Modeling and characterization of underground flows in urban areas by the finite element method

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Abstract Groundwater is the hidden part of the hydrological cycle. This is the reason why some of their characteristics, which are measurable, punctually only, sometimes remain uncertain, they are subject to anthropogenic contamination by domestic and industrial wastewater. Pollution is the number one factor causing groundwater degradation. In this work, we propose to use a numerical simulation model of water movement and solute transfer in the water table of the city of Biskra. The latter is fed by a network of 23 boreholes, generally capturing the Miopliocene formations, which is a predominantly sandy aquifer with a variable thickness depending on the amount of filling. Part of the water exploited for underground flows is characterized by: the flow velocity; the piezometric levels and the direction of flow. The AEP of the city of Biskra comes from this tablecloth. We have done a numerical modeling of subsurface flows by the finite element method, knowing the hydrodynamic parameters and the boundary conditions allow to calculate the distribution of the hydraulic loads. And from which we know the distribution of velocities and the direction of flow. In addition, we simulated the phenomenon of transfer of a dissolved body in porous media and realized the pollutant displacement time map (in perspective) on the study area.

Key words Groundwater; numerical modeling; finite element method; simulation.

I. INTRODUCTION

Underground flows are characterized by: flow velocity; piezometric levels and direction of flow; the latter is dependent on the permeability and porosity of the aquifer. The transfer of solutes by groundwater is related to the geochemistry of aquifer systems. The solubility of minerals depends on their nature and the residence time of the waters. In this work, we propose to use a numerical simulation model of water movement and solute transfer in the water table of the city of Biskra. The numerical modeling of the underground flows by the finite element method, knowing the hydrodynamic parameters and the boundary conditions make it possible to calculate the distribution of the hydraulic loads (piezometries). From which we can know the velocity distribution and the direction of flow. It is possible to simulate the phenomenon of transfer of a dissolved body in porous media (convection-dispersion) and to calculate the evolution of the concentrations in the aquifer under the effect of sampling or possible injection. The model is applied to the Miopliocene aquifer of the city of Biskra to predict the evolution of contamination by solute transfer.

II. DESCRIPTION AND CHARACTERISTICS OF THE STUDY AREA

The wilaya of Biskra is located in South-East Algeria, It consists of two areas quite different from the point of view of relief, climate and vegetation. We are interested, however, in the mobilized volumes which

reach 832.92 million m3, of which 22 million m3 of the surface water is (2,64%) and 810,92 million m3 of the groundwater is (97,36%). The surface water mobilized comes from two dams and intended for irrigation, and groundwater represents the bulk of the resource and is exploited for: Irrigation, A.E. P, the industry. [7] Rock represents the reservoir of groundwater. As a result, it influences their quality and plays an important role in the mode of acquisition of chemistry. The knowledge of the lithological nature of the lands studied makes it possible to explain certain chemical parameters of the waters found there. In addition, a good knowledge of the rocks of the aquifer and the lithological nature of the rocks of recoveries gives us information on the approach to be followed for the establishment of the perimeters of protection. Geology remains a key element of all studies of underground rocks. [4] The climate of the region of Biskra is rigorous, characterized by hot summers and dry winters. [1]. La température moyenne annuelle est de 21°c et les températures minimales de l'air ont été enregistrées au mois de Décembre est Janvier à BISKRA 304°c, les températures maximales: 49,50cen Juillet et Août. **[9]**. Infiltration of aquifers by infiltration is negligible, low rainfall plays almost no role, and a large proportion of precipitated water is evaporated. The most torrential rains for tablecloths are rare. [18] According to the explanatory note of the hydrological map of Biskra, this region is characterized by the existence of four (04) aquifers:

- ✓ Quaternary aquifers
- ✓ The tablecloths of the mio-pliocene sands
- ✓ Tablecloth of the Eocene and Senonian limestones
- ✓ Deep tablecloth (tablecloth of sandstone). [1]

Fig1: Geographical situation of the wilaya of Biskra

III. DIGITAL EXPERIMENTATION AND SIMULATION

The location of these holes in the study area is shown in the following figure:

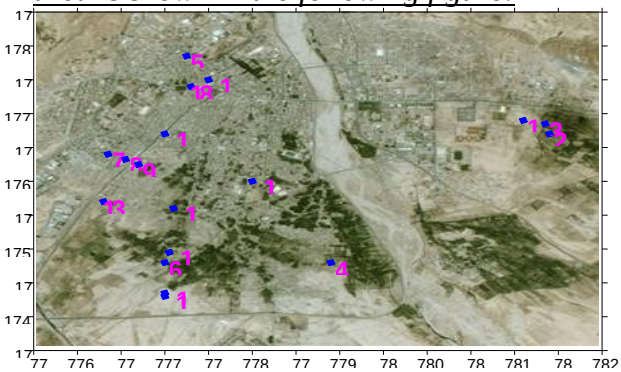

Fig2: Distribution of boreholes in the study area.

The piezometric map (a) is plotted from dynamic drill levels.

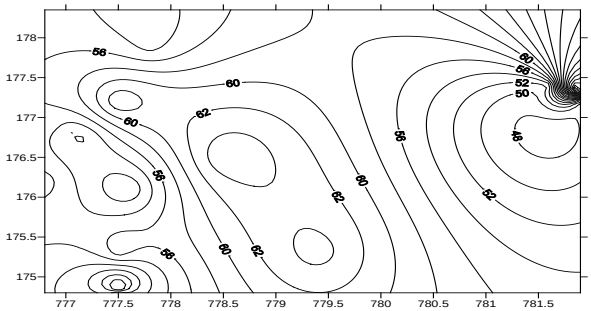

Fig 3: the piezometric map before the simulation

The observation of the piezometric map shows that the directions of the flows can be summarized as follows:

- ➢ Depressions are observed at several zones around some boreholes; which shows local flow directions

caused by heavy pumping. These same boreholes run along the wadi Biskra.

- We can say that the general flow follows the flow of the Oued that is to say North North if the excessive pumping did not come to disturb this direction.

a. The simulation results

Piezometric map (hydraulic load) after the simulation:

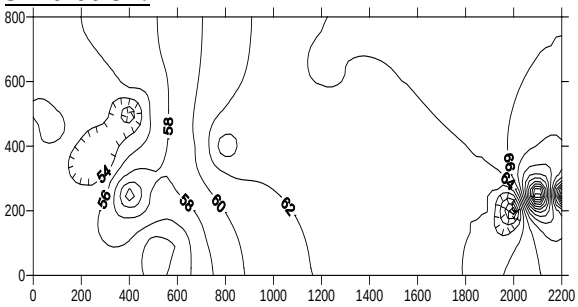

Fig 4: Simulated piezometric map of the Mio-Pliocene aquifer of the study area

It is a map that shows curves of equal hydraulic loads of the studied aquifer. It shows that the hydraulic load is very important in the central part of the study area between (60 and 62 m). They are minimal is decreased (54 and 50 m) especially towards East and West.

Piezometric map with direction of flow and positions of nodes and boreholes

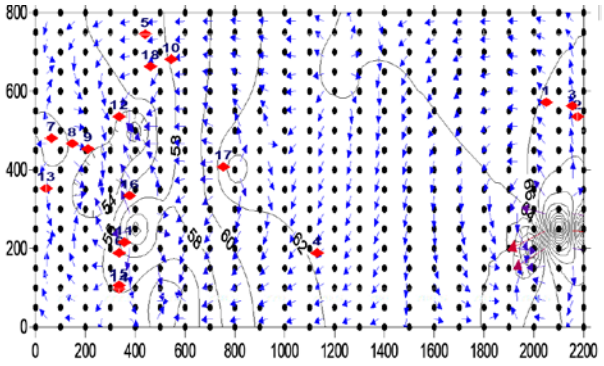

Fig 5: Simulated piezometric map of the Mio-pliocene aquifer of the study area with the direction of flow and position of the nodes and borehole

From The results of the simulation noted that:

- From the Piezometric Chart one can know the hydraulic loads on each node; so we can say that the load in the study area is between Hmin = 42 m and Hmax = 68.5 m
- And from the direction of flow there are localized flow convergences mainly due to excessive pumping. It may be noted that the direction of flow is from East to West.

b. The flow rate

Map shows the flow rate:

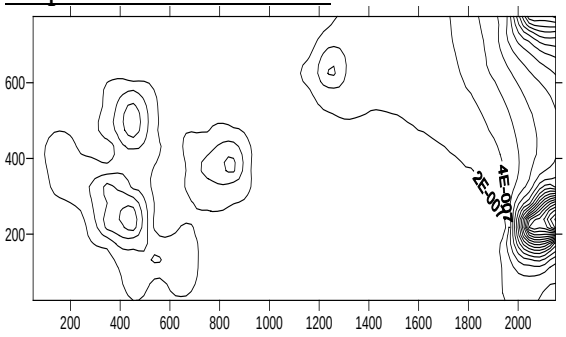

Fig 6: Map of Equal Simulated Flow Rates of the Mio-Pliocene Water of the Study Area

The observation of the figure concerning the groundwater velocity map shows that the flow is relatively uniform and varies in a very small range. It oscillates between 10-5 and 10-8 m / s. This means that in the case of contamination by a pollutant having a fluidity close to water, its displacement will be identical to that of the latter.

IV.POLLUTANT DISPLACEMENT

Map shows pollutant travel time

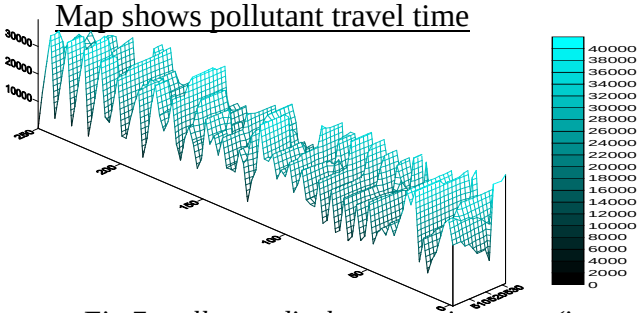

Fig 7: pollutant displacement time map (in perspective) on the study area

Note that the displacement along (Y) is significantly larger than in the direction of (X). What obeys the laws of gravity. The displacement along (X) is weak and closely related to the hydraulic gradient (flow velocity oscillates between 10-5 and 10-8 m / s).

CONCLUSION

Groundwater is often subject to anthropogenic contamination by domestic and industrial wastewater. Pollution is the number one factor causing groundwater degradation.

The mechanisms of pollutant transport in groundwater are governed by numerous phenomena. The main ones are related to the flow of water through the underground porous medium.

Using the finite element method, we have improved the program to make the numerical simulation the results resulting from this simulation allow the tracing of several maps (piezometry, velocity and direction of flow with the displacement of the pollutant).

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