Republic of Iraq

Ministry of Water Resources

General Directorate for Water
Resources Management

Strategy for Water and Land Resources in Iraq

Technical Report Series

Groundwater

TR 06

This document was prepared under the Agriculture Reconstruction and Development Program Strategy for Water and Land Resources in Iraq Component (RAN-C-00-4-00002-00) by Development Alternatives Inc, August 2006.

This document is one of a series of technical reports published by the Ministry of Water Resources addressing issues relevant to strategic planning for the sustainable use of the water and land resources of Iraq.

The technical report presents key challenges and issues facing Iraq related to groundwater.

Report Issue and Revision Record

Rev	Date	Description
P1	August 2006	Preliminary when Phase 1 curtailed

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1 Introduction

1.1.1 There are a number of key references relating to groundwater in Iraq. While being methodical and substantial in the material, the Russian report from 1980s is somewhat outdated and in need of a revision. A more recent work was reported by FAO especially in the NE Iraq. A recently published ‘Geology of Iraq’, a joint effort edited by Jassim and Goff, brought a more recent description of groundwater in Iraq. There is however a need for a document summarising the resource status and listing the key references accessible to both technical users and water managers who are not necessarily groundwater specialists.

1.1.2 This technical note is therefore intended to provide a summary of the historical and current information available on groundwater in Iraq that would enable non-specialists to quickly develop an understanding of groundwater in Iraq. It should also identify the key places to obtain further information.

2 Key Challenges Facing Groundwater in Iraq

2.1.1 The concepts of integrated water resources management are underpinned by the axiom that the separation of groundwater and surface water is an artificial, although often useful, separation. Thus the hydrogeology and groundwater resource development potential can be examined in terms of its interaction with surface water in the relation to irrigation and drainage, potable water supply and sustaining the requirements of the natural environment.

2.1.2 The present total area irrigated in Iraq by surface waters covers only about 25% of Iraq. The river and irrigation systems are critically important sources of potable water in areas where groundwater is unavailable at a quality or in quantities that can support human activity. Groundwater has therefore has the potential to play an important role in the development and in sustaining the environment of the remaining 75% of the country.

2.1.3 Over the course of the project the following key challenges and issues facing Iraq relating to groundwater were highlighted:

- The use of groundwater varies considerably across Iraq, with some regions being solely dependent on groundwater, where as others are predominantly supplied by surface water.
- It appears that groundwater is being used increasingly as a water resource in preference to surface water.
- Unsustainable groundwater abstraction rates have resulted in significant falls in the water level in some areas. As a result many wells have gone dry, or have had to be deepened.
- There are also challenges from groundwater quality, both in terms of salinity, and other types of pollution.

From UN report, 1982:

2.1.4 Generally the cost of groundwater (per m^3) is relatively high owing to the depth of wells and the cost of maintenance. It is emphasised that a large number of new drilled wells are dry or are characterised by a small yield. Many of these wells become dry after a period of time. The water is often highly mineralised and has to be treated before use

2.1.5 The problem of desalination of groundwater has not been dealt with, but it should be possible to solve in 10-15 years time. Solving the problem would be of particular significance in respect to the vast region of Mesopotamia. We note that no real progress has been made in dealing with this issue.

From [Jassim and Goff, 2006]:

2.1.6 In the Mesopotamian Plain most surface water is used for irrigation. Seepage of water from canals or during irrigation raises groundwater levels which can cause soil salinisation when the so-called "critical depth" to groundwater level is reached. During hot seasons water rises to the root zone or surface by capillary action. Evaporation then leads to salt accumulation in the soil. During the rainy season the salt is leached and transported downward by percolating water towards deep groundwater bodies where the salinity continuously increases. To prevent soil salinisation, groundwater levels must be lowered below the "critical depth" by drainage.

2.1.7 We note that more modern strategies tend to focus on water availability and salinity in the root zone and the potential contribution of sub-irrigation with the intention of avoiding the capital cost and increased irrigation demands associated with over-draining. A further consideration is whether a drainage outlet or a salt sink is available and whether ultimately salt is retained within the irrigated area or exported. Exports into the irrigation system, whether by artificial drainage or by regeneration of river flows can promote upstream versus downstream conflicts amongst water users as well as being ecologically unsustainable.

3 PREVIOUS STUDIES

3.1.1 The hydrogeology of Iraq has been documented through a series of major investigations carried out in the past and this report draws heavily on them since no original fieldwork has been carried out. The major investigations and publications (in chronological order) are:

- Parsons, R.M. 1955. *Groundwater Resources of Iraq.* The Ralph M Parsons Company.
- USSR 1982. *General Scheme of Water Resources and Land Development in Iraq.* Volume 1, Book2, Geological and Hydrogeological Conditions. Produced through collaboration between the Ministry of Irrigation in Iraq, and the USSR.
- UN 1982. *Groundwater in the Eastern Mediterranean and Western Asia.* Natural Resources/Water Series No. 9. United Nation Publications.
- FAO, 2004. *Hydrogeology of Northern Iraq.* FAO publications, Rome. We have also looked at data collected in relation to the FAO programme for well-drilling undertaken between 2000 and 2003.
- Jassim A.Z. and Goff, J.C., 2006. *Geology of Iraq*. Dolin Publishers, Prague.

4 HYDROGEOLOGICAL PROVINCES

4.1.1 Iraq belongs to two major hydro-geological provinces, the Nubi-Arabian Provinces and the Taurus Zagros Province [Jassim and Goff, 2006].

4.2 Nubio-Arabian Province

4.2.1 This is made up of the Nubio-Arabian platform comprising of crystalline ("hard") rocks and an unfolded/gently folded sedimentary cover.

4.2.2 Regional groundwater flow occurs in the extensive Mesopotamian aquifer mega system. Intensive groundwater flow occurs in the upper part of the mega system, especially in its SW and NE flanks where several basin-wide aquifer systems or sub-systems with relatively independent groundwater flow occur. The discharge zone of the whole mega system is in the Mesopotamian Zone.

4.2.3 The Mesopotamian Aquifer Mega system of the Nubio-Arabian Groundwater Province consists of five hydrogeologic sub units:

1. The Aquifer System of the Western and the Southern Desert (south-western artesian basin)

2. The Jezira Hydrogeologic Region

3. The Aquifer system of the Mesopotamian Plain, including the Baquba-Tikrit region. The Fatha (Lower Fars) formation outcrops in the Tigris valley in the north or in the Jezira area between the Euphrates and the Tharthar.

4. The Aquifer systems of alluvial fans, Mandali-Badra-Tib Region. The alluvial fans occur along the foot of the mountains along the Iraqi-Iran frontier in southern Iraq. They comprise gravely and sandy sediments deposited by braided rivers. Most of them are hydraulically connected to the Mesopotamian Plain system, except for the series of fans of Mandal-Badra_tib which are hydraulically separated from the plain by low permeability sheet run-off deposits. The lower distal parts of these aquifer systems lie within Iraq, while the proximal higher parts mostly lie within Iran. Groundwater replenishment originates from river-influent seepage where river courses run across elevated outcrops of alluvial fan deposits. In other areas groundwater bodies are fed mostly by precipitation. Groundwater flows regionally from elevated areas of coalescing alluvial fans to the SW or S. Groundwater discharge occurs in the distal portions of the alluvial fans by springs, by the drainage effect of rivers and by evaporation and transpiration

5. The Aquifer System of the foothills, including Erbil-Kirkuk artesian basin. The Aquifer system of the Foothill zone covers a vast NW-SE trending area of approximately 37000 km2. To the east and in central Iraq the area extends up to the border with Iran. In N and NE Iraq it forms a boundary with the high folded zone. The hydraulic parameters vary due to variations in lithology and aquifer thickness. Regional groundwater flow prevails in the Foothill aquifer system, mostly with well-defined regional discharge zone along the main left-bank tributaries of the Tigris River, e.g., the Lesser Zab and Diyala. In addition to the hydraulic boundaries along river courses, structural geological elements (anticlines, faults) often form regionally important hydrogeological boundaries. There are a number of aquifer sub-systems.

4.3 Taurus Zagros Province

4.3.1 A mountain province including a group of Zagros and Taurian Artesian basins. Is located in intensively folded and thrusted rocks, It contains small aquifer systems in hard rocks, clastics and karstified carbonates mostly with local, confined, relatively shallow groundwater flow. However, some of these aquifers act as an external recharge zone in the Mesopotamian Aquifer Megasystem, especially through deep-seated, regional groundwater flow.

4.3.2 Groundwater flow: The occurrence of crystalline rocks and frequent lithological changes result in spatially limited aquifer systems. Therefore no significant regional groundwater flow. Extremely high heterogeneity and anisotropy of karst aquifers that result in uneven regional distribution of karst springs and large differences in the productivity of water wells.

4.3.3 Groundwater recharge is solely due to percolation from precipitation. Discharge takes place in the form of springs in lows and also along the contacting with less permeable rocks [USSR ,1982].

4.4 Principal aquifers

4.4.1 Lithological and structural geological conditions determine the spatial distribution and extent of hydrogeological bodies (aquifers, aquitards) and their hydrogeological environment.

4.4.2 In Iraq fourteen main aquifers/aquifer groups, identified by their relationship to geological formations, can be defined. The surface and near-surface distribution of these aquifers within Iraq is shown in Figure 1.

5 POTENTIAL FOR GROUNDWATER EXPLOITATION

5.1 Introduction

5.1.1 Table 1 outlines the key properties of the hydrogeological provinces and sub units of Iraq.

5.1.2 Figure 2 shows the depth of the water table from the surface.

5.1.3 Figure 3 shows the groundwater salinity of shallow groundwaters.

Table 1: Groundwater Potential and Provinces of Iraq (information from [Jassim and Goff 2006] and [UN, 1982].

	Sub-Hydro-geological Region	**Groundwater Depth**	**Salinity**	**Aquifer**	**Depth of Wells (m)**	**Specific Yield (l/s/m)**	**Transmissivity (m^2/day)**
Major Hydrogeological Region Nubio-Arabian Province	Western and Southern Desert	Depth increases westwards from 10m along the Euphrates to >250m near the Saudi border.		Dibdiba (Miocene-Pliocene)	70-100		
				Limestone(Eocene-Paleocene)	(50-100)-(200-300)	2-5	300-500
				Sandstone(Cretaceous and Older)	150-300	0.02-0.06	300-500
	Jezira Hydrogeologic Region	Generally 10-20m in the central part of the Abu Rassain High, 5m in the main discharge area of the Tharthar lake and less than 1m near salt playas.	Usually 3-5 g/l, but in the discharge area near the salt lakes, the salinity increases to 20g/l.	Lower Fars (Miocene)	20-50		
				Upper Fars (Miocene)	20-50		
	Alluvial fans Mandali-Badra-Tib Region	Greater than 35m in the upper parts of the fans.	Relatively low salinity. The salinity is 1-7g/l increasing from NW to SE		Sand-gravel fan deposits	1-5	Variable (1000-2000 m^2/day where great aquifer thickness. Can be less than 40m^2/day.
	Foothills Aquifer System	Depth to groundwater often varies significantly over short distances due to variable topography. Generally 20-30m	Freshwater, of <1g/l salinity, dominates the eastern part of the Foothill Zone. Irrigation water, of < 3 g/l, exits in other parts. Within the foothill aquifer system, from north to south, the salinity increases from <0.5 g/l to 6 g/l	Bakhtiari (Pliocene and Pleistocene)	10-40	7-20	1,000
				Fars (Miocene and Eocene)	5-20	0.1-0.3	70-80
	Mesopotamian Plain, including the Baquba-Tikrit	Very Shallow (<1m) in the area south of Kut. 1-5m between Kut and Baghdad.	Salinity increases in the central, topographically lower, plain. It is greatest in the southeast.	Quaternary	1-5		
Taurus-Zagros Belt			Dominated by freshwater of <1g/l salinity.	Limestone (Cretaceous)	20		
				Clastic (Cretaceous)	3-5	1-1.5	
				Alluvium			

5.2 Western and Southern Deserts

5.3 Jezira Hydrogeologic Region

5.3.1 The discharge of wells within this zone is generally very low, and many wells have been abandoned. However, near the Tigris and the Tharthar valley there is a possibility of better well yields (up to 30 l/s). [Jassim and Goff 2006].

5.3.2 Despite the relatively high salinity of groundwater (3-5g/l), in most of the region the groundwater has been used for irrigation and watering livestock. This is outside international guidelines but it seems that local sheep breeds can tolerate water with a salinity of up to 12g/l. At depths greater than 25m the salinity increases sharply from 3g/l to over 30g/l. Wells should not be drilled into this saline zone. [Jassim and Goff 2006]

5.4 The Aquifer Systems of Alluvial Fans, Mandali-Badra-Tib Region

5.4.1 The alluvial fans have a high importance for groundwater supply. Hydrogeologically, the fans are complicated aquifers due to their stratification, variable lithology and uneven recharge. Aquifers occur close to the mountain range where the fan deposits are coarsest. The highest transmissivities (1000-2000 m^2/day) occur where the aquifer thickness is highest. More typically the transmissivity is between 300-500 m^2/day, for example in the Mandali area and in the Badra-Zurbatiya area. [Jassim and Goff 2006]

5.4.2 Detailed investigations showed that safe yield assessments of 370 l/s in the Mandali alluvial fan and 256 l/s in the Badra-Zurbatiya fans [Jassim and Goff 2006]. In the foothill area to the southeast, where precipitation is much lover, safe yield estimates may be lower.

5.5 The Foothill Aquifer System

5.5.1 The foothill aquifer system is the most promising hydrogeological unit for regional scale groundwater development in Iraq. The aquifers have an estimated sustainable discharge of between 10 and 40 m^3/s, at depths of 5-50m [FAO Aquastat info on Iraq]. In the north and northeast, groundwater recharge is 2-5 l/s km^2 [Jassim and Goff 2006]. However, pumping in “close-to-river” zones, where induced groundwater resources are formed, can increase the recharge.

5.5.2 Groundwater quality in many areas is adequate for water supply as potable and irrigation water. However, quality is not so good in the south and west, and in places groundwater development is impossible for this reason. Even in areas where groundwater quality is acceptable, excessive pumping can cause intrusion from below during the decline in water head. Thus knowledge of vertical changes in groundwater quality is important where heavy pumping is planned.

5.5.3 The other issue with groundwater development arises because of the high transmissivity. The high transmissivity means that excessive groundwater drawdown could easily occur. Knowledge of the rate of groundwater recharge is therefore of vital importance for future groundwater development assessment.

5.6 Mesopotamian Plain

5.6.1 Upper parts: are favourable for exploitation – well discharge and transmissivity are reported to be high in many areas. The upper aquitard occurring beneath most of the plain protects the lower groundwater body from pollution

5.6.2 Lower Parts: too saline for use. However, in some “close to river zones” influent seepage from rivers or irrigation canals occurs during pumping. However salt-water encroachment from adjacent and deep-seated aquifers into the pumped groundwater body may take place.

5.6.3 Storage of groundwater, compared to surface water storage in artificial reservoirs allows between water quality protection and prevents evaporation losses

5.6.4 Artificial recharge can also improve groundwater quality – under suitable natural conditions, following sufficient pumping, fresh water may extend beyond the close-to-river zone. [Jassim and Goff 2006].

5.6.5 The aquifers on the right bank of the Euphrates River are found at depths of up to 300m, and have an estimated discharge of 13m3/s. Salinity varies between 0.3 and 0.5mg/l [FAO Aquastat info on Iraq].

5.7 Taurus-Zagros Belt

5.7.1 The potential for groundwater extraction is erratic due to the heterogeneity of the karst aquifers. Thus large groundwater withdrawals are often limited to small sites at high-yield karst springs.

5.7.2 However, some of the large cities at the boundary with the adjacent Foothill aquifer system are supplied from wells drilled into the Pila Spi aquifer. There are also important alluvial aquifers along large rivers.

5.7.3 Recently an ambitious FAO project was carried out in the Taurus-Zagros Province and extensive parts of the Foothill aquifer system. By March 2003 about 500 water wells were drilled, capable for pumping 3000 l/s for irrigation and livestock breeding purposes.

6 EXISTING GROUNDWATER USE

From UN report, 1982:

- In around 1950 only a modest number of wells had been drilled in the northern, western and central parts of Iraq. In 1953 – 1957, on the basis of the data which were then available, and at the request of the government, the Ralf Parsons Engineering Company prepared an over-all description of the hydrogeological conditions in Iraq.
- Between 1960 and 1980 more than 2,500 wells were drilled by different government organisations and foreign firms. The majority of the wells were suitable for exploitation. The number of hand-dug wells may be several times greater than that of drilled wells.
- Although surface water is the main source of water supply in Iraq , groundwater is an essential source of supply in the desert areas (which cover about 58% of the country) and some parts of Jezireh and the foothills. Groundwater represents the most important factor for the development of areas in the western desert in the future
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Information obtained through discussions with the Iraqi visitors to Cambridge and from Dr Sadik, of the Groundwater Studies Centre, Baghdad:

- Groundwater use in Iraq is small in proportion to surface water, but is more important in rural areas. It may be the only practical source of water in large areas of the country.
- There is a perception that groundwater is currently used mainly in the northern governorates including Erbil and Sulaymaniyah.
- Groundwater is also used where surface water is not readily available e.g. in Najaf, Anbar and Muthanna governorates.
- There are wells located in other governorates.
- There is no recent estimate of groundwater use for drinking. Older estimates (2000) mentioned an annual use of about 2×10^9 m^3 of which we assume a proportion is returned to the rivers or to groundwater and the remainder is lost by evapotranspiration.
- Both deep (up to 150m depth) and shallow hand-dug wells are used.
- There are a high proportion of private wells (records can be prepared upon request to the general directorate of well drilling).
- There is no sign that groundwater exploitation has been increased in the majority of Iraq. However, the representative from the Ministry of Agriculture and Water Resources in Erbil suggested during the Study Visit that there had been a considerable expansion in groundwater use in parts of Kurdistan as the technology became available and the need for self sufficiency increased and other economic opportunities decreased with the political upheavals following the first Gulf War.
- Groundwater is used for both agriculture and drinking water.
- Wells pump only a few hours a day. Estimates place maximum pumping hours to 16 but on average 8 hours or less a day. Pumping from shallow wells could be as much and as long as deep wells. Normally flow rates for shallow wells do not exceed 15 l/s. Deep wells could reach up to 25-30 l/s. An average shallow well will discharge 5-6 l/s and in areas shallow wells don't produce more than 3-5 m^3/hr. There are no abstraction records maintained. Irrigation area per well varies between 1 to 10 hectares.

7 INSTITUTIONAL ARRANGEMENTS AND GROUNDWATER

National, Governorate, Province, District, Ministries, private/informal sectors.