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4. Geothermal Water Utilization in Slovakia

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Abstract. In Slovakia, the use of geothermal water is bound to the aquifers of Mesozoic, Paleogene and Neogene age. These aquifers are located in the depths of 200 – 5,000 m. The geothermal water temperature reaches the values in the range of 15-240 °C. In the period 2000-2010 the geothermal water was utilized from 46 geothermal wells at 36 sites and from 13 geothermal waters bodies. Reinjection is implemented at one location (Podhájska). The average yield of the 46 exploited wells represents 6,323,167 $m^3.year^{-1}$ (236.65 $l.s^{-1}$). For all of these wells the relevant state water authorities have issued permits for the abstraction of geothermal water, in total amount 17,476,731 $m^3.year^{-1}$ (721 $l.s^{-1}$). Thermal energy potential of geothermal waters within individual units ranges from 1.1 MW_t to 1,316 MW_t. Summary calculated amount of geothermal energy from the geothermal water bodies defined in Slovakia equals to 6,234 MW_t. These values were calculated by geothermal balance method, volumetric method and mathematical modelling. Identified amount of geothermal energy (348 MW_t) in percentage terms compared to summary calculated amount of geothermal energy in Slovakia represents only 5.58 %. The exploited amount of geothermal water has been largely used for recreational purposes and heating of buildings, to a lesser extent for heating of greenhouses and mining air and fish farming.

Key words: geothermal energy, geothermal water abstraction, production potential, porous aquifers, karst-fissure aquifers

4.1. Introduction

The use of geothermal waters in Slovakia is historically associated primarily with the implementation of the spa facilities. Written records of the realization of these objects are known from the late 14th and early 15th century from the area of Turčianske Teplice, Dudince, Piešťany and Rajecké Teplice (Mulík, 1981). The utilization of geothermal water as a source of energy was launched in Slovakia in the second half of the 50s of the previous century. At that time in the spa premises the use of geothermal water was tested for heating buildings in the Spas Piešťany, Kováčová, Sklené Teplice. Trial tests of heat pumps operation in Piešťany, Turčianske Teplice were performed along with the use of heat exchangers and heating of buildings in Piešťany, Turčianske Teplice and Kováčová (Uhliarik, 1977).

Based on the results of research and geological exploration works carried out in the 70s and 80s of the last century, Geological Institute of Dionýz Štúr has earmarked 26 prospective geothermal areas (Franko et al., 1995). In 2007 the 27th geothermal area was allocated - Lučenec Basin (Dzúrik et al., 2007; Vass & Dzúrik, 2007).

After completion of geological works the existing wells gradually began to be used for recreational purposes, heating of greenhouses, unless the physico-chemical characteristics of geothermal water were suitable for the above purposes.

Development of the comprehensive database of geothermal wells, including their utilization was carried out in years 2007 to 2010 under the project „Evaluation of the Geothermal Water Bodies" performed by SGIDŠ. Data used in this evaluation were obtained from users of geothermal water or from Slovak Hydrometeorological Institute (SHMI). Other source of the data about the geothermal water utilization was coming from international project TRANSENERGY (Transboundary Geothermal Energy Resources of Slovenia, Austria, Hungary and Slovakia) described in the article Černák et al. of this issue. The data from TRANSENERGY project were obtained from field inspections and were compared with reported data to SHMI. In terms of Slovak division of geothermal areas this re-evaluation was done in Central Depression of Danube Basin, Levice Block and Komarno high Block.

From 2007 till 2010, the evaluation of geothermal water bodies Slovakia aimed on gradual building up a comprehensive database of geothermal water wells, including their use. In the framework of a geological project assessment of geothermal water bodies was implemented being consistent with the "Concept of geological research and exploration of the Slovak Republic for the years 2002 - 2006 with a prospect to 2010", which in 2002 was approved by the Government Resolution no. 334. This task also resulted from the current Act no. 364/2004, § 3, 4, 6 - processing of registration and evaluation of geothermal waters, as component of the groundwater in Slovakia and Government Resolution no. 46/2004 on the strategy for the implementation of the Water Framework Directive in Slovakia, where the government instructed the Ministers of the Environment, Agriculture, Health, Transport, Posts and Telecommunications to create conditions in their sectors and to ensure fulfilment of tasks in line with the strategy for the implementation of the Water Framework Directive (WFD) in SR according to the approved schedule of works by December 31, 2015.

4.2. Characteristics of geothermal water bodies

Sources of geothermal energy in Slovakia are represented mainly by geothermal waters, which are bound mainly to the Triassic dolomites and limestones of Inner Carpathians nappes; less to the Neogene sands, sandstones

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and conglomerates, or the Neogene andesites and pyroclastics. These rocks as collectors of geothermal waters off discharge areas are located at the depths of 200 - 5,000 m. In general, the temperature of these geothermal waters ranges from 15 to 240 °C. The collectors of geothermal waters with temperature more than 150 °C are located in Danube Basin Central Depression, Vienna Basin, Central Slovakian Neogene volcanics NW part (Žiar Basin), Humenné ridge, Beša - Čičarovce structure (Table. 4.1).

The binding of geothermal waters to those aquifers is evident from their natural discharges. They are conditioned by the folded-nappe tectonics of Mesozoic strata, which created far-reaching folds plunging from the mountain slopes to greater depths. On top of this, the young fault tectonics disturbed the Mesozoic strata by longitudinal and transverse faults. Far-reaching folds enable the connection of infiltration areas with the transition-accumulation ones. The crossing of longitudinal and transverse faults allows the groundwater to ascend to the surface through the Tertiary and Quaternary cover. This applies particularly for the intra-mountain depression. An example is, for instance, a hydrogeothermal structure in the western part of the Liptovská kotlina Basin with natural outflows in Bešeňová (Fig. 4.1). The geothermal waters are bound to the reservoirs without natural springs, or without infiltration areas (Central Depression of the Danube Basin, Levice Block).

In terms of geothermics the Western Carpathians can be divided into two parts, which vary widely in their geothermal activity and spatial distribution of the Earth's heat. Relatively low temperatures and densities of surface heat flux are characteristic for the central and northern part of the Inner Western Carpathians and for the western part of the Outer Flysch zone (30-40 °C at a depth of 1,000 m; 50-60 $mW.m^{-2}$). High subsurface temperatures and high heat flux densities are typical for the Neogene sedimentary basins and volcanic mountains of the Inner Western Carpathians (40-70 °C at a depth of 1,000 m; 70-120 $mW.m^{-2}$). Boundary between these geothermically different areas forms a zone of intensive horizontal temperature gradients, especially at the contact with volcanoclastic complex Pre-Neogene units of the Western Carpathians. The mean temperature at a depth of 1,000 m within the Western Carpathians is 45 °C, the mean heat flux density (arithmetic average of 136 wells) represents 82.1 ± 20.5 $mW.m^{-2}$.

Fig. 4.1 View of the mineral water outflows and travertine mound in Bešeňová (Photo: J. Madarás, 2012 in Liščák et al., 2012)

The highest heat fluxes in the Western Carpathian are in the Eastern Slovakia Neogene Basin (Fig. 4.2). The highest temperatures and heat flux density are in the central and SE parts (60-70 °C at a depth of 1,000 m; 100-120 $mW.m^{-2}$). The high values, namely 74.0 to 109.0 $mW.m^{-2}$ with a mean value of 94.3 $mW.m^{-2}$, were also found in the Central Slovakia Neovolcanites, values higher than 90 $mW.m^{-2}$ are typical for central and eastern part of the Danube Basin. Surprisingly low values, from 40.6 to 69.0 $mW.m^{-2}$ with a mean value of 55.0 $mW.m^{-2}$ were detected in the Vienna Basin. Significantly variable values (52.0 to 79.4 $mW.m^{-2}$) characterize the inner depressions of the Western Carpathians (Franko et al., 1995).

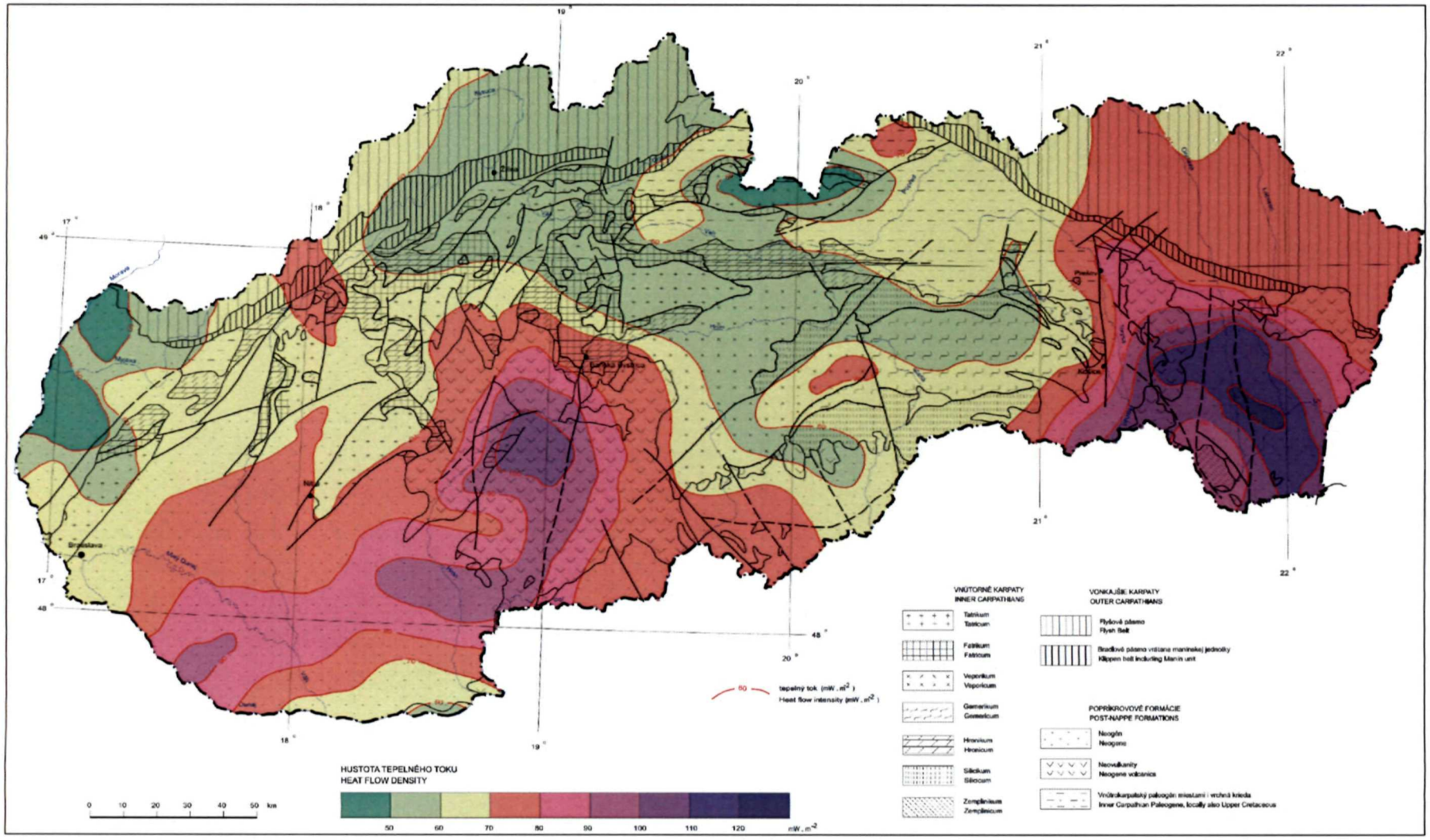

Fig. 4.2 Map of surface heat flow density of Slovakia, with underlay of geologic units (Franko et al., 1995)

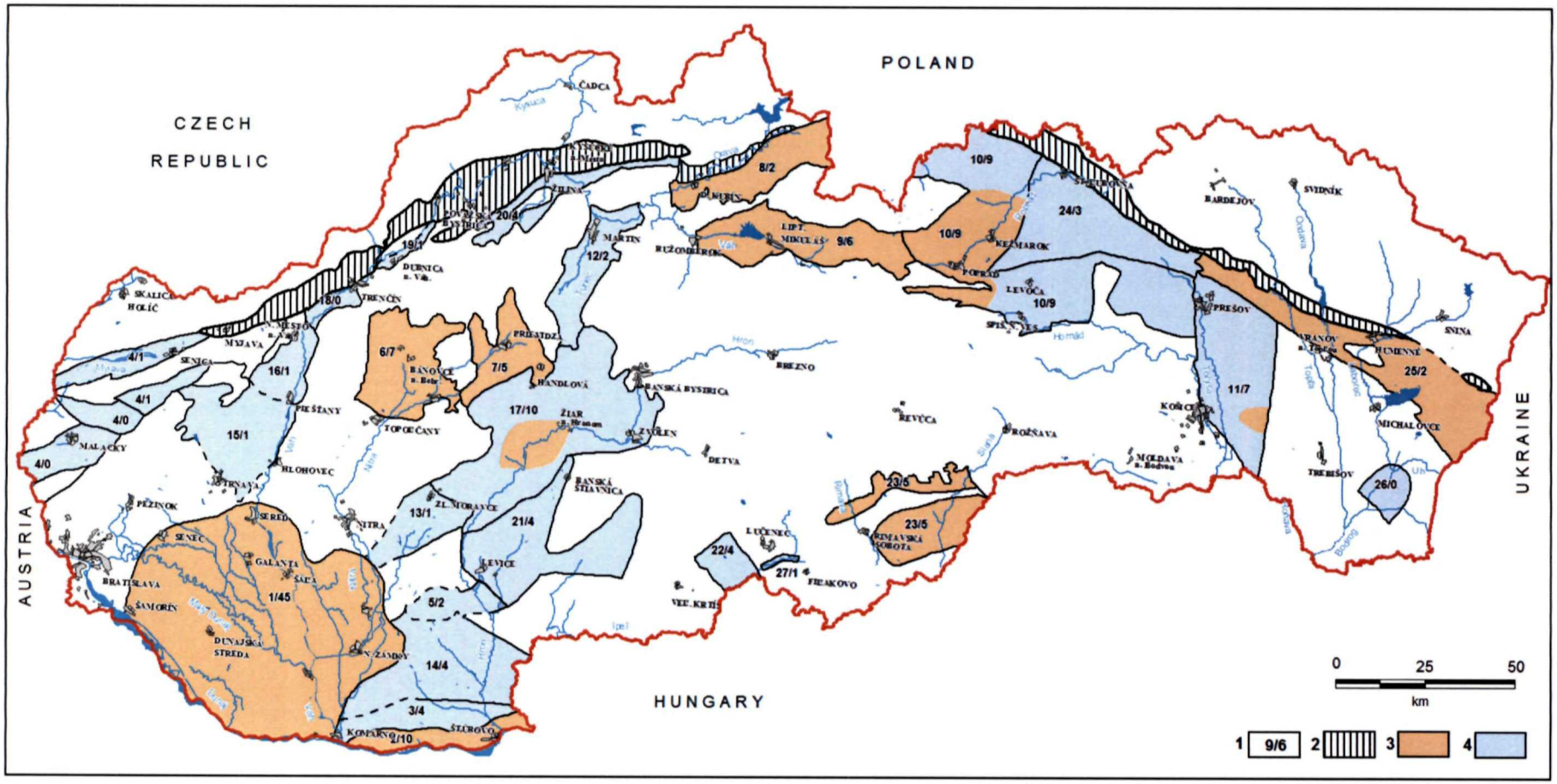

Fig. 4.3 Geothermal areas in Slovakia and status of their evaluation (Remšík in Remšík et al., 2011 – on the basis of Fendek et al., 2004)
1 - Danube Basin Central Depression, 2 - Komárno High Block, 3 - Komárno Marginal Block, 4 - Vienna Basin, 5 - Levice Block, 6 - Bánovce Basin, 7 - Upper Nitra Basin, 8 - Skorušina Basin, 9 - Liptov Basin, 10 - Levoča Basin W and S parts,p 11 - Košice Basin, 12 - Turiec Basin, 13 - Komjatice Depression, 14 - Dubník Depression, 15 - Trnava embayment, 16 - Piešťany embayment, 17 - Central Slovakian Neogene volcanics NW part, 18 - Trenčín Basin, 19 - Ilava Basin, 20 - Žilina Basin, 21 - Central Slovakian Neogene volcanics SE part, 22 - Horné Strháre - Trenč graben, 23 - Rimava Basin, 24 - Levoča Basin NE part, 25 - Humenné ridge, 26 - Beša - Čičarovce structure, 27 - Lučenec Basin

Legend: 1. - serial number of geothermal area/ number of geothermal wells; 2. - Klippen Belt; 3. - geothermal area, in which regional hydrogeothermal evaluation was implemented; 4.- geothermal area, in which regional hydrogeothermal evaluation was not implemented

Based on the distribution of the geothermal water collectors and geothermal field activity 27 prospective areas or structures were identified in the Slovak Republic suitable for obtaining geothermal energy. These defined geothermal areas, or structures, are termed as geothermal water bodies (as stated in the article Tab. 1.1 in the article by authors Černák et al. of this issue, Fig. 4.3).

Within the above defined geothermal areas or structures are present low-temperature geothermal sources of energy (temperature <100 °C), medium temperature sources (temperature 100-150 °C) and high temperature sources of geothermal energy (temperature> 150 °C). The low temperature geothermal sources are located in all 27-delineated geothermal areas, or structures; in 16 of them the medium temperature was detected and only in 5 the high-temperature geothermal energy sources is present. The incidence of the low-temperature, medium temperature and high-temperature geothermal energy sources in relation to individual defined geothermal areas or structures in Slovakia shows Tab. 4.1.

Tab. 4.1 Characteristics of geothermal water body – temperature water at surface

Type sources and their GTW temperature	Geothermal water body	No. of GTW bodies
Low temperature T < 100 °C	Danube Basin Central Depression, Komárno High Block, Komárno Marginal Block, Vienna Basin, Levice Block, Topoľčany embayment and Bánovce Basin, Upper Nitra Basin, Skorušina Basin, Liptov Basin, Levoča Basin W and S parts, Košice Basin, Turiec Basin, Komjatice Depression, Dubník Depression, Trnava embayment, Piešťany embayment, Central Slovakian Neogene volcanics SE part, Žilina Basin, Horné Strháre - Trenč graben, Rimava Basin, Trenčín Basin, Ilava Basin, Levoča Basin NE part, Humenné ridge, Beša - Čičarovce structure, Lučenec Basin	27
Medium temperature T = 100-150 °C	Danube Basin Central Depression, Komárno Marginal Block, Vienna Basin, Topoľčany embayment and Bánovce Basin, Liptov Basin, Košice Basin, Turiec Basin, Trnava embayment, Piešťany embayment, Central Slovakian Neogene volcanics NW part, Trenčín Basin, Ilava Basin, Žilina Basin, Levoča Basin NE part, Humenné ridge, Beša - Čičarovce structure	16
High temperature T > 150 °C	Danube Basin Central Depression, Vienna Basin, Central Slovakian Neogene volcanics NW part (Žiar Basin), Humenné ridge, Beša - Čičarovce structure	5

Legend: GTW – geothermal water

4.3. Geothermal waters abstraction and status of their use

In the period 2000-2010, 141 geothermal wells were registered in Slovakia, which made possible to verify the conditions for the geothermal water formation. Geothermal water was utilized from 46 wells situated in 36 sites within 13 Geothermal Water Bodies. This list does not include geothermal wells, which are used as curative sources under the supervision of the Ministry of Health, with exemption of the source FGC-1 in Čilistov.

In the period 2000-2010 from 46 operating geothermal wells 6,323,167 $m^3.year^{-1}$ (236.65 $l.s^{-1}$) were summarily taken. For all of these wells permits have been issued by relevant state water authorities for the abstraction of geothermal water, totalling 17,476,731 $m^3.year^{-1}$ (721 $l.s^{-1}$). The use of the wells represents 33% of allowances under the reported data on SHMI customers. However, many data are notified at an estimate, since some sampling devices lack of functional measuring equipment.

The largest average amount of geothermal water was collected from the following units of the geothermal waters in the years 2000-2010 (Tab. 4.2): Danube Basin Central Depression, Levoča Basin, W and S parts, Liptov Basin and Komárno High Block. During this period, from the perspective of individual geothermal wells the geothermal water was collected, with the highest exploited volumes values in the range of 100,000 to 1,000,000 $m^3.year^{-1}$ per well (Tab. 4.3).

By the Slovak Constitution, groundwater is the property of the state and the state is controling the utilization of the groundwater (geothermal water) through different Acts and regulations. To differentiate the usable amounts of groundwater (and geothermal water), Slovak legislation has defined principles for usable amounts classification into 3 categories: A, B and C, Appendix 3 in Decree of Government No.51/2008, implementing the Geological Act 569/2007). These categories are calculated based on level of information detail available for its calculation.

In other words we can say that 3 categories are degree of accuracy of calculation. Class A was defined as the amount of geothermal water, which is documented in the operating device for at least three years in terms of its quality, the water level (or pressure) regime and yield. Category B was defined as the amount of water that is determined based on a pilot hydrodynamic test covering at minimum 21 days and documenting the relationship of geothermal and surface water for at least 2 year period. Category C was defined as the amount of water that is calculated by geothermal balance, volumetric method, mathematical modeling and also documented groundwater regime of at least one year following a long series of observations of groundwater.

By the year 2010 available quantity of geothermal water was approved for 15 exploitation wells in category B and for 5 wells in category C.

Tab. 4.2 Annual geothermal water abstraction from geothermal water bodies during period 2000-2010

Name of geothermal water body	GTWU/ AGTW	Annual geothermal water abstraction											WP ($m^3.y^{-1}$)
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Danube Basin Central Depression	20/45	1,564,468	1,655,123	1,516,581	1,671,838	1,855,086	1,904,187	1,827,212	2,414,828	2,293,046	2,256,956	2,247,476	4,756,237
Komárno High Block	4/10	433,441	496,570	495,920	497,770	500,350	486,929	468,070	494,490	571,791	642,629	586,495	1,974,888
Komárno Marginal Block	0/4												
Vienna Basin	0/2												
Levice Block	1/2	119,000	120,000		120,000			9,880	58,600	47,400	45,200	54,000	946,080
Topoľčany embayment and Bánovce Basin	3/7	12,300	230,000	186,500	113,400	130,994	168,842	185,703	185,465	192,889	203,962	207,059	629,020
Upper Nitra Basin	3/5					34,030	180,447	176,362	149,274	181,966	142,987	209,679	1,151,064
Skorušina Basin	1/2			63,600	38,000	37,800		29,500	20,949	38,000	38,000	37,998	1,860,624
Liptov Basin	3/6			332,791	37,600	83,670	621,223	622,008	776,906	1,496,704	1,487,896	1,123,514	1,616,609
Levoča Basin W and S parts	4/9	1,410,480	1,410,480	1,410,480	1,410,480	1,410,480	1,580,480	1,624,789	1,596,255	1,537,587	1,826,938	2,225,475	3,642,408
Košice Basin	0/7												
Turiec Basin	0/2												
Komjatice Depression	0/0												
Dubník Depression	0/4												
Trnava embayment	0/1												
Piešťany embayment	0/1												
Central Slovakian Neogene volcanics NW part	1/10						7,897	5,411	4,117	3,126	2,948	7,730	21,488
Trenčín Basin	0/0												
Ilava Basin	0/1												
Žilina Basin	1/4	48,450	49,100	49,600	65,430	65,850	59,950		60,646	5,5461	45,591	4,6128	70,000
Central Slovakian Neogene volcanics SE part	3/4	145,814	151,862	166,004	167,684	150,199	55,309	57,597	87,724	107,877	141,541	148,927	669,362
Horné Strháre - Trenč graben	1/4	59,096	59,096		51,709	51,709	51,709	16,236	16,284		14,990		180,248
Rimava Basin	0/5												9,000
Levoča Basin NE part	0/3												
Humenné ridge	0/2												
Beša - Čičarovce structure	0/0												
Lučenec Basin	1/1											5,591	346,896

Legend: AGTW – amount of geothermal wells, GTWU – amount of utilized geothermal wells, WP - water abstraction permit ($m^3.y^{-1}$)

Tab. 4.3 Overview of exploited geothermal wells with the highest values – mean yearly exploitaion of geothermal water for the period 2000-2010

Name of geothermal water body	Locality	Well	AAGTW ($m^3.y^{-1}$)	% from WPW
Liptov Basin	Bešeňová	ZGL-1	835,687	74
Levoča Basin W and S parts	Vrbov	Vr-2	716,091	83
	Vrbov	Vr-1	694,794	110
Komárno High Block	Štúrovo	FGŠ-1	408,683	81
Levoča Basin W and S parts	Poprad	PP-1	304,558	29
Danube Basin Central Depression	Senec	BS-1	295,132	78
	Galanta	FGG-2	230,661	70
	Galanta	FGG-3	294,255	89
	Veľký Meder	Č-2	232,512	92
	Horné Saliby	Di-2	198,459	43
	Topoľníky	FGT-1	179,314	59
Bánovce Basin	Bánovce nad Bebravou	BnB-1	156,396	45
Upper Nitra Basin	Nováky-Laskár	Š1 NBII	149,992	26
Danube Basin Central Depression	Veľký Meder	Č-1	148,333	47
	Horná Potôň	FGHP-1	120,015	67
	Dunajská Streda	DS-2	99,704	109

Legend: AAGTW - annual average amount of geothermal water abstraction, WPW - water abstraction permit for well

Fig. 4.4 Well head Č-1 Veľký Meder (Photo: D. Marcin, 2010)

Fig. 4.5 Well head Š1-NBII Nováky – Laskár (Photo: D. Marcin, 2011)

The geothermal water from 23 exploited wells (50%) is taken from the Neogene rock environment (sands, or sandstones) and 23 wells (50%) from the Mesozoic rock environment (Triassic carbonates). According to the value of the average annual collection of geothermal water (2000-2010) from the Mesozoic rock environment were withdrawn 142 $l.s^{-1}$ (60%) and from the Neogene geological environment 95 $l.s^{-1}$ (40%).

The active part of the wells in the Neogene aquifers is approximately at the depth level of about 1,200-1,550 m and in the Triassic aquifers at intervals of about 635-1130 m. The water temperature at the wellheads in the Neogene sediments is 19-91 °C (an average of about 60 °C), the temperature of the water at the wellheads in the Triassic carbonates is 20-80 °C (average of 42.5 °C). The mineralization of geothermal water from sandy col-

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lectors can range from 0.4 to 6.9 $g.l^{-1}$ (an average of 2.5 $g.l^{-1}$), the water mineralization in carbonates varies in the interval 0.5 to 19.6 $g.l^{-1}$ (in average of 3.25 $g.l^{-1}$).

From the regional point of view, the maximum use of geothermal energy in Slovakia is in the regions of Trnava, Nitra and Žilina. The greatest use of geothermal energy in Slovakia is currently for recreational purposes (87% of the number of sources used). Geothermal energy from 22 wells (48% of the sources used) is utilized for the purposes of building heating. The most important is the hospital complexes heating in Galanta as well as mining air heating in the lignite mine in Nováky (Fig. 4.5). In the year-round opened aquaparks and thermal pools based on geothermal water also hotel rooms are heated. This involves the sites of Dunajská Streda, Veľký Meder, Galanta,

Fig. 4.6 Well head FGT-1 Topoľníky (Photo: D. Marcin, 2010)

Fig. 4.7 Well Po-1 Podhájska (Photo: D. Marcin, 2012)

Fig. 4.8 Reinjection well in Podhájska GRP-1 (Photo: D. Marcin, 2012)

Horné Saliby, Senec, Čilistov, Poľný Kesov, Štúrovo, Podhájska, Bánovce nad Bebravou, Malé Bielice, Chalmová, Oravice, Bešeňová, Liptovský Mikuláš, Vrbov, Poprad and Veľká Lomnica.

In agriculture, the geothermal water is exploited from 11 wells (24% of the number of sources used) at 10 sites in winter for greenhouses heating, or plastic greenhouses at forcing the production of vegetables as well as the cultivation of flowers. In the Central Depression of the Danube Basin these wells are in Tvrdošovce, Gabčíkovo Topoľníky (Fig. 4.6), Topoľovec, Čiližská Radvaň, Horná Potôň and Dunajská Streda; in Levice Block in Podhájska and in Liptov Basin in Bešeňová. In Levoča Depression at the site Vrbov the geothermal water is used also for fish farming.

On a single site in Slovakia – in Podhájska – the geothermal water is exploited using re-injection system. Water from the exploitation borehole Po-1 (Fig. 4.7) passes through heat exchangers, in which it transfers the heat to technological water. Thermally utilized geothermal water for greenhouses heating by Slovkvet Company is reinjected into the well GRP-1 (Fig. 4.8) by pipe of a length of 2,300 m. Operating parameters of reinjection are for exploitation well Po-1 (T= 83.4 °C, Q = 5.6 $l.s^{-1}$, $P_{wellhead}$ = 0.385 MPa) and reinjection well GRP-1 (T= 40 °C, Q = 5.0 $l.s^{-1}$) during winter period. Wastewater from Termalpark is discharged into the stream Liska.

4.4. Thermal-energy potential of geothermal waters

Thermal energy potential of Slovakia (TEP) was comprehensively assessed in Geothermal Map of Czechoslovakia 1:500,000 with its total amount 5,804 MWt (Franko et al., 1989). Franko et al. (1990) determined the value of the thermal energy potential (Table 4.4) for the verified amount of 138 MWt and 5,666 MWt estimated amount specified in 25 geothermal areas. Evaluation of TEP in subsequent periods reflects the gradual increase of geological works, which provide information on the geothermal areas character. This information can be classified according to their quality data as predicted and proven. By its nature Geothermal Water Bodies have been divided in areas with amount of renewable geothermal energy (open and semi-open hydrogeological structure), and amount of non-renewable geothermal energy (closed hydrogeological structure). For utilization of geothermal water from closed structures the reinjection is needed.

For evaluation of the thermal energy potential of Slovakia in 1994, data from 61 geothermal wells for the period 1971-1991 were processed (Franko et. al., 1995). Wells verified amount of geothermal water of 900 $l.s^{-1}$ with a temperature of 20 °C to 92 °C and thermal energy 176 MWt. That represented around 3.2% from the total predicted amount of thermal energy. These quantities were bound to hydrogeological structures with renewable amounts of geothermal energy. Taking into account only the amount renewed, then it represented almost 32% of the total renewable and usable quantity of geothermal energy in Slovakia.

In the following period (1999, 2002 and 2009) thermal energy potential in Slovakia was estimated and assessed at amount 5,538 MWt and 6,653 MWt respectively. The use of this potential has been documented at the level of 130.97 MWt in 1999, 2002 (Fendek & Franko, 2000; Fendek, 2002) and in 2009 it was 163.86 MWt (Fendek & Fendeková, 2010).

Table 4.4 Overview of evaluation of thermal energy potential of geothermal waters in Slovakia

TEP till 31.12.1989 (Franko et al., 1990)			
Category	**Predicted amount**	**Proven amount**	**∑TEP**
	GE (MW_t)	GE (MW_t)	GE (MW_t)
ARE	484	138	622
ANE	5,182		5,182
∑	5,666	138	**5,804**
TEP till 31.12.1994 (Franko et al., 1995)			
Category	**Predicted amount**	**Proven amount**	**∑TEP**
	GE (MW_t)	GE (MW_t)	GE (MW_t)
ARE	406	147	553
ANE	4,956	29	4,985
∑	5,362	176	**5,538**
TEP till 30.6.1999 (Fendek & Franko, 2000)			
Category	**Predicted amount**	**Proven amount**	**∑TEP**
	GE (MW_t)	GE (MW_t)	GE (MW_t)
ARE	406	147	553
ANE	4,956	29	4,985
∑	5,362	176	**5,538**
TEP till 30.6.2002 (Fendek, 2002)			
Category	**Predicted amount**	**Proven amount**	**∑TEP**
	GE (MW_t)	GE (MW_t)	GE (MW_t)
ARE	390,5	162,5	553
ANE	4,868,8	116,2	4,985
∑	5,259,3	278,7	**5,538**
TEP till 30.6.2009 (Fendek &Fendeková, 2010)			
Category	**Predicted amount**	**Proven amount**	**∑TEP**
	GE (MW_t)	GE (MW_t)	GE (MW_t)
ARE	490	218	708
ANE	5,798	147	5,945
∑	6,288	365	**6,653**
TEP till 31.10.2011 (Remšík et al., 2011)			
Category	**Predicted amount**	**Proven amount**	**∑TEP**
	GE (MW_t)	GE (MW_t)	GE (MW_t)
ARE	1,307	227	1,534
ANE	4,927	121	5,048
∑	6,234	348	**6,582**

Legend: TEP - thermal energy potential, ARE - amount of renewable energy, ANE - amount of non-renewable energy (need to use reinjection)

Thermal energy potential was assessed in 2011 and in individual geothermal areas of Slovakia, its value was in range from 1.1 MWt to 1316,0 MWt. The total calculated amount of geothermal energy in defined geothermal areas in Slovakia is currently at level 6234,039 MWt (Tab. 4.5).

These values were calculated by geothermal balance, volumetric method and mathematical modelling. Identified amount of geothermal energy (345,04 MWt) in percentage terms compared to total calculated amount of geothermal energy in Slovakia represents only 5.58%.

Table 4.5 Thermal energy potential of geothermal waters in Slovakia (Remšík et al., 2011)

Geothermal water body	Category	Predicted amount		Proven amount		∑TEP	
		GW ($l.s^{-1}$)	GE (MW_t)	GW ($l.s^{-1}$)	GE (MW_t)	GW ($l.s^{-1}$)	GE (MW_t)
Danube Basin Central Depression	ARE	731.0	150.0	488.7	101.11	1,219.7	251.11
Komárno High Block	ARE	133.0	9.7	265.0	17.42	398	27.12
Komárno Marginal Block	ANE		227.5	15.9	2.62	15.9	230.12
Vienna Basin	ANE		511.0	37.0	9.5	37	520.5
Levice Block	ANE		126.0	81.0	20.74	81	146.74
Bánovce Basin	ARE	141.7	12.469	68.8	5.26	210.5	17.729
Upper Nitra Basin	ARE	140.0	29.12	57.9	7.05	197.9	36.17
Skorušina Basin	ARE	166.0	24.0	135.0	18.29	301	42.29
Liptov Basin	ARE	248.0	34.589	121.4	20.36	369.4	54.949
Levoča Basin W and S parts	ARE	424.6	75.4	226.3	34.24	650.9	109.64
Košice Basin	ANE		1,276.4	207.4	78.88	207.4	1,355.28
Turiec Basin	ARE		22.5	19.9	2.65	19.9	25.15
Komjatice Depression	ANE		392.64				392.64
Dubník Depression	ANE		808.3	36.0	3.70	36	812
Trnava embayment	ARE		33.5	14.5	0.55	14.5	34.05
Piešťany embayment	ARE		10.5	10.0	0.18	10	10.68
Central Slovakian Neogene volcanics NW part	ARE		82.6	80.6	9.47	80.6	92.07
Trenčin Basin	ARE		4.6				4.6
Ilava Basin	ARE		1.1				1.1
Žilina Basin	ARE		13.2	57.4	2.95	57.4	16.15
Central Slovakian Neogene volcanics SE part	ARE		26.4	64.1	3.84	64.1	30.24
Horné Strháre - Trenč graben	ARE		6.2	16.0	1.04	16	7.24
Rimava Basin	ARE	284.74	21.121	61.3	1.76	346.04	22.881
Levoča Basin NE part	ANE		1,316.0	19.0	4.55	19	1,320.55
Humenné ridge	ARE	341.0	750.5	6.0	0.41	347	750.91
Beša - Čičarovce structure	ANE		268.7				268.7
Lučenec Basin	ANE			11.20	1.04	11.2	1.04
∑ ARE	ARE	2,610.04	1,307.499	1,692.9	226.58	4,302.94	1,534.079
∑ ANE	ANE		4,926.540	407.5	121.03	407.50	5,047.570
∑ ARE + ∑ ANE	ARE+ANE	2,610.04	6,234.039	2,100.4	347.61	4,710.44	6,581.649

Legend: GW - geothermal water, GE - geothermal energy, ARE - amount of renewable energy, ANE - amount of non-renewable energy (need to use reinjection)

4.5. Conclusion

The assessment of the use of geothermal waters in Slovakia during the period 2000 - 2010 was based on the documentation available from the 141 registered wells and collection of data on geothermal waters as reported by users to the Slovak Hydrometeorological Institute in Bratislava. Based on data processing it can be concluded that geothermal water was utilized from 46 geothermal wells at 36 locations in 13 geothermal water bodies (geothermal areas) during last decade. This list does not include geothermal wells, which are used as healing sources and are at the competence of the Ministry of Health (source FGČ-1 in Čilistov is included in evaluation). Total average yearly amount of utilized geothermal water from 46 geothermal wells is 6,323,167 $m^3.year^{-1}$ (236,65 $l.s^{-1}$). For all of these wells relevant state water authorities issued permits for the abstraction of geothermal water, totalling 17,476,731 $m^3.year^{-1}$ (721 $l.s^{-1}$).

The utilization of geothermal water from wells represents 33% of allowed yield for utilization according to the reported data by customers to SHMI. Most of the reported data is based on estimate, since measuring devices or flowmeters are absent.

The highest average amount of geothermal water utilization in that period was reported in four geothermal waters bodies: Central Depression of Danube Basin, Levoča Basin W and S parts, Liptovská kotlina Basin and Komarno High Block. Geothermal water from 23 utilized wells (50%) comes from the Neogene sediments (sands and sandstones) and 23 utilized wells (50%) comes from Mesozoic sediments (Triassic carbonates) and Paleogene (breccias, conglomerates, sandstones). According to the value of the average annual utilization of geothermal water from period 2000-2010, 142 $l.s^{-1}$ (60%) of geothermal water is withdrawn from Mesozoic and Paleogene sediments and 95 $l.s^{-1}$ (40%) from Neogene sediments.

Thermal energy potential in individual geothermal areas in Slovakia varies from 1.1 MWt to 1,316 MWt. Total calculated amount of geothermal energy in Slovakia represents 6,234 MWt. These values were calculated by geothermal balance, volumetric method and mathematical modeling. To date knowledge identified amount of geothermal energy (348 MWt) in Slovakia represents only 5.58% of total calculated amount of geothermal energy.

The important task for future is continuous updating of knowledge about geothermal structures, the information database of geothermal water utilization and current state of issued water permits. The update should incorporate the information form database of geothermal sources that is treated as healing water under the competence of Ministry of Health with separate status and monitoring policy.

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