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LJUBLJANSKO BARJE

The flat Ljubljansko Barje (a.k.a Ljubljana Moor) at around 290 m a.s.l. extend on the area of 163 km² south of Ljubljana (Central Slovenia). The southern rim is represented by hills up to 1100 a.s.l. consisting of karstified Triassic and Jurassic limestone and dolomite. Ljubljansko Barje is tectonic basin filled with lacustrine and marsh sediments in the central part and on the margins with large alluvial fans. Carbonates of the southern rim are present as bedrock in the large part of the basin.

Introduction

Sedimentation basin of Ljubljansko Barje presents one of the biggest aquifers and important drinking water resources in the central part of Slovenia. Several drinking water wells are present in the area. The biggest system is water field Brest with 13 wells positioned on the Iška River quaternary fan in the south (Fig. 1). Alluvial fan consists mainly of coarse gravel with lenses of sand. In the deepest part it is 110 m thick. The wells are constructed to different depths; from 28 m to 200 m (Fig. 2). Groundwater is mainly pumped from quaternary sediments, because the groundwater in Pleistocene aquifers is polluted with desetilatrazine.

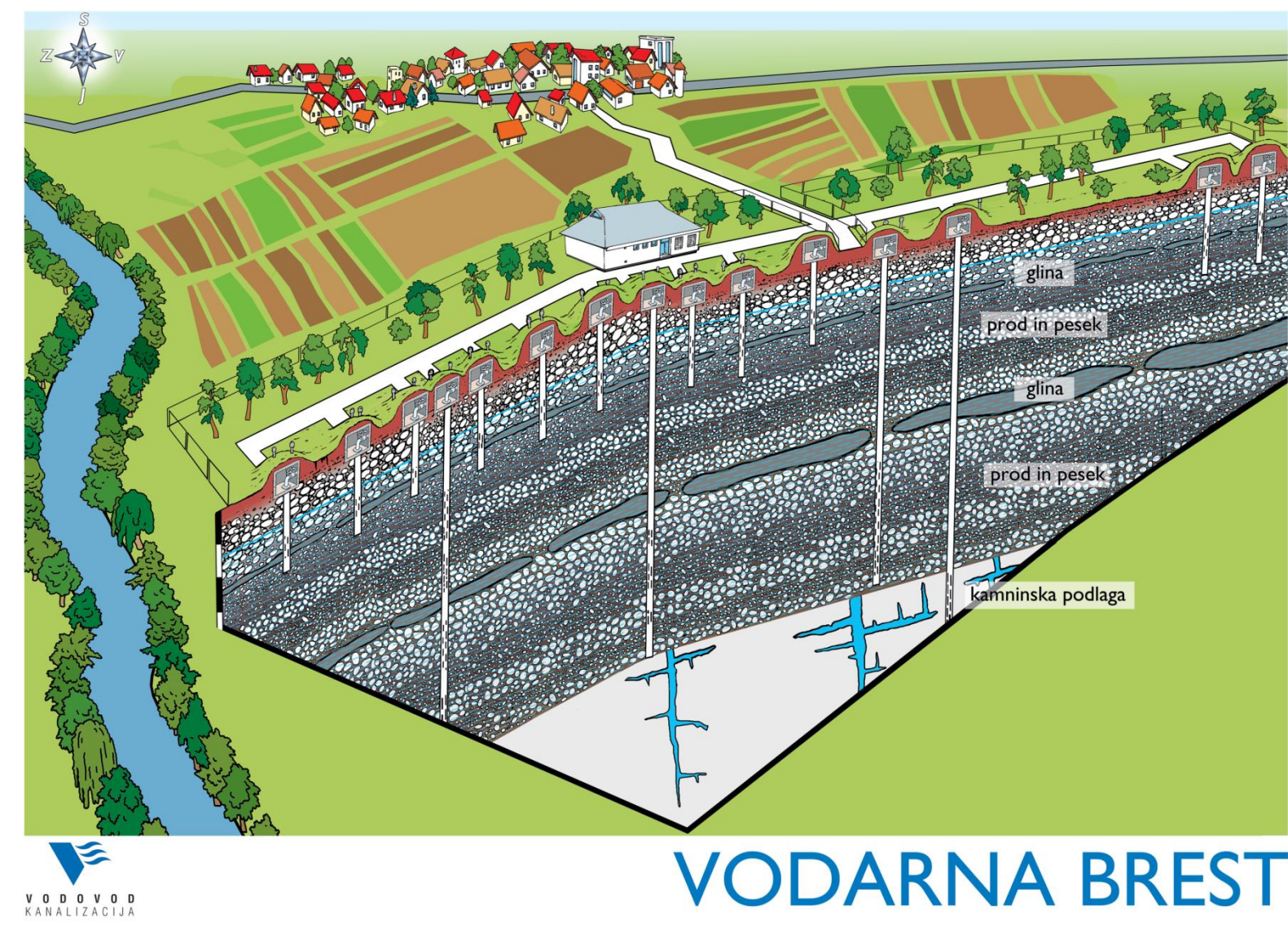


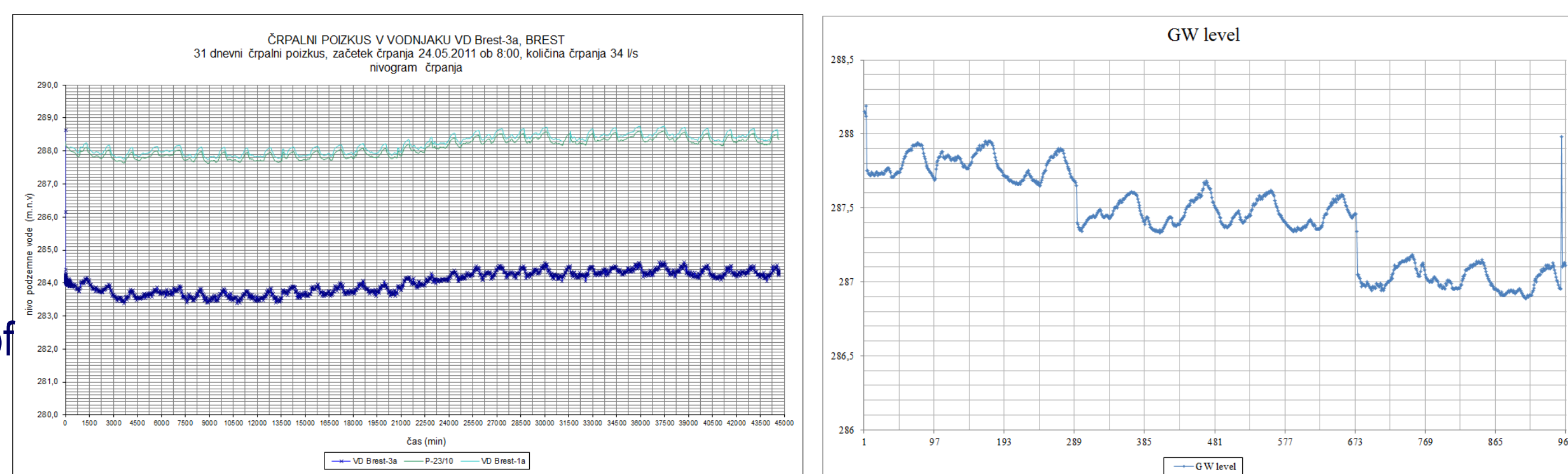
Figure 1: The area of the water field Brest on the Iška River quaternary fan.

Figure 2: The cross section of the aquifer in the area of the Brest wells.

In the recharge area of the well field is developed agriculture and several villages where small business enterprises and farms are present. In the last decade the deterioration of groundwater quality from quaternary sediments was detected. To avoid problems with pollution in 2011 the 210 m deep well was drilled in the Triassic dolomite bedrock (Fig. 2). The dolomite was cracked and cracks were filled with clay. This indicates dolomite carstification. Filters of the well were positioned in the dolomite and quaternary sediments were isolated by casing and cementing.

Groundwater dynamics

Figure 4: Fluctuations of the groundwater in the well.VD Brest-3a



ISOTOPES AS 'FINGERPRINTS'

Isotopes are useful fingerprints and provide information about the origin and renewal rate of groundwater or residence time, its dynamics, as well as the vulnerability to sources of pollution and climate change. In order to understand the hydrogeological system we can combine multi isotope determinations with hydrochemical analyses. $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values give the information about water sources and movement while $\delta^{13}\text{C}_{\text{DIC}}$ is used to describe the biogeochemical reactions controlling alkalinity in the aquifer and to trace the bicarbonate ion as the main anion in the shallow groundwater.

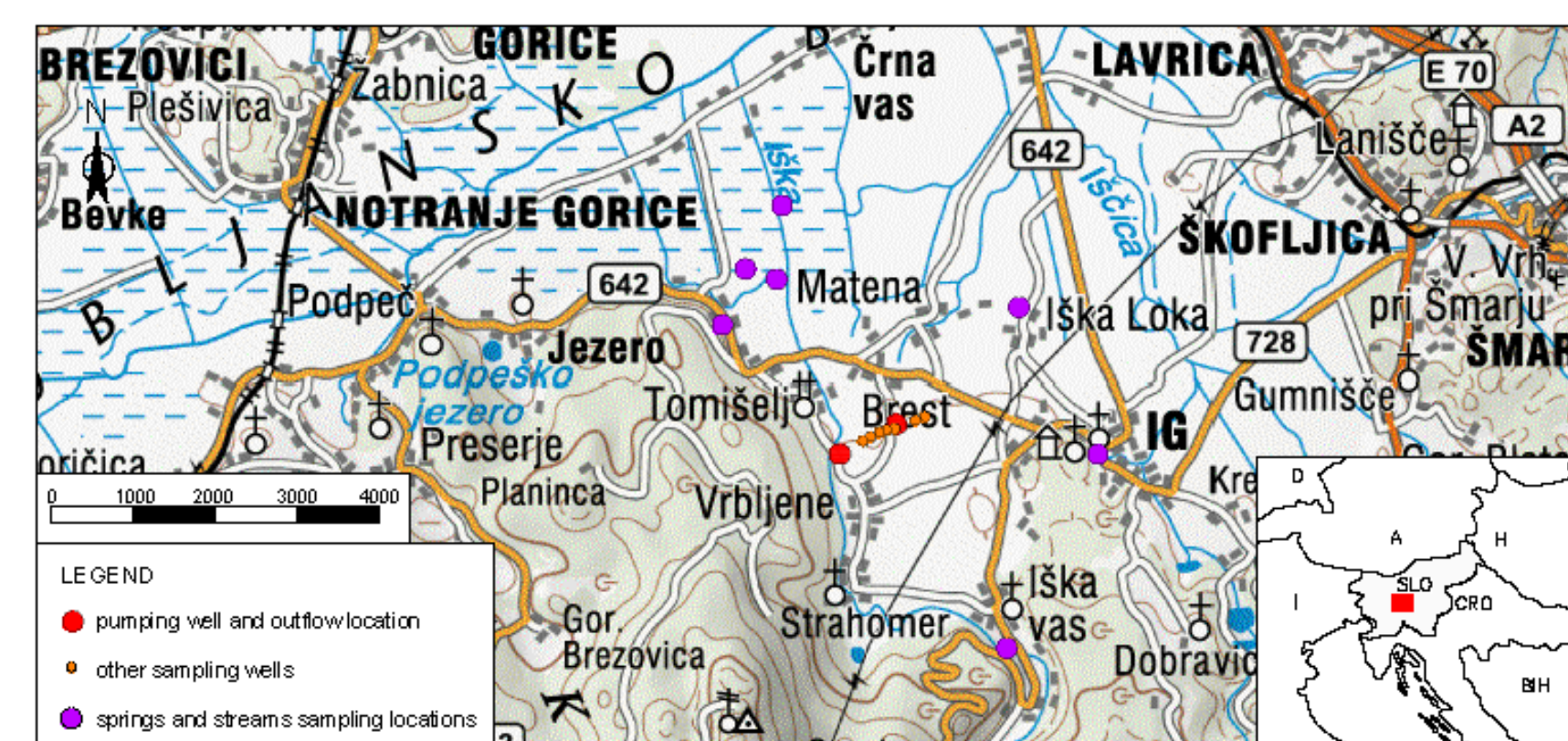


Figure 3: Sampling locations

Pumping tests

The first pumping test of 30 days in VD Brest-3a well was performed after the construction in 2011. The pump has been installed at a depth of 77 m. The entire duration of the test we pumped 34 l/s. The groundwater was sampled at the pipe of the well (Fig. 5) and at the outflow in the Iška River (Fig. 6) where pumped water runs along the fire tube. To compare the water was also sampled at selected wells within the Brest pumping station and some springs and surface waters in the Ljubljana Moor (Fig. 3). Water for $\delta^{18}\text{O}$ and $\delta^2\text{H}$ was collected directly in a 100 mL plastic bottle with an inner cap, while samples for $\delta^{13}\text{C}_{\text{DIC}}$ were filtered over 0.2 μm filter in 12 mL exetainer. Before the analysis the samples were stored in a cool place. Measurements of the physical parameters were carried out in the field with a portable WTW instrument. While pumping intense rains occurred and consequently rise in groundwater level.

The second pumping test was performed in 2013. The pump was installed at a depth of 150 m. Pumping was carried out in three phases under three different flow rates. At the beginning the flow rate was 10 l/s, after three days the flow was increased to 15 l/s, and after a further four days the maximum flow rate of 20 l/s. During this pumping test the water samples were collected only at the pipe of the well (Fig. 5) and at the outflow in the Iška River (Fig. 6). In addition to the isotopic and physical parameters, the water samples for alkalinity, nitrite and pesticides were collected. The weather during the test was sunny and stable.

Challenge

The pumping tests and measurements were carried out to confirm or dispute the conceptual model of Ljubljansko barje that discusses about three separated aquifers. The dolomite aquifer should be recharge only from the Krim-Mokerc mountains in the hinterland and there should be no pollution that originates from human activities.



Figure 6: Outflow in the Iška River



Figure 5: The well VD Brest-3a

Results in 2011

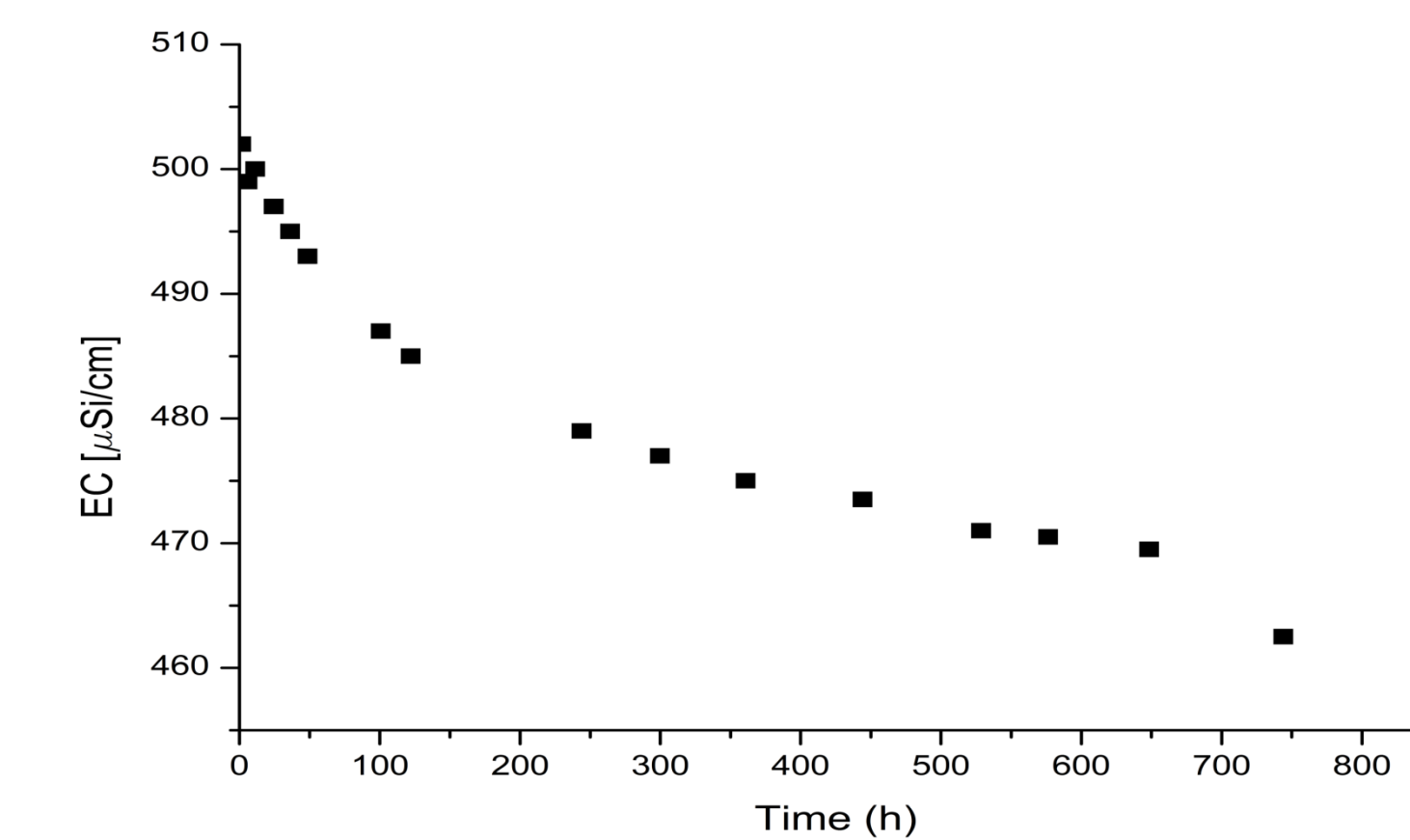


Figure 7: The electrical conductivity during the pumping test

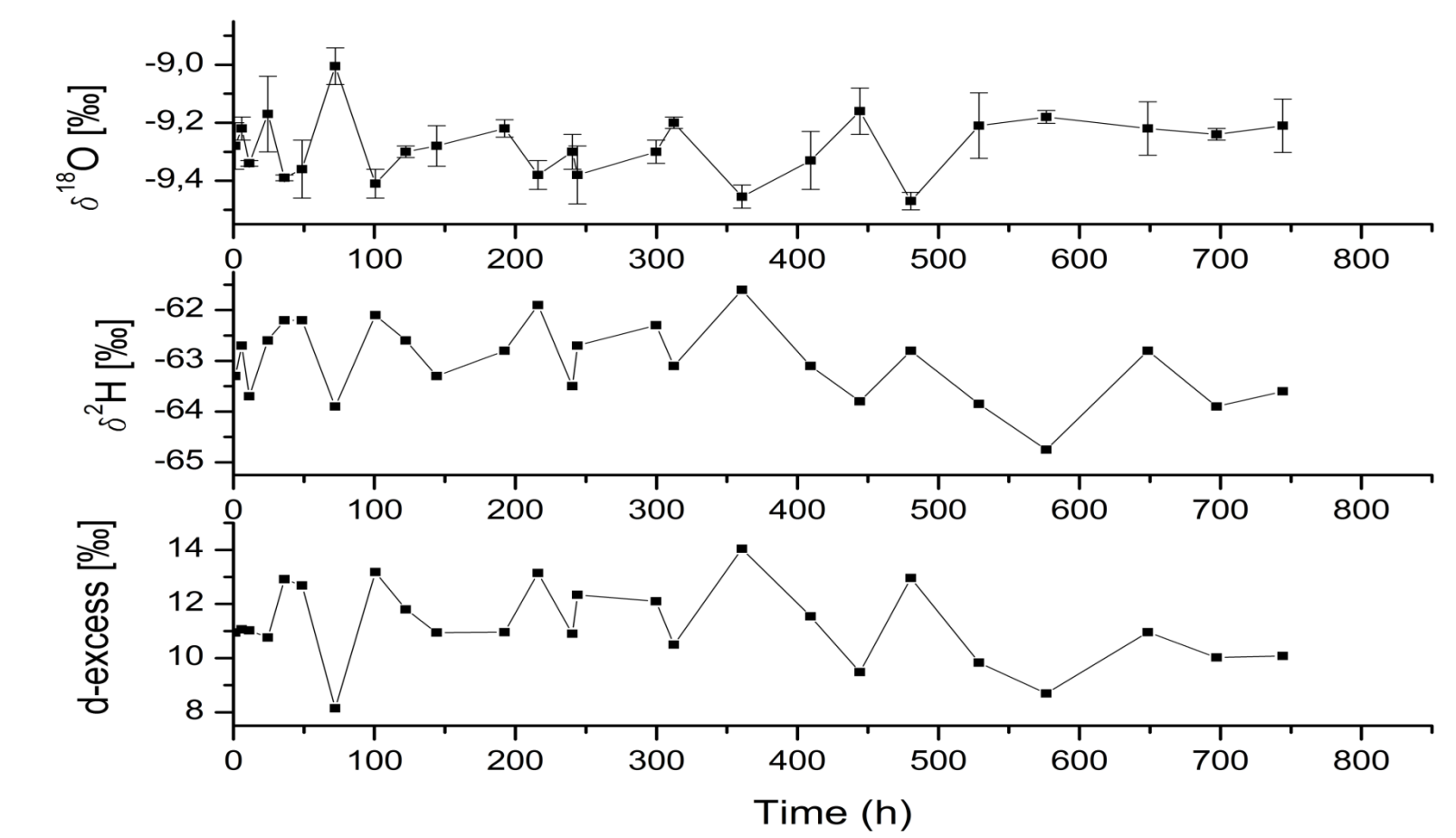


Figure 8: Changing of $\delta^2\text{H}$, $\delta^{18}\text{O}$ and d-excess values during the pumping test

Results in 2013

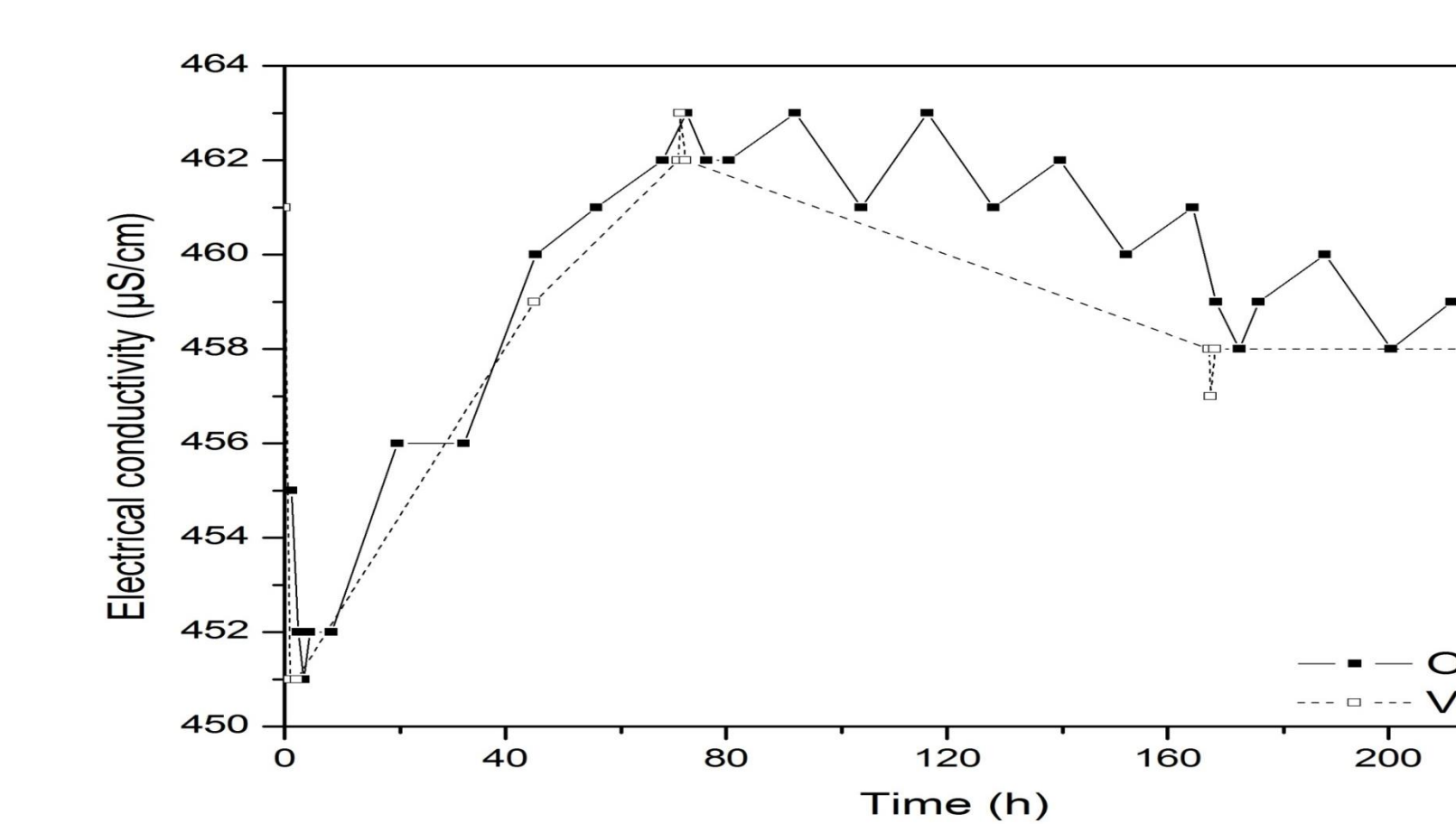


Figure 9: The electrical conductivity during the pumping test

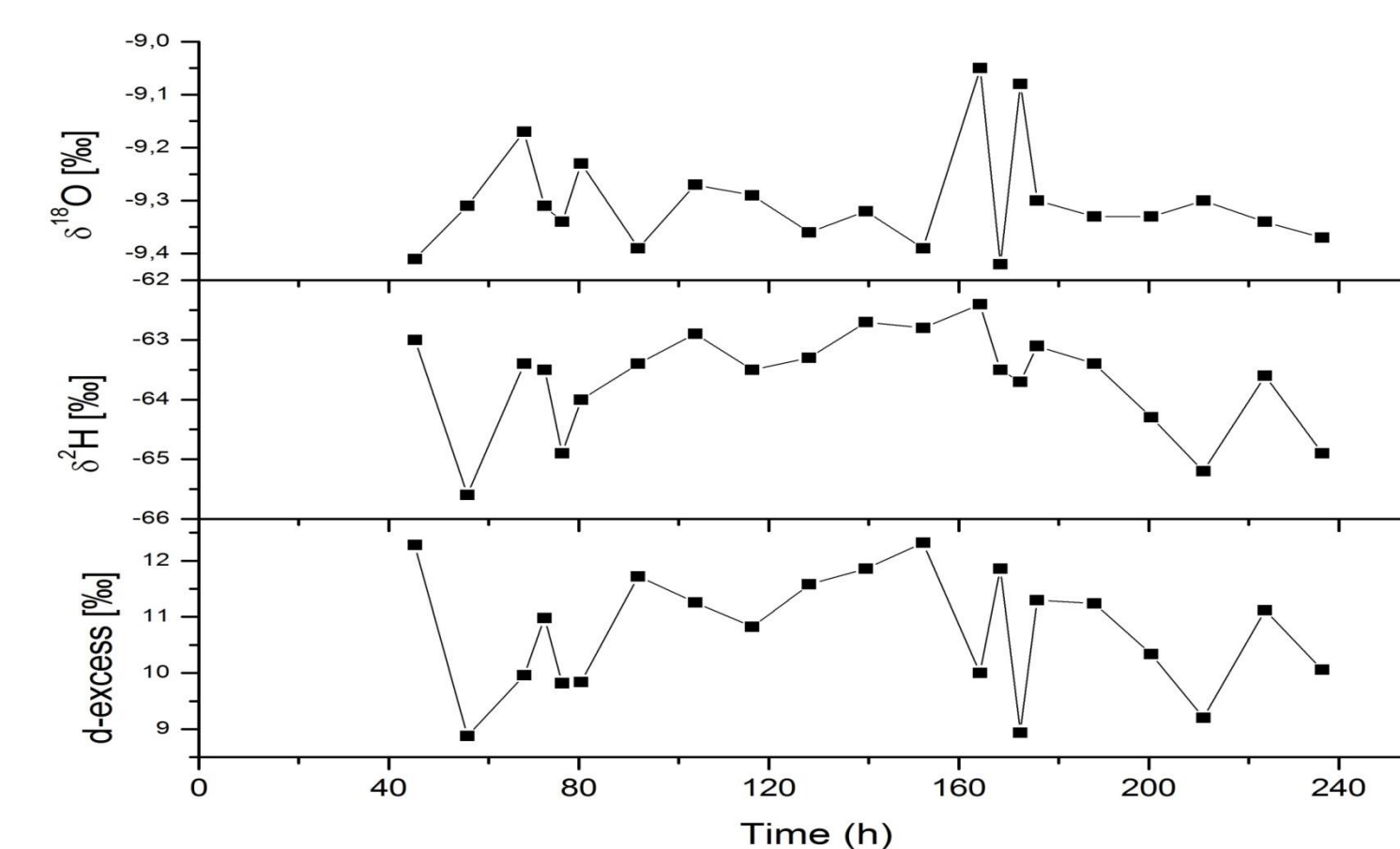


Figure 10: Changing of $\delta^2\text{H}$, $\delta^{18}\text{O}$ and $d\text{-excess}$ values during the pumping test

CONCLUSIONS

In spite of the fact that well screens are positioned in the dolomite bedrock and consequently isotopic composition of groundwater pumped out from karstified aquifer is expected to be significant for higher recharge zone results have shown that groundwater pumped out of the well VD Brest-3a is mixture of water with relatively shallow recharge (in Holocene part of the sediments) and water recharging from higher parts in the mountainous hinterland (in Triassic limestone and dolomite). Isotopic time series are showing no trends depending on pumping rates as well no time depended trends (Fig. 8 and 10). Estimates based on the end member mixing models are showing that ratio between shallow and deeper water originating from higher parts is relatively high conforming groundwater is predominantly from the local origin in the near vicinity of the well field. We can conclude that the results of isotope researches dispute the conceptual model of Ljubljansko Barje that discusses about separated aquifers.