PATTERNS UTILIZED IN THE SIMULATION OF UNDERGROUND WATER FLOW AND THE TRANSPORTATION OF POLLUTANTS IN THE BAHLUI RIVER BASIN

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ABSTRACT. – Patterns utilized in the simulation of underground water flow and the transportation of pollutants in the Bahlui river basin. In the actual context of accelerate economic development, the excessive exploatation of water resources from the underground and the contamination of these with different water pollutants has become a major problem which has enetered the attention of many researchers. For the evaluation of an underground water flow and pollutants transport sistem we have chosen the package of programs MODFLOW which includes a whole series of applications,such as MOC3D, MT3D, MT3DMS, PEST, UCODE, PMPATH, which allow simulations and multiple recalibrations of the capacity of recharging of the aquifers, the flowing of the water towards wells and drillings the transport of a pollutant agent in the underground or the evaluation of the exchange of water between the hidrographic network and aquifers. The sistem targets both the evaluation of the modelation of the underground flowing and the simulation of a punctual polluation of the canvas of groundwater scenery, in the meadow of the river Bahlui, west from Letcani village.

Keywords: MODFLOW package, Bahlui drainage basin, groundwater flow, transport of pollutants

1. INTRODUCTION

In the actual context of accelerate economic development, the excessive exploatation of water resources from the underground and the contamination of these with different water pollutants has become a major problem which has enetered the attention of many researchers. Just as in other domains, the mathematic modelation was utilized, firstly for the understandement of the underground flowing system and secondly, for the prognosis of their evolution (Hiscock, 2006). Continuously developed, these methods offer a powerfull support, efficent and extremely actuall in the study of problems in the underground water flow and of pollutants transport.

In what concerns the implementation (the informatics application) of such numeric models in the solving of problems in underground water flow and and

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pollutants transport in aquifers, at a world wide level there are a series of program packages which deal with the numeric modelation of these parameters such as: FEM, GMS, AQUA3D, PLASM, SUTRA, RNDWALK (Giurmă-Handley, 2006). But, for the evaluation of an underground water flow and pollutants transport sistem we have chosen the package of programs MODFLOW which includes a whole series of applications,such as MOC3D, MT3D, MT3DMS, PEST, UCODE, PMPATH, which allow simulations and multiple recalibrations of the capacity of recharging of the aquifers, the flowing of the water towards wells and drillings, the evalution of the evapotranspiration from the surface of the ground, the transport of a pollutant agent in the underground or the evaluation of the exchange of water between the hidrographic network and aquifers (Fetter, 2001). The sistem targets both the evaluation of the modelation of the underground flowing and the simulation of a punctual pollution of the canvas of groundwater scenery, in the meadow of the river Bahlui, west from Letcani.

2. METODOLOGY

The methodology of application and numeric modelation of simulation of underground water flow assumes the covering of certain work stages (Giurmă-Handley, 2006), realised also in this study and which concern:

- establishing the conceptual model for flowing/transport problems concerning the targeted aquifer;
- the identification of theproper mathematic model for the flowing/transport problems concerning the targeted aquifer (in this case the aplications of the packet of programs MODFLOW);
- establishing the running parameteres of the numeric model;
- exploaiting the model through repeated flowing/transport numeric simulations;
- recalibrating the utilised parameters (through the optimization of the values of certain parameters, the minimization of the deviations between the results of the simulation and the observed values);
- the interpretation of the obtained results and making of the quantitative and qualitative prognosis.

The assimilation of the aquifer with a porous envinroment,with a multilayer structure (2 layers with different hidrofizic charachteristics),in which the flowing process has been considered to be taking place both in an horizontal plan, in the setting of each layer, and in a vertical plan, through interlayer exchanges, infiltration or the ascending movement has also involved calculating the vertical leakance (noted with VCONT) of the aquifer layers. This parameter can be calculated using the formula proposed by Chiang and Kinzelbach (1988):

$$VCONT = \frac{2}{\frac{\Delta V_k}{(K_z)_{j,i,k}} + \frac{\Delta V_{k+1}}{(K_z)_{j,i,k+1}}}$$

where: $(K_z)_{j,i,k}$ and $(K_z)_{j,i,k+1}$ represent the values of hydraulic conductivity of layers k and, respectively, k+1.

In the conditions in which in the meadow of the river Bahlui appears a granulometric differentiation between the superior layer (made of dusty clay) and the inferior one (made of sand and gravel), there is the possibility for a layer of captive water to appear,intermediary with a light semiconfining unit (Martiniuc et.al, 1956). In this situation known in the speciality literature as being a quasi three-dimensional model, because the semicaptive intermediary layer is not included and simulated,the vertical leakance (VCONT) can be calculated after the formula:

$$VCONT = \frac{2}{\frac{\Delta z_u}{(K_z)_u} + \frac{2\Delta z_c}{(K_z)_c} + \frac{\Delta z_L}{(K_z)_L}}$$

where: $(K_z)_u$, $(K_z)_c$, $(K_z)_{j,i,k}$ and $(K_z)_L$ represent the hydraulic conductivities of the superior layer, semicaptive and respectively, the inferior one. The model used for calculation of vertical leakance is shown in Figure 1.

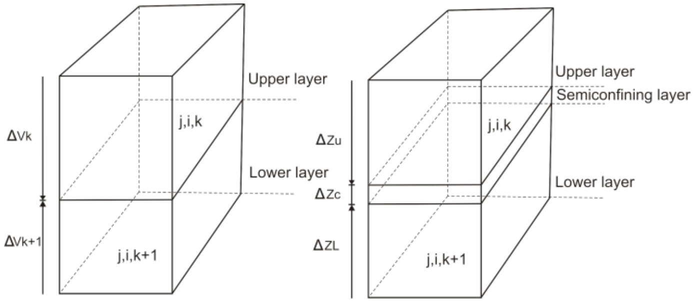

Fig. 1. ***Models caracteristics used for calculation of vertical leakance (VCONT, after Chiang and Kinzelbach, 1988)***

3. HYDROGEOLOGICAL CONDITIONS

The applications have been made for the meadow of the river Bahlu, west from Letcani. We have chosen this sector of meadow because from a hydrogeological point of view it is relatively homogeneous,and the data obtained here can be transferred at the level of the entire meadow of the river Bahlui and his affluents (in the places they meet similar hydrogeological conditions). On the other hand, it is exposed to numerous road and/or railway accidents, with a potential of polluting the canvas of groundwater (the area is situated at the intersection between the Letcani-Botosani railway, with the european road E 583, being extremely „popular” on a local level through the multitude of occured accidents) (Fig.2).

The hydrogeological conditions have been analised based on the information obtained from the Basin Administration for Water Prut-Barlad, at the same time with the making of the construction report of the hydrogeological station

Banu.Besides,the geological and hydrogeological features of the area (concerning the hydrophysiq parameters and the piezometric level of the aquifer from the meadow of the Bahlui) have been processed according to the information obtained about the drillings executed at this station.

Otherwise, from a geological point of view,the meadow of the river Bahlui, from this area, it is characterized by the presence of 2 layers of permeable stones, one made of dusty clay, under the ground level (entic aluviosol, with a thickness of 0,8 m) with a thickness of 5,6-7 m (that thins slightly towards the bed of the Bahlui river) and another made of gravel with boulders and sand, with a thickness of 2,6-3 m (that grows slightly towards the bed of the Bahlui river).

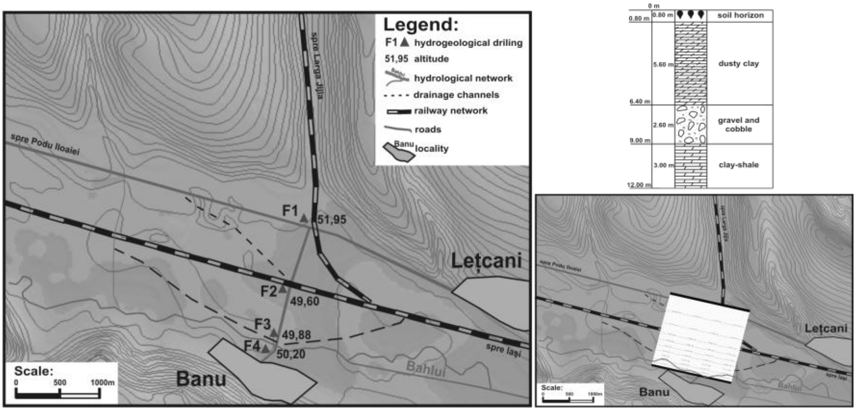

Fig. 2. ***Banu hydrogeological station, the geologic profile of the drilling F1 and the position of the area applied to the numeric modelation of the terrain***

The terrain is utilised as a local field,being crossed by the numerous drainage canals. The space contained between the Iasi-Podul Iloaiei railway, the european road E583 and the Letcani-Botosai railway in the cold season of the year, from the observations made along the last 6 years, is oversaturated with water, at the level of the topographical surface from the end of october until the beginning of april. The situation has been solved only in the last period of time through the construction of a drainage cannal, alongside the Letcani-Botosani railway (on the left side), to evacuate the excess of water resulting after the rains, from that area.

The hydrogeological conditions analised, based on the observation made at the 4 drillings from the hydrogeological station Banu (3 situated on the left side of the Bahlui river, at 1409 m, 596 m and 106 m in front of its minor bed, and one on the right side, which has not been taken in consideration), put in evidence the existance of a relatively constant annual hydrogeological regimen,with maximum values in june and july and minimum in december and january (Fig 3). The depth of the piezometric level rises from the drilling F1 (situated at the biggest distance from the bed of Bahlui) to the drilling F3, as the thickness of the layer of gravel with boulders and sand becomes bigger. The maximum amplitude of variation of the piezometric level in the 3 drillings doesn't exceed 38 cm at drilling F1, 29 cm at drilling F2 and 30 cm at drilling F3, which shows a constancy in the underground flowing regime (Minea, 2009).

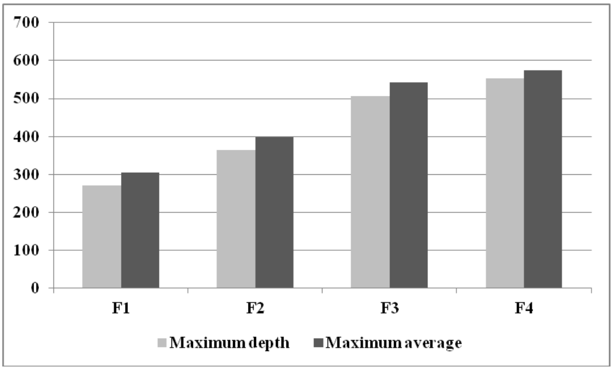

Fig. 3. ***The annual regime of the piezometric level at driling F1,F2 and F3 from the hydrogeological station Banu***

In the bed of the river Bahlu the variations of the water level had had (at the hydrometric station of the Bahlui, situated at 20 km downstream from the analised area, Fig. 5) medium amplitudes of 60 cm and maximum of ofer 2 m, the hydrologic regimen highlighting a maximum in march and april, june and october, when the influence of the river on the water level of the groundwater canvas is bigger, and lower in the summer months (july-august), until september, when the underground contribution in the liquid flow of the river is bigger.

4. APPLICATIONS OF THE MODFLOW PROGRAM IN THE ANALYSIS OF THE UNDERGROUND WATER FLOW AND THE TRANSPORT OF POLLUTANTS IN THE MEADOW OF THE RIVER BAHLUI

For the implementation of the numeric modelation,proposed by the package of programs MODFLOW, to highlight the underground flow and transport of pollutants in the underground, we startes from the next work hypothesis:

- the aquifer envinronment was assimilated to a porous one, with a multilayer structure (2 layers cu different hydrofisic features), in which the flowing process was consideres to be taking place both in a horizontal plan, in each layer, and a vertical plan, through interlayer exchanges, infiltration or ascending movement;
- the hydrogeological conditions have been considered as being of complete saturation of the aquifer layers (as it was noticed for a long perios of the year, from the end of october, until the beginning of april);
- the simulation of the observing points took in account the position od the hydrogeological drillings from the hydrogeological station Banu;

- the pollution situation was realised for a punctul pollution scenery,the transport of the pollutant agent being realised through advection, the flowing being in unique phase.

The analised area contains o surface of 2,25 km^2 , in the layers of the MODFLOW program being divided into 30 lines and columns with a lenght wach of 50 m. As we have mentiones before,the analysis was realised at the level of 2 layers, each with its own specific hydrophysic characteristics. For the first layer were utilised the following hydrophysic parameters: free aquifer layer, with a thickness of the layer of 5 m in the exterior meadow and 3 m in the proximity of the river Bahlui, a high of the hydrostatic level (reported to the base of the aquifer layers) of 9 m for the exterior meadow and of 8 m for the area next to the river Bahlui,a horizontal hydraulic conductiviti of 12 m and a vertical one of 1,2 m (according to the standards proposed by Chiang, Kinzelbach, 1998) and a effective porosity of 20%. The transmissivity was automatically calculated, through multiple recalibrations (using the porgram PEST), the optimum value being of 0,012 m^2/day.

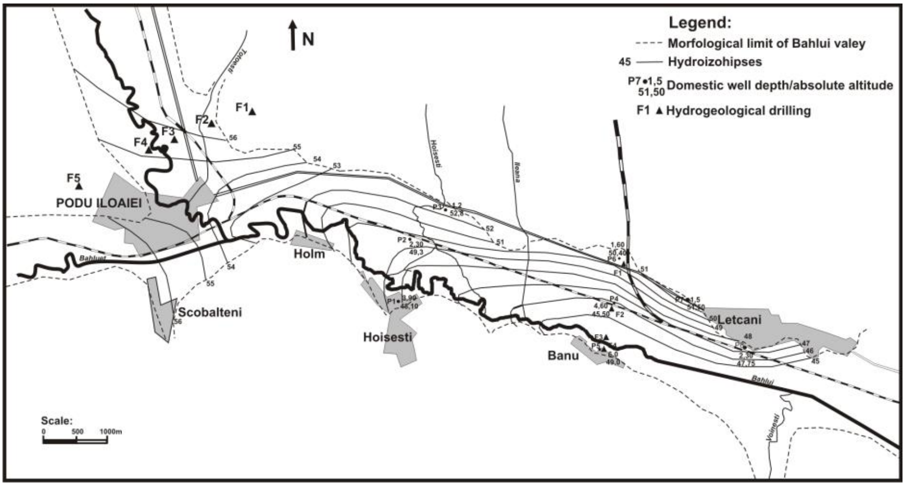

Fig. 4. ***The distribution of the izofreates in the studied area***

The second layer is characterized by the following hydrophysic parameters: free aquifer layer, with a thickness of 4 m, in the exterior meadow and of 5 m in the area next to the river Bahlui, a horizontal hydraulic conductivity of 15 m and a vertical one of 1,5m and an effective porosity of 25%. The transmissivity automatically calculated has the same values as the one calculated for the superior geological layer.

Also,in order to create a corect simulation of the underground flow and the process of transport of pollutants,we simulated the presence of the river Bahlu,the values of the parameters asked by the utilised program being the following:the hydraulic conductance of the river bed (CRIV) being equal qith 1000 m^2/day (appropriate for a hydraulic conductance of the river bed sedimentary deposits, *K*, of 4 m/day, a lenght of the river, for each cell of 50 m, *L*, a width of 15 m, *W*, and a thickness of the silt reported to the layer of waterproff rocks of 3m,*M*,and calculated with the formula CRIV=(K*L*W)/M, after Chiang, Kinzelbach, 1998).

The repeated simulations of the underground flows have highlighted o relatively uniform distribution of the izofreates, a general tendency, just as expected, being of orientation of the flow from the exterior meadow to the minor river bed of Bahlui.

Simulating a situation of pollution was realised in the same hydrogeological conditions, using the same hydrophysic parameters. In natural conditions,the happening of an accident with a polluating effect of the groundwater water canvas, through advection would lead to the polluation of the water of the river Bahlui in about 3-3,5 days, according to the movement or stillnes of the pollutant (Fig. 5).

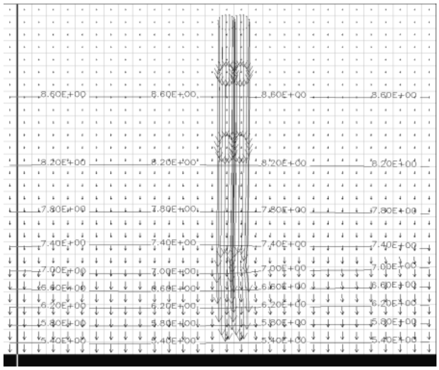

Fig. 5. ***The direction of the pollutant in the case of an accident***

This situation could be fixed,in the case of such an accident with a polluating character, by making an exploitation drilling, positioned on the direction of movement of the pollutant.

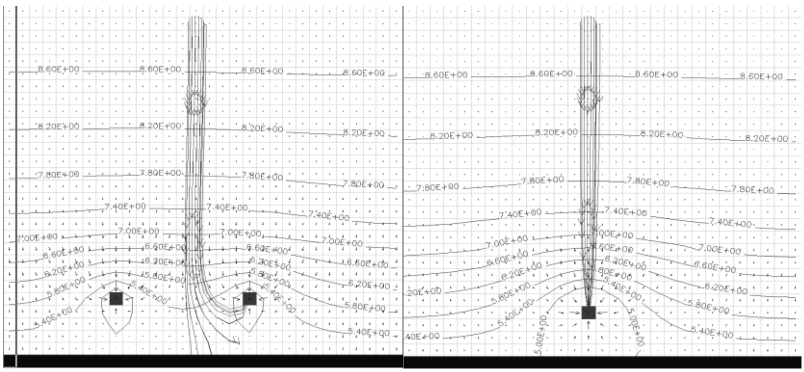

Fig. 6. ***Simulating a situation of pollution and of pumping of the underground water through the different setting of the exploitation drillings***

There were simulated more situation, by positioning some exploitation drillings outside the movement area of the pollutant or on its movement direction, with different levels of water pumping. Thereby, the positiong of underground water exploitation drillings at distances higher than 200 m, doesn't allow pumping the underground water in an efficient way, to diminish the effect of the polluation (Fig. 6, left).

Positioning a drilling on the general direction of flowing of the pollutant allows an efficient pumping, diminishing considerably the effect of the pollutant on the groundwater canvas and a substantial decrease of the quantity of pollutant arrived in the water of the river Bahlui. The pumping rate to alleviate the effect of the pollutant on the water of the river Bahlui, was calculated at 200 m^3/day.

5. CONCLUSIONS

The simulation of a undergrounf water flow and pollutants transport scenery through the application of the package of programs proposed by MODFLOW, in the meadow of the river Bahlui, west from Letcani, allows the obtaining of results that show that such a situation that can happedn at any moment involves o whole series of negative effects on the envinronment. The inherent link, at the level of the relationships underground water-hydrographic network, highlighted by the tendency lines of the underground flow which allow us to evaluate a real situation of pollution in the case if an accident. There have been simulated a number of situations, by placing exploitation drillings outside the movement area of the pollutant or on its movement direction, with different water pumping levels, obtaining a series of values of the pumping rate (over 200 m^3/day) to avoid polluating the water of the river Bahlui through underground infiltrations.

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