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ORIGINAL PAPER

Groundwater resources assessment for irrigable agricultural lands in the Wadi Araba area, southern Jordan

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Abstract The main target of this research paper was to the hydrogeological assessment of the groundwater resources to irrigate 600 ha of irrigable agricultural lands, distributed along the Dead Sea–Aqaba Highway in Umm, Methla, Wadi Musa, Qa' Saideen and Rahma, southern Jordan. Therefore, a comprehensive groundwater study was commenced by drilling eight new wells which can be used to supply irrigable areas with the existing groundwater that would be enriched by the yield of three proposed recharge dams on Wadi Musa, Wadi Abu-Burqa, and Wadi Rahma. The evaluation of the pumping test data of the drilled was carried out using the standard methods of pumping test interpretation. This was based on the available water table measurements at well locations and knowledge of water flow in the general. The sustainable yield of each well was calculated based on the pumping test parameters. The obtained results indicate that pumping out of Beer Mathkor wells should not exceed 1,100 m^3/day in the case of continuous pumping and 8,700 m^3/day in the case of intermittent pumping. Since the water table did not significantly change with small changes in pumping (it took eightfolds of magnitude increase in pumping from approximately 1,100 to 8,700 m^3/day to show a significant drop in the water table equivalent to about 5.5 MCM per year from the aquifer.

Keywords Groundwater · Pumping tests · Sustainable well yield · Irrigation · Arid area

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Introduction

Jordan is considered as one of the ten most water-scarce countries in the world (JWR 2001; El-Naqa et al. 2009). The country, dominated by arid and semi-arid climate, suffers from scarcity of natural water resources and increasing population growth. This has caused an increased demand on water resources and resulted in a wide disparity between water supply and demand (Al-Mimi 1992). Many experts have agreed that the scarcity of water is the gravest environmental challenge facing the country both in the present and in the future (JGE 2001). Therefore, proper assessment, planning, and development of water resources are key elements in the overall social and economic development.

Wadi Araba, portion of Jordan Rift Valley located between the Red Sea and the Dead Sea, has become an important focal point in a progressive movement leading towards economic development. The scarcity of water resources in Wadi Araba has been considered as the gravest problem that the development plan might face (Abu Zir 1989). Therefore, the development of water resources of the area for irrigation purposes will have the highest priority in the Jordan water resources development plan (Smith 1995). Within the Wadi Araba development project area, a report dealing with the main hydrogeological features of groundwater resources and conditions of their development for irrigation purpose was published (Tukan et al. 1990). The report included three parts dealing with basin hydrogeology, groundwater mathematical model, and basic hydrogeological data.

Agriculture development in the Wadi Araba began in the middle of the 1960s and 1970s when a number of wells were drilled by the private sector for irrigation purposes (Al-Dabaseh 2003). Groundwater was the only available source for water supply and irrigation in the region, therefore groundwater was abstracted heavily to meet the need for expansion in agriculture.

This paper deals with the hydrogeological characteristics of the groundwater resources that can be used for irrigation purposes at the Beer Mathkor and Dahl areas within the Wadi Araba area. The main objective of this work is to evaluate the borehole and aquifer tests that were carried out for the new drilled wells in the mentioned sites on May 2009 and supervised by the Aqaba Special Economic Zone Authority/Wadi Araba Development Unit. Special attention is paid to the quantity and quality of water available and conditions of its withdrawal within the study area. A safe yield analysis of groundwater wells is included in the study. Such analysis will be based on the results of the drilling report supplied by ASEAZ and data collected in order to identify the areas of agricultural lands according to certain cropping pattern and the appropriate irrigation patterns.

The wadi floor of the Wadi Araba Basin is composed of alluvial sediments brought from the surrounding mountains in the east and west (El-Naqa et al. 2009). The thickness of the sediment fill is measured in kilometers, but the fresh and brackish groundwater is found in the uppermost portions of the aquifer (Dames and Moore 1979).

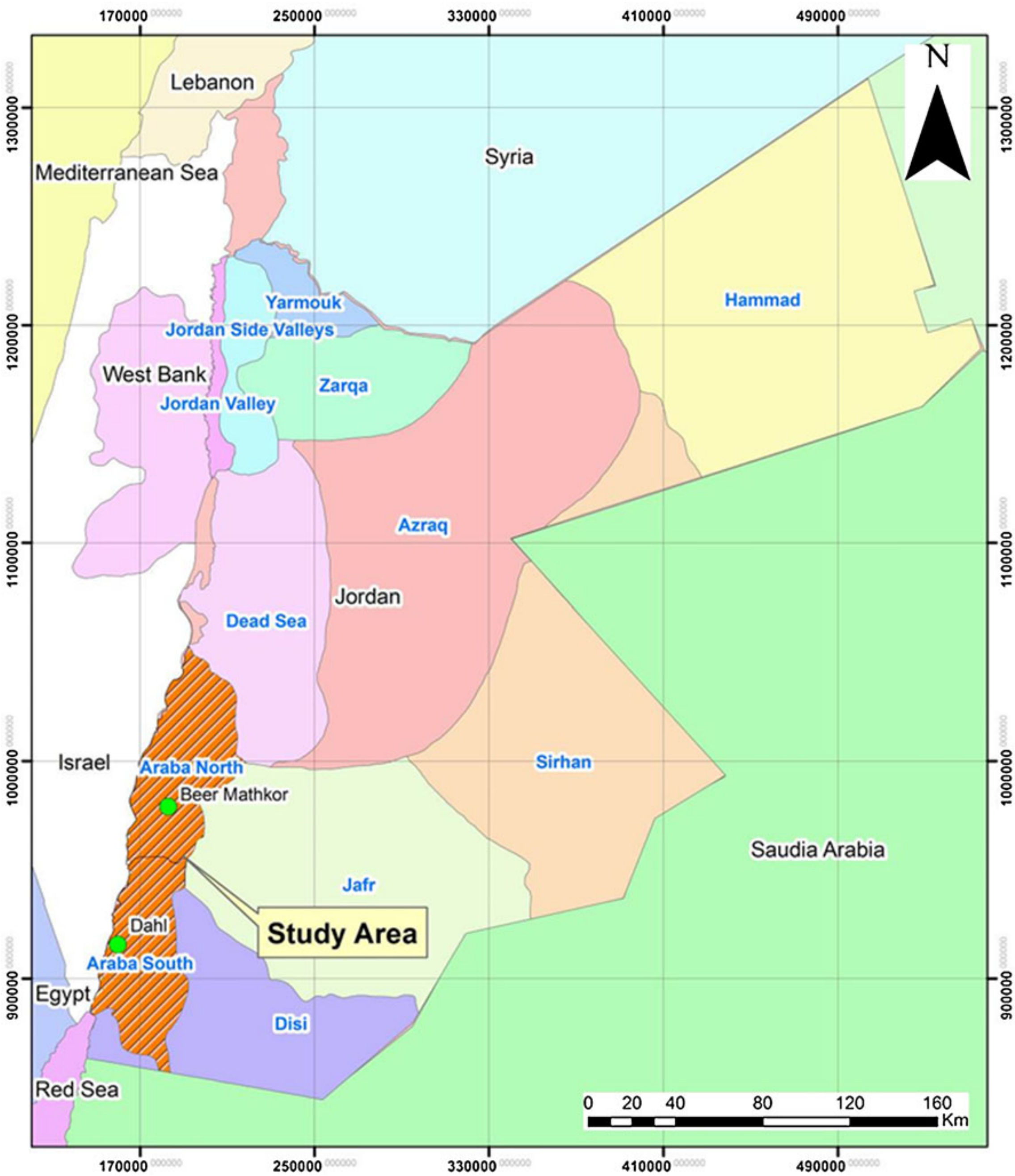

Fig. 1 Location map of the study area

The groundwater flow is directed from the north toward the Red Sea in the south. Recharge comes from precipitation falling on the surrounding mountains in the east and infiltrates there in the barren rocks and flows laterally into the fluviatile and alluvial deposits covering the wadi floor. It seems quite clear that the main groundwater resource within the study area appears to be the Quaternary aquifer system. This aquifer system has the largest continuous extension and the most favorable conditions of its recharge and groundwater development. Consequently, the Quaternary aquifers have been subjected to development for irrigation and domestic water supply for relatively long period but in particular since 1981. Thereby, four well fields to supply corresponding pilot farms were initiated.

Description of study area

The study area falls south of Jordan in Wadi Araba that extends between the southern Ghors, south of the Dead Sea and the Gulf of Aqaba (Fig. 1). The study area consists of two sites: the Dahl site and the Beer Mathkor site. The Dahl site is about 50 km apart of Mathkor site in the northern direction. Figure 2 shows the geomorphology of the Dahl site. However, Fig. 3 presents the location of groundwater wells drilled in the Beer Mathkor area, in addition to streams crossing sites, as well as existing farm distributions.

The terrain in the Beer Mathkor site can be characterized as a moderate terrain of slope 2.4 % within the zone of the wells' distribution at the east side of the Safy main road and becomes a flatter terrain below 1.0 % in the area of existing farm strips. The Dahl well is about 5.0 km far from the eastern side of the Safy main road, and there is no access road to reach this well. The WM1 well is located in the floodplain of a wide stream named Wadi Dahl. A stream flood is characterized as a rocky, tough area, and not easily accessed. The terrain within the Dahl well can be characterized as a moderate terrain of slope 2.4 % and becomes flatter of slope 1.0 % in the range of existing farms.

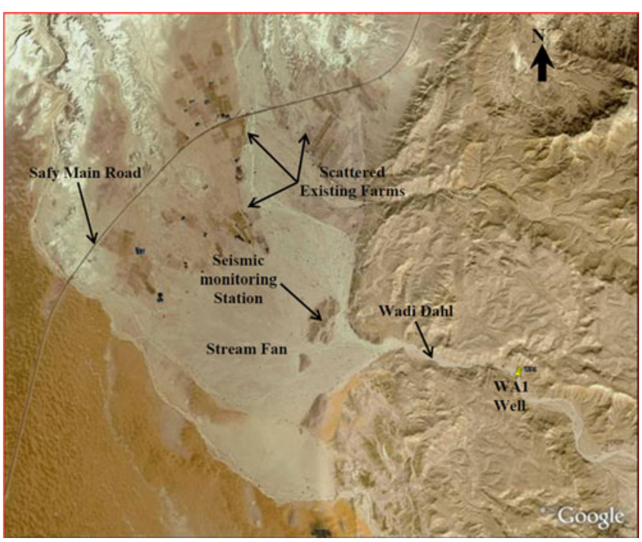

Fig. 2 Google image for Dahl site

In the Beer Mathkor site, the elevation varies between 240 m above sea level (a.s.l) in the eastern direction of the Safy main road at the Beer Mathkor wells (WMSH1, WMSH2, WMSH3, and WMSH4) to 120 m a.s.l along the existing farm strips. In addition, the Dahl site elevation varies between −34.0 m below sea level (b.s.l) at the Dahl well to −180 m b.s.l at existing farms in the vicinity of the main road.

Climate

The average monthly temperature in the south of Jordan ranges from 20 °C to 31 °C. The average relative humidity ranges from 41 % to 63 %. The prevailing winds are from the west. Rainfall generally occurs between September and May with most of the rainfall occurring between December and March. The average annual rainfall is about 75 mm in the project area or less.

Water resources

As mentioned earlier, the project area consists of two sites: the Beer Mathkor site and the Dahl site. Both sites are located within Wadi Araba. The objective of the project is to use the available groundwater resources for irrigation purposes and in order to develop the area.

Seven groundwater wells were drilled during 2008, which are distributed within the Mathkor site while only one well (WA1) is located in the Dahl site. Some of the Mathkor wells (WDMI, WMSH5, and WMSH6) are located at the west side of the main Safy road. A track road of approximately 7.0 km in length in the eastern direction of the main road accesses the rest of the Beer Mathkor wells (WMSH1, WMSH2, WMSH3, and WMSH4). The next was the Dahl site. The Dahl well is about 5.0 km farther from eastern side of the Safy main road; a rough rocky stream route (Wadi Dahl) was used to reach the Dahl well since no access road was available to reach this well as discussed earlier.

Hydrogeological analysis

Methodology of hydrogeological analysis

The objective of the hydrogeological analysis is to estimate the aquifer parameters of the alluvial aquifers in Wadi Araba (Mathkor wells) as well as to model part of an aquifer in order to find the safe yield. The safe yield of a groundwater

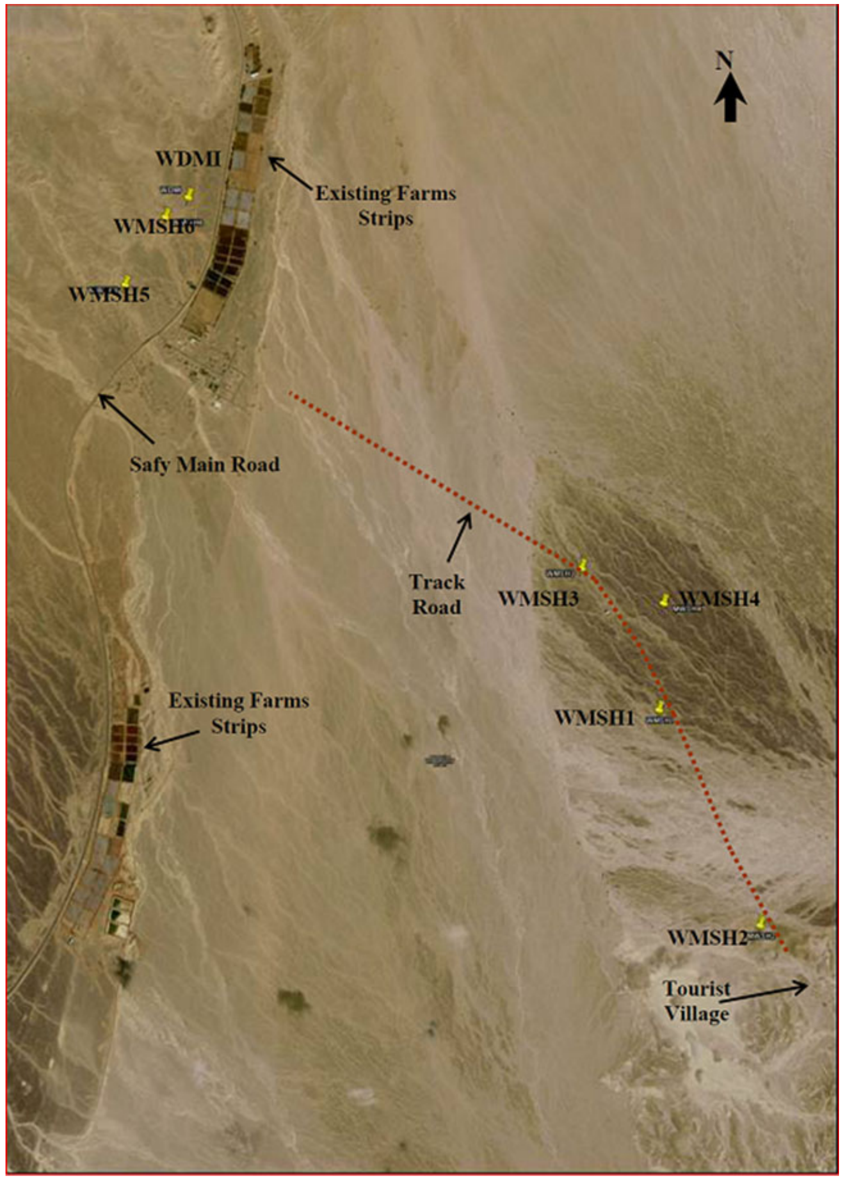

Fig. 3 Google images for Beer Mathkor site

basin or aquifer system is defined as the amount of water that can be withdrawn from it without producing an undesired effect (Todd 1980).

In general and from previous investigations conducted in the study area and the adjacent areas, Iit is indicated that the groundwater flows from the mountains in the east in a westerly direction, with a component towards the north with throughput of water from the area towards the north into the Dead Sea at a rate of 21.7 million cubic meters (MCM)/year (Al-Mimi 1992). The groundwater divide along the mountain ridge east of the Wadi Araba Rift seems to be roughly close to the surface water divides, though it is changeable throughout the study area. In addition, it is well-known that the water salinity in Jordan increases in the direction of groundwater flow, from the areas adjacent to the recharge areas to the discharge areas.

Aquifer systems

Within the study area, the following aquifer systems as distinguished by the National Water Master Plan of Jordan can be pointed out (Fig. 4):

1. Water-bearing sandstones of Cambrian and Ordovician, constituting Disi Group Aquifer System;
2. Kurnub Group Aquifer consisting of Lower Cretaceous sandstones;
3. Water-bearing carbonate rocks of Upper Cretaceous age constituting the so-called Amman-Wadi Sir (or A-B) aquifer system;
4. Alternating water-bearing and water-confining/supporting Upper Cretaceous and Tertiary undifferentiated strata

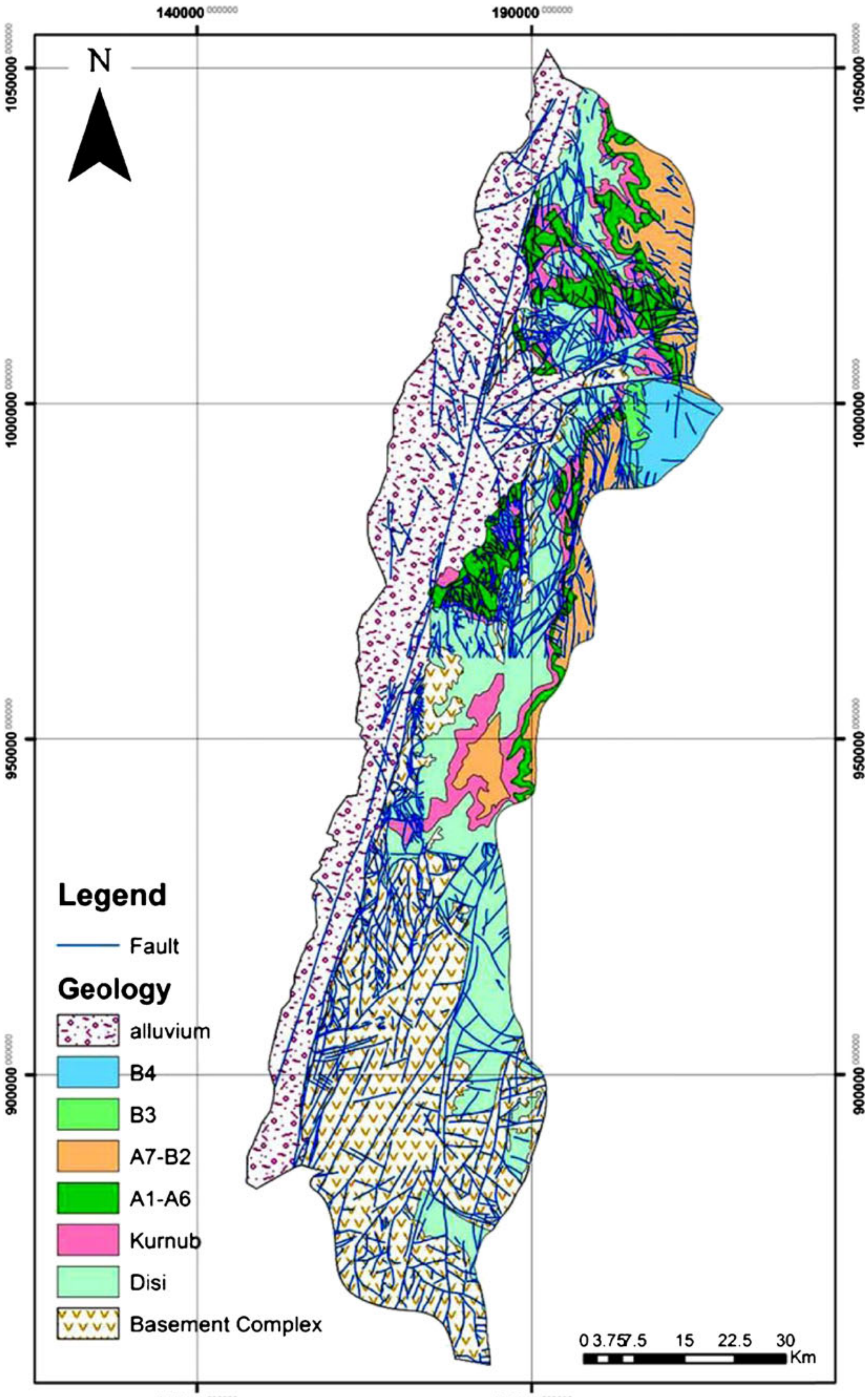

Fig. 4 Hydrogeological rock units nomenclatures in Wadi Araba basin

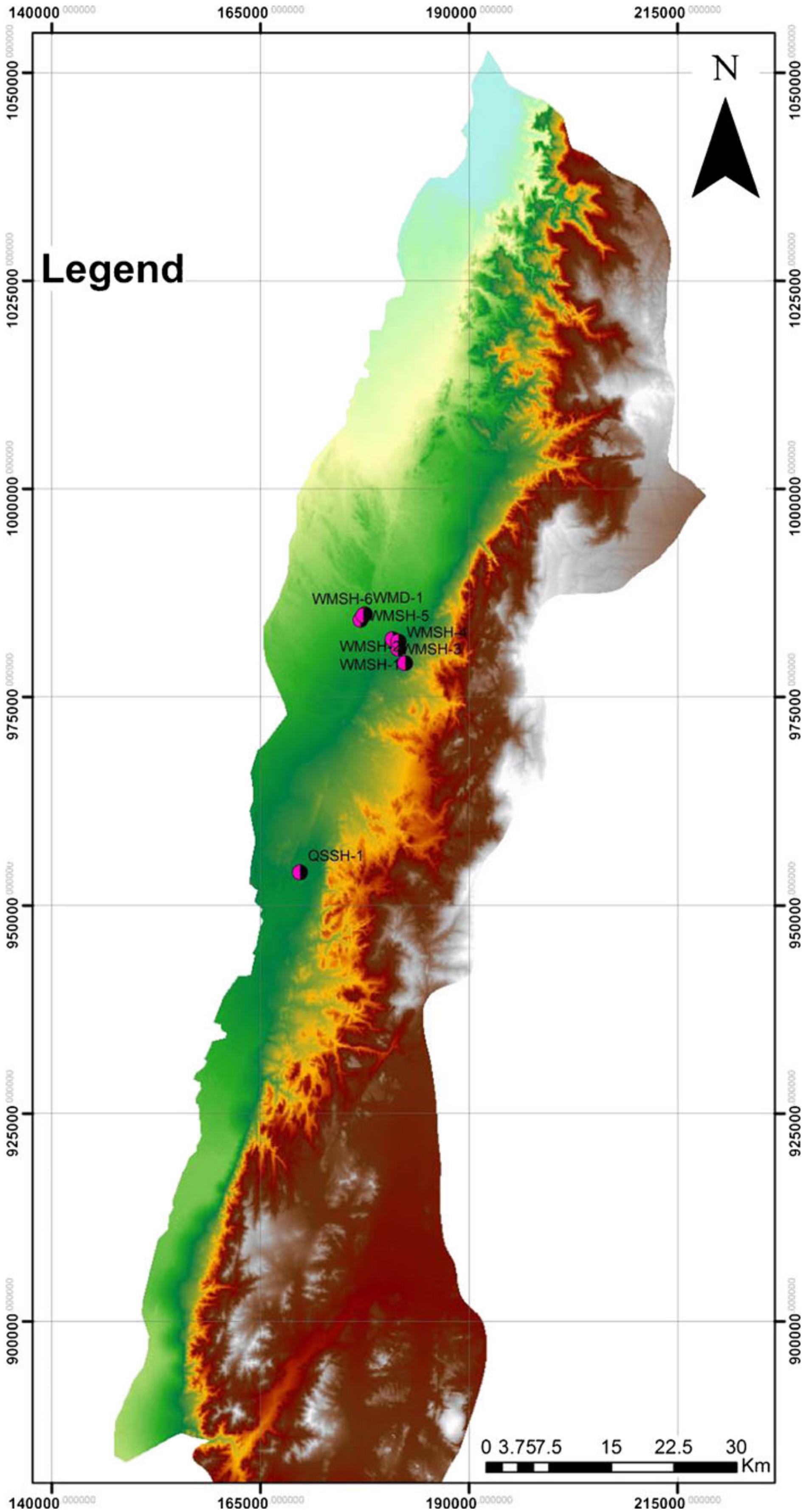

Fig. 5 Location map of new drilled wells in Wadi Araba area

Table 1 Summary data of wells in study area

Well name	Easting	Northing	Elev. (m) a.s.l	TD (m)	SWD (m)	DWD (m)	Q (m^3/h)	Location area	TDS (mg/L)
WMD-1	177,560	984,938	122	980	102.00	374.00	12.0 and then no water	Beer Mathkor site	4,529
WMSH-1	181,512	980,796	201	271	106.60	134.26	58.0	Wadi Musa	2,145
WMSH-2	182,358	979,072	235	420	104.65	177.27	103.0		11,904
WMSH-3	180,873	981,933	172	268	103.60	165.35	57.0		5,083
WMSH-4	181,570	981,639	189	218	118.77	126.01	58.0		1,195
WMSH-5	177,004	984,257	122	328	107.90	265.70	30.0		4,386
WMSH-6	177,362	984,785	124	330	146.95	220.00	5.0		N.A
QSSH-1	169,771	953,991	193	302	84.53	95.12	60	Qa’a Sadeen	
WA-1	191,468	1,023,953	−34	670	–	–	65.0	Dahl site	800

TD total depth of the well in meters, *SWD* static water depth in meters, *DWD* dynamic water depth in meters, *Elev.* elevation of the well top above sea level, *Q* is the discharge of the pumping tests in cubic meters per hour, *TDS* average total dissolved solids of groundwater samples

Disi Group Aquifer System

The Disi Aquifer System consists of Paleozoic sediments, (Cambrian arcosic sandstone, Cambrian fine-grained sandstone, Cambrian dolomites, limestone and shale in alternation, Cambrian massive sandstone and Ordovician massive sandstone (Bender 1974a, b). The basement complex and numerous faults that discontinue the distinction of the aquifer underline the aquifer system. The main extension of this sandstone water-bearing formation is to the north of Wadi Rahma, along the mountain ridge of the basement complex (Abu Taimeh 1988). This aquifer system is supposed to extend into the underground of the eastern portion of the Wadi Araba floor and to be overlain either by the Kurnub Aquifer System or by the Upper Cretaceous Aquifer System, or by the side Wadis Alluvial Aquifers (Abu Zir 1989).

This aquifer recharges the Alluvium Aquifer System in Wadi Araba, directly recharged by rainfall occurring in the

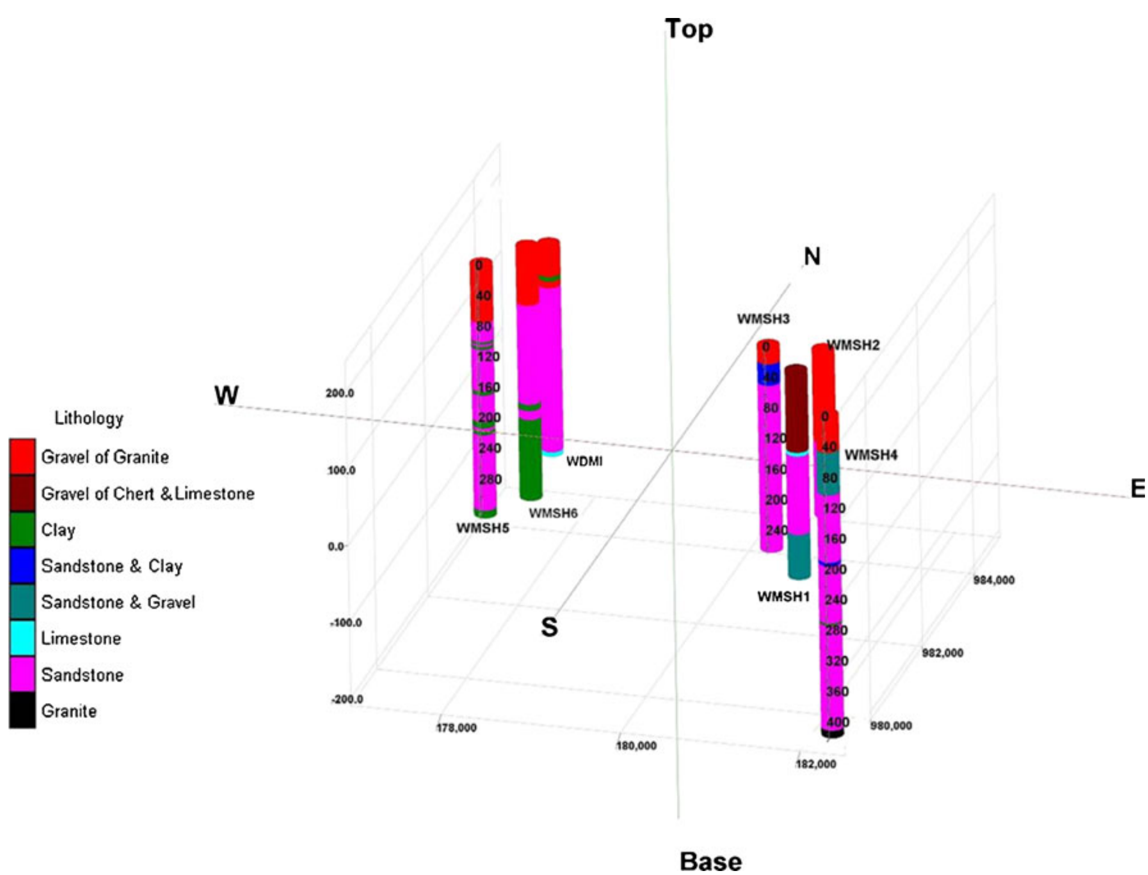

Fig. 6 Lithological logs of drilled wells

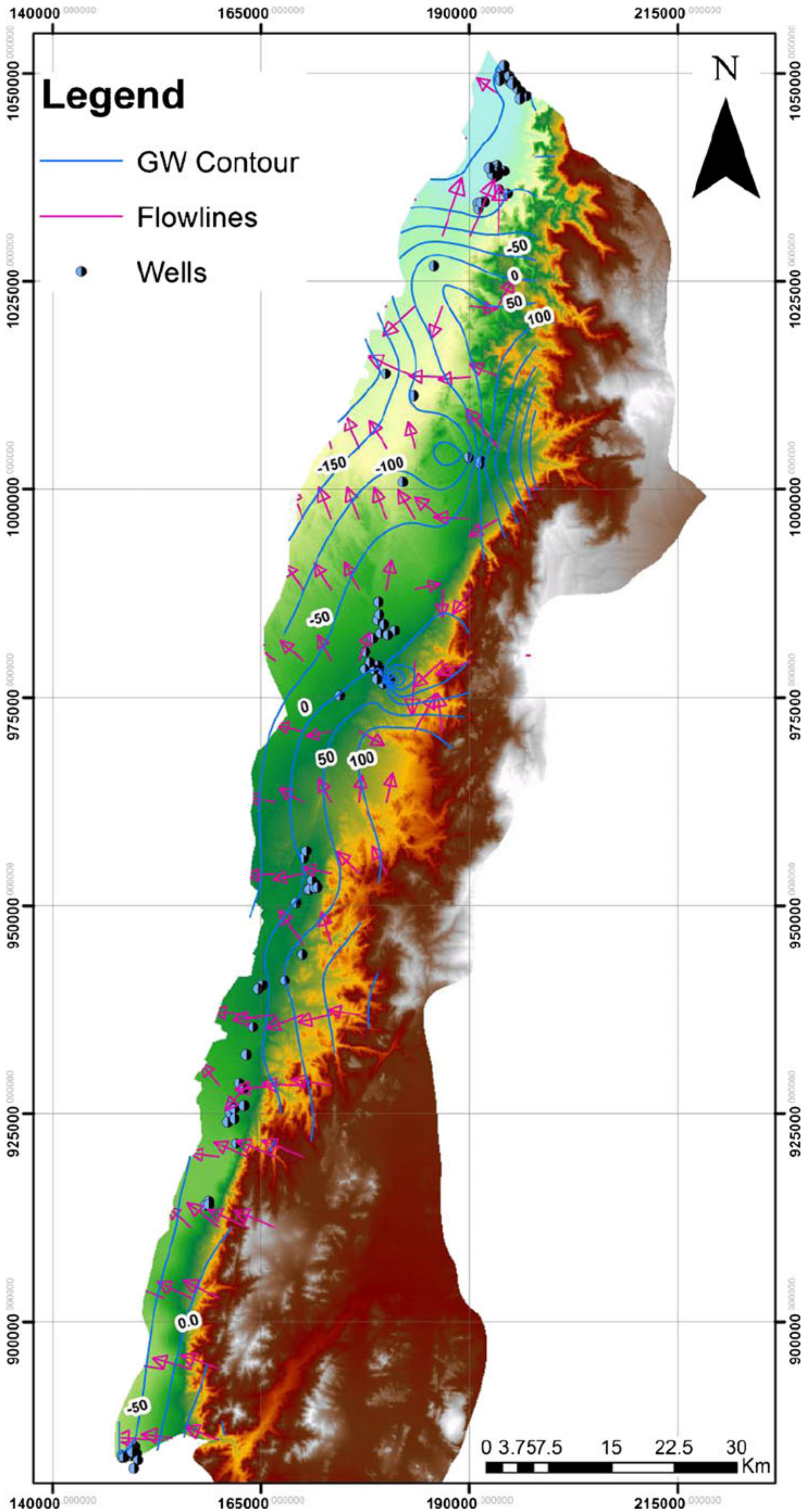

Fig. 7 Groundwater flow direction map of alluvial aquifer system

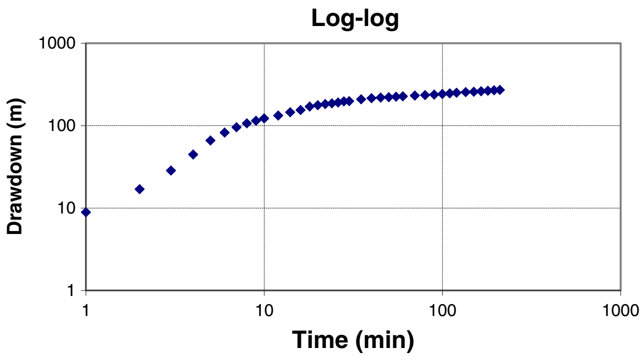

Fig. 8 Time drawdown data of WMD-1 well

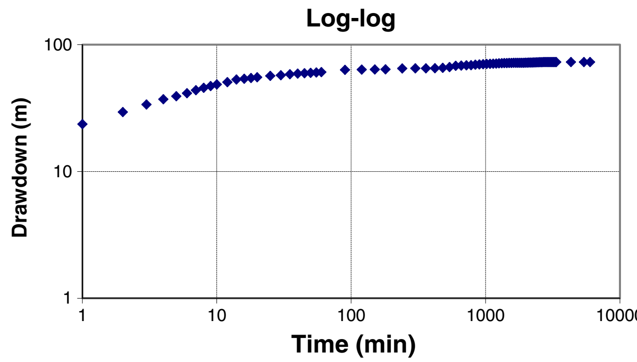

Fig. 10 Time drawdown data of WMSH-2

highlands east of Wadi Araba within the mountain ridge and northern highlands east of the rift province and indirectly by springs at various locations in the tributary side wadis or through bedrock aquifers that discharge into the alluvial aquifers of Wadi Araba (Dames and Moore 1979).

Kurnub Group Aquifer System

The Kurnub Aquifer System of the Early Cretaceous consists of massive, white sandstones, and varicolored sandstones reaching in total a thickness of about 300 m (Bender 1974a, b). It occurs in narrow or rather discontinuous zones or patches along the escarpment overlain by the semipervious to impervious Late Cretaceous sediments that reduce the vertical water recharge (Abu Zir 1989).

The dipping of the Kurnub sandstone concerning the most eastern zone appears to be eastwards to the Jafar Basin and therefore groundwater which flows through this aquifer is most probably partly outside the study area. Nevertheless, there are two promising areas concerning possible groundwater development from the Kurnub aquifer within the basin; the first includes the escarpment foot and side wadi beds between Wadi Dahl and Wadi Fiddan while the second is the escarpment foot and side wadi beds from Wadi Zubda to Wadi Abu Khusheiba (Abedelhamid and Fadda 1993).

The Kurnub aquifer in the basin cannot be considered as a major groundwater source, although it is possible that it discharges into Quaternary aquifers underlying Wadi Araba Floor.

Ajlun and Belqa Group Aquifer System

This aquifer includes the Late Cretaceous sediments with four main aquifers (A4, A7, B2, and B4) out of 12 rock units in both groups. The other formations represent aquicludes separating the different aquifers from each other. Na'ur Formation (A1-2) is considered as a semi-aquifer of local importance. Due to structural and morphological conditions, the aquifer outcrops along the mountain ridge from the recharge area for the aquifers extending further to the east, within the Wadi Fiddan middle watershed and from Wadi Zubda to the Wadi Abu Khusheiba with groundwater attributed to the presence of B2/A7 productive aquifer system.

Alluvium Aquifer System (shallow aquifer system)

This aquifer system underlies the Wadi Araba floor all over the rift from the Dead Sea to the Red Sea with different lithological units in the Quaternary deposits. Most wells in this area are mainly occurring in the fluvial–lacustrine and

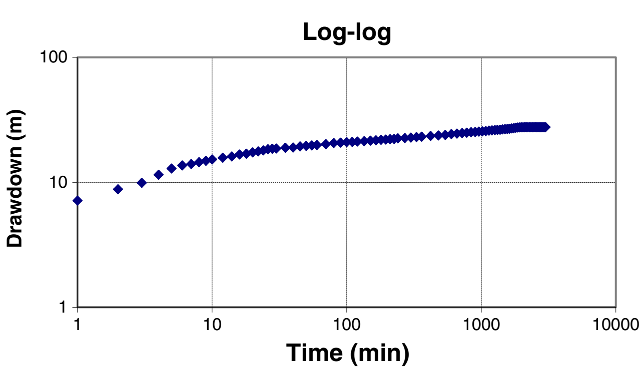

Fig. 9 Time drawdown data of WMSH-1 well

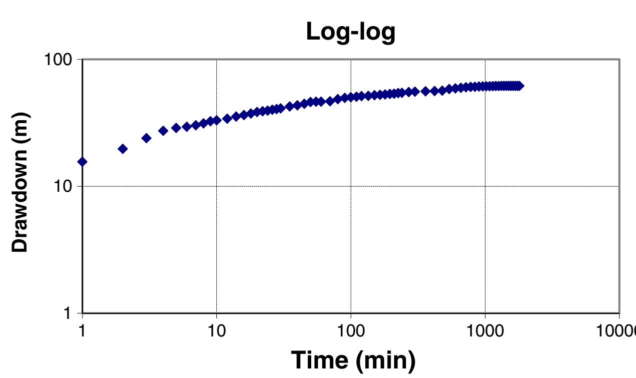

Fig. 11 Time drawdown data of WMSH-3 well

fluviatile deposits, which are composed of conglomerate, gravel and sand, and interfingering occasionally with Lisan formation. The thickness of the Quaternary water-bearing sediments increases going from the east escarpment foot towards the central portion of Wadi Araba. In total, the thickness of these water-bearing sediments is estimated up to 300 m (GTZ 1977). But due to the rift valley structure, considerable irregularities are also evident by outcropping with irregularities of the bedrock.

Drilled wells

Eight new wells have been drilled in the Wadi Musa area with different depths which are mainly located in Wadi Musa at the Mathkor area (Fig. 5). Table 1 summarizes the groundwater well data that includes coordinates, elevation, total depth, static water depth and dynamic water depth and well yield. The depth of the Wadi Musa deep well reaches 980 m, which is the deepest drilled well. The depth of other wells varies between 218 and 420 m. The yield of the drilled wells ranges from 5 m^3/h as in Wadi Musa shallow well no. 1 (WMSH-1) to 103 m^3/h as for the well Wadi Musa shallow well no. 2 (WMSH-2). The lithology of drilled wells is shown in Fig. 8. Most of the drilled wells penetrate the Disi Sandstone Aquifer as well as the Kurnub Sandstone Aquifer. The thickness of the Disi sandstone in the drilled wells ranges between 280 m as in WMSH-2 and approximately 85 m as in well WMSH-1.

At the Dahl area, there is only one flowing well, WA1, with a total depth of 670 m. The other seven wells are at the Mathkor area of two clusters. Three wells are at the western side of the main Safy road and four at the eastern side of the road. Only one well is tapping the deep aquifer, and the rest at shallow aquifer of total depth varies between 200 and 400 m. Such data are the output of the final report of the drilling report in the Wadi Araba project, which was dated 26 July 2008.

The lithological description of the drilled wells is shown in Fig. 6. All the wells tap the alluvial aquifer which contains gravels, cherts, limestone, and sandstones.

Groundwater movement

The direction of groundwater movement within the Alluvial Aquifer System in the study area is from the escarpment foot towards the Wadi Araba floor and from the south to the north, towards the Dead Sea as shown in Fig. 7. Generally, the Quaternary deposits reach a thickness exceeding even 400 m while the saturated thickness itself exceeds 300 m. Of course, the thickness of the Quaternary water-bearing sediments increases going from the east escarpment foot towards the central portion of Wadi Araba, but due to the Rift Valley structure, considerable irregularities are also evident by the outcropping of the bedrock (Energoprojekt Co and Jafar Tukan and Partners 1990).

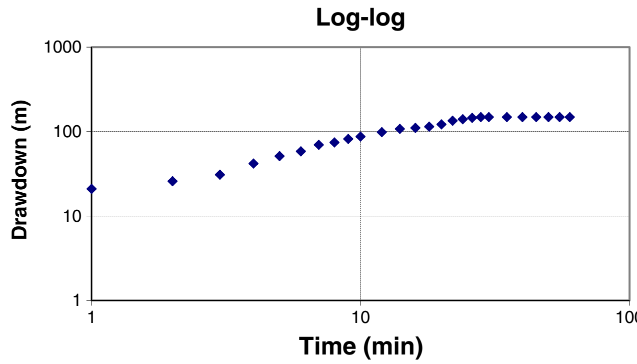

Fig. 12 Time drawdown data of WMSH-5 well

Aquifer tests

The analyses of the pumping test and recovery data were completed using the analytical software AQUIFER TEST PRO for Windows. The Theis and Cooper-Jacob analytical solutions for confined aquifer conditions and Neuman water table standard curve for unconfined aquifer condition were used to obtain a "best fit" to the test data. Plots of the drawdown data showing the results of the analyses are provided in Figs. 8, 9, 10, 11, 12, 13. Strong deviations of the plotted data from theoretical curve or straight-line fits indicate the existence of non-ideal aquifer boundary conditions. For this reason, it was attempted to fit the theoretical solutions to data from the latter periods of the test, as they would better represent the behavior of the aquifer in the long run. Based on this analysis, the geometric mean aquifer transmissivity was estimated to be 21 m^2/day, as is shown in Table 2. The calculated storativity values ranged from 3.55×10^{-5} in well WMD-1 to 2.54×10^{-3} for well WMSH-6. These values, despite being quite different, are within the range of typical values for aquifers (Freeze and Cherry 1979). A relatively low value of storativity was obtained from well WMD-1, which is believed to be more

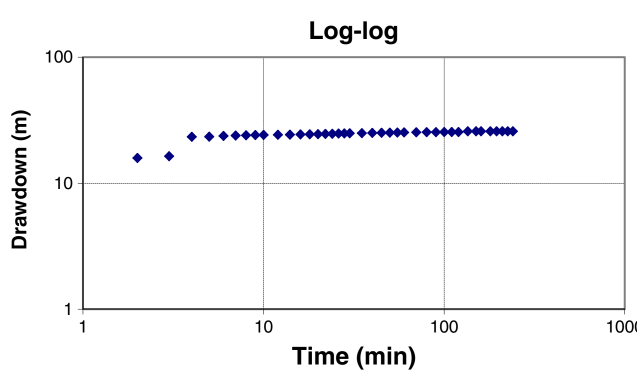

Fig. 13 Time drawdown data o WMSH-6

Table 2 Summary of aquifer parameter estimates

Well No.	Aquifer model	Status	Average tarnsmissivity (m^2/day)	Average storativity
WMD-1	Theis (1935) confined; Cooper-Jacob (1946) confined	Pumping test Recovery test	7.5	3.55×10^{-5}
WMSH-1	Cooper-Jacob (1946) confined	Pumping test Recovery test	36.0	6.75×10^{-5}
WMSH-2	Cooper-Jacob (1946) confined	Pumping test Recovery test	63.8	1.32×10^{-4}
WMSH-3	Cooper-Jacob (1946) confined	Pumping test Recovery test	35.3	6.55×10^{-5}
WMSH-4	Cooper-Jacob (1946) confined	Recovery test	–	–
WMSH-5	Neuman (1975) and Moench (1993, 1996) unconfined	Pumping test Recovery test	1.64	3.4×10^{-5}
WMSH-6	Neuman (1975) and Moench (1993, 1996) unconfined	Pumping test Recovery test	1.58	2.54×10^{-3}

representative of the aquifer performance in summer conditions (confined).

Recovery tests

At the end of a pumping test, when the pump is stopped, the water levels in pumping and observation wells begin to rise. This is referred to as the recovery of groundwater levels while measurements of drawdown below the original static water level (prior to pumping) during the recovery period are known as residual drawdown.

It is good practice to measure the residual drawdown because analysis of the data enable transmissivity to be calculated, thereby providing an independent check on pumping test results. An important application of the recovery method is to make an estimate of the transmissivity by measuring the recovery in the pumped well, itself, when conditions do not permit the construction of observation wells. More precise data can be obtained during the recovery period than during the pumping period because the pump does not disturb the water in the well.

The recovery tests of the drilled wells were interpreted using the Theis recovery equation, and the obtained results were summarized in Table 3.

Table 3 Summary of aquifer parameter estimates by recovery tests

Well no.	Aquifer model	Status	Average Transmissivity (m^2/day)
WMD-1	Theis method	Recovery test	10.23
WMSH-1	Theis method	Recovery test	22.35
WMSH-2	Theis method	Recovery test	13.15
WMSH-3	Theis method	Recovery test	6.89
WMSH-4	Theis method	Recovery test	64.53
WMSH-5	Theis method	Recovery test	1.83
WMSH-6	Theis method	Recovery test	0.88

Estimation of sustainable well yield: continuous pumping

The sustainable yield represents the amount of groundwater discharge that can be diverted and captured by groundwater extraction, subject to the prevailing hydrological conditions and constraints (Maimone 2004; Kalf and Woolley 2005). The approach ensures that a long-term aquifer water balance is maintained without excessive reservoir depletion, but it does not necessarily consider other consequences of the extraction such as reduced groundwater level and discharge flows (Sophocleous 2000; Alley and Leake 2004).

To estimate the maximum allowable discharge ($Q_{\max}$) that will result in the maximum allowable drawdown ($S_{\max}$) at the end of the hydrological year (Eq. 1), when groundwater levels are at their lowest, the need is high to make some rough estimates of the following (Driscoll 1986):

- $S_{\max}$: the maximum allowable drawdown calculated as the maximum allowable pumping water level at the end of the dry season (usually taken as the main water strike) less the seasonal water level decline
- t: time between two rainy seasons, assume 300 days for a climate with a 2-month rainy season
- r: the effective well radius, usually taken as the well radius, r_w
- S: the storativity of the aquifer, somewhere between 0.005 and 0.03 in fracture controlled aquifers
- E: the well efficiency as a fraction of 1, calculated as theoretical drawdown divided by actual drawdown

$$Q_{\max} = \frac{\mathrm{E.S._{max}T}}{0.183\log(2.25\mathrm{T}t/r^2S)} \quad (1)$$

where $Q_{\max}$=is the maximum allowable (sustainable) discharge expressed in cubic meters per day.

Table 4 Summary of the estimated maximum yield (Q_{max}) and maximum drawdown (S_{max}) for each well

Well Name	Easting	Northing	Q_{max} (m^3/day)		S_{max} (m)	Maximum specific capacity (Q/S) (m^3/h/m)	Well efficiency (%)
			Continuous pumping	Intermittent pumping			
WDMI	177,560	984,938	154.7	1,200	350	22.3	0.44
WMSH1	181,512	980,796	376.2	1,392	65	1.90	0.60
WMSH2	182,358	979,072	260.4	2,472	125.9	1.02	0.50
WMSH3	180,873	981,933	157.0	1,368.0	65.7	0.97	0.28
WMSH4	181,570	981,639	31.1	720.0	39.7	6.12	0.28
WMSH5	177,004	984,257	33.5	720.0	88	0.25	0.28
WMSH6	177,362	984,785	24.9	120.0	73	0.07	0.45
QSSH-1	169,771	953,991	38.8	720.0	86.4	4.22	0.28
Total sustainable well yield (m^3/day)			1,076.6	8,712			

Q_{max} estimated maximum sustainable well yield (cubic meters per hour), S_{max} maximum allowable drawdown (meters), Q_{max}/S_{max} maximum specific capacity of the well

Generally, this method gives a rough estimate specially some of the parameters used are normally calculated from step drawdown pumping tests. Based on the available information the results are still acceptable.

Estimation of the sustainable well yield: intermittent pumping

Most wells are pumped intermittently, that is less than 24 h per day. The following formula can be used to estimate the maximum allowable discharge (Q_{max}). The formula is based on the procedure outlined in "Groundwater & Wells," Driscoll 1986 (Eq. 2).

$$Q_{max} = \frac{\mathrm{E.} \quad 0.228 \mathrm{S}_{max} \mathrm{T}}{t_1 \log((t_2 - 1 + t_1)/t_1)) + \log(2.25 \mathrm{T} t / r^2 S))} \qquad (2)$$

where:

- t_1 daily pumping cycle expressed as a fraction of a day, e.g., 12/24 h of pumping equals 0.5 day
- t_2 time between two rainy seasons, assume 300 days for a climate with a 2-month rainy season

In this formula, Q_{max} is expressed in cubic meters per hour, not cubic meters per day as we are pumping for a limited amount of hours in a day. Table 4 summarizes the calculated Q_{max}, S_{max}, maximum specific capacities, and well efficiency for each well.

Chemical composition and quality of groundwater

In addition to the water quantity, the limiting factor of the groundwater development within the study area appears to be its quality for both irrigation and domestic water supply. It has already been reported that the groundwater quality throughout Wadi Araba is quite variable, and its exploitation is connected with quality constraints. The TDS of the drilled wells varies from 1,000 to 12,000 mg/L. The upper 400 m of sandstone aquifer was relatively fresh water with EC of less than 1,000 μS/cm. Below 400 m, the EC increased to 3,500 μS/cm. The quality of groundwater was mentioned in detail in the unpublished report "Study and Design of Beer Mathkor and Dahl Irrigation Project/Wadi Araba," (Consolidated Consultants 2009).

Conclusions

The evaluation of the pumping test data of the drilled wells in the Wadi Araba area was carried out using the standard methods of pumping test interpretation. This was based on the available water table measurements at well locations and knowledge of water flow in the general Wadi Araba region. The sustainable yield of each well was calculated based on the pumping test parameters. The simplified model indicates that pumping out of Beer Mathkor wells should not exceed 1,100 m^3/day in the case of continuous pumping and 8,700 m^3/day in the case of intermittent pumping.

Since the water table did not significantly change with small changes in pumping (it took an eightfolds of magnitude increase in pumping from 1,100 to 8,700 to show a significant drop in the water table equivalent to about 5.5 MCM per year from the aquifer, therefore, a comparison of pressure cones between Beer Mathkor and the active pumping wells was used to reach a crude estimate of the maximum safe yield for the Beer Mathkor wells.

The paucity of data and the complexity of the problem led to numerous problems during the creation and calibration of the results of the model. It should be noted that in order to make a more accurate recommendation for safe yield, a more detailed data regarding boundary conditions, recharge, and initial water table levels would be needed. The model presented here is a good estimate in point of view available data. The data available can give good estimation when it overlapped with pumping test analysis. In order to have a more accurate model, expensive measurements are required to make good data to be available.

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