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Assessment of the discharge regime and water budget of Belo Vrelo (source of the Tolišnica River, central Serbia)

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Abstract. A sufficiently long spring discharge regime monitoring data set allows for a large number of analyses, to better understand the process of transformation of precipitation into a discharge hydrograph. It is also possible to determine dynamic groundwater volumes in a karst spring catchment area, the water budget equation parameters and the like. It should be noted that a sufficiently long data set is deemed to be a continuous spring discharge time series of more than 30 years. Such time series are rare in Serbia. They are generally much shorter (less than 15 years), and the respective catchment areas therefore fall into the "ungauged" category. In order to extend existing karst spring discharge time series, we developed a model whose outputs, apart from mean monthly spring discharges, include daily real evapotranspiration rates, catchment size and dynamic volume variation during the analytical period. So far the model has solely been used to assess the discharge regime and water budget of karst springs. The present paper aims to demonstrate that the model also yields good results in the case of springs that drain aquifers developed in marbles. Belo Vrelo ("White Spring", source of the Tolišnica River), which drains marbles and marbleized limestones and dolomites of Čemerno Mountain, was selected for the present case study.

Key words: groundwater regime, catchment area, real evapotranspiration, dynamic volume, water budget, Belo Vrelo, Serbia.

Апстракт: Довољно дуг низ осматрања режима истицања неког врела омогућује примену великог броја анализа које могу помоћи да се процес трансформације падавина у хидрограм истицања боље разуме. Такође омогућајаву да се одреде: динамичке запремине подземних вода слива карстног врела, параметри билансне једначине, итд. Овде треба напоменути да довољно дуги низ подразумева чињеницу да је неопходно имати непрекидну серију осматрања режима истицања неког врела у временском интервалу дужем од 30 година, што је редак случај у Србији. Најчешће су серије осматрања истицања на врелима знатно краће (испод 15 година) што их на жалост сврстава у категорију хидролошки неизучених сливова. За потребе продужавања постојећих низова истицања карстних врела развијен је модел који, као излаз, поред серије средње месечних протицаја неког врела, даје и дневне вредности реалне евапотранспирације, површину слива и промену динамичке запремине у рачунском периоду. Модел је до сада примењиван искључиво за потребе анализе режима и биланса карстних врела. Сврха овог рада је да покаже да развијени модел даје добре резултате када су у питању и врела која дренирају издани формиране у мермерима. У конкретном случају је изабрано Бело врело (врело Толишнице) које дренира мермере и мермерисане кречњаке планине Чемерно.

Кључне речи: режим подземних вода, површина слива, реална евапотранспирација, динамичка запремина подземних вода, биланс вода, Бело врело.

Introduction

One the key prerequisites for efficient groundwater use for any purpose is knowledge of the hydrogeological characteristics of the area, the qualitative and quantitative characteristics of the groundwater, and the variations in these parameters over time. The aquifer regime is governed by a series of factors, pri-

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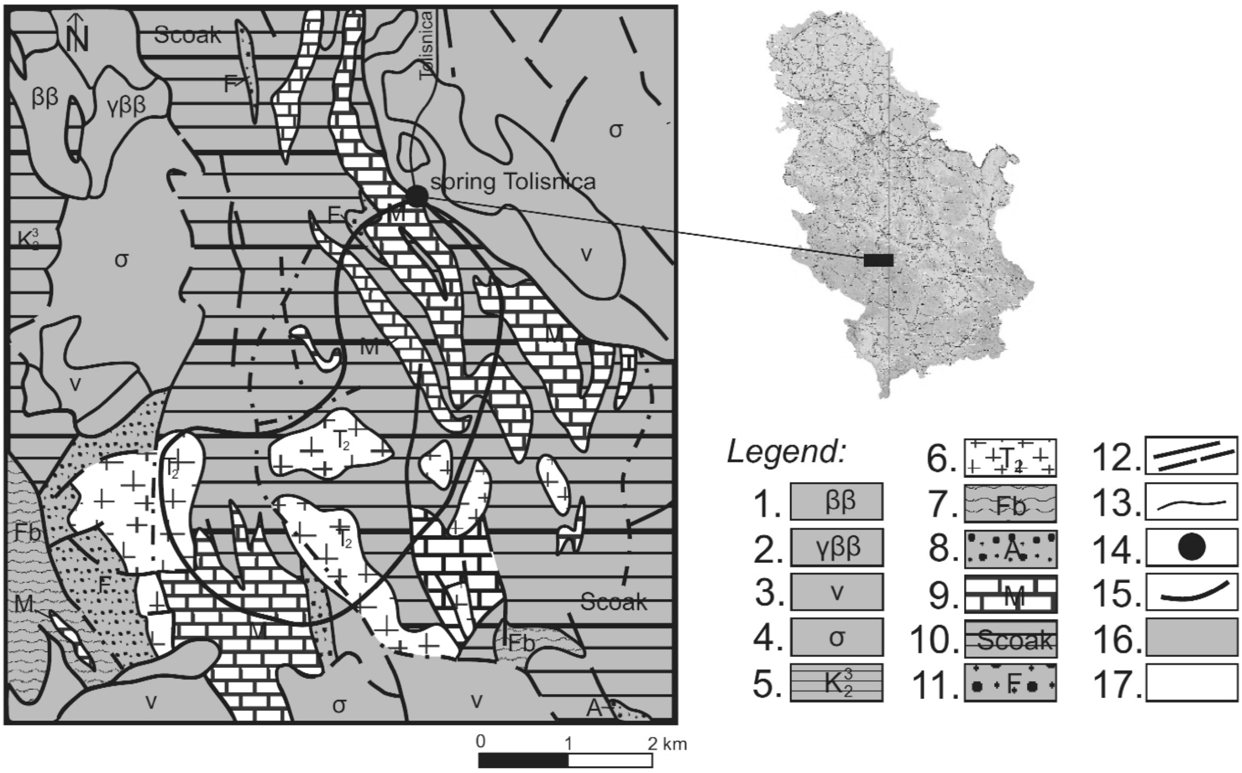

Fig. 1. Location and hydrogeological map of the Belo Vrelo (Tolisnica Spring) catchment (after BRKOVIĆ *et al.* 1977). Legend: **1,** diabases; **2,** gabbro-diabases; **3,** gabbros; **4,** harzburgites, siltstones, schistose mudstones and cherts; **5,** arenites, alevrolytes, schistose slays and cherts; **6,** massive dolomitic marbleized limestones; **7,** schists and biotitic phyllites; **8,** amphiboles; **9,** marbleized limestones; **10,** chlorite-epidote-actinolite rocks; **11,** phyllites; **12,** fault; **13,** surface stream; **14,** spring; **15,** water divide; **16,** fractured aquifer; **17,** karst aquifer.

marily the geological setting and the geomorphological, hydrogeological and climate conditions.

A catchment area is deemed to be gauged if the regime of relevant quantitative parameters has been monitored for at least 30 years. A catchment area is partially gauged if monitoring lasted for 15 to 30 years, and ungauged if the monitoring period was shorter than 15 years (PROHASKA 2003). From this perspective, gauged catchment areas of karst springs in Serbia are extremely rare. There are only two such cases at present: a karst spring near the Village of Žagubica, which is the source of the Mlava River, and Sveta Petka Spring near the City of Paraćin (STEVANOVIĆ *et al.* 2014).

The time series of all the other karst springs are either much shorter (from one to ten years) or there has been no monitoring at all, the latter being more often the case. Assessments of the discharge regime and water budget of ungauged springs, or those that have not been studied in hydrological and hydrogeological terms, can be misleading. To prevent potentially erroneous assessments of the water budget equation parameters in such cases, or to at least ensure reasonable departures from real values, the Department of Hydrogeology of the Faculty of Mining and Geology at the University of Belgrade developed a model that extends relatively short (less than 15 years) time series of karst spring discharges. Apart from extending the length of existing time series, the model provides the catchment size, real evapotranspiration rates and variations in karst spring dynamic volume in the analytical period for which gaps in the existing time series of average monthly discharges have been filled. To date, the model has been tested and applied to about 20 karst springs in Serbia (RISTIĆ 2007; RISTIĆ VAKANJAC *et al.* 2010, 2013, 2014a, 2014b; STEVANOVIĆ *et al.* 2010). The difference between the catchment size computed by the model and the real catchment size of the karst spring resulting from detailed hydrogeological research is up to 10%.

Described below is the outcome of an application of the model, in this case to Belo Vrelo (source of the Tolišnica River), which drains marbles, marbleized limestones and dolomites of Čemerno Mountain.

Geological and hydrogeological characteristics of the extended area of Belo Vrelo

The karst spring of Belo Vrelo is situated in central Serbia, in Ivanjica Municipality (Fig. 1). The drainage area of the spring belongs to the catchment area of the

Fig. 2. Belo Vrelo.

Fig. 3. Smrdljuš Summit of Čemerno Mountain.

Tolišnica River, which in turn belongs to the wider Lopatnica River Basin on the slopes of Čemerno Mountain**.** The upper part of the Lopatnica River Basin features several springs, the largest being: Belo Vrelo (Fig. 2), Konjsko Vrelo (Horse's Spring) and Mala Sokolina cluster of springs (Fig. 1). The altitude of most of the basin varies from 600 to 1000 m, while the edges of the basin in the south are as high as 1581 m a.s.l. (Fig. 3) (at Smrdljuš Summit of Čemerno Mountain).

The area is largely made up of Paleozoic deposits that hold a fractured aquifer. The sediments include phyllites, metamorphic quartz conglomerates, gneisses and schists, as well as marbleized limestones which are highly relevant to this research. In addition to Paleozoic sediments, there are also massive Middle Triassic dolomitic and marbleized limestones, but to a lesser extent. They occur as erosion remnants – peneplains, whose size is about 1.5 km^2. They constitute the margin of a large Triassic belt of Jelica Mountain, with which they are in contact. There are also Upper Cretaceous (Senonian) siltstones and schistose mudstones, overthrust on Senonian-Upper Cretaceous flysch (limestones, marls, sandstones and mudstones). The faults (the most pronounced of which are found in the Rudno–Propljenica zone) are nearly parallel to the plane of overthrust, roughly running in the NNW–SSE direction. Flaking is also evident in the middle of this zone, where Triassic sediments are developed. Young transverse faults are quite common throughout the area (Brković *et al.* 1977).

Limestones, marbleized limestones and dolomites determine to a large extent the hydrogeology of the study area because of their fracture porosity resulting primarily from local tectonic movements. The aquifer stores a considerable amount of groundwater. Towards the surface, these rocks act as hydrogeological collector-conduits, while in the deeper reaches they serve as collector-reservoirs, discharged at the point of contact with semi-permeable and impermeable rocks via springs formed in places where local faults occur, like in the case of Belo Vrelo. The study of the hydrogeological characteristics of the terrain included an analysis of spring discharges, whose minimum-to-maximum ratio was less than 10 and the number of karst features less than one per km^2.

Recharge comes from precipitation and sinking of small surface streams. In the case of fracture porosity, groundwater pathways are determined by the geological formation, extent of fracturing and local hydrogeological conditions. At Belo Vrelo, groundwater circulates within faults, fractures and fissures. Groundwater drainage, or discharge, is gravity-driven and takes place via springs exposed on the ground surface, whose discharge rates vary. Belo Vrelo features the highest discharge rates; the lowest rate ever recorded was 40 l/s in December 1978, while the highest rate was more than 300 l/s. Konjsko Vrelo (Horse's Spring) discharges some 5 l/s and Mala Sokolina springs 2 to 3 l/s. Belo Vrelo emerges on the ground surface below a bend called Tisovski Prevoj, on the northern slopes of Čemerno Mountain, at an altitude of 770 m. The spring is located at a distance of about 3 km from the Village of Tolišnica. The spring discharges through a steep slope at the point of contact between marbleized limestones and impermeable rocks. In the spring area, visible blocks of while marbleized limestones, 3–5 m wide, suggest the existence of a fault that follows the gradient of the terrain (about 30°).

Hydrological monitoring of Belo Vrelo

In 1994, the National Hydrometeorological Service established hydrological stations at several karst springs, including Belo Vrelo. Hydrometric surveys and water level monitoring began on 1 January 1995 and continued through the end of 2002. Table 1 shows mean monthly and annual discharges of Belo Vrelo during the period of monitoring. Generally speaking, maximum discharge rates are usually attributable to snowmelt and spring rains.

and the lowest only 67 l/s, recorded several times in 1995, 1996 and 2001. The 1995–2002 ratio of minimum-to-maximum discharges was 1:6, indicative of a relatively uniform discharge regime of Belo Vrelo. Figure 4 shows the 1996 hydrograph of this spring. The hydrograph includes one prolonged spring maximum (possibly two), and one minimum. The discharge peaks are generally attributable to snowmelt, which started in March/April, and spring rains (April/May/June). If snowmelt and spring rains occurred simultaneously, the hydrograph showed a prolonged peak. If the two events did not coincide, there were two or more lower peaks in the first half of the year. Conversely, the lowest discharge rates were noted in the summer months, when the discharge rates of Belo Vrelo were the lowest.

Table 1. Mean monthly and annual discharges of Belo Vrelo (m^3/s).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
1995	0.124	0.135	0.140	0.150	0.150	0.147	0.111	0.086	0.081	0.070	0.080	0.079	**0.113**
1996	0.078	0.079	0.080	0.109	0.147	0.147	0.117	0.086	0.106	0.115	0.106	0.106	**0.106**
1997	0.104	0.090	0.087	0.129	0.156	0.144	0.143	0.142	0.128	0.120	0.117	0.115	**0.123**
1998	0.115	0.131	0.115	0.127	0.115	0.108	0.103	0.086	0.087	0.100	0.105	0.100	**0.114**
1999	0.102	0.097	0.113	0.110	0.102	0.090	0.085	0.089	0.092	0.098	0.098	0.117	**0.099**
2000	0.123	0.114	0.125	0.109	0.098	0.088	0.081	0.079	0.093	0.089	0.089	0.088	**0.098**
2001	0.071	0.075	0.080	0.094	0.115	0.125	0.127	0.127	0.170	0.205	0.187	0.175	**0.129**
2002	0.247	0.241	0.232	0.264	0.188	0.178	0.172	0.208	0.253	0.266	0.330	0.214	**0.232**
Qav	**0.121**	**0.120**	**0.122**	**0.136**	**0.134**	**0.128**	**0.117**	**0.113**	**0.126**	**0.133**	**0.139**	**0.124**	**0.127**
σ	**0.05**	**0.05**	**0.05**	**0.05**	**0.03**	**0.03**	**0.03**	**0.04**	**0.06**	**0.07**	**0.08**	**0.05**	**0.04**
Cv	**0.45**	**0.45**	**0.41**	**0.40**	**0.24**	**0.25**	**0.26**	**0.40**	**0.47**	**0.51**	**0.60**	**0.37**	**0.35**
Cs	**2.12**	**1.91**	**1.83**	**2.31**	**0.51**	**0.05**	**0.67**	**1.66**	**1.75**	**1.46**	**2.13**	**1.33**	**2.50**
Max	**0.247**	**0.241**	**0.232**	**0.264**	**0.188**	**0.178**	**0.172**	**0.208**	**0.253**	**0.266**	**0.330**	**0.214**	**0.232**
Min	**0.071**	**0.075**	**0.080**	**0.094**	**0.098**	**0.088**	**0.081**	**0.079**	**0.081**	**0.070**	**0.080**	**0.079**	**0.098**

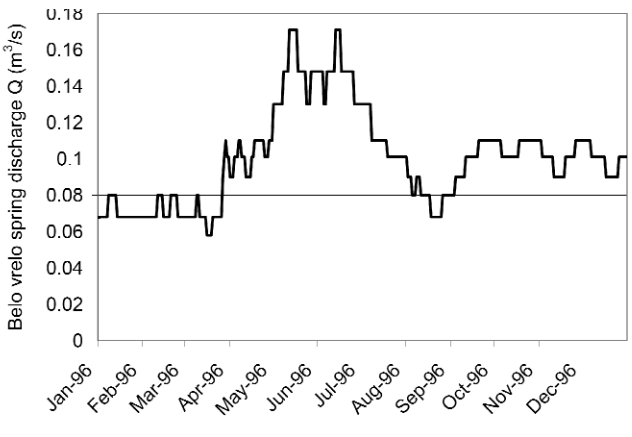

Fig. 4. 1996 hydrograph of Belo Vrelo.

Based on recorded daily discharges, the long-term average discharge for the period 1995–2002 was 0.127 m^3/s. The maximum mean monthly discharge rate was 0.330 m^3/s, registered in November 2002. The minimum mean monthly discharge was 0.070 m^3/s, in October 1995. With regard to absolute daily discharge rates, the highest was 410 l/s on 24/25 December 2002

Autocorrelation and cross-correlation analyses of Belo Vrelo

Correlation analyses of the effect of annual precipitation totals on discharge rates of Belo Vrelo were undertaken to substantiate the above conclusion, or, in other words, to corroborate the correlation between precipitation and discharge. At a calendar year level, the coefficients of correlation were extremely low ($r = 0.275$ for the station at Ivanjica and $r = 0.073$ at Kraljevo). However, when the hydrological year was assessed, the coefficients of correlation were much higher, amounting to $r = 0.465$ at Ivanjica and as much as $r = 0.667$ at Kraljevo. This was a result of the fact that winter (November, December and January) precipitation remained in the catchment area and caused runoff/discharge during the next calendar year, after snowmelt. As a result, this type of analysis generally requires parameter averaging with regard to the hydrological year (1 October to 30 September). Then a cross-correlation analysis was undertaken to examine the effect of daily precipitation totals on discharge rates of Belo Vrelo. Figure 5 shows a cross-correlogram with a 100-day time lag. It is apparent that the strongest correlation between precipitation and discharge was noted after one day, but that there was a pronounced peak after 32 days, which was certainly due to snowmelt.

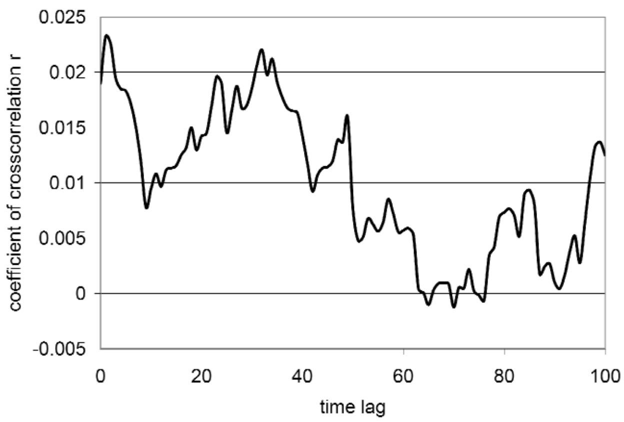

Fig. 5. Cross-correlogram (ČOKORILO ILIĆ *et al.* 2014).

Apart from the cross-correlation analysis of Belo Vrelo, an autocorrelation analysis was undertaken for a time lag of 100 days (Fig. 6). The autocorrelogram showed a strong correlation even after 100 days, corroborating the earlier claim that the discharge regime of Belo Vrelo is relatively uniform (or that the memory is long, 100 days or more).

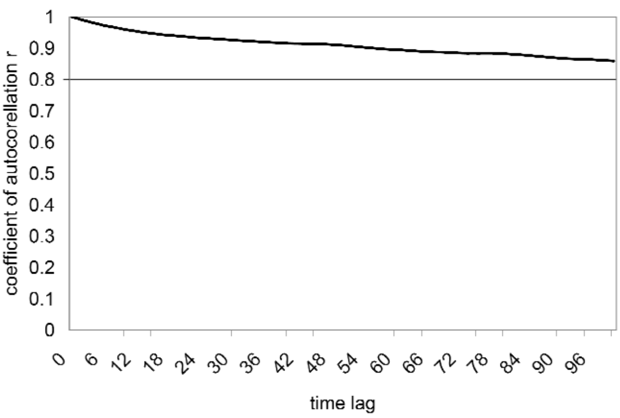

Fig 6. Auto-correlogram.

Recession curve analysis

Groundwater reserves of Belo Vrelo were assessed by recession curve analysis. A proper analysis of the retardation capacity of an aquifer requires a period of at least 90 days after heavy rainfall, with constant drainage and no recharge (aquifer recession). The discharge regime monitoring data revealed that these criteria were fulfilled in 1995, from 8 June to 2 November (a total of 148 days), and in 2000, from 23 March to 21 August (156 days). It should be noted that there was some rainfall during the period, but it had no significant effect on the spring discharge regime, as clearly shown in Figs. 7 and 8. Namely, during that period the rainfall was either torrential in nature, such that a part of the atmospheric precipitation was lost to surface runoff or evapotranspiration, or the precipitation totals did not cause any signification variation in the dynamic volume and thus had no effect on the discharge hydrograph.

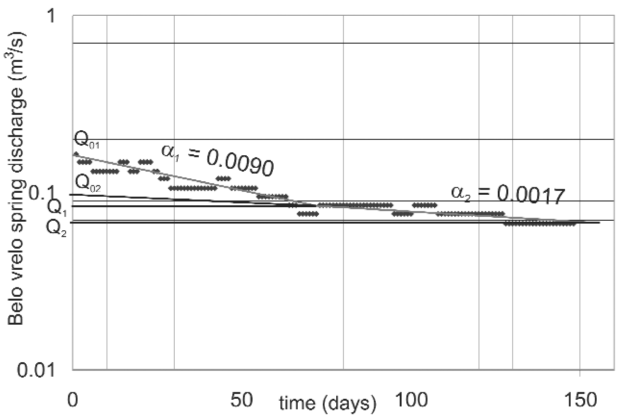

Fig. 7. Analyzed part of the regression stage of the hydrograph, 8 June to 2 November 1995.

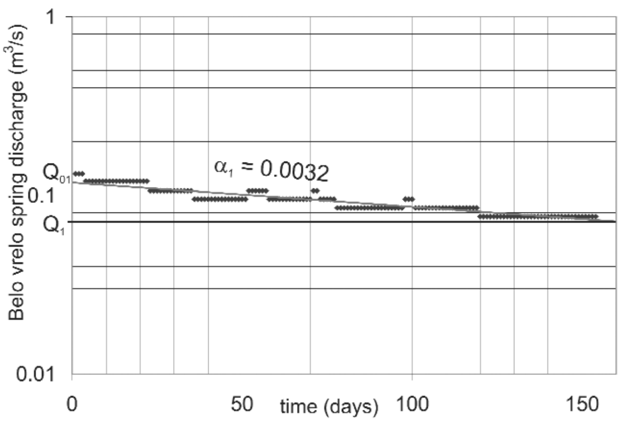

Fig. 8. Analyzed part of the regression stage of the hydrograph, 23 March to 21 August 2000.

Analysis of the regression stage of the hydrograph (Fig. 7) revealed two discharge microregimes, whose characteristics were nearly identical. Maillet's equation (MAILLET 1905; KREŠIĆ & BONACCI 2009) was used to compute the drainage coefficient:

$$\alpha = \frac{\log Q_0 - \log Q_t}{0.4343 \cdot (t - t_0)} \tag{1}$$

It follows from Eq. 1 that during the 1995 recession period (Fig. 7):

$$\alpha_1 = \frac{\log Q_{01} - \log Q_1}{0.4343 \cdot (t_1 - t_0)} = \frac{\log 0.155 - \log 0.081}{0.4343 \cdot 72} = 0.009013$$

$$\alpha_2 = \frac{\log Q_{02} - \log Q_2}{0.4343 \cdot (t_2 - t_0)} = \frac{\log 0.095 - \log 0.072}{0.4343 \cdot 156} = 0.001777$$

Similar results were obtained for the 2000 recession curve (Fig. 8):

$$\alpha_1 = \frac{\log Q_{01} - \log Q_1}{0.4343 \cdot (t_1 - t_0)} = \frac{\log 0.12 - \log 0.072}{0.4343 \cdot 160} = 0.003193$$

The drainage coefficients were of the same order of magnitude and demonstrated average-to-good recession characteristics of the aquifer. These parameters were used to determine the summary volume of the discharged water. In the first case (1995), the summary volume was:

$$V = V_1 + V_2 = \frac{Q_{01} - Q_{02}}{\alpha_1} \cdot 86400 + \frac{Q_{02} - 0}{\alpha_2} \cdot 86400$$

$$V = \frac{0.155 - 0.095}{0.009013} \cdot 86400 + \frac{0.095}{0.001777} \cdot 86400 =$$

$$= 575141 + 4619100 = 5194241 \text{ m}^3$$

and in the second case (2000):

$$V = V_1 = \frac{Q_{01} - 0}{\alpha_1} \cdot 86400 = \frac{0.12 - 0}{0.003193} \cdot 86400 = 3247490 \text{ m}^3$$

Application of the model to fill gaps in average monthly discharge time series

A model developed at the University of Belgrade, Faculty of Mining and Geology, Department of Hydrogeology was used to identify the parameters of the water budget equation, primarily the catchment area of Belo Vrelo. The model comprises several levels; in the present case:

1. Generation of a long-term time series of Belo Vrelo discharges using a mathematical model of multiple nonlinear correlation (MNC) for spatial transfer of hydrometeorological data (PROHASKA *et al.* 1977, 1979, 1995). Here the MNC model was used to extend the time series of average monthly discharges of Belo Vrelo for the period 1960–2009. Figure 9 shows the intra-annual distribution of derived average monthly discharges of Belo Vrelo during the analytical period.
2. Determination of potential evapotranspiration (PET) by means of a modified Thornthwaite equation (RISTIĆ 2007; RISTIĆ VAKANJAC *et al.* 2013).

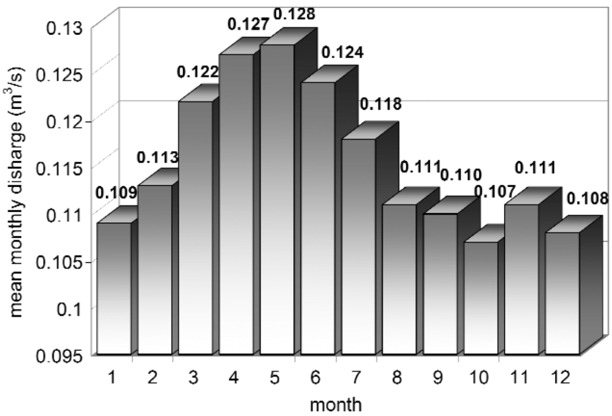

Fig. 9. Intra-annual distribution Belo Vrelo discharge (ČOKORILO ILIĆ *et al.* 2014).

3. Determination of real evapotranspiration (RET), catchment size and water budget of the considered aquifer as follows: for rainy days PET = RET, and for days following rainfall RET was obtained from the exponential equation RET = PET $\Theta^{2\tau}$, where Θ is a dimensionless parameter and τ is the time step (1, 2, 3 ...). For the parameter values Θ = 0, 0.1, 0.2, ..., 0.8, 0.9 and 0.95, the water budget equation was established by calibrating the potential catchment size such that the condition $V_0 \cong V_K$ was fulfilled. Then the function $\Theta = f$ (F) was constructed, where the vertex represented the real catchment area (Fig. 10) (RISTIĆ VAKANJAC *et al.* 2013).

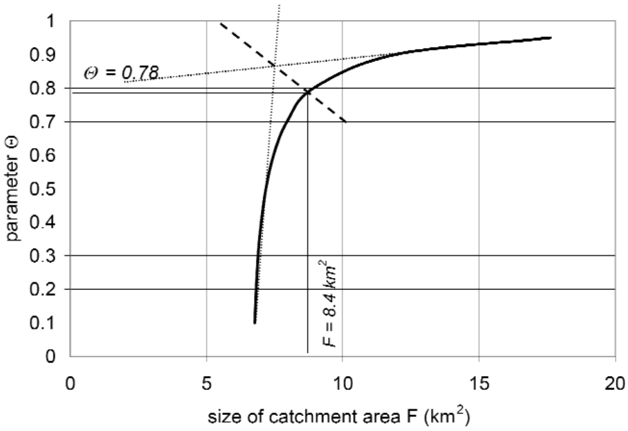

Fig. 10. Function $\Theta = f$ (F) of the Belo Vrelo catchment. (ČOKORILO ILIĆ *et al.* 2014).

The resulting catchment size could be used to compute the parameters of the water budget equation (Table 2). Table 2 shows: the catchment size F (km^2), the long-term average discharge Q (m^3/s), the discharged volume of water W (10^6 m^3), the long-term average runoff modulus q (l/s/km^2), the runoff layer h (mm), the average annual precipitation P (mm), the average annual evapotranspiration E (mm), and the long-term average runoff coefficient φ. To clarify some of the parameters, following are the equations that were applied in the analysis.

- Discharged volume W (10^6 m^3)

$$W = Q \cdot T \tag{2}$$

- Runoff layer h (mm)

$$h = \frac{W}{F} \tag{3}$$

- Runoff modulus q (l/s/km^2)

$$q = \frac{Q}{F} \tag{4}$$

- Average annual evapotranspiration E (mm)

$$E = P - h \tag{5}$$

- Runoff coefficient φ

$$\varphi = \frac{h}{P} \tag{6}$$

where: Q is the average annual discharge in m^3/s, T is a one-year period in seconds, W is the average annual discharge volume (m^3), F is the catchment area in m^2, P is the precipitation in mm, and h is the runoff layer in mm.

Table 2. Summary of Belo Vrelo water budget, 1960–2009.

F	P	E	h	Qav	q	W	φ
km^2	mm	mm	mm	m^3/s	l/s/km^2	10^6 m^3	°
8.6	866.5	445.6	421.0	0.116	13.5	3.62	0.48

Assessment of the dynamic volume of Belo Vrelo

The basic water budget equation for a karst aquifer, with a monthly time step, is:

$$\varphi = \frac{h}{P} \tag{7}$$

where:
P_{ij} - monthly precipitation totals of the karst catchment;
h_{ij} - total monthly karst spring discharge layer;
E_{ij} - monthly sums of actual (real) evapotranspiration in the karst catchment;
V_{ij} - water volume of the considered karst aquifer in the j-th month; and
Δ_{ij} - variation in stored karst groundwater, in the j-th month.

Given that monthly precipitation totals are known quantities and the average monthly runoff layer and monthly sums of real evapotranspiration were generated by the model, Eq. 7 is generally used to compute variations in dynamic volume during the analytical period. Such volume variations in a karst groundwater reservoir, derived in the above manner, are shown in Fig. 11. It is apparent that the total dynamic volume of Belo Vrelo, based on monthly values of all water

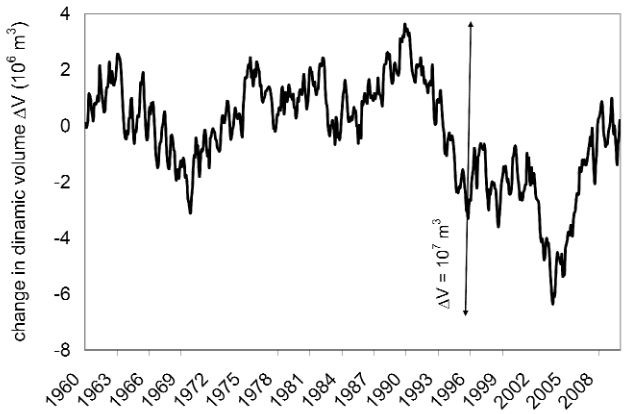

Fig. 11. Variation in dynamic volume of Belo Vrelo.

budget components during the analytical period from 1960 to 2009, amounted to approximately 10^7 m^3.

Conclusion

The general conclusion was that the annual average discharge rate of Belo Vrelo was Q = 0.116 m^3/s. Given that the catchment size of this spring is 8.6 km^2, the long-term average discharge layer during the analytical period was h=421.0 mm. With regard to water abundance, the specific yield of the Belo Vrelo drainage area was found to be 13.5 l/s/km^2, while the derived runoff coefficient suggested that 48% of all precipitation was infiltrated and then discharged via springs. The quality of this bacteriologically safe water is extremely high, such that it can be used for domestic water supply, agriculture and fish farming.

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Резиме

Процена режима истицања и биланса вода Белог врела (извор реке Толишнице, централна Србија)

Хидролошка изученост неког слива подразумева да су осматрања режима квантитативних параметара вршена у интервалу од минималних 30 година. Карстна врела на жалост имају знатно краће низове осматрања (од 1 до 10 година) или, углавном, осматрања до сада уопште нису вршена на њима. Анализе режима истицања и прорачун параметара биланса код ових врела које можемо сврстати у групу хидролошки/хидрогеолошки неизучених сливова, могу понекад довести до погрешних закључака. Да би се потенцијалне грешке одређивања параметара билансне једначине елиминисале код ових случајева, или свеле на разумна одступања од реалних вредности развијен је модел за потребе продужавања постојећих низова релативно кратких серија осматрања истицања из карстних врела (испод 15 година). Једно од врела које нема довољно дуги низ осматрања је и Бело врело (врело Толишнице). Врело није каптирано, налази се у централном делу Србије, територи-

јално припада општини Ивањице (слика 1) и дренира падине планине Чемерно.

У широј зони Белог врела, поред палезојских седимената присутни су у мањем обиму масивни доломитични и мермерисани кречњаци средњег тријаса. Јављају се у виду ерозионих остатака - крпа величине око 1.5 km^2 и чине незнатан огранак великог тријаског појаса планине Јелице са којима су у контакту. Присутни су и алевролити и шкриљави глинци горње креде (сенон), навучени преко сенонско горњекредног флиша (кречњаци, лапорци, пешчари, глинци). Кречњаци, мермерисани кречњаци и доломити имају велики хидрогеолошки значај на испитиваном терену јер имају значајну пукотинску порозност насталу на првом месту као последица локалних тектонских покрета. Ове стене у површинским деловима представљају хидрогеолошке колекторе - спроводнике, док у дубљим деловима представљају колекторе - резервоаре из којих се на контакту са слабо водоносним и водонепропусним стенама врши њихово пражњење путем врела која су формирана у зонама локалних раседа, што је случај и са Белим врелом.

Током 1994. године РХМЗ је успоставио хидролошке станице на више карстних врела међу којима је било и Бело врело. Осматрања водостаја и мерења протицаја су трајала до краја 2002. године. На основу добијених дневних вредности протицаја Белог врела може се констатовати да је средњи вишегодишњи протицај за период од 1995–2002. године износио 0.127 m^3/s (табела 1). Максимални средње месечни протицај се јавио током новембра 2002. године и износио је 0.330 m^3/s. Минимални средње месечни протицај регистрован је у октобру 1995. године и износио је 0.070 m^3/s. Што се тиче апсолутних дневних протицаја, максимални дневни протицај јавио се 24. односно 25. децембра 2002. године и износио је 410 l/s, док је апсолутно минимални протицај у износу од свега 67 l/s регистрован више пута током 1995., 1996., и 2001. године. Однос регистрованих максималних и минималних протицаја за поменути осматрачки период је 1:6 што указује на релативно уједначен режим истицања овог врела.

Ради потврђивања постојеће везе падавине – истицање урађене су корелационе анализе утицаја годишњих сума падавина на истицање Белог врела. Уколико се разматра ова веза на календарском нивоу коефицијенти кореалције су изузетно ниски (p = 0.275 – к.с. Ивањица, p=–0.073 – м.с. Краљево). Са друге стране ако се анализира веза падавине – протицај врела на нивоу хидролошке године, коефицијенти корелације су знатно значајнији и износе за к.с. Ивањица p = 0.465 и за м.с. Краљево чак p = 0.667. Ово је последица чињенице да падавине у току зимских месеци (новембар и децембар) се задржавају у сливу и изазивају отицај/истицање у наредној години када долази до њиховог отапања. Тако да при овој врсти анализа неопходно је вршити осредњавање параметара на нивоу хидролошке године (1. октобар – 30. септембар). Ово потврђује и кроскорелациона анализа (слика 5) на којој се види да је најчвршћа веза утицаја падавина на истицање врела након једног дана, с тим да је изражен пик и након 32 дана што је свакако последица отапања снега.

Прорачун резерви подземних вода извора реке Толишнице извршен је и применом методе анализе ретардационе криве. За валидну анализу ретардационих способности издани потребан је период од завршетка изражених падавина са константним пражњењем без прилива у трајању од најмање 90 дана (рецесија издани). Анализом резултата режимских осматрања може се увидети да је овај услов испуњен током 1995. године, период од 8. јуна до 2. новембра (укупно 148 дана) и током 2000. године, период од 23. марта до 21 августа (укупно 156 дана), када је долазило до константног пражњења врела. Добијени коефицијенти пражњења су истог реда величине, и указују на средња до добра рецесиона својства формиране издани. Ови параметри рецесионих својстава искоришћени су за утврђивање збирне запремине отекле воде.

За потребе дефинисања параметара билансне једначине а на првом месту сливне површине Белог врела коришћен је поменути модел развијен на Рударско-геолошком факултету, Департману за хидрогеологију. Примењен модел се састоји из више нивоа. Коришћењем нивоа 1 осматрачки низ средње месечних протицаја је продужен на период од 1960–2009. године. Средње вишегодишњи протицај овако дефинисаног рачунског низа износи 0.116 m^3/s. Као излаз из нивоа 3 добијена је реална површина слива у износу од 8,6 km^2 (слика 10). Затим су добијене реалне вредности дневних евапотранспирација и промене динамичке запремине на месечном новоу за рачунски период (слика 11). Параметри билансне једначине подземних вода Белог врела срачунати су коришћењем адекватних једанчина (јед. 2, 3, 4, 5 и 6) а њихове вредности су приказане у табели 2.

Генерално може се закључити да са сливног подручја Белог врела просечно годишње истекне укупно 116 l/s Како сливна површина врела Толишница износи 8.6 km^2, средње вишегодишњи слој истицања за рачунски период износи h =421.0 mm. Са гледишта водности подручја, може се констатовати да специфична издашност слива Белог врела износи 13.5 $l/s/km^2$, док на основу срачунатог коефицијента отицаја може се закључити да се 48% од укупно пале воде (падавина) инфилтрира и касније истиче кроз врела. Ова бактериолошки чиста вода и изузетног квалитета може се користити за потребе водоснабдевања локалних домаћинстава, за потребе пољопривреде или пак за потребе рибогојства.