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Simulations of Some Scenarios of Management and Restoration of Berrechid Aquifer (Morocco)

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Abstract*: *Morocco's water resources are highly irregular in space and time. The use of 91 to 94% of the resource mobilized for agriculture over the past two decades, during long periods of drought combined with increased water needs, have clearly highlighted the weaknesses in the balance between water needs and resources. By creating imbalances, in quantity and quality, in most of the country's aquifers, including the Berrechid aquifer, which is also vulnerable to soil surface pollution, unlike confined aquifers, which are relatively protected by their impermeable roof. To overcome these problems, adequate management of groundwater resources is required.To simulate hydrodynamic and hydrodispersive phenomena, we used MODFLOW and MT3DMS software, interfaced with GMS. The conceptual model established previously, which faithfully reflects variations in the piezometric level, in particular the decrease due to the succession of dry periods, is used as a basis for proposing suitable scenarios for the optimal management of these groundwater resources. Various simplified scenarios for the management and restoration of the Berrechid groundwater are examined, in particular artificial recharge and the reduction of the volumes of water pumped for irrigation. The results show that halving current withdrawals would improve the current situation of the Berrechid aquifer by avoiding the emergence of drying zones in 2025. This model that we have developed could therefore be a useful tool for groundwater management and protection in the region.

Index Term: Berrechid, Groundwater, Restoration, Protection, Modeling, MT3DMS, MODFLOW.

I. INTRODUCTION

Morocco, a country with a very contrasting climate, has a low water potential. Therefore, the major challenge it must take up, in order to ensure coherent and global development, is to mobilize, control and above all manage its water resources in a rational way.This groundwater has an underground hydraulic potential which represents the sole and unique water resource in the region; it is the source of the drinking water supply of a large part of the rural areas of the province Berrechid and a part of Settat city.

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Intensive groundwater exploitation has resulted in the presence of localized dewatered areas in most of Morocco's semi-arid to arid classified areas [1], [2]. Water reserves per inhabitant are estimated to be around 500 m^3/inhab/year in 2020 [3]. Several studies highlight the piezometric deficit, following overexploitation, and poor management of water resources in Morocco [4]-[6]. The numerical simulations carried out by MODFLOW in steady-state and transient conditions have made it possible to refine the spatial distribution of the hydraulic characteristics of the aquifer and to evaluate its water balance. Over the entire simulated period, the balance sheet proved to be in deficit; following intense groundwater exploitation, to which is added successive dry periods [7]- [10]. The previously developed model has been used as a tool for forecasting purposes. Various simplified water management scenarios are discussed, including artificial recharge and reduction of pumped water volumes for irrigation.

II. THE STUDY AREA

The Berrechid plain is located in the Atlantic Coastal Basin, which is located between the cities of Rabat and Azemmour and covers an area of approximately 10 470 km^2 (Fig.1). This groundwater is located to the south of the city of Casablanca and is distinguished from the other groundwater tables in the region by the size of its area, which is approximately 1600 km^2. It is part of the quadrilateral formed by the cities of Settat, El Gara, Mediouna and the center of Bouskoura [11].

The hydrogeological limits of the Berrechid aquifer are defined as follows):

- In the South and South-East, the Settat plateau: the latter feeds the groundwater laterally.
- In the North-East, the valley of the Mellah wadi is very heavily encased.
- To the west and northwest, the primary outcrops: a watertight boundary despite the very weak flow towards the Chaouia to the northwest.
- To the north, extension towards the Chaouia nappe: constitutes an outlet for the Berrechid aquifer [12]. Many wadis (Boumoussa, Tamdrost, Mazer, El Ahmeur and Aida) originate on the settat plateau and are lost in the plain (Fig. 1).

Within this domain, the supply is ensured by direct infiltration of rainfall, infiltration of wadi water and lateral underground inflows. Drainage is mainly provided by the Mellah wadi and flows towards the Chaouia. Among the studies that have focused on the Berrechid aquifer [7]- [9], [13]- [20].

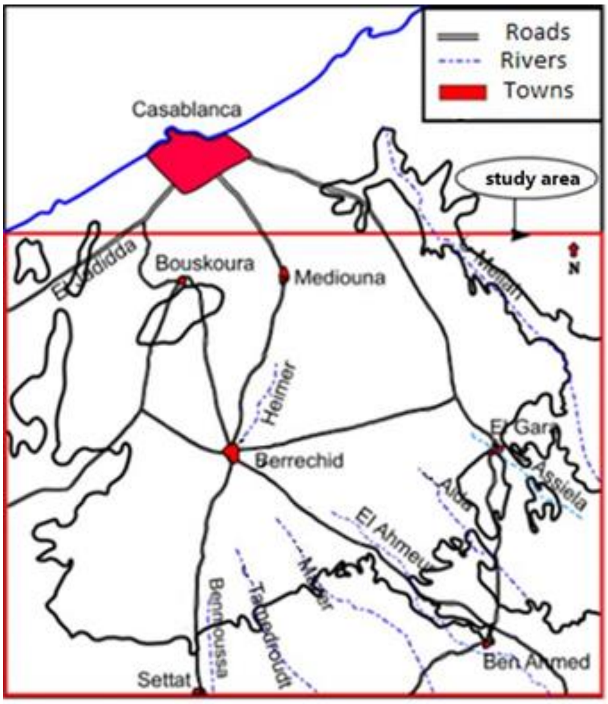

Figure 1. Location of the Berrechid plain [12], [13]

III. MATERIELS AND METHODS

The following sections describe the material and the methodology used in this study.

A.Materials

The hydrodynamic model of the Berrechid aquifer, which was developed using the GMS software developed by the Environmental Modeling Research Laboratory of Brigham Young University, in collaboration with the U.S. Army Engineer Waterways Experiment Station [10], [12], [13] [21], [22].

Hydrodynamic parameters such as permeability, the coefficient of storing, porosity and Piezometric data have been used in the implementation of this conceptual model (Fig. 2) [7], [8].

Our choice of this software is due to the fact that it has several interfaces (MODFLOW, MODPATH, MT3D/MT3DMS) and contains all the necessary tools for modeling and simulation of water and pollutant transfers in groundwater. It allows various types of flow and pollution problems to be addressed using the MODFLOW and MODPATH programs. As tools to support good groundwater management, this digital database has been used to propose appropriate scenarios to overcome the current critical situation.

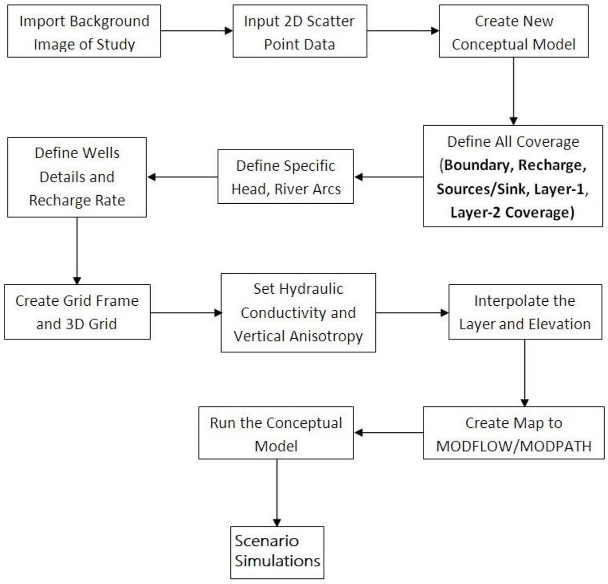

Figure 2 Flow chart for the development of conceptual model for scenarios simulations

B. Methodological Approach

The numerical model that we used was realized thanks to the MODFLOW programs for the flow and MT3DMS for the transport; these two numerical codes are interfaced to GMS 4.0 (Groundwater Modeling System) developed by "Environmental Modeling Research Laboratory of Brigham Young University" in collaboration with "U.S. Army Engineer Waterways Experiment Station [21]. The reserves of the Berrechid aquifer were evaluated and long-term prediction simulations (the year 2025) were carried out using the hydrodynamic model previously developed [7]-[9]. Simplified scenarios for the quantitative management of this aquifer have also been carried out, namely: the one-off injection of surface water from the wadis by artificial recharge and the reduction of volumes pumped for irrigation, as well as their effect on the distribution of nitrate concentrations in 2025.

The average annual change in levies chosen is that adopted by Directorate General Hydraulics [12], which is 9%.

The Berrechid plain is at the surface as a pit of subsidence, limited to the south by the limestone of the Cretaceous, and elsewhere by primary formations consisting of shales and quartzites. The land of filling is formed of marine sandstone dune and the Pliocene [17] (Fig.1), its main aquifer is located between 5 and 30 m depth [12]. The water level survey carried out by the DGH services shows a regular variation of the depth of the water table from South-East to North-West. In the South-East and East, at the foot of the Settatttat Plateau, the depth is 50 m and exceeds 30 m in the center of the plain, while it does not reach 10 m in the North-West and South -East. This corresponds in fact to the topography that decreases in the SE-NW direction [12] (Fig. 3).

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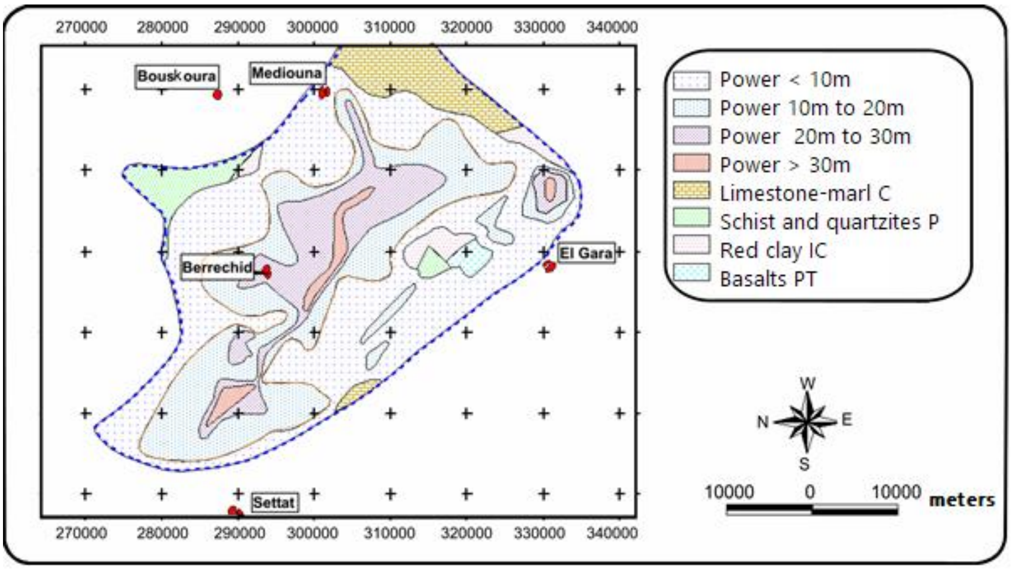

(C: Cenomanian, P: Primary, IC: Infra-Cenomanian)

Figure 3. Distribution of the powers of the circulating groundwater in the Pliocene [12].

IV. RESULTS AND DISCUSSIONS

A. Simulation of the current reserves in the year 2025

The results of the simulations show an increased and continuous decline in the water table, especially in the center where the drops reach 16 m (Fig. 4). The drawdowns are constantly increasing, even leading to dewatering of Pliocene aquifer horizons over relatively large expanses in the South-East, North-west, and North where the lowest water table strengths occur piezometric levels (Fig.5). The sharp drops in the water table will cause progressive dewatering of many wells and will drastically reduce the current reserves in the year 2025.

In addition, overexploitation of the aquifer during these periods of the deficit could also affect the quality of groundwater; recourse to artificial recharge of the aquifer may be necessary.

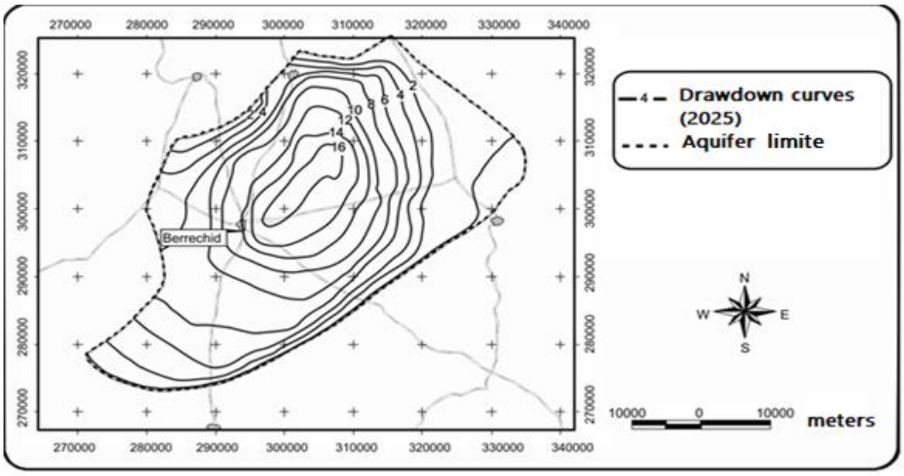

Figure 4. Predictable drawdown curves in 2025.

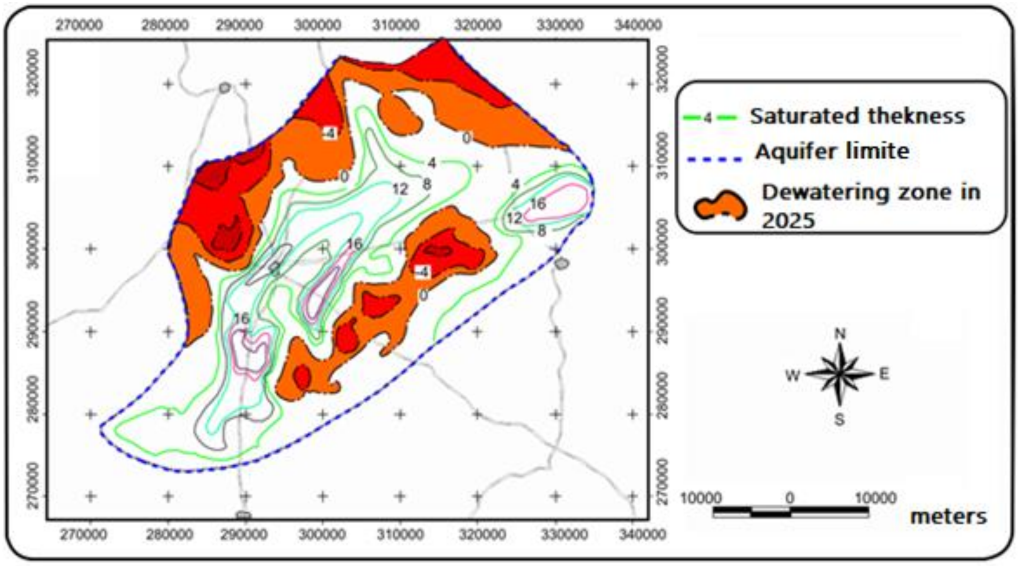

Figure 5. Power curves of the water table in 2025

B. Examination of some scenarios for the restoration of the Berrechid aquifer

The restoration of the groundwater reserves could be based, for example, on adequate facilities favoring artificial recharge or reducing the volume of water pumped for agricultural purposes.

B.1. Scenario 1: Punctual injection in wadis

The Berrechid aquifer depends on the recharge from the effective rains, but also from the floods of the wadis and the settlements of the Settat plateau.

In this scenario, the simulation consists of an artificial recharge, at the level of the five rivers located in the south (Wadis Boumoussa, Tamdrost, Mazer, El Ahmeur and Aida), with a flow rate of 650 l/s per well for one month, a total volume of 8.42 Mm3, while maintaining the same external stress conditions of the water table.

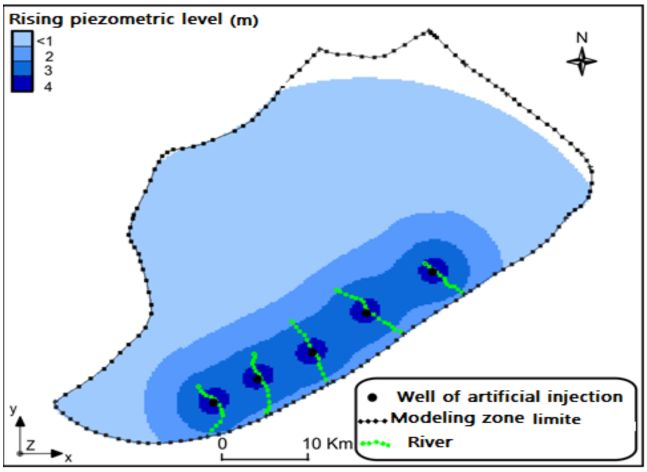

Figure 6. Influence of artificial recharge on the water situation in 2014.

The results of this simulation show that the effect of this artificial recharge is variably felt on almost the entire aquifer, with piezometric level increases that vary between 4 m at the recharge sites in the south, and lower values at 1 m elsewhere (Fig. 6).

The problem of the quantitative improvement of the Berrechid aquifer lies on the one hand, in the supply of water in quantities necessary to achieve this scenario, and on the other hand in the inhomogeneous distribution of this recharge. It may be more appropriate to proceed with the reduction of pumping volumes for irrigation.

B.2. Scenario 2: Reducing pumped water volumes for irrigation

We have conducted pumping volume reduction simulations of 0%, 25%, 50%, and 75% compared to the current flow; this implies that the irrigated areas continue to increase but by the use of more economical irrigation techniques. Good management of the surface water allocated to agriculture will also, in times of drought, save the equivalent of the volume of groundwater made available to this agriculture to compensate for the deficit in surface water.

The analysis of the different simulations shows the power of the water table in 2025, for different values of reduction of the volumes of water pumped into the aquifer:

- with the maintenance of the current level of pumping (110 Mm^3/year) (Fig. 7), the piezometric level drops will continue, with the presence of dewatering zones in the South-East, North-West, and North, which are the less thick of the tablecloth;

- With a reduction of 25% (Fig. 8), the extent of these denuded zones becomes smaller and smaller;

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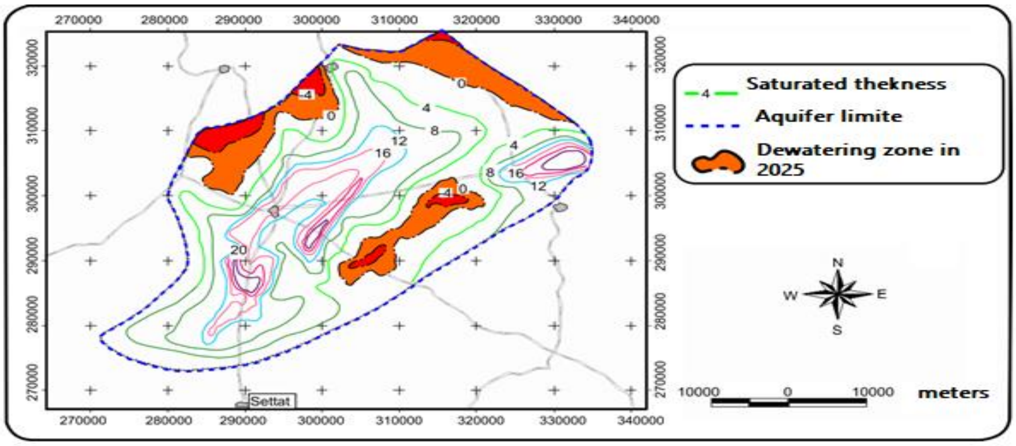

Figure 7. Curves of the thickness of the sheet keeping the current pumping volume.

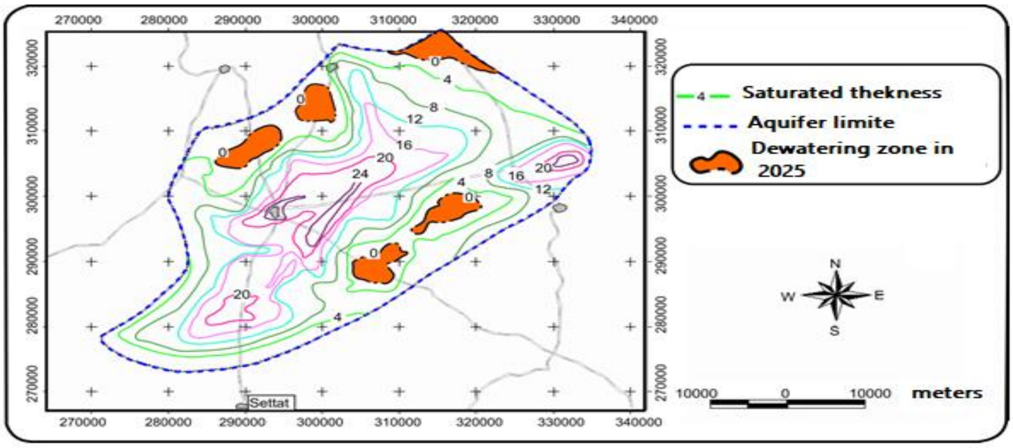

Figure 8. Power curves of the water table after a reduction of the pumping volumes by 25%.

- From a reduction of 50% (Fig. 9), we note the complete disappearance of these dewatering areas in 2025;

- With a reduction of 75% (Fig. 10), the thickness of the aquifer continues to increase, leading to a marked improvement in renewable water resources.

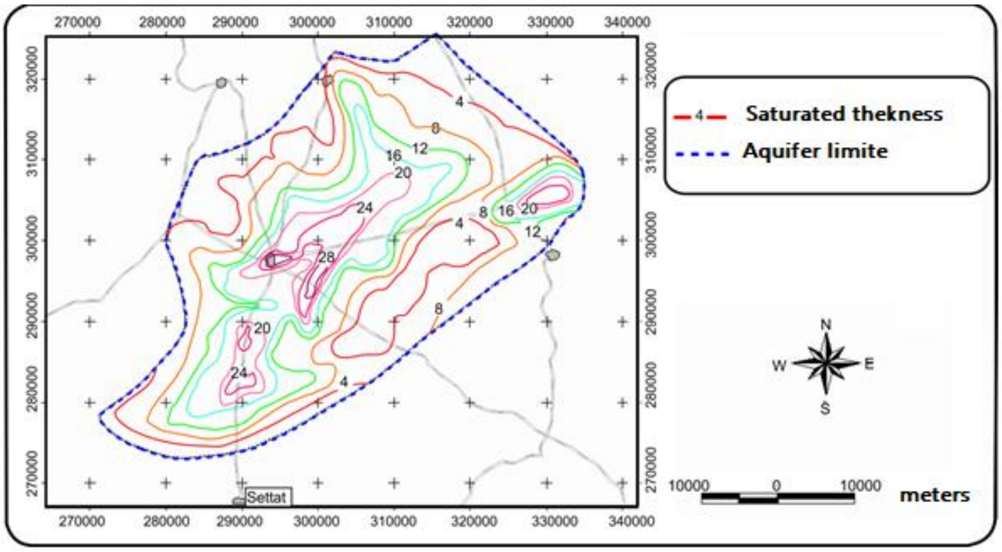

Figure 9. Curves of the power of the water after a reduction of the pumping volumes by 50%.

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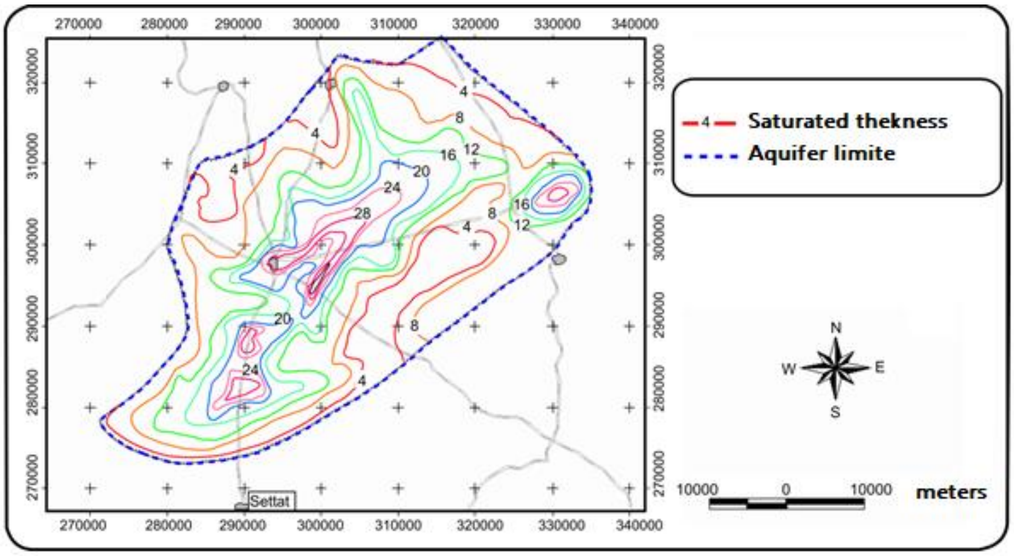

Figure 10. Curves of the power of the water after a reduction of the pumping volumes of 75%.

The results of the simplified management scenarios carried out on the Berrechid aquifer show that the overexploitation of groundwater has resulted in the modification of the water status of this aquifer, which has manifested itself by the dewatering of the production levels which could lead to long term (in 2025, for example), the drying of wells in the shallower aquifer zones (thickness less than 10 m). The hydro-agricultural development, combined with the harmful impacts of the drought observed during the last two decades, has led to overexploitation of the water table which has resulted in reductions that exceed 16 m in some places.

In front of this alarming situation, the simulation of some scenarios of the restoration of its resources was carried out by: - Artificial recharge from wadis located in the Settat Plateau at the recharge boundary south of the aquifer. This experience has shown that the effect of this artificial recharge is felt especially at the injection sites in the south, with piezometric level increases of about 4 m, at most.

- the reduction of the volumes of the samples destined for irrigation. The results of the simulated scenarios show that after respective reductions of 25%, 50%, and 75%, the water table levels will start to increase in 2025, by filling the dewatering areas.

Good quantitative management of the water resources of the Berrechid aquifer will also lead to an improvement in the water quality of this aquifer.

It should also be noted that several factors, still unmanageable, involved in the management of groundwater must also be taken into account, such as climatic hazards, the often numerous and poorly controlled withdrawals, as well as the increasing demand for water and poorly identified.

V. CONCLUSION

The deficit balance encountered throughout the simulation period, which is due to the intense exploitation of groundwater in the region, in addition to which are the dry climatic conditions.

Long-term piezometric simulations, using the GMS software, show this overexploitation of the Berrechid aquifer will dewater the shallower aquifer zones in the long term. These areas are located southeast, northwest, and north where the lowest power of the water table is located. Some scenarios for the restoration of water resources in the Berrechid aquifer were carried out by simulating artificial recharge and reducing pumping volumes for agricultural purposes. The limitation of the use of pumping for irrigation shows that a halving of the current abstractions will significantly increase the water table level by causing the dewatering areas to disappear.

The modification of agricultural practices in use in the area, as well as the treatment of wastewater before their release into the natural environment, can greatly contribute to improving the groundwater quality of this water table.

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