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REDUCING THE EFFECT OF POLLUTION IN EXPLOITED AQUIFERS BY TECHNICAL SOLUTIONS

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Abstract: It is known the fact that water supply from groundwater sources has several advances in spite of high production costs. It is also obvious, in the last decades, than the most important threat against groundwater sources is the pollution. Efficient management of the groundwater sources implies knowing the flow condition in a continuously evolution and technical solutions token in case of an accidental pollution. Nowadays, the most common way to know the groundwater flow condition is the numerical modeling because of it advantages. Necessary technical solutions token for groundwater protection management must be verified in advance because of the economic costs and because the fact than the numerical modeling is an appropriate one. The present paper will show the numerical modeling of the technical solutions token for groundwater protection of the accidental pollution of an exploited aquifer case study.

Keywords: exploited aquifers, groundwater pollution, numerical modeling, technical protection measures

1. INTRODUCTION

As an European country, Romania must improve his infrastructure, in this specific case, the water supply systems for small or large communities. The existent water supply systems in the urban areas are not anymore up-to-date, the used technologies in the past must be the subject of rehabilitation at the demands of the 21st century. It's true the fact that the industry, at the national level, registered in the last two decades a substantially regress, at the same time due to the water flow metering the drinking water consumption decreased too. From the quality point of view, in the drinking water supply systems located in urban centers the groundwater sources is selected. Among the disadvantages of the groundwater sources can be mentioned the high operation costs and the threat of the contamination from various sources. Specific regulations were adopted also in Romania, in order to establish specific rules and restricted activities in the perimeters close to groundwater sources by establishing the sanitary protection zones [1]. Because of its specific particularities consisting in flow conditions (low flow gradients, small flow velocities, water flow in the underground conditions), establishing the sanitary protection zones around groundwater sources does not solve at all the pollution problem.

2. MODEL PRESENTATION

A confined aquifer of 50 meters thickness is considered. The boundary limits of the model are represented by two rivers (Figure 1), River 1 on the western side and River 2 on the eastern side. From the modeling point of view the rivers are considered as fixed boundaries with water levels of their natural slope (about 0.1%). Behind the rivers, the remaining area can be considered as inactive zone. Because the fact that the aquifer is considered as exploited, three fully penetrating extracting wells are considered wit rate of 10 l/s each. The flow rates of the wells were established by taking into consideration the aquifer thickness, existing permeability of the aquifer and the maximum admitted velocity at the entrance in the well. The whole model area closed by two rivers can be considered as a rectangle of 750 meters length and 600 meters width. For a such case study the cell size was established as quadrant shape with extension of 15x15 meters. It is known than the model has the advantage of the mesh refining in the areas of interest like wells or pollution source. For instance, in the area of pollution source and wells location the mesh size were refined at half extensions.

In the first stage the model was completed with the establishing of the pollution source location. Since this accidental pollution can occur on the supposed high way, the location was set on certain position as shown in the Figure 1.

In the next steps containing technical measures to reduce the effects of the pollution implies the same thickness of the aquifer is divided in multiple layers, depending on the type of technical protection measures like retaining walls or absorbing wells. Since the aquifer thickness is about 50 meters two different layers were established, 25 meters thickness each.depth.

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The same problems occur with the wells, where the total flow rate of 10 liters per second of each well is distributed in proportion on the existing layers. The three extraction wells are located in the Western part of the model having the X and Y coordinates as (127,297), (219,414) and (327,522) meters, the origin of the coordinate system being placed on the upper left corner of the model.

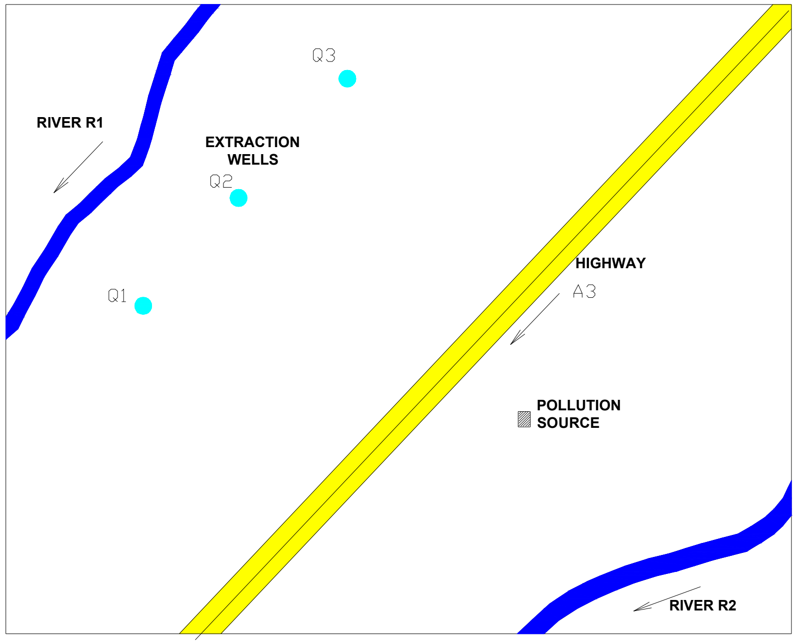

Figure 1. General scheme of the model

The present model was created by using PMWIN general model [2] because of its popularity and easy possibilities offered for users.

In order to estimate the effect of the technical measures against the pollution three observations wells were disposed along the pollutant flume. The problem is to establish the properly location of those wells. An appropriate solution is the PMPATH module of the model, which ensure the path of the moving pollutant particles.

3.WORKING VARIANTS

Three different working variants are used. In the first variant V1_INIT the model is fit with boundary conditions, the values for transmisivity and porosity, the extraction wells with fixed flow discharge values, the observation wells and the location of pollution source having specific boundary conditions for transport model MT3D.

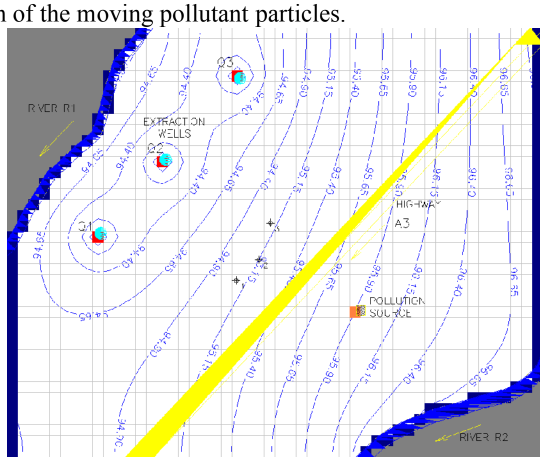

Fig. 2 Contour lines in variant V1_INIT

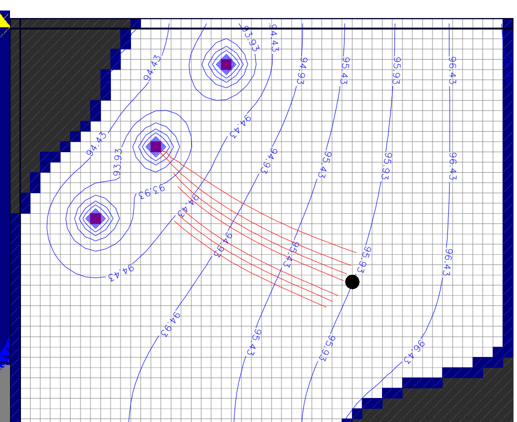

Fig. Path lines from pollution source variant V1_INIT

In the second variant V2-WALL, technical protection measures against pollution is considered like retaining wall located on the path of the pollutant. In this location, from modeling point of view, the hydraulic conductivity of the cells that are subject of the wall is null. Also, it must be specified than the retaining wall is present only in the first layer. Also, in this variant the propagation of the pollutant is observed in these three observation wells.

In the third variant V3_WELL, technical protection measures against pollution is considered an extraction well, with small flow discharge, located in the path flow, before the middle initially extraction well. The same values for concentrations are collected in the observation wells (boreholes) necessary for future comparisons.

4.OBTAINED RESULTS

In all working variants the stress period are represented by eight steps of one year, that are divided automatically in smaller steps by the MODFLOW model. In the graphically representation of the concentrations the time can be shown in other time units as, for instance, seconds. Once the model is completed with necessary input data and running with MODFLOW the contour lines for steady state in the first variant V1_INIT were obtained (Fig.2). By using the PMPATH module the flow paths in the first variant are presented in the Fig.3. The flow path are necessary for the next variants in order the establish the properly location of the technical protection measures as retaining walls (barrier) or extracting well with considerable reduced flow discharge. The concentrations recorded in the observations wells for the first variant V1_INIT are presented in the Fig.4., and the range of the pollutant flume in the same variant after four years transport period in the Fig.5.

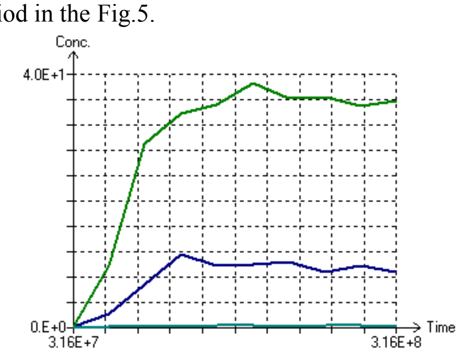

Fig.4. V1_INIT. Recorded concentrations in the observation wells

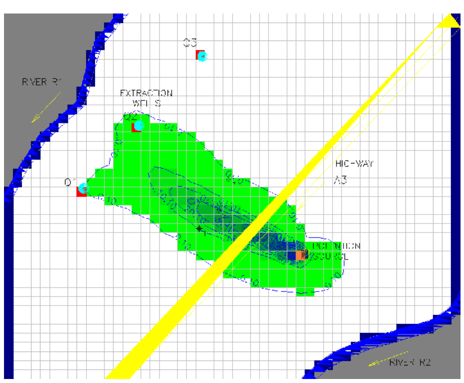

Fig.5. V1_INIT-Polluted range after four years

For the second variant V2-WALL based on the paths obtained in the first variant a barrier is disposed in the way of the pollutant. From technical point of view this measure can be performed by a bentonite or clay wall having the hydraulic conductivity very low (almost impervious). From numerical modeling point of view he corresponding cells have the conductivity very small values or can be set as inactive cells. In the present case study the last option is used, affecting the cells only for the first layer, that being considered technically as horse sense.

Contour lines and flow path, including the location of the retaining wall are presented in the Fig. 6.

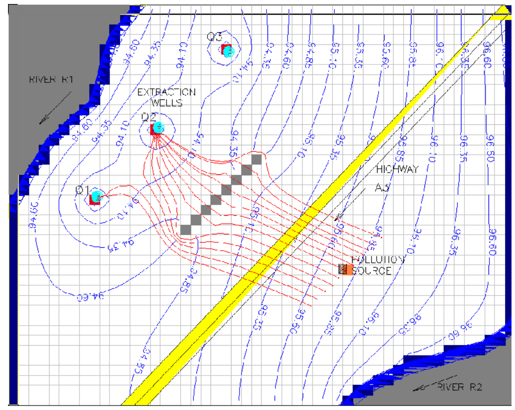

Fig.6 V2_WALL. Contour lines and path lines

It can observed the effect of the retaining by the changed shape of the contour lines and the curved shape of the path lines. By running the transport module of the model with the same transport parameters like in the first variant the concentrations recorded in the observation wells are presented in the Fig.7., and the polluted range in Fig.8.

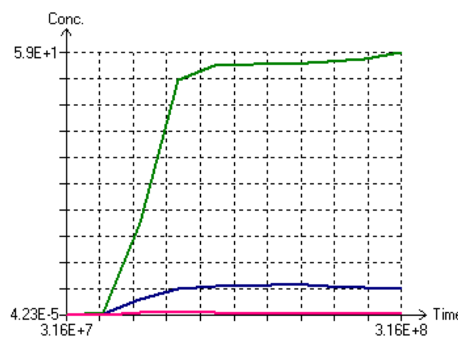

Fig.7.V2_WALL. Recorded concentrations in the observation wells

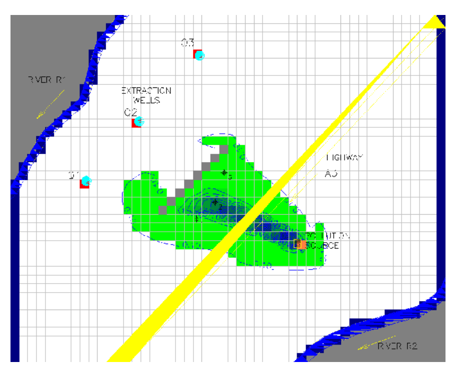

Fig.8. V2_WALL-Polluted range after four years

In the third variant V3_WELL as the protection technical measure against pollution an extraction well is disposed also, on the path of the pollution, that means a location between the pollution source and the extraction wells. The precise location is unknown, multiple solution can be taken into consideration and after running the model the appropriate one is chosen.. Also the subject of the discussion can be the extracted water flow discharge. It must be mentioned the fact than the polluted water must be cleaned by an appropriate technology with corresponding costs.

The well is considered located between the A3 highway and the extraction wells, with one liter per second flow discharge, only in the first layer of the model.

In the same manner from previous variant the results are presented in Fig. 9 and Fig.10.

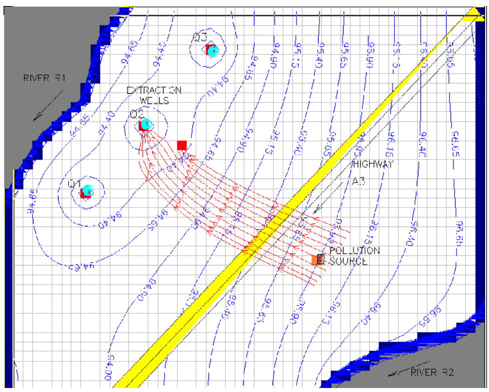

Fig.9 V3_WELL. Contour lines and path lines

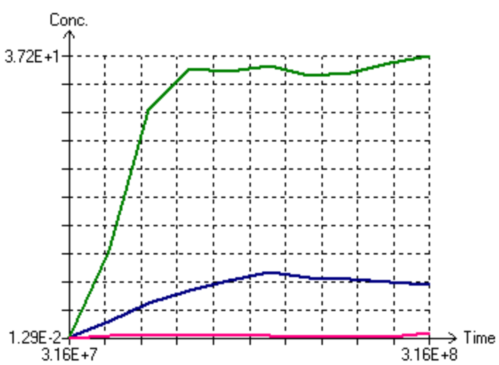

Fig.10.V3_WELL. Recorded concentrations in the observation wells

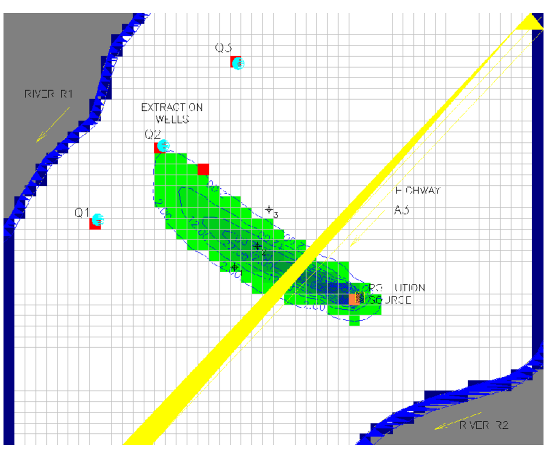

Fig.11.V3_WELL. Polluted range after four years

5. DISCUSIONS. CONCLUSIONS

Establishing sanitary protection zones around pumping wells provided by the actual Romanian normative [1] is a necessary measure but not enough. For such water supply systems adequate models are necessary in order to protect the water sources against the accidental pollution sources. The most appropriate models are the numerical models [2], [2], which offer multiple scenarios consisting flow conditions and transport parameters. The presented case study is general one, even simplistic, but offering some ideas in order to protect the water supply systems against the accidental pollution. For the presented model only two layers were considered, that implying the technical measures as retaining wall or interceptive well to be located in the first layer. For a specific and more complex case study a supplementary number of layers can be added, so that the optimal solution arises by economic reasons.

In the MT3D module of the general MODFLOW model the boundary conditions for the pollution source is considered as 100 concentration on fixed concentration cell, dispersion and convection. No other chemical reactions have taken into consideration, that depending on the specific case study and type of the pollutant. More specific aspects regarding the modeling technique [6],[7], distinctive considerations about numerical dispersion and the ways to ovoid it were ignored.

Also for groundwater supply systems is necessary to dispose in the surrounding field physical observation wells that being useful to calibrate the model from flow and pollutant transport point of view.

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