
Assessment of the development of aquifer management councils (COTAS) for sustainable groundwater management in Guanajuato, Mexico

Philippus Wester · Ricardo Sandoval Minero · Jaime Hoogesteger

Abstract Collective groundwater management by water users—self-regulation—is increasingly advocated as a complement to state regulation. This article analyzes the attempts by the Guanajuato State Water Commission (CEAG) in central Mexico to promote user self-regulation through the establishment and development of 14 *Consejos Técnicos de Aguas* (COTAS; Technical Water Councils). Based on a joint assessment by a former senior CEAG policy-maker and two researchers, Guanajuato's groundwater-management policy is reviewed to understand why user self-regulation was less successful than expected. It concludes that increasing awareness and improving the knowledge base on groundwater is not enough to trigger self-regulation by groundwater users. A wider delegation of responsibilities to the COTAS is necessary, combined with: (1) functioning mechanisms for enforcing groundwater legislation, especially concerning well permits and pumped volumes, and (2) mechanisms that ensure the legitimacy and accountability of users' representatives to both users and state agencies.

Keywords Groundwater management · User self-regulation · Aquifer management councils · Guanajuato · Mexico

Introduction

It is well established that very few examples of sustainable groundwater management regimes exist in areas of intensive groundwater use (Knegt and Vincent 2001; Mukherji and Shah 2005; Shah 2005; Shah et al. 2007; Birkenholtz 2009; Giordano 2009; Theesfeld 2010). Hence, the collective management of groundwater by water users—self-regulation—has increasingly been advocated and studied as an alternative or a complement to state regulation (Blomquist 1992; Lopez-Gunn 2003; Steenbergen and Shah 2003; Custodio et al. 2005; Llamas and Martínez-Santos 2005; Lopez-Gunn and Cortina 2006; Steenbergen 2006; Schlager 2007; Wester et al. 2009). This article analyzes one of the few examples from around the world where user self-regulation has been seriously attempted. In central Mexico, the Guanajuato State Water Commission (*Comisión Estatal del Agua de Guanajuato*, CEAG) has supported the establishment of 14 *Consejos Técnicos de Aguas* (COTAS; Technical Water Councils, or aquifer management councils) since 1998, as a complement to other measures to reduce groundwater extraction. This was a unique effort, as surface and groundwater in Mexico are national property and their administration falls under federal jurisdiction. Although the CEAG had no legal mandate regarding groundwater abstractions and management, it felt compelled to create the COTAS to counter, through user self-regulation, the deplorable administration of groundwater in Guanajuato (Guerrero 1998). The COTAS were conceived as local water-management organizations consisting of all the well owners of an aquifer (an estimated 13,500–16,500 well owners in 14 aquifers) that would work together to regulate groundwater extractions, and at a later stage to stabilize aquifer groundwater levels. To achieve this objective, CEAG developed an integrated groundwater-management policy, consisting of increased stakeholder participation, extensive groundwater-modeling studies, programs to increase water-use efficiency, the creation of a groundwater monitoring network, and communication and capacity building efforts (Sandoval 2004).

Reaching sustainable groundwater extraction levels is critical for Guanajuato (Scott and Shah 2004; Foster et al.

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2004; Wester et al. 2007). All its aquifers are over-exploited, with annual extractions around 1,200 million cubic meters (i.e. 1,200 hm³) above recharge (CEAG 2006). Total groundwater extractions fluctuate around 4,100 hm³ while recharge is around 2,900 hm³ for the whole state (CEAG 2006). This has led to a sustained drop in groundwater levels over a period of 50 years of around 2 m/year on average. Studies by CEAG indicate an average drop in groundwater levels of 2.03 m/year between 1995 to 2000 for all the aquifers in the state, and up to 3.5 m/year near cities (CEAG 2001). Static groundwater levels in 2004 varied from 28 to 175 m below surface level in the north of the state, from 27 to 185 m in the center, from 30 to 140 m in the southwest, and from 10 to 225 m in the southeast of the state (Acevedo-Torres 2004). The areas where most of the groundwater is extracted are the central Bajío region and the Laguna Seca region in the northeast of the state (see Fig. 1). The driving force behind groundwater depletion in Guanajuato has been the large increase in groundwater irrigation, from around 24,000 ha in 1960 to around 250,000 ha in the 1990s (Wester 2008). Although irrigation accounts for some 83% of groundwater extractions in Guanajuato, groundwater is also critically important for industrial and domestic water use: 99.3% of urban and rural water supply is groundwater dependent while industry exclusively uses groundwater (CEAG 2006).

Well before user self-regulation, other attempts were made to regulate and reduce groundwater use in Guanajuato. Since the 1950s, areas of intensive groundwater use in the state were placed under a drilling ban (termed a *veda* in Mexico). With this regulatory instrument, the federal government prohibited

the drilling of new wells in specified zones, unless a prior pump permit was granted and the new well was intended to replace an existing one. In the past 15 years, compulsory pump registration, subsidies for irrigation modernization, and the reform of electricity subsidies have been used by the federal government to reduce groundwater use (Scott and Shah 2004; Mukherji and Shah 2005; CEAG 2006; Wester et al. 2009; Scott et al. 2010). Although the rate of increase in groundwater abstractions has slowed since the 1990s, new wells continue to be drilled and the water table continues to decline unabated.

It was hoped in the late 1990s that user self-regulation of groundwater extractions would prove to be the missing piece in the groundwater management puzzle. Both the federal government, through the National Water Commission (*Comisión Nacional del Agua*; CNA), and CEAG promoted the implementation of participatory bodies to move towards user self-regulation of groundwater use (Marañón and Wester 2000; Maganda 2003; Scott and Shah 2004; Wester et al. 2007). However, 10 years later it appears that the COTAS initiative was not enough for achieving sustained reductions in groundwater extractions and inducing a shift towards improved governance of groundwater resources by water users (Wester et al. 2009). This raises questions about the enabling conditions that are needed for effective user self-regulation and the design of CEAG's groundwater policy.

This article reassesses Guanajuato's groundwater management policy of the past 10 years and the performance of the COTAS. This reassessment is developed through a self-critical dialogue between a former senior CEAG policy-maker and two researchers who studied Guanajuato

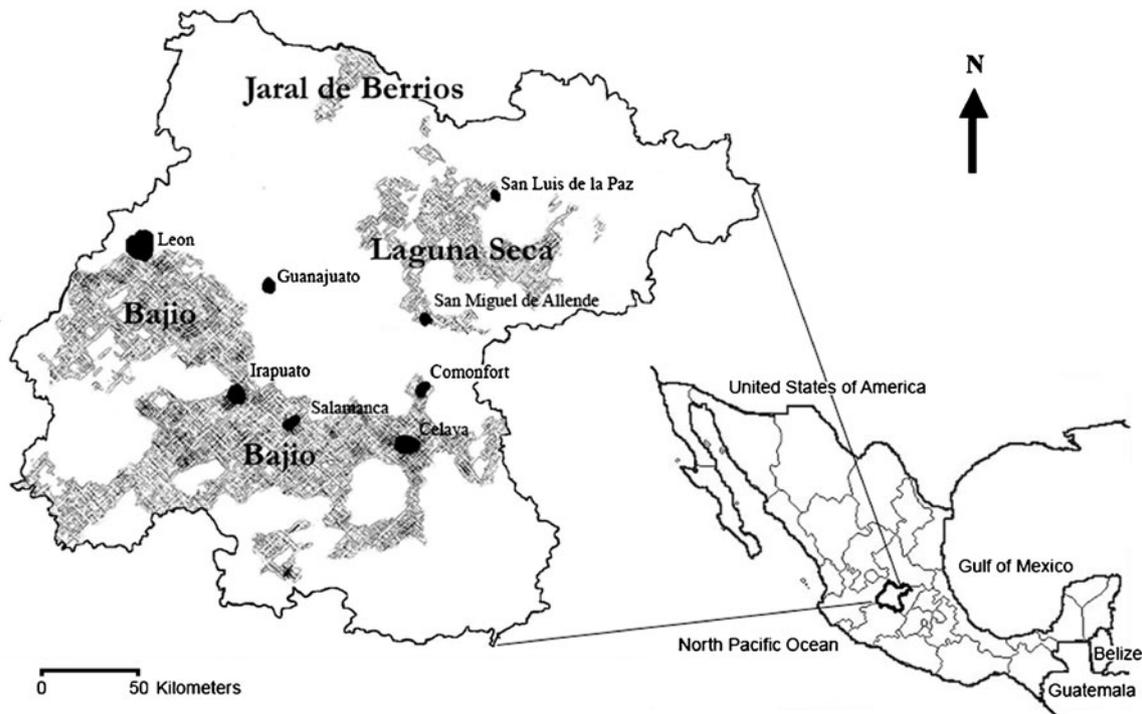


Fig. 1 Areas of intensive groundwater use (grey) and major cities (black) in the State of Guanajuato, Mexico (Source: adapted from Wester et al. 2009)

to's groundwater policies between 1998 and 2007. Building on the perception that self-regulation has not worked as expected, the dialogue juxtaposes the original intentions and perceptions of the policy-maker and the analysis of the researchers to arrive at a better understanding of the complexities of groundwater management. Two main questions structure the dialogue: (1) Why did CEAG's groundwater policies have limited results in addressing the central, self-defined policy challenge of reducing groundwater extractions leading to more sustainable aquifer management, and (2) what is needed for user self-regulation to be a viable and achievable option for reducing groundwater extractions?

Methodology

The material presented in this article is based on two sources, the *experiences* of Ricardo Sandoval as a senior CEAG official from 1998 to 2006, and *research* conducted over a 10 year period by Philippus Wester and from 2003 onwards by Jaime Hoogesteger on groundwater management in Guanajuato. Intensive fieldwork was conducted in 1999, 2000 and 2003, supplemented with a follow up study in 2006 and 2007. The research consisted of interviews with CEAG and CNA officials, COTAS board members and managers and with water users, participant observation at events organized by CEAG to establish the COTAS in 1999 and 2000, and several workshops with COTAS in 2000 and 2007 to discuss research findings. Results were published in Marañón and Wester (2000), Hoogesteger (2004), Sandoval (2004), Wester (2008), Wester et al. (2008) and Wester et al. (2009). Especially the material presented in this article in the section **Results** strongly draws on and adapts the material published in Wester et al. 2009.

The article was written based on an innovative methodology, namely a critical and open dialogue between a former public official responsible for Guanajuato's groundwater policy and two researchers. The dialogue was nurtured by discussions over the years, reading each others publications and writing this article together. In this article, a retrospective approach has been adopted in which the previous research findings and perspectives of the researchers were juxtaposed with the original perceptions and intentions of the policy-maker and his understanding of the rationale behind the policies that were implemented. Special attention was paid to the roles, interests and reference frameworks of groundwater users and other government agencies in groundwater regulation, the institutional setting, and the authors' assumptions concerning each actor's expectations and reactions to the implemented policies. The objective of this dialogue was to deepen the understanding of what has impeded the achievement of user self-regulation and a reduction in groundwater abstractions. This article presents the outcomes of this structured dialogue, indicating where a common understanding was reached by using the phrase “the authors’

shared perception is ...” and where different perceptions continue, with the phrase “it is the ‘researchers’ or former policy-maker’s perception that ...”.

To present the outcomes of the dialogue, the form of a historical narrative was chosen, instead of a conventional analysis of policy impacts. First, there is a presentation of the genesis of the COTAS from the mid to late 1990s in Guanajuato and a reconstruction of the perceptions and policy intentions underlying their establishment. Second, the perceptions, understandings and restrictions that influenced the formulation and implementation of Guanajuato's state water program from 2000 to 2006 are analyzed, focusing on the groundwater component. Lastly, the authors' current understanding of the role of federal and state government agencies and groundwater users in the implementation of CEAG's groundwater policy is presented in the section **Discussion**.

Results

The genesis of the COTAS in Guanajuato from 1995 to 2000

The first experiences with the creation of COTAS was in Querétaro, a neighbor state to the east of Guanajuato, where the CNA closely interacted with industrial users, the city of Querétaro and farmers in developing an aquifer-user committee in the early 1990s. This initiative was based on the recognition that the old, top-down regulatory approach of declaring *vedas* had not worked. Through the establishment of COTAS, the CNA aimed to stimulate the organized participation of aquifer users so that agreements for reversing declines in groundwater levels could be reached. However, as no specific mention of COTAS was made in the National Waters Law of 1992, there was much ambiguity about their characteristics, mandate and structure. Between 1995 and 2000, the CNA did not publish a policy document outlining the structure and tasks of the COTAS or how they should be formed. However, during this period it became clear that the CNA intended the COTAS to be consultative bodies, without a legal status or decision-making powers, in which aquifer users, government water agencies and organized groups from civil society would interact concerning groundwater management, under the auspices of CNA.

It is the shared perception of the researchers and former policy-maker that the CNA was very reluctant to design aquifer management organizations with any real clout in groundwater management. Several of the CNA officials actively involved with designing the COTAS in the mid 1990s have suggested that the COTAS were intended to allow the federal government to reduce extractions by means of voluntary agreements between water users—which were meant to be set up using the ‘reglamentation’ procedure, according to the fifth chapter of the National Waters Law; this to bypass the expensive and legally difficult task of reducing the volumes of concessioned groundwater rights to sustainable levels. When a concessioned volume is to be reduced in Mexican law the term

“rescate” (rescue) is used to refer to an administrative procedure that enables the federal government to reduce the concessioned volumes, with due compensation. This can only be done after the federal government proves, through studies, that aquifers are overexploited. In view of this long legal process, consensual reductions seemed to be a better approach although in the final instance these are not legally enforceable. In any case, the legal validity of this assumption—that a regulation signed by water users’ representatives (and not by every single right-holder) would be enough to give the federal government the capacity to limit existing titles without compensation—is highly debatable.

While the CNA was setting up COTAS in Querétaro and other parts of Mexico, in late 1996 Guanajuato’s *Secretaría de Desarrollo Agropecuario y Rural* (SDAyR; Secretariat of Agricultural and Rural Development) started the formation of COTAS in the Celaya and Laguna Seca aquifers. The CNA was not involved in this initiative, which was a new development in Mexico, as until then the CNA had been in firm control of water management (Wester et al. 2009). The aim of this initiative was to stimulate the participation of the aquifer users in reaching a consensus on how to reduce groundwater extractions (IMTA 1998). As there was no established procedure for creating COTAS, and it was not clear what their attributes would be, SDAyR embarked on an open-ended process to form the COTAS. In SDAyR’s perspective, the formation of the COTAS was to be a “bottom-up” process in which the aquifer users would gain a clear understanding of the gravity of groundwater depletion. Based on this understanding, they would collectively discuss ways to resolve this problem. In contrast to the Querétaro COTAS, where the CNA was the president, SDAyR wanted the COTAS to be more autonomous, with the users electing the representatives and the president. After nearly a year of deliberations, the two COTAS were formally constituted on 28 November 1997.

In early 1998, the responsibility for the formation and supervision of the COTAS within the Guanajuato state government was transferred from SDAyR to the CEAG. This “lateral transfer” from one state agency to another, with preference being given to CEAG, occurred in the context of the new federalism policy initiated during President Zedillo’s administration (1994–2000), which consisted of decentralizing government responsibilities, programs and resources from the federal to the state level. In the water sector, this entailed that State Water Commissions would receive more responsibilities in water management. The *Comisión Estatal del Agua y Saneamiento de Guanajuato* (Guanajuato State Water and Sanitation Commission, CEASG) was created in 1991 by the state legislature to provide potable water, sewage and sanitation services (in 2000 CEASG became the “*Comisión Estatal del Agua de Guanajuato*”, hence this article refers to CEAG throughout to be consistent). Until 1996, CEAG primarily functioned as a financial mediator between the federal government and municipalities, mainly for domestic water supply projects, and was

largely bypassed by CNA in all other spheres of water management. In 1996, the Guanajuato state government decided to broaden CEAG’s mandate from municipal water and sanitation to all aspects of water management, turning it into the main water agency in the state. From 1996 to 1998, the organizational structure of the CEAG was changed, to reflect its new mandate, and a large number of water professionals were hired. However, it is the researchers’ perception that CEAG continued to retain a strong urban orientation, not just in terms of “organizational culture” and orientation, but as demonstrated in the institutional arrangements for groundwater management, which rested heavily on industrial, urban and commercial farming users of groundwater (sharing many of these urban “cultural orientations”) to the exclusion, or at least diminished role, of *ejidatario* (peasant) agricultural water users.

The move to CEAG led to several changes in the structure of the COTAS. The most salient difference was that CEAG decided to form Councils with only water-user representatives on the COTAS board. In the CEAG model, the membership of the COTAS was to consist of all the water users of an aquifer, defined as those extracting groundwater for agricultural, industrial or commercial use, while urban inhabitants would be represented through the municipal water supply companies (Guerrero 2000). The CEAG was quite clear that the COTAS should be a legally recognized organization that would focus on regulating and conserving water. Most importantly, the COTAS were to reverse aquifer overexploitation and recover groundwater levels by reaching agreements on aquifer management and agreeing on actions to regulate, conserve and efficiently use water (Guerrero 2000). To achieve these goals it was foreseen that the COTAS would:

- Propose aquifer rules and regulations for the sustainable use of aquifers
- Propose a local hydraulic plan and participate in the State Water Resources Plan
- Participate in the granting of water concessions
- Monitor the aquifer rules and regulations and the volumes of water extracted

It is the authors’ shared perception that it was not the intention of CEAG that the COTAS would become a water agency with full user control over the aquifers, although the model was partially inspired by the experience of the Edwards Aquifer Authority in Texas, USA. In 1998, a study trip to the Edwards Aquifer was organized for the managers of the COTAS and the new “Social Management Directorate” of the CEAG. However, CEAG clearly did not have a consultative body in mind, which was the model CNA was pursuing. In the CNA model, the COTAS were a mixed organization of government agencies and user representatives focusing on groundwater only, whose main task was to collaborate with, and advise, the CNA in formulating the rules and regulations of an aquifer. However, the COTAS would not participate in decision-making or in granting water-use concessions.

A final important difference between the two models was that CEAG intended the COTAS to be financially and administratively independent, and fully managed by water users.

Besides changes in the structure and objectives of the COTAS, the move to CEAG also changed their formation process. The process followed by SDAyR was replaced by a much quicker approach focused on showing results. By the end of 1998, CEAG had constituted six COTAS in addition to the two already formed in Celaya and Laguna Seca. The remaining six were formed in 1999, bringing the total number of COTAS in Guanajuato to fourteen, to cover all 18 aquifers in the state (the COTAS boundaries did not exactly follow aquifer boundaries). The COTAS were formed as civil associations (a form of non-governmental organizations specific to Mexican law), to ensure that they were legally recognized. Nevertheless, as civil associations they had no formal responsibilities or legal mandate in water-management affairs; therefore, they could work only as groupings of civil society that were to function through their own agenda, mutual agreements and the good will of their members.

CEAG defined three phases for the establishment of COTAS in Guanajuato: legal constitution, establishment of aquifer regulations and organizational development. It aimed to finish the first two phases by the end of 2000, and succeeded in completing the first phase by the end of 1999. The participation of aquifer users, especially farmers, in the formation of the COTAS was restricted. CEAG did not opt for a large-scale convocation of the users but only invited the leaders of diverse organizations to participate in the formation process of the COTAS. In the majority of cases, the representatives of the agriculture sector in the COTAS were commercial farmers or agroindustrialists and the peasant sector (*ejidos*) was largely bypassed. Besides the three agriculture representatives on the COTAS board, three representatives each for the industrial, potable water, and services sectors were selected. Thus, although agriculture used around 80% of groundwater, it only had 25% weight in the COTAS board.

This composition of the COTAS boards, intended by CEAG to give each water-use sector an equal say without regard for their actual economic, social or political importance, did bring together all the water-use sectors, but was to have a marked effect on their development. In particular, the large industries, commercial farmers, and municipal water companies veered the discussion of overexploitation into one of water-use efficiency. Under this rationale they all claimed that they were already working on and using water very efficiently, and that it was the agrarian producers, or small farmers, that were to blame for groundwater overexploitation. Their rationale could be phrased as follows: 'if only all users would use groundwater efficiently the problem of overexploitation would be solved'. Through this rationale they bypassed their own responsibility and difficult task of establishing agreements to downsize the groundwater volumes extracted through the establishment of volume caps and mutual control. However, if this leads to a reduction or

elimination of water 'losses' to deep percolation (which in most aquifers of Guanajuato becomes recharge), without reducing extracted volumes, this strategy only exacerbates the overexploitation of aquifers.

CEAG chose first to form the COTAS, and then to expand user participation. It is the authors' shared perception that by neglecting to bring together the majority of the aquifer users at the start to arrive at a shared understanding of the problems facing the aquifer and the possible solutions, CEAG failed to create a sense of ownership among water users that the COTAS was their organization. Later on, this proved to be an obstacle for their consolidation. The lack of an adequate representation of all the groundwater users in the COTAS made it difficult to reach consensus on reductions in groundwater extractions, and many users did not see the COTAS as user organizations, but as an extension of the state government. Thus, the approach followed in forming the COTAS, namely sticking to timelines without giving sufficient space to reaching agreement between users, restricted their effectiveness. However, through their creation the CEAG created new domains of water governance under its control. By late 1999, the whole state of Guanajuato fell under COTAS which, under the supervision of CEAG, would work to advance Integrated Water Resources Management (IWRM) in their respective aquifers. To the authors' knowledge this is the first time that an IWRM approach based on aquifers as the spatial unit, rather than river basins, was attempted in the world.

Although the COTAS were successfully created between 1996 and 2000, their objective to reduce groundwater overexploitation through user self-regulation did not receive much attention. It is the researchers' perception that they formed part of a political and institutional project of the state government to gain larger control over water management in Guanajuato. The former policy maker's view is that while the COTAS project was part of a wider strategy, in the beginning the aim of effectively monitoring and controlling the extractions was clear and explicit; the limitations were an output of the ineffective interaction between CEAG and its counterparts, as well as the imperfect understanding of the legal framework and the failure in establishing a State Water Law enabling the CEAG to set up a state water-administration structure. In this, CEAG was only partly successful, as the CNA remained in control of groundwater concessions, and largely ignored the COTAS. Also, the move from SDAyR to CEAG initially restricted the effectiveness of the COTAS as many large commercial farmers lost interest, as it was clear that the COTAS would not have any real influence over groundwater extractions. Thus, the struggles between levels of government and government agencies significantly reduced the prospects of the COTAS reaching their goals.

The development of the COTAS from 2000 to 2006

In the period 2000–2006, when Vicente Fox, the former governor of Guanajuato, was president of Mexico, the

government of the state of Guanajuato decided to implement an ambitious program for water management. These efforts were consolidated in the State Water Program 2000–2006, an update of the State Water Resources Plan. This program had three main pillars: (1) understanding the hydrogeology of the state, (2) investing in water-use efficiency and supply augmentation and (3) increasing user awareness and involvement in water management. This ambitious program entailed several components to ease the pressure on groundwater resources. Besides water savings through irrigation modernization, two dams for inter-basin water transfers were projected to import nearly 150 hm³ from the neighboring states of Jalisco and San Luis Potosí, and a target was set to treat close to 90% of the urban wastewater with the aim of establishing water-exchange programs between farmers using groundwater and cities (Sandoval 2004). This section describes how the COTAS developed under this State Water Program between 2000 and 2006.

The development of the 14 COTAS in Guanajuato from 2000 to 2006 strongly depended on the continued support of CEAG, who continued to pay for their operational costs. The state budget for COTAS reached nearly US\$ 4 million, plus another 6 million for research, groundwater modeling and monitoring (CEAG 2006, p. 49). CEAG's efforts to strengthen the COTAS from 2000 to 2006 focused on increasing user participation and formulating a groundwater management model. While the original aim had been to formulate aquifer rules and regulations by 2000, the focus on reducing groundwater extractions moved to the background. Rather, the COTAS were recast as "consensus-building spaces where integrated water management models and programs are to be implemented" (Sandoval 2004, pp 9–10). This new vision was articulated by developing a "groundwater management model" that built on the aquifer studies, mathematical models and different scenario modeling exercises supervised and updated by CEAG.

CEAG, in coordination with the COTAS, developed the groundwater management model in 2002, to focus on concrete actions that would lead to significant reductions in groundwater extractions and foster social participation. The first two elements had already been developed between 1998 and 2002, and consisted of the extensive aquifer studies and the database developed by CEAG and the COTAS on the number and location of groundwater wells. A technical program was set up to make a systematic assessment of the state's aquifers, which included the improvement of the inventory of deep wells, the development of hydrogeological models for 14 aquifers and groundwater quality characterization (Sandoval 2004). During this process, the CEAG identified more than 15,700 groundwater wells (many of which were not registered by CNA), and this data was transferred to the COTAS who further extended and updated the groundwater wells database. This database contained information on the position, depth, legal status, owner and use of every well, and included other details such as the presence of a volume meter, annual allocated water

volume by CNA, and, where possible, extracted volumes. This information was regularly exchanged with CEAG and was made available to the users at the offices of the COTAS and through presentations at workshops; but the users had little interest for this database. The third element consisted of the monitoring of groundwater levels. Starting in 1998, CEAG set up a groundwater monitoring network that grew to 12 deep observation wells and 955 pilot wells, for which the COTAS collect the static level readings twice a year. Based on the aquifer studies, cones of depression were identified in the aquifers and one pilot zone per COTAS covering between 50 to 100 km² and 100 to 300 users was established in 13 COTAS while seven pilot zones were established in the Celaya COTAS.

Based on the wells database, the COTAS identified the groundwater users in the pilot zones, and initiated an intensive process of working with the users to identify and reach agreements on a list of measures to reduce groundwater extractions (Montoya et al. 2004). This program mainly focused on agriculture, and sought to channel the various government support programs for irrigation modernization through the COTAS to these pilot zones. The intention was to produce the same or more crops with less water and energy, hence at a lower cost. Once the measures had been agreed on and funded, the users were requested to form aquifer monitoring committees, to monitor groundwater levels within the pilot zones and evaluate the results of the interventions. They were urged to install meters on their pumps and to carefully monitor pumping hours and electricity use. The long-term objective was that the pilot zones would gradually be expanded, to cover the whole aquifer. Only then would the work start on drawing up the rules and regulations of the aquifers, as CEAG believed that groundwater users would only support and implement the regulations after investments had been made in social participation and water-use efficiency.

As a result of the groundwater management model, the number of users that became members of the COTAS rose from 225 in 2000 to 8,610 in 2006 (of an estimated 13,500–16,500 well owners), and 20 aquifer monitoring committees were formed (CEAG 2006). The COTAS together with government agencies trained around 5,300 users in water issues, including basic hydrology and the groundwater situation in Guanajuato and the specific aquifers, legal water-use issues, water-use efficiency in agriculture and the use of sprinkler and drip irrigation systems. In addition, extensive information campaigns on a "new water culture" were held in schools and at fairs. Another important achievement of the COTAS is that each has updated and verified the database on groundwater wells, in the process identifying many irregular wells. Lastly, for many farmers the COTAS have become an important service window that supports them in their interactions with government agencies. Especially concerning groundwater concession titles, the COTAS play an important role as intermediary between farmers and the CNA and other state and federal agencies, both for obtaining and renewing the titles (most titles are valid

for ten years). The COTAS have also become intermediaries for users wishing to modernize their irrigation systems, and many farmers would like to see this role expanded.

Based on the strong support from CEAG the COTAS matured between 2000 and 2006, and their position and tasks became clearer. They established themselves in most aquifers as platform organizations where water users from different sectors exchanged ideas and set up initiatives for water-management projects within hydrological boundaries. The aquifer monitoring committees led to raised awareness. At a political level the COTAS gained the recognition of the CNA and the 2004 revision to the National Waters Law included an article on COTAS, yet their attributions remain marginal and have been described as supportive to the CNA. Based on these provisions, CNA delegated several programs to the COTAS and gave them a role in supporting the users in the administrative procedures required for the renovation of groundwater-use permits. However, they did not become full-fledged user organizations in which strategies for reducing groundwater overexploitation were devised. As a result, their contribution to achieving significant reductions in groundwater extractions was limited.

During interviews in 2006 and 2007, COTAS board members and CEAG officials frequently mentioned that for the COTAS to have an impact they need to have more responsibilities and delegated authority. Many of the groundwater actors in Guanajuato, especially COTAS board members and CEAG officials, want to convert the COTAS into groundwater management districts with delegated responsibilities to regulate groundwater extractions. In this model, the groundwater districts would receive the delegated authority to advise on and approve the granting of groundwater concessions in collaboration with the CNA, while holding the legal capacity to fine pumpers extracting more than their concessioned volume and to close illegal wells. To fund the COTAS, groundwater users would have to pay an annual fee based on the volume extracted. To make this possible, the mandate of the COTAS would need to be expanded, so that they would share the responsibility for the registration and regularization of wells, the formulation and enforcement of aquifer rules and regulations and the monitoring of groundwater extractions together with the CNA and CEAG. This would also require a formal mandate from the water users holding a groundwater concession title. At present, the COTAS are already involved in these three areas, but they do not have the capacity or legal mandate to arrive at and enforce decisions. Whether the COTAS will become groundwater districts with delegated responsibilities will strongly depend on CNA's willingness to share this water governance domain with groundwater users and on CEAG's support for reaching that goal. The experiences of the past 10 years in this regard are not hopeful. Neither is the legal framework, which does not foresee the delegation of CNA's responsibilities over the administration of water-use permits to other levels of government, or outside of it.

Discussion

The results of the dialogue show that the challenges posed by groundwater overexploitation in Guanajuato have precluded achieving significant results in terms of user self-regulation over the past 10 years. The high hopes placed in the COTAS as an innovative approach to groundwater management have proven to be too optimistic, as they have not yet achieved sustained reductions in groundwater extractions as aquifer water levels have continued to decline unabated and total extracted volumes have increased, according to CEAG studies, from around 4,000 hm³ in 2001 to 4,100 hm³ in 2006 (CEAG 2001, 2006). However, CEAG's groundwater policy has led to a much better understanding of the extent of groundwater overexploitation based on the hydrodynamic groundwater modeling studies it funded. Its policy has also strengthened user participation in the COTAS, which in 2010 has reached 43% of the registered water users (CEAG 2010), and increased public awareness of groundwater overexploitation. Why CEAG's groundwater policy was less successful than hoped for in terms of achieving user self-regulation is discussed in this section, based on the authors' understanding of the original assumptions and expectations underlying the policy and the authors' current perceptions of the challenges posed by groundwater overexploitation. To assess the effectiveness of the COTAS, their development is discussed in relation to the evolution of the institutional environment and the other actions taken by CEAG to improve groundwater management.

It is the authors' shared perception that CEAG's overall approach to groundwater regulation appears to have been insensitive to the influence of the economic and social drivers of groundwater overexploitation. From its unpublished hydroeconomic models it became evident that energy subsidies were detrimental to groundwater conservation, as has been shown for many other cases around the world (Scott and Shah 2004; Shah et al. 2007). Based on the former policy-maker's knowledge of the outcomes of the hydroeconomic models, even under the most optimistic scenarios, only a 20–25% reduction in the volume of overexploitation could be achieved without compulsory well closures. Within the assumptions and the limits of the models, a compulsory reduction in the number of wells seemed to be necessary for effectively balancing the aquifer, a delicate issue that was never analyzed with the users.

The significant support of the CEAG for the establishment and development of the COTAS was originally based on the assumption that organizing aquifer users and raising their awareness of groundwater overexploitation was both a necessary condition for, and would relatively easily lead to, reaching agreements between users on reductions in groundwater abstractions. This would simultaneously improve the enforcement of groundwater legislation. Through the dialogue it has become clear that CEAG's groundwater policy was based on a "rationalist policy" perspective and that it followed a "social engineer-

ing” approach in the late 1990s. Informed by neo-institutionalist ideas on common property management (Ostrom 1992), CEAG assumed that the problem was that groundwater users were not sufficiently aware of the damage they were causing to their aquifers and that if well informed, users would be motivated and able to collectively define mechanisms and agreements to reduce groundwater use. The state through the CEAG had only to create the right environment and provide the correct information, while supporting the CNA to increase its measures for regularizing the groundwater concession titles and identifying illegal wells. Therefore CEAG invested in mathematical aquifer studies and established monitoring networks in all the aquifers to provide the users with reliable and validated information. It was CEAG’s intention that aquifer users themselves would then define the most suitable ways to reduce extractions based on this information. For this, it also established a training and awareness raising campaign. Although very valuable and necessary, the expected outcomes of these efforts ran aground on the rationality of the groundwater users.

The rationale of farmers did not match the expectations and underlying assumptions of CEAG’s groundwater policy. The policy assumed that aquifer users would be willing to participate in decision making for solving the problem of declining groundwater levels if they received proper information and budgetary support for investing in efficient water use. Nevertheless only a very small percentage of the users (3-10%) became involved in the creation of the COTAS (Marañón and Wester 2000). This reluctance to participate was expressed by the following phrase of a farmer “we are not groundwater managers, we are agricultural producers; water management is the responsibility of the state”. Besides, most farmers were skeptical about the idea and feared losing their freedom over groundwater pumping and control (Hoogesteger 2004). There was little demand for COTAS by groundwater users, in particular by cities, industries and the large commercial farmers; and their rapid formation precluded the development of active user participation. Also, the lack of coordination with the SDAyR, whose programs for funding efficient water-use technologies were initially implemented disregarding the plans, models and proposals from the COTAS, contributed to a reduced interest of the agricultural sector in the COTAS. The aquifer users that became actively involved in the COTAS did so because of a conviction that “something” had to be done. The industrial and drinking-water supply sectors mostly blamed the agricultural sector for groundwater over-exploitation and argued that even if they substantially reduced their groundwater extractions this would have a very minor impact on groundwater levels as agricultural use makes up more than 80% of overall extractions. As for the farmers that joined the COTAS, just as for most farmers, their most pressing problems are the profitability of agricultural production and more recently the renewal of the groundwater pumping permits; a situation which is not very conducive to finding strategies to reduce groundwater use.

A stronger detriment to user self-regulation was the institutional environment and legal framework concerning groundwater. As surface and groundwater in Mexico are national property for which the federal government is responsible, the attempt by a state government to take on a larger role in water management was bound to lead to frictions and struggles between levels of government. However, frustration with the lack of action by the CNA to reverse aquifer overexploitation and the slack enforcement of federal groundwater legislation strongly motivated CEAG to take the lead in establishing COTAS in Guanajuato. The original assumption underlying CEAG’s efforts to create COTAS was that CNA’s approach to COTAS was bound to fail as it was creating advisory bodies under its control instead of user organizations. CEAG’s perception in 1998 was that the CNA was forming COTAS to reach consensual agreements on reducing groundwater abstractions so that it would not have to force users to reduce abstractions by buying back groundwater concessions, a legally, politically and financially difficult process. CEAG’s original intention was to create user organizations that would become fully responsible for managing their aquifers and it believed it could do a better job than the CNA. In the 1996–2000 period, the struggles between the federal and state government significantly hindered the efforts to form autonomous and effective COTAS. This changed somewhat in the 2000–2006 period, but even then, CEAG’s models and pilot zones were never recognized by the CNA as a part of its groundwater management strategy. Nevertheless, the COTAS did become more independent in this period, especially with regards to CEAG’s policies and programs. This made their relationship more complex, leading to more discussions and longer negotiations on the planning and implementation of the yearly programs supported by the CEAG.

In terms of governance, it is the authors’ shared perception that it is society as a whole—including “future generations”—that delegates to government the task of safeguarding against aquifer depletion and preserving the waters for all and for the future. The suggested hypothesis is that the institutional environment, mainly the way attributions and jurisdiction over water are distributed, creates a legal system which puts the onus for enforcement and compliance on the CNA. This makes it prone to becoming a hostage of regulatory capture, since there are no checks and balances in place that enable society to control the federal government, which plays the role of both judge and jury. Nevertheless in the past 10 years, first the CEAG and later the COTAS have challenged this hegemonic power of the CNA. The existence of the COTAS and the efforts of Guanajuato’s government have pushed the federal government to open up to delegation and cooperation mechanisms, unthinkable even just a decade ago.

Conclusions

Many attempts have been made in Guanajuato to regulate and reduce groundwater use, including user self-regulation

and state regulation through pumping bans (*vedas*), pumping permits and the reduction of electricity subsidies. To date, these efforts have not led to significant reductions in groundwater extractions, urgently needed to stabilize aquifer water levels. However, CEAG's groundwater policy should not be judged too harshly. Research from around the world has shown that it is very difficult to organize aquifer users and to develop social control over groundwater pumping (cf. Blomquist 1992; Shah et al. 2003; Steenbergen and Shah 2003; Milman and Scott 2010). The "invisible" character of groundwater makes it difficult to determine who is pumping how much and to monitor reductions in extractions. In addition, groundwater is extracted by widely dispersed and numerous pumps controlled by many individuals, who have a strong incentive to maximize groundwater withdrawals to recover high capital investments. Worldwide experience shows that permit systems to regulate groundwater use are very prone to corruption and that establishing groundwater rights is even more difficult than for surface water (Steenbergen and Shah 2003; Fornés et al. 2005; Llamas and Martínez-Santos 2005; Garrido et al. 2006; Schlager 2006; Shah 2009). In contrast to surface irrigation systems, where water users must collaborate to ensure water deliveries, pumpers operate relatively independently from each other. It is only after prolonged periods of pumping that their combined actions result in groundwater overexploitation and the need for aquifer governance becomes germane. However, even if a strong aquifer governance structure is constituted and reductions in groundwater extractions are agreed on, it takes a long time before an aquifer stabilizes and the pumpers see any reward for their restraint. Hence, the incentive for aquifer users to collaborate is limited, which complicates the self-regulation of aquifers by groundwater users.

A former president of the Silao COTAS remarked that water users could never solve the groundwater situation by themselves, but that the authorities would never be able to do it either without the users. This sounds positive and logical, but it forewarns of the inescapable presence, from that moment on, of the aquifer management councils as an actor (agent) with a say in a system that is not working to reduce groundwater extractions. Setting up a participatory institutional arrangement without showing parallel progress in building credible incentives for self-regulation by improving law enforcement, increasing governmental coordination, and developing consistent financial support mechanisms, can lead to additional problems. Promoting user self-regulation without an enabling environment may actually worsen the problem by contributing to the emergence of a new institutional arrangement in which the COTAS do not have the means to contribute to effective groundwater management, while in a way validating the present institutional arrangement.

A fuller delegation of responsibilities to the COTAS appears necessary for them to be effective. In cases where user self-regulation is more advanced, such as in California (Blomquist 1992), the Edwards aquifer in Texas (Donahue 1998; Votteler 2002) and in Spain (Lopez-Gunn

2003; Lopez-Gunn and Cortina 2006), a stronger mandate for groundwater user organizations was a crucial ingredient. In the case of Guanajuato, this would require checks and balances at different levels in order to avoid the creation of new centers of power with no accountability to their constituents or to the state and federal governmental agencies. In order for the COTAS to be effective, the control mechanisms need to be transparent and open to the public. This increase in the COTAS' responsibilities should go hand in hand with an increase in their human, material and financial resources, to enable them to manage and control groundwater use.

Institutional coordination of efforts to reduce groundwater use should receive the highest priority and should be integrated into a policy package which bundles the different efforts that are being undertaken by CEAG, CNA, SDAyR and CFE (the Federal Electricity Commission). Coupling groundwater control with energy consumption would give COTAS, CEAG and CNA a strong control measure. Direct control over pumped volumes is very hard to monitor because of the ease of tampering with volumetric meters. At present CFE, which is almost the exclusive provider of energy for running the pumps, has a detailed database of consumed energy as users are charged volumetrically for the electricity they consume. If this information gets coupled to groundwater depths and electro-mechanical efficiencies of pumps, energy consumption could be used as a control measure for extracted volumes. If such information would become open to the public and to the involved institutions, users could install transparent mutual-control mechanisms.

To further develop COTAS into viable organizations of groundwater users that enable user self-regulation of groundwater extractions, a careful system of checks and balances needs to be developed to ensure accountability, legitimacy and transparency. The COTAS could then become 'social auditors' of the CNA, while helping authorities to perform water administration activities not linked to 'acts of authority' (reserved by law to public officers), based on a clear distribution of roles, means and goals. The water authority would not have to watch and punish every single act of illegality, but would have to respond effectively to the cases reported by the COTAS, thereby building a credible incentive for self-regulation.

To move forward, groundwater users would need to devise aquifer agreements with substantially lower levels of groundwater extractions, either through an adjudication of pumping rights on the basis of mutual prescription (Blomquist 1992) or through a negotiated downward adjustment of groundwater concessions with the federal government. However, this would require far-reaching institutional changes. First, functioning mechanisms for enforcing groundwater legislation, especially concerning well permits and pumped volumes, are needed to create credible incentives for groundwater users to engage in self-regulation. Second, mechanisms are needed to ensure the legitimacy and accountability of users' representatives to both users and state agencies. It is the authors' shared perception that based on the experience of the past

12 years with user self-regulation of groundwater extractions in Guanajuato, it will prove difficult but not impossible to realize these recommendations.

References

- Acevedo-Torres B (2004) Evolución del abatimiento en el nivel de los acuíferos de Guanajuato [Evolution of the drop in groundwater levels in Guanajuato]. *Aqua Forum* 8(37):3–7
- Birkenholtz T (2009) Groundwater governmentality: hegemony and technologies of resistance in Rajasthan's (India) groundwater governance. *Geogr J* 175(3):208–220
- Blomquist W (1992) Dividing the waters: governing groundwater in southern California. Institute for Contemporary Studies, San Francisco
- CEAG (Comisión Estatal del Agua de Guanajuato) (2001) Actualización de los balances de los estudios hidrológicos y modelos matemáticos de los acuíferos del estado de Guanajuato [Update on the results of the hydrological studies and mathematical models of the aquifers in the State of Guanajuato]. CEAG, Guanajuato City, Mexico
- CEAG (2006) Memoria Institucional 2000–2006 de la Comisión Estatal del Agua de Guanajuato (CEAG) [Institutional report 2000–2006 of the Guanajuato State Water Commission]. CEAG, Guanajuato City, Mexico
- CEAG (2010) Planes de manejo de acuíferos (Aquifer management plans). Available at <http://www.guanajuato.gob.mx/ceag/planes.php>. Cited 21 June 2010
- Custodio E, Kretsinger V, Llamas MR (2005) Intensive development of groundwater: concepts, facts and suggestions. *Water Policy* 7(2):151–162
- Donahue JM (1998) Water wars in south Texas: managing the Edwards Aquifer. In: Donahue JM, Johnston BR (eds) *Water, culture and power: local struggles in a global context*. Island, Washington, DC
- Fornés JM, de la Hera A, Llamas MR (2005) The silent revolution in groundwater intensive use and its influence in Spain. *Water Policy* 7(3):253–268
- Foster S, Garduño H, Kemper K (2004) Mexico : The 'COTAS'—progress with stakeholder participation in groundwater management in Guanajuato. World Bank GW-MATE Series Case Profile Collection no. 10, World Bank, Washington, DC
- Garrido A, Martínez-Santos P, Llamas MR (2006) Groundwater irrigation and its implications for water policy in semiarid countries: the Spanish experience. *Hydrogeol J* 14(3):340–349
- Giordano M (2009) Global groundwater? Issues and solutions. *Annual Rev Environ Resour* 34:153–178
- Guerrero V (1998) Participación social en el aprovechamiento sustentable de las aguas subterráneas: El caso de Guanajuato [Social participation in the sustainable use of groundwater: the case of Guanajuato]. In: *Memoria del Simposio Internacional de Aguas Subterráneas, León, México, 7–9 December 1998*, pp 33–42
- Guerrero V (2000) Towards a new water management practice: experiences and proposals from Guanajuato state for a participatory and decentralized water management structure in Mexico. *Int J Water Resour Dev* 16(4):571–588
- Hoogesteger J (2004) "The underground": understanding the failure of institutional responses to reduce groundwater exploitation in Guanajuato. MSc Thesis, Wageningen University, the Netherlands
- IMTA (Instituto Mexicano del Tecnología del Agua) (1998) Resolvamos los problemas del agua! Comité Técnico de Aguas Subterráneas del acuífero de Celaya, Guanajuato [Let's resolve water problems! The technical groundwater committee of the Celaya aquifer, Guanajuato]. Cuaderno de discusión no. 1. IMTA, Jiutepec, Mexico
- Knegt JF, Vincent LF (2001) From open access to access by all: restating challenges in designing groundwater management in Andhra Pradesh, India. *Nat Resour Forum* 25(4):321–331
- Llamas MR, Martínez-Santos P (2005) Intensive groundwater use: a silent revolution that cannot be ignored. *Water Sci Technol* 58(8):167–174
- Lopez-Gunn E (2003) The role of collective action in water governance: a comparative study of groundwater user associations in La Mancha Aquifers in Spain. *Water Int* 28(3):367–378
- Lopez-Gunn E, Cortina LM (2006) Is self-regulation a myth? Case study of Spanish groundwater user associations and the role of higher-level authorities. *Hydrogeol J* 14(3):361–379
- Maganda C (2003) The politics of regional water management: the case of Guanajuato, Mexico. *J Environ Dev* 12(4):389–413
- Marañón B, Wester P (2000) Respuestas institucionales para el manejo de los acuíferos en la Cuenca Lerma-Chapala, México [Institutional responses for aquifer management in the Lerma-Chapala Basin, Mexico]. IWMI Serie Latinoamericana no. 17, IWMI, Mexico City
- Milman A, Scott CA (2010) Beneath the surface: intranational institutions and management of the United States–Mexico transboundary Santa Cruz aquifer. *Environ Plan C Gov Policy* 28(3):528–551
- Montoya J, Barrera J, Ollivier I (2004) El proyecto de Consejo Técnico de Aguas y los programas de manejo de acuífero [The aquifer management councils project and the programs for aquifer management]. *Aqua Forum* 37:20–24
- Mukherji A, Shah T (2005) Groundwater socio-ecology and governance: a review of institutions and policies in selected countries. *Hydrogeol J* 13(1):328–345
- Ostrom E (1992) Crafting institutions for self-governing irrigation systems. Institute for Contemporary Studies, San Francisco
- Sandoval R (2004) A participatory approach to integrated aquifer management: the case of Guanajuato State, Mexico. *Hydrogeol J* 12(1):6–13
- Schlager E (2006) Challenges of governing groundwater in U.S. western states. *Hydrogeol J* 14(3):350–360
- Schlager E (2007) Community management of groundwater. In: Giordano M, Villholth KG (eds) *The agricultural groundwater revolution: opportunities and threats to development*. CAB, London
- Scott CA, Shah T (2004) Groundwater overdraft reduction through agricultural energy policy: insights from India and Mexico. *Int J Water Resour Dev* 20(2):149–164
- Scott CA, Dall'Erba S, Diaz Caravantes R (2010) Groundwater rights in Mexican agriculture: spatial distribution and demographic determinants. *Prof Geogr* 62(1):1–15
- Shah T (2005) Groundwater and human development: challenges and opportunities in livelihoods and environment. *Water Sci Technol* 51(8):27–37
- Shah T (2009) Taming the anarchy: groundwater governance in South Asia. *Resources for the Future*, Washington, DC
- Shah T, Roy AD, Qureshi AS, Wang J (2003) Sustaining Asia's groundwater boom: an overview of issues and evidence. *Nat Resour Forum* 27(2):130–141
- Shah T, Burke J, Villholth K (2007) Groundwater: A global assessment of scale and significance. In: Molden D (ed) *Water for food, water for life: a comprehensive assessment of water management in agriculture*. Earthscan and International Water Management Institute, London and Colombo
- Steenbergen F van (2006) Promoting local management in groundwater. *Hydrogeol J* 14(3):380–391
- Steenbergen F van, Shah T (2003) Rules rather than rights: Self-regulation in intensively used groundwater systems. In: Llamas M, Custodio E (eds) *Intensive use of groundwater: Challenges and opportunities*. Swets and Zeitlinger, Lisse, the Netherlands
- Theesfeld I (2010) Institutional challenges for national groundwater governance: policies and issues. *Ground Water* 48(1):131–142
- Votteler TH (2002) Raiders of the lost aquifer? Or, the beginning of the end of fifty years of conflict over the Texas Edwards Aquifer. *Tulane Environ Law J* 15(2):257–334
- Wester P (2008) Shedding the waters: institutional change and water control in the Lerma-Chapala Basin, Mexico. PhD Thesis, Wageningen University, the Netherlands

- Wester P, Hoogesteger J, Paters H (2007) Multi-stakeholder processes and platforms for surface and groundwater management in the Lerma-Chapala Basin, Mexico. In: Warner J (ed) Multi-stakeholder platforms for integrated water management. Ashgate, Aldershot, UK
- Wester P, Vargas-Velázquez S, Mollard E, Silva-Ochoa P (2008) Negotiating surface water allocations to achieve a soft landing in the closed Lerma-Chapala Basin, Mexico. *Int J Water Resour Dev* 24(2):275–288
- Wester P, Hoogesteger J, Vincent L (2009) Local IWRM organizations for groundwater regulation: the experiences of the Aquifer Management Councils (COTAS) in Guanajuato, Mexico. *Nat Resour Forum* 33(1):29–38