Scenarios of evolution of water consumption and groundwater management in the Gabes Jeffara – Tunisia

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***Abstract* — The oases of Gabes, in the south-east of Tunisia, constitute an unique example of coastal ecosystem. The development of agricultural activity in recent decades, in a semi-arid climate subject to recurring droughts, has led to a very strong demand on groundwater ressources causing the drying of the springs supplying these oases and the lowering of the groundwater levels, with consequent salt intrusions and degradation of oases ecosystems. A hydrodynamic model has been developed for better management of the aquifer. The results of the simulations without management measures highlight the critical situation of groundwater resources related to a considerable increase in groundwater withdrawals since 1970. Different scenarios have been tested with the model, based on the use of alternative resources, on an improvement of irrigation techniques and on a reinforcement of groundwater recharge.**

***Keywords* — Groundwater management, alternative resources, hydrodynamic modelling, Gabes Jeffara.**

I. Introduction

The oases of Gabes, in southeast Tunisia, are a unique example of a coastal ecosystem. The development of agricultural activity in recent decades has led to a very high demand on groundwater resources, causing the springs supplying these oases to dry up and the level of groundwater to fall, with the corollary of saline intrusions and degradation of oasian ecosystems[1]. The Jeffara of Gabes aquifer system (plain of about 10,000 km^2), mainly supplied by the large fossil aquifers of the Sahara, must be preserved; this is why the Gabes Regional Commission for Agricultural Development, with the help of the French Development Agency and the support of BRGM (Bureau de Recherches Géologiques et Minières), has launched a major program called "Management of coastal aquifers in Gabes oases". Closely associating Tunisian scientists, this multidisciplinary project integrating geology, hydrogeology, ecology, socio-economics and integrated water resources management has made it possible to propose sustainable management solutions.

II. Materials and Methods

The development of a hydrogeological model has thus made it possible to test different scenarios for the evolution of water consumption and resource management. The scenarios take into account both the evolution of water demand, linked in particular to the increase in irrigation, and water resource management measures (WRMM), such as the use of alternative resources (seawater desalination, increase in wastewater treatment capacity, treatment and use of oasis drainage water), the strengthening of groundwater recharge and the reduction of groundwater abstraction.

The conceptual model was designed from a geological model with three main aquifers (Fig. 1).

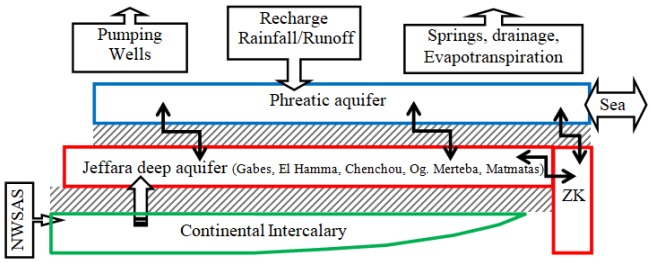

Fig. 1 Conceptual model of Gabes Jeffara aquifers

The model was implemented with Processing Modflow. It consists of a regular grid of 171 rows and 212 columns with 500 m^2 meshes. The main boundary condition of the model is the input of deep water from the Continental Intercalary (CI) that was modelled by imposing variable hydraulic loads along the northwestern boundary of the layer.

III. Results

The simulation results of the various forecast scenarios highlight the critical situation of groundwater resources in the Gabes coastal aquifers. This situation is the result of the exploitation of the various aquifers since the 1950s, followed by the continuous and considerable increase in groundwater withdrawals since 1970, which has been doubled between 1970 and 2014.

The water balance computed in steady and transient states confirm the results of previous studies, especially the groundwater inflow from the CI aquifer (Table 1). The inflow was computed as 3.1 m^3/s in 1950 according to OSS [2]. Our simulations show that it was divided by 4 between 1970 and 2014.

Table 1 Water balances simulated by the model

	1970		2014	
	Inflow (m^3/s)	**Outflow (m^3/s)**	**Inflow (m^3/s)**	**Outflow (m^3/s)**
Inflow from CI	2.93		0.74	
Exchange with the sea		0.19	0.00	0.13
Pumping:		1.88		3.93
Shallow wells		*0.20*		*0.69*
Deep wells		*1.68*		*3.24*
Drainage:		1.00		0.04
Wadis		*0.04*		*0.02*
Springs		*0.96*		*0.02*
Recharge	1.96		1.14	
Evapotranspiration from the water table		1.82		0.99
Groundwater storage			3.20	
TOTAL	**4.89**	**4.89**	**5.09**	**5.09**

The forecast scenarios tested show that the decline in piezometric levels of Jeffara aquifers is likely to continue, with induced effects of a decrease in the exploitable resource, degradation of groundwater quality and increase in operating costs. The impact of overexploitation of groundwater currently appears to be much greater than that of climate change.

The calibrated model has been used to simulate the impact of groundwater exploitation in future according to several management scenarios by referring to the water demand of the Gabes region. Six scenarios were tested with the model over the period 2015-2040 :

- Scenario 1 considers that the withdrawals into the deep aquifer are maintained at the same level as in 2014;
- Scenario 2 considers that the withdrawals into the deep aquifer are extrapolated in a linear way;
- Scenario 3 is based on a trend increase in water demand;
- Scenario 4 is based on a reasonable increase in water demand;
- Scenario 5 consists of introducing water resource management measures and applying them to the operating flows selected for scenario 3.
- Scenario 6 consists of introducing water resource management measures and applying them to the operating flows selected for scenario 4.

The simulation results of scenarios 1 to 4 (without management measures) highlight the critical situation of groundwater bodies in the Gabes region. But the simultaneous implementation of all the management measures combined with a control of the evolution of water demand (scenario 6) compared to a "laissez-faire" situation (scenario 3), makes it possible to significantly reduce the destocking of groundwater resources (Table 2).

IV. Discussion

The results of the simulations show that it is imperative to reduce groundwater withdrawals by about 2 m3/s compared to the situation in 2014 and that this reduction is possible by combining all the proposed measures. The groundwater flow simulation model developed as part of this project can thus provide valuable operational support for groundwater management in drought conditions, in particular by allowing different operating scenarios to be compared.

Table 2 Water balances simulated by the model in 2040 for scenarios 3 and 6

	2040 – Scenario 3 (without water resource management measures)		**2040 – Scenario 6 (with** water resource management measures)	
	Inflow (m^3/s)	**Outflow (m^3/s)**	**Inflow (m^3/s)**	**Outflow (m^3/s)**
Inflow from CI	0.32		0.32	
Exchange with the sea	0.08	0.04	0.003	0.169
Pumping:		8.91		4.00
Shallow wells		*0.876*		*0.08*
Deep wells		*8.037*		*3.92*
Drainage:		0.002		0.02
Wadis		*0.002*		*0.020*
Springs		*0.000*		*0.006*
Recharge	2.47		2.47	
Evapotranspiration from the water table		0.36		0.95
Groundwater storage	6.45		2.83	
TOTAL	**9.32**	**9.32**	**5.63**	**5.63**

V. Conclusion(s)

This study highlighted the overexploitation of Gabes Jeffara aquifers, linked to a sharp increase in irrigated areas, particularly private areas, excluding oases [3]. The impact of overexploitation of groundwater currently appears to be much greater than that of climate change.

Simulations carried out over the period 2015-2040, using the hydrodynamic model developed as part of the project, show that the situation will quickly become critical if no measures are taken: pump dewatering, saline intrusion, disappearance of wetlands, complete drying up of springs. The implementation of a set of appropriate management measures (reduction of withdrawals, strengthening of recharge and use of alternative water resources) is nevertheless likely to stop the decline of groundwater levels.

References

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