Institutional Frameworks for Managing Groundwater in Rural Arizona and Sonora

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Abstract

The conceptual framework of the *New Water Economy* (Aguilera Klink, 2006) is applied to analyze the institutional frameworks governing groundwater management in rural Arizona, United States, and Sonora, Mexico. This framework emphasizes the changes in infrastructure, management style, and societal values related to water resources in three stages: the expansion, the transition, and the consolidation of water management. Through those water is progressively conceptualized as a commodity, as a productive input, and finally as an eco-social active. The importance of this analysis lies in the fact that both states share the core territory of the Sonoran Desert, which means they have similar climatic, hydrologic, and ecologic characteristics. However the region is literally cut and differentially impacted by socio-economic, policy, and cultural differences across the international border dividing the United States and Mexico. The countries and the states have different profiles that can make a comparison difficult, however by looking at selected indicators and interviewing stakeholders in each case it was possible to define a profile of rural groundwater management in both states, and to identify opportunity areas that are common to them, and that could help to achieve adaptive groundwater management facing future global changes. The analysis in general terms locates rural Arizona in a transitional stage where socio-ecologic and conservation aspects are progressively recognized, while rural Sonora is located in an expansion stage, since it is still trapped in the issues of infrastructure development and water supply. These stages are not absolute or irreversible, though.

Key words: groundwater, Sonoran Desert, rural water management, New Water Economy, water management institutions.

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1. Introduction

As the populations in Mexico and the United States have urbanized during the last half of the 20th century (in the U.S. this process began earlier), most of the financial resources and management efforts in the water sector have been directed to the procurement of adequate potable water and sanitation services in the cities (Aboites, 2009; Jacobs and Stitzer, 2007). The allocation of resources to urban development is accompanied by a lack of attention to water resources in rural localities (Jacobs and Stitzer, 2007).

In the region of the Southwest U.S. and Northwest Mexico this represents a huge challenge because enough water of certain quality should be supplied to people in one of the most arid regions of North America: the Sonoran Desert and its surrounding steppe. This eco-region lies mainly in the states of Arizona and Sonora, but it is literally cut through by the international border between the U.S. and Mexico. Both states have similar climatic and biodiversity conditions and urban growth rates that surpass those of their respective countries (Wilder et al. 2012), but political and socio-economic features are different, as well as water institutions concerning groundwater. While Sonora is under the mandate of a unique federal law that regulates both surface and groundwater, Arizona initiated in 1980 an institutional transformation that allowed the creation of the Active Management Areas (AMAs), one of the main policy instruments for protecting groundwater resources in places with high water demand (largest cities and irrigation districts).

The higher attention given to cities could be justified from a demographic and economic point of view, but it is also true that cities cover only small spots in comparison to the entire territory of states. For example, in the case of Arizona the most populated localities are mainly within the boundaries of the AMAs, which represent only 13% of the state's area. The non-AMAs portion equals 87% of land and is home to almost one million Arizonans (Jacobs and Stitzer, 2007). From this non-AMAs population more than 650,000 live in rural places (localities ≤ 2,500 people according to the US Census Bureau, 2010). In the case of Sonora, Mexico, more than 65% of the people live in the five main municipalities of the state, but these only represent 19% of land, while the rest of population is dispersed in the remainder 81% of the territory where most of the small and rural localities are located (in Mexico a rural locality is also ≤ 2,500 people, according to the National Institute of Statistics and Geography, INEGI, 2010).

Therefore when we talk about water management in rural settings, the importance may be not only in the population size, but in the integrity of ecosystems, land, and natural resources. The remainder non-urban territory in Sonora and Arizona is the repository of the natural richness of these states, and its importance will grow greater as water policies increasingly include the management of eco-social systems at the river basin level, not only the management of water alone (Aguilera-Klink, 2008). In addition to this, rural communities in Arizona and Sonora usually occupy the upper sections of the basins whose streams flow down towards bigger cities in the river valleys. Then the basins' hydrographic networks connect rural and urban settings although they are virtually decoupled in water policy-making.

Considering the above, the general objective of this document is to make a comparative analysis of the water institutions governing groundwater in rural settings of Arizona and Sonora. The specific purposes are: a) to describe the institutions (law, policy, and management) of groundwater in rural localities in Arizona and Sonora; b) to compare potential results of rural groundwater management between the states; and 3) to define the stage of evolution of the institutional frameworks for rural groundwater in both states according to the conceptual tools presented in the literature review. The fact that Arizona and Sonora share similar geographic and hydroclimatic conditions while varying social, cultural and political basis, gives a good opportunity to make comparative research in terms of water institutions and its effects on water resources. The policy lessons derived from this comparison can help to understand groundwater management in other arid rural places of the world.

The organization of this article is as follows: the next section presents a review of the concept "institution" and what it means in the water policy sector. The section also describes the elements of the *New Water Economy* framework applied in this comparative analysis to observe the stages of water policy. The third section summarizes the methods and procedures utilized for integrating primary and secondary data on Arizona and Sonora. The fourth section includes the results of the analysis for each of the states, and the comparison between their institutional features and management. This leads to the last two sections presenting the conclusions and the policy recommendations derived from the analysis respectively.

2. Conceptual background

This paper focuses on institutions. These are considered in a broader sense as the formal and informal "rules of the game" that set the boundaries for human action in specific contexts, allowing social groups to adapt (or not) to changing circumstances in their resources (Kelly and Adger, 2000). Saleth and Dinar (1999) argue that water institutions in particular are influenced by several factors such as economic, demographic, political and constitutional structures; and the influence of these factors is formalized in three inter-related aspects: legal frameworks, policy issues, and administrative arrangements. In short, institutions can be defined through the interactions between law, policy, and administration. The analytical components of these aspects are summarized in Table 1.

Table 1. Analytical Components of Water Institutions

Legal Framework	Policy Issues	Administrative Arrangements
• Legal treatment of water and related resources. • Format of water rights. • Provisions for conflict resolution. • Provisions for accountability. • Scope for private sector participation. • Centralization tendency. • Degree of legal integration within water law.	• Project selection criteria. • Pricing and cost recovery. • Inter−regional/sectoral water transfer. • Private sector participation. • User participation. • Linkages with other economic policies.	• Spatial organization. • Organizational features. • Functional capacity. • Pricing and finance. • Regulatory and accountability mechanisms. • Information, research, and technological capabilities.

Source: elaborated by author after Saleth and Dinar, 1999.

Although water sector evaluations tend to be centered on performance according to values of efficiency, efficacy, and equity (Saleth and Dinar, 1999), in this case a different approach is sought. It is assumed that water institutions are guided not only by economic and rational decision-making dynamics, but also by philosophical and socio-cultural principles that dictate which the priorities are and how water is socially and politically constructed. In coherence with this perspective, a conceptual framework –the New Water Economy Framework (NWEF) - is applied for analyzing the evolution of water institutions in three stages characterized by different underlying perspectives on the relationships between society and water (Aguilera-Klink, 2006,

2008).These are the expansion, the transition, and the consolidation stages. The author also provides a set of dimensions that differ between stages.

- ***The Expansion stage:*** it is characterized by an engineering focus centered on infrastructure building to provide full coverage of water and sanitation services to population, and water for industrial, agricultural, and energy production. It is believed that high availability can foster socio-economic development by itself, so maximizing supply is the main purpose of policy actions as water is seen as a basic necessity and a factor of production. At this point, environmental issues are not a concern for managers, nor for the general public, which is not very participative in decision-making related to water. Finally, since most of economic resources are directed to physical infrastructure, reliable data generation is almost inexistent and planners don't use factual information on resources' distribution and uses.

- ***The Transition stage:*** although we can see changes in the institutional dimensions in this stage, a new perspective on water-society connections is not yet fully developed. More attention is given to demand-side issues because supply has been more or less guaranteed. Priorities and current practices related to water use and management are discussed, as well as the necessity of implementing conservation incentives. Environmental concerns are gradually spreading through several groups of the population (although they are not generalized yet), and public participation is becoming an important component of management. Social conflicts around water also begin to appear, but this is a manifestation of the multiple competing water functions that are entering to the negotiation. Some sectors emphasize the necessity of reliable data, but gaps are still observed and temporal analyses of water use and management are not available for planning. In summary, the transition stage can be considered as the midpoint between the expansion and the consolidation stages (Aguilera-Klink, 2008).

- ***The Consolidation stage:*** in this stage it is recognized that water resources satisfy multiple economic, social, and environmental functions, both quantitative and qualitative. This means that water is considered and eco-social active, and not only a factor of production or a social active alone (Aguilera-Klink, 2008). From this perspective, water policy lies within the boundaries of Integrated Water Resources Management (IWRM), therefore management of water resources is expanded to include the entire territory in which ecosystem functions

interact with human demands. At this point a cognitive shift has occurred among managers and population, who now are also concerned by environmental issues associated to water and land. Public involvement in decision-making is crucial in water planning and management, as well as the development and use of reliable data, both of the current and historic development of water resources at the basin level.

Both, the institutional aspects of Saleth and Dinar (1999) and the stages and dimensions of the NWEF of Aguilera-Klink (2006, 2008) are combined in Table 2 to serve as analytical tool for this document. Progressive changes in the water institutions will manifest in the different dimensions grouped in the three institutional aspects: law, policy, and management. Although all the dimensions proposed by Aguilera-Klink (2008) lie mainly in the aspects of policy and management, in theory some of the changes could eventually lead to deeper law modifications (for example the changes in social constructions of water). The concepts in Table 2 will be utilized to analyze the institutions of rural groundwater in Arizona and Sonora in the next sections.

Table 2. Dimensions of institutional evolution of water policy

Institutional Aspects	Dimensions	Expansion Stage	Transition Stage	Consolidation Stage
Policy	Policy issues	Physical infrastructure development: more reservoirs and diversions.	Demand-side policies.	Integrated Water Resources Management, consideration of water cycle.
Management	Management goals	Guaranteeing supply, also flood control.	Both supply and flood control are guaranteed, now attention centers on practices in rural and urban settings.	Water management became territory management (land+ ecosystems+ water+ people).
Policy	Priorities	Full coverage of urban water and sanitation; supply water for agricultural irrigation.	Past priorities are questioned; economic vision of water begins to change.	Priorities now include compatible uses according to the basin features (human + nature).
Policy- Law	Importance of environment	Low attention to environmental issues associated to water.	Social perception about environmental issues is developing and reaching more sectors of population.	Environmental values have a central position in management.

Institutional Aspects	Dimensions	Expansion Stage	Transition Stage	Consolidation Stage
Policy- Law	Social constructions about water	Water is a basic necessity, and a factor of production.	Water is an input for production, but also a social active.	Water is an eco-social active.
Policy-Management	Role of civil society	Low social conflict and deficient public participation in decision-making.	Increasing social conflict and public participation in water decision-making.	Public participation becomes central. High level of social conflict reflects multiple functions of water.
Management	Efficiency considerations	Low concerns for technical efficiency in water use and distribution. There are no incentives for this.	Concerns for efficient use and distribution appear. Incentives are discussed, and some are applied.	Water conservation is fundamental. Incentives and public intervention for water savings generalize.
Management	Data generation for decision making	No statistical data on water management aspects.	Reliable data are a concern, but there are still gaps in generation of information.	Reliable data are available and incorporated in decision-making.

Source: elaborated by author after Aguilera-Klink, 2006, 2008; and Saleth and Dinar, 1999.

3. Methods and procedures

Primary and secondary sources of data were used in this document. Primary data consisted in two interviews conducted with specialists in water institutions in Arizona and Sonora respectively. The interviewee in the Arizona section was the current Deputy Assistant Director for Water Planning in the Arizona Department of Water Resources.[2] She is responsible of two programs: Statewide Planning, and Colorado River Management; and also is the Tribal Liaison of the ADWR. In the Sonora section the interviewee was an independent consultant with 10 years of experience in natural resources management, rural development, and ecological planning; and current postdoctoral researcher at El Colegio de Sonora, Mexico. He is also part of a research

[2] Full names are omitted to keep confidentiality of informants in the paper, although they are public figures. **The interviewees made clear that responses to the questions for this research are personal opinions and not the opinion of the organizations they represented at the time.**

project on resilience in the Sonora River Basin System, and an expert in rural use of water. Both interviews occurred in May, 2014 (see outlines of interviews in the annex).

Secondary sources of data (documentary and online) on water policy, rural groundwater, and complementary socio-economic information on Sonora and Arizona were compiled between January and May, 2014. The main sources were: 1) Arizona Department of Water Resources (ADWR); 2) US Census Bureau, 3) US Bureau of Economic Analysis; 4) Rural Water Association of Arizona; 5) US Department of Agriculture; 6) State Water Commission in Sonora (CEA-Sonora); 7) Institute of Statistics and Geography in Mexico (INEGI); 8) National Water Commission in Mexico (CONAGUA); and 9) Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food in Mexico (SAGARPA). Both primary and secondary data were integrated and analyzed according to the conceptual framework described in the background section. The analysis focused on the content of policies and management rules governing groundwater in rural settings in Sonora and Arizona to specify the stage of development in which each state can be located.

4. Results

4.1.Rural GW management in Arizona

4.1.1. Socio-economic and demographic context

Arizona is the sixth largest state in the United States of North America with an area of 295,234 square kilometers (km^2) divided among 15 counties. The total population in 2010 was approximately 6.4 million people, 90% of them concentrated in urban settings (5,740,659) and 10% in rural localities (651,358) (US Census Bureau, 2010). The Gross Domestic Product in 2008 was 249 US billion current dollars (US Bureau of Economic Analysis, 2009). Historically the state's economy was based on the "Five C's" (copper, cattle, cotton, citrus, and climate), but currently agricultural production represents less than 1% of the GDP (Field to Market, 2012).

4.1.2. Water features

For water administrative purposes, the ADWR has divided the territory in seven planning areas. North to south and left to right these are: 1) Western Plateau; 2) Eastern Plateau; 3) Upper

Colorado River; 4) Central Highlands; 5) Lower Colorado River; 6) Active Management Areas; and 7) the Southeastern Arizona area (see Figure 1).

The surface water sources in Arizona include the main river systems in the state divided in 18 different watersheds according to the United States Geological Service (USGS). There are also several dams in the river systems, and 20 of these can storage more than 20,000 acre-feet (acf) each (ADWR, 2010: 19-22).

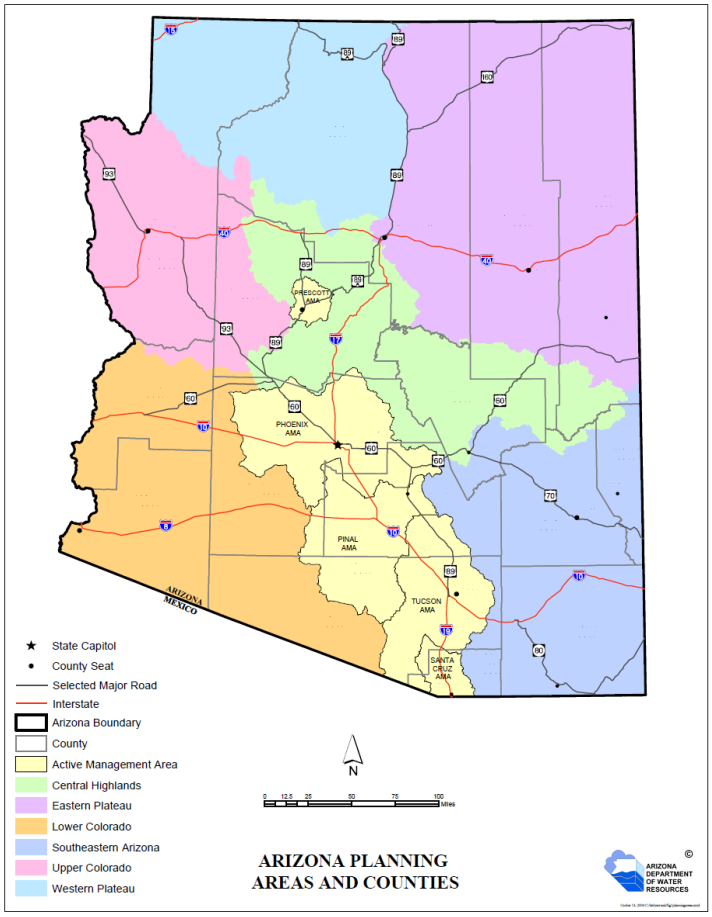

Figure 1. Water Planning Areas in Arizona State.
Source: ADWR, 2004.

The groundwater sources are located into the basins within each planning area. In Table 3 the number of basins, reported wells and yields, and estimated natural recharge are summarized. There are more than 12,000 reported wells distributed among 51 basins. These have a reported median yield of almost 33,000 gallons per minute, and estimated natural recharge between 1,900 and 2,165 thousand acf/year, however there are gaps in the ADWR's data tables. Almost half of the reported wells are located in the AMAs, but the volume extracted there is the 4th lowest of the planning regions. This is a direct reflect of the policies aimed at protecting groundwater sources in the AMAs (Jacobs and Holway, 2004).

Table 3. Groundwater basins, reported wells and well yields in the seven planning areas

Planning Area	Groundwater basins	Reported wells	Reported median yield (gallons per minute)	Estimated natural recharge (in 1000 acf/year)
Western Plateau*	6	99	1,290.5	N.A.
Eastern Plateau	1	386	500.0	319.0
Upper Colorado River**	9	474	4,365.0	280.0-284.0

Planning Area	Groundwater basins	Reported wells	Reported median yield (gallons per minute)	Estimated natural recharge (in 1000 acf/year)
Central Highlands	5	563	975.0	319.0-380.0
Lower Colorado River***	11	1,653	13,376.0	490.0-601.4
Active Management Areas	5	5,235	4,363.0	235.8
Southeastern Arizona	14	4,025	7,798.0	260.8-345.2
TOTAL	51	12,435	32,667.5	1,904.6-2,165.4

Source: elaborated by author after ADWR, 2010. Arizona Water Atlas, Volume 1. Executive Summary.
*The reported wells and yield are missing for the Grand Wash Basin, and the estimated natural recharge is missing for five of the six basins in the Western Plateau Planning Area.
**The reported wells and yields are missing for Meadview Basin, and the estimated natural recharge is missing for the Peach Springs Basin, both in the Upper Colorado River Planning Area.
***The reported wells and yields are missing for two of the basins in the Lower Colorado River Planning Area.

The average annual water supply in Arizona between 2001 and 2005 was 7.5 million acf (or 9.3 thousand million m^3); 54% from surface sources (2.8 million acf, or 68% of the surface supply corresponds to the Central Arizona Project, CAP), 43% from groundwater, and 3% from effluent. In this same period, agriculture demanded 75% of Arizona's supply, 20% went to municipal use, and 5% to industrial use. Agriculture is the largest user sector in all the planning areas except by the Eastern Plateau (ADWR, 2010: 50-65). With the exception of the AMAs region almost all cultural uses of water in Arizona (water diverted for agricultural, municipal, and industrial uses) depend on groundwater extractions, especially the water used by rural communities (Jacobs and Stitzer, 2007).

4.1.3. Rural groundwater institutions

In terms of groundwater institutions Arizona has been very active since the 70's and 80's when the CAP (aimed at bringing water from the Colorado River through a 330-miles canal) was under risk of not being completed because federal funds were conditioned to take state's actions towards the reduction of groundwater overdraft. This pushed forward the enactment of the Groundwater Management Act (GMA) in 1980 whose main objectives were 1) to control severe overdraft in the state, 2) to provide a means to allocate Arizona's limited groundwater resources to meet in an effective way the needs of the state, and 3) to augment groundwater through development of other water sources (Jacobs and Holway, 2004).

The GMA permitted the establishment of the ADWR, the development of CAP, and the regulation of water rights. The Department has three levels of water management: 1) the statewide

provisions, applicable to all parts of territory where no severe overdraft is present; 2) the Irrigation Non-Expansion Areas (INAs) where no new land can be put under irrigation, but other groundwater uses are not restricted; and 3) the AMAs where enforcement is stronger since these areas have higher populations and water demands (Jacobs and Holway, 2004).

Rural water is regulated by statewide provisions, with no specific mandatory policies as those existing in INAs and AMAs. This gap is one of the main observations of Jacobs and Stitzer (2007) in relation to rural groundwater management, and according to the Deputy Assistant Director for Water Planning of the ADWR there is no regulatory authority of the ADWR with respect to groundwater management outside the AMAs. The two basic limits to groundwater use are: 1) all groundwater must be pumped from wells that are in compliance with the state law, and 2) the use of groundwater must be beneficial and reasonable. In summary, there is largely no support that ADWR can provide to entities with issues associated to groundwater use in rural areas (personal communication with the author, May 2014).

In terms of securing water for the future, while AMAs have the Assured Water Supply Program requiring developers to demonstrate a 100-years supply for new divisions, in the rest of the state developers only have to demonstrate an adequate supply. Jacobs and Stitzer (2007:175) indicate that subdivisions are frequently approved even if supply is inadequate. When a declaration of adequate supply cannot be obtained, the only legal requirement for the developer is the full disclosure of this information to buyers (ADWR, 2010).

This does not mean that rural groundwater is managed according to *laissez- faire* principles. The ADWR have advanced several initiatives for non-AMAs areas, but only in some cases these have been specifically targeted at the rural sector, for example: 1) The Rural Watershed Initiative Program; 2) The Arizona Drought Plan and its corresponding legislation; 3) The Statewide Water Conservation and Drought Program; 4) The Rural Water Legislative Study Committee; and 5) The Statewide Water Advisory Group (SWAG).

Maybe the most rural-focused and permanent of the programs is the Rural Watershed Initiative (RWI). It is an effort to generate a collaboration structure for rural groundwater by providing technical and financial assistance to watershed partnerships in non-AMAs areas. The program began in 1998 and by 1999 received 1.2 U.S. million dollars from the Legislature to develop information supporting planning in the watershed partnerships, although the funding was progressively declining in the following years. In total 17 partnership groups are currently

participating in the Initiative (see Figure 2). In the Arizona Water Atlas published by the ADWR (2010) there is a succinct summary of the main policy and management issues identified by members of these partnerships, as well as their successes and results. During 2004, the ADWR also conducted direct-contact interviews to define the most important concerns among 246 rural water providers. The results were diverse among the planning areas and watersheds, but still most of the providers coincided in: 1) the lack of capital for infrastructure improvements and repairs; and 2) the inadequate storage capacity to meet peak demand and drought events (ADWR, 2004).

When asked about the success of the RWI, the Deputy Assistant Director for Water Planning of the ADWR indicated that evaluation depends on how we define success. As a result of the initiative many beneficial studies have been done and hydrologic data have been collected. Also the partnership groups have learned to work together to advance the knowledge of their rural watersheds. However if success is defined as the actual development of new water supplies for rural communities, there has been little progress derived from this particular initiative (personal communication with the author, May 2014).

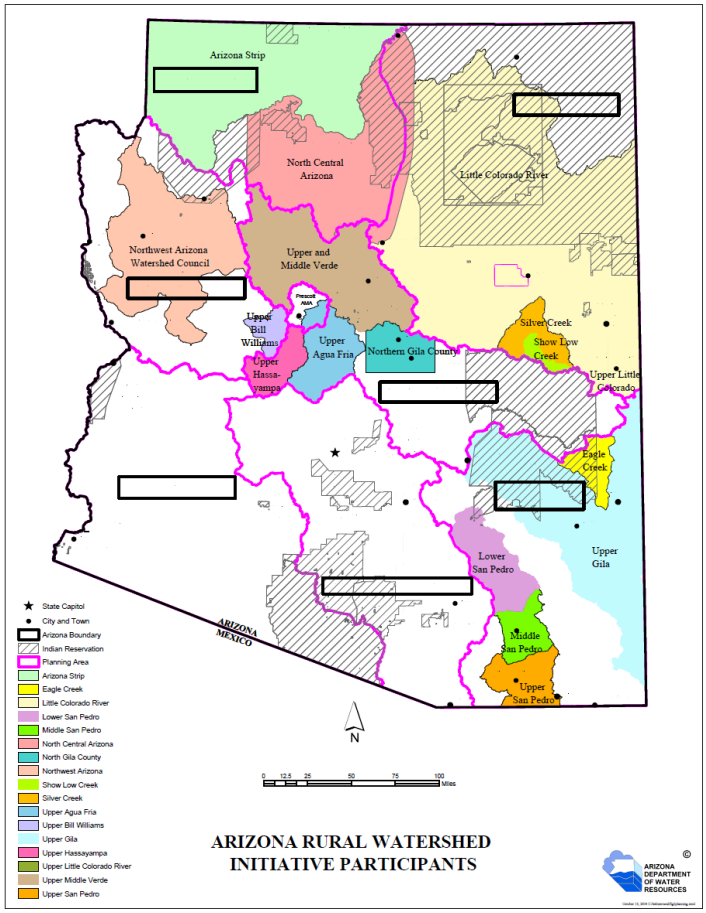

Figure 2. Rural Watershed Partnerships.
Source: ADWR, 2004.

Another aspect that could have helped in the development of better data in the rural areas is the 2005 legislation change that expanded water reporting and planning statewide and required that all community water systems submit a Water System Plan including a Water Supply Plan, a Drought Preparedness Plan, and a Water Conservation Plan. It also required that all community water systems submit an annual report of water withdrawals, diversions and deliveries (ADWR, 2010: 45). In relation to this, the ADWR interviewee mentioned that these mandatory

plans are not fully developed and they are useless with respect to providing solutions in times of drought in the rural communities. The annual reports have been inconsistent and spotty, making it difficult to use them in the WRDC process[3] (personal communication with the author, 2014).

4.1.4. The future of rural groundwater management in Arizona

The Rural Watershed Initiative Program and the 2005 legislative changes seem to have fostered the creation of a collaborative interaction between rural stakeholders and water authorities, however there still remain the pending issues of lack of resources, aging infrastructure, and no additional water sources or storage facilities to face drought. The ADWR interviewee indicated that the future issues of rural groundwater management will be associated to increasing demands and limited supplies (personal communication with the author, 2014). Rural population in Arizona is expected to more than double in the next 50 years, so shortages are highly probable in these areas (Jacobs and Stitzer, 2007: 173). Additionally the lack of water in specific spots is not going to prevent population increases since in rural Arizona people are willing to haul water between places (ibid., p. 175). This should be seriously considered together with the lack of generalized public involvement in rural water issues and the traditional neglect of ecological water requirements in rural water management.

4.2.Rural GW management in Sonora

4.2.1. Socio-economic and demographic context

Sonora is the second largest state in Mexico, its area of 179,503 km^2 is divided between 72 municipalities. The total population according to the 2010 census was 2,662,480 people, 86% living in urban areas (2,289,733), and 14% in rural localities (372,747) (INEGI, 2010). Sonora had somewhat the same economic basis than Arizona (agriculture, cattle, mining, and also fishing because of the coastal line of the Gulf of California), but currently the major contributor to the state's GDP is the tertiary sector (services such as restaurants, commerce, tourism, etc.). The GDP in 2008 was 373,529 million Mexican pesos (around 28.5 billion US dollars) (INEGI, 2010).

[3] The WRDC refers to the Water Resources Development Commission.

4.2.2. Water features

Water management in Sonora is based on five planning regions delimited by the main river basin systems (see Figure 3). Northwest to southeast, they are: 1) Sonoyta River, 2) Concepcion River, 3) Sonora River, 4) Yaqui River, and 5) Mayo River (CEA Sonora, 2008). In the Sonoyta River region the 6% of the population lives in rural localities, in the Concepcion River 12%, in the Sonora River 7%, in the Yaqui River 14%, and in the Mayo River 40%, being this the planning region with the higher proportion of rural population (ibid., p. 17).

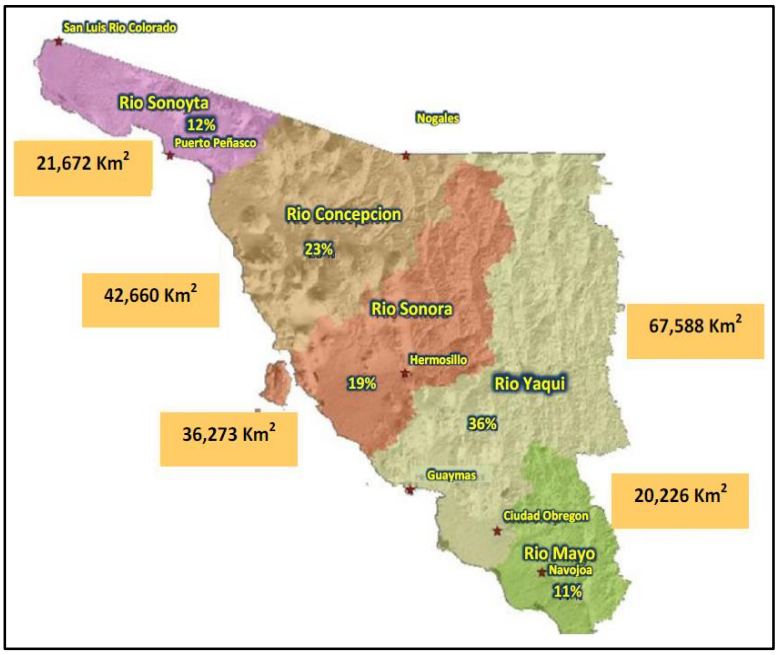

Figure 3. Water planning regions in Sonora State indicating their total and % area with respect to the state.
Source: CEA Sonora, 2008

There are 60 aquifers in Sonora's territory, and their recharge area rounds 195,793 km^2. The most important are: 1) Caborca (Concepcion River region); 2) Costa de Hermosillo and Rio Sonora (Sonora River region); 3) Valle del Yaqui (Yaqui River region); and 4) Valle del Mayo (Mayo River region). Extractions in these five big aquifers represent almost half of total groundwater extractions in Sonora. Several aquifers are classified by the Federal Government as overexploited (total extractions surpass total recharge), and they are concentrated in the north and center of the state, where relative water availability is lower (see Table 4).

Table 4. Overexploited aquifers in the planning regions of Sonora State

Planning Region	# of Aquifers	# of Overexploited aquifers	Total Recharge in million m^3/year	Total Extractions in million m^3/year
Sonoyta	3	2	142.40	250.70
Concepcion	17	4	587.50	552.66
Sonora	10	7	646.00	903.58
Yaqui-Matape	24	4	961.20	608.97

Planning Region	# of Aquifers	# of Overexploited aquifers	Total Recharge in million m^3/year	Total Extractions in million m^3/year
Mayo	6	1	686.30	244.86
TOTAL	60	18	3023.40	2560.77

Source: CEA Sonora, 2008.

In terms of water uses, the total volume concessioned for consumptive and non-consumptive uses in 2008 was about 6.6 thousand million m^3/year; 42% was met with groundwater and 58% with surface sources. According to CEA Sonora (2008) 92.7% of volume for consumptive uses corresponds to agricultural activities, 5.3% to municipal supply, 1% to industry, and less than 2% to livestock and other uses. It should be clarified that estimations are based on the records of the Public Registry of Water Rights (REPDA) and these titles contain only the volume concessioned, which is not necessarily the same than the actual volume extracted or diverted. Additionally metering of water use is not generalized in rural settings in Sonora.

4.2.3. Rural groundwater institutions

In Sonora there is no state-level capacity for legislating on water resources and no separate legislation for groundwater. The 1992 Act on National Waters (LAN in Spanish), alone with its associated rules, is the federal legal frame that works over both surface water and groundwater in the country. The National Water Commission (CONAGUA) was born in 1989 and is responsible for the enforcement of LAN. Its actions are administered at the regional level through Basin Organizations. The corresponding regional regulator in Sonora is the Northwest Basin Organization (OCNO). Below the regional regulator there are also Basin Councils, which are much more local in nature and have no legislative power. The Groundwater Technical Committees (COTAS) are also lower-level institutions to manage aquifers and are concerned specifically with advisory and monitoring tasks related to underground sources. The COTAS are supposedly autonomous bodies constituted by stakeholders coming from different social sectors. However not all the aquifers in Sonora have COTAS, and the representativeness is not guaranteed in the cases they do exist. The informant for Sonora state indicated that when people in rural communities in the Sonora River Basin are asked whether they know the corresponding COTAS, everybody can report that there is a small fee paid by each farmer for agricultural permits and a portion of that goes to pay the administrative person of the COTAS, but they don't know the actual Committee.

It is very difficult to evaluate the effectiveness of an institution that people even don't know (personal communication with author, May 2014). According to the interviewee the COTAS' members are willing to work with people, but they lack the economic and material resources to fully reach the population depending on an aquifer.

The LAN states that allocation of groundwater to user sectors should take into account the geo-hydrologic conditions of the aquifer, and users may not surpass the limited volume allocated according to their water rights title. However there is no complete, reliable and systematic measurement of water consumptions in rural communities, so supervising compliance is difficult if not impossible. One specific policy instrument of the Federal Government is the "Decreto de Veda" (a kind of "closure decree") (CONAGUA, 2014) forbidding new wells in overexploited zones, but not all the aquifers have their studies of availability updated yet, so it could take a while between the recognition of overexploitation and the actual issuance of a decree.

A big issue in rural Sonora is the role played by the Mexican Agrarian Reform in the social construction of water and land for agricultural production, which is a milestone of the rural life in Mexico. The *ejido* land concessions occurred between post-revolutionary times (1920) and up to the last decades of the 20th century. The access to land in most cases was coupled with access to water in a kind of communal concession. The land concessioned was property of the nation, and beneficiaries could usufruct it without actually owning it, so leases or sells were prohibited until 1992 when constitutional modifications set the conditions for a land privatization process that is still occurring today.

However, the ejido concept has been the basis for a long-standing "consciousness" of traditional appropriation of resources in rural-agricultural production that contradict modern legal and market logics. The traditional appropriation is similar to the "first in time, first in right" ideology of surface water appropriation in Arizona, but contrary to Arizona that has different rationales for surface and groundwater, the traditional use principle in rural Sonora seems to expand and cover both surface and groundwater, which become interchangeable, even if people should modify their water title specifications (which they usually don't do), or have to invest high amounts of money to dig a deep well (which the average farmer/rancher doesn't have).

In this sense, according to the informant, there is a decoupling between the current practices of rural users, and the legal appropriation of water and the policies pursued by CONAGUA. The mismatch is associated to the traditional uses of water by rural communities because for them it is

more important to have been using the water during several decades than having the legal title for demonstrating or evidencing their rights to it. The problem comes when people approach the government agencies to ask for support and the first thing that agencies require is the official water title (personal communication with author, May 2014). Sometimes more than financial resources, lack of legal knowledge is the barrier to systematization of management rules in the rural water sector. Another frequent issue is purchasing or selling water in the local communities (an incipient rural market for agricultural use), but users never fill a request for modification of right holder name with CONAGUA, so for the agency it is very difficult to know who the users are, and what is actually happening in the field.

In terms of municipal use of water, in most of the rural communities in Sonora aging infrastructure, lack of financial resources, and variable water supply are the main concerns associated to water services, as expressed in several rural municipal development plans (Municipal Development Plans of San Miguel de Horcasitas, Rayon, Opodepe, and Cucurpe, 2004).

4.2.4. The future of rural groundwater management in Sonora

The biggest issues for rural groundwater in Sonora seem to be limited water supply, limited financial resources, and lack of alternatives to face drought events. Although rural population growth rates are not expected to be as high in Sonora as they are in Arizona, the population increase will threaten an already delicate equilibrium in rural communities. Most of policies and programs of CONAGUA have been targeted at municipal supply development by supporting the building of infrastructure, and much less attention has been given to rural water issues. The interviewee argues that even if he hasn't an "apocalyptical" view of climate change, it definitively should be considered in rural planning because more variability and extreme events can be expected for the Sonoran Desert. Additionally the low or null consideration of ecosystem uses of water will pressure the future sustainability of the basins since rural populations enjoy and recognize the ecosystem services of water, but they do not cognitively link the services with the water required to sustain those. These issues will be observed in the medium and long term together with the difficulties in regularization of rural water rights (personal communication with author, May 2014). These problems can be fostered in part by the lack of knowledge and systematic and organized public participation in rural water policy.

5. Conclusions: comparing Sonora and Arizona

Arizona has institutional advantages in groundwater for urban settings and big irrigation systems in comparison to Sonora, but both states face big challenges in the rural sector. The lack of infrastructure and financial resources, the lack of preparedness to face drought or extreme climate events, the low and not generalized rural public involvement in decision-making and planning, and the neglect of integrated ecosystem-human perspectives for managing groundwater are problems right now and their effects will be more evident in the future.

According to the conceptual framework, Sonora rural groundwater institutions can be classified in the expansion phase. The policy actions are still directed to securement of municipal supply and agricultural production without questioning current uses, and basic legal aspects of water rights are still missing. Infrastructure and supply development are big concerns, while environmental uses of water are not yet recognized. Even if the interviewee reported that public discontent sometimes appear in Sonoran rural communities, public participation almost never is organized and systematic (personal communication with author, May 2014). Construction of water as an eco-social active can be present in the discourse, but it is not observed in concrete actions; while incentives for conservation are almost inexistent (municipal bills tends to be fixed-rate, and agricultural cost of water is negligible and applies only if the concessioned volume is surpassed). Data generation is very limited because there are not systematic records on water concessions, nor generalized metering of rural agricultural and municipal uses.

In the case of Arizona, even though its statewide groundwater policy corresponds mostly to a transition-consolidation phase, in rural settings it mostly match the expansion-transition stages. Social construction of water is not yet that of an eco-social active. Surface and groundwater management have separate legislation and this promotes a non-integrated vision of management at the basin level. Supply for cultural uses is still a concern in some of the rural watersheds and the environment's role in water provision and uses is not generally recognized (there are notable exceptions as those of the Upper San Pedro Partnership, USPP) (Serrat- Capdevila et al., 2009). On the other hand, public involvement and data generation have improved as a result of the RWI, but consolidation is not reached yet (see Table 5).

Table 5. Comparison of institutional dimensions and stages between Arizona and Sonora

Institutional Aspects	Dimensions	Arizona	Sonora
Policy	Policy issues	Infrastructure required for guaranteeing supply and adaptation to drought.	Infrastructure required for guaranteeing supply and adaptation to drought.
Management	Management goals	Supply and quality in some cases.	Coverage/continuous service.
Policy	Priorities	Mostly human supply, but in some places ecological uses are considered.	Human supply.
Policy- Legal	Importance of environment	Recognized in some watersheds, especially concerning biodiversity.	Barely recognized. Environmental services are appreciated but not connected with water requirements of ecosystems.
Policy- Legal	Social constructions about water	Depending on the watershed, eco-social functions are recognized.	Water is seen as a productive input and basic resource for livelihoods.
Policy-Management	Role of civil society	High involvement thanks to the RWI, but effectiveness is questionable.	Public participation structures are set by government, little room for down-top initiatives. Society is just reactive.
Management	Efficiency considerations	Recognized, but not strongly enforced outside AMAs.	Recognized, but not enforced or incentivized.
Management	Data generation for decision making	Not systematic, not all places, although RWI has improved this.	Almost inexistent for many of the communities.

6. Policy recommendations

Derived from this analysis there are several general policy recommendations that can be applicable to the rural groundwater management sectors in both Sonora, and Arizona:

- **Development of intermediary water management offices for rural communities and not only for big irrigation districts, cities, or large rural producers.** The ADWR has tried to cover this gap by its RWI program, however the Initiative lacks the financial resources to provide more technical and economic assistance, so community plans have not been able to really help securing other supply sources to face drought or future population growth. In the case of Sonora, local intermediary offices are required to

effectively communicate legal issues to rural population and helping in the regularization of water rights. The COTAS could be a good institution to further advance these purposes. The funding not necessarily has to come all from governmental sources, but public-private arrangements can work.

- **Performance evaluations and data generation systems are required.** This is "a must" for both states because if there are no reliable and systematic data, it is very difficult to plan effectively for the future. Although lack of metering and scarce financial resources prevent the development of continuous data collection, one-time/one-sample surveys can be a first helpful step to begin with. One possibility to operate these studies is the NGOs' professional work. NGOs' rural projects can be financed by funding private agencies in the U.S., but in Sonora this could be difficult since there are not many rural NGOs. Further networking between private stakeholders, general public, civil associations, and government agencies is necessary.
- **Integrated eco-social education.** Public education efforts should be directed to show the interconnections between ecological and human systems at the basin level. If rural water users do not see themselves as part of a broader social-ecological system, it would be difficult for them to understand the implications of urban and rural impacts on their resources. Universities and extension agencies could be the first organizations to call for these kind of educational materials, and NGOs, local agencies and mass media could be the cheapest initial ways for distributing information.

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APPENDIX: INTERVIEWS' GUIDES

QUESTIONS ON ARIZONA GROUNDWATER MANAGEMENT IN RURAL LOCATIONS
Specialist: Deputy Assistant Director for Water Planning. ADWR.

1. From your point of view, which are the main current issues in groundwater management in rural Arizona?
2. What is your perspective in relation to the Rural Watershed Initiative of 1999? Do you think it had worked so far? Why yes, or why not?
3. How the farming policies in the US affect rural groundwater management in Arizona?
4. How much are environmental uses of water considered in rural groundwater management in Arizona?
5. How much rural population is involved in groundwater management in their communities?
6. Which do you think would be the main issues or challenges for rural groundwater management in Arizona towards 2030? And 2050?

ENTREVISTA SOBRE MANEJO DE AGUA SUBTERRÁNEA EN LOCALIDADES RURALES DE SONORA
Specialist: Private consultant and Researcher. Morohui. El Colegio de Sonora.

Desde su punto de vista particular…

1. ¿Cuáles son los problemas actuales que existen en la gestión del agua subterránea en localidades rurales del estado de Sonora?
2. ¿Cuáles son las políticas públicas más importantes para la gestión del agua subterránea en localidades rurales de Sonora?
3. ¿Cuáles son las organizaciones (gubernamentales, sociales y/o privadas) con las que la CONAGUA trabaja más cercanamente para la administración del agua subterránea en comunidades rurales?
4. ¿Qué tan involucrada considera que está la población rural en la gestión del agua subterránea?
5. ¿Qué tan importantes son los usos ambientales del agua, o los usos de agua por parte de los ecosistemas para la gestión rural del agua subterránea?
6. ¿Cuáles cree que serán los problemas o retos más importantes de la gestión de agua subterránea en localidades rurales en 2030? Y en 2050?