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HYDROGEOLOGY OF THE DOLNA BANYA THERMAL WATER BASIN

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ABSTRACT

The study is devoted to mineral water occurrences at Kostenets, Dolna Banya, Momin prohod, Pchelinski bani, revealed within the Kostenets graben depression. Specific geological, hydrogeological and hydrochemical conditions of the above mentioned occurrences of mineral water are the reasons for treated them as parts of a common hydrogeological structure, denoted as Dolna Banya thermal water basin.

Scope and boundaries of the basin are delineated. A description of individual mineral water occurrences is presented. The discharge of each of them is assessed on actual measurements and observations of discharge regime. The total outflow of mineral water from the occurrences of the Dolna Banya thermal water basin recently amounts to 53 l/s. The hydrochemical characteristic of mineral waters is presented as well as regularities in the distribution of composition and temperature.

A conceptual computer model of the Dolna Banya thermal water basin is compiled and it is used for determining the cathcment areas for each of the mineral water occurrences. The model confirms hydraulic connection between specific parts of the basin and in the meanwhile studies the determination of Kostenets occurrence of mineral water as an autonomous part of the basin.

INTRODUCTION

The Dolna Banya thermal water basin is located in the central part of west Bulgaria, between the Rila Mountain and the Ihtiman Sredna Gora Mountain. Four mineral water occurrences are revealed in the basin: Kostenets, Dolna Banya, Momin prohod and Pchelinski bani. The region under investigation belongs to the Maritsa River catchment area, comprising the southern slopes of Cherni rid of the Ihtiman Sredna Gora Mountain, the eastern slopes of the Shumnatitsa heights, northeastern slopes of the Rila Mountain and the Kostenets valley.

A. Boue and A. Viquesnel provided first data about the geology of the area. Later the area is studied by G. Zlatarski, G. Bonchev, S. Bonchev, P. Bakalov etc. Results of geological mapping in the area are summarized by Dimitrova and Katskov (1990), Iliev and Katskov (1990, 1993) in the geologic map of Bulgaria in scale M 1: 100 000 – map sheets Velingrad and Ihtiman.

First analysis of mineral water composition were carried out by N. Dobrev (1905) and Azmanov (1929, 1940). Data about the capture of water sources in the mineral water occurrences are presented in the papers of G. Vasilev (1938, 1939), B. Radoslavov (1939) and Pavel Petrov (1943). Data about mineral waters of the mineral water occurrences are published by P. S. Petrov (1964). Hydrogeological conditions of the four mineral water occurrences are analyzed by K. Shterev (1964), who includes them in the "Kostenets area" and draws attention to its hydrochemical zoning.

For the first time the mineral water occurrences of Kostenets, Dolna Banya, Momin prohod and Pchelinski Bani are grouped under the name "Dolna Banya basin" by P. Petrov etc. (1970). According to the last authors the basin is a graben structure, shaped by the faults between the Rila-Rhodope massif and the Srednogorie, and the major recharge area is located down the northeastern part of the Rila Mountain. Authors did not make overall assessment on hydrogeologiacal conditions in the region - their investigations were concentrated mainly on the individual occurrences of mineral water within it.

In the present study the separate mineral water occurrences are considered as integral parts of a general hydrogeological unit, denoted by the authors as Dolna Banya thermal water basin. The last unit is described through detail review of all available reference information and the results of field investigations, conducted by the authors in 2001 – 2003 period. Actual data for mineral water discharge, temperature, chemical composition and radioactivity are presented as well.

DOLNA BANYA THERMAL WATER BASIN

From geological point of view the area under investigation is represented by: Precambrian metamorphic formations – gneiss, amphibolite, shale and marbles, Paleozoic granitoid plutons, Upper Cretaceous granodiorite intrusions, Paleogenic continental depositions down the Rila Mountain slopes, Neogene -Quaternary lake-river depositions and Quaternary alluvial depositions in the Dolna Banya valley.

The major water bearing formations collecting thermal (mineral) water in the region are Rila-Western Rhodopes batholite and Upper Cretaceous intrusions within the Srednogorie and the Rhodopes massif. Thermal waters have an infiltration genesis, they are accumulated and circulate along fractures and tectonic zones within the above described Paleozoic granitoids and Upper Cretaceous intrusions. Both

rock complexes may be treated as parts composing a united hydraulic reservoir, denoted as Dolna Banya thermal water basin.

Boundaries of the basin (Fig.1) are delineated on the base of geologic map of Bulgaria in scale 1: 100 000 and hydrographical network of the region. They coincide with the boundaries of Rila-Western Rhodopes batholite and Upper Cretaceous intrusions outcrops and the surface water divides.

Northern part of the basin is composed of granodiorites of the Gutsal pluton and diorites of the Plana pluton, and the southern one – of granitoids of the Rila-Western Rhodopes batholite with individual intruded bodies of the Upper Cretaceous.

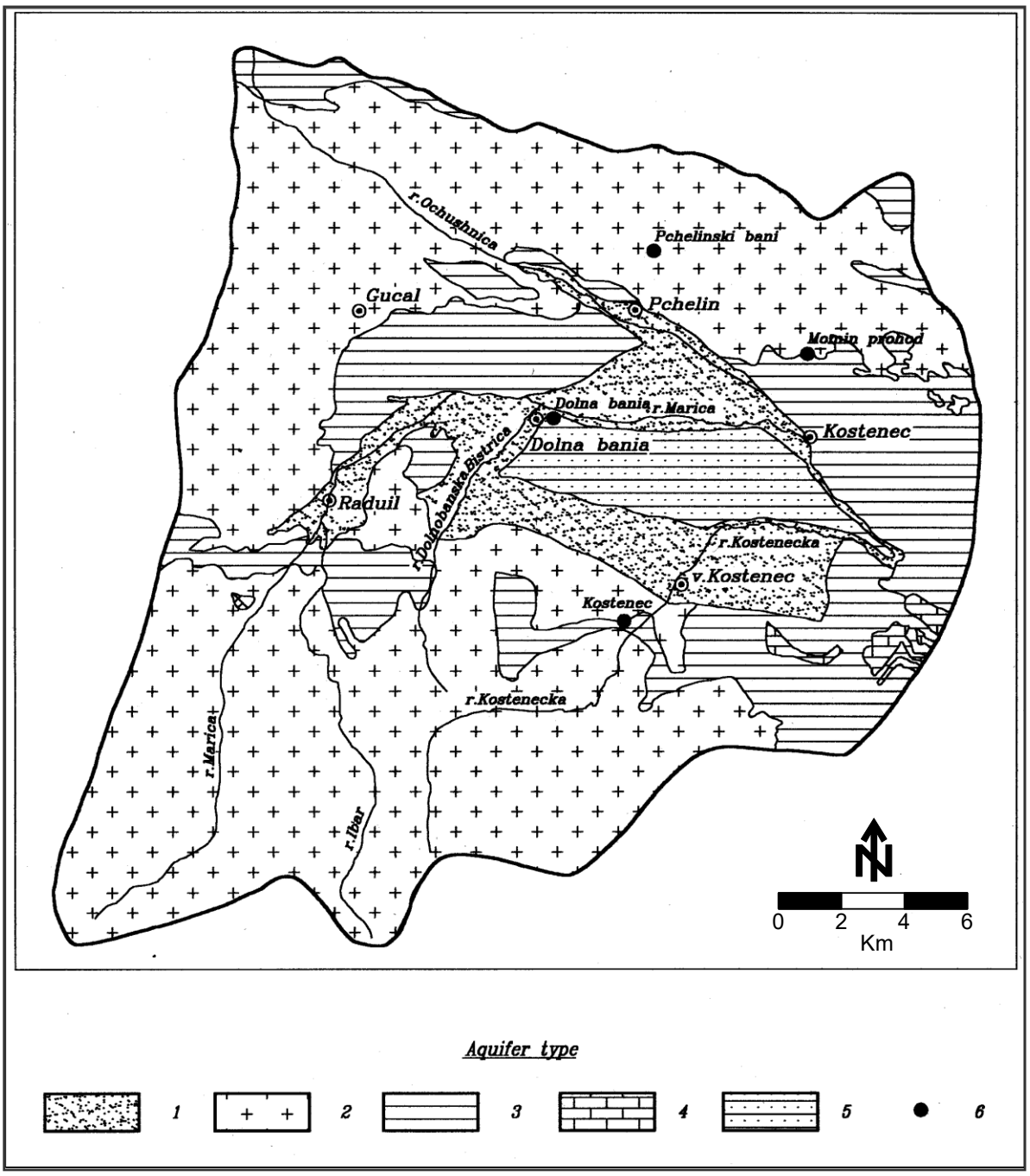

Figure 1. Hydrogeological map of Dolna Banya thermal water basin
1 - Porous aquifer in Quaternary deposits (gravel, boulder, sands and loamy sands), middle to high water bearing capacity; 2 – Fractured aquifer in Paleozoic and Upper Cretaceous intrusions (granites and granodiorites), low to middle water bearing capacity; 3 – Non aquiferous geological formations in Precambrian metamorphic complex (gneiss, shale, amphibolite) and Paleogenic sediments (conglomerate, sandstone, argellite, bituminous shale and coal); 4 – Fracture-karst aquifer in Dobrostan formation (Precambrian fractured and karstified marbles), middle to high water bearing capacity; 5 - Non aquiferous geological formations in Pliocene depositions (clay, sand and breccia-conglomerate); 6 – Location of the mineral water occurrences

Hydraulic link between ground water from both parts is complicated by faulty structures of the Maritsa fault. The south-verging over-thrust, where granites and metamosphites are thrust over Paleogenic sediments, follows the line Borovets – Raduil – Kostenets, presents a hydraulic impermeable boundary for groundwater flow to northern direction. That impermeable boundary probably brings to showing of mineral waters in the Kostenets occurrence of mineral water, which is treated as an autonomous part of the Dolna Banya thermal water basin.

Paleozoic and Upper Cretaceous intrusive formations contact directly only in the western part of the basin in the location between the town of Dolna Banya and village of Raduil, where the hydraulic link of ground water is direct. In the central and eastern part of the basin (Kostenets – Dolna Banya depression), Precambrian metamorphites and Tertiary and Quaternary sediments outcrop on the surface. In the depression, below the Neogene and Quaternary deposits there are granites and granodiorites, established in boreholes. That is a reason for supposing the availability of zones of direct contact between Paleozoic granites of the Rila-Rhodope massif from south and the Gutsal pluton. This is a precondition for establishing a hydraulic connection between ground water accumulated in both structures. In that parts the hydraulic connection between waters, accumulated in both complexes is realized through tectonically fractured Proterozoic gneiss, which represent a secondary collector of mineral waters in the Dolna Banya mineral water occurrence.

Discharge areas

Drainage of mineral water in the basin is performed by four thermal spring occurrences - Kostenets, Dolna Banya, Momim prohod and Pchelinski Bani. Results from the actual investigations, performed by the authors in the period 2001 - 2003, and the data obtained from regular observations during the 1983-2001 period, are shown on Figure 2. The trend of discharge changes of mineral water occurrence is visualized by linear function. Unessential decrease of the total discharge from all mineral water occurrences is established. The reasons for this will be investigated in the future. Now the total outflow from the four occurrences of mineral water is assessed to 53 l/s.

Kostenets mineral water occurrence. Mineral water springs in a dislocation of east-west direction, at the boundary between granites of the Rila-Rhodope batholit and the Paleogenic sediments. The major recharge area of those waters is located in the northeastern part of the Rila Mountain. The occurrence of mineral water were presented by two natural springs (at elevation 850 m) and three boreholes. Before the beginning of borehole-hydrogeological exploration (1960) the discharge of springs had changed from 3.3 to 4.2 l/s, and water temperature - from 35 to 41.7 °C. Thermal springs dried after drilling the boreholes and their exploitation. Now, only one of the drilled boreholes is exploited (Well № 2), with a depth of 444.70 m. There is a catchment aiming the exploitation of the well in a mode of artesian flow, and now its discharge amounts to nearly 14.3 l/s for temperature of the water 46 °C.

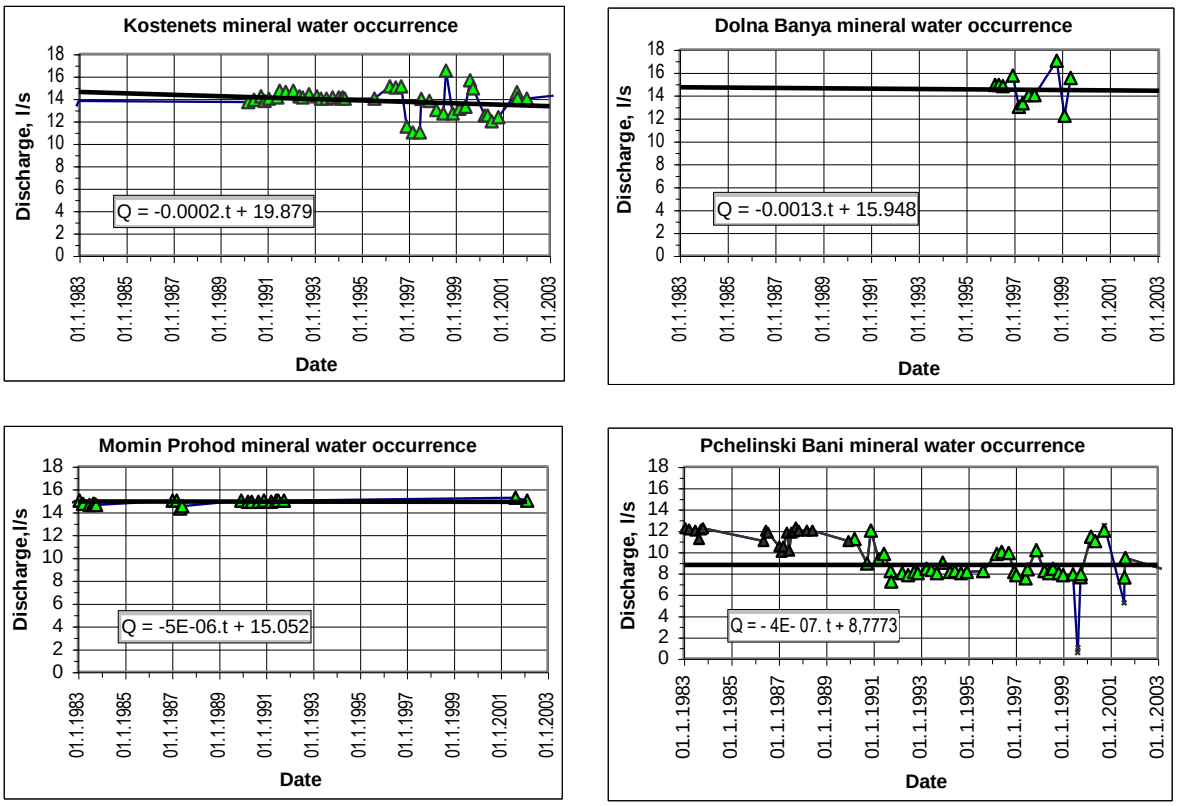

Figure 2. Visualization of data, obtained from regime observations on the discharge of mineral water occurrences for 1983 – 2003 period

Dolna Banya mineral water occurrence. The occurrence of mineral water is located on the right branch of the Ludja dere River, which is an tributary to the Maritsa River. Before the capture thermal water had been out flowing at three locations in the river terrace at an elevation of 615 m. During the time of the spring capturing it was established that water outflows from crystalline schists along a dislocation of nearly 1 m width and east-west direction. Initially the spring had a discharge from 2,25 to 4.0 l/s for temperature of the water of 56 °C. Due to drilling boreholes the discharge of spring was reduced to 1.4 l/s. As a consequence a hydraulic equilibrium was established between water sources, and recently the exploitation resource of the mineral water occurrence is assesses to approximately 15 l/s, for temperature of water in the range 56 - 62 °C (from the spring and from the exploitation boreholes, respectively).

Momin prohod mineral water occurrence. It is located on the southern slopes of the Sredna Gora Mountain, in the valley of the Bashnitsa River. Mineral water outflows from faulted and fractured granodiorites of the eastern part of the Gutsal pluton, at elevation 538 ÷ 540 m. Nearby the spring zone there is a contact of dislocated Precambrian gneiss and gneiss-shales, which are an impermeable boundary for seepage of mineral water. Major fault and fractured systems near the springs are directed in east west and north-northwest – south-southeast. Before the capture mineral waters had been draining from 10 springs, ordered on the fault zone in a distance of 25 m. Temperature of water in individual springs had been changing from 20 to 68.8 °C, and their total discharge before capturing amounted to 11.10 l/s. After the capture of thermal springs in 1936 at elevation, which is maintained even now, discharge was established at 15.00 l/s for temperature of water 65.4 °C. The captured spring of the Momin prohod mineral water occurrence flows at the lowest elevation in the thermal water basin with a constant discharge of 15 l/s.

Pchelin mineral water occurrence. The terrain is composed of the granitoids of the Gutsal pluton. Mineral water before the capture had been drained through several small springs, coming from a faulty zone of 3 to 10 m width, with an east-west direction and steep slope. Springs had appeared in a location, where the fault is crossed by tectonic fractures of north-south direction. Rocks in and near the faulty zone are hydrothermally altered. Total discharge of springs before the capture amounted to 11.17 l/s, and after - 11.7 l/s, for temperature of the water 73°C. This mineral water occurrence represents a seismo-hydrogeological phenomenon – for all severe earthquakes, taken place in Bulgaria and neighbor countries there is a reduction of the spring discharge. Three boreholes of depth 349 to 497 m were drilled in the period 1965 – 1967. One of them was closed, the second was equipped as a seismohydrogeologic observation point, which does not function recently, and the third is set to reserve exploitation water source. Recently the discharge of "Pchelin" spring amounts to nearly 8.8 l/s.

Physical and chemical characteristic of mineral water

There is a certain chemical and genetic similarity in the composition of mineral waters of the four mineral water occurrences. Thermal mineral waters from the Kostenets mineral water occurrence (46 °C), Dolna Banya mineral water occurrence (62 °C), Momin prohod mineral water occurrence (65 °C) and Pchelin mineral water occurrence (73 °C) contain nitrogen, helium, with medium to heavy radioactive content and total dissolved solids from 0.29 to 0.96 g/l, and high content of fluoride (up to 12.5 mg/l) and silica (up to 127 mg/l H_2SiO_3). In the aspect of cation composition waters are characterized as sodium, and anion composition – from hydro carbonate -sulfate (Kostenets) to sulfate (the other three mineral water occurrences). Availability of some rare and disseminated microelements is established, increased are the micro-contents of Li, Ga, Ge, W etc. Spring waters from the Pchelin bani have the highest temperature (73 °C), and those in Momin prohod – the maximum radioactivity (up 580 emanes).

Regularities in the distribution of composition and temperature of mineral water in the basin show the way of seepage through water-bearing rock formations. Paleozoic granitoids of the Rila-West Rhodope batholite are older and therefore, fractures in them are "more rinsed", i.e. water-soluble salts are removed and ground water, formed and circulating in them has a lower quantity of total dissolved solids. An example is the composition of the mineral water from the Kostenets mineral water occurrence. Paleozoic granitoids of the Rila-West Rhodope batholite are older and therefore, fractures in them are "more rinsed", i.e. water-soluble salts are removed and ground water, formed and circulating in them has a lower quantity of total dissolved solids. An example is the composition of the mineral water from the Kostenets mineral water occurrence.

Table 1 Hydrogeological and physico-chemical characteristics of mineral waters in the Dolna Banya thermal water basin

Mineral water occurrence	Elevation	Discharge	Tempe rature	Radioactivity (content of Radon)		Parametric formula
-	m	l/s	°C	eман	Bq/l	-
Kostenets	824.47	14,3	46	33 ÷ 86	122 ÷ 318	$M = 0.29\frac{(CO_3 + HCO_3)^{42} SO_4^{42} Cl^7}{Na^{95} Ca^5}\ pH = 9.2$
Dolna Banya	608	15.0	56 ÷ 64	50 ÷ 270	185 ÷ 999	$M = 0.60\frac{SO_4^{68} (HCO_3 + CO_3)^{18} Cl^6}{Na^{94} Ca^6}\ pH = 8.8$
Momin prohod	537	15.0	65	560	2072	$M = 0.98\frac{SO_4^{80} HCO_3^{12} Cl^5}{Na^{81} Ca^{16}}\ pH = 7.5$
Pchelinski Bani	632.9	8.8	73	120	444	$M = 0.98\frac{SO_4^{80} HCO_3^{11} Cl^5}{Na^{87} Ca^{11}}\ pH = 7.2$

Upper Cretaceous neointrusions are significantly lower and therefore less rinsed, which directly affects the higher content of dissolved components in accumulated in them waters. That explains the enhancement of quantity of total dissolved solids, concentration of sulfates, fluorides, meta-silica acid in northern

direction – from Rila to the Srednogorie. In the same direction content of hydrocarbonates and values of pH are relatively reduced. There is a regular increase of temperature of mineral water in northern direction, which is due to higher depth of ground water circulation.

Summarized information about discharge and main physic-chemical parameters of mineral waters from the four hydrothermal mineral water occurrences in the Dolna Banya thermal water basin is presented in table 1.

HYDRODINAMIC MODEL OF THE DOLNA BANYA THERMAL WATER BASIN

The conceptual computer model of Dolnd Banya thermal water basin is generated to determine the hydrogeological conditions in the basin. The purpose of the model is to confirm the basic hypothesis presented above, to determine the recharge areas of each occurrence of mineral water and to investigate the hydraulic link between the occurrences. Because there is no specific data for filtration parameters of the basic lithological formations, their typical values are used. The model is general and its future improvement is forthcoming.

Hydrodynamic conditions of the Dolna Banya thermal water basin are illustrated by a computer model, generated by module MODFLOW 96. Boundaries of modeled field coincide with boundaries of distribution of granites from the Rila-Rhodope massif and granodiorites of the Gutsal and Plana plutons, which form the Dolna Banya thermal water basin.

Outer boundaries of the basin are considered impermeable (barrier) boundaries. The south-verging thrust, which supports the ground water flow from the Rila-Rhodope massif towards the central parts of the basin, is assigned as an impermeable inner boundary.

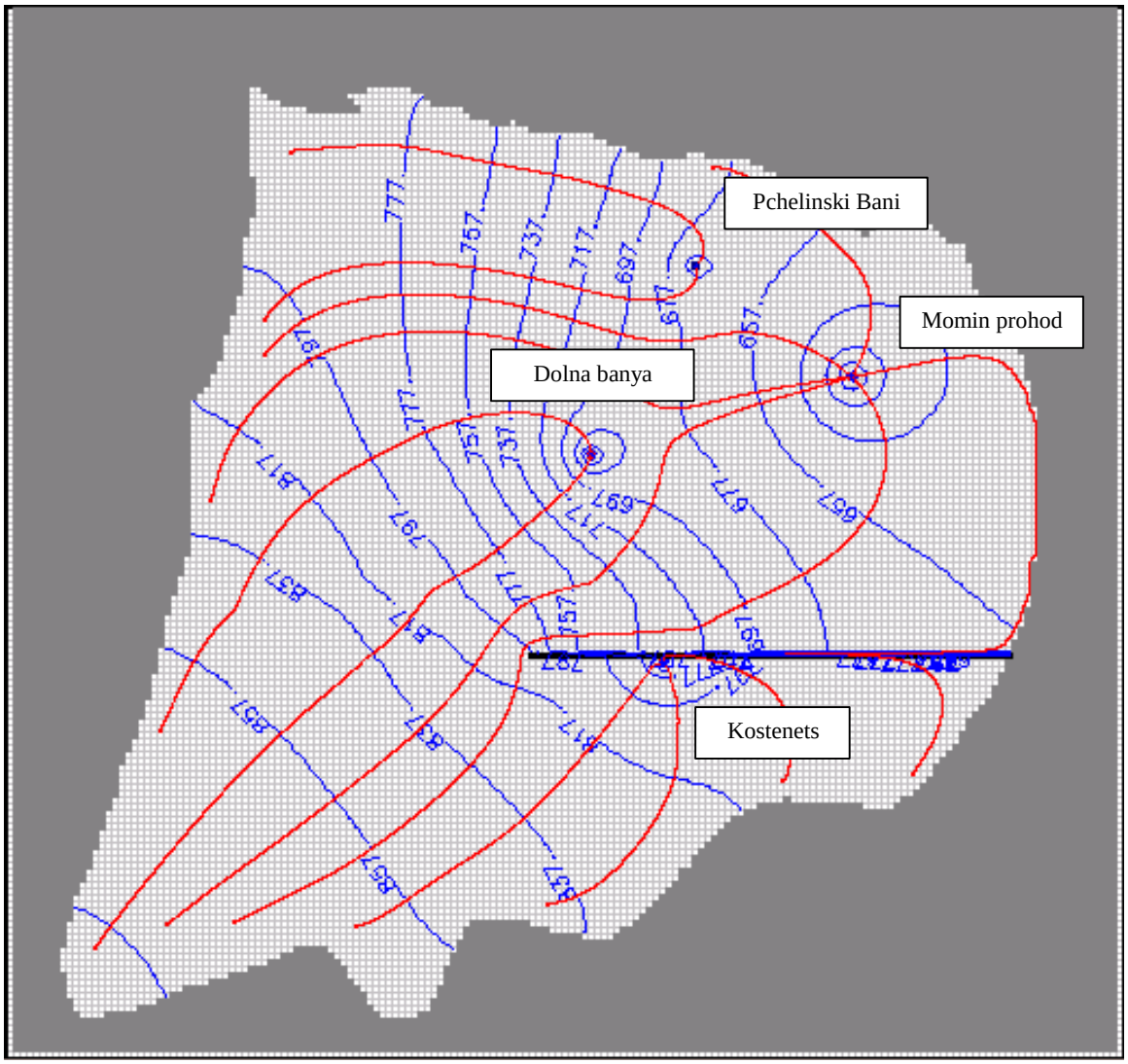

Figure 3. Conceptual model of Dolna Banya thermal basin

Thermal water basin is reduced to a homogeneous unconfined-confined aquifer of the following parameters. Bottom of the aquifer– 300 m; Top of the aquifer – 400 m; Hydraulic conductivity – k = 0.08 ÷ 0.2 m/d; Transmissivity - T = 8 ÷ 20 m^2/d; Thickness of the aquifer – m = 100 m; Active porosity – n_o = 0.05.

The modeled area is transformed in a discrete type by the method of finite differences through a square grid of nodes with 171 columns and 161 rows.

In both main recharge areas of ground waters in the basin – the Rila Rhodope massif and the Ihtiman Sredna Gora the values of infiltration are assigned as $1{,}3.10^{-5}$ m/d and $0{,}8.10^{-5}$m/d, respectively. In the central parts of the basin, Kostenets – Dolna Banya valley a zero value for infiltration is assigned. A constant head (boundary condition of first order) is assigned for the box approximating the capture at "Pchelin" – absolute elevation of water head 632.9 m. Average annual discharges for the boxes, approximating the mineral water occurrences of Momin prohod, Dolna Banya and Kostenets, namely Momin prohod - 15 l/s; Dolna Banya - 15 l/s; Kostenets – 14.3 l/s. The hydrodynamic grid of ground flow is generated through the module MODFLOW96 for steady-state conditions. Results from modeling are shown in Figure. 3.

Presence of hydraulic connection between individual parts of the thermal water basin is confirmed. The recharge areas of the four mineral water occurrences are well determined: mineral water occurrences of Momin prohod and Dolna Banya are recharged from the both areas, recharging of the Pchelin bani mineral water occurrence is done extremely through the Ihtiman Sredna Gora, and the discharge of Kostenets mineral water occurrence is completely to recharging from the Rila Mountain.

The Kostenets mineral water occurrence may be treated as an autonomous part of the thermal mineral basin, which is shown in Fig.3. The effect of the impermeable boundary is explained by the higher elevation of draining of mineral water – nearly 200 m higher than Dolna Banya and Pchelin. Differences in the composition of waters from the Kostenets mineral water occurrence in comparison to waters from other mineral water occurrences are explained through that model - mineral water there has the lowest quantity of total dissolved solids and temperature for the whole basin, which is due to the proximity of the recharge area.

CONCLUSIONS

Dolna Banya thermal water basin has complicated structure and hydraulic links between its parts. Four occurrences of mineral water are revealed within the basin – Kostenets, Dolna Banya, Momin prohod and Pchelinski Bani. Boundaries and scope of the basin are delineated, recharge areas of the groundwater are determined. Hydrogeological descriptions of each individual occurrences of mineral water are given.

The discharge of each one of them is assessed on the basis of actual measurements and analysis of data obtained from regular observations. Up-to-date the total discharge of mineral water is assessed to 53 l/s. Hydrochemical characteristic of mineral water is given. Regularities in distribution of mineral water composition and temperature are described.

Conceptual computer model of Dolna Banya thermal water basin is generated through the module MODFLOW. It confirms the hydraulic links between the parts of the basin and also clarifying the separation of Kostenets mineral water occurrence as an autonomous part of the basin. Model is conceptual and it generalizes the hydraulic conditions in the basin, so that a continuation of hydrgeological investigations in the area is recommended as follows:

Studying the basin structure of basin and connection between the four occurrences of mineral water;

Studying the effect of global climatic changes on mineral water resource by a comparative analysis of regime observations with data for changes of climatic elements;

Investigation with the objective of collecting a more detailed information and model calibration and optimization.

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