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THE IMPACT OF WATER EXTRACTION FROM DRILLED WELLS ON THE PHREATIC

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Abstract. Nowadays, worldwide, even in the economically developed countries, for what is the need to improve irrigation facilities, all kind of technical, organizational, institutional and scientific solutions are sought. The improvement of irrigation systems can be driven by the evolution or the altering of their performance parameters and goals during the operation process.

The goals are various: some are related to the achievement of enhanced performances as regards the agricultural, economical and hydraulic efficiency of the irrigation system; some are related to the proper evacuation of excess surface water and the regulation of groundwater levels via drainage systems; some are related to the trend to reduce the amount of eroded soil to a minimum and to ensure a better and cheaper protection of soils.

Performance becomes strategic when it takes the form of an activity carried along a number of years, situation when it becomes possible to assess the way in which resources have been used and what has been the value of the operational level. Also it is possible to review the objectives of the long-term operation and of all operational procedures, so to make the irrigation system proper and compliant to the farmers', managers' and community's demands.

Introduction

1.1. Piezometric regime of groundwater levels

The groundwater layer within the studied area is characterized by several specific elements. Within the hydrological balance, inputs are represented by local precipitation, infiltrations from outside the area, respectively from the hillsides and from the Prut river bed (when water levels are high in river Prut). The outputs are: the drainage generated by the bed of Prut river when surface water levels are below the piezometric level of groundwater layer and the vertical upward flow which may

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reach close to the ground surface, from where it is to be consumed by evaporation processes that take place at ground surface and by plant respiration.

Drillings have been made in the context of hydro-geological studies by D.A. Prut in order to make operational an observation and monitoring network in the area. From these drillings resulted that the groundwater layer within the water meadow is pressurized due to its continuity and to the fact that it is linked to the layers from the slope areas, which are located at higher levels. This pressure is permanent. The groundwater layer from the water meadow may be temporarily pressurized also by the Prut river, during the season of high levels, especially within its boundary area and on a certain influence distance (generally up to the collecting channel that is located in the middle of the meadow, on a route parallel to that of the river).

Another important feature of the groundwater layer is related to the fact that due to the continuous supply from the hillside area, water relatively rich in salts is coming, originating from the washing of saliferous marls from the lithological structure of the hillsides area.

The depth of the groundwater real level was the one where groundwater appeared when study drillings have been completed. This depth is reaching 3-5 m in the pre-terrace area, 2-3 m in the central zone of the area and 3-5 m in the sandbank area (due to the natural drainage of river Prut bed).

This depth is the factor that is influencing the magnitude of the ascending groundwater flow and thus the amount of salts that reach the active layer of soil from the groundwater layer. This depth has values of under 1 m in the small pre-terrace area, 1-2 m in the central area and 2-3 m in the sand bank area [1], [2].

Several researches about the evolution and salinization state of aquifers in flood plains have been done in Romania and worldwide ([3], [5], [6], [7], [8], [9], [11], [15]).

1.2. The variation in time and space of the groundwater mineralization degree. The intense mineralization of waters inside the Albita–Falciu section is determined by underground supplies from the hillside area, with salts dissolved in the aquifer from the existing Sarmatian marls within the geological structure of this zone, the highest concentrations being detected in the pre-terrace area. In the other areas, and especially in the zone located in the proximity of the river, during periods with high water levels, due to infiltrations from the river bed, has been noticed a decrease of salt concentration in the groundwater layer. The study was conducted using existing data from the DAP hydrogeology service (data that include the physico-chemical analysis of groundwater and the ion balance, for the drillings within the hydrogeological stations located within the Albita-Fălciu section). Tests were performed two times a year, in May and September, and are reflecting the quality of groundwater from the deep captive aquifer. The measured values of fixed residue are shown in table 1 and refer to the 1996-2007 study period [14].

Tab. 1 - Groundwater mineralization (fixed residue, mg/l) measured in May and September during 1996 – 2007

Year	Month	Râşeşti drillings			Vetrişoaia drillings			Fălciu drillings		
		F1	F3	F4	F1	F2	F3	F2	F3	F4
1996	May	1220	1190	698	1166	1378		790	618	1366
	Sept	1866	689	790	1050	1010		722	696	1270
1997	May		692	858	2200			1356	1328	1460
	Sept	2816	712	846	2052	2056		1360	1338	1350
1998	May	2180	489	570	2044	2042		1128	936	928
	Sept	2406	750	600	2108	2142		1110	1080	1294
1999	May	2741	2768	639	1398	1640		1173	1570	1482
	Sept	958	755	462	2108	2142		1028	950	1478
2000	May	380	2746	810	1494	1592		1006	1318	938
	Sept	756	2889	794	889	1038	380	1903	1106	2054
2001	May		2800							
	Sept		1900							
2002	May	1335	1955	877	1493	1313	1809	2692	1671	2639
	Sept	1298	2350	828	1708	1591	1823	1341	1488	3111
2003	May	769	823	670	1378	621	1720	1088	1155	3054
	Sept	797	820	688	950	1164	1518	1412	1567	3119
2004	May				656	896	1640	2531	1560	3416
	Sept			740	1566	1659	2364	3200	3304	3484
2005	May	2172	1238	790	1826	537	1859	1170	1578	3113
	Sept	1170	1851	730	2296	518	1590	3138	3181	3125
2006	May		2027						3552	
	Sept		691						2969	
2007	May		2362						4688	

In relation to the multiannual average value of fixed residue in different drillings and for the two periods the following elements have been noticed:

- the average multiannual values of the fixed residue are smaller at Râşeşti, maintaining the same level at Vetrişoaia and Falciu;
- on a transversal direction across the river Prut there is no significant difference between the drillings nearby the river Prut (F1), within the four hydrogeological stations and those located further away. Hence, we can state that the influence of Prut River on groundwater mineralization is weak;
- in some drillings large variations in time have been detected. For example the drillings F1-F2 (Vetrişoaia) are featuring the same variation as the Rasesti F1 drilling, but has been noted a significant increase of the fixed residue (this being more obvious since 1999). In F3 Râşeşti drillings (2768 mg/l in May 1999, 2746

mg/l in May 2000), F2, F3, F4 drillings from Falciu (the latter varying from 928-1600 during 1995-1999, up to 2054 mg/l in fall 2000) and during 2002-2007 this value increased to more than 3000mg/l;

- during the extremely dry year of 2007, the fixed residue measured in May, after a very dry winter, during which the groundwater has been very poorly supplied with precipitation water, the salt concentration in groundwater recorded the highest values of the whole range of considered data (by example in the F3 Falciu drillings the measured value was 4688 mg/l).

2.Methodology

2.1. The influence of weather patterns on groundwater levels. Climatic factors that are influencing the hydrogeological balance and the changes of groundwater levels are mainly the wintertime precipitations and the summertime droughts. The influence of the water balance has been analyzed for drillings remotely located from River Prut and representative for the pre-terrace zone (the F3 drillings on each hydrogeological cross section). Average apparent monthly levels within drillings have been correlated with the monthly mean values of water deficit (ETP-P) (fig. 1 and fig. 2).

From these graphs it can be seen that in the pre-terrace zone the influence of water surplus or deficit on groundwater levels is obvious. During months with excess water or water deficit the groundwater depth is minimal, the depths varying from drilling to drilling, in relation to the local topographic conditions. For the central zone, the correlation of groundwater in F2 drillings and water deficit are inconclusive, the correlation coefficient being very small, due to the fact that the groundwater levels regime is almost equally influenced by the climatic regime, by the river Prut and by the type of exploitation that takes place in the drainage network and the irrigation systems from this area.

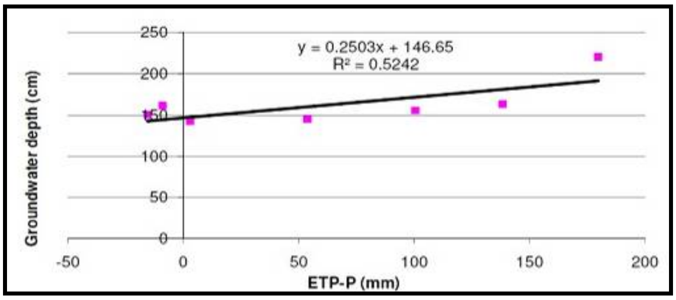

Fig. 1 - The relation between the water deficit (ETP-P) and the apparent depth of water in drilling (average monthly values, January-July 2007) for F3 Râşeşti drilling

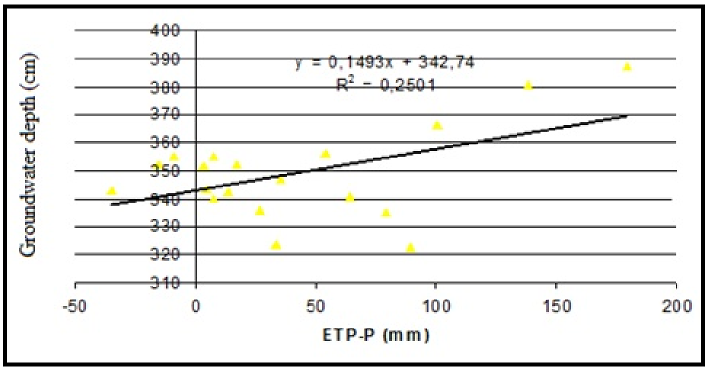

Fig. 2 - The relation between the water deficit (ETP-P) and the apparent depth of water in drilling (average monthly values, 2006) for F3 Vetrişoaia drilling

2.2.The studied area: geology and hydrology. The Vetrişoaia facility (fig. 3) is located upstream Lunca Banului at a distance of about 14.4 km, and consists of three drillings. By drilling have been noticed the following features: at a depth of 7,00 m occurs a semi-aquifer horizon (clayish weak sand) with a thickness of 2.80 m, followed by a 2.20 m sand layer and the aquifer itself, with gravel and sand, of only 0.90 m thickness. In the drilling the water carrying layer has been intercepted at 7.00...12.40 m, while the piezometric level has been stabilized at 1.50 m (level 16.71 m). The cover layer of the aquifer and semi-aquifer is made of sandy clays and dusty sandy clays with a total thickness of 7.00 m. In terms of mineralization degree the underground water from the bank ridge area is weakly brackish (0.820 g/l), and its reaction is weakly alkaline (pH = 7.4).

In general the thickness of the aquifer layer is decreasing from the wetland's upstream area towards its downstream area and has an average value of 7.37 m in the bank ridge area, 5.26 m in the pre-terrace area and 4.65 m in the central area of the wetland, having a high hydraulic conductivity K = 14 ÷ 21 m/day.

Basic data (hydrological elements for the calculus of the water bed in the Vetrisoaia area) of the aquifer are:

- the necessary extraction discharge $Q \leq 42.9$ l/s;
- the number of strata: $n_{str} = 3$;
- the distance between the water wells' line and the river: $l_0 = 560$ m;
- the groundwater depth: h = 7 m;
- the groundwater thickness: $H_m = 5.9$ m;
- the inner radius of the screen $r_c = 0.2731$ m;
- the position of the hydrostatic level: 1,5 m beneath the ground level (16.71 m);
- rainfall: during the year when the measurement took place,

N_{max} = 800 mm, N_{min} = 600 mm.
- the filtration factors (Darcy): K_1 = 8.64 m/day, K_2 = 20.5 m/day, K_3 = 50 m/day;
- the groundwater bed has been collected between 7.00 m and 12.90 m.

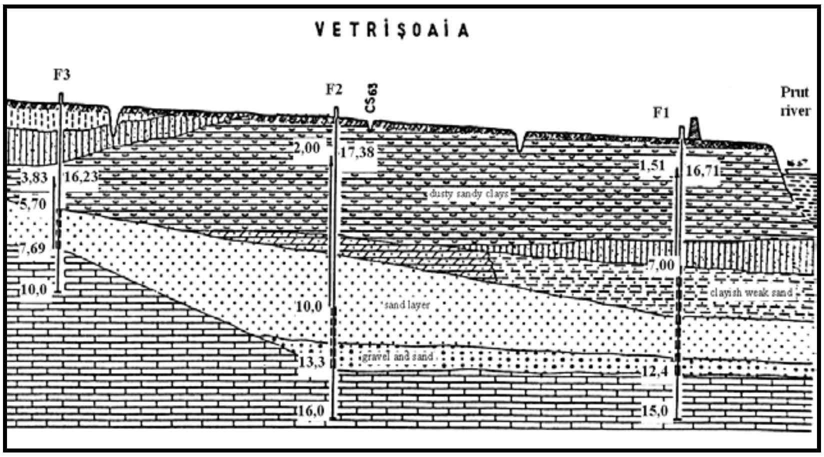

Fig. 3 - Hydrogeological profile

3.Results and discussion

The simulation of the salinization processes has been performed with the digital modeling software Visual MODFLOW 4.2. [4], [10]. The abstraction flow distributed to the irrigation plot (with a 50% improvement degree) that is 95.7 l/s, has been simulated by means of eight abstraction wells, spaced at a distance of 75 m, this being an abstraction front of a length of 583 m, the flow of one well being of 11.96 l/s, resulting in a level difference of s = 5.71 m, for a filtration coefficient K_{ech} = 19.37 m/day. The level distribution levels and those for the piezometric levels calibrated with the survey and abstraction wells [12], [13] are presented in fig. 4.

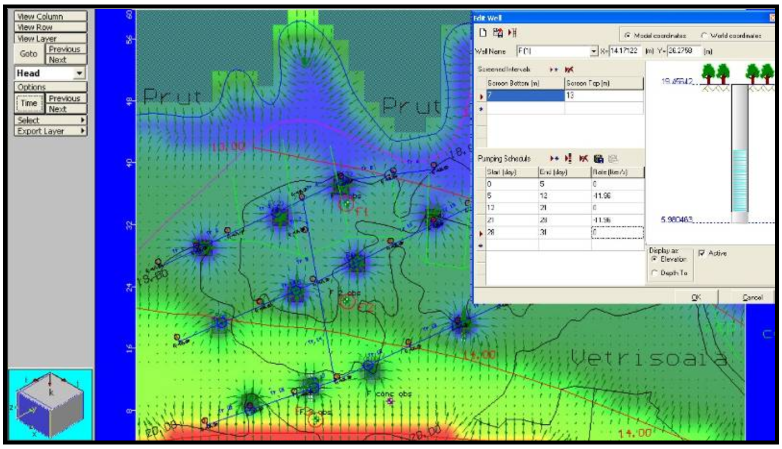

Fig. 4 - Computing of pumping flow depending on survey and abstraction wells

The concentration of water soluble salts in water and its distribution before pumping and at pumping in the aquifer is shown in fig. 5.

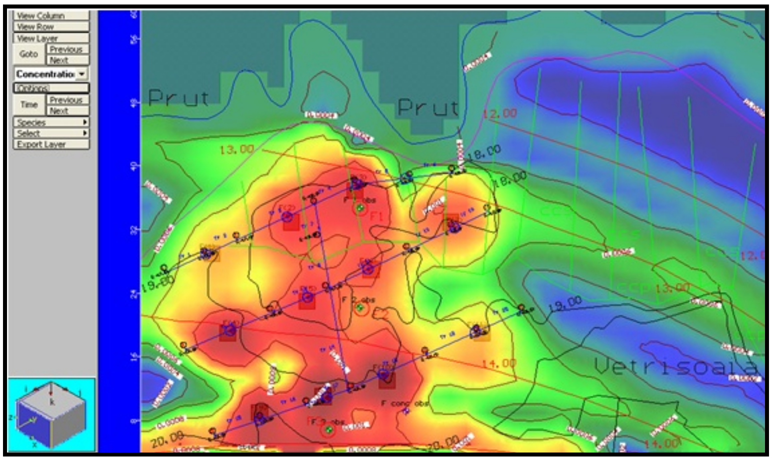

Fig. 5 - Distribution of the concentration of water soluble salts, pumping from aquifer

After running the software, it has resulted that within the soil's active layer, in the pre-terrace area, are entering the amounts of salts given in Table 2. (monthly amounts).

In the sandbank area of the studied zone the groundwater and salt flows are generally much diminished due also to the natural drainage exercised by Prut river bed during periods of low water levels, to the strata average permeability down to groundwater table and to the high levels of the terrain compared to the central zone. However, in this region there are some areas located at low levels (by example the F1 drilling from Vetrişoaia section), where the natural drainage of the river Prut occurs only on shorts periods (when the groundwater levels are below the average level within the sandbank zone, when groundwater is located at a small depth and helps the lifting of salts within the groundwater layer).

Tab. 2 - Amounts of salts (t/ha) that are rising from aquifer towards soil's active stratum in the pre-terrace area, during irrigation from groundwater

Year/ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total year
1996				0.06	0.09	0.092	0.076	0.054					0.372
1997		0.038	0.048		0.053	0.09	0.082		0.096				0.407
1998		0.029	0.021	0.035	0.052	0.109	0.158	0.140	0.187				0.731
1999			0.165	0.09	0.275		0.310	0.291	0.118				1.25
2000			0.61	0.281	0.237	0.211	0.145	0.104		0.115			1.45
2001			0.068	0.073	0.086		0.112	0.078		0.129			0.54
2002	0.071	0.084	0.05	0.046	0.054	0.066		0.074	0.099			0.116	0.66
2003			0.123	0.079	0.061	0.061	0.043	0.036	0.049		0.055	0.027	0.53
2004			0.009		0.006	0.007	0.005	0.005	0.007	0.009			0.05
2005			0.015			0.057	0.022	0.011	0.022	0.021			0.15
2006													0.17
2007			0.077	0.107	0.119	0.147	0.079						0.53

The amount of salts coming from the phreatic layer gradually increased soil salinity, especially in the central and the pre-terrace areas due to low levels.

Conclusion

The water level of the river Prut highly influences the phreatic levels' regime in the sand bank area, while its influence in the central area is less and almost none in the pre-terrace area. The impact of the fluctuation of Prut River's water level reduces with the distance between the sand bank and the pre-terrace area.

By modeling the flow with the Visual MODFLOW software we have obtained:

- the map of the hydroisohypses and the velocity field in the studied area;
- the flow modeling has been performed and the concentration of salts in groundwater has been demonstrated.

The dominant influence of the climatic regime (water excess or deficit) emerges in the pre-terrace area.

Phreatic mineralization has the highest values in the pre-terrace and central areas of the meadow and the lowest in the sand bank area, due to the infiltrations from the river Prut.

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