Groundwater Management in Yemen

Draft Synthesis Report

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1 Background

• Figure 1 Yemen

Yemen has a total land area of 527,970 km^2 and is located on the south-western edge of the Arabian Peninsula. It has borders with Saudi Arabia in the north, Oman in the east, the Arabian Sea and the Gulf of Aden in the south, and the Red Sea in the west. The present Republic of Yemen was formed in 1990 from the unification of the former Yemen Arab Republic and the People's Democratic Republic of Yemen.

The mainland has four distinct agro-climatic zones. To the west and south-west are relatively flat coastal plains, they are hot and arid with rainfall less than 50mm/yr. However, these plains are important agricultural areas and are crossed by numerous wadis that drain water from the adjoining Yemen Mountain Massif which rises to 3,760m above sea level. Rainfall is 300-500 mm/yr on the western and southern slopes of the massif, but it can be as much as 1,000 mm/yr in places. In the east is the Eastern Plateau. This too is hot and dry. Rainfall is rare but when it does rain it can lead to extensive flooding. In between the mountains and the Eastern Plateau is a sand desert. Rainfall and vegetation are practically non-existent except along the margins. To the north lies the Rub Al Khali desert which extends into Saudi Arabia covering some 500,000 km^2 and is one of the most inhospitable places in the region.

Yemen's population is almost 21 million (2005) with an annual growth rate of 3.2 percent. The average population density is 40 inhabitants/km^2 but most of the population is in fact concentrated in the west where rainfall is more favourable. It the rate of population growth continues then it could reach over 30 million by 2030.

Although agriculture contributes only about 10 percent towards GDP the sector employs more than 45 percent of the total economically active population and provides livelihood for more than two thirds of the population. Women are involved in nearly all agricultural activities, providing 44 percent of the population economically active in this sector. But cultural traditions keep them at a lower status and prevent them from gaining control over important household resources. The total area of cultivatable land is 1,650,000 ha, although only 1,200,000 ha are actually cultivated. Irrigated farming accounts for 454,000ha. Crops grown include staple foods such as cereals, fruit, and vegetables as well as livestock and dairy. Domestic wheat production is only about 20 percent of national demand. The rest is imported at a cost of US$315 in 2004. Food exports include Coffee, bananas, onions, and fruit.

2 Water resources and water use

Both surface and groundwater resources together with an assessment of water withdrawals are summarized from the FAO AQUASTAT data base in Table 1. Renewable surface water resources are modest at just over 2,000 MCM/yr which is the runoff from the main wadis. It does not include the smaller catchments. Renewable groundwater is estimated to be 1,500 MCM/yr which comes mainly from infiltration in the main river beds. Some 270 MCM/yr of surface water in the major wadis runs into the sea as does 280MCM of groundwater. Overall the water availability is only 97 CM/capita/yr which is well below the World Bank's water poverty level of 1,000 CM/capita/yr.

The annual water demand for domestic and industrial use, and agricultural consumption is currently 3,400 MCM/yr which far exceeds the renewable resource of 2,100 MCM/yr. As in many other countries in the region, agriculture is by far the biggest consumer of water –

over 3,060 MCM/yr which is 90 percent of total water use. Most of the water is withdrawn from groundwater – springs, wells, boreholes – and this has led to serious groundwater depletion as withdrawals far exceed annual groundwater recharge.

• Table 1 Annual water resources and water use in Yemen (from FAO AQUASTAT 2000)

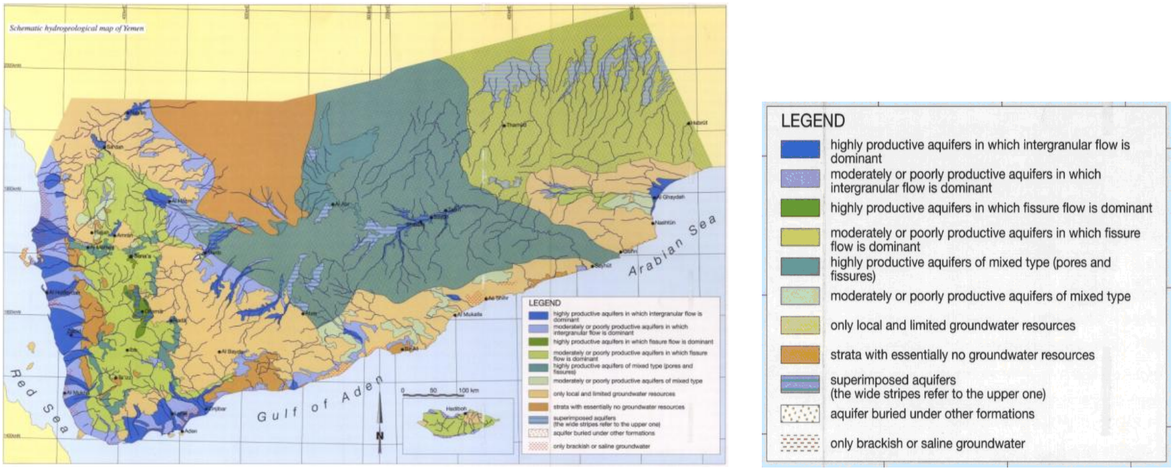
Resource	**Renewable**
Surface water (MCM)	2,000
Groundwater (MCM)	1,500
Overlap (between sw and gw)	-1,400
Total (MCM)	2,100
Dam capacity (MCM)	462
Total/capita (CM)	97
Withdrawals	
By sector	
Agriculture (MCM)	3,060
Domestic (MCM)	272
Industrial (MCM)	68
Total withdrawals (MCM)	3,400
Water withdrawal/capita (CM)	162
By source	
Surface water (MCM)	1,000
Groundwater	2,400

Wadi flood flows are the main source of surface water and this tends to be in the form of flash floods and are short-lived. Some 217,000 ha are irrigated using spate irrigation. A few of the main wadis have a base flow which is fed from groundwater having been recharged from earlier flood events. So there is significant overlap between surface and groundwater resources (Table 1). Extensive man-made terraces constructed for agriculture are very effective in slowing down the flooding and conserving surface water both for agricultural use and for recharging aquifers. Large-scale examples of runoff absorbing zones are the Tihama, the Tuban-Abyan coastal plains, and the Ramlat Al-sabatayen and Arub'a Alkhali deserts.

Yemen has a long history of capturing surface water and storing it. Early civilizations were founded on the great Ma'areb dam. More recently this was reconstructed with a storage capacity of 400 MCM. Over 1,000 small dams have been constructed by the government but their total capacity is only about 80 MCM.

3 Groundwater supply and demand

Figure 2, based on the UNESCO aquifer classification, shows the main aquifer systems that are relevant for practical groundwater abstraction down to 400-600m below ground level.



• Figure 2 The main aquifers of Yemen

This demonstrates the diversity of aquifer systems across the country and the variation in hydrogeological conditions that have led to a wide range of groundwater development systems.

Table 2 lists the main aquifer systems together with estimates of recharge, abstraction rates and groundwater storage. Highly productive aquifers exist along the coast in alluvial-filled wadis and in the fans and deltas created by the continuous process of flooding and sedimentation. Important aquifers exist in the Tihama plain, Tuban Abyan, Ahwar, and Mai'ah in the south; Ramlat-as-Sagatayn in the west and south, and the wadi Hadramout.

In the Highland Plains there are the important sedimentary aquifers in the Sadah, Amran, Sana'a, Ma'bar-Dhamar plain, and Rada Basins. They have good transmissivity and favourable recharge conditions. In the east are the Mukalla sandstones which constitute the largest aquifer complex in Yemen with moderate productivity that continues over into Saudi Arabia and Oman.

• Table 2 Abstraction, recharge, and storage in main aquifer complexes

Aquifer	**Recharge (MCM/yr)**	**Withdrawals (MCM/yr)**	**Storage (MCM)**	**Remarks**
Tiham Quaternary aquifer	550	810	250,000	Quaternary aquifer
Southern Coastal Plains	375	225	70,000	Several Quaternary aquifer units
Extended Mukalla Complex	500	575	10,000,000	Cretaceous sandstone
Highland Plains	100	500	50,000	Various isolated units
Total	1525	2110	10,370,000	

The volume of water stored in the groundwater systems (Table 2) acts as a buffer to fill the gap between abstraction and recharge. For small wadis systems the stored volume is of the same order of magnitude as the average annual recharge. Thus the buffer function is very limited. At the other end of the scale there is the Extended Mukalla Complex where the estimated total storage is substantially greater than the abstraction and so there is a considerable buffer between the two. There may well be other constraints that limit the amount of storage that can be abstracted but as yet an appropriate storage management strategy has not been worked out for the Extended Mukalla Complex, nor for any other regional aquifer system in Yemen.

3.1 Sana'a basin

One of the most studied groundwater systems is in the Sana'a basin – an inter-mountain plain located in the Central Highlands that serves Sana'a city, the capital of Yemen. The climate is semi-arid with an average annual rainfall of 235 mm at Sana'a. The geology and hydrogeology of the aquifer systems is quite complex but estimates by one international consultant in 2000 indicated that annual recharge was about 46 MCM against an annual withdrawal of 248 MCM which means there is an over-abstraction of some 202 MCM from aquifer storage. Some 205 MCM of this was for agriculture, 38 MCM for water supply and 5 MCM for industry. The total abstraction is predicted to reach 354 MCM by 2010 and 622 MCM by 2025.

This serious over-exploitation of groundwater means that water tables across the basin continue to fall at 2-6 m/yr. Plans for the next 15 years include consolidating the water scarcity awareness programme; stronger enforcement of the water laws, the introduction of a 'water cost'; continued field investigations to better understand groundwater; and consolidating research and capacity building programmes.

4 Drivers for change

Yemen's groundwater resources are finite and so the challenge facing the country in general, and Sana'a Basin in particular, is how to produce more food and enhance farmer incomes with less water while meeting the increasing demands for more water from households and industry. Competition between the sectors is increasing, the demand for improvements in efficiency are rising and so too is the pressure to more clearly define water rights. The most serious problems occur in the important basins such as Sana'a, Amran, Sa'adah, Rada'a, Rasyan, Tihama, Abyan, and Tuban where the lack of groundwater is constraining human and agricultural development.

Yemen has traditionally managed its water resources well for many centuries. Farmers terraced their land to capture rainfall and spate irrigation helped in sustaining agricultural production, control erosion, and recharge aquifers. Local water management traditions were more than adequate for water needs. However, the advent of pumping and the exploitation of groundwater resources upset the balance between available resources and economic development. Groundwater exploitation stimulated economic development but little account was taken of the finite nature of the resource. At the same time farmers abandoned their surface water management practices as they could not compete with the alternative of mining groundwater.

However, the severity of the water crisis was not felt until recently. Initially the available water resources were considered to be sufficient to meet demands. Net abstractions were not much greater than natural recharge. But the expanding population caused rapid expansion in the irrigated agriculture to satisfy the need for food and for the high value crop qat, a popular crop in Yemen. It also gave rise to increases in drinking water demands, especially in urban areas where populations increased faster as a result of migration from rural to urban areas.

The magnitude of the problem was not well understood until the groundwater levels began to fall significantly. But this did not mean less abstraction. It only served to increase pumping costs and in some cases wells just dried up or farms became unprofitable and were abandoned.

4.1 Water supply and sanitation

At present only 32 percent of the population have access to public drinking water systems and only 21 percent have access to public sanitation networks.

Existing household and industrial water supplies are far from satisfactory in the urban and industrial sectors were water losses are high – about 50 percent. These are blamed on inadequate management and poor maintenance. However, as these represent only 10 percent of water use it is argued that strategies to improve water use efficiency in agriculture can generate most benefit.

Data on domestic water use were not available in the Country Report but the government is taking steps to gradually move away from the role of sole investor and service provider towards that of facilitator and regulator. In urban water supply, a reform program is underway to decentralize responsibility to locally accountable utilities that will ultimately become self-financing. In rural water supply, the government still retains a strong involvement because of the poverty reduction mandate, but is increasingly promoting decentralized approaches, and involving beneficiaries in funding.

Desalination is one option for urban water supply and in 2002 the total installed gross desalination capacity was 28 MCM/yr. More will be needed to offset the decline in groundwater availability.

Waste water treatment is also causing concern. Treatment plants are concentrated in the cities and have difficulty coping with the increase in demand. For example, the treatment plant for Sana'a city was designed for 25,000 CM/day but it now has to deal with more than 50,000 CM/day. The Ministry of Agriculture and Irrigation considers this water to be harmful and it should be appropriately treated in a way that prevents environmental pollution.

4.2 Agriculture

Yemen has a free market in agricultural products (except for the importation of qat). The country profits from its comparative advantage by importing much of its cereals requirements and using its scarce water to produce higher value crops. The profitability of agricultural production and the consequent good performance of the agricultural economy in recent years has been driven by policies that have promoted the development and use of water resources. These policies, particularly energy policies, have contributed greatly to the recent strong growth of agriculture (5.5% average annual growth rate 1996-2000) and of agricultural employment (growing at 4% a year). However, these policies, coupled with the poor extension service to increase water-use efficiency in irrigation, have also encouraged over-abstraction of groundwater.

Agriculture is the largest water consumer – 90 percent of annual water withdrawals. Reports suggest that water use efficiency is only about 35 percent and this is often cited as the main reason for unsustainable water use. Poor efficiency is blamed on unclear water rights which leads to unregulated abstraction, fuel subsidies and low import duties on agricultural equipment, high returns on cash crops, and inefficient irrigation practices. Efforts to improve irrigation efficiency have targeted conveyance efficiency rather than the adoption of a comprehensive on-farm water management approach, which would have been more effective at preventing unproductive non-consumptive losses such as excessive evaporation. However, it is not all bad news. Water wastage from irrigation can mean good return flows to the aquifers and this is not usually taken into account. The efficiency focus is on the farm rather than at basin level.

Savings in agricultural water consumption are seen as one way of providing more water for domestic use. However, transferring water from one sector to another is not without problems. In the absence of a system of generally accepted and legally protected water rights, sectoral water shares are determined by resource capture. Administrative reallocations involving forcible appropriation of water resources by urban water utilities have not worked in the past and have only served to delay water availability to cities, leading in some cases (such as Taiz) to a water crisis. There are also tribal divisions to

consider as well as the rapidly changing social landscape as urban populations grow into the rural areas (as in Sana'a). It is clear that any future institutional arrangements for meeting the growing water needs of municipal and industrial sectors would have to be based on agreement between concerned parties, especially inhabitants of neighboring rural areas that will provide water to the cities.

Valuable groundwater continues to be used to produce high value crops but the revenues that farmers often make are not usually invested in their farms. Rather they invested in fixed assets such as new houses and real-estate. The large capital generated by transforming groundwater into qat – a high value social crop that takes up about 50 percent of the irrigated area – or similar high-value cash crops could be redirected towards local sustainable economic activities that are not dependant on intensive water use and that can generate income in these regions when the aquifers become exhausted.

4.3 Environment

Groundwater pollution has not yet received much attention in Yemen. Groundwater quality has not been studied in great detail in terms of its suitability for intended use as irrigation water or drinking water. Nor has groundwater pollution. But this is not to say that it is not important. Cities and industries discharge untreated domestic and industrial wastewater in peri-urban areas. While dangers of urban wastewater pollution are more visible, there is also a potential pollution hazard to aquifers from untreated wastewater from rural settlements.

Groundwater pollution in urban zones is already occuring. Sewage water from Sana'a is leaking from stabilization ponds into the groundwater near Rawda. Nitrate levels in deep groundwater used for domestic purposes in Sana'a city are above normally accepted concentrations (105-160 mg/l) and are associated with high chloride levels and high EC values. Water recycling is not a general practice in the industrial sector, which in many cases chooses to acquire additional water supplies instead.

Saline intrusion is also a problem along the coastal areas. A recent study in Al-Jar in the northwest of Yemen some 8km away from the Red Sea, mentioned that the EC increased from 225 to 3,480 µs/cm (at 25°C) due to sea water intrusion into the aquifer. During the past 10 years there has been huge investment in this area leading to the cultivation of more than 3,500 ha of mango trees and the drilling of about 2,000 wells.

In order to protect vulnerable areas the government, in 2002, passed a decree proclaiming Sa'dah, Sana'a and Ta'iiz as protected areas and handed the responsibility for monitoring these critical areas to the National Water Resources Authority (NWRA).

5 Groundwater management

Confronted with the challenge of managing acutely scare groundwater resources, the government first sought technical solutions and the development of new resources. But this has now changed to an integrated water management approach that includes both a basin approach and self regulation by groundwater users. Experience in other countries such as Turkey, Philippines, Mexico, and Columbia, have shown that involving communities in dealing with scarce water resources and transferring responsibility for water management to end users can greatly improve resource use efficiency.

The National Water Resources Authority (NWRA) has started the process and regional water management plans have been prepared for Taiz and Hadramawt basins, and are nearing completion for Tuban-Abyan and Sa'adah basins. The pace of plan preparation is slow, in part because technical capacities for integrated water resources management are still weak, and the infrastructure to gather information (such as hydro-meteorological

monitoring network and reliable water quality labs) is either non-existent or has only very limited coverage. Technical support is needed from other countries, which have successfully implemented such approaches.

5.1 Institutions and regulatory framework governing groundwater

Since reunification of the country in 1990, notable progress has been made towards improving water sector governance. This includes the consolidation of water management functions under the National Water Resources Authority (NWRA set up in 1995), and the formation of the Ministry of Water and Environment (MWE in 2003) with most water sector agencies administratively linked to it. This resulted in the water sector as a whole, and water management in particular, gaining representation at government cabinet level. The responsibility for irrigation, however, which represents 90 percent of water use, remains with the Ministry of Agriculture and Irrigation (MAI). But MAI continues to be heavily focused on surface water infrastructure development rather than on groundwater use.

After a prolonged process of consensus building, in 2002 Yemen enacted water legislation to provide a legal basis for controlling groundwater withdrawals. It includes measures like licensing and registration requirements for wells and drilling rigs, and more strict control regimes in water stressed catchments. The Water Law also supports decentralization by encouraging the formation of basin committees, and this means working closely with Local Councils to implement water management measures. But for all of this to translate into effective water management, communities have to be mobilized in support of the water resources management plans. Without their consent, water plans and policies cannot be implemented since implementation mechanisms work through a bottom-to-top approach. 'Basin co-management', whereby stakeholders and state institutions forge a partnership for managing water resources at catchment level is seen as the way forward. But as yet only the Basin Committee in Sana'a has been formed. Further developments are constrained by the limited local presence of the NWRA.

In the agricultural sector community based water management is seen as a key to improving water use efficiency. Pilot projects are now underway to support the formation of Water User Associations to empower farmers to take responsibility for improvements in water management which can lead to increased productivity and improved farm incomes.

Recently the National Water Resources Authority started a programme of registrations and licensing for the water well drilling companies. But records show that up to May 2005 only 70 rigs were licensed and only 1,000 wells were registered and licensed.

5.1.1 Groundwater monitoring

Monitoring climate data and resource information is essential for good planning and management of resources. But monitoring networks do not yet have a long tradition in Yemen. Even rainfall, which in many countries has been systemically observed for more than a century, was only recorded at seven stations prior to 1960. New stations installed in the 1960s and 70s have gaps in the records and some have been abandoned.

There is a strong correlation between population density and rainfall monitoring station density. The density of rainfall stations is also influenced by the expected rainfall amounts. And this is one of the reasons why there so few rainfall stations in low rainfall zones such as the coastal plains.

There are only a few groundwater level monitoring networks and most are in the major wadis in the Sana'a, Sadah, and Marib basins. Groundwater quality has not studied in

great detail. However, most resources studies have measured groundwater quality in terms of its suitability for irrigation or drinking water. Many electrical conductivity measurements have been made for this purpose in almost all parts of the country and so there is a reasonable picture emerging about groundwater quality.

The hydrological and meteorological networks are not operated centrally. Local and regional networks are run by different organizations. Most of the stations started as project stations and where then transferred to the government agency that commissioned the project. As a result there is not yet any national standardization of equipment and monitoring practices.

6 Future perspective

The Yemen government is pursuing a growth oriented strategy to produce more locally grown food and expand urban and rural water supply to accommodate the rapidly growing urban and rural populations and improve health conditions.

To achieve this Yemen has formulated the National Water Sector Strategy and Investment Program (NWSSIP) to overcome its critical water shortages and the potential risk of groundwater contamination and degradation from unregulated wastewater disposal. This was initiated in 2003 following the re-organization of the water sector and included a multi-stakeholder process to prepare a consolidated strategy, action plan, and investment programme for the water sector as a whole. Essentially it involves making better use of existing groundwater supplies including artificial recharge and demand management, seeking alternative sources such as desalinated water, and re-using wastewater. In the medium term the plan is to give priority to potable water supplies and to manage groundwater storage depletion for irrigation on the basis of the national development plans.

The critical water situation clearly calls for a review of agricultural policy and a reconsideration of some old concepts about self-sufficiency and food security, especially in the light of new developments in world trade. Furthermore, export-crop farming needs to planned with water as the limiting resource considering that what is being exported is in fact water. Agricultural extension needs to be stronger in order to improve irrigation efficiency. Small agricultural industries are needed at least to substitute imported manufactured products such as juices and similar agricultural-based commodities. Also, higher yield crops that use less water should be encouraged and efforts made to increase the value added to farm produce so that farmers can afford to buy modern water-saving irrigation networks.

Desalination is seen by some as a magical solution to water scarcity, while others see it as an expensive technology, especially when the desalinated water needs to be transported over long distances or pumped to high altitudes. But this is likely to become an essential part of a wider water resource provision particularly for urban coastal communities.

But the pace of planning is slow, partly because technical capacity is weak and there is a lack of infrastructure to gather information. Indeed the shortage of qualified people will be a major constraint to the development of the water sector as a whole.

Yemen also faces the challenge of decentralizing its water services with more responsibility being passed to local authorities and to Water User Groups in the agricultural sector. In 2002 World Water Vision identified a number of key questions that Yemen will need to answer:

- Will decentralization and democratization empower communities to select their own level of water services?

- Will the trend towards transferring management of water systems to water users continue, and will these users be assigned stable water user rights?
- Can governments and service providers form effective public-private partnerships and develop a service-oriented approach to water management, accountable to users?
- Will Yemen be prepared to adopt integrated approaches to land and water management?
- Will it serve to reinforce or decrease farmer dependence on the government?
- What incentives and accountability mechanisms need to be put in place to motivate and enable farmers to finance most, if not all, of the cost of their irrigation systems?
- Will members of WUAs have access to credit?
- What kind of agricultural extension, marketing, and agri-business development strategies are needed in order to improve the profitability of irrigated agriculture?

The future success of groundwater management will depend on the answers to these important and wide ranging questions that go well beyond the influence of the water sector.

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