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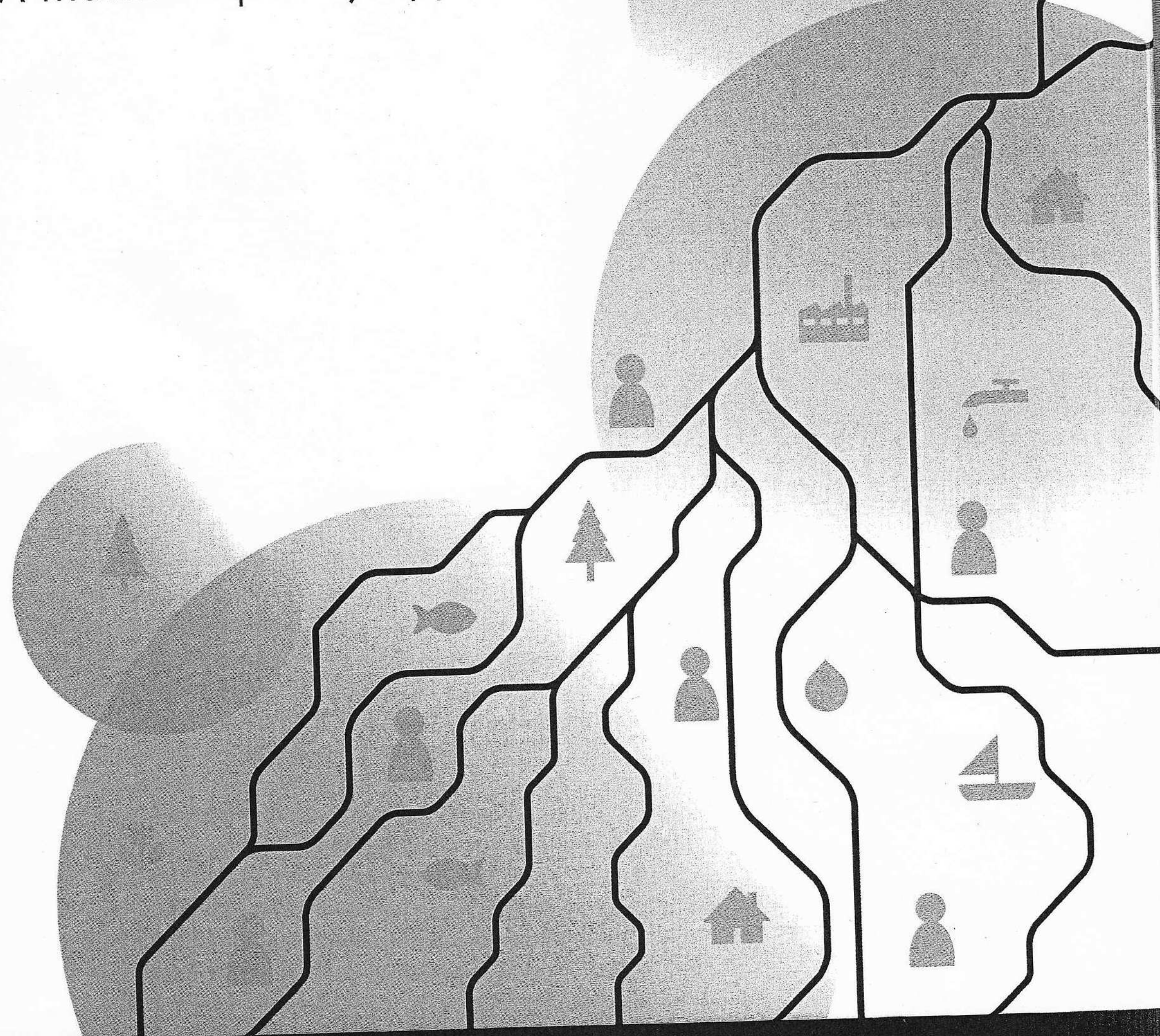
Transboundary Water Resources Management

A Multidisciplinary Approach



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4.9
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4.9.1
Introduction

During the last decade there have been many activities aiming to improve water management amongst neighbouring countries [1, 2]. Many such projects have been initiated worldwide but, with the exception of the European Union (EU) territory, only very few have been successfully implemented or even started.

The project Sustainable Development of Hungarian–Serbian Transboundary Aquifer (SUDEHSTRA) was carried out from June 2007 till August 2008. It was one of the cross-border cooperation programmes funded by the European Union (ERDF/INTERREG IIIA/Community Initiative) whose objective and tasks were fully in line with the EU Water Framework Directive (WFD; EC 2000/60) and EU Groundwater Daughter Directive targets.

The benefits of this cross-border project are supposed to range from the national level to the very local one:

1) strengthening bilateral technical cooperation and enabling the exchange of information between the neighbouring countries;
2) improving national, regional and local water practice;
3) creating an ambience to facilitate the realization of the targets of the EU Water Framework Directives;
4) building local technical capacities;
5) increasing public awareness of the importance of water issues and of sustainable use of water and its protection from pollution;
6) developing tools for appropriate groundwater management and monitoring at all levels.

4.9.2
Study Area

The aquifer system under study is located between the Danube and Tisa (Tisza) rivers and extends to the vicinity of Kiskunfelegyhaza on the Hungarian side (north) and to Vrbas in Serbia (south). The main groundwater consumers are the cities and industries of Szeged, Kiskunhalas, Baja, Tompa, Hódmezővásárhely (Csongrád and Bács-Kiskun Counties in Hungary) and Subotica, Sombor, Bačka Topola, Vrbas, Kula (in total 16 municipalities in Serbia, Vojvodina province, Bačka region). The study area is populated by over 800 000 inhabitants, about 40% of whom are on the Hungarian side of the border.

The Pannonian basin (or the Great Hungarian Basin) represents a geographical and geological entity that spreads over the territory of several countries. The central portion is in Hungary while the marginal parts belong to Romania, Slovakia, Slovenia, Croatia and Serbia (Figure 4.9.1).

The Pannonian basin is a typical lowland, whose height above sea level is mainly 70–120 m. The flat relief features various geological structures, such as loess plateau, loess terraces and alluvial plains, and small depressions in between prevail.

The region has a moderate continental climate with an average annual air temperature of 11 °C and rainfall of 575 mm per year. The whole hydrographic network belongs to the river basin of the Black Sea. It is assumed that about 99% of surface waters are water flows of a transitory nature, while only about 1% comes from rainfall within the region. The major rivers are the Danube and the Tisa. At the Hungarian–Serbian border the average annual river flow of the Danube is around $2500\,m^3\,s^{-1}$, while for the Tisa the average is $700\,m^3\,s^{-1}$.

Figure 4.9.1 Location map of study area.

4.9.3 Groundwater Distribution and Use

Systematic geological research in this region began at the end of the nineteenth century. The first data about the geological structure date came from the drilling of artesian wells. Later on, systematic searches for oil reserves resulted in numerous studies and maps reconstructing paleogeographic conditions and improving the knowledge of geological structures [3–5]:

- Pre-Cambrium and Paleozooic metamorphic schists are the oldest rocks and represent a deep fundament for younger sedimentary rocks, mainly of Tertiary age. Mesozoic sediments mostly of Triassic and Cretaceous ages are also widely distributed in the basin's basement.
- The thickness of the Tertiary (Badenian, Sarmatian, Pannonian and Pliocene) sediments is variable in different parts of the terrain, from a few tens to over two thousand metres.
- Quaternary (Pleistocene and Holocene) sediments are dominant throughout the study area and cover the older sediments. Their thickness varies from a dozen to 200 m.

In the vertical section, water-bearing layers with intergranular porosity interfinger with impermeable strata. Sandy-gravel sediments represent major aquifer systems. Their thickness varies from less than 10 m up to 50 m, but is generally of the order of 10 to 20 m. The transmissivity coefficient ranges from 10^{-5} to $10^{-4}\ m^2\ s^{-1}$. The semi-permeable or fully-impermeable sandy clays often disconnect aquifer layers, which has resulted in the artesian character of the latter.

Groundwater (GW) resources are vital for the economy and society, as well as for the development of both countries. Within the framework of the International Commission for the Protection of the Danube River (ICPDR) activities and the Roof Report for 2004 [6], the transboundary aquifer system of Hungary–Serbia was preliminary separated into two parts: one large GW body in Serbia named CS_DU 10, and five in Hungary (P.1. and P.2. groups). The total area is assumed to cover around 27 000 km^2.

The region completely satisfies the demand for drinking water from the ground. There are more than 300 sources and centralized waterworks of different sizes, from the very small demand of small villages to the very large ones of supplying water to more than 100 000 consumers. There are over 1200 operational deep wells, belonging either to those waterworks or to small industrial enterprises and individual farms. However, data concerning their pumping rates and drawdown are not always collected, particularly on the Serbian side of the border.

Most of the wells for water supply are drilled to a depth of 50–150 m, but some reach 250 m or even more (600 m in Szeged). The well capacity ranges from 5 to 25 $l\ s^{-1}$, depending on geology, applied drilling techniques, construction materials, well development and other factors [7]. In the past, many wells were over-pumped and forced beyond their optimal capacities, which caused them to deteriorate quickly. Therefore, many were replaced or revitalized. There are some indications of local drawdown; many wells which were previously artesian are characterized today by a static groundwater table lower than 10 m below the surface.

The conceptual hydrogeological model includes five main aquifer layers to a depth of some 2500 m (Figure 4.9.2). The first two (Quaternary and Upper Pliocene), which are most prominent and characterized by the presence of fresh groundwater, are utilized mostly for drinking water supply and for irrigation. The deeper layers are also used in the water supply of some cities (e.g. Szeged) or for geothermal or balneotherapeutical purposes: thermal water is used for recreation and medical purposes in several spas in both countries, while geothermal energy is more efficiently used in Hungary. The number of wells that tap deeper aquifer layers with thermal waters is over 100 on the Hungarian side, while in Serbia there are some 15–20 such wells.

In the Hungarian part of the study area the estimated exploitation is $2\,m^3\,s^{-1}$, 60% of which is used for municipal water supply and irrigation, and the rest is employed for industrial purposes. In Serbia it is assumed that the current exploitation of the transboundary aquifer is around $2.8\,m^3\,s^{-1}$, of which $1.2\,m^3\,s^{-1}$ are used by individual industry and farms. Groundwater is also used for irrigation purposes, but to a lesser extent because of rain-fed agriculture and the surface waters from the rivers and channels. Tapping of shallow aquifer layers is prevalent in Serbia, whereas the deeper aquifer layers are more exploited in Hungary.

4.9.4 Proposed Measures for Sustainable Utilization of the Aquifer Systems

On the Hungarian side of the model domain a MODFLOW based model was built [8] to investigate the hydrodynamic regime of the shallow aquifers.

The preliminary SUDEHSTRA hydrodynamical model was conceived and built as a multilayer model with ten layers (five water-bearings and five semi-permeables between them). Hydraulic parameters are approximated on the basis of provided documentation as representative values for the whole layer. Owing to insufficient data of the groundwater regime this initial model covered only steady state flow conditions.

The obtained results are useful for preliminary evaluation. They show insignificant regional depletion of groundwater for the simulated extraction rates (similar to the existing ones or with a slight increase in Hungary), and positive effects for simulated artificial recharge. The former is most likely due to the fact that the main pressure on groundwater extraction is shared between different water-bearing layers. Whereas in Serbia the main tapping is from the second and third aquifer layers, for the water supply of the main Hungarian consumer Szeged and for geothermal energy, the deeper aquifer layers (fourth and fifth) are intensively used.

Some of the concrete proposals of the SUDEHSTRA project include [9]:

- centralize the waterworks at municipal and regional levels (incorporate small village waterworks into municipal ones);
- keep existing sources functional as an integral part of future water supply systems;

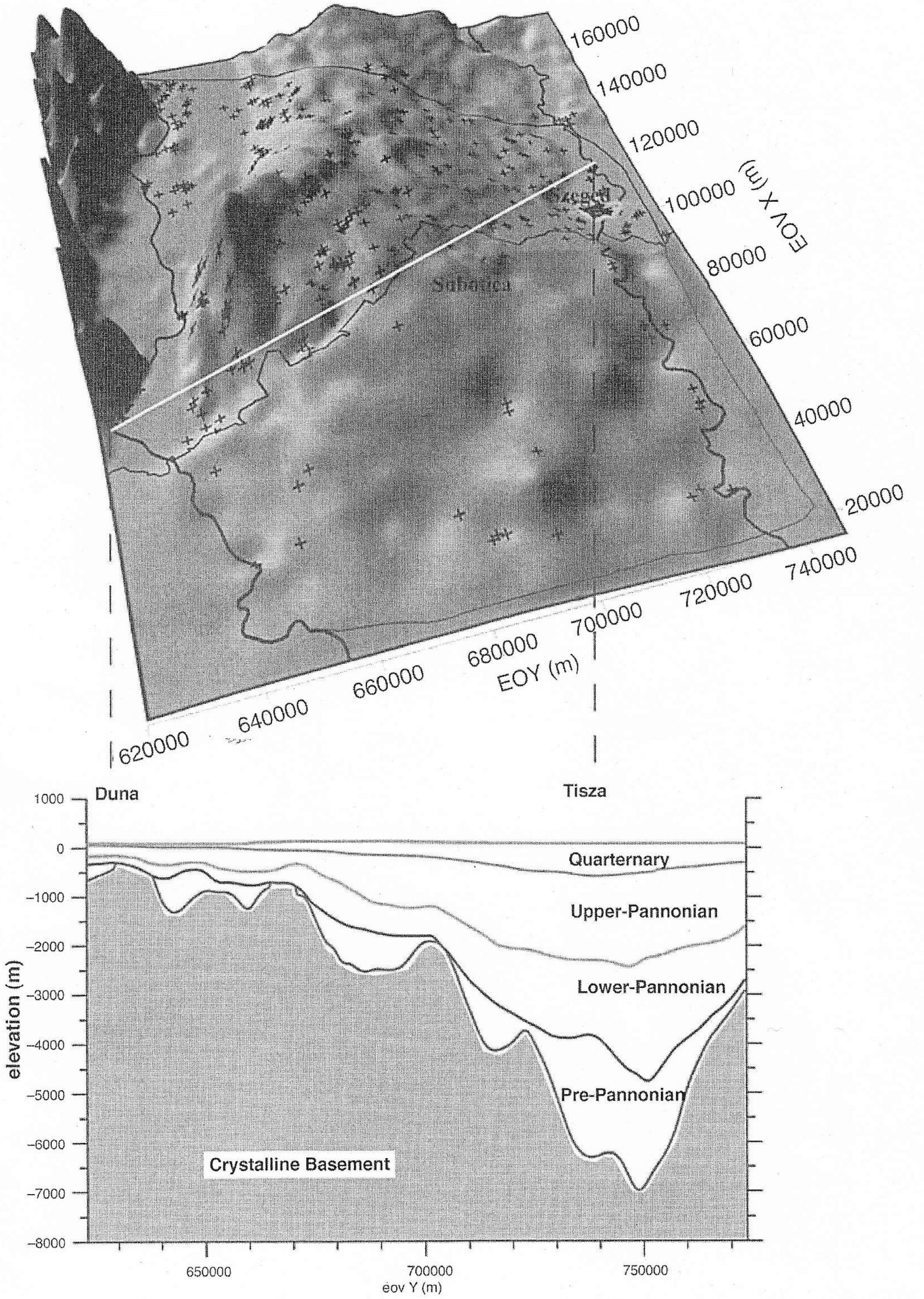

Figure 4.9.2 Three-dimensional model and general cross section through the study area between Danube (Duna, in the west) and Tisa River (Tisza in the east). Note: 'Pannonian' layers are considered to be the local Hungarian classification; in fact, the Upper Pannonian is of Pliocene Age.

- establish systematic monitoring of extracted water quantities and groundwater table fluctuations;
- reduce the pollution of water and soil to the maximal extent;
- introduce complex water treatment, particularly where problems with organic components or increased concentration of Fe, Mn, As is recognized;
- delineate the sanitary protection zones of water sources in accordance with criteria, taking into consideration primarily the local hydrogeological conditions and residence time for the pollutant transport (as recently reviewed legislation in the two countries required);
- introduce river bank filtration along major rivers such as the Danube and the Tisa;
- initiate a survey for artificial recharge, where natural conditions would be assumed to be promising for such interventions.

In line with last two proposals the alternative water sources are also analysed. Alluvial deposits along the Danube have the largest potential for water supply of the population and industry, but Tisa alluvium should not be neglected. The Danube alluvium has been studied as one of the most promising sources for the regional water supply of northern Serbia. In the vicinity of Apatin, 40–50 m thick and very permeable alluvial deposits, gravel and sands (average transmissivity $T = 2 \times 10^{-2}$ $m^2 s^{-1}$) enable the tapping of some 0.25–0.3 $m^3 s^{-1}$ per 1 km distance along the riverbank [10].

4.9.5 Conclusion

For this project numerous activities were undertaken, such as a local waterworks enquiry, field survey and measurements, the establishment of a GW monitoring network, the creation of a GW initial database, common workshops and seminars for local capacity building, and water-saving promotional activities. As one of the results of the project, an initial conceptual hydrogeological and hydrodynamical model was created and tested.

The results of the conducted survey enabled the proposal of many concrete measures and activities for better management and sustainable development of the groundwater as a very important and even sole resource in large parts of this region. The proposals that can be considered most important are: (i) opening of new sources for regional water supply based on alluvial groundwater and (ii) centralizing waterworks at municipality levels so that water will be adequately treated and protected from pollution.

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4.10 Transboundary Groundwater Resources Extending over Slovenian Territory

Petra Meglič and Joerg Prestor

4.10.1 Introduction

Despite its small area, Slovenia has a very and complex hydrogeological structure. Therefore different hydrogeological boundaries and characteristics for groundwater bodies and transboundary groundwater bodies were used for their delineation.

4.10.2 Transboundary Groundwater Resources

Slovenian territory (20.273 km^2), as seen on the world map of groundwater resources 1 : 50 000 000, is an area with a complex hydrogeological structure [1]. Only the