

3.2 Description of the Rječina and Zvir springs catchment area case study, Croatia

Title of Case Study	Catchment area of the Rječina and Zvir springs
Location (region, Country)	Western Croatia
Other information	Transboundary (SI-HR border) karst aquifer

Description of Case Study (background information on the region)

The case study is located in western Croatia and stretches from the Adriatic coast to the mountainous area to the north that encompasses parts of eastern Ćićarija, the peaks of the V. Snežnik (1796 m) in Slovenia and the mountainous area of west Gorski Kotar, including parts of Risnjak (1528 m) and Snježnik (1505 m). It has dominant karst features. The primary part of the catchment consists of shallow-water carbonates, mostly limestones and dolomites with subordinate carbonate breccias, deposited from the Lower Jurassic to the Eocene. The Rječina spring is a speleological object with known horizontal spreading in the subsurface of approximately 300 m and a depth of over 50 m below the spring level. The majority of the cave system is filled with groundwater, however, during the dry season the underground channels have no direct connection with the retention areas and the spring water present consists only of the last remaining outflow in the cave channels. Groundwater at the Zvir spring discharges from the sunken cave channel that was developed along the expressed tectonic fissures in the Upper Cretaceous limestone on the west bank of the Rječina River. The spring is permanent and is the major water supply resource when the Rječina spring discharge is reduced or the spring dries up. The maximum measured discharge of the Rječina spring is 45 m³/s, and the minimum value is zero. The minimum discharge of the Zvir spring is 0.9 m³/s, and the maximum discharge is 18 m³/s.

Description of problem (why is this location chosen for a Cases Study)

Karst aquifers in the Croatia have a fundamental importance to water supply. Due to their specific hydrogeologic properties, these aquifers are sometimes difficult to use because of the high discharge variations of the karst springs and are almost always sensitive to pollution. With an aim to better understand karst aquifers, different research methods are used to study the karst groundwater system in Croatia. The spring hydrograph and the stable isotope ($\delta^{18}\text{O}$, $\delta^2\text{H}$) compositions in the water samples collected from the Rječina and Zvir springs and precipitation were analysed and used to characterize the karst aquifer. These springs are the major source for the water supply of the Kvarner Bay area.

Methods to be used in the Case Study (analytical and isotope techniques, modelling)

A mean residence time (MRT) of groundwater was calculated for stable isotope $\delta^{18}\text{O}$ using lumped parameter approach by applying the exponential model, combined exponential-piston and dispersion models to isotopic input (rainfall) and output (spring) data sets during 2011–2013. The LUMPY software was used.

Results from this Case Study

The recession coefficient obtained from the hydrograph analysis indicates only a fast-flow spring component at the Rječina spring. The lack of the base-flow spring component is the primary reason for the spring drying out during the dry periods. The low recession coefficient of

the Zvir spring indicates a base-flow and discharge from well-drained fissures and fractures in the spring catchment area during the low water stage.

The MRTs of 3.24 and 3.6 months for the Rječina spring and 7.2 months for the Zvir spring suggest the presence of recent groundwater recharge from precipitation, as well as fast groundwater flow. The cumulative age distributions show that the proportion of water younger than 1xMRT at both springs was more than 50% and that the proportion of water younger than 2xMRT was more than almost 90%.

Knowledge of the pollutant travel times through a groundwater body is necessary for the early warning of deterioration and the efficient protection of groundwater quality. For the investigated springs, it is fortunate that the largest part of their hinterland is not burdened by potential pollutants.

Impact - how this Case Study contributes to the overall project aims

This Case Study describes an important transboundary karst aquifer between Croatia and Slovenia. It demonstrates the use of groundwater age for assessment of groundwater vulnerability.

Name of pilot area / aquifers / type: Catchment of the Rječina and Zvir springs / karst aquifer		Country: Croatia Region: western Croatia (HR-SI border aquifer)		
Study level	Transboundary : ☒ X	Regional: ☐	Local: ☐	Single well(s): ☐
Type of observations <i>(choose one of the options, create separate template if needed for each type if each type need specific information)</i>	☐ Short screened observation wells (not pumped) ☐ Long screened observation wells (not pumped) ☐ Pumped wells, long screens in one aquifer ☐ Pumped wells, long screens over multiple aquifers ☒ X Springs ☐ Other (eg. research wells; indicate type and information on pumping):			
Approximate location of pilot:				
Geological cross section / conceptual model of the pilot area:				
Name of Shape- / Geopackage file defining the area: HoverHRPilotSub.shp		Projection to be used: HTRS96/TM		

Hydrological parameters:	Mean annual precipitation (mm or range in mm)	Mean annual groundwater recharge (mm or range in mm)	Mean annual groundwater recharge temperature (°C)	Thickness of unsaturated zone (range in m)
	1500-3500	750-1750	3-13	0-800
Pumped wells only		Typical pump discharge of sampled individual well (m ³ /day):	Typical pump discharge of complete well field (m ³ /day): <i>If relevant</i>	
List of aquifers and aquitards in pilot area		No. of confined or semiconfined aquifers in pilot area:	No. of unconfined aquifers in pilot area: 1	
Aquifer no. (aqf): 1 Aquitard no. (aqt): Aquiclude no. (aqc):	Aquifer/aquitard type and/or name	Lithology (<i>Resource WP6 terminology</i>)	Depth range (m)	GW age range (yr)
Aqf-1:	Rijeka springs aquifer	Karstic limestone	> 1000	< 1
Porosity type	Porous: ☐	Fissured: ☐	Karst: X	Fissured and porous / dual porosity: ☐
Applied tracer age indicators (³ H, ³ H/ ³ He, ⁸⁵ Kr, ³⁹ Ar, ¹⁴ C, ³⁶ Cl, ⁸¹ Kr, ⁴ He, CFCs, SF ₆ , etc.) Applied recharge temperature indicators (¹⁸ O, D, noble gases)		Aquifer-1 ¹⁸ O		
Number of sites (wells/springs) with age indicators		Aquifer-1 1-5: X 5-10: ☐ 10-25: ☐ >25: ☐		
GW age range (GAR) GAR-1: Modern (< 60 yr) GAR-2: Old (> 60 yr and 10 kyr) GAR-3: Paleowaters (> 10 kyr)		Aquifer-1 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐		
Groundwater age ranges (GAR) estimated by:		Tracer based estimates ☐ Flow and age model simulations X Combination of model and tracer estimates ☐ Expert judgement: ☐		
Objective of age dating studies:				
Basic research or General groundwater management	Assessment of pollutant history	Assessment of the efficiency of remediation and mitigation measures	Indication of vulnerability of aquifers and water supply wells	
X			X	

Water Usage <i>(not relevant for observation wells)</i>	Water supply		Irrigation	Industry	Other	
	X					
Geoenergy related activities <i>(not relevant for observation wells)</i>	Shallow Geo-T	Deep Geo-T	Hydrocarbons		Nuclear waste disp.	CO₂ storage
Mining activities <i>(not relevant for observation wells)</i>	Construction materials		Minerals / metals	Coal	Other	
REFERENCES						
OPEN Access reports and papers (PDF versions made available in EGDI repository making them downloadable via maps and keyword / free text searches):			Reports and papers with restricted access: Brkić, Ž., Kuhta, M. & Hunjak, T. (2018): Groundwater flow mechanism in the well-developed karst aquifer system in the western Croatia: Insights from spring discharge and water isotopes. Catena (Cremlingen), 161, 14-26.			
Remarks / other relevant information: 						