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Transboundary unconfined alluvial aquifers (Slovenia – Croatia)

Patricia Buškulić[1], Jelena Parlov[1], Zoran Kovač[1], Nina Rman[2]

Transboundary groundwater resources are very important sources of water for different uses and represent a significant role in some region, although monitoring and management are an major issue (Ganoulis, 2007). The Bregana – Obrežje (Slovenia) / Sava – Samobor (Croatia) aquifers were identified by the International Network of Water-Environment Centres for the Balkans (INWEB) inventory as transboundary aquifers. The Bregana – Obrežje aquifer is in hydraulic connection with upstream Krško and Čatež aquifers (Slovenia) and they extend along the Sava River from Krško to the Slovenia – Croatia national border. Sava – Samobor aquifer (or Samobor – Zaprešić aquifer) stretches from the national border till the Zagreb aquifer. Bregana – Obrežje aquifer covers an area of 4 square kilometers whereas Sava – Samobor aquifer covers 54 square kilometers. Those aquifers form a single hydraulic system, i.e. a transboundary unconfined alluvial aquifer system that spreads along the Sava River. These areas were formed in the same geological period by the same deposition mechanisms and they $(a,r,b,e_n,h_U,h_D,\theta_s-\theta_r,\alpha,n,K_s)$ are hydraulically connected by groundwater and surface water flows. Aquifers consist of Quaternary sediments mainly composed of sand and gravels with a very thin surface deposits. Sediments were deposited during the Middle and Upper Pleistocene (lacustrine-marshy deposits) and Holocene (alluvial deposits) (Velic and Saftic, 1991; Velic and Durn, 1993). Hydraulic conductivity of the aquifers varies from 0.002 to 0.043 m/s. Saturation thickness at low waters ranges from 2 to 10 m in the Slovenian part and from 4 to 42 m in the Croatian part, while during high waters it is 2 to 12 m in the Slovenian part and 4 to 46 m in the Croatian part. Sava River is in direct hydraulic connection with the aquifers and represents the main source of recharge. Fluctuations in the Sava River water levels dominantly influence the changes in groundwater levels. During high waters, the Sava River gives water to the aquifers, while during low and medium waters it drains the aquifers in some parts (Posavec, 2006). The exception is the northwestern area between Krško and the Nuclear power plant Krško, where the Krško aquifer discharges into the Sava River most of the year (Barešic et al., 2020). The general groundwater flow direction is from west to east or south-east, which coincides with the Sava River flow direction. Groundwater flow velocities vary from 8 to 28 m/day (conservative approach with an effective porosity value of 10%). The lateral boundary conditions of the aquifer system are inflow boundary in the north near Krško, no flow (impermeable) boundaries in the northeast and southwest, and outflow boundary near Podsused. Groundwater inflows, along the national border, fluctuate significantly and depend on hydrological conditions. The hydraulic connection between these aquifers exists during the lowest waters and it is never disturbed. Different problems arising in transboundary groundwater resources monitoring and management, such as lack of common monitoring systems, limited data sharing between neighboring countries, data interpretation, data modelling and a lack of political willingness for collaboration (Ganoulis, 2007). The significant detected problem is changes in groundwater levels

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in Zagreb and Samobor – Zaprešic aquifer. One of the major cause of lowering of groundwater levels is deepening of the Sava riverbed, influenced by construction of hydroelectric power plants on the Sava River upstream from the city of Zagreb, river regulation and gravel exploitation. The main goal is to set up a cooperative framework so that institutions from both sides can effectively work together and ensure effective monitoring and management of transboundary aquifers (Ganoulis, 2007).

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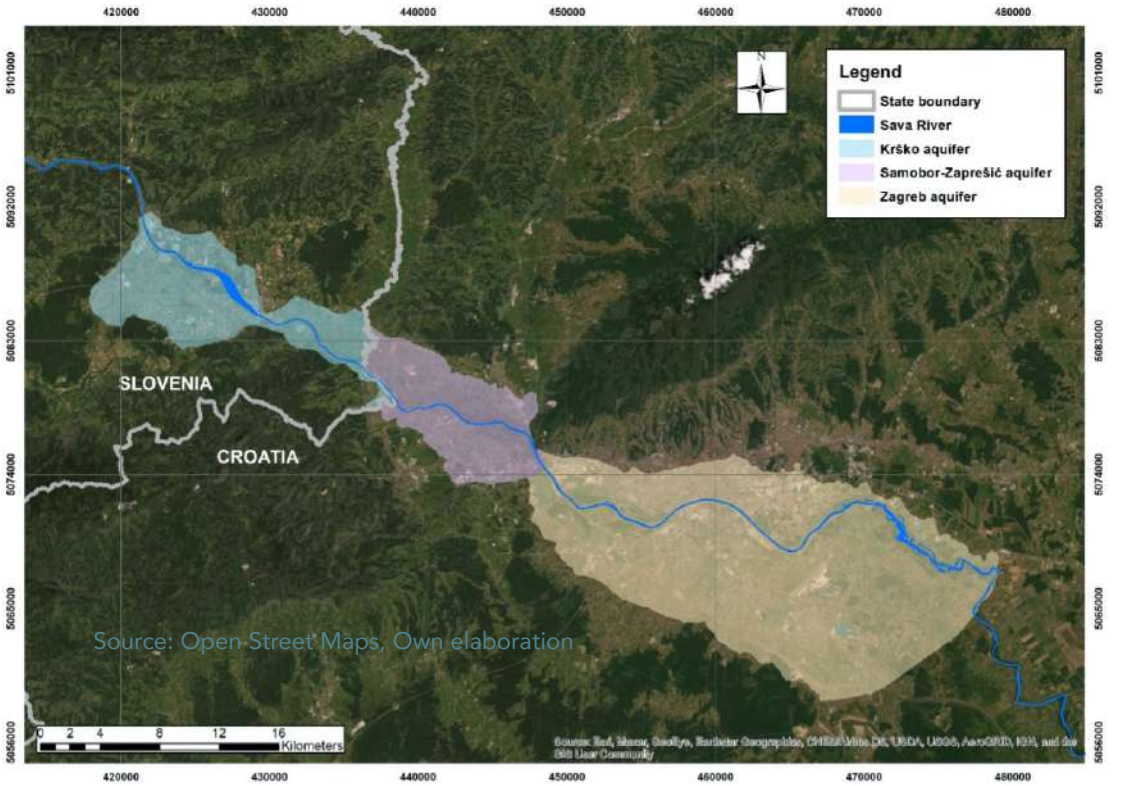
Figure 1.
The geographical position of the transboundary aquifers (Slovenia – Croatia)



Source: Open Street Maps, Own elaboration