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GROUNDWATER TYPES IN SOUTHEAST SREM

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Abstract: The region of Southeast Srem is rich in ground waters, which is of great significance to agricultural production. The objective of this paper was to designate the zones of different groundwater types from the aspect of recharge, based on the analysis of groundwater regimes in the study area. A very complex groundwater regime in Southeast Srem, which depends on a great number of natural and some anthropogenic factors, makes it difficult to designate clearly the zones of the three main types of groundwater regime. Still, the boundaries of the zones of groundwater regime types were defined based on the results of correlation analysis of the basic factors affecting the groundwater regime. Zone I includes the climatic type of groundwater. Its fluctuation corresponds to the vertical factors of water balance (precipitation and evaporation) and it is not affected by the river water level. This zone extends North and East of the line Putinci, Golubinci, Stara Pazova, Batajnica, Dobanovci, mainly in the area of the loess plateau. Within the zone, groundwater is at a relatively great depth. Only exceptionally, in the valleys, it appears almost on the surface. Zone II includes the climatic-hydrological groundwater type, which is the transition between the climatic type and the hydrological type. The fluctuation of groundwater regime is affected both by the effect of vertical balance factors, and by the effect of watercourses. Climatic-hydrological groundwater type covers the central and the lowest part of the study area and the South part of the middle terrace. Zone III is classified as the hydrological groundwater

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type and it covers the riparian areas along the Sava and the Danube. The aquifer is hydraulically connected with the river Sava.

Key words: Southeast Srem, groundwater, climatic type, climatic-hydrological type, hydrological type.

Introduction

Southeast Srem extends between 44° 40' and 45° North latitude and 19° 50' and 20° 25' East longitude. It is bordered by two rivers: the South border of the area is the river Sava, and the East border is the Danube. The area of interest to this study covers about 86,300 ha. It is rich in groundwater, which has a great significance for agricultural production. Groundwater level monitoring was organised by the middle of the 20th century.

The greatest number of piezometers was installed in towns, e.g. in New Belgrade and Zemun, as well as in the alluvial area, but there are fewer piezometers in the central part of the area. The aim of this paper was to analyze the groundwater regime in the study area and to designate the zones with different groundwater types from the aspect of recharge.

Material and Methods

The measured data presented in this paper refer to the period 1980 - 2004, although some measurements were interrupted. To attain the most uniform data coverage of the study area, 32 piezometers and 3 batteries of piezometers were singled out and subjected to in-depth analysis (Figure 1).

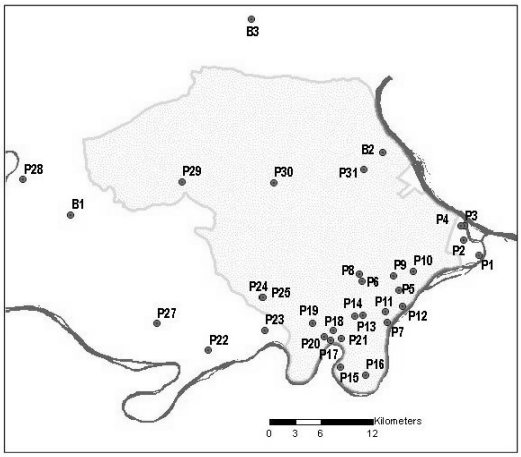

Fig. 1. - The situation with the positions of the analyzed piezometers

The absolute elevations of groundwater level were calculated for each piezometer, based on the data on the measured groundwater depth in piezometers and benchmark elevations (elevations of piezometer zero), (Gregorić, 2008).

The mean monthly values of groundwater level were calculated aiming at the comparison of the results and the comparison with the data on precipitation, evapotranspiration and discharge through pumping plants. Based on these data, correlation coefficients were calculated for the piezometer readings and water levels on the nearest gauges on the river, and correlation coefficients for groundwater levels and precipitation. The above results were of use in the classification of groundwater regimes.

Groundwater regime in a given region is usually defined as one of the following three types:

- climatic,
- hydrological,
- climatic-hydrological.

Groundwaters were classified (i.e. assigned to groundwater types: climatic, climatic-hydrological, or hydrological) based on the correlation analysis of the dependence of groundwater level on precipitation. Namely, the significance of the role of precipitation in the formation of groundwater regime was determined by the hydrological (statistical correlation) method of groundwater study (Vuković, 1967, 1985).

The method is based on the statistical processing of the results of long-term monitoring of groundwater regime and on the computation of the strength of correlation with hydrological and meteorological factors. The resulting continuity equation (balance equation) for a given region has the following form:

$$P-E+D-O+h_D-h_O\pm\Delta R=\varepsilon\Delta H \qquad (1)$$

where:

P – precipitation (mm)
E – evapotranspiration (mm)
D – surface inflow to the study area (mm)
O – surface runoff from the study area (mm)
h_D – subsurface recharge of the study area (mm)
h_O – subsurface discharge from the study area (mm)

ΔR – change in moisture in the zone of aeration, in mm of water column (the negative sign signifies moisture increment in the zone of aeration, and the positive sign means moisture reduction)
ε – effective porosity, and
ΔH – change in groundwater level (mm).

As in equation (1) it is only precipitation and groundwater level that can be easily measured, a relation should be established between them. The analysis of the connection between precipitation and change in groundwater level is justified in the area which is distant from open waterways, and during the period when the influence of evapotranspiration (which is the most sensitive factor of the continuity equation) is minor

In the riparian belt, where the formation of groundwater regime is primarily influenced by underground recharge and discharge, and where the factor of vertical balance (precipitation and evapotranspiration) is neglectful, the correlation between water level in the streams and the groundwater level is crucial.

Results and Discussion

A very complex groundwater regime in Southeast Srem, which depends on a great number of natural and some anthropogenic factors, does not allow a clear designation of the zones of the three main types of groundwater regime. Still, the boundaries of the zones of groundwater regime types were defined based on the results of correlation analysis of the basic factors affecting the groundwater regime. Figure 2 presents the situation plan of Southeast Srem, with plotted boundaries of the zones.

Zone I includes the climatic type of groundwater. Its fluctuation corresponds to the vertical factors of water balance (precipitation and evaporation) and it is not affected by the river water level. During the winter-spring period, when precipitation is more significant than evaporation, groundwater is replenished and the level of groundwater rises, (Katić, 1979). Oppositely, in the summer–autumn period, the level of groundwater drops because of the precipitation deficit and excessive evapotranspiration. Soil and topography also have a significant effect on the character of fluctuation. This zone extends North and East of the line Putinci, Golubinci, Stara Pazova, Batajnica, Dobanovci, mainly in the area of the loess plateau. Within the zone, groundwater is at a relatively great depth. Only exceptionally, in the valleys, it appears almost on the surface.

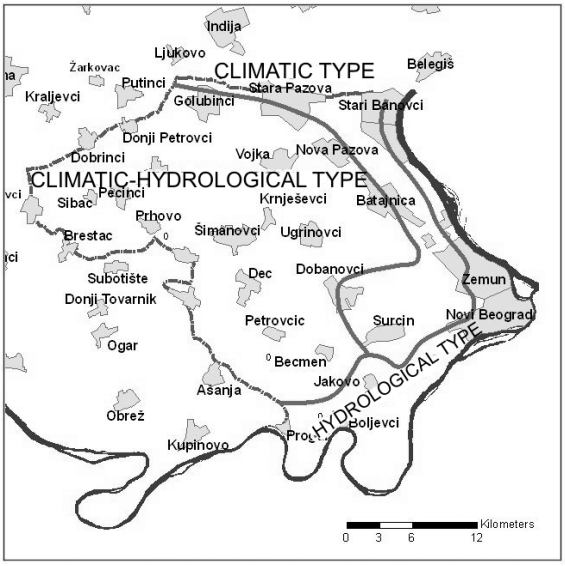

Fig. 2. – The zoning of Southeast Srem according to groundwater regimes

Figure 3 presents an example of climatic type of groundwater - piezometer at Nova Pazova. Annual fluctuations show the minimum in October or November. The range of fluctuation at this location in the study period was 3.35 m, and the mean depth to groundwater level was 2.66 m (terrestric soil-automorphic-drainage class IV). The dependence of groundwater level on precipitation is expressed by correlation coefficient r=0.87

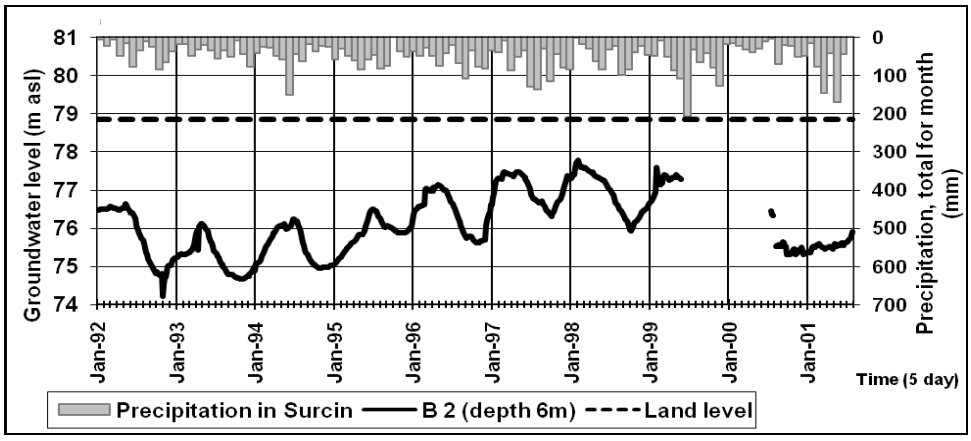

Fig. 3. – Dependence of groundwater level on precipitation, according to data measured by piezometer B2- Nova Pazova (weather station Surčin)

Zone II includes the climatic-hydrological groundwater type, which is the transition between the climatic type and the hydrological type. This means that the fluctuation of groundwater regime is affected both by the effect of vertical balance factors, and by the effect of rivers. Climatic-hydrological groundwater type covers the central and the lowest part of the study area and the South part of the middle terrace. The central part is most endangered by high levels of groundwater. Groundwater occurs mainly very shallowly and often (at some places every year, and on average once in 3 - 4 years) jeopardizes the normal agricultural production. The condition is aggravated by the existence of a great number of micro depressions in which water is retained for longer periods. High water is retained for 2 - 3 months. In Southeast Srem, it is in this area that the greatest part of the detailed canal network is constructed. In the South part of the middle terrace, the terrain is intersected with groundwater. Only the numerous locally lower parts of the terrain are endangered.

A characteristic example of climatic-hydrological type of groundwater is the piezometer P30 in Krnješevci. The range of fluctuation was 2.8 m (Figure 4). Mean depth to groundwater was 1.18 m. During the study period (1979–2004), the level was less than 0.5m from the surface in 17% of the total number of readings. The statistical processing (Figure 5) shows that the correlation coefficient between the precipitation and the level rising in the winter-spring period was 0.58, and the correlation coefficient with the Sava water level was 0.57

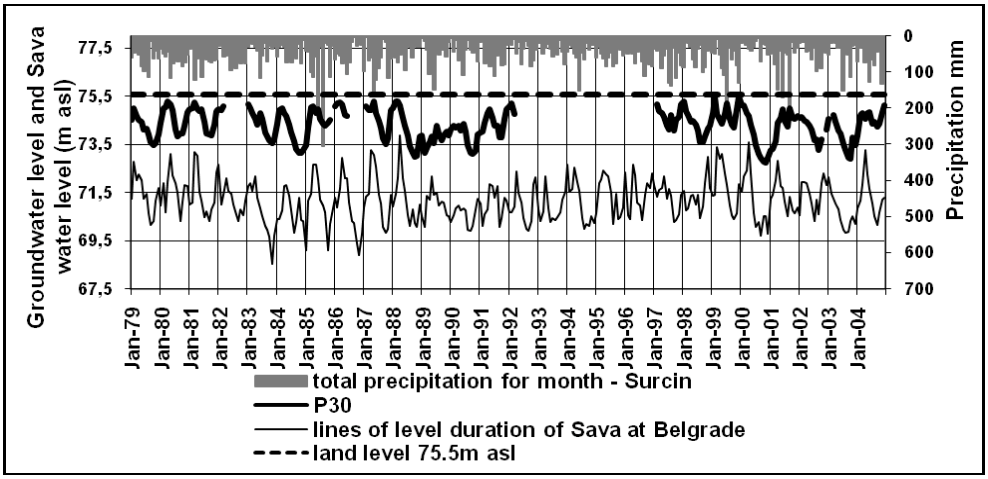

Fig. 4. – Relation between groundwater level on piezometer P30 at Krnješevci and the Sava water level, and precipitation, based on the Belgrade gauge data (MTS Surčin)

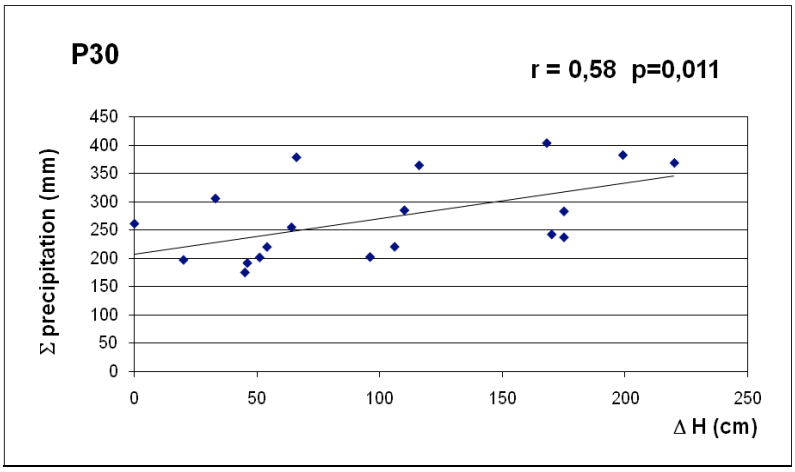

Fig. 5. – Relation between the rise of groundwater level on piezometer P30 and precipitation in the winter period

Zone III covers the riparian areas along the Sava and the Danube. Water regime here largely depends on the water regime in the rivers and the recharge from the higher terraces – this is the hydrological type of groundwater. Usually, the higher terrains along the rivers are not at risk by groundwater. The same refers to the areas with Belgrade water-supply wells installed along the river Sava.

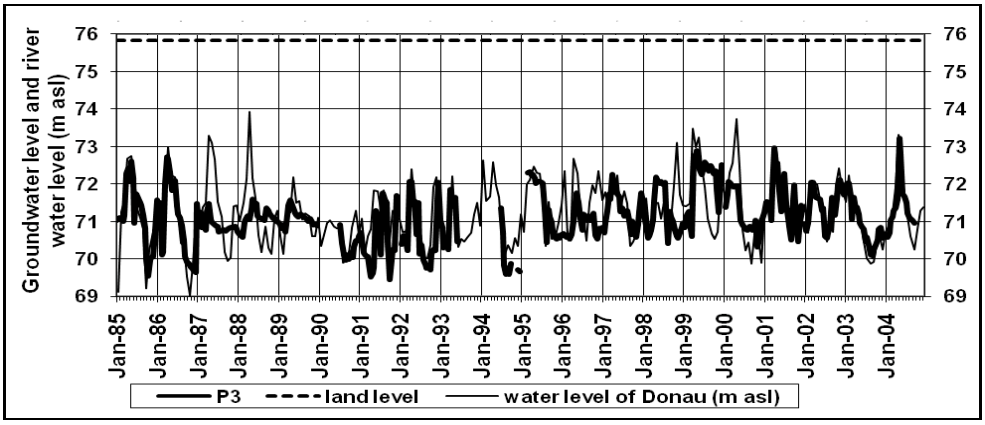

Fig. 6. – Relation between groundwater level in piezometer P3 Zemun and the Danube water level, based on the gauge data in Zemun

Piezometers P2, P3, P4 have a very strong correlation with the Danube water level. They are near the river and there are no wells in the vicinity that could obstruct their natural regime. Fluctuation ranges from 2.5 m to 3.5 m. Figure 6 presents parallelly groundwater level curve on piezometer P3 and the Danube water level curve. The indubitable influence of water level on the formation of groundwater regime classifies this site as hydrological type of groundwater.

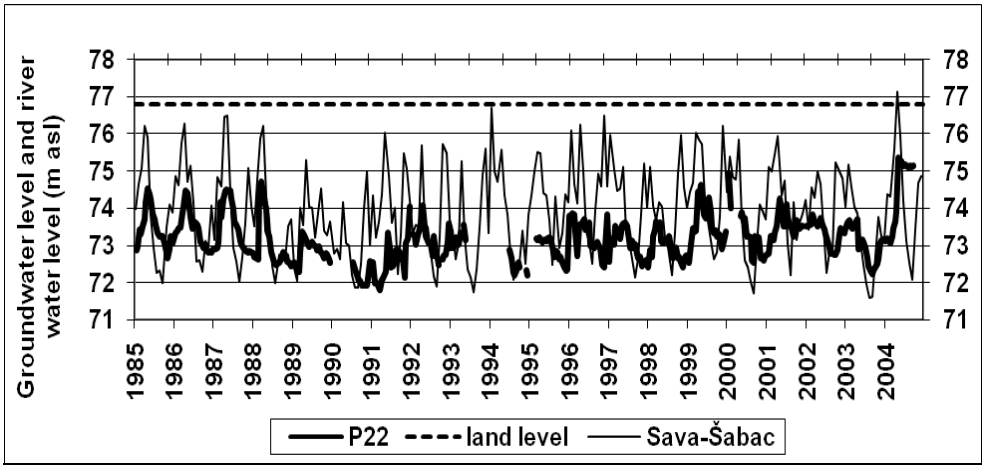

Fig. 7. – Relation between groundwater level in piezometer P22 Kupinovo and the Sava water level, based on the gauge data at Šabac

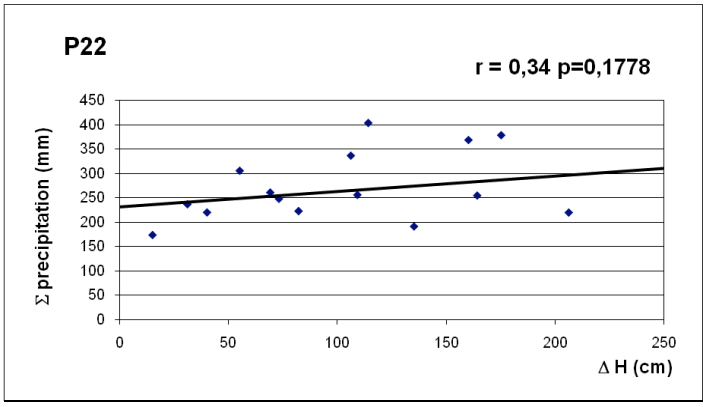

Fig. 8. – Relation between groundwater level increase on piezometer P22 and precipitation, during the winter period

Piezometers P6, P8, P22, P23 are in hydrological regime, but outside the influence of the wells. Figure 7 presents parallelly the Sava water level curve at Šabac and water level curve for piezometer P22 at Kupinovo. The correlation is good, which is also proved by the significant correlation coefficient: 0.54. Figure 8 shows that the relation between the increase of groundwater level in piezometer P22 and precipitation sum in the winter period was not significant (correlation coefficient 0.17).

All piezometers in the Sava riparian area belong to hydrological groundwater regime, because the aquifer is in hydraulic connection with the river Sava. The degree of hydraulic connection is determined by local conditions, by direct hydraulic connection of the aquifer and the river, if the bed is cut in the aquifer, or by indirect connection through the semi-permeable, aleurite-clayey roof of the aquifer (Josipović, 1983).

Conclusion

A very complex groundwater regime in Southeast Srem, which depends on a great number of natural and some anthropogenic factors, makes it difficult to designate clearly the zones of the three main types of groundwater regime. Still, the three zones were defined based on the analysis of dependence of groundwater level on precipitation and river water level. Zone I includes the climatic type of groundwater. Its fluctuation corresponds to the vertical factors of water balance (precipitation and evaporation) and it is not affected by the river water level. This zone extends North and East of the line Putinci, Golubinci, Stara Pazova, Batajnica, Dobanovci, mainly in the area of the loess plateau. Within the zone, groundwater is at a relatively great depth. Only exceptionally, in the valleys, it appears almost on the surface.

Climatic hydrological groundwater type covers the central and the lowest part of the study area and the South part of the middle terrace. The central part is most endangered by high levels of groundwater which occurs mainly very shallowly and often (at some places every year, and on average once in 3 - 4 years) jeopardizes the normal agricultural production. High water is retained for 2 - 3 months.

Zone III is classified as the hydrological groundwater type. It is hydraulically connected with the rivers and occupies the riparian areas along the Sava and the Danube.

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TIPOVI PODZEMNIH VODA JUGOISTOČNOG SREMA

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R e z i m e

Područje jugoistočnog Srema obiluje podzemnim vodama koje imaju veliki značaj za poljoprivrednu proizvodnju. Cilj ovog rada bio je da se analizom režima podzemnih voda posmatranog područja izdvoje rejoni sa različitim tipovima podzemnih voda sa stanovišta njihovog prihranjivanja. Veoma složen režim podzemnih voda na području jugoistočnog Srema, koji zavisi od velikog broja prirodnih i nekih antropogenih faktora, otežava jasnu rejonizaciju područja jugoistočnog Srema u odnosu na tri osnovna tipa režima podzemnih voda. Ipak, na osnovu rezultata korelacione analize osnovnih faktora koji utiču na režim podzemnih voda, definisane su granice rejona pojedinih tipova režima podzemnih voda. Rejon I obuhvata klimatski tip podzeme vode, čije oscilacije odgovaraju vertikalnim faktorima vodnog bilansa (padavinama i isparavanju) i nisu pod uticajem vodostaja reka. Područje se povlači severno i istočno od linije Putinci, Golubinci, Stara Pazova, Batajnica i Dobanovci, uglavnom na području lesnog platoa. Unutar ovog rejona podzemne vode su na relativno velikoj dubini, a samo su izuzetno u dolinama skoro na površini terena. Rejon II zahvata klimatsko hidrološki tip podzemne vode, koji je prelaz između klimatskog i hidrološkog tipa, kod koga se uočavaju i uticaj faktora vertikalnog bilansa, kao i uticaj vodenih tokova na režim oscilacija podzemne vode. Klimatsko hidrološki tip podzemne vode zahvata centralni najniži deo analiziranog područja i južni deo srednje terase. Rejon III su priobalne površine uz Savu i Dunav na kojima je zastupljen hidrološki tip podzemnih voda, na kojima je izdan u hidrauličkoj vezi sa rekom Savom

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