

3.15 Description of the Mura-Zala transboundary aquifer case study, Hungary-Slovenia

Title of Case Study	Hungarian-Slovenian Transboundary Thermal Aquifer
Location (region, Country)	Mura-Zala basin, Hungary, Slovenia
Other information	This study was carried out within the framework of the T-JAM project (Thermal Joint Aquifer Management: Screening of geothermal utilization, evaluation of thermal groundwater bodies and preparation of joint aquifer management plan in the Mura-Zala basin) between 2009 and 2011 as part of the Slovenia-Hungary Operational Programme 2007-2013, and was co-financed by ERFA. It was performed by the geological surveys of Hungary and Slovenia. A monitoring and management plan was developed in cooperation with the West-Transdanubian Water Directorate of Hungary.

Description of Case Study (background information on the region)

The Mura-Zala basin mainly covers NE Slovenia and SW Hungary, with minor parts in Croatia and Austria. It is located in the southwestern part of the Pannonian basin and is one of the deepest Pannonian sub-basins. Its thickness varies between 4,000-6,000 m in the deepest parts with 2,500-3,000 m thick Pannonian (Miocene) sediments. The thermal groundwater flow direction is from Slovenia to Hungary. Although the existence of transboundary geothermal aquifers was “common knowledge”, little bilateral scientific hydrogeological cooperation was established before 2009.

The shallow groundwater flow system is in unconfined Quaternary aquifers (referred to as Aquifer 1), while the confined part of the Quaternary is referred to as Aquifer 2. The underlying Pliocene delta- and alluvial plain aquifers (Ptuj-Grad Formation in Slovenia, Zagyva and Somló-Tihany Formations in Hungary; Aquifer 3) are part of the intermediate flow system and contain thermal water in their deeper parts. The deep regional thermal groundwater flow system is developed in the Mura/Újfalu aquifers (Aquifer 4).

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

The foreseen socio-economic development of the transboundary Mura – Zala region predicted a large increase in thermal water demand (Rman et al., 2011; Rman and Fuks, 2012) in line with the renewable energy goals set out in the Directive of the European Commission on the promotion of the use of energy from renewable sources (2009/28/EC). This had to be done by respecting the environmental objectives and the goals of the Water Framework Directive.

Although a successful transboundary surface water management scheme has been in operation between Hungary and Slovenia for several decades, the Slovenian-Hungarian Water Management Commission started discussions about transboundary groundwater resources only in 2011. The aims of this study were to understand and identify the groundwater flow paths, and to delineate transboundary aquifers based on thermal and cold groundwater geochemical and isotope properties in the Mura-Zala basin. The results were presented to the

Permanent Bilateral Slovenian-Hungarian Water Management Commission and the transboundary thermal aquifer delineated in the study was proposed to be acknowledged by the ICPDR as a Danube basin level important transboundary groundwater body. It has to be mentioned, that the transboundary groundwater bodies between Slovenia and Hungary are not yet officially delineated, and there is no common management of thermal groundwater.

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

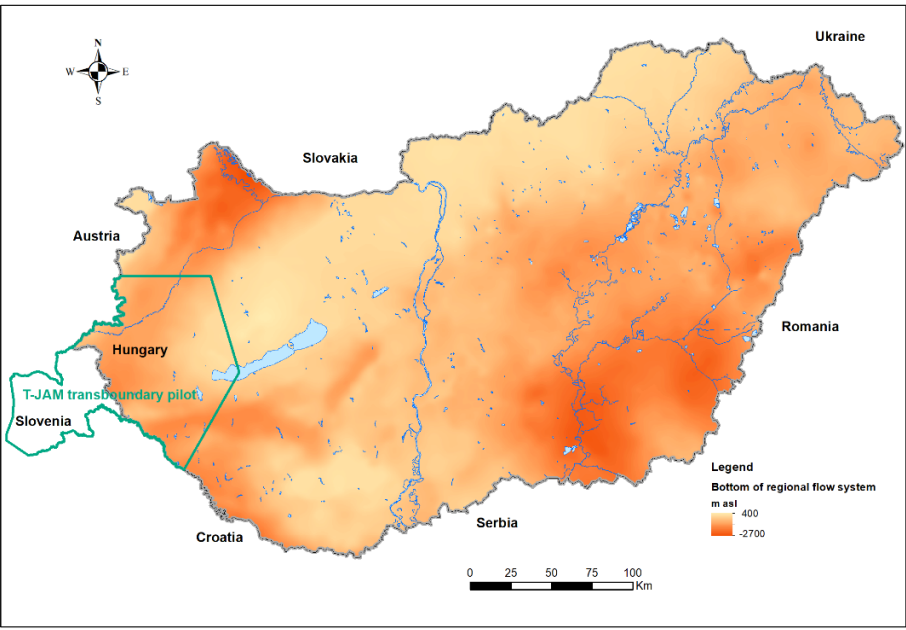
$\delta^{18}\text{O}$ and δD were determined using a GasBench-II preparation system and a Thermo Finnigan delta plus XP spectrometer (Institute for Geochemical Research of the Hungarian Academy of Sciences). ^{14}C measurements were carried out from the DIC content of groundwater precipitated with barium-chloride in the field during sampling after adding saturated NaOH. The radiocarbon activity of benzene was counted by ultra-low level liquid scintillation analyser (PerkinElmer Quantulus 1220; Hydrosys Lab. Ltd). Stable carbon isotope ratios were determined by conventional stable isotope ratio mass spectrometry (Thermo Finnigan delta plus XP). Water samples for noble gas analyses were collected in copper tubes and measured by a VG5400 noble gas mass spectrometer. Carbon-13 and noble gases were analysed in the Hertelendi Laboratory of Environmental Studies in the Institute of Nuclear Research of the Hungarian Academy of Sciences Strontium and chlorine stable isotopes were measured by the University of Waterloo. A 3D steady-state hydrogeological numerical modelling was performed in VisualModflow with a grid size of 500×500 m and a vertical extension of 2 km.

Results from this Case Study

The hydrogeochemical-isotope survey (Rman et al., 2011d; Szócs et al., 2012) contributed to the characterization of different transboundary aquifers. Most of the δD and $\delta^{18}\text{O}$ data of the groundwater from the Mura/Újfalu aquifers are positioned on the meteoric water line, showing precipitation origin. The ^{14}C values indicate older than 20,000 years residence times. The $\delta^{18}\text{O}$ and δD values are more positive than the “typical ice-age” groundwater values which suggests a recharge during a warmer period of the Pleistocene. Based on the numerically modelled travel times of water particles, the majority of thermal groundwater in the Mura/Újfalu aquifer might have been recharged into the flow-system before the last ice age, most probably in the Riss-Würm interglacial period (between 93,000-132,000 years BP). Based on this case study the thermal groundwater of the Mura/Újfalu aquifer could be clearly distinguished from the deeper groundwaters which show no (or only limited) connection to the regional thermal groundwater flow system. Based on the scientific results a transboundary thermal groundwater body was outlined and a guide to its sustainable use was prepared.

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

This case study contributes to the establishment of a harmonized database on groundwater age indicators with data on paleo waters. It is a good example how harmonized, common data interpretation and numerical modelling of two geological surveys could confirm the existence of a transboundary aquifer. The study helps to define residence time categories for large basins and regional groundwater flow systems.

Name of pilot area / aquifers / type: T-JAM transboundary pilot/ Quaternary and upper Miocene sedimentary aquifers / porous	Country: Hungary, Slovenia Region: Zala-Mura Basin
Study level	Transboundary : ☒ 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 ☐ 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:		Projection to be used: ETRS 1989 LEAE		
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)
	750-900	40-90	11	1-80
Pumped wells only		Typical pump discharge of sampled individual well (m ³ /day): 6 – 115 (4-80 l/min) at sampling	Typical pump discharge of complete well field (m ³ /day): <i>Not relevant</i>	
List of aquifers and aquitards in pilot area		No. of confined or semiconfined aquifers in pilot area: 3		No. of unconfined aquifers in pilot area: 1
Aquifer no. (aqf): 4 Aquitard no. (aqt): 0 Aquiclude no. (aqc): 1	Aquifer/aquitard type and/or name	Lithology (Resource WP6 terminology)	Depth range (m)	GW age range (yr)
Aqf-1:	Quaternary fluvial-limnic alternating sedimentary sequence locally aeolean	alternation of unconsolidated sedimentary hydrogeofacies/ Loess	1 – 160 (thickness 15–135)	>60 – 1,000
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-2:	Quaternary fluvial-limnic alternating sedimentary sequence	alternation of unconsolidated sedimentary hydrogeofacies	35 – 260 (thickness 85–100)	> 10,000
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-3:	Pliocene - upper Miocene fluvial-limnic alternating sedimentary sequence	alternation of unconsolidated sedimentary hydrogeofacies	125 – 1080 (thickness 30–950)	> 10,000
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-4:	upper Miocene deltafront and deltaplain sediment sequence	Sandstone	200 – 1550 (thickness 0-1046)	> 10,000
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐



Aqc-1:	upper Miocene basin fill	Siltstone, marlstone		
Porosity type	Porous: X	Fissured: ☐	Fissured and porous / dual porosity: ☐	No hydraulically active porosity: ☐
Applied tracer age indicators (^3H , $^3\text{H}/^3\text{He}$, ^{85}Kr , ^{39}Ar , ^{14}C , ^{36}Cl , ^{81}Kr , ^4He , CFCs, SF_6 , etc.) Applied recharge temperature indicators (^{18}O , D, noble gases)		Aquifer-1 ^3H , ^{14}C - $\delta^{13}\text{C}$, $\delta^{18}\text{O}$, δD , noble gases		
		Aquifer-2 ^{14}C - $\delta^{13}\text{C}$, $\delta^{18}\text{O}$, δD , noble gases		
		Aquifer-3 ^3H , ^{14}C - $\delta^{13}\text{C}$, $\delta^{18}\text{O}$, δD , noble gases		
		Aquifer-4 ^{14}C - $\delta^{13}\text{C}$, $\delta^{18}\text{O}$, δD , noble gases		
Number of sites (wells/springs) with age indicators		Aquifer-1 1-5: X 5-10: ☐ 10-25: ☐ >25: ☐		
		Aquifer-2 1-5: X 5-10: ☐ 10-25: ☐ >25: ☐		
		Aquifer-3 1-5: X 5-10: ☐ 10-25: ☐ >25: ☐		
		Aquifer-4 1-5: ☐ 5-10: X 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%: X >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐		
		Aquifer-2 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X		
		Aquifer-3 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X		
		Aquifer-4 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X		
Groundwater age ranges (GAR) estimated by:		Tracer based estimates ☐		
		Flow and age model simulations ☐		
		Combination of model and tracer estimates X		
		Expert judgement: ☐		
Objective of age dating studies:				
Basic research or General	Assessment of pollutant history	Assessment of the efficiency of remediation and mitigation	Indication of vulnerability of aquifers and water	



groundwater management			measures		supply wells	
X						
Water Usage <i>(not relevant for observation wells)</i>	Water supply		Irrigation	Industry	Other	
	X				Balneology, Orchid farm	
Geoenergy related activities <i>(not relevant for observation wells)</i>	Shallow Geo-T	Deep Geo-T	Hydrocarbons		Nuclear waste disp.	CO ₂ storage
		X				
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 EGD repository making them downloadable via maps and keyword / free text searches): Nádor, A., Lapanje, A., Tóth,Gy., Rman, N., Szőcs, T., Prestor, J., Uhrin, A., Rajver, D., Fodor, L., Muráti, J., Székely, E., 2012: Transboundary geothermal resources of the Mura-Zala basin: a need for joint thermal aquifer management of Slovenia and Hungary. GEOLOGIJA 55/2, pp. 209–224, Ljubljana 2012. doi:10.5474/geologija.2012.013			Reports and papers with restricted access: Szocs, T., Rman, N., Suveges, M., Palcsu, L., Toth, Gy., Lapanje, A., 2013: The application of isotope and chemical analyses in managing transboundary groundwater resources. Applied Geochemistry 32 (2013) 95–107 doi:10.1016/j.apgeochem.2012.10.006.			
Remarks / other relevant information:						