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Exchange Groundwater - River : Stream Mikkes Basin (Morocco)

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Abstract: The Mikkes basin is located at the north center of Morocco. It comprises of three different zones which represent diversified geologies and which shelter a phreatic and confined aquifer in Sais basin and a shallow aquifer in the Tabular Middle Atlas. It shows a rough oceanic system supported by the groundwater. The important decrease of water level in the aquifers of Mikkes basin has been observed since the beginning of 1980. This decrease is probably effected by a combination of dryness and overexploitation, which had also an influence on the springs and the river flowing. For the Sais groundwater, the positive correlation and proximity of temporal fluctuations curves between the river flow and the piezometric level outside of the flood periods, supports the assumption of a supply-drainage exchange between the aquifer and the river. The resemblance of the variation curves of the piezometric level of groundwater and deep groundwater hints the existence of a hydraulic connection between the piezometric water table and the level from the river. However the reflection of a very strong infiltration within Tabular Middle Atlas does not make it possible to demonstrate a positive correlation between the level of the river and the groundwater.

Key words: Morocco % Stream Mikkes % Groundwater–river exchange % Flow % Piezometric % Geology % Infiltration

INTRODUCTION

In a semi-arid country like Morocco, the water resources play a fundamental role in the socio-economic activities. Rational management is the key to a sustainable development, which commands a balance between exploitation and protection. Integrated management of surface and groundwater often guarantees the success of this delicate balance between exploitation and protection of the resource. This article investigates the exchanges between the river and the groundwater by the studying the Mikkes basin upstream dam Echahed Sidi. The basin presents a good example as such, on premise of its position of three zones with a structural geology and diversified reservoirs. The purpose of this article is to examine the interplay between the groundwater and the river and its main controlling parameters for these interactions in the stream of the Mikkes basin. Furthermore this article would like to provide essential knowledge for a sustainable and integrated management of water resources.

Presentation of the Study Area: The stream Mikkes is an affluent of the stream Sebou. Its water is regulated by the dam of Sidi Echahed whose watershed is located between the cities of Meknes and Fez. The region contains the cities of Ifrane, Ain Taoujdat and many other centers. The described region amount an area of about 1600 km ² (Fig. 1).

The Watershed of the Mikkes Is Drained by Four Tributaries: Oued N'ja and Oued Atchane in right bank, Tizguit and Oued Akkous in left bank. The former drives the Sais plain and the latter drives Meknes plateau and El Hajeb-Ifrane Tabular Middle Atlas. The basin is characterized by an important number of springs that emerge in diverse Hydrogeological context (overflow springs, emerging springs, fault springs.) (Fig. 2).

The Study Area Covers Three Different Structural Sets: El Hajeb-Ifrane Tabular in the South, which is dominated by carbonate formations (Limestones and Dolomites Lias) and strong fractures. The Sais basin in the center is

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formed by Lacustrine Limestone and Fauvist Sand of Pliocene; and Marls of Miocene. In the North, the Prerif is formed mainly by Marls Miocene and Clays Trias (Fig. 2). The central Mikkes basin is a part of the Sais basin, which is furthermore a central part of the South Rifain Trough. Previous studies (Taltasse, [1], Ait brahim, [2], Fassi, [3] and Essahlaoui, [4]) show that probably the origin of this basin is linked to the dislocation Lias substratum, which is under the Neogene cover. It forms a large graben, which extend from the Tabular Middle Atlas in the south to Prerif domain in the north according a N-S direction. This basin is affected by a Hercynian accident directions (NE-SW and NW-SE) and other typical alpine (E-W and N-S). This network favors the infiltration of the water in the El Hajeb-Ifrane Tabular upstream of the basin and the drainage of surface waters by rivers in the center and in the north (Tizguit, Atchane, Jdida, Akkous and N'ja) (Fig. 1 and 2).

From south to north of the basin the altitude decreases thus the precipitation, while temperatures raise. The accurate maximum height of rainfall is recorded at the Tabular Atlas; Ifrane station (altitude 1600 m), whereas the minimum of rainfall is observed at the downstream basin at the Sidi Echahed station (altitude 190 m). The determination of the inter-annual average height rainfall in the watershed during the period of 1968-2005 is rather approximative on premise of there being few stations of measurement and changes in the relief basin. The rushed water blade is about 484 mm (Belhassan K and al, [5]).

According to De Martonne E., [6], I[1] calculated is about 18 mm/C° thus, the basin is a semi arid climate (10 <I <20).

The runoff is a manifestation of lithological nature, climatic conditions and the geological history of the region. El Hajeb-Ifrane Tabular is composed by Limestone and Dolomite Limestone Lias which is deemed to be very permeable. Thus, the basin presents a few rivers and low runoff. In addition, the Prerif and Sais are generally located in areas with a low permeability and therefore a numerous rivers and strong runoff.

The hydrogeological context of the different regional structures implies the existence of three groundwater tables. El Hajeb-Ifrane Tabular is a free-water table circulating in the Limestones and Dolomites. It is supplied directly by precipitation. Overflow springs located in the piedmont are the natural outlets. Clays Triassic and Paleozoic Schist form impermeable substratum of this aquifer. These carbonate formations burrow under the Mio-Plio-Quaternary cover the right South Rifain Trough for to become a deep confined aquifer. The depth of the Miocene Marls forming the roof of this aquifer is about 1500 m at drilling Ain Allah (IRE[2] N° 2370/15). The Plio-Quaternary formations as they are a phreatic water-table of Sais.

The sampling points for the phreatic water-table of the Mikkes basin are characterized by a high proportion of wells, which are mainly representing by farmers, which mean a total exploitation of 90 %. The drilling inventory amount 6 %. These points ensure drinking water supply and the irrigation and its flows speed rarely exceeds 10 L/s. Further irrigation is provided by springs and streams (4 % of total exploitation). The thickness of this aquifer varies from a few meters to 120 meters (ABHS[3]-Anzar Conseil, [7]).

For the Sais and Tabular Liasic aquifers, there are several further sampling points, which are mainly constituted by drilling. The number of sampling points and equipment has been proceeded steadily since the 80s. These points are mainly for drinking water supply to the Fez city, Meknes and Ifrane and some are used for irrigation. The depth of the Liasic roof increases in the north to over 1000 m in contact of Rides prerifaines (drilling point of Ain Allah). The flow of intake capturing Lias vary from a few L/s to more than 100 L/s: 10 to 40 L/s in Tabular, 100 L/s in the Sais and more than 100 L/s in the East of the Ain Taoujdat flexure where the Liasic aquifer is being covered by a thick Marl layer, where all intakes are artesian (ABHS - Anzar Conseil, [7]).

RESULTS AND DISCUSSION

Surface Water: Flow measurements have been followed since 1968 by the Water Services (now called ABHS). The collected Data have been analyzed by this agency. Figure 3 shows the evolution of these flows at the El Hajra station until 2001, which has been replaced since 2002 by the Sidi Echahed station, which is localised slightly in downstream. It shows that the flow decreases rapidly with time since 1968, ranging between 0 and 2 m^3/s since the beginning of 80s. The inter-annual module for the period between 1968-2005 amount 1.94 m^3/s. Furthermore figure depicts the influence of the average annual rainfall on the average annual flow of the river. Generally the flows show trend corresponding to precipitation before 1980, but 1980 onwards the flow curve demarcates from the rain curve. Actually, the flowing behaviour is getting lesser and lesser correlated with precipitation being anthropogenic sample is increasing in a strong way.

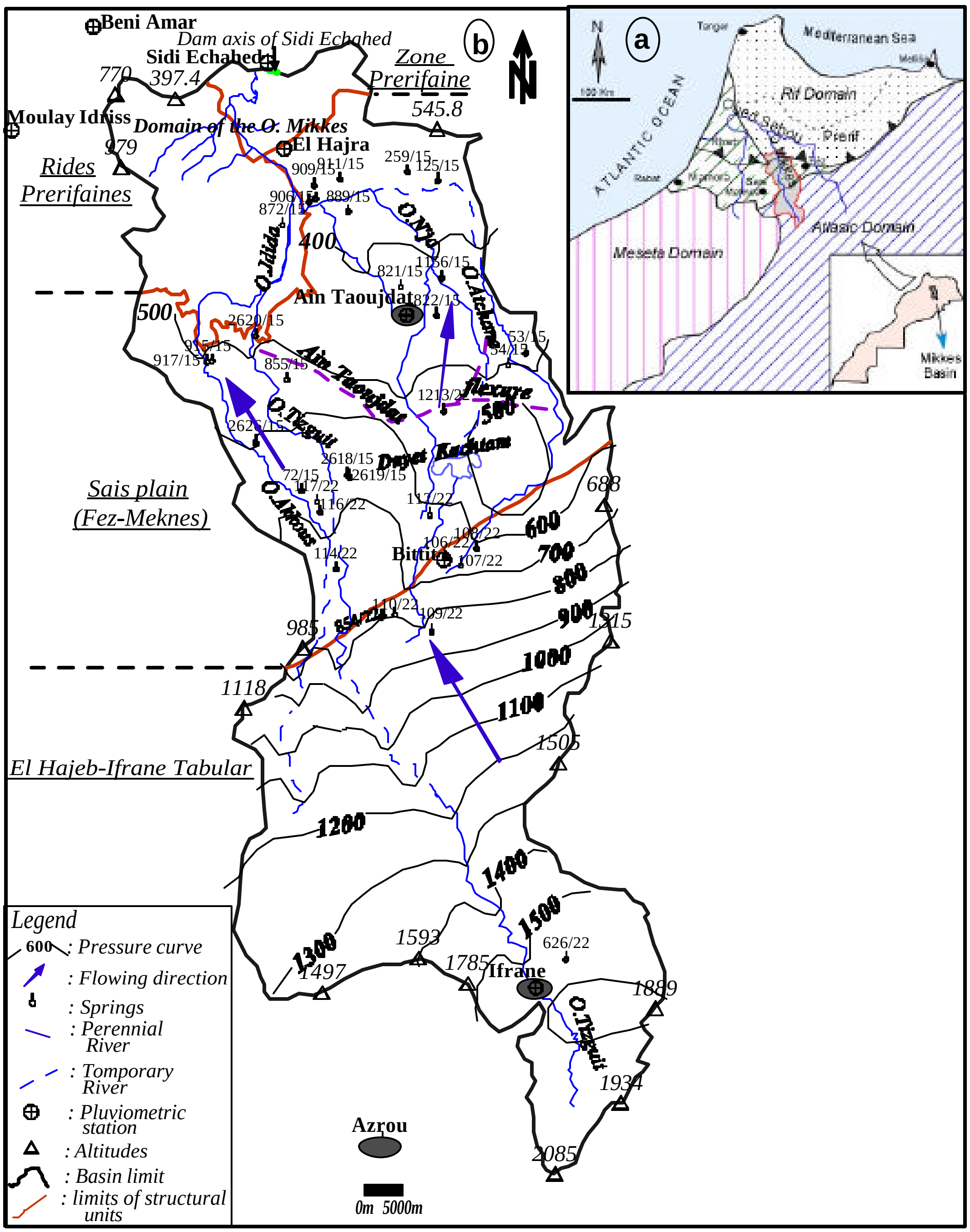

Fig. 1a: Location of the Mikkes basin, b-Water system and piezometric map 2005 of the study zone free-water table (taken from the topographic map 1/100000, geology division, Rabat, Morocco, 1943)

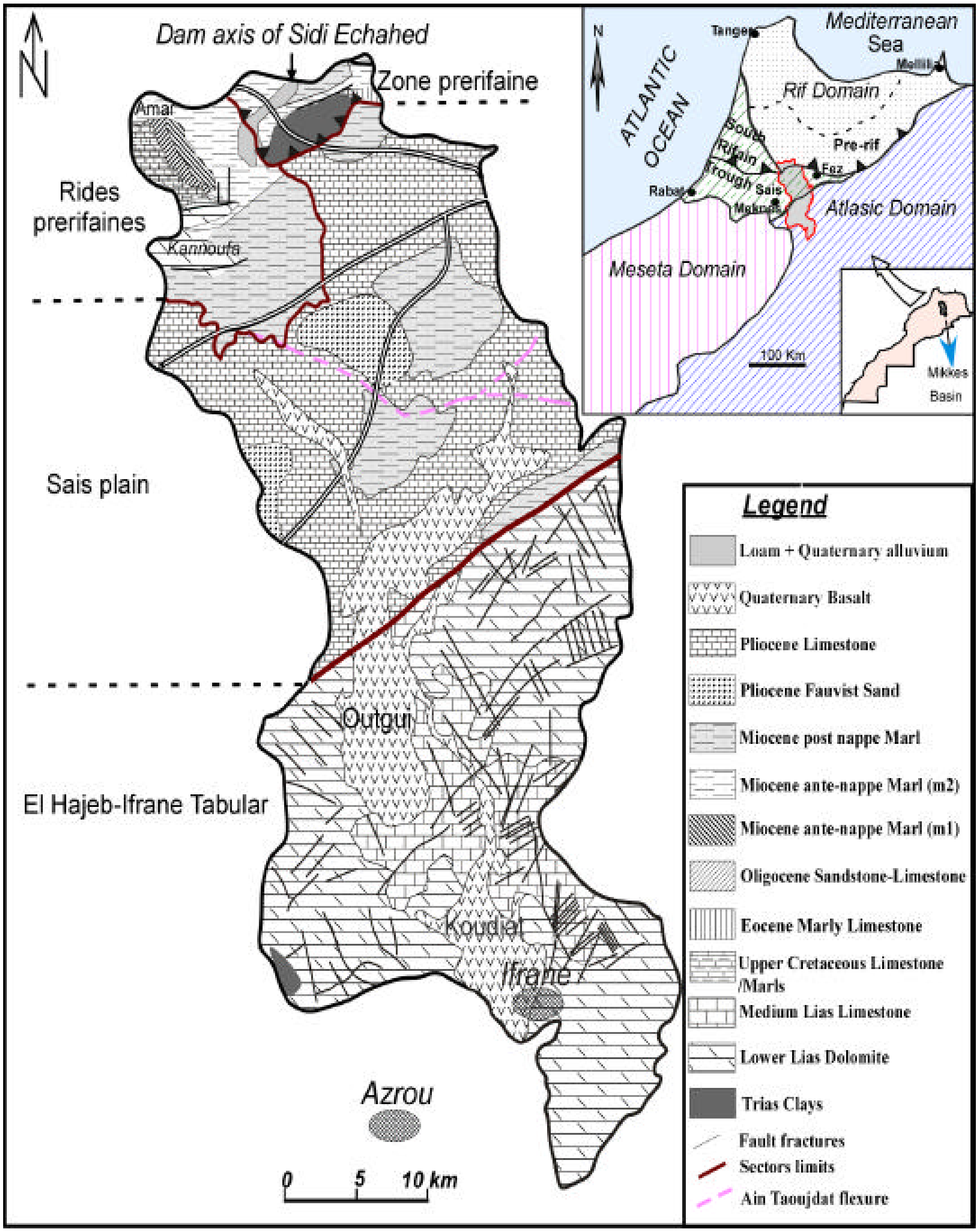

Fig. 2: Geological map of the Mikkes basin (taken from the geological map 1/100000, geology division, Rabat, Morocco, 1975).

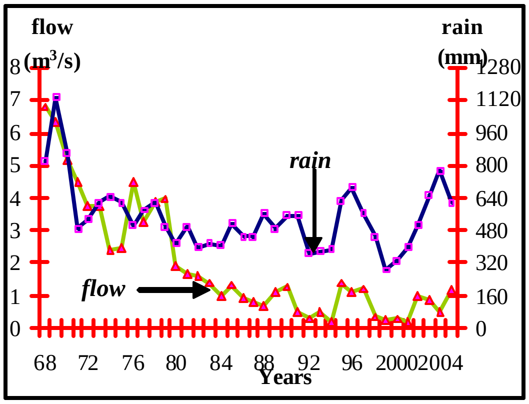

Fig. 3 Annual precipitation /annual stream flows of the Mikkes river (1968-2005).

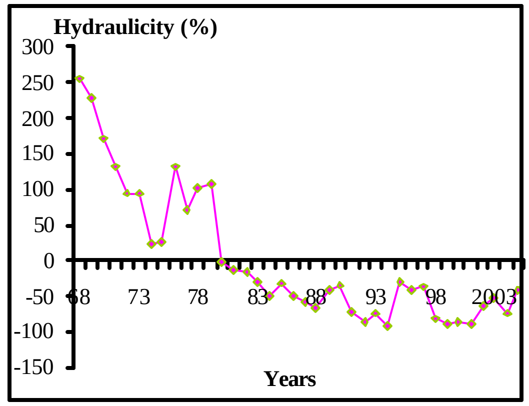

Fig. 4 Annual flowing (1968-2005).

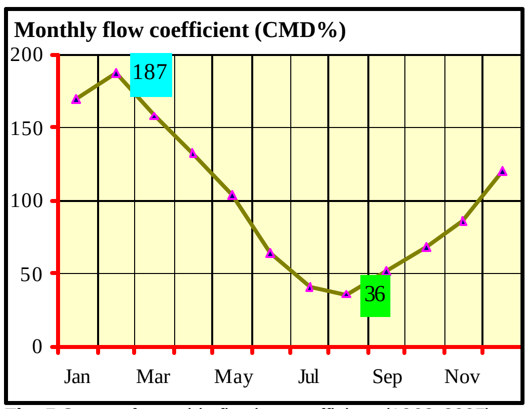

Fig. 5 Curve of monthly flowing coefficient (1968-2005).

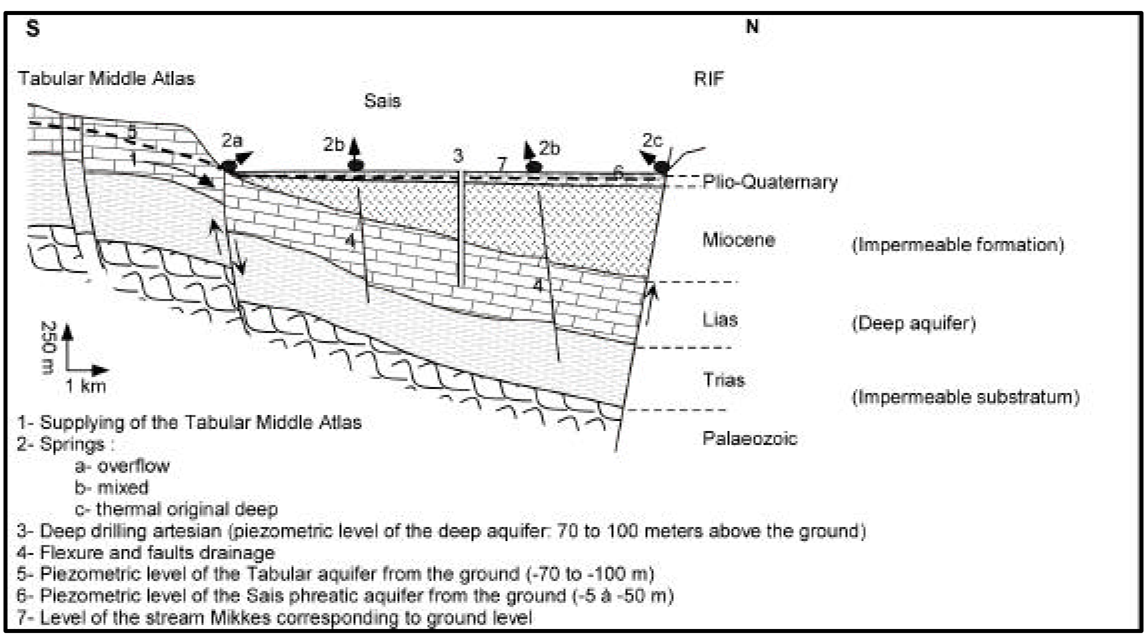

Fig. 6 Diagram showing the hydrogeological context of the Mikkes springs.

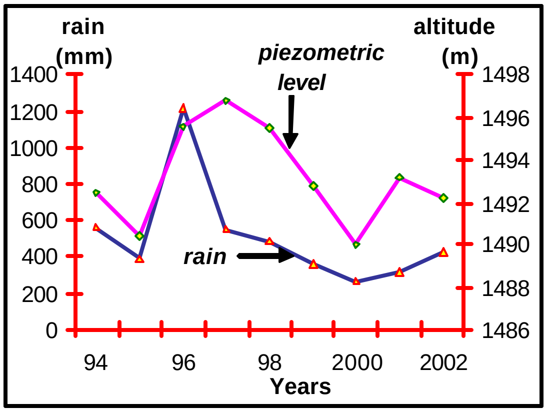

Fig. 7 Relation between rain and piezometric level of the Tabular aquifer (1994-2002).

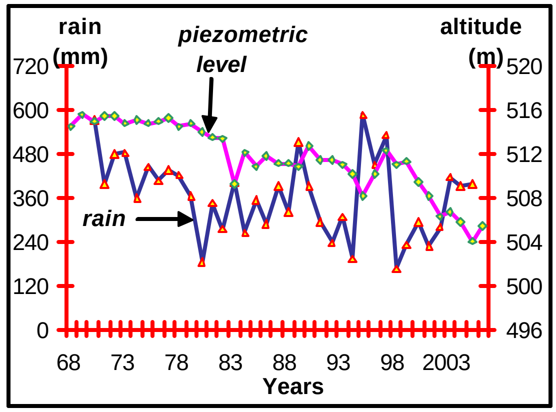

Fig. 8 Relation between rain and piezometric level of the Sais aquifer (1968-2006)

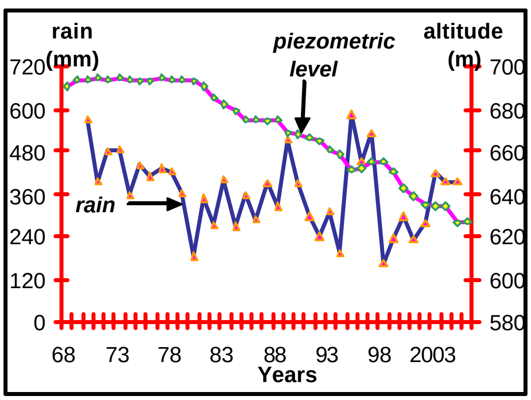

Fig. 9 Relation between rain and piezometric level of the confined aquifer deep (1968-2006)

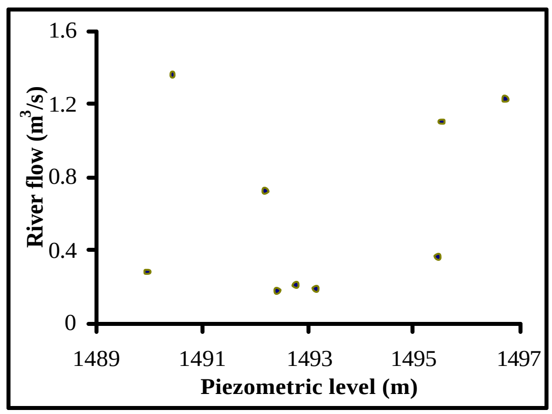

Fig. 10 Relation between piezometric level of the Tabular and river flow (1994-2002).

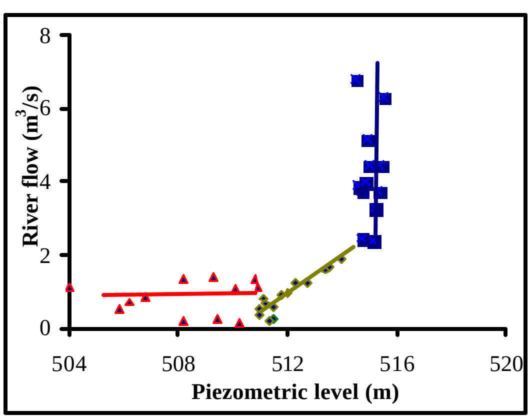

Fig. 11 Relation between piezometric level of the Sais aquifer and river flow (1968-2005).

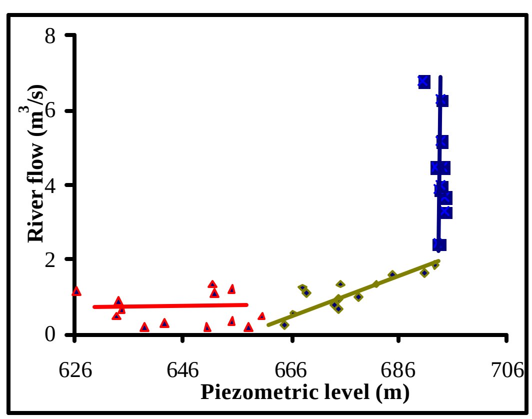

Fig. 12 Relation between piezometric level of the Sais groundwater deep and river water flow (1968-2005).

For better characterizing of the change in the water regime of the stream Mikkes, the annual hydraulicity[4], which involves the inter-annual module for the period between 1968-2005 is shown in figure 4. Before 1980, the hydraulicity values were positive, but post 1980, the values become negative.

This phenomenon could be attributed to the fact that the Tabular surface layers were almost saturated with water before 1980. This saturation was mainly due to two factors: the high rainfall and low sample. The number of samples did not exceed a few hundred in the Sais aquifer and a few dozen at the Liasic aquifer (Sais deep aquifer and the El Hajeb-Ifrane Tabular). This had an influence on the distribution of infiltration/runoff. Indeed, a high aquifer promotes the runoff and therefore a positive hydraulicity. On the other side, after 1980 there was a decreasing in the piezometric level resulting in desaturation of superficial layers of Tabular triggered by low rainfall and an increase in the number of sample points for drinking water and irrigation purposes. The samples in 2001 exceeded thousands of water points in the Sais phreatic water-table and hundreds at Liasic aquifers and low rainfall promoted infiltration at depends of runoff water, which resulted in negative hydraulicity. In short, the relation rainfall-flow depends on water status of the unsaturated zones of the aquifer.

The curve of monthly flow coefficients (CMD[5]) for a period of 37 years (fig. 5) shows a rough oceanic system characterized by two hydrological seasons: the January-to-March river flow is marked by high flows and the July to September river flow is marked by low flows. The regime is generally at a low flowing (1.36 L/s/km^2). The period of high flows is demonstrated by a maximum flow in February and whose monthly flow ratio is about 187 ? (Fig. 5). The period of low flows is demonstrated by a minimum flow in August when the baseflow is about 700 L/s; the portion of streamflow that comes from groundwater basin. The lowest monthly coefficient flow correspond an average of about 36 ? (Fig. 5). It is more a drainage stream of the aquifer than a stream of receiving of runoff rainwater.

Groundwater: The stream Mikkes basin includes three major aquifers: South, it notes the existence of the Tabular aquifer that become in charge under the Miocene Marls at Sais basin (Fig. 6) and it with Plio-Quaternary form a multilayer aquifer. The hydrodynamic characteristics of reservoirs vary with fracturing, karstification and the lateral - vertical variation of facies. The data of pumping tests show that the Plio-Quaternary reservoir has transmissivities ranging from 10G^{5} m/s to 10^{-2} m/s with a geometric average of 10^{-4} m/s. For both Liasic reservoirs (Sais and Tabular), the transmissivities are between 10G^{5} and 10G^{1} m/s with an average geometric of 10G^{3} m/s.

Springs: The springs of the river Mikkes basin are natural outlets of aquifers (Plio-Quaternary and Liasic) and supply the tributaries of this river. The influx of water in these springs comes from either Liasic confined aquifer or by the Tabular aquifer or by both (Fig. 6).

The analysis of these springs' flow shows a decreasing trend in general, however, the reactions are different depending to the typology and hydrogeological context, as reflected in following three cases:

- Springs have completely dried up in 2005 as Ain Hijja (IRE N° 112/22), Boukhnafer (IRE N° 125/15) and Ain Chrarda (IRE N° 259/15), which otherwise had flow of 380 L/s, 100 L/s and 90 L/s respectively, before 1970. They are springs of emergence and discharge of the Plio-Quaternary phreatic aquifer. This has a significantly influence on the river and a reducing of his flow.
- Springs have experienced significant flow up falls to 90% or more, as in the case of Ain Sidi Chafi (IRE N° 2618/15) whose flow was 130 L/s before 1970, but dropped to 15 L/s in 2005 and Sidi Allal (IRE N° 909/15) whose flow was 100 L/s before 1970, but just 4 L/s in 2005.

In both cases, this is undoubtedly caused by overexploitation of the aquifer due to intensive agricultural development around this region after 1970.

- Springs with lower fluctuations in flow, from 15 to 65 % as in the cases of Ain Bitti AEP (IRE N° 106/22), whose flow before 1970 was 1900 L/s and 1324 L/s in 2005 and Ain Akkous (IRE N° 114/22), whose flow before 1970 was 400 L/s and 195 L/s in 2005. These are principally the overflow springs Liasic Tabular aquifer, which are localised along the contact Sais plain and Tabular Atlas (fig. 1 and 6). The hydrogeological regime of these springs is a karst type. Overexploitation has less influence on the flow of these springs due to the karst characters, in recall that the karst system has an organization surface (alimentation basin) and vertical organization (interdependence between different outlets or springs). This is different of aquifers in porous milieu. The contributions of these springs to the river are estimated during the 1935-1988 period of around 79 % and those of groundwater is approx 21 % (DRHS[6], [8]).

The mixed springs are also considered as springs with low fluctuations. This is in the case of Ghara (IRE N° 1156/15), whose flow was 500 L/s before 1970 and 18 L/s in 2005. These are springs that generally linked their emergence to the presence of faults or flexures and flows come in varying proportions to the deep aquifer and the surface aquifer (Fig. 6).

The hydrothermal springs are considered among the springs of Mikkes basin as having a relatively low drying. In the case of Skhounat Mhaya spring (IRE N° 872/15), whose flow was 200 L/s before 1970 and 140 L/s in 2005. The average temperature of Skhounat amount around 38 C°. The water from these springs comes from high depths. The speed of the rising is rather fast that the temperature had no time to equilibrate with the temperature of the surface enclosing. Theoretically, waters in these springs could be from precipitation, infiltrated down fairly deep into the crust through fractures and is warming up "convective" by other fractures (Fig. 6).

It is clear that the springs in Sais phreatic aquifer suffered maximum depletion. The springs with a deep or mixed origin are known as low flow variation springs. This is explained by the relative position of piezometric level and the river level. The Sais phreatic aquifer whose depth does not exceed 100 m is easily influenced by rainfall. While the confined deep aquifer with depths more than 1000 m, is less influenced by the rainfall. In addition, difference in geological features of these reservoirs does influence the runoff coefficient. This results in a drop in pressure for confined aquifer (without influencing the flow of springs) and reduced level of saturation for the aquifers (Sais phreatic and Tabular), thus drying up of subordinated springs.

Piezometry: Depending on the basin morphology, the flowing is generally from south to north with a drainage axis at the river. The flexure Ain Taoujdat is a line of shared groundwater resulting a flowing in a SE-NW in the Meknes plateau and a flowing from SW-NE in the Sais plain. Rides prerifaines_are impervious limits, the water shares to the east and west.

At the Sais plain, the average hydraulic gradient amount about 1 %, two features deserve mentioning:

- Near to Ain Taoujdat flexure, the hydraulic gradient becomes higher. This explains the high flows at the level of mixed springs[7]. This zone is conducive for the water infiltration.
- Further north, the hydraulic gradient drops, which explains the high drying or complete drying up of emergence springs from the Sais phreatic aquifer (IRE N° 125/15, IRE N° 259/15) and hence the drying up of Oued Atchane.

A piezometric dome is observed at Dayet kachtam, which corresponds to supplying area by infiltration of water from the Oued N'ja and Oued Atchane.

Tabular level – in general the flowing is fairly regular from SE to NW following the basin morphology and the lineaments NW-SE, with a higher hydraulic gradient in the order 3 % and it is in this zone where the Ribaa-Bittit springs emerging (Fig. 1 and 6).

The piezometry was followed in the Tabular in the only available measure: by drilling 1448/22 (Fig. 7). For the Sais phreatic aquifer, all piezometers show a similar evolution and only piezometer data 199/15 (Fig. 8) is presented. For deep confined aquifer, piezometric data 290/22 (Fig. 9) is presented with long history and a good follow-up. The inter-annual fluctuations are about 0.87 m/year in the Tabular aquifer (Fig. 7). For the Sais phreatic aquifer, the piezometric level remained stable between 1968 and 1980 and the drop in water levels after 1980 was about 0.38 m/year (Fig. 8). For deep confined aquifer, the piezometric fluctuations have been showing a sharp decline 2.3 m/year on average, since start of the 80s (Fig. 9).

The influence of rainfall on piezometry aquifers of the Mikkes basin is clearly visible in figures 7, 8 and 9. The overall decline in rainfall results in a tendency to an overall decline and continuing of piezometric level of the aquifers in the basin. Heavy rains in 1995, 1996 and 1997 gave a slightly rise of the piezometric. However, water levels have been on the decrease, since 2000 onwards, despite heavy rains even.

The drop of the groundwater levels of Mikkes could be the combined effect of drought and sample. The groundwater Mikkes basin does not have the same sensitivity to drought due to the following:

- The Tabular aquifer, low draining by rivers is sensitive to multi-year drought. Their fluctuation follows multi-year cycles.

- The Sais phreatic aquifer is supplied directly by precipitation. Recharge from one year is comparable to another and such fluctuations are called "annual".
- The Sais deep confined aquifer is the least sensitive to rainfall variations as it is not directly supplied by precipitation.

The sampling points and their equipment have been increasing steadily since 1980s with an increase of more than 100 intakes a year, which shot to 147 sampling points per year (on average) since 2000 (ABHS - Anzar Conseil, [9]).

Exchanges Groundwater-river: The analysis of the flow springs and groundwater level of the Mikkes basin shows a parallel decrease with the flow of the river. This reflects a strong interconnection between surface water and groundwater in the basin. Nevertheless, such relations vary in time and space. The direction of exchanges is based on the relative river level positions and piezometric levels in Sais phreatic aquifer. The study of the relations between groundwater levels and flow of the river is used to follow these interactions through the following figures.

The graph has shown in figure 10 shows no correlation between the flow of the river and the groundwater level. This lack of correlation can be explained by important infiltration (very fractured reservoir, karstic) confirmed in the Middle Atlas Tabular. This infiltration is estimated at 32 % and evapotranspiration at 68 %, which corresponds to a zero runoff. The flowing of the river depends mainly to the resurgence overflow springs, which represent about 79 % of supply water.

For Sais phreatic aquifer, three zones can be distinguished on the figure 11. The first one is for levels below 511 m, the second is for levels between 511 and 514 meters and the third for levels higher than 514 m. The first is relatively low flows (<2 m^3/s), it is characterized by independence between the flow of the river and the piezometric level groundwater. The second is characterized by a significant dependence between the flow and the piezometric level groundwater. The third flows above 2 m^3/s and it is characterized by an almost independence between flows and piezometric levels: the flow of the river rises to the same level of the groundwater.

Thus, low groundwater level means low flows in the river that do not appear to be affected by changes. The rainfall water infiltrates into the unsaturated zone, but less than the saturated zone to influence the level groundwater. For levels between 511 and 514 m, a good correlation between the piezometric level and flow of the river emphasizes a close relation between the groundwater and the river. This range of level presents a renewable resource by charging and also the level which flow overflow springs. Piezometric levels above 514 m (and below the surface topography), correspond to a flow mainly from flood runoff that are not reflected on the heights of the groundwater given by the runoff speed more than the infiltration speed in the groundwater.

Like the Sais phreatic groundwater, Sais deep groundwater has three main zones as well: one for levels 664 m or below, the second for levels from 664 to 692 m and the third is for levels 692 m or higher (Fig. 12).

It's clear that even if the two Sais aquifers are separated by a thick series Marls Miocene age; they are in direct/indirect communication. Due to limited outcrop Liasic, the recharge quantity from rainfall that can occur is quite low. However, in the adjacent area to Tabular Atlas, where the Miocene is thin or nonexisting, the Liasic is in direct contact with the Plio-Quaternary. In these areas, where the piezometer Liasic is less than the Plio-Quaternary, a drainance may occur from the Plio-Quaternary, which is representing a supply of water for the Liasic. The total volume of the vertical flowing is low, especially when compared to the flow of Liasic drainance to Plio-Quaternary. Drainance of the Plio-Quaternary to Lias may be important in places[8] (Mac Donald, [10]).

The overall balance of the Mikkes basin for the period from 1968 to 2005 can be estimated as follows Turc L., [11]):

$$PE=P-ETR=R+1$$

Where
PE: Effective Precipitation
P: The rushed water blade in the watershed of Mikkes
ETR: Real Evapotranspiration in the watershed of Mikkes
R: Runoff
I : Infiltration
With:

- P = 484 mm.
- ETR; it's calculated by the methods of Coutagne, [12], Turc, [13] and Thornthwaite, [14], is 411 mm.
- The effective rain is 15 % spread between the runoff and groundwater flow. This gives a runoff coefficient of 9 % and a coefficient of infiltration of 6 % (Belhassan K., [15])

The previous studies made on the infiltration into the Tabular Atlas showed that the infiltration coefficient is very important, while the runoff is very low to zero. This can be explained by the fact that formations of the Tabular reservoir are permeable and non-erodible, thus springs flow Tabular have low declines.

In the Sais plain and in the Prerif, runoff is important, while the infiltration is low. The predominant formations are generally little permeable and erodible, thus the flow of springs emergence and discharge of Sais groundwater have been significant declines.

CONCLUSION

The exchanges of groundwater-river in the stream Mikkes basin were studied using geological, hydrological and hydrogeological data.

The calculation of the hydraulicity shows that for years before 1980 the values of hydrauliciy were positive, while after 1980 the values become negative in spite of the heavy rainfall recorded for some years between them. The negative hydrauliciy is the result of sample increasing after 1980, which become huge in the beginning 2000s. This fact constitutes the disruption of hydrological regime and thus the behaviour of aquifers.

The regime of the Mikkes river is a rough oceanic system supported by the groundwater. The period of high flows is evident from the month of December. The water seeping into the Liasic Limestone emerges as a springs or supply laterally phreatic aquifer or streams during the period of low flows level (the baseflow is about 710 L/s).

The springs from the Liasic groundwater are springs with low fluctuations in the flows, while springs of emergence and discharge of the surface-water table of Sais are springs which have shown significant declines.

Piezometric fluctuations show that the level of groundwater Mikkes basin is stable before 1980 when the hydraulicity of the stream was positive, while after 1980, a lower piezometric level is observed on premise of negative hydraulicity, thereby confirming the interconnection between surface systems and underground system.

The groundwater-river exchange is strongly influenced by the geology of the terrain and the component runoff-infiltration. At Sais basin where formations are little permeable, the infiltration is low and the relation of the river flow piezometric level can be distinguished in three zones corresponding to three different periods (the period of low flows level, supply-drainage period and flood period). In Tabular Atlas where geological formations are highly permeable, infiltration is very strong and the relation between the flow of the river and the piezometric level does not demonstrate a positive correlation.

ABBREVIATIONS

[1] The most used index is that of De Martonne E., 1942. It depends on the annual precipitation P (mm) and the average annual temperature T (° C):

$$1 = \frac{P}{T+10}$$

[2] Inventory of Water Resources of Morocco.

[3] Hydraulic Basin Agency of Sebou

[4] The hydraulicity is the difference between the module and the module considered inter-annual as a percentage of the latter.

$$\frac{Q_{annual} - Q_{inter-annual}}{Q_{inter-annual}}.100$$

[5] The monthly flow coefficient is defined as the ratio of the monthly average flow and the module inter-annual (inter-annual average calculated on a number of years). It can represent the percentage distribution of monthly during the year.

$$C_m = \frac{Monthly\ Average\ Flow}{Inter-Annual\ Module}\ .100$$

[6] Hydraulic Regional Direction of Sebou.

[7] Darcy's law gives: Q = k.S.i. with Q the flow, K the permeability, S the surface runoff and i the hydraulic gradient. This formula shows that the flow increases with the hydraulic gradient. This is a horizontal flow of groundwater.

[8] A drainance is a vertical flowing through a semi-impermeable layer. It can be ascending or descending according to the relative position of piezometric levels of phreatic aquifer and deep aquifer.

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REFERENCES

1. Taltasse, P., 1953. Geological and hydro-geological research in the lake Fez-Meknes basin. Notes and Mem. Serv. Géol. No. 115, Rabat, Morocco.
2. Ait brahim, L., 1991. Tectonic brittle and recent statements of constraints the North of Morocco. Contribution to the study of Seismotectonic risk. Thesis. Es Sci. Mohammed V University, Fac. Science, Rabat, Morocco.
3. Fassi, D., 1999. The superficial formations of geological time to the current land use. Notes et Mem. Serv. Geol. No. 389, Rabat, Morocco.
4. Essahlaoui, A., 2000. Contribution to the recognition of aquifer Meknes-Fez basin of (Morocco). Geoelectric prospecting, hydrogeological study and water resources inventory. Thesis. In Sc Appl. Univ Mohammed V. Mohammedia School of Engineers, Rabat, Morocco.
5. Belhassan, K., M.A. Hessane, O. Fassi Fihri and S. El Rhaouti, 2007. Interactions between Surface Waters and Groundwater in the Oued Mikkes Basin.1st MAPG Iternational Convention, Conference and Exhibition organized, in Palais of the Congresses at Marrakech, the 28 to 31at October, 2007.
6. De Martonne, E., 1942. New global map of the aridity index. Annals geography No. 288. October-November, pp: 241-250.
7. ABHS - Anzar Conseil, 2005. Study of the groundwater modelling of the Fez-Meknes (Sais) plain. Technical Report, Mission I: Analysis and critical studies in the plain by ABHS, pp: 107.
8. DRHS, 1989. Exploration of deep-water approach infiltrations in the Middle Atlas Tabular, applying of global model to reservoirs. Technical Report. Mor project 86/004, pp: 75.
9. ABHS - Anzar Conseil, 2004. Inventory of taxpayers' irrigation water and drinking-industrial water (AEPI) from the groundwater of the Fez-Meknes plain. Market 6 / 2003 ABHS / F., pp: 90.
10. Mac Donald and Partners, 1990. Establishment and development of the operating model of the groundwater Fez-Meknes basin. Final Report Lid Mac Donald Partners, Cambridge, England, pp: 370.
11. Turc, L., 1955. The water balance of land: the relationship between precipitation, evapotranspiration and runoff. Ann. Agrou., pp: 5-131.
12. Coutagne, A., 1954. Some considerations on the evaporating power of the atmosphere, the effective flowing deficit and the maximum flowing deficit. The white coal, pp: 360-369.
13. Turc, L., 1961. Evaluation of water needs for irrigation, potential evapotranspiration, streamlined and updated. Ann. Agron. Volume XII, pp: 13-49.
14. Thornthwaite, C.W., 1948. An approach toward a rational classification of climate. Geogr. Rev., 38: 55-94.
15. Belhassan, K., 2005. Interactions between surface water and groundwater in the Mikkes basin. Memory (DESA). Univ. Sidi Med Ben Abedllah, Fez. Morocco.