Chapter 24

Jezira Tertiary Limestone Aquifer System

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

german cooperation
DEUTSCHE ZUSAMMENARBEIT

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

ESCWA
United Nations Economic and Social Commission for Western Asia

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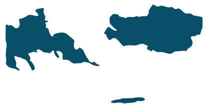


Jezira Tertiary Limestone Aquifer System

EXECUTIVE SUMMARY

The Jezira Tertiary Limestone Aquifer System (JTLAS) comprises two Paleogene Formations: an Eocene (main aquifer) and a Lower Oligocene Formation. It extends from the Jezira Plain on Syria's northern border (Upper Jezira area) into the south-eastern Anatolian Highlands in Turkey.

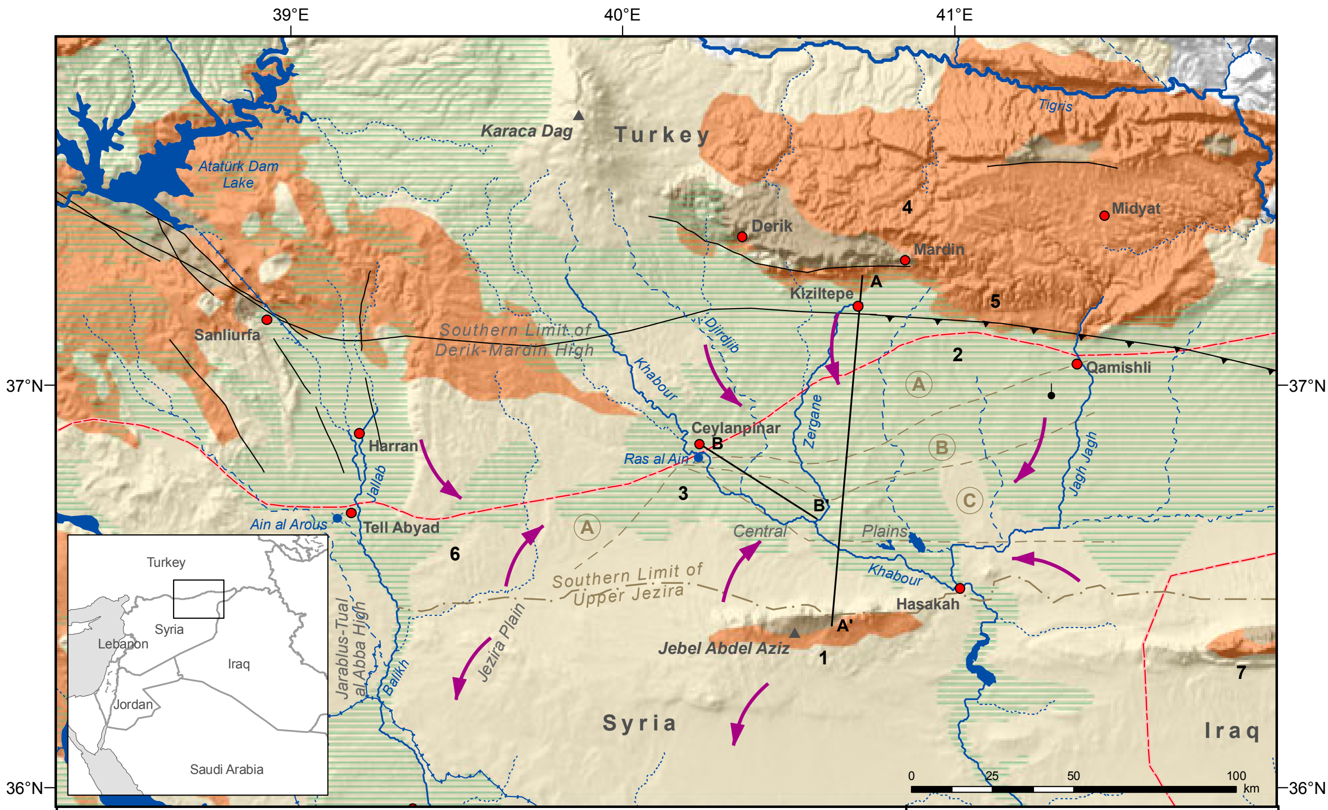
Large volumes of groundwater flow from recharge areas in the highlands to groundwater discharge areas along the Syrian border, where many springs, most importantly the Ras al Ain and Ain al Arous Springs, discharge from the aquifer system. Until approximately 2000, these springs discharged a total volume of more than 1,200 MCM and formed the principal source of surface flow in the Balikh and Khabour Rivers, which are the main tributaries of the Euphrates River in Syria.

In recent years, there has been a significant shift away from rain-fed irrigation to groundwater irrigation in the area and today almost 6,000 wells (around 2,000 in Turkey and 4,000 in Syria) abstract about 3,000 MCM/yr of water from the aquifer system. These high abstraction levels have significantly affected the groundwater regime and led to a dramatic decrease in springs discharge. Thus the springs at Ras al Ain, which used to supply 87% of the total discharge from the aquifer have practically dried up.

BASIN FACTS

RIPARIAN COUNTRIES	Syria, Turkey
ALTERNATIVE NAMES	Turkey: Midyat Aquifer
RENEWABILITY	Medium to high (20 - >100 mm/yr)
HYDRAULIC LINKAGE WITH SURFACE WATER	Strong
ROCK TYPE	Karstic
AQUIFER TYPE	Confined
EXTENT	14,000 km^2
AGE	Tertiary (Eocene to Oligocene)
LITHOLOGY	Limestone
THICKNESS	200-300 m ≥700 m in the east
AVERAGE ANNUAL ABSTRACTION	3,000 MCM
STORAGE	7,400 MCM
WATER QUALITY	Fresh (220-700 mg/L TDS) to saline (1,400-4,700 mg/L TDS)
WATER USE	Mainly agricultural/domestic
AGREEMENTS	-
SUSTAINABILITY	The springs which used to feed the Balikh and Khabour Rivers have dried up

OVERVIEW MAP



Jezira Tertiary Limestone Aquifer System

- Selected city, town
- International boundary
- River
- Intermittent river, wadi
- Canal, irrigation tunnel
- Spring
- Bore-hole
- Freshwater lake
- Direction of groundwater flow
- Groundwater quality zones:
  - (A) Fresh Ca-HCO_3 type water
  - (B) Brackish $CaSO_4$ type water
  - (C) Saline NaCl-CaCl type water

- Ecocene; Oligocene outcrops of the aquifer system
- Pre-Eocene Formation outcrops
- Approximate subsurface extent of the aquifer system
- Zone of agricultural development (selection)
- A_A' Hydrogeological cross-section
- Faults
- Mountain

Specific features:

1 Jebel Abdel Aziz Anticline
2 Qamishli Anticline
3 Ras al Ain Anticline
4 Mardin Anticline
5 South Mardin Fault Zone
6 Tell Abyad Anticline
7 Sinjar Anticline

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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Introduction

LOCATION

The Jezira Tertiary Limestone Aquifer System is situated beneath a plateau area, which stretches from northern Syria into south-eastern Anatolia in Turkey. It extends across the Upper Jezira Basin, in the area between the towns of Qamishli, Hasakah and Tell Abyad in Syria, and Sanliurfa and Kiziltepe in Turkey as shown in the Overview Map (see also Figure 1).

AREA

The Upper Jezira Basin lies to the south of the mountains of the Derik-Mardin High between the Euphrates and Tigris Rivers. It comprises plains at altitudes of 350-500 m asl, most notably the Harran, Ceylanpinar and Kiziltepe Plains, which merge into the vast Upper Jezira Plateau. The mountain chain is dominated by the Karaca Dag volcanic massif (altitude: 1,919 m asl), which is adjoined in the west by a zone of hills north of Sanliurfa, and in the east to the highlands between Mardin and Midyat (altitude: 1,000-1,254 m asl). Various streams flow south from the mountain area and converge in the Upper Jezira Plain to form the Balikh and Khabour tributaries of the Euphrates River.

The Jezira Tertiary Limestone Aquifer System covers an area of 14,000 km^2, of which 8,500 km^2 lies in Syria and 5,500 km^2 in Turkey. The following main geo-physiographic features were used to delineate the aquifer system: the Balikh River in the west, the Jagh Jagh River in the east, the South Mardin Fault Zone and the southern limit of the Derik-Mardin High in the north, and the Jebel Abdel Aziz Anticline in the south.

CLIMATE

The southern part of the Jezira Tertiary Limestone Aquifer System lies in a semi-arid climatic zone, while the northern mountainous part reaches into more humid climatic zones. Average annual precipitation varies from around 300 mm in the south to 800 mm at the top of the Karaca Dag Mountains. A mean annual precipitation of 450 mm may be assumed for the catchment area.[1] Precipitation is concentrated during the cool winter season (0°C-10°C). No rain falls during the summer season when temperatures rise between 30°C and 45°C. Mean annual potential evaporation is 1,000-1,300 mm.[2]

POPULATION

In Syria, the Jezira Tertiary Limestone Aquifer System extends over the governorates of Hasakah and Raqqah. A total of 1.2 million people live within the boundaries of the delineated basin, of which 90% live in Hasakah Governorate.[3] In Turkey, the aquifer system extends over the provinces of Mardin and Sanliurfa. A total population of 1.8 million lives in the districts of these provinces that fall within the delineated basin, of which 62% live in Sanliurfa.[4]

OTHER AQUIFERS IN THE AREA

In Syria and in the plains of Turkey, the Jezira Tertiary Limestone Aquifer System is covered by aquiferous Miocene to Quaternary Formations, most notably the Upper and Lower Fars Aquifer System (see Chap. 25). In the Kiziltepe Plain in Turkey, the main exploited aquifer is made up of Pliocene-Quaternary talus and conglomerate deposits.[5] In the Syrian Jezira, the extensive Pliocene-Quaternary Radd Aquifer adjoins the Jezira Tertiary Limestone Aquifer System in the east. Collapse structures which developed in the Miocene Lower Fars gypsum aquifer serve as groundwater discharge funnels from the underlying Jezira Tertiary Limestone Aquifer System.

The Cretaceous Formation that underlies the Jezira Tertiary Limestone Aquifer System is found at great depth (≥1,200 m) and has hydrocarbon indications and saline groundwater, which limit its exploitation and means that it cannot be considered a productive aquifer.[6]

INFORMATION SOURCES

Hydrogeological interest in the Jezira Tertiary Limestone Aquifer System developed mainly because of the discovery of one of the largest karst springs in the world in the Ras al Ain area.[7] Hence most of the information collected on the aquifer system over the past 50 years comes from this area. The Overview Map was delineated based on various local and regional references drawn from both riparian countries.[8]

Hydrogeology - Aquifer Characteristics

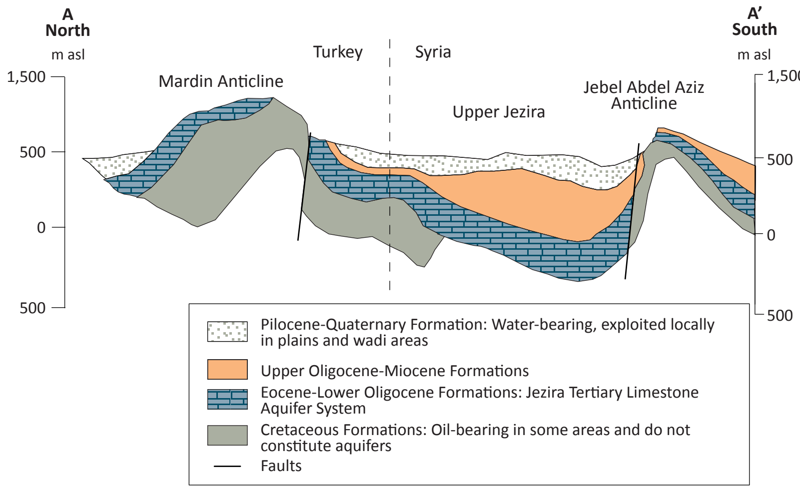
AQUIFER CONFIGURATION

The Jezira Tertiary Limestone Aquifer System is exposed on the surface in the highlands in the northern part of the catchment. The aquifer is covered by volcanic rocks in the Karaca Dag Mountain area and by Miocene to Quaternary sedimentary deposits in the plains to the south. The top of the aquifer system descends from more than 1,000 m asl in the outcrop areas in the highlands to 200-400 m asl in the border area between Syria and Turkey.[9] The aquifer system again appears on the surface in the core of the Jebel Abdel Aziz Anticline on the southern margin of the Upper Jezira. However, this area is assumed to be situated outside the catchment of the Jezira Tertiary Limestone Aquifer System.

The lower boundary of the aquifer system consists of an aquitard of marls and marly limestones of Upper Cretaceous (Maastrichtian) to Paleocene age. The top of the aquifer system is formed by the overlying volcanic rocks in the Karaca Dag Mountain massif and by confining layers of Neogene age in the plain areas. The lateral boundaries are defined by:

- To the north, the South Mardin Fault Zone and the southern limit of the Derik-Mardin Uplift[10] where outcrops of the underlying Upper-Cretaceous-Paleocene aquitard (Pre-Eocene on the Overview Map) are found in some areas.
- To the south, the northern limit of the Sinjar Trough in Iraq,[11] where fault-related structures – most notably the Jebel Abdel Aziz-Sinjar Anticlines – and the general bedding of the geological formations suggests groundwater flow towards the south (see Overview Map and Figure 1).
- To the east, the Jagh Jagh River, where the Paleogene sediments drop down to great depths,[12] suggesting that the river channel may represent a fault.
- To the west, the Balikh River which also seems to represent a fault bordering the Jarablus-Tual al Abba High.[13]

Figure 1. Generalized hydrogeological cross-section along the Jebel Abdel Aziz-Mardin Anticlines

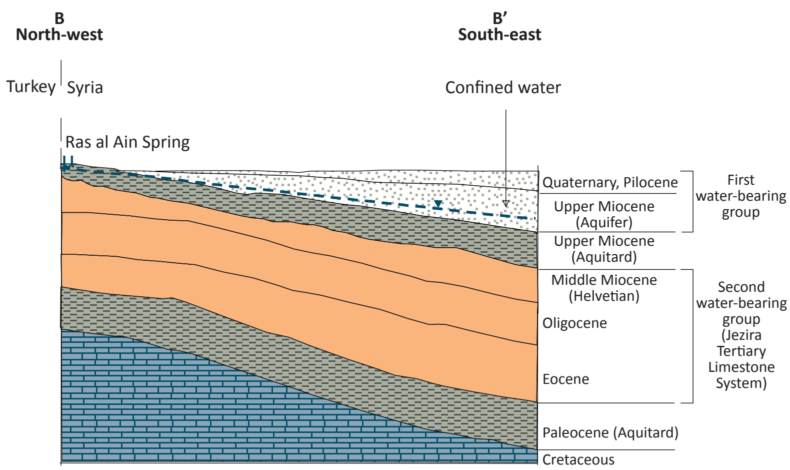


Source: Redrawn by ESCWA-BGR based on FAO and UNDP, 1966.
Note: The figure shows the position of the Eocene Formation (Jezira Tertiary Limestone Aquifer System) with respect to other formations in the Upper Jezira Basin.

STRATIGRAPHY

The Jezira Tertiary Limestone Aquifer System consists of three formations as shown in Figure 2: two karstic formations that constitute the main aquifers and a massive formation in the middle that is water-bearing, mainly in tectonically active faulted areas. A brief description of these formations is given in Table 1.

Figure 2. General stratigraphy of the Ras al Ain area



Source: Redrawn by ESCWA-BGR based on ACSAD et al., 2003.

Table 1. Lithostratigraphy of the Jezira Tertiary Limestone Aquifer System

PERIOD	LITHOLOGY	COMMENTS
Helvetian (Middle Miocene)	Sandstones and limestones with some dolomites; commonly fissured and karstic.	Exposed widely in Turkey and in the Ras al Ain Anticline area where it was tapped by shallow wells.
Oligocene	Massive and marly limestones with some dolomites and marly dolomites.	Usually not water-bearing but locally acts as part of the aquifer system near faults and folds, especially in a narrow belt along the border from Qamishli to Ras al Ain.
Middle to Upper Eocene	Karstic limestone with original fissures and secondary dolomitization.	Main water-producing formation commonly known as the Jezira Tertiary Limestone;[a] denominated as the Midyat Formation in Turkey, where it comprises massive limestones at the base, followed by marls and chalky limestones at the top.

Source: Geyh, 2004; ACSAD et al., 2003; FAO and UNDP, 1966.
(a) Elsewhere in Syria, the Middle to Upper Eocene Formations are known as the Jadala and Sinjar and are placed in the Palmyra Group (Burdon and Safadi, 1963).

AQUIFER THICKNESS

The thickness of the Jezira Tertiary Limestone Aquifer System is generally around 200-300 m in Turkey.[14] In Syria, the thickness of the formations generally increases towards the south (Figure 1) and east where about 570 m of Eocene was penetrated in the Qamishli bore-hole (see Overview Map).[15] The Helvetian Formation usually has a thickness of 50-60 m.[16]

AQUIFER TYPE

In Turkey, groundwater in the Sanliurfa-Harran-Ceylanpinar area was under artesian conditions until about 1970 when the pressure began to drop significantly following intense abstraction. The aquifer system at Ceylanpinar is now unconfined in every location.[17] In Syria, the Jezira Tertiary Limestone Aquifer System is confined in the plain areas in the southern part of the basin, with artesian spring discharge.

AQUIFER PARAMETERS

The large water volumes that used to discharge from the Jezira Tertiary Limestone Aquifer System in some springs indicate high transmissivities in the karst aquifer. However, these high transmissivities are limited to a small radius around the group of springs comprising the Ras al Ain Springs where transmissivity values of 3 and 4 m^2/s were recorded.[18] Transmissivity values generally decrease significantly away from the spring discharge zones toward the east and south where they are most commonly in the range of 0.012 to 0.04 m^2/s.[19] A value of $5x10^{-2}$ was given for storativity.[20]

Hydrogeology - Groundwater

RECHARGE

The main recharge areas of the Jezira Tertiary Limestone Aquifer System are the Derik-Mardin Mountain chain where relatively high precipitation over Quaternary deposits and fractured limestone and basalt outcrops provide favourable conditions for rainfall and runoff infiltration. Most of the recharge occurs during winter and spring when precipitation can infiltrate. In the absence of precipitation data, it was assumed in the 1960s that average annual precipitation in the catchment area was in the order of 450 mm, and that as much as 150 mm of this rainfall would infiltrate over limestones and basalts in the catchment of the Ras al Ain Springs, mainly in Turkey.[21] Furthermore, it was concluded that a recharge area of 8,100 km^2 is required to replenish the annual discharge of the Ras al Ain Springs,[22] which was calculated at an average of 1,219 MCM/yr for the period 1943-1959.[23] Using recent available information, annual recharge in the catchment area[24] is estimated to fluctuate between $9x10^{-1}$ BCM (for a dry year with 500 mm precipitation) and 1.77 BCM (for a wet year with 800 mm precipitation).[25] This means that the catchment area would receive about 92 mm of recharge during dry years and 180 mm during wet years.

FLOW REGIME

The prevalence of a complex tectonic setting characterized by a number of folds and faults intruded by basaltic flows interferes with the development of a regional groundwater flow direction across the basin.[26] Hence, groundwater generally flows from high areas in the north and south to the low-lying central plains and wadi channel beds (see Overview Map).

STORAGE

The volume of water stored in the aquifer system that feeds the Ras al Ain Springs comprises the majority of the groundwater in the Jezira Tertiary Limestone Aquifer System and has been calculated as 7,400 MCM, or the equivalent of six years of discharge at the average natural rate.[27] Considering that there are several more springs that discharge from the system, the volume of water in storage within the aquifer system is likely to be significantly higher. However, it is not known how much is stored within the Jezira Tertiary Limestone Aquifer System alone.

DISCHARGE

The importance of the Jezira Tertiary Limestone Aquifer System is reflected by the discharge volume of several large springs such as Ras al Ain and Ain al Arous (within the boundaries of the delineated basin) and Ain al Arab (west of the Balikh River).[28] The total discharge of these springs used to exceed 52 m^3/s,[29] but has recently decreased dramatically to about 3 m^3/s.[30] The Ras al Ain Springs used to discharge 45 m^3/s, or 87% of total discharge from the aquifer system, have disappeared completely since 2001 (see also Chap. 2).[31]

On the Jagh Jagh River, springs with a 2-3 m^3/s discharge occur at the south-western foot of the Midyat Plateau in Turkey, upstream from Qamishli.[32] Two large karst springs, the Beyazsu and Karasu Springs, discharge 4.25 m^3/s and 4 m^3/s respectively from the Midyat Aquifer north-east of the Kiziltepe Plain.[33]

The groundwater regime of the Jezira Tertiary Limestone Aquifer System has been significantly altered over recent decades. Intensive groundwater pumping through a large number of wells in Syria and Turkey has resulted in a dramatic drop in the water level in this aquifer system, which has in turn led to a lower total discharge from karst springs in an area of 2,000 km^2 to the south of the town of Ras al-Ain.[34] During the last 20 years, intensive pumping from wells for irrigation has placed heavy pressure on groundwater supplies in both Syria and Turkey.[35]

WATER QUALITY

The chemical and isotopic compositions of groundwater in the aquifer system show important variations with respect to increasing depth, progressive confinement from north to south, and the geological facies changes. Three main types of groundwater were identified (see Overview Map):[36]

- **Fresh Ca-HCO_3-type water:** Found in springs and shallow wells close to the unconfined-confined limit with a Total Dissolved Solids (TDS) value of 370-720 mg/L and temperatures of 19°C-22.5°C. This type of water occurs in the northern part of the basin (Zone A) where the water percolates and flows in short and shallow paths as in the main spring at Ras al Ain. The isotope data suggests that this group of water is essentially recent meteoric water and that the increase in TDS is related to the evaporation effect.

- **Saline NaCl-CaCl-type water:** This mineralized (1,400–4,700 mg/L TDS) thermal (30°C-38°C) water (Zone C) is drawn from deep wells that tap the confined zone of the aquifer system. It is derived by mixing groundwater from the Jezira Tertiary Limestone Aquifer System with water from the underlying Upper Cretaceous Formation. This is essentially paleo-recharge water, which entered the aquifer system about 10,000 years ago.

- **Brackish $CaSO_4$-type water:** Admixed water which exhibits medium salinity (700-3,750 mg/L TDS) and temperature (25°C-31°C) and is formed by the mixing of the groundwater in Zones A and C. This type of water is found in both unconfined and confined zones (Zone B) and represents recharge water from both the Pleistocene epoch and recent times.

EXPLOITABILITY

The following criteria were used to delineate the exploitable areas of this aquifer system:

- **Depth to top of aquifer:** The average depth to the top of the aquifer ranges between 100 m bgl and 200 m bgl with the greatest depth occurring in the southern areas near the Jebel Abdel Aziz Anticlines (Figure 1). Hence drilling depth is not a limiting factor to exploitability.

- **Depth to water level:** Depth to groundwater is about 5 m bgl near the Ras al Ain-Qamishli Anticlines and Jebel Abdel Aziz, rising to 40-55 m bgl in the intermediary central plains[37] and in the Kiziltepe Plain to the north. This indicates that groundwater is shallow enough for exploitation.[38]

- **Water quality:** Less than 10,000 mg/L and hence not a limiting factor.

Hence the entire area of the aquifer system as delineated in the Overview Map is considered to be exploitable, although the existence of saline Paleo water in the southern areas of the basin (Zone C) may limit exploitation of the aquifer system in the future.

Groundwater Use

GROUNDWATER ABSTRACTION AND USE

In the past, groundwater extraction from the Jezira Tertiary Limestone Aquifer System constituted only a minor source of domestic and irrigation water supply compared to the readily available water from large springs, surface water diverted from the nearby Euphrates River, or abstraction from overlying shallow aquifers. In recent years, however, exploitation of the aquifer system has increased substantially on both sides of the border with approximately equal levels of abstraction in Syria and Turkey.[39]

In Turkey, groundwater investigations in the Sanliurfa-Harran-Ceylanpinar area began in 1955. State Hydraulic Works (DSI) has been drilling wells for domestic water supply since 1957, while it started groundwater exploitation for irrigation purposes in 1967. Recently, DSI started drilling wells for local farmers on contract basis. It was estimated that about 2,000 wells[40] are found in the area with a total abstraction of around 1.38 BCM[41]. Wells in the area have an average depth of about 200 m, reaching 400 m in some cases. Most wells abstract water from the Jezira Tertiary Limestone Aquifer System (Midyat Aquifer in Turkey), but a small number extract from the alluvium.[42] The number of registered bore-holes drilled in the aquifer rose significantly in the last decade and groundwater extraction appears to have increased considerably in the Kiziltepe Plain and adjoining areas in the Syrian Jezira Plain.[43]

In Syria, groundwater in the Qamishli region was exploited from 1955 onward, when preparations were made for the construction of dams on the Jagh Jagh River in Turkey. Soon after, a number of wells were drilled, mainly along river channels to compensate for the reduction in surface water flow. Most of these wells were extracting water from the shallow Plio-Quaternary deposits. Over the years, the number and depth of wells increased and by 2000, 3,797 wells were abstracting 1.59 BCM of groundwater.[44] About 83% of this water (1.32 BCM) is drawn by private wells with the highest abstraction taking place in April and August (Figure 3).

Agricultural land use within the delineated basin has undergone significant change in recent years as rain-fed agriculture was increasingly replaced by groundwater irrigation.[45] The total irrigated land area in Hasakah Governorate in 2010 was officially estimated at 358,000 ha, of which about 45,000 ha were irrigated by rivers and springs, while 313,000 ha were irrigated by wells (see also Chap. 2).[46]

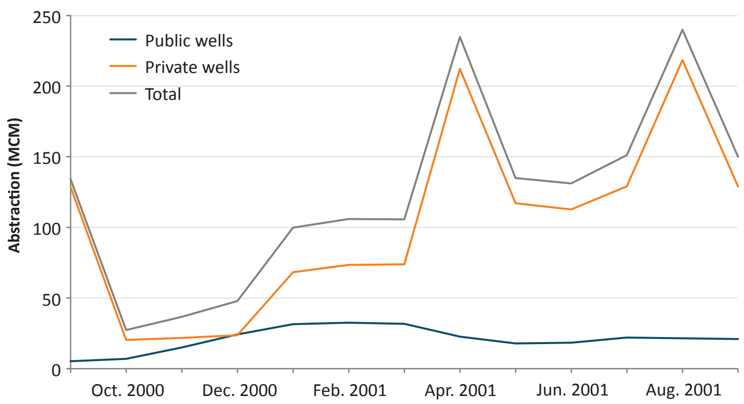
GROUNDWATER QUALITY ISSUES

The overexploitation of the Jezira Tertiary Limestone Aquifer System and intensified land use as part of the Southeastern Anatolia Project (GAP) (see Chap. 1 and 3) in the upper part of the delineated basin suggests that groundwater quality may have been affected. Pollution from pesticides and fertilizers has been suspected.[47] However, no data was available to verify this.

Two main factors indicate that the aquifer system may become a reservoir of deep saline water in the long run:

- Reduced freshwater recharge as a result of increased surface water use in the GAP area in Turkey, as this would allow an increase in the proportion of the deeper saline water in the system.
- Continuous overdraft of fresh bicarbonate water through groundwater mining in Syria and Turkey, which would increase the proportion of deep saline water that enters the aquifer system through mixing.

Figure 3. Monthly distribution of total groundwater abstraction in the Ras al Ain area in Syria (2000-2001)



Source: Compiled by ESCWA-BGR based on ACSAD et al., 2003.

SUSTAINABILITY ISSUES

The large volume of spring water discharged from the aquifer system in the Ras al Ain area has been dramatically reduced as the groundwater level dropped due to heavy groundwater extraction from wells in the adjoining plain areas. Groundwater levels have been dropping at an average rate of 1.68 m/yr for the period 1999-2003 in the Ras al Ain area.[48] The suspension of abstraction from 1,650 wells since 1998 did not result in a groundwater level rise or an increase in spring discharge.[49] This suggests that the aquifer system cannot be sustained without controlled measures to secure freshwater replenishment from the high mountain areas, particularly along the border of the aquifer system.

The spring of Ain al Arous, source of the Balikh River, Syria, 2010. Source: Andreas Renck.

Agreements, Cooperation & Outlook

AGREEMENTS

There are currently no water agreements in place for the Jezira Tertiary Limestone Aquifer System, which is shared between Syria and Turkey. However, the two countries have signed several agreements on the sharing of surface water from major rivers. From the point of view of groundwater, the most important is perhaps the 2009 Turkish-Syrian Strategic Cooperation Council Agreement which states that water is a focal point for cooperation between the two countries with specific emphasis on improving water quality, the construction of water pumping stations and joint dams, as well as the development of joint water policies (see Chap. 1).

COOPERATION

Cooperation between Syria and Turkey on surface water issues did not explicitly mention or take into consideration the need to cooperate over groundwater issues.

OUTLOOK

The present state of the Jezira Tertiary Limestone Aquifer System suggests that while it was reasonable to focus on the Ras al Ain area in the past, a wider and more regional approach to hydrogeological investigation and groundwater resource management woud be more appropriate in the future.

Agricultural fields along the Syrian-Turkish border, Turkey, 2010. Source: Adel Samara.

Notes

1. Burdon and Safadi, 1963.
2. Kattan, 2002.
3. Central Bureau of Statistics in the Syrian Arab Republic, 2010.
4. Turkstat, 2010 cited in City Population, 2010.
5. Günay et al., 1996.
6. Geyh, 2004.
7. Burdon and Safadi, 1963.
8. Aghanabati, 1993; BGR and ACSAD, 1984; FAO and UNDP, 1966; Cater and Gillcrist, 1994; and Brew et al., 1999.
9. FAO and UNDP, 1966, Fig VII-II.
10. Cater and Gillcrist, 1994.
11. Kazmin, 2002.
12. Geyh, 2004.
13. Sawaf et al., 1993.
14. FAO and UNDP, 1966.
15. Burdon and Safadi, 1963; FAO and UNDP, 1966.
16. Geyh, 2004.
17. Gurer, 2008.
18. Geyh, 2004; FAO and UNDP, 1966.
19. FAO and UNDP, 1966.
20. Ibid.
21. Burdon and Safadi, 1963.
22. This means that the headwaters of the Khabour River Basin, which extends across the Mardin High-Basalt Plateau north of the delineated area in the Overview Map (see Chap. 2), would contribute to recharge.
23. Burdon and Safadi, 1963.
24. ACSAD et al., 2003 calculated an area of 9,840 km^2, which is somewhat higher than the 8,100 km^2 previously assumed by Burdon and Safadi, 1963.
25. ACSAD et al., 2003.
26. Geyh, 2004.
27. Burdon and Safadi, 1963.
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