prior to 2019, recovery of stored groundwater in Arizona was geographically constrained: LTSCs could only be used to withdraw water within the same AMA where the water the LTSC represents was stored [8]. As each AMA covers multiple groundwater subbasins,[18] this policy allowed pumping of water from a different subbasin than that in which the water was recharged yet still provided a regional constraint. With the passage of the Colorado DCP, the AWBA was given the extraordinary authority to exchange existing LTSCs between AMAs for a limited time, ending December 2026.[19] This policy shift assists Arizona in meeting its commitments under the DCP by facilitating transfers of water entitlements. Yet the policy may have hydrogeologic implications, as it allows pumping of water from groundwater basins other than those in which that water was stored.

Recovery of water for LTSCs is also contingent upon water levels at the location of withdrawal. Recovery wells may not be located in an area experiencing more than 4 ft average annual decline in the water level [8].[20] This rule aims to ensure recovery of stored water does not impact neighboring wells or exacerbate deteriorating aquifer conditions.[21]

Institutional Arrangements

The AWBA is housed at ADWR, which provides administrative and technical support. ADWR performs its managerial duties in coordination with the Central Arizona Water Conservation District (CAWCD), which manages and operates the CAP. ADWR is responsible for the allocation and regulation of the use of Colorado River water. ADWR is also responsible for the permitting of USFs, GSFs, and the management of LTSC accounts [24]. CAWCD serves as the chief manager and operator of the CAP and contracts delivery of Colorado River water to AWBA storage facilities.[22] GSFs and USFs are regulated by ADWR but managed by their respective permittees; these permittees must manage and maintain their recharge facilities in order to assure safe conditions for future usage.

The AWBA is governed by a seven-member committee: Five have full voting rights and two are nonvoting

15. For more information on the permitting process to transfer LTSCs among entities, the application to do so can be found on the ADWR website under "transfer long term storage credits."

16. For additional information on variation in LTSC availability, see [22, 23].

17. This pricing is different than what the public may pay for an LTSC in any particular year.

18. Subbasins in each AMA are listed in the A.R.S. § 45-411. See https://law.justia.com/codes/arizona/2016/title-45/section-45-411.

19. This change was made in the legislature via SB1227/HB2545.

20. This constraint means that withdrawals of groundwater are allowed even while a notable level of drawdown is occurring. The basis for selecting 4 feet average decline as the threshold at which withdraws would be prohibited is not known, and personnel at AWBA commented that this was likely a negotiated number, and not based on a technical assessment of recharge or recovery potential (personal communication, AWBA, April 30, 2019).

21. Although groundwater storage and recovery is highly regulated and tracked through LTSC, permits also allow pumping of groundwater that naturally occurs within the basin. In many locations, rates of groundwater withdrawal exceed rates of recharge, leading to declining water levels.

22. Cite to the AWBA website.

state legislators. The committee reviews and approves the AWBA's annual plan of operation, the annual budget, and operational agreements, among other tasks [18]. The ADWR director serves as the committee chairman. Three members are appointed by the governor to represent (1) a large CAP municipal and industrial subcontractor, (2) a representative of an entity holding a mainstream Colorado River contract, and (3) a person knowledgeable in water resource management.[23] The president of CAWCD or their designee also serves as a member of the Authority.[24] The final two nonvoting members of the AWBA governing committee are the president of the Arizona Senate and the speaker of the Arizona House of Representatives, or their designees.[25] Members serve 6-year terms.[26]

Costs and Financing

The operation of the AWBA is financed through a variety of means (see http://www.azwaterbank.gov/Background/Funding.htm). The AWBA primarily obtains revenues through statewide groundwater withdrawal fees of US$2.50 per acre-foot of extracted groundwater and a US$0.04 ad valorem property tax collected in Maricopa, Pinal, and Pima counties.[27] AWBA funding also comes from state legislative appropriations from the General Fund for water banking and groundwater replenishment purposes. Finally, the AWBA receives monies from authorized interstate banking entities in California and Nevada,[28] including US$8 million from the Southern Nevada Water Authority (SNWA) and US$100 million from Nevada as part of an interstate water banking agreement, intended to develop alternative water supplies for Nevada.

Although not a core funding source, the AWBA also received US$8 million in "shortage reparation" funds from SNWA pursuant to a shortage-sharing agreement between Arizona and Nevada. The purpose of these funds is to assist Arizona in offsetting impacts related to Colorado River shortages because Arizona agreed to take a greater proportion of the reductions. The AWBA has used these funds to purchase and store water.

In carrying out its operations, the AWBA can also request that its GSF partners, as recipients of in-lieu water, pay a share of the water delivery costs.[29] For simplicity, these costs are paid directly to CAWCD. Additionally, the AWBA can collect fees from persons and Indian communities in the state that have entered into water banking services agreements with the AWBA.[30]

DISCUSSION

Since its inception in 1996, at a cost of roughly US$400 million through 2018, the AWBA has developed over 4 million acre-feet [26] of LTSCs that can be tapped when Colorado River shortages in the Lower Basin materialize. Several factors were key to the implementation of the AWBA, including strong state support and availability of Colorado River water for storage. The state's legal and regulatory framework that enables groundwater recharge, the financial structures that create the revenues needed to accrue LTSCs, and state agency involvement in both the AWBA and groundwater recharge in the state are essential to the functioning of the AWBA. The availability of Colorado River water and the CAP infrastructure are other key elements, as without those, recharge would not be possible.

Long-term functioning of the Bank may be impacted by future availability of Colorado River water or other, substitute supplies (such as effluent) for recharge. The volume of unused Colorado River water available to the AWBA has been decreasing since 2010, and shortage conditions in the Lower Basin may occur as soon as 2021. The Western United States, including the Colorado River basin, is experiencing what is currently a 20-year drought [27]. Such droughts, which recur in the paleoclimate record, are expected to become more frequent and intense under climate change. Reduced availability of Colorado River water means future AWBA operational activities will likely shift from emphasizing storage to a greater emphasis on water management, including the distribution of LTSCs [18, 28].[31] Although providing a means to weather shortage conditions is the primary mission of AWBA, these shifts may both create operational challenges for the AWBA and limit its long-term functioning.

23. A.R.S. §45-2421(A).
24. *Ibid.*
25. (A.R.S. §45-2421(F).
26. (A.R.S. §45-2421(C).
27. (A.R.S. §45-2425(B)); see [25].
28. (A.R.S. §45-2425(B)). Approximately 600,000 acre-feet has been stored in Arizona's aquifers for future use in southern Nevada.
29. (A.R.S. §45-2455(C)).
30. (A.R.S. §45-2458).
31. When the AWBA was established in 1996, it was anticipated that the state's unused Colorado River supplies would diminish over time. In fact, the enabling legislation only authorized the AWBA to acquire Colorado River water through 2016. This provision has since been repealed, and the duties of the AWBA expanded.

First, questions remain about water recovery. The emphasis of the AWBA, particularly during its first decade and a half, has been on recharge. Recharge was conducted without thorough plans for recovery and, in some cases, without full hydrogeologic knowledge of the groundwater basins. Although much of the water stored in USFs and in GSFs is located in proximity to infrastructure for recovery, 25% of water stored in USFs is located in areas where no wells or other infrastructure exist to recover or to transport recovered water [26]. Recovery of that water will either require the construction of additional infrastructure or indirect recovery through the exchange of LTSCs at locations closer to demands. This presents challenges related both to cost and timing, as if such infrastructure is not in place when a shortage occurs, it may not be physically feasible to get the water to constituents the AWBA aims to serve. Additionally, in some, at least one site (the Tonopah Desert Recharge Project) recharged water was stored in an aquifer known to have naturally occurring high levels of arsenic and fluoride [26]. Although water is no longer recharged to that site as discontinued after studies of the treatment costs, water recovered from that storage facility will require treatment if it is to be used.

Second, there is the issue of balancing stored supplies with demands. Although a large quantity of water has been stored for future use, that supply is not infinite. Reductions in the future availability of water for recharge may mean limited opportunities to replenish water in storage if it is utilized. Further, storage is not fully efficient, as some water will migrate out of the aquifer and other water may not be fully recoverable. It will be important to ensure the recovery of stored water does not have negative impacts. The 5% cut to the aquifer assigned when calculating LTSCs at USFs may inadequately represent the true losses from storage. The flexibility in the system that allows for recovery of LTSCs from locations other than where the water was stored means additional checks may need to be put in place to ensure the availability of water for recovery without hydrologic impacts. Additionally, although Arizona laws closely control the recovery of recharged water, the abstraction of other water in the aquifer is governed by other laws that do not fully restrict pumping.[32] Thus, groundwater levels may continue to drop in locations where recharge has occurred.

32. For a commentary on some gaps in Arizona groundwater law, see [29].

Finally, it is worth noting that although the AWBA serves a critical role in firming supplies for use during times of shortage, these activities have other implications. Arizona's water banking program was initially designed to provide drought security for CAP contractors. Water stored by the AWBA for this purpose would otherwise have been available for other purposes, including remaining in the Colorado River to support ecosystems or for downstream uses. As with most water management, the decision as to what to prioritize and how is sociopolitical rather than technical concerns. As has already occurred, through the expansion of the AWBA to support tribal water needs, for use in interstate banking, and most recently to facilitate exchanges as part of the DCP, the role of the AWBA will likely continue to morph over time with the pushes and pulls of societal demands and governmental choices.

CONCLUSION

Today, the AWBA is an example of a public institution with a 20-year history of using conjunctive management to maximize the use of renewable water supplies. The AWBA has served as a massive insurance policy against future water shortages on the Colorado River. Although this insurance policy provides benefits to water users both within and beyond the state, the value of this insurance policy has not yet been tested, since to date, a shortage leading to the distribution of LTSCs has not occurred. The effectiveness of the AWBA will depend on how well the availability of water for storage and currently stored supplies match with future recovery needs.

KEY TERMS AND ACRONYMS

Acre-feet (AF) – A volume of water that would cover one acre at a height of one foot. Equivalent to 325,851 gallons or 1233 cubic meters.

Active Management Areas (AMAs) – Specific regions within Arizona designated by the Arizona Groundwater Code as subject to groundwater regulations that are more stringent than the rest of the state due to historic overdraft conditions.

Arizona Water Banking Authority (AWBA) – A governmental agency created by the Arizona legislature to store the unused portion of Arizona's annual Colorado River entitlement.

Central Arizona Project (CAP) – An aqueduct that diverts Colorado River water and conveys that water to central and southern Arizona.

Groundwater Savings Facility (GSF) – A permitted location at which indirect recharge occurs when surface water is used in lieu of groundwater pumping.

Long Term Storage Credits (LTSC) – System for accounting used within the state of Arizona for tracking of water stored underground. Each LTSC reflects permission to withdraw one acre-foot of stored water, with some restrictions.

Underground Storage Facility (USF) – A permitted facility that physically stores water in an aquifer. Water enters a USF through direct recharge.

AUTHOR CONTRIBUTIONS

Anita Milman conceptualized, researched, and wrote the original draft. Cameron Bonnell, Rita Maguire, Kathryn Sorensen, and William Blomquist contributed to research, review, and editing of the article.

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