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Assessment of groundwater flow dynamic using GIS tools and 3D geological modeling: Case of Sisseb El Alem-Nadhour Saouaf basin, Northeastern Tunisia

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ABSTRACT: Sisseb El Alem-Nadhour Saouaf (SANS) basin, is located in the Northeastern Tunisia, where groundwater systems are often exposed to rapidly reserve overexploitation, changing recharge amounts and quality degradation. A three-dimensional (3D) regional hydrogeological model of SANS basin was developed in order to understand the geometry of subsurface and its implications on groundwater dynamics. The 3D model was built by the interpretation of 2D seismic reflection profiles, calibrated by wire line logging data of oil wells, hydraulic wells and geologic field sections. After checking efficiency of interpolation methods by geostatistical tools, validated model highlighted the impact of faults system on the aquifer geometry and structure. Thus, Plioquaternairy and Oligo-Miocene aquifers in the study area represent important geometric variations and cumulated thickness affected by intensive fractures which divided the system into 4 sub-basins (Bled Ktifa, Sisseb, El Alem and Nadhour Saouaf). Moreover, vertically, geological modeling shows 11 hydrogeological layers, with different hydrodynamic characteristics. This study was benefic to propose a conceptual model for the SANS system and to identify the recharge zones and the over-pumped areas which are affected by a significant evaporation rates and reveal large fluctuations of flow dynamic. These results suggest the critical importance of building a various GIS database and testing numerical geological models on groundwater flow dynamic assessment.

KEYWORDS: SANS basin, 3D geological model, geophysics, groundwater flow, Conceptual Model.

1 INTRODUCTION

In order to ensure sustainable management and continuing supply of the population's water resources, the increasing demand for groundwater needs to be organized and monitored on the basis of an overall assessment that includes the quantity and the quality of groundwater [22], [36].

Recent hydrogeological research confirms that depletion of groundwater reserves constitutes the most common problem for groundwater in many arid areas around the world [39], [40], [35], [23], [29]. Therefore, a sustainable groundwater management strategy requires a deeper comprehension of geological frame and reserve quantification in order to guarantee continuous supply for future generations. Groundwater resources management, preservation strategies, and subsequently ecology and human life, are highly influenced by the comprehension of hydrosystems.

Groundwater dynamic are classified as a response to many external forces, including rainfall, exploitation, evaporation, contamination and as an output of the groundwater system [52]. it is essential to understand the process and the phenomena controlling the response of groundwater system exposed on these stresses. Many approaches were used for simulation and prediction of the groundwater dynamic [46], [50], [41], but, the geometry of aquifer systems are often not highlighted despite of its importance on the groundwater reserve estimation. In fact, the internal organization of the basin, their interactions and their boundary conditions are usually the results of approximations due to the misunderstanding of the geological context or a simplification of the geometry adopted by the hydrogeologists. Indeed, the subsurface geology has a major impact on the groundwater levels variability. The geometrical heterogeneity of aquifers and the presence of lithologic varied layers make difficult the comprehension of the hydrodynamic process of aquifers. Similarly, the evolution of tools that new technologies, especially mathematical modelling, provide today are very helpful to facilitate the building of 3D geological models, the comprehension and the conceptualization of aquifer system.

The main purpose for this study is to develop a conceptual model to assess the groundwater chemistry and to understand the groundwater flow, using surface and subsurface data such as geophysical, hydrological and hydrodynamic. Actually, to date, no comprehensive regional study on groundwater proprieties and geochemical characteristics of SANS basin have been elaborated. Thus, in this region, it is difficult to access to the subsurface data, like lithology, geological structure, fracture systems and stratigraphy, due to the heterogeneity of geological frame and the scarcity of geophysical prospection. This study shows that it is advantageous to combine different approaches (geologic structure, geochemical tracers and geophysical prospections) to develop a comprehensive hydrogeological conceptual model.

2 STUDY AREA

Kairouan, Central Tunisia, is characterized by a succession of plains and mountains. It is limited, in the East, by many Sebkhas (Cherita, Kelbia and Sidi El Hani). In fact, it is divided into two under different geographical regions; in the East, a plain with a little bumped relief and on the West, a very variable topography, where exist several heights giving rise to the Nebhana basin. This basin is located, according to the UTM projection system (Carthage zone 32N), between the coordinates 540000 and 3900000 Eastward and 615000 and 4005000 Northward. The study area covers 1650 Km2, in which 550 000 of habitants supply on groundwater via municipal and individual wells (INS, 2014). The topographic elevation ranges between 0m, on Sebkhat El Kelbia, and 1340m on Djebel Serdj.

The surface drainage network, which is very dense, is constituted by several perennial and non-perennial wadis (Nebhana, Essid, Amor, El Hamra, Ermal, Rogal, El Khioua, El Ouja). It contributes enormously to the groundwater recharge. The surface water of these rivers is carried to the large continental depression named Sebkhat El Kelbia. The region of SANS is characterized by an arid to semi-arid climate. The precipitation varies considerably from year to year. The amount of precipitation is less than 402 mm/year with high temporal and spatial variability. Daily mean temperature varies between 9°C in the winter to 34°C in the summer with July and August being the hottest months. The potential evapotranspiration is about 1460mm/year. In fact, this basin is subject to several climate changes and most hydroclimate simulations show an increase in temperature and a decrease in precipitation.

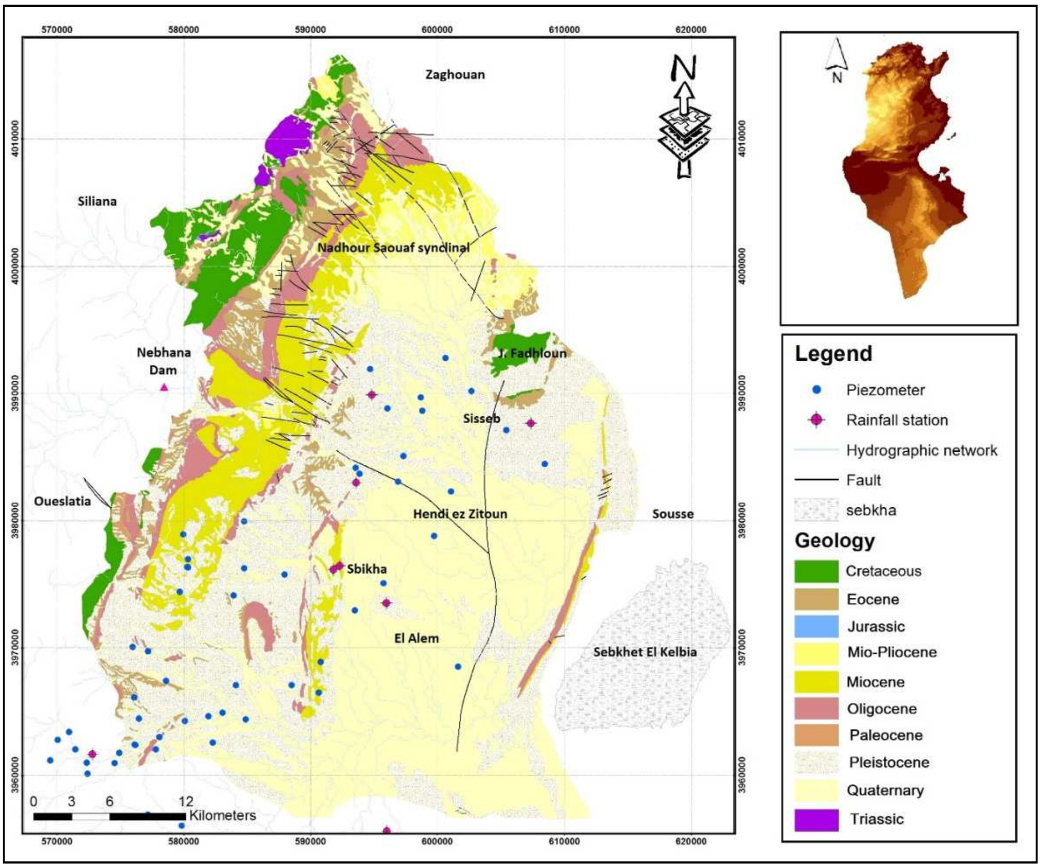

Fig. 1. Location map and regional geology of Sisseb El Alem – Nadhour Saouaf basin

2.1 REGIONAL GEOLOGICAL AND HYDROGEOLOGICAL SETTING

The geology of the Tunisian Atlassic “Dorsale” and the NS axis, which Nebhana basin belongs, have been the object of several studies [16], [14], [27], [28], [44], [15], [49], [47], [12], [17], [4], [38], [1], [18].

Despite these numerous studies, aquifer characterization using geophysical data and geochemical tracers, remain limited [4], [8], [30], [31], [21].

On the structural plan, Sisseb El Alem – Nadhour Saouaf basin extends of the basin of Ouesslatia on the West, up to the plain of Djebibina Alem basin, in the East. The basin is boarded on the west by an orographic axis Ouesslet Edjehaf of direction N30 [18]. It includes the structures of the orogenetic complex Ouesslet Bou hajar. Its Northern continuation, characterized by the structure of Edjehaf, comes to hug against a second orogenetic axis. Besides, the sector is situated in the South of the continuation of the NS axis, which makes the study area a crossroad between two major tectonic accidents [45], [1].

The stratigraphic series outcropping within the SANS basin are generally of Trias to Quaternary in age. In fact, Boudabbous and Fkirine mountain are pierced by Triassic evaporites. Those Triassic outcrops consist of two important facies: Saliferous (clay, sandstone, gypsum) and grey to dark grey limestone. Jurassic deposits outcrop on Ben saidane, Fkirine, kef El Azaiez and Zaress mountain [15]. It is characterized by thick stratigraphic series of interbedded limestone, with 215 m of thikness on Fkirine mountain.

Cretaceous deposits outcrop on Ouesslet and Bou Hajar mountains, on the NO of the basin on the Nadhour Saouaf synclinal and Fadheloun mountain. Paleocene series consist on green marls with intercalations of sandy limestone, gypsum and glauconite clays. It outcrops especially on Bou Hajar mountain and on Nadhour Saouaf synclinal. On Bou Dabbous and Jebil mountains, Eocene deposit are characterized by carbonaceous deposit represented by marl and nummulitic limestone of Ypresian and/or early Lutettian age. For the Oligocene series, they are exposed enormously on the Dekhila, Draa Souatir and Boumorra regions. It consists on interbedded fine sandstone, sands, gypsifereous marls and discontinuous sandy marl lenses [1].

The central area of the basin is overlaid by detrital deposits of late Tortonian Messisian age. It comprises conglomerates, gravels, sands and silty sands. These continental deposits, becomes rich in clays layers towards the North of the basin. Quaternary deposits are known by important changes in the lithology and thickness. It is screened in the detrital layers of continental sands, clay, gravels and conglomerates. It lies in many regions of Sisseb El Alem – Nadhour Saouaf basin uncomfortably on older sediments in age.

The aquifers of the SANS basin are particularly spread in the Plioquaternary and Oligo-Miocene detrital series which is known by its important accumulated thicknesses and high porosity (25% and 30%). Field works and subsurface prospection highlights sandy local aquifers with important petrophysical and hydrodynamic characteristics. In fact, Oligocene and Miocene deltaic deposits present the most important deep reservoirs in the Northeastern Tunisia [24], [7], [33], [6], [5], [25].

In the SANS basin, through hydraulic wells pumping test, different hydrodynamic parameters (T, K, Q) are calculated for the aquifer layers, using OUAIP software (BRGM). Hydrodynamic parameters are presented in the table below (Table 1).

Groundwater flow of the aquifers in the SANS basin is directed from North to South to the Sebkhat of Kelbia.

Table 1. groundwater hydrodynamic parameters in SANS basin (Internal report of hydraulic wells, DGRE)

Aquifers	**Hydraulic parameters**		
	Transmissivity (m^2/s)	**Permeability (m/s)**	**Exploitation (l/s)**
Oligocene Sisseb El Alem	**$2*10^{-3}$**	**10^{-5} - 10^{-1}**	**10 – 40**
Miocene Sisseb El Alem	**10^{-3}**	**10^{-3} - 10^{-5}**	**10 – 20**
Plio-Quaternaire El Alem	**$5*10^{-3}$**	**10^{-3} - 10^{-5}**	**10 – 15**
Oligocene Nadhour Saouaf	**$2*10^{-3}$**	**10^{-5} - 10^{-1}**	**10 – 40**

3 METHODOLOGY

3.1 DATA ACQUISITION AND HYDROGEOLOGICAL DATABASE DESIGN

- **Climate data**

Climate data used in the current study includes data describing temperature, rainfall, relative humidity and the evapotranspiration. The rainfall data were kindly made available by 9 rainfall stations from the General Direction of Water Resource.

- **Geological and geophysical data**

The geological setting of SANS basin is very complex, and well geological data range from sparse, on the region of Nadhour Saouaf, to very concentrated, on the region of Sisseb and El Alem. Subsurface data such as geostructural, geophysical and hydrological data are very important in groundwater flow comprehension. However, it is difficult to access to the subsurface data, like lithology, geological structure, fracture systems and stratigraphy, due to the heterogeneity of geological frame. Although, geophysical methods have been developed so that prospections cover larger areas.

Moreover, geophysical data are an excellent source of information in areas with scarce borehole data and heterogeneous frame. To reach the aim of the study, a various database was collected and performed in order to prepare the inputs for the numerical model. This data base consists of 2D seismic sections and 23 wire line logging of petroleum well from The Tunisian Compagny of Petroleum Activities. The interpretation was done by means of the following tools: SMT, PETREL and ROCKWORKS.

To identify the aquifer layers, fields sections and the Vertical Seismic Profiles (VSP) of the oil wells were used to calibrate the geo-seismic interpreted sections. The choice of the interpolation methods was guided by a geostatistical study which considers the correlation coefficient and the anisotropy ratio. In our case, kriging was used. It is one of the most used statistical methods to create geological models, isochron and isobaths maps. Using the Neuralog software, logging curves were digitalized in the appropriate scale and then reconstructed using Interactive Petrophysics (IP) for lithostratigraphic interpretation.

– **Hydrological data**

The hydrological data considered in this research consists of stream networks and watersheds characterization. Hydrologic information was extracted from the SRTM (Shuttle Radar Topography Mission) of SANS basin using the Arc Hydro tool. These data are characterized by a good efficiency and a high spatial resolution 30 x 30 m which make it very suitable for use in stream network and watershed delineation.

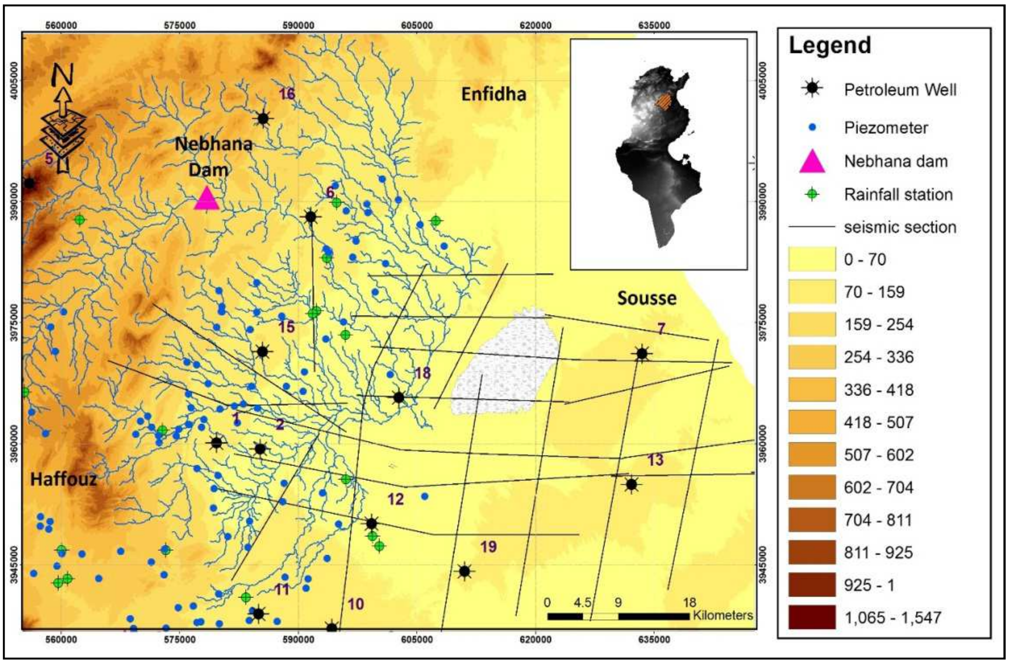

Fig. 2. location of seismic sections, hydraulic and petroleum wells piezometer, and sampling point

3.2 GIS MAPPING TECHNIQUES

GIS mapping techniques, which are based on geostatistics approaches, constitute an excellent tool for analyzing the spatial variability of hydrodynamic parameters, geological data, geochemical trends and water quality. Here, the ArcMap package was very useful to superpose the different layers of information and make the interpretation easier.

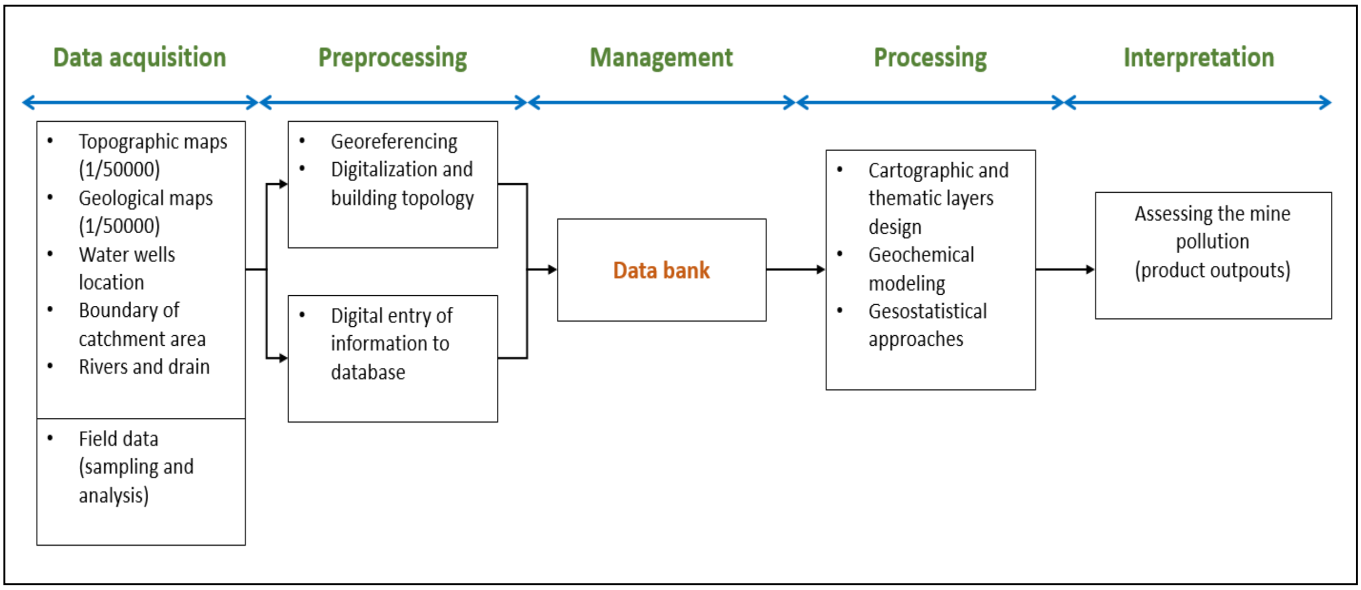

Fig. 3. Gis mapping process

3.3 THREE-DIMENSIONAL MODELING

Integrated mathematical modelling proves significantly successful, owing to an unusual wealth of available geological, geophysical, geochemical and hydrogeological data. The 3D stratigraphic model is built in order to understand the aquifer geometry and illustrate the complexity of the hydrogeology setting of the study area. For that, the “solid modeling” package provided by Rock Works software is used. The resolution of the model is 1000 m × 1000 m × 5 m. the resulting grid consists of 44 X-nodes × 31 Y-nodes × 45 Z-nodes so the model contains 61380 nodes.

When dealing with the geological modeling, it is necessary to determine the appropriate interpolation method. The most used statistical method is kriging. Several mathematical models were performed to adjust the interpolation method and both simple kriging represent the same accuracies as well as ordinary kriging. So that, we have chosen the simple one.

4 RESULTS AND DISCUSSIONS

4.1 3D HYDROSTRATIGRAPHIC MODELING

The 3D hydrostratigraphic model was developed in this study to assess the geometry of aquifers and their vertical relationships.

– **Stratigraphic interpretation**

Seismic reflexion is the most used method to highlight the aquifer structures; it has been performed in many studies to reconstitute the aquifers architecture [13], [34], [31], [6], [5], [25], [26], [43].

In this paper, we suggest the interpretation of a seismic section L1 (Figure 4).

The direction of the first section L1 is NNE-SSW (Figure 4). It is located in the middle of the SANS basin. The line shows 3 sub-basins separated with NW-SE faults in flower form. The sub-basins are in compressive structure and seems to be controlled by the triasic activity in the zone. To the north, the geo-seismic section shows the Ktifa-Guelta synclinal which is bedded by the thick series of the Lower Eocene. Along the monoclonal of Draa Souatir, the Plioquaternary filling of Ktifa-Guelta synclinal relies on an anticlinal poured towards the west, named the Ktifa anticlinal. It is in fact the continuity of the Fadheloun mountain and present in the Draa Souatir side a major fault which represent a hydrogeological impermeable limit between two different sub-basins, the Sisseb and the El Alem basins. To the north of Ktifa structure, NE-SW faults affected a little syncline where the Plioquaternary, Oligocene and Miocene series are not very thick (100-200 m). Further south, the Kairouan-El Hadedja syncline present very thick stratigraphic series and it can reach 700 m of thickness on the El Hadedja area. It is limited to the south by the structure of Zlama and Bir Ben Zina. The Zlama synclinal is crossed by the ZAW-1 well, it shows important Plioquaternary, Miocene and Oligocene thicknesses, it is about, respectively, 500 m, 630 m and 300 m.

Many seismic lines are oriented EW and shows the structure of El Alem, Sebkhat El Kelbia and Kondar. These lines show important thicknesses of the Plioquaternary, Oligocene and Miocene deposits. The majority of the faults are, strike-slip NE-SW and EW faults and bordered the structure of el Alem, Sebkhat El Kelbia and Kondar basin. The structure is in fact in horst and grabens. The geometry of these complex horsts and grabens, detected on the studied seismic lines, is known in the SANS folded basin. In fact, at the Oligocene, dextral and sinistral transtensional movements began and continued until the Tortonian, when the thick sedimentary series were taken again in transpressional movements generating echelon folds within the grabens (Nebhana graben).

The Miocene (Burdigalian – Serravallian, the late Tortonian, and the Messinian) is characterized by several intensive geodynamic events [31]. Actually, most normal faults reach the Neogene layers and are likely to have been reactivated during the later Tortonian, generating a change in the tectonic process and thus a stress field in a compressional and transpressional context. Intensive tectonic movements are also observed on the Miocene and Pliocene. As a result, many faults were than reactivated. [31] explained the role of these tectonic events on inherited fault and the coexistence of extensive and compressive structures. These high potential tectonic activities are the cause of many hydrogeological implications, the aquifer systems are divided into small sub-basin and the Collapsed compartments have accumulated significant quaternary deposits. The difference in thickness is closely linked to erosion and sediment yield of mega structures formed.

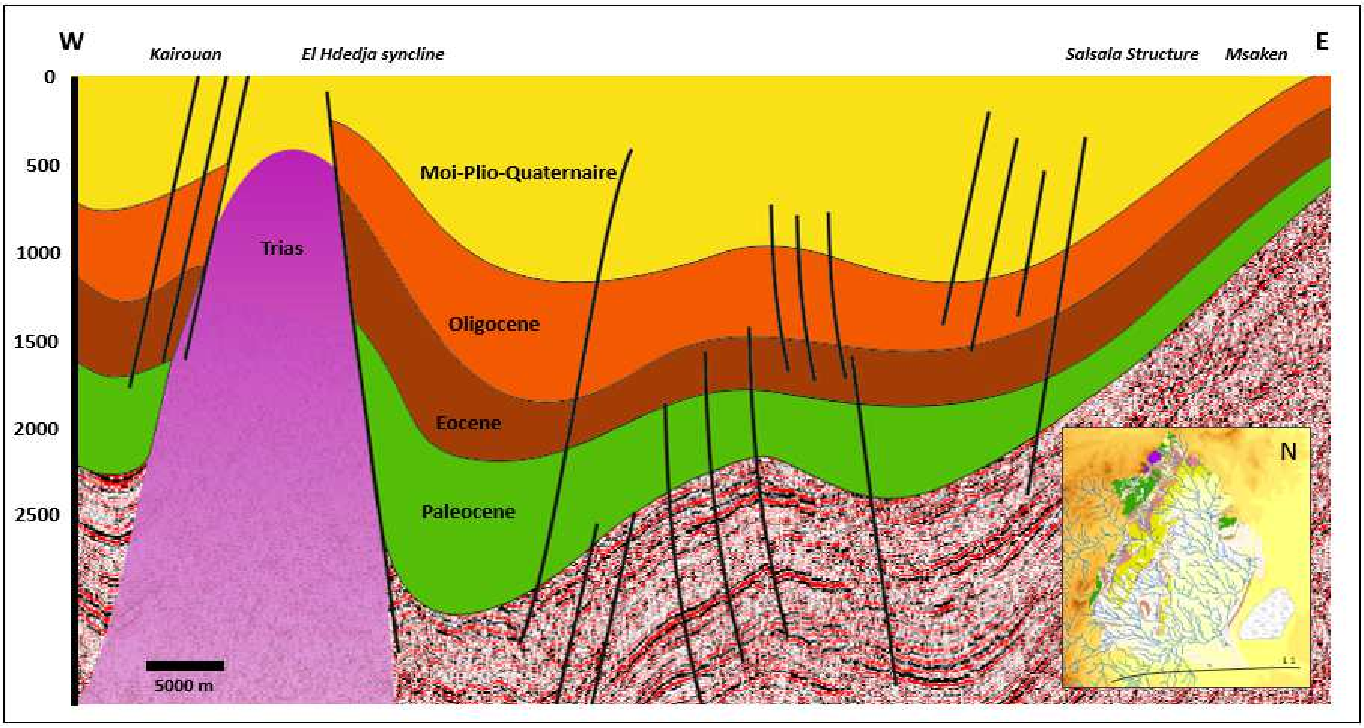

Fig. 4. Example of interpretation of the seismic section L1

- **Aquifer layer lithologic characterization**

The robustness and the efficiency of the 3D hydrostratigraphic model is relative to the detail required by the geological data to be modeled. The model established is based on many geophysical data and also verified with previous sedimentologic field sections [16], [8], [1], [31], [26]. One of the initial steps in the setup of hydrogeological classification is identifying appropriate lithologic units and consequently stratigraphic units. However, the lithologic units as textural characteristics provide important information like depositional conditions and primary control on water transmissivity and aquifer potential. This characterization was developed using the internal reports of ETAP and DGRE. The 3D hydrostratigraphic model of SANS shows 11 distinct lithostratigraphic layers.

Unit 1: The El Haria formation consists of claystone with occasional thin marly limestone interbeds and strings down to 850 m on Kairouan plain. The top part of El Haria consists of a light grayish-green claystone with light gray calcareous rich interbeds becoming predominately light to medium gray.

Unit 2: lower Eocene (Ypresian), represented by the Boudabbous formation and El Gueria Formation. The upper part of the formation consists of a light to medium grey, firm to moderately hard, calcareous to slightly dolomitic shale. This shale is organic rich and downward to argillaceous, bioclastic, limestone mudstone with glauconite and pyrite. These sediments were deposited in a shallower open marine environment. These folded limestones of this formation, with the marl bedrock is in fact a discontinuous confined aquifer in the region.

Unit 3: The Upper Eocene deposits of the Souar formation are very thin and can reach 600 m and 800 m of thickness. It consists on thin bedded marl layer (Burollet, 1956) and forms an extensive bedrock for the Oligo-Miocene aquifers and it is crossed by many drilling wells [24]. In the syncline Nadhour - Saouaf the Souar formation was intersected from 330 m by Sidi Abdelkader well (IRH: 10475/2), located 2 km west of Jebel Fadheloun.

Unit 4: Oligocene (Rupelian – Chattian) is represented predominantly by shales with interbedded sandy shales and sandy dolomites. A zone of interbedded shales and limestones exists at the base these deposits. The shales are vari-colored at the top grading to dark brown and grey. It forms the lower section of the Fortuna formation. The thickness of these deposits can reach 300 m and it outcrops in the monclinal structure of Dekhila, Draa Souatir, Jebel El Batene and Bou Morra synclinal. It represents low permeability and it forms a potential aquifer capted by numerous deep boreholes.

Unit 5: The Oligocene - lower Miocene represent the middle unit of the Fortuna formation. It is characterized by dolomites with shale intercalations. The dolomites are light grey, hard to very hard, crystalline to sucrosic and occasionally grade to sandy dolomites. The thickness of these layers can touch 220 m.

Unit 6: the lower Miocene (Aquitanian – Burdigalian) is represented by sand with minor shale interbred and argillaceous intercalations. The sands are clear to translucent to white and light grey, fine to very coarse grained, moderately to well sorted with occasional glauconite rich zones. It forms the Upper section of the Fortuna formation and represent 60 m of thickness. It outcrops on the Nadhour Saouaf basin.

Unit 7: The Middle Miocene (Langhian) consists on dolomite with thin interbeds of shale. The dolomite is light grey to grey, slightly anhydritic with a sucrosic texture. The interbedded shales are medium to dark grey. The thickness of these deposits is over 15 m and constitute an aquitard between the Oligocene and the Miocene aquifer. Never the less, it could be permeable in many areas since its reduced thickness [48].

Unit 8: the middle Miocene (Langhian – Serravallian) is represented by clay layers which are generally soft, amorphous to blocky, very carbonaceous with abundant coal fragments. These sediments were deposited in a shallow marine environment with probable periods of fluvial influence and sub-aerial exposure.

Unit 9: The upper Miocene (Serravallian – Tortonian) consists on the Beglia formation which is represented by massive sandstone and coarse, sometimes brittle with clay levels. The sandstones predominate at the base and clay intercalations are more toward the top with continuous passage to lignite. The thickness of these sediments reached 360 m and represent a high hydrodynamic potential.

Unit 10: The Saouaf formation [9], [8], consists of alternating sand or sandstone, marl and lignite. The rare interbedded thin lignite in the lower part, become thicker towards the top. The power of this formation is of 480 m on Henchir El Gonnara area.

Unit 11: The Upper Miocene-Pliocene and Quaternary deposits consist of interbedded unconsolidated sands silts, and clays with occasional limestone interbeds [14]. Below 330m the sand content increases and the grain size increases from fine to medium in the upper part to coarse to gravel near the base. The total power of these series can reach 600m in the Hdedja region and to Kairouan area and it constitute a potential aquifer. The unconformities mark these deposits since it is bedded in one time by the Upper Eocene and the Souar formation in Henchir Nahal and Jebel Fadheloun and in an another time by the Saouaf formation and Beglia in the Hdedja area.

Chronostratigraphy				Formation	Max thickness (m)	Lithology	Hydraulic Conductivity (m/s)
	Quaternary		Pleistocene	Alluvium	200		$10^{-3} < k < 10^{-1}$
			Villafranchian		16		$10^{-9} < k < 10^{-7}$
NEOGENE	Pliocene		Piacenzian	Segui	1200		$10^{-5} < k < 10^{-3}$
			Zanclean				$10^{-10} < k < 10^{-8}$
	Miocene	L	Messinian				$10^{-9} < k < 10^{-7}$
			Tortonian	Oum Dhouil	820		$10^{-3} < k < 10^{-1}$
		M	Serravallian				$10^{-3} < k < 10^{-2}$
			Langhian				$10^{-5} < k < 10^{-3}$
		E	Burdigalian	Ain Ghrab	20		$10^{-8} < k < 10^{-7}$ $10^{-3} < k < 10^{-2}$
			aquitanian	Fortuna	500		$10^{-8} < k < 10^{-7}$
PALEOGENE	Oligocene		Chattian				$10^{-5} < k < 10^{-3}$
			Rupelian				$10^{-3} < k < 10^{-1}$
	Eocene		Priabonian	Souar	600		$10^{-10} < k < 10^{-8}$
			Bartonian				
			Lutetian	Boudabbous	400		$10^{-5} < k < 10^{-3}$
			Ypresian				
	Paleocene		Thanetian	El Haria	50		$10^{-10} < k < 10^{-8}$
			Danian				

Fig. 5. hydrostratigraphic chart of SANS basin

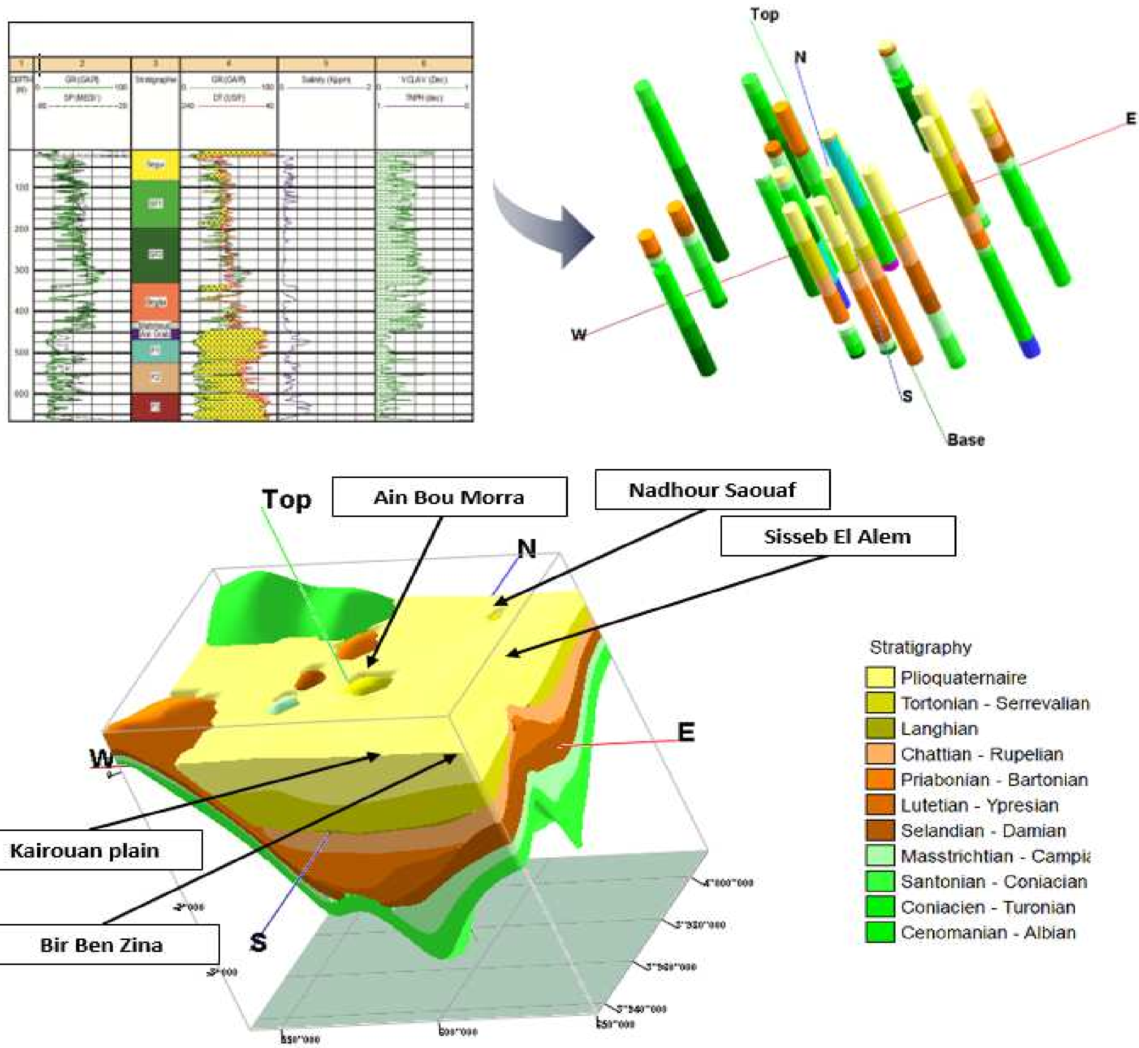

Fig. 6. 3D hydrostratigraphic model of SANS basin

4.2 GROUNDWATER FLOW DYNAMIC IN THE SANS BASIN

The geological study reveal that there is 5 aquifer layers (Segui, Oum Dhouil/Beglia, Ain Ghrab, and Fortuna formations), These potential aquifers are divided into 4 lateral sub-basins due to the intensive tectonic activity in the SANS basin.

Elaborated hydrostratigraphic models of fractured sub-basins based on a discrete approach offer good resolution characterization of structural properties of these aquifers, Groundwater flow is determined by the characteristics of the fracture network, including properties such as fracture density, length, orientation, aperture and connectivity.

General direction of groundwater flow is NW-SE, the piezometric levels are increasing all over the years, In general, tendency of piezometric curves remained variable, The piezometric level presents an irregular evolution, characterized by a continuous drop during the last years under the influence of the irregularity of precipitation, the evaporation ratio and the overexploitation.

The direction of groundwater flow coincides appreciably with the direction of streams, piezometric curves present a speed, generally, convex (Fig, 11) indicating a linear supply insured by infiltrations of surface water.

In the region Nadhour-Saouaf, piezometric contours are very tight and the hydraulic gradient range between 0,021 and 0,007, which confirms the good circulation of groundwater in the Oligo-Miocene aquifer, this speed of curves is caused by good transmissivity (2*10-3 m2/s), amplified by the high topographic slope, to southward, hydraulic gradient became more and more low and can reach 0,0004.

To the Southeast, in the El Guelta area, the piezometric level coincides with the topographic elevation, especially at Henchir Ain Fkirine area, indicating its emergence, it is also the case of Bled Saadia, which is an accumulation zone of surface water, Indeed, it represents a potential area of aquifer recharge, this finding is validated with the DEM data and the flow accumulation instruction of the arc hydro tool.

In Sisseb region, hydraulic gradient is about 0,001, This region present thick deep Oligocene layers (100 - 250 m), Award the NW, hydrodynamic parameters are very important due to the homogeneity of lithologic series, To the south, in El Alem area, lithostratigraphic reservoirs layers become more heterogenic and lenticular and hydraulic gradient is less important (0,0003).

Combining these finding, a conceptual model for SANS basin was established, Actually, the foundation of this hydrogeological investigation is based on sufficient reliable information and modeling results to develop an understanding of how a definite groundwater system works.

Piezometric study highlights the impact of subsurface geometrical setting and topographic slope on groundwater flow dynamic, Actually, groundwater flow in a regional point of view is divergent and it is difficult to understand its tendency, the current study shows that:

(1) the most important recharge rates are located in the north, in Nadhour Saouaf synclinal, where Oligocene sandstone series outcrops, the infiltration coefficient is about 13,5% of effective rainfall.

(2) In the region of Djebibina, along the Khrioua and Keseb flood, rain water reach directly to the Oligo-miocene aquifer, it is not the case for Oued El Ogla and Oued Sahel because the implementation of two dams, is about 9,7 Mm3/year.

(3) Since the implementation of Nebhana dam, recharge ratio is decreasing and it is about 2,43 Mm3/year.

(4) To the west of Djebibina, Eocene marl constitute a no-flow boundary.

(5) In the monoclinal of Sbikha, and Draa Souatir area, recharge rates increase and reach 13,5 % of effective rain, in fact, Oligocene sandstone outcrops in these areas and it forms a permeable limit, In the south of Jebel Fadheloun, Eocene and cretaceous limestone outcrops and constitute a permeable limit also.

(6) in Sisseb El Alem area, hydraulic gradient is very low, the decrease of groundwater levels highlighted that El Alem and Ktifa sub-basin are two separated basins and can never be the same hydrogeological system.

(7) the SANS system cannot be separated to Kairouan plain system, they are connected and there is an important flow exchanged, it constitutes a head dependent flow boundary (Cauchy or mixed condition).

5 CONCLUSIONS

The objective of this study was to establish links between geological framework, groundwater quality, groundwater residence times, and piezometric fluctuations on the scale of SANS basin.

To attain this objective, the study combined geological modeling, fracture system, with groundwater chemistry and groundwater residence time.

At the sub-basin scale, it is extremely important to assess utility of geological modeling in the comprehension of groundwater flow dynamic, Refereeing to hydrostratigraphic model, SANS basin is composed by 4 sub-basins: Nadhour Saouaf, Sisseb, El Alem, which are connected and Guelta-Ktifa which constitute an independent compartment, At a lithologic point of view, SANS basin contains 11 lithologic units, which represent heterogenic values of permeability and hydraulic conductivity, Combined with structural model and fracture system given by seismic section interpretation, lithostratigraphic study highlighted 4 superposed thick aquifers contained in permeable units (Segui, Beglia or Oum Dhouil, Ain Ghrab and Fortuna formations), Thickness of these aquifer vary between 23 m for Ain Ghrab aquifer and 400 m for Fortuna aquifer.

Porosity values varies between 20% and 35% for the Fortuna aquifers, 25% and 30% for Beglia aquifers.

Global exploitable resources are calculated using difference between the Eocene bedrock, given by the 3D stratigraphic model, recharge ratio and piezometric fluctuation and it is estimated to 20,3 Mm3/year.

It is clearly important to understand regional and local hydrostratigraphic setting of fractured sub-basins to build a comprehensive groundwater flow model, characteristics of the fracture network, structural geometry such as fracture density, length, orientation, aperture and connectivity, are very important in the groundwater flow dynamic comprehension, General flow direction is directed from West to East to the Mediterranean Sea and from North to South to Sebkhat El Kelbia, Hydraulic gradient is high in Nadhour Saouaf area and very low around Sisseb El Alem area, This deviation of hydraulic gradient values is due to the multi-scale undulation of the water table, which generally induces a hierarchically nested flow structure formed by local flow systems.

Indeed, geochemical tracers are linked with the local geology to more understand groundwater flow directions, It shows that TDS represent high values and increase groundwater moves rapidly along short and shallow pathways within local flow systems and slowly along long and deep pathways within intermediate or regional flow systems.

These pathways affect the amount of time during which the groundwater and rock interact, and subsequently determine the physical and chemical properties of the groundwater.

Therefore, the interpretation of response of aquifer to the stresses should be done with consideration of factors including aquifer type, paleogeography setting, regional tectonic activity, petrophysic parameters, geochemical tracers, and in-situ filed piezometric measurement.

This study brings a new and original understanding of the groundwater system within the context of its geological history, It not only characterizes the natural groundwater flow dynamic of the study area, but also contributes to better understanding the hydrogeological frame and conceptualizing SANS aquifer system, for future numerical hydro-meteorological and hydrodynamic modeling.

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