Chapter 26

Dibdibba Delta Basin

Neogene Aquifer System (South-East): Dibdibba-Kuwait Group

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

german cooperation
DEUTSCHE ZUSAMMENARBEIT

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Neogene Aquifer System (South-East): Dibdibba-Kuwait Group

Dibdibba Delta Basin

EXECUTIVE SUMMARY

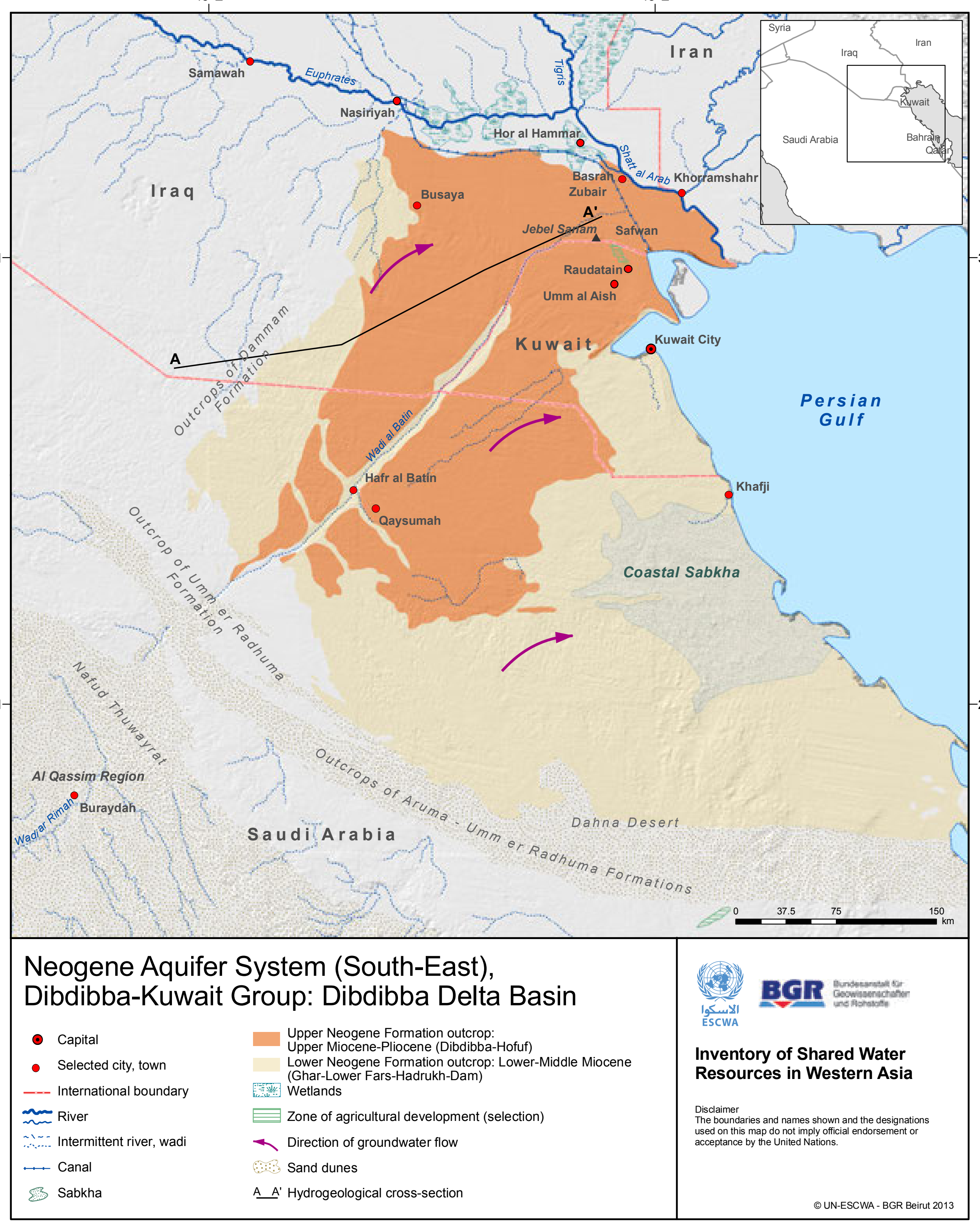
The Neogene Aquifer System (South-East) represents the northern extension of the Neogene Aquifers, which overlie the Paleogene Formations in the north-east of the Arabian Platform. The aquifer system is located mainly within the boundaries of the Dibdibba Delta basin, which is formed by the Wadi ar Rimah-Wadi al Batin that extends from the Arabian Shield in the west to the mouth of Shatt al Arab.

The basin stretches across three countries and comprises three aquiferous formations, known as Dibdibba, Lower Fars and Ghar Formations in Iraq and Kuwait, and Hofuf, Dam and Hadrukh Formations in Saudi Arabia. Groundwater has traditionally been abstracted mainly from the Upper Dibdibba Formation in southern Iraq and Kuwait or the Lower Hadrukh Formation in Saudi Arabia, which are mainly sands and gravels of continental origin. In recent years, abstraction of groundwater from these aquifers seems to be limited by two main factors: dewatering of the Dibdibba Formation, which has become largely unsaturated in several areas, and inversion of downward groundwater flow from the Neogene to the Paleogene Formations in heavy abstraction areas.

BASIN FACTS

RIPARIAN COUNTRIES	Iraq, Kuwait, Saudi Arabia
ALTERNATIVE NAMES	Ad Dibdibba Stony Desert, Ad Dibdibba Alluvial Fan, Dibdibba Plain, Kuwait Plain
RENEWABILITY	Very low to low (0-20 mm/yr)
HYDRAULIC LINKAGE WITH SURFACE WATER	Medium
ROCK TYPE	Porous
AQUIFER TYPE	Unconfined (central areas), Confined (coastal areas)
EXTENT	153,000 km^2
AGE	Cenozoic
LITHOLOGY	Predominantly sands and gravel
THICKNESS	30-200 m (common range) Max.: 550 m
AVERAGE ANNUAL ABSTRACTION	Iraq: ~370 MCM Kuwait: 88 MCM
STORAGE	Iraq: 1.26 BCM
WATER QUALITY	Brackish to saline (2,500 mg/L to 15,000 mg/L TDS)
WATER USE	Mainly agricultural
AGREEMENTS	-
SUSTAINABILITY	Water level decline and inversion of vertical flow due to over-exploitation

OVERVIEW MAP



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Introduction

LOCATION

The term Dibdibba Formation was introduced in 1938 for a type locality in the Zubair area to describe a Late Miocene-Pleistocene Formation, which extends over the Dibdibba Plain from the city of Basrah in Iraq to the northern part of Kuwait and the Wadi al Batin area in Saudi Arabia.[1] The Neogene Dibdibba Formation was deposited in a geographical area known as the Dibdibba Alluvial Fan or Delta.[2] This Inventory uses the term Dibdibba Delta to refer to the basin, while the term Neogene Aquifer System (South-East) refers to the aquifer system in this area. In Kuwait, this Neogene Aquifer System is denominated as the Kuwait Group Aquifer.

AREA

The Neogene Aquifer System (South-East) was formed during the Pleistocene pluvial phases, when a river flowed through Wadi ar Rimah and Wadi al Batin. This wadi system, which is the longest in the Arabian Peninsula, descends from the northern Arabian Shield to the north of the Gulf coast and used to extend further inland during the Pleistocene.[3]

The main part of the Dibdibba Delta basin is occupied by an alluvial fan which slopes north-east from about 400 m asl on its south-western side to 100 m asl on its northern side, with a low gradient of 1-1.2 m/km.[4] Since its formation in the wetter intervals of the Pleistocene, the main wadi has become deeply entrenched into the old alluvial fan, so as to reach Paleogene (Umm er Radhuma Dammam Formations) bedrock in the upper two thirds of the fan. Paleogene bedrocks are also exposed around the fan.

The boundaries assumed for the Dibdibba Delta basin are: the Gulf coast in the east, Paleogene (Dammam and Umm er Radhuma) outcrops in the west (around 350 km in east-west direction), the sand dunes of the Nafud Thuwayrat and Dahna Desert in the south, and the natural marsh systems (Central and Hammar) of the Shatt al Arab Wetlands in the north (around 480 km in north-south direction). The basin extends from the Wadi al Batin area in north-eastern Saudi Arabia into Kuwait and south-eastern Iraq.

For the purpose of this Inventory, the above-mentioned boundaries have been used to calculate the area of the shared aquifer system. The aquifer system covers around 153,000 km^2, of which 71% (109,000 km^2) is in Saudi Arabia, 18% in Iraq (28,000 km^2), and the remaining 11% (approx. 16,000 km^2) in Kuwait. Over 14,000 km^2 of the total area is covered by a sabkha.

CLIMATE

The climate in the Dibdibba Delta basin is arid with an average annual rainfall of around 100 mm. In some wet years, rainfall may exceed 200 mm with limited runoff causing floods in some wadis, in particular Wadi al Batin. More humid conditions prevailed in the area during wetter phases of the Quaternary period, the most recent being between 5,500 and

Khor al Zubair port, Basrah, Iraq, 2012. Source: Earth & Marine Environmental Consultants.

10,000 years ago[5] when the Wadi ar Rimah and Wadi al Batin formed one continuous river system (see Box 1 below).

POPULATION

Several medium-sized towns are situated in the area comprising the Neogene Aquifer System (South-East). The total population in the delineated basin that lies in Iraq is approximately 200,000, while around 2.5 million people live in the area that lies in Kuwait, mainly in urban areas. In Saudi Arabia, about 400,000 people live in the Hafr al Batin area. The total population living in and around the Dibdibba Delta basin can thus be estimated at around 3.5 million, including the population of the smaller villages and nomadic populations.

OTHER AQUIFERS IN THE AREA

The Neogene Aquifer System (South-East) is underlain by Paleogene carbonate aquifers: the Dammam and Umm er Radhuma Aquifers. The Dammam Aquifer provides the main source of brackish groundwater exploited in Kuwait. The Umm er Radhuma Aquifer is situated at great depth in this area, and contains mainly saline groundwater. The upper member of the Neogene Aquifer System (South-East) - the Dibdibba Formation - is overlain by alluvial Quaternary deposits in the area near Basrah and Hor al Hammar in southern Iraq and the northern part of Kuwait. The alluvial sediments are generally unsaturated but can be aquiferous, particularly in the coastal areas.

INFORMATION SOURCES

This chapter mainly uses information from Iraq and Kuwait. In Saudi Arabia, the Neogene Formations are mainly exploited further south-east in the region of Hofuf-Hasa, where they form part of the larger Umm er Radhuma-Dammam Aquifer System that extends to the Aruma Formation in this area.[6] Information on the part of the Dibdibba Delta basin that lies in Saudi Arabia is therefore not available. The Overview Map was delineated based on Mukhopadhyay et al., 1996.

Hydrogeology - Aquifer Characteristics

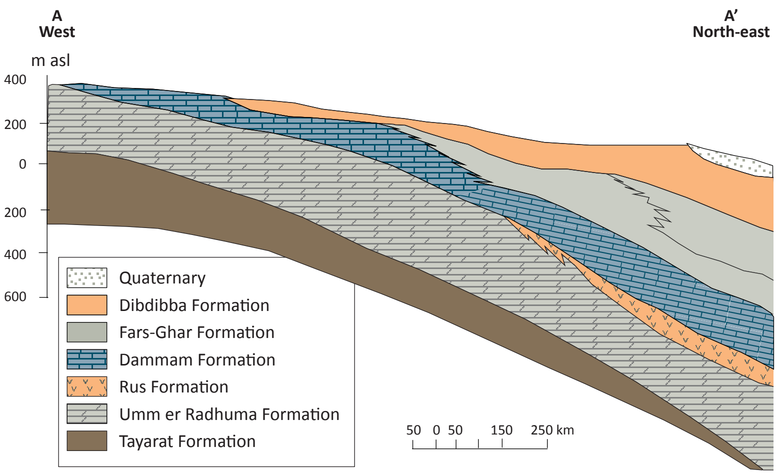
AQUIFER CONFIGURATION

The Neogene Formations rest disconformably over the Paleogene rocks and are overlain by Quaternary sediments at the mouth of the delta (Figure 1) where heavy loads of alluvial materials must have been deposited by both the Euphrates and Wadi ar Rimah-Wadi al Batin river systems.[7] The basin has a gentle slope in the west that becomes more pronounced farther east where the three Neogene Formations were deposited and preserved. Only a thin layer (Dibdibba Formation) can be found in the west.

STRATIGRAPHY

The Miocene sediments that constitute the main part of the Neogene Aquifer System (South-East) were deposited within the Zagros Foredeep, which was formed on the boundary between the stable Arabian Shelf and the Zagros Mountain Uplift. Massive supply of continental to deltaic clastics occurred and shallow marine shales accumulated in the rapidly subsiding Zagros Foredeep.[8] These sediments are thin in the western areas adjacent to the Paleogene outcrops, but quite thick and situated at great depth in the eastern coastal and offshore areas such as the area of Zubair, where they contain oil resources (Figure 1). The Neogene Aquifer System (South-East) has been subdivided into three formations, which are briefly described in Table 1.

Figure 1. Geological cross-section of the Neogene Aquifer System (South-East)



Source: Redrawn by ESCWA-BGR based on Al-Jawad et al., 2001.

Upper Formation (Dibdibba/Hofuf)

The Dibdibba Formation of southern Iraq and Kuwait covers the period from the Late Miocene to Pleistocene and is considered to have a similar fluviatile origin and the same characteristics as the Hofuf Formation.[9] The Dibdibba Formation constitutes a huge gravel fan with mainly coarse gravel and sand deposits, which accumulated during the Pliocene-Pleistocene in a sedimentary basin at the lower end of Wadi ar Rimah. In Iraq, the formation was defined as sand and gravel containing pebbles

Table 1. Lithostratigraphy of the Neogene Aquifer System (South-East)

PERIOD	FORMATION NAME AND GENERAL LITHOLOGY, PER COUNTRY		
	IRAQ	KUWAIT	SAUDI ARABIA
Pliocene	Dibdibba	Dibdibba	Hofuf
Upper Miocene	Continental (fluviatile): gravelly sand, often calcretized with subordinate clays.		
Middle Miocene	Lower Fars	Lower Fars	Dam
	Lagoonal: alternating beds of limestone, anhydrite, gypsum, clay and marls with subordinate sandstone.	Continental (fluviatile): calcretized sandstone.	Coastal (shallow marine littoral with supply of clastics): sandy and silty clay, calcareous marl, fossilferous limestone, sandstone and shale.
Lower Miocene	Ghar	Ghar	Hadrukh
	Continental (fluviatile): sands and gravels, rare clays, anhydritic and calcretic sands.		

Source: Compiled by ESCWA-BGR based on Mukhopadhyay et al., 1996; Alsharhan and Nairn, 1997; Ziegler, 2001.

of igneous rocks, including granite and quartz often cemented into hard grits. In Kuwait, the Dibdibba Formation has been subdivided into two units: a lower unit (Miocene-Pliocene) made up of coarse-grained, poorly sorted, gritty and pebbly sandstone cemented with chalky carbonate,[10] and an upper unit (Pliocene-Pleistocene) composed of gravelly sand and sandy gravel with gypsiferous cement.

Middle Formation (Lower Fars/Dam)

At the end of the Lower Miocene, a transgression of the sea intruded into the area; lagoonal conditions prevailed in the north-eastern corner of the Dibdibba Delta basin and lagoonal evaporitic sediments (Lower Fars) were formed in a considerable thickness.[11] The shallow marine littoral sediments with the terrigenous clastics of the Dam Formation were deposited in the south-eastern part[12] while continental (fluviatile) clastics continued to be deposited over much of the basin during the Middle Miocene, with some interfingering with the Lower Fars towards the east. In Kuwait, the Lower Fars Formation is described as well-sorted sand and sandstone interbedded with silty sand, clay and clayey sand with thin limestone beds and gypsum layers in the lower horizons of the formation.[13] In the area of Wadi al Batin on the Iraq-Kuwait border, the Lower Fars Formation is composed of claystone, marl and limestone.[14]

Lower Formation (Ghar/Hadrukh)

Deposition of this formation occurred under conditions varying from continental to littoral and deltaic.[15] In Iraq, the Ghar Formation consists of sands and gravels with rare anhydrite, clay and sandy limestone interbeds, while in most of Kuwait it is represented by marine to terrestrial coarse-grained, unconsolidated sandstone with a few thin, sandy limestone, clay and anhydrite layers. In southern Kuwait, the Ghar Formation has a gradational contact with the Lower Fars Formation and the two formations constitute an undifferentiated complex.[16] The Hadrukh Formation consists of calcareous to silty sandstones and sandy limestones and coquina beds.[17]

AQUIFER THICKNESS

Bore-hole data indicates that the total thickness of the Neogene Aquifer System (South-East) increases along the Wadi al Batin from 100 m in the south-west to about 550 m near its mouth. On average, the Dibdibba Formation constitutes about 150 m within the aquiferous sequence, with a thickness range of between 30 and 200 m.[18] South-west of the town of Busaya in Iraq, measurements in a water well showed the Dibdibba Formation comprises from its base upward: 21 m of gravelly sandstone, 60 m of medium-grained pink sandstone, and 18 m of calcareous sandstone.[19] The aquifer thickness decreases westward, leaving a large part of the formation unsaturated. The Lower Fars (Fatha) Formation has a minor presence in southern Iraq with a thickness of 40 m, while the Ghar Formation may reach a maximum thickness of 200 m.[20]

AQUIFER TYPE

The Neogene Aquifer System (South-East) is generally unconfined although confined conditions may exist in deeper layers of the aquifer complex. In general, the whole Neogene sequence forms one continuous aquifer system. The upper tens of metres of the sequence are unsaturated in many areas, especially west and north of the Wadi al Batin channel.

AQUIFER PARAMETERS

Hydraulic parameters of the Neogene Aquifer System (South-East) vary widely according to lithologic variations and saturated thickness. In general, higher aquifer productivity is found in the central gravel plain of Wadi al Batin with relatively thick and coarse sediments, while the aquifers in the flood plain areas may contain higher clay contents and have a lower productivity. The range of transmissivity values recorded in Kuwait increases from less than 1.15×10^{-4} m^2/s in the south-west to 1.73×10^{-2} m^2/s in the north-east for the aquifer system as a whole.[21] Similarly, a range of transmissivity values between 3.35×10^{-4} and 2.49×10^{-2} m^2/s is reported from Iraq.[22] The highest transmissivity value (2.95×10^{-2} m^2/s) was recorded for the unconfined Dibdibba Formation around Safwan.[23] The storage coefficient of the aquifer system was found to range between 1.8×10^{-2} and 8×10^{-2} in the southern part of Kuwait, where the aquifer system is unconfined, and about 1×10^{-4} in the northern part where it is confined.[24] The highest value (2×10^{-1}) was recorded in the Safwan-Zubair area in Iraq.[25]

Hydrogeology-Groundwater

RECHARGE

The aquifer system is fed by an extensive watercourse (Wadi ar Rimah-Wadi al Batin) that extends hundreds of kilometres into the Arabian Shield. Sources of recharge therefore are not only the rainstorm events within the Dibdibba Delta but also, and perhaps more importantly, the surface and subsurface flow of freshwater in this watercourse since the Pleistocene time.

Isotope data suggests that the Neogene Aquifer System (South-East) was recharged during more humid and cooler periods 20,000-30,000 years ago[26] and 5,500-10,000 years ago.[27] The occurrence of recharge under the present climatic conditions, though highly irregular, has also been observed, mainly in areas where karstic features developed in the Neogene-Paleogene Formations (mainly the Umm er Radhuma Formation). Recharge through this formation in the central Gulf region (82,100 km^2), which incorporates the entire Saudi part of the Neogene Aquifer System (South-East), ranged from nil to 2,706 MCM over the period 1952-1978.[28] The average recharge for this period was 547 MCM (6.7 mm/yr).

Variations of recent recharge during dry and wet years have reportedly ranged between 2.2 and 12 mm/yr for the Dibdibba Formation in Iraq.[29] The range of recharge values observed in southern Iraq (from 0.25 mm/yr in the western area to 26 mm/yr in the Safwan area)[30] may indicate a significant decrease in recharge in the south-west/north-east direction.[31] Estimates of natural annual groundwater recharge computed for the Iraqi part of the Dibdibba Plain vary between 30 and 90 MCM.[32]

In topographic depression areas in northern Kuwait (Raudhatain and Umm al Aish), occasional rainstorms cause freshwater ponding that infiltrates and forms freshwater lenses floating over the brackish water. In these areas, an average annual recharge of 850,000 m^3 has been estimated. Annual recharge to the entire aquifer system in Kuwait was estimated to be in the order of 58.5 MCM. The recharge rate included recharge from infiltration, subsurface inflow, and upward leakage from the Paleogene Dammam Aquifer.[33]

FLOW REGIME

In the northern areas, where the ground slopes from about 270 m asl in the extreme south-west to the lowlands of Iraq, groundwater flows towards the Shatt al Arab. In the southern part, the ground surface drops towards the Gulf through a series of discontinuous scarps, plateaus and plains, and groundwater flow is slightly deflected to the east. The elevation of the water table in the Neogene Aquifer System (South-East) descends from 130 m asl in the upstream area at Wadi al Batin and in southern Kuwait, to less than 5 m asl in the discharge zone.[34] At the downstream end of the aquifer system along the coast and the Shatt al Arab Depression, the groundwater is in direct contact with the sea or leaks into overlying Quaternary sediments and salt flats. Parallel to the Gulf coast in Kuwait, a belt of saline water forms a boundary to the brackish water of the Dammam Aquifer, causing an upward flow of groundwater into the overlying Neogene Aquifer System (South-East). The groundwater ultimately discharges from the Neogene Aquifer System (South-East) and through overlying Quaternary deposits into the sea and evaporation flats in the coastal area.

STORAGE

It is estimated that the Neogene Aquifer System in the Dibdibba Delta basin may hold around 11 BCM of groundwater,[35] which is about 10% of what has been estimated for the Negoene Aquifers as a whole in the Arabian Peninsula.[36] However, a large part of the Dibdibba Delta is now unsaturated. The uppermost exploited brackish water horizon in the Safwan-Zubair area, which has a saturated thickness of nearly 20 m, has storage of 1.26 BCM.[37] No other estimates were recorded in the literature.

DISCHARGE

Natural discharge from the Neogene Aquifer System (South-East) occurs mainly in the Gulf coastal area and the Shatt al Arab lowlands, through evaporation from shallow water tables and seepage into overlying Quaternary sediments, riverbeds and sabkhas.

WATER QUALITY

The groundwater in the Neogene Aquifer System (South-East) is generally brackish to saline with high lateral and vertical variations. Groundwater salinity increases horizontally along the flow path, as well as vertically across the different lithological units of the aquifer system.

In southern Iraq, two salinity layers can be distinguished in the Dibdibba Formation, separated by consolidated silty clay beds. The upper horizon has Electrical Conductivity values between 2,400 and about 11,000 μS/cm, with an average range between 2,500 and 7,000 μS/cm.[38] Lower salinity values of about 1,000 mg/L TDS are found in morphologic depressions, where present-day recharge occurs.[39] The salinity contained in the second layer normally exceeds 15,000 mg/L. The separation between the two layers with different salinity may be related to low permeability layers or to a transitional salinity increase, with less saline water floating above water with higher salinity. The cause of the high salinity in the deeper horizons of the aquifer may be a connection with seawater or leakage from deeper carbonates (Upper Eocene Dammam Formation), which contain saline groundwater in this part of Iraq.[40]

In Kuwait, the overall salinity of the aquifer system ranges from 4,000 mg/L in the south-west of the country to 18,000 mg/L and higher in the north-east. An exception are the freshwater lenses in the Upper Dibdibba Formation in the Raudhatain and Umm al Aish Depressions, formed by the infiltration of runoff from infrequent rainstorms.[41] Relatively high boron (B^{3+}) concentrations between 9×10^{-1} mg/L and 2.5 mg/L are found in wells in the Dibdibba Formation in Iraq.[42]

EXPLOITABILITY

The Neogene Aquifer System (South-East) comprises a shallow aquifer system with water levels at relatively shallow depth. In some areas, the groundwater level is situated below the Dibdibba Formation and this unit is unsaturated. Exploitability depends mainly on the saturation level and water quality. Both of these parameters seem to be most favourable along the eastern bank of the Wadi al Batin and near the mouth of the delta where freshwater leakages from shallow lenses may occur. Areas along the coast, especially on the north-eastern tip of the Dibdibba Delta, are expected to be least suitable for exploitation.

Khor al Zubair port, Basrah, Iraq, 2012. Source: Earth & Marine Environmental Consultants.

Groundwater Use

GROUNDWATER ABSTRACTION AND USE

In southern Iraq, the aquifer system has been exploited through a large number of – mostly hand-dug – wells in the area west of Basrah, mainly from the Upper Dibdibba Aquifer. An official survey found that nearly 5,000 wells were in use in this area in 1998.[43] Annual groundwater abstraction for agricultural purposes was estimated at around 370 MCM in the 1980s.[44] A substantial part of the extracted water returns back to groundwater through the permeable pebbly sand soils (a return flow of about 84%).[45]

In Kuwait, exploitation of the Neogene became significant in the mid-1980s with a noticeable shift to the drilling of bore-holes that tap both the Neogene and the Dammam Formation below it. Abstraction from the Neogene and the Dammam Formation reached 91.6 MCM and 118.9 MCM respectively in 1988.[46] Annual abstraction from both the Neogene and the Dammam was estimated at 88 MCM in the 1980s, excluding extraction from private wells.[47] This groundwater exploitation resulted in:

- Vertical leakage from the Neogene Aquifer System downward into the Dammam Aquifer has been reversed.
- A 191 MCM/yr reduction in the groundwater storage in the Neogene Aquifer System (South-East), including 30.8 MCM/yr from the Dibdibba Aquifer.
- A 26% drop in the volume of outflow from the aquifer system. The draw-down in the Neogene Aquifer System (South-East) resulted in a 5-20 m drop in the water table in the border area between Kuwait and Saudi Arabia.[48]

GROUNDWATER QUALITY ISSUES

Groundwater in the Dibdibba Delta Basin is not suitable for human consumption with the exception of limited freshwater lenses near Raudhatain and Umm al Aish in northern Kuwait and in the Sabriah and Barjisiyah oilfields near Zubair in southern Iraq. The two freshwater lenses in Kuwait may have been polluted by oil spills during the second Gulf War in 1991.

SUSTAINABILITY ISSUES

The hydraulic connection with the Paleogene system – in particular the Dammam Aquifer – may influence the sustainability of the Neogene Aquifer System (South-East). Reversal of the hydraulic gradient downward and the flow of groundwater from the Neogene into the Dammam Aquifer have been observed for more than 20 years. This could represent a major risk to the productivity of the Neogene Aquifer System (South-East).

BOX 1

The Wadi ar Rimah-Wadi al Batin System

Extending across north-eastern Saudi Arabia, south-eastern Iraq and much of Kuwait,[49] the Rimah-Batin Wadi System is the longest wadi system in Arabia.[50] It is one of three[51] great west-east through-draining wadis on the peninsula[52] and used to be made up of major perennial rivers during the Late Pleistocene epoch.[53] Extending over a distance of about 970 km[54] from the Arabian Shield north-eastward to the southern part of Iraq, the system drains an area of about 174,400 km^2.[55] It crosses the borders of three countries: Iraq, Kuwait and Saudi Arabia. The Wadi ar Rimah-Wadi al Batin formed the Dibdibba Plain,[56] which is a sheet gravel blanket. The courses of Wadi ar Rimah and Wadi al Batin are now separated by the sand dunes of Nafud Thuwayrat. The Wadi ar Rimah system drains an area of over 112,000 km^2 and, although its lower course is largely sand filled, it still carries water in the wadi course. Wadi al Batin has a modern channel with some perennial water as well as many shallow ephemeral distributaries that fan out across the broad nose of Dibdibba Alluvial Fan.[57]

SEDIMENTOLOGICAL PROPERTIES

The landscape around Wadi ar Rimah consists of a wide flat pediplain on which coarse- to fine-grained Quaternary sediments have accumulated, mainly in eroded pediments and alluvial fans. The nature of the alluvial fans depends mainly on the kind of outcropping rocks. In granitic terrains, the fine-grained detritus allows only a low gradient of the slopes, whereas sharp terrace edges in areas of crystalline schists are mostly cut into the rocks.[58] The wadi channels are filled by fine clastic material with a high percentage of gypsum, while thin gravels, sands and fanglomerate-like sediments cover the older, smoothly eroded pediments.[59] The Wadi al Batin area is a 7-10 km wide alluvial fan with a relief of up to 57 m.[60] The surface is covered with gravel ridges (up to 20 m high) and inter-ridge depression erosional patterns.

HYDROLOGICAL FEATURES

The Wadi al Batin and Wadi ar Rimah were connected during the Quaternary wetter phases (until about 5,500 years ago) to constitute a major river system[61] that comprised two rivers separated by a highly faulted and fractured area covered by avalanches of wind-blown sand.[62] The carving of the wadi across the peninsula suggests the prevalence of a period of rainfall considerably greater in magnitude than any such periods during the Pleistocene.[63] Evidence that fluvial flow was available much more frequently and with a greater volume than today includes the well-defined Wadi al Batin Valley which is cut deep enough to uncover the underlying Tertiary Formations and the elevated terraces of older gravel.[64]

HYDROGEOLOGICAL CHARACTERISTICS

The Wadi ar Rimah-Wadi al Batin System (Figure 2) is a clear example of the concentration of groundwater by fractures where, in this case, the pathway of two old rivers is traced by a fault zone.[65] The lateral change in geology beneath the wadi system also appears to have a significant effect on its hydrogeological characteristics. West of the Buraydah-Unayzah area, the Basement allows increased surface runoff and evaporation, and decreased infiltration; hence no recharge from present precipitation occurs and shallow groundwater is only found in localized areas. The hydrogeological situation changes in the Buraydah-Unayzah area and further east, where present-day recharge occurs and the productivity of wells increases as a result of water circulating through joints and pore volumes in sedimentary rocks.[66]

Table 2 shows the exploitable amount of groundwater stored in the Rimah-Batin Wadi System. The water is found even under the part of the system covered by sand,[67] which is believed to have been a major source of water for the aquifers in the Al Qassim region.[68]

The water level is generally around 20 m bgl and wells abstracting water are commonly lowered to the fractured part of the Basement or the Saq Sandstones and other sedimentary formations, with generally higher salt content in the upper zone. The groundwater has a highly variable degree of mineralization. The general salinity range was reported to be 1,000-8,700 mg/L TDS.[69] However, values of up to 41,000 mg/L TDS have been found in localized areas beneath the wadi bed.[70] Extremely high nitrate levels up to 570[71] and 1,000 mg/L NO_3^- have been reported in some areas.[72] Isotope data indicates that the salt content of the water increases with the resident time of the water, mainly through the process of tertiary evaporation and recycling.[73]

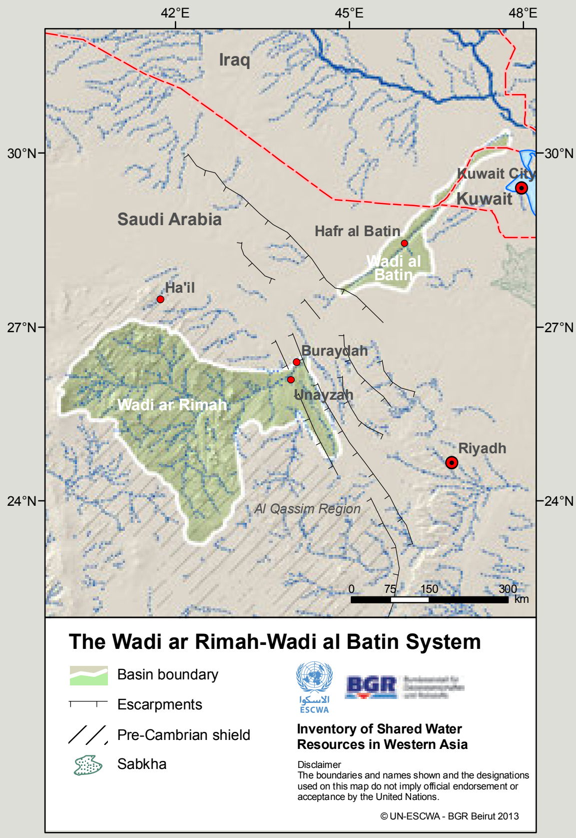
GROUNDWATER USE

Historically, three oasis towns in Saudi Arabia have survived on the shallow groundwater in this area: Buraydah, Unayzah and Hafr al Batin.[74] Further east, the shallow groundwater is heavily abstracted from the gravels of the Dibdibba Alluvial Fan, which was deposited by the Wadi al Batin. The isotopic composition of freshwater (500-1,800 mg/L TDS) perched in the Dibdibba Formation indicate that this is present-day recharge water.[75] This water forms a key source of groundwater for populations in the area of Raudhatain and Umm al Aish in Kuwait.

SUSTAINABILITY AND MANAGEMENT ASPECTS

The fertile arable lands created by runoff in the Wadi ar Rimah have allowed for agricultural development since the early 20th century in the upstream areas of the Rimah-Batin Wadi System, mainly around the towns of Buraydah and Unayzah.[76] Similarly, agricultural development in northern Kuwait and south-eastern Iraq depends heavily on the runoff in Wadi al Batin. In both of these areas, the shallow fresh groundwater is underlain by very saline water. Upconing of saline water already occurs[77] and poses a major risk to the sustainability of this alluvial system.

Figure 2. The Wadi ar Rimah and Wadi al Batin catchment area



Source: Compiled by ESCWA-BGR based on Sowayan and Allayia, 1989.

Hafr al Batin area, Saudi Arabia, 2007. Source: Drh104.

Table 2. Generalized hydrogeological information on the alluvial sediments in the Wadi ar Rimah-Wadi al Batin area

CATCHMENT AREA[a] (km²)	STORAGE (MCM)	POTENTIAL ABSTRACTION CAPABILITIES (MCM/yr)	GROUNDWATER ASSESSMENT	WATER QUALITY
174,400	4,000	20	Shallow supplies are available; some irrigation.	Generally poor; specific conductivity 2,000-5,000 µS/cm.

Source: Compiled by ESCWA-BGR based on Ministry of Agriculture and Water in Saudi Arabia, 1984.

(a) Data shown in the table is from source reference. Edgell, 2006, states an area of 112,000 km² for the catchment. This Inventory used GIS ArcMap Application to calculate an area of 114,000 km².

Agreements, Cooperation & Outlook

AGREEMENTS

There are no water agreements in place for the Neogene Aquifer System (South-East), which is shared between Iraq, Kuwait and Saudi Arabia.

COOPERATION

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

OUTLOOK

The quantity and quality of available groundwater in the Neogene Aquifer System (South-East) suggest that it could sustain agricultural development in the central gravel plain, along the eastern bank of Wadi al Batin and near the mouth of the delta. On the plain itself, the aquifer system may have some potential as a source of recharge to the underlying Paleogene Formations, especially where the two aquifer systems are used as a common source of groundwater.

Kuwait, 2011. Source: Cajetan Barretto.

Notes

1. Alsharhan and Nairn, 1997, p.443.
2. Edgell, 2006.
3. Holm, 1960 cited in Edgell, 2006.
4. Ibid.
5. Edgell, 2006.
6. Tokhais and Rausch, 2008.
7. Edgell, 1997; Bakiewicz et al., 1982.
8. Ziegler, 2001.
9. Ibid.
10. Mukhopadhyay et al., 1996.
11. Ibid.
12. The Dam Aquifer does not extend beyond the area of Hasa (Edgell, 1997) and, hence, may not be part of the Neogene Aquifer System in the Dibdibba Delta basin.
13. Mukhopadhyay et al., 1996.
14. Al-Mashadani, 1995.
15. Alsharhan and Nairn, 1997; Ziegler, 2001.
16. Mukhopadhyay et al., 1996.
17. Ziegler, 2001.
18. UN-ESCWA and BGR, 1999.
19. Jassim and Buday, 2006.
20. Jassim and Goff, 2006.
21. Mukhopadhyay et al., 1996.
22. Al-Jawad et al., 1989.
23. Haddad and Hawa, 1979.
24. Mukhopadhyay et al., 1996.
25. Haddad and Hawa, 1979.
26. Pike, 1985 and Quinn, 1986 cited in Mukhopadhyay et al., 1996.
27. Edgell, 2006.
28. Faulkner, 1994.
29. Al-Mashadani, 1995.
30. Haddad and Hawa, 1979.
31. Assaf and Al-Suhail, 2001.
32. Al-Jawad et al., 2001.
33. Barrat et al., 1992.
34. Mukhopadhyay et al., 1996.
35. Al-Jawad et al., 2001.
36. Al Alawi and Abdulrazzak, 1993.
37. Al-Jawad et al., 2001.
38. Hassan et al., 1989.
39. Al-Jawad et al., 1970.
40. Parsons, 1957; Al-Jawad et al., 1970; Al-Rawi, 1983.
41. Mukhopadhyay et al., 1996.
42. Haddad and Hawa, 1979.
43. Al-Jawad, 1999.
44. Hassan et al., 1989.
45. Haddad and Hawa, 1979.
46. Mukhopadhyay et al., 1996.
47. This average dropped significantly as a result of much lower abstraction rates during the 1990-1991 Gulf War (UN-ESCWA and BGR, 1999).
48. Barrat et al., 1992.
49. Edgell, 2006.
50. Ibid.
51. The other two are Wadi as Sahba in central Arabia and Wadi ad Dawasir further south. The lower courses of all three wadi systems are now largely sand filled (Edgell, 2006).
52. McClure, 1978.
53. Edgell, 2006.
54. Ibid.
55. Ministry of Agriculture and Water in Saudi Arabia, 1984.
56. Powers et al., 1966.
57. Ibid.
58. Hotzl et al., 1978.
59. Ibid.
60. Al-Sulaimi and Pitty, 1995.
61. Edgell, 2006.
62. El-Baz, 2010.
63. McClure, 1978.
64. Anton, 1984.
65. El-Baz, 2010.
66. Hotzl et al., 1978.
67. Edgell, 2006.
68. El-Baz, 2010.
69. Moser et al., 1978; Sowayan and Allayia, 1989.
70. Sowayan and Allayia, 1989.
71. Ibid.
72. Moser et al., 1978.
73. Ibid.
74. El-Baz, 2010.
75. BGR et al., 1999.
76. Sowayan and Allayia, 1989.
77. Ibid.

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