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Hydro-Geological Context of Groundwater Mikkes and Different Variations of its Springs Flows (Morocco)

K. Belhassan

Department of Geology, Faculty of Sciences Dhar Mehraz

Abstract: The Mikkes basin is located in the north center of Morocco and comprises 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. Hydro-geological setting has a controlling influence on the ambient conditions of springs (the i.e. flow rate) and the governing hydro-geological processes are reasonably well understood. Springs are points of concentrated discharge from groundwater flow systems. This study presents the relationship between hydro-geological context of groundwater Mikkes stream and different variations of its spring's flows. The recharge of aquifers depends on rainfall and evapo-transpiration. The drought which the basin has been known since the 80s could have an impact on the reserves of the groundwater aquifers. The rainfall deficit through the period between 1968-1979 and 1980-2009 is around 18% in the Tabular Atlas and 30% in the Saïs plain. It could be followed by a decline in water piezometric levels of the aquifers basin thus, a decline in spring's flows. The springs in Saïs phreatic aquifer suffered a maximum depletion. The springs with a deep or mixed origin are known as relatively low flow variation springs. The stability of the flow of a spring depends mostly on the extent and storage capacity of the flow systems that feed it. Spring water is always a mixture of water that infiltrated at different times and in different places. This mixing property of springs can lead to complex patterns of variability in flow. Actually, the variations of the fall of spring's flows could be linked to a different hydro-geological context of these springs.

Key words: Morocco % Mikkes % Aquifer % Drought % Level piezometric % Spring's flows % Hydro-Geological context

INTRODUCTION

The importance of water resources is evident and its management through all levels is imperative, especially in Mediterranean countries which are semi arid where water demand is highly required for irrigation and for the drinking [1-5]. The water resources which are available in Morocco are limited. They are also subjected to cyclical extremes variations i.e. succession of cycles of severe drought [6]. This drought has become more frequent in the recent decades and it will definitely aggravates the overexploitation [7].

The Mikkes basin is among the basins of Morocco which have known a significant drought in their water reserves. The hydro-geological context of its 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, which is supplied directly by precipitation. Triassic clays and Paleozoic schist form impermeable substratum of this aquifer. These carbonate formations burrow under the Mio-Plio-Quaternary cover in the right of South Rifain Trough which forms a deep confined aquifer. The depth of the Miocene Marls forming the impermeable roof of this aquifer is about 1500 m in contact with Prerif Ridges at drilling point Aïn Allah (IRE N° 2370/15) [8]. The fractured rocks constitute the groundwater reservoirs [9]. The main parameters for the migration of fluids in fractured rocks are the main geological characteristics of the fracturing, drainage, topography and rainfall [10-13].

Conceptually, the groundwater system associated with springs is simple. It consists of:

- A recharge area where water enters the subsurface;
- An aquifer or set of aquifers through which the water flows; and
- A discharge point where water emerges as a spring.

Corresponding Author: Department of Geology, Faculty of Sciences Dhar Mehraz.
Mob: 212 663-75-95-44, E-mail: kaltoumbelhassan@yahoo.com.

The existence of a spring requires that below the surface (the area commonly called the subsurface), the infiltrating water encounters a low permeability zone and is unable to continue to move downward as fast as it is supplied at the surface; as a result, the water spreads laterally until it intersects the land surface where erosion has lowered the topography to the water's level.

A range of geological structures and topographic features can direct water to the surface and form a spring. Many seeps and small springs are associated with topographic depressions where the water table intersects the earth's surface. Larger springs usually are formed where geological structures, such as a faults and fractures, or layers of low-permeability material, force large amounts of water to the surface.

The object of this article is to investigate the different hydro-geological context of the Mikkes groundwater’s and its influence to the difference spring’s flows. Furthermore this article provides essential information about a sustainable and integrated management of water resources.

MATERIALS AND METHODS

The data included climatic data (i.e. precipitation and temperature), hydrometric data and water level-monitoring data from piezometers installed in Mikkes aquifers. For the study of climate context, two meteorological stations are chosen; one of them is in the Tabular Atlas while the other is in the Saïs plain. The Ifrane station (altitude Z = 1600 m) is characterized as Tabular and El Hajra station (altitude Z = 215 m) in the Saïs plain. They present this series of precipitations measuring from 1968 to 2009 and temperatures between 1968 and 2009. The data analysis for seasonal droughts of Ifrane and El Hajra stations show the extent of drought in the Tabular and in the plain. The magnitude of the drought is characterized in temporal and spatial terms.

Generally, groundwater levels fluctuate according to the characteristics of precipitation events (i.e. amount, duration and intensity) and various hydro-geological variables (i.e. topography, thickness of the unsaturated zone and matrix composition of saturated and unsaturated materials). The knowledge of piezometric data is of vast interest in many applications, such as assessing groundwater flow direction and identifying recharge zone of the aquifer [14]. The study of piezometric variations of the groundwater Mikkes basin was conducted to understand the impact of climatic parameters on the groundwater resource. The variations in the piezometric levels were followed in time and space. The observations were made at annual time scales. The piezometry was followed in the Tabular in the only available measure: by drilling 1448/22. For the Saïs phreatic aquifer, all piezometers show a similar evolution and only piezometer data 199/15 which is presented. For deep confined aquifer, piezometric data 290/22 is presented with long history and a good follow-up.

The supplying regime of aquifers is submitted to the rate and speed of infiltration, which depends essentially on the vertical permeability of the land. The height and rhythm of rainfall play a role which can be more or less considerable depending on the depth and type of the aquifer horizon (i.e. confined or free). The piezometric surface of the free-water table, in natural conditions, fluctuations in levels, often important, directly related to the rhythm of rainfall and the intensity of evapo-transpiration [15].

Using flows of principal springs Mikkes data show in general a decreasing spring’s flow. Then, factor analysis was conducted to classify the springs Mikkes. The reactions are different depending to the typology and hydro geological context, as reflected in following three cases: Springs have completely dried up in 2005, (2) Springs have experienced significant flow up falls to 90% or more, (3) Springs with fluctuations in flow, from 30 to 64 %.

Description of Study Area

The Water of the Stream Mikkes: 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, Aïn Taoujdat and many other centres. The described region covers an area of about 1600 km^2 (Fig. 1).

The Watershed of the Mikkes Is Drained by Four Tributaries: River N'ja and River Atchane in right bank, River Tizguit and River Jdida in left bank. The former drives the Saïs 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 Hydro-geological context (overflow springs, emerging springs, fault springs, etc.) (Figs. 1, 2).

The Data of Pumping: Tests show that the Liasic reservoirs -Saïs and Tabular- have transmissivities ranging between 10^{-5} to 10^{-1} m^2/s with a geometric average of 10^{-3} m^2/s. The Plio-Quaternary formations as they are in the phreatic groundwater of the Plio-Quaternary -Saïs aquifer-. The thickness of this aquifer varies from a few meters to 120 m. This Plio-Quaternary reservoir has transmissivities ranging between 10^{-5} m^2/s to 10^{2} m^2/s with a geometric average of 10^{-4} m^2/s [16].

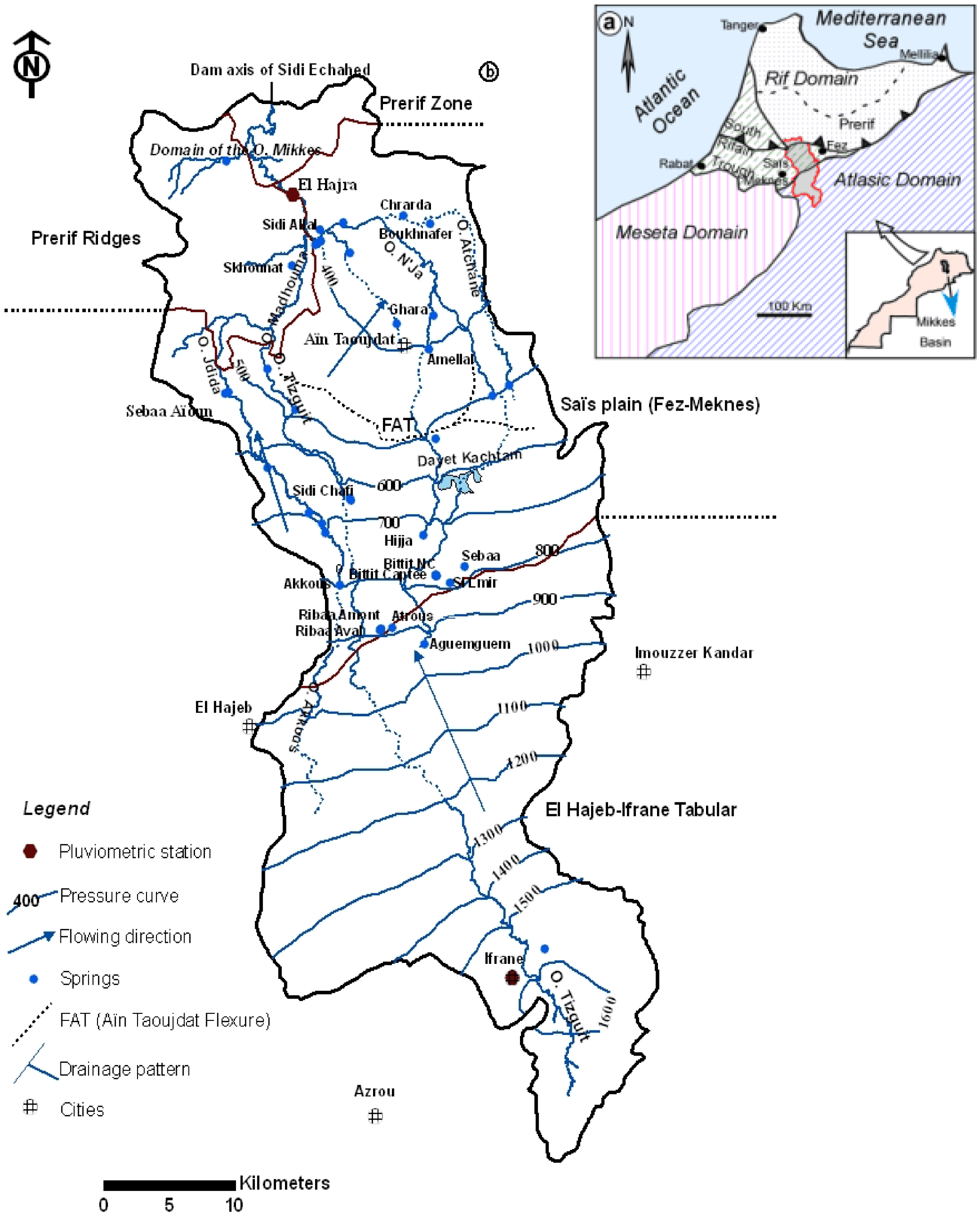

Fig. 1: a. Location of the Mikkes basin, b. Drainage pattern and piezometric map 2009 of the free-water table Mikkes (taken from the topographic map 1/100000, geology division, Rabat, Morocco, 1943)

The Existence of a Spring: Requires that the subsurface is unable to transmit water as fast as it is supplied so that the potentiometric surface intersects the land surface. A range of geological structures and topographic features can thus bring water to the surface; [17] provides a more comprehensive discussion. The discharge of large amounts of groundwater requires some combination of a large recharge area, a high recharge rate and a high permeability for large volumes of water to be concentrated at a single point [18].

The Springs of the Stream 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 Liasic Tabular Middle Atlas, it come from either Liasic confined aquifer or by the unconfined aquifer or by both (Figs 1, 2, 3).

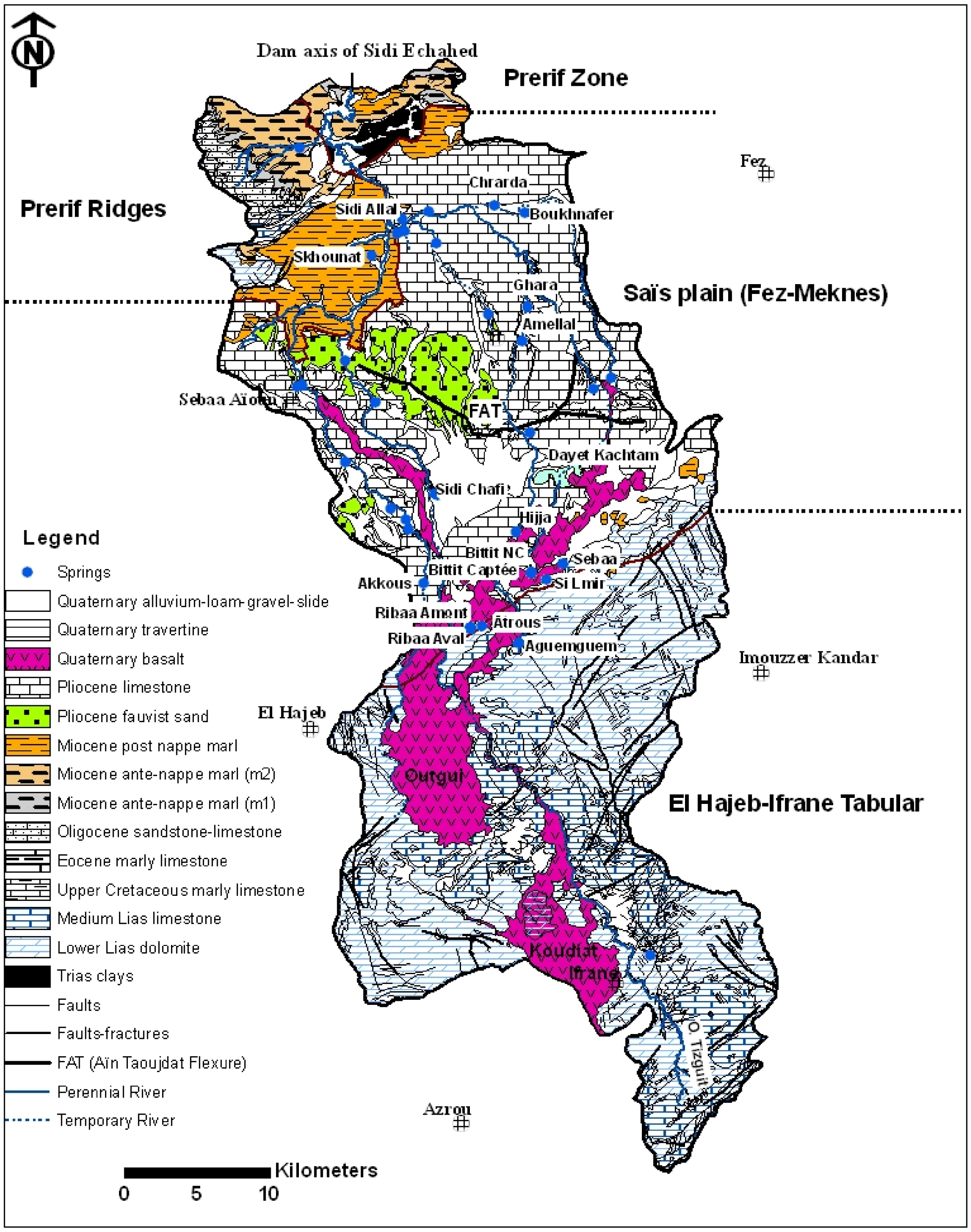

Fig. 2: Geological map of the Mikkes basin (taken from the geological map 1/100000, geology division, Rabat, Morocco, 1975)

The Sampling Points: For the phreatic water-table of the Mikkes basin are characterized by a high proportion of wells; mainly farmers represent 90% of total exploitation while drilling inventory represents 6%. These points ensure drinking water supply, irrigation and its flows speed rarely exceeds 10 L/s. Furthermore irrigation is provided by springs and streams (4% of total exploitation). The thickness of this aquifer varies from a few meters to 120 meters [16].

For the Saïs and Tabular Liasic aquifers, there are also several further sampling points, which are mainly constituted by drilling. The number of sampling points and equipment has been preceded steadily since the 80s. These points are mainly for drinking water supplies 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 Prerif Ridges (drilling point of Aïn Allah). The flow of intake capturing Lias vary

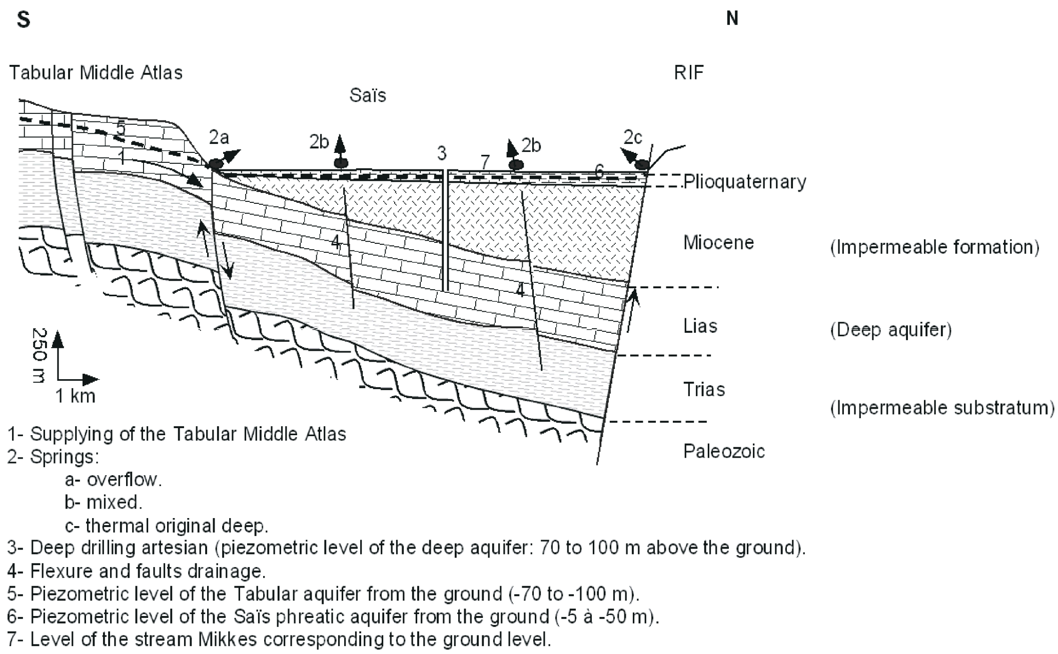

Fig. 3: Diagram showing the hydrogeological context of the Mikkes springs

from a few L/s to more than 100 L/s: 10 to 40 L/s in Tabular, 100 L/s in the Saïs and more than 100 L/s in the east of the Aïn Taoujdat flexure where the Liasic aquifer is being covered by a thick marl layer, where all intakes are artesian [16].

RESULTS AND DISCUSSION

Precipitation - Evapotranspiration: The precipitations are distributed very unevenly in the space and in the time (Fig. 4). In the space, from south to north the altitude increases. Thus, the minimum annual rainfall average is registered in the Saïs plain (station El Hajra). Throughout in the Mikkes basin, a general decrease in precipitation has been observed. This decline begins since 80 years. In the Tabular, the average annual rainfall recorded through 42 for the years between 1968-2009 was 965 mm. It varies significantly from year to year, ranged between 623 mm in 2007 and 1865 mm in 1996. The annual rainfall average during the period between 1968-1979 was 1112 mm, while for the period between 1980-2009, it was 907 mm. The deficit of rainfall in the Tabular is about 18%. In the Saïs plain, the annual rainfall average which is recorded through 42 years for the period between 1968-2009 was 365 mm. The annual rainfall average has shown inconsistent patterns from year to other, i.e. varying between 189 mm in 2007 to 633 mm in 1996. The annual rainfall average between 1968 and 1979 was 463 mm, while it was 326 mm between 1980 and 2009.

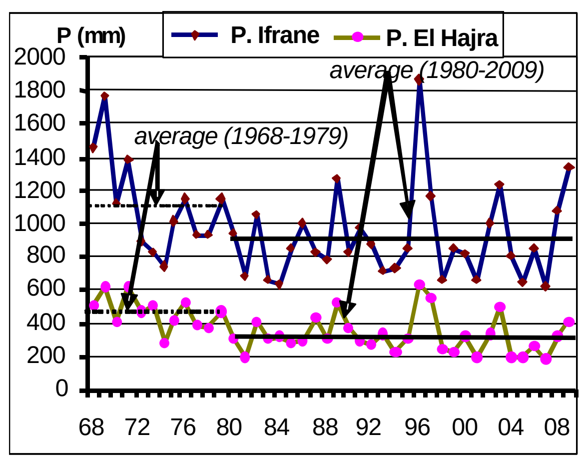

Fig. 4: Annual pluviometry at Ifrane and El Hajra stations (1968-2009)

The deficit is around 30%. This downward rainfall is generalized throughout Morocco and it characterizes the drought years, but it is not in the same way in mountain as in plain (Fig. 4).

Evapo-Transpiration: (1968-2009) is one of the main parameters of water balance. The method used for evaluating the real evapo-transpiration (ETR) and/or potential (ETP), in this researches paper, is that of Thornthwaite (1948) [19]. In order to compare the ETP change in Tabular and Saïs plain, Tables 1, 2 show the monthly evolution of ETP for the two representative

Table 1: Hydric balance of El Hajra (1968-2009)

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Annual
P (mm)	11	32	44	57	48	46	43	43	28	11	1	1	365
ETP (mm)	110	72	39	24	20	26	39	51	80	120	162	156	899
P-ETP	-99	-41	5	33	28	20	5	-8	-52	-109	-161	-155	
RFU	0	0	5	38	50	50	50	42	0	0	0	0	
ETR	11	32	39	24	20	26	39	51	70	11	1	1	325
Deficit	99	40	0	0	0	0	0	0	10	109	161	155	574
Surplus	0	0	5	33	28	20	4	-8	-42	0	0	0	40

Table 2: Hydric balance of Ifrane (1968-2009)

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Annual
P (mm)	34	76	122	147	125	136	107	111	62	26	9	11	965
ETP (mm)	88	55	29	15	13	17	28	38	62	96	132	125	699
P-ETP	-54	21	93	131	113	119	79	72	0	-70	-123	-114	
RFU	0	21	50	50	50	50	50	50	50	0	0	0	
ETR	34	55	29	15	13	17	28	38	62	76	9	11	387
Deficit	54	0	0	0	0	0	0	0	0	20	123	114	312
Surplus	0	21	93	132	112	119	79	73	0	-50	0	0	578

stations. The evolution of the monthly ETP at El Hajra and Ifrane is coincided. The seasonal rhythm is uni-modal; generally characterized by a strong contrast between winter season - marked by high precipitation and little evapo-transpiration- and summer season - having little rainfall but high evapo-transpiration. Furthermore, the annual reading of potential evapo-transpiration (ETP) is greater in El Hajra than the one in Ifrane (i.e. 899 against 699 mm), which is due to thermal differences between the Saïs plain and the Tabular Atlas. The real evapo-transpiration (ETR), which reflects the actual water sampling through the atmosphere, is relatively stable at both stations: El Hajra (325 mm) and Ifrane (387 mm). Furthermore, the water deficit (DH = ETP - ETR) is disproportionate between the two stations, it is two times higher in El Hajra than Ifrane (i.e. 574 against 312 mm). This shortage of water is needed to satisfy potential evapo-transpiration. The confrontation of real evapo-transpiration and precipitation is an indication for surplus water (SH = P - ETR) - supplying the flow in all its forms. The surplus water is 40 mm in El Hajra while in Ifrane it shows a considerable amount which is around 578 mm. Thus, the stream Mikkes is supplied by the Tabular Middle Atlas well watered (Tables 1, 2).

Geological and Hydro-Geological context of Groundwater Piezometric Map of 2009: The measurement piezometric level made in 2009 can established the piezometric map (Fig. 1) for all combined levels and showing the main flow direction which is from the south to the north; depending on the basin morphology with a drainage axis at the river. Moreover, the existence of the Aïn Taoujdat flexure which 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 Saïs plain. Prerif Ridges are impervious limits, the water shares to the east and west.

The hydraulic gradient shows variations that can be induced by the lithology of the reservoir (Plio-Quaternary formations in Saïs plain and carbonates formations in the Tabular Middle Atlas) and/or by fracturing (very important fracturing in the Tabular Middle Atlas than Saïs plain) [8].

At the Saïs plain, the average hydraulic gradient is around 1%, there are two points there which deserve mentioning:

- Near to Aïn Taoujdat flexure, the hydraulic gradient becomes higher.
- Further north, the hydraulic gradient drops down.

At Tabular Middle Atlas sector, in general, the flowing is fairly regular from the SE to the NW following the basin morphology and the lineaments SE-NW. The many faults combined with fractures and cracks of Liasic reservoir give a high permeability to the aquifer formation [8]. Thus, a higher hydraulic gradient which is the order 2%; in this zone where the Ribaa-Bittit springs emerging (Figs 1, 2, 3).

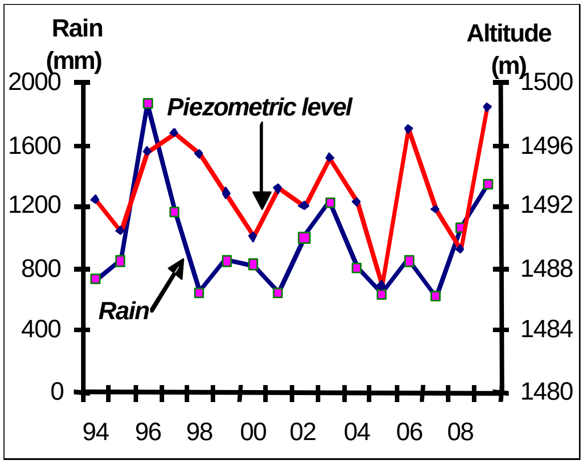

Fig. 5: Relation between rain and piezometric level of the Tabular aquifer (1994-2009)

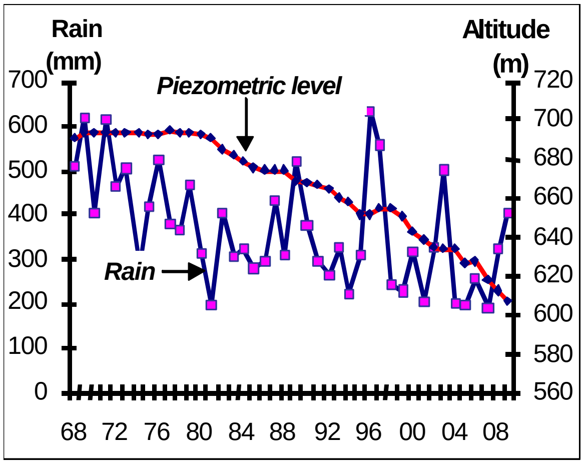

Fig. 6: Relation between rain and piezometric level of the deep confined aquifer (1968-2009)

Pizeometric Fluctuations: For the Tabular aquifer, piezometer 1448/22 (Fig. 5) shows a decrease of 11 m between 2005 and 2009. Starting from 1995, a significant rise in water level of the water table coincides with that of rainfall. The piezometric level shifts 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. Furthermore, the surplus water in Ifrane has a considerable amount of 578 mm, representing approximately 60% of the total rainfall during the period between 1968-2009 (Table 2). It is established that more than half of the precipitation contributes the renewal of water supplies. This may be explained by significant infiltration, predominantly of permeable carbonate formations recognized in the Tabular Middle Atlas and strong fracturing of land (Fig. 2). Whereas for the year 2001 and despite an increase in rainfall, the level of free-water table declines. The rain infiltration has a lesser effect on the supply of water table due to overexploitation of the reservoir and results in an imbalance between the exploitation and supplying; the excessive increase of numbers of the sampling which has experienced the region in 2001 [16]. The years 2008 and 2009 were wet years in Morocco and in particular in the Mikkes basin. The rainfall is significant and is followed by a significant increase in the level Tabular aquifer; groundwater level drops 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 decline in water level after 1980 was about 33 cm/year (Fig. 6). This sharp drop in water level of the aquifer was associated with high stress climate constraint, which the region has known for 80 years accompanied by an increase in sampling for water supply (drinking and irrigation). As it has been mentioned already, the deficit of water in the Saïs plain between the period 1968-1979 and 1980-2009 is around 30%. In addition, the evapo-transpiration 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 interannual rainfall (1968-2009). Consequently, any rainfall deficit is considered as a mark on the evolution of underground water resources because of evapo-transpiratoires times so that the succession of deficit through years leads to a depletion of the water. Nevertheless, the level of Saïs free water table has risen approximately 4 m, from 1995 to 1997 and by 9 m from 2008 to 2009, in response to effective recharge. This enhancement is also reflected by the thickness of the saturated zone is much more important. Furthermore, the increase of water level superficial aquifer can be direct, (i.e. by the infiltration of rainfall; water excess of years between 1995-1997 and 2008-2009. However, this is could be on premise of a supply connection between the Tabular groundwater and the superficial aquifer and/or a hydraulic connexion between the level of that aquifer and the deep confined aquifer. Actually, the two aquifers of Saïs communicate through the faults and flexures or through the semi -permeable Marly layers [20].

For the deep artesian confined aquifer, the monitoring of piezometric fluctuations shows a sharp decline in water levels since the beginning of 80s (Fig. 7). The variation of water level is around 2.87 m/ year on average; primarily due to the drought suffered by

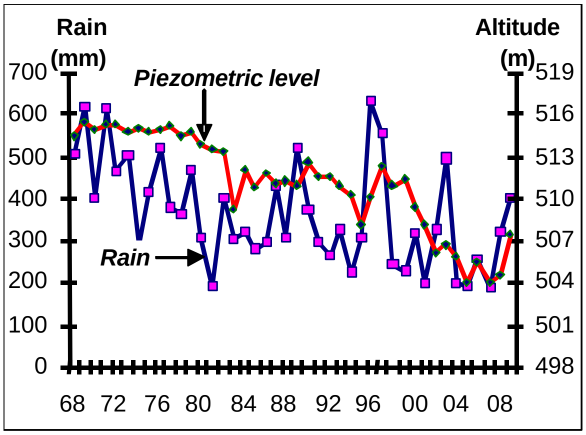

Fig. 7: Relation between rain and piezometric level of the Sais phreatic aquifer (1968-2009)

the region during these years and exploitation of the groundwater. In addition, the overexploitation of this confined aquifer - for drinking or irrigation, caused the drop in artesian pressure and subsequent decline in piezometric levels in the water table. The annual destocking average is estimated at more than 100 Mm^3/year since 1980, resulting in an overall deficit of about 2 Milliards m^3. The overexploitation of groundwater resources - short and medium term drinking-water supply Fez and Meknes cities. Moreover, the disappearance of artesian on whole drilling and the drying up of springs will constrain ONEP (National Office of Drinking Water) to be equipped with means exhaust for artesian drilling initially and to review appropriate case of their replacement. Such degradation of the resources will have an adverse impact on the heavy investments at the irrigation sector, also it will affect tourism investments that established without taking into account the social and economical consequences that may bring it forth [21]. However, higher precipitation (1995-1997) seems to be the reason for rise of about 4 m in the piezometric level.

Generally, the fall in water levels at different water tables is related to rainfall deficit that this region has been experiencing for 80 years which is accompanied by the increase in water demands. Free-water table are much more susceptible to discharge compared to the confined aquifer [22]. As a result, the water table of the Mikkes basin does not demonstrate a uniform sensitivity to the drought:

- 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 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 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.

Between 1995 and 1998, the different sectors of the Mikkes basin demonstrated similar rise in piezometric, on premise of inter water-table relations of the basin. The rainfall directly influences the level of the Tabular aquifer by direct infiltration, permeable carbonate formations and strong fracturing (Fig. 2) and as known that the Liasic confined aquifer is the extension of Tabular. Thus, the Tabular Middle Atlas supplies the Saïs deep aquifer and by aboucher the Saïs phreatic water-table.

Different Variations of Spring's Flows - Hydro-geological Context of the Groundwater: The springs Mikkes which have completely dried up in 2005 and they which experienced significant flow up falls to 90% or more are the springs of emergence and discharge of the Plio-Quaternary phreatic aquifer. The predominant formations of phreatic Saïs are generally little permeable and erodible, thus a high runoff and low infiltration (Figs 1, 2). Because of the shallow depth of groundwater near surface water, transpiration directly from groundwater by vegetation can intercept groundwater that would otherwise discharge to surface water. The reduction in surficial aquifer water levels affects the runoff and water table base flow characteristics within the affected area of the surface water basin and reduces available quantities of water to spring flow. As a consequence, the flow of springs emergence and discharge of Saïs groundwater have been the most significant declines [23]. In other hind, this is undoubtedly caused by overexploitation of the aquifer due to intensive agricultural development around this region after 1970 (Table 3).

The springs with fluctuations in flow, from 30 to 64 % are principally the overflow springs Liasic Tabular aquifer; Ribaa-Bitti springs (i.e Aïn Bittit (captée), Aïn Bittit (non captée), Aïn Aguemguem, Aïn Si Lmir, Aïn Sebaa, Aïn Ribaa (amont), Aïn Ribaa (aval), Aïn Atrous, Aïn Hijja and Aïn Akkous). The mixed springs are also considered as springs with relatively low fluctuations (i.e Ghara). The hydrothermal springs (i.e Skhounat) are considered among the springs of Mikkes basin as having a relatively low drying (Table 3).

Table 3: Flows of principals' springs of Mikkes basin

Springs	Q before 1970 (L/s)	Q 2005 (L/s)	Deficit (%)
Boukhnafer	100	0	100
Ain Chrarda	90	0	100
Ain Sidi Chafi	130	15	88
Sidi Allal	100	4	96
Ribaa-Bittit complex	6075	2177	64
Ghara	500	181	64
Skhounat	200	140	30

The common occurrence of large springs in carbonate aquifers shows that the flow must be organized in some way that results in convergent flow lines to springs and the concept of self-organized channel networks as a result of dissolution is the most plausible explanation [24].

The Liasic Tabular Middle Atlas is considered as a karstic aquifer which is characterised by a complex heterogeneity, created and developed by groundwater flows [25], which in return determines a high dynamic variability in space and time. Generally, springs Tabular aquifer present natural exits for the groundwater to the surface of the lithosphere. They are springs of the Ribaa-Bittit complex that overflow at contact line of El Hajeb-Ifrane Tabular and Fez-Meknes basin at North (Figs 1, 3). Their total mean discharge is 5.2 m^3/s [20]. It is very difficult to precisely classify the karst springs because there are always certain exceptions which deny or at least make the classification uncertain [26]. The principal springs are perennial. An intermittent (temporary) spring results often as an out - flow of another more regular spring situated at lower level. The discharge variability analysis shows that each spring is a different case. Their behaviour ranges from very stable to very instable irrespective of their discharge amount or their altitude. Even springs that were once assumed to be supplied by the same karstic network showed different variability [20]. Thus, overexploitation has less influence on the flow of these springs. The Bittit spring (IRE N° 106/22) is the most significant of all springs Tabular which is an average annual discharge amount 1.3 m^3/s [27-29]. The hydrogeologic system of Bittit has a very significant storage capacity, allowing storage of a significant recharge from rainfall and snow melting, without causing brutal floods. High storage capacities reflect high fracture porosity due to intense tectonic jointing. Water which slowly passes through such a jointed aquifer delivered by long-term; low-discharge runoff [30]. Thus, the spring discharge is indeed quite constant all the year around. The presence of sandy dolomites at the base of the Liasic aquifer suggests the existence of an aquifer with interstitial porosity and relatively slow flow. However, in spite of the great storage capacity of this karstic aquifer, the springs discharge shows a regular and significant lowering tendency due to a long drought period that considerably reduced the aquifer recharge [31]. Actually; this karst system is different of aquifers in porous milieu. The contributions of these springs to the river are estimated during the years between 1935-1988 of around 79% and those of groundwater is approx 21% [32]. Thus, springs flow Tabular have low declines.

The mixed springs are also considered as springs with low fluctuations; i.e. Ghara, N° IRE 1156/15 (Table 3). These are the 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. 3). In addition, the relationship between massive limestone and dolomites of Lias, permeability and groundwater flow show a good demonstration by the important of mixed springs of the Mikkes River, which effect in a higher drainage. In fact, the quantities of extractable water in the deep aquifers are much less than the calculated reserves. Indeed, the depth of pumping water is economically and technically limited to 250 meters or less. This means that the water of large deep groundwater in the order of thousands of meters, can deliver a small portion of their reserves under pressure, but the rapid fall of piezometric level stops very quickly the possibility of exploitation. Furthermore, mixed springs flows have low declines.

The hydrothermal springs are as mixed springs of Mikkes basin as relatively low drying springs; i.e. Skhounat; IRE N° 872/15 (Table 3) due to the water which comes from high depths (deep aquifer). In general, thermal springs commonly occur along fault zones owing to enhanced vertical permeability afforded by fracture zones [33]. The speed of the rising is rather fast so that the temperature had no time to equilibrate with the temperature of the enclosing surface. Theoretically, waters in these springs could be derive from precipitation, infiltrated down fairly deep into the crust through fractures and is warming up "convective" by other fractures (Fig. 3). Water convection along the Prerif thrusting front and the structural unit boundaries should favour the emergence of the most important thermal springs [34]. The Prerif is considered a post-tectonic basin where Upper Miocene sediments and Jurassic to Middle Miocene chaotic blocks accumulated [34]; the main formations are made up of marl, clay and carbonate sediments. Triassic saline domes, which are widespread over a large area and are also found at different depths in the couloir Prerif [35]. The Tabular Atlas, mainly made up of Mesozoic carbonate rocks, together with the regional tectonic structures of the Prerif, represent the main infiltration areas that supply the deep aquifers [8]. In addition, the thermal water during its ascent loses some of its features deep. In particular, temperature is the emergence for various raisons (adiabatic relaxation of the deep gas, mixed with cold water surface, clogging deposits phyllosilcates, etc.) [36-39]. Furthermore, water of hydrothermal springs at its rising, given its geological and hydrological, is always influenced by the vertical drainance resulting mixing of the waters of the different reservoir levels. Although the thermal water is a mixing of the deep - warm water and the cold - surface water. Re-equilibration upon cooling and/or mixing processes, which affect the estimated temperatures at depth, cannot be excluded in the waters from the Prerif. Hence, the calculated temperature can only be assumed as indicative [40]. The average temperature of Skhounat is around 31°C.

CONCLUSION

The Mikkes basin is mainly characterized by significant irregularity in rainfall during the year and on year-to-year basis. The seasonal rhythm is uni-modal; generally characterized by a strong contrast between winter season and summer season. The magnitude of the temporal-spatial drought between period 1968-1979 and 1980-2009 shown a deficit of rainfall in the Tabular which it is about 18% and it is in order 30% in the Saïs plain. As a consequence, this drought ensued in marked reduction of natural water, which triggering excessive groundwater exploitation and led to continuous decline in levels of groundwater. Nevertheless, at annual scale, the drought does not show a uniform sensitivity on premise of peculiar geology of each reservoir, for instance, the phreatic water-table shows annual fluctuations, whereas the Tabular aquifer shows cyclical fluctuations and the deep confined aquifer does not show a clear sensitivity to drought. However, heavy rainfall since 1995 is reciprocated by piezometric increase, at times reaching 4 m in Mikkes aquifers explaining the inter-groundwater interactions. In addition, these developments illustrate the contrasting changes in the hydrological regime of groundwater and the importance of the infiltration of irrigation water in the aquifer supplying.

The piezometric map of Mikkes established in 2009 shows a general direction of flowing from the south to the north, with variable hydraulic gradient from upstream to downstream.

The springs of emergence and discharge of the Plio-Quaternary phreatic aquifer suffered a maximum depletion. The karst springs and springs with a deep or mixed origin are known as relatively low flow variation springs. The main points of the spring's discharge that led to this conclusion are as follows:

- The discharge depends on climatic variations (drought or rainy years).
- The relative position of piezometric level and the river level. The Saïs phreatic aquifer whose depth does not exceed 100 m is easily influenced by rainfall. The spring reacts quickly to rainfall and to climate changes (drought and rainy years). Thus, the maximum discharge. While the confined deep aquifer with depths more than 1000 m, is less influenced by the rainfall. The spring does not react directly to rainfall and to drought. Thus, the minimum discharge.
- The difference geological feature of these reservoirs affects 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 (Saïs phreatic and Tabular), thus drying up of subordinated springs.

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