The Future of Groundwater in California

Lessons in Sustainable Management from Across the West

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Table of contents

Executive summary

The 2014 Sustainable Groundwater Management Act (SGMA) created, for the first time and on an unprecedented scale, a mandate to change how groundwater is managed statewide in California. While enacting SGMA was a tremendous step forward, communities and water districts now face the considerable challenge of creating successful groundwater management programs.

This report is aimed at helping California's water managers, public water agencies, county commissioners, city planners, and others better understand the suite of tools and approaches that can be used to enhance the sustainable management of groundwater. Specifically, we consider four categories of management tools—regulatory, incentive-based, agency supply augmentation and protection, and education and outreach—to evaluate how these tools are being used to address water quantity, water quality, and surface water and groundwater interaction challenges. We present nine comprehensive case studies of groundwater management across the Western United States to highlight how these tools have been used to address those challenges. The case studies represent basins that have a range of water uses—agricultural, municipal, or mixed water use, as well as basins with diverse hydrologic, political and social settings.

Effective groundwater management takes time and requires significant resources and commitment on the part of water managers and communities. Each groundwater management program presented in this report relies upon a variety of interdependent tools and actions to meet management goals. The case studies illustrate the importance of building trust, having sufficient data, using a portfolio of management approaches, assuring performance, and access to funding. Given the similarities between the goals of SGMA and those described in the case studies, these themes emerge as crucial to the successful implementation of California's landmark groundwater legislation.

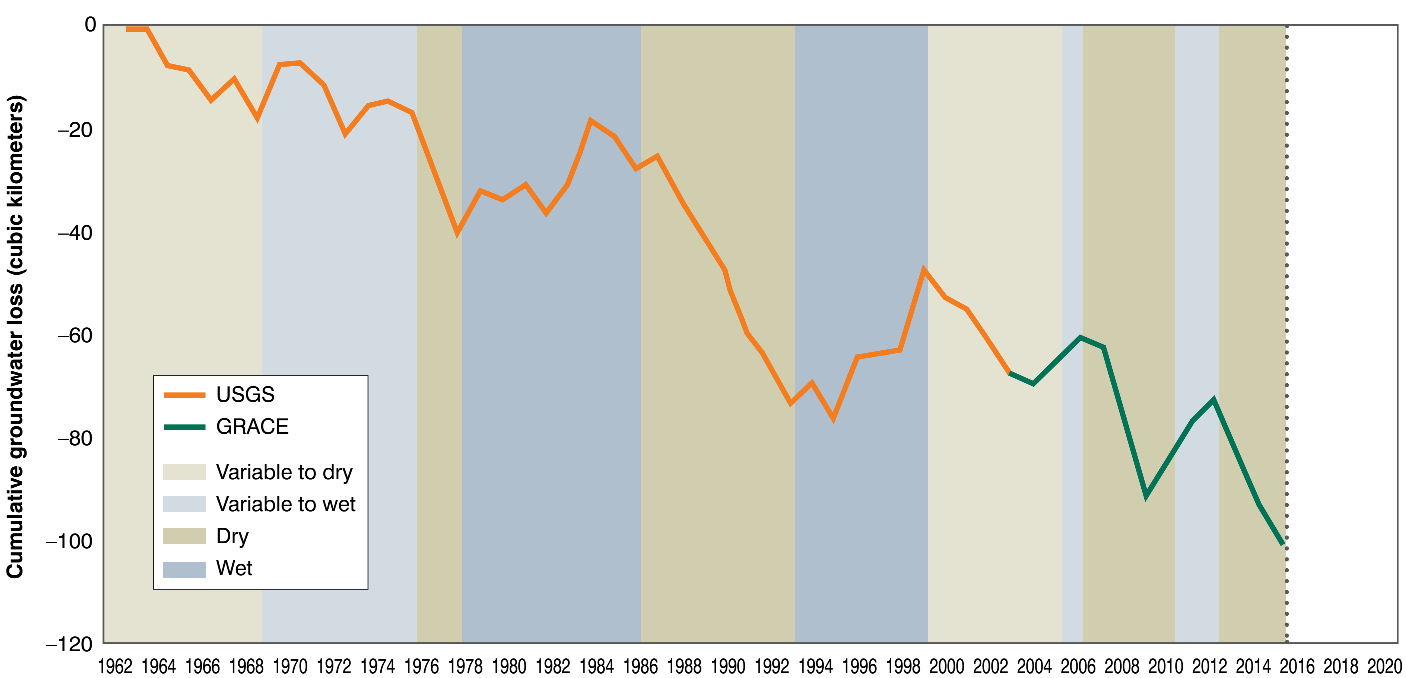
Background

Groundwater provides about 40 percent of California's total annual water supply and serves as a critical buffer against drought and climate change. But while groundwater is an effective buffer during dry periods, the resource needs time to recover after it has been pumped. At current rates of groundwater use, flooding events and wet periods will not be sufficient to recharge groundwater in key basins to support long-term sustained use, as shown in Figure A.1 that highlights cumulative groundwater loss in California's Central Valley since the 1960s.

The trend of increasing groundwater use amid cycles of drought has exacerbated groundwater depletion, water quality degradation, land subsidence, and depletion of interconnected surface water throughout the state. California's SGMA arose out of a recognition that the integrated management of the state's water resources is essential to meeting its water management goals, and that when properly managed, groundwater resources will help mitigate the effects of drought and climate change to communities, farms, and the environment.

FIGURE A.1

Cumulative groundwater loss in California's Central Valley during periods of wet and dry conditions



Source: Union of Concerned Scientists with data from the University of California Center for Hydrologic Modeling (UCCHM). (2015). Sustainable Groundwater Management in California. Retrieved from http://www.ucsusa.org/global-warming/regional-information/california-and-western-states/sustainable-groundwater-management-act. Design: EDF


Growing consumer demand for almonds has led California farmers to plant hundreds of thousands of acres of new trees over the past two decades. Almonds and other permanent crops do not have the flexibility of forgoing water in a dry year, as do annual crops like tomatoes or strawberries.

RICHARD THORNTON/SHUTTERSTOCK

SGMA requires the formation of local groundwater sustainability agencies (GSAs) and the development of groundwater sustainability plans to address the following "undesirable results" as defined in the Act:

- Chronic lowering of groundwater levels
- Degraded water quality, including the migration of contaminant plumes that impair water supplies
- Seawater intrusion
- Land subsidence that substantially interferes with surface land uses
- Reduction of groundwater storage
- Depletions of interconnected surface water that has significant and unreasonable adverse impacts on beneficial uses of the surface water

While California has a long history of managing a complex surface water storage and distribution system, managing surface water and groundwater as an integrated system presents some very distinct challenges. Surface water typically involves public agency control of storage and conveyance infrastructure, and groundwater often involves privately owned infrastructure and land, which can present a challenge for water managers as they attempt to fulfill SGMA's requirements.

Fortunately, groundwater is being managed successfully in many places across the West, and much can be learned from case studies of groundwater management in these areas that include urban and agricultural settings. This report summarizes nine case studies of groundwater management in six states—Arizona, California, Colorado, Nebraska, Oregon, and Texas—and presents key lessons learned in an effort to inform and foster effective groundwater management in California.

Groundwater management strategies

The case studies presented in this report focus on the tools and actions water managers use to directly influence water use and availability and could be considered for inclusion in GSA sustainability plans.

Tools used to achieve management goals

Groundwater management districts featured in the case studies generally rely upon a suite of interdependent tools rather than a single policy or regulation to influence water user behavior. Groundwater management tools fall into four distinct categories: regulatory tools, incentive-based tools, agency supply augmentation and protection, and education and outreach. Specific tools are described in the case studies included in the appendix and, in every case, multiple tools are used simultaneously.

Regulatory tools

Regulatory tools often form the backbone on which more sophisticated incentive-based tools are built. Regulatory tools require water users to take certain actions and are not intended to provide direct incentives, financial or otherwise, for water users. Examples include metering of wells (whether self-reported or monitored), best management practices (BMPs) without cost-share, and moratoria on new wells.

- Moratoria (or limits) on new wells or irrigated acreage
- Permitting system for wells
- Quantified and allocated irrigation or pumping rights
- Certification of irrigated acreage
- Metering of wells (self-reported or monitored)
- BMPs without cost-share (user pays)
- Continuing education requirements

Incentive-based tools

Some groundwater management tools are designed to provide incentives to influence change in water use behavior. Taxes, fees, or surcharges, as well as energy management practices (i.e., load control), are examples of tools that provide financial incentives for behavior change. Other tools, such as land retirement projects, credit-based systems to offset new groundwater development, water transfer systems that allow individuals to move water use to where and when it is most needed (for example by trading groundwater storage credits or use permits within a specific geographic area), and landowner-led recharge, also rely on economic valuations of water or underlying land assets for users who participate. In instances where groundwater managers seek to encourage users to adopt best management practices, cost-sharing programs can also provide financial incentives to participate while also fostering trust between users and managers.

- Taxes, fees, or surcharges
- Land retirement projects
- Managed aquifer recharge (land-owner is lead)
- Offset programs
- Transfer systems for credits, permits, or rights
- BMPs with cost-share
- Energy management practices (i.e. load control)

Agency supply augmentation and protection tools

Water managers often take additional actions at the district or regional level to achieve sustainable water use. Water supply augmentation and protection measures can support or supplement other management tools that more directly influence water user behavior. For example, water districts may pursue stream augmentation projects to enhance the effect of water user conservation on instream flows, or invest in water recycling systems that contribute to conjunctive use efforts by water users to recharge an aquifer. Conjunctive use efforts led by agencies—for example, construction and maintenance of dedicated recharge basins—also fall under this category.

- Stream augmentation projects
- Managed aquifer recharge
- Aquifer storage and recovery
- Infrastructure upgrades paid for by water supplier or rates
- Reservoir operations
- Seawater intrusion barriers
- Use of recycled water

Education and outreach tools

Water managers can help users better understand the consequences of their behavior and opportunities to improve groundwater sustainability via outreach and education initiatives. Efforts focused on highlighting current and future basin conditions and challenges, such as ongoing overdraft, can promote learning and enhance engagement within communities. Such tools can take many forms, including informational reports, guidance documents, and websites that aim to educate water users on best management practices or update community members on relevant management initiatives and activities. Targeted trainings, workshops, and conferences that engage participants around specific water-focused topics or the development of educational curriculum that advance water education in schools are additional examples.

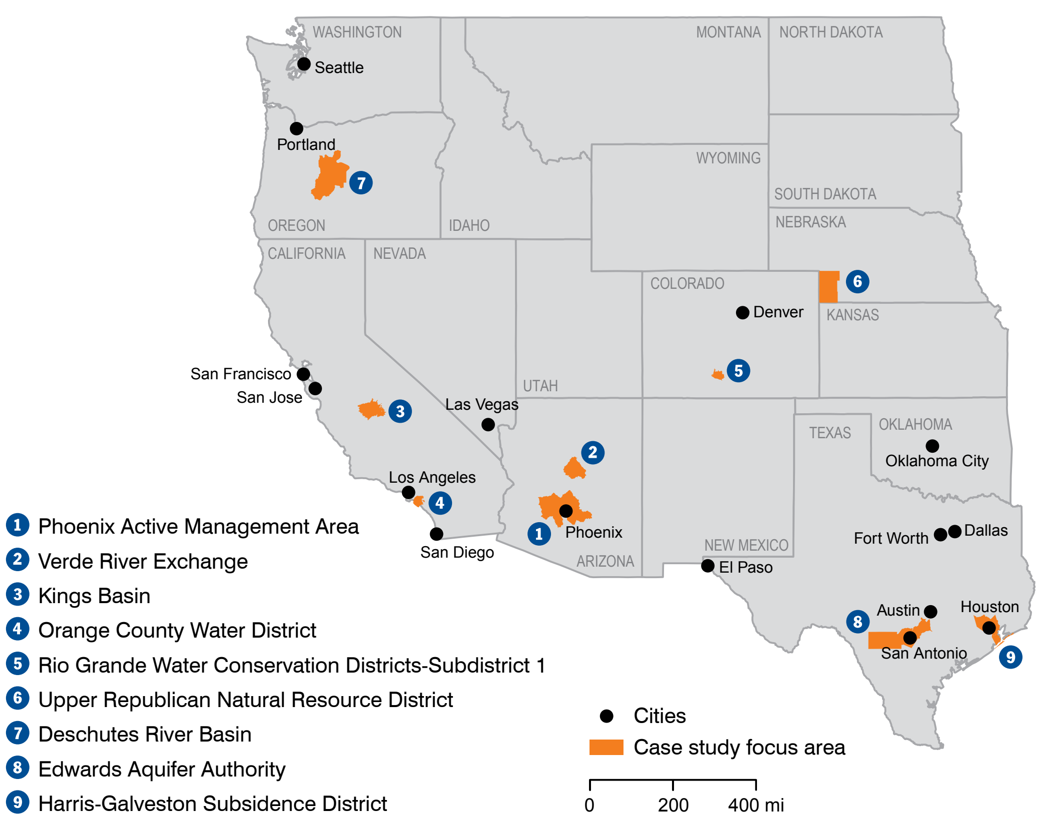
- Educational programs and community engagement events
- Program reports and updates
- BMP guidance documents
- Data tools and informational websites

Overview of case studies

The following case studies demonstrate groundwater management strategies formed in response to a variety of hydrologic challenges and social settings. The case studies bring together research and local insight on the management tools and actions various regions are using to address issues ranging from water quantity and quality to surface water depletion challenges. Tables B.1 through B.4 (pages 10 and 11) highlight prominent groundwater challenges faced across case studies, as well as key regulatory, incentive-based, and agency supply augmentation and protection tools used to address these challenges, respectively. All case studies also employ education and outreach tools to educate water users. While it is often difficult to pinpoint a single policy or tool responsible for the success of each program—and indeed, some of the cases have ongoing management challenges—the most prominent elements of each case study are emphasized in the summary.

FIGURE B.1

Overview map



Source: EDF with case study boundary data from multiple sources. See individual case studies for specific source information.

TABLE B.1

Groundwater challenges across case studies

State	Management area	Dominant water use(s)	CHALLENGES ADDRESSED (SGMA UNDESIRABLE RESULTS)					
			Lowering of GW levels	Seawater intrusion	Land subsidence	Reduction of storage	Surface water depletion	Degraded GW quality
AZ	Phoenix AMA	Ag/Urban	●		●	●		●
	Verde River Exchange	Ag/Urban	●				●	
CA	Kings Basin	Ag	●			●		●
	Orange County Water District	Urban	●	●				
CO	Rio Grande Water Conservation District	Ag	●			●	●	
NE	Upper Republican NRD	Ag	●			●	●	●
OR	Deschutes River Basin	Ag/Urban					●	
TX	Edwards Aquifer Authority	Ag/Urban	●			●	●	●
	Harris-Galveston Subsidence District	Urban	●	●	●	●		

TABLE B.2

Regulatory tools used across case studies

Management area	REGULATORY TOOLS						
	Moratoria or limits on new wells/irrigated acreage	Permitting systems for wells	Quantified and allocated irrigation/ pumping rights	Certification of irrigated acreage	Metering of wells (self-reported)	Metering of wells (monitored)	BMPs without cost share
Phoenix AMA	●	●	●	●	●		●
Verde River Exchange							
Kings Basin							
Orange County Water District					●		
Rio Grande Water Conservation District	●	●	●		●		
Upper Republican NRD	●	●	●	●		●	
Deschutes River Basin	●	●	●		●		
Edwards Aquifer Authority		●	●		●		●
Harris-Galveston Subsidence District		●	●		●	●	

The tables on pages 10 and 11 *include information collected during development of this report and are not necessarily comprehensive of all challenges faced or management tools employed in each management area.*

TABLE B.3

Incentive-based tools used across case studies

Management area	Taxes, fees or surcharges	Land retirement projects	Managed aquifer recharge (landowner is lead beneficiary)	Offset program	Recharge, depletion or storage credits	Transfer of credits, permits or rights	BMPs with cost-share
	INCENTIVE-BASED TOOLS						
Phoenix AMA					•	•	
Verde River Exchange				•	•		
Kings Basin			•			•	•
Orange County Water District	•						
Rio Grande Water Conservation District	•	•		•	•	•	
Upper Republican NRD	•	•				•	•
Deschutes River Basin	•			•	•	•	
Edwards Aquifer Authority				•		•	
Harris-Galveston Subsidence District	•						•

TABLE B.4

Agency supply augmentation and protection tools across case studies

Management area	Stream augmentation projects	Managed aquifer recharge (agency lead)	Aquifer storage and recovery	Infrastructure upgrades (paid for by agency)	Reservoir operation	Seawater intrusion barriers	Recycled water
	AGENCY SUPPLY AUGMENTATION AND PROTECTION TOOLS						
Phoenix AMA		•	•	•	•		
Verde River Exchange							
Kings Basin		•		•	•		
Orange County Water District		•		•	•	•	•
Rio Grande Water Conservation District	•	•		•			
Upper Republican NRD	•			•			
Deschutes River Basin	•			•			
Edwards Aquifer Authority	•		•	•			
Harris-Galveston Subsidence District				•	•		

CASE STUDY 1 / ARIZONA

Phoenix Active Management Area

The Phoenix Active Management Area (AMA) encompasses a groundwater basin with agricultural and urban water uses. To address declining groundwater levels and land subsidence within the AMA, water managers established a goal to attain safe-yield, defined as the long-term balance between annual groundwater withdrawals and recharge, by 2025. To work toward this goal, AMA water managers developed a regulatory system to limit irrigated acres and established a system to enhance long-term storage through facilitated groundwater recharge, which takes advantage of conjunctive use mechanisms by using surplus surface water as recharge. While the AMA still struggles with localized areas of groundwater level declines, it has reached its overarching goal of safe yield for the basin.

CASE STUDY 2 / ARIZONA

Verde River Exchange

Arizona's Verde River Valley supports historically dominant agricultural water uses and a rapidly growing, groundwater-dependent urban population. Significant increases in groundwater pumping have lowered groundwater levels in some areas and threaten Verde River surface flows. The Verde River Exchange, administered by local non-profit Friends of Verde River Greenway, is a community-driven, voluntary groundwater mitigation pilot-program designed to support continued development and growth, while protecting river flows and their cultural, economic, and ecological benefits in the region. To do this, the Exchange creates credits by incentivizing Verde Valley water users to voluntarily reduce their water usage. These credits can then be purchased by other Verde Valley water users seeking to reduce their water footprint and the impacts of their groundwater use. Launched in 2016, the Exchange could offer a scalable solution for mitigating the impacts of groundwater pumping on the Verde River and for stabilizing water supplies for future residents.

CASE STUDY 3 / CALIFORNIA

Kings Basin

The Kings Basin is a predominantly agricultural region wherein water managers seek to mitigate groundwater quality degradation and groundwater level declines. To address these issues, the Kings River Conservation District has placed a strong emphasis on community engagement through data-driven educational outreach and other trust-building actions. The district assists growers in irrigation system reviews and water use efficiency and also uses dedicated recharge facilities and on-farm recharge to make use of floodwater. Recharge programs in the district have the capacity to recharge over 100,000 acre-feet annually and have helped reduce rates of groundwater level declines.

CASE STUDY 4 / CALIFORNIA

Orange County Water District

The Orange County Water District is situated in an almost entirely urban area, with 98% of water use going toward municipal and industrial sectors. The district goals are to protect and enhance groundwater quality and availability, which have been impacted by groundwater level declines and seawater intrusion. With no regulatory authority to control pumping, the district employs a pricing mechanism as an incentive for water retailers to purchase water imported from outside of the district rather than pumping groundwater. The District's innovative pricing scheme—in combination with basin recharge, seawater barriers, water recycling, and education and outreach initiatives—exemplify a portfolio of approaches that work together to promote cost efficiency, improved water quality and enhanced basin sustainability.

CASE STUDY 5 / COLORADO

Rio Grande Water Conservation District (Subdistrict No. 1)

Primarily an agricultural region, the San Luis Valley has experienced significant groundwater level declines. The Subdistrict manages water within its boundaries to mitigate stream depletion resulting from local groundwater pumping and thereby remain in compliance with an interstate water use agreement for the Rio Grande and Conejos Rivers. The Subdistrict places a fee on groundwater pumping to encourage irrigators to improve on-farm efficiency, switch to less water-intensive crops, and take advantage of the federal fallowing program Conservation Reserve Enhancement Program (CREP), which pays agricultural producers to take their land out of production permanently or for a certain period of time. The program has succeeded in recharging more water than required to offset surface water depletions.

CASE STUDY 6 / NEBRASKA

Upper Republican Natural Resources District

The Upper Republican Natural Resources District (NRD) manages groundwater level declines, surface water depletion, and groundwater quality degradation in an almost exclusively agricultural basin. Organized in 1972, the NRD uses multiple tools to mitigate groundwater declines and satisfy requirements of an interstate compact with Colorado and Kansas pertaining to surface water flows. Examples include a moratorium on drilling new wells, a well permitting system, "land occupation" taxes, a strict cap on groundwater pumping with both formal and informal water markets, and stream augmentation projects. The NRD also has strong community involvement and support for monitoring and enforcement in the District.

CASE STUDY 7 / OREGON

Deschutes River Basin

The Deschutes Basin aims to maintain instream water rights and scenic waterway flows while accommodating existing agricultural use and population growth through new groundwater development. To accomplish these goals and meet requirements of the state Scenic Waterways

When properly managed, groundwater resources will help mitigate the effects of drought and climate change on communities, farms, and the environment.

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Act, the Deschutes Groundwater Mitigation Bank purchases existing surface water rights and sells corresponding mitigation credits to new groundwater pumpers. These mitigation credits have helped to preserve streamflow while allowing the approval of new groundwater permits in the basin.

CASE STUDY 8 / TEXAS

Edwards Aquifer Authority

The Edwards Aquifer program was established to manage and protect groundwater levels and groundwater-fed spring flows which are critical to the survival of several endangered species in the basin. The Edwards Aquifer Authority uses an aggregate cap on groundwater pumping for its mixed agricultural and urban user base, along with tradable permits to limit groundwater withdrawal. The Edwards Aquifer Authority encourages participation in a water trading market, which has resulted in the maintenance of minimum spring flows, despite a recent drought. Water trading has succeeded as an effective management tool by minimizing transaction costs, developing a functional online trading platform, limiting constraints as to how users divide their allocations, and establishing specific caps in state law.

CASE STUDY 9 / TEXAS

Harris-Galveston Subsidence District

Water use in the Harris-Galveston Subsidence District is mostly industrial and municipal. The District is addressing land subsidence, groundwater level declines, and seawater intrusion by using fees and educational programs to encourage use of surface water in lieu of groundwater. Groundwater usage is limited to a percentage of an individual user's total water demand. If that percentage is exceeded, the user is subject to fees intended to discourage overuse of groundwater. While the district lacks a growth management strategy, rates of groundwater level declines have decreased.

Summary of lessons learned

with implications for SGMA implementation

A review of the case studies reveals several lessons in effective groundwater management that coalesce around five recurring themes: the importance of building trust, the need for data to inform management decisions, using a portfolio of management approaches, assuring program performance, and having sufficient funding. These themes, as described below, can have significant implications for the successful implementation of California's Sustainable Groundwater Management Act (SGMA).

Building trust

Groundwater management often requires asking people to change what they do in a way that has an actual or perceived financial impact. This requires establishing trust within that group of people—acceptance of a fair system that will allow them to use a sustainable amount of groundwater that supports their livelihood over the long-term.

In addition to broad community involvement from the early stages of planning, there are specific things that water managers can do to build trust. Using data to illustrate current groundwater conditions and simulate future impacts can lend credibility to water managers, as well as create a sense of ownership in the future of the program. Water managers in the Kings Basin in California, for example, used data-driven groundwater models to convey how

Agricultural economies, as well as the communities and ecosystems they support, depend on having clean, reliable groundwater resources.

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local areas and individuals' properties could be impacted by future groundwater declines. This educational approach enabled people to see and understand the connection between the goals of the program and their personal situation as landowners and agricultural producers who rely on groundwater to maintain their livelihood.

Effective groundwater management requires sufficient water resources data that water users and community members trust.

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A second method of trust building involves including key stakeholder groups within the community in the planning process so they can understand, support and vouch for the groundwater management program. In the case of Kings Basin, water managers included fisheries groups in the groundwater management process who used their positive past experiences with the community to build trust for the new groundwater policies.

Lastly, providing beneficial resources to the community can strengthen relationships with the same people affected by groundwater management programs. For example, the Upper Republican Natural Resources District manages recreational areas and provides the community with cost-sharing programs for planting trees intended for windbreaks. Such non-adversarial community programs have helped the District build trust and acceptance of challenging groundwater use restrictions in the face of interstate litigation.

SGMA requires sustainability plans developed by a Groundwater Sustainability Agency (Agency) to include an explanation of Agency decision-making methodology and describe how the Agency encourages active involvement of stakeholders in that process. Arguably the most significant lesson learned from the case studies is that meaningful community and stakeholder engagement early in the process helps build trust and cooperation that leads to more effective groundwater management. And while the case studies demonstrate different ways to achieve trust between parties, they all involve building trust slowly and intentionally, which can be the difference between successful and unsuccessful groundwater management programs.

The need for data

As with the Kings Basin, the Edwards Aquifer Authority made water use data publicly available, which increased transparency and helped ensure buy-in from program participants.

In addition to using open data to build trust, data are also critical for effective decision-making. In the Upper Republic Natural Resources District, for example, irrigation wells in the District have been fully metered to measure water consumption since 1981 and the District has also maintained a groundwater well measurement database since 1972. Water level monitoring and water use tracking are used to detect trends and support groundwater policies.

One of the "undesirable results" that SGMA requires Agencies to address is the depletion of interconnected surface water. Minimum thresholds—the rate or volume of surface water depletions caused by groundwater use that has adverse impacts—need to be established and supported by sufficient data that inform computer models or equally effective methods of analysis. Regardless of the analytical method chosen, the case studies indicate that effective groundwater management largely depends on the gathering, management and analysis of sufficient water resources data.

Using a portfolio of approaches

Groundwater management cannot be achieved overnight, nor can it be accomplished by a single policy, regulation or project. It is important to recognize that multiple tools, added and built upon gradually, are necessary for successful groundwater management. In nearly every basin, including those featured in this report, advances in groundwater management begin with some form of permitting framework, tracking system, educational component, and revenue source for management. After these are in place, additional tools can be added based on local conditions.

For example, prior to implementing a groundwater market in the Edwards Aquifer, groundwater managers had to first establish a system of groundwater pumping permits and then place a cap on overall groundwater use. Only after binding regulatory limits were placed on groundwater did the incentive arise to participate in rights transfers, which could be either permanent or temporary in nature. This example also illustrates that incentives can be a component of a groundwater management portfolio, but they require many other policies to support them. Furthermore, there are limits to what price mechanisms alone can do to reduce water demand, especially in California. While groundwater users may not be required to pay for water directly, they pay indirectly via energy costs and property taxes on irrigated land.

SGMA requires plans developed under the Act to include a description of the projects and management actions the Agency has determined will achieve groundwater basin sustainability. The lessons learned from the case studies clearly demonstrate the benefit of a portfolio approach to groundwater management. Agencies that include a wide-range of actions in their plans will greatly increase both their chances of success and the approval of their plans by the California Department of Water Resources (DWR).

Assuring performance

The case studies demonstrate the importance of sufficient monitoring networks and enforcement protocols. Any policy is only as good as the monitoring and enforcement behind it. Without adequate monitoring to detect noncompliance followed by subsequent enforcement measures, there will often be an inclination to ignore regulatory requirements. Monitoring and enforcement are an underappreciated aspect of groundwater management that incurs monetary, social, and political costs. This is especially true in areas where groundwater managers live and work alongside the very people whose actions they must manage. For this reason, it is critical to have political and community support, as well as sufficient financial and

Successful groundwater management requires a portfolio of approaches, developed and built upon over time.

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personnel resources, to carry out monitoring and enforcement. When routine meter inspection by the Upper Republican NRD revealed that a groundwater user was bypassing the flow meter to irrigate in excess of the allocated amount, the district revoked the violator's right to irrigate their land indefinitely, which resulted in a penalty of millions of dollars of potential crop revenue. The district received wide-spread support from the community for the decision because it trusted and supported the district's management of their valuable resource.

DWR will periodically review approved SGMA Plans to ensure they remain consistent with the Act and are likely achieve the sustainability goal for their respective groundwater basins. This review will include determining whether an Agency has 1) exceeded any established minimum thresholds, 2) implemented projects and management actions consistent with its Plan, and 3) addressed any data gaps to reduce levels of uncertainty.

Funding

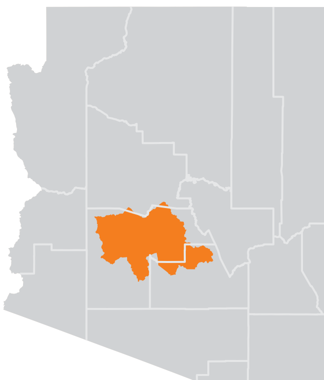
It is difficult to imagine a scenario involving effective groundwater management without sufficient funding to carry out appropriate management actions. Virtually all of the case studies directly or indirectly demonstrate the need for sufficient funding to achieve groundwater management objectives. Whether it is the need for infrastructure to shift from groundwater use to surface water, as in the case of Harris-Galveston Subsidence District; the development and use of computer models employed by Kings Basin; the monitoring network established and maintained by the Edwards Aquifer Authority; or, the groundwater recharge facilities constructed and operated by Orange County Water District, they all required significant financial resources to achieve success.

When evaluating SGMA plans, DWR will determine whether the Agency has the financial resources necessary to implement the Plan. Even at their most basic level, GSAs, as envisioned under SGMA, require staff dedicated to engaging stakeholders and preparing groundwater sustainability plans to succeed. Beyond that, significant funding is necessary for implementing the projects and management actions contemplated in the SGMA plans. Securing sufficient funding will be one of the biggest challenges faced by many GSAs as they work to achieve sustainability, and the cases studies included in this report offer valuable insight on a variety of funding mechanisms being used across the west to support successful groundwater management.

Case studies

CASE STUDY 1 / ARIZONA

Phoenix Active Management Area



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CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

Lowering of groundwater levels

Degraded groundwater quality

Land subsidence

Reduction of storage

PREDOMINANT WATER USES

Agricultural

Urban

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Regulatory

- Metering of wells (self-reported)
- System of grandfathered groundwater rights with allotments
- Permitting system for new and existing wells
- Prohibition on new irrigated acreage
- Best management practices (without cost-share), including mandatory water conservation requirements and water loss limitation requirements
- 100-year Assured Water Supply requirement

Incentive-based

- Transfer system for groundwater rights
- Long Term Storage Credits

Agency supply augmentation and protection

- Managed aquifer recharge
- Reservoir operation
- Infrastructure upgrades
- Aquifer storage and recovery

Education and outreach

See page 26 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- An overarching safe yield goal for an entire groundwater basin will not address localized negative impacts associated with pumping depressions; considering spatial resolution is important to establishing a goal that will achieve the desired results.
- Basin management strategies that do not include enforcement provisions for limiting extractions are not likely to be effective in achieving safe yield.
- Tools and analyses for establishing baseline conditions and metrics are important for evaluating the effectiveness of groundwater management activities against external impacts.
- Designing successive management plans around evolving best management practices allows for the gradual implementation of stricter regulations and encourages the adoption of new technologies.
- Well-structured regulatory mechanisms can effectively and significantly reduce municipal and agricultural demand. Tiering the implementation of stricter regulations over time can give water users time to adapt to the increased regulations. Tiering also drives towards safe yield while not cutting off rights or impeding growth.
- Requiring demonstration of adequate water supplies and other BMPs incentivizes the creation of more data, modeling, and measurement, because applicants have incentives to develop increasingly sophisticated information about the aquifer, information is shared with the regulator and incorporated into the ongoing understanding of the system.

Background and governance

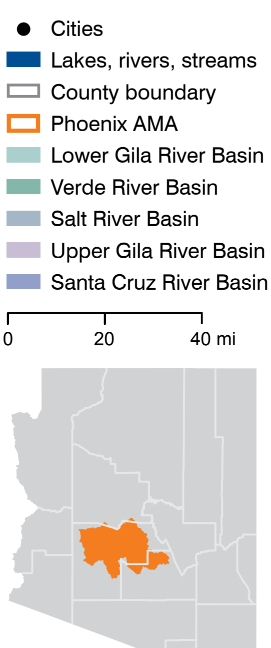
Historically, groundwater in Arizona has been pumped faster that it can be naturally recharged (ADWR, 2008). Well pumping has caused groundwater depressions, and severe groundwater overdraft has also caused a lowering of the land surface, known as subsidence (ADWR, 1999a). Subsidence has led to extensive flooding and physical damage to the land surface and infrastructure (ADWR, 1999b). Groundwater depletion also has led to the loss of aquifer storage space and some water quality issues. In addition, there are endangered species listings and Endangered Species Act litigation over riparian fishes, birds, and habitat in Arizona; groundwater is an essential component in sustaining the streamflow and habitat of these ecosystems.

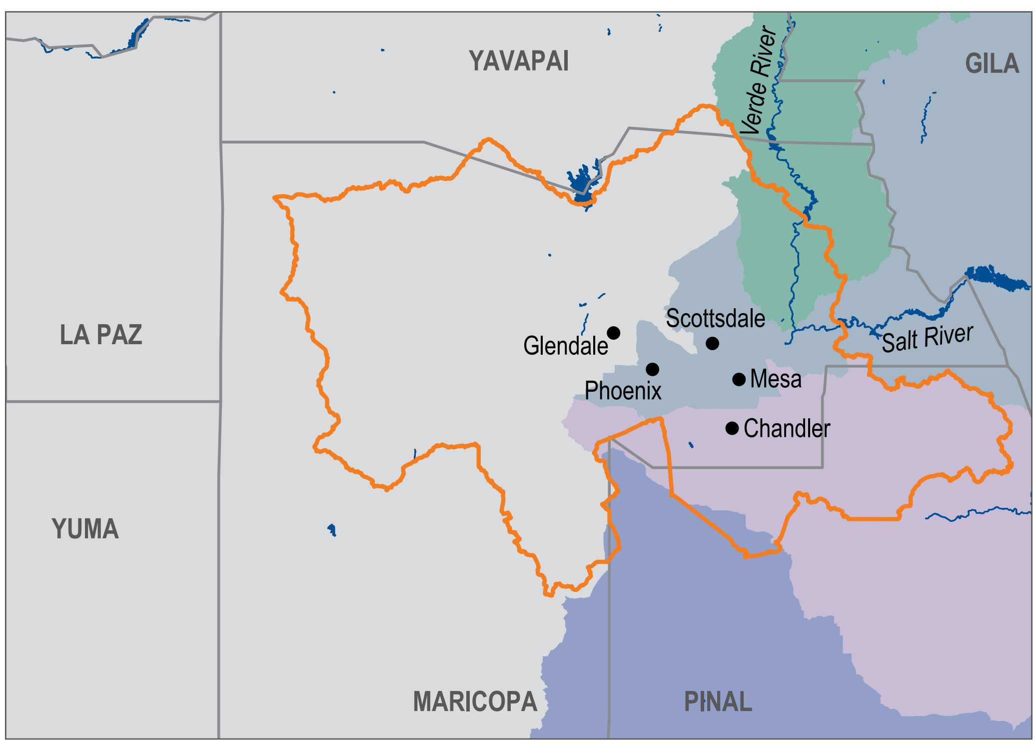
In 1980, the Arizona legislature passed the Groundwater Management Code ("the Code"), a comprehensive legal framework for groundwater regulation (Arizona Groundwater Management Code, 1980b). Prior to this point, there were minimal regulatory constraints on groundwater use in Arizona. The Code established Active Management Areas (AMA) in the regions where groundwater overdraft was most severe. The five AMAs include Prescott, Phoenix, Pinal, Tucson, and Santa Cruz (Figure 1.2, page 22).

The Arizona Legislature established a centralized state agency, the Arizona Department of Water Resources (ADWR), to implement the Code (Arizona Groundwater Management Code, 1980a). One of the responsibilities of the Department under the Code was to develop a series of management plans for each AMA. Plans were to be prepared for each of the five management periods between 1980 and 2025 (1980–1990, 1990–2000, 2000–2010, 2010–2020, and 2020–2025) to create the flexibility needed to meet the changing and growing needs of the AMAs.

The Phoenix Active Management Area ("Phoenix AMA" or "AMA") covers 5,646 square miles in Arizona and consists of seven groundwater basins, including the East Salt River, West Salt River, Hassayampa, Fountain Hills, Rainbow Valley, Lake Pleasant, and Carefree sub-basins (Figure 1.1). The climate in this area is semiarid, with an average annual precipitation of seven

FIGURE 1.1
Phoenix Active Management Area

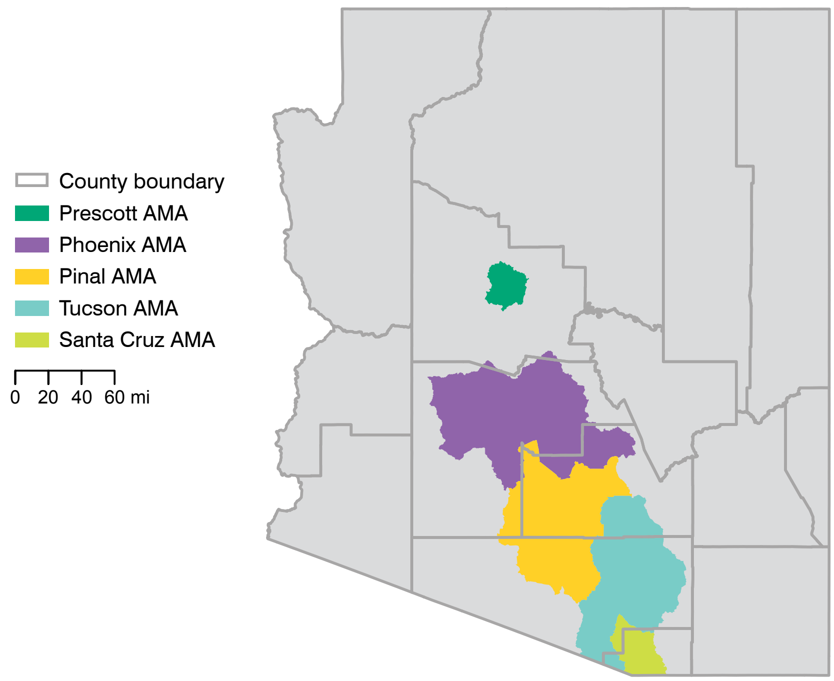




Source: EDF with Phoenix AMA boundary data from ADWR Open Data, 2017

FIGURE 1.2

Arizona Active Management Areas



Source: EDF with AMA boundary data from ADWR Open Data, 2017

inches (ADWR, 1999a). Land use in the Phoenix AMA consists of large urban areas, agricultural and industrial uses, and native desert. The largest urban center in the AMA is the City of Phoenix, which is the most populous city in Arizona. Other population centers in the AMA include Scottsdale, Chandler, Tempe, Mesa, Glendale, and Gilbert.

Water supply sources in the Phoenix AMA include surface water (Salt, Verde, and Gila rivers on the east and the Colorado River from the northwest), groundwater, and effluent. Several major canal systems transport surface water to and within the AMA, and several regulated water storage reservoirs on the nearby river systems produce a reliable and safe water supply for many areas within the AMA (ADWR, 1999a).

On average, annual water demand in the AMA is approximately 2.2 million acre feet. Of this 2.2 million, 1.5 million acre feet come from surface water sources and treated effluent (ADWR, 2011). Approximately 0.7 million acre feet are pumped from groundwater aquifers within the AMA each year (ADWR, 2011). Approximately 45% of water demand comes from agricultural users (including tribal agriculture), with 47% of demand from municipal users and the remaining 84% from industrial users.

Water management in the Phoenix AMA is primarily carried out by the ADWR, in conjunction with several additional entities. The ADWR administers state laws, explores management methods, and develops management plans. The ADWR oversees the state's surface water and groundwater supplies and represents Arizona in interstate and federal issues.

The Arizona Department of Environmental Quality (ADEQ) and the ADWR collaborate on the Groundwater Quality Management Program. Groundwater quality directly impacts groundwater quantity, and vice versa. The ADEQ has the lead role in protecting the quality of the state's ground and surface waters. Federal laws such as the Safe Drinking Water Act, Clean Water Act, the Comprehensive Environmental Response Compensation and Liability Act, and the Resource Conservation and Recovery Act also impact water quality programs in Arizona.

Finally, it is important to note that there are some Native Nations present within or surrounding the Phoenix AMA, including the Gila River Indian Community, the Salt River Pima-Maricopa Indian Community, and the Fort McDowell Indian Community. Native American Nations are recognized sovereignties and are not subject to the same management structures as other water right owners in the state.

Program management goals

The state-wide goals established by the Code are to control severe overdraft and to allocate and increase groundwater resources in Arizona through the use of conservation measures (ADWR, 2011).

The goal of the Phoenix AMA is to achieve safe yield by the year 2025 (ADWR, 2016). Safe-yield, as defined in the Code, means "to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial groundwater recharge in the active management area." A.R.S. § 45-561 (12).

Safe-yield in the Phoenix AMA is defined as a state in which groundwater withdrawal does not exceed recharge, and thus it is not a pre-determined amount. The allowable extraction under safe-yield varies depending on natural, incidental and artificial recharge.

By achieving safe yield, managers hope to halt overdraft and its associated undesired effects. The Phoenix AMA Management Plans implement management tools such as conservation measures and augmentation measures to attain safe-yield, as discussed in further detail below.

Tools used to achieve management goals

The portfolio of approaches used to meet the state and AMA goals include regulatory, incentive-based, and supply augmentation and protection tools, as well as education and outreach. Phoenix AMA management plans include a variety of tools that have been adopted over time for each water use sector to gradually implement new requirements and conservation targets and adaptively meet the basin goals.

Regulatory tools

The Code contains regulatory provisions, some of which apply to all AMAs and some of which are AMA-specific. Statewide regulations address well registrations, water quality, and transportation of groundwater across basin and sub-basin boundaries. AMA-specific regulations address groundwater withdrawal rights, new developments, and requirements for users to measure and report groundwater use, all with the goal of creating a comprehensive program to manage existing and new groundwater use.

Metering of wells (self-reported)

All non-exempt wells (wells which pump over 35 gallons per minute) in AMAs must use an approved measuring device (i.e. meter) (ADWR, March 2016). Annual water use reports must be submitted to ADWR and must include an accurate record of the amount of withdrawals, delivery, and use of all water withdrawn from the well.

System of grandfathered groundwater rights with allotments

Certain historical uses may receive a type of "grandfathered" right, which allows continued groundwater withdrawals based on the historical type and amount of the use. Irrigation Grandfathered Rights (IGFR) are based on historical irrigation of two or greater acres of land. Type 1 Non-Irrigation Grandfathered Rights are created when land has permanently been retired from agriculture. Type 2 Non-Irrigation Grandfathered Rights were originally allocated to those who withdrew groundwater from a non-exempt well historically for a non-irrigation use between 1975 and 1979. Type 2 rights provide an allotment of water based on the highest year of groundwater pumped for a non-irrigation use. Users must apply to the ADWR to create all three types of grandfathered rights.

Permitting system for new and existing wells

All groundwater withdrawals within an AMA require a water right, permit, or service area right from the state, except for groundwater withdrawn from exempt wells (which pump 35 gallons per minute or less) (ADWR, 2008).

Withdrawal permits may be issued by ADWR for new withdrawals of groundwater in AMAs that cannot be served by any of the grandfathered rights discussed above. Withdrawal permits are limited to non-irrigation uses, and generally involve permits for uses such as industrial use, mining, dewatering, and poor-quality groundwater withdrawal.

Service area rights authorize domestic water suppliers (cities, towns, private water companies, and irrigation districts) to withdraw groundwater within defined service areas to supply to their customers.

Prohibition on new irrigated acreage

Irrigated agriculture cannot be expanded beyond acreage irrigated during the late 1970's (ADWR, March 2016). Each farm using groundwater for irrigation purposes was issued an IGFR, which allows the agricultural user to withdraw enough water to reasonably grow crops that were historically grown on the land. The amount of acres that may be irrigated is limited by the right; however, the quantity of water that may be extracted for use on those IGFR acres is not limited by the farm's annual allotment, unless the farm is enrolled in the best management practices or BMP program (described below).

Best management practices without cost-share (user pays), including mandatory water conservation requirements and water loss limitation requirements

The Code directs ADWR to create a management plan with specific, required management practices meant to bring the basin into balance and meet the safe-yield management goal. The Phoenix AMA management plan requirements differ by water user type (e.g. large municipal water provides, agriculture, industries), and each category has specific water conservation requirements that are adapted over time to meet the AMA management goals.

For example, beginning in 1987 as a part of the First Management Plan, large municipal providers (a city, town, private water company, or irrigation district serving more than 250 acre-feet of water per year) operating in an AMA were required to participate in a Gallons-per-Capita per Day program (GPCDP) that assigns an annual total gallons per-capita per day allotment. In 2008, the Modified Non-per-Capita Conservation Program (MNPCCP) was added, giving large municipal providers with an Assured Water Supply program (AWS, described further below) the option to be regulated under the GPCDP or MNPCCP; large municipal providers without an AWS were required to enter the MNPCCP (ADWR, March 2014). Providers regulated under the MNPCCP are required to implement a public education program and defined BMPs. The number of BMPs that a provider must implement (in addition to the public education program) ranges from one to ten BMPs depending on the providers' size as determined by the number of connections it maintains (ADWR, October 2011). There are fifty-three BMPs to choose from ranging from BMPs that focus on public awareness to rebate/incentives to research/innovation (ADWR, October 2011).

Agricultural users must manage water use with an allotment based on historic cropping patterns or they can choose to opt into a regulatory agricultural best management practices program (ADWR, March 2014). The BMP program allows the farm the flexibility to grow crops different from those historically grown, and to double crop in exchange for implementing on-farm water efficiency improvements.

Industrial users (including water uses for turf facilities, dairies/feedlots, mines, electric power plants, and sand and gravel operations) are required to implement the most currently available conservation technologies that allow for reasonable economic returns (ADWR, March 2014). Additionally, all industrial users are required to avoid waste and make diligent efforts to recycle water.

Further, conservation requirements state that system losses for large municipal providers and irrigation distribution system losses are not to exceed ten percent annually (ADWR, March 2016).

100-year Assured Water Supply requirement

The Assured Water Supply (AWS) Program puts into place regulations that limit the use of groundwater by new subdivisions. In an AMA, anyone who offers subdivided or un-subdivided land for sale or lease must demonstrate an assured supply of water to ADWR before the land may be marketed to the public. To obtain a Certificate of AWS, the developer must demonstrate that the water supply will be of adequate quality, will be available for the next 100 years, will be consistent with the safe yield management goal of the Phoenix AMA and with the Management Plan, and that the developer is financially capable to construct necessary water facilities.

Incentive-based tools

Most of the regulation under Phoenix AMA management plans is non-incentive-based in that it mandates certain conservation requirements and other measures to control and offset groundwater use. However, the plans do provide flexibility in how water users can meet the requirements.

Transfer system for groundwater rights

Certain types of water rights can be transferred and marketed, allowing additional flexibility and incentives to reduce or change uses. Type 1 Non-Irrigation Grandfathered Rights can only be transferred with the land to which it is appurtenant. Type 2 Non-Irrigation Grandfathered Rights, however, may be sold or leased anywhere within the AMA.

Long-term storage credits

In 1986, the Arizona Legislature established the Underground Water Storage and Recovery Program which allows persons with surplus supplies of water to store that water underground for recovery at a later date. When eligible water is stored for over a year, ADWR issues Long Term Storage Credits. Credits can be recovered for various reasons, including establishing an AWS or fulfilling replenishment obligations. Long Term Storage Credits can be transferred to another long term storage account holder (ADWR, 2015). A market for long term storage credits has emerged as a way for municipal and industrial users to satisfy increasing demands (West Water Research, LLC, 2014).

Agency supply augmentation and protection

There are several major agency supply augmentation and protection initiatives underway within the Phoenix AMA. Examples of managed aquifer recharge, reservoir operation, infrastructure upgrades, and aquifer storage and recovery are mentioned below. These projects allow the Phoenix AMA to better manage available surface water and groundwater resources in a conjunctive manner.

Managed aquifer recharge

The Central Arizona Groundwater Replenishment District (CAGRD), which replenishes the aquifer through recharge facilities for a fee, was developed as a way to prove an Assured Water Supply. Established in 1993, The CAGRD is governed by the Central Arizona Water Conservation

District (ADWR, March 2016). The AWS and CAGRD provide some flexibility by allowing new municipal developments to meet their requirement to prove an AWS by offsetting their groundwater extraction.

Reservoir operation
The Salt River Project (SRP), the oldest multipurpose federal reclamation project in the United States, serves as one of the primary water providers for much of Central Arizona. The SRP owns and operates four reservoirs where it stores surface water from the Salt and Verde Rivers and it also has the right to pump groundwater (Conjunctive Water Management, 2006). Both surface and groundwater supplies from the SRP are used to meet area demands for water; surface water being the primary resource in wet years and groundwater supplies being used extensively in drought years. During wet years, surface water is also used to recharge the aquifer for future use (Conjunctive Water Management, 2006).

Infrastructure upgrades (paid for by agency)
The Colorado River is the state's largest resource for renewable water supplies. The Central Arizona Project (CAP) brings 1.5 million acre-feet of water from the Colorado River to Central and Southern Arizona along a 336-mile long system of aqueducts, tunnels, pumping plants, and pipelines (ADWR, March 2016). The CAP, managed and operated by the Central Arizona Water Conservation District, served to switch the source of supply for many water users, effectively reducing the significant groundwater declines experienced in the AMA prior to construction of the canal.

Aquifer storage and recovery
The Arizona Water Banking Authority (AWBA) was established in 1996 to increase utilization of the state's Colorado River entitlement by providing facilities to bank under-utilized supplies (sometimes as long term storage credits) by storing it in aquifers and in underground storage facilities (ADWR, March 2016). Stored water is used to provide a buffer of supply to be used in times of a shortage declaration on the Colorado River, for the purpose of securing water supplies for the state.

Education and outreach
Management Plans provide information on best management practices that water users can adopt as part of their required conservation measures. ADWR issues a low water use plant list, and makes other conservation materials and reports available to the public. ADWR provides conservation research tools and resources to encourage low water use lifestyles that targets residents, businesses, water providers, and communities, to design and implement their own water conservation strategies. ADWR also supports Arizona's Project WET, which provides workshops and curriculum for children's water education and programs for community engagement, as well as the Water Management Assistance Program which supports conservation specialist positions, monitoring, planning assistance, community outreach and education efforts (ADWR, 2014).

Monitoring and enforcement
The ADWR monitors the total quantity of water from any source (including effluent) that has been withdrawn, diverted, received, used, and delivered, as well as an estimate of total lost and unaccounted for water. Every irrigation district, city, town and private water company must submit 1) an annual report that includes a map of the water distribution system, 2) the number of miles of lined and unlined canals in the system or the water mains, storage and treatment facilities, 3) the total quantity of water that was withdrawn, diverted, received, used and delivered, and 4) estimate of total lost and unaccounted for water.

The ADWR monitors IGFR water use through the use of annual reports, crop reports, energy use records, aerial photography, and remote sensing satellite-based data (ADWR, 1999c). The annual water withdrawal and use reports are the primary means for determining compliance with conservation requirements (ADWR, 1999c). Well-measuring devices and equipment are standardized and checked regularly. The ADWR reserves the right to conduct official audits of annual reports to verify the accuracy of annual reports. The ADWR also reserves the right to conduct field investigations and inspections. Budgeting constraints may strain the breadth and availability of investigation or audit procedures.

The ADWR supports a voluntary "consent order" approach to enforcement. This approach allows a water user in violation of the rules and programs to mitigate the violation in exchange for a waiver or reduction of the civil penalties. Such mitigation can include agreeing to adopt conservation measures, guarantee future compliance, or other strategies to mitigate the effect and impact of the violation.

Minor violations or non-compliance may be met with an advisory letter upon discontinuance of the violation (ADWR, 1999c). More serious violations may be met with fines, probationary periods, the development of mitigation programs, contested hearings, cease and desist orders, and civil penalties of up to $10,000 per day for violations directly related to illegal withdrawals, transportation, or use of groundwater (ADWR, 1999c). Criminal penalties may be imposed in extreme cases. A violation may bring further regulations upon a provider or user, and continued violations could bring about criminal penalties. However, the ADWR aims to promote cooperation, taking each violation on a case-by-case basis.

The ADWR publishes a report of Compliance and Enforcement Measures taken. For instance, in fiscal year 2009, the ADWR collected approximately $333,000 from compliance and enforcement related activities. Within that year, there were 15 Irrigation Grandfathered Rights out of compliance with their 2006 and 2007 flexibility accounts.

Financing

A portion of operating costs for the regulatory programs (permitting, Assured Water Supply, etc.) are generated through program administrative fees (such as AWS application fees, permit application fees, etc.). All other financing for the planning programs is derived from an annual appropriation to ADWR from the legislature. Budgets for ADWR have seen significant cuts in recent years, which has impacted ADWR's staff capacity and its ability to institute management plans pursuant to the statutory timelines.

Evaluation

For the Phoenix AMA, the goal of safe-yield is met when total annual basin extraction does not exceed recharge. This definition evaluates success on a basin-wide level and thus may overlook the localized impacts of pumping. Therefore, the AMA could meet its goal of safe-yield, and yet see significant groundwater declines in particular areas, which may cause subsidence, fissures, and/or increase the cost of pumping in those areas. Described as the "Swiss cheese" effect in the aquifer – areas surrounding recharge facilities swell with recharge, while areas surrounding wells see declining water levels. Recharging in the same areas that have significant pumping depressions could help mitigate this effect.

The strategies used in the Phoenix AMA neither place a firm limit on the annual volume of groundwater that may be pumped, nor for the most part, take into account the amount which may be sustainably pumped in order for safe-yield to be met. The major exception is for new developments, which must show they have a 100-year AWS that meets the goal of safe-yield. In the case of municipal providers participating in the MNPCCP, there is the risk that participants are incentivized by cost considerations to choose the lowest-cost BMPs, which may not be the most effective option. Agricultural users, on the other hand, may already be incentivized to use water efficiently, as the costs of pumping are quite high, and agricultural users are the first to lose their CACP supply in times of shortage on the Colorado River.

ADWR officials have reported progress in reversing decades of groundwater mining (Governor's Water Management Commission, 2001). The ADWR asserts that overdraft figures have not been climbing and the Phoenix AMA is near or has already attained safe-yield. However, it is not clear what the effect of the management strategies have been on this achievement. For example, while aggregate municipal extraction has declined as population has increased, it is not clear whether that is due to time trends, or to the requirements on municipal providers. Efficiency is expected to improve over time, with or without regulation.

In a few primary interviews, interviewees did not credit the AMA's achievement of safe-yield to the groundwater conservation measures specifically. Rather, credit has largely been given to the excess CAP surface water that the AMA has enjoyed. Agricultural users, in particular, have relied heavily on CAP water. However, by the year 2030, agricultural users will not have access to an incentive pool of CAP water and may replace a portion of that source with groundwater. In addition, CAGRD has earmarked CAP excess water for Assured Water Supply. However, projected shortages on the Colorado River may lead to an elimination of any CAP excess.

Finally, the ADWR has in the past faced severe budget cuts, while evolving management plans and their programs place more labor on the ADWR. For instance, each water provider regulated under the MNPCCP plan must have its plan reviewed and approved by the ADWR in order to be in compliance. Budget cuts are also to blame for the delay in adoption of the Fourth Management Plan for the AMA.

Even with these challenges and the various factors contributing to the reductions in groundwater declines, the aquifer underlying the Phoenix AMA has improved significantly from where it was prior to the adoption of the Groundwater Management Code. The provisions of the code, including the regulatory, incentive-based, and education and outreach tools, together with significant supply augmentation and protection due to source-switching from groundwater to Colorado River water via the Central Arizona Project, created the portfolio of approaches that has been critical for stepping back from significant overallocation and overuse. The Phoenix metropolitan area has essentially tripled in population since the code was enacted, and despite that the region has made significant progress towards safe yield. The combination of groundwater controls and the availability of a replacement supply created an environment that was remarkably successful in shifting water use over time away from unsustainable groundwater pumping.

Lessons learned

The following are key lessons from the Phoenix Active Management Area:

- An overarching safe yield goal for an entire groundwater basin will not address localized negative impacts associated with pumping depressions; considering spatial resolution is important to establishing a goal that will achieve the desired results.
- Basin management strategies that do not include enforcement provisions for limiting extractions are not likely to be effective in achieving safe yield.
- Tools and analyses for establishing baseline conditions and metrics are important for evaluating the effectiveness of groundwater management activities against external impacts.
- Designing successive management plans around evolving best management practices allows for the gradual implementation of stricter regulations and encourages the adoption of new technologies.

- Well-structured regulatory mechanisms can effectively and significantly reduce municipal and agricultural demand. Tiering the implementation of stricter regulations over time can give water users time to adapt to the increased regulations. Tiering also drives towards safe yield while not cutting off rights or impeding growth.
- Requiring demonstration of adequate water supplies and other BMPs incentivizes the creation of more data, modeling, and measurement, because applicants have incentives to develop increasingly sophisticated information about the aquifer, information is shared with the regulator and incorporated into the ongoing understanding of the system.

Resources

Interviewees and case study reviewers: Thank you to Peter Culp (Managing Partner, Culp and Kelly, LLP), Jennifer Diffley (Junior Partner, Culp and Kelly, LLP), Michelle Moreno (Public Information Officer, Arizona Department of Water Resources), and Steve Olson (Principal, Olson Policy Services) for their time and insights in constructing this case study.

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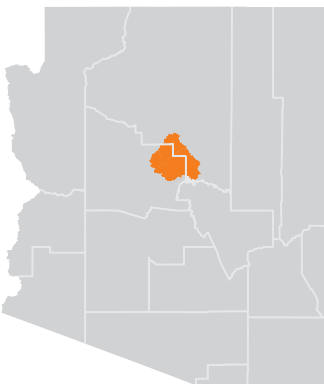


CASE STUDY 2 / ARIZONA

Verde River Exchange

AUTHOR

Chris Kuzdas

CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

Lowering of groundwater levels

Surface water depletion

PREDOMINANT WATER USES

Agricultural

Urban

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Incentive-based

- Voluntary groundwater offset program

Education and outreach

See page 37 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- Transparency, trust, and thoughtful local engagement provide an essential foundation to successfully implement new programs to deal with groundwater issues.
- Carefully convening diverse local interests can over time provide a powerful platform to discuss, deliberate, and implement locally acceptable and appropriate solutions.
- Groundwater mitigation can be done in a way that allows growth and development, while securing water supplies for the future.
- Developing groundwater mitigation policies and procedures that are effective and workable takes time and requires a deep understanding of local places and state level context.
- Respecting local water and property rights, as well as the diverse needs of water stakeholders, is critical for developing mitigation structures that are effective and feasible.
- Despite a complex array of state and federal water law and water rights structures, workable mitigation structures can still be developed to overcome broader institutional hurdles.
- Effective mitigation requires a dedicated and committed group of individuals to provide ongoing support and management, as well as dedicated staff and program resources.

Background and governance

Within Arizona's growing Verde Valley region, which includes the cities and towns of Clarkdale, Cottonwood, Camp Verde, and Sedona, groundwater is the sole potable water supply for residents.

The Verde River Basin (Figure 2.1) covers 6,230 square miles, and the Verde River is one the last remaining perennial, free flowing rivers in the Southwestern U.S. A large portion of the river—from Beasley Flat to Horseshoe Reservoir—is a federally designated "Wild and Scenic River" (USDA, 2004). Nearly all of the river's flow in the upper section near its headwaters, which begins 21 miles north of Prescott, originates as spring water in two groundwater basins, the Big Chino and Little Chino Basins.

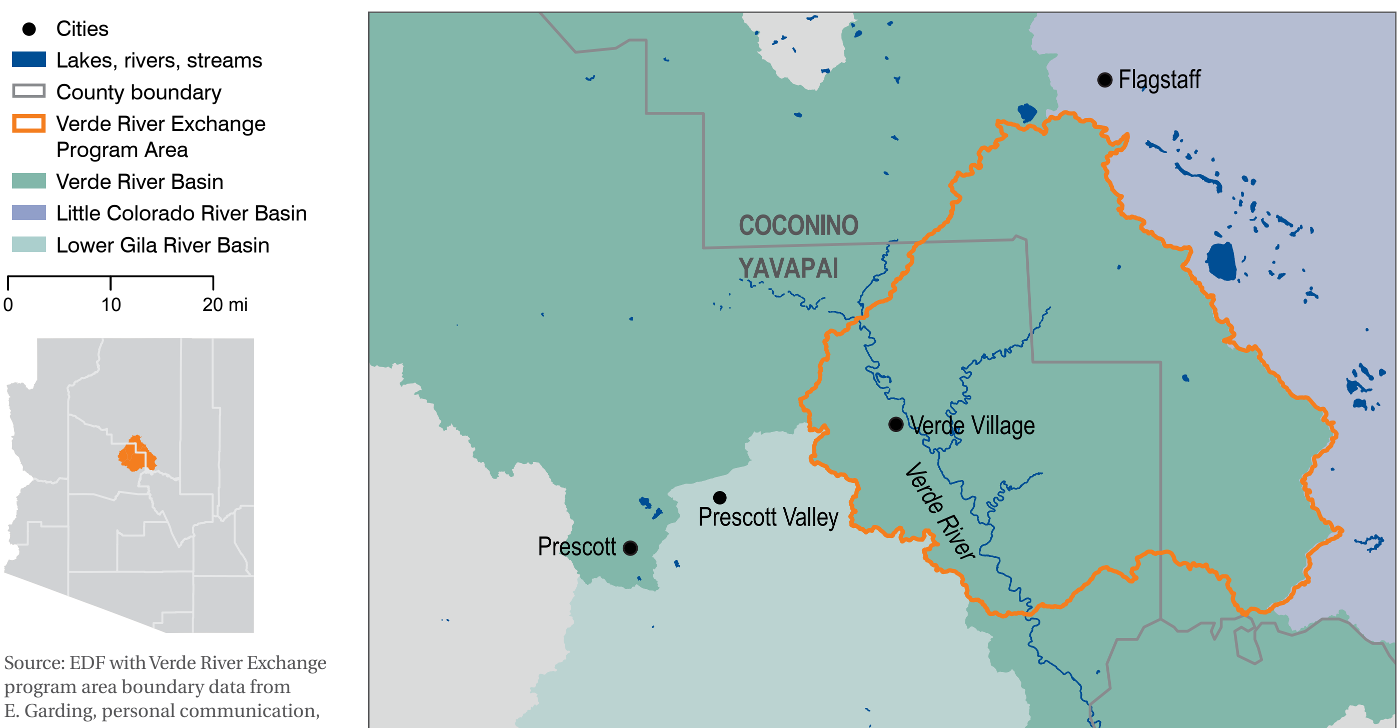
The Verde provides important habitat for a large diversity of fish and wildlife species, including the endangered Southwest Willow Flycatcher and the Razorback Sucker. The Verde corridor contains one of the last remaining Fremont Cottonwood/Goodding Willow gallery forests in the world (TNC, 2016). Research has found that up to 80% of species present in the region rely in some way on the river's riparian corridor in their life cycles (Neary et al., 2012).

The river is also critical in supporting the agricultural, rural lifestyle and high quality of life found in the Verde Valley. Agriculture and ranching are prominent in the basin, and agriculture is primarily composed of small and medium-sized farms and cattle ranches. Primary crops grown in the valley include hay, corn, fruit trees, and wine grapes. In recent years, the Verde Valley has gained recognition as a wine-producing region, with the industry's total economic contribution to the region estimated at about $25 million annually (Glenn, 2011). In total, researchers have suggested that 16% of the Verde Valley's economy can be directly attributed to the river—including around $90 million earned from river-related recreation and tourism (Verde River Basin Partnership, 2016). The Verde River also is a significant water supply for the Phoenix area.

In recent decades, communities in the Verde Valley have experienced rapid population growth, increasing from about 15,000 residents in 1980 to 55,000 in 2000 and about 65,000

FIGURE 2.1

Verde River Exchange



Source: EDF with Verde River Exchange program area boundary data from E. Garding, personal communication, August 10, 2017 residents in 2010 (Verde River Basin Partnership, 2016). As the Verde Valley region has grown, the number of wells pumping groundwater has also grown, increasing from about 200 wells registered in 1950, to over 6,000 wells registered in 2010. Over a recent ten-year period, the Arizona Department of Water Resources (ADWR) estimated that water tables at many locations in the region have been declining, including in Clarkdale and Cottonwood (ADWR, 2009; Verde River Basin Partnership, 2015). Further, since groundwater provides the base flow of the Verde River (Leake & Pool, 2010), increased groundwater pumping reduces flows in the Verde River over time. This is compounded by drought and other threats. In recent years during summer months and at certain diversion points in the Verde Valley, some stretches of the river have registered minimal or no flows, largely due to inefficient diversion structures that divert most of the river's flow.

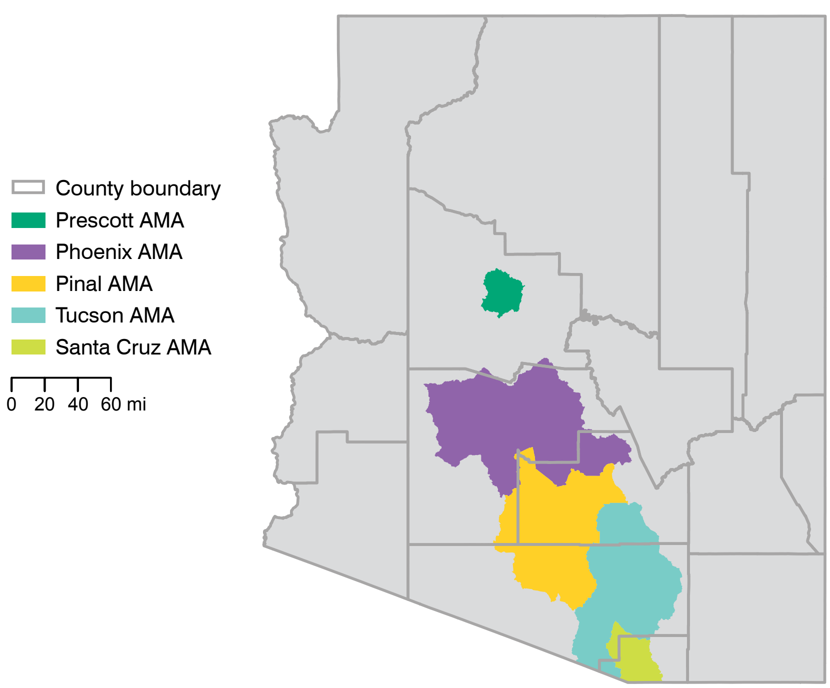
In 1980, the Arizona legislature passed the Groundwater Management Act, an extensive legal framework for regulating groundwater. Prior to this legislation, few restrictions were in place to limit groundwater use. The law established Active Management Areas (AMAs) only in the regions where groundwater overdraft was most severe (Figure 2.2), leaving groundwater outside these areas largely unregulated. See the Phoenix case study (page 20) for more about groundwater management within Arizona's AMAs.

NOTE: With the exception of the Prescott AMA where groundwater within the AMA is regulated, groundwater in the Verde River Basin, and throughout many rural parts of Arizona, remains largely unregulated and the adjudication process for surface water rights is ongoing.

While the Groundwater Code does allow for creation of new AMAs, such propositions are extremely controversial in most rural areas, and may be viewed by residents as unresponsive to local needs or as an intrusion on property rights. In the San Pedro region there have been a

FIGURE 2.2

Arizona Active Management Areas



Source: EDF with AMA boundary data from ADWR Open Data, 2017 number of efforts to create a more customized management structure, similar to an AMA, but as of this writing, none of these efforts have succeeded.

In the Verde River Basin, and throughout many rural parts of Arizona, groundwater remains largely unregulated and rights to surface water have yet to be finally adjudicated. The Prescott AMA where groundwater within the AMA is regulated, is an exception in the Verde River Basin. The Arizona General Stream Adjudication process was initiated in the 1970's as a result of a number of lawsuits seeking to clarify conflicting rights and address the need to establish claims to water for tribal land based on Federal Reserved water rights. While the adjudications have been ongoing for decades, the validity, quantity, and priority of most water rights in the state remain unresolved.

One of the most complicated issues being addressed in the adjudications is the bifurcated system of management of surface water and groundwater. In Arizona water law, there is minimal recognition of the connection between surface water and groundwater. Therefore, the courts must determine how and where tributary groundwater becomes surface water. These two types of water are managed under two completely separate legal systems. Groundwater outside of established management areas, in non-AMA Arizona, is largely managed under a "reasonable use" doctrine, meaning groundwater can be pumped regardless of impacts if that water is put to reasonable and beneficial use. Surface water is managed under the prior appropriation doctrine, a system of "first in time, first in right," where the first person to put the water to beneficial and reasonable use acquires a right superior to later appropriators. This situation has been in place for so long that considerable financial commitments and investments have been made and management planning has occurred around the ambiguities created by this bifurcation.

Within the Verde Valley, many wells may be determined to be drawing water from the Verde's "subflow" zone (Pool et al., 2011). The Arizona Supreme Court has defined subflow as "…those waters which slowly find their way through the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream." (*Maricopa County Mun. Water Conservation Dist. No. One v. Southwest Cotton Co.,* 1931). This has significant implications on the in-process adjudication of surface water rights in the Verde region. It is uncertain how many wells will be found to be pumping "subflow" and thus to require a historic surface water right. At the same time, even groundwater outside the legal subflow zone is ultimately hydrologically connected to surface water resources in the area (Leake & Pool, 2010). If not mitigated, continued and increased groundwater pumping will reduce flows in the Verde River over time (Marshall et al., 2010).

The Verde River Exchange

The Verde River Exchange (the Exchange) is currently a small, voluntary, pilot groundwater mitigation program. It arose from discussions among community leaders and water experts concerned about the threats facing the Verde River and their implications for the long-term prosperity of the region, as well as the lack of existing and workable management tools for addressing these challenges. Starting in 2013, a small, diverse group of Verde Valley stakeholders began an exploratory process and dialogue that eventually led to the creation of the Exchange. The group agreed on a set of working principles, based on trust, respect, and the importance of locally developed and managed solutions. All parties shared a broad interest in a prosperous future for the Verde Valley that included a healthy Verde River. Ultimately, the group sought a way forward that respected water and local property rights, that allowed for growth and development to proceed in the Verde Valley, and that protected river flows.

While some Verde-area leaders have been involved in these issues for decades, and there had been growing interest in determining what locally driven approaches might offer a viable way forward to deal with water challenges in the Verde region (i.e., Garrick et al., 2011; Limbrunner et al., 2011), there are few relevant pilots and programs within the state of Arizona from which to learn. Consequently, the stakeholder group in the Verde Valley invested significant time and effort in detailed examination of Arizona water policy, rights, and institutional context, and in sharing information about solutions that had previously been discussed in the watershed. The group also invested in learning from other parts of the American West where communities were confronting similar water supply challenges. As a result of this shared vetting effort, the group agreed to further pursue a groundwater offset approach based on voluntary mitigation and market-based concepts. Using market-inspired concepts as a base, the group worked to specify a locally viable mechanism and procedure by which current or existing groundwater users could voluntarily offset the impact of their pumping on the Verde River's flows. To implement this mechanism, the group developed a program to test, demonstrate, and implement the offset mechanism, called the Verde River Exchange (verderiverexchange.org).The Exchange builds on similar groundwater mitigation programs in other states (though these have typically been in a regulatory, rather than voluntary, context). The group itself also evolved into a local Advisory Council to help govern the Verde River Exchange and to develop the incentives, guidelines, and procedures for the mitigation program. The Exchange is administered by local non-profit Friends of Verde River Greenway, and the Advisory Council consists of a group of local stakeholders, including partner non-profit organizations, water users, experts, and community leaders. The Exchange was launched in the summer of 2016 with the announcement of two pilot mitigation projects. Two vineyards, Page Springs Cellars & Vineyards and Caduceus Cellars/Merkin Vineyards purchased credits through the Verde River Exchange to offset a portion of their groundwater use for the year. The credits were created when another irrigator agreed to forego nearby water use on their pasture. As of spring 2017, the Exchange program is working to expand the program and increase the number of projects and program participants.

NOTE: EDF is a partner on the Verde River Exchange Advisory Council, along with The Nature Conservancy and a number of representatives from other local interests.

Program management goals

The Verde River Exchange works toward achieving the following goals:

- Provide an opportunity for local water users in the Verde Valley to voluntarily reduce their water footprint while protecting river flows and water supplies for the future.
- Ensure a prosperous future in the Verde Valley by demonstrating a voluntary groundwater mitigation tool that could allow for continued development and growth while protecting river flows and their cultural, economic, and ecological benefits.
- Develop and demonstrate a locally-based, solutions-oriented program that can provide an example of a viable approach for addressing groundwater challenges in rural Arizona.

Tools used to achieve management goals

The Exchange is a voluntary program, and thus relies on incentive-based tools and education and outreach to help manage groundwater in the Verde Valley.

Incentive-based tools

Voluntary groundwater offset program

The Exchange provides an incentive-based mechanism for current and future water users in the Verde River watershed to voluntarily offset the impacts of increased water use. The Exchange aims to reduce the total amount of water removed from the river and its connected groundwater system through a "balancing," or offset mechanism. To do this, the Exchange works with a water user who is willing to voluntarily reduce their recent and historic water usage. This unused water is then recorded by the Exchange as a "water offset credit"—water that has been returned to the Verde River system. These credits are purchased by another water user who seeks to reduce their "water footprint" and the impacts of their groundwater use. Through this offset mechanism, the voluntary program demonstrates how new and continued uses of groundwater may be maintained while minimizing net impacts on the system.

The offset mechanism employed by the Exchange functions through supply and demand. Mitigation "supply" refers to projects that reduce consumptive use, thus "supplying" credits to the program. Mitigation "demand" is created by a groundwater pumper who purchases the credit that has been generated based on a supplier's reduction in use.

Supply and demand need to be thoughtfully matched to ensure that the mitigation supply is appropriate to offset the mitigation demand. The geographic location of a specific water use is a major determining factor for its suitability as a mitigation project. To address this issue, the Exchange divides the Verde Valley into three distinct mitigation zones based on hydrologic and water use characteristics. A buyer must purchase mitigation in an appropriate mitigation zone. Matching mitigation supply and demand by zone ensures that water offset credits created and retired on behalf of the buyer will offset their use in a nearby location, and thereby advance the goals of the Exchange.

Mitigation supply projects involve making temporary changes to existing surface water or groundwater uses to reduce consumptive use and generate mitigation credits. The Verde River Exchange and its partners select supply projects based on established program criteria and due diligence that includes a review of relevant water use and water right information.

Although other types of supply projects will be explored in the future, forbearance agreements are currently the primary contractual tool for mitigation projects. A forbearance agreement is a contract with a water user to abstain from the use of all or portion of their water for a given period. Currently the Exchange records credits based on forbearance agreements that involve reducing or ceasing water use (generally irrigation water use) for a few months to a full irrigation season. The volume of unused water resulting from the supply project is estimated based on a standard set of procedures and guidelines that have been developed, and is recorded as a "water offset credit" by the Verde River Exchange.

On the "demand" side, mitigation buyers purchase water offset credits for a given year, allowing others to be paid to use less. The Exchange uses conservative trading ratios to account for uncertainties and assumptions in the calculation of consumptive use: the mitigation buyer is required to purchase mitigation that is 1.25 times the amount of the groundwater use that is being offset.

Generally, mitigation buyers are groundwater users within the Verde River Exchange project area who are interested in reducing their "water footprint." To be eligible to purchase credits, buyers either have an existing groundwater use; or are new users (with uses beginning after January 1, 2015) whose groundwater withdrawal location is outside of the mapped floodplain Holocene alluvium. Thus far (as of spring 2017), the Exchange has worked only with existing (as opposed to new) groundwater users as buyers. To effectively offset uses associated with new development, different and longer-term sources of supply will need to be developed

Mitigation buyers receive a Water Offset Certificate that commemorates their participation in the Exchange and documents their purchase of water offset credits. Certificates represent an offset of water use, in acre-feet, for the calendar year in which the certificate is issued. The offset can be renewed annually, contingent on available supply. Recognizing that participants may include numerous types of water users (for example irrigators such as vineyards; hospitality industry users; other commercial water users; and individual domestic users), the Exchange has developed policies and guidelines that facilitate the involvement of specific types of water uses and users such as residential, agricultural, and other specific types of commercial users.

Education and outreach

Targeted education and community outreach are an important part of the strategic mission of Friends of Verde River Greenway and its Verde River Exchange program. Transparency and building local trust have been and continue to be important focus points of the new program. The Exchange's Advisory Council includes a diverse set of local stakeholders and water interests, and members play an important role ensuring that the Exchange continues to play a valuable and constructive part in the local Verde Valley community. The Exchange recognizes mitigation credit buyers in public forums, events, and on its website and provides buyers with certificates that can be displayed publicly and that draw attention to the contribution the buyers have made in helping to offset the negative impacts of groundwater pumping in the region. Exchange representatives also regularly meet with stakeholders individually and in small groups, and give presentations to various water and community interests regarding the new program. The Exchange is also continuing to produce educational materials for both credit sellers and buyers who are interested in participating in the program, and further uses its materials and presentations as a platform to engage the community more broadly and enhance awareness of water issues in the region.

Monitoring and enforcement

Mitigation supply projects are typically implemented through contracts that include monitoring provisions to verify contract compliance and successful project implementation. The Exchange has also partnered with the Bonneville Environmental Foundation (BEF) in order to provide a means of third-party verification of mitigation supply projects. The verification process, while still evolving, currently involves a review by BEF based on a project evaluation checklist, to ensure that projects meet program criteria. The Exchange is also exploring the potential of registering credits with Markit™ Environmental Registry through a partnership with BEF's Water Restoration Certificate program.

Financing

The Verde River Exchange program aims to be financially sustainable in the long term, and is working towards this goal as a part of its strategic plan. While individual groundwater users purchase water offset credits, general program activities are currently funded through philanthropic partners and supporters of Friends of Verde River Greenway and its partners.

Evaluation

While in its early stages, in general the initial pilot projects and the launch of the Verde River Exchange program have been received positively by the community. The Exchange has made extensive and thoughtful efforts from the beginning to discuss the program with interested parties, solicit feedback, and share information about the mechanics and benefits of the program. The Verde River Exchange has made a successful start in demonstrating that groundwater mitigation concepts can work in the Arizona context- as evidenced in part by the selection of the Exchange as one of five finalists in Arizona's state-wide Water Innovation Challenge in 2016, an event that was sponsored by The Arizona Community Foundation, the Morrison Institute for Public Policy, and Republic Media. The Exchange has developed the tools, internal policies and procedures, and management structure to continue building a robust program into the future. To build on the initial success of the program, the Exchange and its Advisory Council have developed a longer-term strategic plan and continue to reflect on the first year of success along with what, if any, adjustments to internal program policies and procedures might be needed as the program expands into the future. Since the Exchange is housed within Friends of Verde River Greenway, the Exchange undergoes a standard, regular program evaluation and strategic planning processes, and engages in ongoing dialogue with community members and stakeholders about the program's strengths and challenges.

Lessons learned

The following are key lessons from the Verde River Exchange:

- Transparency and thoughtful local engagement provide an essential foundation to build trust and successfully implement new programs to deal with groundwater issues.
- Carefully convening and facilitating diverse local interests can over time provide a powerful platform to discuss, deliberate, and implement locally-appropriate and acceptable solutions.
- Groundwater mitigation can be done in a way that allows growth and development, while securing water supplies for the future.
- Developing groundwater mitigation policies and procedures that are effective and workable takes time and requires a deep understanding of local places and state level context.
- Respecting local water and property rights, as well as the diverse needs of water stakeholders, is critical for developing mitigation structures that are effective and feasible
- Despite a complex array of state and federal water law and water rights structures, workable mitigation structures can still be developed to overcome broader institutional hurdles.
- Effective mitigation requires a dedicated and committed group of individuals to provide ongoing support and management, as well as dedicated staff and program resources.

Resources

Interviewees and case study reviewers: Thank you to Benjamin Bryce (Law and Sustainability Fellow, Arizona State University), Jocelyn Gibbon (Principal, Freshwater Policy Consulting, LLC), Chip Norton (President, Board of Directors, Friends of Verde River Greenway), Steve Olson (Principal, Olson Policy Services, LLC), Kim Schonek (Verde River Water Transactions Manager, The Nature Conservancy), and Anne Mariah Tapp (Principal, Canyon Country Consulting, LLC) for their time and input in constructing this case study.

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CASE STUDY 3 / CALIFORNIA

Kings Basin

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CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

Lowering of groundwater levels

Reduction of storage

Degraded groundwater quality

PREDOMINANT WATER USES

Agricultural

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Incentive-based

- Managed aquifer recharge (landowner lead)
- Transfer systems for surface water rights
- Best management practices (with cost-share)

Agency supply augmentation and protection

- Managed aquifer recharge (agency lead)
- Infrastructure upgrades (paid for by agency)
- Reservoir operation

Education and outreach

See page 44 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- Data-driven models and robust outreach efforts can demonstrate that local groundwater problems often require basin-level solutions. This helps unite stakeholders around common management goals.
- Inclusive regional management plans can encourage, prioritize, and help fund integrated, collaborative tools to achieve multiple basin management goals.
- Developing and implementing regional projects is key to building trust among basin stakeholders.

Background and governance

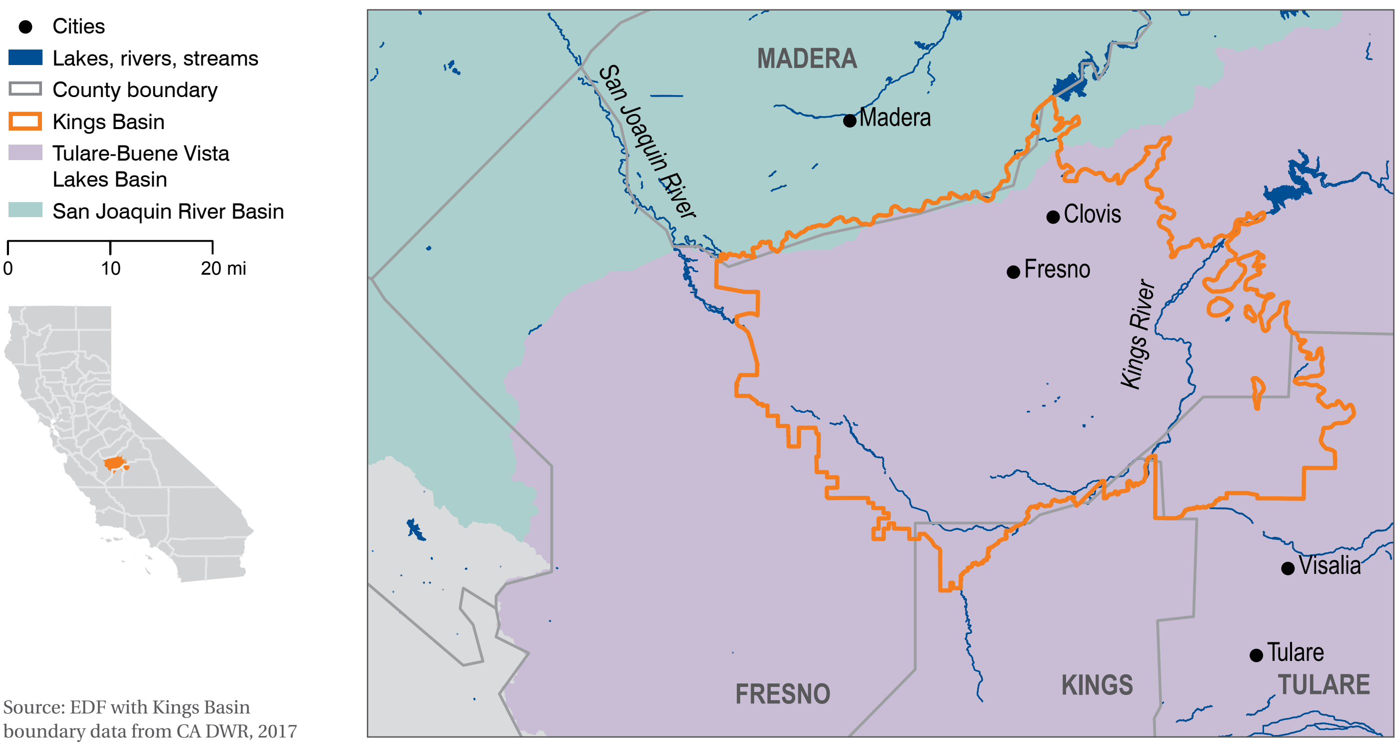
The Kings Basin, a sub-basin of the San Joaquin Valley Groundwater Basin, covers 1,540 square miles, including parts of Fresno, Kings and Tulare Counties (Figure 3.1). The basin is in chronic overdraft. On average, it loses between 100,000 and 160,000 acre-feet of groundwater each year from an estimated total storage capacity of 93 million acre-feet (Kings Basin Water Authority, 2012). In some portions of the basin, this pattern of over-extraction has created the threat of total dissolved solids (TDS) and nitrate migration in the water table. Water quality degradation associated with these contaminants has compromised water security for several communities that rely exclusively on groundwater (Kings Basin Water Authority, 2012).

Groundwater in the basin generally flows from the northeast, where soils are more rechargeable, to the southwest, where thick clay in some portions of the region limits recharge potential (Water Resources and Information Management Engineering, Inc., 2007). The two major sources of surface water are the San Joaquin River and the Kings River. Both provide water for irrigation and groundwater recharge, distributed through an extensive canal network maintained by federal and local agencies. The Kings River and its tributaries also support habitats for fish (though never a consistent anadromous fishery) and migrating birds (Kings Basin Water Authority, n.d.-b).

The Kings Basin supports significant agricultural production, with crops ranging from grapes and figs to nuts and stone fruit. Irrigated lands are the largest source of water demand in the basin and comprise roughly 75% of the total basin area; 12% is in urban use and the remaining 13% is undeveloped (D. Orth, personal communication, November 14, 2016). The largest urban center is Fresno with a population of 980,000 (U.S. Census Bureau, 2016). Anticipated shifts from agricultural to urban land use and from temporary to permanent crops within the agricultural sector can have profound impacts on water use within the basin, but it remains to be seen how much the passage of the 2014 Sustainable Groundwater Management Act (SGMA) will affect these trends going forward. SGMA created the first statewide mandate in California to manage groundwater sustainably. It will require several parts of the state to reduce water use from historic levels.

FIGURE 3.1

Kings Basin



Source: EDF with Kings Basin boundary data from CA DWR, 2017

Groundwater management efforts by several agencies and private entities in the Kings Basin have been underway for some time prior to SGMA. Among many others, the Kings River Conservation District (KRCD), the Kings River Water Association (KRWA), and the Kings Basin Water Authority (KBWA) have facilitated water management planning, groundwater monitoring and data collection, regional project development, water delivery and recharge, and more. Historically, however, local agency efforts were not well aligned as each managed only for the water resources within their respective boundaries. This lack of coordinated data collection and planning efforts limited the potential for meaningful solutions to the shared issues threatening groundwater resources (Tufenkjian, 2013).

Senate Bill (SB) 1938, passed in 2002, spurred creation of four groundwater management plans in the basin. These plans formalized existing management efforts, in partnership with the California Department of Water Resources (DWR) and other local entities, to regularly study groundwater levels and to execute voluntary recharge projects. They reflected a statewide effort to increase coordination to address groundwater issues, which persisted in the basin.

FACT: The California state legislature passed Assembly Bill (AB) 3030 in 1992 to provide local water agencies resources to manage groundwater and encourage coordination between local entities through joint-power authorities or a Memorandum of Understanding. SB 1939, passed in 2022, created requirements for groundwater management plans as eligibility criteria for state funding, including documentation of public involvement, Basin Management Objectives, and monitoring protocols.

KBWA emerged from efforts by KRCD, Alta Irrigation District, Consolidated Irrigation District, and Fresno Irrigation District in 2009 to expand regional collaboration and planning beyond the SB 1938 plans (Tufenkjian, 2013). As of 2012, the Authority was comprised of 17 official members and 37 interested parties, representing cities, counties, water districts, and environmental and environmental justice organizations. Together, they developed the Kings Basin Integrated Regional Water Management Plan (IRWMP). The plan provides a forum for assessing regional needs, joint management planning, and prioritizing applications to state IRWMP funding for water management projects. However, participation in the Plan is voluntary and does not require local jurisdictions to meet any objectives related to the groundwater depletion, supply reliability, and water quality challenges facing the basin.

Basin management goals

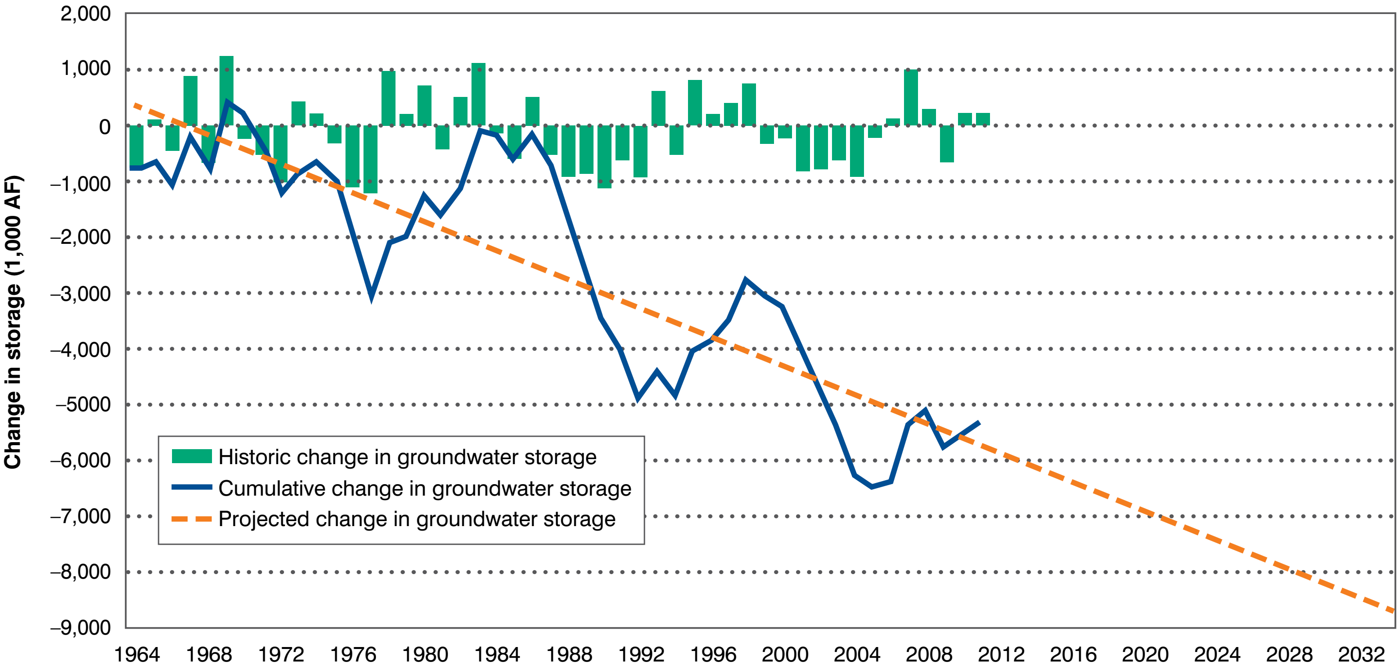
The Kings Basin has been operating under severe overdraft conditions for many years (Figure 3.2, page 43). California's five-year drought, as well as operational changes to statewide water delivery systems resulting from endangered species protections in the Sacramento-San Joaquin River Delta and pumping actions in adjacent basins, has exacerbated this rate of depletion. Groundwater quality, closely tied to water availability, is another ongoing challenge for the Kings Basin. In several areas, declining water tables have resulted in the migration, infiltration, or concentration of contaminates—in particular, TDS and nitrates (KBWA, 2012).

The IRWMP for the Kings Basin was developed to achieve the following goals:

- Halt, and ultimately reverse, current overdraft and provide for sustainable management of surface and groundwater;
- Increase water supply reliability, enhance operational flexibility, and reduce system constraints;
- Improve and protect water quality;
- Provide additional flood protection; and
- Protect and enhance aquatic ecosystems and wildlife habitat.

FIGURE 3.2

Change in Kings Basin groundwater storage by year



Source: Kings Basin Integrated Regional Water Management Plan, 2012

Tools for achieving management goals

Water managers in the Kings Basin use an array of strategies to encourage more sustainable water use.

Incentive-based tools

Managed aquifer recharge (landowner lead)

On-farm irrigation and distribution systems help reduce overdraft when surface water intentionally delivered in excess of demand seeps through unlined ditches or fields to replenish groundwater. Both local water agencies and landowners have a strong incentive to manage available water resources conjunctively because capturing flood flows for recharge, for example, can be a much less expensive source of water to replenish groundwater supplies that basin water users depend upon than water purchased in dry years from the state water market at premium prices.

More recently, in 2011, KRCD and Sustainable Conservation, an NGO, initiated a pilot project to spread high-flow floodwaters across farmland (J. Choperena, personal communication, August 19, 2016). Such projects, like the Terranova Ranch On-Farm Flood Capture and Recharge Project, have the potential to boost the basin's average annual water supply by tens of thousands of acre-feet (California Roundtable on Water and Food Supply, 2015). This approach also preserves croplands by preventing their conversion to single-use recharge areas.

Nitrate levels in many groundwaters in the Kings Basin have increased over the past several decades due to the expansion of agricultural practices and other human sources like wastewater treatment plants. Some irrigation districts in the region are concerned about applying flood-water on farmland due to the potential to infiltrate nitrates from agricultural soil into the water table and consequently further degrade water quality. Targeted pumping efforts, recharge of clean water sources, and proper nutrient management practices, however, may have the potential to help dilute or mitigate contaminant concentrations in some cases (Harter, et al., 2012).

Other complications associated with recharging croplands include the potential for floodwater to damage or kill crops, depending on the time of year and type of crop. Farmers would like compensation for bearing this risk. Some irrigation districts in the Kings Basin are currently discussing a program to provide this incentive (D. Orth, personal communication, August 17, 2016).

Transfer systems for surface water rights

Aging infrastructure, urban growth, diminishing supply, and rising treatment costs pose water quality and quantity challenges to Kings Basin municipalities that rely entirely on groundwater (KRCD, 2007). The Cities of Clovis and Fresno have constructed surface water treatment facilities and implemented a water transfer program with Fresno Irrigation District (FID) to reduce reliance on stressed groundwater resources. Use of existing surface water, delivered by FID to the cities in-lieu of groundwater, helps reduce overdraft and leaves more water in the aquifer for withdrawal during dry years. The incentive driving this exchange is the cost of developing alternative water supplies for each use.

Similarly, Alta Irrigation District (AID) is developing a water exchange program to simultaneously address water quality issues and recharge the basin (AID, 2012). Disadvantaged communities with limited potable groundwater will receive treated surface water from the Kings River to help meet their drinking water needs. In exchange, these communities reduce their groundwater use, effectively banking groundwater reserves for irrigators to draw from later. This system should reduce localized hydraulic mounds in and surrounding some small communities that may be high in nitrites and relocate the water to agricultural areas in the region for irrigation and nitrogen uptake (E. Osterling, personal communication, May 19, 2017).

Best management practices (with cost-share)

Water agencies in the Kings Basin have supported implementation of a number of best management practices in the region through individual district subsidy programs, in particular funding well meter installations and irrigation system reviews to optimize delivery efficiency for water users. Water agencies also provide support in applications for state funding, such as the IRWMP grant program. Basin agencies have provided funding matches for IRWMP projects involving basin water users that advance water recycling, well metering, floodwater capture and utilization for recharge, and more.

Agency supply augmentation and protection

Managed aquifer recharge (agency lead)

A number of basin agencies have invested in dedicated recharge basins to enhance groundwater supplies. Currently, agencies in the Kings Basin maintain over 10,000 acres of recharge ponds and flood control basins with the capacity of recharging over 100,000 acre-feet of water in a single year (E. Osterling, personal communication, May 19, 2017).

Reservoir operation

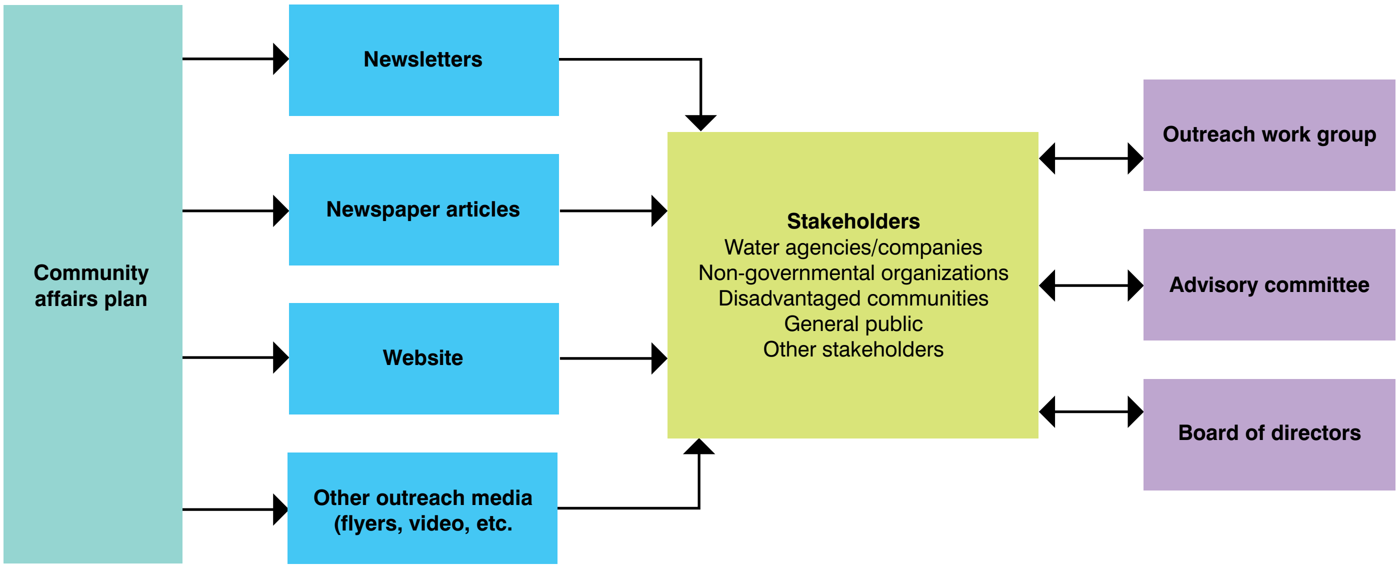
Three entities manage the Pine Flat Reservoir on the Kings River through a cooperative agreement: (1) The U.S. Army Corps determines flood releases, (2) KRWA manages the conservation storage, and (3) KRCD operates the hydropower plant. The reservoir successfully captures, conserves, and manages the runoff from the Kings River that is not released to retain reservoir capacity for flood control; downstream water agencies can capture flood releases for groundwater recharge when they occur, as discussed above.

Education and outreach

Groundwater management in the Kings Basin is largely a stakeholder-driven process. The IRWMP began identifying and engaging stakeholders—including water agencies, counties, environmental justice communities, recreational interests, fishery advocates, and others—in

FIGURE 3.3

The Kings IRWMP Community Affairs Plan



Source: Kings Basin Integrated Regional Water Management Plan, 2012

2004 to help develop the plan (KRCD, 2007). The governance structure for the KBWA today fosters collaborative resource management by providing opportunities for participation and joint project development. For example, local disadvantaged communities that cannot afford the cost of becoming official members of the joint powers authority can still participate in IRWMP planning as non-paying Interested Parties (KBWA, 2012). Following the Community Affairs Plan (Figure 3.3), an Outreach Work Group now leads stakeholder engagement efforts for the IRWMP. These include maintaining a website, public meetings, and distribution of numerous newspaper articles, e-mails, and printed materials.

Outreach involving the Kings Integrated Groundwater and Surface Water Model (Kings IGSM) was instrumental in bringing the IRWMP's diverse parties together. The data-driven, analytical tool reveals groundwater and surface water interactions in the basin and helped IRWMP members collectively understand groundwater conditions, both locally and regionally. Using the model, IRWMP members could evaluate how different water management strategies, such as distributed recharge, would affect water supply and quality. That understanding helped spur joint action towards basin management goals.

NOTE: Well permitting is not included in this case study as a tool used by the local water management agencies to achieve management goals because cities and counties in the Kings Basin are responsible for permitting well construction, alteration, and destruction activities Permits to drill wells in unincorporated areas in the basin are issued by the Fresno County Department of Public Health, Division of Environmental Health; the Kings County Community Development Agency, Building Division; and the Tulare County Environmental Health Services Division. Incorporated cities in the counties issue permits for wells drilled within their boundaries.

Monitoring and enforcement

To inform management efforts, KRCD began monitoring groundwater trends in 1987 using voluntarily submitted data from various local, state, and federal agencies. Today, KRCD publishes annual groundwater level reports based on data obtained from about 1,100 production wells and dedicated monitoring wells across the region based on monitoring records from 19 different agencies (KBWA, 2012). KRCD does not maintain a database of metered groundwater-use data, but approximates use by tracking water-table depth.

KRCD well level data helped inform development of the Kings IGSM by the KBWA, discussed above, which simulates surface water and groundwater systems in the entire Kings Basin (KRCD, 2007). The model, developed in 2007, evaluates water supply and flood management outcomes under different scenarios, such as climate change and increased pumping.

KRCD and other water agencies are currently discussing how or if a local numeric model could be utilized for SGMA. Discussions are also underway regarding how to continue to balance privacy interests of well owners with the need to better understand basin conditions in order to create solutions to persistent threats created mostly by overdraft. The district would like to collect more depth data by installing additional dedicated monitoring wells and daily data loggers, but that effort may soon be carried forward instead by newly formed Groiundwater Sustainability Agencies (E. Osterling, personal communication, May 19, 2017).

In 2003, the Regional Water Quality Control Board initiated the Irrigated Land Regulatory Program (ILRP) to prevent agricultural runoff from impairing surface waters. The program expanded to include groundwater in 2012. Growers in the Kings Basin (and throughout California) are now required to monitor their water quality and take corrective actions when impairments are found. Using ILRP data and on behalf of the Kings River Water Quality Coalition Authority, KRCD is in the process of establishing regional accounting of on-farm nitrate use in an effort to keep surplus nitrates from leaching into the water table (D. Orth, personal communication, August 16, 2016).

Beyond ILRP, there has been no regulatory driver for groundwater data collection in the Kings Basin. Efforts by KRCD and others to maintain information on groundwater conditions and develop groundwater models have only informed the voluntary management efforts described above.

Financing

Water agencies in the Kings Basin accrue funds through various methods. Irrigation districts raise revenue through water delivery charges based on the volume of surface water delivered to customers. KBWA, though, is funded by an annual dues payment paid by each member (KRCD, 2007). IRWMP stakeholders also contribute the use of facilities, such as canals, and volunteer their time for plan operations and implementation.

FACT: Proposition 218 in California, passed in 1996, constrains local agencies' abilities to raise funds beyond the cost of service (i.e., the cost of water delivery) by requiring a vote on any increases in tax, assessment, or certain user fees. This limits the availability of many management strategies for local agencies. Districts may also issue bonds of indebtedness to finance projects, though highly leveraged districts, subject to debt limits, may have only limited capacity to do so.

The IRWMP also receives funding from state, federal or private grants and loans, which typically help fund infrastructure projects. Since 2001, the Authority has leveraged over $35 million in financial support for use toward planning activities and to construct projects that address multiple program management goals, from water conservation to critical water quality needs of disadvantaged communities (DACs) in the basin (KBWA, n.d.-a). Some DACs, especially smaller ones, lack the resources to cover the full cost of preparing funding applications for such grants. KBWA charges a nominal amount to some of these communities to cover application preparation costs. This provides a demonstrated financial commitment from DAC beneficiaries while welcoming their active engagement in addressing water issues.

A variety of other entities have helped fund implementation of water management tools in the basin. Recharge projects beyond the IRWMP are sometimes funded by private foundation grants. Companies such as Coca-Cola and General Mills have funded some recharge projects to ensure that their supply chain is resilient to future water shortages and that they can continue sourcing crops in California (J. Choperena, personal communication, August 19, 2016). The Almond Board of California has partnered with Lawrence Berkeley National Laboratory to better understand the potential of using California's almonds orchards for groundwater recharge (Nidver, 2016).

Evaluation

The Kings Basin suggests what is possible when diverse interests in water management recognize their interdependency and work together towards common goals. Prior to the IRWMP, independent management efforts among the many basin water agencies only exacerbated groundwater problems (Tufenkjian, 2013). Although the IRWMP is non-regulatory and participation in projects is optional, as consistent with state law, the forum provided by the KBWA helped promote common goals and mutually beneficial solutions.

One of the most important factors in bringing the many IRWMP stakeholders together was outreach conducted with the Kings IGSM. By displaying current groundwater conditions and projecting future basin impacts associated with individual actions, the data-driven model illustrated the need to make local management decisions from a basin perspective (D. Orth, personal communication, January 25, 2017). Over time, the diverse IRWMP stakeholders came to respect each other's distinct objectives, overcame initial mistrust, and began to develop common goals for the basin. Importantly, these established relationships now reinforce trust in and commitment to the IRWMP's efforts. Members vouch for each other even in the face of external criticisms of water management efforts (D. Orth, personal communication, January 25, 2017).

Ironically, development of the Kings IGSM itself proved the need to establish common goals. Data used to develop it was largely collected under confidentiality agreements to protect well owner information, but some IRWMP stakeholders later wanted to use the model's predictive ability to assess water management scenarios at a scale that would compromise that privacy. There is ongoing discussion about how the model should be used to respect these differing perspectives, which reveals the value of creating unifying visions for basin management up front (D. Orth, personal communication, January 25, 2017).

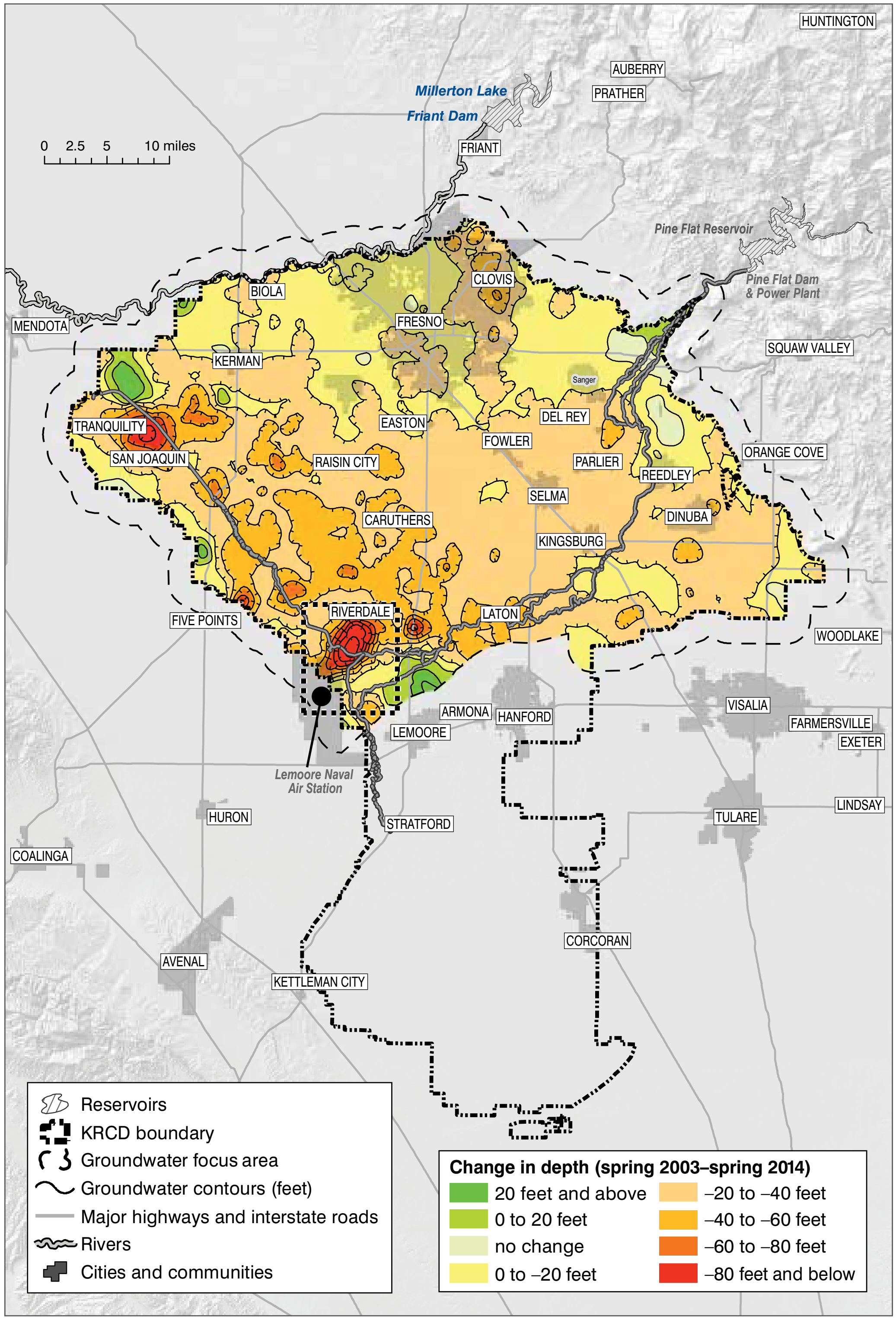
As outlined in the IRWMP and pursuant to other existing authorities, groundwater managers and users from different agencies have succeeded in recharging some areas of the Kings Basin. These efforts have provided one of the best examples of how to realize win-win solutions, for example through collaborative on-farm recharge programs between water agencies and landowners. Extensive, voluntary water level monitoring among water agencies and landowners was an important additional management tool in these efforts, as it informed what parts of the basin were experiencing the most severe overdraft. These have been critical steps towards reaching sustainability goals and could be a model for groundwater managers across the state.

However, the IRWMP is nonbinding and does not require that local jurisdictions meet any objectives to curb overdraft and reverse declining groundwater levels. Despite the expansion of recharge projects in the basin and some associated slowing of groundwater decline, overdraft conditions have persisted. Figure 3.4 (page 48) shows that groundwater levels declined across the majority of the basin from 2003-2014, with large areas subject to a 20 or 40 foot drop in water table elevation and smaller areas showing a 60, 80, and even 100 foot decline. The estimated change in storage from 2003–2014 is a decrease of 3,166,439 AF, or 287,858 AF per year on average (KRCD, 2014). Larger reductions of groundwater in storage occur during drought years when surface water supplies are constrained, even exhausting water recharged in wetter years (KRCD, 2014).

The IRWMP faces some additional challenges. The Kings Basin has considerable capacity to absorb additional wet-year floodwaters, but there are constraints in expanding conjunctive use

FIGURE 3.4

Change in Kings Basin groundwater storage



Source: Kings River Service Area Annual Groundwater Report, 2014

Note: There has been some recent debate within the Kings Subbasin regarding the quality of some data used in past years to develop contours in the western half of the subbasin (as depicted in Figure 3.4) due to gaps in understandings, especially as they relate to well design. As a function of SGMA compliance, which requires the development of Groundwater Sustainability Plans, a Kings Subbasin Technically Advisory Committee is currently going back through the data and regenerating contours and storage change calculations (E. Osterling, personal communication, September 19, 2017).

facilities, including access to and cost of prime recharge lands, limited conveyance capacity, and access to surface water (KRCD, 2005). These must be balanced with considerations of how to use recharge to address water quality impacts and depletions of interconnected surface water and groundwater. Future state funding for IRWMPs is also uncertain. Proposition 1 provided $34 million to IRWMPs in the Tulare/Kern area, but funds from Proposition 50 and 84 are nearly exhausted. Paying members are exploring alternative funding and seeking ways to reduce their own fees, which, according to KRCD, could impact programmatic funding for the IRWMP. Keeping the IRWMP's stakeholders cooperatively engaged will likely be an ongoing challenge as well.

Lessons learned

The following are key lessons from the Kings Basin:

- Data-driven models, coupled with robust outreach efforts, can demonstrate that local groundwater problems require basin-level solutions, which helps unite diverse stakeholders around common management goals.
- Clarifying objectives for model use prior to model development will help manage expectations and avoid misunderstandings regarding its use.
- Inclusive regional management plans can encourage, prioritize, and help fund integrated, collaborative tools to achieve multiple basin management goals.
- Developing and implementing regional projects is key to building trust among basin stakeholders.

Resources

Interviewees and case study reviewers: Thank you to Joe Choperena (Senior Project Manager, Sustainable Conservation), David Orth (Former General Manager, KRCD), Eric Osterling (Manager of Water Resources, KRCD), and Cristel Tufenkjian (Manager of Community and Public Relations, KRCD) for their time and input in constructing this case study.

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CASE STUDY 4 / CALIFORNIA

Orange County Water District

AUTHOR
Drew Palmer

CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

Lowering of groundwater levels

Seawater intrusion

PREDOMINANT WATER USES

Urban

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Regulatory

- Metering of wells (self-reported)

Incentive-based

- Fees and surcharges on groundwater pumping
- Agency supply augmentation and protection

Agency supply augmentation and protection

- Managed aquifer recharge (agency lead)
- Recycled water
- Seawater intrusion barriers
- Reservoir operation
- Infrastructure upgrades (paid for by agency)

Education and outreach

See page 58 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- Strong and comprehensive legislation, such as the Act that created the Orange County Water District, gives the groundwater manager the authority to implement a suite of management tools – from metering wells to controlling water supply to implementing large-scale recharge and recycling projects – all of which are essential to the basin's success.
- Innovative pricing mechanisms can promote equity, flexibility, and sustainable groundwater use within a basin – without capping water use. However, success is dependent on access to imported water, which is not an option for many basins.
- Collaborative and transparent management processes through annual reports, regular meetings, and purposeful community engagement promote participation and enhance trust within the basin.
- Financial resources are vital to supporting basin management and operational activities.

Background and governance

The Orange County groundwater basin (Figure 4.1) serves as the primary water source for approximately 2.4 million residents of the northern and central portions of Orange County, California (OCWD, 2015d). The groundwater basin contains an estimated 66 million acre-feet (af) of water (OCWD, 2015d)—over one million of which is considered "usable capacity" (OCWD, 2014)—and covers approximately 350 square miles (Herndon & Markus, 2014).

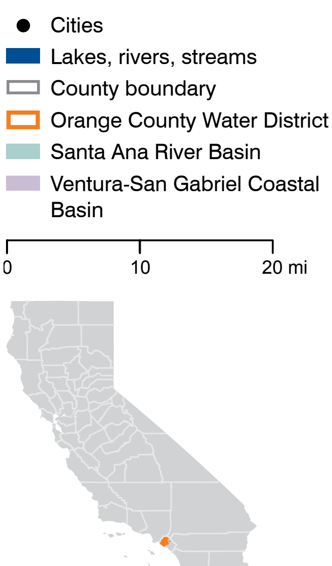
The basin is primarily recharged by the Santa Ana River, which flows from the San Bernardino Mountains through Orange County into the Pacific Ocean (OCWD, 2015d). The river provides the largest source of natural recharge of the groundwater basin, though its flow can fluctuate considerably depending on annual precipitation and amount of flow siphoned off for use upstream in San Bernardino County (Herndon & Markus, 2014).

FACT: The Orange County Water District was formed out of the Santa Ana Basin Water Rights Protective Association, which was established by the local Farm Bureau to combat diminishing water supply, prevent flood damage, restore basin water quality from ocean seepage, and protect water pumping rights. The new District was granted authority to litigate for water rights, import supplemental water, and capture flood and runoff water for the basin. District directors were elected according to property ownership, one vote for each $100 of property owned.

When Orange County doubled in population in the 1920s, the groundwater basin proved unable to meet the growing water demands of the area. Residents were spurred to action when it was discovered that declining water levels in the basin were leading to seawater intrusion and contamination of the portions of the basin nearest the ocean. This threat, together with the need to reduce overdraft, combat seasonal flooding of the Santa Ana River and curtail "outsider" pumping from Los Angeles, led to the formation of the Orange County Water District (OCWD or District), in 1933, through state legislation (District Act) (OCWD, 2014).

FIGURE 4.1

Orange County Water District



Source: EDF with Orange County Water District boundary data from S. Strand, Orange County Water District, personal communications, July 31, 2017

The primary task of this new authority was to safeguard the sustainability of the basin, both in volume and quality.

Since its inception, the District has grown in size and population—from around 160,000 acres to over 240,000 and from 120,000 residents to around 2.4 million (OCWD, 2015d). As a result of the rapid suburban development in Orange County since 1950, the use of basin water for agricultural production has fallen from 86% of water extracted (Maven, September 3, 2013) to only around 1% in 2016 (OCWD, 2016). As of 2016, almost all water pumped from the basin is for residential and commercial use.

OCWD does not directly provide water for homes and businesses, but instead manages the basin for 19 local municipal water retailers who pump from the basin from approximately 400 groundwater wells. The District is responsible for all aspects of managing the basin and its operations—determining and assessing pumping fees, monitoring and forecasting basin conditions, and conducting recharge and conservation operations.

OCWD is governed by a 10-member board of directors, each of whom represents a geographic division of the District. Seven of these members are elected from their respective divisions, while the directors from the cities of Anaheim, Fullerton, and Santa Ana are appointed by their respective city councils. Board members serve four-year, renewable terms (OCWD, 2015b). Water retailers—mostly local municipalities—who pump from the basin work closely with the OCWD Board to monitor usage, report demand forecasts, and advise on management strategy and operations. With a full-time staff of over 200 (OCWD, 2015c), and funding through a mixture of property tax and groundwater pumping revenues, the OCWD is a robust authority, fully equipped with the resources needed to manage the basin and its operations.

OCWD fills the need for cooperative groundwater management as groundwater use remained largely unregulated within the State until the passage of California's 2014 Sustainable Groundwater Management Act (SGMA). The Act was designed to alleviate problems associated with the lack of formal management and regulation of many California basins. The law requires the state Department of Water Resources to publish data on groundwater levels as well as a set of "best management practices" for local groundwater users. In turn, those users must come together and create Groundwater Sustainability Agencies (GSAs) and Plans (GSPs) over the next three to five years so that they attain basin sustainability within 20 years of adopting the plans.

Both the District and municipal retailers were heavily involved in the development of the SGMA law, and OCWD's current management structure is almost completely compliant with the new legislation. Under a special SGMA provision, OCWD has already been designated an "exclusive local agency" in the Act, and therefore does not have to formally become a GSA or develop a GSP. The only requirement of SGMA that is currently unmet by the District is the inclusion of all DWR Basin 8-1 land in a management program. There are currently several small portions of the DWR Basin 8-1 that are not under OCWD jurisdiction, and the District is currently developing plans to collaborate with entities in those areas to fulfill the new legislative requirements (Herndon, 2016). OCWD, in collaboration with other agencies, submitted an Alternative submittal to DWR in December 2016 per CA Water Code Section 10733.6 to comply with SGMA. Aside from submitting the Alternative, OCWD is not planning any significant policy or organizational changes due to the new legislation (G. Woodside, personal communication, July 15, 2016).

Program management goals

Undesirable effects (as defined in the Act) within the basin relate to groundwater quality and declining groundwater levels. The key threat to groundwater quality is seawater intrusion from the Pacific Ocean on the western edge of the basin. Key threats to groundwater levels in the basin include water overdraft by basin pumpers, lack of natural recharge due to droughts or reduced stream flow, and leakage of groundwater out of the basin.

OCWD has three stated goals concerning groundwater basin management:

- Protect and enhance groundwater quality;
- Protect and increase the basin's sustainable yield in a cost-effective manner;
- Increase the efficiency of District operations (OCWD, 2015d).

The District also promotes environmental goals of nature conservation and sustainable care of the ecosystems around District-owned land and facilities, particularly in the Prado Basin, an area of constructed wetlands below Prado Dam.

Tools used to achieve management goals

Regulatory tools

Metering of wells (monitored)

Within the basin, wells operated by municipal water districts, cities, and one private water company are fitted with calibrated flow meters—collectively, this accounts for 97% of all basin water use. These entities report this use to OCWD on standardized forms (OCWD, 2015d).

NOTE: In California, regulatory authority over well construction, alteration, and destruction activities rests with local jurisdictions (cities, counties, or water agencies). In Orange County, permits to drill wells are issued by the Orange County Division of Environmental Health in all parts of the County except in the Cities of Anaheim, Buena Park, Fountain Valley, Orange, and San Clemente. These cities issue permits for wells drilled within their boundaries. Therefore, well permitting is not included in this case study as tool used by the water management agency, OCWD, to achieve management goals.

Incentive-based tools

Fees and surcharges on groundwater pumping

OCWD charges water users per acre-foot of water pumped to regulate over-pumping. Since there is no formal cap on the aggregate quantity that can be pumped nor specific allocation to different water retailers, the District instead uses a pricing mechanism to incentivize individual retailers to use the optimal amount for their municipality and not to over-pump.

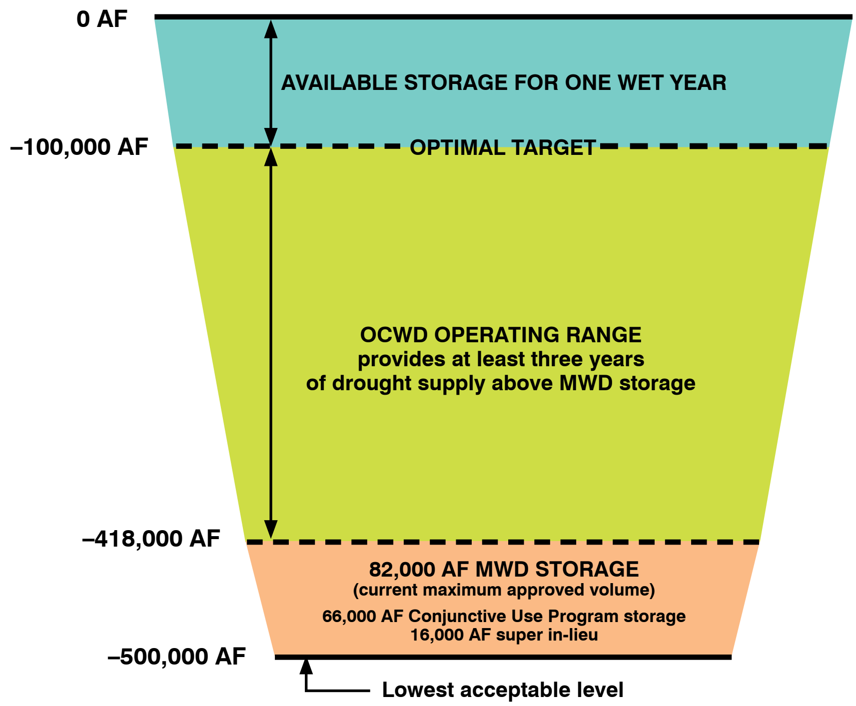
In a typical year, the basin (augmented by existing systems for enhancing groundwater recharge) can sustainably meet about 70% of the District's total water demand. The remaining water demand cannot be sustainably extracted, and so municipal retailers independently purchase imported water from the Metropolitan Water District of Southern California (MWD) through the Orange County affiliate organization, the Municipal Water District of Orange County (MWDOC). This water is transported to Southern California using aqueducts from the Colorado River and the State Water Project and is routed to the municipalities inside the District. MWD serves as a reliable source of water, and OCWD and municipal retailers do not currently face threats of supply shortages when contracting with MWD (G. Woodside, personal communication, July 15, 2016). There are long-term supply shortage concerns with imported water due to climate change and other factors.

FACT: The State Water Project is a state-run system of aqueducts and reservoirs that bring water from central and northern California down to the water-scarce areas of Southern California. MWD is the largest contractor of State Water Project water.

OCWD uses three main mechanisms to ensure that the basin is not overdrawn in any given year (i.e., relative to the annual aggregate pumping target): the *Basin Pumping Percentage* (BPP), the *Replenishment Assessment* (RA), and the *Basin Equity Assessment* (BEA) (OCWD, 2014).

FIGURE 4.2

Strategic basin operating levels and optimal target



Source: Orange County Water District Management Plan, 2015

FACT: The Replenishment Assessment was established as the original price mechanism in 1954, allowing the Orange County Water District to purchase supplemental water from the Metropolitan Water District of Southern California. The Basin Equity Assessment and Basin Pumping Percentage were subsequently introduced in the 1960s as additional controls to preserve basin supply, as shifting basin conditions and over-pumping threatened the aquifers.

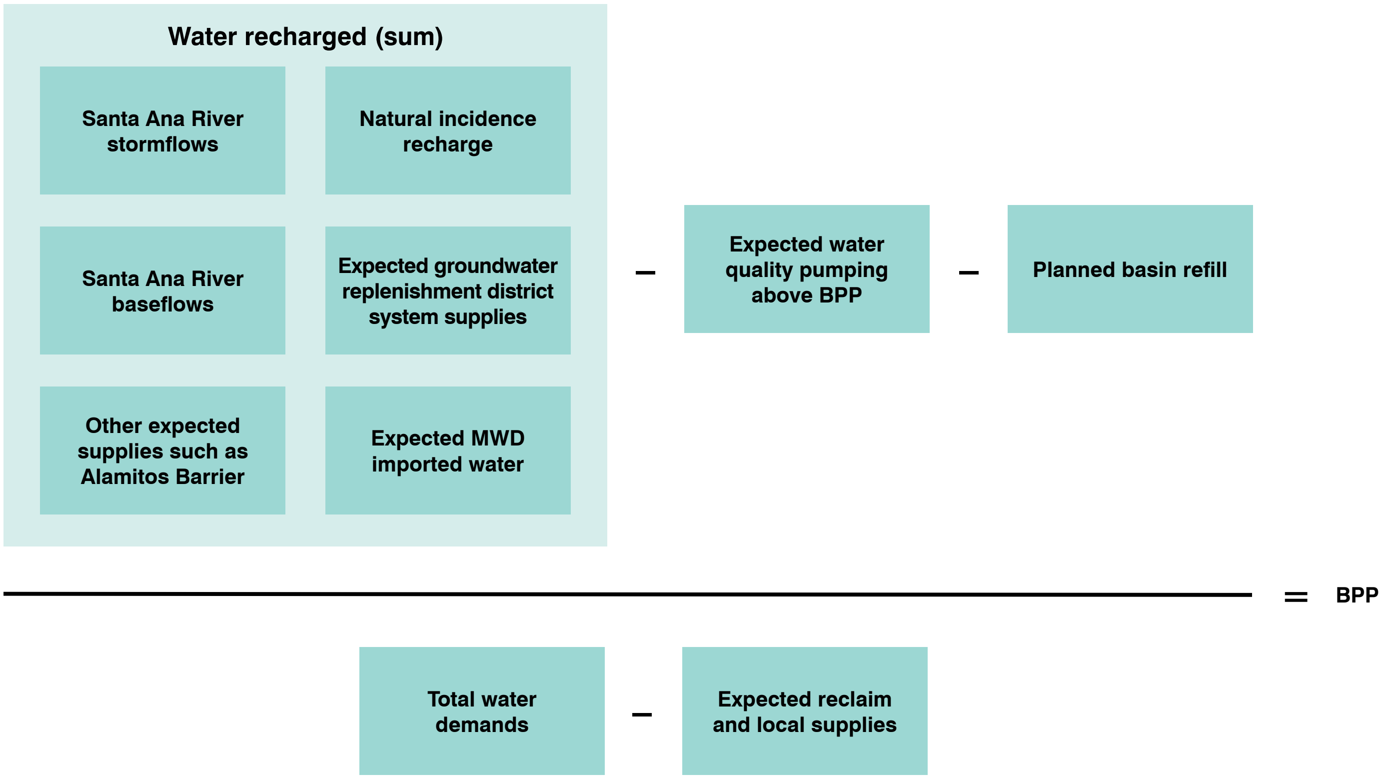
In order to determine the BPP, OCWD first estimates a quantity of water than can sustainably be drawn from the basin that year using monitoring wells and computer modeling. OCWD updates the basin model every 3–5 years and the model is approved by a Model Advisory Panel made up of groundwater modeling experts. OCWD has set a policy that short-term pumping may exceed water recharge as long as the accumulated overdraft stays within a predefined “safe operating range” (Figure 4.2).

Once determined, this number is then divided by the projected demand for water in the District to calculate the BBP, the percent of total annual water demand that can be safely provided by the groundwater basin (Figure 4.3, page 56). The District aims for this percentage to be as high as possible, and it has recently hovered around 70% (OCWD Groundwater Management Plan, 2015). OCWD must hold a public hearing each year to set the BPP (OCWD, 2015d).

Each water retailer that draws from the basin pays the flat RA rate for each acre-foot of water they pump up to the BPP percentage of their total (actual) demand. A retailer whose percentage of water pumped from the basin (i.e., relative to their total demand) exceeds the BPP pays the BEA cost in addition to the RA on the percentage of pumped groundwater in excess of the BPP. For example, for a BPP set at 70%, a municipality projecting a demand of 50,000 af for the upcoming water year (July 1–June 30) would pay the RA for the first 35,000 af, and the RA+BEA for any additional water pumped. The BEA rate is set so that the RA rate plus the additional BEA

FIGURE 4.3

Calculation of the basin pumping percentage



Source: EDF with data from the Orange County Water District Management Plan, 2015

rate adds up to the cost of imported water. This mechanism is designed to make water retailers indifferent between pumping above the BPP and importing water, which limits the amount of basin water drawn. For the 2015–16 water year, OCWD set the BPP at 70%, the RA at $322/af, and the BEA at $587/af (OCWD, 2015a). Figure 4.4 (page 57) shows the historical costs of the RA fee, the cost of producing groundwater, and the cost of importing water from MWD. The RA fee closely mirrors the full cost of producing groundwater, but is slightly lower due to additional capital and operational costs of pumping. To recover the difference between the revenue generated by the RA and BEA and the overall cost of operating, the District utilizes a small portion of the property tax levied in Orange County along with income from leases of District property. Some projects are also partially funded through state and federal grants (OCWD, 2015d).

Agency supply augmentation and protection

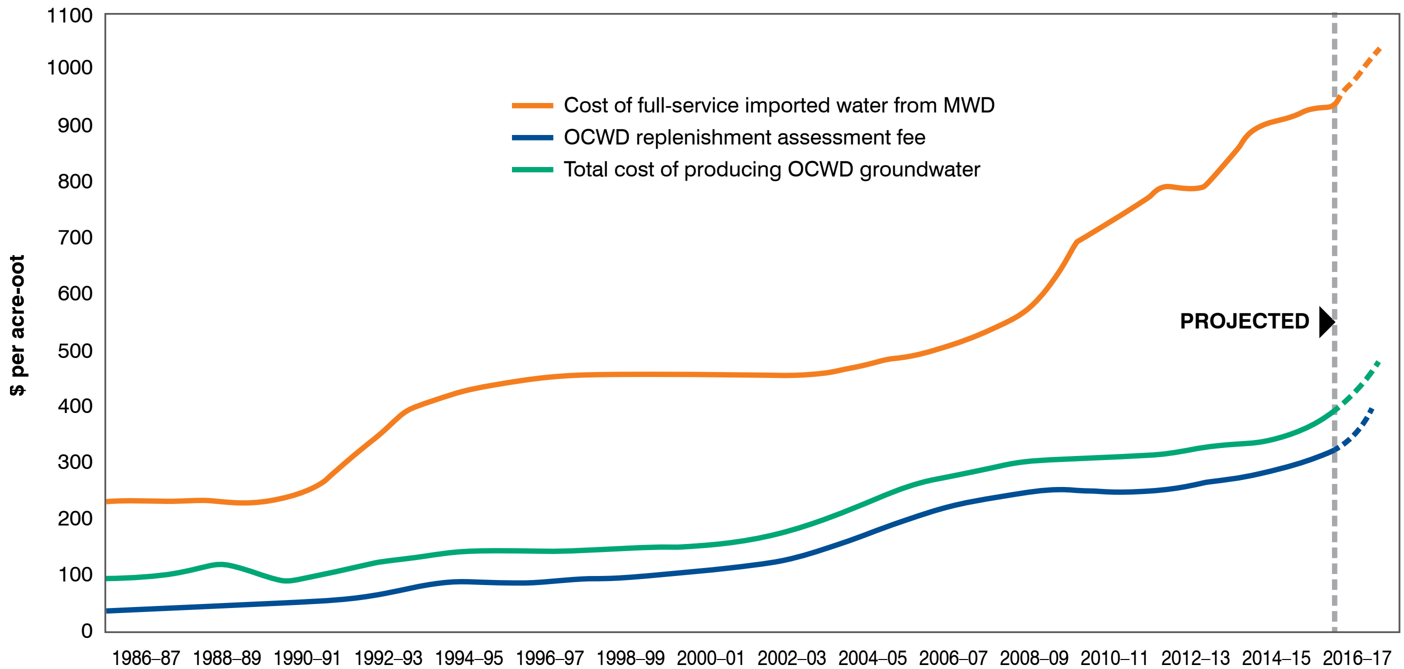
Since Orange County is largely decentralized and suburban, an organization like OCWD can function well as a centralized authority since there is no one large municipality to take on that leadership role. There are several major basin management operations that are run by the District and funded using the revenues from the RA and BEA fees described above.

Managed aquifer recharge (agency lead), including use of recycled water

Since the basin provides approximately 70% of the annual water demand inside the District, OCWD's foremost priority is adequate recharge of the aquifer to ensure sustainable levels of pumping into the future. The District owns a six-mile section of the Santa Ana River—the main

FIGURE 4.4

Cost of OCWD basin water and MWD imported water



Source: 2014–2015 Engineer's Report on the Groundwater Conditions, Water Supply and Basin Utilization in the Orange County Water District, 2016

source of natural basin recharge—as well as a robust system of recharge basins, pipelines, and dams that collect and recharge runoff from the river basin. These facilities are located on the eastern, inland side of the groundwater basin, where proximity to the mountains results in coarser soil more suitable for water percolation (OCWD, n.d.) In total, the District operates about 1,100 acres of these infiltration basins—almost two square miles (Maven, September 3, 2013).

In addition to natural recharge, OCWD recharges imported water purchased from MWDOC into the aquifer—using surface recharge basins—to boost total recharge. OCWD also injects recycled wastewater into the basin directly through injection wells. A growing portion of this artificial recharge comes through the District's innovative Groundwater Replenishment System (GWRS). This joint project with the Orange County Sanitation District (OCSD), the largest of its kind in the world (OCWD, 2015c), recycles wastewater from homes and business in the District—water that normally would be dumped in to the Pacific Ocean—using a three-step process: microfiltration, reverse osmosis, and an ultraviolet light/hydrogen peroxide treatment. The resulting water after this treatment is certified drinking-water quality and can be injected back into the basin. Recycled water can currently be produced at approximately half the cost of importing water from the MWD, while also using less energy (OCWD, 2015c). OCWD aims for the GWRS to supply an ever-larger share of water recharge into the basin (G. Woodside, personal communication, July 15, 2016).

Seawater intrusion barriers

The preeminent risk to the basin's water quality is seawater intrusion. Well-known since the creation of the District, the problem of seawater contamination in the aquifer has been a key consideration in the infrastructure design, pumping locations, and pricing scheme of water extraction. Portions of the shallow aquifers close to the Pacific coastline are especially vulnerable to intrusion. After low water levels caused the ocean to intrude several miles inland into the basin in the 1950s, OCWD began construction of freshwater hydraulic "barriers" equipped with injection wells that pump supplemental freshwater directly into the basin to hold back the sea (OCWD, 2014). The Talbert Seawater Intrusion Barrier and the Alamitos Seawater Intrusion Barrier are the two major barrier sites, comprising 36 and 43 injection wells, respectively (OCWD, 2015d). Currently, water injected at Talbert is exclusively recycled water from OCWD's wastewater reclamation facility, while water at Alamitos is approximately 50% recycled and 50% imported from MWD (OCWD, 2015d).

Reservoir operation

OCWD engages in a variety of natural resource conservation initiatives, most notably in the Prado Basin. The Prado Dam, which spans the Santa Ana River upstream from the District, was built for flood control and flow management; OCWD owns and manages around 2,000 acres in the flood plain just behind the dam (G. Woodside, personal communication, July 15, 2016). To mitigate potential environmental damage caused by temporary stormwater capture behind Prado Dam, OCWD has funded and operated conservation efforts since the 1980s—including planting native wildlife, controlling invasive plants, and providing special protection for several threatened species. In addition to this significant work in the Prado Basin, OCWD also actively participates in habitat management and wildlife preservation initiatives when building and expanding its facilities throughout the District (G. Woodside, personal communication, July 15, 2016).

Education and outreach

OCWD actively works to engage residents and communities inside its borders through various water education and outreach programs. A public affairs team with five full-time staff is dedicated to operating these programs, which reach over 7,000 people annually. For example, staff have given more than 70 off-site presentations and over 200 on-site tours to community leaders and groups (G. Woodside, personal communication, July 15, 2016). Other programs include tours of the groundwater recycling facility, educational programming for kids about water conservation, and annual outreach events like the Children's Water Education Festival, Groundwater Adventure Tour and the OC Water Summit. Further, OCWD publishes annual reports on its operations and promotes stakeholder participation through regular hearings, requests for comment, and workshop sessions—all to engage retailers who use basin water.

Monitoring and enforcement

OCWD collects pumping data from municipal water retailers, who collectively operate approximately 400 pumping wells. All entities pumping more than 1 af/year from the basin are required to report production data to the District every six months. For each of the approximately 200 large-capacity municipal and privately-owned supply wells operating within the basin, production data must be reported monthly, and production volumes are verified by OCWD field staff (OCWD, 2015d).

These reports help OCWD stay on track to match their expected pumping projections, and are used for fee assessment and storage capacity maintenance. In addition to this verification process, the District also uses a network of over 500 District-owned monitoring wells to conduct more comprehensive well monitoring every year in June (Maven, September 3, 2013), with smaller samples done quarterly and monthly (G. Woodside, personal communication, July 15, 2016).

Data is aggregated into an electronic database called the Water Resources Management System (WRMS). Individual well data is not made publicly available in real time (G. Woodside, personal communication, July 15, 2016), but the annual *Engineer's Report* issued by OCWD gives detailed, aggregated basin metrics from the previous year. OCWD provides any and all data upon request. OCWD also provides a summary of basin storage conditions on its web site that is updated monthly.

The robust authority given to the District and the careful design of the pricing scheme deters water retailers from falsifying or failing to report usage. While the need for enforcement mechanisms does not appear to be a pressing concern for the District, mechanisms exist in the legislation to punish those who fail to report or willfully misrepresent their pumping activity in the basin. For example, under the District Act, filing a fraudulent water production report and tampering with basin equipment are classified as misdemeanor crimes. Failing to pay the RA fees on time results in a 1% interest fee per late month, and failing to file a production report on time results in a penalty of 10% of the amount owed to OCWD. In an interview, an OCWD representative noted that retailers almost never commit such violations, and described the relationship between the District and the water producers in positive terms (G. Woodside, personal communication, July 15, 2016).

Financing

For the 2015 fiscal year, the Replenishment Assessment paid by water retailers provided almost $90 million in operating revenue—a significant majority of its $103 million total operating revenue. The BEA accounted for a much smaller share (less than 1%), an indication of the effectiveness of the equity assessment in discouraging over-pumping. OCWD also collected $23 million from Orange County property taxes, as well as other sources of revenue including investment income and capital gains. The District's operating expenses—$125 million in 2015—were spilt between water purchases (30% of operating expenses), water recycling (24%), depreciation/amortization (23%), and administrative costs (23%). Supplemental water purchases from MWD, the largest single operating expense, reached $38 million (OCWD, 2015c). While these expenses and revenue net out to a small loss, the District reported almost $180 million in cash and investments in 2015 (OCWD, 2015c), a substantial cushion that meets the District's required reserve holdings as well as covers expenses between the twice-annual RA payments from retailers (G. Woodside, personal communication, July 15, 2016).

In addition to year-to-year costs of purchasing MWD water, maintaining infrastructure, and well management, OCWD also invests in long-term capital projects such as expansion of the GWRS, construction of new surface recharge basins, and new seawater barrier injection wells. The District reported over $950 million in assets in 2015, almost $700 million of which were capital assets (OCWD, 2015c). OCWD obtains a large share of its capital financing through 20- and 30-year infrastructure loans from the State of California (G. Woodside, personal communication, July 15, 2016). Long-term debt totaled almost $550 million (OCWD, 2015c), and debt payment is factored into budgeting when the District sets RA rates each year.

Evaluation

The Orange County groundwater basin is a unique example of a successful groundwater management partnership between urban municipalities. The District's innovative pricing scheme, in combination with basin recharge, seawater barriers, water recycling, and education and outreach initiatives—exemplify a portfolio of approaches that together work to promote cost efficiency, improved water quality, and enhanced basin sustainability.

The mechanisms described above give OCWD the flexibility to adapt to changing supply conditions. In times of drought—or when other factors prevent full recharge of the basin—the District can lower the BPP to incent the water retailers to pump less and import more. The adaptive pricing scheme also allows the District to adjust pumping in response to one of the biggest threats to the aquifer—seawater intrusion into the basin. In 2003, OCWD created the Coastal Pumping Transfer Program (CPTP). This program modifies the RA/BEA pricing structure to incent less pumping in portions of the basin near the ocean which are vulnerable to seawater intrusion (PR Newswire, October 13, 2003). The CPTP adjusts the BEA for different municipal retailers based on location, to incent producers near the coast to pump less water than the BPP and inland producers to increase their pumping above the BPP by a corresponding amount. Lower pumping near the coast prevents seawater contamination and reduces groundwater loss to Los Angeles (OCWD, June 19, 2013).

Since the District Act establishing the OCWD became law over 80 years ago, the District has a broad and stable mandate to exercise its statutory authority to manage pumping rates, control supply, monitor water use, and build projects (OCWD, January 2015). The decentralized political geography of the area—as well as the relatively small geographic area of the basin—strengthens relationships among municipalities in the District, who have a long history of shared governance in the absence of a clear urban center of the county. In phone interviews, both OCWD and a water retailer described the relationship between the District and pumpers in largely favorable terms.

However, one potential drawback to the District's pricing approach is that while the pricing mechanism creates the correct incentive to limit groundwater pumping, the BPP somewhat erodes the incentive for municipalities to limit their total water demand. The District's definition of demand – limited to pumped groundwater and purchased surface water – does not incent municipalities to *privately* invest in water-saving innovations, such as water recycling facilities. More generally, as the price difference between basin groundwater and replacement surface water from MWD increases, OCWD may face greater pressure from water retailers to allow unsustainable withdrawals from the basin.

One currently unresolved policy disagreement in the District—what should be counted as water demand?—provides a general illustration of the tensions that can arise when policy choices have distributional consequences. OCWD determines how many acre-feet each retailer may pump at the RA based on the BPP share of "water used." OCWD includes water pumped from the basin and supplemental imported water in this measure, but does not include, for example, recycled water. This definition has created a conflict with Irvine Ranch Water District (IRWD), which owns and operates its own water recycling facility. In accordance with the OCWD Act, OCWD does not consider IRWD's recycled water supply when calculating IRWD's "total water demand" for the BPP. IRWD filed a suit against the District in 2016 to fight this policy, which, if reversed, would increase the amount IRWD can pump out of the basin at the RA rate before the BEA kicks in (IRWD, n.d.). Other retailers in the District claim that they stand to pay more if IRWD prevails, thus raising tensions.

Lessons learned

The following are key lessons from the Orange County Water District:

- Strong and comprehensive legislation, such as the Act that created the Orange County Water District, gives the groundwater manager the authority to implement a suite of management tools—from metering wells to controlling water supply to implementing large-scale recharge and recycling projects—all of which are essential to the basin's success.
- Innovative pricing mechanisms can promote equity, flexibility, and sustainable groundwater use within a basin—without capping water use. However, success is dependent on access to imported water, which is not an option for many basins.
- Collaborative and transparent management processes through annual reports, regular meetings, and purposeful community engagement promote participation and enhance trust within the basin.
- Financial resources are vital to supporting basin management and operational activities.

Resources

Interviewees and case study reviewers: Thank you to Paul Weghorst (Executive Director of Water Policy, Irvine Ranch Water District) and Greg Woodside (Executive Director of Planning and Natural Resources, Orange County Water District) for their time and input in constructing this case study.

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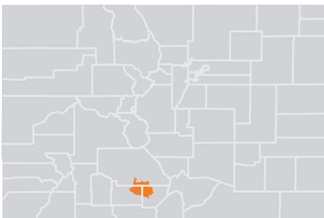
CASE STUDY 5 / COLORADO

Rio Grande Water Conservation District (Subdistrict No. 1)



AUTHOR
Katherine Rittenhouse

CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

- **Lowering of groundwater levels**
- **Reduction of storage**
- **Surface water depletion**

PREDOMINANT WATER USES

- **Agricultural**

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Regulatory

- Moratorium on new wells
- Permitting system for wells
- Quantified pumping rights
- Metering of wells (self-reported)

Incentive-based

- Fees
- Offset program with transferable recharge credits
- Land retirement projects

Agency supply augmentation and protection

- Stream augmentation projects
- Infrastructure upgrades (paid for by agency), including managed aquifer recharge

Education and outreach

See page 68 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- Fees on groundwater pumping and incentives to fallow land can be effective methods to reduce groundwater use.
- Community support for water management goals helps enable successful implementation of programs, such as land retirement and pumping fees.
- Water users will rely on surface water to avoid a groundwater pumping fee.

Background and governance

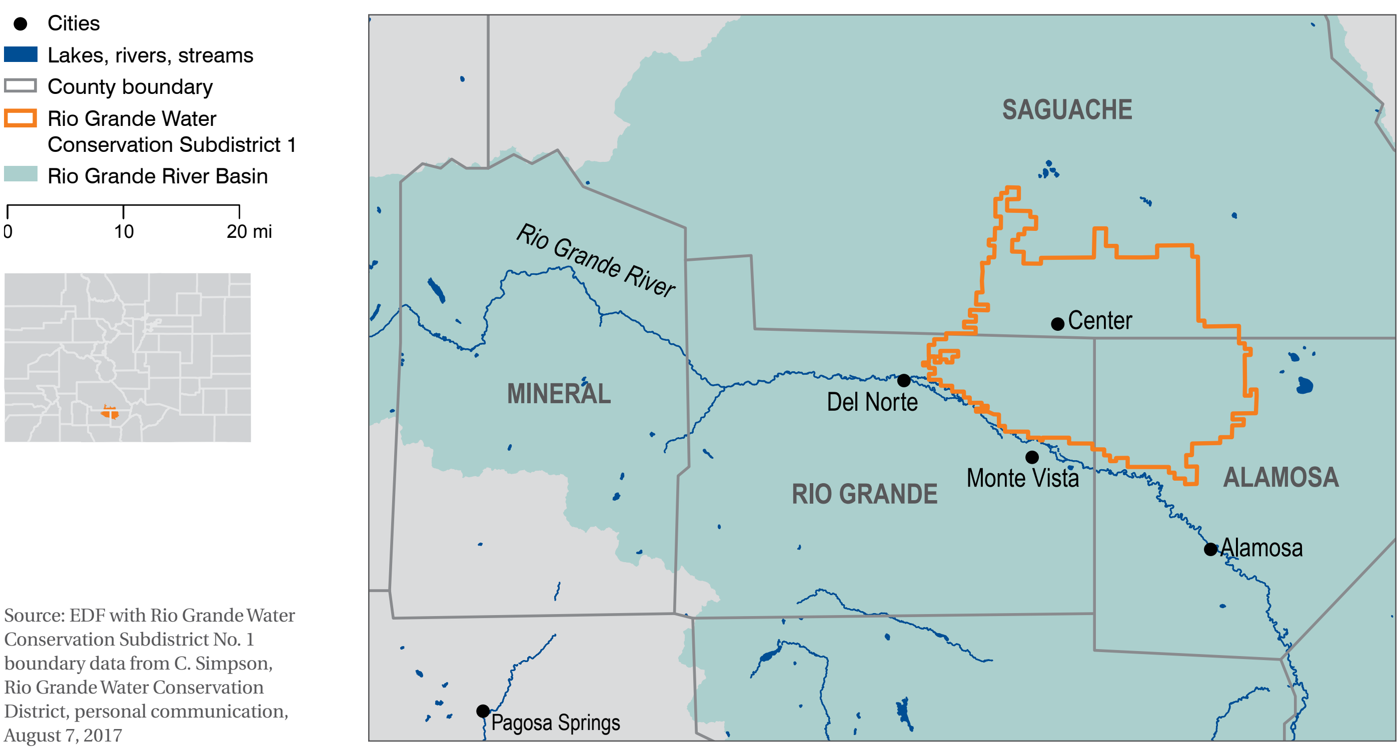
The San Luis Valley, situated between the San Juan and Sangre de Cristo mountain ranges in southern Colorado, lies above two aquifers. One of the aquifers is confined, which means it is pressurized and separated from the overlying unconfined aquifer by relatively impermeable layers of clay. These aquifers, along with surface water from the Rio Grande, Conejos and other rivers and streams, have historically sustained the production of potatoes, alfalfa, and small grains in the region. Groundwater is a critical resource since the valley's average rainfall is only seven inches per year.

Within the valley, the Rio Grande Water Conservation District ("RGWCD" or the "District"), a Special District created by the Colorado General Assembly in 1967, protects and enhances water resources within most of the Rio Grande River basin (Figure 1). The District encompasses all or portions of five counties in Colorado: Alamosa, Rio Grande, Conejos, Saguache and Mineral Counties. Within this five-county region, approximately 35% of water withdrawals are from groundwater resources and 65% are from surface water resources. Over 98% of water in the valley is used to irrigate crops. Of the remainder, half is used for aquaculture, and the rest is distributed between domestic use, livestock, public supply and mining (USGS, 2010).

The groundwater system in the basin is generally hydrologically connected to the Rio Grande River and other surface water systems, which flow through the valley. Historically, a portion of the unconfined aquifer underlying the valley has been separated from the Rio Grande by a shallow groundwater divide, known as the "Hydraulic Divide." This historically hydrologically-distinct area within the San Luis Valley is known as the "Closed Basin" (RGWCD, 2014). However, over-extraction of groundwater from the unconfined aquifer of the Closed Basin and diminished inflows from prolonged drought have caused the divide to move closer to the river, joining the Closed Basin in the San Luis Valley to the Rio Grande in some areas, and thus creating a link between groundwater withdrawals in the Closed Basin and surface water depletions in the Rio Grande River.

FIGURE 5.1

Rio Grande Water Conservation District Subdistrict No. 1



Source: EDF with Rio Grande Water Conservation Subdistrict No. 1 boundary data from C. Simpson, Rio Grande Water Conservation District, personal communication, August 7, 2017

Water rights in Colorado are governed by prior appropriation law, often described with the phrase "first in time, first in right" (DWR, n.d.-b) Farmers have been using surface water to irrigate their crops in the area since the 1800s. Mainly in response to a severe drought in the 1950s, coupled with development of available electricity and improvements in turbine pumps, farmers began drilling wells to access the vast groundwater supplies under the valley. However, pumping groundwater only further reduced the surface water available to those with senior rights due to the interconnected nature of the surface and groundwater (C. Simpson and A. Davies, personal communication, July 13, 2016). Colorado has officially recognized this link between groundwater and surface water since 1965, when legislation was passed requiring the State Engineer to evaluate a well's potential injury to surface water rights holders before granting new permits (DWR, n.d.-a). In 1972, in order to restrict the impact of groundwater withdrawals on senior surface water rights holders in Division 3, the Colorado State Engineer imposed a moratorium on new wells in the Rio Grande Basin outside of the Closed Basin, and in 1981 that moratorium was extended to include new wells within the Closed Basin (Johnson, 2008).

Colorado is legally obligated under the 1938 Rio Grande Compact ("Compact") to deliver water from the Rio Grande and Conejos rivers downstream to New Mexico and Texas. In 1966, those states sued Colorado for violation of the Compact, but agreed to stay their litigation on the condition that Colorado would use all available measures to meet its obligation under the Compact going forward. Water management in the area is motivated in large part by this obligation (Johnson, 2008).

In light of this obligation, and in an effort to protect surface water rights holders, the Colorado General Assembly required the State Engineer to adopt rules governing groundwater use in the valley. Since the early 1970s, the Rio Grande has gone through a number of stages of water management. The first attempt by the State Engineer to restrict groundwater use was litigated, and eventually rejected by the courts. A federal project to reclaim water in the Valley which was otherwise lost to evaporation, known as the Closed Basin Project, was envisioned to provide water to the Rio Grande and Conejos River systems to offset the effect of well pumping on the surface water supply. The Closed Basin Project ultimately failed to provide the necessary additional water to completely offset groundwater use. The Rules Governing the Withdrawal of Groundwater in Water Division No. 3 (the Rio Grande Basin) ("Rules") are the latest step in this process. While not yet approved by the courts, the Rules are expected to come into force in a form close to their draft version (Rio Grande Groundwater Use Rules, 2015). They will require all non-exempt well users (essentially all wells except for domestic, livestock, fire, and small commercial wells) in the Rio Grande Basin to either take part in a subdistrict, which must replace or otherwise remedy all injurious depletions of surface water caused by groundwater pumping within its boundaries and provide for the sustainability of the aquifer(s), or conduct such replacement and sustainability on an individual basis through an augmentation plan.

NOTE: Injurious Stream Depletions are defined in the Rules as "Stream Depletions that deprive senior surface water rights in [the Rio Grande Basin] of water that would have been physically and legally available for diversion in the absence of the Stream Depletions and that must be replaced or Remedied to prevent material injury to senior surface water rights; it also means Stream Depletions that unreasonably interfere with the State's ability to fulfill its obligations under the Rio Grande Compact, with due regard for the right to accrue credits and debits under the Compact." (Rio Grande Groundwater Use Rules, 2015).

RGWCD will oversee and advise any subdistricts within the boundaries of the District, which form to comply with the forthcoming Rules. Special Improvement District No. 1 ("Subdistrict 1" or "the Subdistrict") was the first to form, and is the only subdistrict currently operating under an approved management plan within the Rio Grande basin. It is proactively complying with the Rules before formally required to do so (C. Simpson and A. Davies, personal communication, July 13, 2016). Water users in the Subdistrict recognized that it was in their interests to use their resources sustainably and are attempting to do so in a way which causes the least harm to the agricultural economy.

The Subdistrict, composed of 174,000 irrigated acres and approximately 3,000 irrigation wells in portions of three counties, was recognized as a legal entity in 2006 (San Antonio, Los Pinos and Conejos River Acequia Preservation Association v. Special Improvement District No. 1 of the Rio Grande Water Conservation District, Colo. 2011). The supervising and decision-making body in the Subdistrict is a Board of Managers, consisting of ten landowners or legal representatives of landowners within the Subdistrict, and one member of the RGWCD Board of Directors. Landowners within the Subdistrict voted on the composition of the Board of Managers, deciding that it must at all times include members who reside in each of the counties with portions in the Subdistrict, as well as stockholders and water users from several ditch companies. The Board created the overall Management Plan for the Subdistrict and the more detailed Rules and Regulations that put this plan into effect (RGWCD, n.d). While the Board may update the Rules and Regulations as they see fit within the scope of the Management Plan, any changes to the Management Plan must be confirmed by the State Engineer and, if that decision is appealed, by the Colorado courts. The current Management Plan was approved by the State Engineer, whose decision was appealed, and then went through the Division 3 Water Court, The Water Court approved the Management Plan with some minor revisions. This decision was further appealed to the Colorado Supreme Court, which upheld the decision of the Division 3 Water Court.

FACT: In Colorado, there is a state court system dedicated entirely to water-related issues. There are seven water courts, corresponding to the seven major river basins in the state. Among other things, these water courts may grant surface and groundwater rights (Hoffman and Zellmer, 2013).

Program management goals

In the effort to protect stream flows and restore and maintain groundwater levels, the Subdistrict has set the following goals:

- Restore groundwater levels in the unconfined aquifer to only 200,000-400,000 acre-feet (af) below storage levels in 1976 (from over 1,000,000 af below in 2006), and thereafter "maintain a sustainable irrigation water supply."
- Address surface water concerns to "protect senior surface water rights," and "avoid interference with Colorado's obligations under the Rio Grande Compact."
- Avoid state-imposed curtailment of water use, by developing its own management plan that leverages economic incentives (Subdistrict No. 1, 2009).

NOTE: This range (200,000–400,000 af below storage levels in 1976) was chosen because it encompassed the groundwater level during a relatively stable period in the 1990s, when it was widely acknowledged that there was enough water to irrigate crops throughout the valley. Although water managers do not know for sure, it is thought that this level will also be high enough to restore the Hydraulic Divide (C. Simpson and A. Davies, personal communication, July 13, 2016).

Tools used to achieve management goals

The portfolio of approaches used to meet the Subdistrict goals include regulatory tools, incentive-based tools, agency supply augmentation and protection, and education and outreach.

Regulatory tools

Moratorium on new wells

In recognition that the confined and unconfined aquifers were over-appropriated, the Colorado State Engineer placed moratoriums on the issuance of permits to construct new groundwater wells, in order to prevent impacts to existing water rights and the state's prescribed water deliveries under the Rio Grande Compact. The Confined Aquifer New Use Rules for Division 3 allow for new uses of groundwater in the basin, but only in those specific and limited circumstances where 100% of the new water diversions will be replaced to the aquifer. This allows for the potential of a changed use while satisfying the intent of the moratorium—to manage groundwater to prevent stream depletions that impact other water rights and water delivery obligations.

Permitting system for wells

The State Engineer will only issue a well permit for a new or expanded use of groundwater if such a plan is in place to offset 100% of the new depletions and only after that plan has been judicially approved by the Division 3 Water Court. Permits are also conditional upon applicants submitting pertinent well construction information to the State Engineer (DWR, June 30, 2005).

Quantified pumping rights

Anyone applying for a new right to withdraw groundwater from the confined aquifer or confined aquifer system must either acquire and retire an existing right that uses an equivalent amount of water from the same hydrologic zone, or develop an aquifer recharge system replacing the entire amount of new depletions, so that there is no net increase in diversions from the confined aquifer, thereby preventing injury to other users. Water savings from crop shifting do not qualify as a permitted offset (DWR, June 30, 2005).

Metering of wells (self-reported)

Wells that are subject to the Rules and Regulations within Subdistrict 1 are also subject to the Colorado State Engineer's Rules Governing the Measurement of Ground Water Diversions in the Rio Grande Basin (DWR, June 30, 2005). These rules require all non-exempt wells in Division 3 to have installed and to maintain a totalizing flow meter at the well owner's expense, or use an alternative method to measure annual water flow (DWR, June 30, 2005). Whichever approach is taken, the rules require that measurement is accurate within 5% of the actual volume pumped, which must be verified by a certified well meter tester a minimum of once every four years. Well owners must report their groundwater use to the Subdistrict and to the Colorado Division of Water Resources annually.

Incentive-based tools

Fees

Subdistrict 1 incents agricultural groundwater users to reduce their pumping by assessing a fee on the net volume of groundwater withdrawn. The Board of Managers is authorized each year to set the fee at a level up to $75/acre-foot of net groundwater withdrawn; currently it is at this maximum price. Groundwater users may reduce their pumping by switching to less water-intensive crops, increasing on-farm efficiency, or planting fewer crops.

Offset program with transferable recharge credits

Agricultural water users may offset their groundwater pumping and avoid the associated fee by acquiring Surface Water Credits. These Credits are earned for each acre-foot of water imported into the Subdistrict and used to recharge the unconfined aquifer. Credits are earned for any water which is brought into the Subdistrict, not consumed for beneficial purposes, and is introduced into the unconfined aquifer (Subdistrict No. 1, 2009). Any Credits that a water user receives first go towards offsetting groundwater pumping, giving them a value of $75/acre-foot. If the total amount of Surface Water Credits a water user receives is greater than the total volume of groundwater pumped for the year, the excess credits may be banked for use in the next year, or sold directly to other groundwater users. However, the choice to bank or sell only applies to Credits leftover after fully offsetting groundwater pumped for the year. By December of each year, the Board of Managers publishes a list of all Credits available for exchange, trade, lease or sale. Anyone interested in purchasing a Credit can then independently contact the Credit sellers, and negotiate a price. All transactions are reported to the Subdistrict by the purchaser, as part of the annual farm unit data (Rule and regulations of the RGWD Subdistrict No.1, January 15, 2013).

Land retirement projects

Subdistrict 1 also offers agricultural groundwater users the choice of receiving payment in exchange for fallowing their land through the federal Conservation Reserve Enhancement Program (CREP). Typically, acres eligible for participation in CREP are those which have been irrigated with at least six inches of groundwater in at least four of the years within the period 2002–2007, *and* meet one of the following criteria: (1) were irrigated with six inches within the last 24 months, *or* (2) were enrolled in a voluntary fallowing program within the last 24 months *and* physically and legally capable of irrigation, *or* (3) are currently enrolled in a voluntary fallowing program (CREP, n.d.).

Generally, CREP offers a standard price per acre fallowed, with the requirement that the land is fallowed for 15 years. Lands located in areas with a greater impact on stream flow (the Focus Area), as well as lands that are permanently retired, are eligible for a higher price per acre fallowed. CREP does not take total water savings from fallowing a particular acre into account in its pricing scheme.

As part of the fallowing contract, acres fallowed through CREP must engage in approved conservation practices. Options include: establishment of permanent native grasses and forbs, permanent wildlife habitat, shallow water areas for wildlife, and wetland restoration. CREP will pay for 50% of the costs of implementing these conservation strategies on participating acres (Factsheet: CREP—Colorado Rio Grande, February 2015).

Fallowing contracts are awarded equally to all eligible lands on a first come, first served basis. As of February, 2016, 48 landowners with a total of over 5,000 acres had contracted with CREP on either a temporary or permanent basis. The estimated rate of groundwater savings for fallowing previously irrigated land is two acre-feet per fallowed acre (C. Simpson and A. Davies, personal communication, July 13, 2016).

Agency supply augmentation and protection

Stream augmentation projects

The Subdistrict is required to replace or otherwise remedy depletions to surface water caused by groundwater pumping within its boundaries, and that cause harm to surface water rights holders or interfere with Colorado's obligations under the Compact. The amount of surface water depleted by pumping is determined through the Rio Grande Decision Support System ("RGDSS") model, based on well-level data from the Subdistrict, amount of recharge to the aquifer, and other factors. Once the total amount of injurious depletions caused by groundwater pumping is determined, the Subdistrict is responsible for either replacing that amount, or contracting with senior surface water rights holders to remedy the reduction in some other manner (i.e., paid compensation). In 2015, approximately 59% of surface water depletions from groundwater pumping were remedied by the Subdistrict through means other than replacing that water to the stream (RGWCD, 2016).

NOTE: The Rio Grande Decision Support System (RGDSS) inputs historical and observed climate, agricultural, groundwater, and streamflow data (including the observed change in aquifer storage data) to the groundwater model MODFLOW. MODFLOW is a U.S. Geological Survey tool, and an international standard, for modelling groundwater systems and groundwater-surface water interactions (USGS, June 5, 2017). The State Engineer's Rules for groundwater pumping in the Rio Grande specify the RGDSS model as the method for determining impacts on surface water flows. Surface water rights holders have challenged these rules in the courts, claiming that the model under-represents the effect of groundwater pumping on surface water resources. However, the model and its development were successfully defended in the courts, with only minor changes required (D. Wolfe, personal communication, July 15, 2016).

Infrastructure upgrades (paid for by agency), including managed aquifer recharge
The Subdistrict finances new infrastructure developments to enhance recharge capacity, for example by purchasing dedicated recharge basins, and maximizes allowable diversions from the Rio Grande River, for example by improving the operation of ditches and headgates (Subdistrict No. 1, 2009).

Education and outreach

RGWCD's management efforts include public education on, and research into, water conservation, water use efficiency, improved water management, and agricultural water use (Subdistrict No. 1, 2009). It maintains a website with other outreach materials publicizing upcoming events, management efforts, and other information for local stakeholders in individual subdistricts.

Monitoring and enforcement

Water users report their volume pumped annually in order to calculate the amount they owe to the Subdistrict in fees. By the State Engineer's rules, flow meters must be verified to be in working condition by a licensed pump installer, a representative of the meter manufacturer, or a qualified well tester at the time of installation—and by a qualified well tester every four years thereafter. A qualified well tester is defined as "a person or entity who is annually certified by the State Engineer as qualified to determine the accuracy of a flow meter, perform a power conversion coefficient test on a Well, and perform a Well efficiency test" (DWR, June 30, 2005). The self-reported readings from the measurement devices are reviewed by the Division of Water Resources, and a large portion of them are independently field verified by Division personnel each year. Failure to comply with the rules may subject the well owner/user to court proceedings and to the costs of the state in enforcing the rules.

CREP participation requires monitoring and compliance reviews, which can include inspections of diversion structures and fields to ensure irrigation is not occurring.

Financing

The Subdistrict earns revenues by assessing fees upon groundwater users and landowners. All acres in the Subdistrict that were groundwater irrigated as of 2006 are subject to an Administrative Fee of up to \$5/acre, and a CREP Fee of up to \$12/acre, regardless of whether they currently use groundwater for irrigation. In addition, groundwater use is subject to a Variable Fee of up to \$75/acre-foot pumped (the groundwater assessment).

Revenue from the Administrative fee goes to fund the Subdistrict's operations, and revenue from the CREP fee helps to fund the fallowing incentives offered to irrigators. While the majority of the CREP fallowing incentives are funded with federal dollars, there is a requirement that the

Subdistrict provides 20% of the total project cost, including additional annual incentives, annual water retirement payments, and bonus payments for land in high-impact areas (CREP, n.d.). Funding has been secured to enroll up to 40,000 acres in 15-year or permanent fallowing contracts in Subdistrict 1 through CREP. Revenues from the Variable Fee, fund protection of surface water rights through the replacement or remedy of surface water depletions caused by groundwater pumping, as well as infrastructure improvements (Subdistrict No. 1, 2009).

Evaluation

The goals of Subdistrict 1 are to restore groundwater levels, maintain a sustainable irrigation supply, and address surface water concerns. The Subdistrict has utilized two approaches to achieve its goals—a price-based approach and participation in CREP. The fee per net unit of groundwater pumped incents groundwater users to reduce the amount of water they use to irrigate crops. It does not suggest or require a method for that reduction, but allows water users to take advantage of the lowest-cost opportunities to reduce water use. These may come in any form, including efficiency improvements, crop switching, or technology innovations. CREP incents landowners to fallow their irrigated acres. Water users in the basin thus have a portfolio of options to choose from to reduce groundwater pumping.

Subdistrict 1 began operations in 2012. Water levels in the unconfined aquifer of the Closed Basin in the San Luis Valley have been monitored since 1976, through 27 RGWCD monitoring wells (Davis Engineering Service, Inc., n.d.). The Subdistrict uses the running five-year average to gauge the storage level in the aquifer, and measures that level against its goals. This metric allows for the fact that short-term fluctuations may not be indicative of medium- and long-term trends.

Conservative approaches and assumptions in every plan year since inception have resulted in the surface water system impacts by Subdistrict well operations being slightly overcompensated for its injury. Though drought conditions contributed to the further decline of water levels in the aquifer at the beginning of the Subdistrict's operations, levels have been on the rise since a low in 2013. Near historical average annual runoff of streams in 2014 and 2015 coupled with groundwater withdrawal declines of 32%—from 300,000 acre-feet in the 2011 irrigation year to 205,000 acre-feet in 2015 are major contributors to the aquifer recovery. The groundwater withdrawal decline can be attributed to a combination of land fallowing through participation in CREP and efficiency enhancements in response to the Variable Fee. In 2015, 5,854 acres had been enrolled in CREP, including 2,762 acres which were permanently fallowed, and 3,092 acres enrolled in temporary (15-year) contracts. The Subdistrict estimates that in the past these acres were irrigated with a total of approximately 10,000 acre-feet annually (RGWCD, 2016). This transition was possible in part because of the community's support for program management goals. Residents largely recognize that historic water use was unsustainable and have been willing to make changes to maintain their old way of life as much as possible.

The program has not been without challenges, however. These include the intrusion and cost to farmers in an agricultural area where the profit margin is already small. Another potential challenge is well owner self-reporting. Well owners are required to have a verified monitoring device to determine the water pumped from the well. However, they self-report the meter readings, which determine the amount that they will pay under the Variable Fee. The self-reporting may lead some to misreport their meter reading in order to pay less for their water use. However, the Subdistrict does monitor total water applications by farm and commodity for anomalies (C. Simpson, personal communication, August 8, 2016). In addition, the Division of Water Resources has a team of six employees specifically tasked with ensuring that meters are working correctly and that readings are accurate. There is generally a high degree of compliance with metering requirements, and major anomalies can be checked against power data, with which water use is correlated (D. Wolfe, personal communication, July 15, 2016). The Subdistrict and the Division of Water Resources have monitoring and enforcement mechanisms to assist in the program's operation.

The multiple strategies employed by the Subdistrict will ensure that surface water depletion caused by groundwater withdrawals are replaced or remedied. Fallowing land and assessing fees on groundwater use will also aid in the goal of restoring and maintaining groundwater levels, although the level of the fee or the amount of land slated for fallowing will likely need to be adjusted as the Subdistrict learns more about how water users respond to the current incentives. In addition, since Subdistrict 1 is part of a larger water basin, it is crucial that other well users comply with the forthcoming state Rules in a timely manner.

Lessons learned

The following are key lessons from the Rio Grande Water Conservation District Subdistrict No. 1:

- Fees on groundwater pumping and incentives to fallow land can be effective methods to reduce groundwater use.
- Community support for water management goals helps enable successful implementation of programs, such as land retirement and pumping fees.
- Water users will rely on surface water to avoid groundwater pumping fees.

Resources

Interviewees and case study reviewers: Thank you to Craig Cotton (Division Engineer, Colorado Division of Water Resources), Allen Davey (Engineer, Davis Engineering Service, Inc.), Cleave Simpson (General Manager, Rio Grande Water Conservation District) and Dick Wolfe (State Engineer/Director, Colorado Division of Water Resources) for their time and input in constructing this case study.

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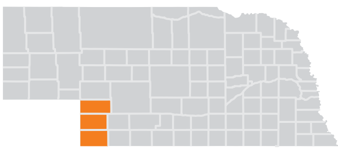
CASE STUDY 6 / NEBRASKA

Upper Republican Natural Resources District



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CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

- **Lowering of groundwater levels**
- **Reduction of storage**
- **Surface water depletion**
- **Degraded groundwater quality**

PREDOMINANT WATER USES

- **Agricultural**

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Regulatory

- Moratorium on new wells
- Permitting system for wells
- Metering of wells (monitored)
- Certification of irrigated acreage
- Quantified and allocated irrigation rights

Incentive-based

- Taxes
- Land retirement projects
- Best management practices with cost-share
- Transfer system for groundwater rights

Agency supply augmentation and protection

- Stream augmentation projects
- Infrastructure upgrades (paid for by agency)

Education and outreach

See page 77 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- Strong regulatory authority with extensive data collection are used together to track attainment of strict basin-wide goals.
- Regulations should be adjusted as needed over time based on external and internal conditions.
- Strong enforcement of regulations is possible, even in tight-knit communities, when the regulations are supported through outreach and communication.
- Projects that provide regulatory certainty may be preferred to incentive-based systems despite relatively high costs.

Background and governance

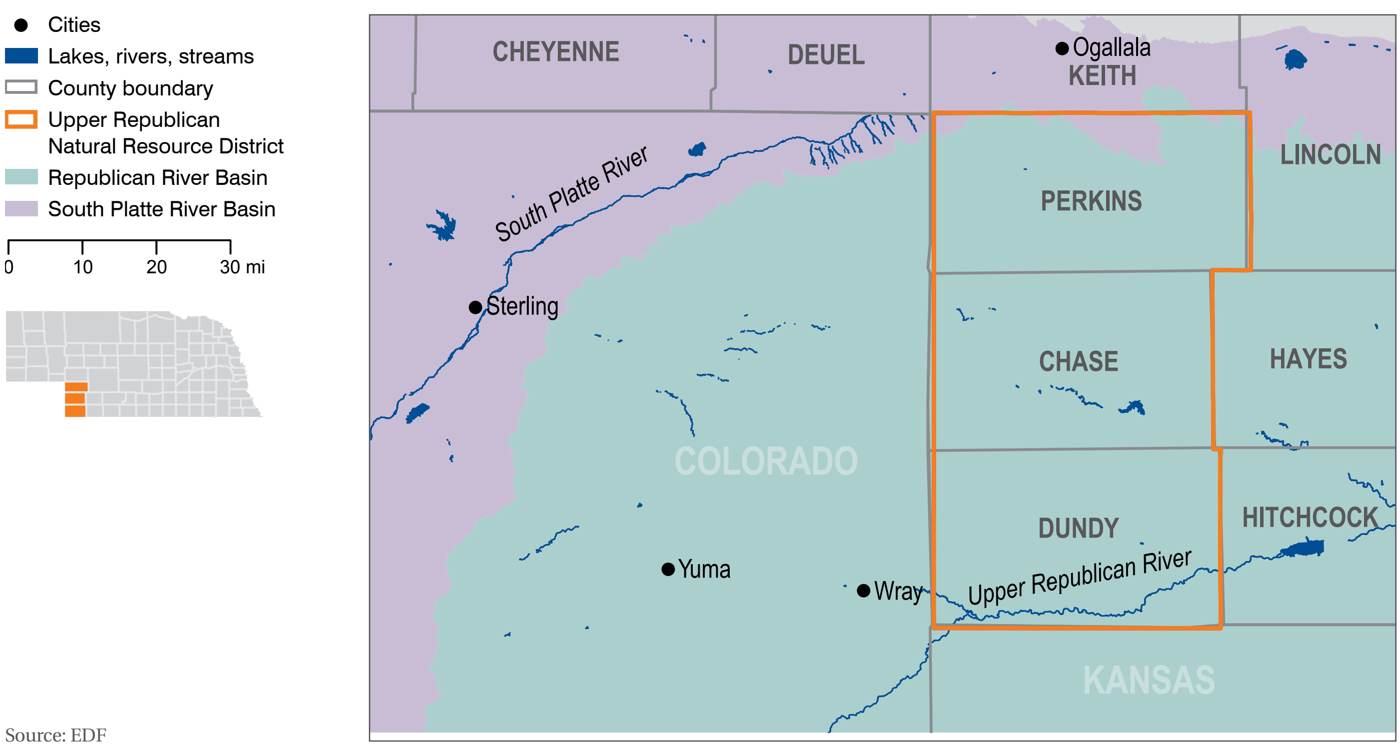
The Upper Republican Natural Resources District (URNRD) encompasses Chase, Dundy, and Perkins counties in southwestern Nebraska, totaling 1.73 million acres of land (See Figure 6.1) (URNRD, 2016b). Approximately 56% of the total acreage is used as cropland while rangeland accounts for 40% of total land area. Nearly half of cropland is irrigated, most of which is irrigated using groundwater (99.3%). URNRD is located in the Republican River Basin, which spans Nebraska, Kansas, and Colorado. The URNRD overlies the High Plains Aquifer, which is one of the largest aquifers in the world and covers parts of eight states, from Texas to South Dakota. Much of the basin has interconnected groundwater and surface water. The area has a semi-arid continental climate where average annual precipitation is 17"–20" with annual evapotranspiration of 53" (URNRD, 2016b). Extensive agricultural land use is complemented by pockets of industrial and urban development to sustain the farming families in the area. There are fourteen communities in the District, with a total combined population of about 9,000 residents (U.S. Census Bureau, 2013). Residential and commercial water use in the district is minimal (Jenkins, 2012). The primary crops grown in the region are corn, wheat, and soybeans. There are acres of sunflowers, millet, potatoes, alfalfa, forage sorghum and sugar beets as well.

Groundwater levels have been declining for decades in the URNRD. Estimates of declines since the 1950s are as much as 50 feet in localized areas (McGuire, 2014). Groundwater use across the three states in the broader Republican River Basin has impacted surface water flows, prompting interstate litigation. Groundwater quality has been impacted by fertilizer use in the predominantly agricultural area, as evidenced by elevated concentrations of nitrate in groundwater.

Since their creation in 1972, Nebraska's 23 Natural Resources Districts (NRDs) have had the responsibility of managing groundwater quantity and quality in the state. The NRD system is unique to Nebraska with boundaries based on Nebraska's major river systems, allowing Districts

FIGURE 6.1

Upper Republican Natural Resources District



Source: EDF

to better tailor management practices to local conditions (NARD, 2016). Further, in contrast to a number of western states that specifically designate geographically confined groundwater management areas, Nebraska's NRD network covers the entire state. They were created to manage a range of natural resource concerns including flood control, soil erosion, irrigation run-off, and groundwater quality and quantity issues. NRDs have the power to raise revenue through taxing, fees, and fines, as well as set rules and enforce them when necessary (NDNR, 2011).

Other agencies in Nebraska with water management roles are the Nebraska Department of Natural Resources (DNR), which has chief responsibility for surface water quantity, and the Nebraska Department of Environmental Quality, which is responsible for surface water quality and point source pollution of surface water and groundwater. Surface water use in Nebraska is controlled by prior appropriation, best explained as the "first in time, first in right" doctrine, with preference set during shortage (NDNR, 2012). Groundwater is owned by the state for the benefit of the public, and the state follows the American Reasonable Use Rule with a "correlative" twist (NDNR, 2011). This means that overland owners may put groundwater to any beneficial use on their land so long as they do not create harm to other users in the area (Getches, Zellmer, & Amos, 2015).

Groundwater management in the District is complicated by the need to remain in compliance with the Republican River Compact of 1942. The Republican River Compact is an interstate agreement between Kansas, Nebraska, and Colorado that allocates virgin surface water supply from the Republican River Basin among the three states. Compliance with the compact is overseen by the Republican River Compact Administration (RRCA). Groundwater was not widely used in the basin when the Republican River Compact agreement was first drafted and was therefore not a factor that the parties considered. This omission created future problems between the states when well irrigation became feasible. Following a 2002 settlement, depletions to stream flows caused by all groundwater use are accounted for in Republican River Compact calculations (URNRD, 2016d). Importantly, the Compact does not specify an instream flow right in Nebraska, although under the Compact, the state is obliged to limit or offset depletions to stream flow in aggregate. While the states have engaged in significant litigation over the past two decades, relations have improved in recent years—with all three states signing joint resolutions seeking a long-term strategy for renewed cooperation in the Basin.

Due to conflict between groundwater and surface water users, Nebraska established an integrated surface water and groundwater management law (integrated management law). The law requires the DNR to establish hydrologic connection of surface water and groundwater and to determine whether a basin is fully appropriated. The Republican River Basin is currently designated as a fully appropriated basin. As such, the NRDs in the Basin, including the URNRD, are required by state law to develop an Integrated Management Plan (IMP) with the DNR to aid in management of surface water and groundwater in the basin (NDNR, 2011).

The URNRD has maintained a groundwater well measurement database since 1972 (URNRD, 2016c). The District measures more than 400 irrigation wells twice annually, in the spring and fall, to monitor static water level (URNRD, 2016c). These wells are a combination of private and public wells. Data from monitoring wells are compiled and used to detect trends in the region, for Republican River Compact compliance purposes and general awareness within the basin. Additionally, the RRCA maintains a comprehensive groundwater model, the Republican River Compact Administration Ground Water Model (RRCA model), which was originally developed to understand groundwater use and the spatial distribution of groundwater pumping impacts on streamflow (RRCA, 2003). The RRCA model uses MODFLOW-2000 with additional modules and is managed by the three states under the compact. MODFLOW estimates streamflow depletions over a 50-year time period. The model is updated on a regular basis and the data are available online. The information is used to inform the Basin's IMP.

Program management goals

While managing groundwater depletion for the sake of water users within URNRD is a top priority, compliance with the Republican River Compact is the driving force behind the many of URNRD's management tools. Management goals for the URNRD are:

- Protect groundwater quantity and develop management programs to extend groundwater reservoir life to the greatest extent practicable.
- Reduce the potential for non-point source contamination of groundwater and surface water.
- Manage impacts on surface water related to interstate surface water compact.
- Reduce groundwater use by 20% from the 1998-2002 average for Republican River Compact compliance.

Tools used to achieve management goals

Regulatory tools

Moratorium on new wells

The quantity of wells in the URNRD is capped through a moratorium. In 1997, the URNRD put in place a well-drilling moratorium on new wells (replacement wells are allowed) (URNRD, 2015). Domestic wells and range livestock wells that pump less than fifty gallons per minute are exempt from the moratorium. These two categories account for negligible amounts of water use compared to irrigation wells.

Permitting system for wells

All replacement wells require a permit before construction, with the exception of wells that pump less than fifty gallons per minute. Permits must be approved by the Board and replacement wells are subject to the same provisions as the wells being replaced, as outlined in the District's rules and regulations (URNRD, 2015).

Metering of wells (monitored)

Permitted wells must be equipped with a flowmeter to monitor water use (URNRD, 2015). District technicians are allowed access to these meters and manually inspect and take readings from the meters (see "Monitoring and enforcement, page 77).

Certification of irrigated acreage

A cap on irrigated acres was initiated at the same time that the district placed a moratorium on new wells (URNRD, 2015). The district limits the number of certified irrigated acres allowed in the district and no new irrigated acres are allowed. Acres that are now certified were certified to represent the area that is actually irrigated. For example, corners of a field would not be certified if an irrigator was using only center-pivot irrigation. Each irrigated acre is allocated a specific number of inches of groundwater that the operator is allowed to pump. Regulating the volume of groundwater pumped helps to ensure that water quantity goals are met. This level of regulation provides a level of certainty around water use projections that regulating irrigated acres and wells alone cannot.

Quantified and allocated irrigation rights

In 1978-1979, the URNRD became the first NRD in the state to regulate groundwater use (URNRD, 2016a). The URNRD allocated each acre the right to irrigate with 20 inches of groundwater per year. Since then, the District has increased the stringency of its regulations by reducing the annual allocation. For the 2013–2017 period, each certified irrigated acre is allocated 13 inches per year, or 65 inches over the five years. Irrigators may choose to distribute their allocation over the five years in any way they choose (URNRD, 2015). In determining the five-year allocation, the Board considers water availability, Republican River Compact compliance as determined by the most recent IMP, and how much water is reasonably needed to grow crops.

Groundwater users who pump less than their total allocation in the five-year allocation period carry forward the unused balance to subsequent allocation periods (URNRD, 2015). Currently, for every 1" of carry forward used beyond 7.5" per acre, 2" of carry forward is lost. This "2–1" penalty also applies to all borrowed allocation (URNRD, 2015).

Incentive-based tools

Taxes

While URNRD levies taxes on irrigated property and irrigators themselves primarily to fund District projects, these taxes provide incentive for agricultural water users to transition to non-irrigated cropping systems (see “Financing,” page 78).

Best management practices with cost-sharing

The URNRD has subsidized the cost of soil moisture probes since 2011. While the District received funding for the program from the Nebraska Environmental Trust and U.S. Bureau of Reclamation in the past, it is now solely funded by the URNRD. The URNRD also provides a well decommissioning cost-share program.

Transfer system for groundwater rights

The District allows limited transfer of groundwater rights. All transfers must be approved by the URNRD Board of Directors (URNRD, 2015). Allocations must remain within a “floating township,” defined in the Rules and Regulations as “a set of thirty-six (36) sections lying in a contiguous block,” equal to 36 square miles. Transfers may not result in an increase in water use from the historic consumptive use, defined broadly as “the amount of water that has previously been consumed under appropriate and reasonably efficient practices” (URNRD, 2015). In addition, any increase in 50-year streamflow depletion that will occur as a result of the transfer must be offset by decertifying sufficient certified acres (URNRD, 2015).

A specific form of informal transfer allowed in the District is pooling. Pooling is defined in the Final Rules as “any contract approved by the Board in which groundwater allocations are combined.” The Board may approve pooling of groundwater allocations granted to irrigated tracts with a common interest in ownership or tenancy. No pool may include more than one floating township. At the end of each irrigation season, water use within the pool will be averaged across the tracts in the pool to determine carryforward. Such carryforward is limited to three years of annualized allocation.

Agency supply augmentation and protection

Stream augmentation projects

URNRD helps increase streamflow to ensure compliance with the Republican River Compact through stream flow augmentation projects and land retirement. The first such project, the Rock Creek Augmentation Project, was completed in 2012, at a cost of $21 million (URNRD, 2016d). In 2011, the URNRD purchased and converted to rangeland over 3,000 irrigated acres. The land purchased for retirement was chosen in part because it was determined (using MODFLOW) that pumping groundwater from that location has little negative impact on streamflow. The water that otherwise would have been used for irrigation on those acres is piped to the Republican River to enhance streamflow in years that action is required for Nebraska to maintain compliance (McCabe, 2013). The acres purchased were located entirely within the URNRD, with funding coming from the NRD’s taxing authority. The project has pumping capacity of approximately 20,000 acre feet per year.

Another irrigation retirement and augmentation project is the trans-basin Nebraska Cooperative Republican Platte Enhancement Project (N-CORPE), located in Lincoln County, Nebraska, within both the Republican River Basin and Platte River Basin. In 2012, four of Nebraska's NRDs (the Upper Republican, Middle Republican, Lower Republican, and Twin Platte) purchased 16,000 irrigated acres for $83 million when a corporate farm went on the market in Lincoln County (N-CORPE, 2015). The approximately $120 million land and infrastructure project is funded by an occupation tax on irrigated acres. Similar to the Rock Creek project, the irrigated cropland was retired to rangeland so water that would otherwise be used for irrigation can instead be piped into the Republican Basin (URNRD, 2016d). However, roughly half of the wells involved are from outside of the Republican River Basin, providing benefits to the basin while minimizing negative impacts on its groundwater. The annual capacity of this project is about 65,000 acre feet. The state may use water from either or both of these projects to help ensure Republican River Compact compliance in a given year.

Education and outreach

The Upper Republican NRD has maintained education and outreach programs since first regulating groundwater use in the 1970s. Monthly board meetings are open to the community and are well attended, especially when new policies are announced. URNRD maintains a high level of transparency and produces press releases at least biweekly to keep the community up-to-date on issues in the district. These press releases are printed in the local newspaper as well as distributed by mail. The District works with local schools and student camps to teach youth about groundwater (for example, younger students create "edible aquifers" while older students learn about decommissioning wells) and the NRD's role. URNRD collaborates with the nearby Natural Resource Conservation Service district conservationist to provide trainings and workshops regarding soil health and soil moisture probe use. Lastly, the District has recently started hosting an annual Water Conference. The conference brings in water engineers, lawyers and policy experts, and other water resource professionals to discuss water issues in the District and across the state and U.S. In its second year as of 2017, the conference has been well-received and provides a space for dialogue about water management. Due to the District's long history of groundwater management and continual education efforts, the community in URNRD is well-informed on local issues.

Monitoring and enforcement

Irrigation wells in the District have been fully metered to measure water consumption since 1981 (URNRD, 2016c). Staff of the District manually inspect every meter annually to confirm their working condition and meter readings. If the District finds that a user has damaged a meter or misreported their consumption, the Board has the authority to enforce the allocation requirements. Its powers of enforcement are broad, ranging from issuing a warning to revoking water rights. The URNRD has revoked irrigation rights for intentional misrepresentation of consumption and received support from the community for such stringent enforcement of District regulations.

In 2010, it was discovered that several irrigators installed underground piping to bypass the meters used by the district to measure water use. URNRD responded with unprecedented penalties including the permanent loss of irrigation rights for nearly 1,500 acres of cropland and decertification of another 800 acres for 10 years. In total, these penalties were estimated at roughly $3 million. The community was supportive of URNRD's decision. Following the 2010 case, the general manager of URNRD stated that the district's enforcement rules "are written for the 0.1 percent of people who are willing to cheat society. The rest of folks are willing to accept the rules and live by them" (Hovey, 2010).

Water quality testing services are provided by the URNRD and public and private wells across the District are sampled each year for contaminants (URNRD, 2016e). Private well monitoring is primarily left to the well owner or water user. However, the URNRD encourages private well owners to monitor their water quality by providing test kits to individuals in the District for domestic and livestock water wells at no charge (URNRD, 2016e).

Financing

The NRDs have multiple sources of funding (property, occupation, and grants) and their mandate includes flood management, recreation, soil conservation, education, as well as groundwater management. The Nebraska Legislature empowered the Natural Resources Districts to levy taxes on taxable property in their districts, including taxes whose revenues may be used for groundwater management activities. The URNRD also uses an occupation tax leveled against all irrigators in the district to fund projects such as N-CORPE. Currently, the rate is $10 per irrigated acre, the highest amount the state allows. In the URNRD, occupation taxes generate $4.4 million annually (Fanning, 2012). The 2015 income from tax was $4.4 million from occupation tax and $2 million from property tax assessment. Additionally, the District also occasionally applies for various grants to supplement its revenue.

Evaluation

The Upper Republican NRD has implemented a highly sophisticated groundwater management program in an area with high intensity irrigation and high scrutiny due to interstate water agreements. The district maintains and manually inspects an impressive number of metered wells for both water level monitoring and water use tracking, made possible thanks in part to a substantial budget. Further, URNRD utilizes a broad portfolio of tools and continually evaluates and adjusts district rules based on experiences. URNRD has also been able to accomplish its goal of compliance with the Republican River Compact while minimizing the impact of compliance on water users in the district.

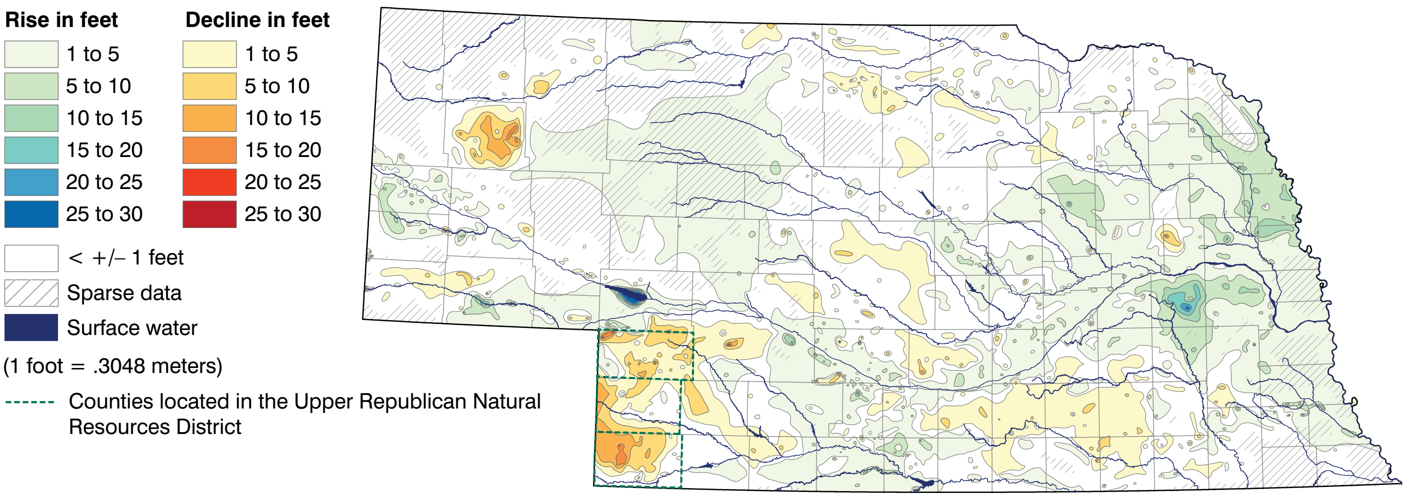
However, the long-term issue of declining groundwater level persists. While the groundwater decline in the district is lesser today than what was predicted in a USGS 1988 study, the district has so far been unable to stabilize groundwater levels (Figure 6.2, page 79).

The specific irrigation allocations have presented a challenge for the district as initial allocations were large enough that many water users have large amounts of water "banked" for use in future years. The result is that there may be reduced incentive to conserve water for the future. The district has attempted to address this by introducing restrictions on carryover accounting.

While the stream augmentation projects have been very expensive (over $100 million together, without operating costs), they have been successful in ensuring Republican River Compact compliance for the URNRD and other NRDs in the Basin. Such programs have potential to incur high political costs in addition to financial debt, energy costs, and potential lost tax revenue. However, the projects in URNRD have been supported by the majority of irrigators in the District as stream augmentation has prevented widespread irrigation shutdowns previously proposed by Kansas to ensure Nebraska's Compact compliance. Use of groundwater from retired land could potentially exacerbate long-term groundwater decline if pumping capacity exceeds the amount of irrigation water that otherwise would have been applied to the land if left in production. The N-CORPE Board has expressed interest in developing policies to ensure that long-term pumping for stream augmentation does not have this effect. Compact calculations are complex across years. As a result, groundwater has been pumped from the project in drought years, however, the projects will also likely not be used in some drought years immediately following wet periods. For example, if either project had existed in 2012 neither would have been used despite 2012 being one of the driest years on record. Other regulatory approaches could have been used to help the District comply with the Republican River Compact. However, the stream augmentation projects provide regulatory

FIGURE 6.2

Groundwater change from 2006–2016



Source: Conservation and Survey Division, School of Natural Resources, University of Nebraska—Lincoln, 2016

certainty in compliance and allow the District to avoid imposing further direct water use restrictions on irrigators, or worse, cutting off irrigation entirely for some users.

Lessons learned

The following are key lessons from the Upper Republican Natural Resources District:

- Strong regulatory authority with extensive data collection are used together to track attainment of strict basin-wide goals.
- Regulations should be adjusted as needed over time based on external and internal conditions.
- Strong enforcement of regulations is possible, even in tight-knit communities, when the regulations are supported through outreach and communication.
- Projects that provide regulatory certainty may be preferred to incentive-based systems despite relatively high costs.

Resources

Interviewees and case study reviewers: Thank you to Don Blankenau (Attorney for N-CORPE) and Nate Jenkins (Assistant Manager, Upper Republican Natural Resources District) for their time and input in constructing this case study.

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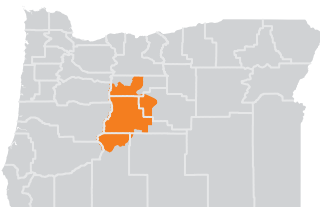
CASE STUDY 7 / OREGON

Deschutes River Basin



AUTHOR

Drew Palmer

CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

Surface water depletion

PREDOMINANT WATER USES

Agricultural

Urban

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Regulatory

- Limits on new wells
- Permitting system for new and existing uses of groundwater
- Quantified pumping rights
- Metering of wells (self-reported)

Incentive-based

- Offset program tied to water mitigation banks
- Transfer system for flow mitigation credits
- Flow mitigation credits
- Fees

Agency supply augmentation and protection

- Stream restoration projects
- Infrastructure upgrades (paid for by agency)

Education and outreach

See page 87 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- Close collaboration between state water agencies (such as OWRD) and local non-profits (such as DRC) results in constructive engagement that helps determine best management practices from both micro and macro perspectives.
- Although it still has room for improvement, the DRC Water Bank is an example of how a single, central water bank can operate to meet strict caps on new water use by trading new credits for old water rights.
- OWRD's incorporation of stakeholder feedback gives local water users, non-profits, and nature advocacy groups a voice that fosters effective contributions to continuing improvement efforts.
- Regular program evaluation and specific review criteria allow OWRD to consistently evaluate progress and adjust policy when needed to face new challenges and ensure that long-term goals are met.

Background and governance

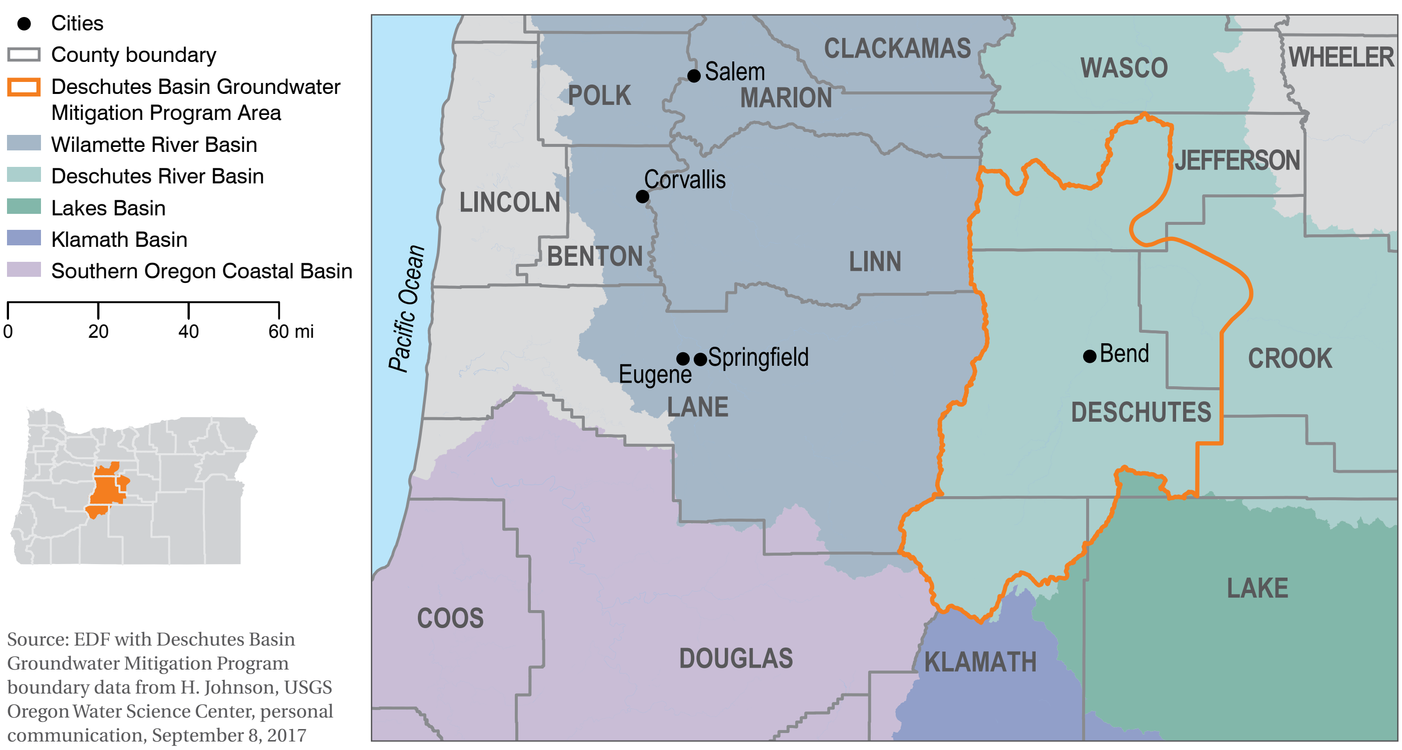
Historically, Oregon used primarily surface water to meet water demands, but new surface water appropriations have been limited by the state since the early 1900s. When central Oregon's population and development soared at the end of the 20th century, growing municipalities, small hobby farms, and recreational facilities began turning to groundwater to supply their needs (Deschutes River Conservancy, n.d.-a). Legislation enacted during the same period (the 1970 Scenic Waterway Act, the 1987 Instream Water Right Act, and the 1991 Scenic Waterway Flows) to protect Oregon's rivers and streams fully closed new surface water allocations, leaving groundwater as the only source of new access to freshwater. The region's rapid growth and associated increase in water demand were key drivers of the development of the management program to reduce groundwater usage. They continue to be important considerations in management strategies for the region, since current population projections show no signs of slowing (Newton, Perle, & Polvi, 2006).

The Oregon Water Resources Department (OWRD), irrigation districts, and other local and regional authorities regulate all water usage in the Deschutes River Basin (Basin). The State of Oregon holds all the waters (surface water and groundwater) of the State in trust for the public. Agricultural production in central Oregon requires a significant amount of irrigated crop land—over 240,000 acres (Deschutes Water Alliance, 2008). Along parts of the Deschutes River, roughly 90% of the river's water is diverted from the stream for irrigation during the growing season (Deschutes River Conservancy, n.d.-b). This is accomplished through a series of irrigation canals and pipelines and is managed by various irrigation districts.

In 1970, Oregon passed the Scenic Waterways Act (Act), which designated certain rivers as "scenic waterways"—including large sections of the Deschutes—and charged the state of Oregon with, among other things, preserving the "free-flowing character of these waters in quantities necessary for recreation, fish, and wildlife uses" (Scenic Waterways Act, 2007). The Act delegated management of scenic waterways to the Oregon Parks and Recreation Department (Sussman, 2013).

FIGURE 7.1

Deschutes Basin Groundwater Mitigation Program



Source: EDF with Deschutes Basin Groundwater Mitigation Program boundary data from H. Johnson, USGS Oregon Water Science Center, personal communication, September 8, 2017

The Act was amended in 1995 to include mandatory assessments of groundwater pumping. The amendment required OWRD to assess whether new groundwater permits would "measurably reduce" scenic waterway flows to the detriment of the "free-flowing character," which required OWRD to determine if there was a hydrological connection between groundwater and surface water flows (Or. Rev. Stat. § 390.835; OWRD, 2008).

OWRD coordinated with the U.S. Geological Survey (USGS) to survey the upper Deschutes Basin section (shown as the Deschutes Basin Groundwater Mitigation Program area in Figure 7.1, page 82). Covering around 4,500 square miles—66% publicly owned—the upper Deschutes Basin has 220,000 acres of irrigated farmland (G. Hubert, personal communication, May 15, 2017). Groundwater recharge consists mostly of natural precipitation and flows from other basins; its discharge supplies over 75% of total streamflow downriver (Lieberherr, 2008). The USGS provided key information about the relationship between groundwater and surface water in the Deschutes Basin through the use of the Deep Percolation Model, developed in Bauer and Vaccaro (Gannett et al., 2001), to quantify complex interactions including evaporation, snow accumulation/melt, runoff, and recharge.

The model results confirmed prior studies by finding a definitive hydrologic connection between groundwater and surface river flow in the Upper Deschutes Basin, indicating the potential for groundwater pumping beyond the level at the time of the study's publication to violate the "measurable reduction" stipulation in the 1995 legislation.

In response, OWRD suspended all pending applications for groundwater permits (Lieberherr, 2008). Then, OWRD assembled a broad coalition, the Deschutes Basin Steering Committee, to develop mitigation strategies to facility streamflow reductions (Sussman, 2011). This committee was unable to reach consensus on which mitigation strategies should be implemented and the task of designing a mitigation plan was instead passed off to OWRD's Water Resources Commission (Lieberherr, 2008).

In 2001, state legislation authorized the creation of a mitigation program using a system of credits and banks. The Water Resources Commission (WRC) conducted multiple rounds of public hearings, requests for comment, and input from over 250 local citizens and organizations, and officially enacted the Deschutes Basin Groundwater Mitigation Program (GMP) (Figure 7.1) and the Mitigation Bank and Credit rules in September 2002. These rulings were immediately met with a lawsuit in November 2002, filed by WaterWatch and 13 other local groups. This lawsuit was largely centered on the timing of impact of the increased groundwater extraction. WaterWatch asserted that while the mitigation program would increase streamflows during the summer, it would actually reduce them in the spring and fall, when flows are most important to fish populations. In 2005, the Oregon Court of Appeals struck down the rules. The legislature then codified the WRC plan later that year, reinstating the GMP (Sussman, 2013).

ADDITIONAL RESOURCE: For more information on the process of developing the mitigation program, see the September 2002 report found at http://apps.wrd.state.or.us/apps/misc/wrd_notice_view/Default.aspx?notice_id=41

Program management goals

The purpose behind the Deschutes GMP is to protect the quantity of streamflow for recreational, fish, and wildlife uses. The GMP contains the following three goals:

- To maintain scenic waterway and instream water right flows,
- Facilitate restoration of Middle Deschutes River flows, and
- Accommodate growth through new groundwater development (OWRD, 2008).

ADDITIONAL RESOURCE: More information on wildlife and habitat issues in the Deschutes Basin with links to various sources can be found from the Oregon Watershed Enhancement Board website, available at http://www.oregon.gov/OWEB/pages/index.aspx

Tools used to achieve management goals

The GMP is designed to allow for continued expansion of groundwater extraction without subtracting from existing surface water rights or creating a "measurable reduction" to the flow under the Scenic Waterways Act. In practice, this means that no new applications for groundwater extraction permits can be approved until the corresponding calculated reduction in streamflow can be properly mitigated.

The GMP is a cap and trade system, and accordingly uses a combination of regulatory tools and incentive-based tools, as well as some education and outreach, to meet the management goals.

Regulatory tools

Limits on new wells

The GMP places an aggregate cap on the rate of groundwater that can be withdrawn through new groundwater permits at 200 cubic feet per second (cfs) (OWRD, 2007). This cap can be adjusted by OWRD during the course of routine program assessment, subject to a state administrative rule change and engagement of a public rules advisory committee. Additional legislation to expand the cap may be required in the future if the advisory committee cannot reach consensus on adjustments.

Permitting system for new and existing uses of groundwater

This aggregate limit is allocated to groundwater permit applicants by the state through final orders. The pie charts in Figure 7.2 (page 85) show breakdowns of the 200 cfs of groundwater allocation as of 2012. By 2012, 71% of the total allotment had been issued as final orders or approved permits, leaving 29% of the cap available. Almost 89% of total allocation was designated for municipal or quasi-municipal use,with just over 8% for irrigation and the remaining fraction for other uses (OWRD, 2014). Most pumping designated as "quasi-municipal" is done by private water developers. The percentage allotment and its distribution have largely persisted since 2012. More recently, though, applications for new uses of groundwater have increased with an upward trend in development (G. Hubert, personal communication, May 15, 2017).

OWRD is responsible for processing applications for groundwater permits. After OWRD receives these applications, it sends the applicant an "Initial Review," which lays out the mitigation credit requirements for the application. When these credits are obtained, after a 30-day public comment period and a 45-day protest period, the application can be approved and the final order and permit granted (Deschutes River Conservancy, 2016a). The time between application and final approval is typically 6–12 months, but has been longer in the past (L. Wilke, personal communication, August 11, 2016). A permit applicant has five years from the date of the final order to secure the required mitigation. If the applicant does not secure mitigation before the five-year deadline, the application is cancelled. This helps reduce speculation under the cap (G. Hubert, personal communication, May 15, 2017).

Quantified pumping rights

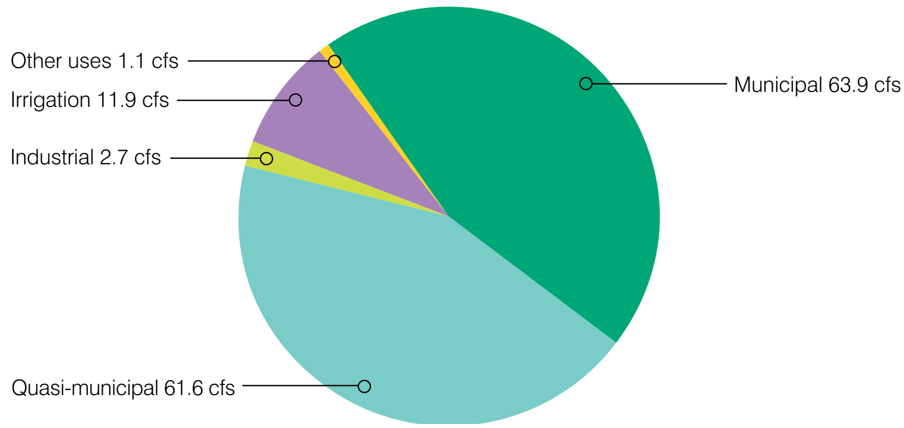
Groundwater permits issued by the state define rights to pump a volume of water in acre-feet (af) as well as a maximum allowed rate of pumping.

Metering of wells (self-reported)

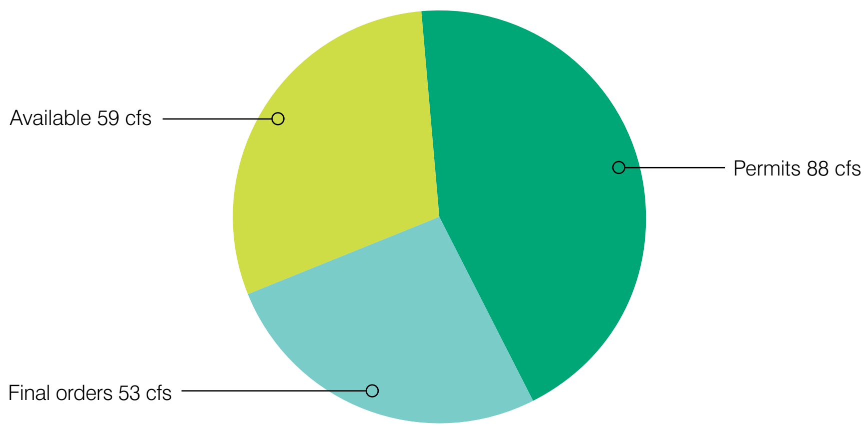
OWRD requires that meters be installed on new wells whose pumping permits are approved. Users are required to record water use monthly and self-report the amount of pumping

FIGURE 7.2

Distribution of the 200 cfs allocation cap (2012)



Amount of water in cfs of the 200 cfs allocation cap that has been allocated under new permits and final orders.



Amount of water in cfs of the 200 cfs allocation cap that has been allocated under new permits and final orders by type of use.

Source: Deschutes Groundwater Mitigation Program, Five-Year Program Evaluation Report, 2014

captured on these meters to OWRD annually to ensure that groundwater extraction remains within their approved allotment (L. Wilke, personal communication, August 11, 2016).

Incentive-based tools

Offset program tied to water mitigation banks

In the Deschutes, the state requires newly permitted groundwater users to obtain adequate mitigation credit to offset the effect of their pumping within the 200 cfs allocation cap in order to preserve streamflow. These credits are measured in acre-feet of water, like groundwater permits, to allow pumpers to adjust the number of credits they need to purchase based on their water needs. However, mitigation credits do not offset the exact amount of water pumped, but rather only the "consumptive" portion, which excludes the fraction of water withdrawn that will not be consumed (for example, by a crop) but instead absorbed back into the ground. Because credits only offset the consumptive portion of groundwater use, they operate slightly differently than the groundwater permits allocated under the overall 200 cfs cap, which restricts the total rate of groundwater use (OWRD, 2014). One mitigation credit is equal to one acre-foot of annual consumptive volume of water, and on average 1.8 credits are needed per acre of land for irrigation use each year (Deschutes River Conservancy, 2016b). Examples of offsets include leasing water to instream flow, permanent transfers of water instream, allocations of conserved water, and releases of stored water (OWRD, 2008). Underlying water rights for this protected water must have a priority date sufficient to reliably secure allocations and create a streamflow benefit.

FACT: Irrigation in central Oregon typically requires 3 acre-feet of water per acre per year. Of this, 60% is generally considered to be "consumptive," which yields a conversion factor of 1.8 af per acre each year of mitigation requirements. For quasi-municipal uses, 50% of water use is considered consumptive, due to large irrigated areas or golf courses. Typically, 40% is considered consumptive for municipalities (G. Hubert, personal communication, July 11, 2017).

The GMP does not require strict drop-for-drop mitigation at the exact site of pumping. Instead, water mitigation is balanced through seven "zones of impact." OWRD uses the zones of impact, which were delineated at the time of the development of the mitigation program, to assign each application for groundwater pumping a zone where the extraction will reduce streamflow; the corresponding credit to offset this well must be purchased from a water right in the same zone. Six of these zones are stream- or reach-specific while the seventh is assigned to a new groundwater applicant when their pumping may affect more than one localized zone. This scheme ensures that areas of the basin that are more heavily pumped for groundwater are also being replenished equivalently into the river or stream that is most affected by the extraction.

Transfer system for flow mitigation credits

The main mechanism for purchase and sale of mitigation credits are state-chartered water banks, which act as a virtual coordinator between parties. The Deschutes River Conservancy (DRC), a local non-profit involved in many facets of sustainability, preservation, and water leasing in the basin, operates the main water bank, the DRC Bank. Applicants for new groundwater pumping purchase credits from the water bank to offset the loss of discharge to the stream created by the pumping. Current holders of surface water rights may sell or lease existing rights to the water bank. The leases, held in trust by the state, reduce the amount of stream water they are permitted to divert. The DRC has conducted instream leasing, or buybacks of water rights, to increase the amount of flow protected instream in the basin—even before the groundwater mitigation program began.

FACT: From its founding in 2003 until 2008, the bank was known as the Deschutes Water Exchange.

Banks are not the sole source of mitigation, and not all mitigation transactions are facilitated through water banks (Aylward, n.d.). Surface water rights holders can also directly lease their rights to instream use purely to restore streamflow or for flow restoration associated with a mitigation project. They can also permanently sell their rights to someone else. Only the DRC's state-chartered bank can apply for, market, and convey temporary mitigation credits from instream leases, and it must be party to the lease. Any party may hold credits based on an instream transfer or other type of permanent mitigation project (L. Wilke, personal communication, August 11, 2016).

FACT: If the water right is in an irrigation district, the district must have a policy that allows leases and transfers of water. The lease or transfer of water requires landowner and district signatures (G. Hubert, personal communication, May 15, 2017).

Flow mitigation credits

There are two types of mitigation credits used as offsets: temporary and permanent. Temporary credits are purchased and renewed on an annual basis using temporary instream leases of existing water rights. As of 2016, temporary credits can be purchased from the DRC Bank for $120 per credit per year and a fixed $250 one-time setup fee. These credits must be re-purchased annually, and availability is not guaranteed. Because of the high turnover and temporary nature of the mitigation credits, the ratio of water protected instream to groundwater pumped must be 2:1. This rule forces the bank to hold one purchased credit in reserve, as a back-up, for every temporary credit actually used in case the water right source of the credit used for the mitigation becomes unavailable, or else risk permit regulation or cancellation (Deschutes River Conservancy, 2015). Temporary credits need to be purchased on an annual, calendar-year basis and are not pro-rated for periods less than a year (Deschutes River Conservancy, 2015).

Permanent credits, on the other hand, constitute one-time purchases that permanently transfer an existing water right instream to create mitigation credits that can then be used to mitigate for new groundwater permits at a 1:1 basis. As of 2016, permanent credits typically sell for between $2000 and $3000 per credit (from the DRC's Bank), depending on the source of the water right and the zone of impact. Permanent credits sold by water right consultants can cost up to $6000 per credit or more, but few are sold at this price (G. Hubert, personal communication, May 15, 2017). While credit prices are currently centrally determined by the bank, the DRC had in the past experimented with an auction to determine the price of mitigation credits.

NOTE: A large backlog of demand for mitigation credits had developed by 2004. In order to develop the market and get a signal on the appropriate value of the credits, the Deschutes River Conservancy Bank offered 36 credits up for auction. The design was an online/telephone first-price, ascending-bid auction. The auction resulted in only two sales, since few bids exceeded the confidential reserve price of $2,500/credit.

Fees

Anyone applying for a new groundwater permit must participate in the mitigation credit market if they are not already operating their own mitigation project (OWRD, 2008). Application for groundwater permits are submitted to and processed by OWRD. Since 2013, this one-time application has a base fee of $1150. Additional fees based on several factors can bring this total to over $3000 and may be subject to increases in future budget cycles.

Agency supply augmentation and protection

Streamflow restoration projects

In addition to maintaining the water mitigation bank, the DRC works closely with local landowners and irrigation districts, state and federal agencies, and other partners to implement flow restoration projects (DRC, Upper Deschutes Watershed Council, & Oregon Department of Fish and Wildlife, 2008). The DRC's efforts have concentrated on reducing diversions along the middle reach of the Deschutes River by helping to implement water delivery efficiency projects, for example by installing canal piping that reduces seepage, and water rights transfers and leases to instream flow. These projects have generated a five-fold increase in Middle Deschutes stream flows during summer months, which is when hot temperatures and irrigation diversions most threaten fish and wildlife (DRC, n.d.-b).

Education and outreach

In accordance with the mandatory legislative evaluation of the program, OWRD solicits feedback from stakeholders in the region to give them a chance to express concerns or propose improvements to the GMP and its associated rules and policy. This gives state and local interested parties a voice to modify the GMP to fit the changing needs of society.

Monitoring and enforcement

The DRC Water Bank and OWRD work together to ensure compliance on both sides of the mitigation program: instream flows and groundwater pumping. Instream flows are monitored using remote telemeters as well as random inspections from both DRC and OWRD staff. Local irrigation districts, which provide much of the water leasing supply to DRC, also perform their own compliance inspections (DRC, 2015).

Compliance by the groundwater user is more difficult to enforce. Well owners self-report the amount of pumping captured on their meters to ensure that groundwater extraction remains within their approved allotment. The amount of pumping approved is calculated to provide adequate supply for the determined consumptive use based on the type and size of the property. OWRD retains the right to require additional mitigation if the estimated consumptive portion becomes higher than originally calculated (L. Wilke, personal communication, August 11, 2016).

Problems can arise with failure to re-obtain temporary credits for the upcoming year, or from property ownership transfer. OWRD has revoked permits of users that remain delinquent on mitigation credits for an extended period of time. OWRD estimated that there are 4 to 5 permit holders who habitually fall into this non-compliance category, and the department is working on the best way to curtail these problems in the future (L. Wilke, personal communication, August 11, 2016).

Financing

The annual per-credit fee of $120 plus additional application fees fund the operations of the water bank and mitigation programming. From the inception of the DRC Water Bank until 2007, credit fees were lower ($70) because the bank was subsidized to help it get started. The price increased to $105 when the Bank became self-funded in 2008 (DRC, 2015) and to $120 per credit in 2016 to cover higher lease payments and increases in state lease fees (G. Hubert, personal communication, May 15, 2017). These revenues fund the leasing of instream water for mitigation and reserve credit holdings (52%), staff and other administrative expenses (38%), and a fund set aside for non-mitigation related restoration projects (10%) (DRC, 2015). Rapid growth and development in central Oregon may require the DRC Bank to increase future credit prices to cover added bank operation and staff costs, as well as an incentive program to increase the amount of water leased instream to meet new demands.

More detailed financial information on the costs and revenues of the Deschutes GMP is not readily discerned. There are two major operators of the mitigation program—OWRD and the DRC. Since OWRD is a state agency and oversees many basins and groundwater programs, there is not a breakdown of the staffing and operational costs of the Deschutes program specifically. Likewise, the financial reporting of the DRC—a 501(c)3 non-profit organization which operates many water leasing and other programs aside from GMP—aggregates costs and revenues across projects, and does not give a specific breakdown of the costs of running its groundwater mitigation bank.

Evaluation

The fundamental objective of the GMP is to prevent the loss of instream surface water flow due to groundwater pumping. So far, instream flow requirements established by the mitigation program have been met (OWRD, 2014). The OWRD has to conduct annual and five-year reviews of the GMP to ensure continuing compliance.

The annual review details data on all aspects of the program, from participation and permit metrics to discussion of development and mitigation activity. These reports provide a look back at the past year, while the five-year evaluations examine long term trends and provide assessment of policy efficacy and changes to the design of the program.

The Water Resources Commission of the OWRD conducts the five-year reviews. There are three stated "mitigation review criteria" that the WRC uses to evaluate the groundwater mitigation program:

- Whether scenic waterway and instream water right flows continue to be met on at least an equivalent or more frequent basis as compared to long-term, representative base period flows established by the Department;
- Evaluation of the mitigation program, associated mitigation, and the zones of impact; and
- Evaluation of the effectiveness of mitigation projects and mitigation credits that involve time-limited and permanent instream transfers, instream leases, and allocations of conserved water from canal lining and piping projects (OWRD, 2014).

The Commission uses two tools to evaluate the program to measure its success against these stated criteria: an instream flow model and tracking of data from groundwater permits, mitigation projects, and mitigation credit transactions (OWRD, 2014). OWRD developed the instream flow model and calibrated it using historical flow data in the region from 1966–1995 from various gauging stations. The model then calculates and estimates effects of mitigation projects and groundwater pumping on overall streamflow in the basin (OWRD, 2008). This allows OWRD to evaluate the net impact of the GMP on surface flows and assess whether the legislative requirements are being met.

While the program is currently maintaining baseline conditions on an annual basis, the GMP faces some challenges. A common concern expressed by many stakeholders was problems associated with zones of impact. Currently, as part of the permit application approval process, OWRD determines in which zones of impact mitigation must be provided for each project. A problem raised in the feedback process was that this system of determination is detrimental to areas that might be a secondary zone of impact. As one river conservation group explained, a proposal with 70% of its impact on River Basin A and 30% of its impact on Basin B will only have to mitigate for Basin A, since it is the "main" recipient of impact.

One potential solution to this problem would be a system to allocate fractions of credits to different zones of impact. In the example above, instead of allocating entire credits to one zone, the Water Bank could use 70% of the price of each credit to mitigate in Basin A and the remaining 30% for Basin B. While this may induce a larger administrative burden on the Water Bank to calculate these shares and work with fractional credits, it has the potential to more equitably distribute mitigation around the various zones of the basin. Similarly, surface water availability and the cost of protecting water to provide credits can vary from zone to zone, but could be allocated accordingly (G. Hubert, personal communication, May 15, 2017).

Another concern, as previously mentioned, is that the GMP does not adequately ensure compliance with the mitigation requirements for temporary mitigation credits. This problem highlights a fundamental tradeoff between the costs and benefits of stricter compliance scrutiny. Due to the extremely large geographical size of the Basin, OWRD would need to spend significant time and resources to increase the number of random inspections or to implement universal inspections. OWRD would need to weigh the cost of performing these additional expenses against the benefits of potential increased compliance and decrease in potentially inaccurate self-reporting.

Another concern relates to the impacts on ecosystems. The water banking system of mitigating groundwater pumping through restored stream flow bolsters flow during the summer at the expense of winter flow. This is because most instream transfers to generate mitigation credits only occur during the summer irrigation season, while groundwater pumping occurs year-round. The Oregon Department of Fish and Wildlife (ODFW) expressed that, while total streamflow volume has increased on an annual basis as a result of the program, the volatility of how this mitigation occurs can be harmful to fish and wildlife that need sufficient streamflow even in the irrigation off-season (OWRD, 2015b). Additionally, the timing of impacts to aquatic habitats from pumping themselves is not well-known.

Also, even when groundwater pumping is fully mitigated instream on a volumetric basis, there is still an effect on temperature. Pumping decreases the rate of natural flow of cold groundwater into the river system (baseflow). This has raised average temperatures in some parts of the river system, which can upset temperature-sensitive habitats of fish and plants (OWRD, 2015a).

ODFW recommended changes to how OWRD collects and reports streamflow data. They urged the department to take into account this seasonal variability and asserted that annual and seasonal aggregate reporting can overlook acute events in the flow data that would be catastrophic to fish populations. ODFW suggested that reporting on the variability of flows and in time periods that are crucial for fish will help increase transparency of the effect of the program on these species (OWRD, 2015b).

The 2015 Deschutes Mitigation Draft Report also listed several other minor concerns and challenges that are being addressed moving forward. One concern noted was the possibility of the 200 cfs allocation cap inducing speculative permits in anticipation of a future moratorium due to the cap being reached. The report noted, however, that the long process required to obtain final mitigation, several years at the least, currently has provided an effective deterrent for this behavior. This type of speculation has also been deterred by the 5-year time limit from the issuance of the final order to obtain mitigation (DRC, 2015). If no mitigation is provided within this period, OWRD will cancel the final order and not provide a permit.

Another concern raised was the increase in the number of projects, especially suburban housing developments, using loopholes in the program. Developers have begun to circumvent mitigation requirements by drilling one well for every three houses, which places them in the "exempt-use" category and allows them to avoid having to provide mitigation. If this continues to happen, the cumulative effects of this mitigation evasion may end up having noticeable impact on stream flows (DRC, 2015). The Oregon Legislature has not authorized any changes to these statutory exemptions at this point. Currently, the exempt use of groundwater for domestic purposes limits the amount of water that can be pumped from a single well (regardless of the number of homes it serves) to no more than 15,000 gallons (0.05 af) of water per day (L. Jaramillo, personal communication, May 17, 2017).

Currently, it appears that the relatively small numbers of buyers and sellers on both sides could hinder the expansion of direct mitigation apart from the water bank, but this could change if the number of program participants grows to a size where more flexibility becomes a clearer incentive in the system.

Lessons learned

The following are key lessons from the Deschutes River Basin for western groundwater management.

- Close collaboration between state water agencies (such as OWRD) and local non-profits (such as DRC) results in constructive engagement that helps determine best management practices from both micro and macro perspectives.
- Although it still has room for improvement, the DRC Water Bank is an example of how a single, central water bank can operate to meet strict caps on new water use by trading new credits for old water rights.
- OWRD's incorporation of stakeholder feedback gives local water users, non-profits, and nature advocacy groups a voice that fosters effective contributions to continuing improvement efforts.
- Regular program evaluation and specific review criteria allow OWRD to consistently evaluate progress and adjust policy when needed to face new challenges and ensure that long-term goals are met.

Resources

Interviewees and case study reviewers: Thank you to Gen Hubert (Water Leasing Program Manager, Deschutes River Conservancy), Lisa Jaramillo (Transfer and Conservation Section Manager, Oregon Water Resources Department), and Laura Wilke (Flow Restoration Program Coordinator, Oregon Water Resources Department) for their time and input in constructing this case study.

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CASE STUDY 8 / TEXAS

Edwards Aquifer Authority

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CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

- **Lowering of groundwater levels**
- **Degraded groundwater quality**
- **Reduction of storage**
- **Surface water depletion**

PREDOMINANT WATER USES

- **Agricultural**
- **Urban**

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Regulatory

- Permitting system for new and existing wells
- Quantified and allocated pumping rights
- Metering of wells (self-reported)
- Best management practices without cost-share (user pays)

Incentive-based

- Fees
- Transfer system for groundwater rights
- Offset program for conservation efforts

Agency supply augmentation and protection

- Aquifer storage and recovery
- Infrastructure upgrades (paid for by the agency)

Education and outreach

See page 100 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- A trading program can be an effective tool for groundwater management. In the Edwards Aquifer, a cap and trade program successfully reduced annual pumping and maintained minimum spring flow levels, despite the recent drought. The program's success appears to be due to:
  - An explicit, specific cap as defined in state law.
  - Minimizing transaction costs.
  - A straightforward online trading platform.
  - No constraints on how users divide their allocations.
- Robust and constructive public feedback coupled with program evaluation can build trust and encourage buy-in from program participants and other stakeholders.
- Challenges to groundwater management implementation include initial opposition to protecting species and surface water.
- Making water use data publicly available increases transparency, which builds trust and helps to ensure buy-in from program participants.

Background and governance

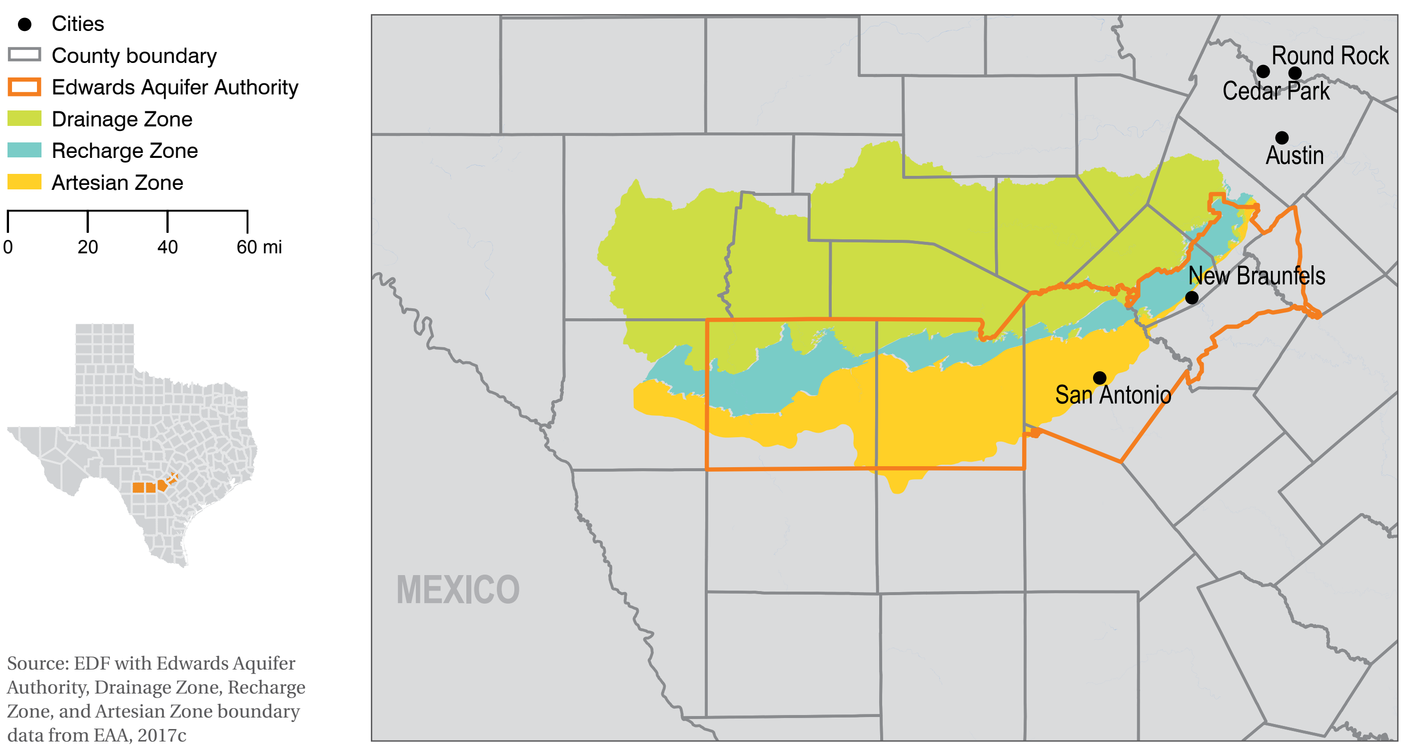
The Edwards Aquifer (Figure 8.1), which is considered one of the most productive aquifers in the U.S., spans a 4,350-square-mile area and underlies parts of 11 counties in west-central Texas (Smith et al., 2005). The aquifer is the primary source of water for approximately two million people who reside within and around its boundaries in the City of San Antonio, as well as for downstream users in the Nueces, San Antonio, Guadalupe, and San Marcos river basins (Votteler, 1998). It also provides habitat for numerous aquatic and subterranean species, a number of which are threatened or endangered.

The sources and volume of recharge can vary greatly from year to year. While it is not certain how much water enters the Edwards through inter-formational flow, such as from other adjacent aquifers, estimates range from 5,000 to 60,000 acre-feet per year (EAA, 2011). Roughly 75–80% of the Edwards' water replenishment occurs when water runoff from the catchment area flows in streams and rivers and percolates into faults along the recharge zone surface (Eckhardt, 2016a). Other sources include precipitation that falls directly on the recharge zone; surface water reservoirs; and neighboring groundwater systems such as the Trinity aquifer.

While most of the Edwards carries freshwater, a deeper portion of the aquifer is less pervious and water is stored there for longer periods of time, absorbing minerals from the surrounding limestone and becoming saline. Figure 8.2 (page 95) shows the hydrogeological features of the Edwards Aquifer (Eckhardt, 2016a). In this area, freshwater typically flows closer to the surface while saltwater is contained deeper underground. If the aquifer is overdrawn, the more saline, generally non-potable, water may move further up, contaminating the freshwater and reducing the total potable volume available. However, studies have indicated that such contamination, if it does occur, may be temporary, as new recharge will force the saltwater back down (Ewing & Wilbert, 1991). The residence time of the water within the aquifer, which determines its salinity, varies from a few hours to several years, and depends on a number of factors including depth and location.

FIGURE 8.1

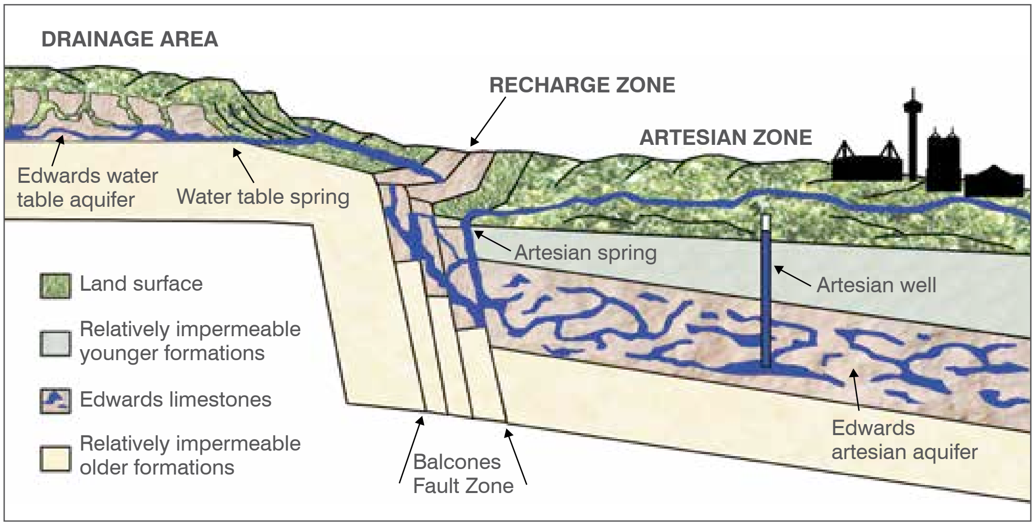
Edwards Aquifer Authority



Source: EDF with Edwards Aquifer Authority, Drainage Zone, Recharge Zone, and Artesian Zone boundary data from EAA, 2017c

FIGURE 8.2

Hydrogeological features of the Edwards Aquifer



Source: Courtesy Graphics, 2017

Groundwater is either naturally discharged from springs, many of which are clustered within the Comal and San Marcos systems, or withdrawn from drilled wells (USGS, 2016). While the former is used for sustaining important species habitat, providing freshwater flows to the bay and estuary, and supporting the recreational economies in the Cities of Braunfels and San Marcos, the latter provides a significant amount of the agricultural, municipal, and industrial supply in south-central Texas. Cities such as San Antonio, New Braunfels, Uvalde, and San Marcos were founded around the Edwards' prolific artesian springs and over time, as population increased and technology advanced, several wells have been drilled to supplement the yield from natural discharge. In recent decades, water scarcity and quality issues, together with increasing municipal demand, have impacted wildlife that depends on the aquifer's spring-flow and associated habitat, and some species, such as the Texas Blind Salamander, the Fountain Darter, the Comal Springs Riffle Beetle, and the San Marcos Salamander, are now endangered or threatened (Eckhardt, 2016b).

Following a historic ten-year drought, the Texas Legislature established the Edwards Underground Water District (EUWD) in 1959 to monitor the aquifer and support conservation, but granted it no authority to limit the quantity of water pumped (Uddameri & Singh, 2012). For decades, the EUWD surveyed the Edwards and argued that reducing withdrawals was a requisite for sustainable groundwater use, but state legislators were disinclined to sanction such authority.

However, in 1991, environmental interests brought a lawsuit against the U.S. Fish and Wildlife Service (USFWS), claiming that the Service failed to protect aquatic species and subterranean fauna to the extent mandated by the Endangered Species Act (ESA). In part as a response to that suit, the Texas State Legislature established the Edwards Aquifer Authority (EAA), granting it responsibility for:

- Sustaining federally protected aquifer-dependent species
- Ensuring effective management of the aquifer
- Identifying and addressing recharge initiatives for the aquifer
- Preventing water pollution.

In 1992, the USFWS recommended that the State of Texas, or a relevant regional groundwater management authority, produce a Habitat Conservation Plan (HCP), or a dashboard of strategies to ensure the preservation of aquatic biota. In exchange for this, the USFWS would, through powers accorded it under the ESA, issue an Incidental Take Permit (ITP), absolving the Authority of culpability if their actions cause a certain amount of "take" of covered biota, which is broadly construed to mean *harm to* but not necessarily *elimination of* (A. Hardberger, personal communication, July 2016). In other words, the ITP waives the strict liability of the ESA to protect endangered and threatened species, as long as the conservation measures delineated in the HCP are deployed.

In 1993, the Texas Legislature passed the Edwards Aquifer Authority Act (Act), which authorized water regulators to govern withdrawals from the aquifer by mandating that groundwater rights be permitted. The Act required that the State of Texas, via the EAA, maintain continuous minimum springflow at the Comal and San Marcos springs to protect endangered aquatic and subterranean species. The exact amount of continuous minimum springflow was later determined to be 30 cubic feet per second (cfs) and the Act also established an annual cap in aquifer withdrawals, both of which are detailed further below.

FACT: In Texas, groundwater rights are generally protected under the Rule of Capture, which grants landowners the right to capture water beneath their property. Within the state, groundwater use is regulated by Groundwater Conservation Districts across 16 groundwater management areas.

The Act created the Edwards Aquifer Authority (Authority or EAA), which manages groundwater use in a portion of the San Antonio segment of the aquifer that underlies 3,600 square miles of surface area, extending into eight counties: Atascosa, Bexar, Caldwell, Comal, Guadalupe, Hays, Medina and Uvalde. Figure 8.1 (page 94) illustrates this region.

Over the years, the Act has been strengthened through the passage of additional pieces of complementary legislation. Presently, the Authority, governed and directed under the most current version of the Act, has jurisdiction over eight counties, and is comprised of a 17-member board of directors who are advised and assisted on downstream water issues by the South Central Texas Water Advisory Committee (SCTWAC). Fifteen of its members are elected, each from a different district, and serve staggered four-year terms, while two nonvoting members are appointed, one through a majority vote of the SCTWAC, and one by the Commissioners Court of Medina County or Uvalde County, and serve four-year terms.

To achieve its conservation mandate, the Authority drafts and executes groundwater management and strategic plans, monitors water quality, availability and compliance, and coordinates with regional, state, and federal authorities and agencies to carry out different programs. Additionally, the Authority enforces permit conditions and monitors and reports on aquifer conditions. While it has been required to review and submit its Groundwater Management Plan (GMP), which expounds its strategy to achieve these deliverables, to the Texas Water Development Board every five years, as of the current Texas legislative session, it no longer needs to seek Texas Water Development Board review, and can continue operations independently.

The Authority also works with the San Antonio Water System (SAWS) to achieve springflow protection. Through the development of the Edwards Aquifer Habitat Conservation Plan (HCP), the Authority leases space to store regional water in the SAWS Aquifer Storage and Recovery program (ASR) (SAWS, 2012). The Authority also collaborates with the cities of San Marcos and New Braunfels, as well as Texas State University, to collect and analyze quality and quantity data. The USFWS enforces the mandates set by the ESA, and monitors whether the Authority is compliant with its regulations regarding covered species and spring-flows.

Program management goals

The Authority established and codified its initial goals based on suggestions provided by USFWS, which were generated by analysis USFWS conducted using available data. These targets were in accordance with what was determined to be an adequate level of water retained within the Edwards to support endangered species at times of record scarcity, benchmarked against rainfall during the ten-year drought. The initial goals included:

- Aggregate direct pumping from the aquifer be limited to 450,000 acre-feet per year, to be achieved by 2004
- Within 10 years, this limitation be further reduced to 400,000 acre-feet per year by 2008
- A special drought management plan be drafted and implemented during severe droughts, or when water level in the J-17 index well in Bexar County falls below 625 above mean sea level, that further restricts aggregate pumping to 350,000 acre-feet per year
- Additional interruptible withdrawals of 88,000 acre-feet be allowed if water level in the J-17 index well is above 665 feet above mean sea level
- All wells for domestic or livestock use be registered with the appropriate regional water authority to monitor their impact on the aquifer (Spear, 1992).

In 2007, the Texas Legislature amended the EAA Act, raising the cap from 400,000 acre-feet to 572,000 acre-feet per year while codifying the EAA's Critical Period Management Plan's drought reduction triggers and amounts and requiring the development of an HCP through the creation of a partnership of regional stakeholders, called the Edwards Aquifer Recovery Implementation Program (EARIP). The EARIP developed the HCP and associated springflow protection measures, including a 30 cfs target. The plan was approved by USFWS in 2013. (EARIPESS, 2009). Additionally, the EAA adopted ancillary conservation plans.

The Authority's 2016–2020 Strategic Plan goals can broadly be organized into two thematic categories:

1. Aquifer management and protection goals, which include:
   - Sustaining federally protected aquifer-dependent species.
   - Ensuring effective management of the aquifer.
   - Identifying and addressing recharge initiatives for the aquifer.
   - Preventing water pollution (EAA, 2015).
2. Organization effectiveness goals, which include:
   - Conducting research that enhances understanding and effective management.
   - Developing an inclusive, service-oriented organization.
   - Building shared value in the EAA mission.
   - Sustaining fiscal stability (EAA, 2015).

Tools to achieve management goals

The portfolio of approaches used to meet the initial and current goals include some regulatory tools and education and outreach, but are largely based on incentive-based tools and agency supply augmentation and protection projects.

Regulatory tools

Permitting system for new and existing wells

State law requires all new and existing wells that withdraw water from the Edwards Aquifer first obtain a permit from the Edwards Aquifer Authority (Edwards Aquifer Authority Act, 1993). Wells drilled on or before June 1, 2013 are exempt from the requirement to obtain a withdrawal permit provided that the well (1) is not capable of producing more than 1,250 gallon of water a day or

(2) is metered and does not produce more than 1.4 acre-feet of water in a calendar year (Edwards Aquifer Authority, 1993).

Quantified and allocated pumping rights

The groundwater management framework adopted by the Authority relies on an approach commonly referred to as Cap and Trade, in which a maximum allowable level of water withdrawals is established (i.e., the "Cap"), permits to extract the available resource are allocated to individual pumpers based on their historic use, and pumpers can trade their permits to match their usage to the allowable level of withdrawals (discussed below). The Authority commenced operating the cap-and-trade program in 1996 and allocated the first set of permits based on historical groundwater pumping and use rates to applicants who paid the necessary application and registration fees and demonstrated, through corroborating documentation, that they had beneficially used aquifer supply in any one year within the 1973–1993 period. This tool was adopted expressly for its ability to protect historic users of the Edwards Aquifer and to meet the legislatively-mandated cap of 30 cfs at Comal and San Marcos springs.

Since the cap's adoption, the Texas Legislature has granted the Authority abilities under its Critical Period Management Plan (CPMP) to reduce yearly withdrawals during scarcity by a set percentage, interrupting access for even regular permit holders conditionally based on the severity of the drought. However, the authority has set a floor, currently at 320,000 acre-feet per year, below which withdrawals are not to drop (RECON Environmental, LLC et al., 2012). During a critical period, all municipal, industrial, and irrigation-use permit holders are required to submit monthly, rather than annual, reports.

Metering of wells (self-reported)

All municipal, agricultural, and industrial wells within the regional domain of the authority must be registered, have meters installed, and permits must be granted for any water withdrawn from them. However, a well may be exempt from regulation if: (1) it produces 25,000 gallons of water or less for domestic or livestock use; or (2) it was drilled prior to June 1, 2013, and either does not produce more than 1,250 gallons of water a day or is metered and does not produce more than 1.4 acre-feet of water per year (EAA, 2016b). Municipal, agricultural, and industrial users operating non-exempt, metered wells, are required to record their water withdrawals monthly and report usage annually.

Best management practices without cost-share (user pays)

The EAA requires certain municipal, industrial, and irrigation permit holders to develop and implement individual groundwater conservation plans, and to assist with this process, the EAA develops a regional Groundwater Conservation Plan as a guide. Conservation under these plans is to be achieved through the implementation of best management practices that have documented improvements in water-use efficiency. Permit holders have flexibility to choose their own appropriate best management practice, but they are required to implement some type of approved best management practice as part of the individual groundwater conservation plan (EAA, 2014). Well owners must also practice prescribed or voluntary conservation strategies.

Incentive-based Tools

Fees

An aquifer management fee is assessed on permitted agricultural and non-agricultural users of Edwards Aquifer groundwater. The aquifer management fee for municipal and industrial permit-holders is $40 per acre-foot of groundwater authorized to be pumped (EAA, 2016a). Fees or agricultural users are charged on groundwater actually used during the preceding year and this fee is limited to $2 per acre foot (per the Edwards Aquifer Authority Act) (EAA, 2016a).

Transfer system for groundwater rights

EAA's management approach creates flexibility by allowing permit holders to trade in a market-based setting. Permit-holders can engage in voluntary trades, either to permanently transfer their water rights or to lease them out over a specified period, and have a great deal of latitude as to how to structure the transaction; in most cases, they may sell or lease all or any portion of their entitlements at any price they deem appropriate. While the EAA reassures that there are unlikely to be any detrimental or heterogeneous hydrogeological effects of pumping over space, analysis conducted by the EARIP did conclude that decreasing pumping near the spring systems has a positive impact on flow volumes, particularly in the case of San Marcos Springs (EARIPESS, 2009). As such, when the Authority realized that a number of transfers occurring between 2007 and 2009 enabled pumping to be localized around the springs in the eastern region of its jurisdiction, it passed the only major local constraint, colloquially referred to as the Cibolo Creek Rule, which restricts water users to the west of Cibolo Creek in Bexar County from selling their entitlements to those east of it.

The Authority provides access to, but does not maintain, a voluntary online trading platform which lists water permits for sale, along with seller contact information, permit number, minimum and maximum acre-feet for sale, transfer type, and contract lengths (North American Water Exchange, 2016). The online tools create a straightforward, transparent process to facilitate purchases and sales with limited transactions costs. The mandatory caps drive conservation within the district, and the trading system allows flexible redistribution of resources within those caps (Ballew, 2014). When water is scarce and additional, conditional caps are put in place due to drought or other supply and demand variances, the market can respond dynamically with a change in value of the resource.

Offset program for conservation efforts

The HCP, which has a term of 15 years, contains conservation measures to ensure the protection of species designated as endangered or threatened by the USFWS to the extent mandated at the state-level in the Act, and at the federal-level in the ESA.

The Voluntary Irrigation Suspension Program Option (VISPO) allows eligible permit-holders of irrigation rights to suspend all or a portion of their withdrawals for a specified time in exchange for monetary compensation. If the water level at a certain index well declines to or below 635 feet above mean sea level, measured by the Authority on October 1 every year, then the program is deployed and participants cease withdrawals for the next calendar year beginning January 1 (RECON Environmental, LLC et al., 2012).

The Regional Water Conservation Program (RWCP) provides municipalities with financial remuneration to refrain from pumping half of conserved water for a period of 15 years, with the goal of conserving 20,000 acre-feet of the total permitted or exempt volume (RECON Environmental, LLC et al., 2012). The RWCP supports municipal water providers through low-flow toilet programs and leak detection.

Agency supply augmentation and protection

Aquifer storage and recovery

The Authority collaborates with the SAWS to carry out the Edwards Aquifer Habitat Conservation Plan-related Aquifer Storage and Recovery (ASR) Program. SAWS conducted initial pilot projects and studies for aquifer storage and recovery in the mid-1990's and has since expanded its facility by purchasing additional land for more storage capacity and improving treatment infrastructure. The EAA began leasing water to the SAWS for storage as part of the regional Habitat Conservation Plan for protection of spring flow and endangered species (RECON Environmental, LLC et al., 2012). Excess Edwards Aquifer drinking water can be stored in the ASR facility when water supplies are abundant and can be withdrawn later for use during times of scarcity, providing a baseload supply during extended droughts and increasing reliability of the water supply (SAWS, 2012).

Education and outreach

The EAA provides several education and outreach tools to assist water users in meeting conservation requirements. As noted above, certain users are required to implement individual groundwater conservation plans. The EAA develops the regional Groundwater Conservation plan as a guide, which includes detailed information on various best management practices that water users may implement to meet the plan requirements (EAA, 2014).

The EAA also hosts and participates in community events with conservation themes, and provides educational programs for adults and children of all grade levels that address a variety of water use, hydrology, and conservation topics. Additionally, the EAA provides a significant amount of data and information to the public. For example, the agency is a host of "aquifer awareness tools" designed to teach the public about the aquifer (EAA, 2017a).

Monitoring and enforcement

The Authority maintains a robust monitoring program of water use through the meters installed on most wells. To minimize inaccuracies resulting from human error or tampering, a remote well metering program has been implemented (EAA, 2017b). Additionally, the Authority sends staff to all permitted wells once a year to take manual readings and ascertain that meters are functioning as intended and maintains a database of several months of usage data, and this information is publicly available.

Monitoring the pumping of permitted water through remote array readings and manually inspecting the status of installed meters creates a significant incentive for users to self-report accurately. This is further supported by the considerable legal power afforded to the Authority by the State of Texas to penalize infractions. In the event of an infraction, the Authority may impose a penalty of no less than $100 and no more than $1,000 per violation per day, and in extreme cases the Authority may revoke the violator's permit to pump (EAA, 2016b).

The mandates set by the Act are enforceable by state law, and in the case that a covered facility violates them, whether related to withdrawals or contamination, the Authority may impose an administrative penalty, generally a fine between $100 and $1,000 for each infraction and each day that the infraction is not corrected. In some cases, the Authority may also file a civil suit in a state district court to recover a penalty between $100 and $1,000 for each violation, for every day the violation continues, and for attorney fees (EAA, 2016b). It also reserves the right to seek injunctive relief regarding water use, and has the power to enter land to enforce it, although it generally seeks permission in most circumstances.

Financing

The authority adopts an annual budget before the commencement of every fiscal year, which aligns with the calendar year, and maintains its finances in accordance with the enterprise fund system. Operations are accounted for in a manner similar to a private business; revenues and expenses are recorded as they are earned and incurred, respectively, regardless of when the cash flows occur. The budget is organized into two major areas: the General Fund, for which revenues are derived almost completely from an aquifer management fee of $40 per acre-foot of groundwater authorized to be pumped, levied on all municipal and industrial permit-holders, as well as a fee of $2 per acre-foot of groundwater actually pumped, levied on agricultural permit-holders; and the Edwards Aquifer Habitat Conservation Plan Fund (EAHCP), for which revenues are primarily derived from an aquifer management fee of $44 per acre-foot authorized to be pumped levied on municipal and industrial permit-holders (EAA, 2016c). Revenues raised from this combined aquifer management fee of $84 per acre-foot account for most of the authority's budget. Total revenues for FY 2015 were recorded at $51,281,771, a slight decrease from $51,502,662 in FY 2014 and $37,745,052 in FY 2013 (EAA, 2016a).

Payments made by municipal and industrial permit-holders account for virtually all of the General Fund's annual operating revenues, and an almost negligible amount of annual non-operating revenues are also raised through miscellaneous sources including permit application fees (EAA, 2016c). The General Fund capitalizes the authority's daily operations, such as staffing, debt servicing, legal and laboratory services, and conservation grants. In addition to this, it is used to maintain several other, smaller funds established for specific purposes, such as the Abandoned Well Closure Assistance Fund, through which the authority provides financial assistance to low-income well owners who must take certain measures to comply with standards regarding abandoned wells. Revenues raised through compliance settlements are directed towards projects that aim to provide for conservation and aquifer protection activities through the Conservation/Aquifer Protection Fund (EAA, 2016c).

Funding from the EAHCP finances several conservation measures, such as VISPO and the EAHCP-related ASR program.

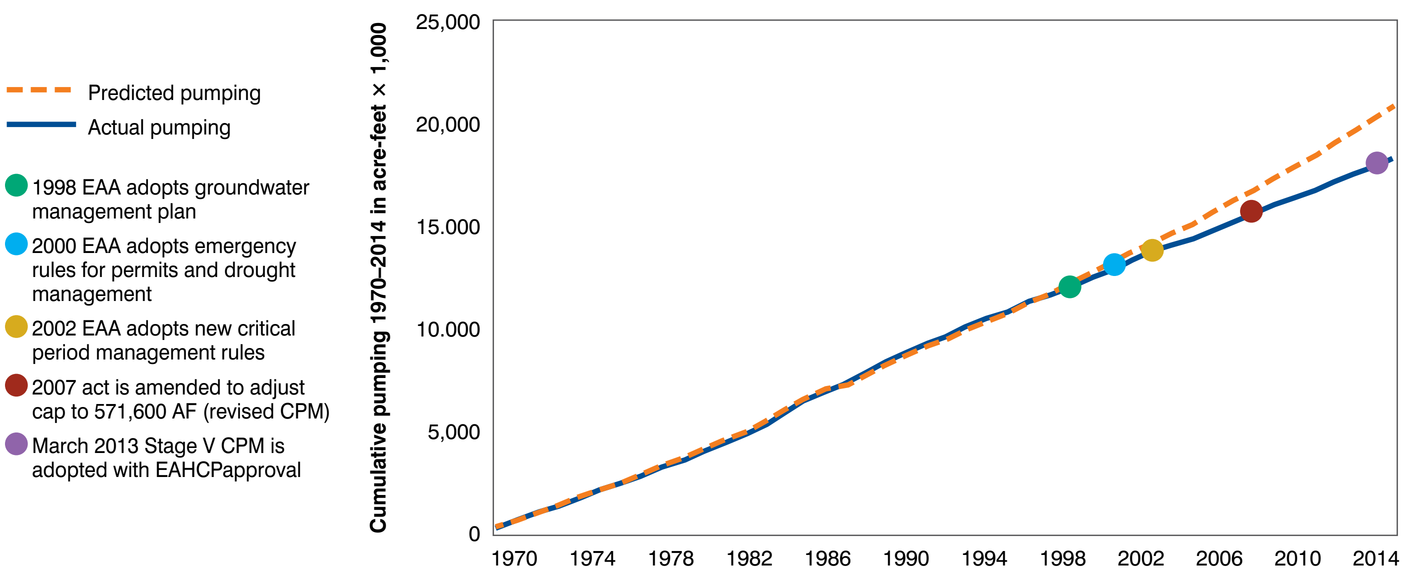
Evaluation

Annual aggregate pumping in the Edwards Aquifer has consistently remained below the cap set in 2007. According to data collected and furnished by the Authority, the average annual increase in pumping between 1947 and 1997 was 6,100 acre-feet. Since then, following the commencement of the permitting program, this growth trend has stopped, despite a population increase of ~670,000 in the regulated region. With the implementation of the CPMP strategies, summer peak pumping rates have also stabilized.

Further, as illustrated in Figure 8.3, actual permitted pumping volumes in 2014 were 2.6 million acre-feet below what was predicted by a population growth model for the period 1997–2014 (Hamilton & Winterle, 2017). Of the 2.6 million acre-feet, 1.95 million acre-feet have discharged at the spring systems, benefitting the aquatic ecosystem, and

FIGURE 8.3

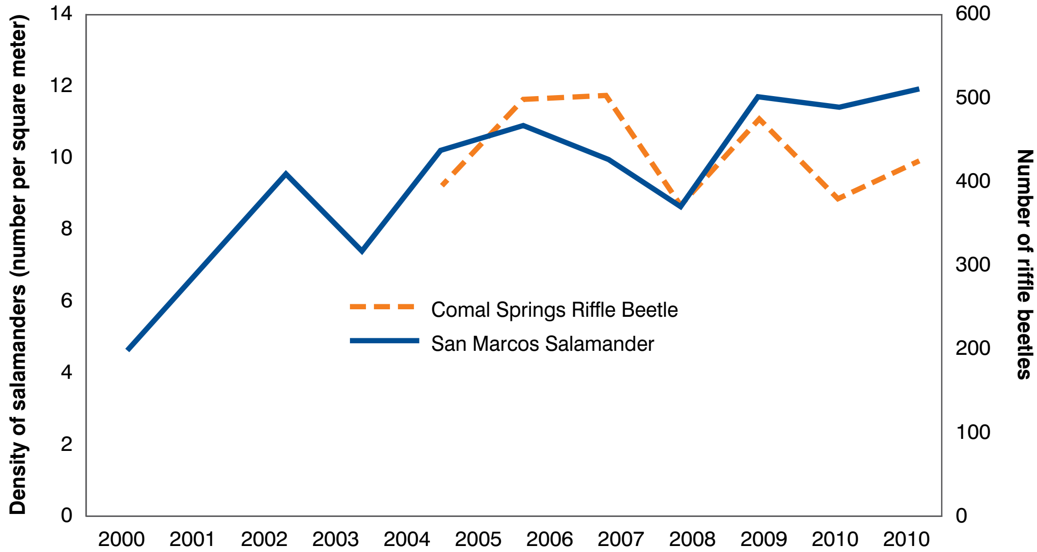
Predicted vs. actual groundwater pumping in the Edwards Aquifer (1970–2014)



Source: The EAA Act: A Success Story, 2017

FIGURE 8.4

Revival of endangered species (2000–2010)



Source: Water Policy, 2014

650,000 acre-feet have remained within the aquifer. Average flow has been ~90 cfs higher at Comal Springs, ~45 cfs higher at San Marcos Springs, and the water level in the San Antonio J-17 index well has been ~17 feet higher, compared to counterfactual scenarios produced by simulations modeling these statistics in the absence of the Authority's system and CPMP plan. Further, it is believed that Comal Springs would have gone dry and aquifer levels would have been below what they were during the 1950s drought of record, had no regulation been implemented.

Data collected on certain endangered species highlights a relatively steady revival as well (Figure 8.4), and modeling conducted by EARIP indicates that the current management framework should continue to support this trend (Debaere et al., 2014).

Based on spring flows, groundwater elevations, and the recovery of endangered species, the management program seems to be adequate in maintaining water quantity and sustaining threatened biota. The combination of management tools used by the Authority—from flow augmentation and recharge to cap and trade—were key to this success. The EAA does not expect to make any future adjustments to the cap.

As of this last legislative term, the Authority still operates under direction from the Texas Legislature, however, it enjoys considerable independence with programs and initiatives detailed therein.

Water trading is one increasingly utilized approach for mitigating issues typically realized when managing a common-pool resource, such as scarcity, contamination, and biodiversity loss. Proponents of water markets extol their efficiency and flexibility, arguing that negotiated transactions provide a transparent process to determine the price of water and voluntary exchanges of permits lead to the reallocation of water rights to those users who most value them, or who use them most productively. Furthermore, they allow regulators to place a cap onthe total number of permits issued over any trading period, and therefore, in this case, a limit on the amount of water that can be withdrawn. The magnitude to which these benefits are realized is generally contingent on the design aspects described above and discussed below, such as the cap, scope, flexible mechanisms, ancillary programs, monitoring and verification, and enforcement.

Theoretically, setting a cap on use, as a policy instrument, can efficiently manage scarcity and catalyze investments to increase efficiency, and therefore in the case of groundwater markets, can reduce the intensity of water use. In practice, the degree to which this occurs depends on the restrictiveness of the ceiling. As mentioned earlier, an analysis of permit trading at Edwards reveals that, over the period from 1998 to 2012, few trades were executed—only eight percent of all permits were transferred—and prices were fairly volatile. This could indicate that allocating based on historical use happens to have been a relatively efficient distribution. Alternatively, a historical, use-based allocation may not provide compelling incentives among those who have been granted initial permits, as they are guaranteed an annual quota adequate to proceed without making significant adjustments to their business-as-usual operations. While they may sell or lease their excess permits to other permit-holders, the profusion of permits in the market would create an excess of supply (and attendant lack of demand from existing users), diminishing the permit price.

Another important dimension of good water markets is the minimization of transaction costs. While trading is bounded to some extent over Cibolo Creek, within these regions there are no other significant restrictions to the spatial reorientation of pumping, eliminating the cost of physically transporting water. The online permit trading platform, and lack of constraints governing how permit-holders divide up their allocation to sell or lease also contributes to the reduction of transaction costs.

Still, despite growing demand from urban users, many of the trades that did occur were between agricultural users. The thinness of trade out of the agricultural sector may reflect the hesitancy of agricultural users to engage in transactions that are perceived to benefit industrial or municipal use, a historically contentious issue among regional farmers.

Lessons learned

The following are key lessons from the Edwards Aquifer Authority:

- A trading program can be an effective tool for groundwater management. In the Edwards Aquifer, a cap and trade program successfully reduced annual pumping and maintained minimum spring flow levels, despite the recent drought. The program's success appears to be due to:
  - An explicit, specific cap as defined in state law.
  - Minimizing transaction costs.
  - A straightforward online trading platform.
  - No constraints on how users divide their allocations.
- Robust and constructive public feedback coupled with program evaluation can build trust and encourage buy-in from program participants and other stakeholders.
- Challenges to groundwater management implementation include initial opposition to protecting species and surface water.
- Making water use data publicly available increases transparency, which builds trust and helps to ensure buy-in from program participants.

Resources

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CASE STUDY 9 / TEXAS

Harris-Galveston Subsidence District

AUTHORS

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CHALLENGES FACED (SGMA UNDESIRABLE RESULTS)

- **Lowering of groundwater levels**
- **Seawater intrusion**
- **Land subsidence**
- **Reduction of storage**

PREDOMINANT WATER USES

- **Urban**

TOOLS USED TO ACHIEVE MANAGEMENT GOALS

Regulatory

- Permitting system for wells
- Quantified and allocated pumping permits
- Metering of wells (self-reported and monitored)

Incentive-based

- Price setting and disincentive fees
- Best management practices

Agency supply augmentation and protection

- Reservoir operation
- Infrastructure upgrades (paid for by the agency)

Education and outreach

See page 113 for education and outreach tools to achieve management goals.

LESSONS LEARNED

- A goal to reduce groundwater pumping by a certain percentage of demand is an effective means to reduce subsidence, but may not be effective in reducing overall water use.
- Disincentive fees can encourage users to shift from groundwater to surface water to meet their water demands.
- The strategy to convert from groundwater to surface water shifts the supply from one resource to another, but does not address the long-term issue of demand reduction.
- Shifting from groundwater to surface water requires significant funding for the infrastructure necessary to change the source of water supply.
- Infrastructure associated with surface water augmentation projects can have negative impacts on the environment that may offset gains elsewhere.

Background and governance

The greater Houston area in the upper Gulf Coast has been adversely affected by land subsidence—possibly more than any other metropolitan area in the United States. Land subsidence is the loss of surface elevation due to removal of subsurface support, including the withdrawal of fluids such as groundwater and petroleum (USGS, 2017).

In the Harris-Galveston region, subsidence has resulted from chronic water level declines and has caused loss of groundwater storage, an increase in flood severity and frequency, extensive damage to industrial and transportation infrastructure, and profound loss of wetland habitat (Coplin & Galloway, 1999). In the coastal environment, by the late 1990's, as much as 10 feet of subsidence had shifted the position of the coastline (Coplin & Galloway, 1999), threatening wetland-associated industries like outdoor recreation and commercial and recreational fisheries. Further, due to the interrelated effects of sea level rise, loss of wetlands, and reduced sediment supply, the shoreline was eroding at an average rate of 2.4 feet per year and was projected to increase the sea level four inches by 2050 (Paine & Morton, 1986).

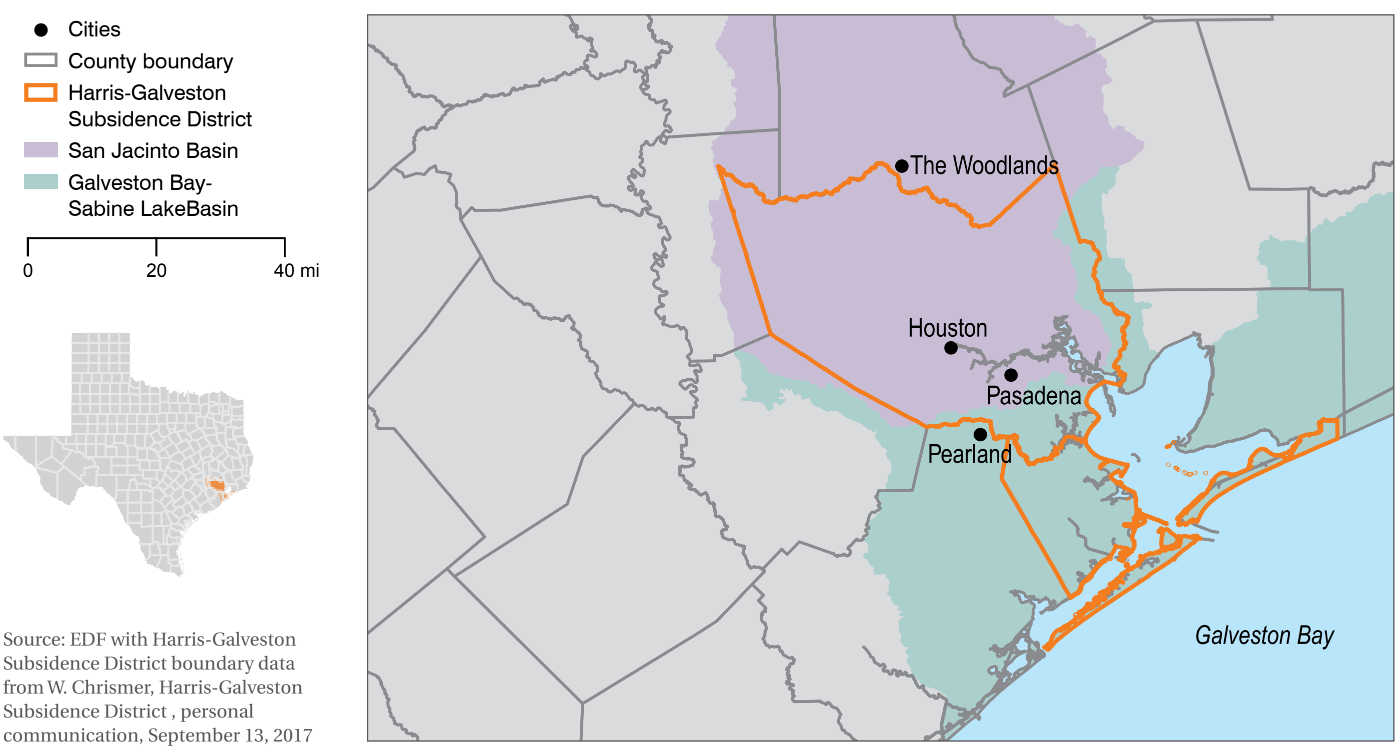
With strong municipal and industrial support, the Texas Legislature established the Harris-Galveston Subsidence District (District) in 1975 as a special district to regulate groundwater withdrawal throughout Harris and Galveston Counties for the purpose of minimizing land subsidence (HGSD, 2014) (Figure 9.1). The District regulates groundwater withdrawal in both Harris and Galveston Counties, managing a 2,170-square-mile region of the upper Gulf Coast (Neighbors & Thompson, 1986).

With over 4.5 million residents, Harris County is the most populous county in Texas and the third most populous county in the United States (U.S. Census Bureau, 2014). The county includes the sprawling metropolis of Houston, an industrial and diverse city that extends to Galveston Bay.

Galveston County is located on the plains of the Texas Gulf Coast, just south of Harris County in the southeastern part of the state. Galveston's population is significantly lower than

FIGURE 9.1

Harris-Galveston Subsidence District



Source: EDF with Harris-Galveston Subsidence District boundary data from W. Chrismer, Harris-Galveston Subsidence District , personal communication, September 13, 2017

Harris County's at just over 300,000 (U.S. Census Bureau, 2014). Galveston is bounded on the northeast by Galveston Bay, on the northwest by Clear Lake, and on the south by the Galveston Seawall and the Gulf of Mexico (MapTechnica, 2017). The Galveston Bay estuary is Texas' leading bay fishery and also supports recreation and tourism industries (Coplin & Galloway, 1999). In both Harris and Galveston Counties the majority of agricultural land is allocated for grazing (Texas A&M IRNR, 2017a).

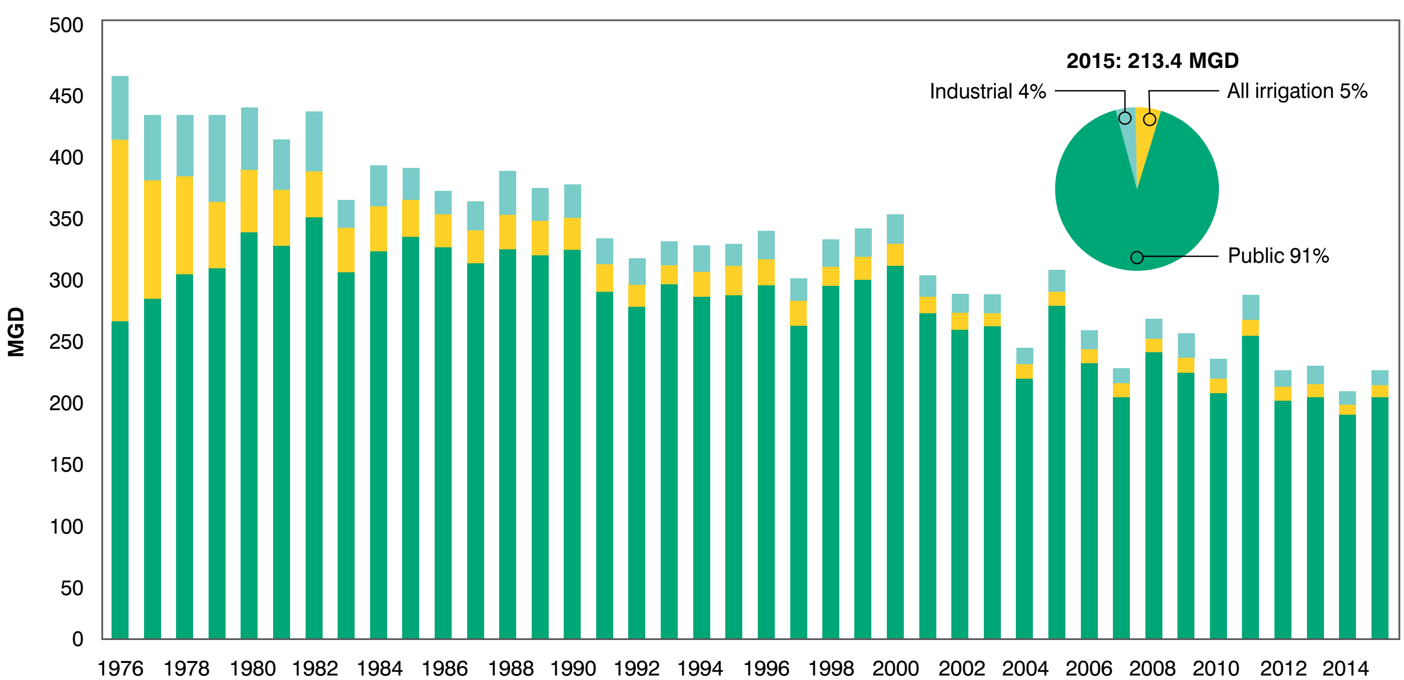
Land and water usage in the counties is similar. Galveston County is comprised of 85% non-working land, 10% grazing land, 4.4% cropland, and under 1% dedicated to wildlife management (Texas A&M IRNR, 2017a). In Harris County, 76% of the county is deemed non-working land, 15% is for grazing, 3.5% for crop, and 5% for wildlife management (Texas A&M IRNR, 2017b). Public use accounts for the vast majority of groundwater withdrawals in the District, while outdoor irrigation accounts for only 4% of total water use in both counties (Figure 9.2).

Groundwater withdrawal in the region is the leading cause of land subsidence, imperiling the aquifers on which the counties rely. Well users in Harris and Galveston Counties pump the majority of their groundwater from the Chicot, Evangeline, and Jasper aquifers, which are part of the Gulf Coast System—a vast coastal aquifer system that extends throughout the margin of the coastal plain of Texas and Louisiana into Florida. Because of the hydrologic connection between these aquifers, water-level changes that occur in one aquifer can affect water levels in the connected aquifer. Although water quality within the Chicot and Evangeline varies spatially and with depth, groundwater is mostly determined to be fresh, but becomes more saline closer to the coast.

To minimize land subsidence, the District manages groundwater withdrawals through permitting and regulation. The District is led by a four-member District Management Team including a general manager, monitoring and compliance deputy manager, permitting and water conservation deputy manager, and an administrative officer. A 19-member Board of Directors represents municipalities, industry, agriculture, and utility districts (Kasmarek et al.,

FIGURE 9.2

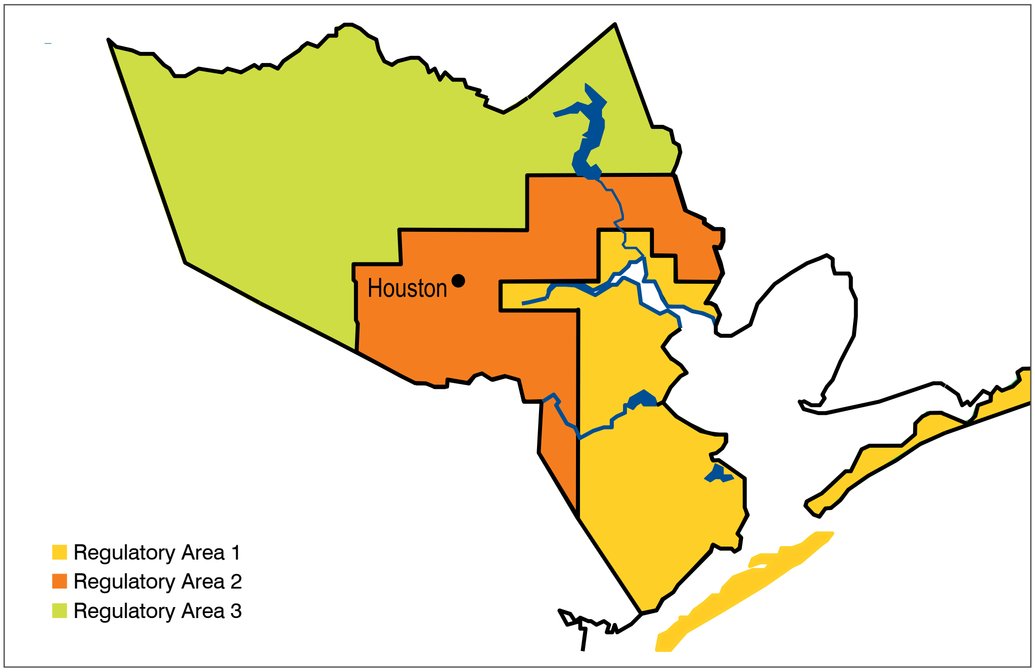
Groundwater withdrawal by year and use in Harris-Galveston management area



Source: Harris-Galveston Subsidence District, Annual Groundwater Report, 2015

FIGURE 9.3

Regulatory Areas within the Harris-Galveston Subsidence District



Source: Harris-Galveston Subsidence District, Regulatory Plan, 2013

2015). The District aims to limit groundwater use to a fixed percentage of total water demand, specific to three geographic subdivisions of the District. These subdivisions are referred to as Regulatory Areas 1, 2, and 3 (Figure 9.3).

The District also oversees two Regional Water Authorities (RWAs), which exist in Regulatory Area 3 as well as other ancillary agencies such as the City of Houston that secure adequate surface water and reduce dependence on groundwater. The RWAs in Regulatory Area 3 (North Harris County RWA and West Harris County RWA) were created to implement a Groundwater Reduction Plan for each region, with the aim of replacing reliance on groundwater with surface water use. These plans must be approved by the District by a majority vote from the Board. To meet these goals of "converting" groundwater use to surface water use, RWAs fund and construct water distribution infrastructure as well as set fees for groundwater and surface water use.

Program management goals

Groundwater districts across Texas are required to develop goals to provide the most efficient use of groundwater (Texas Water Development Board, 2017). The legislative purpose of the Harris-Galveston Subsidence District is to provide for the regulation of groundwater withdrawal in the district to end subsidence, which contributes to or causes flooding in the district, including rising water resulting from a storm or hurricane (TX SDLL § 8801, 2017).

The enabling legislation directs the board to formulate a plan to control and prevent subsidence in the district, which must "reduce groundwater withdrawals to amounts that will restore and maintain sufficient artesian pressure to control and prevent subsidence" (TX SDLL § 8801, 2017).

The District has established specific water supply goals in its Regulatory Plan to achieve its overarching purpose. Goals are established for each of the District's three Regulatory Areas to reduce groundwater withdrawals by specific deadlines.

The District's goal is to reduce groundwater withdrawal to no more than 20% of total water demand in Regulatory Areas 2 and 3, and to no more than 10% in Regulatory Area 1. Essentially, the District aims to change the source of water supplied from groundwater to surface water sources.

Tools used to achieve management goals

The portfolio of approaches developed for the Harris-Galveston Subsidence District include regulatory tools, incentive-based tools, supply augmentation and protection projects, and education and outreach. To achieve the groundwater target objectives for each Regulatory Area, the District has discretion to regulate groundwater withdrawals and to establish management tools to meet the objectives. Additionally, the RWAs, under the purview of the District, carry out the District's management goals in Regulatory Area 3 by funding and overseeing surface water distribution projects, setting prices for groundwater withdrawal and surface water, and sending aggregated well data from customers to the District annually. Where municipal services are not available, Municipal Utility Districts serve similar functions, namely, providing groundwater utility services, enforcing prices and compliance measures for well customers, and collecting pumpage fees.

Regulatory tools

The District's enabling legislation gives it the authority to regulate and permit groundwater withdrawals, require metering and reporting, adopt rules requiring the use of water conservation measures to reduce groundwater withdrawals, and to coordinate with local governments to establish water conservation goals, guidelines, and plans, among other authorities (TX SDLL § 8801, 2017).

Permitting system for wells

New water wells are required to be registered through the District by submitting a registration that solicits information on the well drilling company, well location, intended use, and current water use practices. The District determines whether the well requires a permit or is exempt. The District then begins the permitting process that includes a public hearing and board approval. The permitting process takes between 45 and 90 days. The District grants a permit to an applicant if the Board decides there is ample proof that there is no other available supplemental source of alternative water supplies at prices competitive with those charged by the District. Specific relevant factors include:

- The quality, quantity, and availability of alternative water supplies at prices competitive with those charged by suppliers of alternative water supplies within the District.
- The economic impact of denying an applicant a permit in relation to the effect on subsidence that would result.
- The applicant's water conservation measures.
- The applicant's compliance with other relevant requirements (TX SDLL § 8801, 2017).

NOTE: Wells that only serve a single family and have a casing diameter of five inches or less are exempt from the District's permit requirements. Additionally, the permitting requirements do not apply to monitoring wells, leachate wells, dewatering wells, hand-pumped wells, or windmills. To be exempt from having to meter a well, permittees must estimate their water use in their annual pumpage report that is sent to the District.

The District Regulatory Plan allows anyone who wants a well to have the ability to get a permit if they stay within the limitations of the Plan. Well permits require an application fee of $200 to authorize groundwater withdrawals for new wells, $50 for renewal applications, and $500 to approve and drill an emergency well within seven days. These funds cover the costs of issuing permits and performing the District's regulatory functions.

Quantified and allocated pumping permits

Allocation of groundwater pumping is done at the Regulatory Area level. In Regulatory Area 3, RWAs are free to implement their own strategies for reducing demand for groundwater and converting groundwater pumping to use of surface water resources. For instance, the RWAs may choose to aggregate the wells under one permit or they may choose to individually permit each well, although no Authority has individually permitted wells to-date. Still, in every instance, each permittee must operate within the pump limits established in the permit. It is a violation of the Harris-Galveston Subsidence District Rules to pump any amount of water over the amount authorized by the permit.

Metering of wells (self-reported and monitored)

The well owner or operator is required to keep monthly records on groundwater withdrawals and provide these records to their RWA according to their rules and regulations. While there are roughly 1000 wells within the RWAs, the District also receives pumping reports from cities, industries, and individuals outside of the RWAs. A member of the District staff conducts a personal inspection of each well annually. If it appears that an individual has violated the terms or conditions of a permit or has failed to comply with the law, the District may file suit and charge monetary penalties (Neighbors & Thompson, 1986).

Incentive-based tools

Price setting and disincentive fees

RWAs in Regulatory Area 3 set the cost of retail water in dollars per thousand gallons for both groundwater and surface water. Generally, fees consist of a Base Fee that applies to all authorized use, and a Disincentive Fee applied by the District to water users that are non-compliant with the Regulatory Plan (HGSD, 2013a).

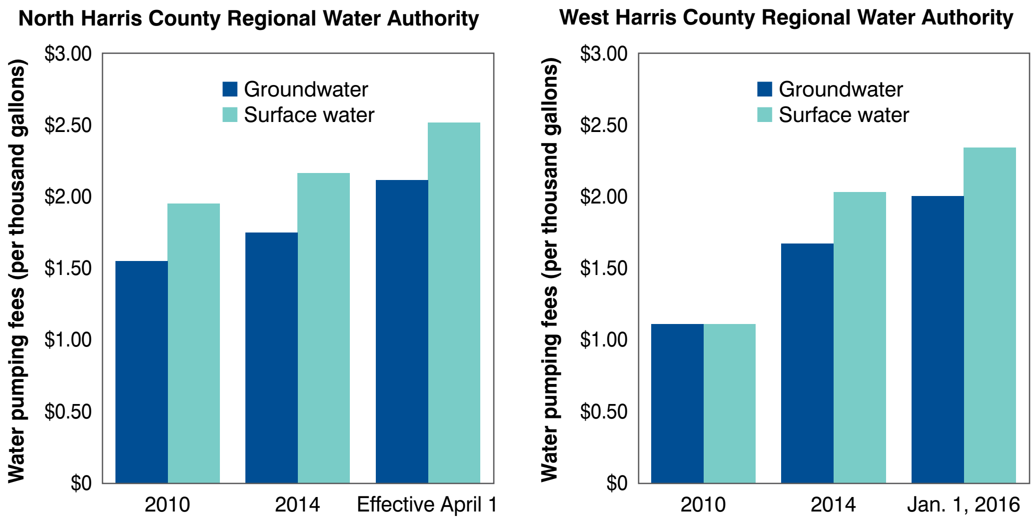
Fees vary slightly across RWAs. For example, West Harris County RWA charges $2.25 per 1,000 gallons for groundwater ($750 per acre-foot) and North Harris RWA charges $2.40 per 1,000 gallons ($800/acre-foot) to pump groundwater (Figure 9.4, page 112) (Arrajj, 2016). These fees are primarily set to cover budget costs of the individual RWA (WHCRWA, 2014), not to encourage reduction in usage, which is primarily accomplished through the District-level disincentive fee. The District lacks taxing authority, and RWAs set pumpage fees based on individual water usage instead of levying a general tax, which would unfairly spread the costs of high volume groundwater users over the entire community.

Although future water rates are not given in advance by the RWAs, some water providers expect prices to rise to $5.00/1,000 gallons ($1,666/acre-foot) by 2025 as the county focuses on reducing groundwater demand along with the rest of Texas. The rising cost of water is the greatest conservation tool according to an RWA representative, though RWAs ensure customers they commit to set water fees as low as possible for as long as possible.

To discourage groundwater usage over the percentage limits in each Regulatory Area, the District mandates a disincentive fee of $8.46 per 1,000 gallons ($2,333/acre-foot) to be applied to any groundwater withdrawal exceeding the Regulatory Area targets (HGSD, 2016). The disincentive fee is designed to create an economic incentive for sustainable groundwater use and to encourage compliance with the District's Regulatory Plan. Some well users have decided to pay the disincentive fee upon renewal instead of paying higher capital costs all at one time (Michael Turco, personal communications, July 2016).

FIGURE 9.4

Water pumping fees of regional water authorities



Local authorities are raising water pumping fees in 2016 to help pay the cost of expensive new pipeline projects

Source: Community Impact Newspaper, 2016

Since 2001, only about $500,000 in disincentive fees have been levied out of a potential $60 million annually if requirements were not met (Michel, 2006). This indicates that the disincentive fee is effective and is working well to induce the transition to surface water sources.

The Board may exempt a permittee from a disincentive fee if a permittee:

- Lacks an alternative water supply.
- Is located outside of the service area of any regional water supplier.
- Provides an acceptable groundwater conservation plan to the District (HGSD, 2017).

Best management practices

Permittees with a total water demand greater than 10 million gallons per year can avoid the disincentive fee through compliance with milestones contained in a certified Groundwater Regulation Plan (GRP). In this scenario, a permittee may submit a GRP to the District's Board of Directors for certification. To qualify, the GRP must outline specific plans for groundwater reduction including (1) infrastructure requirements and timetable of construction, (2) explanation of how infrastructure costs will be financed, (3) identification of water supply source and evidence of sufficient rights (HGSD, 2013b). The Board of Directors may, during consideration of certifying a GRP, require additional information, milestones, or reports as a condition of issuing the certification.

Agency supply augmentation and protection

With the District's oversight, RWAs reduce groundwater dependence through the use of new surface water distribution infrastructure.

Reservoir operation

In the 1940's, upstream reservoirs and canals allowed the first deliveries of surface water to Galveston, Pasadena, and Texas City, though groundwater remained the primary source until the 1970s. In 1973, the City of Galveston began converting to surface water supplied from Lake Houston, an 18-mile reservoir on the San Jacinto River that stores water for municipal, industrial, recreational, mining, and irrigation purposes. In the late 1970s, the cities of Pasadena and Texas City converted from groundwater pumping to surface water supplies from the San Jacinto River and the Brazos River, respectively. Today, the City of Houston receives most of its water from Lake Livingston.

Infrastructure upgrades (paid for by agency)

Faced with increasing water demand due to population growth, Harris and Galveston Counties are continuing to find ways to augment their water supplies. The Luce Bayou project began construction in January of 2016 and is expected to be complete in July of 2019 (Coastal Water Authority, 2017). The City of Houston is charged with the planning and development, and RWAs share the funding costs. The $350 million project includes a 26-mile system of pipes and canals that will provide up to 500 million gallons of water per day to communities in the greater Houston area (Coastal Water Authority, 2017). The project will provide additional surface water deliveries by channeling water from Trinity River to Lake Houston, where it can be treated and delivered throughout the Harris-Galveston region through 107 miles of pipelines and canals (Coastal Water Authority, 2017). Once the water is in Lake Houston, the RWAs and the City of Houston will increase the water treatment capacity to 400 million gallons per day by 2025 (Al Rendl, personal communications, June 2016). An expansion of the Northeast Water Purification Plant, in addition to new transmission lines, pump stations, and storage facilities will be constructed to deliver the water to municipal utility districts (MUDs). Transfer of additional raw water supplies to Lake Houston will allow counties to meet their objectives of converting groundwater to surface water. Districts will not use all of this additional supply immediately, but increasing water capacity now will help in future times of shortage (Al Rendl, personal communications, June 2016).

Education and outreach

Groundwater management strategies in the Harris-Galveston region extend beyond enforcement and regulation. The District and Regulatory Area 3's RWAs engage in community outreach and youth education as a correlative strategy to promote conservation messages. Working with Texas A&M University, the District's Outdoor Irrigation Program encourages best water management practices on residential and commercial landscapes using media and outreach (Turco, 2016). The District has partnered with the "Water My Yard" program, which sends automated emails or text messages to inform participants of the optimal amount of water needed on their landscape based on local weather conditions (Turco, 2016).

Additionally, the District has partnered with local cities to implement the WaterWise Program in elementary schools throughout the District. "Be a Water Detective" is a District-developed classroom curriculum on the water-cycle, water conservation, and subsidence geared towards 4th and 5th grade students. In 2015, the program reached over 70,000 children in Harris, Galveston, and Fort Bend Counties. With many new homes being developed with water-saving fixtures, the program has expanded its effort to include additional water savings measures not typically found in new homes, and widening the water conservation potential of the program.

WaterWise sponsors pay $35.40 for each student and in return, a groundwater credit is issued to the sponsor in the amount of 84,000 gallons to be used over 20 years. Depending on a groundwater user's pumpage costs, participating in WaterWise could reduce expenses for users. Groundwater credits can be used to offset the Regulatory Plan requirements when alternative sources of water are scarce or otherwise unavailable. Sponsors are thus financially incentivized to encourage conservation measures among future water users and utilize this program to promote water conservation within their utility district or municipality.

Despite attempts at engaging communities, some MUD directors have expressed concern over poor communication in the surface water conversion process. MUD directors in some districts believe RWAs have not adequately educated them and their customers about the reason behind the rising cost of water, resulting in confusion and customer complaints. However, according to the North Harris County RWA, most people in the community understand the value of water conservation.

Monitoring and enforcement

Generally, a water meter is required for all permitted wells and at the point of connection for all alternative water supplies used to meet District regulatory requirements. The well owner is required to test the accuracy of each water meter and submit a certificate of the test results at the owner's expense. The owner must read each water meter and record the meter reading and the actual amount of pumpage in a log at least monthly. The District may request a copy of the log, or to inspect the log anytime during reasonable business hours. The well owner must read the meter within 15 days before or after the date the permit expires and must report the readings to either the regional water supplier or the District.

Board Members, the General Manager, and District agents and employees are entitled to carry out investigations necessary to ensure compliance with these rules. After proper notice or prior permission has been given, agency officials may enter the property to conduct an investigation. The Board may authorize the General Manager to initiate a suit for injunctive relief, or to recover a civil penalty ranging from $50 to $5,000 per day for each violation.

Other monitoring measures include two systems used by the Municipal Utility Districts to measure the amount of groundwater and surface water that their districts receive. RWAs use a computerized monitoring system to control water distribution among districts by triggering the opening and closing of valves to release or retain water depending on a district's needs.

Financing

The District's expected budget for 2016 was $3.12 million in revenue with an estimated $3.54 million in expenses. The District is funded primarily through well applications fees, annual permitting fees, and disincentive fees. Infrastructure projects are largely funded through Regulatory Area 3's RWA pumpage fees and revenue bonds. All fees, with the exception of the disincentive fee, are used for administrative and day-to-day operations of the District. The Science and Research Fund is sourced entirely through disincentive fees. The District's General Manager explained that the District's regulatory plan of curtailing groundwater use has had a negative impact on available revenue (Al Rendl, personal communications, June 2016). Consequently, it is likely that District fees will increase in the future. Additionally, increases in the retail price of water by the RWA's and the City of Houston require the District to raise the disincentive fee in the future to ensure that the disincentive fee remains a disincentive.

In 2015, the District's Board of Directors allocated $1.4 million from disincentive fees to enhance the understanding and effective management of the Gulf Coast Aquifer System (HGSD, 2015). Projects recommended for the Science and Research Fund include: estimating the subsidence-neutral yield of an aquifer storage and recovery project, determination of subsidence impacts of brackish groundwater development, and the evaluation of the impact of groundwater credit use during a prolonged period of drought. Estimated expense associated with these projects was $450,000 for 2016 (HGSD, 2015). Future years will include a regulatory plan update process that will begin in 2018, extend through at least 2022, and cost about $1.5 million.

Evaluation

The design of the Harris-Galveston Subsidence District is well-suited for the goal of converting from groundwater use to surface water use. While there are still subsidence concerns in several areas of the region as described below, there is also ample evidence of overall success. However, other factors, in addition to subsidence reduction, warrant consideration when evaluating regional success from a larger scope. Specifically, issues of overall water demand, environmental impacts, and availability of surface water resources should be considered when analyzing the effects of the management strategy on the overall sustainability of the Harris-Galveston region.

When the District first mandated groundwater withdrawal reductions in 1975, compaction of subsurface sediments in the Chicot and Evangeline Aquifers began to subsequently slow in eastern parts of the greater Houston region, near the bay system (Coplin & Galloway, 1999). Additional water supplied from Lake Livingston in the late 1970s was sufficient to significantly reduce groundwater use and ultimately led to a recovery of water levels over a large area. A reduction in the rate of compaction was further observed with the curtailment of withdrawals and conversion to imported surface water from Lake Houston on the San Jacinto River. In later years, water levels in the aquifers began to recover and rise as much as 200 ft. in the Chicot and 240 ft. in the Evangeline (Coplin & Galloway, 1999). The slowing of compaction rates and rise of water levels is concentrated on the eastern Harris-Galveston region.

Total groundwater use throughout the District continues to decline. Water level declines have locally and temporally halted in eastern regions of the Regulatory Areas. However, subsidence is occurring in northern and western Harris County due to increasing water use and groundwater withdrawal for public and industrial use. Thus, the area of active subsidence has shifted from the low-lying, tide-affected areas towards slightly higher elevations inland—particularly in the area of the North Harris County Regional Water Authority.

Currently, the regulation and pricing mechanisms put in place by the District do not directly induce reductions in water demand. Rather, they provide economic incentives to invest in surface water capital projects that will replace groundwater pumping. This strategy directly addresses the problems of subsidence that groundwater pumping causes, but may not effectively curb demand. Since groundwater reductions are mandated in terms of percentage of total demand, rising overall demand may not necessarily reduce the level of groundwater extraction. For example, a "tightening" requirement that lowers allowable groundwater pumping from 20% of demand to 10% will have zero effect on the amount of groundwater pumped if demand doubles over that same period. Reducing total demand, then, plays a key role in ensuring that percentage reductions in groundwater withdrawals translate into reductions in the actual amount of water used. Thus, the implication and lesson is that restricting groundwater pumping based on a percentage of overall demand may work towards achieving a goal aimed at reducing subsidence, but it may not be effective at reducing overall water use.

Another key challenge faced by the District is the availability of infrastructure and resources (Michael Turco, personal communications, July 2016). While the region contains an abundance of water resources from ample precipitation and bodies of water, meeting growing water demands requires augmenting surface water distribution while focusing on conservation strategies.

With the regulatory strength of the District, RWAs have committed billions of dollars to convert from groundwater to surface water use, while the District has addressed the concerns of RWAs regarding short term alternative supply loss. Until the Luce Bayou and associated projects are complete, the Harris-Galveston region lacks additional sources of water. In the event of a treatment plant malfunction—as occurred in 2012—RWAs will be faced with the challenge of transporting water among cities. The president of the North Harris County RWA explains that none of their districts have run out of water in the past 70 years, and attributes the region's reservoirs to the "foresight of Houston's forefathers" in taking early measures to ensure Harris-Galveston maintains adequate water supplies (Al Rendl, personal communications, June 2016). These reservoirs, along with other water distribution infrastructure, address Harris-Galveston's biggest challenge: getting surface water to the regions that need it. As Harris and Galveston Counties are compelled to reduce groundwater pumping, the District and RWAs will look toward surface water projects to meet conversion objectives.

While extremely helpful to the reduction of groundwater usage, surface water conversion projects have raised environmental concerns. The Luce Bayou project is projected to impact one of the nation's most productive and commercially valuable bay and estuary system, and some critics claim the project perpetuates an endless cycle of meeting growing water demands by building more pipes, canals, reservoirs, and dams.

An analysis conducted by the National Wildlife Federation suggests that increasing freshwater withdrawals from the Trinity, San Jacinto, and other tributaries would destroy over 200 acres of protected wetlands and threaten the health of Galveston Bay by increasing salinity (Johns et al., 2004). Further, Luce Bayou's environmental impact report reveals that the project may also introduce invasive plants and animals to the watersheds, which would affect water quality, infrastructure, and wildlife. In response to these critiques, the Coastal Water Authority agreed to donate 3,000 acres of protected wetlands to offset the damages and move forward with the Luce Bayou project.

Lessons learned

The following are key lessons from the Harris-Galveston Subsidence District:

- A goal to reduce groundwater pumping by a certain percentage of demand is an effective means to reduce subsidence, but may not be effective in reducing overall water use.
- Disincentive fees can encourage users to shift from groundwater to surface water to meet their water demands.
- The strategy to convert from groundwater to surface water shifts the supply from one resource to another, but does not address the long-term issue of demand reduction.
- Shifting from groundwater to surface water requires significant funding for the infrastructure necessary to change the source of water supply.
- Infrastructure associated with surface water augmentation projects can have negative impacts on the environment that may offset gains elsewhere.

Resources

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