UTILIZATION OF THE FREEWAT PLATFORM - FREE OPEN-SOURCE TOOL FOR GROUNDWATER RESOURCE MANAGEMENT, WITHIN PILOT AREA BANAT PLAIN

Dr.eng.Ada PANDELE
Dr.eng. Irina SERPESCU
Dr. eng. Emil RADU,
Eng. Marin MINCIUNA

National Institute of Hydrology and Water Management, **Romania**

ABSTRACT

FREEWAT Platform is a free open-source tool for water resource management created within the frame of HORIZON 2020 project ***FREE and open source software tools for WATer resource management,*** financed by the EU Commission. The project's Consortium is constituted by partners from various water sectors from 10 EU countries, plus Turkey and Ukraine and large stakeholders' involvement is thought to guarantee results in its dissemination and exploitation.

The FREEWAT platform is an integrated modelling environment for the simulation of water quantity and quality in surface and groundwater, with an integrated water management and planning module. The core of the platform is represented by a SID&GRID framework, a GIS integrated physically-based distributed numerical hydrological model based on a modified version of MODFLOW 2005 and transposed to the QGIS desktop.

One of the specific objective of the project is to support the FREEWAT platform utilization in an innovative participatory approach gathering technical staff and relevant stakeholders (policy and decision makers) in designing scenarios for the proper application of water policies. Through creating a common environment among water research/professionals, policy makers and implementers, FREEWAT project main impact will be on enhancing science- and participatory approach and evidence-based decision making in water resource management, hence producing relevant and appropriate outcomes for policy implementation.

The article present utilization of the FREEWAT platform to create a model for a Romanian pilot area – Banat Plain – and how the model can be used in order to improve the water resource management activities for the local water authorities and other local stakeholders. There will be presented the data used to develop the hydrogeologic conceptual model of the study area, the FREEWAT platform's modules used to create, and running and calibrate the model, the model results – quantitative status assessment and the scenarios simulated for improvement of the water management.

Keywords: integrated water management, open source software, public domain GIS, integrated modelling environment

INTRODUCTION

FREEWAT is a HORIZON 2020 project financed by the EU Commission under the call WATER INNOVATION: BOOSTING ITS VALUE FOR EUROPE. FREEWAT aims at promoting water resource management by simplifying the application of the Water Framework Directive and other EU water related Directives through the use of state-of-art simulation tools. The main result of FREEWAT will be an open source and public domain GIS integrated modelling environment for the simulation of water quantity and quality in surface water and groundwater with an integrated water management and planning module. [5]

The pilot site **Banat Plain** is the Romanian case study of FREEWAT project. The Banat Plain area is possible to be problematic in terms of public water supply for the future, in condition of climate changes, so it is important to estimate the groundwater resources availability for the shallow aquifer, which can be a supplementary water source for the area. In present, the shallow aquifer, which is in good status from quantitative point of view, is used like drinking water supply source only for domestic use and in industrial and agricultural activities.

SHORT DESCRIPTION OF THE FREEWAT PLATFORM

The FREEWAT platform aims to simplify the management of the complex process that involves implementing the Water Framework Directive and other water policies of the European Union. It appears due to the need to move towards a faster pace in achieving the goals of the European water directives. FREEWAT could help experts to face challenges such as water security and food security, water pollution, increased water demand, as well as climate variability and its associated risks.

The overall approach of the FREEWAT project includes coordination of the previous EU and national funded research to integrate existing selected software modules for water management in a single open-source and public domain model-based GIS integrated platform – called FREEWAT PLATFORM, building capacity around the platform by means of dedicated trainings and case studies implementation, supporting the FREEWAT application in an innovative participatory approach that gathers technical staff and relevant stakeholders.

FREEWAT platform is in fact a QGIS plug-in, linking this GIS with the hydrological model MODFLOW, allowing the simulation of the whole hydrological cycle and integrates the following tools:

A whole module for calibration, uncertainty and sensitivity analysis

- A module for solute transport in unsaturated zone
- A dedicated module for water management and planning that will help to manage and aggregate all distributed data coming from the simulation scenarios
- A module for crop growth and water requirements in agriculture
- Tools for dealing with groundwater quality issues
- Tools for analysis, interpretation and visualisation of hydrogeological data.

Input and output data are managed through a SpatiaLite Data Base Management System and the platform integrates one of the latest and most complete version, to date, of MODFLOW, named MODFLOW-OWHM (One Water Hydrologic Flow Model).[3]

UTILISATION OF FREEWAT PLATFORM – CASE STUDY BANAT PLAIN

Besides coding the QGIS FREEWAT plug-in, the project comprises 14 case studies, to be conducted in several European and non-European countries. One of these case studies was conducted at Banat plain, Romania. This case study aims to evaluate groundwater resources in the phreatic aquifer and their availability for any future necessities, taking into consideration the Programs of Measures developed within the RBMP and based on the area socio-economic development.

Banat Plain description

Banat Plain case study cover an area of approximately 1200 km^2 and is situated in western part of Romania, between Mures and Timis rivers (Figure 1).

From geomorphological point of view Banat Plain is a recent subsidence alluvial plain with shallow valleys (2-4 m), strong meanders, deserted floodplains and buried terraces partially covered with proluvial - deluvial deposits. [1]

From geological point of view, the studied area belongs to the South-East part of the Pannonian Basin. Its foundation is composed of Higher Precambrian crystalline. Over these strata are disposed discordant sedimentary deposits belonging to Cretaceous (Senonian), Neozoic and Quaternary. [2]

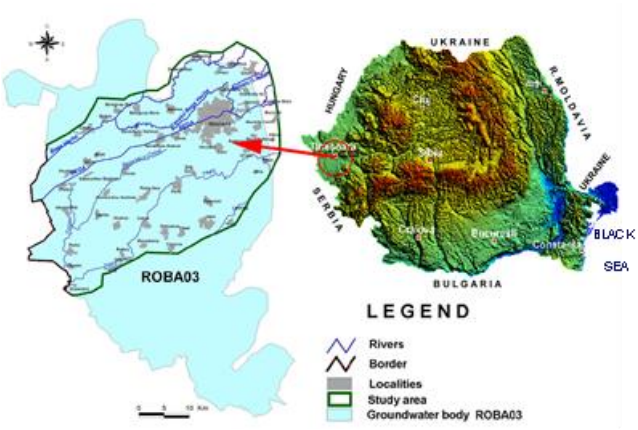


Figure 1- Study area location

The study objective was the shallow aquifer located in floodplain and terrace alluvial deposits (Upper Pleistocene – Holocene age) and the information concerning this aquifer come from the observation wells belonging to the National Hydrogeological Network. Based on these wells were developed hydrogeologycal cross – sections who provided information concerning spatial development of the alluvial deposits (Figures 2 – 4).

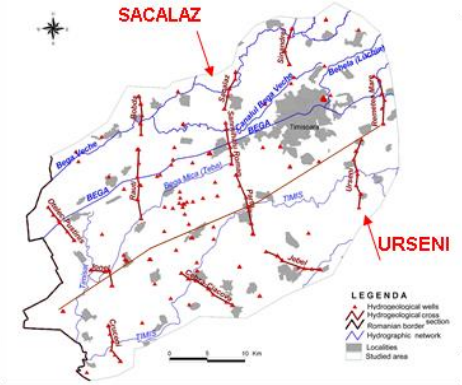


Figure 2 – Hydrogeological cross section location

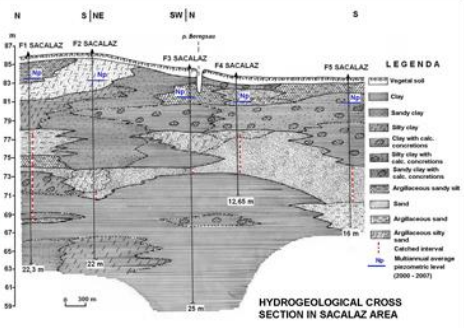


Figure 3 – Lithofacies variation of the alluvial – prolluvial deposits in the study area (Sacalaz area)

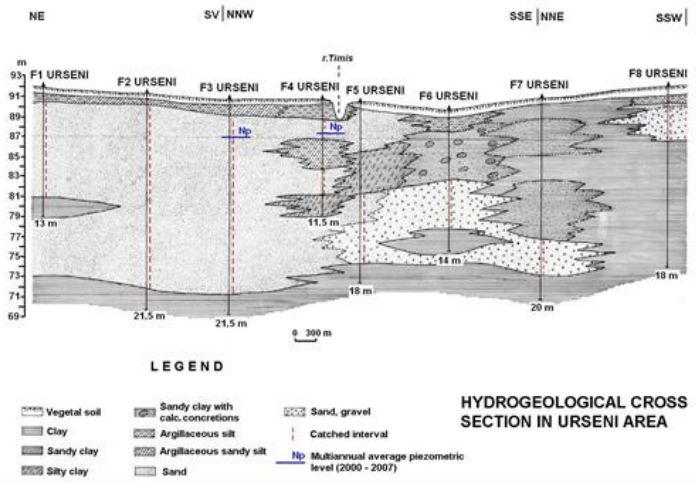


Figure 4 - Hydrogeological cross-section in the South East part of the study area (Urseni)

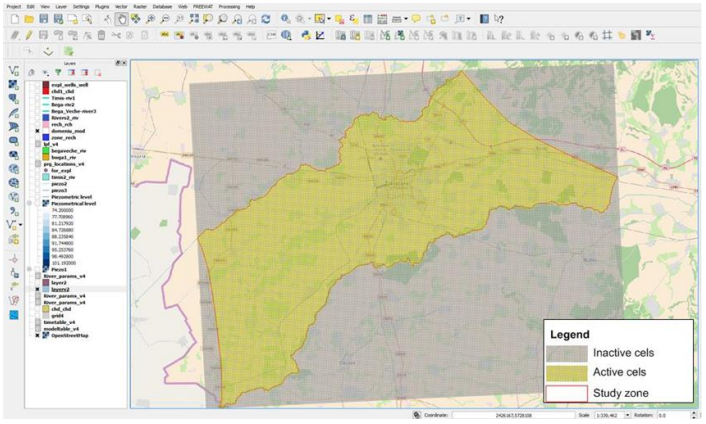
The analysis of geological cross-sections shows that the deposits, from lithological point of view, are made by argillaceous +/- silty sands, sands with gravels that alternate with sandy +/- silty clays, argillaceous +/- sandy silts. The granulometry decreases in the study area from North – East to South - West, as the transport potential of the surface water flow decreases. The bottom of the aquifer is around 15 m in floodplain and terrace areas and around 30 m in interfluves.

Conceptual model and input data

Prior to the building a model itself, general concept of water movement and water balance in river basin area should be established, based on available data and knowledge. Thus it was established that the aquifer is unconfined and the average multiannual hydrostatic level is at depths of 1 – 5 m in the floodplain and terrace areas and 2 – 7 m in interfluves areas. The saturated zone thicknesses ranging between 7 and 37 m and hydraulic conductivity values ranging between 10 and 30 m / day. The study zone is crossed by three rivers from North – East to South – West: Timis River, Bega Veche River and Bega Channel. The aquifer recharge is made mainly from precipitations and the aquifer discharged by 32 pumping wells. The groundwater resources are evaluated on 45,60% from entire available water resources. Finally, based on the existing data, the aquifer was conceptualized as ***one-layer unconfined aquifer, connected directly to the three rivers and recharged mainly by precipitation.***

Model calibration and running scenarios with FREEWAT Platform

First step in modelling was creation of the model grid, composed 51084 cells with dimensions of 250m x 250m of which only 19705 were active (Figure 5).



A one-layer groundwater flow model has been used to evaluate the groundwater resource for the shallow aquifer. The model layer 1 (shallow aquifer) was defined as unconfined and the wetting option was activated. The average thickness of the modeled layer is about 20 m.

Figure 5 – Horizontal discretization of the modeled domain

The model set-up was realized using data regarding the piezometric levels, rivers trajectories and relatiosn with the aquifer, aquifer recharge from precipitation, aquifer discharge by exploitation wells. (Figure 6).

From temporal discretization point of view the model was run in steady-state with 1 stress period.

The main initial condition were represented by the imput data: initial piezometric heads map, hydraulic conductivity, abstraction values from wells, surface water levels, porosity, precipitations.

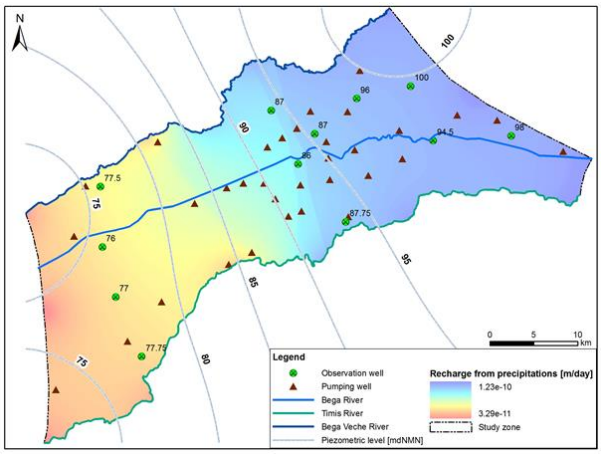


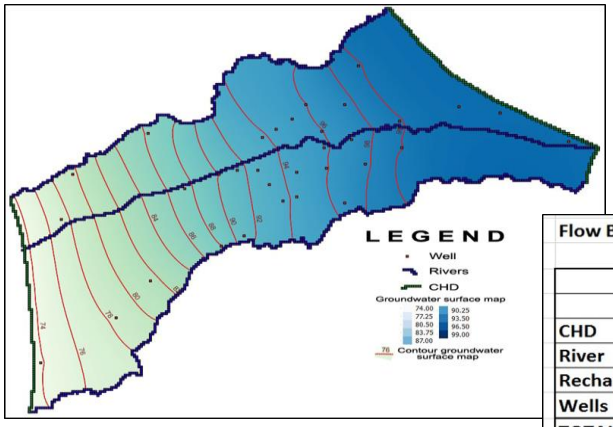
Figure 6 – Hydrodynamic setup

Input data files were created using QGIS facilities, which proved the efficiency of modelling software integration within the GIS.

There were established boundary conditions and initial data used for building the model simulating the steady-state condition.

Model calibration was done manually adjusting the parameters, consisted of hydrogeologic parameters - hydraulic conductivity (3 zones were created with the conductivity value at between 3 and 20 m / day) and river conductance, until a best possible match between measured and calculated piezometric values in the model.

The calibration was performed in steady-state conditions using mean data of piezometric heads of phreatic aquifer the 2005 year. Differences from the comparison between the two set of values of piezometric levels result in a calculation error flow model (in this case 0.50 m).



Flow Budget

	actual	
	IN (m/s)	*OUT (m/s)*
CHD	0	-0.04146
River	0.00009	-0.03801
Recharge	0.10910	
Wells		-0.02970
TOTAL	0.10919	-0.10917

Figure 7 – Calibrated piezometric map and flow budget after calibration

According to the mathematical flow model developed, the aquifer is recharged primarily by percolation of precipitation (about 109 l / sec). Following exchanges with the three rivers flow, on 224 Km river sections, the phreatic aquifer take from the river 0.1 l/sec and gives it 38 l/sec. By exploitation wells, take out from the aquifer approx. 3 l / sec and by the downstream limit from the model is leaving 41 l / sec.

The model create with FREEWAT was used to simulate the changes in precipitations forecasted for years 2021 and 2071 (the model run in steady state, was not simulate a transient process). In a previous project - CCWaters - a series of studies of the climate change projected for the 2021-2050 and 2071-2100 time horizons were conducted for the Banat Plain, under the conditions of the A1B emission scenario.

The future climate change signal for the Banat Plain, under the A1B emission scenario, can be summarized as follows: for the period 2021-2050, a moderate increase of the mean temperature is expected: 1.6-1.7°C (winter), 1.1-1.2°C (spring), 1.8-1.9°C(summer), 1.6-2.0°C (autumn); for the period 2071-2100 , the mean temperature is expected to increase by 3°C for all seasons, with 4.1-4.5°C in summer. [4]

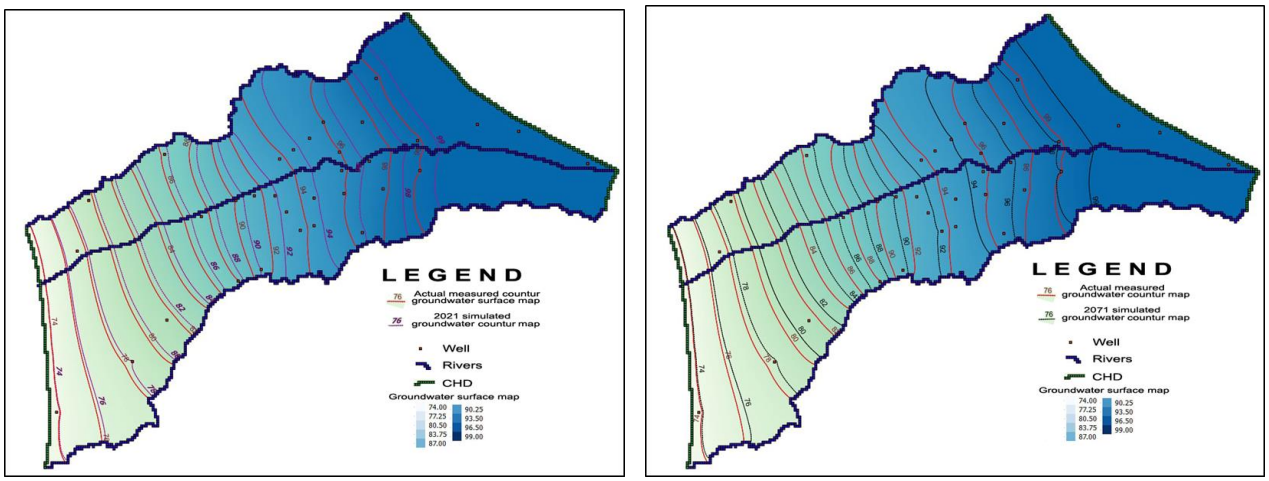
For precipitation, the climate signal is not very clear, the variability between various models being very high, giving high uncertainties to the results; more consistent results were obtained for summer over the period 2071-2100 when a decrease of about 25% for test area is expected. [4]

Scenario for 2021

- Mean annual temperature will increase with 1.6% and the precipitation will drop with 4.2%. These changes induce a decrease recharge for the aquifer about 8.5%.
- The model results show in this case that the groundwater levels drop within the entire modeled area, with a maximum of 0.73 m around Timisoara. Comparing with the actual situation, the result will be a decrease of the entire groundwater resource, fact proved also by the decrease of the outgoing groundwater debit through the downstream boundary from 41.4 l/s to 35.5 l/s.

Scenario for 2071

- Mean annual temperature will increase with 3.5% and the precipitation will drop with 5.3%. These changes induce a decrease recharge for the aquifer about 15%.
- The model results show in this case that the groundwater levels drop within the entire modeled area, with a maximum of 1.72 m around Timisoara. Comparing with the actual situation, the result will be a decrease of the entire groundwater resource, fact proved also by the decrease of the outgoing groundwater debit through the downstream boundary from 41.4 l/s to 31.2 l/s.



- *Figure 8 – Model results for the climate change scenarios 2021 and 2071*

CONCLUSION

The Banat Plain area is an area with possible issues in terms of public water supply for the future, in condition of climate changes, so it was important for water authorities and other local stakeholders to have an estimation of the groundwater resources availability for the shallow aquifer, which can be a supplementary water source in the future. In present, the shallow aquifer, which is in good status from quantitative point of view, is used like drinking water supply source only for domestic use and in industrial and agricultural activities.

The MODFLOW groundwater model of the shallow aquifer situated in Banat Plain area simulated the groundwater flow in an unconfined porous aquifer connected to three rivers, which can be use as potential water resource for population in the future.

The FREEWAT platform allowed the evaluation of groundwater resources in the phreatic aquifer for the future, according to the climatic scenario forecast for 2021 and 2071 and also the impact of the exploitation increasing.

Utilization of the FREEWAT platform helped also to achieve Romanian team's project goals:

- create a numerical model for the shallow aquifer of Banat plain capable to forecast the evolution of the aquifer in response to different solicitations related to the climate changes and change in water balance through the creation of different scenario
- improve the existing knowledge of groundwater bodies within studied area (lithology, hydrogeology, quantitative and qualitative status)
- run two main scenarios – ***impact of climate change*** and ***modification of the groundwater exploitation regime***, in accordance with measures included in the RBMP and analyzing their impact
- implication of the local authorities and other stakeholders within the project activities, through discussions that we had during organized focus-group - the modelling principles and the basis of conceptual model of the area were presented to local stakeholders and the scenarios were discussed especially with local water authorities.

Through creating a common environment among water professionals and policy makers FREEWAT main impact is on enhancing science and participatory approach and evidence-based decision making in water resource management, hence producing relevant and appropriate outcomes for policy implementation.

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