HYDROGEOLOGICAL INVESTIGATIONS ON THE AQUIFERS ALONG THE JORDAN RIFT VALLEY ESCARPMENT

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KEYWORDS: Ground Water, Jordan Rift Valley, Water Resources.

ABSTRACT

This paper present some research activities results of the joint research project "water resources evaluation in the Jordan Rift Basin". The instigations were conducted on both sides of the Jordan River. In **Wadi el Qilt** between Jerusalem and Ramallah groundwater flow is determined by the tectonical structure of the area. The salinity increases from west to east. In the **Jericho area** the hydrochemistry shows that the high Cl value, in the eastern part is derived from three main sources: 1) anthropogenic effect of sewage inflow. 2) agricultural backflow. 3) deep brine water and dissolution of salts from Lisan layers. **Wadi al Kafrein** east of the Jordan River is part of the drainage systems from the mountains around Amman down eastwards to the Jordan Valley. The hydrochemistry shows that Mg and Cl represent the dominating single ions. The salinity is low at wells along the stream bed and it increases towards the Jordan River. In **Wadi Shueib** north of Wadi Al Kafrein investigations dealing with the assessment of ground water – vulnerability and hazard mapping using remote sensing techniques were conducted. The results will be presented in a special paper during this conference. The **Decline in the Dead Sea Level** is causing a lost of 370 Mio m3/a of freshwater to the Dead Sea through the over exploitation of waters which formerly fed the Dead Sea. Geoelectric measurements and hydrogeological tests were conducted to clear this phenomena.

INTRODUCTION

The results in this paper are part of the investigations of the German-Israeli-Jordanian-Palestinian multilateral project for the sustainable utilization of aquifer systems in the Jordan Rift between the years 1997 to 2004.

The investigations were concentrated on the geology and hydrogeology of the lower Jordan rift between Fazael-Salt area in the north and the northern part of the Dead Sea in the south (Fig.1).

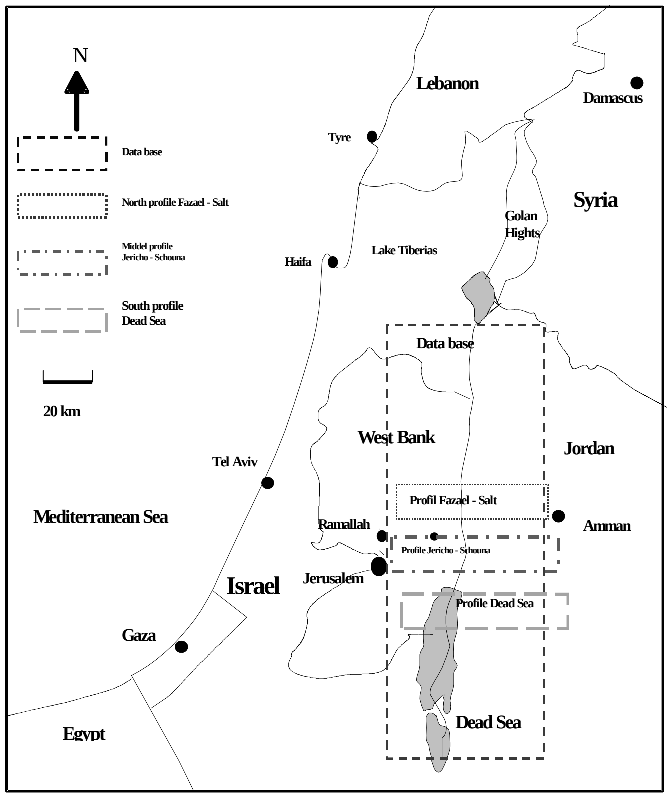

Fig. 1: Multi-lateral Project, areas of investigations.

Scientists from universities, research institutions and commercial companies in Germany, Israel, Jordan and the Palestine joined their skills and experiences to carry it out. It also has allowed close, continuous and collegial cooperation between partners of all parties, even in the most difficult political circumstances.

The main fields of activity included:

- Geology and hydrgeology of the groundwater and surface water;

- Water quality, pollution sources, salinity and salinization sources and processes, vulnerability evaluations;
- Database management systems;
- Development of software tools for the visualization and analysis of the gathered data;
- Quantitative modeling of groundwater flow and solute transport processes.

1. Method and Objectives

Modern methods were applied in this joint research project including:

- Computerized database with geological, hydrogrological and geochemical and climatic data;
- Detailed geological mapping and geological and hyrogeological cross-sections for significant parts of the investigated area;
- Analysis and inference of seismic lines;
- Detailed hydrological surveys and geochemical analyses, including isotopes and REY, for the identification of salinity sources and the connections between aquifers;
- A more refined definition of the aquifer boundaries and inter-connections, and hydrological links with the Jordan river, the Jordan Valley and the Dead Sea;
- Conceptual hydrogeological models of various sub-areas and aquifers;
- Pumping and injection tests in a many wells of the area;
- In depth study of the link between the presence of saline water and fresh water bodies in the aquifers;
- Evaluation of the fresh water losses to the Dead Sea;
- Construction of quantitative models for the simulation of groundwater flow in two-dimensional horizontal configurations ("The Eastern Aquifer") and in three dimensions (Jerusalem-Marsaba-Feshcha area).

The results of this joint research program are essential for the infrastructure planning and development of this region.

2. RESULTS AND DISCUSSION

Following are some obtained results through the Karlsruhe research team and other teams involved in the research program:

a. Wadi el Qilt:

The Wadi Qilt (Fig. 2) basin on the west side of the Jordan River represents a major drainage system from the Judean Mountains area between Jerusalem and Ramallah downwards east to the Jordan Valley. The hydrochemistry of the waters remains almost constant within the study area. Only by approaching the Jordan Valley an increase in Mg is observed due to the change of the aquifer rocks from limestone to dolomite. In the wells close to the Jordan Valley high TDS (total dissolved solides) and Cl concentrations indicate an influence of Jordan Valley groundwater.

The flow velocities in the spring system are quite high documented by discharge peaks following closely rainfall peaks. In the well system flow velocities are very slow and the residence time is very long prevailing groundwater ages of some thousand years.

The groundwater flow (Fig. 2) is determined by the structure following the regional dip and joint directions, which are in the study area identical. The normal fault of the lower Wadi el Qilt has an important influence on the groundwater movement.

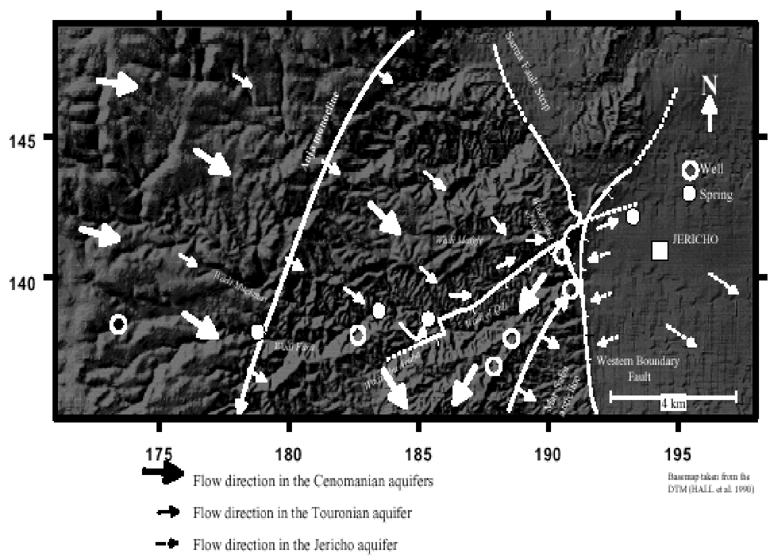

Fig. 2: Conceptual model of the groundwater flow in Wadi el Quilt and Jericho area (Wolfer, 1998).

b. Wadi al Kafrein

Beside the geology and hydrogeology a Tracer test in Kafrein reservoir in Jordan was performed. Fig. 3 projected input sites for tracers Uranin and Eosin and location of sampled well AN 1025.

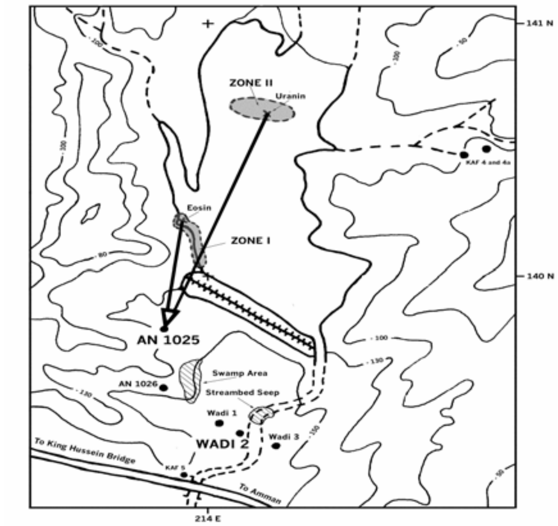

Fig. 3 projected input sites for tracers Uranin and Eosin and location of sampled well AN 1025 (Linz 1999)

Figure 4 shows the Travel time and concentration of tracers samples Eosin (after 68 days) and Uranin (after 90 days) of well AN 1025 as a results of the tracer test.as results of the tracer test.Uranin and Eosin and location of samples well AN 1025.

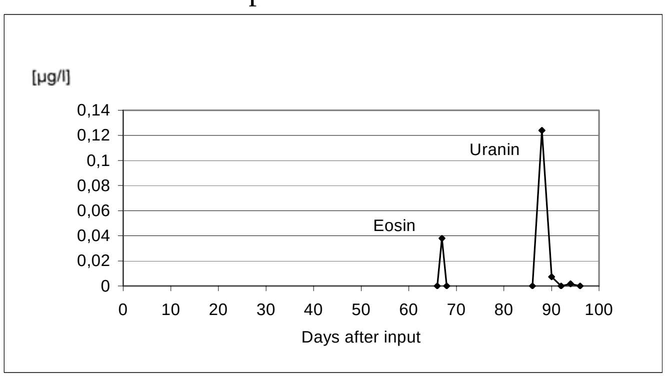

Fig. 4 :Travel time and concentration of Eosin (after 68 days) and Uranin (after 90 days) in well AN 1025 (Linz, 1999)

The test proves that water flow in the deeper reservoir filling reaching the well by under flowing the dam. It was found that the activation of the main seepage sources needs an initial minimum reservoir storage to produce enough water pressure

c. Ground water - Vulnerability mapping in Wadi Schueib

The Wadi Shu'eib catchment area is situated at the eastern side of the Jordan Rift Valley about 15 km west of Amman and about 20 km northeast of the Dead Sea. It covers an area of about 185 squkm. The study investigated to what extent conventional procedures of data acquisitation for mapping groundwater vulnerability and groundwater hazards in regions lacking reliable spatial and measured data can be enhanced with remote sensing data information. For the groundwater-vulnerability and hazard assessment the area-wide information obtained from the multispectral classification concerning the land-use (vegetation, build-up areas, indirect information about the soil and infiltration conditions) is used (Werz & Hötzl, 2004). More details are included in a separate paper in this conference.

d. Shallow unconsolidated aquifers in lower Jordan Valley

Geophysical investigations of the shallow aquifer in lower Jordan Valley were conducted using the Frequency Dependent Electromagnetic (FDEM, MaxMin I-8). A steep resistivity contrast between the fresh and saltwater bodies is expected in some parts of Jordan Valley. Therefore electromagnetic techniques, namely the APEX MaxMin I-8 apparatus was applied for their differentiation in the unconsolidated aquifer (Toll, 2004)

The map in Fig. 5 shows the sounding locations of MaxMin measurements. However salinization of Jordan Valley soils proved to be far too high (see chemical soil analysis) and no deep response could be obtained. Therefore a method applicable in highly conductive environments (Frequency Dependent Electromagnetic, FDEM, MaxMin I-8) was chosen.

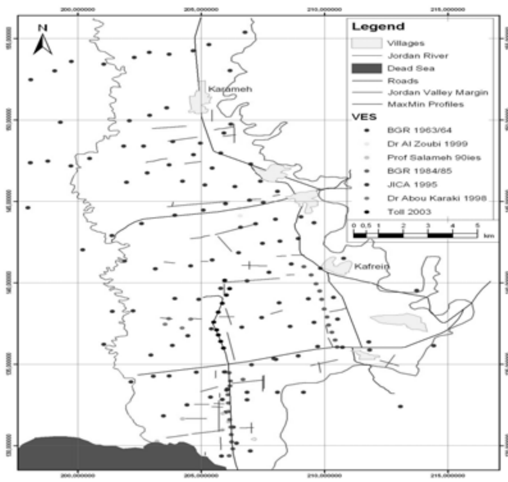

Fig. 5 : Map showing the locations and the lines of the geophysical lines and other measurements (Toll, 2004).

e. Hydrochemical Investigation for the Pleistocene Wells and springs from Jericho Area

The chemical composition of ground water from the Pleistocene wells in the Jericho area shows that the high TDS (Fig. 6) and Cl values, especially in the eastern Alami wells, is derived from three main sources (Khayat, 2004). These are: 1) anthropogenic effect of sewage inflow and 2) agricultural backflow, and third 3) deep brine water and in situ dissolution of salts from Lisan layers.

As a result one possible remediation process can be the maintenance and new establishment of a sewage system network at places where Jericho is lacking of such systems and still depends on septic tanks. Also special attention should be taken for the methods of applying agricultural fertilizers, where many farmers used banned chemicals with uncalculated amount. Moreover, the over-extraction of water lead to up conning of deep brine water, this can be managed through regulating the pumping rate, leaving a sufficient period for aquifer recharge.Many sources of salinity are still unclear yet, and need further investigation including studies of minor and trace elements, water and solutes isotopes which are good assessment tools to qualify, quantify and identify the salinity and its sources.

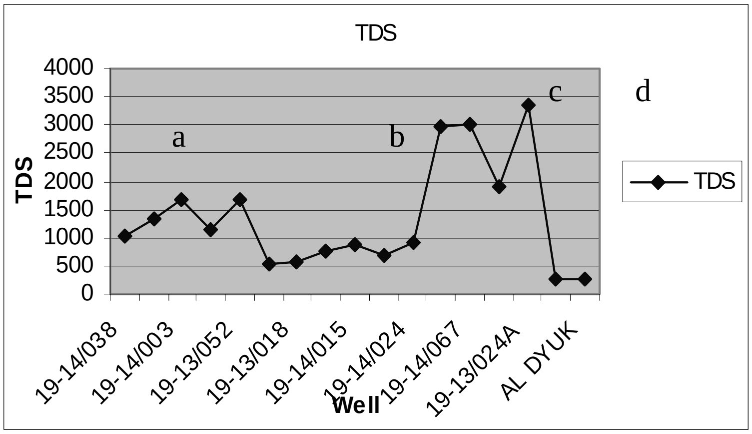

Fig. 6: TDS in different wells in Jericho area (Khayat, 2004).

f. The Decline in the Dead Sea Level and its Impacts on the Groundwater Resources of its surrounding areas

The riparian states of the Dead Sea are nowadays loosing 370 Mio m3/a of freshwater to the Dead Sea through the interface readjustment mechanisms as a result of their over exploitation of waters which formerly fed the Dead Sea (Salameh, 1999).

Geoelectric sounding measurements and other hydrogeological tests showed that the areas underlying the coastal aquifers, which formerly were occupied by DS water, are gradually becoming flushed and occupied by freshwater. That fresh water becomes salinized due to the residuals of Dead Sea water in the aquifer matrix. The present salinity of that matrix is lower than that of the Dead Sea water. At the same time salt dissolution from the Lisan Marl formation is causing collapses along the shorelines in the form of sinkholes tens of meters in diameter and depth.

g. Groundwater modelling

Modelling is as a tool is essential for the evaluation of water resources, Following are two examples of the modelling in the studded area:

1. Modelling of the shallow aquifer in the Jericho Area

The model domain is selected using geological, topographical maps and groundwater contour information displayed as ArcView themes. The constructed polylines (Fig. 7) are then used to construct the fine elements mesh within the soft wear GeoSys/RockFlow.

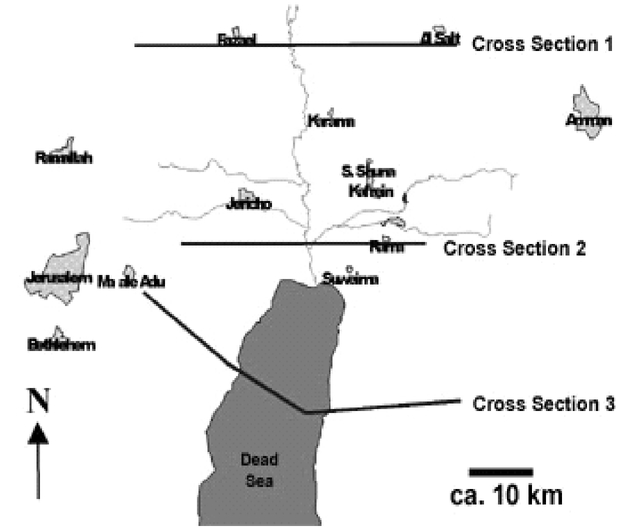

Fig 7: constructed polylines in the study area

The hydraulically active fresh water layer has an assumed thickness of 20 m initially. The geometry is achieved using the before mentioned mapping method and appropriate surface grid data constructed with surfer. A permeability of 8 m/d is assigned for the whole domain.

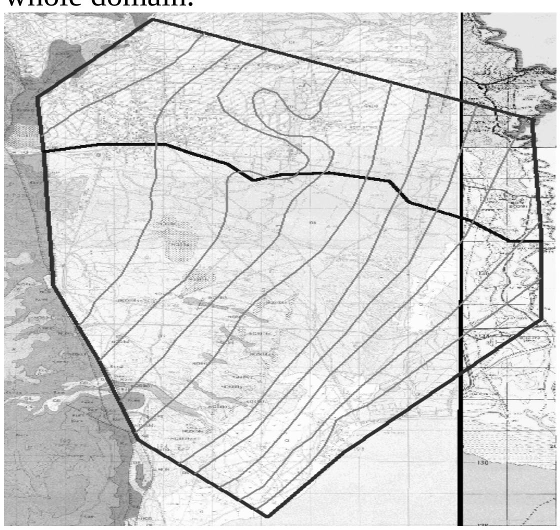
Fig.8: Boundary and geometry of the constructed model

2. Three D- Model Jerusalem-Marsaba-Feshckha area

The project area is located in the eastern slopes of the Judea anticlinorium, which descends towards the Dead Sea in a number of undulations creating a structure of parallel asymmetric folds in the northeast – southwest direction. The ground water extraction model (Fig. 9, Guttman et al 2003) shows a groundwater level difference map at the end of the simulation period (A3 is winter 2004) and A0 as a the start of scenario calculation.

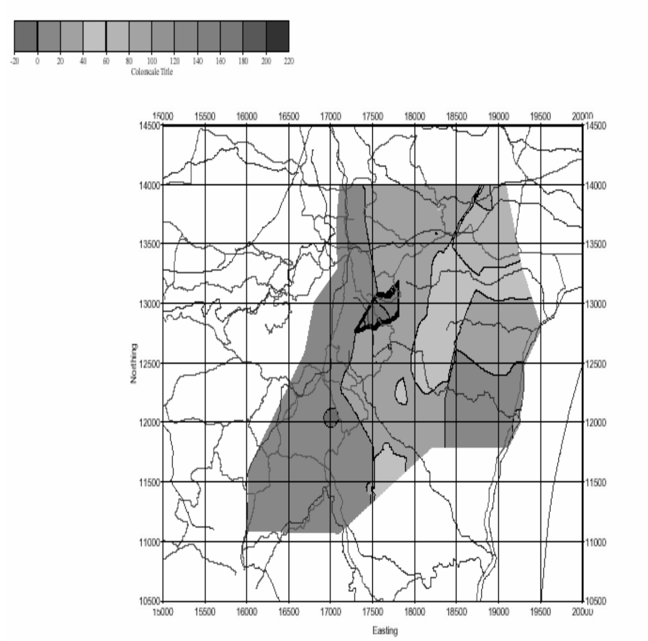

Fig. 9: Groundwater level differences map at the end of the simulation period (A3 for winter 2004) and A0 as a basis and start of the scenario, Guttman et al 2003).

3. Conclusions

The research results of the of the German-Israeli-Jordanian-Palestinian multilateral joint project for the sustainable utilization of aquifer systems in the Jordan Rift are very valuable for the developing of the studded region. Following results are now available:

- A modern computerized database with geological, hydrogrological and geochemical and climatic data;
- Detailed geological mapping with geological and hyrogeological cross-sections ans seismic lines;
- Detailed hydrogeological, geochemical, isotopes analysis for the identification of salinity sources and the connections between aquifers;
- Conceptual hydrogeological models of various sub-areas and aquifers;
- Results of pumping and injection tests conducted in study area;

- Evaluation of the fresh water losses to the Dead Sea;
- Construction of quantitative models for the simulation of groundwater flow in two-dimensional horizontal configurations (“The Eastern Aquifer”) and in three dimensions (Jerusalem-Marsaba-Feshcha area).

4. ACKNOWLEDGMENTS

The authors would like to express their thanks to the German Ministry of Education and Research (BMBF) supporting and funding the project: Water Resources Evaluation for a Sustainable Development in the Jordan Rift Basin, German – Israeli – Jordanien and Palestinian Joint Research Program. The authores are thankful for the Ministry of Science, Israel, and the Ministry of Irrigation, Jordan for there data providing and Help

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