Chapter 23

Taurus-Zagros

INVENTORY OF

SHARED WATER RESOURCES IN WESTERN ASIA (ONLINE VERSION)

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Taurus-Zagros

EXECUTIVE SUMMARY

The Taurus-Zagros Mountain range extends across Iran, northern Iraq and Turkey. Geological formations within this range constitute shared aquifer systems in some areas along the boundaries of these countries. Three such areas are identified and described in this chapter: the Halabja-Khurmal and the Central Diyala Basins between Iran and Iraq, and the Zakho Basin between Iraq and Turkey. Other shared basins may possibly exist but remain unknown because of the complexity of the tectonics in the area.

In the Halabja-Khurmal Basin, groundwater is exploited in the Bekhme (Cretaceous) and Pila Spi (Paleogene) Aquifer Systems. The groundwater originates in the high mountains of Iran and flows towards the Derbendikhan Dam Lake in Iraq. A total annual recharge of 214 MCM occurs in the basin, and natural discharge of groundwater occurs mostly through springs.

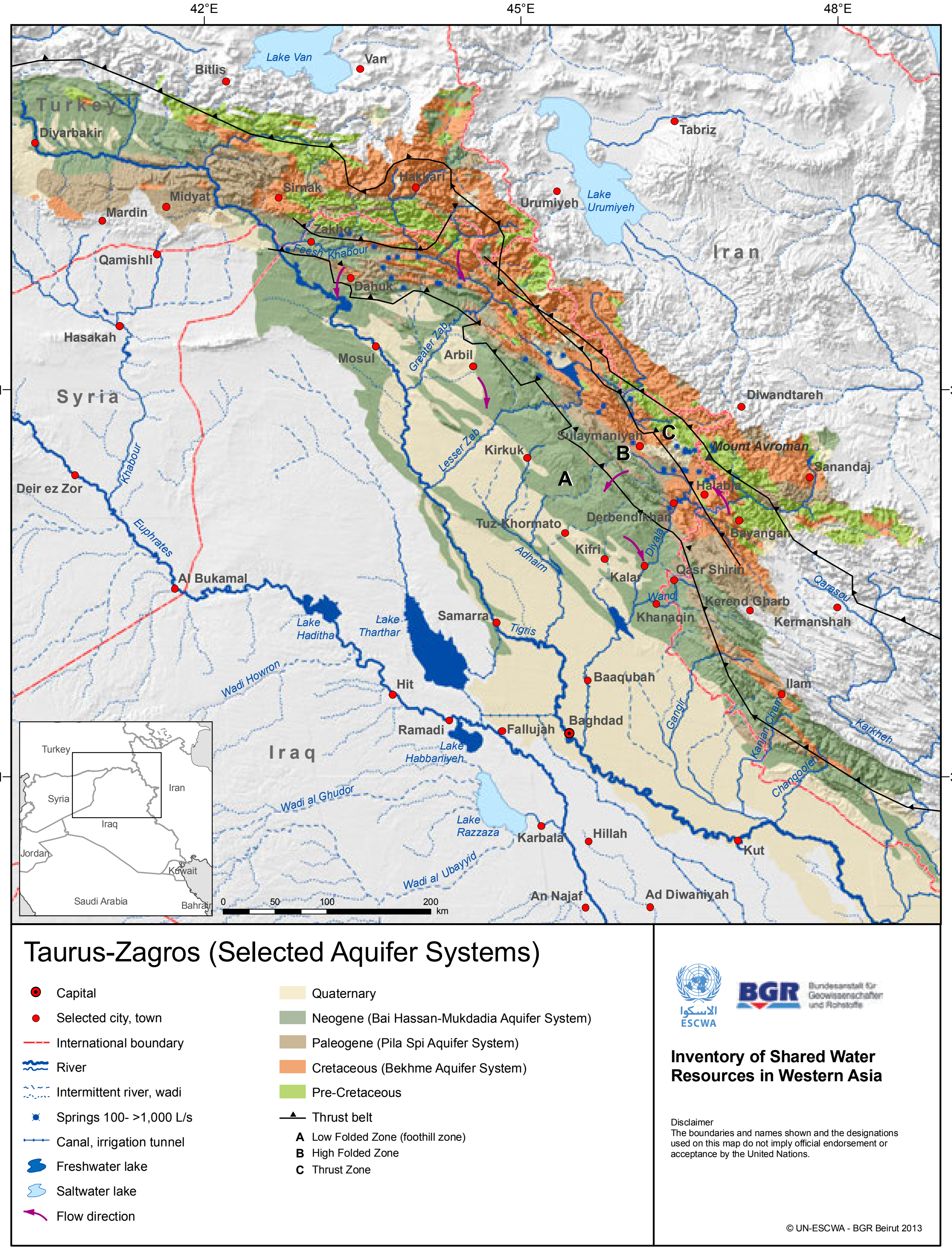
In the Central Diyala Basin, water is abstracted from the Bai Hassan-Mukdadia (Neogene) Aquifer System. A few springs are reported to discharge into this area and recharge is in the order of 50 mm/yr. Groundwater flow is mainly towards the Diyala River and the quality of water deteriorates with depth due to the presence of evaporites.

Both the Neogene and Paleogene aquifer systems are exploited in the Zakho Basin in the north, which receives about 188 MCM/yr of water. A considerable amount of this water is discharged through springs.

BASIN FACTS

RIPARIAN COUNTRIES	Iran, Iraq: Halabja-Khurmal and Central Diyala Basins Iraq, Turkey: Zakho Basin
MAIN AQUIFERS	Bai Hassan, Bekhme, Pila Spi
ALTERNATIVE NAMES	-
SHARED BASINS	Central Diyala, Halabja-Khurmal, Zakho
RENEWABILITY	Medium to high (20-300 mm/yr)
HYDRAULIC LINKAGE WITH SURFACE WATER	Strong
ROCK TYPE	Bekhme, Pila Spi: carbonate, karstic Bai Hassan: intergranular
AQUIFER TYPE	Semi-confined
EXTENT OF CATCHMENT	Central Diyala: 11,760 km^2 Halabja-Khurmal: 566 km^2 Zakho: 1,960 km^2
AGE	Bai Hassan, Pila Spi: Cenozoic Bekhme: Mesozoic
LITHOLOGY	Shale, limestone, sandstone
THICKNESS	Bekhme: ≤1,000 m Pila Spi: ~1,500 m Bai Hassan: ≥2,500 m
AVERAGE ANNUAL ABSTRACTION	-
STORAGE	-
WATER QUALITY	Fresh (≤1,000 mg/L TDS) except in deeper layers of Central Diyala Basin saline (3,000 mg/L TDS)
WATER USE	Mainly agricultural
AGREEMENTS	-
SUSTAINABILITY	-

OVERVIEW MAP



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LOCATION

The Taurus-Zagros Mountain range extends across Iran, northern Iraq and Turkey in a north-west/south-east direction. Shared aquifer systems exist in three border areas (see Overview Map):

- The Halabja-Khurmal Basin, where groundwater originates mainly in Iran.
- The Central Diyala Basin, with water that originates in Iran and Iraq as part of the Diyala River hydrological system.
- The Zakho Basin, which contains water originating in Iraq and Turkey as part of the Feesh Khabour River hydrological system.

These areas are examined in more detail below.

AREA

The groundwater in the Taurus-Zagros Mountain range forms an integral part of the hydrological system of the Tigris River Basin (see Overview Map and Chap. 3). The northernmost part (Thrust Zone) consists of rugged mountains, mostly over 2,000 m asl, which are intersected by deep valleys. South of the Thrust Zone, long, linear, asymmetrical folds form the High Folded Zone (approx. 900 m asl) and the Low Folded (Foothill) Zone (approx. 100-500 m asl). In this area, groundwater is mainly exploited in intermountain basins[1] that lie between a series of anticlines and synclines. The surficial geology and geomorphic features in the Taurus-Zagros Mountain range is shaped by the course of the Greater Zab River (see Chap. 4), which is controlled by a deep-seated regional fault. East of the Greater Zab, all mountains and valleys have typical linear shapes and are oriented in a north-east/south-west direction, which is referred to as the Zagros direction in this context. West of the Greater Zab, the mountains, ridges and valleys shift to an east-west orientation, known as the Taurus direction in this context.[2]

CLIMATE

The Taurus-Zagros Mountain range is generally characterized by cold, snowy winters and long, dry summers. Precipitation is concentrated in the colder mountain and foothill areas with maxima occurring on the high peaks along the Iran-Iraq border. In general, precipitation rates decrease from north-east to south-west. The region receives practically no precipitation during summer (June-September). The rainy season usually lasts from mid-October to early May, with the highest precipitation occurring in January. Average recorded data from 18 stations in northern Iraq indicates a maximum of 1,466 mm/yr for the period 1958-2002 in the north-eastern mountains and a minimum of 487 mm/yr for the period 1978-1990 in the south-western areas.[3] In western Iran, the annual average precipitation based on data from 140 stations for the period 1965-2000 ranged between 300 and 1,050 mm.[4] Air temperature varies between 10°C and 25°C, with mean annual temperatures of 10°C-15°C in the region of Dahuk, Halabja and Zakho, and 20°C-25°C in the Kirkuk and Tuz-Khormato areas in Iraq. The area of Qasr Shirin in Iran experiences annual average temperatures in the range of 15°C-20°C.[5] Reference evapotranspiration calculated for several stations across northern Iraq was found to be in the range of 1,000-1,700 mm/yr.[6] No data was found for evapotranspiration in Iran or Turkey.

POPULATION

The total population of the three areas where shared groundwater resources occur in the Taurus-Zagros Mountain range is estimated at around 1.44 million, including major towns such as Derbendikhan and Zakho in Iraq; Gharb, Gilan, Qasr Shirin and Sar Pole-Zahab in Iran, as well as small towns in Turkey such as Baskoy and Kapili. More detailed information on population distribution is included in relevant sections below.

INFORMATION SOURCES

With limited data available on groundwater resources in the Taurus-Zagros Mountain range in Iran and no information for Turkey, most of the information in this chapter is drawn from several studies in Iraq, most notably the hydrogeological investigations in northern Iraq published by FAO.[7] The Overview Map was delineated based on various local and regional references.[8]

Overview of Aquifer Systems

MAIN AQUIFER SYSTEMS

Three types of aquifer systems are known to exist in the Taurus-Zagros Mountain range: two in the High Folded Zone and one in the Low Folded Zone as shown in Table 1. The aquifer systems are denoted by the name of the most commonly known formations. A brief description of each aquifer system is given below.

Bekhme Aquifer System

The aquifer system consists of thick and intensively karstified carbonate layers that are often made up of massive 100-500 m thick banks. The Bekhme Aquifer System covers a large surface area and comprises several formations that extend across the High Folded Zone in east-west and north-west/south-east directions (see Overview Map). It contains large groundwater reserves and has a medium to high production of good-quality water. Wells drilled to 100-150 m bgl yield up to 40-50 L/s of water with very little drawdown.[9] In addition, many springs issue from locations where the karstic carbonates come into contact with non-carbonate rocks. A 2001-2002 groundwater monitoring programme[10] recorded an average discharge of 1.24 BCM from 46 springs and spring groups in the Iraqi governorates of Sulaymaniyah and Dahuk, which border on Iran and Turkey respectively (Table 2). Rainwater infiltration was estimated to reach up to 50%, while the aquifer system has a transmissivity of between 1.0×10^{-4} and 9.2×10^{-2} m^2/s.[11]

Pila Spi Aquifer System

The Pila Spi Aquifer System crops out extensively in the High Folded Zone. However, in the Low Folded Zone it is confined as it is covered by thick Miocene and Pliocene formations and Quaternary sediments. The degree of karstification is similar to that in the Bekhme Aquifer System, but the limestones of these younger formations are often argillaceous, which causes fracture systems to be less well developed.[12] Thus while the Pila Spi Aquifer System may contain relatively less groundwater reserves, the productivity of wells (40 L/s) is comparable with that of the Bekhme Aquifer System. Wells are usually 120-150 m deep except in areas where high artesian pressure prevails and water is struck at around 50 m bgl. An average effective infiltration of 30%-40% of rainfall into the aquifer system was estimated and the range of transmissivity is 4.0×10^{-5} to 4.9×10^{-1} m^2/s.[13] Table 3 shows that the Pila Spi Aquifer System has a significantly lower average total discharge than the Bekhme Aquifer System in Sulaymaniyah and Dahuk Governorates.

Table 1. Main aquifer systems in the Folded Zones of the Taurus-Zagros Mountain range

ZONE	AQUIFER TYPE	MAIN FORMATION	OTHER FORMATIONS/ DEPOSITS
High Folded Zone	Karst	Bekhme	Qamchuga, Dokan, Kometan, Bekhme, Akra, Sarmord
	Fissured-karstic	Pila Spi	Sinjar, Khurmal
Low Folded (Foothill) Zone	Intergranular	Bai Hassan (Upper Bakhtiari)	Mukdadia (Lower Bakhtiari), unconsolidated sediments (Quaternary)

Source: Compiled by ESCWA-BGR based on Stevanovic and Markovic, 2004.

Table 2. Spring discharge from the Bekhme Aquifer System (2001-2002)

GOVERNORATE	NO. OF SPRINGS/ SPRING GROUPS	TOTAL DISCHARGE (L/s)		
		MEAN	MINIMUM	MAXIMUM
Sulaymaniyah	28	33,019	7,813	72,232
Dahuk	18	6,403	1,861	14,941
Total	46	**39,422** (1.24 BCM)	**9,674** (0.31 BCM)	**87,173** (2.75 BCM)

Source: Compiled by ESCWA-BGR based on Stevanovic and Markovic, 2004.

Table 3. Spring discharge from the Pila Spi Aquifer System (2001-2002)

GOVERNORATE	NO. OF SPRINGS/ SPRING GROUPS	TOTAL DISCHARGE (L/s)		
		MEAN	MINIMUM	MAXIMUM
Sulaymaniyah	12	4,724	1,134	12,766
Dahuk	18	3,119	2,019	9,816
Total	30	**7,843** (0.25 BCM)	**3,153** (0.99 BCM)	**22,582** (0.71 BCM)

Source: Compiled by ESCWA-BGR based on Stevanovic and Markovic, 2004.

Bai Hassan Aquifer System

The Bai Hassan Aquifer System, which covers most of the Low Folded Zone, consists of heterogeneous unconsolidated materials that are generally highly productive, with the discharge of many wells exceeding 30 L/s. A typical characteristic of this system, however, is the repetition of fine-, medium- and coarse-grained sediments within the same aquifer horizon as a result of which the productivity of wells drilled to the same depth can be highly variable. Artesian conditions prevail in the deeper horizons, especially around the lower reaches of major rivers such as the Diyala, Greater Zab and Lesser Zab, where thick deposits of fine Quaternary materials overlie the Neogene formations. More than 90% of the 2,000-3,000 wells drilled into this system have a total depth of 200 m or less. Many of the wells are no longer operational.[14] An estimated 22%-25% of rainfall infiltrates into the aquifer system and the range of transmissivity is $1.0\text{x}10^{-6}$ to $5.3\text{x}10^{-1}$ m^2/s.[15] The average total discharge of springs emanating from the Bai Hassan Aquifer System in the Sulaymaniyah and Dahuk Governorates (34 MCM) is almost an order of magnitude lower than the discharge from the Pila Spi Aquifer System during the same period (Table 4).

STRATIGRAPHY

Table 5 briefly describes the formations that contribute to an understanding of shared aquifer systems in the Taurus-Zagros Mountain range. Formation names mentioned in this overview section are mainly found in the literature from Iraq. Different names are generally used in Iran and Turkey and some of them are included in the relevant sections below.

Table 4. Spring discharge from the Bai Hassan Aquifer System (2001-2002)

GOVERNORATE	NO. OF SPRINGS/ SPRING GROUPS	TOTAL DISCHARGE (L/s)		
		MEAN	MINIMUM	MAXIMUM
Sulaymaniyah	2	263	45	673
Dahuk	11	817	262	5,141
Total	13	**1,080** (34 MCM)	**307** (9.7 MCM)	**5,814** (183 MCM)

Source: Compiled by ESCWA-BGR based on Stevanovic and Markovic, 2004.

Table 5. Lithostratigraphy of the aquifer systems in the Taurus-Zagros Mountain range

AGE		FORMATION	LITHOLOGY	THICKNESS (m)	WATER-BEARING CHARACTERISTICS
Quaternary	Pleistocene to recent	-	Gravel, clay and sand	10-100	Hydraulically connected; form one aquifer system in the Low Folded Zone
Neogene	Pliocene	Upper Bakhtiari (Bai Hassan) Lower Bakhtiari (Mukdadia)	Conglomerates and clay-stones, partly sandstones and siltstones	≥2,500-3,000	
	Miocene	Upper Fars (Injana) Lower Fars (Fatha)	Mainly sandstones (Injana) and evaporites (Fatha) with some conglomerate at the base	L. Fars: 400-900 U. Fars: 500	Very low groundwater yield with acidic or salty water
Paleogene	Middle-Upper Eocene	Pila Spi-Gercus	Mudstones, sandstones and shales	65-400	A major aquifer system of fissured-karstic nature in the High Folded Zone
	Paleocene-Eocene	Kolosh-Sinjar-Khurmal	Shales, limestones and dolomites	≥1,000	Sinjar is part of the Pila Spi Aquifer System where it is not separated from the Pila Spi Formation by the flysch deposits of the Gercus Formation
Mesozoic	Cretaceous	Bekhme-Akra-Kometan	Mainly limestones and dolomitized limestones	Few hundreds to ~1,000	A major karst aquifer system in the High Folded Zone

Source: Compiled by ESCWA-BGR based on Stevanovic and Markovic, 2004.

The Halabja-Khurmal Basin

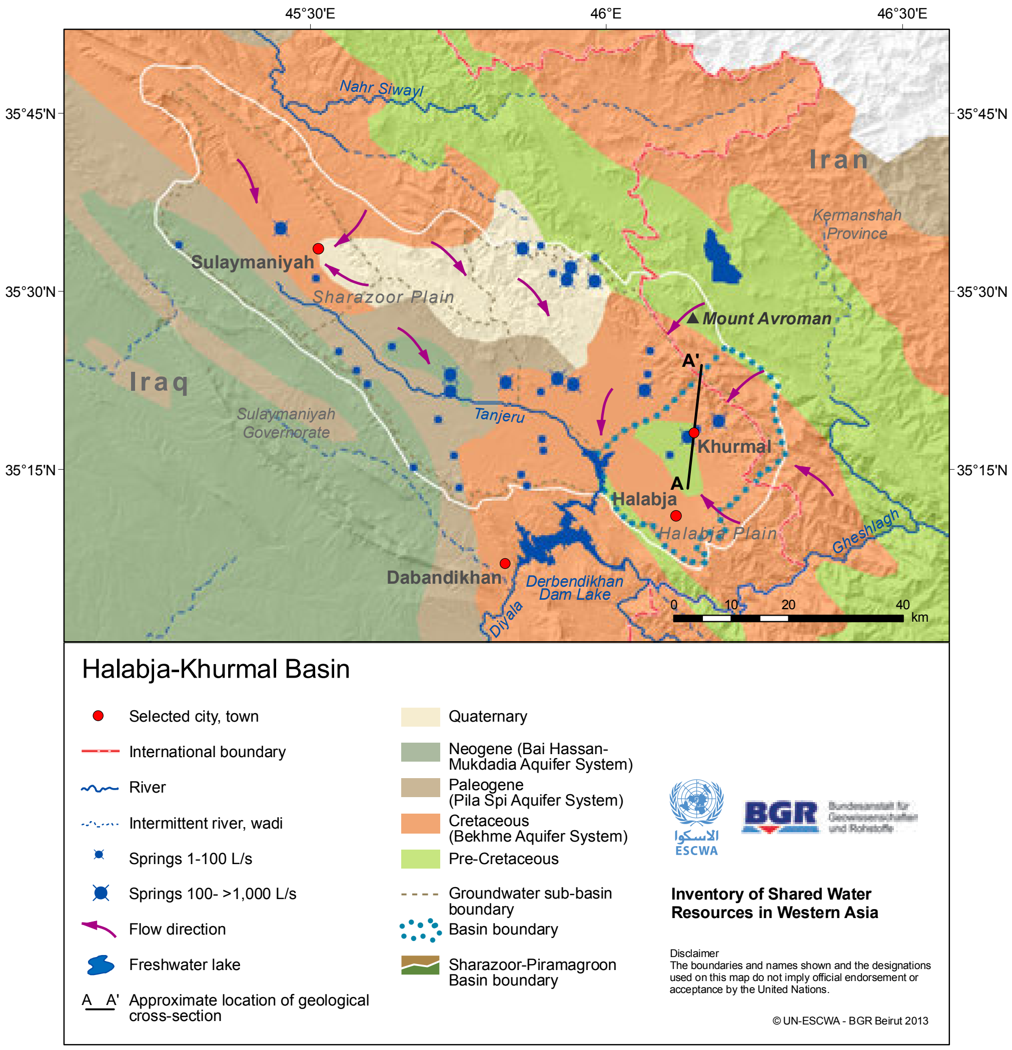
INTRODUCTION

The Halabja-Khurmal Basin is the easternmost of four sub-basins within the Sharazoor-Piramagroon Basin,[16] previously known as the South-eastern Sharazoor Hydrogeological Basin.[17] The Sharazoor-Piramagroon Basin straddles the Iran-Iraq border (Figure 1 and 2), extending across the Iraqi governorate of Sulaymaniyah and the Iranian province of Kermanshah. Due to lack of data, the groundwater boundary of the Sharazoor-Piramagroon Basin in Iran has not been clearly defined.[18] As part of the Sharazoor-Piramagroon Basin, the Halabja-Khurmal sub-basin covers a total of 566 km^2, of which 141 km^2 is located in Iran and 425 km^2 in Iraq.

Mean annual precipitation in the area of the Halabja-Khurmal Basin lies around 675-680 mm (Sulaymaniyah, Derbendikhan),[19] decreasing to 500 mm (Kermanshah) further to the east. The region is characterized by cycles of dry and wet years. Air temperature in the basin ranges from 3°C in January to 32°C in July, with an annual average of 17°C-19°C. To the east of the basin, Kermanshah has a moderate mountain climate. Precipitation falls mostly in winter and the average temperature in the hottest months is around 22°C.

The Halabja-Khurmal Basin has an estimated population of 95,550 inhabitants, who mainly live in the Halabja District of Sulaymaniyah Governorate in Iraq.[20] In Iran, the basin

Figure 1. Overview Map of the Halabja-Khurmal Basin



Source: Compiled by ESCWA-BGR based on Salahalddin, 2007; Stevanovic and Markovic, 2004; Aghanabati, 1993.

comprises small parts of Kermanshah and Kurdistan Provinces, but they are very sparsely populated.

HYDROGEOLOGY

Aquifer characteristics

A wide range of geological units (Late Jurassic to recent deposits) exist in the area, including the three main aquifer systems described above. The area has the following main hydrogeological characteristics:

- Occurrence of karstic and fissured-karstic aquifers (Bekhme and Pila Spi Aquifer Systems) on the edges of the basins.
- Highly productive intergranular deposits (Bai Hassan Aquifer System) often filling the basins.
- Variable permeability and lateral/horizontal changes in lithology of basin layers.

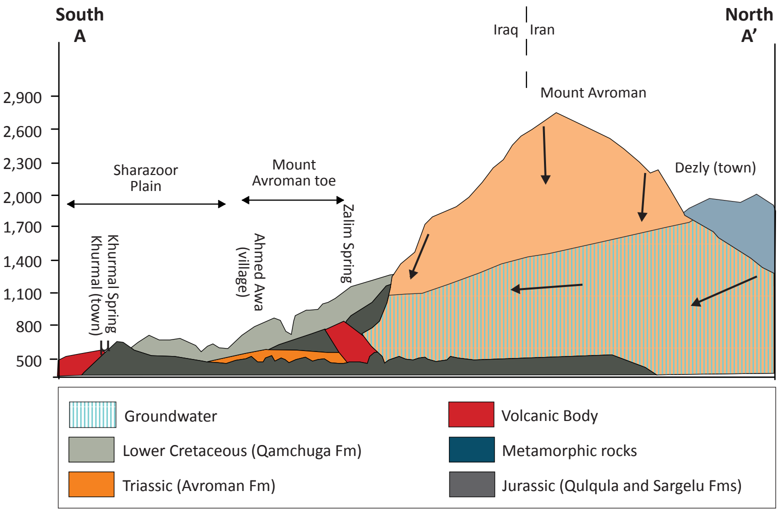
Quaternary deposits overlie the Cretaceous and Paleogene aquifer systems in the Halabja and Sharazoor Plains, creating confined conditions in both systems in this area.[21] Together with the Jurassic formations, the Cretaceous and Paleogene aquifer systems of the Thrust Zone are drained by numerous springs, some of which are of major importance.

Groundwater

Groundwater in most of the Sharazoor-Piramagroon Basin, including the Halabja-Khurmal sub-basin, originates in high mountains in Iran such as Mount Avroman. Groundwater flow more or less coincides with surface water flow and is directed towards the Derbendikhan Dam Lake in Iraq[22] (Figure 1 and 2). A total annual recharge of 214 MCM occurs in the Halabja-Khurmal Basin, mainly via direct infiltration through the exposed rocks.[23]

Natural discharge of groundwater in the Halabja-Khurmal Basin occurs through springs and subsurface drainage. There are two large karstic springs (Zalim and Shiramar) and several smaller ones (Bawakochak, Khurmal, Sargat) in the area. Spring discharge represents the main groundwater outflow in the Halabja-Khurmal Basin. Discharge of the main Zalim Spring during the period 2004-2006 fluctuated between 8.8 and 1.1 m^3/s, with a mean value of 3.9 m^3/s.[24] The presence of aquifer systems drained by up to 400 springs in the neighbouring Nawsud District in Paveh County in Kermanshah Province in Iran has also been reported.[25] Water in the Sharazoor-Piramagroon Basin is generally considered fresh (1,000 mg/L TDS),

Figure 2. Geological cross-section of Mount Avroman and the Zalim Spring



Source: Redrawn by ESCWA-BGR based on Salahaldin, 2007.

Table 6. Groundwater production in the Halabja-Khurmal Basin in Iraq

TYPE OF DISCHARGE	NO. OF WELLS	TOTAL ANNUAL PRODUCTION (MCM)
Springs	-	157
Deep wells	860	16
Shallow wells	230	1.8
Total	1,090	174.8

Source: Compiled by ESCWA-BGR based on Salahaldin, 2007.

with minimum values observed in wells closer to the recharge area in the Halabja-Khurmal sub-basin.

GROUNDWATER USE AND SUSTAINABILITY ISSUES

No information was available on water production and use in the Iranian part of the basin. In Iraq, springs and wells in the Halabja-Khurmal Basin produce 175 MCM/yr. Table 6 shows that about 90% of the water originates from springs. Current water demand is about 157 MCM/yr of which 145 MCM/yr (92%) is used for agricultural purposes.[26]

A report by FAO[27] suggests that optimal exploitation of water resources in the Halabja-Khurmal Basin could be achieved in the following ways:

- Tapping karstic spring water at the edges of the basin through gravity systems and the development of highly productive springs.
- Developing shallow alluvial and terrace aquifers including artificial recharge.
- Deep-well drilling in karstic areas in the foothills or in recent deposits.

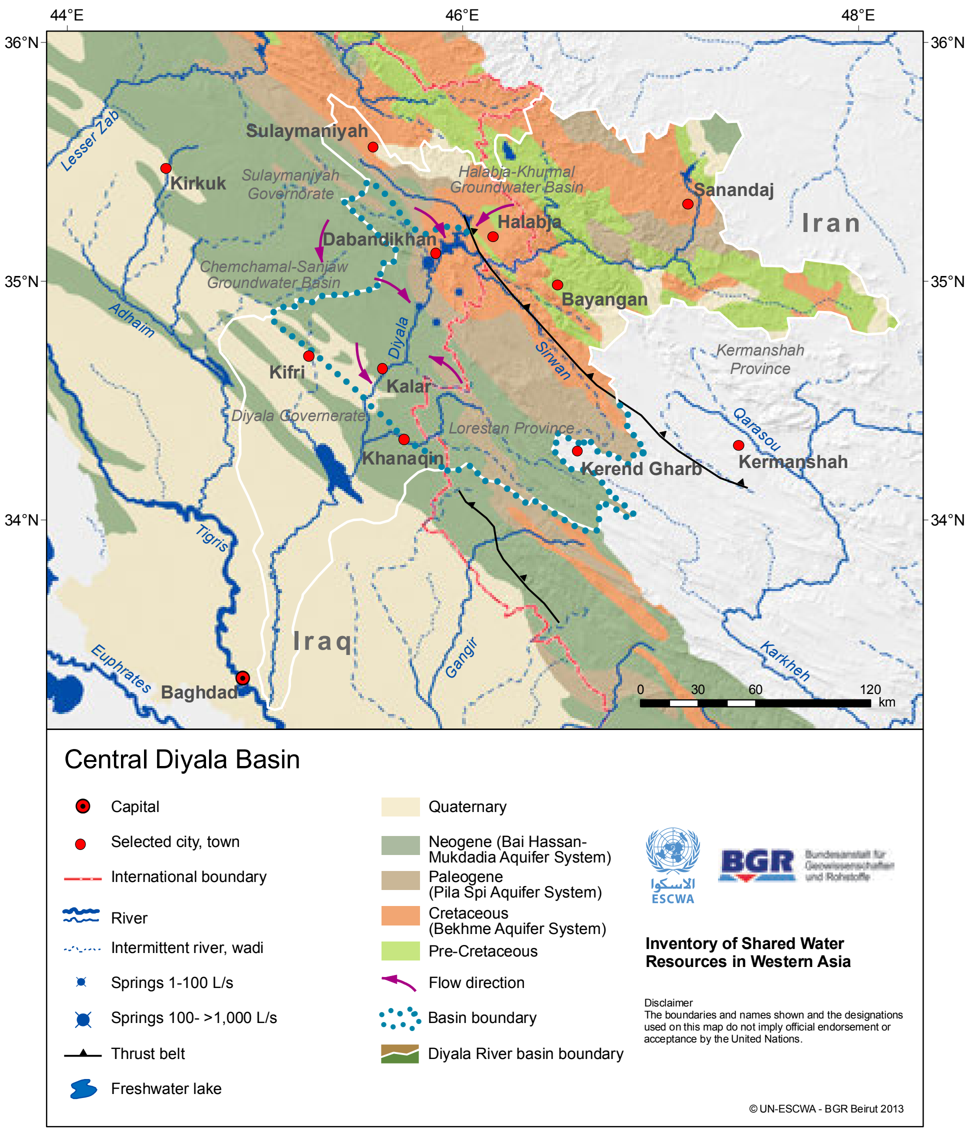
The Central Diyala Basin

INTRODUCTION

The Central Diyala Basin lies mainly in the Low Folded Zone, but also partly in the High Folded Zone along the Iran-Iraq border. It stretches across the eastern part of Diyala Governorate in Iraq and the western part of Lorestan Province in Iran (Figure 3). For the purpose of this chapter, the basin is defined by tentatively extending the groundwater divides of the Halabja-Khurmal and Chemchamal-Sanjaw Basins across the Iraq-Iran border along major thrust faults (northern and southern boundaries, respectively) and the Diyala River Basin (eastern and western boundaries, see Chap. 4). Within the boundary of the suggested delineation, the basin covers a total area of 11,760 km^2, of which 6,350 km^2 are located in Iran and 5,410 km^2 in Iraq.

The climate in the Foothill Zone is semi-arid with hot summers and mild to cold winters. Precipitation occurs mainly between September and May. The Central Diyala Basin around Khanaqin has an average annual precipitation of 330-350 mm.[28] The average annual temperature is 21°C, with highs around 32°C in summer and

Figure 3. Overview Map of the Central Diyala Basin



Source: Compiled by ESCWA-BGR based on Stevanovic and Markovic, 2004; Salahalddin, 2007; Aghanabati, 1993; Sorkhabi, 2012.

lows of 5°C in winter.[29] Total potential annual evaporation was reported to be about 1,750 mm in 2001.[30] The evaporation rate is likely to be higher in the Kalar-Kifri area.

The Central Diyala Basin comprises around 312,300 inhabitants, with around 224,700 people living in parts of Kermanshah Province in Iran,[31] and around 87,600 inhabitants in parts of Sulaymaniyah and Diyala Governorates that lie in the Iraqi part of the basin.[32]

HYDROGEOLOGY

Aquifer characteristics

The main aquifer in this basin is the Neogene (Bai Hassan-Mukdadia) Aquifer System. The Bai Hassan Formation is an aquifer with high potential and sometimes forms a single aquifer with the overlying Quaternary sediments, especially in the southern areas (Kalar). The Mukdadia Formation is also considered an aquifer, though it is less promising. The exploitable saturated thickness of the Bai Hassan-Mukdadia Aquifer System is estimated at 60-200 m in different sub-basins.[33] The aquifer system is basically unconfined with a shallow water table. Confined conditions exist where the overlying Quaternary deposits exhibit high clay content. Differences in lithology often cause semi-confined to confined conditions in the deeper layers. Transmissivity values of 100 m^2/d ($1.2x10^{-3}$ m^2/s) and 350 m^2/d ($4.0x10^{-3}$ m^2/s) were reported in the Central Diyala Basin.[34] However, variable permeability and lateral/horizontal changes in the lithology of basin deposits often result in highly variable productivity.[35] Some springs discharge from the Pila Spi Formation, especially where it is in contact with other formations, but there is no information on the potential and use of the aquifer system.

Groundwater

Major rivers such as the Adhaim, Gangir and Lesser Zab flow through the foothill areas and may contribute significantly to direct and indirect groundwater recharge.[36] In the Central Diyala Basin, groundwater recharge rates were reported to range between 40 and 53 mm (11.8% of an average rainfall of 332 mm[37] and 17.3% of an average rainfall of 308 mm).[38] Both in Iran and Iraq, groundwater flows mainly towards the Diyala River and storage in Iraq has been estimated at between 500[39] and 1,050 MCM[40] in Iraq. Storage in Iran is unknown.

The unconfined upper part of the aquifer is locally drained to the Diyala River. The discharge of the lower confined aquifer system is not well defined but may be connected to the upper part. A few morphological springs are reported to discharge low volumes into the Central Diyala Basin.[41] Similar springs may exist in the Iranian part of the basin. In general, natural discharge of the confined system seems to be limited, indicating possible upward leakage to the upper unconfined system. Good-quality groundwater (<1,000 mg/L TDS) is found along the Diyala River and, in general, salinity increases away from the river. Deep wells contain saline water derived from the Lower Fars (Fatha) Formation but salinity rates generally do not exceed 3,000 mg/L.[42]

GROUNDWATER USE AND SUSTAINABILITY ISSUES

Actual annual abstraction from the confined aquifer in the Central Diyala Basin is estimated at around 6 MCM from 80 wells, with very limited effect on groundwater levels.[43] No abstraction is reported in Iran, but groundwater discharge from qanats[44] can be assumed.[45]

Landscape near Penjwin, Iraq, 1991. Source: Ed Kashi/VII.

The Zakho Basin

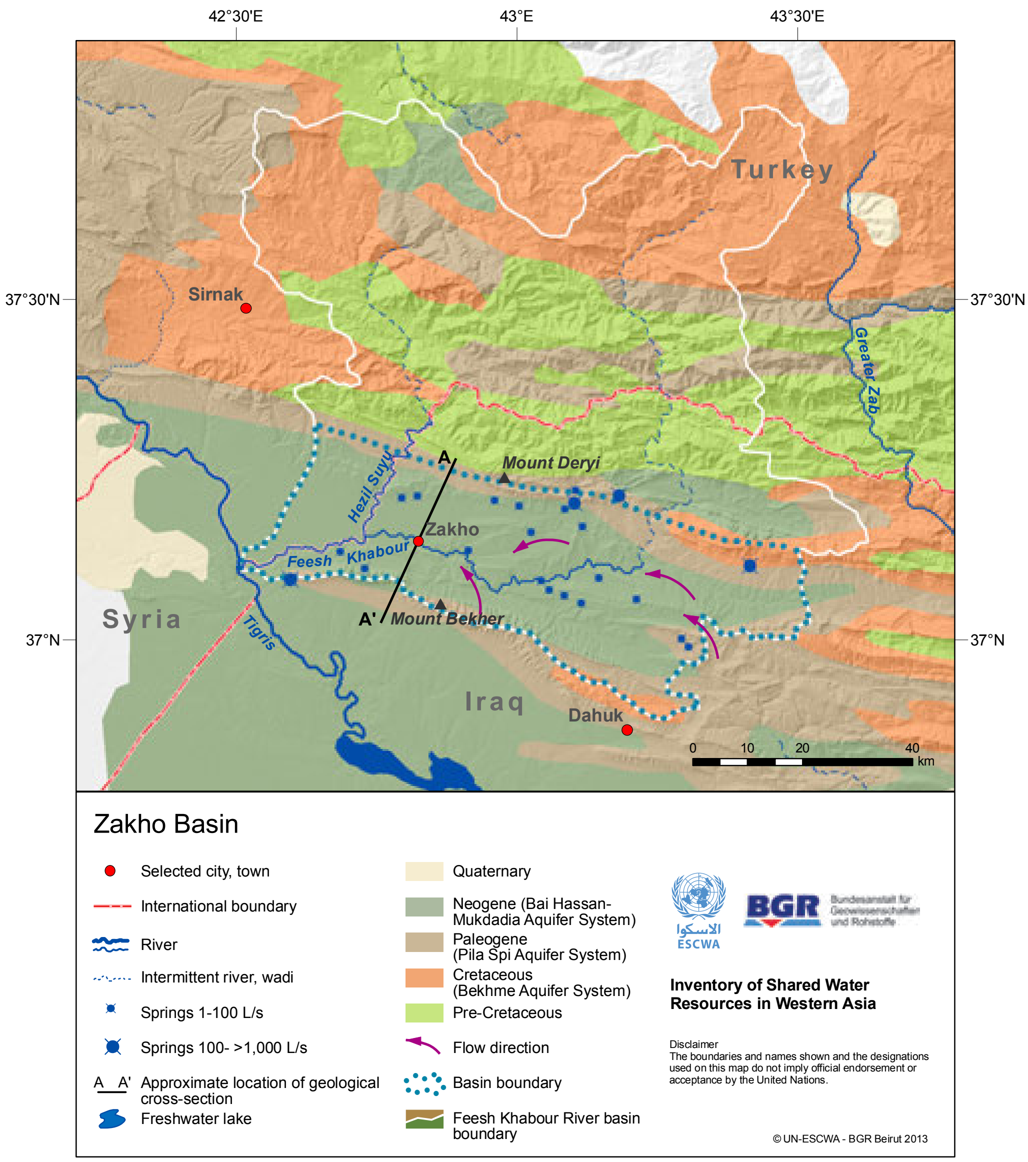
INTRODUCTION

The Zakho Basin stretches across the border between Iraq and Turkey. It constitutes the lower part of the Feesh Khabour River (a Tigris River tributary, see Chap. 4), and is bound from the east and west by the boundary of Feesh Khabour and from north and south by two anticlines, of which one is aligned with the southern border of the river basin. In Iraq, the Zakho Basin lies at an altitude of 500-600 m asl, with the surrounding mountains rising to 1,600-1,800 m asl. The basin is underlain by thick layers of productive recent deposits. Within the boundary of the suggested delineation, the basin covers a total area of 1,960 km², of which 1,695 km² are located in Iraq and 265 km² in Turkey (Figure 4).

Average annual precipitation in the Zakho Basin in Iraq is estimated at 707 mm,[46] with high inter-annual variation. Temperatures range from about 6°C in winter to over 30°C in summer.

The population in the Zakho Basin is estimated at 733,000 inhabitants, with 628,900 people

Figure 4. Overview Map of the Zakho Basin



Source: Compiled by ESCWA-BGR based on Aghanabati, 1993; Stevanovic and Markovic, 2004.

living in Dahuk Governorate in Iraq[47] and the remaining population living in parts of the Sirnak Province in Turkey.[48]

HYDROGEOLOGY

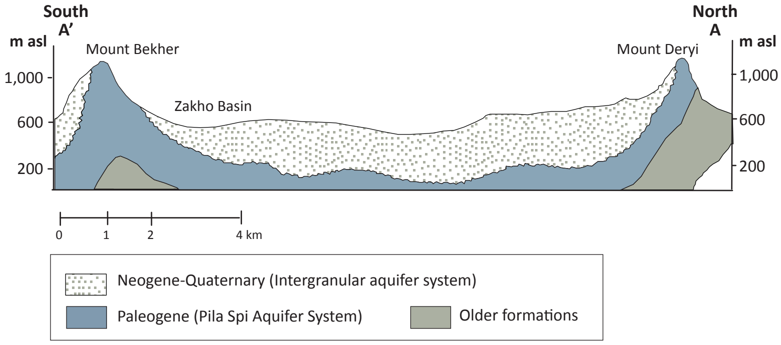
Aquifer characteristics

The upper, dominant water-bearing formations in the Iraqi part of the Zakho Basin are made up of Quaternary deposits and Neogene clastics formations of the Bai Hassan and Mukdadia Formations (Figure 5), and to a lesser extent of Upper and Lower Fars (Injana and Fatha) Formations. They form an unconfined aquifer system with a collective flow type centred on the Khabour River. The system seems to extend briefly across the Khabour and Hezil Rivers into Turkey[49] where it is bordered by a major fault in the north and obscured by younger volcanic deposits to the west of the Tigris River, north-east of Syria. The Paleogene, with its chalky limestone of the Pila Spi Formation, appears only at the axis of the two parallel anticlines that embrace the Zakho Basin. The Paleogene underlies the Neogene clastics at depth and forms a second confined groundwater aquifer system with the fine clastics Gercus Formation.[50] However, the chalky limestone of the Midyat Formation that overlies the Gercus Formation in Turkey appears on the surface further to the north and west, with the Paleogene extent reaching Diyarbakir to the north and Mardin to the west.[51] The older Cretaceous aquifer system, which is widely present in north-eastern Iraq, plunges deep under the Zakho Basin.

Groundwater

In Iraq, the Zakho Basin has a catchment area of about 1,107 km^2. Within the catchment, it is assumed that 31% of the average annual rainfall (707 mm) infiltrates into the ground but only 23% reaches the aquifer systems.[52] This would mean that a total of 188 MCM/yr of water (160 MCM/yr in the intergranular aquifer system and 28 MCM/yr in the fissured-karstic aquifer system) enters the basin as renewable resources.[53] A considerable amount of the recharged volume is discharged through springs, especially those issuing from the fissured-karstic aquifer. A major spring (Deraboon) issuing near the Iraqi-Turkish border at the contact between the Pila Spi Formation and the less permeable overlying Lower Fars (Fatha) Formation is reported to have a discharge of 0.83-1.13 m^3/s (see Overview Map).[54]

Figure 5. **Hydrogeological cross-section of the Zakho Basin**



Source: Compiled by ESCWA-BGR based on Stevanovic and Markovic, 2004.

GROUNDWATER USE AND SUSTAINABILITY ISSUES

Groundwater abstraction in the Iraqi part of the basin takes place mainly from the interganular Bai Hassan aquifer. In the early 1980s an estimated total of 24.3 MCM of good-quality (<700 mg/L TDS) water had been abstracted (9.5 MCM from deep wells and 12.3 MCM as spring discharge).[55]

As recharge far exceeded abstraction, it was suggested that up to 800 new wells could be drilled in the basin.[56] Additional abstraction could take place as follows:[57]

- Developing the shallow intergranular aquifer in alluvial plains and terraces
- Drilling deep wells in karstic areas in the foothills
- Tapping groundwater from springs

In order to mitigate drought in the area, it was also suggested that wells should be drilled to tap the low yield of brackish water in the Upper Fars-Lower Fars Formations as a back-up reserve.[58]

The city of Dahuk with the Zagros Mountains in the background, Turkey, 2005. Source: Ed Kashi/VII.

Agreements, Cooperation & Outlook

AGREEMENTS

There are no water agreements in place for any of the shared aquifer systems that occur in the Taurus-Zagros Thrust Belt.

COOPERATION

Iraq and Turkey have established a number of technical committees on water issues. However, they mainly deal with surface water issues and Iraq has not discussed shared groundwater management with any of its neighbours. Iran also does not cooperate with Iraq or Turkey over issues of shared groundwater management.

OUTLOOK

The strong interaction between surface water and groundwater in the Taurus-Zagros Thrust Belt entails that future cooperation will have to address conjunctive development and use of the two resources.

Lake Van, Turkey, 2010. Source: Adel Samara.

Notes

1. Stevanovic and Markovic, 2004.
2. Ibid.
3. Ibid.
4. Raziei et al., 2008.
5. Izady, 1992.
6. Stevanovic and Markovic, 2004.
7. Ibid.
8. Stevanovic and Markovic, 2004; Aghanabati, 1993; Sorkhabi, 2012.
9. Stevanovic and Markovic, 2004.
10. Ibid.
11. Ibid.
12. Krasny et al., 2006.
13. Stevanovic and Markovic, 2004.
14. Ibid.
15. Ibid.
16. Salahalddin, 2007.
17. Stevanovic and Markovic, 2004.
18. Salahalddin, 2007.
19. Over 40 years (<1962-2002) of mean annual precipitation data is available from the stations at Sulaymaniyah (675 mm) and Derbendikhan (680 mm). Stevanovic and Markovic, 2004.
20. Based on Central Organization for Statistics in Iraq, 2010a (2009 estimate) and Iraq Information Portal, 2012.
21. Al-Tamimi, 2007.
22. Salahalddin, 2007.
23. Ibid.
24. Ibid.
25. Ministry of Energy in Iran, 1988.
26. Salahalddin, 2007.
27. Stevanovic and Markovic, 2004.
28. Al-Tamimi, 2007.
29. Stevanovic and Markovic, 2004.
30. Stevanovic and Iurkiewicz, 2008.
31. Based on Statistical Center of Iran, 2006 (2006 census).
32. Based on Central Organization for Statistics in Iraq, 2010a (2009 estimate) and Iraq Information Portal, 2012.
33. Stevanovic and Iurkiewicz, 2008, p. 174.
34. Al-Jawad et al., 2008; Al-Sudany, 2002; Al Furat Company for Studies and Design of Irrigated Projects, 2002.
35. Stevanovic and Markovic, 2004.
36. Ibid.
37. Al-Tamimi, 2007.
38. Ahmad et al., 2005.
39. Al-Tamimi, 2007.
40. Stevanovic and Iurkiewicz, 2008.
41. Parsons, 1957.
42. Krasny et al., 2006.
43. Ahmad et al., 2005.
44. An underground conduit, between vertical shafts, that leads water from the interior of a hill to villages in the valley.
45. FAO Aquastat, 1997.
46. Stevanovic and Markovic, 2004.
47. Based on Central Organization for Statistics in Iraq, 2010a (2009 estimate) and Iraq Information Portal, 2012.
48. Based on Turkstat, 2010 (2010 census).
49. The Neogene in Turkey is represented by the Beygur and Siirt Formations, while the Midyat is equivalent to Pila Spi (Altinli, 1966).
50. Stevanovic and Markovic, 2004.
51. Abdulazim, 2009.
52. Tarmo, 1983, in Stevanovic and Markovic, 2004.
53. Stevanovic and Markovic, 2004.
54. Ibid.
55. Tarmo, 1983 in Stevanovic and Markovic, 2004.
56. Ibid.
57. The thick intergranular (Bakhtiari) sediments that fill the central plain of the Zakho Basin suggest that groundwater exploitation in the basin takes place in a similar manner to the Central Diyala Basin.
58. Stevanovic and Markovic, 2004.

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