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1410 Zagorje ob Savi

# HYDROGEOLOGICAL REPORT for gaining the concession for thermal groundwater use in Zagorje ob Savi

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Center: **CENTER FOR GEOTECHNOLOGY AND GEOLOGY**

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# 1. GENERAL GEOLOGICAL AND HIDROGEOLOGICAL SITUATION

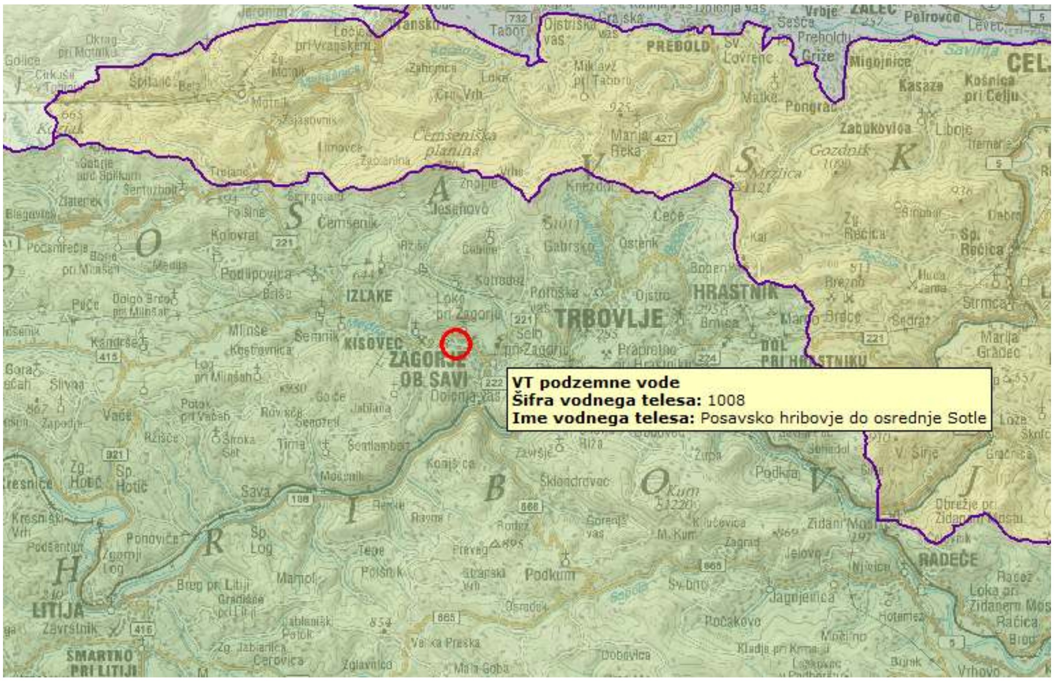
## 1.1 SUBJECT OF CONCESSION

### *1.1.1* Object for exploitation

Object of exploitation is an existing pumping well KT-1/97, which is located in Zagorje ob Savi.

### *1.1.2* The boundaries of groundwater body

Underground water on observed location belong to a water body of aquifer system named VTPodV – 10089 Posavsko hribovje of osrednje Sotle.




**Picture 1:** Observed location and water body (source: Environmental atlas (Atlas okolja); MOP ARSO, may 2011)

The water body is formed in fractured and unstratified upper Triassic dolomites ($T_3^1$).

The thermal water is a combination of warm water which is flowing through the faults from depths, and cold water from the neighboring dolomite aquifer.

### *1.1.3* Proposed exploitation

The proposed exploitation of thermal water from the pumping well KT-1/97 is 10 l/s or 864 $m^3$/day. The purpose of discussed exploitationis to use the water for heating purposes of the primary school in Zagorje.

## 1.2 DESCRIPTION OF THE AREA

The town of Zagorje ob Savi lies in central part of Slovenia in Posavje hills. The city lies in a valley formed by the river Medija and Kotredeščica. The valley is perpendicular to the deep valley of the Sava river. Elevation of Zagorje is about 269 m above sea level and is surrounded by peaks Kobiljek in the west with an elevation of 920m, Vinski vrh (616 m asl) in the north and Hrastelova skala (434 m above sea level) to the east. Zagorje ob Savi is located about 4.5 km southwest of Trbovlje and about 8.7 km southeast of Trojane.

## 1.3 LOCATION OF WATER CATCHMENT

Water catchment represents of the pumping well KT-1/97 and is located in the mine Zagorje ob Savi, directly on the main road Zagorje ob Savi - Kisovec.

Coordinates (ETRS89) of the well KT-1/97 are:

X: 110504

Y: 499575

Z: 248,71 asl


**Picture 2:** An aerial photo of the location of pumping well KT-1/97 (source: Environmental atlas (Atlas okolja); MOP ARSO, may 2011)

## 1.4 HISTORY

### *1.4.1* Start of exploitation

The pumping well KT-1/97 was drilled in 1997 for the purpose of monitoring the effects of de-watering and re-watering of the underground mine cavity Kotredež and surrounding area and at the same time defining the hydrogeological characteristics of the rock. Hydrogeological studies at that time shown that the location of the most heated thermal zone is in the central block of dolomite.

In 2004, company Preliv d.o.o., conducted an extensive pumping test. The purpose the test was sampling of the water to determine its quality and to define the possibilities for exploitation after the completion of re-watering the mine.

### *1.4.2* Previous research

First geological records of tertiary layers between Zagorje and Laško were interpreted by Marlot (1850). He considered the entire tertiary as Miocene. Beyrich (1854) and later Lipold (1857) in their report of geological mapping described the araa as western part of Laško syncline (the area west of the Zagorje). Broader area was investigated in 19th century by Roll (1858), Zollikofer (1859, 1862), Stur (1864), Hoernes (1876), and Bittner (1884). Their investigations and reportslaid the foundation of stratigraphy and tectonics of Laško syncline. Teller (1907) within the mapping Austro-hungarian monarchy published the sheet Celje and Radeče.

Surface around Zagorje was also covered with geological mapping from Kuščer (1964, 1967), Jelen (1992) and Grad et al (1996). In 1999, Placer created a kinematic model of Laško syncline, which largely explains the structure of the Posavske folds.

In 1990 the Geological Survey Ljubljana produced a study on the *Possibility of obtaining warm water from the dolomite aquifer in the area of the mine pit Kotredež in Zagorje.* Irgo (1995)created *Preliminary analysis of the economic viability of exploitation warm water from the mine pit Kotredež (Phase 1).* Subsequently, Preloiv, d.o.o. conducted a vast pumping test in pumping well KT-1/97 in order to determine regional hydrogeological, geothermal and geochemical characteristics .

## 1.5 GEOLOGY

### *1.5.1* Geological structure and formation of the area

Geological description was taken from Basic geological map of Yugoslavia, sheet Ljubljana in scale 1: 100,000 (Premru, 1980).

MIDDLE TRIAS - UPPER *LADINIJ ($T_2^2$)*

The oldest rocks in the vicinity of Zagorje ob Savi are middle Triassic or upper ladinian dolimites. Dolomites are white, crystalline, and alternating from between dolomitized limestones. Dolomite is found in a narrow strip between North West of Kisovec to the east of Šemernika, and east of Zagorje.
The thickness of dolomite layers ranges between 200 m and 500 m.

UPPER TRIAS AND LOWER JURA (T, J)

Lower part of above mentioned carbonate complex built of light gray limestone (micrite and sparite) with poorly expressed stratification. At several points, the limestone alternate between dolomitized limestone and dolomite. Limestone is found north of Jablana and west of Čolniša or south of Zagorje.

Amid the limestone dolomite is found, which is of light gray color and finely to coarsly crystalline. Dolomitization is secondary. It occoured in the Triassic and Jurassic part of the profile. Dolomite occurs south of Zagorje in the strip, which stretches from west to east. Outcrops of dolomite are also found in the town of Zagorje ob Savi (Ocepkov hrib). Layers have a thickness between 500 and 1000 m.

Near Zagorje ob Savi colorful breccia with layers of limestone lies discordantly on the middle and upper Triassic dolomite. . Thick grained breccia is of gray color with reddish brown binder and pieces of limestone and marl limestone. Layer thickness is about 200 m.

TERCIAR – UPPER OLIGOCEN ($Ol_2$)

Oligocene layers are represented by alternations of conglomerates, sandstones, siltstones, marl and limestone. These layers are called the Soteška layers. Lower part is represented with alternations ofconglomerate, gravel, sand, silt and clay. These layers represent footwall of the mine. Above them lies about 20 m thick layer of coal.. Hanging wall consist of sandy marl, marl and marly limestone.

Soteška layers are around 190 m thick.

Above the Soteška layers (hanging wall) lies semi - lithified marine mudstone (sivica) with lenses of silt and sandy silt. The minimum thickness of semi – lithified marine mudstone (sivica) is 80 m.

Zagorje ob Savi mine is mainly made of above described formation.

TERTIARY – MIOCEN ($M_2^2$)

Over sivica Miocen limstone-quartz conglomerates are deposited, with different alternations to sandstone. Pebbles of the conglomerate are incrustated with lithothamnian coatings. Miocene layers are found north of the Zagorje ob Savi and are pulled up in the strip from west to east.
Layer has thickness of about 150 m.

TERTIARY IN QUATERNARY (Pl, Q)

South of the Zagorje ob Savi, between clay and loam layers, well-rounded pebbles of different origin can be found..

QUATERNARY – HOLOCENE (s)

In some places, older layers are covered with scree and rubble from the dolomite and limestone.

### *1.5.2* Geological structure of discussed inner zone

The area in which the Zagorje ob Savi mine is located lies in the south wing of the great Tertiary basin. Under the Tertiary, which represents the footwall of rich coal layer, Triassic dolomites are found. Deep below the Triassic dolomite lays the Paleozoic base (C, P).

### *1.5.3* Tectonics

In tectonic terms the area belongs to the Zagorje subzone and in the Laško syncline, which is made of Oligocene and Miocene layers. The axis of syncline is oriented from west to east. The syncline is between Moravče and Log.

Area is cut by many neotectonic faults. The main faults are Trboveljski and Medija fault, extending from northwest to southeast, Ržiški fault and the Sava fault, which runs from west to east.

### *1.5.4* Hidrogeological conditions

Hanging wall, which is composed primarily of lithified marls is impermeable. When marls crack, these layers become permeable and became similar to other fractured aquifers. Collapsed zones become conductors or accumulator of groundwater, depending on conditions. In the mine pit Kotredež there is about 1 $m^3$/min of inflow of water from the hanging wall. All overburden are is made of Oligocene semi – lithified marine mudstone (sivica), which is completely waterproof and is reliably protecting the mine pit from water inflow of the upper tertiary aquifers.

In the south wing of the main basin lies Triassic dolomite almost everywhere below the tertiary layer. This is an important and abundant fissured aquifer. On the surface the dolomite outcrops in the area of Ocepkov hrib (340 m asl), which occupies about 0.12 $km^2$ in area of Toplice and Podstran. Dolomite is cracked by faults in the individual, hydraulically more or less separated uniform blocks. Central (thermal) block is separated from the western massive by Zagorski and Ržiški fault. In hydraulic terms this border is distinct, as was found by analyzing the impact of the mine pits Loke and Kotredež.
From dolomite aquifers in the northern wing of the tertiary basin is separated by impermeable pseudozilian layers. The contact between pseudozilian layers and dolomite in the south wing is lateral. The imeprmeable barrier shows that massive reductions in water levels in the dolomite of the pit Kotredež did not cause any effect on the springs and catchment in the north wing of the basin. From these it follows that there will not be major inflow of cold groundwater in Kotredeški (thermal) block of dolomite aquifer from surrounding blocks or from the north, west or southwest side. As the most likely possibility, therefore, remains the inflow from the eastern side. Most cold water is expected from dolomite massif in the wider area of Ravenska vas. This assumption also shows the direction of rising water temperatures in the dolomite pit Kotredež.

Tectonic zone east of Ocepkov hrib represents a hydraulic barrier, which runs from Zagorje to the northeast. Obviously, the cold water percolates through the large surface of a fault zone. Dolomite from Ocepkov hrib issurrounded from all sides by impermeable layers, so the infiltration is possible only through the dolomite on surface. In addition, there is the possibility of infiltration of river Media at a relatively short section. The probability of this happening very low because of colmatation of the main channel and a relatively less permeable layers of the bedrock. Infiltration of rainfall is low due to steep slopes. The inflow is estimated below 100 l / min and is not considered in the calculations. Dolomite outcrop is therefore important only as the area which could potentially contaminate groundwater. For several years before closing the Kotredež pit, inflow of groundwater into the pit has stabilized. At that time it 140 l/s was pumped out from the pit, of that 120 l/s from dolomite and about 20 l/s from overburden and other parts of the mine. As a result of pumping water in the mine was lowered for a delta of 410 m.. The temperature of the total water at the pumping station about 110 m above sea level was 26.5 ° C, at the outflow of the mine pit was 25 ° C. The average water temperature in the drainage corridor was 29.5 ° C. The water temperature from the crack was very different, the highest measured was 33.6 ° C. This temperature was taken as the maximum temperature of thermal water that flows from the depth and is mixed with cold water in the dolomite aquifer.

### *1.5.5* Source of water

Water in the thermal Triassic dolomite aquifer represents a mixture of warm water that flows along the faults from unknown depth, with cold water from the neighbor blocks of dolomite aquifer.

### *1.5.6* Description of the catchment area

The pumping well KT-1/97 was drilled in 1997. Drilling was carried out by rotary method with rolling chisel till the final depth of 424.5 m below ground level. Dynamic groundwater level was on the depth of 410 m, during drilling . The Drainage of of the whole mine Zagorje ob Savi was conducted from the mine pit Kotredež. Because of lowered water table, the borehole was drilled dry in almost whole depth. The borehole has casing of steel tubes to the depth of 102.9 m. Section through the Oligocene layer (78 m) is entirely cemented. From the depth of 102.9 meters to the final depth of 424.5 m the borehole drilled through heavily cracked dolomite. This part is equipped with steel screen. The profile of the borehole KT-1/97 with geological and technical data is given in Annex 4.

Groundwater that will be pumped from the well will be used for heating of elementary school. Then the cooled water will be discharged into the river Media.

Returning the cooled water back into the aquifer is not economically possible for several reasons:

- The influence radius of pumping well would be too large because of relatively high hydraulic conductivity coefficients. Cooled water would have to be returned to the aquifer on a fairly large distance into a drainage borehole with all the supporting infrastructure Otherwise, there the effect of cool water would be too big on a thermal groundwater.
- When pumping 10 l/s, groundwater lowering would be virtually .
- Before pumping groundwater for dewatering the mine, there was a few thermal springs from which the water flowed into the river Media. After dewatering started the springs ran dry. Even after the stopping the mine exploration and rewatering the mine, the springs did not reappear. In a case of draining cooled water from heating

purposes of the school in the Media river, we would partially establish it's the original conditions before dewatering the mine.

# 2. POTENTIAL SOURCE OF WATER

## 2.1 SUITABILITY OF EXPLOITATION OF GROUNDWATER

### *2.1.1* Water quality

#### 2.1.1.1 BASIC PHYSICAL AND CHEMICAL PROPERTIES OF WATER

Department of Public Health Maribor conducted sampling for extended chemical analysis of water from the wells (D-analysis of drinking water). An analysis is given in Annex 6. Results of the analysis shows that we deal with a low-temperature thermal water similar to other thermal waters from carbonate aquifers in Slovenia. The chemical composition of water is within adequate norms for drinking water, while the microbiological analysis is not adequate because of the presence of coliform bacteria. The reason for the occurrence of coliform bacteria in thermal water could be because of equipment for pumping tests, sampling error, or because of the fact that the dolomite was without water (dry due to mine drainage) not long before the analysis. We expect that the microbiological image would stabilize after the stabilization of the groundwater level.

#### 2.1.1.2 GEOCHEMICAL PROPERTIES OF EXPLOITED WATER

Only basic analyses of groundwater were conducted in the well KT-1/97. From the analysis given in Appendix 6 it is shown that the concentration of calcium and magnesium in water samples increased. This is evidence that the groundwater flowing through carbonate rocks, in our case, through dolomite. Electrical conductivity of groundwater samples was 530 µS/cm, pH 7.2, temperature 27.6 ° C.

### *2.1.2* The possibility of using the exploited groundwater

The report *Project of preliminary assessments of economic viability of extracting hot water from the mine pit Kotredež (Phase I) (Veselič et al, 1995)* shows possible ways for use of thermal water and heat recovery. In this report the possibility of using the thermal energy for heating of rooms in the existing mine workshops, heating sports facilities and for mushroom cultivation were examined. It also examines the possibility to use hot water for a group of indoor swimming pools and outdoor pool, which was planned for construction in 1995 in the area of the existing mine. The preliminary analysis showed that there is enough water to heat all of the above users together. After flooding the mine hot water from well KT-1/97 was not exploited anymore. In 2011 the municipality of Zagorje ob Savi, within a re-mining project, decided to use hot water for heating for elementary schools in the area of mining facilities.

### *2.1.3* Problems associated with the various use of exploited groundwater

During operation of the Zagorje mine about 140 l/s was pumped out of Kotredež pit, of this 120 l/s from dolomite and about 20 l/s from the hanging wall.. Groundwater in dolomite was lowered for 410 meters at that time and it was constant. Water pumped from borehole was drained into the Media River.

Before mining took place in this area there was many constant thermal springs, which where drained in the river Media. After the lowering of groundwater started the springs dried up. The most famous was a thermal spring Toplice, after which a part of the Zagorje region got its name. The estimated flow was from 5 l/s to 7 l/s.

With pumping around 10 l/s of hot water for heating the elementary school, the situation of groundwater will not differ significantly from the initial conditions.

## 2.2 CONSERVATION OF GROUNDWATER BODIES

### *2.2.1* The volume of the aquifer system and the nature of hydrodynamic boundaries

#### 2.2.1.1 SIZE AND POSITION OF AQUIFER SYSTEM

##### 2.2.1.1.1 Description of the aquifer structure

Triassic dolomite represent a large and important confined aquifer with fissure porosity where the groundwater is under pressure. In places where the Triassic dolomite outcrop at the surface (Ocepkov hrib, Toplice and Podstrane) the aquifer is an uncofined with free surface of groundwater. Several strong tectonic faults pass through the territory, which divide the dolomite massif into individual hydraulically more or less separate blocks. This can be seen on the map in Annex 2.

##### 2.2.1.1.2 A description of the aquifer subsystems (local aquifers)

Dolomite aquifer is uniform, with fissure porosity. With the pumping test (Božović, 2004) in the well KT-1/97 transmissivity of dolomite aquifer was estimated from 8.8 x $10^{-3}$ m/s to 9.15 x $10^{-2}$ m/s. Values may be substantially different from fault zones to areas of compact rock.
Oligocene hanging wall is impermeable and forms an upper barrier to the dolomite aquifer.

#### 2.2.1.2 CHARACTER OF HYDRODYNAMIC BARRIERS OF AQUIFER SYSTEM

##### 2.2.1.2.1 Impermeable borders

Dolomite massif and the fissured aquifer are split into several individual hydraulically more or less separate blocks because of strong faults. These faults represent a hydraulic barrier, so the flow from the warm aquifer to the aquifer with cold water and vice versa is minimal.

Above the dolomite aquifer impermeable Oligocene layers are located, which represent thick impermeable barrier. Thus, the inflow of water and potential contamination of the dolomite aquifer is minimal.

Deep under the dolomite lie Permian – Carboniferous, which is also impermeable and represent the lower limit of dolomite aquifer.

#### 2.2.1.2.2 The boundaries and areas of infiltration

Water in the thermal Triassic dolomite aquifer represents a mixture of warm water that flows from the depths of the faults, with cold water from the neighboring blocks of dolomite aquifer. Dolomite aquifer is confined above and below by impermeable layers, so the flow of water from this direction is minimal.

Infiltration into the aquifer is only possible by dolomites on the surface of Ocepkov hrib in the area of Terme and Podstran and infiltration of the Media river in a relatively short section of the Ocepkov hrib.

#### 2.2.1.2.3 Streamlines

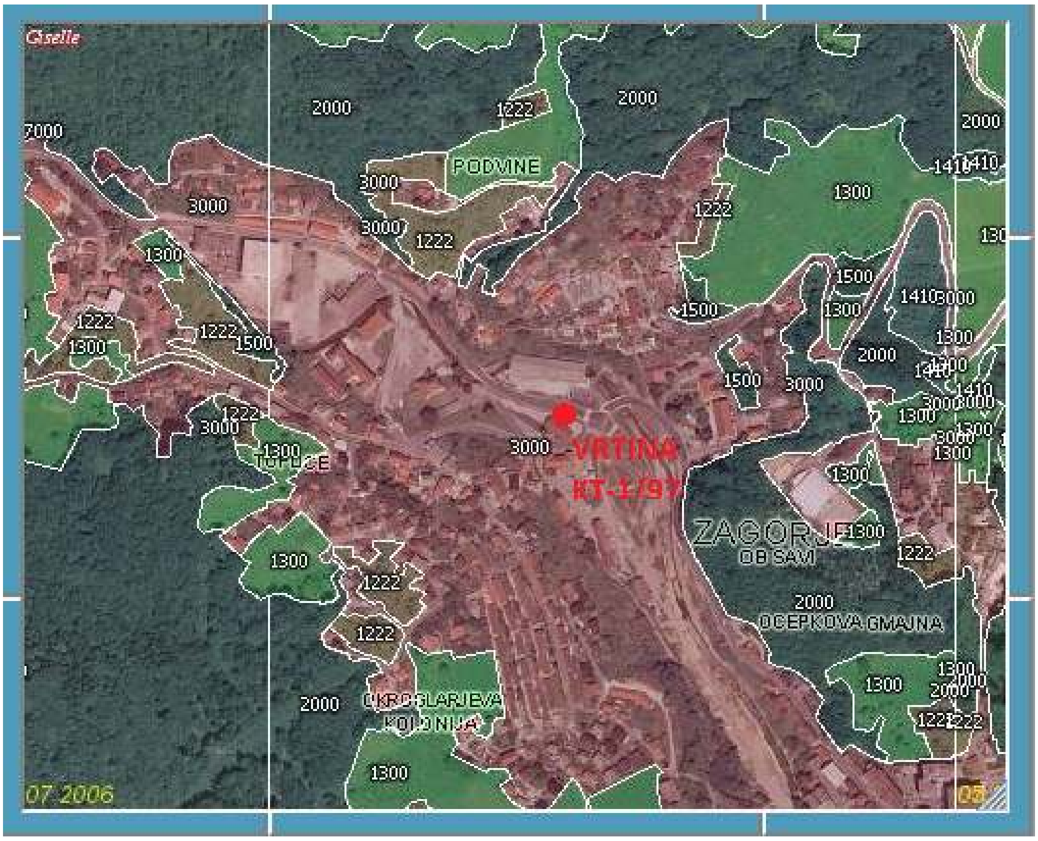
The thermal water flows into the dolomite aquifer through faults from the deep and mixes with cold water from the neighboring blocks (Veselič, 1995). Across the area there are many faults, which divide the aquifer into several parts. According to data from wells and KT-1/97 and Kz-14/81 groundwater flows from west to east. Most likely the water percolates from the thermal block through the fault zone in the eastern block with cold water. Before closing the pit Kotredež the groundwater flowed in the opposite direction, from the eastern block in the central thermal block, because of a major depression in the thermal block created by long drains in the pit Kotredež.

### *2.2.2* Risk of contamination, vulnerability and threats to the aquifer system, a natural protection of the source

2.2.2.1 CONTAMINATION RISK

#### 2.2.2.1.1 Dependence on water quality from urbanization and other uses of space

Greater part of the area is covered with practically impermeable Oligocene layers that protects the aquifer from potential contamination from the surface. Significant infiltration is possible only on the dolomite surface of Ocepkov hrib, Toplice and Podstran, which are only partially populated.




**Picture 3:** An aerial photo of surroundings of the well KT-1/97 **- land use**. Ocepkov hrib southeast of the well, Toplice west of the well and Podstrane southwest of the well are covered with dolomite, where pollution infiltration could be a possiblitiy.. Marked in red are urban areas, light green represent meadows and forests are represented in dark green. (source: http://rkg.gov.si/GERK/viewer.jsp)

#### 2.2.2.1.2 Dependence of the quality of water from the exploitation regime (pumping volume)

The amount of pumping from well KT-1/97 will not affect the quality of hot groundwater. Water will be used for heating not than drinking water. During operation of the mine pit Kotredež about 140 l/s of water was pumped out. The amount needed for heating of elementary school is 10 l/s, which is less than 10% of the amount needed for mine dewatering.

### 2.2.2.2 THREATS OF WATER SOURCE POLLUTION

#### 2.2.2.2.1 Diffuse source of pollution

Diffuse sources of pollution are urbanization, transport, industry, especially mining, which is present in Zagorje ob Savi. As mentioned several times, the considered area is covered with thick layers of Oligocene, which are practically impermeable in hydrogeological sense, thus penetration of possible contaminants is unlikely. Below the Zagorje mine a thick layer of Soteške layers (Oligocene) are deposited, which protects the aquifer from intrusion of mine water.

Diffuse pollution would only be possible on the dolomite area of Ocepkov vrh, the area of Toplice and Podstran due to urbanization and traffic, and a in a short section of Media river. The river bed of Media is likely to be colminated (filled with clay), so the infiltration would be extremely small.

#### 2.2.2.2.2 Point sources of pollution

Point source pollution is possible in the range of Ocepkov vrh, Toplic and Podstran, with a possible sewer leak.

#### 2.2.2.2.3 Pumping and draining

Following the closure of the mine Zagorje the pumping and draining of the mine shafts has stopped. Then the groundwater is still rising 410 m in depth near surface (3 m below ground level). Water is still increasing very slowly.

#### 2.2.2.2.4 Groundwater recharge

Groundwater recharge is still taking place, due to finishing of pumping as a result of mine closure.

#### 2.2.2.2.5 Aquifer intervention or catchment area intervention that change the natural sensitivity of the water body

Interventions in the aquifer is being handled with the extraction of coal in Zagorje ob Savi mine. Pit passages also affected the dolomite aquifer. During passage crations water inflows through cracks occurred. Miners were forced to pump and drain ground water in the quantity of 140 l/s.

Following the closure of the mine pumping the groundwater also stopped. This has led to almost complete flooding of the mine.

Other interventions in the aquifer are not known.

#### 2.2.2.2.6 Existing activities that may endanger the water source with pollution

Spills of petroleum products and other pollutants can endanger the area Ocepkov vrh, Podstran and Toplice, and polluting the river Media in the upstream Ocepkov vrh.

#### 2.2.2.2.7 Existing activities which endanger the water supply by continuous pollution

Continuous contamination is present due to urbanization, traffic and industry. Extensive (extended) analysis of water from well KT-1/97 in Annex 6 shows that chemical composition of water was within the drinking water (at that time), while the microbiological analysis was not adequate because of the presence of coliform bacteria.

### 2.2.2.3 VULNERABILITY OF WATER SOURCE

#### 2.2.2.3.1 Type of soil above the aquifer and the type of soil its catchment area

Most areas on the Oligocene impermeable layers are urbanized. Dolomite outcrops Ocepkov hrib, Toplice and Podstran are less populated. Wider area of Zagorje is covered with meadows and woods.

#### 2.2.2.3.2 Bedrock composition of saturated and unsaturated zone of the aquifer

The interpreted aquifer is made from fissured upper dolomite. At the location where well KT-1/97 is situated, dolomite aquifer is fully saturated with ground water. In the area of dolomite outcrops Ocepkov vrh, Terme and Podstran a small part of the dolomite aquifer is partly saturated.

#### 2.2.2.3.3 Thickness of unsaturated zone of the aquifer

In the observed area, groundwater is sub artesian, which means that the dolomite aquifer is fully saturated with groundwater.

Under Ocepkov vrh the thickness of the unsaturated aquifer is about 100 m.

#### 2.2.2.3.4 Structure and type of the aquifer

The aquifer was formed in lower Triassic dolomite and has fissure porosity. On the location of the well KT-1/97 the aquifer is confined, which means that groundwater is under pressure. Water is currently located about 3 m below ground level, which means that is sub artesian. The area of Ocepkov hrib where the dolomite outcrops are, the aquifer is unconfined with a free surface.

#### 2.2.2.3.5 Distribution of surface water and connection with the aquifer

River Media runs through the town of Zagorje ob Savi and about 50 meters east of the well KT-1/97. Media flows to Sava river at the end of a zagorje valley. Media is flowing on the dolomitic surface some 100 m below the hill Ocepkov vrh. Infiltration of surface water to the dolomite aquifer is possible in this part the, but due to colmatation (filled with clay) of Media's main channel infiltration substantially lowered.

On the east side of Zagorje ob Savi Kotredeščica river runs. Kotredeščica flows into Media about 1.3 km south of the location of the well KT-1/97. Kotredeščica flows mainly on Tertiary rocks, and has no contact with carbonate rocks. Both rivers are of type torrential stream.

#### 2.2.2.3.6 The morphological characteristics of the aquifer and catchment area

Dolomite aquifer is split with faults into individual, more or less hydraulically separate blocks, as shown on Figure 2. Only in the area of Ocepkov hrib (340 m asl), in the area of Toplice and Podstran the dolomite aquifer outcrops. Dolomite outcrops are partially urbanized and partially overlapping the meadows and woods.

Thermal water is filling the dolomite aquifer from the depths. Because of the complex geological structure of the terrain, we can not specify how far the catchment area of the aquifer.

#### 2.2.2.3.7 The speed of contaminant transport to groundwater level

On the top of dolomite aquifer lies a thick layer of impermeable Oligocene layers. The well KT-1/97 is situated on the area of where these layer thickness is about78 m. Due to the poor permeability of these layer, the infiltration of potential pollutants is almost impossible.
The possibility of infiltration of any contaminants resulting from urbanization and traffic is only possible on dolomite outcrops Ocepkov hrib, Toplice and Podstran. In these areas, the infiltration of precipitation is relatively small, due to steep slopes.
We estimated the speed of flow of contaminants by gradients of the slope, fissures of dolomite layer and the thickness of unsaturated zone. Given the thickness of the unsaturated zone under Ocepkov hrib (about100 m) and other parameters we estimate that contaminant would need between 2 and 3 days to reach groundwater.

#### 2.2.2.3.8 The speed and spreading of potential contaminants from the spill area to capture point

Due to the morphology of the aquifer the flow of potential pollutants is minimal. The direction of groundwater flow in the dolomite aquifer is from west to east. With the coefficient of permeability 1.3 x 10-5 m/s, the groundwater gradient 0.003 and dolomite porosity 1%, the speed of groundwater flow in the dolomite aquifer is about 9 cm/day.

**Fact remains that the use of thermal water is not for the drinking purpose but heating elementary school in Zagorje ob Savi.**

#### 2.2.2.3.9 Natural protection of source against the transport and spreading of contaminants in the aquifer and towards the caption point

Natural protection over the dolomite layers is represented as organic soil and forest ground. Oligocene layers serve as protection, since the permeability of these layers is very low.

#### 2.2.2.3.10 The possibility of rehabilitation of emergency

Immediate removal of pollutants.

## 2.3 REACHABILITY OF GROUNDWATER RESOURCE

### *2.3.1* Depth to groundwater

The company Rudnik Zagorje v zapiranju d.o.o. is conducting continuous measurements of groundwater level and temperature in the well KT-1/97. Recent measurements of groundwater level in the well shows that water is about 3 m below the surface of the borehole, and is still rising slowly. Groundwater well is sub artesian type.

Below the hill Ocepkov vrh the depth to water table is up to 100 m. The aquifer is unconfined and has free groundwater surface.

### *2.3.2* Necessary technology in order to exploit economic quantity and quality of water

In the hole will be installed adequately pump which will pump 10 l/s of water from the depth of 30 m below the surface to the planned elementary school.

## 2.4 UTILIZATION OF GROUNDWATER RESOURCE

### *2.4.1* Yield of the aquifer

#### 2.4.1.1 HYDROGEOLOGICAL PARAMETERS OF THE AQUIFER

##### 2.4.1.1.1 The coefficient of permeability

During operation of the Kotredež pit hydrodynamic parameters of the dolomite aquifer were assessed after several methods. The coefficient of permeability varies within 6.5 x $10^{-6}$ m/s to 1.3 x $10^{-5}$ m/s (Veselič, 1995).

With long pumping test, which took place from 11.06.2004 to 12.08.2004 permeability coefficient of the dolomite was calculated. It rangers between 1.83 x $10^{-4}$ m/s and 1.76 x $10^{-5}$ m/s with estimated dolomite aquifer thickness of 500 m (Božovič, 2004).

##### 2.4.1.1.2 Transmisivity

Transmisivity of the dolomite aquifer was also evaluated during mining process in Kotredež pit. Transmisivity ranges between 2.3 x $10^{-3}$ $m^2$/s to 1.2 x $10^{-2}$ $m^2$/s.

Well test in 2004 showed that the well KT-1/97 is very perspective. Transmisivity of the dolomite aquifer ranges between 8.8 x $10^{-3}$ $m^2$/s to 9.15 x $10^{-2}$ $m^2$/s.

##### 2.4.1.1.3 The thickness of the aquifer

According to a *Report of preliminary project analysis, commercial viability of extracting hot water from the pit Kotredež*, an average thickness of the dolomite aquifer about 500 m.

#### 2.4.1.1.4 Permeability

Pumping test in well KT-1/97 in 2004 showed that the dolomite aquifer has high permeability and vast reserves..

#### 2.4.1.1.5 Porosity

We estimate that the Triassic dolomite porosity is about 1 %.

#### 2.4.1.1.6 Coefficient of elastic storage

Elastic storage coefficient was calculated using the following equations:

$S_1 = n * \gamma * b * \beta$ $S_2 = \gamma * b * \alpha$

$S = S_1 + S_2$

| | |
|---|---|
| S | coefficient of elastic storage |
| n | porosity |
| γ | specific weight of water |
| β | dynamic compressibility of water |
| α | dynamic coefficient of vertical compressibility |

Thus, the coefficient of elastic storage of the dolomite aquifer is 0.38.

#### 2.4.1.1.7 Radius of influence

Radius of influence was calculated on the basis of data obtained with the pumping test in 2004.

When pumping water from the well with Q = 13 l/s the lowering of groundwater amounted to $s_1$ = 1.6 m in well KT-1/97 $s_2$ = 0.6 m in observation well Kz-14/81. The distance between the wells is L = 300 m. In the calculation, we summarize the averaged transmisivity obtained by pumping test T = 1.04 x $10^{-2}$ $m^2$/s. The influential radius (R) was calculated according to Theim equation for closed aquifer (Batu, 1998):

$$s_0 - s_R = \frac{Q}{2\pi T} \ln\left(\frac{R}{r}\right)$$

Thus ,

$$R = e^{\left(\frac{(s_0 - s_R)2\pi T}{Q}\right)} + r$$

*R ≈ 1023 m*

$s_0$ lowering in the well (2,65 m)

$s_R$ lowering in the distance of the influence radius (R = 0 m)

r distance from the pumping well to the observation well (300 m)

R radius of influence (m)

T transmisivity (1,04 x $10^{-2}$ $m^2/s$)

Q the amount of pumping between the pumping test (26,3 l/s)

The influential radius between pumping 26,3 l/s was 1023 m.

When pumping 13 l/s the influential radius is around 320 m.

When pumping the desired amount of 10 l/s provided for heating the elementary school, the influential radius extends about 300 m from the pumping well.

### *2.4.2* The yield of catchment (well KT-1/97)

#### 2.4.2.1 REQUIRED HEIGHT OF WATER LIFTING

According to data from measurements of which company Rudnik Zagorje v zapiranju d.o.o. is performing in the well KT-1/97, groundwater level was at a depth of 2.19 on 2/17/2011 mount of the well. This corresponds to an altitude of 246.5 asl. Pumping test in 2004 showed that by pumping Q = 13 l/s the dynamic groundwater level stabilize at the altitude of 230 m asl, or 18.7 m below the mount of the well.

When using desired amount of thermal water from the well (10 l/s), the groundwater table will decrease for a = 2.7 m. For security reasons, the pump would be placed slightly lower on the depth of at least 30 m below ground level.

It is necessary to consider the height difference between the mounts of wells and future facilities (elementary school).

#### 2.4.2.2 ALLOWABLE WATER SPEED IN THE AQUIFER AND QUANTITY OF PUMPING

Required amount for heating of elementary school is Q = 10 l/s.

Maximum allowed inflow velocity of water in the well is 1.4 * $10^{-4}$ m/s. Inflow velocity was calculated using the following equation (Vukovic, Soro, 1990):

$$v_{max} = \left(\sqrt[3]{k}\right) / 30$$

$v_{max}$ = 1.4*$10^{-4}$ m/s

$v_{max}$ - Maximum input rate (m/s)

k - Permeability coefficient (m/s)

#### 2.4.2.3 MAXIMUM FLOW IN THE CATCHMENT

Given the technical characteristics of the well KT-1/97 the maximum flow of water is calculated l/s

$$Q_{\max} = v_{\max} * b * D * \pi$$

$Q_{max}$ = 39 l/s

$Q_{max}$ - Maximum capacity (l/s)
b - length of screen (322 m)
D - Diameter (0.1095 m)

## 2.5 THE AVAILABLE GROUNDWATER RESOURCE

### *2.5.1* Evaluation of water resources

The thermal water of the dolomite aquifer represents a mixture of warm water that flows into the faults from the depth and cold water from the neighboring blocks of dolomite aquifer. Due to the complex structure of the area, the flow of groundwater in the aquifer is not fully defined. Therefore, the data were taken from the report *Option of obtaining hot water from the dolomite aquifer in the area of the mine pit Kotredež in Zagorje mine - C7-0630-215/6-1990.* Report of the study, conducted by Kuščer, shows measurements of groundwater inflows into the Kotredež pit. Kuščer estimated that the inflow in the 6th horizon is 7.2 $m^3$/min (117 l/s), and the 8th horizon of 9.5 $m^3$/min (158 l/s).

# 3. PROTECTION OF THE WATER SOURCE

## 3.1 PREVIOUS RESTRICTIONS OF THE PROTECTED AREA AND DETAILS OF OTHER MEASURES TO PROTECT THE SOURCE AGAINST POLLUTION

The well KT-1/97 has no water protection zones, because it was not designed for drinking water purposes.


**Picture 4:** Map of water protection zones location of the well KT-1/97 (source: Environment atlas (Atlas okolja), MOP ARSO, may 2011).

# 4. MONITORING PROGRAM

## 4.1 PURPOSE

### *4.1.1* Method of controlling the recharge of groundwater body

Monitoring of groundwater has been active since 2003. We suggest that control of recharge groundwater bodies is carried out by measuring the water level in the well, and measuring the temperature at several depths. Temperature measurements are necessary to ensure the reproducibility of thermal energy. Before the beginning of production submersible water level meter, flow meter and several thermal sensors should be installed in the well. .All these parameters should be measured continuously.

### *4.1.2* Methods of controlling the hydraulic characteristics of the well

Hydraulic characteristics of the well are determined by monitoring the constant flow of pumping from well, by measuring water level and temperature at several depths.

### *4.1.3* Method of temperature control and chemical composition of groundwater

The temperature of thermal water in the well is determined by monitoring the water temperature at greater depths.

## 4.2 THE PLAN

### *4.2.1* Objects of monitoring

Objects of monitoring is the pumping well KT-1/97.

### *4.2.2* Parameters subject of monitoring

- On the field: flow, water level in temperature of groundwater

### *4.2.3* Frequency of observations

- Flow measurements, groundwater level and temperature measurement: continuous interval of 1 hour with internet access to data.

### *4.2.4* Method of monitoring

- Measurement of level and temperature of groundwater should be carried out with immersion probe that is mounted in the well.
- The flow should be monitored by flow meter and should be installed on the hose between the pump and the future elementary school.

# 5. LITERATURE


1. Batu, V., 1998. Aquifer hydraulics. A comprehensive guide to hydrogeologic data analysis.
2. Božovič, M., 2004. Poročilo o črpalnemu poskusu na vrtini KT-1/97 v Zagorju, Preliv, d.o.o., Ljubljana.
3. Legen, I. in sod., 1997. Rudarski projekt Piezometer KT-1/97. Podjetje za geotehnična dela, Ljubljana.
4. Premru, U. In sod, 1980. Osnovna geološka karta SFRJ v merilu 1 : 100.000, list Ljubljana. Geološki zavod Ljubljana.
5. Premru, U., 1983. Tolmač osnovne geološke karte SFRJ list Ljubljana. Geološki zavod Ljubljana.
6. Veselič, M. in sod, 1990. Možnosti pridobivanja tople vode iz dolomitnega vodonosnika na območju jame Kotredež Rudnika Zagorje – Separatno poročilo k študiji C7-0630-215/6-1990. Geološki zavod Ljubljana, r.o., Ljubljana.
7. Veselič, M. in sod. 1995. Projekt preliminarne analize ekonomske upravičenosti pridobivanja tople vode iz jame Kotredež (I. FAZA). Irgo, d.o.o., Ljubljana.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