

SUPPLEMENT TO THE PAPER “GROUNDWATER DYNAMICS  
BETWEEN PLANINSKO POLJE AND SPRINGS OF THE  
LJUBLJANICA RIVER, SLOVENIA” FROM BLATNIK ET AL. (2019)  
PUBLISHED IN ACTA CARSOLOGICA 48/2

DODATEK K ČLANKU »DINAMIKA PODZEMNE VODE MED  
PLANINSKIM POLJEM IN IZVIRI LJUBLJANICE, SLOVENIJA»  
OBJAVLJENEM V ACTA CARSOLOGICA 48/2

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## INTRODUCTION

The article of Blatnik *et al.* (2019) “Groundwater dynamics between Planinsko Polje and springs of the Ljubljana River, Slovenia” published in *Acta Carsologica*, 48/2 focused on describing the hydrogeological behaviour of the aquifer between Planinsko Polje and the springs of the Ljubljana River. The authors analysed the effect of different high water events that occurred between January 2015 and May 2018. Interpretations were based on hydrographs obtained by continuous measurements of water level, temperature and specific electric conductivity in selected ponors, springs and water active caves located in the area between Planinsko Polje and the

springs of the Ljubljana River. Through these interpretations, different conceptual hydrological models about the dynamics and directions of the flow in the aquifer have been proposed and tested. A flow connection was proposed between the Hrušica Plateau, estavelles located at the NW border of Planinsko Polje, and caves Gradišnica (W2) and Gašpinova Jama (W3) close to town Logatec. In this supplement we provide new data recorded during unusual hydrological event in August 2018. These further support and stress the importance of connection between the Hrušica Plateau and Logatec region (W2 and W3).

## THE EVENT OF AUGUST 2018

Between the 23<sup>rd</sup> and the 26<sup>th</sup> August 2018, an important rainfall event occurred above the recharge area of the Ljubljana River. The total amount of rain varied

greatly from one location to the other, with cumulative rainfall rates switching from 60 mm to 173 mm within a few kilometres distance (Fig. 1). While most of the area

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southern from Planinsko Polje registered a total rainfall amount between 60 and 80 mm (Fig. 1), the area around the Hrušica Plateau recorded cumulative rainfall rate between 150 and 173 mm, with the majority of the rain falling within a 13 hours period on the 25<sup>th</sup> of August. This is especially visible at the meteorological stations Vodice, Logatec and Vrhnika, which respectively measured a total rainfall amount of 93, 114 and 124 mm for this day (ARSO 2020a).

The uneven spatial distribution of the rain resulted in different hydrological reactions within the entire Ljubljana River recharge area (Fig. 2). As an example, the discharge of the Ljubljana River increased rapidly from 2.5 m<sup>3</sup>/s to 71 m<sup>3</sup>/s, and reached peak flow on August 26<sup>th</sup> at 6:00. Conversely, the Unica River started to react half a day later due to the lower quantity of precipitation in southern part of the recharge area. The discharge recorded at the gauging station of Planinsko Polje slightly

increased from a base flow value of 2.6 m<sup>3</sup>/s to a maximum of 11.1 m<sup>3</sup>/s on August 27<sup>th</sup> at 15:30.

On Planinsko Polje the Unica River was entirely drained by the eastern line of ponors and did not reach the northern ponor area. Accordingly, the water level response in caves connected to the drainage from Planinsko Polje was small. The cave Vetrovna Jama pri Laški Kukavi (E2) registered a 1.7 m high increase of water level on August 26<sup>th</sup> at 4:00, prior to the increase of the Unica River discharge. Then, the level oscillated around 0.8 m and stayed stable at 1 m also after the discharge of Unica River increased. In Najdena Jama (W1) the level increased for 1.2 m and stayed stable during the whole period.

Due to the high amount of rainfall in the Hrušica Plateau, the hydrological response observed in the caves located on its eastern border was significantly different (Fig. 2). The water level increased for 37 m in the cave

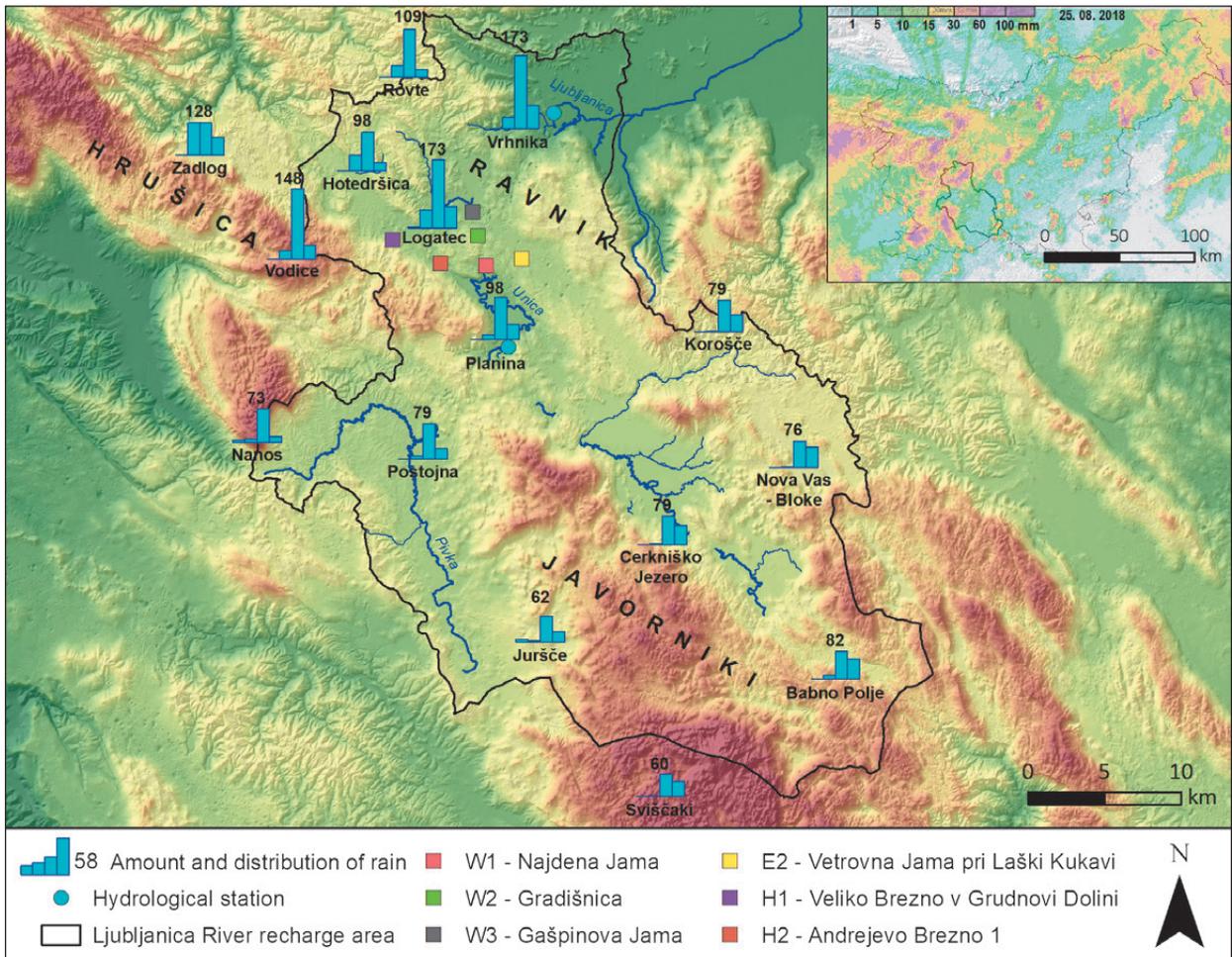


Fig. 1: Distribution and total amount of rainfall recorded between the 23<sup>rd</sup> and the 26<sup>th</sup> of August 2018 in the Ljubljana River recharge area. Inset shows the radar distribution of rainfall above Slovenia and the Ljubljana River recharge area on 25<sup>th</sup> August 2018 (ARSO, 2020a). Elevation data have been obtained from ARSO (2020b).

Veliko Brezno v Grudnovi Dolini (H1), with an initial increase of 33 m in only 6 hours (August 26<sup>th</sup> at 4:00). The logger position in Andrejevo Brezno 1 (H2) is above the water level at low and medium flow conditions. The hydrograph shows peak of high floods and is delayed and less abrupt. The peak level in H2 was recorded on the August 27<sup>th</sup> at 0:00. The reaction in H1 was simultaneous to the increase of discharge at the springs of the Ljubljana River (Fig. 2). This indicates a fast response of the system to the high quantity of rain that infiltrated through the unsaturated zone.

Records from Gradišnica (W2) and Gašpinova Jama (W3) show almost identical response of the water level with a maximum increase of 14 m on August 26<sup>th</sup> at 6:00. The relatively strong response at W2 and W3 in the absence of flow Planinsko Polje supports our previous assumption on flow connection between the eastern border of Hrušica Plateau (H1) and the Logatec region (W2/W3).

Level hydrographs in W2/W3 correlate with that in

H1, showing some peaks and inflections with an up to 2h delays. The level responses fit well into the concept presented in original paper of Blatnik *et al.* (2019). This assumes a flow restriction downwards from W2/W3, which keeps the uniform level in the W2/W3 region and another restriction between H1 and W2, which causes the backflooding of the H1 region.

Blatnik *et al.* (2019) demonstrated that water originating from the Hrušica Plateau periodically flows towards the estavelles near Grčarevec and consequently recharge Planinsko Polje during the onset of high-water periods. Similarly, the same estavelles behave like ponors and drain water back into the aquifer when the flood is receding in the polje. This assumption was proved by analysing both water level and temperature dynamics in the cave Andrejevo Brezno 1 (H2) and in Planinsko Polje (Blatnik *et al.* 2019). During August 2018 event, the water level in Andrejevo Brezno 1 (H2) barely reached the level of polje, so that the estavelles were not activated.

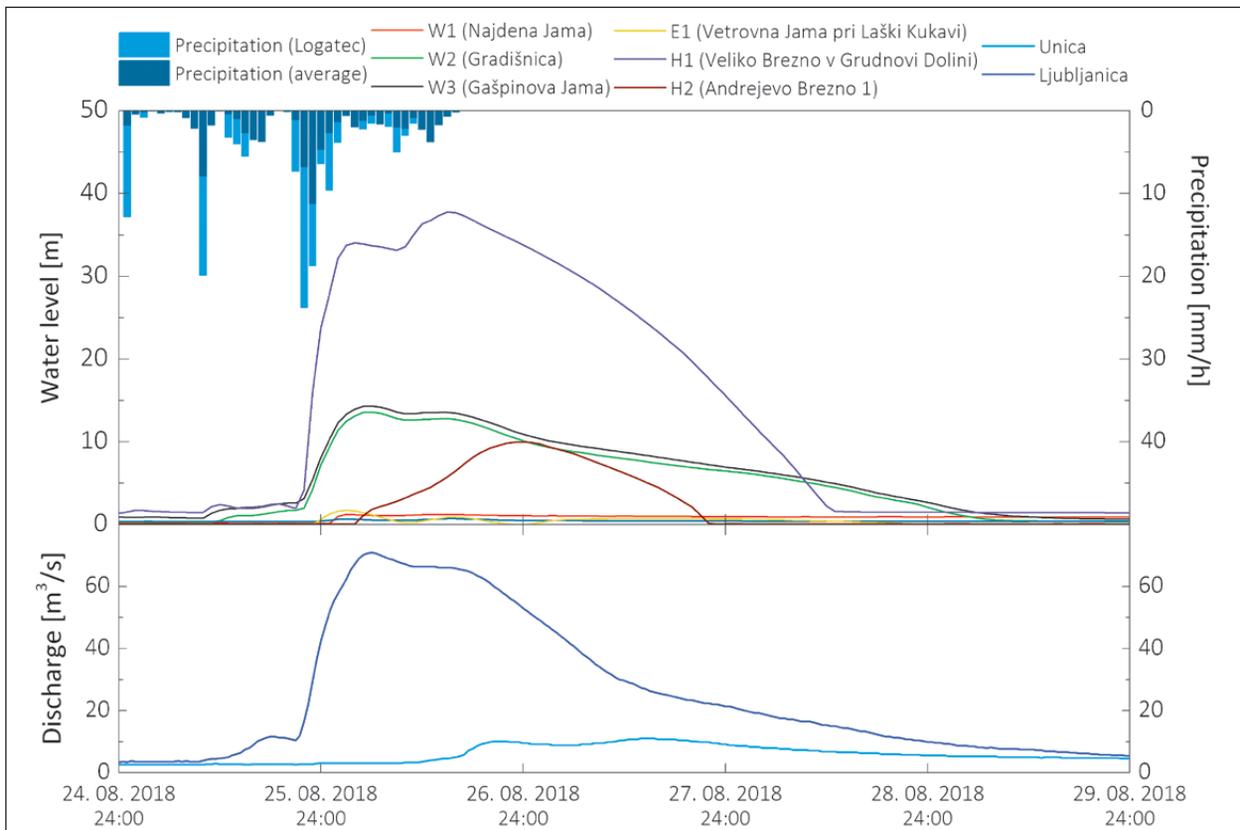


Fig. 2: Hydrological data of the event of August 2018 showing precipitations, increase of water level and flow discharges in selected caves and rivers after the intense rainfall event of August 2018. Average precipitation depicts the mean hourly precipitation of the entire Ljubljana River recharge area, computed based on data coming from 9 rain gauges installed in the catchment. Discharge data were provided by ARSO (2020c).

## CONCLUSIONS

The data of the August 2018 event give further evidences to the concepts presented by Blatnik *et al.* (2019) on the flow connection between the border of Hrušica Plateau and the Logatec region. This implies a zone of high hydraulic transmissivity within the Idrija Fault Zone, which is otherwise acting as a regional flow barrier. The data also demonstrate that this flow may present an important

contribution of the total outflow at the springs of Ljubljana region.

Last but not least, only long term observations can capture variety of hydrological events and responses, which are necessary to build reliable conceptual models of aquifer's structure and functioning.

## ACKNOWLEDGEMENTS

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## REFERENCES:

- ARSO, 2020a: Meteorological archive.- [Online] Available from: <http://meteo.arso.gov.si/met/sl/archive/> [Accessed June 30<sup>th</sup> 2020].
- ARSO, 2020b: Lidar data fishnet.- [Online] Available from: <http://gis.arso.gov.si/> [Accessed June 30<sup>th</sup> 2020].
- ARSO, 2020c: Hydrological archive.- [Online] Available from: <http://vode.arso.gov.si/hidarhiv/> [Accessed June 30<sup>th</sup> 2020].
- Blatnik, M., Frantar, P., Kosec, D. & F. Gabrovšek, 2017: Measurements of the outflow along the eastern border of Planinsko Polje, Slovenia.- *Acta Carsologica*, 46, 1, 83–93. DOI: 10.3986/ac.v46i1.4774
- Blatnik, M., Mayaud, C. & F. Gabrovšek, 2019: Ground-water dynamics between Planinsko Polje and springs of the Ljubljana River, Slovenia.- *Acta Carsologica*, 48, 2, 199–226. DOI: 10.3986/ac.v48i2.7263

## POVZETEK

Članek »Dinamika podzemne vode med Planinskim poljem in izviri Ljubljane, Slovenija«, ki je bil objavljen v *Acta Carsologica* 48/2, se je v osnovi osredotočil na raziskave pretakanja podzemne vode med Planinskim poljem in izviri Ljubljane. Med rezultati so bila izpostavljena tudi nova dognanja o smereh pretakanja podzemne vode, ki so bila ugotovljena na podlagi zveznih meritev vodostajev, temperature in specifične električne prevodnosti vode ter testiranja z numeričnimi hidravličnimi modeli.

Med drugim je bila ugotovljena domnevna smer pretakanja vode iz jam Veliko brezno v Grudnovi dolini (H1) in Andrejevega brezna 1 (H2), ki se nahajata na vzhodnem pobočju planote Hrušica. Od tu naj bi se voda v času visokih vodostajev pretakala v več smeri, in sicer proti estavelam pri Grčarevcu (SZ rob Planinskega polja) ter proti območju Logaškega ravnika, kjer se nahajata jami Gradišnica (W2) in Gašpinova jama (W3). Pričujoč dodatek k članku potrjuje pretekle domneve, v njej pa opisuje

jemo manj običajen padavinski dogodek iz konca avgusta 2018, ko je na območju Hrušice padla mnogo večja količina padavin kot v preostalem delu porečja Ljubljanice. Rezultat je bil rahlo povišan pretok Unice, pri katerem je voda dosegla le vzhodno skupino požiralnikov na Planinskem polju. Posledično so se vodostaji v nekaterih dolvodno ležečih jamah Vetrovna jama pri Laški kukavi (E2) in Najdena jama (W1) zelo malo povišali (< 2 m). Mnogo bolj izrazit in zelo hiter je bil dvig vodostaja v jamah na pobočju Hrušice (do 37 m v H1). Porast vodostaja v jamah Gradišnica (W2) in Gašpinova jama (W3) je bil znaten (14 m), prav tako je do odziva in viška prišlo le malo po porastu v Velikem breznu v Grudnovi dolini (H1). Ob teh predpostavkah in dejstvu, da je bil dotok iz Planinskega polja zelo skromen, je hidrološka povezava med

planoto Hrušico na eni strani Idrijske prelomne cone in območjem z Gradišnico (W2) in Gašpinovo jamo (W3) na drugi strani nedvoumna. Meritve s tem podkrepijo tudi domneve, da se na proučevanem območju nahajajo zožitve in različno prevodna območja Idrijske prelomne cone, ki vplivajo na zelo sinhrono dinamiko vodostajev. Proučevan padavinski dogodek je nakazal tudi, da je dotok iz območja Hrušice lahko zelo izdaten, saj se je najvišji pretok Ljubljanice (~71 m<sup>3</sup>/s) izrazito presešel tistega na Unici (11 m<sup>3</sup>/s). Pričujoč dodatek k članku torej potrjuje domneve v predhodno opisanem članku, hkrati pa tudi poudarja pomen dolgoročnih meritev v kraških vodonosnikih, ki v množici medsebojno podobnih zabeležijo tudi nekatere manj običajne, a za interpretacije zelo pomembne dogodke.