# Characterization of Hydrogeologic Conditions of Transboundary Groundwater Body Karavanke in Slovenia

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## INTRODUCTION

Karavanke are a mountain range on the border between Slovenia to the south and Austria to the north. The countries share common groundwater body in Karavanke chain, which mostly consists of karstic aquifers. According to Water Framework Directive (WFD) (200/60/EC), common principles are needed to improve the protection of community waters in terms of quantity and quality, to promote sustainable water use, to contribute to the control of transboundary water problems, to protect aquatic ecosystems, and terrestrial ecosystems and wetlands directly depending on them, and to safeguard and develop the potential uses of community waters. Average annual groundwater recharge of the groundwater body Karavanke is one of the highest in comparison with other groundwater bodies in Slovenia (Andjelov et al., 2012).

## MONITORING OF GROUNDWATER BODY KARAVANKE IN SLOVENIA

Four gauging stations were established in the western part of the groundwater body where three of them (Javorniški potok, Završnica and Mošenik) were set to measure naturally discharging groundwater from karstic aquifers and one was set to monitor the groundwater outflow from road tunnel Karavanke. The results of two-year hydrological monitoring show specific Alpine groundwater regime with some particularities owing to deep circulation and long retention time of groundwater flow.

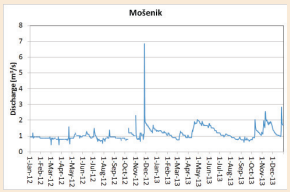

## GEOLOGICAL SETTING

Big part of the Karavanke chain consists of karstified rocks, mostly Triasic limestone and dolomites and Paleozoic carbonates. Majority of the karstified rocks are located in northern Karavanke (Borovski vrh, Obir and Peca) and on wider area of Košuta unit (Kepa, Stol, Košuta, Olševa) (Brenčič & Poltnig, 2008). Groundwater discharges from the groundwater body Karavanke either as large karstic springs of Javornik stream, Završnica, Mošenik, Hajnžev graben or as the artificial outflow from road tunnel Karavanke and former mine Mežica.

## MOŠENIK SPRINGS

Based on average discharge in years 2012 and 2013 (1,116 $m^3/s$), Mošenik springs are one of the most abundant springs of the groundwater body Karavanke. Their recharge area, estimated by average discharge and average long-term effective precipitation of the area (about 1450 mm/yr), amounts 24,3 $km^2$, which is about two times larger than orographic watershed at the monitoring site. It shows that springs discharge groundwater from greater karstic area which probably extends in East - West direction, conditioned by the direction of the Košuta fault zone.

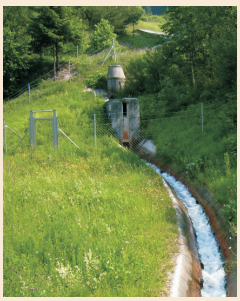
First monitoring results show that discharges of Mošenik does not directly reflect precipitation in the catchment of the spring. Anyhow, discharge is highly dependent on snow melting processes in high Alpine region. The smallest discharges of the springs are common for late summer (August, September) and late winter (February, March) although average monthly discharges rarely drop under 800 L/s. The highest average discharges appear in November and December and in May and June.

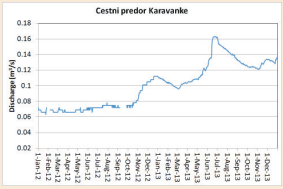



## KARAVANKE ROAD TUNNEL

On both sides of the tunnel Karavanke, there is a significant groundwater outflow of 275 L/s - 505 L/s, with the majority of the outflow on the northern part of the tunnel (from 200 L/s to 350 L/s) (Brenčič & Poltnig, 2008). The main aquifer on the area represents Schlern upper Triassic dolomite. The catchment of the groundwater outflow in southern part of the tunnel was confirmed by the tracing experiment performed in year 2011, where slow groundwater outflow from the schlern dolomite was confirmed (Petrič et. al, 2011); the first trace of the uranine tracer was detected approximately 15 months after the injection (Petrič & Kogovšek, 2013).

The two-year hydrologic monitoring in years 2012 and 2013 at the southern outflow from the road tunnel Karavanke showed the discharge amplitude of 100 L/s, where minimum discharge amounted 63 L/s. Based on average discharge of the outflow (101 L/s) and average long-term effective precipitation of Presušnik valley area (1420 mm/yr), the recharge area of the outflow was estimated on 2.24 $km^2$.

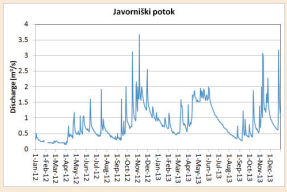


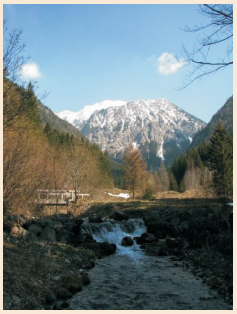



## JAVORNIK STREAM

The monitoring site of Javornik stream is located 3.5 km downstream the main spring. The orographic catchment at the monitoring site amounts approximately 16.5 $km^2$, from which accounted the catchment area of the springs Veliki and Mali Javornik alone 2.93 $km^2$. Based on the two year monitoring results and long-term effective precipitation, the catchment area at the monitoring site amount 18.2 $km^2$ which is comparable to the catchment area determined by orographic divide.

Javornik stream shows quite good correlation between precipitation and the discharges because of a large proportion of surface water outflow at the monitoring site. Minimum discharge in years 2012 and 2013 at the monitoring site amounted 151 L/s. The highest mean monthly discharges occurred in May and November. The lowest mean monthly discharges in years 2012 and 2013 were typical for February and August.




## ZAVRŠNICA SPRINGS

Završnica springs represent one of the most important water resources for Jesenice municipality. Based on average long-term discharge of the springs (0,380 $m^3/s$) and recharge rate from effective precipitation (1560 mm/yr), the recharge area of the springs was set on 7,7 $km^2$, which is about 30% smaller than the orographic recharge area at the gauging station, which suggests that part of Mošenik catchment area extend into eastern orographic recharge area of Završnica springs.

The lowest average discharges of the springs are typical for March and April and the highest for June and July. This implies on higher altitudes of Završnica springs recharge area compared to the Mošenik springs recharge area, as melting of the snow in Završnica catchment area starts later in the summer. The chemical analyse of Završnica springs contain lower contain rates of Mg:Ca than Mošenik springs, which confirms that Mošenik springs aquifer contains a higher proportion of dolomite.

## CONCLUSIONS

The appearance of all three natural outflows from the groundwater body Karavanke is conditioned to Košuta fault system on the contact between permeable carbonates and lower permeable clastites. The Mošenik spring is the most water abundant outflow from the body as it appears in the area where Košuta barrier fault system reaches the minimum altitude. Specific discharges at low water condition of the springs decline from east toward west in accordance with the decline of water source abundance and with the increase of spring location altitude. Long retention times of groundwater have been identified by isotopic and tracing experiment (Brenčič & Poltnig, 2008, Petrič & Kogovšek, 2013).

Common average discharge of all four monitoring sites amounts 2.41 $m^3/s$ (0.731 $m^3/s$ at low water conditions), without taking into account quantitative important groundwater outflow from Mežica mine. Groundwater body Karavanke therefore represents important drinking water resource in Slovenia, which need to be properly managed and protected. Existing hydrological monitoring gave us an important insight into hydrological regime and some properties of the recharge areas of the gauging stations, but will be much more reliable when longer time-series of the data will be available. Additional tracing experiments would give an important insight into the dynamic of groundwater flow, where set of sampling locations should also be extended to the Austrian territory.

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