THE KARSTIC FLOW SYSTEM IN UJA AREA –WEST BANK: AN EXAMPLE OF TWO SEPARATED FLOW SYSTEMS IN THE SAME AREA

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ABSTRACT

Uja spring is the largest spring in the Eastern Basin of the Judea-Samaria Mountain in the West Bank. In the vicinity of the spring outlet there are three production wells (Uja 2,3,4). The Uja spring is characterized by large discharge fluctuations. It was conjectured that the drying of the spring in dry years is the result of pumping in the nearby Uja wells. This conjecture follows the assumption that the spring and the wells are hydrological connected and are supplied by the same reservoir.

A detail investigation of the spring discharge, the hydrological setting of the spring and of the wells and the wells water level measurements, shows that the spring and the wells are hydrologically separated and the pumping from the wells has no influence on the spring discharge.

There is a local, very karstic aquifer, which feeds the spring; the discharge depends on climatic variations (drought or rainy years). In contrast the Uja wells draw water from a deep, separate, aquifer. A similar hydrological situation exists in En Samiya area, where the Palestinian Authority utilizes water from the En Samiya spring (Upper aquifer) and from the wells (lower aquifer). The important consequences of this analysis on the management strategy of the water supply of the area are concluded in this paper.

HYDROGEOLOGICAL BACKGROUND

The area under study extends geographically from the water divide running along the Ramallah anticlinal axis in the west to the Jordan Valley in the east, and from the Fari'a Wadi in the north, to the Wadi Kelt in the south (Fig. 1).

The stratigraphic profile exposed in the study area varies from the Lower Cretaceous age to young formations of the Holocene age. Ancient formations of Cretaceous age, composed mainly of limestone layers, are exposed in the area of the Ramallah anticlinal axis. The Judea Group layers, constituting the regional aquifer in the area, are exposed to the east of the Lower Cretaceous layers and in the Hebron anticlinal axis. Farther east, near the Jordan Valley and throughout the Judean Desert, the formations of the Mt. Scopus Group are exposed. Young formations of Pleistocene-Holocene age are exposed in the Jordan Valley and on the shores of the Dead Sea as well as in inland wadis and valleys (Guttman, 1995,2000).

The area is characterized by intensive fault systems in a general E-W direction. These fault systems form grabens, horsts and step structures. The throw of these faults ranges from some tens of meters to about 100-150 m'.

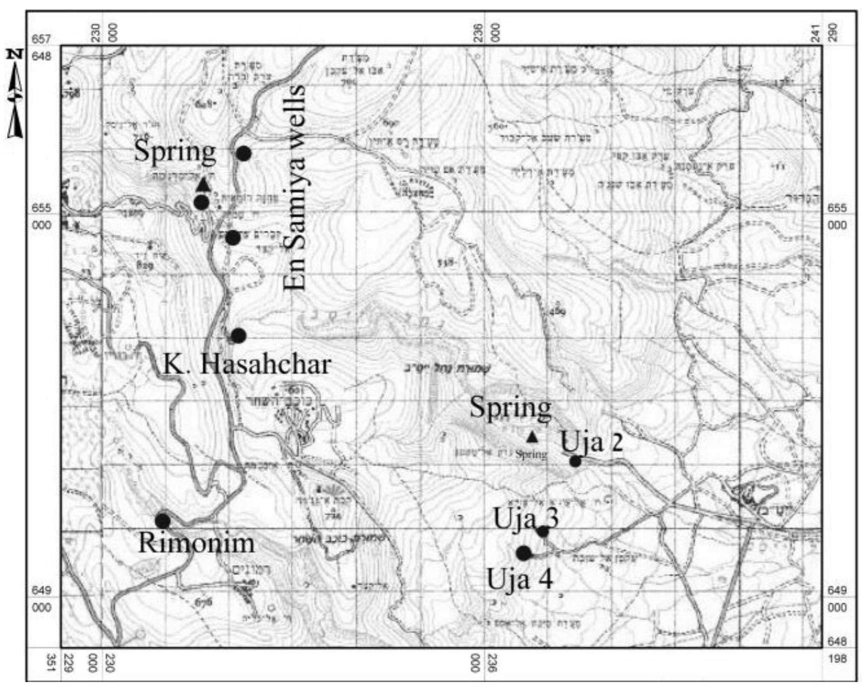

Fig. 1- Location map

The area is semi arid to arid zone, characterized by sharp fluctuations in precipitation. On the high mountains in the west, the average rainfall ranges from 500 to 700 mm/yr (Jerusalem - 554 mm/yr, and Ramallah - 647 mm/yr). Towards the east and southeast there is a sharp drop in precipitation over a relatively short distance. In the Jordan Valley, the average rainfall ranges from 100 to 150 mm/yr (Jericho 163 mm/yr). Precipitation decreases to less than 100 mm/yr on the Dead Sea shores.

The Judea Group aquifer, with a thickness of about 800 to 850 m, comprises several sub-aquifers. According to water level measurements, two sub-aquifers may be identified in most of the study area: the Upper aquifer and the Lower aquifer. The Upper aquifer generally includes the Bina, Veradim and Aminadav Formations, and at times the aquiferous horizons in the Bet Meir tongue. The Lower aquifer includes the Givat Yearim and Kefira Formations and at times the aquiferous horizons in the Soreq Formation (Guttman 2000).

According to the well findings, the hydraulic separation between the two aquifers is primarily in the mid-lower section of the Bet Meir Formation, composed of bluish-greenish clay, marl and chalk. The separation is manifested in the difference in water levels in the two sub-aquifers, the level in the upper aquifer being higher than that in the lower aquifer. For example; in En Samiya and Uja area about 200 m difference between En Samiya and En Uja springs on the one hand, and the wells tapping the lower aquifer on the other (Shaliv, 1980, Guttman, 1980,1995,2000).

THE UJA SPRING

Uja spring is the largest spring in the Eastern Basin of the Judea-Samaria Mountain, West Bank. In the vicinity of the spring outlet there are three production wells (Uja 2,3,4). The Uja spring is characterized by large discharge fluctuations (Fig. 2). For example, in 1993 (very rainy year) the yearly discharge was about 18.5 MCM. In the drought year of 1999 the yearly discharge was about 2.4 MCM only. In drought years the spring dried up during the summer period.

There are discharge measurements since 1944. These data allow us to analyze the spring behavior and its flow mechanism. The spring flow is characterized by large annual and yearly fluctuations (Fig. 2).

Detailed analysis of the spring discharge shows a quick response to climate changes (drought period beside very rainy periods). The strong correlation between rainfall (taking Jerusalem station) and the spring fluctuation is shown in Fig. 3. The maximum discharge appears a little after the rainiest month. It can be seen that the discharge dies out towards the end of the winter season. Most of the time (except in very rainy years like 1992) large storage is not required in order to maintain a high and steady flow for a long period.

The depletion curves of the spring look very linear with different depletion coefficient (t_0) between rainy years. The linearity of the depletion curve shows that the system has only one flow component and not two flow components that are very typical for carbonatic systems. Possible explanation to it is the existing of a very developed karstic system in the recharge area of the spring and rapid flow of the groundwater towards the spring (Guttman 1980, Rosenthal 1978).

In average rainy years the depletion coefficient (t_0) is between 130-180 days. In very rainy years (1983, 1993) the depletion coefficient (t_0) is much greater and varies between 540 to 620 days. In contrast to the rainy years, in drought years the depletion coefficient (t_0) is very small- less than 65 days (Table 1).

The differences in the depletion coefficient, means that the size of the recharge area that fed the spring is not constant and it changes according to the distribution of the rainfall. Because we are dealing with a very karstic aquifer, it is important to look not only on the yearly rainfall, but also on the monthly rainfall. For example, in 1987 the total amount of rainfall in Jerusalem station was 677.2 mm' (higher than the average) but the spring discharge die out very quickly. The calculated depletion coefficient (t_0) was 47.7 days. In 1988 the total rainfall was similar (666.60 mm'), but the spring depletion was less than in 1987. In 1988, the minimum discharge (end of summer) was much high than in 1987 (fig. 2). The reason is the difference in the rainfall distribution during the winter. In 1987 the rainiest month was at the beginning of the winter (November 1986) while in 1988 the rainiest month was on February 1988.

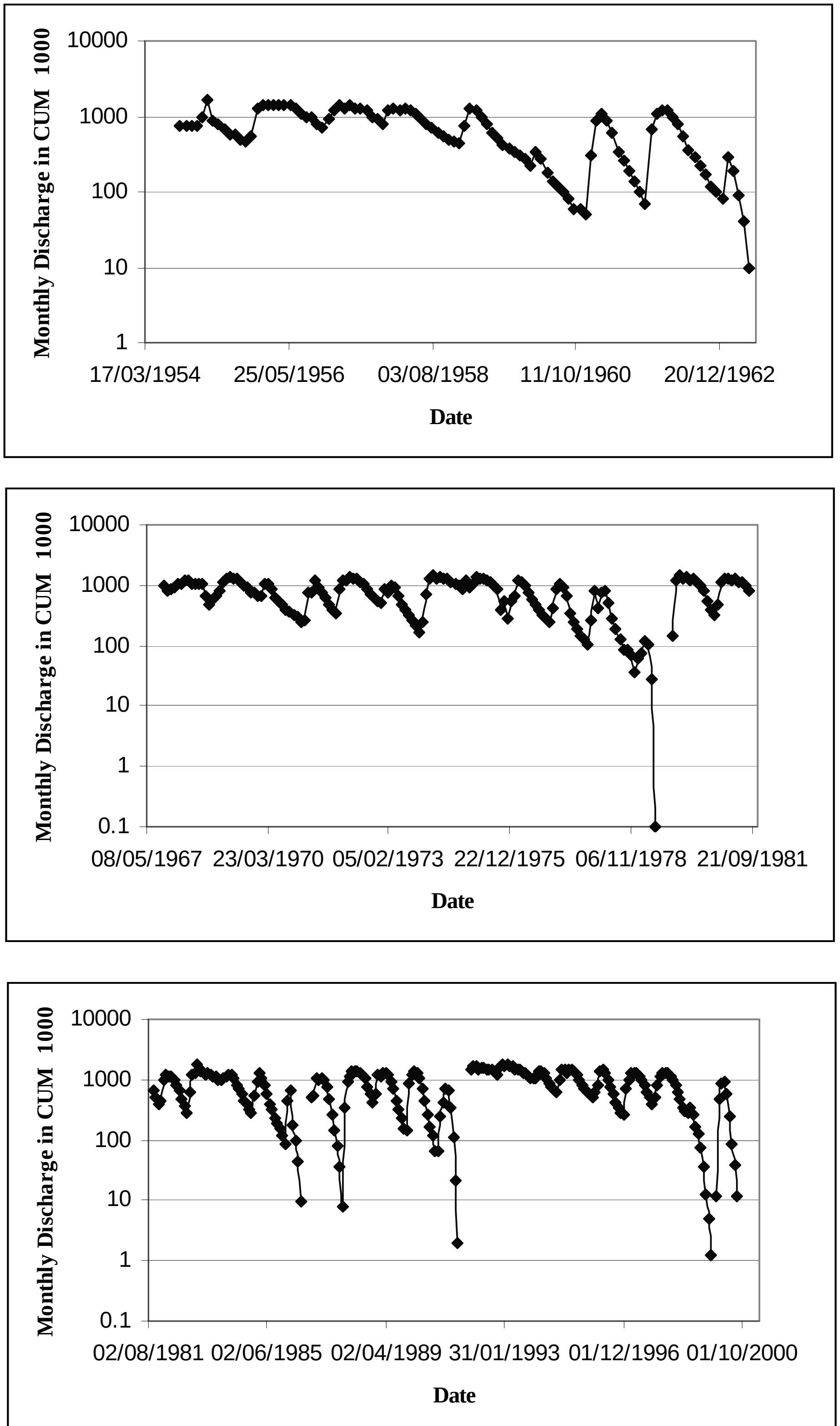

Fig. 2-The Discharge behavior of the Uja spring

For the calculation of the minimal recharge area, the actual replenishment rainfall value that was taken for rainy years was 250 mm', for average years value of 150 mm' and for drought year value of 100 mm'. The results shows that the calculated recharge area that fed the spring varies between 50 Km^2 in rainy years to 15-20 Km^2 in average years and less than 10 Km^2 in drought years (Table 1).

Table 1: Depletion coefficient and calculated recharge area in several years

Year	Depletion coefficient (t_0) In days	Max. Discharge (Cum*1000)	Calculated recharge area (Km^2)
1959-1960	180	2951	20
1962	138.7	1993	13
1974-1979	305.1	5480	36
1983	623	10895	44
1984	171.6	2685	18
1985	117.2	1834	12
1987	47.7	642	6.4
1990	65.9	1098	11
1991	21.1	187	1.9
1993	543.3	12293	49
1996	130.6	2727	18
1999	45.8	246	2.5

In drought years, like 1999, the size of the recharge area is small, the depletion coefficient is low and the spring is dried up during summer time, while in very rainy years, the depletion coefficient is high and the recharge area of the spring is large and the storage is quite big to maintain summer flow.

There is long-term reduction in the summer discharge as seen in the periods like 1974-1976, 1983-1986, 1992-1999 (Fig. 3). This behavior can be explained by the fluctuations in the precipitation (monthly and annually) that are very common to arid zone and it influence on the size of the recharge area. In rainy year, the size of the recharge area is big and the spring discharge is high and it can decrease in average and drought years that might follow the rainy year.

The results show that we are dealing with a very karstic system (spring) that reacts immediately to changes in the monthly and yearly precipitations at his recharge area. The results show that the spring behavior is constant during the last 60 years of record- many years before the Uja wells started to pump water from the lower aquifer.

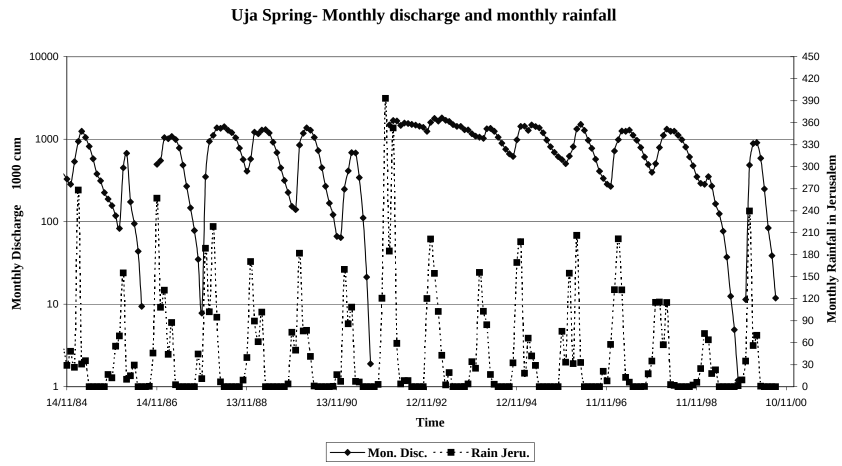

Fig. 3- Monthly discharge in the spring and the rainfall in Jerusalem station

THE UJA WELLS

In the vicinity of the spring, there are four wells (Uja wells), which have been drilled to the lower aquifer (Fig. 1). The first well (Uja 1) was drilled in 1964 by the Jordanian authority to a depth of 288 m' and later had been deepened by the Israeli authorities to depth of 536 m'. This well was open in the upper part of the lower aquifer. In 1974 a new well (Uja 2) was drilled to depth of 615 meter in order to replace the old well. Later, at the beginning of the eighties, another two wells were drilled few kilometers south to the spring. Uja 3 was drilled to a depth of 738 meter and Uja 4 to a depth of 650.50 meter. The three wells (Uja 2,3,4) are open and pump from the lower aquifer of the Judea Group.

The water level in the wells varies between 200 meter bsl (below sea level) to 280 meter bsl (Fig. 4), which is higher than those in the Fazael and Gitit wells to their north, and those in the Jericho wells to their south. Consequently, a local hydrological barrier (water divide) exists in the area. The local water divide creates conditions so that groundwater flow in the area to the north of the Uja wells is towards the Jordan Valley while groundwater flow in the area south of the Uja wells is towards the Dead Sea springs.

The spring outlet is around 20 meter bsl (below sea level). There is a difference of more than 200 meter between the spring outlet and the water level of the lower aquifer. Such a large difference means a hydraulic separation between the aquifer that feeds the spring and the aquifer form, which the wells are pumping.

The hydraulic separation between the spring and the wells is combined to the fact that the spring behavior remains the same along the last 60 years of record and did not change as a result of the pumping from the Uja wells or any other wells located upstream (Kochav Hashachar, Rimonim and En Samiya wells).

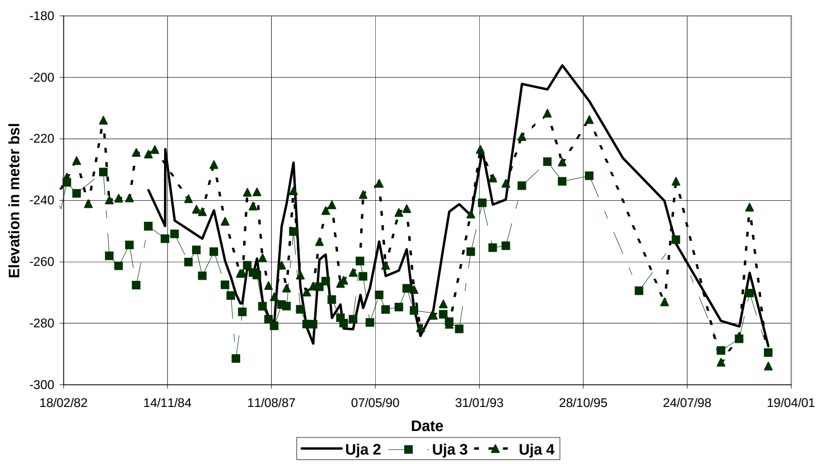

Fig. 4- Water level in Uja wells

CONCLUSION

It has been assumed that the spring drying in drought years is a result of the pumping in the nearby Uja wells. This conjecture follows the assumption that the spring and the wells are hydrological connected and are supplied by a common reservoir.

A detail investigation of the spring discharge, the hydrological setting of the spring and of the wells and the wells water level measurements, shows that the spring and the wells are hydrologically separated and the pumping from the wells does not influence the spring discharge. The main points of the study that led to this conclusion are as follows.

- The outlet of the spring is from the base part of the upper Judea Group aquifer, while the wells are pumping from the lower Judea Group aquifer.
- The spring reacts quickly to rainfall and to climate changes (drought and rainy years). Thus, the maximum discharge occurs about a month after the rainiest month of each year (Fig. 3). Similarly, the depletion starts immediately after the end of the rain season (except in very rainy years like 1992 and 1993).
- The spring depletion shows a quick drop in discharge, implies that there is no large reservoir that may store water from previous years.
- The behavior of the spring is the same along the last 60 years of record, long before the wells have started to pump. It follows that variations of the spring discharge are related to natural changes only.
- The existence of a hydrological separation between the two systems, spring and wells, is also supported by the difference in the water level of about 200 meter among the two.

The conclusion is that **a local, very karstic aquifer feeds the spring**; the discharge depends on climatic variations (drought or rainy years). In contrast the Uja wells draw water from a deep, separate, aquifer. A similar hydrological situation exists in En Samiya area, where the Palestinian Authority utilizes water from En Samiya spring (Upper aquifer) and from wells (lower aquifer).

From the management strategy of the water supply in the West Bank, the results of the study shows that the policy to drill deep wells and to pump from the lower aquifer near the spring outlets was right and no influences between the two sub aquifer has been observed.

REFERENCES

Guttman J. (1979): Jordan Valley - Hydrogeological Conditions in the Cenomanian Aquifer on the Margins of the Jordan Valley, TAHAL Consulting Engineers Ltd. 01/79/26 (in Hebrew).

Guttman J. (1980): Gitit, Kana and Samar Area - Calibration of a Digital Model for Reconstruction of Groundwater Movement in the Lower Aquifer of the Judea Group, TAHAL Consulting Engineers Ltd. 01/80/96 (in Hebrew).

Guttman J., Zuckerman H. (1995): Flow Model in the Eastern Basin of the Judea and Samaria Hills, TAHAL Consulting Engineers Ltd. 01/95/66 (in Hebrew).

Guttman J., (2000): Hydrogeology of the Eastern Aquifer in the Judea Hills and Jordan Valley- Final Report. Mekorot no. 468.

Kronfeld J., Vogel J.C., Rosenthal A. (1990): Natural Isotopes and Water Stratification in the Judea Group Aquifer (Judean Desert), Israel J. Earth Sci., Vol. 39, pp. 71-76.

Rosenthal A. (1978): Non-Equilibrium of $^{234}U/^{238}U$ Isotopes in the Water of the Judea Group Aquifer on the Eastern Slopes of the Judea and Samaria Hills. M.Sc. thesis, Tel Aviv University (in Hebrew).

Shaliv G. (1980): Bet Shean and Eastern Samaria Basins - Updating of Hydrogeological Model, TAHAL Consulting Engineers Ltd. 01/80/51 (in Hebrew).