2.1 Management, Protection and Sustainable Use of Groundwater – Results of Long-Term Technical Co-operation in the Middle East

Schelkes, K., Hobler, M., Schmidt, G. & Steinbach, V.

2.1.1 Introduction

Groundwater represents the main water resource in most parts of the arid and semi-arid regions of the Middle East and Northern Africa. Adequate groundwater management is a prerequisite for the sustainable use of the scarce water resources. Groundwater protection measures have to be incorporated in integrated water management activities as an important feature for sustainable development. To fulfil these requirements, the German Federal Institute for Geosciences and Natural Resources (BGR) supports since several decades some national ministries and institutes as well as international organisations which are operating in the groundwater sector in this region.

During the seventies and eighties, work was mostly concentrated on the assessment, exploration and use of groundwater resources. In the following years the interest in groundwater protection issues grew continuously. This shift in interest was induced by the improved knowledge of the processes and events influencing the groundwater regime and the quality of the groundwater. Better understanding of groundwater issues made it obvious that groundwater protection is one of the main pillars for sustainable use of the scarce water resources in the Near East. It was not acceptable any more to diminish the potable groundwater resources by often irreversible contamination. The trend from quantity oriented to more quality oriented groundwater studies can easily be seen in the changes in the focal points of the projects as shown in this paper.

This improved knowledge led to changes in the people's mind. Sustainable and careful use of the scarce groundwater resources became a key issue. Consequently, project activities were not only concentrated on advice for the use of modern methods, e.g. for the preparation of planning documents, but also for the preparation of groundwater-related guidelines and policies as part of an overall strategy for better groundwater resources management. Based on the understanding that the guiding principles for sustainable groundwater use have to be implemented by governments and their administrations, this last topic forms now a fundamental part of German Technical Co-operation and is an important component of the ongoing groundwater related projects.

The following examples of bilateral and international co-operation show the changes in the types and goals of technical co-operation projects. The presented results highlight the groundwater situation in the Near East and should provide understanding for the wide range of problems related to the groundwater situation.

2.1.2 Bilateral co-operation: Jordan

In the early projects, the assessment of the groundwater resources was based on the results of geophysical investigations and hydrogeological field work. These investigations and the interpretation of the results were mostly carried out by foreign organisations and their contractors. The partner institution often played a minor role because of insufficient knowledge and experience especially in modern geophysical, mathematical and hydrogeological methods and lack of adequate equipment. To overcome this situation, improvement of the infrastructure and the qualification of the personnel of the partner institutions got high priority in all co-operation projects and formed an essential part of the overall project strategy. In turn, the role of the project partners in the Near Eastern countries changed with improving qualification. More and more, investigations and data interpretations were carried out by the specialists of the partner institution. Scientists and technical specialists of the foreign organisations assisted as advisors only. Support and advice in learning and using modern methods in groundwater management and groundwater protection are today well to the fore.

Groundwater cooperation projects with Jordan and groundwater models and modelling results in particular, are examples for this development as shown in the following.

Support for the preparation of the National Water Master Plan (NWMP) in 1977 was one of the first major groundwater activities of the BGR in Jordan (GTZ 1977). Data collection was mostly done by the Natural Resources Authority of Jordan (NRA), data interpretation and map preparation by German specialists. This NWMP was the first comprehensive study of the water resources of the entire country. It gave an overview of the water situation and served as a general planning basis for about twenty years. Thematic maps show the hydrogeological situation, e. g. favourable areas for ongoing or potential groundwater exploitation and available volumes of stored groundwater. For the new NWMP the same boundaries of water basins have been used as they had been defined during that survey.

In the following years, co-operation of BGR with Jordan was concentrated on other sectors like geology and geophysics. Studies in the water sector continued on a quite different level with an investigation of the possibilities to supply an envisaged oil shale processing plant at El Lajjun with water. Fig.2.1.1 shows the location of the study area in the Mujib basin and Fig. 2.1.2 an impression of the landscape and the base flow in the upper Wadi Mujib. The data collection and the field work for this hydrogeological study was supported by the Water Authority of Jordan (WAJ). Most of the hydrogeological interpretation as well as the numerical modelling were still done by BGR but on-the-job-training was already an important issue.

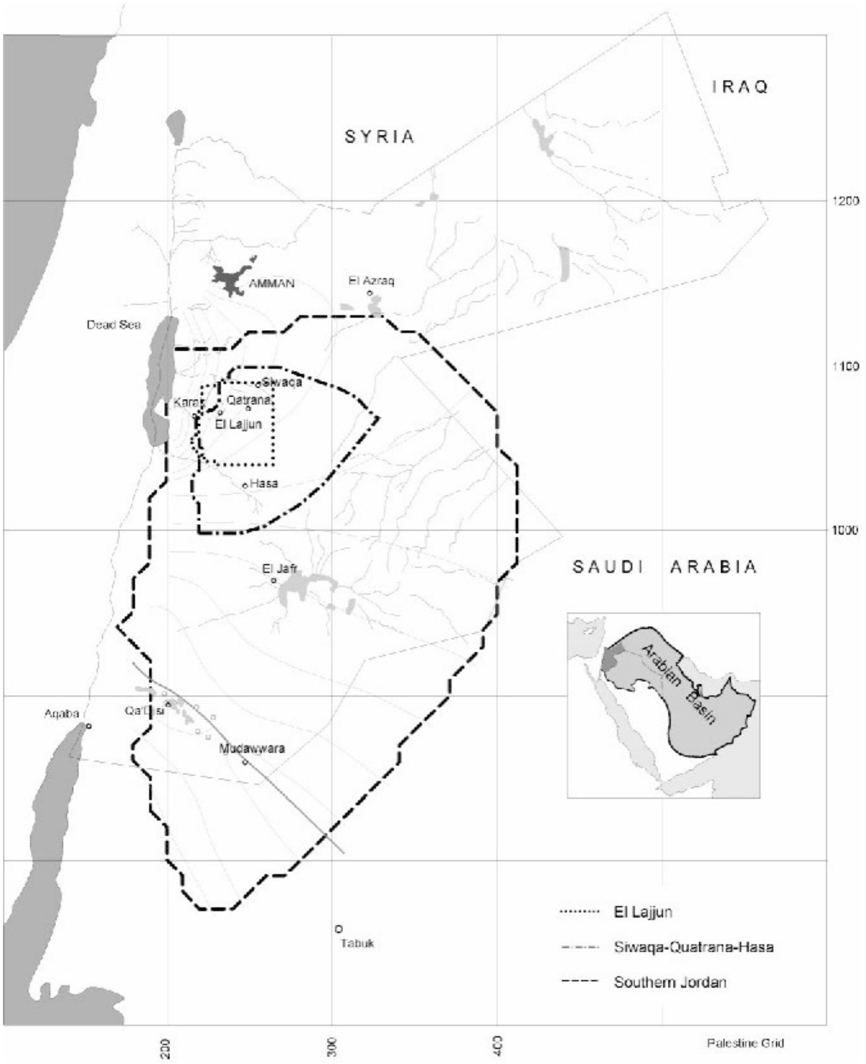

Fig. 2.1.1. Areas of the numerical model investigations 1985 – 1990

Based on the hydrogeological set-up, it was possible to calculate the water balance of the Wadi Mujib basin with the help of a numerical model (Fig. 2.1.3). The results showed very clearly that the quantities of recoverable groundwater from the upper aquifer have been widely overestimated in the past. The water abstraction from this aquifer for drinking water (including e.g. a well field for the supply of Amman) and industrial purposes already exceeded the recharge in that area. Any future demand has to be extracted from aquifer storage (Bender et al. 1989).

Fig. 2.1.2. Baseflow in the Upper Wadi Mujib

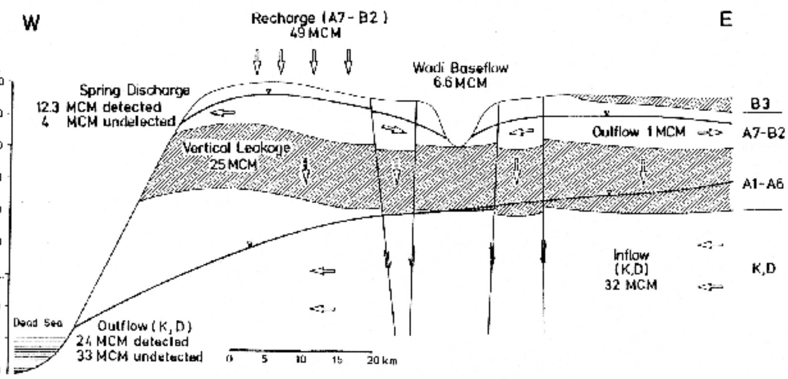

Fig. 2.1.3. Groundwater balance for the Mujib basin

The result of this "El Lajjun Oilshale Feasibility Study" was one of the reasons to investigate the groundwater situation in much more detail. It was the first of four technical co-operation projects in Jordan, which included numerical groundwater flow modelling as a major component.

The following list gives an overview of the various numerical models for the time period from 1985 to 2002 (for locations see Fig. 2.1.1 and 2.1.6):

- El Lajjun Model, (Schelkes, 1986)
- Siwaqa-Qatrana-Hasa Model, (Schmidt, 1989; validated 2001)
- South Jordan - Natural Aquifer Depletion Model, (Schmidt, 1989)
- Numerical model for the Muwaqqar well field, (Brunke, Khalifeh and Al Mahamid, 1996)
- 3D-Groundwater Model of Northern Jordan, (Brunke, 1995; revised 1998)
- Numerical model of the Siwaqa-Qatrana-Hasa well field (Khalifeh and Al Mahamid, 1998)
- Well field models (Corridor well field, Musaitbeh well field), (Khalifeh and Al Mahamid, 1999/2000)
- 3D-Groundwater Model of Jordan (ongoing development)

As it can be seen, in the beginning modelling was mostly done by specialists from BGR. As a result of on-the-job training and of advanced training courses, modelling was more and more accompanied and carried out by the Jordanian counterparts. This effect confirms the importance of capacity building as an integral part of co-operation projects.

The next co-operation project on "Groundwater Resources of Southern Jordan" started in 1987 and lasted until 1990. It included capacity building, the establishment of a hydrogeological data bank and the preparation of a map of the groundwater resources of Southern Jordan as well as the preparation and installation of two specific groundwater models (Schmidt and Hobler 1994).

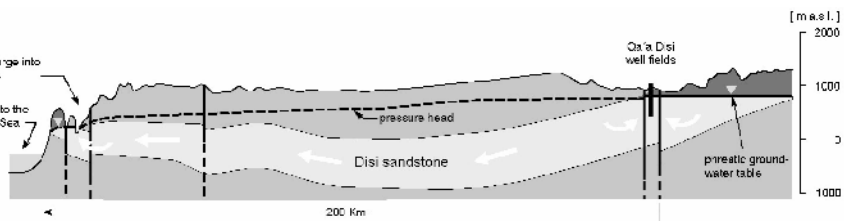

Fig. 2.1.4. Sketch of the flow system in the deep sandstone aquifer

The first of these models, the "South Jordan - Natural Aquifer Depletion Model" was planned as an overall evaluation of the groundwater potential of Southern Jordan. The model takes the natural time-dependent behaviour of the aquifer system on a long term into account. The calculations are based on the assumption that the whole system was filled with water at the end of the last humid period, approximately 5000 years ago. The model (location see Fig. 2.1.1) was intended to simulate the natural long-term depletion of the aquifer system during these 5.000 years. Fig. 2.1.4 shows a two-dimensional sketch of the flow system with the high groundwater potential in the southern part of Jordan and the deep depression of the Dead Sea which forms the base level for the flow system in the deeper aquifer.

It could be shown that the aquifer system in Southern Jordan is continuously under depleting conditions with a time-dependent decreasing outflow rate. The groundwater system is affected by the Wadi Sirhan depression at shallow to medium depths and by the Dead Sea at greater depths. The model gives a rough picture of the time-dependent behaviour of the flow system and the available groundwater resources in Southern Jordan. The calculated present distribution of groundwater levels compares fairly well with recent measurements of the groundwater level in the deep aquifer (Fig. 2.1.5). Since groundwater level observations are missing in large areas of the model domain, a real calibration is not yet possible. The model is therefore only one possible, even plausible representation of the system (Schmidt et al. 2002).

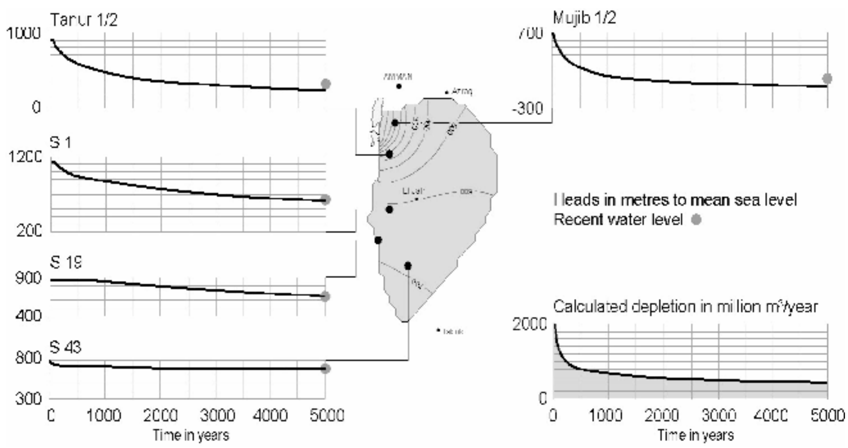

Fig. 2.1.5. Calculated groundwater-head contours of the deep sandstone complex as results of the three-dimensional South-Jordan model. After 5000 years of continuous depletion the calculated heads are close to the monitored water levels. During the recent time the calculated groundwater flow to the Dead Sea amounts to about 400 MCM annually.

The second model, a detailed flow model of the Siwaqa-Qatrana-Hasa well fields (see model area in Fig. 2.1.1), was planned as a contribution to an optimal management of the well fields for the water supply of Amman. The groundwater situation in part of the model area was already studied in the earlier "El Lajjun model". Due to overpumping, modelling results showed a high yearly drawdown. With the new model it was possible to study the reaction of the aquifer in more detail and to calculate various groundwater abstraction scenarios. The main model results confirmed that water table drawdown continued since 1984 and reached 20-30 m after 10 years and 30-40 m after 20 years in the main well fields. It was obvious that groundwater withdrawal created a mining situation. Based on these results a strategy for a more sustainable groundwater abstraction was developed

(Schmidt and Hobler 1994). Due to severe water shortages in Amman, the Water Authority of Jordan was not able to follow these recommendations during the next few years.

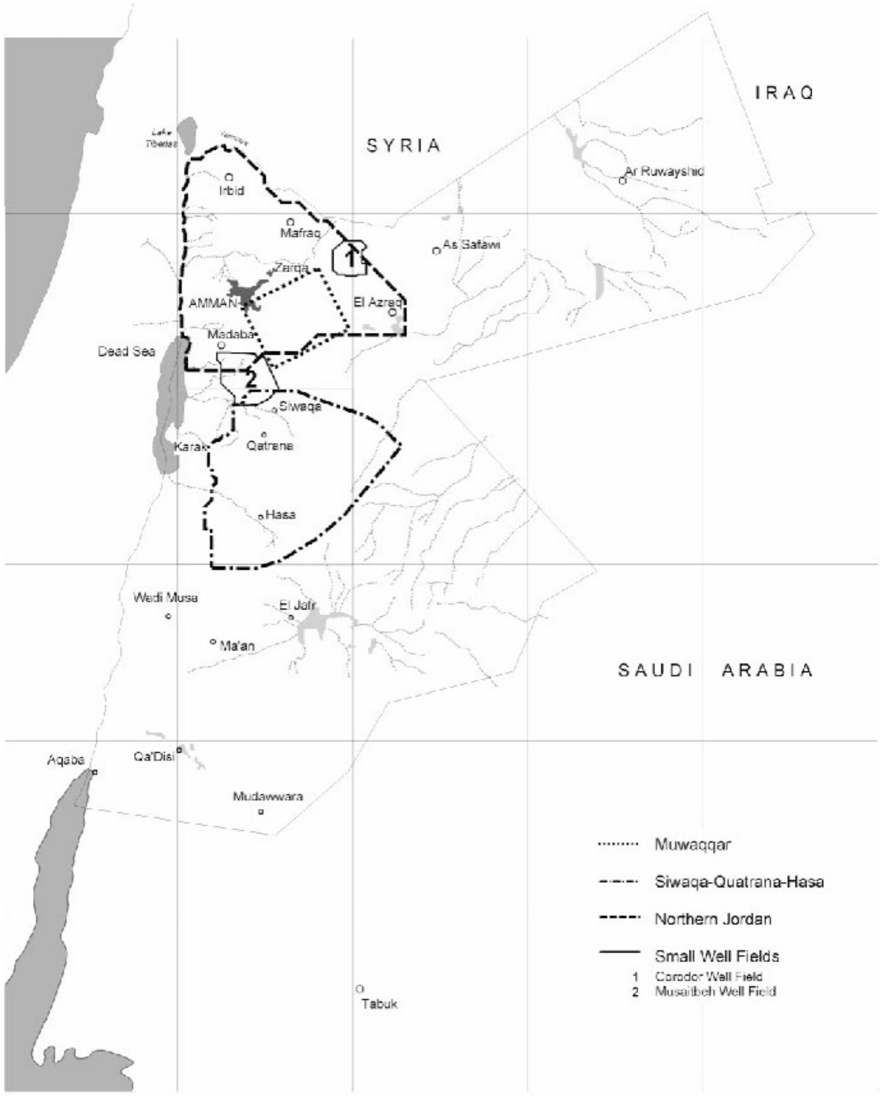

Fig. 2.1.6. Areas of the numerical model investigations in the Northern Jordan project

The next project, "Groundwater Resources of Northern Jordan", started mid 1991 and can be seen as a complement to the South Jordan Project. The main objectives included capacity building as the central topic, development of a data bank and creation of a map of the groundwater resources potential (Margane et al. 2002). As part of the assessment of the groundwater resources, a flow model was developed that takes all of the main aquifers of northern Jordan into consideration (see Fig. 2.1.6). Other than with the more generic South Jordan model, the intention was to create the model as an instrument for advising the Water Authority in the safeguarding and improvement of the drinking water supply of Jordan.

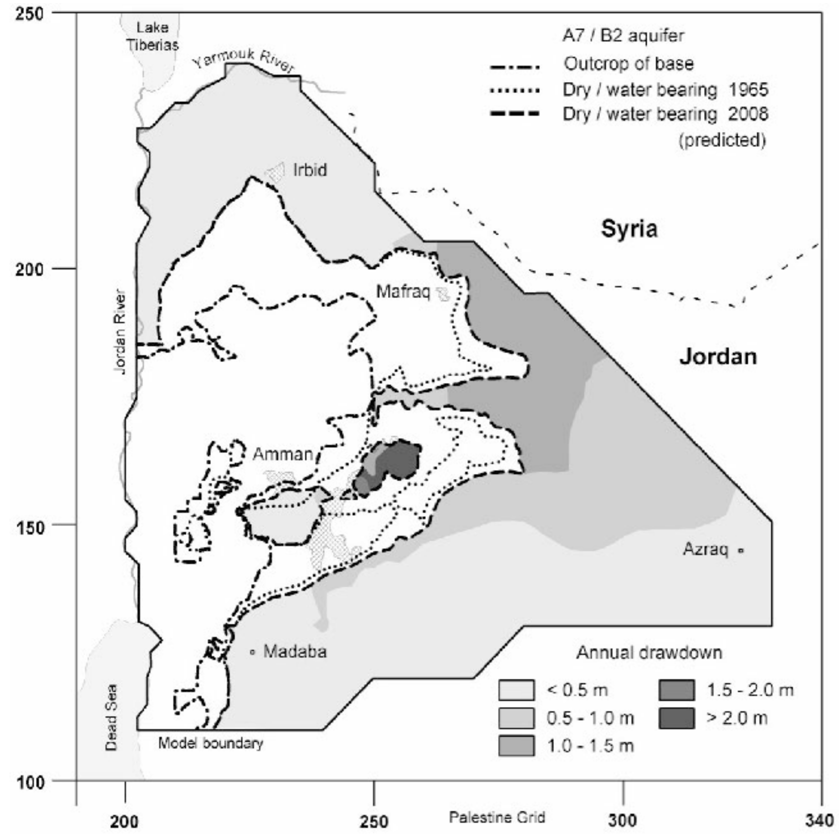

Fig. 2.1.7. Predicted annual drawdown and shift of the limit of dry / water bearing part of the A7/B2 aquifer (Groundwater model of Northern Jordan)

The data base for this model was much better than for the South Jordan model. Model reliability was proved by the good agreement of calculated discharge with spring discharge data. The model results illustrated again the severe consequences of an annual groundwater withdrawal rate of more than 200 MCM, an amount in excess of the recharge rate. Groundwater mining has now become common and the drawdown of the water table reached a typical mean value of about 1m/a in the main abstraction areas. Some springs dried up after approximately 30 years of groundwater development (see Fig. 2.1.7).

As part of the advanced training, the Jordanian counterparts also developed a new model of the Siwaqa-Qatrana-Hasa well fields with a different computer code. The model takes all available new data like abstraction and water level monitoring into account (Fig 2.1.6). The results confirmed the findings of the earlier model of 1989. Within the framework of a technical co-operation project, the model of 1989 has also been validated in 2001. This project dealt with the validation of numerical groundwater models developed and implemented by the BGR during the last 25 years in various countries.

In the last years of the North Jordan Project more emphasis was given to groundwater protection problems. It became obvious that aspects of groundwater quality are often more important than quantitative aspects. Methods for the prevention of contamination of the scarce groundwater resources by agriculture, industry, private users, waste dumps etc. were introduced as project topics. Groundwater vulnerability maps (Fig. 2.1.8) and maps of hazards to groundwater were developed for the first time in Jordan for the Irbid area in the north and an area near Amman (Margane et al. 1999).

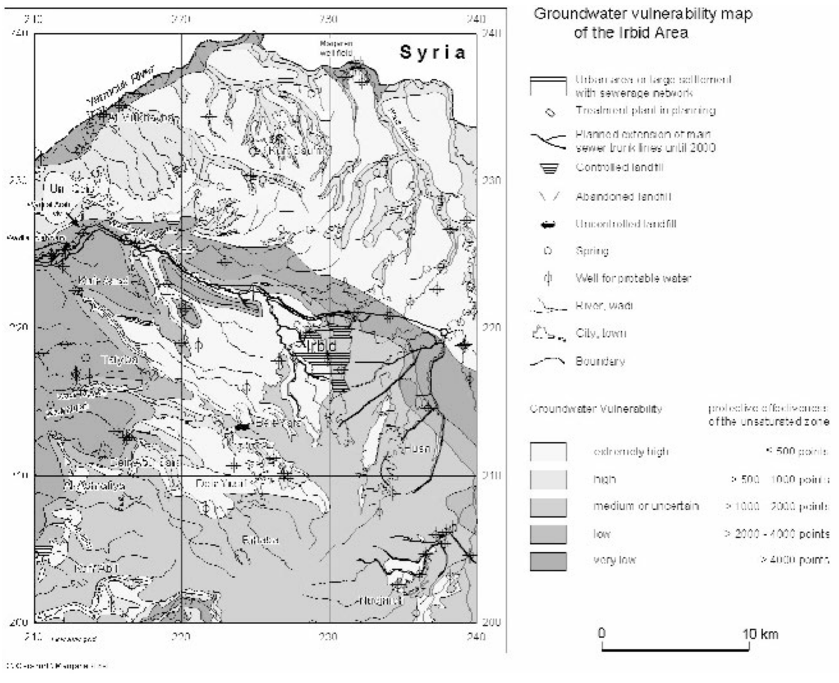

Fig. 2.1.8. Groundwater vulnerability map of the Irbid area

The maps were prepared as tools for land-use planning, which takes aspects of groundwater protection into account. The vulnerability map of the Irbid area showed for example, that the "Wadi el Arab" well field is at risk to become polluted. The establishment of a groundwater protection zone for this well field is therefore very important and will be a major topic of the ongoing cooperation project (Margane et al. 2003). Another step in the improvement of groundwater quality measures was the establishment of a groundwater protection zone for the "Pella spring (Tabaqat Fahel)". The spring is used for the water supply of Irbid. For the first time a groundwater protection zone was officially installed in Jordan and local authorities were instructed on the necessary measures (Fig. 2.1.9).

Fig. 2.1.9. Groundwater protection zone at the Pella spring (Tabaqat Fahel)

The main goals of the new cooperation project on "Groundwater Resources Management" include the elaboration of measures for groundwater protection and their implementation by the Ministry of Water and Irrigation (MWI). This coincides with the German Technical Co-operation strategy to advice governmental organisations in the policy sector as a prerequisite for optimal water management. The activities include the elaboration of guidelines for the delineation and implementation of groundwater protection zones at real sites. These activities serve as examples for the application of concepts which prevent groundwater contamination by the analysis and evaluation of groundwater vulnerability. Other topics are the examination of salt water intrusion problems and the evaluation of the effects of anthropogenic contamination by groundwater modelling including contaminant transport. The recommendations for preventive groundwater protection and the guidelines will be disseminated by the Ministry of Water and Irrigation in co-operation with other Jordanian organisations, ministries and stakeholders in the environmental and water sectors. In addition, support will be given for the hydrogeological part of the new National Water Master Plan. This also includes the development of a groundwater model for Jordan.

2.1.3 International co-operation: ACSAD and ESCWA

Since many years BGR co-operates with two international organisations in the Middle East, namely ACSAD ("The Arab Center for the Studies of Arid Zones and Dry Lands") and ESCWA ("United Nations Economical and Social Commission for Western Asia"). The role of these organisations as multipliers of knowledge to other Arab countries is an important aspect for the co-operation. This implies that ACSAD and ESCWA personnel are qualified to advice specialists of the member countries in modern methods of groundwater management and protection. The organization of advanced training courses, workshops and expert group meetings and the compilation of guidelines are therefore some of the most important topics of the cooperation.

These guidelines take general aspects of the situation in the whole region into account and can be used as a basis for national guidelines of the different Arab countries.

Since important groundwater systems are often shared between different countries, management on the national level has its limitations. Examples of shared aquifer systems in the Arab region are the Nubian-Sandstone aquifer in northern Africa and the Disi, the Paleogene and the Basalt aquifers in the Arabian peninsula. Shared groundwater resources bear an immanent potential for conflicts between countries, especially if the groundwater resources are scarce. This also holds if groundwater contamination affects the groundwater quality in a neighbouring country. Therefore, not only surface water basins but also shared groundwater resources need to be managed in bilateral or multilateral co-operation. International organisations can initiate the dialog between the involved countries. They can assist and support the process of a co-operative management of the shared resources and help in the prevention of conflicts between the different parties. Strengthening of this role is another important aspect of the co-operation with ACSAD and ESCWA.

Advanced training of the staff of ACSAD was therefore one of the main topics in all projects during the long time of co-operation. From 1988 to 1996 project tasks included methods for groundwater protection and groundwater management in general. Special emphasis was given to modern methods of geohydraulics, groundwater modelling and isotope hydrology. ACSAD specialists were prepared to carry out training courses in these fields. As an example, a groundwater management plan was developed for the Palmyra basin in Syria. Fig. 2.1.10 shows the groundwater situation in that basin.

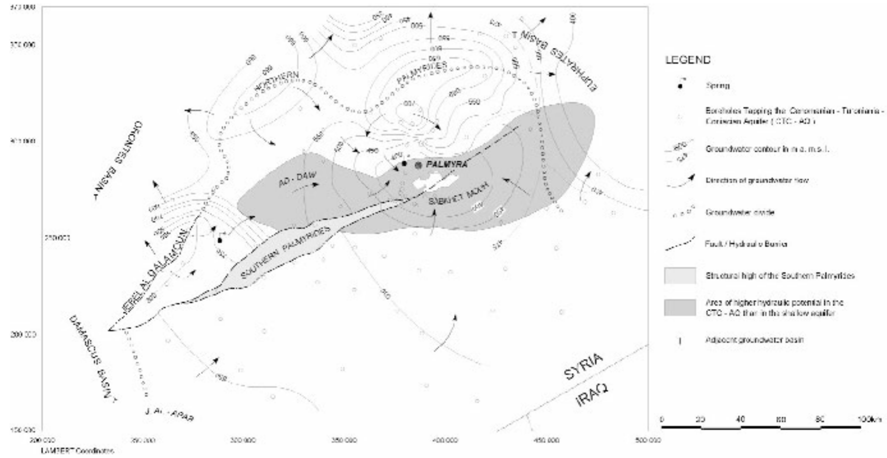

Fig. 2.1.10. Regional hydraulic setting of the Palmyra basin

The goal of the next project was the management, protection and sustainable use of groundwater and soil resources. During the first project phase (1997-2000) the main emphasis was on capacity building in hydrogeological and soil science studies and the dissemination of knowledge in specific workshops. In the ongoing second phase, the strengthening of the national and regional competence in the groundwater sector and the elaboration and implementation of guidelines were the main topics. New or improved methodological approaches are being applied and tested in pilot areas. These studies also serve for on-the-job training of specialists from participating national institutions. Maps of soil and groundwater vulnerability, hazards and risks of contamination were compiled, groundwater and transport models developed and a groundwater and soil information system installed. Based on the results from the pilot areas, guidelines for monitoring, protection and sustainable development of groundwater and soil resources were prepared. Awareness of the consequences of careless use of the scarce water resources is a precondition for the sustainable development of the resources. Dissemination of project results in regional workshops is therefore an important project task. Awareness and information days for stakeholders as well as information of the public in any possible way are essential for the success of such projects.

Three areas have been chosen as pilot areas in three different countries of the ACSAD region: the Damascus Ghouta plain in Syria, the Beka'a valley in Lebanon and the coastal area of Ras El-Jebel in Tunesia. General hydrogeological and soil science surveys were carried out for the Ghouta and the Beka'a valley. Sets of thematic maps including groundwater vulnerability maps and maps of heavy metal distribution in soil were compiled (Margane et al. 2003). In a second step, more specific studies were selected for each of the three pilot areas. Studies on heavy metals were carried out in the Ghouta Plain and on nitrate fluxes in the Beka'a valley. This included model calculations on contaminant transport in general. The effects of overexploitation of groundwater, salt water intrusion and contaminant transport are topics of the work in the Ras El-Jebel coastal area. The main purpose of these studies was advanced training in modelling contaminant transport including chemical reactions and density effects and the use of models in decision making processes. One result of the contaminant transport calculations is shown in Fig. 2.1.11 (Altfelder 2003). Contaminants spread widely from three waste dumps (two existing and one planned) in the central Beka'a Valley. The predicted concentration of pollutants will be highest near the newly planned waste dump, but the spreading will be very low as a result of an appropriate construction method of the dump. The northernmost waste dump seems to be the most dangerous one with respect to groundwater contamination.

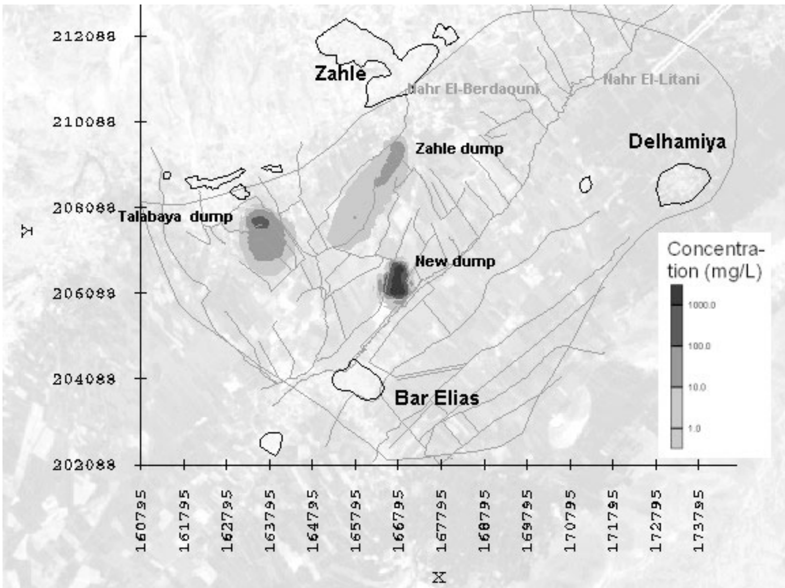

Fig. 2.1.11. Calculated plumes of nonsorbing nondegrading contaminants in the upper aquifer of the Beka'a valley 13 years after an assumed contaminant input

Cooperation with ESCWA and its member states in the field of water resources is going on since about ten years. During the first phases of this project, the main emphasis was concentrated on two topics. The first one was knowledge transfer of new methodologies in the groundwater sector mostly in form of workshops and advanced training courses. The new methods include remote sensing, use of environmental isotopes and application of transport models in hydrogeology. Reports were prepared on project results and distributed to the member countries.

The second focal point of the project activities was the evaluation of regional studies on groundwater systems in the ESCWA region. The hydrogeology of the Basalt aquifer of Syria and Jordan and of the Paleogene aquifer in the Arabian peninsula have been described in two comprehensive reports (ESCWA 1996 and 1999). For the storage of the data, a GIS based data bank on regional aquifers was developed. The project tasks also included advice on groundwater related problems for ministries in the various countries.

In the ongoing phase, the management of internationally shared aquifer systems has the highest priority. This has to be seen in light of the above mentioned conflict potential of shared water resources. Therefore, the project supports the ESCWA member states in questions of an integrated management of such shared groundwater resources. Bilateral committees have been established to improve the regional co-operation. Compilation of guidelines for an integrated water resources management, for example priorities for water allocation, water resources protection, use of non-conventional water resources, water rights and reduction of water consumption is also an important task of the project team. Naturally, the guidelines have to be modified for the purpose of the respective countries. As in earlier phases, results of all activities will be presented and discussed in workshops and disseminated in the member countries.

2.1.4 Conclusions

In general, the groundwater resources of the Near Eastern and North African countries are fairly well known. The knowledge on groundwater protection issues is also increasing continuously. Many new tools like GIS and data bank systems, groundwater and transport models, remote sensing methods and hydrochemical methodologies for the management of the groundwater resources and their protection are available. Important next steps are the elaboration of guidelines and policies and the implementation of groundwater protection measures e.g. in the national laws. At the same time, the information on groundwater protection and sustainable use of the resources has to be presented to the public and disseminated to stakeholders using appropriate methods.

A very important issue is the use and management of shared groundwater resources. The problem is not new, but the significance of the problem was not noticed for a long time. Therefore, it is a ‚new‘ task for many governments. Advice in handling this task, in finding a consensus between different countries and in preventing them from conflicts could be provided by organisations working on an international level. This is another good reason to support organisations like ACSAD and ESCWA.

All of the BGR groundwater projects aim to ensure a safe supply of good quality drinking water for the population. The interests of the various competing users have to be taken into account on national and also international levels. To fulfil these requirements integrated groundwater management systems have to be established and guidelines and policies for various aspects of groundwater protection and groundwater use including e.g. wastewater treatment and reuse or water price structure have to be elaborated. These complex tasks can only be worked out successfully in co-operation with other scientific disciplines such as geosciences, soil and environmental sciences and disciplines dealing with water rights and water supply.

Acknowledgements

The examples presented here are based on the results of various technical co-operation projects. Many scientists from BGR, the WAJ and MWI in Jordan, ACSAD in Damascus and ESCWA in Beirut have worked together with the authors in these studies. The authors wish to thank all these colleagues. They are mentioned in the text and the respective publications.

References

Altfelder S (2003) pers. comm., see: Tätigkeitsbericht BGR 2001/2002, 65 S, Hannover

Bender H, Giesel W, Knoop RM, Schelkes K, Rashdan J (1989) Feasibility study on the groundwater development for the water supply of an oil shale processing plant in Central Jordan. Proc. Int. Symp. on Groundwater Mangement: Quantity and Quality, IAHS Publications No. 188, pp 571-579, Wallingford, UK.

Bender H, Hobler M, Klinge H, Schelkes K (1989) Investigations of Groundwater Resources in Central Jordan. Desalination, 72, pp 161-170, Amsterdam, The Netherlands

ESCWA (1996) Investigation of the Regional Basalt Aquifer System in Jordan and the Syrian Arab Republic. E/ESCWA/ENR/1996/11, United Nations Publication, ESCWA, Amman

ESCWA (1999) Groundwater Resources in Paleogene Carbonate Aquifers in the ESCWA Region: Preliminary Evaluation. E/ESCWA/ENR/1999/6, United Nations, New York

GTZ (1977) National Water Master Plan of Jordan. Vol. IV (Authors: Vierhuff, H. & Trippler, K.), Hannover

Margane A, Hobler M, Almomani M, Subah A (2002) Contributions to the Hydrogeology of Northern and Central Jordan. Geologisches Jahrbuch, Reihe C, Heft 68, 52 S.

Margane A, Hobler M, Droubi A, Rajab R, Subah A, Khater AR (2003) Groundwater Vulnerability Mapping in the Arab Region. in: Water in the Middle East and in North Africa: Resources, Protection, and Management (ed. Zereini F)

Margane A, Hobler M, Subah A (1999) Mapping of Groundwater Vulnerability and Hazards to Groundwater in the Irbid Area, N Jordan. Z. angew. Geol., 45 (4), pp 175-187, Hannover

Schmidt G, Hobler M (1994) Groundwater modelling in Central and Southern Jordan. In: Proceedings of the First Jordanian Mining Conference (23.-25.04.1994), pp 239-252.

Schmidt G, Hobler M, Söfner B (2002) Investigations on Regional Groundwater Systems in North-East Africa and West-Asia. Proc. Int. Conf. on Aquifer Systems in Arid Zones: Managing Non-Renewable Resources.- Tripoli, Libya, Nov. 1999, UNESCO 2002, pp 195-203, (on CD), to be published in 2003 as Technical Documents in Hydrology, No. 42

http://www.springer.com/978-3-540-20771-9

Water in the Middle East and in North Africa
Resources, Protection and Management
Zereini, F.; Jaeschke, W. (Eds.)
2004, XVII, 369 p., Hardcover
ISBN: 978-3-540-20771-9