Local groundwater governance in Yemen: building on traditions and enabling communities to craft new rules

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Abstract Local groundwater management in Yemen and the means by which stakeholders can work together to improve water governance are discussed. In the last few decades the discourse on groundwater management in Yemen has increasingly been cast in terms of crisis, triggered by rapidly declining water tables around cities and in the main agricultural areas. However, in some places in Yemen, communities have responded by implementing local rules that have reduced conflict and provided more reliable and equitable access to water. This trend towards development of local groundwater governance is described, and could make a major contribution in realizing the goals of national water-sector policies and strategies. Twenty-four cases have been identified from different parts of the country and five cases are presented in detail. The article discusses how the process of local management could be nurtured and how it could contribute to rebalancing water use in several parts of Yemen.

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Introduction

Yemen has a predominantly arid climate and is generally extremely water scarce. Two thirds of the country is classified as hyper-arid with less than 50 mm rainfall per year and most of the rest is classified as arid with less than 200 mm rainfall. Average annual rainfall above 250 mm is only found in the mountainous regions, where most of the population is concentrated, with some areas receiving 800 mm. Rainfall is the primary source of water, most of which is rapidly lost due to evaporation. Only about 6 % of rainfall is captured in the surface-water systems in wadis as spate (flood) flow amounting to about 2 billion (10^9) cubic meters (BCM) annually (World Bank 2010).

Groundwater is a vital resource for water use throughout Yemen. Groundwater withdrawals were estimated at 2.5 BCM/year, which amounts to about 70 % of total water use of the country. The aquifers in Yemen, which are distributed throughout the country, consist mainly of alluvial, sandstone, limestone and volcanic formations. Alluvial aquifers which are formed in wadi beds from sand and gravel unconsolidated deposits are the most common (MOMR and TNO IAG 1995; Shahin 2006). The aquifers contain large water reserves of about 35 BCM with annual recharge of about 1.3 BCM (World Bank 2010). The rate of groundwater overdraft is currently twice the recharge rate, and is increasing, bringing depletion of water reserves, inequity, and shortages, with negative socio-economic consequences. Some major aquifers are being depleted even more rapidly.

Historically, Yemen developed elaborate systems of formal and informal norms, rules and laws to govern the use of its water resources, primarily surface water, in a sustainable and fairly equitable manner (Varisco 1983; Handley 2000; Moore 2011). Yemen's heritage of managing water includes not only the famous Marib dam in central Yemen, mountains wrapped with terraces, and a multitude of surface irrigation systems based on diversion

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dams and springs and ingenious soil conservation methods (such as stone mulching), but also the social capital of institutional arrangements for leadership, water allocation, resource mobilization, and conflict resolution (Dasgupta et al. 2009). Water governance is currently challenged by rising water demand, aquifer depletion, expansion of irrigated agriculture, urbanization, and loss of natural recharge (Abu-Hatim and Mohamed 2009).

The most common results of groundwater depletion felt by the local communities are increased well depths, increased pumping costs and reduced water quality. In response to these problems, as discussed further in this report, local water users in some areas have taken initial steps to prevent further harmful development of water resources, avoid wasteful use, harvest rainwater, replenish groundwater, and ensure access to water for drinking and domestic use. Many communities now require spacing between wells, and some have closed or restricted usage of wells that interfere with domestic water sources. Individual farmers have done things such as switch to more efficient irrigation technologies, adjust cropping patterns, and share in the investment and use of wells and pipe networks. However, as depletion of fossil aquifers continues at rapid rates, much more may need to be done. A change to better management of shared common pool resources of surface and groundwater cannot be accomplished by individual users acting on their own, and neither can the government acting alone overcome the problems. Instead, cooperation among stakeholders is essential for improving water governance.

Local groundwater governance is a community-based management system consisting of a set of mostly informal institutional, socio-economic and cultural arrangements and norms, often only in oral form, that regulate and safeguard the sustainable scarce water supplies (Shah 2009; van Koppen et al. 2007). Local management systems can permit decentralized, democratic and collective management and monitoring of groundwater resources by water users. There are examples from high-income countries, in particular the American West and Spain (Brooks 2002). Van Steenbergen (2003) documented a number of examples of local management of groundwater from various socio-political backgrounds in Pakistan, India, Egypt and Mexico. There is a growing interest in reviving local traditions and developing local institutions for water management as a way of improving the effectiveness of water governance. In South India, development of local groundwater governance institutions has reduced water consumption but at the same time brought economic growth—such was the experience in several projects in Andhra Pradesh (van Steenbergen 2010). Perhaps surprisingly, many of the most important impacts have come not from strict law enforcement or punitive sanctions, but instead emerged through improvements in communication, local groundwater monitoring, and sharing of information.

Local groundwater management could play an essential role in adapting to growing water scarcity and realizing the goals of Yemen's National Water Sector Strategy and Investment Program (NWSSIP) and the National Water Sector Support Program. Effective and equitable water governance at the local level, with stakeholders cooperating in various ways, including through water-user groups, associations, local councils and other institutional arrangements, could be crucial for achieving the objectives underlying the Water Law and NWSSIP, as it develops institutions that can work as effective partners with national and basin-scale activities to improve water management. Considerable work has been done on promotion of water users' participation which mainly concentrates on how farmers and other stakeholders might take part in government projects and programs (Bruns and Taher 2009). This article emphasizes what communities do themselves, and how government can participate in community-driven water governance, particularly by providing support to inform and enable local problem-solving.

This article documents a number of cases of local groundwater management in Yemen and discusses how to support this trend and how to scale it up. The article discusses ways of strengthening water governance and building institutions for community-driven water management, and outlines a sequence of practical steps to help communities assess their situation, consider principles, goals, and options, reach agreement, and carry out practical actions to adapt to water scarcity and improve water management. The report then suggests a number of practical opportunities to promote and extend community groundwater management—including documenting good examples, sharing information, better analysis of local aquifer systems, training of support groups (drillers, local councils, security forces), facilitating deliberation and consensus-building, supporting implementation of local initiatives to manage groundwater, and appropriate engagement with larger-scale basin and national water-management institutions.

Enabling factors for local groundwater management in Yemen

The local groundwater management practices in some rural communities in Yemen were facilitated by a number of enabling factors that encouraged water users to sustain and develop these practices. An overview of these factors is given in the following.

Wealth of traditional knowledge in water-resources management

Yemen's communities have a long engagement with managing land and water resources, demonstrated not only by physical works such as terraces, diversion dams and canals but also by an array of customary institutions for organizing collective action; regulating access to land for cultivation, grazing, and water harvesting; and resolving conflicts by discussion, mediation and arbitration through networks of social relationships (Lichtenthaeler

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2003). Traditional spate irrigation institutions: established leadership roles and norms for shared contributions; allocated rights to water (primarily through upstream-first-served rules suited to uncertain and highly variable flows); and provided processes for dealing with conflicts. Many of these arrangements date back centuries, and some are recorded in historic documents—though conflicts are common too, with management across tribal boundaries being particularly challenging (Varisco 1983).

Local governance not only concerned surface water, but in some cases also related to the use of groundwater. In the past in Shabwa and Hadramawt, for instance, local laws ensured that any new *qanat* (canal) that was to be developed could not interfere with existing ones. If a newly constructed *qanat* was found to interfere with an existing one, work on it would have to be stopped immediately (Baquhaizel et al. 2011). Another age-old groundwater management rule is the *harim* (border) that has its origins in the Sunnah (statements approved by the Prophet (Peace Be Upon Him) considered as legally binding precedents). The *harim* defines a protected area around a spring, *qanat*, or well—where no other source could be developed and contaminating activities were forbidden. The *harim* is usually defined as 250 m from the spring or well in soft rock terrain and 500 m in hard rock area (van Steenbergen 2006).

Increased depletion of groundwater

Over the last several decades, tube wells and motorized pumps have been used to supply growing populations and extend irrigation. The development of new wells has expanded rapidly and water tables have declined in many areas. The economic boost in the 1970s and the 1980s, in addition to the remittances from workers in Gulf countries (which accounted for billions of US dollars), opened intensive investment in groundwater irrigation. The area under groundwater irrigation in Yemen has increased from 37,000 to 500,000 ha in a matter of 40 years. As a result, the annual decline in groundwater levels is typically 2.5–4.5 m in many areas, with Sana'a Basin exceeding this and the decline being closer to 6 m/year (Hydrosult et al. 2010). The escalation of groundwater drawdown motivated water users to set up and respect some mutual actions to protect their aquifers.

Institutional water-sector reforms

The main legal instrument promulgated to manage groundwater is the 2002 Water Law. The Water Law spells out licensing requirements for new wells and describes new institutional water-management arrangements such as the Basin Councils and formal water-users associations (WUAs). Even so, many wells continue to be unlicensed. Some communities seeking to stop potentially harmful wells have sought support through local councils, security authorities, courts, and the branches of the National Water Resource Authority. Regrettably, such efforts have often been difficult, time-consuming, and fruitless. Even so, the fact that well development is in principle no longer a 'free for all' and needs to be licensed under the Water Law, has offered a source of legitimacy to local initiatives in introducing restrictions and rules. Under many water-sector projects—in drinking water supply and in irrigation—WUAs and smaller water user groups (WUGs) are being promoted. Much of the discussion of groundwater regulation has concerned enforcement of the Water Law, with high numbers of unlicensed wells being drilled and their associated cases being seen in courts.

Raised competition/conflicts over water

Until recently, local conflicts on groundwater development were exceptional, but they are more common now, for instance in Amran and Sana'a Basins. Whereas Lichtenthaeler (2003) observed that, in spite of falling water tables, there were no conflicts over water in Amran in 2000; however, by 2010, protests and blockages had become common (Lichtenthaeler 2010).

As discussed in the following, many communities have sought to prevent harm to existing users, most notably by norms restricting well spacing and banning export of water from their area by tankers. In other cases farmers have closed disputed wells, invested in groundwater recharge, or have connected separate wells by a shared network of pipelines, allowing water to travel from one area to the other. The agricultural wells also double in several cases as sources of domestic water supply and private village pipe networks supplying domestic water-supply services. However, these efforts have also been constrained by a variety of factors, including limited understanding of aquifers, lack of knowledge about management options, conflicting interests, difficulty in developing local understanding and consensus, and lack of external endorsement and support for local-level regulation.

Examples of local groundwater management in Yemen

Table 1 lists a number of cases of local groundwater management in Yemen and Fig. 1 depicts the location of these cases on the hydrological map of Yemen. These cases were identified mainly through informal networks. One remarkable point was that it was relatively easy to identify examples, especially in the highland districts, suggesting that local regulation of groundwater may not be exceptional and instead seems to be occurring in many places throughout the country. In the coastal areas, where groundwater overuse issues are in places equally severe, there appeared to be fewer examples of local management, probably due to the larger complexity of the water systems (conjunctive use of spate irrigation and groundwater) and larger aquifer systems.

In general, the local rules can be categorized based on their purpose under two types:

1. Rules which preserve common interests: These include closed or restricted usage of wells that interfere with

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Table 1 Cases of local groundwater management

Case number	Place (reference)	Type of management	Local rule
1	Wadi Qarada, Bani Hushaish, Sana'a (this study)	Informal norms, Leadership, WUA	Restrict well drilling, recharge weirs in wadi bed, well sharing
2	Khrabat Muhyab, Bani Matar, Sana'a (this study)	Informal norms, WUA	Restrict well drilling, well spacing
3	Wadi Dhelaa, Hamdan, Sana'a (this study)	Informal norms, Leadership, WUA	Well spacing, well sharing, dam development
4	Al-sinah, Almaafer, Taiz (this study)	Community organization	Well distance, blocking out well development in sensitive areas, permission by the National Water Resources Authority (NWRA) only with consent of the cooperative
5	Wadi Areesha, Nahem, Sana'a (this study)	Informal norms, Water user association (WUA)	Restrict well drilling, ban on tankers, well-depth limit
6	Hejraht al-Asham, Jabal al-Sharq- Dhamar (this study)	Informal norms	Restrict well drilling
7	Qarwa Beshar, Jahanah, Khawlan, Sana'a (this study)	Informal norms	Restrict well drilling
8	Wadi Sana'ah, Dhamar (this study)	Informal norms	Spring protection by zoning, distance rule
9	Wadi Akarem, Dhamar (this study)	Leadership	Restrict deep drilling in the main wadi
10	Bani Garban, al-Kafr District, Ibb (this study)	Community organization	Protection zone
11	Al-Gawaref, Ibb (this study)	Informal norms	Ban on irrigation of qat (type of shrub)
12	Wa'alah, Amran (this study)	WUA	Ban on water transport by tankers
13	Bait Sarhan and Alhamrmaly, Amran	Leadership	Ban on water transport by tankers
14	Al Ma'akhad, Amran	Leadership	Ban on water transport by tankers
15	Qa'a Al-Shams, Amran	Leadership	Ban on water transport by tankers
16	Bani Maymoun, Amran	Leadership	Tankers only within village
17	Al Aroosi, Mehan, Sana'a	Informal norms, Leadership	Closure of disputed wells, agreement on reservoir operation
18	Al Mashra, Damar (this study)	Leadership	Ban on drilling
19	Wadi Al-Har, Anss, Dhamar (this study)	Community organization, Leadership	New agricultural wells only if they serve drinking water too
20	Mawia, Taiz (this study)	WUA	Joint WUA to regulate new well development, replacement of qat in some areas
21	Wadi Al Zabaira, Qadas; Al Mawasit District, Taiz (van Steenbergen 2006)	Informal norms, Community organization	Restrict/ban well drilling, closure of disputed wells
22	Hijrat al-Muntasir, Amran (Lichtenthaeler 2010)	Informal norms, Leadership	Ban on new drilling
23	Al-Wahda, Al-Maafir, Taiz (Ward and Al-Aulaqi 2008)	WUA	Ban on new wells, non-well owners to share in existing wells
24	Zuberia, Wadi Siham, Hodeidah (Bonzanigo and Borgia 2009)	Informal norms	Prevent new shallow development by referring cases to Local Council and NWRA

drinking/domestic water sources, preventing water transfers from the area to urban areas/sale of water, restriction on water withdrawal from dams and rules governing management of recharge structures.

2. Rules which preserve individual interests: These include respect of minimum spacing between wells, limitation on maximum well depth, and right of individuals to share/buy water from existing wells.

An overview of the first five cases, based on field investigations, is given in the following.

Wadi Qarada, Bani Hushaish, Sana'a

One example of local management of groundwater concerns Wadi Qarada in Sana'a Basin. The spate floods in the wadi are diverted to irrigate the land, but more importantly they recharge the shallow aquifers. Grapes, in different varieties, are the almost exclusive crop in the area. Because the area is open, it is prone to frost and growing qat is not an option.

There are over 100 wells in the area—typically these are 300 m apart. Up to 2002, well drilling continued unabated, with a 15-m decline per year until the water table reached 320 m below ground level in 2008. For example, the groundwater levels in the Sana'a Plain had shown a steady decline from less than 30 m below ground surface in the early 1970s to more than 150 m below ground surface in 1995 (Hydrosult et al. 2010). Sulphur and fluoride concentrations increased with depth. In anticipation of the new Water Law, additional wells were developed that were subsequently capped and are not yet used.

The production of the wells over the years also dropped to less than 50 %. For a long time the answer

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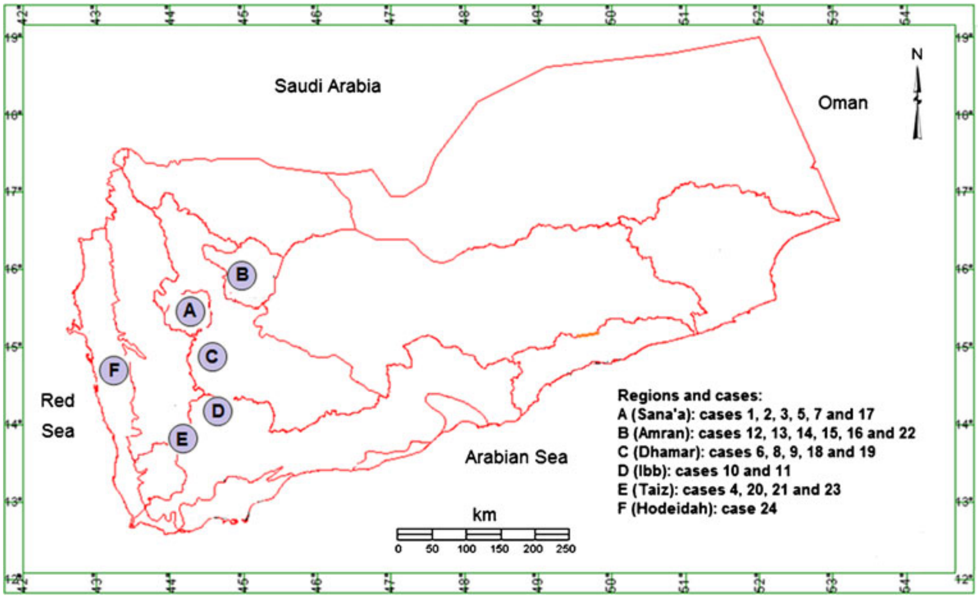

Fig. 1 Schematic map of major watersheds (*red lines*) in Yemen with approximate locations of cases (Map source MOMR and TNO 1995)

to water scarcity was to invest in new and deepened shared wells, rather than in shared conveyance networks. The cost of developing a well is considerable however, and can go up to YR 40 million (USD 180,000). Part of the resistance to investing in modernized irrigation systems was the skepticism, partly well founded, on the usefulness of drip systems, as these would not work with the widely spread root system of the old grape plants.

In 2003 two WUAs were established for the area—Al Qarada and Al Ashraf. This was triggered by the Sana'a Basin Water Management Project, which also worked on creating awareness and increasing the interest for improved irrigation systems. Membership grew over the years: Al Qarada started with 70 members but now has 130 members. The WUAs regulate and monitor the drilling of wells. The way it works is that if in the area of the Al Qarada WUA unlicensed drilling is about to start, a complaint will be lodged to the government by the Al Asharaf WUA. This is done to preserve harmony in the area of Al Qarada. The reverse process is initiated by al Qarada if unlicensed drilling is planned in Al Asharaf. Thus the two communities act as a check and balance on each other.

Recharge in the area greatly improved after the construction of 47 cascade check dams in the riverbed under the Sana'a Basin Water Management Project during the year 2010. The check dams are a series of low elevation barriers (up to 1.5 m) constructed progressively across the wadi bed starting from the upstream by placement of loose stones in the wadi bed. These structures serve two purposes: the first is to reduce the speed of flow in the wadi and the second is to impound excess water during spate flows and thereby increase the recharge of shallow groundwater and divert water to irrigation canals on both sides of the wadi beds. The speed of the water is still sufficient to ensure that sediment is removed. A comparison of this type of structure with recharge from surface storage dams found that the check dams are significantly more effective in recharging local aquifers, particularly in comparison with large dams. The value of incremental recharge due to cascade dams was three times more than the incremental recharge at a masonry gravity dam, and the cost of construction was only one fifth of the cost of construction of the gravity dam (Alderwish 2010).

Khrabat Muhyab, Bani Matar, Sana'a

The main water source of the Khrabat Muhyab area is the run-off from nearby mountains, which feeds aquifers and springs. Over the years farmers have moved to groundwater irrigation, typically pumping water from wells 150–180 m deep. The wells, if only because of their cost, are shared by many families. A typical well may have 17 shares and ownership between 25–30 families.

Following a violent conflict in a nearby area over the sharing of water from a dam that was to be built by the government, farmers decided to regulate the use of water in their area. The establishment of the WUA, called 'Belad Albustan', was triggered by seeing the conflict and hardship arising from overuse of groundwater in nearby areas; it was not set up by any project but created at the initiative of concerned farmers. The WUA initially regulated the seven wells in Khrabat Muhyab village. Minimum rules were set on the distance between wells. Wells were to be at least 500 m apart, but depending on the location the distance can be even larger. The minimum distance to a spring, for instance, is 2,000 m.

Whereas the WUA initially covered seven wells in two villages, its usefulness has been recognized and it now covers the area of 58 wells in eight villages. The membership went up from 80 to several hundred. The

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development of new wells in the area is not allowed unless a clear need for a new well (rather than getting water from an existing well) is proven and the minimum distance is observed. Improved irrigation techniques are relatively exceptional in the area and there appears to be a good scope for improving water management on this front too.

Wadi Dhelaa Hamdan, Sana'a

Wadi Dhelaa is located 15 km west of Sana'a and has a long history of irrigated agriculture. The area receives surface spate flows from the 4-km long Matba tributary of Wadi Dhelaa and in the past was supplied both by surface flows from the river bed and by ancient *qanats* or horizontal wells. Sabean inscriptions inside the tunnel of the *qanats* suggest that they were developed at least 2,000 years ago. Over the years, the tunnel was gradually deepened to keep up with fluctuating water tables. Land levels also increased over time, due to sediment from the adjacent hills. Until 50 years ago, dugwells were a source for irrigation and drinking water. At that time grapes, apricots and maize were the main crop, mixed with marginal qat and fuelwood.

As the *qanat* ran dry from 1982 onwards, and as shallow wells started to fail around 1990, farmers shifted over to deep wells, now boring up to 300 m deep with water tables between 150 to 200 m below ground level. The shift to deep wells coincided with a transition to growing mainly qat, as the deep wells sustained a higher value crop. In Dhelaa five wells have been developed all under shared ownership. Ownership in the wells is divided in shares, corresponding to half a day's water supplies (contingent on availability of high voltage electricity). The shares may be owned by up to 30 families per well, and some families have shares in more than one well. Moreover, the five wells in Dhelaa are connected through a shared pipeline system. This makes it possible to irrigate the entire area from different wells and to compensate for the temporary breakdown of one deep well by sourcing water from another well. In Dhelaa a minimum distance on new wells has also been imposed. This used to be 500 m from an existing well, but has now increased to 700 m.

Within these distances it is not allowed to develop a new well, but one can always buy water from one of the existing wells. Because all landowners are interconnected and because everybody has a share in at least one well; enforcement of this rule has had to overcome problems. Farmers in Dhelaa came to the regulated and shared system after seeing the severe decline in groundwater levels in nearby Shamlan where many wells were developed in a very short timeframe. The rule was introduced gradually, under the leadership in this case of the local sheikh (tribal leader) family. There is no water users association in Dhelaa. If there were a conflict about the local regulations, then the local council, security forces or members of parliament could be called upon. In fact, if there are conflicts, it is on the joint running of the shared wells: who is first, how to compensate for power outages, and how to pay for the cost of maintenance and repairs.

The wells in Dhelaa are not only used for agriculture; they are used for drinking water supply as well. The community has in fact built up their own water-supply system from the same wells. Special pipes connect to different sections of the small town. This developed over the years. The wells were initially for irrigation, but were next connected to the mosques and then to individual households and public water points.

The water table has more or less stabilized. The main drinking water well for instance has had to be deepened by 6 m over the last 3 years but other wells are stable. The seeming balance is also attributed to the construction of a recharge dam upstream of wadi Dhelaa. The work was initiated by the sheikh family at the end of the 1990s. The dam was subsequently upgraded in 2002 to a 25-m high structure with a sand core and riprap covering. The dam is over dimensioned; even in the recent wet year it has not filled more than a third of its capacity. The dam, however, is reportedly successfully contributing to recharge in the area.

Al-sinah, Almaafer, Taiz

Al-sinah area is located 30 km west of Taiz in wadi Al-asloom, Almaafer District, Taiz Governorate. The area consists of 12 groups of villages with a total population of approximately 18,000 (2004 census). It is well-known in Yemen for its cooperative society. The story of Al-sinah cooperative society dates back to the end of 1960s, when the community decided to establish it to start water and electricity projects but also to facilitate education and health improvements. Al-sinah cooperative society stands out as an example of long-term institutionalized local development and resource management.

Al-sinah basin contains 35 agricultural bore wells, owned by farmers either individually or shared. Most of these wells were developed in the 1970s. The average depth of wells is 260 m, but the water table is found at 96 m below ground level. However, the water table is declining continuously; a decline of 6 m was observed during the year 2010.

Water and electricity are the cooperative society's main activities. The cooperative society owns three wells. Water is pumped to four elevated tanks, perched on top of the mountain, and then distributed to homes via a network of pipelines. Approximately 1,900 homes are subscribed to the network. The water is provided for drinking and domestic purposes only; it is prohibited to use water for agriculture. Al-sinah cooperation association has few remarkable features that earmark it as an outstanding example of local water management:

- Democratic structure. Management is elected every three years with an elaborate structure of 12 election assemblies. There is no traditional local leader. The preference is for people of high integrity. There are no

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big social and income differences in the community and education is widespread even among women.

- Conditional partnership with public agencies. The Al-sinah cooperation association systematically liaises with public agencies and has sought specific support for parts of its investment program where public agencies had the right thing to offer. However, the association has refrained from being automatically involved in projects.

The association also plays a role in local groundwater management. Within the area a distance between wells in the range of 500 m is observed. One striking example of the application of this rule was in the mid 1990s, when well drilling in the neighbouring hamlet was thought to threaten the sustainability of the Al-Sinah water supply well field. The association bought up some scattered fields in this neighbouring hamlet, then drilled wells there and subsequently capped the wells. Because local people respect the "500 m between wells" rule, the capped wells prevented any other water development in the area and the Al-Sinah water supply was protected.

The Al-sinah association also works together with the Taiz branch of the National Water Resources Authority (NWRA). The NWRA is (as of 2005) not issuing any well drilling permits without consulting the association and obtaining a written consent from the association. Since 2008 no more well drilling permits had been issued. The association is trying to affirm this rule by declaring the area as a protected zone. Further, to boost groundwater recharge, the al-Sinah association is working with the Social Fund for Development on the construction of a storage dam. The association has obtained the required land with its own resources. In addition the association is working with local councils to maintain and rehabilitate traditional cisterns and ponds.

Wadi Areesha, Nahem, Sana'a

Wadi Areesha is located about 70 km east of Sana'a. Until 25 years ago, groundwater was available at 50–70 m below ground level. In this region attempts to discover good quality deep groundwater have failed. However, the area still has sufficient groundwater at lesser depths and it is carefully guarded. Sana'a Basin Water Management Project implemented some activities in the area which mainly aimed to improve water-use efficiency, groundwater recharge and support for WUAs. Wadi Areesha dam is the most important water structure in the area, which was initiated to improve recharge to the mainly shallow wells in the area. In 1995, the community decided to construct Areesha dam hoping that water will re-appear in wells located downstream. The dam was rehabilitated in 2008 with support of the Sana'a Basin Water Management Project (SBWMP). Now all wells are located around the reservoir, from which water is pumped to the fields through pipes up to 4-km long. The WUA of Areesha dam undertakes operation and maintenance of the dam.

A number of rules were agreed upon. There is a ban on drilling wells too deep, with the limit set at 200 m. However, there is no restriction on the distance between wells. Another local rule is a strict ban on direct water withdrawals from the reservoir and on selling water outside the area. Tankers are not allowed into the area—neither to collect water from the shallow wells nor from the dam reservoir. The investment in wells and pipelines is collective, with groups consisting of 15–20 farmers.

Lessons from local initiatives

There are several conclusions to be drawn from these cases:

- First, there is a high level of collective local management in several cases—often introduced very recently. Communities established informal mutual agreements on local rules which consist of measures such as well spacing, closure of disputed wells, and bans on sales to water tankers. In some cases wells are interconnected. There is often considerable community effort to improve groundwater recharge. The notion that groundwater development is an individual affair is in many cases not correct: deep wells in particular are costly and are shared between a large number of farmers. In some cases several wells in a local area are connected to one another so that water can be shared in case of well failure. Some wells are not exclusive for agriculture, but instead feed local self-supply village drinking water systems—as for example in Dhelaa.
- Second, local management is in some cases encouraged by projects such as the awareness and social mobilization activities under the Sana'a Basin Water Management Project or the Groundwater and Soil Conservation Project. In other cases, communities come together after having seen disaster striking nearby areas or after having been faced with conflicts occurring in their own area. In general, such conflicts trigger a response, as in the case of Hijrat-al-Muntasir village. They are preferable to the default situation where wells continue to be developed unabatedly and the 'race to the bottom' is unchecked (van Steenbergen and Shah 2003).
- Thirdly, the Water Law and the licensing procedures imbedded in it are important, though not necessarily in a direct way. The fact that wells in principle need to be licensed has conspicuously signaled that groundwater is no longer an open access resource and restrictions should apply. This has given impetus and strength to local groundwater management. Invoking the licensing procedures under the Water Law is one of the instruments in local water management, as the case of Al Qarada shows. From the Sana'a Basin Water Management Project there are examples of villages pressuring local councils and the National Water Resources Authority to more effectively regulate and

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license. In an essentially tribal society this demand for regulation—local and central—is remarkable.

- Fourth, where local groundwater management is in place, the initiative may be taken by a local sheikh, by another respected leader or by a WUA, as in Wadi Al Zabaira. There may be many sources of local leadership, not necessarily the traditional sheikh. In Khrabat, farmers themselves established a WUA and this WUA subsequently attracted more members. Some rules may be explicit and are managed by local organizations, but other rules exist as norms and expected practices and do not require a specific organization to support them.
- Fifth, the local rules and regulations concern a broad range of measures—location and depth of wells, recharge measures, management of reservoirs and, in some exceptional cases, cropping bans. Their impact can be high and they are an important component in managing local water resources. It is in fact hard to see how groundwater use in Yemen can be regulated without it being built on a foundation of local acceptance and initiative.
- Sixth, community-based organizations take multiple forms: informal and formal, small and large, for piped domestic supply and for irrigation, and already play a significant role in water management, particularly in the operation and maintenance of piped drinking-water systems. Collective action to improve infrastructure and provide services, in water and other sectors, has repeatedly proved feasible in Yemen, but needs adequate autonomy and a supportive environment to be sustainable. The Social Fund for Development is a recent example that shows that, despite differences in wealth, power, gender, tribal identity, and other factors, communities in Yemen can deliberate and come to considered decisions about how to invest and manage in ways that are socially inclusive and emphasize serving the needs of all, including those who are poor and vulnerable (Jennings 2007; El-Gammal 2008). Local efforts could be facilitated through support by a well-managed program, with skilled field staff who are ready to listen to and work with the whole range of stakeholders, helping to make sure that benefits are not captured by a few but instead are distributed in a just manner among all stakeholders.
- Seventh, efforts for the development of agriculture and the water sector during the last 40 years were generally state centred and often ignored or disrupted local traditions of water management, attempting to install formal institutions that were often less meaningful, less inclusive, and less accountable.

Scope for improved local groundwater management in Yemen

The examples show that various forms of local groundwater regulation are feasible, and yield specific, practical benefits, such as reducing conflicts, assuring priority access to water for domestic use, and providing more equitable and reliable sharing of scarce water. However, local efforts are often constrained by various factors, including lack of technical understanding of aquifers, lack of knowledge about effective approaches, and lack of external support for enforcing rules. So, considerable scope exists to further promote community groundwater governance in Yemen. Several options can be suggested to support rural communities in improving water management:

1. Promote awareness and knowledge extension on water related issues

   Groundwater is invisible, and the ways it flows through aquifers are often slow, complex and hard to understand, making groundwater governance difficult. The intensive use of groundwater is something of the last few decades and there is no prior experience on what would constitute effective or sustainable management of groundwater, despite Yemen's long experience with locally managed governance of surface water. In both urban and rural areas of Yemen, however, there is growing awareness of the dangers of depletion, that groundwater is not a vast or unlimited sea but instead is a limited and diminishing resource, and that excessive withdrawal by users poses a shared problem that requires combined and integrated action to solve. As discussed in the previous, this has provided the basis of action in some areas and should provide the basis for action in far more areas in the country. Improving local groundwater institutions requires the facilitation of local governance processes and creation of a better understanding and awareness of the groundwater potential. Much more could be done to make hydrological information from technical studies and official monitoring programs available to water users, and to synthesize local knowledge and experience as part of participatory mapping and analysis of local conditions and options for improved water management.

   A recent synthesis of research on groundwater in the Sana'a Basin provides some useful hydrogeological information on groundwater flows. Hydraulic conductivity (except for a few outlying observations), was mostly less than 2 m/d for sandstone aquifers, and much less for alluvium and volcanic aquifers, equivalent to moving only less than a kilometre per year (Hydrosult et al. 2010). The research shows that aquifers, rather than being a single vast common pool, are instead a layered mosaic of smaller pools, interrupted by faults and other geological formations, with groundwater only flowing slowly between different areas. The implication is that local communities are the ones who most immediately suffer the impacts of high withdrawals, and correspondingly, local areas would retain most of the short- and medium-term benefits of reducing extraction, for example by shifting to more efficient irrigation techniques, and increasing groundwater recharge. The relatively small scale of short and medium-term impacts on aquifers means that the local scale of villages, districts, and small sub-basins is crucial for organizing collective action by stakeholders.

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2. Incorporate informal management into water sector formal management policies

   The importance and scope for local community groundwater management is acknowledged in the first principle in the recent Sana'a Declaration for a Yemeni Water Partnership of 2011, which was endorsed by the Cabinet of Ministers in 2011. Also it was acknowledged in professional and academic publications (Hellegers et al. 2008). More widespread engagement of local institutions for groundwater governance will provide a better foundation for peaceful negotiation and management of the challenging issues of shifting water from agriculture to urban needs, in ways fair and acceptable to all those involved. Local groundwater management needs to be more actively encouraged, and could complement other developments in water institutions in the last 10 years (such as the Water Law, National Water Resources Authority, Basin Councils and Water Users Associations).

   Various projects, including the Community Water Management Project (CBWMP), Groundwater and Soil Conservation Project (GSCP), and Sana'a Basin Water Management Project (SBWMP), have shown that water user groups and water-user associations can play an important role in efforts to improve water management (Bruns and Taher 2009). Considerable scope exists to enhance and expand such efforts, in ways that will also make them more locally sustainable, especially through greater integration with decentralized activities at the scale of local communities, sub-basins and districts. Several immediate options are:

   - Document and upscale existing examples of effective local management. Engage farmer leaders from good practice areas in spreading the message, exchanging ideas, and creating a movement of local groundwater management, particularly in the hotspot areas.
   - Integrate promotion of community groundwater management in the large ongoing irrigation programs—in particular the National Irrigation Project (NIP), the Ground Water and Soil Conservation Project, and the possible successor programs.
   - Systematically engage key support groups in the local management of groundwater, working with local councils, with security forces and with well drillers—giving examples of community water management and the provision of the Water Law. Consider supporting local associations within these groups such as drillers associations with self-regulating rules and codes of good practice.
   - Work on improving connections between the different new water management organizations (Basin Councils and WUAs) and local management of groundwater. Engage existing WUAs—including the ones created in rural water supply projects—in community groundwater management.

3. Revive and adapt customary and traditional rules

   Much of the discussion of water management has been framed in terms of technical concepts of integrated water-resources management and regulation through formal institutions. Less has been done to understand customary and religious principles applicable to dealing with increasing water scarcity (which can be seen as ways of realizing important principles of Integrated Water Resources Management (IWRM) in a locally meaningful way). The specific ways these might apply to a particular local problem are something for which local discussion and deliberation are crucial. However, in the context of Yemen, principles such as ensuring access to drinking water ("right of thirst"), using water frugally and preventing waste, avoiding harm, encouraging productive use of resources, balancing private and public interests, and assuring orderly distribution of water that respects customary norms and rights, offer powerful ideas for developing more effective, locally meaningful institutions for water governance.

   Before the advent of deep tubewells and motorized pumps, water use was inherently limited to the amounts available from spate flows, springs, rainfall, and shallow groundwater. Customary norms and rules for these water sources have been eroded or forgotten in some areas. At current rates of extraction, the fossil water in deeper aquifers will be depleted within years or decades, as has already occurred in some areas (Ward 2009). Hence, the revival of customary rules is of particular importance in areas facing severe depletion.

4. Develop simple monitoring tools for local water users

   Recent research on governance of shared resources such as groundwater has emphasized how monitoring by users is often crucial to the feasibility and success of governing commons (Ostrom 2009). A particular challenge in dealing with groundwater is that it is not visible like surface water, making it harder to understand and hard to monitor. Thus, the feasibility of management will often depend on identifying actions that can be monitored and finding rules for which violations can be easily detected and enforced, rather that attempting management that depends on extensive, and often expensive, technical analysis. Governance of groundwater is more likely to succeed if it is based on simple rules that are easy to understand and monitor, rather than complex, technically based licensing regulations. Considering the feasibility of monitoring helps to understand the measures communities have already undertaken, those that might be most likely to work, and the ways in which technical information might help to enhance understanding and governance of groundwater.

   Table 2 outlines groundwater management actions and variables that could be subject to regulation, ranked in terms of their visibility, roughly divided into three groups with high, moderate and low visibility. The table highlights in italic some actions and variables that are more visible and more likely to be influenced by intervention; these include some such as drilling of

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Table 2 Managing and monitoring groundwater: visibility and implications for local management

No.	Visibility	Variables	Examples of relevant management actions or indicators
1	High	Drilling new wells	Moratorium on new wells. Presence of drilling rig
2		Deepening or replacing existing wells	Presence of drilling rig, existing well, and irrigation
3		Spacing of wells	Minimum distance, e.g. 500 m
4		Selling water to tankers	Forbidding export. Require formal water rights and approval
5		Abstraction for domestic water	Hauled by people or donkeys; piped use can be metered
6		Crop type	Ban on bananas, alfalfa, qat or other crops with high water demand
7		Crop area	Limits on expansion
8		Water conveyance technology	Switching from canals or pipes
9		Irrigation method	Flood, furrow, basin, sprinkler, bubbler, drip
10	Moderate	Duration of irrigation	Hours, seasons
11		Fuel consumption	Volume (litres) of diesel
12		Excess irrigation	Runoff, weeds, non-beneficial evapotranspiration
13		Providing water to neighbours	Pipes, water flows
14		Community approval of well drilling	Consultation and consensus by community and local council
15		Government approval of well drilling	Licenses
16		Depth to water table	Depth (m) from ground surface
17		Well recovery rate	Time (hours) to restore static level
18		Aquifer recharge	Terracing, check dams, basins
18	Low	Quantity abstracted	Meters to measure volumes in m^3
20		Impact on other wells and springs	Drying up nearby wells or springs, cone of depression
21		Aquifer transmissivity	Lateral flow, m per unit of time
22		Aquifer storage capacity	m^3 of water per m^3 of aquifer

new wells and well spacing, that currently receive attention; some such as irrigation efficiency, that have been demonstrated to be feasible and could be further encouraged; and others such as crop type and area and recharge, that have received relatively less attention. The table also helps to point out the difficulties faced by any approach that would rely on quantitative data on withdrawals, aquifer storage and flows, due to the difficulty of observation and associated costs, technical complexity and uncertainty. At the same time, the table makes clear that there are a range of options for intervention, and overreliance on a single measure would be risky and miss important opportunities that could be gained through more diversified approaches, which communities can customize to fit local conditions.

Promote participation and inclusion

Experience in Yemen and internationally (Shah 2009; van Steenbergen 2006; van Steenbergen 2010) shows the potential for community-driven approaches, which could involve stakeholders in a sequence of practical steps, supported by information and responsive enforcement by national and basin institutions. Balancing water use with inflows, where feasible, and equitably coping with water scarcity will depend on local water-users working together, as Yemenis have done historically. The challenges are different in different locations, depending on the local community structure, its leadership and economic interests. These challenges differ between the different aquifer systems—the limestone areas, the sandstone aquifer and volcanic aquifers—as well as the coastal alluvial systems.

Table 3 Participatory water assessment (PWA)

- Initial meetings can bring stakeholders together to discuss local water problems, past efforts, and examples of what has been done elsewhere.
- Sketch maps can be used to identify water resources and problems (along with topographic maps, air photos, and remote sensing images if available).
- Trends in water use, well numbers and depths, irrigated area and other factors can be plotted on graphs and maps.
- Joint walks to observe water sources and water uses provide a way for participants to consider actual conditions and discuss problems.
- Reviewing relevant values helps identify priorities and principles that should guide the search for solutions. In the context of Yemen, important values are likely to include customary and Islamic values of assuring access to drinking water, avoiding waste and harm, orderly access, productive use of resources, and balancing of public and private interests.
- Envisioning a desirable future that could result from better management of shared resources is a crucial stage, synthesizing ideas from earlier steps, reacting to current problems and the scenarios most likely to occur if changes are not made, and coming up with feasible, desirable shared visions for a better future.
- Participants can then consider specific practical steps that they could take to respond to local problems and priorities, moving towards a future they want. This could include assuring access to adequate supplies of water for drinking and domestic use, preventing harmful changes, reducing waste, replenishing groundwater, adapting agriculture to increasing water scarcity and improving livelihoods. Discussion should emphasize what communities, at the level of households, villages, and districts could do using their own capabilities and resources, but might also identify what more they might be able to accomplish with aid from outside.
- Agreement should be established on some practical steps that communities can do on their own, deciding who will do what, and when to meet again to review progress and discuss problems, solutions and further steps that could build on initial accomplishments.
- Periodic meetings can be held to follow up on what has occurred, work out ways to deal with problems that have arisen, and take further actions to improve water management.

In all these areas the depth of aquifers differs, as does the interplay between surface and groundwater, and the interdependence between different water abstraction sites, and the pressures from rural and urban demand.

A process for supporting community water governance can be organized in a series of steps. This should concentrate at the level of villages and districts, appropriately integrated with activities at the sub-basin, governorate, basin and national scale. This could be done at relatively low cost. While key activities need to be carefully carried out, it would be feasible to scale up for widespread implementation and meaningful results with a time frame of a few years.

A community-driven process should start by working in districts where there is substantial interest from local leaders and citizens in finding better ways of dealing with water scarcity, and where some local initiatives already exist. Initial workshops and training can prepare district councillors and others to go out to communities and help them assess and improve local water management. Table 3 outlines key steps for a process of participatory water assessment.

Conclusions

Community-based groundwater management can be considered as an essential building block for efficient, sustainable and equitable use of groundwater in Yemen. The existence of examples in many parts of the country, especially in the highland areas, indicates that local rules concerning groundwater are not at all exceptional and their number might be expanded with moderate interventions at relatively low cost. Local management approaches are diverse and location specific, and good understanding of the local socio-political and economic factors should be taken into consideration in any support efforts by the formal agencies. Local groundwater management can be promoted through different tools such as extension of good practices—preferably from farmer to farmer and from community to community—providing basic technical information to understand local hydrogeology and groundwater availability, supporting local groundwater management in different water development projects and programs, providing support to establish WUAs (informal and formal), committees and community organizations and encourage their active participation in project implementations. Effective enforcement that responds to local priorities in a positive way can also be important. Local and national institutions would complement each other, working at multiple scales to inform and enable improved water management by stakeholders working together.

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