PRELIMINARY EVALUATION ON THE RATIO BETWEEN THE SURFACE AND UNDERGROUND RIVER SUPPLY IN EASTERN ROMANIA

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ABSTRACT. Preliminary evaluation on the ratio between the surface and underground river supply in Eastern Romania. In the last decades, the classic methodology for evaluating the base flow index (BFI), as the characteristic medium hydrograph, was replaced by new specialized algorithms, as HYSEP, PART, BFLOW, Eckhardt ş.a. The goal of this study is to determine the base flow index (BFI) within four hydrometric stations located on few rivers characterized by different phisical-geographic conditions from Eastern Romania (Lepşa – Lepşa river, Cuejdiu – Cuejdiu river, Băceşti – Bârlad river and Tg. Frumos – Bhlueţ river). The calculations were made both by using the classical methodology, and by a new algorithm proposed by Eckhardt in 2005 and 2008. Through comparing results, it is proved that the new determination methods for the underground intake reveal in a more accurate manner the climatic and geologic relations of the analyzed rivers (BFI - Lepşa 35%; Cuejdiu 45%; Băceşti >50%; Târgu Frumos >50%). As a result, the higher underground intake for the rivers flow modifies the method of calculation of hydrological balances, and thus, changes in water resources management.

Keywords: surface and underground supply, base flow index (BFI), Eckhardt method, Eastern Romania.

1. INTRODUCTION

The evaluation of the hydrological network supply is an important aspect in hydrological studies, both theoretically, and practically. As part of the flow from a basin, the underground supply of rivers was often associated as result of the interaction between the local climatic and geological conditions. For Romania, studies linked to evaluation of the supply sources were descriptive, and briefly treated this subject, many authors resuming to making reference to data published in synthetic, general works (Tăbăcaru-Roşescu, 1957; Ujvári, 1957, 1959, 1972; Lvovici and Ujvári 1958; Lăzărescu, Panait 1958), whose results being afterwards taken over in the works of Pantazică (1974), Tăbăcaru-Roşescu (1972a, b, 1974), *Râurile României* [Rivers of Romania] (1971), Lăzărescu and Ţuca (1979), Badea et al. (1983). In the last decades, the identification of the supply sources was subject to some works, which approached either the classical methodology (Vartolomei, 2007), or applied new methods of delimitation of the supply sources (Hârjoabă et al. 1997; Hârjoabă and Amăriucăi 1998; Minea, 2012).

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Globally, there have been developed few identification techniques for underground supply, both by using characteristic medium hydrograph (Vitvar et al., 2002), and by developing some models based on specialized algorithms HYSEP (Sloto and Crouse, 1996), PART (Rutledge, 1998), BFLOW (Arnold and Allen, 1999), UKIH (Piggott et al., 2005) and Eckhardt (2005, 2008).

2. DATABASE AND METHODOLGY

Data come from four hydrometric stations (Fig. 1) belonging to National Administration of Hydrology, drown up in certain physical-geographical conditions in order to identify the specific characteristics of the base flow index (Table 1).

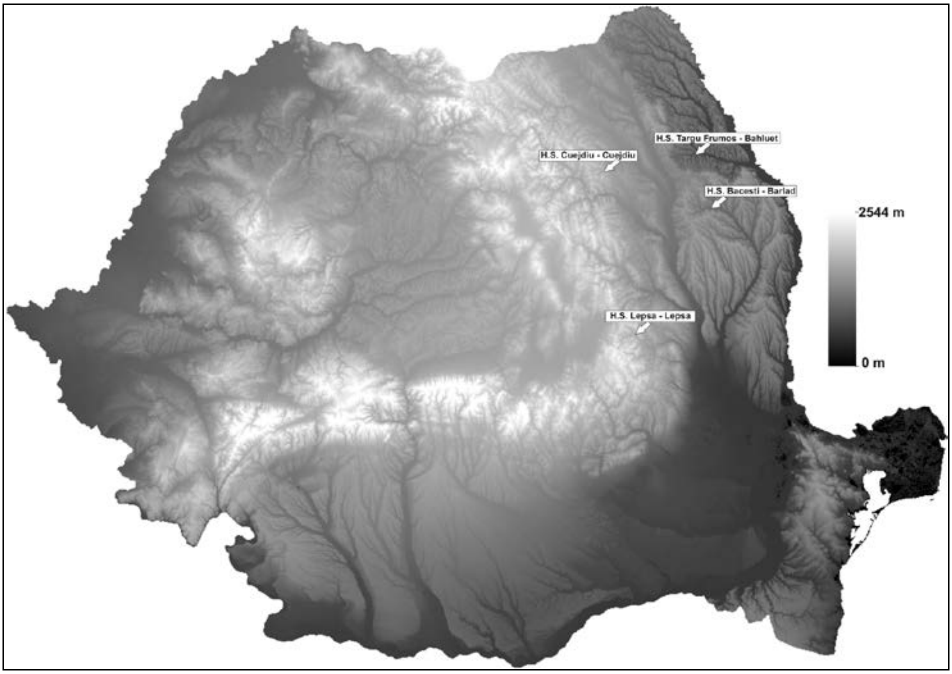

Fig. 1. Geographical position of the hydrometric stations

Table 1. Geographical conditions of the analyzed hydrometric stations

No.	Hydrometric station	River	Medium height of the basin (m)	Surface of the basin (km^2)	Relief	Observation period	Average annual discharge (m^3/s)
1	Lepșa	Lepșa	1022	71	mountain	1978-2012	1.16
2	Cuejdiu	Cuejdiu	680	98	mountain	1978-2012	0.48
3	Băcești	Bârlad	290	215	plateau	1978-2012	0.34
4	Târgu Frumos	Bahlueț	272	68	plain hill	1978-2012	0.15

Through applying certain algorithms to the basins from Eastern Romania (both in the mountain, and in the plateau area) we realized few preliminary evaluations of the base flow index.

Our analysis of the base flow index starts from two types of methodologies: one used in Romanian literature, based on the section of the characteristic medium year's hydrograph, proposed in the hydrologic synthesis Râurile României [Rivers of Romania] (1971), and other based on an algorithm proposed by Eckhardt (2005, 2008):

$$\mathrm{Si} = \frac{(1-\mathrm{BFImax})ab_{i-1} + (1-a)\mathrm{BFImax}Q_i}{1-\mathrm{aBFImax}}$$

where Si is base flow at time i, BFImax – base flow index maximum, a is a recession constant and Q_i is total stream flow at time i.

Eckhardt (2005) suggests that the figures used for BFI max (non-measurable parameter) are between 0,70 and 0,80 for perennial streams with porous aquifers, 0,50 for ephemeral streams with porous aquifers, and 0,20 and 0,25 for perennial streams with hard rock aquifers. As for the filter parameter *a*, it was analyzed based on the daily medium flows from the hydrometric stations of the basin, based upon the relation (Eckhardt, 2008):

$$Q_{i-3}>Q_{i-2}>Q_{i-1}>Q_i>Q_{i+1}>Q_{i+1}$$

where: Qi is considered if there are at least five days with decreasing flows (recession period, Fig. 2).

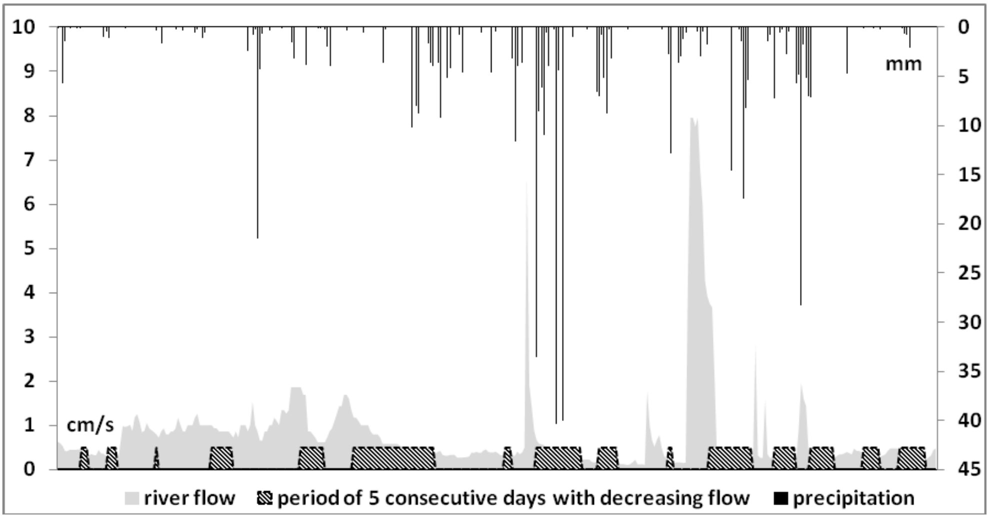

Fig. 2. Identification of the periods with at least five days with decreasing flows (recession period) for Bahluieț river (to the hydrometric station Târgu Frumos, in 2000)

If decreasing flows overtake at least five consecutive days, the general equation of the flow Qi=aSi. The figures of parameter *a* could be thus determinated based on $S_{i+1}=f(S_i)$ relation, taking into account just the recession periods for every analyzed station (Fig. 3).

For the analyzed station, the figures of parameter a are: 0,925 for upper basins of Barlad and Bahluet Rivers, 0,945 for Cuejdiu River, and 0,955 for the upper basin of Putna.

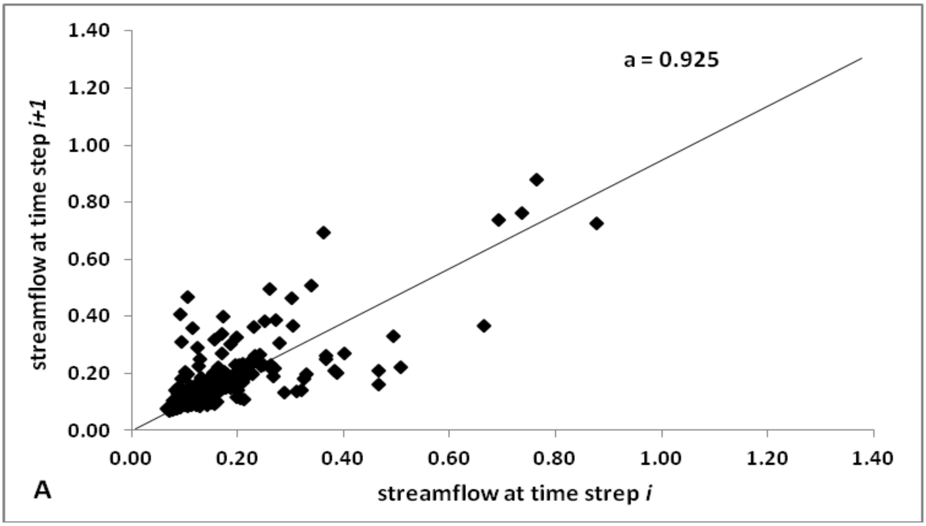

Fig. 3. Scatter plot of streamflow Q_{i+1} against Q_i during recession periods for the upper basin of Bahluieț river

3. RESULTS AND DISCUSSIONS

The identification of the base and underground supply for each of the four considered station, based on two types of methodologies, led to different results. Using on the section of the characteristic medium year's hydrographe located in representative points, Zaharia Liliana (1999) observed that in the upper basin of Putna river the superficial supply represents 75% from all supply sources, of which 45% means the pluvial supply, and 30% the nival supply (the snow cover is present here seven month a year, with decade average thickness between 0,1 and 7,1 cm). Applying the same methodology for Cuejdel river basin, it was reached the conclusion that the underground supply is not more 35% from all supply sources, and for the rivers from the plateau and from the plain hill area from Eastern Romania, the supply is mostly pluvial (50%), and from the snowmelt (35%). The underground intake in the plateau and in the plain area is not more than 15% (after Ujvari, 1972; Pantazică, 1974; Butelcă, 2012).

But a more detailed analysis of the hydrologic regime of these rivers reveal two important aspects, well-known to specialists: during the cold season, especially in the mountain area, precipitations are quartered the most as snow and ice covers, and during the warm season there are repeated phenomena of drought and dryness, induced by lack of rainfall.

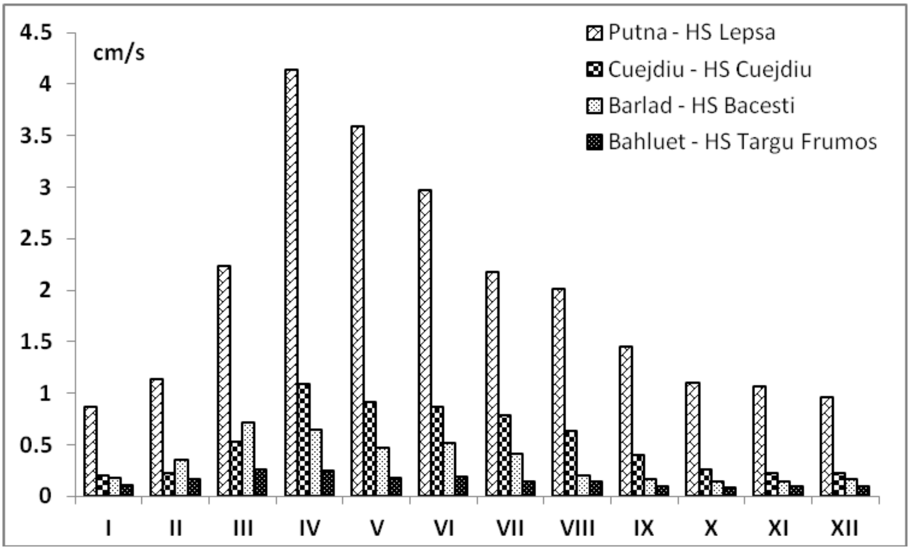

Fig. 4. The hydrologic regime of the analyzed rivers

Moreover, in the Moldavian Plateau area it was estimated that the frequency of dryness and drought periods is quite high (Minea and Stângă, 2004; Minea et al., 2005). These phenomena appear mostly in the end of summer, and the beginning of autumn (Fig. 4), so share of the underground supply increases significantly, especially when the periods without rainfalls are extended to more than 10 days. In these conditions, the river flow is assured entirely by the underground supply. Thus, within the general equation of the rivers flow $Q_i=S_i+U_i$, the surface supply could be eliminated, the measured flow of the rivers being entirely from underground sources ($Q_i=U_i$).

In this respect, we applied the methodology proposed by Eckhardt (2005, 2008). By applying the aforementioned algorithms it has been calculated the underground intake within the flow of the analyzed rivers. The figures of BFImax used in the algorithm, taking into account the specific geologic conditions, varied between 0,4 for the upper basin of Putna and for Cuejdiu basin, and 0,75 for the upper basins of Bârlad and Bahlueț. In these conditions, the calculated figures of the base flow index oscillate between 35% for the upper basin of Putna, 45% for Cuejdiu basin, and over 50% for the upper basins of Bârlad and Bahlueț. These figures integrate within those mentioned in the literature (Hârjoabă et.al 1997; Hârjoabă and Amăriucăi, 1998), that identifies an underground intake of 68% for Asău river (at Asău hydrometric station), of 53% for Tutova river (at Rădeni hydrometric station), and of 60,6 %, for Bahlueţ river (at Târgu Frumos hydrometric station), for the beginning of the ‛90s (Table 2).

Table 2. The underground intake within the flow of the analyzed rivers

No.	Hydrometric station	River	The underground intake calculated through classic methods	Reference	The underground intake calculated through Eckhardt method
1	Lepșa	Lepșa	25%	Ujvari (1972) Geografia României vol. I (1983) Zaharia (1999)	35%
2	Cuejdiu	Cuejdiu	35%	Ujvari (1972)	45%
3	Băcești	Bârlad	15%	Ujvari (1972) Butelcă (2012)	>50%
4	Târgu Frumos	Bahlueț	15% - 20%	Ujvari (1972) Pamtazică (1974) Vartolomei (2008)	>50%

4. CONCLUSIONS

The results thus obtained by using algorithms proposed by Eckhardt (2005, 2008) indicate that the contribution of underground rivers flow (often ranging between 40-50% in favor of underground supply) reflects in a more accurate manner the climatic and geological realities of the analyzed rivers (with increasing frequency of droughts and dryness in the plateau and plain area, and respectively a different ratio between retention and the ability to release water within the sedimentary deposits of the Eastern Carpathians mountain habitat). Also, a higher underground intake for the rivers flow modifies the method of calculation of hydrological balances, and thus, changes in water resources management.

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