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Relationship Between River and Groundwater: Water Table Piezometry of the Mikkes Basin (Morocco)

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Abstract: The Mikkes river basin is located in the north-central portion of Morocco and comprises three different zones that represent diversified geologies. This basin has phreatic and confined aquifers in Saïs sub-basin and a shallow aquifer in Tabular of Middle Atlas. The interpretation of the aquifers' piezometric maps of the Mikkes basin and certain piezometric sections located in the Tabular - Saïs area, concludes that the regional direction of the flow of groundwater is north-westwards according to the topography followed by the river. In addition, the Mikkes basin structure has influenced the direction of flow. Actually, this suggests a strong relationship between River and groundwater.

Key words: Morocco · Mikkes Basin · Piezometry · River – Groundwater Relationship

INTRODUCTION

Hydraulic exchanges between groundwater and rivers are difficult to observe directly. There are fluxes, directed from aquifer to the river, which materialize the main outflow of unconfined aquifers [1]. In the intake area of confined aquifers the flux is from river to the aquifer.

The study of exchange aquifer- River is illustrated by the interpretation of Mikkes piezometric map of free water tables and of certain piezometric sections in the Mikkes basin, for understanding the relationship between the groundwater levels and the river flow.

General Geological Background of Mikkes Basin: The study area crosses three different structural units: El Hajeb - Ifrane Tabular in the south and which is predominated by the carbonate formations (limestone and dolomites of Lias) and whose the fracturing is strong, Saïs basin in the central portion consists of lacustrine limestone and tawny sands of Pliocene and Miocene marls. The Prerif is located in the north, formed mainly by Miocene marls and clays Triassic [2-10] (Fig. 1).

Hydro-geological structures of the region indicate the existence of three aquifers. El Hajeb - Ifrane Tabular Atlas corresponds to a phreatic water table in limestone and dolomite. It is supplied directly by the precipitation. The overflow Springs located the piedmont constitute the natural outlets. Triassic clays and Palaeozoic schists form the impervious substratum of this aquifer. These carbonate formations go under the Mio-Plio-Quaternary cover at southern Rif trough to become a deep confined aquifer. Thick Miocene marl constitutes the upper confining strata for this aquifer, which is about 1500 m deep as per the drilling log of bore well at Aïn Allah (IRE N° 2370/15). Plio-Quaternary formations constitute Saïs phreatic water table [2-9].

Piezometric Map of Mikkes Groundwater: A map of water table elevation (hereafter mentioned as free-water table piezometric) in Mikkes basin, has been published in 2009. It was traced (Arc GIS 9.3) from the data base of water table levels of Saïs plain (Fez-Meknes) phreatic aquifer and of El Hajeb-Ifrane free-water table (ABHS - Fez data base). The piezometric map is the basic tool in hydrogeology for identifying the hydraulic gradients and the flow directions. This map is obtained by linear interpolation of piezometric levels.

Figure 2 illustrates the free-water tables piezometric of Mikkes basin. It represents aquifer levels with intervals of 100 m. Piezometric levels observed in the basin are between 400 and 1600 m. The upstream portion of the basin is located at its south-eastern end. The drainage pattern and the main sources of the basin are also shown in the Figure.

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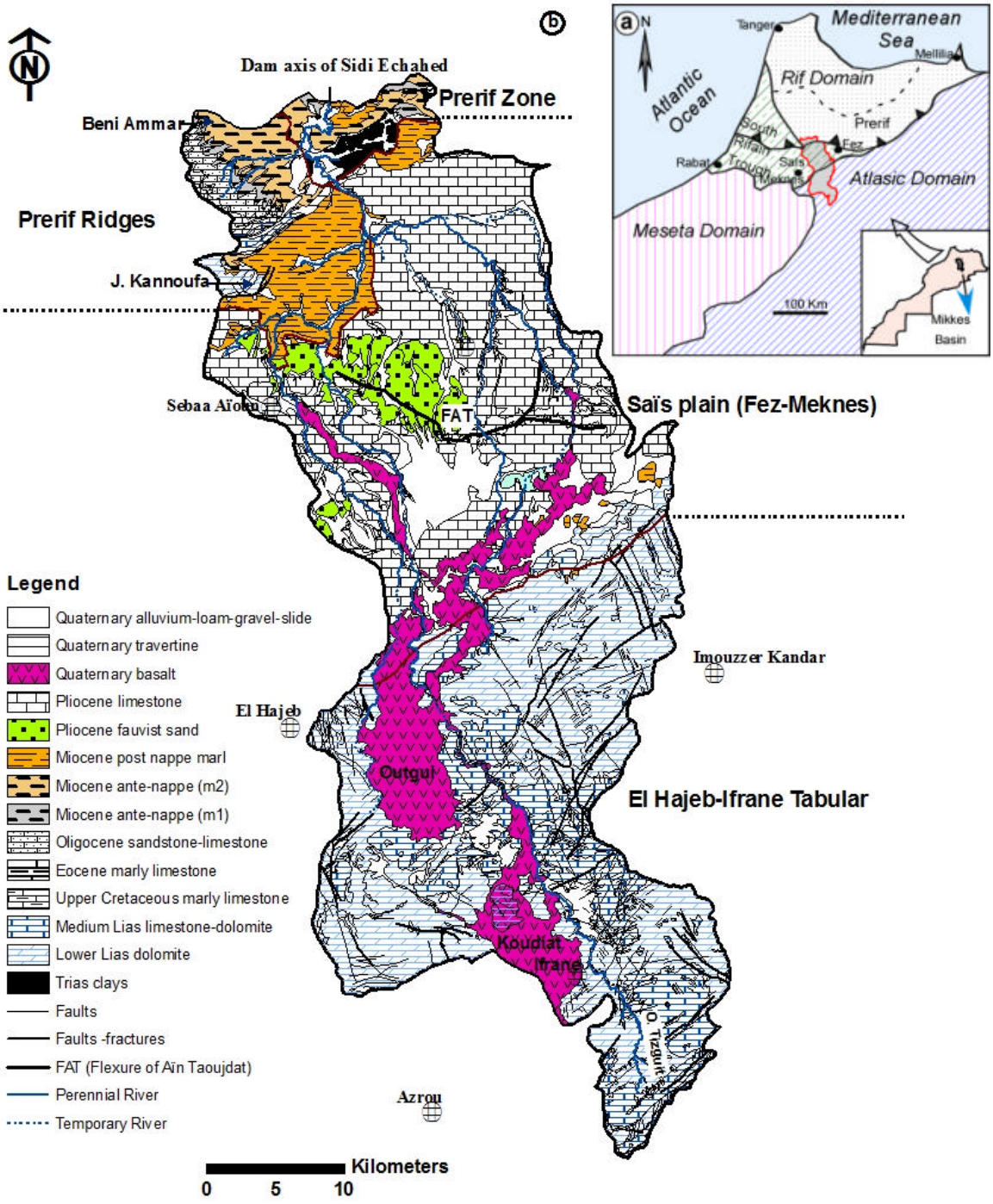

Fig. 1(a): Situation of basin Geological, (b) map of the Mikkes basin (taken from the geological map 1/100000, geology division, Rabat, Morocco, 1975)

The realization of the piezometric map of the Mikkes basin shows that the flow of groundwater throughout the basin is moving from South to North. The direction of flow is towards the river, demonstrating that there are connections between the aquifer and main river or its tributaries. In upstream basin, the topographic elevation seems responsible of flow directions; oriented toward the Tizguit River.

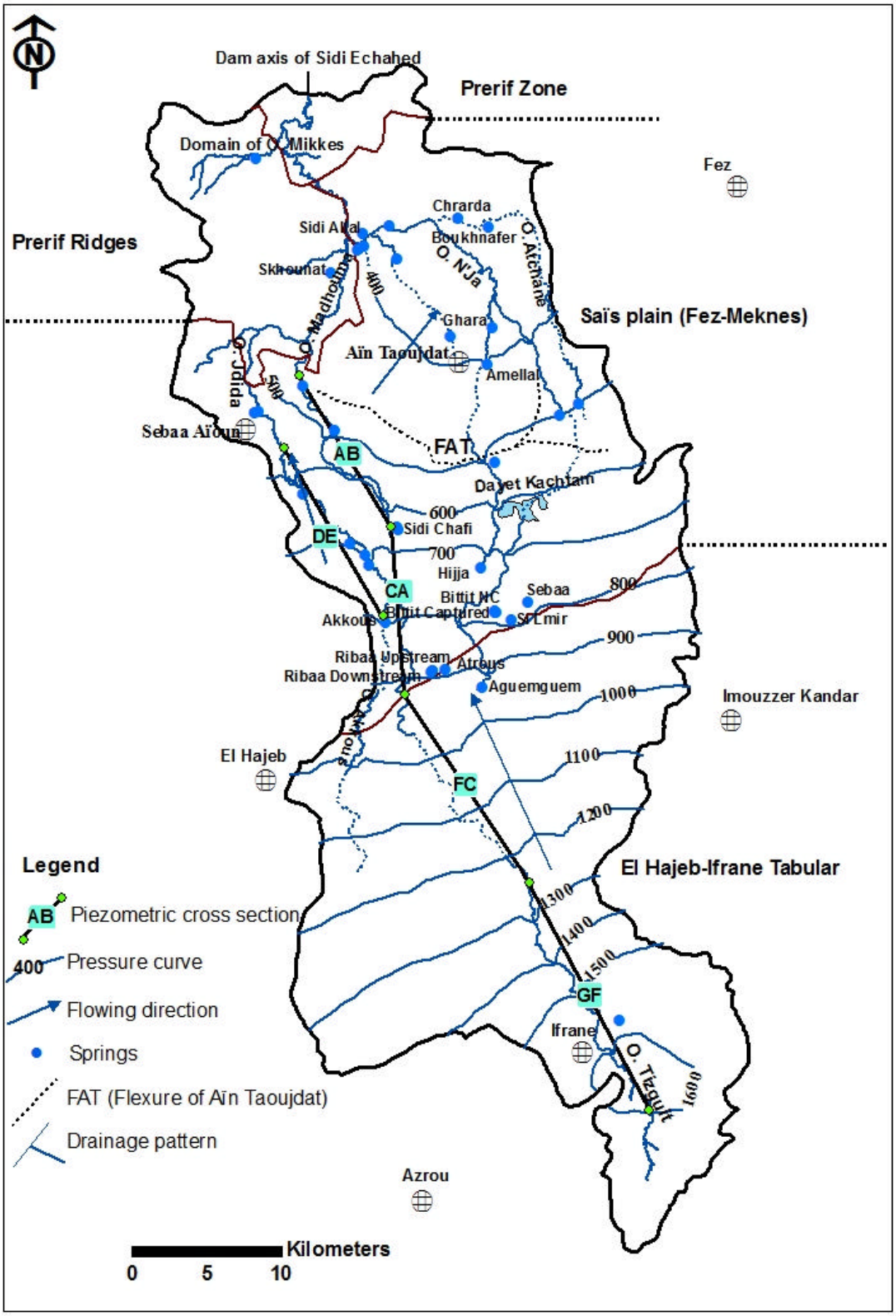

Fig. 2: Water table elevation map of Mikkes Basin water tables (2009) and location of the piezometric cross sections in the Mikkes watershed

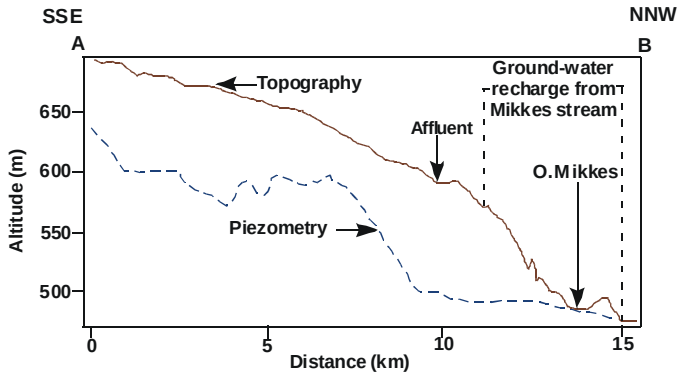

Fig. 3: Cross section AB showing the Saïs groundwater recharges

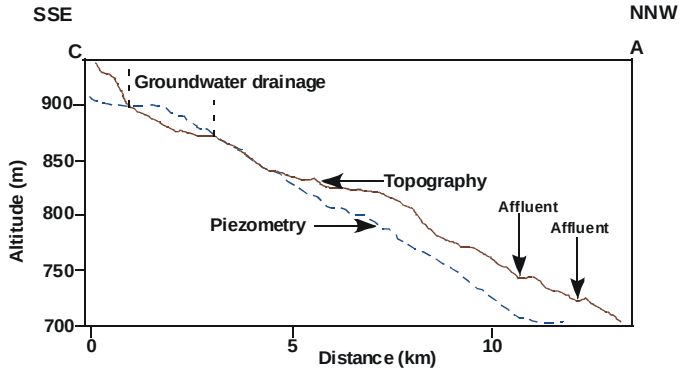

Fig. 4: Cross section CA showing the Saïs groundwater drainage

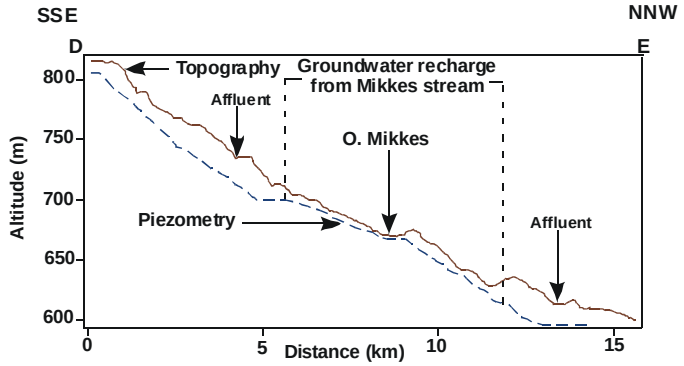

Fig. 5: Cross section DE showing the Saïs groundwater recharges

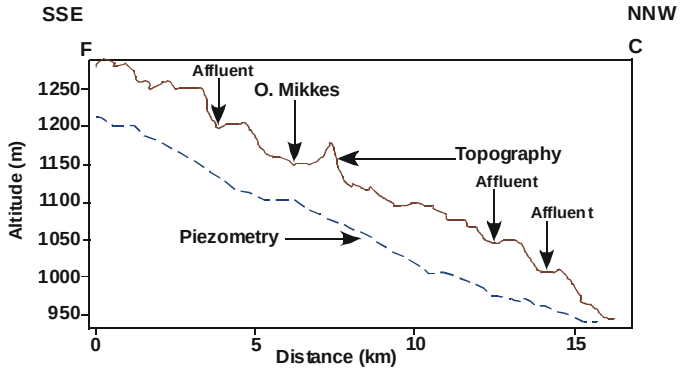

Fig. 6: Cross section FC showing relationship: aquifer - river

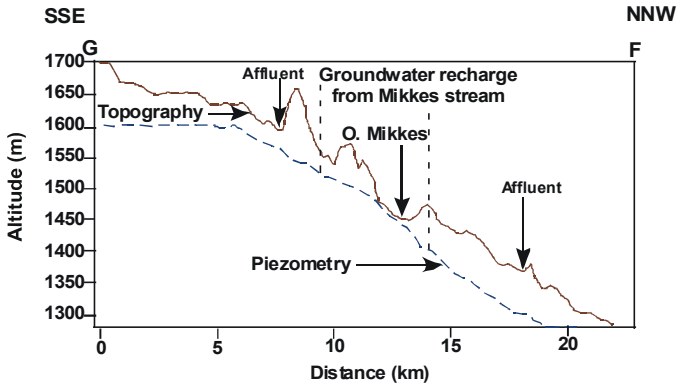

Fig. 7: Cross section GF showing the Tabular groundwater recharge

In the centre of the basin, flow directions are oriented toward the Tizguit River. However, deviations are observed near of secondary river beds: tributaries of the N'Ja River. In downstream basin, the Mikkes River influences the directions of groundwater flow near its bed, but it loses in north-east (tributaries of the N'Ja River) and in southwest basin (Akkous River). At these locations, the topographic gradient is low and as previously mentioned, the hydraulic connection with an aquifer is probable. In summary, in some sectors, the Mikkes River has an influence on groundwater flow. While, in other sectors, the relationship between surface runoff and groundwater flow is less evident.

At basin scale, the geological structure seems to influence the flow directions. In the Saïs plain, the flow is generally S-N with drainage axis at the river. Flexure of Aïn Taoujdat (FAT) is a dividing line of groundwater, resulting a SE-NW and a SW-NE flowing streams. Prerif Ridges are an impermeable boundary and at this location the water divide between the east and west. In the Tabular Atlas, the general flowing is from SE to NW along the SE-NW lineaments [9].

Hydraulic gradients are also spatially variable. These spatial variations are probably due to variations in topography and to local variations in hydraulic conductivity. In the Saïs plain, the average hydraulic gradient is about 1%, two features deserve special mention:

- Near to the flexure of Aïn Taoujdat (FAT), the hydraulic gradient becomes higher.
- Further north, the hydraulic gradient becomes lower.

In the Tabular Atlas, the hydraulic gradient is higher compared to that observed in Saïs. It is about 2% and in this area Ribaa-Bittit springs emerge (Fig. 2).

Piezometric Sections: The piezometric cross sections in the Mikkes basin were performed from the combination of topography and piezometric data. Three cross-sections performed in Saïs plain and two in the Tabular Atlas (Fig. 2). The greatest variations in altitude of the basin are represented.

In Saïs, the difference in piezometric level between the upstream and downstream follows the topography of all sections. Figure 3 illustrates the cross section AB, oriented SSE-NNW. This section presents a piezometric elevation of about 158 m and a hydraulic gradient of 0.011 m/m. Figure 4 shows the cross section CA, oriented SSE-NNW. It shows a piezometric elevation of about 273 m and a hydraulic gradient of 0.020 m/m. Figure 5 illustrates the cross section DE, which is oriented SSE-NNW. It shows a piezometric elevation of 236 m and a hydraulic gradient of about 0.015 m/m.

In the Tabular Atlas, the cross section FC oriented SSE-NNW presents a piezometric elevation of 306 m. The hydraulic gradient of this section is on the order of 0.02 m/m (Fig. 6).While for the cross section GF oriented SSE-NNW, the piezometric elevation is 385 m and the hydraulic gradient is 0.02 m/m (Fig. 7).

The correlation between topography and groundwater level is the main result by the realization of cross-sections in the Mikkes basin. Indeed, piezometric level closely follows topography of the basin and, despite of terrain irregularities. An area where this link is less strong was probably due to uncertainties and inaccuracies caused by lack of database. The cross section CA confirms that the Mikkes River acts as a drain of the groundwater. While, AB, DE and GF sections confirm that Mikkes groundwater acts as a drain of the River. While, the cross section FC confirms that there is no obvious interconnection between the groundwater and the River. Some tributaries of the Mikkes River (identified

by arrows on sections) appear to be hydraulically connected to ground water reservoir, but seem to have only a local effect on the drainage of water table.

Highest level piezometry, near the El Hajeb Ifrane Tabular suggests that recharge is presented on this sector of basin, except for some places where silt-clay deposits are present in surface. Nevertheless, the upstream Tabular corresponds to highly fractured bedrock promoting infiltration from precipitation. Thus, at the upstream basin there is a significant water contribution to the reservoir, which maintains to a high groundwater level in the southern basin. Topography influences groundwater flow data from 1960s to 1970 [11].

CONCLUSION

The study of piezometry in the Mikkes basin; piezometric map and piezometric sections allow to conclude that the regional direction of groundwater flowing is towards the northwest. This direction follows the orientation of the River and topography, thus, underscoring a relationship between groundwater and the River in the Mikkes basin.

Piezometric map of Mikkes free-water tables (2009) shows that the directions of flows moving towards the River. Surface of the Mikkes free-water tables varies between 1600 m in the east of Ifrane city and 400 m in the extreme northwest of Saïs plain. In El Hajeb-Ifrane Tabular, the general ground-water flow direction is a fairly regular, from SE to NW with a hydraulic gradient near to 2%. This direction follows the geological structure of El Hajeb-Ifrane Tabular and particularly the SE-NW orientation of the main faults. In the Saïs plain the flow seems to split up into two: in the east, the flowing is towards the north with a very low gradient of about 0.5%. But in the west, the ground flows to the NW with an average gradient of 2%. Actually, this direction is closely related to the structure of Saïs Flexure of Aïn Taoujdat (FAT).

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