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Piezometric Variations of Mikkes Groundwater Basin (MOROCCO)

K. Belhassan

Department of Geology, Faculty of Sciences, Dhar, Mehraz

Abstract: Mikkes basin is located in the north center of Morocco and consists of three different zones that represent diversified geologies. This basin shelters a phreatic and confined aquifer in Saïs basin and a shallow aquifer in Tabular of Middle Atlas. Piezometric variations of Mikkes groundwater basin could be conditioned by climatic changes and regional geology. Actually, the annual piezometric variation shows a drop in water levels at different water tables, which is due to the combined effects of reduction in water supplies (precipitation) that has reduced the natural recharge of groundwater and the increase in pumping which is increasing year by year for more than 80 years in this region. In addition, Free-water tables are much more susceptible to discharge compared to the confined aquifer. Thus, the water tables of the Mikkes basin do not demonstrate a uniform sensitivity to the drought. High rainfall between 1995 and 1997 had affected the groundwater levels of Mikkes with an increase in piezometric level. The monthly piezometric variations of free water tables are characterized by a seasonal operation: groundwater recharge and discharge.

Key words: Morocco % Mikkes groundwater % Piezometric variations % Rainfall % Geology

INTRODUCTION

The stream Mikkes is a tributary of the stream Sebou. Its waters are regulated by Sidi Echahed Dam. Its catchment area is located between the cities of Fez and Meknes. The region contains the cities of Ifrane, Aïn Taoujdat and other centres, with an area around 1600 km² (Fig. 1).

Several studies have been carried out on groundwater of the Mikkes basin; Belhassan [1], Belhassan *et al*. [2], Belhassan [3], Belhassan [4], Belhassan *et al*. [5].

The variations in the piezometric levels were studied according to time and space. The observations were made at annual - monthly time scales. The piezometry was studied in the Tabular in the only available measure: by drilling 1448/22. For the Saïs phreatic aquifer, all piezometers show a similar evolution, thus piezometer data 199/15 is presented in this study. For deep confined aquifer, piezometric data 290/22 is presented with long history and a good follow-up.

This article aims to evaluate piezometric variations of the Mikkes groundwater basin and to know the main parameters can be conditioned the change in piezometric level.

Regional Geology: The area of study covers three different structural sets: El Hajeb-Ifrane Tabular in the South. The Saïs basin in the centre and Prerif in the North (Fig. 1).

The El Hajeb-Ifrane Tabular is a free-water table circulating in the dolomitic and limestones formations of the lower and middle Lias outcrop, which is supplied directly by precipitation. Layers of the Trias rock salt separate these formations from the Paleozoic substratum.

At the Northern limit of the Tabular Atlas, the limestones and dolomitic formations sink toward the North, under the Fez-Meknes Neogene basin and rest on the Southern Rif Substratum.

Under the Fez - Meknes basin, the structure of the Lias is very apportioned by faults and flexures where some of which appear at the surface. The superficial layer is marly Miocene series keeping the Lias groundwater under pressure; the Saïs confined aquifer. Resting over these series, a complex of Plio-quaternary formations (sands and limestones…) hold the superficial groundwater; the Saïs phreatic aquifer. The two groundwater communicate through the faults and flexures or through the semi - permeable marly layers (Latati [6]) (Fig. 1).

Corresponding Author: K. Belhassan, Department of Geology, Faculty of Sciences, Dhar Mehraz.
Mobile: +212 663-75-95-44.

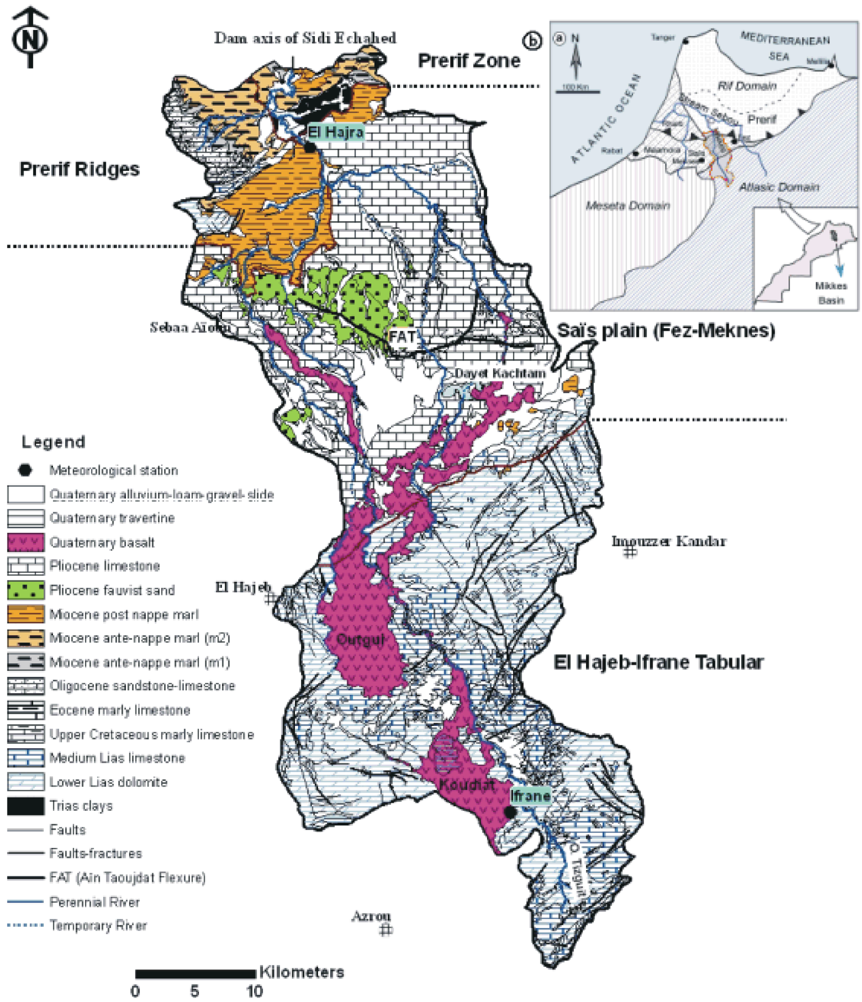

Fig. 1: a. Situation of the Mikkes basin, b. Geological map of the Mikkes basin (extracted from the geological map 1/100000, Rabat, Morocco, 1975)

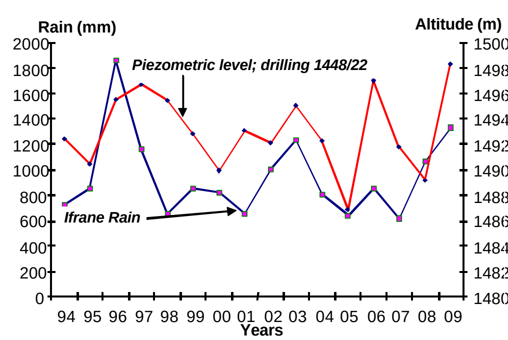

Fig. 2: Relation between rain and piezometric level of the Tabular aquifer (1994-2009)

Annual Piezometric Variations: For the Tabular aquifer, piezometer 1448/22 (Fig. 2) shows a maximum piezometric in order of 1498 m in 2009 and a minimum of about 1487 m in 2005. Thus, this shows a decrease of 11 m through the period for years between 2005 and 2009. Starting from 1995, a significant rise in level of the free-water table coincides with increase in rainfall in the corresponding period. The piezometric level had shifted from 1490.45 m in 1995 to 1496.74 m in 1997. This demonstrates that in this sector, the rain infiltration has a large effect on water supply. This may be explained by significant infiltration, predominantly of permeable carbonate formations recognized in the Tabular Middle Atlas and strong fracturing of land (Fig. 1). Groundwater of the Middle Atlas Tabular are only original meteoric precipitation (rain and snow) whose 35 to 40%, which infiltrates into the limestone karst and reappears mainly to the periphery of the Tabular Middle Atlas in contact with the Lias and Trias (Ben Tayeb & Leclerc, 1977 in ressources en eau du

Maroc, Tome 3 [8]). The years 2008 and 2009 were wet years in Morocco, particularly in the Mikkes basin. The rainfall is significant and is followed by a significant increase in the level Tabular aquifer; groundwater level rises from 1489.15 in 2008 to 1498.35 m in 2009.

For the Saïs phreatic aquifer, the piezometric level has remained stable for the years between 1968 and 1980. The decrease in water level after 1980 varies from one piezometer to another. This drop in piezometric level started to increase since 1998 in the central area. An average value of 1m/year can be used for this aquifer (ABHS [9]). In piezometer N° IRE 199/15, the decline in water level after 1980 was about 33 cm/year (Fig. 3). This sharp drop in water level of the aquifer was associated with high stress climate constraint, which the region has experienced for more than 80 years accompanied by an increase in sampling for water supply (drinking and irrigation). The evapo-transpiration is calculated by Thornthwaite's method at El Hajra station for the period 1968-2009 is 89% of the total rainfall. Thus, the surplus water (Thornthwaite balance method) is only 11% of inter-annual rainfall (1968-2009). Between the periods 1968-1979 and 1980-2009, the decrease in rainfall, had dropped from 463 mm (1968-1979) to 326 mm (1980-2009). Thus, the excess water decreases from 26% (1968-1979) to 6% (1980-2009) (Belhassan [7]).

Between 1995 and 1997, the groundwater level had risen about 4 m after a sharp increase in rainfall at the Mikkes basin in 1996. The wet years 2008 and 2009 were, accompanied by an increase in piezometric groundwater level, which roses from 504.61 m to in 2008 to 507.48 m in 2009 (Fig. 3). Actually, this increase in water level is considered as direct-indirect and could be explained by: (1) direct infiltration of precipitation, (2) the existence of a relationship between Tabular aquifer and Saïs phreatic aquifer and (3) the existence of a relationship between the level of this Saïs superficial groundwater and the Saïs deep groundwater.

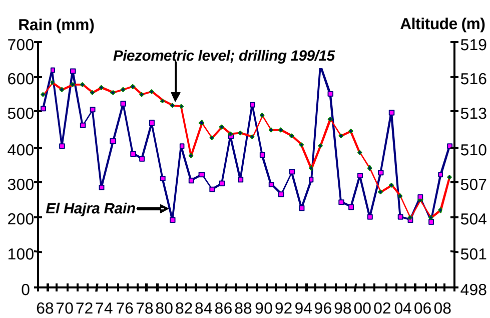

Fig. 3: Relation between rain and piezometric level of the Saïs phreatic aquifer (1968-2009)

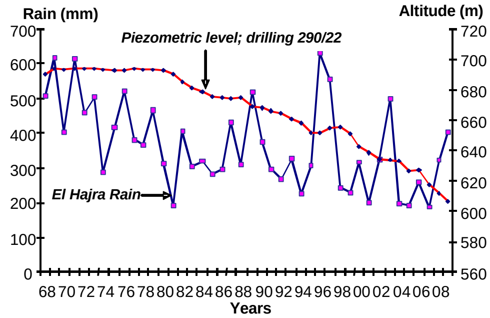

Fig. 4: Relation between rain and piezometric level of the deep aquifer (1968-2009)

The deep artesian confined aquifer it is the most affected aquifer by exploitation in Mikkes Basin. The piezometer N° IRE 290/22 is particularly can be considered as a representation for over- samples in the Fez-Meknes groundwater and which is performed sampling of water supply for drinking and irrigation. Therefore, reinforces the negative balance of this aquifer (ABHS [9]). The monitoring of piezometric fluctuations shows a sharp decline in water levels since the beginning of 80s (Fig. 4). The variation of water level is around 2.87 m/year in average; primarily due to the drought that this region had suffered from during 80's period and exploitation of the groundwater. In addition, the general decline in groundwater levels results in a decline in artesian pressure, drilling N° IRE 2365/15 (Fig. 5).

However, the higher precipitation through the period (1995-1997) seems to be the reason for the 4 m increase in the piezometric level. It is obvious that rainfall promotes to the rise in piezometric level of confined aquifer. Consequently, interactions between the three Mikkes groundwater are reported. While, for the years 2008 and 2009 which are considered wet years, they had no effect on increasing of the level of deep groundwater.

The aquifers of the Mikkes basin do not demonstrate a uniform sensitivity to the drought:

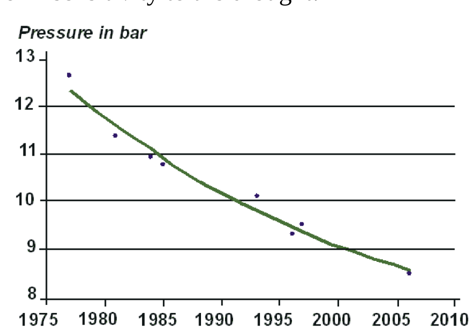

Fig. 5: Decline in artesian pressure of Fez-Meknes confined aquifer

- The free-water table of El Hajeb Ifrane Tabular is sensitive to multi-year droughts; therefore, fluctuations in this sector follow the multi-year cycles.
- The Saïs phreatic water-table is supplied directly by precipitation. The recharge is comparable from one year to another. It shows fluctuations called "annual".
- The Saïs confined aquifer is the least sensitive to variations in rainfall because it is not directly supplied by precipitation. Nevertheless, it has been the most exploited in the Mikkes basin, to satisfy the drinking and irrigation demands.

Monthly Piezometric Variations: The monthly measurements of piezometric levels of Mikkes groundwater basin have shown a seasonal evolution of the groundwater supply.

For the Tabular free-water table, its regime is simple which is marked by the “rise in water level” phase and “fall in water level” phase. The maximum piezometric in level is reached in February, after a maximum rainfall in December. Then, the piezometric drops in parallel with the drop of rainfall from December. During the rainy season, groundwater is recharged by infiltration of rainfall. However, in the dry season, the water table discharges and its level drops because there are inputs from the infiltration of rainfall. This reduction in groundwater levels is the essential fact of evapotranspiration (Fig. 6).

For the Saïs phreatic aquifer, the hydro-geological regime is characterized by a simple regime alternating periods of rise and fall in water level (Fig. 7). It is possible to observe a reversal of the direction exchange depending on the season: during period of low water, the River drains the aquifer and in times of high water, it feeds groundwater.

The maximum piezometric of Saïs phreatic groundwater is reached in April-May-June, after rising rainfall. The piezometric decline begins at the end of regular rainfall and reaches a minimum in July, August and September. The season of low water corresponds on one hand, to the discharge of groundwater; the lower precipitation and increased evapotranspiration. On other hand, the discharge of the groundwater reservoir can also be linked to increased exploitation during this season.

By comparing the hydro-geological regime of the Saïs phreatic aquifer and of the Tabular aquifer, it is noticed that the maximum piezometric of Tabular groundwater follows immediately that of the rainfall. While for the Saïs phreatic aquifer, the rise of the piezometric level reaches its maximum after 3 months. The different geological formations characterizing each reservoir basin influences the flowing. In Saïs plain, the formations characterizing the reservoir are Plio-Quaternary (sand and limestones...) that promote runoff (high drainage density). In Tabular Atlas, the reservoir is dominated by Lias limestone and Lias dolomite and which is characterised by strong fracturing which results a high permeability and a high infiltration. Actually, recharging of this Tabular aquifer is immediately following precipitation.

For the Saïs deep aquifer, it is a confined groundwater; it does not have an obvious sensitivity to variation in precipitation. Its exploitation by artesian drilling to satisfy the water needs prevents demonstration

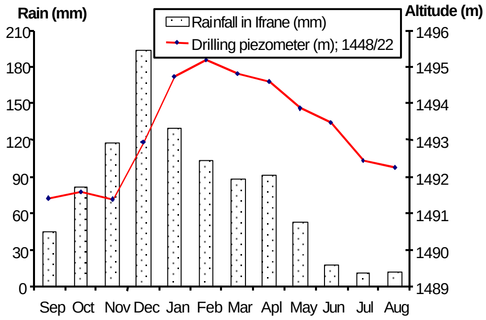

Fig. 6: Relation between monthly rainfall and monthly level of the Tabular aquifer (1994-2009)

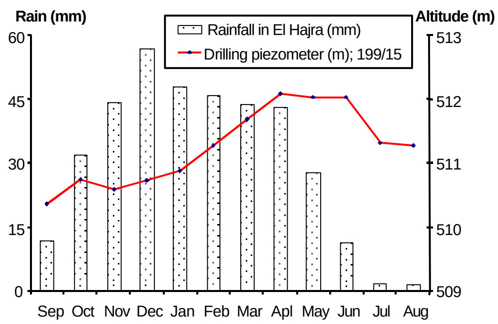

Fig. 7: Relation between monthly rainfall and monthly level Saïs phreatic aquifer (1968-2009)

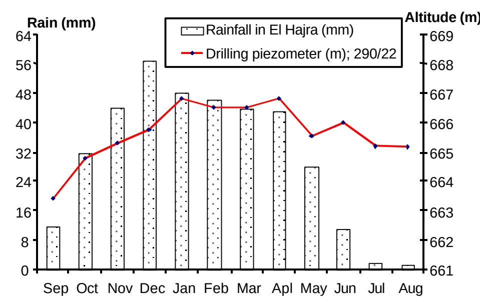

Fig. 8: Relation monthly rainfall and monthly level of the confined aquifer (1968-2009)

the clear emergence of a relation between rainfall and groundwater level. The rainfall episodes are imperceptible on the piezometric curve (Fig. 8). The rise in piezometric level is a function of distance from the outcrop (long time of soil transport) and exchanges between local groundwater.

CONCLUSION

According to the study of variations in groundwater level and comparing it with variations of average rainfall amounts in Mikkes basin, we can conclude the following for both annual scale and monthly scale:

At the annual scale, generally, the continued decline of groundwater levels in aquifers is linked to the decline in rainfall and it is also linked to the exploitation of its aquifers. Heavy rainfall in the years 1995, 1996 and 1997 resulted in an increase of about 4 m in Saïs groundwater level and 6 m for the Tabular free-water table, which explains the interconnection between these aquifers. The years 2008 and 2009 (wet years) are accompanied by an increase in free-water table level (Saïs phreatic aquifer and Tabular aquifer). However, the confined aquifer level continues to decline. This decline explained by the overexploitation of this reservoir. Actually, the aquifers of the Mikkes basin do not demonstrate a uniform sensitivity to the drought.

At the monthly scale, piezometric variations of free-water table (Saïs phreatic aquifer and Tabular aquifer), are characterized by a seasonal operation: a groundwater discharge during dry season and a groundwater recharge during rainy season.

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