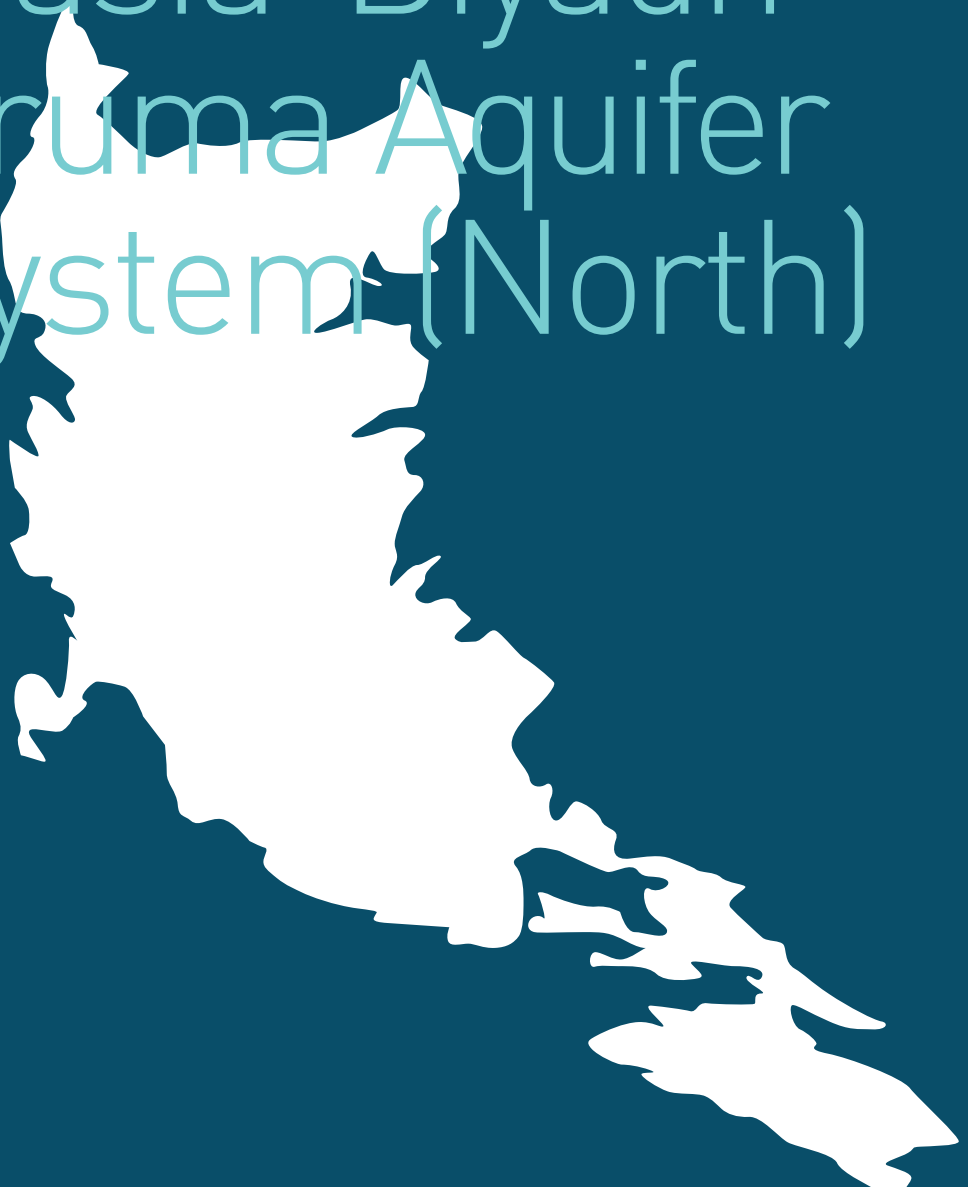
Chapter 13

Sakaka-Rutba

Wasia-Biyadh-Aruma Aquifer System (North)



INVENTORY OF
SHARED WATER RESOURCES IN WESTERN ASIA (ONLINE VERSION)

How to cite
UN-ESCWA and BGR (United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe). 2013. Inventory of Shared Water Resources in Western Asia. Beirut.

Wasia-Biyadh-Aruma Aquifer System (North)

Sakaka-Rutba

EXECUTIVE SUMMARY

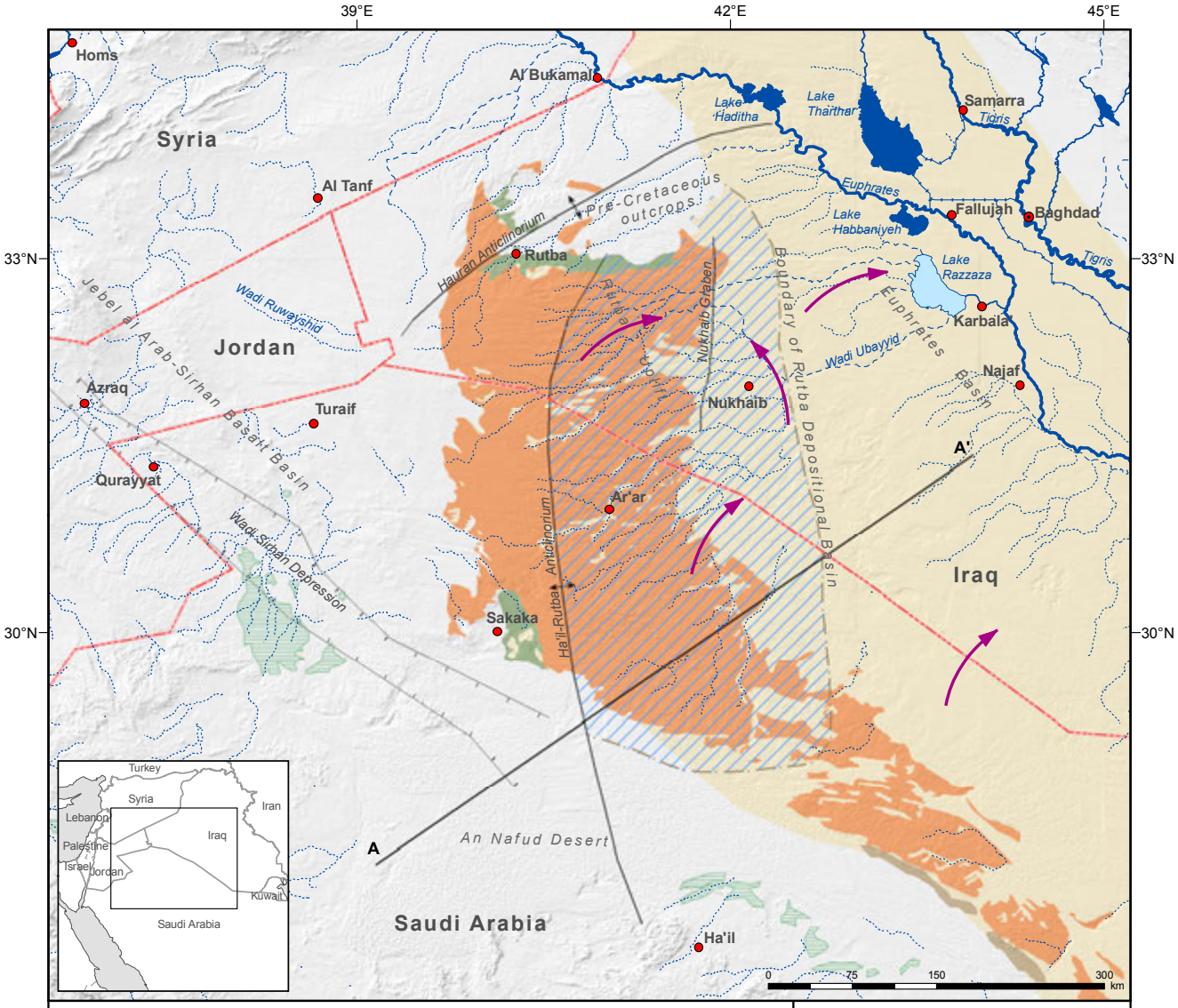
The Wasia-Biyadh-Aruma Aquifer System (North) lies on a high plain (400-800 m) that extends across the western Rutba High in Iraq and the Widyan Plain in Saudi Arabia. Also referred to as Sakaka-Rutba, the Wasia-Biyadh-Aruma Aquifer System (North) constitutes an important aquifer system in the area with freshwater flowing through six aquiferous units (Rutba-Ms'ad-Hartha-Tayarat in Iraq and Sakaka-Aruma in Saudi Arabia). Exploitation depth ranges between 200 and 400 m bgl.

The use of this aquifer system is currently limited due to its remoteness and the harsh environment in the area but the towns of Ar'ar and Sakaka in Saudi Arabia and Rutba in Iraq presumably rely on the aquifer system for their water supply. The Wasia-Biyadh-Aruma Aquifer System (North) is a promising aquifer system that could be used to encourage agricultural development in this pediment region, especially around the wadi areas where soils are fertile.

BASIN FACTS

RIPARIAN COUNTRIES	Iraq, Saudi Arabia
ALTERNATIVE NAMES	Iraq: Rutba-Ms'ad-Hartha-Tayarat Saudi Arabia: Wasia Group Sakaka-Aruma
RENEWABILITY	Very low to low (0-20 mm/yr)
HYDRAULIC LINKAGE WITH SURFACE WATER	Weak
ROCK TYPE	Mixed
AQUIFER TYPE	Unconfined at/near outcrop areas Confined further away
EXTENT	~112,000 km^2
AGE	Mesozoic (Middle to Late Cretaceous)
LITHOLOGY	Sandstones, locally calcareous or argillaceous
THICKNESS	Iraq: 250 m Saudi Arabia: 400 m
AVERAGE ANNUAL ABSTRACTION	≥ 30-35 MCM
STORAGE	..
WATER QUALITY	Fresh to slightly brackish (400-3,000 mg/L TDS)
WATER USE	Domestic and irrigation
AGREEMENTS	-
SUSTAINABILITY	-

OVERVIEW MAP



Wasia-Biyadh-Aruma Aquifer System (North): Sakaka-Rutba

- Capital
- Selected city, town
- International boundary
- River
- Intermittent river, wadi
- Canal
- Saltwater lake
- Freshwater lake
- A A' Geological cross-section
- Sakaka/Rutba-Ms'ad outcrop
- Aruma/Hartha-Tayarat-Digma outcrop
- Wasia-Biyadh outcrop
- Approximate subsurface extent of the aquifer formations
- Approximate extent of exploitable area
- Direction of groundwater flow
- Zone of agricultural development (selection)
- Graben
- Anticline

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Inventory of Shared Water Resources in Western Asia

Disclaimer
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

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The Wasia-Biyadh-Aruma Aquifer System in this Inventory

The Wasia, Biyadh and Aruma Formations extend across the Arabian Peninsula over a distance of about 2,400 km from north-eastern Iraq to the southern coast of the peninsula, with a width that varies between 350 km and 1,450 km and covering a total area of about 1,923,000 km^2 (see 'Overview and Methodology: Groundwater' chapter, Map 1).

The large geographical extent and the lithostratigraphic variations within the formations suggest that they can be divided into three sections, as described below:

- **In the northern section**, the Biyadh Formation disappears completely, while the Wasia (known in this area as the Sakaka)[1] forms an aquifer system with the overlying Aruma Formation that continues across the border into the Rutba area in Iraq (see current chapter).[2]

- **In the southern section** near Wadi Dawasir, the sandstones of the Biyadh and Wasia grade together with the Aruma to form a thick sandstone unit, known as the Cretaceous Sands,[3] which extends to the Yemeni border. The stratigraphically correlatable sandstones across the border are known as the Tawila Group in Yemen.[4] This section is presented in Wasia-Biyadh-Aruma Aquifer System (South) Tawila-Mahra/ Cretaceous Sands (see Chap. 12).

- **In the central section**, both the Wasia and Biyadh Formations are present and constitute one aquifer system inside Saudi Arabia, which may extend as far east as the western boundary of the Shu'aiba Formation. Beyond that, the two aquifers are separated by the well-developed dolomitic limestone of the Shu'aiba.[5] The Wasia Aquifer extends to Bahrain where it is currently not used due to high salinity and excessive depth. Hence, while the central section of the Wasia-Biyadh is a major aquifer system inside Saudi Arabia, it is not considered a shared aquifer.

The Tuwaiq Escarpment, An Nafud Desert, Saudi Arabia, 2006. Source: Marcel Baptiste.

Introduction

LOCATION

The Wasia-Biyadh-Aruma Aquifer System (North) lies beneath a high plain across the north-western border between Iraq and Saudi Arabia (the Widyan Plains-Rutba Uplift). The general location of the aquifer system is defined by the boundary of the Rutba depositional basin in the east, the Jebel al Arab-Sirhan Basalt Plateau in the west, the An Nafud Desert in the south, and the Pre-Cretaceous outcrops in the vicinity of the Hauran Anticlinorium, which limits the northern extension of the aquifer (See Overview Map).

AREA

This chapter focuses only on the small area in the northern section of the aquifer system that is considered to be shared. The aquifer system was delineated on the basis of available information, resulting in an area of around 112,000 km^2, of which 49,000 km^2 lies in Iraq and 63,000 km^2 in Saudi Arabia. This area extends along the arid western part of the Iraqi-Saudi border, which consists of a pediment plain (serir)[6] known as the Widyan[7] Plain in Saudi Arabia and the Western (Rutba) Desert in Iraq. South of the border, this high plain, which is between 400-800 m asl, dips gently north-eastwards with a gradient of 10-20 m/km from the great An Nafud Desert into south-central Iraq towards the Euphrates River at an elevation of 100-200 m asl.[8]

CLIMATE

The Western Desert along the Iraqi-Saudi border is characterized by low precipitation (50-100 mm/yr) and very high surface evaporation (2,500-3,000 mm/yr).[9] Precipitation is extremely variable in time and space, and may sometimes exceed 40 mm in 24 hours. The maximum daily recorded precipitation at some stations exceeds the total recorded amount during a whole dry year. Most precipitation occurs in the form of sudden downpours, which reduces evaporation rates and hence induces recharge.

Average temperatures in the Rutba district in Iraq drop to 2°C in winter and reach 38°C in summer.[10] In the Saudi part of the basin, temperatures range between 8°C in winter and 41°C in summer time.[11]

POPULATION

This aquifer system lies in one of the least populated areas in Western Asia with population densities ranging from 2-5 inhab./km^2 in Saudi Arabia to 6-25 inhab./km^2 in Iraq.[12] Total population within the delineated area is estimated at around 420,000 people. The three main towns are Rutba (55,000 inhabitants) in Iraq,[13] and Sakaka (197,000 inhabitants) and Ar'ar (165,000 inhabitants) in Saudi Arabia.[14] In addition, a few thousand nomads move freely across the borders and are mostly based in the Al Ruwayshid[15] area in Jordan.

OTHER AQUIFERS IN THE AREA

Fractured limestones and sandstones of Paleozoic to Mesozoic age (Muhaiwir, Mulussa, and Ga'ara Formations in Iraq; Jawf and Juba Formations in Saudi Arabia) are exploited in the northern and southern parts of this area respectively. These formations are exploited as local aquifers around the towns of Sakaka[16] and Rutba[17] but there is no information that suggests that they extend in between to constitute a shared aquifer system.

INFORMATION SOURCES

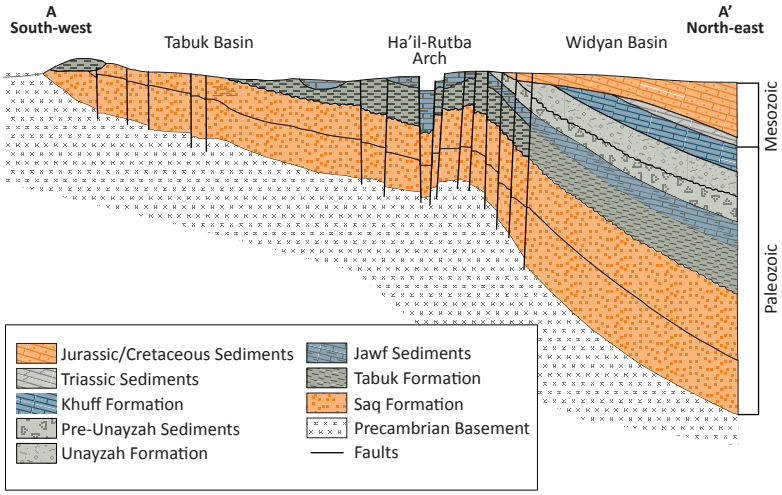
Most of the hydrogeological information used in this chapter comes from Iraq, while no recent sources were available in Saudi Arabia. Hardly any information is available on water use from the Wasia-Biyadh-Aruma Aquifer System (North). The Overview Map was delineated based on several references from both riparian countries.[18]

Hydrogeology - Aquifer Characteristics

AQUIFER CONFIGURATION

The northern section of the Wasia-Biyadh-Aruma Aquifer System stretches across the Widyan-Rutba Plateau. Geologically the Widyan-Rutba area developed as a depositional basin, and is distinct from the Tabuk Basin to the west, from which it is separated by the Ha'il-Rutba Arch and associated faults (Figure 1). The Ha'il-Rutba Arch is the longest arch in Western Asia, extending across the Arabian Peninsula from the northern border of Saudi Arabia into Iraq. It is covered by 4-6 km of Paleozoic-Mesozoic clastic sediments.[19] The arch was mainly formed during the Cretaceous-Early Tertiary due to the northward extension of the Ha'il Arch from northern Saudi Arabia into Iraq where it joined with the Rutba High.[20] North of the border, the Rutba area is part of a high carbonate plateau, which is separated from the low karstified Paleogene carbonate and gypsum to the east and south-east by a low depression filled with Pleistocene gravel. This is known as the Nukhaib Graben.[21] The Rutba High resulted from a huge uplift (known in Iraq as the Rutba Uplift) that was active between late Permian and Paleogene (Eocene) time.[22] Figure 1 shows that while the Jurassic/Cretaceous Formations, which include the Sakaka-Rutba Aquifers, constitute thin units in faulted areas, their thickness increases significantly towards the north where they are no longer confined within fault zones. Towards the east and west, the Wasia-Biyadh-Aruma (North) Aquifer System is overlain by up to 300 m of younger sediments of Paleogene and Neogene age (see Chap. 16), while in the north older pre-Cretaceous rocks crop out due to folding by the Hauran Anticlinorium.

Figure 1. Generalized lithostratigraphic cross-section of the Widyan and Tabuk Basins



Source: Redrawn by ESCWA-BGR based on Alsharhan and Nairn, 1997.

Table 1. Lithology of the formation units in the Wasia-Biyadh-Aruma Aquifer System (North)

COUNTRY	FORMATION	LITHOLOGY	COMMENTS	SOURCE
Saudi Arabia	Sakaka (Wasia)	Fine- to medium-grained, cross-bedded sandstone, siltstone, and shale.	Main aquifer; outcrops form a rough, maturely dissected plateau with scattered hills near the town of Sakaka.	Ministry of Agriculture and Water in Saudi Arabia, 1984.
	Aruma	Mainly shallow water limestone locally replaced by dolomites, with impure dolomite and shale occurring in the upper units.	Crops out for 1,600 km beyond the Sakaka-Rutba area across central Saudi Arabia, with outcrops decreasing in width from 200 km at the Iraqi-Saudi border to 20 km in the Rub'al Khali area.	
Iraq	Rutba	Fine- to coarse-grained, cross-bedded quartz sands, which are locally calcareous or argillaceous.	Main aquifer; equivalent to the Sakaka Sandstone of the Wasia Group; passes laterally into the Ms'ad Formation.	Jassim and Buday, 2006a.
	Ms'ad	Alternating siltstone, marl and sandstone with beds of limestone and dolomite.	Conformably overlies the Rutba Formation throughout its outcrop area and entirely replaces it 140 km east of the town of Rutba.	
	Hartha	Marl, dolomite and dolomitic limestone beds comprising stacked 10-15 m thick cycles of cross-bedded calcareous sand-stone.	Partly correlates with the Aruma Formation.	
	Tayarat	Rubbly, porous, chalky limestone, locally dolomitized and sandy.	Upper part of the formation in the western areas is replaced by the phosphatic Digma Formation.	

Source: Compiled by ESCWA-BGR.

STRATIGRAPHY

Table 1 gives a brief description of the formations that constitute the Wasia-Biyadh-Aruma Aquifer System (North). A lithostratigraphic correlation of the formations is shown in Figure 2.

AQUIFER THICKNESS

In Saudi Arabia, the Sakaka Formation is thickest near the town of Sakaka where the exposure is 285 m thick. The formation thins in the north-east towards Iraq, where a thickness of only 40 m has been recorded beneath the Trans-Arabian Pipeline (Tapline). The Aruma is also thickest just west of the town of Sakaka where it reaches a thickness of 145 m.[23] In Iraq, the Rutba Formation is 30-40 m thick near the town of Rutba and thins to the east due to its transition into the Ms'ad Formation.[24]
The thickness of the Ms'ad Formation varies from 45 m near Rutba to 97 m about 140 km east of the town. A thickness of 160 m has been recorded for the Hartha Formation about 40 km east of Rutba. South of the town of Rutba, however, its thickness is significantly reduced to 35 m compared to 48 m for the Tayarat Formation in the same area. The thickness of the Tayarat increases towards the east, reaching about 350 m near the town of Ansab.[25]

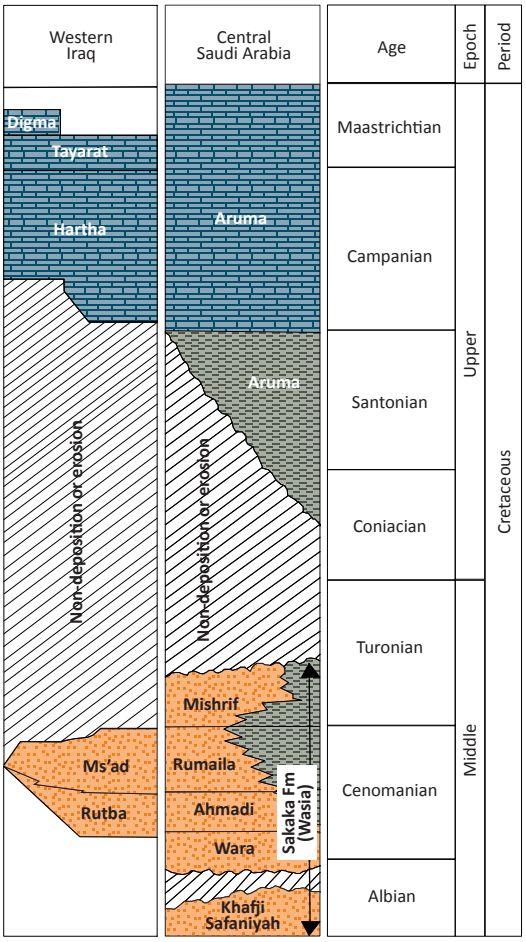
AQUIFER TYPE

In Saudi Arabia, unconfined conditions exist at or near the outcrop areas of the main aquifer units and flowing artesian conditions are found farther away.[26] Artesian conditions are related to the overlying fissured limestone of the Umm er Radhuma Formation and, in some areas, the Sakaka-Rutba Sandstones.[27] In Iraq, all formations within this aquifer system are predominantly confined.[28]

AQUIFER PARAMETERS

Data on the hydraulic parameters of this aquifer system is very scant. The limited information available from the Sakaka area (1978 data)[29] indicates that transmissivity of wells in the outcrop area ranges between $3x10^{-4}$ and $2.8x10^{-3}$ m^2/s, and the storage coefficient lies between $6.7x10^{-4}$ and $9.8x10^{-4}$. Transmissivity values in the Rutba area have been recorded for the Cretaceous and the underlying older rocks. Different studies obtained a range of $3.5x10^{-3}$ to $5.8x10^{-3}$ m^2/s and $2.8x10^{-3}$ to $6.9x10^{-3}$ m^2/s.[30] These values are similar to those obtained for the Sakaka area. However, transmissivity values of $4.0x10^{-2}$ to $1.0x10^{-1}$ m^2/s may be found in karstified areas.[31]

Figure 2. Lithostratigraphic correlation of the formations in the Wasia-Biyadh-Aruma Aquifer System (North)



Source: Redrawn by ESCWA-BGR based on Alsharhan and Nairn, 1997; Jassim and Buday, 2006b; Jassim and Buday, 2006a.

Hydrogeology - Groundwater

RECHARGE

Although the occurrence of direct replenishment of the aquifer system from rainfall would seem unlikely in this arid environment, several factors suggest that restricted quantities of recharge water may be reaching the aquifer system in localized areas within the basin, either directly from rainfall or indirectly via wadi beds and fractured zones:

- The occurrence of numerous faults and wadi systems would enhance the percolation of surface water, particularly Wadi Hauran along the Hauran Anticlinorium that is cut by several faults.
- The basin is a high carbonate plateau and the shallow formations overlying the main aquifer are mainly fractured carbonates with very high permeability that may allow for the percolation of surface water.[32]
- The presence of relatively shallow bicarbonate-dominated groundwater with low salinity (<1,000 mg/L) near the town of Rutba, which lies on the crest of the Hauran Anticlinorium, indicates that recharge takes place in this area.[33]
- Isotope data shows that many groundwater samples from the Rutba area contain tritium concentrations up to 70 TU, which means that present-day recharge water must be percolating into the aquifer system.[34]

Thus the aquifer system may presently be replenished with limited quantities of water. It is estimated that a total recharge of 242 MCM/yr takes place through the Hartha and Tayarat Formations.[35] No recharge data exists for the Rutba, but it is likely to be significantly less due to the very limited exposure of this formation. No information is available for the Saudi Arabian part of the aquifer system.

FLOW REGIME

In general, groundwater in the Wasia-Biyadh-Aruma Aquifer System (North) flows in a north-easterly direction towards its final outlet in the Gulf and the coastal plains. The Sakaka-Rutba area has not been subject to heavy abstraction that could influence this natural groundwater flow and, hence, the piezometric surface faithfully reflects morphology, which allows the groundwater to move across the border in a north-easterly direction. An exception occurs in the vicinity of the Nukhaib Graben where groundwater from the Rutba Uplift flows mostly towards the graben en route to its final discharge zone, the central depression in the Mesopotamian Plain.

In the Sakaka area, the depth to water increases northwards and in 1979 the static water level was 200 m bgl at the town of Sulaymaniya near the Iraqi border.[36] North of this, in the Rutba area across the border, the static water level was still 200 m bgl in 2006, which would indicate that groundwater levels have not changed significantly in about 25 years.[37] In the Nukhaib area to the east, the depth to water is less than 200 m bgl while in the Rutba area farther west it drops to 300 m bgl. The depth of exploitation bore-holes ranges between 200 and 400 m bgl. The relatively shallow groundwater in the Sakaka-Rutba Basin can most easily be tapped along the eastern margin of the basin.[38.]

STORAGE

It was estimated that the total volume of water with acceptable quality (TDS = 2,000 ppm) that can be extracted from a depth of 300 m in the Wasia-Biyadh Aquifer System in Saudi Arabia is in the order of 500 BCM.[39] The volume of groundwater stored in the Sakaka-Rutba area is expected to be significantly less than this figure, although no information could be found on either the volume of water in storage or how much of it is extractable.

DISCHARGE

The only evidence of natural discharge is in the Nukhaib Depression around the town of Nukhaib, with discharge following the main direction of faults in the area. Groundwater flowing into the depression from elevated areas forms an elongated north-west/south-east sabkha or mudflat upstream of Wadi Ubayyid. Otherwise the water stays underground until its final discharge zone, the central depression in the Mesopotamian Plain.

WATER QUALITY

In general, groundwater of acceptable quality can be found in the Sakaka-Aruma and younger rocks in the southern part of the basin as well as in underlying older formations that are preserved in the basin.[40] Groundwater in this section is fresh in the south (Sakaka area) and becomes slightly more brackish towards the north (Rutba area) as described below.

The Sakaka area

Based on 1978 data, groundwater in this sub-zone was found to have a TDS range of 400-1,800 mg/L.[41] The lowest salinity (TDS = 400-600 mg/L) was obtained from wells in the outcrop area of the Sakaka Formation around the town of Sakaka. Dominant cations and anions were shown to be sodium-calcium and chloride-sulphate respectively, and some of the water had an unusually high concentration of magnesium (Mg). Farther north, towards the Iraqi border (Ar'ar-Jalamid area) the TDS increases to 1,000-1,800 mg/L. This increase in salinity was observed in wells drawing water from the Aruma Formation. Water in these wells is calcium-sulphate type changing to sodium-sulphate with increasing mineralization.

The Rutba area

Groundwater in this area has a TDS range of <1,000-3,000 mg/L[42] although it may be over 4,000 mg/L in the Tayarat and Hartha Formations, especially in the southern part.[43] The lowest salinity values occur in the recharge areas around the towns of Rutba and Nukhaib. The groundwater is suitable for domestic use, irrigation and watering livestock.[44]

Recent data indicates that salinity may have increased across the aquifer system as shown below:[45]

- **Rutba Formation:** 1,000-6,000 mg/L TDS
- **Hartha Formation:** 1,500-5,500 mg/L TDS
- **Tayarat Formation:** 1,500-4,000 mg/L TDS

EXPLOITABILITY

West of the Ha'il-Rutba Arch, the productivity of the Cretaceous Formations is very limited and highly unpredictable[46] due mainly to facies change as the formations become phosphatic towards Jordan and marly or argillaceous farther north towards Syria.[47] Furthermore, this part lies mostly within the Central Hammad hydrogeological region, where groundwater is stagnant[48] and the Cretaceous Formations act as an aquitard.[49]

- **Depth to top of aquifer:** The depth of exploitation bore-holes (200-400 m bgl) is significantly less than 2,000 m.[50]
- **Depth to water level:** The depth to water was reported to be 200 m bgl (2006 data) in the area around the border; no data was available from other areas.[51]
- **Water quality:** TDS values of groundwater (<1,000-3,000 mg/L) are within the selected upper limit of 10,000 mg/L.[52]

Hence the aquifer system is exploitable mainly east of the Ha'il-Rutba Arch (see Overview Map), over an area that was estimated to be around 87,000 km^2, of which 35,000 km^2 lies in Iraq and 52,000 km^2 in Saudi Arabia.

Artificial lake near Dumat al-Jandal, Saudi Arabia, 2006. Source: Walter Callens.

Groundwater Use

GROUNDWATER ABSTRACTION AND USE

The main abstraction of groundwater probably occurs around the towns of Ar'ar and Sakaka in Saudi Arabia and Rutba in Iraq, where water is used for domestic and irrigation purposes. In addition, the aquifer system is the main water source for the nomadic populations and their livestock. In the central area of the aquifer system within Iraq, some 40 wells abstract 30-35 MCM/yr of water.[53]

No data is available on the total volume of water abstracted in the entire area. However, considering that 1,000 m^3/cap./yr is the recommended agricultural water requirement[54] and assuming that abstraction is halved due to the lack of adequate water infrastructure, water abstraction is estimated at 200-300 MCM/yr.

GROUNDWATER QUALITY ISSUES

There are no water quality issues, except for the possible increase of salinity with depth in the future, if wells are deepened to the pre-Cretaceous Formations underneath.

SUSTAINABILITY ISSUES

At present, there are no sustainability issues within the area of the aquifer system, and none are foreseen in the near future.

An Nafud Desert, Saudi Arabia, 2004. Source: Banco de Imágenes Geológicas.

Agreements, Cooperation & Outlook

AGREEMENTS

There are no water agreements in place for the northern section of the Wasia-Biyadh-Aruma Aquifer System which is shared between Iraq and Saudi Arabia.

COOPERATION

No information was available regarding cooperation between the riparian countries on the aquifer system.

OUTLOOK

The Wasia-Biyadh-Aruma Aquifer System is a promising aquifer system that could be used to encourage agricultural development in this pediment region, especially around the wadi areas where soils are fertile.

The desert between Sakaka and Tayma, Saudi Arabia, 2006. Source: Walter Callens.

Notes

1. The name Sakaka Sandstone has previously been used for a Devonian Formation now called the Jubah Formation. The Sakaka Sandstone referred to in this chapter is part of the Cretaceous Wasia Group.
2. Christian, 2000. This aquifer system also extends to the Hammad regions of Syria and north-eastern Jordan where the equivalent formations (Ajlun and Belqa) act as an aquitard (Barthelemy et al., 2010) (A1/A6) or contain stagnant groundwater (BGR and ACSAD, 1984) with high salinity (Margane et al., 2002) (A1/B7). They will therefore not be considered in this chapter. Area calculations are made within the boundaries of Iraq and Saudi Arabia.
3. Ministry of Agriculture and Water in Saudi Arabia, 1984.
4. Van der Gun and Ahmed, 1995.
5. Othman et al., 1986.
6. The Arabic word "serir" literally means "bed", and is used to describe a flat plateau area.
7. The name Widyan (plural of wadi) reflects the fact that thousands of shallow wadi channels oriented down-dip are found on this pediment that is covered with desert pavements of cherry gravels (Vincent 2008).
8. Jassim and Buday, 2006b.
9. Krasny et al., 2006.
10. Central Organization for Statistics in Iraq, 2012.
11. Central Department of Statistics and Information in Saudi Arabia, 2011; El-Nesr et al., 2010.
12. CIESIN, 2010.
13. Central Organization for Statistics in Iraq, 2010.
14. Central Department of Statistics and Information in Saudi Arabia, 2004.
15. SIWI, 2000.
16. Abunayyan Trading Corporation and BRGM, 2008.
17. Krasny et al., 2006.
18. Ministry of Agriculture and Water in Saudi Arabia, 1984; Jassim and Buday, 2006b; Krasny et al., 2006; and Abunayyan Trading Corporation and BRGM, 2008.
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48. ACSAD, 1983.
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50. Krasny et al., 2006.
51. Ministry of Agriculture and Water in Saudi Arabia, 1984, Krasny et al., 2006.
52. Ibid.
53. Jawad, 2011.
54. SIWI, 2000.

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