TRANSBOUNDARY GROUNDWATER RESOURCES EXTENDING OVER SLOVENIAN TERRITORY

P. MEGLIČ, J. PRESTOR

Geological Survey of Slovenia, Ljubljana, Slovenia

E-mail: petra.meglic@geo-zs.si

Slovenian territory (20.273 km^2), seen on the World map of groundwater resources 1: 50.000.000, appertains mainly to area with complex hydrogeological structure. Only western and north-eastern border sections cross major groundwater basins. Northeastern part belongs to bigger major groundwater basin (Panonian basin) with medium groundwater recharge between 15 and 150 mm per year (Figure 1). Western edge only touches major groundwater basin (river Po) with medium groundwater recharge between 15 and 150 mm per year (Figure 1). Complex hydrogeological structure, which covers most of Slovenian territory, extends from northwest from Italy and Austria over the Alps to Dinarides. Dinarides pass from Slovenia to Croatia and further to the southeast onto Balkan Peninsula. Very important water resources are exploited from Dinaric karst and fissured aquifers extending over Slovene-Croatian state border. Major "Panonian" groundwater basin is developed on wider area between Wiena, Budapest and Belgrade with very important drinking and thermal water resources actually exploited by Slovenia, Austria and Hungary. The sustainable cross border management of these resources will certainly be crucial for the future use. The major groundwater basin of river Po and neighbouring Adriatic rivers plain is developed mainly on Italian territory below Alps. It provides very important groundwater resources for actual highly populated Italian territory and represents very important resources for future use in Slovene coastal and border area of high actual development.

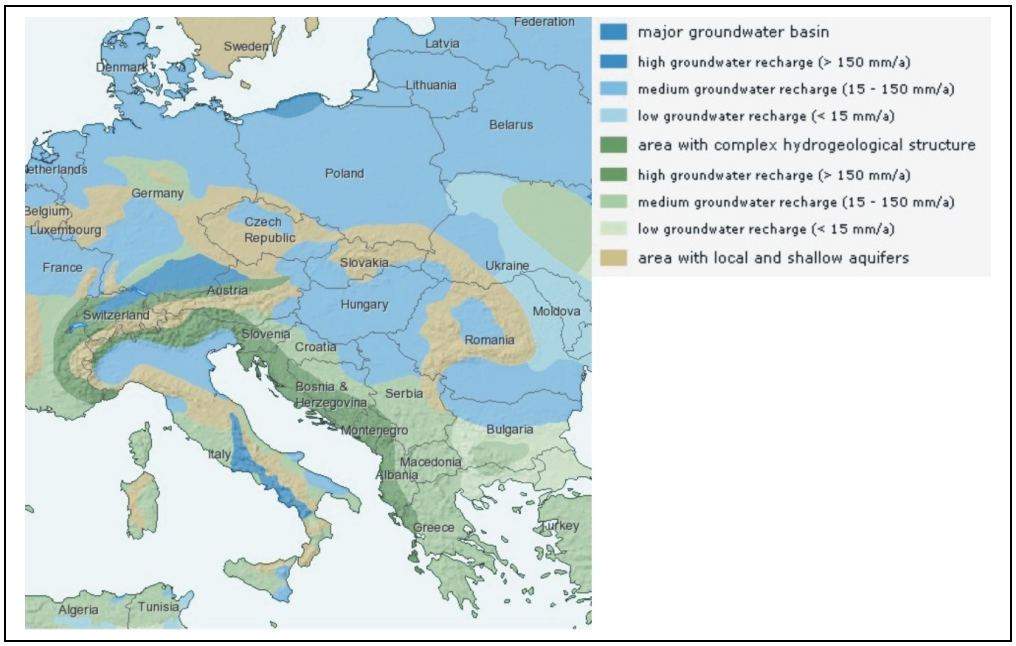

Figure 1: Crop from the World map of groundwater resources (BGR & UNESCO, 2007).

On the international hydrogeological map of Europe (1: 1.500.000) there are shown all larger and important aquifer systems in Slovenia crossing the state border (marked with numbers in circle), groundwater bodies in Slovenia (yellow line) and surface river basin divide between Adriatic sea and Danube river (violet line).

Important aquifers very evidently extend over state border to neighbouring countries (Figure 2) - Croatia, Italy, Austria and Hungary:

1. Limestone and dolomite aquifers in Karavanke (extending over state border to Austria);
2. Alluvial gravel aquifers of Drava and Mura (extending over state border to Austria);
3. Sand and clay aquifers on Goričko (extending over state border to Austria and Hungary);
4. Alluvial gravel aquifers of Drava and Mura (extending over state border to Hungary and Croatia);
5. Local carbonate and sand aquifers in Sotla river basin (extending over state border to Croatia);
6. Alluvial gravel aquifer of Sava (extending over state border to Croatia);
7. Carbonate fissured and karst aquifers in Kolpa river basin (extending over state border to Croatia);
8. Very karstified carbonate aquifers in river basin of Adriatic sea between Kvarner and Trieste bay (extending over state border to Italy and Croatia);
9. Very karstified, generally limestone aquifers in river basin of Adriatic sea and Soča – Brestovica (extending over state border to Italy);
10. Alluvial gravel aquifers of Vipava and Soča river basin (extending over state border to Italy);
11. Fissured, predominantly dolomite and limestone aquifers of west part of Soča and Sava Dolinka watershed (extending over state border to Italy).

Every aquifer is further divided and characterized according to the existing knowledge on aquifer systems, where direct cross-border groundwater flow is recognized. There are also aquifer systems where direct cross border has not yet been recognized or it is actually recognized as of low importance. We are expecting that the database of characterized aquifer systems will quickly grow in following years.

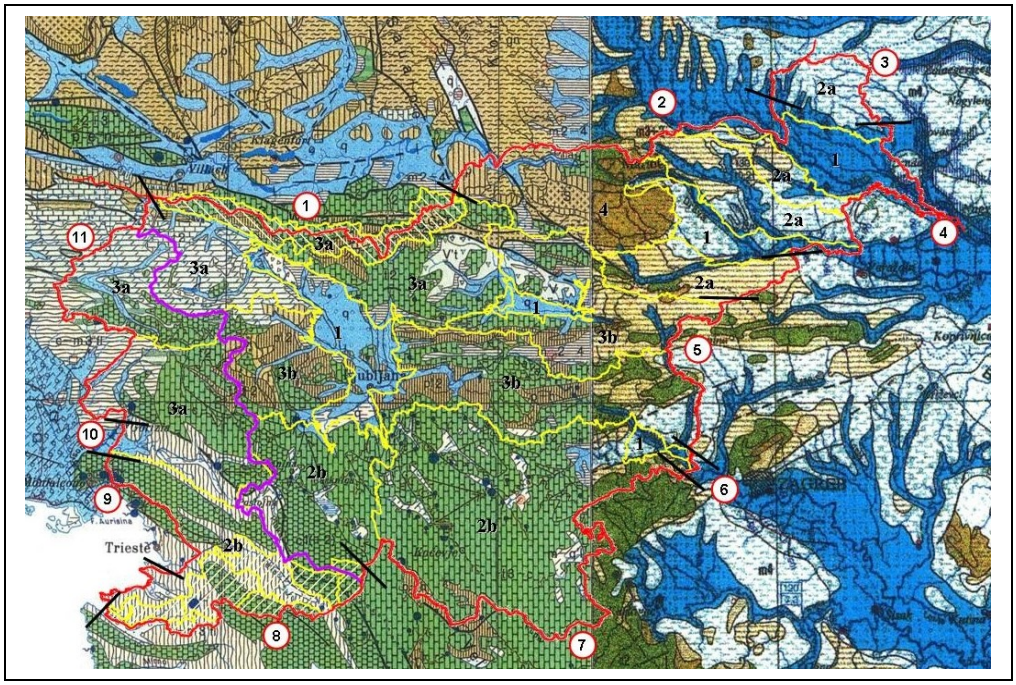

Figure 2: Crop from International hydrogeological map of Europe with marked Transboundary aquifer systems and groundwater bodies in Slovenia (Karrenberg e tal., 2004). Result of the first delineation (Tavzes et al., 2004) of groundwater bodies - marked on map with number and letter as followed:

1. Aquifer systems in alluvial sediments (intergranular porosity);
2. Aquifer systems in sedimentary rocks and unconsolidated dominantly non-alluvial sediments;
   a) dominantly intergranular porosity;
   b) dominantly karst porosity;
3. Aquifer systems in hydraulic complex system adapted to intensely folded mountain zones;
   a) dominantly karst porosity;

b) dominantly fissured porosity;

4. Aquifer systems in basement geological strata.

Groundwater Bodies (GWB) and Transboundary Groundwater bodies in Slovenia were delineated and characterized according to WFD (Water Framework Directive) and Slovenian legal basis (regulation): Rules on methods for determining water bodies of groundwater (Uradni list Republike Slovenije, 2003) and Rules of determining water bodies of groundwater (Uradni list Republike Slovenije, 2005). The delineation of individual groundwater body and groups of groundwater bodies was performed accordingly to the regulation and was based on porosity and lithology boundaries, productivity and extent boundaries, catchments basin boundaries, flow lines, interstream boundaries, junctions with large affluent, recovering and potential use boundaries (water protection areas), tracer experiments results. Methodology for delineation was adapted after BRGM (2003), where groundwater bodies are classified in (1) aquifer systems in alluvial sediments, (2) aquifer systems in sedimentary rocks and unconsolidated dominantly non-alluvial sediments, (3) aquifer systems in hydraulic complex system adapted to intensely folded mountain zones, (4) aquifer systems in basement geological strata and (5) aquifer systems in low permeable strata and local and limited water resources. The last one in Slovenia wasn't defined. More detailed methodology is described in Prestor et al. (2004). Every groundwater body is then further divided in one to four important aquifers, which are laterally or vertically subsequent.

Cartographic base for delineation of Groundwater Bodies and Transboundary Groundwater bodies in Slovenia is the latest Hydrogeological map (1:250.000), which is made on base of international standard legend adopted after IAH (Struckmeier & Margat, 1995).

There are three main tectonic units in Slovenia also having an important role at the groundwater bodies' delimitation:

I The Southern and Eastern Alps – dominantly karst and also fissured aquifers, hydraulic complex system intensely folded mountain areas including Periadriatic igneous rocks as a basement rocks as also volcanoclastic rocks and fissured aquifers;

II External and internal Dinarides – dominantly karst aquifers, minor part fissured aquifers and also very low permeability layers (for example flysch) with local and limited small aquifers;

III Tertiary and Quaternary sediments of the Panonian basin – dominantly alluvial Quaternary gravel, sandy gravel aquifers in strong connection with surface streams and non-alluvial sediments, dominantly sandy and silty gravel aquifers with low or no connection with surface streams and often of confined or semi-confined type.

Transboundary groundwater body, till now delineated by both neighbouring countries, is Karavanke GWB, extending over state border to Austria. The major factors in determining boundaries of the common GWB Karavanke were, in both Slovenian as well as Austrian side, geological and hydrogeological characteristics. The common Transboundary GWB Karavanke on the Austrian side of the border was delineated as a "group of groundwater bodies with prevailingly karst aquifers". On the Slovenian side of the border, the common Transboundary GWB Karavanke was delineated as a group of groundwater bodies in "hydraulic complex system adapted to intensely folded mountain area built of different aquifers and aquifer systems". At the preparation of water management plan of the common GWB Karavanke, it is necessary to consider that in some parts a cross-boundary groundwater flow exists while in other parts it doesn't. Those areas of detected cross-boundary flow will therefore have to be studied more in detail than other areas.

The other bigger transboundary project was focused on the state between Slovenia and Croatia, on the Dinaric karst on Istria peninsula. The main objective of the project was common hydrogeological research of the area, but without bilateral delineation of groundwater bodies.

The third very important transboundary project co-financed by Interreg program was characterized the transboundary thermal water resources between Slovenia and Austria (Bäk et al., 2007). The mutual and common development of GIS and Hydrogeological data was performed including compilation and improvement of the expert knowledge about the transbounary structures and thermodynamics, extending

also further to the Panonian basin on Hungarian territory. The future trilateral transboundary aquifer system can be expected.

Geological Survey of Slovenia is also participating on project called eWater in the frame of the EU eContent plus programme. One of the principal objectives of the project and its "Multilingual cross-border access to ground water databases" (eWater) is to increase the cross-border availability, accessibility and re-usability of spatial data on quality, location and use of subsurface waters. The objective of the project will be achieved by developing a WEB GIS portal for hydrogeological data of the participating countries, accessible on world web page www.ewater.eu. The envisaged cross-border portal is meant for EC itself, national and river basin water authorities, water suppliers, added-value data service providers, insurance companies, planning and controlling organizations, as well as the general public. Participating countries are Slovenia, Austria, Czech Republic, Denmark, France, Hungary, Italy, Lithuania, Netherlands and Slovakia.

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