GROUNDWATER 3D MODELLING

Bodog Marinela*, Todea Adela Olimpia *

*University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048, Oradea, Romania, e-mail: marinelabodog@gmail.com; adela_venter@yahoo.ro

Abstract

Numerical models for determining the level and shape of the groundwater are able to solve large and complex groundwater problems, which vary widely in size, nature and real life. With the appearances of different programs and software any modeling study can be done if some information is known such as: spatial heterogeneities, anisotropy and soil conductivity. However, the success of any modeling study depends to a large extent on the availability and accuracy of the measured / recorded data required for that study. Identifying the data needs of a particular modeling study and collecting / monitoring the necessary data are an integral part of any modeling exercise. This paper presents the process of three-dimensional modeling of groundwater in an experimental field in Ciumeghiu Area, Bihor County.

Key words: software, water drainage, groundwater, numerical model, calibration.

INTRODUCTION

The location, timing, and amplification of the hydrological accountability of natural or man-made events depend on a wide range of factors - for example, nature and weather events impact on groundwater, their properties, and the connections they make with rivers and oceans in which they shed. Groundwater models offer an additional perspective on the complex behavior of irrigation and drainage systems when they are properly designed. (Hanson and Ayars, 2002)

Groundwater management and policy decisions must be based on knowing the past and current behavior of the groundwater system, the likely response to future changes, and understanding the uncertainty in these responses. (Kumar, 2014)

Groundwater systems are affected by natural processes and human activity and require continuous and directed management to maintain the status of groundwater resources within acceptable limits, while providing the desired economic and social benefits. (Merz, 2012)

A groundwater model is any method of calculation that represents an approximation of a groundwater system. (Man et al, 2010) While groundwater models are, by definition, a simplification of a more complex reality, they have proven to be useful tools over several decades for addressing a range of groundwater issues and supporting the process decision. (Sabău et al, 2007)

The model of the groundwater flow in the Ciumeghiu area represents the three hydrogeological layers and the paleontological sediments encountered during the drilling. At the bottom of the channel in the upper layer the horizons were determined: superficial sandy clay and sand, in both the aquifer being present.

MATERIAL AND METHOD

The buried paleontological aquifer is treated as a higher hydraulic conductivity layer embedded in the resistant rock. The resistant rock represents a regional aquifer with a lower conductivity. The filling of the groundwater layer is done through the upper part by infiltration. The basic altitude of this aquifer is set to 120 m and to a thickness of 30 m. The hydraulic conductivities of resistant rock and paleontological aquifers are 0.03 m/day and 0.46 m/day.

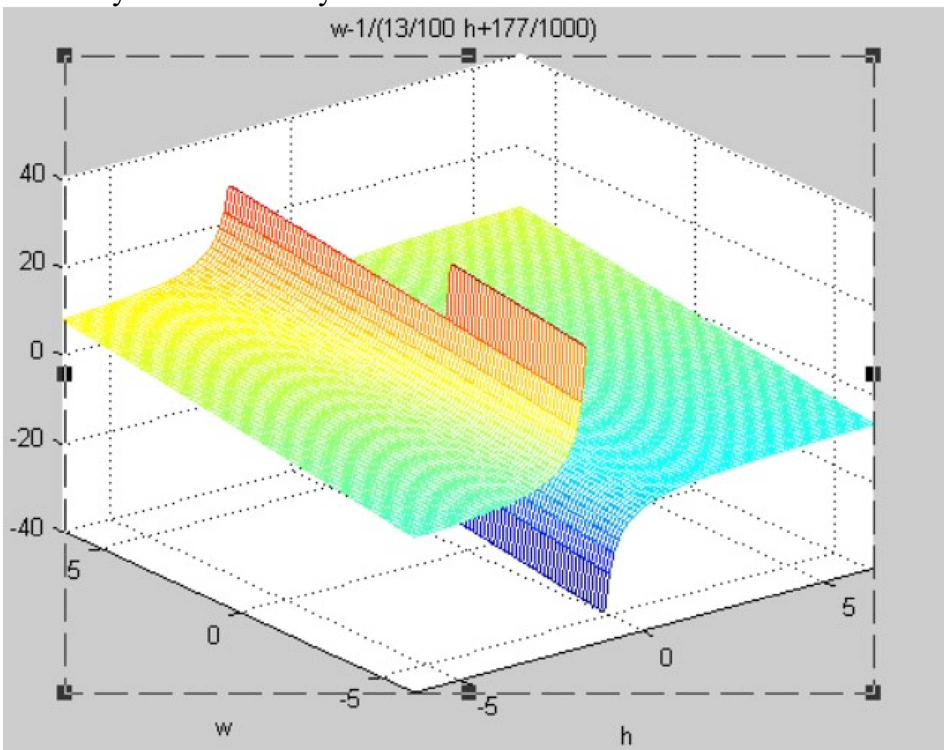

Fig. 1 Tridimensional view of the aquifer in Ciumeghiu area

From the pumping test data it was observed that the aquifer layer separates deep and shallow aquifers with the vertical hydraulic resistance resulting in a semi-restricted condition for the deep aquifer. (Bodog M. et al, 2009) The aquifer has a thickness of 11 m over the entire model range with a hydraulic conductivity of 0.005 m/day.

The model is constructed using the MATLAB program, and the aquifers are treated as extending over the entire domain of the model (Fig. 1). The only boundary imposed on the system is the general one, that is to say, raising groundwater levels (0.8 m below the underground surface) at the discharge point in the northwest corner.

The model uses filling, evapotranspiration and groundwater flow to maintain water balance for inter-aquifer flow. This allows the model to respond appropriately to inter-aquifer demands, such as pumping, imposed by the water balance in the system.

The model covers 5000 m X 6000 m of the Ciumeghiu field. The borehole is located in the middle of the model range, so that the effects of pumping can be detected along the paleontological layer in equal measures. The model domain incorporates all the observation wells on the site. Each cell has 50 m^2, resulting in 120 rows and 100 columns. The topographic data were taken from the digital elevation maps of the basin.

RESULTS AND DISCUSSION

In order to estimate the water filling rates of the groundwater in the Corn Field of Ciumeghiu, different methods were used. The hydrographic analyzes of the last 20 years suggest that the rate of filling of the maize field after cleaning is 5-12% of the annual precipitation, depending on the climate and the location of the river basin.

In this study, recharge rates were calculated using the analysis of trends in the controlled aquifer (non-pumping aquifer), the data being then extrapolated to each soil based on its hydrogeological properties and vegetation cover type.

A recent study by the Bihor Agricultural Directorate indicates that the groundwater level in Ciumeghiu increases by 10 cm per year. The groundwater level observed at 900 m away from the well, increased by 10 cm in 2014-2016 confirming the upward trend. In addition, the drilling carried out by private supply located approximately 2 km to the north, in an experimental field, also registered increases of 10-20 cm per year during the period 2012-2014.

The average annual increase of the groundwater level (15 cm) simply refills the groundwater deposits. Despite the episodic events of winter rainfall in November 2016 and the drought later that year, data from this area indicate that in 2016 only 10 cm were added to the groundwater deposit (Fig. 2). Most of the groundwater recharge was discharged into stream beds as a base stream.

The groundwater filling rate in 2016, estimated in table 1 below, is higher than the average and represents about 31% of the annual rainfall.

Two thirds of this filling was obtained through the event with episodic precipitation and a few other small events between January and February 2016.

Based on the numbers in table 1, a daily transient recharge model was constructed as an input for the MATLAB program and the results were compared with rates from hydrographic analysis from other parts of the maize field. The average recharge calculated from the groundwater represents 12% of the average rainfall in the area - in accordance with the recharge values for other parts of the maize field.

Although there was a significant amount of filling water, only a small volume was added to the underground storage. Between December 2015 and December 2016, so over a period of one year, watering increased only 70 mm - the equivalent of adding 7 mm to the recharge in 2016. In other words, for every mm of recharge added to storage a little over 17 mm they were downloading from the field.

Table 1

Groundwater level recharge in 2016

Filling mode	Rain fall (mm)	Increasing groundwater level (mm)	Filling (mm)	Filling rate (% rainfall)	Decreasing (mm)	Final Fill (mm)
Spring-episodic	156,4	430	35	22	25	10
Autumn-winter	195	850	71	35	61	10
Total (annual)	**351,4**	**1280**	**106**	**30,65**	**86**	**10**

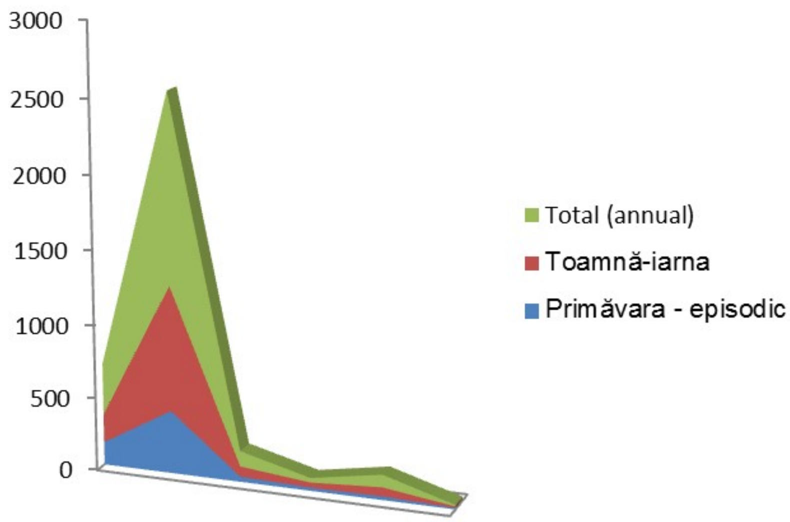

Fig. 2 Representative image of the rainfall

The water levels in the shallow and deep aquifers were mainly calibrated by adjusting the vertical and horizontal hydraulic input conductivities for evapotranspiration and the extinction depth from which evaporation occurs in the surface aquifer. The equilibrium model was calibrated using the ends observed in the observation bores.

The observed depths versus the models up to watering (Fig.3) suggest that the standard error of the estimates is 0.041 m, with a correlation coefficient of 0.962. The maximum and minimum differences of the observed data with respect to the models are 0.2 m and 0.009 m respectively.

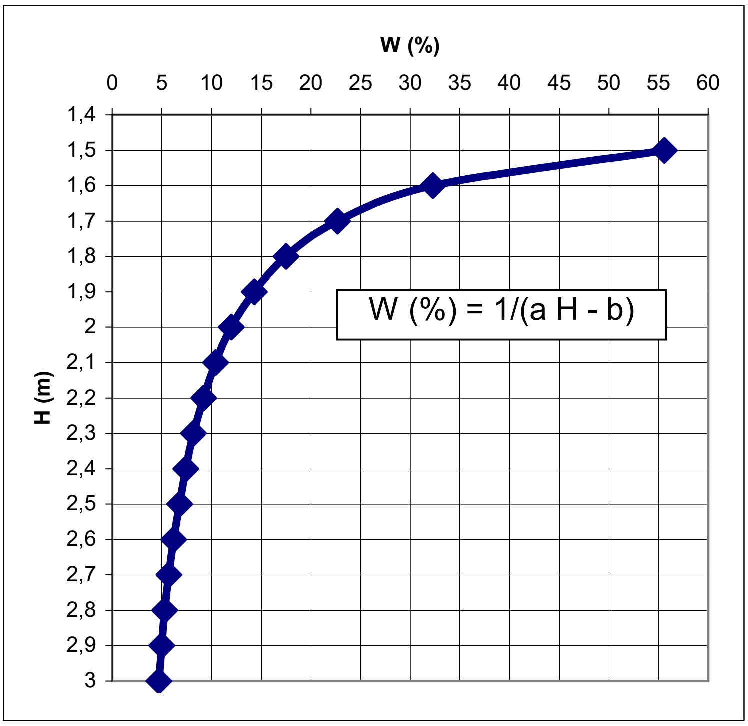

Fig.3 – The correlation between the phreatic level (H) and the medium humidity

The riverbed is about 1.5 m below the main floor of the valley, so the watering is closer to the surface. These results were confirmed by the measured data from the monitoring bore before pumping. The discharge of saline water from the deep and shallow aquifers along the waterway is confirmed by salinity measurements of the surface flow on the experimental field.

CONCLUSIONS

The determined model responds to recharge events faster than those observed on the ground. For example, the calculated aquifer head rises immediately after rain events, while recordings show a delay of approximately two weeks.

The explanation for these differences lies in the fact that the model domain is treated as being uniform in terms of hydraulic properties, that is, a permanent water regime has been considered, and the aquifer layers have identical thicknesses throughout the model domain. Despite these shortcomings, it is remarkable how the model responds accurately to changes in water balance for each stress period, despite the simple conceptualization of the study area.

The transitory model can be run to simulate the impact of different climatic scenarios (such as decreased precipitation and higher episodic recharge), pump capacity, pumping and to estimate the lateral extension / narrowing of the water. In addition, this study has shown that a simple simulation of a large agricultural area can be performed to build numerical models that achieve similar results with long-term field measurements.

REFERENCES

1. Bodog M. et al, 2009, Some aspects regarding the usage of the program DrenVSubIR to the projection of the drainage on the heavy soils with a high content of clay, Revista Lucrări științifice. Seria Agronomie, Editura "Ion Ionescu de la Brad", Iași, 52(1): 455-460, ISSN 1454-7414, http://www.revagrois.ro/PDF/2009_1_457.pdf
2. David I., 1996, Hidraulică, Vol. I şi II, Institutul Politehnic „Traian Vuia", Timişoara
3. Domuţa C., Sabău N.C., Tuşa C., Kleps Cr., 2000, Irigarea culturilor, Ed. Universităţii din Oradea.
4. Hanson și Ayars, 2002, Strategies for reducing subsurface drainage in irrigated agriculture through improved irrigation, Irrigation and Drainage Systems 16: 261–277
5. Kumar, C. P., 2014, "Groundwater Data Requirement and Analysis", Scientific Essay, ISBN (eBook): 978-3-656-75554-8, GRIN Publishing GmbH, Munich, Germany
6. Merz, S.K. and National Centre for Groundwater Research and Training, 2012, "Australian Groundwater Modelling Guidelines", Waterlines Report Series No. 82,
7. Murray–Darling Basin Commission, 2001, "Groundwater Flow Modelling Guideline", Report prepared by Aquaterra
8. T.E. Man, N.C. Sabău, Cîmpan Gabriela, Bodog Marinela, 2010, Hidroamelioraţii, Editura Aprilia Print Timisoara,
9. Sabău N.C. et al, 2007, Irrigation Influence On Water Consumption, Yield And Water Use Efficiency In Alfalfa In The Crişurilor Plain, Analele Universităţii din Oradea, Fascicula Protecţia Mediului, Vol. XVII (45-52)