Wolfgang Wagner

Groundwater in the Arab Middle East

Springer

Groundwater in the Arab Middle East

Wolfgang Wagner

Groundwater in the Arab Middle East

Springer

Wolfgang Wagner
Hohenzollernstr. 21
30161 Hannover
Germany
uwwagner@gmx.de

ISBN 978-3-642-19350-7 e-ISBN 978-3-642-19351-4
DOI 10.1007/978-3-642-19351-4
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011931780

Cover design: deblik, Berlin

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

To Ursula and to my colleagues and friends in the Arab countries

If all the waters would be salty and man would have to change it to achieve its sweetness, great efforts would arise to man. The sublime Creator has saved, in his grace, his creatures these efforts through the effect of the sun on the water of the sea and the rise of the vapour from the sea; the winds then disperse these vapours wherever he wants, and it arrives as rain water at these locations. That is then stored in rivulets within the mountains and under the earth. He then brings out part of the water and lets flow wadis and rivers, and springs and wells appear in such a degree that it is sufficient for the creatures for 1 year until rain comes again in the following year.

Al Qazwini Zakariya ibn Muhamad ibn Mahmud abu Yahya, ca. 1262 (AH 665)

Introduction

The region covering the Arabian Peninsula and the adjoining northern Arabian countries coincides approximately with a specific large geologic structure: the Arabian Plate. Politically the region includes the countries of the Arabian Peninsula together with the northern Arab countries: Al Mashreq – the eastern part of the caliphate or of the Arab World. In a geographic political view the region may be denominated Arab Middle East (Ash Sharq al Awsat) or Western Asia.

The Arab Middle East with an area of 3.7 million km^2 forms a small subcontinent between the Mediterranean Sea, Red Sea, Arabian Sea, the Gulf and, in the north, the Zagros–Taurus mountain chains. About 90% of the region are semiarid to arid steppe or desert areas. As perennial rivers exist only in the northern and western margins of the Arab Middle East, the use of groundwater resources is an essential basis for the economic development and survival of the countries. The region includes 12 Arab countries; water demand/supply previews indicate precarious situations in the near future for most of these countries.

The idea of compiling a book on "Groundwater in the Arab Middle East" arose from the professional activities of the author as hydrogeologist in the services of the German Government between 1965 and 1998, much of which was devoted to groundwater projects in the Middle East. The information presented in the book is based on reviews of a large number of publications, reports and documents as well as on field experience in various Arab countries.

The groundwater projects in the Middle East, in which the author had the chance to participate, were carried out in the framework of Technical Cooperation between national or international institutions of the region and the Federal Institute of Geosciences and Natural Resources, BGR, Hannover, partly in connection with activities of the German Agency for Technical Cooperation, GTZ, Eschborn. The projects were sponsored by the Ministry for Economic Cooperation and Development, Bonn. Regional information on groundwater conditions in the Middle East were obtained, in particular, through long-term assignments of the author to international institutions: The Arab Centre for the Studies of Arid Zones and Dry Lands of the Arab League (ACSAD), Damascus, and the United Nations Economic and Social Commission for Western Asia (ESCWA), Amman and Beirut.

Contents of the Book

The book gives an outline of prevailing hydrogeologic conditions on the Arabian Plate together with the geologic background. Emphasis is given to relationships between the main features influencing the hydrogeologic conditions:

- Regional and sub-regional geologic developments
- Paleogeographic conditions
- Morphology
- Climate and paleo-climate

and the resulting hydrogeologic features:

- Formation of aquifers
- Distribution of major aquifers
- Major groundwater flow systems
- Occurrence of renewable and fossil groundwater

Information on groundwater conditions in the various hydrogeologic sub-regions of the Arabian Plate is presented in a summarized form with comparative evaluations of hydrochemical and isotope data from different hydrogeologic units. Reported data on hydraulic aquifer parameters, recharge rates and groundwater flow volumes are listed with a view to arrive at characteristic values under specific hydrogeologic and climatic conditions.

The review of hydrogeologic conditions in this book is obviously a look back to information accumulated by the scientific–technical community during the past decades. It does not deal, in detail, with main actual problems and techniques for groundwater utilization, such as quantitative assessments of groundwater resources, groundwater management planning, legal aspects of safe groundwater exploitation and groundwater protection, artificial measures for groundwater management.

The presentation of groundwater conditions refers prevailingly to the state of knowledge in the late 1990s but includes information from more recent publications. For some areas, no recently updated information has been available. This will not affect the relevance of the description of the general hydrogeologic conditions, but the state of groundwater exploitation, of water quality and of remaining resources may have changed significantly in some areas during short periods.

The area considered in the outline of groundwater conditions covers approximately the Arabian Plate, as delineated in Chap. 1, with minor deviations: political boundaries are not coinciding with the plate boundaries, e.g. in the north, where the plate extends into Turkish territory. Information on the following countries is included: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, West Bank and Gaza, Yemen. Relevant information from results of investigations and research in Israel is considered, but no attempt is made for including an outline of hydrogeologic conditions in Israel.

Remarks on Graphic Presentations, Transcriptions and References

Much of the information presented in this book is shown in a generalized manner.

Maps are included as rough sketch drawings indicating locations and geographic, geologic or hydrogeologic features. The sketch maps are intended to provide a general orientation of locations and features mentioned in the text. Geographic latitudes and longitudes are indicated at the frame of most sketches.

For discussion of hydrochemical and isotope data, standardized diagrams are used, mainly Piper diagrams and plots of $\delta^{18}O/\delta^{2}H$ data.

In the trilinear "Piper diagram" (Piper 1944), concentrations of major ions in meq% are plotted in a cation triangle and an anion triangle, and the cation and anion points of one water analysis are combined through projection into a diamond field (Fig. 1.5). Hydrochemical water types are generally defined according to the predominant cation and anion of a water group. Frequently, major ions of groundwaters from a specific aquifer and area vary over considerable ranges and the definition of water types has to include more than one cation and/or anion (e.g. Ca–Na–HCO_3–Cl type water).

The $\delta^{18}O/\delta^{2}H$ plots are presented in a uniform scale with $\delta^{18}O$ between −9‰ and +3‰ and $\delta^{2}H$ between −70‰ and +15‰. For orientation two meteoric water lines are shown on each $\delta^{18}O/\delta^{2}H$ diagram (Fig. 1.6): the Global Meteoric Water line (GMWL, $\delta^{2}H=8\times\delta^{18}O+10$) and the Mediterranean Meteoric Water Line (MMWL, $\delta^{2}H = 8 \times \delta^{18}O + 22$).

Transcriptions of Arabic location names are made in a somewhat simplified manner:

- Symbols for characters which do not exist in English script are omitted, such as hamza ء or ain ع,
- Duplication of consonants are largely avoided
- The feminine ending with the Arabic consonant h ه is written as "a" (not "ah")
- The consonant dad ض is written as dh

In order to avoid multiple citations of references within the text, evaluated publications are generally listed at the end of each sub-chapter, except for direct quotations. In Chap. 1, relevant publications are, in most cases, cited also at the appropriate passages of the text.

Denomination of Stratigraphic Units

Names of stratigraphic units have been adopted as commonly applied in the hydrogeologic literature of the concerned countries or regions. Generally, litho-stratigraphic units are denominated "formation" or, in relation to hydrogeologic features, "aquifer" or "aquitard", e.g. "Umm er Radhuma formation", "Umm er Radhuma aquifer", "Rus

formation", "Rus aquitard". The term "group" is applied, where several formations compose a larger stratigraphic or hydro-stratigraphic complex, but no definite differentiation has been followed between the terms formation, group or super-group.

In the geologic literature of the Arab countries, the Cretaceous has been subdivided into

- Lower Cretaceous (up to Albian) and Upper Cretaceous (Cenomanian to Maastrichtian)

or

- Early Cretaceous (up to Aptian), Middle Cretaceous (Albian–Turonian), Late Cretaceous (Coniacain–Maastrichtian)

In this book, the differentiation into Lower Cretaceous and Upper Cretaceous is applied.

Acknowledgements

The activities in projects, carried out by the author in Arab countries, involved the cooperation with a great number of specialists from national and international institutions. It will not be possible to name all colleagues who directly contributed to the knowledge which is summarized in this book. Especially extensive professional information and stimulations were received from Jean Khouri in Damascus, Bader Hirzalla in Aman, Hans Bender and Mebus A. Geyh in Hannover. A special privilege was the opportunity to participate in discussions with Louis Dubertret and D.J. Burdon, scientists who had established fundamental parts of the hydrogeology of the Middle East.

Particularly valuable information on groundwater investigations or problems in specific countries or sub-regions has been provided by the following colleagues: Abdulla Droubi, Refat Rajab, Watheq Rasoul Agha, Nabil Rofail, Said Zahra in Damascus (ACSAD), Aziz Ghadban and Hisham Abu Ayyash in Damascus, Adnan Al-Baeini in Soueida, Rifaat Haoui in Aleppo, Samir Hijazin, Mohammad Almomani, Raja Gedeon, Jamil Rashdan, Ali Subah in Aman, Bassam Adib Jabir and Hassan Jaafer in Beirut, Amitabha Mukhopadhyay in Kuwait, Mohamed Sager Al-Asam, Muhamed Saeed Abdullah and Muhamed Abdul Haq in Dubai, Waleed K. Al-Zubari in Bahrain, Eduard Boeckh, Manfred Hobler, Armin Margane, Christian Neumann-Redlin, Hellmut Vierhuff in Hannover (BGR), Yucel Yurtsever in Vienna (IAEA), Omar Touqan, Omar Joudeh, Mohamed J. Abdelrazzak in Aman and Beirut (ESCWA).

The missions and investigations in the different Arab countries were supported ex-officio, but in many cases also through personal encouragement, by officials and political representatives of many ministries, governmental authorities and institutions in the concerned countries, in Germany and in organizations of the United Nations and of the Arab League. That support as well as the contribution of information from the above mentioned colleagues and of many scientists, who are not mentioned here explicitly, is gratefully acknowledged.

Several authors whose publications were used rather extensively for compilation of the book should be included in the acknowledgements: V.P. Ponikarov et al. (1967a, b): geology and hydrogeology of Syria; Zuhair Kattan: isotope hydrologic aspects in Syria; Friedrich Bender and collaborators: geology of Jordan; Elias

Salameh: various features of the hydrogeology of Jordan; Al-Sayari and Zötl (1978), Jado and Zötl (1984) and H.S. Edgell (1997): hydrogeology of Saudi Arabia; Alsharhan et al. (2001): hydrogeology of the eastern part of the Arabian Peninsula; John W. Lloyd: hydrogeologic aspects of various areas of the Middle East.

The author is also indebted to a considerable number of specialists of BGR (Hannover) for their essential contributions for the execution of groundwater projects in Arab countries in various geoscientific fields.

Special thanks have to be extended to Springer Verlag and to Mr. E. Balamurugan and his team of SPi Technologies India in Chennai for the efforts in editing and publishing the book.

Contents

List of Figures

List of Tables

Chapter 1
The Arabian Plate: Geology and Hydrogeologic Characteristics

1.1 Geology and Main Orographic Units

1.1.1 Geologic and Structural Features

1.1.1.1 Arabian Plate

The Arabian Plate extends approximately over the region known as Arab Middle East, which includes the Arabian Peninsula together with the adjoining northern Arab countries (Al Mashreq). Until the early Tertiary, the Arabian Plate was connected to the African Plate, one of the huge main plates of the earth crust. During the Tertiary, the sector which became the Arabian Plate was separated from the African Plate with the opening of the Red Sea and Gulf of Aden rift structures.

Descriptions of the regional geological framework of the Arabian Plate can be found in publications by Ponikarov et al. (1967a), Powers et al. (1966), Bender (1974a), Beydoun (1991), Alsharhan and Nairn (1997), Alsharhan et al. (2001), Al-Sayari and Zötl (1978).

The development of the Arabian Plate included the following main stages (Beydoun 1991):

- The basement of the plate was formed during the Precambrian as part of the Nubo-Arabian craton.
- During the Paleozoic until the Permian, the sector comprising the present Arabian Plate occupied a marginal shelf position on the Gondwana supercontinent.
- In the early Mesozoic, plate boundaries developed on the northeast, southeast, north and northwest margins with the opening of the Neo-Tethys and the Indian Ocean.
- During the middle to late Tertiary, collision of the Arabian Plate with the Eurasian continent compressed and modified the north and northeast margins of the plate, and rift tectonics opening the Red Sea–Dead Sea graben and the Gulf of Aden created a new northwest margin and the south and southwest margins.

W. Wagner, *Groundwater in the Arab Middle East*,
DOI 10.1007/978-3-642-19351-4_1, © Springer-Verlag Berlin Heidelberg 2011