Cardon Research Papers
in Agricultural and Resource Economics

Research Paper 2014-02
Fall 2014

The Formative Political Economy of the Central Arizona Groundwater Replenishment District

Taylor D. Shipman
JPMorgan Chase & Co.

Paul N. Wilson
The University of Arizona

Department of Agricultural and Resource Economics
College of Agriculture and Life Sciences
The University of Arizona

TThis paper is available online at http://cals.arizona.edu/arec/publications/cardon-research-papers

The Formative Political Economy of the Central Arizona Groundwater Replenishment District

Taylor D. Shipman
Senior Analytics Manager
JPMorgan Chase & Co.
Columbus, Ohio
taylor.shipman@gmail.com

and

Paul N. Wilson
Professor
Department of Agricultural and Resource Economics
P.O. Box 210023
University of Arizona
Tucson, Arizona 85721-0023
pwilson@ag.arizona.edu

Departmental Working Paper 2014-02
Department of Agricultural and Resource Economics
University of Arizona
Tucson, Arizona, U.S.A.

The Formative Political Economy of the Central Arizona Groundwater Replenishment District

Abstract

In 1995 Arizona implemented a set of rules designed to require new development to use "renewable" (non-groundwater) water supplies. Many of the key provisions of the rules were developed by the regulated community itself, including the creation of a legal mechanism—known as the Central Arizona Groundwater Replenishment District—designed to aid compliance with the rules. The District enables developers to pay a small fee to pass the burden of acquiring renewable water supplies for their proposed development to the District. Over the last 15 years, the District has amassed a considerable debt obligation to acquire renewable water supplies on behalf of its thousands of member communities, creating a yet-undefined future water supply acquisition cost for an estimated 200,000 homeowners in central Arizona. This research explores the political economy behind the creation of the District and characterizes its formation using a Nash model of cooperative negotiation with bargaining power.

Key Words: Central Arizona Groundwater Replenishment District, Mutual Gains, Paper Water, Triangulation, Water Management

1. Historical Background

The first half of the 20th century was a time when water management was almost exclusively supply-side—focused squarely on water supply augmentation, development, and legal apportionment. Encouraged by the Reclamation Act of 1902 to "make the desert bloom," farmers expanded their irrigated lands into the desert, with the help of large water storage and delivery projects (Jacobs and Worden 2004). The introduction of new pumping technology in the 1930s and 1940s enabled Arizona farmers to irrigate farmland that was once too far from surface water supplies to be considered irrigable. Arizona quickly entered a new era of agricultural production. In the period from 1940 to 1953, irrigated crop production in Arizona expanded from 500,000 acres to over 1.3 million acres, causing irrigated water demand in Arizona to rise from approximately 1.5 million acre-feet (MAF) to 4.8 MAF (Kelso, Martin and Mack 1973; Glennon 1991) per year. Arizona's population similarly grew over the same period, nearly doubling its population with the addition of over 400,000 new residents. In nearly every corner of the state, the rate of groundwater pumping quickly surpassed natural recharge rates. The "Ice Age" waters in Arizona's aquifers, deposited in an era when Arizona's climate was significantly wetter than it is today, were being rapidly depleted by the state's numerous agricultural production wells. With the groundwater and surface waters of the state's interior managed largely by irrigation districts, Arizona leaders soon turned to the Colorado River as the critical "next bucket" of water to serve the state's agricultural and municipal water needs.

In 1922, years of bitter political wrangling culminated in the signing of the Colorado River Compact by the seven states of the Colorado River basin. The Compact divided the Colorado into Upper and Lower basins and allocated rights to the river's presumed average flow among the seven states. Arizona was allocated 2.8 MAF of the 7.5 MAF allocated to the Lower Basin states. The quantity of Arizona's right was more than it could put to use at the time; with much of the state's water demand located hundreds of miles from the river and no infrastructure to move vast quantities of water inland, the majority of Arizona's apportionment was left in the river to be used downstream by irrigation districts in California or flowing into Mexico as surplus to the international agreement guaranteeing Mexico 1.5 MAF annually. Ultimately, Arizona leaders believed that its entitlement to the Colorado River was only as good as its ability to put it to beneficial use. To protect Arizona's entitlement, Arizona leaders began to craft plans to put the water to beneficial use by conveying it far inland to central Arizona farms.

1.1 The Central Arizona Project

In 1944, Arizona Senator Carl Hayden formally proposed to construct an aqueduct to bring the water from the Colorado River into central Arizona. It took 24 years of negotiations for the aqueduct, known as the Central Arizona Project (CAP), to be authorized. The enabling legislation—the Colorado River Basin Project Act of 1968—supported Arizona's right to divert water through the CAP, but declared the CAP's diversion right junior to all other existing rights on the River. Believing the loss in priority to be worth the exchange, Arizona accepted the terms and began engineering the CAP in 1973. Progress was halted in October 1979 by a threat made by the Secretary of the Interior Cecil Andrus that unless Arizona adopted a statewide groundwater management code, the federal government would not allow Arizona to divert Colorado River water for the CAP. The Arizona state legislature responded to Andrus' threat by passing the Groundwater Management Act in June of 1980, and construction continued on the

336-mile system of canals, pumping stations, and secondary distribution systems comprising the CAP aqueduct (Needham 2005).

Financing the CAP would be an enormous undertaking. At over $4 billion, the full cost of the CAP was too much for Arizona to bear, particularly for the farmers for whom much of the water was intended. With some negotiation, the federal government agreed to front the cost of the project, and Arizona agreed to repay roughly half of the cost. For this purpose, Arizona established a special taxing district called the Central Arizona Water Conservation District (CAWCD) to oversee both the operations of the project and the repayment of the federal loan, which was to commence upon declaration of substantial completion of the CAP aqueduct. A particularly important clause in the loan's contract was that the interest charged on the portion of the project dedicated to delivery of municipal and industrial water would be approximately 3.3 percent, while deliveries of agricultural water would be interest free (Governor's CAP Advisory Committee Report 1993, p. 80).

Prior to construction of the CAP, expectations were that non-Indian agriculture would buy approximately 60 to 80 percent of the CAP supply for the first few decades of operation (Wilson 1992). It was also believed that as central Arizona urbanized and developed the infrastructure to be able to accept CAP water for residential use, non-Indian agriculture's share of the CAP allocation would diminish due to agriculture's lower priority right. But economic realities prevented the realization of these expectations (Wilson 1997). Half of the eligible agricultural landowners in the CAP service area (Maricopa, Pinal, and Pima Counties) declined to contract for CAP water when it became available because it was too expensive. For those districts that did contract for CAP supplies, the availability of lower cost water supplies (groundwater, surface water, and effluent) reduced demand for CAP water, and as a result, water deliveries to non-Indian agriculture declined by 48 percent between 1989 and 1991 (Wilson 1992).

Unable to force CAP water upon farmers and irrigation districts, Arizona began to craft water policies and programs to encourage agricultural water users to accept CAP water. Among these programs have been the agricultural pool program and the groundwater savings program (Megdal and Shipman 2008). Other policies and programs have been developed to maximize the use of CAP water by the municipal sector. These include the Arizona Water Banking Authority, the Assured Water Supply Rules, and the Central Arizona Groundwater Replenishment District. The authority for all these programs stems from the Groundwater Management Act of 1980.

1.2 The Groundwater Management Act of 1980

Arizona's Groundwater Management Act (GMA)—widely regarded as a progressive groundwater code when it was enacted into law in 1980—marked the beginning of a new era of water management in Arizona. It created the Arizona Department of Water Resources (ADWR) to manage the state's water resources, and established four Active Management Areas in central Arizona, delineated by natural hydrologic boundaries, to allow for greater local management of the state's water resources. Each Active Management Area (AMA) is required to create five management plans, each ten years in duration. To gradually bring the problem of groundwater overdraft under control, the management plans are designed to become more restrictive with time. The GMA also mandated a number of conservation practices from the municipal and industrial (M&I) sectors and prohibited agriculture from irrigating land in the AMAs that did not have an Irrigation Grandfathered Right (IGFR).

The GMA enabling legislation also established a single, guiding management goal for each AMA to direct the water management activity within the AMA throughout the five management periods. The Phoenix, Tucson, and Prescott AMAs were created with the management goal of achieving safe yield by 2025, with “safe yield” meaning “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” (Arizona Revised Statutes §45-562; §45-561). Because safe yield is measured over the entire AMA, the water table may be declining in some areas of the AMA as long as these areas are offset by rising water levels elsewhere in the AMA. By contrast, the management goal for the heavily agricultural Pinal AMA was to “allow development of non-irrigation uses, preserve the agricultural economies for as long as feasible, and preserve water for future non-irrigation uses” (ARS §45-562). This management goal, once termed “planned depletion,” was designed to preserve the agricultural economy of the Pinal AMA for as long as is economically feasible. A fifth Active Management Area, the Santa Cruz AMA, split off from the southeastern portion of the Tucson AMA in 1994 to allow greater focus on the area’s unique hydrology and international issues (Colby and Jacobs 2006). The Santa Cruz AMA’s management goal is “to maintain a safe-yield condition in the active management area and to prevent local water tables from experiencing long-term declines” (ARS §45-562).

1.3 The Assured and Adequate Water Supply Rules

From a water conservation perspective, one of the most important provisions of the GMA was simply a reinforcement of a 1973 state law regarding water supply adequacy for subdivisions. Under this law, real estate developers were required to obtain a determination from the state regarding the availability of water supplies prior to the sale of new subdivision lots (ARS 45-108). Developers demonstrating “inadequate” water supplies for a subdivision were required to disclose this information to potential buyers, but were nevertheless allowed to sell lots to willing buyers. The 1980 GMA supersedes this law in the AMAs by prohibiting the sale or lease of subdivided land in an AMA for which an Assured Water Supply has not been demonstrated. According to Arizona law, not all developments are subdivisions. The definition of a subdivision in the GMA is linked to the real estate section of the Arizona Revised Statutes, which defines a subdivision as having six or more lots and containing at least one parcel of less than 36 acres (ARS §32-2101). If a development does not fit the definition of a subdivision under this statute, it is not required to obtain an Assured Water Supply determination from ADWR, but, like all lot sales outside the AMAs, it is still subject to the 1973 Water Adequacy Statute. All subdivisions within the AMAs not served by a designated water provider must obtain a Certificate of Assured Water Supply from ADWR under the GMA. The demonstrated water supply requirements for areas both inside and outside AMA boundaries are collectively known as the Assured and Adequate Water Supply Rules.

To obtain a Certificate of Assured Water Supply, a subdivision must demonstrate that: (1) the water supply is physically, legally, and continuously available for 100 years; (2) the water meets water quality standards or is of sufficient quality; (3) the proposed water use is consistent with the management goal of the AMA; (4) the proposed water use is consistent with the current management plan of the AMA; and (5) the developer has the financial capability to construct any necessary water storage, treatment, and delivery systems.

While the GMA established these basic criteria for demonstrating an Assured Water Supply, it did not provide ADWR with clear instructions regarding how to enforce compliance with the management goals of the AMAs. To this end, ADWR drafted a more rigorous set of Assured Water Supply Rules in November 1988 to require new development in the safe yield AMAs to demonstrate that the assured water supply is primarily renewable. The Draft Rules, as they are called, met with strong resistance from the Arizona real estate development community, and even drew criticism from agriculture (Avery, et al 2007; Glennon 1991). Of particular offense to developers was the provision of the draft rules that limited exactly how much groundwater could be used to demonstrate an Assured Water Supply. Since the allowable groundwater was to be measured on an acre-foot per acre basis, the number of residences per acre for new developments would be limited in the AMAs. Furthermore, the allowable groundwater supply was restricted even if the groundwater right was an agricultural Irrigation Grandfathered Right, effectively reducing the value of agricultural land and weakening the incentive for conversion from agricultural to residential land use (Glennon 1991). Recognizing the political power of the opponents of the Draft Rules, ADWR quickly yielded and established a committee to evaluate the potential economic impacts of the draft rules.

Several years of public process, mainly between the real estate development community and the Department of Water Resources, followed the failure of the 1988 draft rules. Short of not developing, development interests had several ways to comply with the Draft Rules' proposed limitation on groundwater pumping, including purchasing CAP water, utilizing existing water farms outside AMAs (prior to 1991), obtaining a water service agreement from a municipal water provider with a CAP allocation or other surface water rights, or obtaining rights to use effluent (Glennon 1991). In reality, however, economic and legal difficulties rendered many of these options impractical at best for many subdivisions (Avery et al 2007).

With time, different ideas surfaced for addressing the need for new growth to rely on renewable water supplies. One idea led to the authorization of single-county replenishment districts in 1990, eventually leading to the formation of the Phoenix Groundwater Replenishment District and the Santa Cruz Valley Water District. The Phoenix Groundwater Replenishment District, taking the approach of making membership mandatory for the entire Phoenix AMA, failed to garner the support of the City of Phoenix, which was not comfortable with the district's proposed governance and tax structure (Buschatzke 2007). The Santa Cruz Valley Water District (SCVWD) was created as a temporary entity to "facilitate water resource management" in the Tucson AMA, and more specifically, to augment the renewable water supply of the AMA and perform replenishment on behalf of its members (ARS 48-4802; SCVWD 1993). The SCVWD was given a variety of powers and duties, including the construction of recharge projects, cooperation with government entities, issuance of revenue bonds, and the ability to adopt groundwater replenishment responsibilities (SCVWD 1993). While the District reported a "significant" level of interest in its services during the planning period, it performed limited activities in the Tucson AMA related to water augmentation, recharge site identification, and policy coordination from 1991 to 1993, and was later eclipsed by a more permanent and convenient replenishment authority, the Central Arizona Groundwater Replenishment District (CAGRD). While the statutes giving replenishment authority to the Phoenix GRD and the SCVWD still exist, these local, now inactive replenishment authorities are not likely to be revived (Buschatzke 2007; Megdal 2007).

With this historical background, this paper outlines the current structure and operational practices of the CAGRD with specific attention given to water management implications within an aquifer and an AMA. The analysis of the formation of this water management institution begins with the presentation of a mutual gains negotiation model followed by a discussion of a triangulated data gathering approach for understanding the political economy of the negotiation process. A discussion of the results, and evaluative remarks on their implications for Arizona's water management future, conclude the paper.

2. The Central Arizona Groundwater Replenishment District

In 1993, the real estate development community proposed a compromise with the Arizona Department of Water Resources in the form of a replenishment authority under the auspices of CAWCD. This replenishment authority is known as the Central Arizona Groundwater Replenishment District (CAGRD). CAGRD was created to give the development community an efficient and practical means of complying with the criterion of the Assured Water Supply (AWS) rules that new growth in the Active Management Areas rely primarily on renewable water supplies (Ferris, Megdal and Eden 2006). Unlike the previously authorized replenishment districts, CAGRD was authorized as a multi-county replenishment authority to operate in the Phoenix, Pinal, and Tucson AMAs to serve members who voluntarily join the District. CAGRD members are classified as either Member Service Areas (water providers) or Member Lands (subdivisions).

2.1. Member Service Areas

A "water provider" is defined in the Arizona Revised Statutes as a "city, town, private water company or irrigation district that supplies water for non-irrigation use" (ARS §45-561). A water provider seeking to comply with Criterion 3 of the Assured Water Supply Rules (which relates to the consistency of the demonstrated water supply with the management goal of the AMA) may join CAGRD as a Member Service Area (MSA) (ARS §48-3780). Membership in CAGRD automatically fulfills Criterion 3 (CAGRD Executive Summary). Still, to obtain a Designation of Assured Water Supply, the MSA must demonstrate that the proposed water supply meets the four other criteria of the AWS rules. Membership in CAGRD legally transfers the replenishment obligation from the MSA to CAGRD. CAGRD then has up to three full calendar years from the year that the groundwater replenishment obligation is incurred to fulfill its replenishment obligation (ARS §48-3771). The cost of replenishment is fully paid by the MSA on a per acre-foot basis.

2.2. Member Lands

The other type of CAGRD member is the subdivision, or Member Land (ML). The Assured Water Supply rules state that a real estate developer must obtain a Certificate of Assured Water Supply for a proposed subdivision to enable plat approval and authorization of sale or lease from the Department of Real Estate (ADWR 2001). The developer may meet the requirement that the proposed water supply must be primarily renewable by legally and physically obtaining renewable supplies to serve the subdivision, or by enrolling the subdivision as a CAGRD Member Land (ML); as with MSAs, membership in the CAGRD automatically satisfies Criterion 3 of the AWS rules. To enroll, the applicant must define the boundaries of the property, specify the number of individual units to be built, agree to provide the CAGRD with water use data for the purposes of calculating the annual replenishment obligation, and pay an Enrollment Fee per housing unit. Member Lands not containing a golf course are classified as Category 1 Member Lands; those MLs with a golf course are classified as Category 2 Member Lands. Category 1 MLs pay annual replenishment reserve charges and replenishment reserve fees, pursuant to ARS 48-3772(E); Category 2 MLs, that is, subdivisions with a golf course, are exempt from these charges and fees, pursuant to ARS 48-3774.01(C). The Enrollment Fee is annually established by CAGRD, and was $23 per home for the year 2007-08. In addition to the Enrollment Fee, the ML is also required to pay an Activation Fee prior to the issuance of a public report for the subdivision, pursuant to ARS 48-3772(A). Enrollment and Activation fees are established annually by CAGRD, with Activation Fees set individually for each AMA. The difference between the Enrollment Fee and the Activation Fee is that the developer must pay the Enrollment Fee to enroll the subdivision as a Member Land in the CAGRD, but does not have to pay the Activation Fee until just prior to construction. A subdivision served by a water provider with a designation of Assured Water Supply does not need to apply to ADWR for a Certificate of Assured Water Supply; the developer need only obtain a written commitment of service from the designated provider to demonstrate compliance with the AWS rules (ARS 45-576(A, F)).

2.3. Location of CAGRD Replenishment

The basic requirement for the location of replenishment is that it must occur within the same AMA as the excess groundwater pumping. But in the Phoenix AMA, the CAGRD has the additional statutory requirement that, "to the extent reasonably feasible," groundwater pumped out of the east portion of the AMA must be replenished in the east subbasin of the Salt River Valley, and pumping in the west portion of the AMA must be replenished in the west portion of the AMA (ARS 48-3772(G); 48-3772(I)). In the Pinal and Tucson Active Management Areas, the CAGRD is not required by statute to replenish in the same subbasin as the excess groundwater pumping. Nevertheless, the CAGRD does make an effort to replenish excess groundwater as close to the site of pumping as possible; in the Tucson AMA, when feasible the CAGRD replenishes excess groundwater pumped in the northern part of the AMA at recharge facilities in Marana and Avra Valley; likewise, the preferred recharge site for pumping from the southern portion of the Tucson AMA is the Pima Mine Road Underground Storage Facility (Neal 2007).

2.4. CAGRD Replenishment Costs

The CAGRD replenishment rate consists of four parts: a Water and Replenishment component, an Administrative component, an Infrastructure and Water Rights component, and a Replenishment Reserve charge (Table 1). The Water and Replenishment component includes all costs of purchasing and transporting water supplies, and is computed separately for each AMA. The Administrative component covers the administrative costs of CAGRD replenishment, and is the same for all AMAs. The Infrastructure and Water Rights component is designed to cover the costs of securing rights to long-term water supplies, and is computed separately for each AMA. (In practice, the Infrastructure and Water Rights component is considered inadequate for its intended purpose.). The Replenishment Reserve charge is paid by MSAs and Category 1 MLs, and covers the cost to the CAGRD of establishing and maintaining a replenishment reserve of long-term storage credits for each AMA, per ARS §48-3780.01. Because the replenishment rates are designed to cover the previous year's replenishment obligation, much of the revenue that supports CAGRD's statutory obligations is lagged by at least one year.

2.5. *Governance, Operations, and Planning*

The CAGRD is not a district in the sense of being an autonomous entity; it is simply an expansion of the authorities of the CAWCD to include groundwater replenishment. As such, the CAGRD is managed by CAWCD staff and governed by the Board of Directors of CAWCD. Water providers serving CAGRD Member Lands must annually report to CAGRD and ADWR the volume of groundwater and the volume of excess groundwater delivered to each parcel within the Member Land (ARS §48-3775a). Similarly, water providers serving CAGRD Member Service Areas must annually report to CAGRD and ADWR the total volume of groundwater and the total volume of excess groundwater delivered within the service area. In the Phoenix and Tucson AMAs, the volume of excess groundwater is then multiplied by an annually increasing "minimum reporting factor" to calculate the volume of replenishment

Table 1: CAGRD Replenishment Assessment Components

COMPONENT	COST BASIS	2007-08 RATE (per AF)[1]
Administrative[2]	Total cost of administering the CAGRD	$28
Infrastructure & Water Rights[2]	Costs of purchasing water rights and developing infrastructure to deliver and replenish water	$79
Water & Replenishment[3]	Cost to purchase, transport, and recharge/replenish water supplies	$112; $87; $133
Replenishment Reserve[3]	Costs to establish and maintain a replenishment reserve for each AMA	$21; $25; $25
TOTAL COST OF CAGRD REPLENISHMENT: Phoenix AMA $28+79+112+21 = **$240** Pinal AMA $28+79+87+25 = **$219** Tucson AMA $28+79+133+25 = **$265**		
[1] Where appropriate, multiple rates are given for Phoenix, Pinal, and Tucson AMAs, respectively		
[2] Uniform across AMAs		
[3] Computed separately for each AMA		

CAGRD must do on behalf of each member. The minimum factor is multiplied by the member's groundwater use to determine the volume of excess groundwater to be reported. The factor depends on the nature of the member (Member Land or Member Service Area), the date of enrollment, and the AMA. For example, if Rancho Sahuarita Water Company pumped 1,100 AF of groundwater in 2007, ADWR would first determine the portion of this pumping that is considered "excess" groundwater, then Rancho Sahuarita would multiply this volume of excess groundwater by CAGRD's excess groundwater reporting factor for a Member Service Area in the Tucson AMA for 2007—that is, 9/30ths, or 0.3. ADWR's determination of the volume of excess groundwater is based upon the water provider's share of the basin's natural recharge, among other things specifically related to the water provider. If the volume of excess groundwater is 1,000 AF for Rancho Sahuarita, then the replenishment obligation for Rancho Sahuarita would be 300 AF (1,000 x 0.3) in 2007. The excess groundwater replenishment factor increases through time. The purpose of the replenishment factor is to ease the transition for CAGRD members into paying the relatively high cost of CAGRD replenishment.

Pursuant to ARS §48-3775, CAGRD must submit a Conservation District Annual Report to ADWR by August 31 of each year showing the groundwater replenishment obligations incurred and satisfied in the previous calendar year. The CAGRD must replenish each AMA's aggregate replenishment obligation within three calendar years. Water providers serving MSAs pay the CAGRD for the replenishment of the entire service area's annual excess groundwater consumption, and recover the cost in their rates. With Member Lands, individual parcels are charged for the replenishment CAGRD performs on their behalf in the form of an assessment on their property tax.

To demonstrate that its activities are in compliance with the management goals of the AMAs, the CAGRD must submit a Plan of Operation to the Director of the Arizona Department of Water Resources every ten years describing the activities for each active management area that the CAGRD proposes to undertake during the following one hundred calendar years (ARS §45-576.02C). The plan must include the following information for each of the three AMAs:

- Cumulative groundwater replenishment obligations and the extent to which those obligations have been met in the 10 years preceding submittal of the plan;

- An estimate of the CAGRD's current and projected groundwater replenishment obligations for current members for the 20 calendar years following the submission of the plan;

- An estimate of the CAGRD's projected groundwater replenishment obligations for the 100 years following the submission of the plan for current members and potential members based on reasonable projections of real property and service areas that could qualify for membership in the 10 years following the submission of the plan;

- A description of the water resources that the CAGRD plans to use for replenishment purposes during the 20 calendar years following submission of the plan and water resources potentially available for groundwater replenishment purposes during the subsequent 80 calendar years;

- A description of the CAGRD's current replenishment reserve activities in each AMA for the 10 years preceding the current plan and planned replenishment reserve activities for the ensuing 10 years to be undertaken pursuant to ARS §48-3772E;

- A description of any facilities and projects to be used for replenishment and the replenishment capacity available to the district during the 20 calendar years following submission of the plan;

- An analysis of potential storage facilities that may be used for replenishment purposes;

- A description of the CAGRD's capability to meet the current and projected groundwater replenishment obligations for the 20 years following the submission of the plan; and

- Any other information that the director may require.

One of the key requirements of the Plan of Operation is the demonstration that the CAGRD's water portfolio is reliable and secure. However, the standards for this demonstration are different from the AWS standards for individual water providers and developers. The CAGRD must provide a description of water it "plans" to use to fulfill 20 years of replenishment obligation and water "potentially available" for the remaining 80 years of the standard 100-year AWS demonstration. Other entities must acquire firm water supplies for 100 years. No statute requires the CAGRD to possess secure water supplies to meet its obligations for 100 years, as is the requirement for non-CAGRD members.

The temporary nature of CAGRD's water supply portfolio requirement may be justified, however. Since the CAGRD replenishes water after it has been pumped, it may logically follow to allow the CAGRD some flexibility in obtaining water supplies to meet its obligation. Water providers must demonstrate the physical availability of groundwater, the reliability of the customer's water supply is physically unaffected by the CAGRD's ability to demonstrate the future availability of water supplies. Also, the risk of losing one particular water source demonstrated on paper is reduced by allowing the CAGRD to assemble a diverse water supply portfolio, which is more difficult to do with more economically scarce long-term water supplies. CAGRD appears to be a good candidate for cobbling together the "left over" water supplies that would not otherwise be used to demonstrate 100 years of water (Holway, Newell, and Rossi 2006).

As originally envisioned, the CAGRD for the first decade of its existence fulfilled most of its replenishment obligation using "excess" CAP water—unused CAP entitlements, un-contracted CAP supplies, and surplus Colorado River supplies. However, by the late 2000s, excess CAP water supplies began to dwindle as CAP subcontractors (primarily Indian tribes) began to use their CAP allocations. In 2011, CAGRD commissioned a study to survey the water supplies that could potentially be purchased and/or developed to support its replenishment demand. Following the study, the CAGRD launched a number of water supply acquisition initiatives. These initiatives require substantial sums of money up front to fund the water rights purchases, and in the case of effluent supplies, an additional cost to treat the water to a quality sufficient to replenish in recharge basins. These costs have directly impacted both fees (10x increase over seven years) and rates (2x increase over seven years).

To protect the customers of the CAGRD from having to pay the highest market price for increasingly scarce water supplies, and to avoid having a crisis of water supply availability, the 2001 GWMC recommended that legislation be drafted to require the CAGRD to establish a "replenishment reserve" of up to 20% of CAGRD's 100-year replenishment obligation. The replenishment reserve, instituted in 2004, consists of long-term storage credits that are stored on behalf of the members of the CAGRD for each AMA. The Replenishment Reserve Fees must be paid by new members as of 2004 and are based on the AMA's Replenishment Reserve Charge and the volume of each member's projected built-out replenishment obligation (Ferris, Megdal, and Eden 2006). The benefit of the replenishment reserve is that it does not force CAGRD to purchase 100-year firm supplies and therefore compete with water providers, many of them

CAGRD members themselves. It also allows CAGRD the flexibility to take advantage of short-term water supplies at reasonable cost as they become available.

2.6. Water Availability Status

In 1999, an additional responsibility was added to CAGRD's already unenviable list of obligations with the passage of House Bill 2262, the Water Sufficiency and Availability Act. The statute allows any city, town, or private water company that qualifies as a CAGRD Member Service Area to meet the physically available water supply criterion of the Assured Water Supply rules by entering into a contract to have CAGRD deliver water where it is physically accessible. In effect, water providers unable to receive a designation of AWS or renew their designated status due to physical constraints may contract with CAGRD to receive up to 20,000 acre-feet of water per year for recharge in the location of recovery or for direct delivery. Upon approval of CAGRD's application to grant "Water Availability Status" to the water provider, CAGRD and the water provider are free to contract for *ex ante* deliveries (ARS §45-576.07B). Rates for water deliveries per a Water Availability Status contract do not include a replenishment reserve component. As of December of 2007, the City of Scottsdale was the only MSA that has executed a Water Availability Status contract with CAGRD, at a maximum of 3,460 acre-feet per year. Essentially, the Water Availability Status provision extends the responsibilities of the CAGRD from helping all members demonstrate the availability of a renewable water supply to helping some members with the more basic requirement of showing that water is physically available to begin with.

2.7. Alternatives to the CAGRD: Underground Storage, Savings, and Replenishment Programs

For entities possessing a CAP subcontract, there are several alternatives to the CAGRD that facilitate compliance with the AWS rules. The Underground Storage, Savings, and Replenishment Program was originally authorized in 1986, and later expanded in 1994. The program was developed to help achieve Arizona's goal of fully utilizing (and thereby protecting) its entitlement to the Colorado River by facilitating replenishment of CAP water.

2.7.1. Groundwater Savings

Groundwater savings program represents one of the pillars of the Underground Storage, Savings, and Replenishment Program. It is essentially a partnership between irrigation districts looking for low-cost water supplies and cities looking to make use of available renewable supplies, including CAP water and, to a lesser extent, effluent. Per the Assured Water Supply rules, a municipal water provider must offset all pumped groundwater that is deemed "excess." Participation in the Groundwater Savings program helps accomplish this by allowing the municipal provider to purchase CAP water and resell it to the partnering irrigation district (or individual farmer in some cases) at a cost that competes with the district's cost of pumping groundwater. The irrigation district therefore uses CAP water "in lieu" of the groundwater it would have pumped, and the municipal provider earns storage credit for the "saved" groundwater.

To participate as a Groundwater Savings Facility, an irrigation district must receive a permit from ADWR to register as a Groundwater Savings Facility (GSF). To receive a permit, a district must demonstrate legal and physical ability to pump groundwater, and prove to ADWR that the CAP water to be subsidized by the water provider would be substituted on a gallon-for-gallon basis for the groundwater that would have been pumped by the district (ARS §45-

812.01(B)). A farmer whose land lies within an irrigation district that holds a valid GSF permit automatically qualifies to receive CAP water through the Groundwater Savings Program.

To partner with a particular GSF, a municipal water provider must obtain a Water Storage Permit from ADWR (ARS §45-831.01(A)). Water stored at a GSF by a permitted water provider may be recovered at any time. However, if the water provider wishes to recover some of the water stored at a GSF after the end of the calendar year, it must obtain a long-term storage account with ADWR to be able to keep a record of its generated storage credits. For example, if 100 AF are stored at a GSF in August and are not recovered until the following January, then the stored water is added to the utility's long-term storage account. Since the water was not recovered within the same calendar year as it was stored, the long-term storage credits available to the utility are 95 percent (95 AF in this case) of the original volume stored; the remaining five percent (5 AF) are a non-recoverable "cut to the aquifer" for the simple purpose of aquifer replenishment. Only water providers with a Designation of Assured Water Supply from ADWR may earn long-term storage credits.

To illustrate how the groundwater savings program works, consider an example of "Water Company X" in Tucson. Possessing a CAP allocation but unable to deliver it directly, the Company may use its CAP allocation indirectly through participation in the groundwater savings program. After obtaining a Water Storage Permit, Water Company X may coordinate with "Irrigation District Y" to deliver its subcontracted CAP water to Irrigation District Y for a price that competes with other water sources the District would have used. Once the delivery has occurred, Water Company X may then recover none, part or all of the resulting groundwater savings credits anywhere within the AMA at any time.

2.7.2. *Underground Storage*

The underground storage program differs from groundwater savings in that it physically adds water to the aquifer by directly recharging surface water using injection wells, streambeds, or constructed spreading basins. Any water supply that meets the standards of the Arizona Department of Environmental Quality may be directly recharged; effluent treated to high quality standards (ADEQ Class A) is often recharged through streambeds. As with indirect recharge, the stored water retains its legal character upon recovery. For example, groundwater that is recovered using water storage credits generated with CAP water is legally considered CAP water upon recovery, though it may be chemically dissimilar from CAP water and recovered many miles from the location of storage. Effluent is considered to be its own category of water—neither groundwater nor surface water; upon recovery, it is still simply "effluent."

As with groundwater savings, water stored at an Underground Storage Facility (USF) may be recovered directly by installing pumping wells near the recharge site and wheeling the water on the CAP aqueduct or other distribution system, or indirectly by pumping groundwater in another location and extinguishing storage credits from the storer's long-term storage account (CAWCD May 2007). In addition, water recovered after the end of the calendar year in which the storage occurred is considered recovery of long-term storage credits and is subject to the five percent "cut to the aquifer" (ARS §45-852.01).

2.8. *Emergence of 'Paper Water' Management*

Arizona's storage and recovery programs are truly innovative water management practices in the sense that they have maximized the use of renewable supplies, achieved the full use of Arizona's Colorado River entitlement, successfully stored large volumes of water to mitigate the impact of future drought, and moved Arizona closer to offsetting gross overdrafts in some of the state's most unbalanced aquifers (Colby and Jacobs 2006). Yet part of the reason these programs are considered innovative is that they gained wide support from disparate interests to achieve these policy objectives. This process naturally required some compromises, often in the form of policies and provisions that may be considered less desirable from a long-term water management perspective.

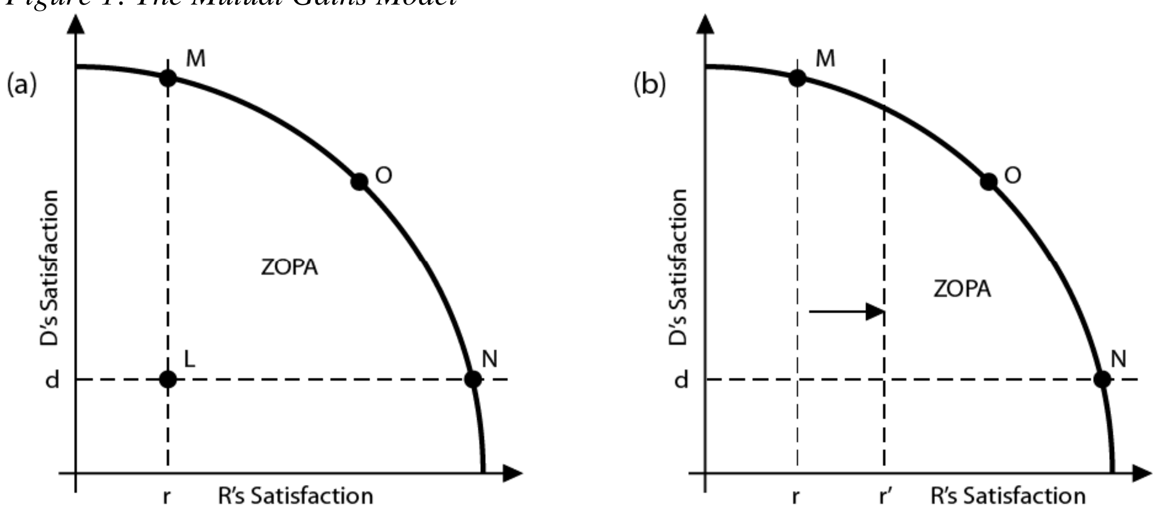
One result of these provisions often debated in the Arizona water community is the "paper water" system as a disincentive for water users to correct local aquifer drawdowns. Paper water refers to "the accounting methods used to track the amount of water added to and removed from underground aquifers in the AMA and for water that passes into and out of the boundaries of the AMA" (Schwarz 2006). The paper water system was developed in the 1980s as a critical step toward managing the groundwater resources of the AMAs. It provides a legal accounting procedure for monitoring water users' groundwater pumping and replenishment. However, the paper water system is criticized for monitoring groundwater pumping and replenishment at the AMA level rather than a more local level (Vincent 2006). The AMA-level accounting stance effectively treats the AMA like a giant bathtub, where the water level quickly equalizes in the tub regardless of the locations of inputs and outputs. Critics of this system point out that because aquifers do not behave like bathtubs, reliance on a system that allows groundwater to be replenished far from the area of pumping enables localized water level drawdowns to continue. Thus, the paper water system enables a water utility to be in full compliance with the AWS rules on paper while dewatering a portion of an aquifer that is far from the location of existing renewable water supplies. This is seen as a problem for two reasons: (1) the water utility does not have to pay for any environmental damages from dewatering the aquifer; and (2) renewable supplies will eventually have to be imported to provide the residents of the community served by the water utility with a stable supply of wet water.

The paper water system was developed to allow urban and suburban growth to continue in the AMAs by delaying the cost of physically transporting renewable water supplies. Built upon and taking full advantage of the paper water system is the CAGRD. The enormous popularity of the CAGRD has engendered concern that the paper water system is enabling growth to occur without regard for the future cost of that growth on future residents (Tenney 2007). As the cost of replenishment increases, homeowners in CAGRD member subdivisions will be forced to pay these higher costs. In addition, some of these communities may need to invest in the physical infrastructure to directly deliver CAP supplies as their wet water supplies dwindle. To date, the potential implications of paper water reliance have not been explicitly analyzed.

3. Conceptual Model: A Mutual Gains Approach

A mutual gains model provides a useful tool for understanding the political economy of the CAGRD's formation. The mutual gains model is an analytical framework for negotiated agreements predicated on the assumptions that negotiating parties understand each other's interests and their agreements yield net gains for all parties. Figure 1 illustrates the principles of the mutual gains model. For our purposes, think of player D as the real estate development sector and Player R as the regulator, ADWR. Each axis represents the satisfaction (or gains) index of the negotiating parties: player D's satisfaction increases northward along the *y* axis; player R's satisfaction increases eastward along the *x* axis. Each player has a reservation value with respect to the negotiation, a "best alternative to negotiated agreement" (BATNA), depicted as lines *d* and *r* in Figure 1. Negotiation occurs only when both parties expect to be better off by negotiating; therefore, for each party, the expected return must be greater than the BATNA. The marginal point of negotiation is the intersection of the BATNAs for the two parties—point L in Figure 1a, a sort of worst-case scenario for negotiation. To the northeast of L lies the zone of potential agreement (ZOPA). The ZOPA is bounded by the negotiation possibilities frontier (NPF), which represents the set of efficient agreements yielding the maximum possible gains from negotiation. Some points along the NPF favor player D (as in point M); other points favor player R (point N).

Figure 1: The Mutual Gains Model



During a negotiation, a party may increase the position of their own BATNA or decrease the position of the opposing party's BATNA by using information advantage, threats, or better negotiating skills to influence the opposing party's perception of the negotiation. Figure 1b illustrates a situation where R is able to increase its position from *r* to *r'* during negotiation. R's maneuver raises the level of satisfaction required to entice R to negotiate, and eliminates from the set of efficient agreements those that were previously most favorable to D. Each party should therefore work to strengthen their BATNA relative to their opponent's BATNA prior to and during negotiation.

John Nash extended the mutual gains model to develop the economic theory of bargaining power in a negotiated agreement (Dixit and Skeath). The Nash bargaining model further requires that (1) the negotiated outcomes are invariant if two parties' payoffs increase proportionally; (2) efficient outcomes are achieved; and (3) irrelevant (non-efficient) alternative outcomes are ignored. Figure 2 graphically illustrates Nash's cooperative solution to a negotiated agreement with bargaining power. D's BATNA is to accept a rule prescribed by R, at a cost of *d*. In other words, if negotiations fail, D cannot expect a better outcome from R's prescribed rule than *d*.

Now let R's gains from negotiation be designated as *x* and D's gains be designated as *y*. The set of efficient agreements forming the negotiation possibilities frontier (NPF) will therefore take the functional form of $y = f(x)$. Any negotiated agreement will result in the following gains for the two parties:

R receives a total payoff of x-r;

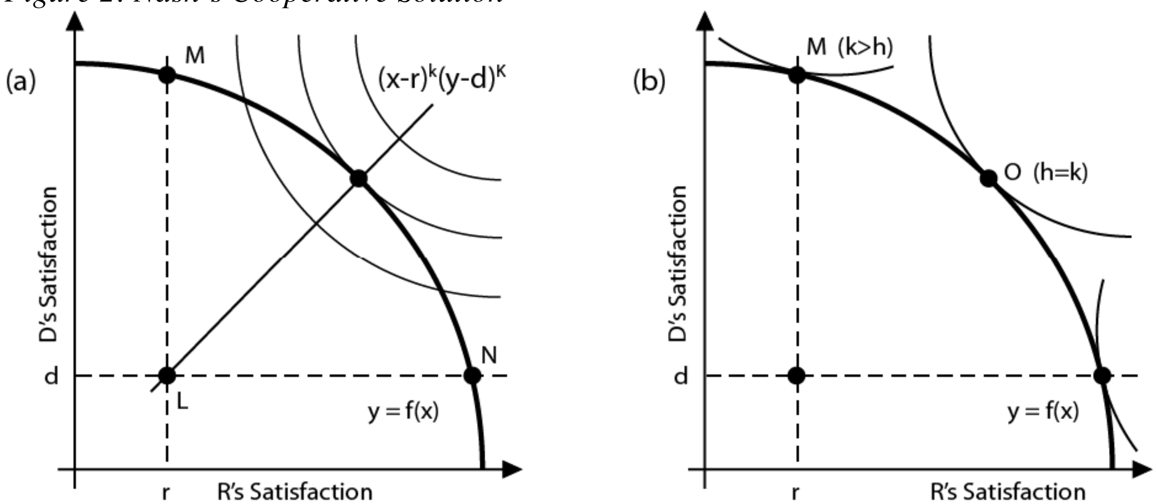
D receives a total payoff of *y-d*.
Let the division of gains received by each of the bargaining parties be designated such that R receives an *h*-proportion of the surplus, D receives a *k*-proportion, and *h* and *k* sum to one. Maximizing

$(x-r)^h(y-d)^k$ subject to $y = f(x)$ (1)

Gives the unique Nash cooperative solution:

$(x-r)/h = (y-d)/k$ (2)

Figure 2: Nash's Cooperative Solution



The bargaining power parameters *h* and *k* are critical to the final negotiated outcome. First, because the proportions of bargaining power affect the shape of the objective function, a range of efficient, optimal solutions to negotiation is possible. Each optimal solution in this range lies along the NPF, and all are possible Nash solutions to the cooperative agreement. If one party's bargaining power increases, they are able to influence the objective function such that the set of available contract curves—and, therefore, the set of optimal solutions—is moved in their favor. An increase in *h* corresponds to an increase in (*x-r*) and a decrease in *k* and in (*y-b*). An increase in *h* also tips the balance of favorable outcomes toward R and away from D. When *h* equals *k*, the negotiated agreement reaches point O, and the gains from negotiation are evenly distributed between R and D; when h equals 1, R possesses all the bargaining power in the negotiation, and an agreement is reached with outcome N, favoring R exclusively; conversely, when D holds all the bargaining power, an agreement is reached with outcome M, favoring D exclusively. Any range of outcomes is possible when the bargaining power is shared between R and D—that is, *h* and *k* are such that $0<h,k<1$.

The Nash cooperative agreement demonstrates that agreements or rules formulated in the mutual gains framework will depend upon the balance of bargaining power between the negotiating parties. Bargaining power comes in many forms. Superior negotiating skills naturally improve bargaining power. Threats (to walk away from the negotiation, for example) may also shift the balance of bargaining power in a negotiation. Information advantages may also translate into bargaining power, if used to alter the content of the body of data under contemplation, to shape options and perceptions of reality, or to alter the order or valuation of possible outcomes (Bartlett 1973). With the outcome so contingent upon the balance of bargaining power, each negotiating party will seek to improve its own BATNA in negotiation by changing the other party's perception of the negotiation, decreasing the BATNA of the opposing party, and/or increasing its own proportion of bargaining power.

4. The Political Economy of the CAGRD

Understanding the impact of a particular policy can be traced back to the political economy of its formation, development, and governance. This section presents a triangulated qualitative analysis of the CAGRD's past, present and potential future influences on Arizona water policy.

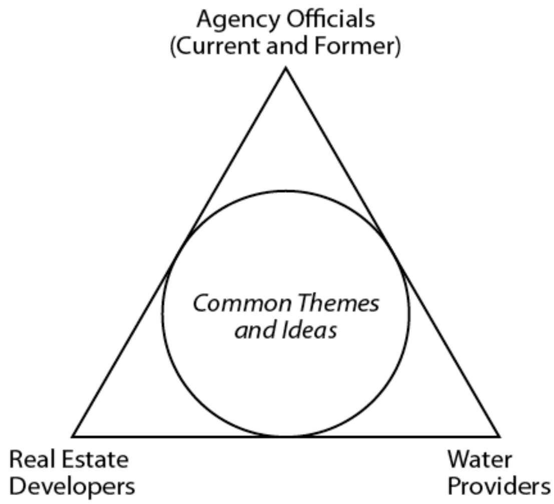
4.1. Analytical Approach

Accurate, reliable information is the foundation of effective policy analysis. Depending on the research question and the particular policy being examined, this information may be quantitative or qualitative in nature. Often economists analyze policies using only quantitative data. They do so at their own peril. Some of the most important policy questions require a journey into the world of qualitative evaluation, and failure to take this journey increases the risk of producing an ultimately ineffectual analysis. Quantitative measures, though widely accepted as the standard for evaluation, often do not adequately capture the complexities of the issue at hand. As we will see later in this study, understanding a policy's political, social, and emotional context may yield economic insights that would not be gleaned from quantitative data analysis.

One established qualitative method of policy evaluation is *triangulation*. The term triangulation refers to the idea, first explained by Denzin (1978) and then promoted by Donald Campbell, that "every method has its limitations, and multiple methods are usually needed" (Patton 2002). As in geometric triangulation, where the surveyor uses multiple points to calculate his position, triangulation in policy evaluation involves the use of multiple evaluation methods or data sources, including both quantitative and qualitative approaches (Patton 2002). Denzin (1978) identified four different types of triangulation; only data triangulation is utilized in this study

Standardized, open-ended interviews were conducted of individuals who are knowledgeable about the research topic. The goal of these interviews was to gain multiple perspectives and thus maximize the accuracy and relevance of the study. The interviews were geared primarily toward the analysis of the political economy of the CAGRD's formation. Attempting to elucidate the formative political economy of the CAGRD without seeking multiple perspectives on its establishment and impacts would have resulted in a rather myopic and incomplete analysis. Interviewee candidates were selected based on their affiliation with a particular target group that presumably would have a unique perspective on the CAGRD and its formation: current and former government agency officials, water providers, and members of the development community. Figure 3 illustrates the principle behind data triangulation. Qualitative data gathered from multiple perspectives allows the researcher to compare among these perspectives and discern common themes and ideas in what he hears and observes. These common themes and ideas form the basis for the development of a coherent, reliable explication of the CAGRD's formation.

Figure 3: Triangulation of Multiple Perspectives



4.2. Data

Interviews were conducted in June and July of 2007 to gather information from 20 individuals considered knowledgeable about the CAGRD. Roughly equal numbers of interview candidates were selected for each interview target group: water utility officials; real estate developers and development interests; and current and former government agency officials, including CAGRD staff (A list of interviewees can be found in Shipman (2008)). For about half of the interviews, two people served as interviewers, both taking notes that were later compared. A standard, open-ended interview protocol was used to guide the discussion. The basic interview protocol consisted of the following questions:

- Why did the CAGRD form? Describe the events leading to its formation.

- To what extent would it be feasible to require subdivisions to comply with the AWS rules without joining the CAGRD?

- From your perspective, has the existence of the CAGRD affected development (numerically or geographically) in the Phoenix, Pinal, or Tucson AMAs? If so, how?

- How would developers cope with CAGRD capping membership outright?

- Describe the ideal solution to the growing enrollment problem, from your perspective.

- Does the location of replenishment within an AMA matter? Why or why not?

While a protocol was used to guide the discussion, additional questions were asked in order to expand upon issues important to the interviewee. In closing, interviewees were allowed to share any additional comments or concerns regarding the CAGRD that he or she felt had been omitted from the discussion. After all the interviews were conducted, the interview responses were studied to identify areas of agreement and disagreement from the different perspectives regarding the CAGRD's formation, its private and social costs and benefits, and possible solutions to some of the issues surrounding it.

4.3. Results

4.3.1. The CAGRD's Formation

The Central Arizona Groundwater Replenishment District formed in response to a number of legal and political pressures. The first and most immediate pressure was the need to empower the Active Management Areas to achieve safe-yield by 2025. While the Arizona Groundwater Management Act of 1980 originally outlined what would become the Assured and Adequate Water Supply (AWS) rules in 1995, the language in the GMA enabling ADWR to adopt the AWS rules was unclear, and as of 1993 they had not yet been adopted. In fact, ADWR had attempted to introduce AWS "Draft Rules" in 1988, but a strong negative reaction to the Draft Rules from Arizona's residential developers and homebuilder associations caused them to be quickly suspended. Essentially, the Draft Rules failed because they lacked an "institutional mechanism to help developers comply" with the progressive statutes. The relative ease with which the Draft Rules were repealed stands as a testimony to the real estate development community's power over the details of its own regulation. It also strongly suggested to ADWR that the support of the development community would be crucial to the survival of subsequent AWS rules. Eventually, negotiations between ADWR and key members of Arizona's development community paved the way for the adoption of an agreeable "institutional mechanism" in the form of the CAGRD.

Another source of pressure leading to the formation of the CAGRD was Arizona's desire to maximize the use of its Colorado River entitlement. One reason behind this desire was the depletion of the aquifers in central Arizona. A more pressing motivation, however, was the fear among Arizona water managers that the use of Arizona's unclaimed apportionment by California and Mexico would enable Congress to revisit the River's allocation to permanently reduce Arizona's entitlement. Decades earlier, this same fear initiated and sustained Arizona's rally behind the authorization, funding, and construction of the CAP aqueduct. Now, it appeared that constructing the aqueduct was not enough to put CAP water to beneficial use; though substantially complete by 1993, its annual conveyance capacity was disappointingly underutilized by over one million acre-feet (CAP 2005). As predicted by William Martin and Robert Young during the design phases of the CAP, the price of CAP water was not competitive with the cost of groundwater. Hence, irrigation districts that signed take-or-pay contracts for CAP water were left in the position of having to pay for water that its member farmers were not taking or paying for. Since agriculture was unable to afford the water deliveries the CAP was designed to facilitate, Arizona's Colorado River entitlement remained underutilized and, perhaps, available for the taking. Short of forcing the agricultural and municipal sectors to directly use more CAP water, CAP identified artificial recharge as a quick and relatively inexpensive means of putting the rest of the entitlement to use.

In the face of these two major pressures, the CAGRD came as a unique solution to two of the state's biggest water management problems: the depletion of groundwater supplies and the inadequate use of Arizona's Colorado River entitlement. Notwithstanding the failure of the Phoenix Groundwater Replenishment District, the real estate development community felt that interest in an entity offering replenishment services remained significant, particularly in the private sector, and that a voluntary-membership approach might be more widely supported. So, in 1992, representatives from a large developer of master-planned communities met with the Director of ADWR to present the idea of a voluntary-enrollment replenishment entity. The Director, recognizing the opportunity to gain the real estate development community's support for the AWS rules by giving them a mechanism of compliance, supported the idea. The contingent of developers then spoke with members of the CAP board, who supported the idea as a means of using more CAP water and agreed to provide oversight of the replenishment authority should it succeed. In short, as Avery, Consoli, Glennon, and Megdal (2007) aptly put it, "a deal was struck." Within months, the Fennemore and Craig law firm was retained by the small group of real estate developers to draft the legislation, and on April 22, 1993, the Groundwater Replenishment District Act became law.

Applying Nash's cooperative bargaining model may help to clarify and deepen our understanding of the political economy surrounding the CAGRD's formation. In the early 1990s, ADWR was attempting to regulate the use of groundwater to support new real estate development by adopting the Assured Water Supply rules in the Active Management Areas. The three central AMAs of Phoenix, Pinal, and Tucson were experiencing rapid population growth, and residential development was a significant source of revenue for the state of Arizona. As such, Arizona's political leaders were generally in support of population growth. Arizona's real estate development community, in turn, depended upon the openness of Arizona's water policies toward new connections—particularly those using groundwater. Accordingly, water policies that would potentially restrict Arizona's rate of population growth were seen as a threat to Arizona's economy in general and the development community in particular.

As insisted upon by numerous sources (including one of the individuals who spearheaded the creation of the CAGRD on behalf of his real estate development firm), the CAGRD was the result of a cooperative negotiation. Several parties played some part in advancing the negotiation, but ADWR and the real estate development community were the two most important players. Applying Nash's bargaining model, ADWR plays the role of the regulator and the development community represents the regulated interest. As was demonstrated earlier, the negotiated outcome strongly depends upon the balance of bargaining power in the negotiation. During the negotiations that led to the formation of the CAGRD, the balance of power was skewed toward the development community—that is, in Equations (1) and (2), the real estate development community (player D) had more bargaining power ($k>h$) than ADWR (player R). The primary source of the development community's bargaining power was the swift revocation of the AWS Draft Rules in 1988, which demonstrated the real estate development community's power to control its own regulation, and effectively served as a warning to ADWR that the development community had the power to prevent the AWS rules from being adopted unless ADWR somehow helped them comply with the rules. Many of the individuals interviewed for this study believed that the development community's bargaining power was so strong that the AWS rules would never have been passed without some conciliatory measure like the CAGRD. In other words, the real estate development community's best alternative to negotiated agreement (BATNA) was simply the status quo, where new homes could rely upon groundwater without having to offset the pumping with replenishment. But ADWR's leaders could not afford to allow the Groundwater Management Act to remain ineffectual with respect to municipal groundwater consumption; rather, these leaders knew that they had a responsibility to get the AWS rules passed and get the safe-yield AMAs on track to meeting their statutory management goal of achieving safe-yield by 2025. Put another way, ADWR's BATNA was the failure of the AWS rules and the loss of safe-yield as an achievable objective for the AMAs. With so much to lose, ADWR recognized that negotiating with the real estate development community was the only way forward.

The development community was able to leverage its bargaining power in the cooperative negotiation with ADWR and capture a large share of the gains from the negotiation in the form of a developer-friendly replenishment district. Several provisions of the CAGRD testify to the power of the development community in shaping the CAGRD's enabling legislation: (1) the cost of enrolling in the CAGRD (initially $23 per home) is not only far below the cost of delivering renewable supplies directly but is also below the typical development impact fee for new residential water connections in most cities (in 2008, Tucson Water charged $1,940 per home) (Tucson Water website 2008); (2) the cost of replenishment is passed entirely to the homeowner (ARS §48-3778); and (3) CAWCD does not have the legal authority to limit CAGRD enrollment. These provisions significantly reduced the impact of the AWS rules on the development community by minimizing the cost of compliance by instituting a low enrollment fee, passing the financial responsibility to the homeowner, and legally guaranteeing a simple means of AWS rule compliance for years to come. As a result of the CAGRD's generous provisions, the AWS rules had little effect on the magnitude or pattern of urban development in central Arizona. Virtually all the interviewees—water providers, water agency officials, and real estate developers alike—agreed with this basic conclusion.

4.3.2. *Initial Effects of the CAGRD*

The creation of the CAGRD as an authority of the CAWCD paved the way for the adoption of the Assured Water Supply rules in February 1995. The two policies are inextricably linked; nearly all of the individuals interviewed for this study argued that without the CAGRD, the AWS rules would never have been adopted because the real estate development community would have used their political influence to prevent it. To illustrate the interconnectedness of the AWS rules and the CAGRD, several of the interviewees considered our question regarding whether it would be feasible to force developers to comply with the AWS rules without the CAGRD to be simply "naïve." "It would never have happened" was a common response to this question, and from the firm resolve of the interviewees representing the development community, it appears likely that developers would never have allowed a situation in which they were required to demonstrate use of renewable supplies without something resembling the current CAGRD—and never will.

The CAGRD provided a simple means for developers to comply with the AWS rules, and therefore allowed developments to continue to rely on groundwater as they had before. After the AWS rules were passed, subdivisions continued to rely on groundwater for their physical water supply as they had before the rules were passed. The only difference between before and after the AWS rules is that owners of homes platted after 1995 that are not in the area of a designated water provider and are legally considered part of a subdivision are now paying higher property taxes to have the CAGRD bring CAP water into their AMA to replenish the groundwater they have used. On an Active Management Area level, this is a big step. The AWS rules have been successful in terms of bringing the water budgets of the Phoenix and Pinal AMAs closer to safe yield. In some ways, the state has the CAGRD to thank for allowing that to happen. But neither the AWS rules nor the CAGRD address the problem of "dry members" continuing to pump groundwater in areas that are suffering from severe groundwater declines. So in effect, the

CAGRD has been a benefit to the AMAs in that it has enabled physical water supplies to be brought into the AMAs per the AWS rules; however, it has also been a curse in that it has enabled development to occur regardless of the location of renewable water supplies. Furthermore, it is the conviction of several individuals interviewed for this study that the CAGRD has decoupled land use and water planning and has thus made it more difficult not only to avoid pumping groundwater in areas of severe overdraft, but also more difficult to develop the integrated physical infrastructure necessary to efficiently deliver renewable water supplies to these problem areas.

4.3.3. *Secondary Effects of the CAGRD*

It is the secondary effects of the CAGRD that have attracted the most criticism: the rapid rate of enrollment in the CAGRD, and the location of CAGRD members relative to the location of the renewable water supplies that are replenished on behalf of the members.

4.3.3.1. *Enrollment*

Preeminent among the issues faced by the CAGRD is the fact that its membership has exceeded nearly all expectations since its initial Plan of Operation was approved in 1995. Initial projections estimated that CAGRD's replenishment obligation in 2014 would be about 37,000 acre-feet; by 2004, the estimate had been revised upward to 97,700 acre-feet (Avery et al 2006). Enrollment of Member Land homes in the CAGRD through the end of 2006 exceeded the projections of the 2004 CAGRD Plan of Operations by nearly 47,000 units—more than 25 percent over projections (CAWCD July 2007). Table 2 summarizes CAGRD's member enrollment since 1995 and Figure 4 illustrates the District's replenishment obligation over the same time period.

The high rate of enrollment in the CAGRD reflects the simplicity of the decision to enroll. Little is required of real estate developers or water providers wishing to enroll as Member Lands or Member Service Areas. Developers enrolling subdivisions must pay a simple enrollment fee of $23 per home; water providers pay no fee, but simply enter into a contract to have the CAGRD replenish their excess groundwater pumping. The CAGRD enrollment process essentially eliminates the cost of complying with the criterion of the AWS rules demanding use of renewable supplies, as well as the risk of someday violating this criterion. Even MSAs that are not able to meet the physical availability criterion of the AWS rules may contract with the CAGRD to have wet water delivered to their service area, per the Water Availability Status provision added in 1999. Furthermore, many water providers with CAP allocations and access to indirect methods of using their CAP allocations (i.e. groundwater savings and underground storage facilities) have still joined the CAGRD because it is an easy way (and sometimes the only realistic way) to demonstrate the availability of 100 years of renewable water supplies to meet their future demand. Thus, for most developments and for some cities, the CAGRD is easily the lowest cost means of complying with the AWS rules.

There is also evidence to suggest that developers are enrolling homes earlier than necessary. Construction of ML homes through 2006 lagged Plan projections by nearly 17,000 units, or 18 percent below projections. Accordingly, actual replenishment obligations resulting from member pumping in 2006 were about 11,500 acre-feet, almost 23 percent below projections (CAWCD July 2007). CAWCD staff suspects that some of these homes may be registered

Table 2: CAGRD Enrollment Summary, as of January 2, 2008

CAGRD Member Land

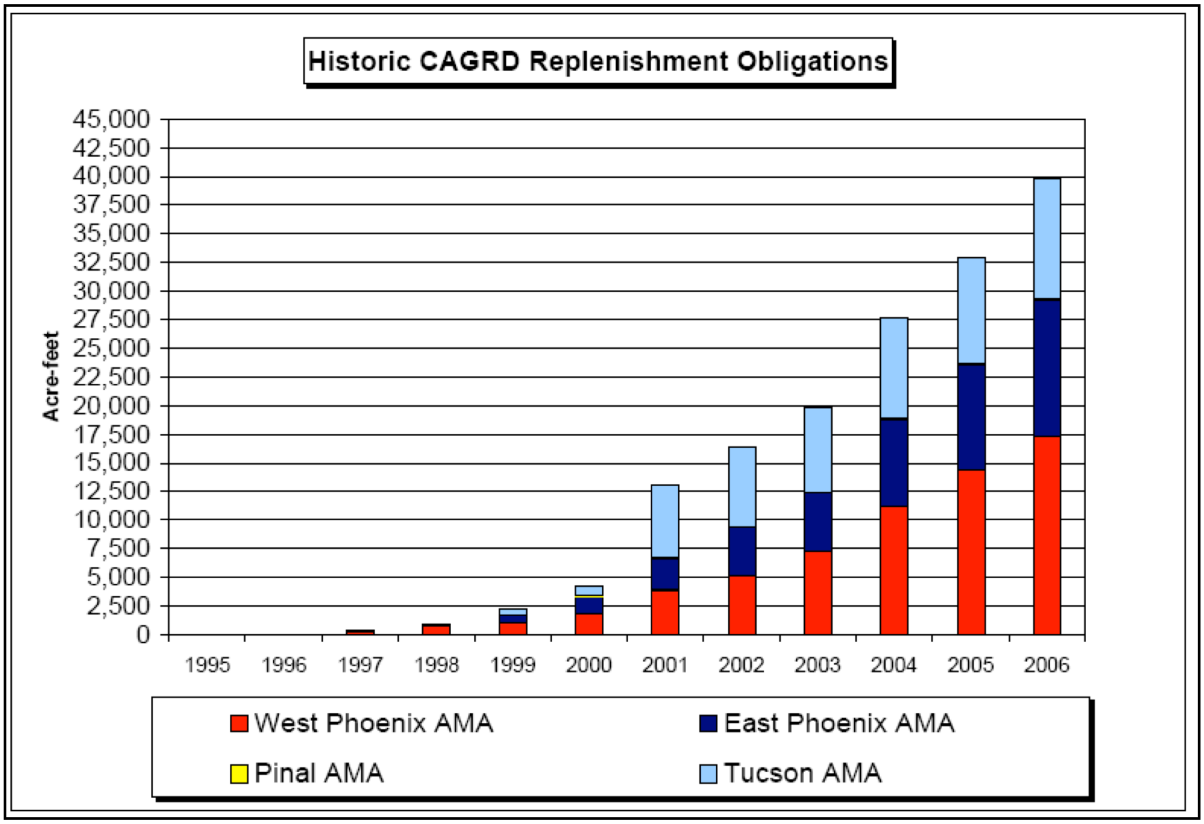
Enrollment Summary

Year	Phoenix AMA - West		Phoenix AMA - East		Pinal AMA		Tucson AMA		Total	
	#MLs	#Homes	#MLs	#Homes	#MLs	#Homes	#MLs	#Homes	#MLs	#Homes
1995	1	132	1	16	0	0	2	36	4	184
1996	11	2,714	18	1,831	1	11	7	529	37	5,085
1997	18	4,639	23	2,551	5	404	17	1,250	63	8,844
1998	10	1,888	38	2,767	5	361	2	389	55	5,405
1999	21	4,900	35	3,845	10	776	5	672	71	10,193
2000	24	9,527	30	3,740	18	15,004	8	6,554	80	34,825
2001	28	10,079	12	2,097	12	2,922	9	3,510	61	18,608
2002	30	6,536	11	4,454	6	520	7	2,534	54	14,044
2003	76	17,119	18	2,882	6	1,331	16	2,042	116	23,374
2004	91	13,046	10	2,453	9	2,509	13	2,042	123	20,050
2005	99	13,669	27	4,603	14	3,509	15	2,682	155	24,463
2006	94	28,057	34	5,505	25	23,832	16	2,310	169	59,704
2007	27	10,889	12	4,139	13	7,783	9	1,304	61	24,115
Pending*	14	7,354	10	480	4	2,962	5	890	33	11,686
Total	**544**	**130,549**	**279**	**41,363**	**128**	**61,924**	**131**	**26,744**	**1,082**	**260,580**

* As of January 02, 2008
ML = Member Land Subdivision

Source: CAGRD website, http://www.cagrd.com

Figure 4: CAGRD Replenishment Obligations, 1995-20



Source: CAGRD website, http://www.cagrd.com

decades before they are actually constructed. One obvious explanation for the early enrollment phenomenon is that real estate developers are hedging against the risk that complying with the AWS rules may not be so cheap and easy in the future. In a sense these developers are buying an option: while the CAGRD door is wide open to new members today, it is unlikely to remain that way for long, as the CAGRD's cheap primary water supply, excess CAP water, disappears with rising demand for CAP and Colorado River supplies. The high enrollment in the CAGRD is a direct result of the low cost of enrollment.

The water agency officials and the water provider staff interviewed for this study tended to speak differently about the enrollment problem than the interviewees representing the real estate development community. Individuals in the former group tended to frame the growing enrollment problem as a lack of regulatory control, wherein CAGRD needs the explicit authority to limit enrollment before acting on the issue, but would never be able to obtain this authority because the real estate development community would not allow it. Individuals in the latter group, while affirming the observation that the real estate development community would not stand for CAGRD capping enrollment, discussed the issue as a matter of money. Interviewees representing the development community conveyed the sense that developers would be willing to pay much more to ensure compliance with the AWS rules than they are currently paying through membership in the CAGRD. This is a salient point. While CAGRD does not have the legal authority to deny or otherwise limit enrollment, it does have the authority to change its enrollment fee. Nearly all of the interviewees in the real estate development community group felt that CAGRD, instead of focusing on what it cannot do to control enrollment, should focus on what it can do: change the price.

Accurately predicting the response to price changes is difficult, however. The CAGRD has never changed the enrollment fees for new Member Lands and the price elasticity of demand for CAGRD enrollment is unknown. Nevertheless, higher enrollment fees would encourage potential CAGRD members to consider other ways to comply with the AWS rules rather than joining the CAGRD by default. Some alternative methods of compliance include the establishment of a private replenishment cooperative, a higher degree of effluent reuse for non-potable and replenishment purposes, direct delivery of CAP supplies, purchase of extinguishment credits, and construction within the service area of a designated water provider. If CAGRD is concerned that its membership has grown beyond its ability to provide replenishment services, the District ought to consider increasing its enrollment fee to decrease the rate of enrollment to reasonable levels. CAGRD is not the only available option for real estate developers seeking to comply with the AWS rules, but with exceedingly low enrollment fees it appears that CAGRD membership is basically the only option being considered by developers. Increasing the fee may help to reduce enrollment, increase conservation of groundwater in some areas, provide CAGRD with the financial resources to acquire the water supplies to meet its replenishment obligation, and increase the incentive for cooperation among water utilities seeking to use renewable supplies directly.

4.3.3.2. *Location of Replenishment*

Another secondary effect of the CAGRD is that it has allowed development to occur far from the CAP canal and existing artificial recharge projects, contributing to the reliance upon "paper" water to comply with the Assured Water Supply rules. Per the AWS rules, the basic spatial requirement for CAGRD's replenishment is that it must be within the same AMA as the excess groundwater pumping (i.e. if groundwater is pumped in the Tucson AMA, it must be replenished in the Tucson AMA). While CAGRD replenishes in USFs and GSFs that are close to the CAP aqueduct to minimize costs for its members, most of its members are pumping groundwater many miles from the location of replenishment. Over time, the hydrologic disconnect between pumping and replenishment may have serious consequences for some members. Avery, Consoli, Glennon, and Megdal (2007) framed this problem in terms of "wet" members and "dry" members:

> "Wet" members are located in close proximity to CAGRD's recharge and delivery infrastructure, so that the member service area or the water provider serving an ML is pumping groundwater in reasonable proximity to the site of replenishment. In such areas, groundwater levels are likely to remain stable. In other instances, the site of pumping is located far from the CAP delivery system and storage sites that CAGRD has used, thus far, to meet its replenishment obligations. In these "dry" areas, the hydrologic impacts of pumping are not mitigated by replenishment. (p. 351)

The existence of "dry" members is a source of concern for many people in Arizona's water community, including those interviewed for this study. In an issue statement drafted in 2000 regarding the CAGRD, the Tucson AMA Safe-Yield Task Force opined that this imbalance may lead to physical availability problems for some CAGRD members (Tucson AMA Safe-Yield

Task Force, 2000). In order to maintain the physical water supply of these “dry” members, infrastructure will need to be constructed to directly deliver CAP supplies to their service areas. For such members, reliance upon the CAGRD is likely to be a “bridge” to comply with the AWS rules until it is necessary or efficient to deliver renewable supplies directly. Yet for other members who are within the area of hydrologic impact of replenishment or have stable groundwater supplies for other reasons, it may prove to be more cost-effective to continue to pump groundwater and pay the CAGRD for its replenishment services.

Therefore, any policy seeking to adjust the apparent imbalance of physical water supplies is faced with a complex and delicate matter. Each municipal water provider or private water company faces a unique set of conditions related to physical water availability, water quality, water demand, distance to renewable supplies, and so on. Requiring all water providers to immediately transition to direct delivery of renewable supplies would not even be plausible, let alone efficient. Instead, the comparative economics of groundwater pumping and infrastructure development will likely guide each AMA’s physical water supplies into equilibrium in the long run. The question is, how long will it take? And what will it cost? And who will pay for it?

Many people in Arizona are concerned about the CAGRD, and they have their reasons: the size of CAGRD’s member enrollment; the way the CAGRD eliminates the incentive for developers to seek out renewable water supplies rather than simply sink wells to serve the new development; the way CAGRD has enabled development to rely on “paper water” and sprout in “dry” areas; CAGRD’s ability to obtain enough water supplies to fulfill its growing replenishment obligation; the potential for CAGRD to receive preference in the allocation of CAP water so that it can fulfill its replenishment obligation; and so on. This study has attempted to show that some of these issues could be resolved by some simple price changes. It is certainly true that the high rate of enrollment strains CAGRD’s ability to meet its replenishment obligation in a time of growing competition for renewable water supplies. However, the high member enrollment in the CAGRD is a function of the low cost of enrollment; by raising the cost of enrollment, CAGRD will in theory cause potential members to consider other options of complying with the Assured Water Supply rules and reduce the rate of enrollment. It is also true that the CAGRD has enabled the geography of urban development in Arizona to remain relatively unfazed by the AWS rules. But the practical alternative to the CAGRD would have been the failure of ADWR to institute the AWS rules. If it would have been possible to have the AWS rules and not the CAGRD, development would likely have occurred closer to existing sources of renewable water supplies to reduce the cost of importing renewable water supplies to the new homes. It is also possible under this scenario that more partnerships would have occurred between and among private and municipal water utilities to further reduce the cost of importing renewable supplies. While it is too complex to simulate what development patterns might have been under an alternate policy scenario, we can examine the potential long-term impact of the CAGRD for the development that has occurred. This analysis suggests that the CAGRD actually creates an incentive for a water utility to transition from groundwater to direct delivery of CAP water far sooner than if the utility were not a member of the CAGRD. In its present form, the CAGRD encourages the use of the paper water system in the short run with a low enrollment fee, but may discourage its use in the long run with a high replenishment rate.

5. Concluding Remarks

Following the passage of the Groundwater Management Act (GMA) in 1980, the Arizona Department of Water Resources (ADWR) sought ways to support the management goals of the active management areas (AMAs) established by the GMA legislation. Because the Phoenix, Tucson, and Prescott AMAs were created with the management goal of achieving safe yield by 2025, ADWR needed to institute policies to encourage the use of renewable water supplies in these areas. ADWR attempted to do this with the Assured Water Supply Draft Rules in 1988. The rejection of the Draft Rules by Arizona's real estate development community persuaded ADWR to allow members of the development community to create a mechanism to help them comply with the inevitable Assured Water Supply (AWS) rules. The mechanism created by the real estate development community in 1993 is the Central Arizona Groundwater Replenishment District (CAGRD).

At the time of its passage, the CAGRD was considered to be a critical policy instrument for enabling the passage of the AWS rules. Fifteen years into the existence of the CAGRD, this assertion is still the consensus in Arizona's water community. Yet it is also largely recognized that the CAGRD has enabled and perhaps encouraged the spatial distribution of physical ("wet") water supplies to remain imbalanced by encouraging the hydrologic disconnection between the locations of groundwater pumping and replenishment. While the CAGRD is not exclusively to blame for this, it has undoubtedly played a significant role in removing the incentive the AWS rules were designed to create—that is, to replace groundwater pumping with the use of renewable water supplies. Instead of renewable water being directly delivered to a new subdivision, the subdivision may enroll in the CAGRD and demonstrate use of renewable water supplies indirectly. The subdivision continues to pump groundwater locally and replenish this groundwater remotely in an area that is very unlikely to hydrologically benefit the subdivision's local groundwater resources. Therefore, while the intention of the AWS rules was to correct this imbalance of physical water supplies, the CAGRD effectively negates the ability of the AWS rules in the short to medium term.

Economic theory, however, suggests that in the long run, equilibrium of physical water supplies will emerge. Groundwater users will only continue to pump groundwater until the cost of pumping is equal to the cost of importing a renewable water supply. The CAGRD affects the timing of the switch point between the two resources by raising the cost of groundwater pumping with a replenishment fee. Because the cost of replenishment is very high relative to the cost of pumping groundwater, CAGRD members are likely to have earlier switch points than non-CAGRD members. This provides some insight into the long-term effects of the CAGRD. While in the short term the CAGRD enables new growth to continue to pump groundwater, thereby exacerbating the spatial imbalance of physical water supplies in the three central AMAs, in the long term it appears that the CAGRD will also hasten the regional transition to direct delivery of CAP water because of the increasing cost of replenishment borne by the members.

This study underscores some important policy considerations for CAGRD, and shows that CAGRD has several tools at its disposal to resolve some of the concerns surrounding the District. First, while the rate of enrollment in the CAGRD has raised concerns among many water providers, enrollment will decline by increasing CAGRD's enrollment fee. To date, CAGRD has kept its enrollment fee very low, sending a signal to real estate developers that CAGRD is willing and able to accommodate growth with ample water supplies. Since the growing competition for CAP supplies clearly shows that renewable water supplies are and will continue to be economically scarce, CAGRD's fee structure must signal this scarcity on the enrollment side if it wishes to ensure that it grows at a more moderate pace.

Another cause of concern is the way in which the CAGRD encourages new real estate development to hydrologically disconnect groundwater pumping and replenishment. But as Shipman (2008) found, the CAGRD replenishment rate is critical in determining the switch point between pumping groundwater and importing CAP water for the CAGRD members. Therefore, the CAGRD replenishment rate may be an effective policy tool, together with ADWR's water level decline standard, to control the timing of when water utilities will transition from a less sustainable water management regime (groundwater pumping) to a more sustainable one (direct use of renewable supplies).

A Postscript

The initial analysis for this paper was completed in 2008. In the six years since this paper was written, CAGRD has made several critical policy changes. In an effort to generate a funding source for water supply purchases to support its Member Land replenishment obligation, the CAGRD has significantly increased its Enrollment and Activation fees. The Enrollment Fee has increased ten-fold, from $23 per home in 2007/08 to $237 per home in 2014/15, while the Activation fee has risen from $63 per home in 2007/08 to $260 per home in 2014/15. CAGRD has signaled that the Activation Fee will continue to rise to over $800 in the Tucson AMA and over $1,000 per home in the Phoenix and Pinal AMAs. Similarly, replenishment rates have increased significantly. The following table summarizes the CAGRD replenishment rates as of the 2014/15 rate cycle.

Table 3: Updated CAGRD Replenishment Assessment Components

COMPONENT	COST BASIS	2014/15 RATE (per AF)[1]
Administrative[2]	Total cost of administering the CAGRD	$45
Infrastructure & Water Rights[2]	Costs of purchasing water rights and developing infrastructure to deliver and replenish water	$294
Water & Replenishment[3]	Cost to purchase, transport, and recharge/replenish water supplies	$172; $155; $196
Replenishment Reserve[3]	Costs to establish and maintain a replenishment reserve for each AMA	$63; $70; $80
TOTAL COST OF CAGRD REPLENISHMENT:		
Phoenix AMA	$45+294+172+63	= **$574**
Pinal AMA	$45+294+155+70	= **$564**
Tucson AMA	$45+294+196+80	= **$615**
[1] Where appropriate, multiple rates are given for Phoenix, Pinal, and Tucson AMAs, respectively		
[2] Uniform across AMAs		
[3] Computed separately for each AMA		

Acknowledgements

This research was made possible by funding from the University of Arizona's Technology and Research Initiative Fund, administered by the Water Sustainability Program at the Water Resources Research Center in Tucson, Arizona. Many people provided invaluable guidance and support for this study, particularly Sharon Megdal, Keiron Bailey, Daoqin Tong, Ken Seasholes, Cliff Neal, Randy Edmond, and Phillip Guertin.

References

Andrus, C. Transcription of interview with B. Leverton, dated 6 June 2005. Central Arizona Project Oral Histories. Online. Available at http://www.cap-az.com. [Accessed June 2007.]

Arizona Department of Water Resources, Assured Water Supply Program Detailed Information Brochure, Revised November 2001.

Arizona Department of Water Resources, Pinal Active Management Area Draft Management Plan for the Second Management Period, 1990-2000. April 1998.

August, Jr., J.L., and G. Gammage, Jr. "Shaped by Water: An Arizona Historical Perspective." In *Arizona Water Policy: Management Innovations in an Urbanizing, Arid Region,* eds., B.G. Colby and K.L. Jacobs, pp. 10-25. Washington, DC: RFF Press, 2006.

Avery, C., C. Consoli, R. Glennon, and S.B. Megdal. "Good Intentions, Unintended Consequences: the Central Arizona Groundwater Replenishment District." *Arizona Law Review* 49, no. 2, 2007.

Bartlett, R. *Economic Foundations of Political Power*. New York: Free Press, 1973.

Bodenchuk, J. Personal interview, 26 February 2008.

Buschatzke, T. Personal interview, 3 August 2007.

Central Arizona Groundwater Replenishment District. "Executive Summary: Relationship to AWS Rules." Online. Available at http://www.cagrd.com. [Accessed 20 October 2007.]

Central Arizona Project, "2004 Cumulative Delivery and Revenue Report." 29 July 2005.

Central Arizona Project, "CAP Subcontracting Status Report, October 1, 2007." Online. Available at http://www.cap-az.com. [Accessed 29 February 2008.]

Central Arizona Project. *Outlook 2003: Municipal Demand Projections for CAWCD's Service Area Assuming Historic Data through January 2003*. Vols. 1 & 2.

Central Arizona Water Conservation District, "Conceptual Plans to Recover Stored Water." Draft, 24 May 2007, p. 13.

Central Arizona Water Conservation District, "Continued Discussion Regarding CAGRD Revenue Generation Strategies, Agenda Item 6." CAWCD Board Meeting Agenda, 25 July 2007.

Colby, B.G. and K.L. Jacobs. " Water Management Challenges in an Arid Region: Key Policy Issues." In *Arizona Water Policy: Management Innovations in an Arid, Urbanizing Region*, eds. B.G. Colby and K.L. Jacobs. Washington, DC: RFF Press, 2006. p. 1.

Denzin, N.K. *The Research Act: A Theoretical Introduction to Sociological Methods*. New York: McGraw Hill, 1978.

Dixit, A. and S. Skeath. *Games of Strategy*. New York: W.W. Norton & Co., Inc., 1999.

Ferris, J., S.B. Megdal and S. Eden. "An Introduction to the Central Arizona Groundwater Replenishment District." Unpublished document, the University of Arizona Water Resources Research Center, January 2006.

Glennon, R.J. "Because That's Where the Water Is: Retiring Current Water Uses to Achieve the Safe-Yield Objective of the Arizona Groundwater Management Act." 33 *Arizona Law Review* 89, 1991.

Governor's Central Arizona Project Advisory Committee Report, 1993.

Governor's Water Management Commission, Final Report, December 2001. Online. Available at http://www.azwater.gov/dwr/Content/Publications/files/FinalReport.pdf. [Accessed 10 December 2007.]
Holway, J., P. Newell and T.S. Rossi. "Water and Growth: Future Water Supplies for Central Arizona." Global Institute of Sustainability, Discussion Paper #1. Draft, 13 June 2006.
Jacobs, K., and M.A. Worden. "Water in Arizona: Challenges Met and Remaining." In *Arizona's Water Future: Challenges and Opportunities,* 85th Arizona Town Hall Background Report. Tucson: The University of Arizona, 2004.
Kelso, M.M, W.E. Martin, and L.E. Mack. *Water Supplies and Economic Growth in an Arid Environment: An Arizona Case Study*. Tucson: The University of Arizona Press, 1973.
Megdal, S.B. Personal interview, 6 August 2007.
Megdal, S.B. and T.D. Shipman. "Gains from Trade: Arizona's Groundwater Savings Program." Unpublished draft paper, University of Arizona Water Resources Research Center, 2008.
Neal, C. Personal interview, 26 May 2007.
Needham, R.A. "An Impact Assessment of Water Conservation in Agriculture: the Arizona Groundwater Management Act of 1980." Unpublished master's thesis, Department of Agricultural & Resource Economics, University of Arizona, 2005.
Patton, M.Q. *Qualitative Research and Evaluation Methods*, 3rd Ed. Thousand Oaks, CA: Sage Publications, Inc., 2002.
Santa Cruz Valley Water District, "Plan of Permanent Operation and Administration, Vol. 1," 1993.
Schwarz, A. "Paper Water vs. Wet Water: CAGRD Replenishment in the Tucson AMA." Unpublished paper, University of Arizona Water Resources Research Center, May 2006.
Shipman, T.D. "An Economic Analysis of the Institutional, Spatial and Temporal Dimensions of the Central Arizona Groundwater Replenishment District: Implications for Arizona's Water Future." Unpublished M.S. Thesis, Department of Agricultural and Resource Economics, University of Arizona, Tucson, AZ, 2008.
Tenney, W. "A Municipal Water Provider's View of the CAGRD, or How to Tame An Elephant." Unpublished paper, May 2007.
Tucson AMA Safe-Yield Task Force. Issue Outline: Central Arizona Groundwater Replenishment District, Draft, 12 July 2000.
Vincent, J.A. "What Lies Beneath: The Inherent Dangers of the Central Arizona Groundwater Replenishment District." *Arizona State Law Journal* 38, no. 857 (2006).
Wilson, P.N. "An Economic Assessment of Central Arizona Project Agriculture." A report submitted to the Office of the Governor and the Arizona Department of Water Resources. 1992.
Wilson, P.N. "Economic Discovery in Federally Supported Irrigation Districts: A Tribute to William E. Martin and Friends." *Journal of Agricultural and Resource Economics* 22, no. 1 (1997): 61-77.