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Mexico – The 'Cotas': Progress with Stakeholder Participation in Groundwater Management in Guanajuato

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GW•MATE provided general advice to Comisión Nacional del Agua (CNA) on the preparation and implementation of the World Bank-funded MASAS Project for the stabilization of selected Mexican aquifers through (among other measures) the consolidation of aquifer management organizations (the so-called COTAS). More specifically GW•MATE members have had periodic interaction during 2001-03 with Comision Estatal de Aguas de Guanajuato (CEAG) on their efforts to promote COTAS for a number of specific aquifer systems in Guanajuato state. This profile provides an impression for an international audience of the progress and way forward of the COTAS in Guanajuato. A very generous acknowledgement is due to the senior staff of the CEAG, the CNA-Subdirección General Técnica (SGT) and the COTAS of Irapuato and Silao-Romita for the constructive dialogue which made writing the profile possible, but the opinions expressed are those of the authors alone.

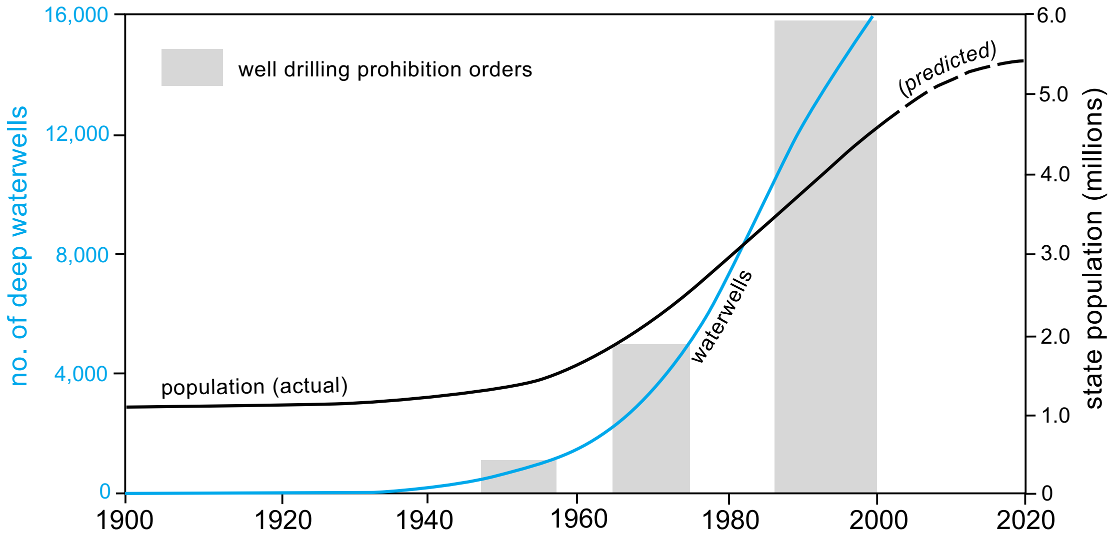
RATIONALE UNDERLYING PARTICIPATORY AQUIFER MANAGEMENT

Guanajuato State in northern central Mexico has witnessed major population growth since the 1950s, and now has some 4.5 million inhabitants (Figure 1). It is situated in the upper part of the Lerma-Chapala river basin in an area of elevated intermontane valleys of relatively low and markedly seasonal rainfall.

The state was traditionally one of livestock production with important associated agro-industrial enterprises, such as milk products, leather processing and shoe manufacture. But from the 1950s onwards, under strong central government stimulus, the industrial base was broadened and strengthened through the construction of an oil refinery plus petrochemical complex and a major thermoelectric generation plant. By the early 1970s this, and the associated demographic pressure, had led to considerable stress on groundwater resources, reflected by the rate of waterwell drilling (Figure 1). And there are now around 17,000 wells abstracting in the order of 4,000 Mm^3/a, which is estimated to be about 1,200 Mm^3/a more than the renewable resource. The hydrogeological conditions and groundwater resource status of the Silao-Romita and Irapuato-Valle aquifer systems are typical of much of Guanajuato State, and are illustrated in Box A.

Guanajuato State is striving to become a dynamic industrial and commercial center, with 15 important urban areas and almost 30% of its economy linked directly to the agricultural base. Groundwater sources supply 99% of domestic water supply, almost 60% of water use in agricultural production and all industrial demand in the state. But the groundwater resource crisis is a real impediment to development. Aquifer depletion is widely occurring at rates of 2-3 m/a and has some costly and critical side effects, such as escalating operational and replacement costs for urban and rural water-supply sources, deteriorating groundwater quality and/or salinity, and land subsidence damage to public infrastructure and private property.

Figure 1: Growth of population and water well drilling in Guanajuato State illustrating the ineffectiveness of well drilling prohibition orders



The dynamic of groundwater exploitation followed both economic triggers and technological innovation (increasingly efficient deep-well pumps and improved power networks). In Mexico water resources are administered under federal jurisdiction, but down-the-years the corresponding authority has lacked operational capacity to confront the problem of unauthorized abstraction and the development drive has always dominated in the face of weak water law enforcement.

In the 1990s major efforts were made by federal government (the CNA) to register and administer the groundwater abstraction and use rights system. However, lack of local operational resources and failure to mobilize user cooperation has eroded the system. Lack of consistent enforcement has meant that those who decide not to follow the rules are usually not sanctioned, thus deterring the rest of the user community to cooperate or comply with the regulation processes.

Attempts to constrain groundwater exploitation in Guanajuato included three periods of nominal 'waterwell drilling bans', but the number of deep wells appears to have more or less doubled during each of these periods (Figure 1). From this experience it was concluded that passing legislation and creating public policy without corresponding capacity for field implementation cannot be effective when the policy is, in effect, in contradiction of socioeconomic trends stimulated by other policies.

After the new Mexican Water Law was promulgated in December 1992, the CNA promoted nationally the establishment of civil society organizations (COTAS or 'technical groundwater committees' in Spanish) to help address the challenge of groundwater resource management, especially in about 100 overdrafted aquifers. While overall responsibility for groundwater resource legislation and administration rests with the federal government, Guanajuato State embarked on a complementary and ambitious program to confront the groundwater resource crisis with two main lines of action:

- execution of new hydrogeological studies and numerical aquifer models to consolidate the technical foundation for improved groundwater resource management
- promotion of the necessary social foundation for more effective groundwater management through formation of 14 groundwater user's associations, which are intended to evolve towards aquifer management organizations (AMORs) – they come together with representatives of surface water irrigation districts and other organizations in the 'state water user council' but their relation with overall Lerma-Chapala river basin management is still not fully resolved.

Each individual COTAS has been supported by the Guanajuato State Government since 1998 (via a state trust fund called FIPASMA) to the extent of an office base, three staff, a vehicle, groundwater monitoring equipment and computer facilities. This represents a total investment of some US$ 4.0 million in capital and operation during the period 1998-2003. The CNA has recognized the potential of the Guanajuato COTAS by agreeing to inject economic resources into the FIPASMA, while the FIPASMA Committee has empowered CEAG Director to retain fund allocations from any COTAS not complying with certain performance indicators.

The governing board of a COTAS (Figure 3) is constituted exclusively from groundwater users, and it deploys its operational staff to implement a work program agreed annually with CEAG via FIPASMA. They also receive technical support from CEAG staff, local universities and technological centers, and interact with local CNA staff on the legal dimension of groundwater resource administration (Figure 3). The overall concept is that groundwater resource management must rely more directly on local social agreements to implement adaptive measures, based on best-available scientific understanding.

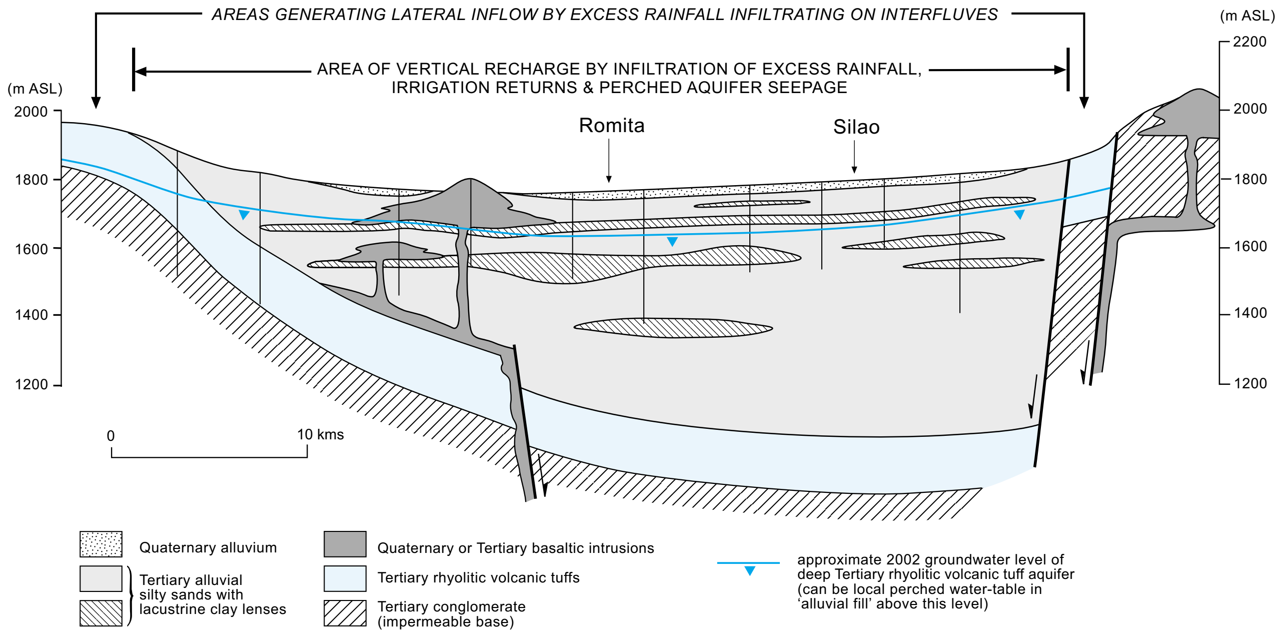
The COTAS of Guanajuato have thus created a permanent mechanism for water user — state government — federal government interaction, in which each COTAS (as a civil association with its own structure and finance) has the chance of seeking new agreements and funding from the other local sources and of adjusting to their particular local context. It should be pointed out that in Guanajuato alone extremely different socio-economic environments occur between the most developed areas in the vicinity of the larger cities and the more rural areas with traditional livestock rearing and fodder cultivation. It is thus essential for the COTAS in different areas to define their own priorities, based on a common agenda but flexible goals.

BOX A: THE SILAO-ROMITA & IRAPUATO-VALLE AQUIFER SYSTEMS

The aquifers of Guanajuato State mainly occur in a series of elevated basins separated by ranges of hills. The Silao-Romita aquifer system (Figure 2) comprises a thick sequence of mainly Tertiary alluvial sediments interrupted by occasional lacustrine clays, overlying a more extensive rhyolite tuff and intruded by Tertiary and Quaternary diabases and basalts.

Prior to significant well drilling, groundwater was encountered at shallow depth in a phreatic aquifer extending to 60 m bgl, but this was rapidly depleted by abstraction. Today the deeper part of the Tertiary alluvial deposits together with the underlying rhyolite tuff provide most groundwater to wells with static groundwater levels locally reaching 100m bgl (Figure 2), but perched water-tables occur above the more extensive lacustrine clays, especially along the surface water irrigation area of the Guanajuato river.

Figure 2: Schematic hydrogeological cross-section of the Silao-Romita aquifer system



The aquifer systems are replenished by a number of different mechanisms (Table 1):

- lateral subsurface inflow from neighbouring interfluves, especially where these are formed by the outcrop of the Tertiary rhyolite aquifer
- vertical recharge directly from excess rainfall or indirectly from surface watercourses, together with returns of excess irrigation by either surface water or groundwater but the estimation of each of these presents significant uncertainty, and the presence of local perched aquifers (intercepting or delaying part of the vertical recharge) further complicates the picture.

Table 1: Current estimates of groundwater balance for selected aquifer systems

PARAMETER (in Mm^3/a)	AQUIFER SYSTEM SILAO-ROMITA*	IRAPUATO*
NO. OF ACTIVE WATER WELLS	1360	1960
AQUIFER OUTFLOW		
Well Abstraction	363	649
proportion used for irrigation	89%	78%
AQUIFER INFLOW		
Net Subsurface Inflow	141	222
Drained Storage	67	218
Vertical Recharge**	155	209
(incl Irrigation Return)	(?)	(38)
AQUIFER RECHARGE AVAILABLE	296	431
TOTAL LICENCED ALLOCATION	118	619

* *based on CEAG data for 2002*
** *treated as unknown in groundwater balance and estimated by difference*

Although the precision of the groundwater balance is open to question, and will need to be improved to provide a sound basis for future groundwater management decision-making, it is clear that these aquifers have for long been excessively abstracted, leading to a substantial annual overdraft on aquifer storage (Table 1) and to pumping lifts which threaten the viability of many types of irrigated agriculture.

The scope of potential activities, envisaged by Guanajuato State, to be undertaken by the COTAS can be classified into the following broad categories:

- capacity building in support of the implementation of groundwater management plans
- promotion of resource management-related projects, appropriate to solving specific local problems
- support to the federal government in groundwater rights administration
- improving awareness of groundwater management needs, by means of public communication campaigns and via the child education system
- a range of groundwater user service provision from representing user interests in state negotiations to assisting individual users in dealing with groundwater permit applications and efficient technical and financial well operation
- achieving financial sustainability through seeking member subscriptions and by linkages with appropriate public and private partners.

APPRAISAL OF MANAGEMENT STRATEGIES & RESOURCE UNCERTAINTIES

To be successful, measures must be socially realistic, economically viable and institutionally sound. Incentives are needed to accelerate incipient changes in groundwater use patterns resulting from steadily-declining aquifer water-levels, which are leading to rising costs of groundwater production because of:

- the need for well deepening/re-drilling and pump re-dimensioning/replacement
- the increased electricity consumption for water pumping.

It is suspected that a substantial part of the present farming regime (agricultural crops and irrigation techniques) will become uneconomic, even with the current level of rural electricity subsidy, when groundwater levels approach 120 m bgl.

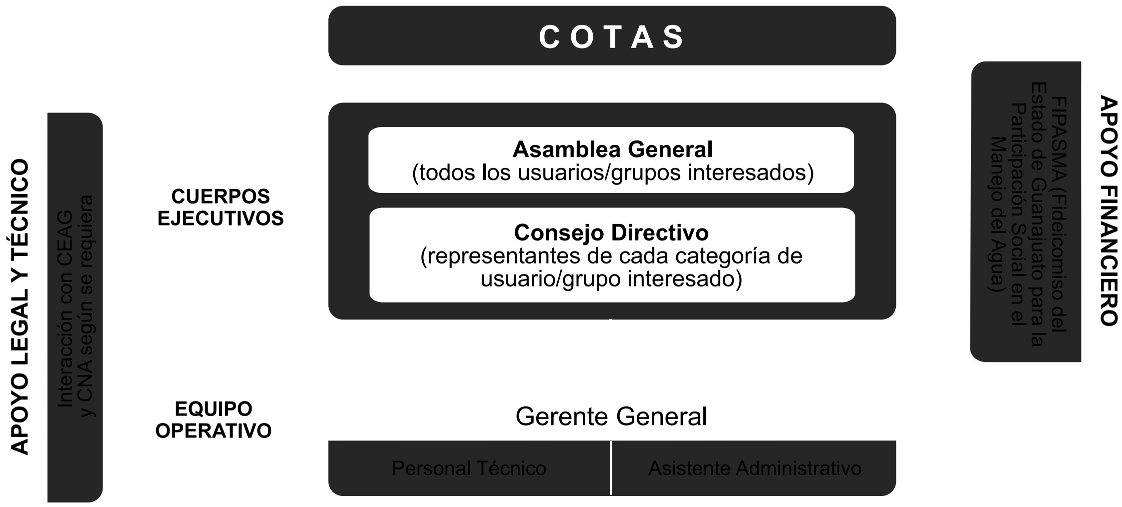
The potential groundwater resource management measures are summarized in Table 2 — in order of probable ease of implementation on the ground, if viewed from the reality of current institutional conditions and as judged by the reaction of various users and COTAS officials. It is noteworthy that the feasibility of all of these options is dependent upon having an effective system of groundwater rights in place, given that they involve reducing or reallocating groundwater use.

Some combination of the first four options would appear best in the shorter term — with SAGARPA (Ministry of Agriculture & Rural Development), CNA and CEAG working closely with the COTAS to gain the confidence and commitment of farmers as regards:

- the financial and operational feasibility of introducing agricultural water-saving measures
- the long term economic benefit that will accrue if these savings are in fact 'left in the aquifer'
- the fact that constraints on water demand do not necessarily imply reduced farm incomes, and that the fundamental objective is to increase unit water productivity (in terms of income per m^3).

Additionally, there is scope locally for aquifer recharge enhancement by construction of flow-baffles in the hills along small creeks to enhance streambed infiltration, by emplacement of drainage columns to enhance floodwater infiltration on the plains, and by measures to reduce soil erosion and retain runoff on permeable hill slopes. However, such methods have not (as yet) been proven effective as regards recharging the deep aquifer, and may intercept some discharge to the Lerma River required to support downstream users.

Figure 3: General administrative and operational structure of the COTAS of Guanajuato



The evaluation of groundwater resources, and their modelling for management purposes, has advanced considerably in recent years as a result of CNA and CEAG initiative. But it is complicated by the local geological conditions — with extensive volcanic hill country forming distant recharge areas which feed groundwater into broad valleys containing a thick fill of alluvial, lacustrine and volcanic deposits. This complex geology leads to:

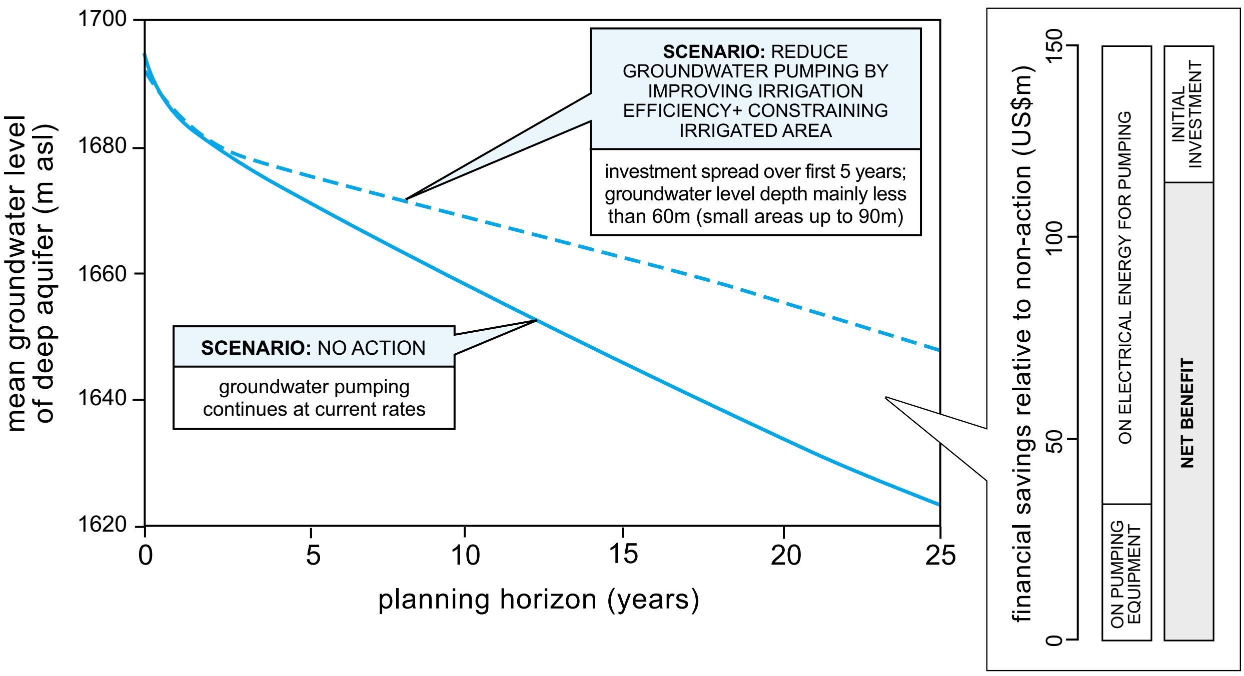
- the necessity for somewhat arbitrary lateral boundaries for modelled aquifer units, concentrating on the valley floor areas (where almost all of the groundwater abstraction and thus data are concentrated) which have uncertain relations with the recharge areas in the neighbouring hill country
- the presence of a multi-layer aquifer system in which the deeper aquifer horizons are usually the main water resource interest but have uncertain relations to overlying (now perched) aquifer horizons.

Table 2: Summary of potential groundwater management measures

MEASURE	APPROACH	IMPEDIMENTS
Reduce Electrical Energy Subsidy	most direct way to provide incentive for pumping reduction – present legislation allows CFE to restrict application of the subsidised tariff (09) to water-right volume	requires that water right register is reasonably up-to-date, and that there is federal political will and increased state involvement; also may need provision to protect the poorest farmers otherwise may aggravate poverty alleviation efforts
Substitution of Lower Water-Demand Crops	agronomic advice, seed distribution, etc for progressive substitution of lower water demand crops without changing overall agro-production regime	probably most feasible option in short term, although groundwater resource saving may be limited and requires constraint on expansion of irrigated area and/or double cropping to ensure 'real water savings'
Denouncing of Groundwater Use Rights	indemnify well owners who denounce groundwater use rights and seal their wells, in effect making annual compensation payment with farmers possibly continuing in dryland cropping; this might be financed from the anticipated saving in electrical energy subsidy	requires that water right register is reasonably up-to-date; in some cases water-right may be hypothetical since waterwell is dry or much diminished in yield, thus actual contribution to reducing groundwater resource imbalance would be less; risk of creating social problems due to migration of marginal farmers to cities could be counteracted by encouraging their collective organisation to share waterwells, irrigation hardware and crop marketing
Improved Irrigation Water Use Efficiency	provide grant/loan finance and extension services to facilitate introduction of water use efficient irrigation techniques within same general agro-production regime	only results in real groundwater resource saving if non-beneficial evapotranspiration or other unrecoverable water losses reduced and if no expansion of irrigated area and/or double cropping allowed (water-right reduced); some agronomic and marketing support will be needed
Radical Changes in Agroproduction Regime	introducing intensive horticulture under plastic covers or in glass-houses with drip irrigation and ferti-irrigation techniques	large investments and sustained extension services required; may be problems with product marketing and great effort needs to go into commercialization – thus can only be considered as a long term measure
Urban Wastewater Collection & Reuse	provide more groundwater to satisfy rising urban water demand (thus reducing this constraint on industrial/commercial expansion) and returning wastewater locally for agricultural reuse thereby greatly increasing overall water productivity	considerable scope but at present proportion of urban areas with mains sewerage is generally low (25-35%) implying that most wastewater being returned to shallow aquifer within urban area and not directly available for agricultural reuse; in longer run mains sewerage installation might be financed from current scheme to reinvest water levies, but considerable care will be needed to control wastewater quality, types of crop irrigated and pollution of any vulnerable aquifers

The resultant uncertainty in the estimation of groundwater balance components (and implicit in numerical aquifer management models) is, however, not such as to bring into question the urgent need for demand-side management measures. While the valley-fill deposits in most areas are very thick with a large volume of aquifer storage reserves still available, and there is no evidence that these become excessively saline at depth, the falling groundwater levels are calling into question the viability of some agricultural activities (and greatly reducing the profitability of others). Moreover, recent hydroeconomic modelling of the declining groundwater table clearly demonstrates very positive benefit/cost ratios for numerous management actions, compared to those of the 'no action scenario' (Figure 4).

Figure 4: Output of management scenario modelling for the Silao-Romita aquifer system using current MODFLOW numerical aquifer model integrated with economic data for selected agro-production regimes



However, it is useful to appraise the methods employed to evaluate aquifer groundwater balances (Table 3) and the approach of treating vertical recharge as an unknown — identifying both the potential levels of uncertainty and any pitfalls in application to groundwater management decision-making.

The main areas for concern in terms of longer-term aquifer management are:

- potentially erroneous evaluation and steady-state assumption for the subsurface inflows to the managed aquifer units, especially since these represent a major proportion of the calculated recharge
- possibility of systematic errors between the value of subsurface inflows and aquifer storage drained, which would have important implications for predictive modelling
- lack of more detailed understanding of the relation between irrigation return flow and deep aquifer recharge — thus some uncertainty whether measures designed for irrigation water-saving (both in distribution and at field level) will definitely benefit the groundwater level status of the deep aquifer.

Most of these uncertainties cannot be resolved by a short term campaign of data collection, and simply have to be born in mind when interpreting the outputs from numerical groundwater models and formulating related aquifer management strategies. In the longer run, improved aquifer monitoring (including better spatial and vertical control over monitoring points), coupled and integrated with field-scale investigation of the soil-water system under differing cultivation and irrigation regimes, should help to improve understanding and thereby refine aquifer management strategies.

ASSESSMENT OF PROGRESS ACHIEVED BY COTAS

In the initial phase the main objective of the COTAS was essentially consensus-building for future integrated water resources management and for demand-management initiatives, and emphasis has been put upon:

- establishing dialogue with, and improving data on, groundwater users
- providing services to the groundwater user community
- supporting public awareness campaigns on the importance, status and needs of groundwater resources
- facilitating, and assisting with, groundwater level, use and quality monitoring.

For these, and future, tasks it is important not to consider the COTAS in isolation, but as independent intermediate organizations positioned between individual users or user groups and the offices of state and federal government charged with overall responsibility for administration and protection of groundwater resources (Table 4). Although the COTAS have provided services to groundwater users they:

- are primarily organizations in which all categories of groundwater user can be grouped and represented
- need generally to seek a broader base of active membership to ensure they are truly representative.

Each COTAS is establishing a directory of all groundwater users to facilitate communication. The COTAS call at least two General Assembly meetings of groundwater users each year, to debate key groundwater resource issues, actions that are being taken and measures that are needed, and also have individual meetings with smaller groups of users. In addition the COTAS Governing Board meets more frequently to assess progress and to provide guidance to the General Manager on the work program—these boards have simultaneously become an important vehicle for inter-sectoral dialogue on groundwater resources.

Table 3: Appraisal of methods employed to establish aquifer groundwater balances

PARAMETER	METHOD OF ESTIMATION	POTENTIAL PITFALLS
Waterwell Abstraction (WWA)	from well census, usually based on installed pump capacity and pumping periods for each individual well or wells representative of different classes	probably most reliable parameter, especially where based on recent field survey, but best when estimates are reconciled with independent figures for agricultural use derived from data on irrigation technique, crop type, etc
Subsurface Inflow (SSI)	inflow (or sometimes outflow) across cells forming permeable boundaries of modelled area estimated from aquifer transmissivity (T) values and hydraulic gradient (I) measurements	prone to uncertainty due to potential errors in T for precise cell where I measured; moreover, questionable whether (for subsequent long term predictive modeling) this gradient and inflow will remain constant
Aquifer Storage Drained (ASD)	based on average value of groundwater level drawdown over given year and storage coefficient for strata drained – usually specific yield (Sy) of valley-fill deposits or volcanic rocks but locally semi-confined values – derived from textbooks (with some corroboration from pumping tests)	piezometric data now relatively good (but uncertain for deep aquifer in places where perched aquifers present) but Sy is notoriously difficult parameter to predict from geological description and prone to sharp variations with depth in stratified deposits – thus danger in assuming constant values during long term aquifer drawdown
Vertical Recharge Components	estimated as difference between above parameter estimates (WWA-SSI-ASD) because insufficient data on potential subcomponents – direct rainfall recharge, streambed recharge, returns from surface water/ groundwater irrigation, infiltration from in situ sanitation, leakage from perched aquifers (which may have intercepted all above)	without independent estimation subject to compound errors but in model auto-calibration routines these should be identified; however for developing long term management strategy and making model predictions need to establish relationship between deep aquifer recharge and irrigation water returns/streambed infiltration which will be modified by management actions

As part of the effort to strengthen dialogue with groundwater users, the COTAS have achieved significant success in providing user-oriented services such as:

- legal advice on setting-up the necessary documentation to obtain correct groundwater use rights and/or to gain access to public support programs
- electro-mechanical efficiency assessments for waterwell pumps, and advice on improving efficiency.

To complement these services, the Guanajuato State Water Council is promoting an agrometeorological information center providing weather forecasts with the ultimate aim of improving irrigation practice.

Some COTAS produce materials (such as magazines, posters and stickers) to draw public attention to the 'groundwater resource crisis' and create a water conservation culture. Others participate regularly in public meetings and have gained presence in the local media as opinion leaders. This involves some risk of the propagation of misconception and misrepresentation, but the gain in terms of putting groundwater issues at the top of the local agenda largely compensates for the occasional drawbacks. An even more ambitious local initiative was the Groundwater Vulnerability & Risk International Workshop, organized by the Irapuato-Valle COTAS in Salamanca in May 2003, to seek solutions for the problems created by heavy pollution of the shallow aquifer and the risk of pollution of the deep aquifer because of the land subsidence phenomenon.

All the COTAS have worked with CEAG on periodic piezometric measurement campaigns based on a monitoring network of 927 waterwells plus 10 deep observation wells monitored twice annually since 1998. They have also received a copy of the CEAG groundwater users register, which includes the geographical reference, construction details and user information for some 15,700 waterwells, and are performing valuable work in assisting the state government to validate, update and correct this database. However, this process is still a significant distance from satisfactory completion, and it is important that renewed efforts are made, in collaboration with the CNA and the CFE (Federal Electrical Power Commission) to generate a reliable user database in the REPDA (Public Water Rights Register) – subsequently CNA action will be needed to ensure that each user has a 'title deed' in which the licensed abstraction conforms to the groundwater right and corresponds to the current reality.

CRITICAL ISSUES FOR FUTURE SUCCESS

The fundamental goal of the COTAS (as conceived) is to provide the social foundation to promote measures to slow down, and eventually eliminate, aquifer depletion. It is clear from the experience to date that the COTAS cannot achieve this goal alone — but neither could the 'water administration' achieve it without the COTAS. The institutional complexity of groundwater resource administration and protection is evident in Table 4. Given the urgency to mobilize on groundwater management, it is vital for federal and state government offices (especially the CNA) to review and strengthen interfaces with the COTAS, so as to ensure that this initiative in 'bottom-up' management does not flounder because of lack of action on complementary 'top-down' legal procedures and policy decisions.

The task of groundwater resource management requires a true partnership between the federal water resource administration (CNA), the state water agency (CEAG) and the COTAS. A significant current impediment is the lack of capacity of the CNA water administration to enforce the existing groundwater legislation as regards groundwater use rights and clandestine waterwell drilling. The improvements in the groundwater user register being brought about mainly by COTAS action with the support of CEAG is, however, an important step in the right direction. Completion of this priority task could be facilitated through CNA-CEAG agreement to inject additional funds into FIPASMA, which would allow the COTAS to undertake the necessary field and office work under the supervision and authority of the CNA, albeit that the status of the abstraction volumes concerned will need special legal consideration.

Table 4: Groundwater management functions—illustrating potential scope and necessary interaction of the COTAS

FUNCTIONS	USERS	COTAS	CEH or CC	CEAG	CNA-GE/OC	OTHERS
obtaining/conforming with groundwater use rights	R	s			E	
well/system operation and maintenance	R	s		s		
measurement of groundwater abstraction	R	s			E	
formulate/implement groundwater management plans	R	c	c	s	E	R
denounce clandestine wells/well drilling	c	R			E	
denounce potential sources of groundwater pollution	c	R			E	s
reconcile groundwater and energy use data	c	R		s	s	s
maintain profile of groundwater users/uses	c	R		s	E	
up date aquifer resource status information		R		s	s	
promote general public awareness campaigns		c	R	R	s	
groundwater level, use and quality monitoring	c	c		R	R	
mobilize and evaluate COTAS contribution	c		c	R		
regularly update groundwater rights system	c	c			R	
control wastewater/solid waste disposal and reuse	R*	c		s		E
resolve disputes of groundwater users/polluters	c	c		s	R	c
formulate/implement water-saving measures	R*	c	c	c	E	c
formulate/implement land-use planning	c*	c	c	c		R&E

R responsible
E enforce
c contribution
s support

COTAS – aquifer management organization
USERS – individual or association of groundwater users
CEH or CC – state water resources council or river basin council
CEAG – state water development agency
CNA-GE/OC – national water resources commission (state or national office)
OTHERS – federal/state/municipal agencies for land-use planning, environmental control or agricultural production and advice

* land developers may perform this role rather than users

There is a risk that some COTAS – as they become more and more involved in a wide range of local water related activities – may lose sight of the fundamental goal of slowing down, and eventually eliminating, aquifer depletion. To re-assert the fundamental goals it would be a valuable for each COTAS (with the active collaboration of CEAG) to prepare a concise 'executive mission statement' (of about 8-page length), which includes a description of local groundwater occurrence, a diagnosis of the current status of groundwater resources and quality, the preferred management options to achieve sustainability and their implications for users and stakeholders.

In this executive mission statement, and in the follow-up management actions, it will be vital to put greatest emphasis on achieving 'real groundwater resource saving', and not just on introducing more efficient water use technology. Measures that reduce water losses by non-beneficial evaporation or seepage to bodies of poor-quality water are the primary need, whether in irrigated agriculture or in the urban context. The rationale is simple but its implementation can be complex. Groundwater saving programs are intended to reduce consumptive water use, as far as possible without compromising farmer incomes through increasing the unit economic water use productivity. But they also require:

- concomitant reductions in the volumes of groundwater abstraction rights and, in many cases, constraints on the land area under irrigated agriculture
- reallocation of groundwater use rights for non-consumptive urban and industrial use, which subsequently returns reclaimed wastewater to the rural areas for reuse in agricultural irrigation.

It will also be necessary to intensify the collaboration of the COTAS with agricultural extension, support and commercialization agencies, bearing in mind the critical role of irrigation demand management in the overall groundwater resource strategy. Moreover, because of the relevance of surface water irrigation efficiency and availability for groundwater resources, it would be sensible to agree complementary representation between the COTAS and the so-called Irrigation District Module organizations.

Groundwater quality issues should not be overlooked and it will be equally important to minimize the risks of groundwater salinization and pollution. An important start on this work has been made by CEAG through the consolidation of a groundwater quality monitoring network and a program of aquifer pollution vulnerability mapping and pollution source inventory in priority areas. This, however, is not an end in itself, but more a means to facilitate COTAS and community participation in groundwater quality management, and making real progress here will require the political will and coordinated efforts of a number of state government offices (Table 4).

A short term plan to fund the COTAS over the 5-year period from 2004 via an extension of FIPASMA is in hand. In the longer term financial sustainability has to be achieved, preferably by using part of the groundwater abstraction rights fee (collected by federal government) to finance operating costs. At present, the FIPASMA budget for COTAS support (provided by state government) is equivalent to about 2% of the 'water resource fees' collected in the state of Guanajuato. Other possible financing mechanisms include:

- injection of federal funds to FIPASMA to allow the COTAS (on behalf of the CNA) to perform work at field level related to groundwater resources administration
- charging groundwater users a COTAS membership quota for representation and services provided.

Since integration is the key element for the success of the COTAS model, there needs to be continued scope for COTAS staff to put together the different programs for both financial support and non-monetary assistance from federal, state, municipal or private bodies, according to local circumstances and needs. Up to present the smaller municipalities have shown more willingness and diversification in their support of the COTAS, whereas the bigger cities (such as Leon and Celaya) have been more reluctant to relate to and to finance the COTAS initiative efforts.

There can be little doubt that community participation is an essential component to achieve progress on management and protection, and the COTAS is a valuable institutional model in this respect. But it must be recognized that constructive community action does not come without the careful facilitation of local government and that stakeholder/user organizations cannot deliver success in the conservation of groundwater resources without the complementary and supporting action of all levels of government involved – in effect that 'bottom-up action' needs to be facilitated by 'top-down provisions'.

Since state government has periodically to evaluate the COTAS on progress towards their fundamental groundwater management goals, there is a strong argument for setting them 'performance indicators'. Such performance indicators could have three semi-independent facets:

- first, those relating to groundwater resource status, which would include average groundwater level trends, reductions in groundwater abstraction volume and improvements in water use productivity
- second, and much more difficult to measure, an indicator of groundwater quality
- third, institutional indicators such as the proportion of groundwater users that are 'active members' of the COTAS, their level of self-finance and the level of REPDA completion.

However, it is important to recognize that the first two of these sets of indicators are dependent on collaborative action, and failure to achieve the desired progress on them would not necessarily imply under-performance by the COTAS themselves.

Publication Arrangements

The GW•MATE Case Profile Collection is published by the World Bank, Washington D.C., USA. It is also available in electronic form on the World Bank water resources website (www.worldbank.org/gwmate) and the Global Water Partnership website (www.gwpforum.org).

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