Report on Bad Radkersburg – Hodoš pilot area model

Authors: Tadej Fuks, Mitja Janža, Dejan Šram and Andrej Lapanje in cooperation with MAFI, GBA

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Description The report presents the results of the scenario modelling in the Bad Radkersburg – Hodoš pilot area of the Transenergy project. The modelling comprises 3D groundwater flow and heat transport simulations.

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5.3 Scenario modelling

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1 INTRODUCTION

The report presents the results of the scenario modelling in the Bad Radkersburg – Hodoš pilot area of the Transenergy project. The modelling comprises 3D groundwater flow and heat transport simulations.

In 2008, a deep geothermal borehole was drilled in Korovci (SI) (Kraljić 2008a and 2008b), about 5,3 km away from the nearby spa resort in Bad Radkersburg (A) where water is produced from the same aquifer. The maximum projected production rate from the borehole Kor-1gα will not exceed 20 l/s (Lapanje et al. 2012). The projected utilization in Korovci caused concerns on the Austrian side on a potential impact of production in Korovci on wells in Bad Radkesburg.

The aim of the numerical modelling was to determine the potential impacts of different utilization strategies in Korovci on the nearby geothermal wells in Bad Radkersburg. The modelling was performed for the optimization of utilization of these geothermal resources.

Major questions that were addressed are:

- What impact of abstraction in Korovci on thermal water production in Bad Radkersburg can be expected?
- What would be the impact in case of implementation of reinjection in a geothermal doublet scheme in Korovci?

The answers to the above questions were provided with the use of a pilot area model and scenarios in which different model set-ups were implemented.

2 NUMERICAL MODELLING

Scenario modelling is a second step in the modelling process, based on a steady state model. A detailed model setup description can be found in the report on the steady state model.

2.1 Abstraction

According to available data, the thermal water from Pre-Neogene rocks is currently abstracted in Bad Radkersburg (Rad-2 and Rad 3/3a) and Benedikt (Be-2/04). The abstraction rates are listed in Table 1.

Table 1. Abstraction data.

Well name	Abstraction depth interval (m)	Abstraction rate [m^3/day]
Be-2/04	823.27 - 1857.34	864
Rad-2	1792 - 1857	1200
Rad 3/3a	1769 - 1858	720

2.2 Material properties

Data used in the modelling is sparse, therefore definition and spatial distribution of values of parameter is subject to errors. To estimate uncertainty of the modelling results, several scenarios, using range of parameters values, were simulated.

Sensitivity analysis indicated that hydraulic conductivity is the model parameter that has the largest impact on the model output. Therefore, different values of hydraulic conductivity in the main aquifer in the Raba fault zone were tested, ranging from 10^{-5} to 10^{-7} m/s, depending on the scenario. In addition, aquifer thickness and specific storage values were adjusted in each scenario.

In the reinjection scenarios also different values of porosity, longitudinal and transverse dispersivity were tested.

Table 2 contains values of parameters, used in the pilot area model.

Table 2. Parameters used in the pilot area model.

Parameter	Neogene	Basement	
		Raba fault (RF) zone	Outside RF zone
Horizontal hydraulic conductivity [m/s]	1×10^{-7}	$1 \times 10^{-5} – 1 \times 10^{-7}$	5.8×10^{-8}
Vertical hydraulic conductivity [m/s]	1×10^{-9}	$1 \times 10^{-5} – 1 \times 10^{-7}$	5.8×10^{-8}
Porosity	0.2	0.1-0.2	0.05
Specific storage [1/m]	1×10^{-4}	$1 \times 10^{-4} – 1 \times 10^{-5}$	1×10^{-4}

Heat conductivity of solid [W/mK]	2	5	5
Heat conductivity of fluid [W/mK]*	0.65	0.65	0.65
Expansion coefficient [1/K]*	0	0	0
Volumetric heat capacity of solid [JK/m^3]*	2.52×10^6	2.52×10^6	2.52×10^6
Volumetric heat capacity of fluid [JK/m^3]*	4.2×10^6	4.2×10^6	4.2×10^6
Longitudinal dispersivity [m]	5	5 - 150	5
Transverse dispersivity [m]	0.5	0.5 - 15	0.5
Anisotropy of solid heat conductivity [W/mK]*	1.16×10^{-5}	1.16×10^{-5}	1.16×10^{-5}

* Default values in FEFLOW

3 RESULTS

3.1 Abstraction in Korovci without reinjection scenarios

For the purpose of determining the effects of planned production in Korovci on other wells, 8 different scenarios without reinjection have been developed (Table 3). In order to incorporate uncertainty, related to defined parameter values, ranges of parameters values were implemented.

Table 3. Scenarios for abstraction in Korovci (without reinjection).

Scenario	Hydraulic conductivity of RF [m/s]	Aquifer thickness [m]	Specific storage	Production rate [l/s]
1	1×10^{-6}	70	1×10^{-4}	20
2	1×10^{-6}	150	1×10^{-4}	20
3	1×10^{-6}	300	1×10^{-4}	20
4	1×10^{-6}	150	5×10^{-5}	20
5	1×10^{-6}	150	1×10^{-5}	20
6	1×10^{-7}	150	1×10^{-5}	20
7	1×10^{-5}	150	1×10^{-5}	20
8	1×10^{-6}	150	1×10^{-5}	40

Table 4. Computed drawdown after 50 years in production in Korovci for all scenarios.

Scenario	Computed drawdown Kor-1ga [m]	Computed drawdown Kor-2g [m]
1	14.5	5.0
2	14.5	5.0

3	13.5	4.7
4	14.5	5.0
5	14.5	5.0
6	15	5.2
7	11	4.5
8	30	9.3

For the initial conditions computed hydraulic heads after 30 years of thermal water production in Bad Radkersburg were used. This way, present state of the aquifer and head distribution was approximated. All production scenarios were simulated for 50 years period.

Figures 1 and 2 show the computed heads after 50 years of production (without reinjection) in Korovci. The constant production rate is set to 20 l/s in all scenarios except scenario 8, where it is set to 40 l/s. It is an extreme abstraction rate which is used to show sensitivity of the model to abstraction rate. In scenario 7, hydraulic conductivity in Raba fault zone was set to higher value.

Scenarios 1 to 6 produce similar results. The computed drawdown in scenario 7 is lower than in other scenarios, but the effects extend further away from the production borehole Kor-1gα (Figure 9).

Effects of the production in Korovci are detected in Bad Radkersburg only in scenarios 7 and 8, whereas the effects in Benedikt are not seen in any of the scenarios (Figure 10).

Based on sensitivity analysis hydraulic conductivity and specific storage were found the most sensitive parameters of the model.

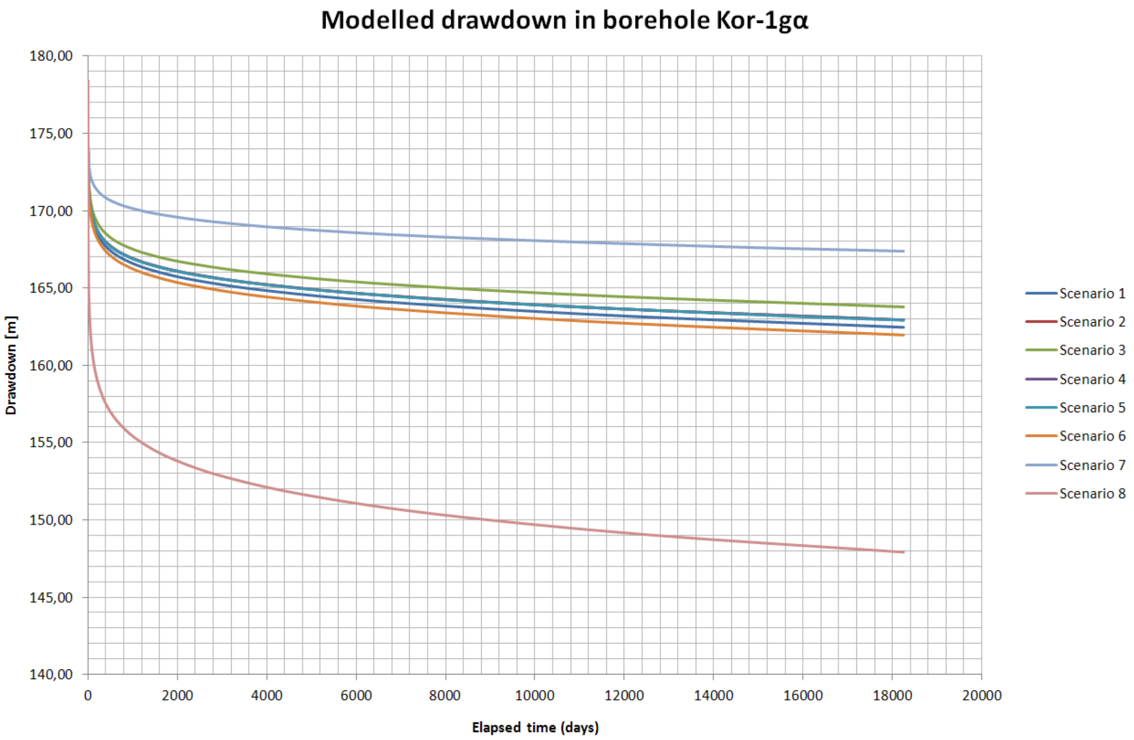

Figure 1. Modelled hydraulic heads in borehole Kor-1gα. Simulation time 50 years.

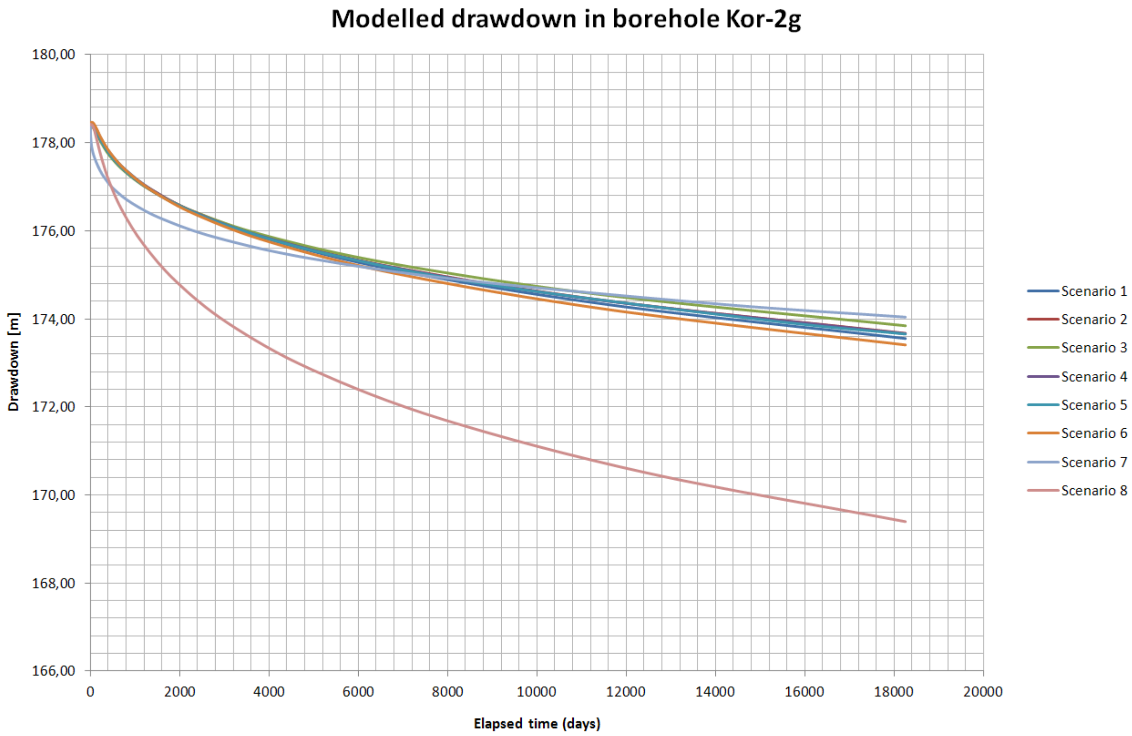

Figure 2. Modelled hydraulic heads in borehole Kor-2g. Simulation time 50 years.

Figure 3 shows the computed drawdown for scenario 1 after 50 years of simulation. It shows no impact after 50 years of production on the Bad Radkersburg wells. The drawdown in the production borehole Kor-1gα after 50 years of production is 14.5 m.

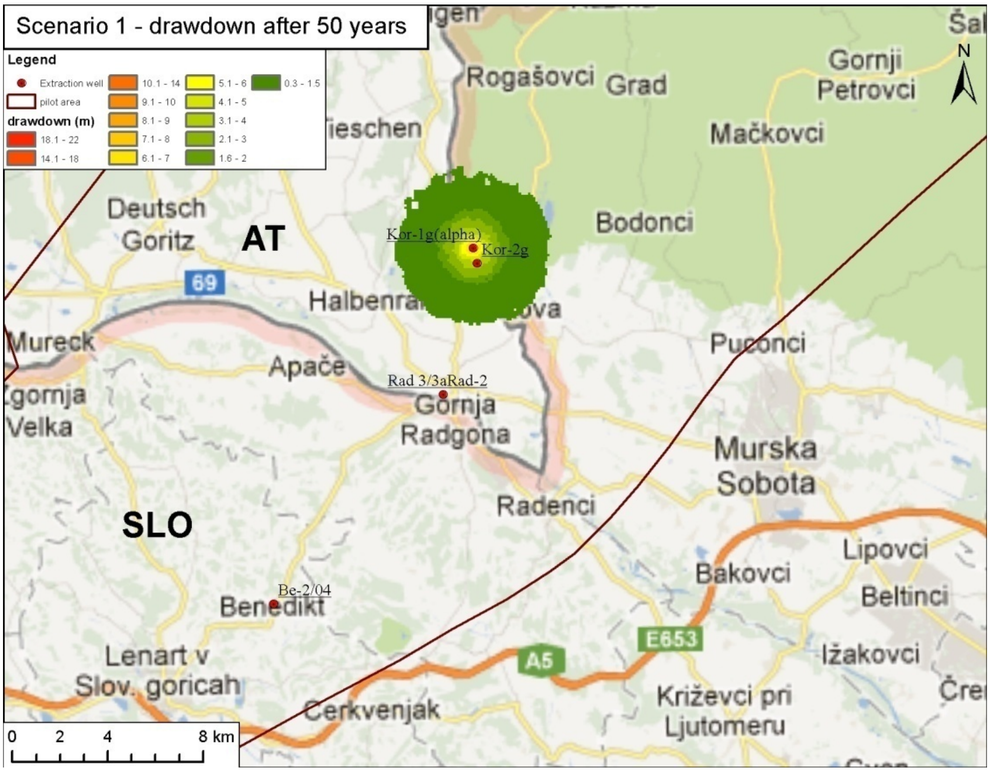

Figure 3. Scenario 1 – computed drawdown after 50 years of production in Korovci (without reinjection).

Figure 4 shows the computed drawdown for scenario 2 after 50 years of simulation. The drawdown does not reach the Bad Radkersburg wells in this case after 50 years of production. The drawdown in the production borehole Kor-1gα after 50 years of production is 14.5 m.

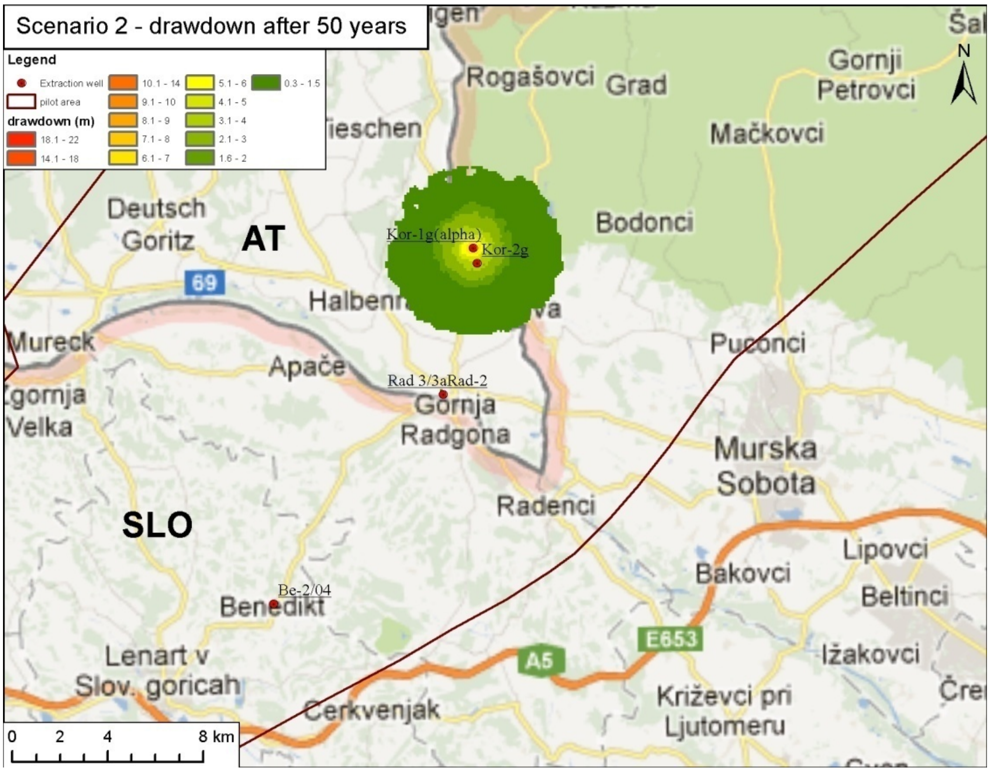

Figure 4. Scenario 2 – computed drawdown after 50 years of production in Korovci (without reinjection).

Figure 5 shows the computed drawdown for scenario 3 after 50 years of simulation. The drawdown does not reach the Bad Radkersburg wells in this case after 50 years of production. The drawdown in the production borehole Kor-1gα after 50 years of production is 13.5 m.

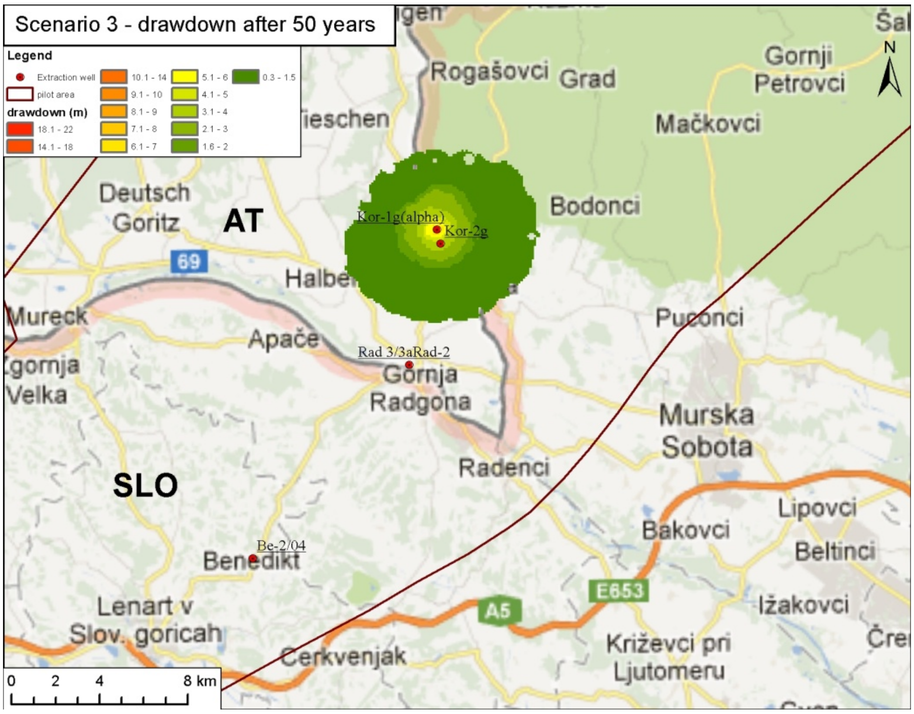

Figure 5. Scenario 3 – computed drawdown after 50 years of production in Korovci (without reinjection).

Figure 6 shows the computed drawdown for scenario 4 after 50 years of simulation. The drawdown does not reach the Bad Radkersburg wells in this case after 50 years of production. The drawdown in the production borehole Kor-1gα after 50 years of production is 14.5 m.

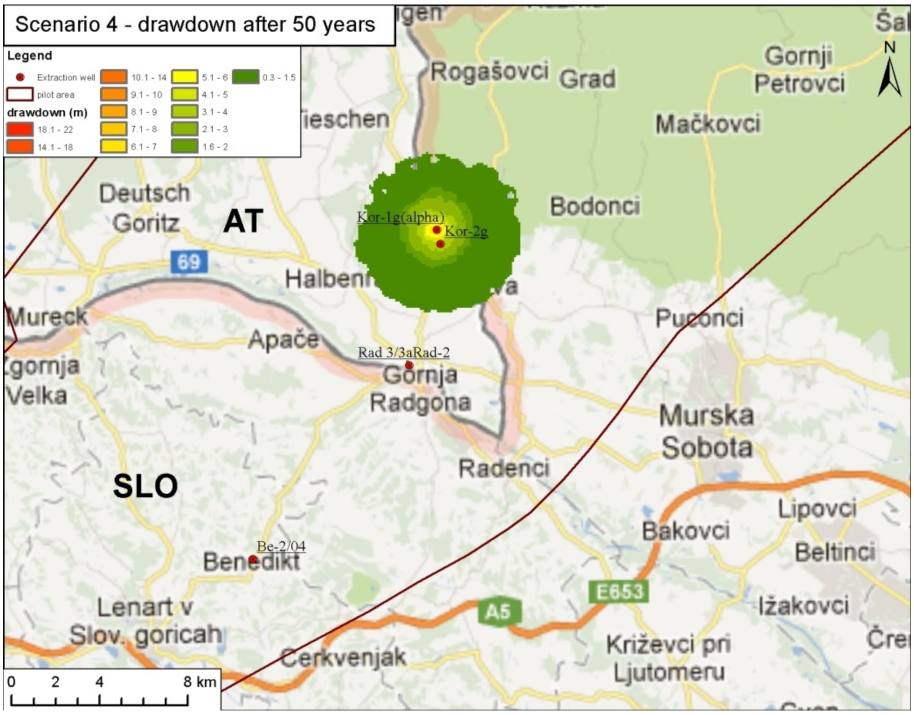

Figure 6. Scenario 4 – computed drawdown after 50 years of production in Korovci (without reinjection).

Figure 7 shows the computed drawdown for scenario 5 after 50 years of simulation. The drawdown does not reach the Bad Radkersburg wells in this case after 50 years of production. The drawdown in the production borehole Kor-1gα 50 years of production is 14.5 m after.

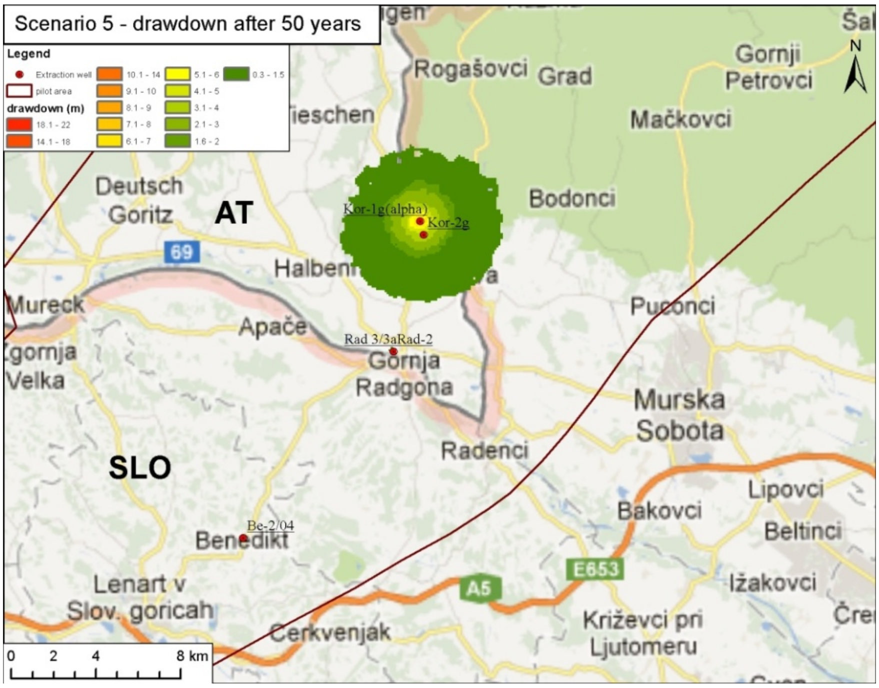

Figure 7. Scenario 5 – computed drawdown after 50 years of production in Korovci (without reinjection).

Figure 8 shows the computed drawdown for scenario 6 after 50 years of simulation. The drawdown does not reach the Bad Radkersburg wells in this case after 50 years of production. The drawdown in the production borehole Kor-1gα years of production is 15 m after 50.

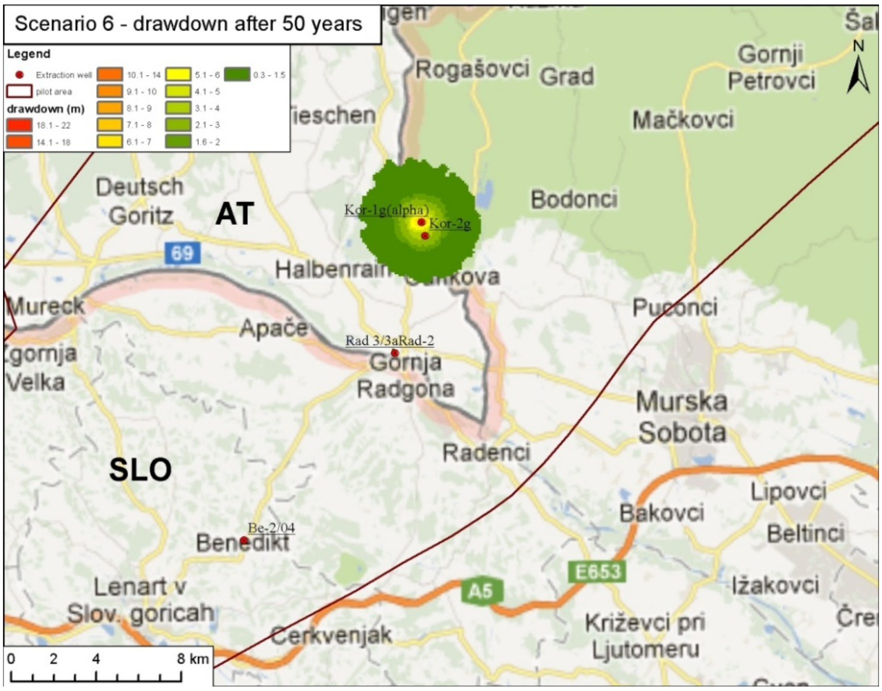

Figure 8. Scenario 6 – computed drawdown after 50 years of production in Korovci (without reinjection).

Figure 9 shows the computed drawdown for scenario 7 after 50 years of simulation. The drawdown in the production borehole Kor-1gα is 11 m and reaches Bad Radkersburg.

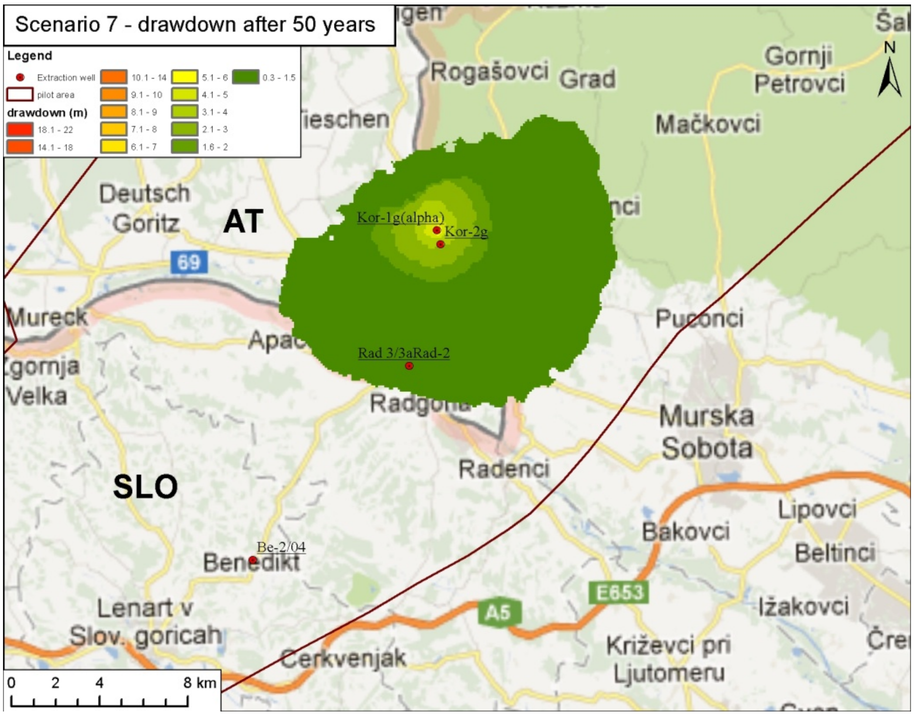

Figure 9. Scenario 7 – computed drawdown after 50 years of production in Korovci (without reinjection).

Figure 10 shows the computed drawdown for scenario 8 after 50 years of simulation. The drawdown in the production borehole Kor-1gα is 30 m. The effects of production in Korovci reach the Bad Radkersburg boreholes in this case.

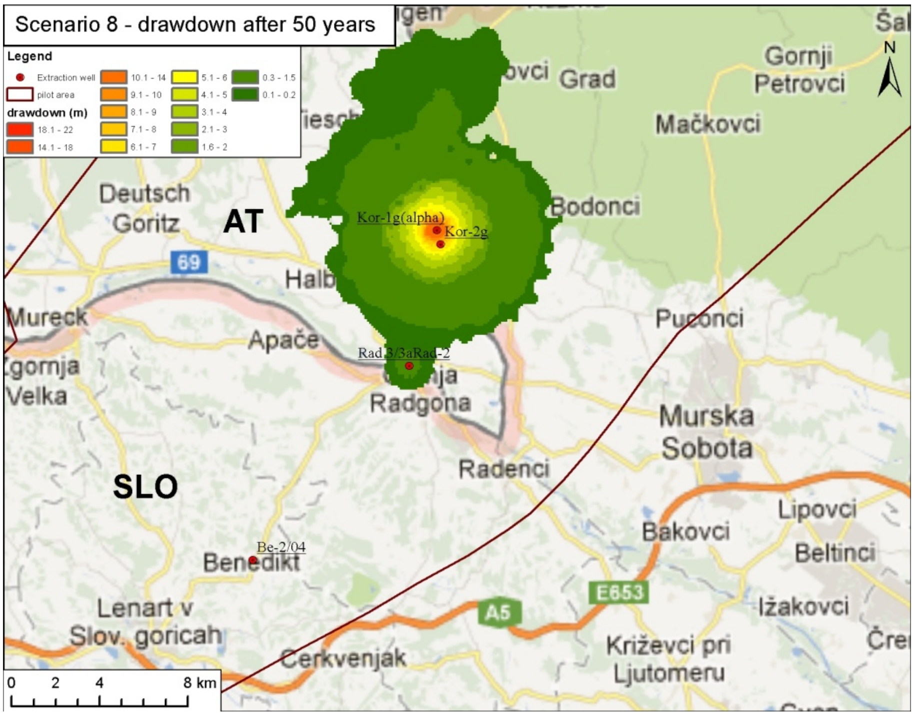

Figure 10. Scenario 8 – computed drawdown after 50 years of production in Korovci (without reinjection).

3.2 Reinjection scenarios

The aim of the reinjection scenarios was to determine the potential cool-down effects of reinjection in well Kor-2g. The temperature of reinjected water was set to 35 °C. The production (Kor-1gα) and reinjection (Kor-2g) zones are 700 m apart. Scenarios developed for this purpose are listed in the table below.

Table 5. Reinjection scenarios in Korovci.

Scenario	Longitudinal dispersivity	Transverse dispersivity	Hydraulic conductivity [m/s]	Reinjection rate [l/s]	Simulation time [days]
1	5	0.5	1×10^{-6}	20	365000
2	50	5	1×10^{-6}	20	365000
3	150	15	1×10^{-6}	20	365000
4	150	15	1×10^{-5}	20	36500
5	150	15	1×10^{-5}	40	36500

Table 6. Modelled temperature decrease in production borehole Kor-1gα for all scenarios.

Scenario	Temperature decrease [°C]
1	0.3
2	0.3
3	0.6
4	0.6
5	3.9

Three additional numerical observation points were added. Those are shown in Figure 11.

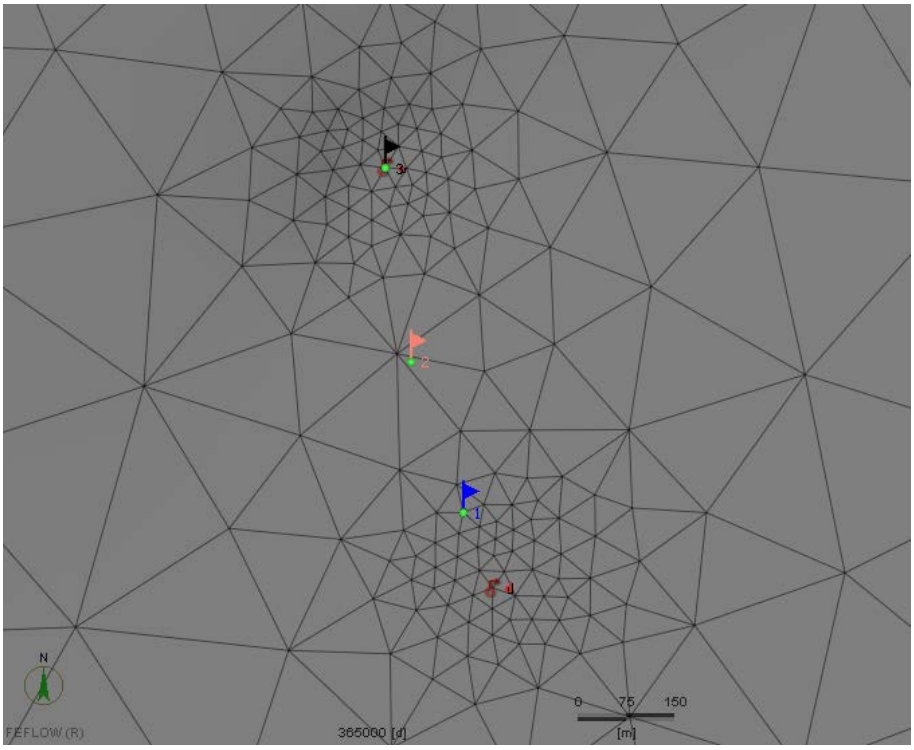

Figure 11. Observation points in reinjection scenarios; d – reinjection borehole Kor-2g, 1 and 2 – numerical observation points, 3 – observation point set in the production borehole Kor-1gα

Figures 12 to 17 show the effects of the reinjected water in the observation points for the first 3 scenarios. The effects reach the production borehole in roughly 500 years (180000 days). However, the temperature decrease after 1000 years of simulation is very low and does not exceed 1 °C in any of those scenarios.

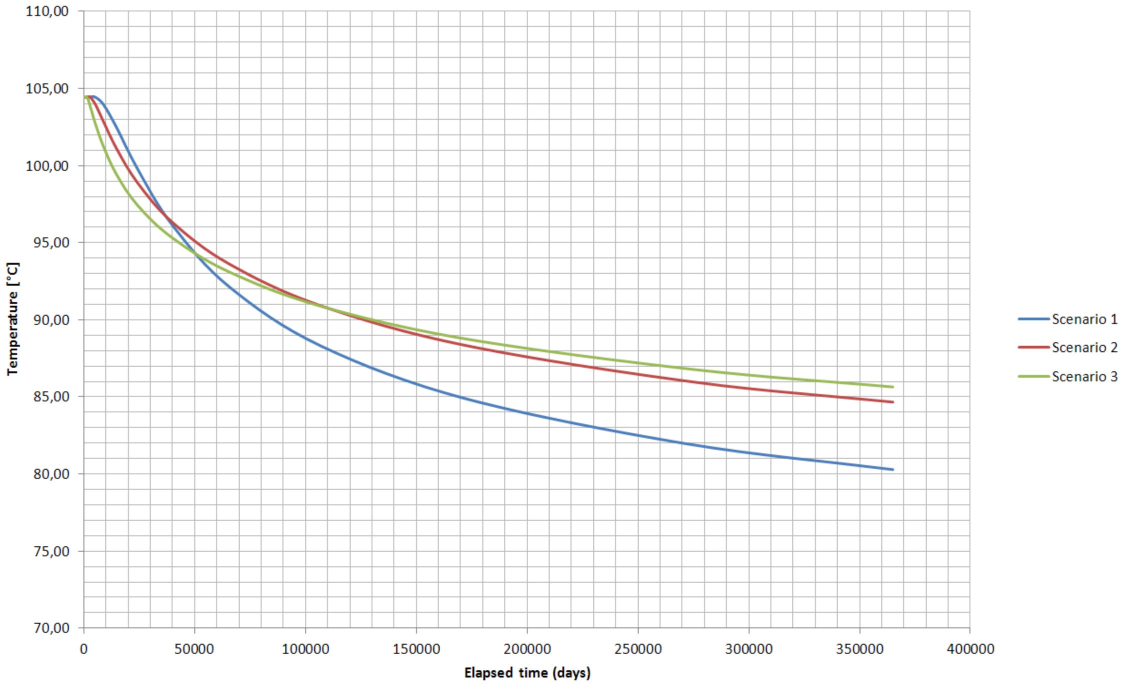

Figure 12. Modelled temperature decrease in observation point 1 – scenarios 1, 2 and 3.

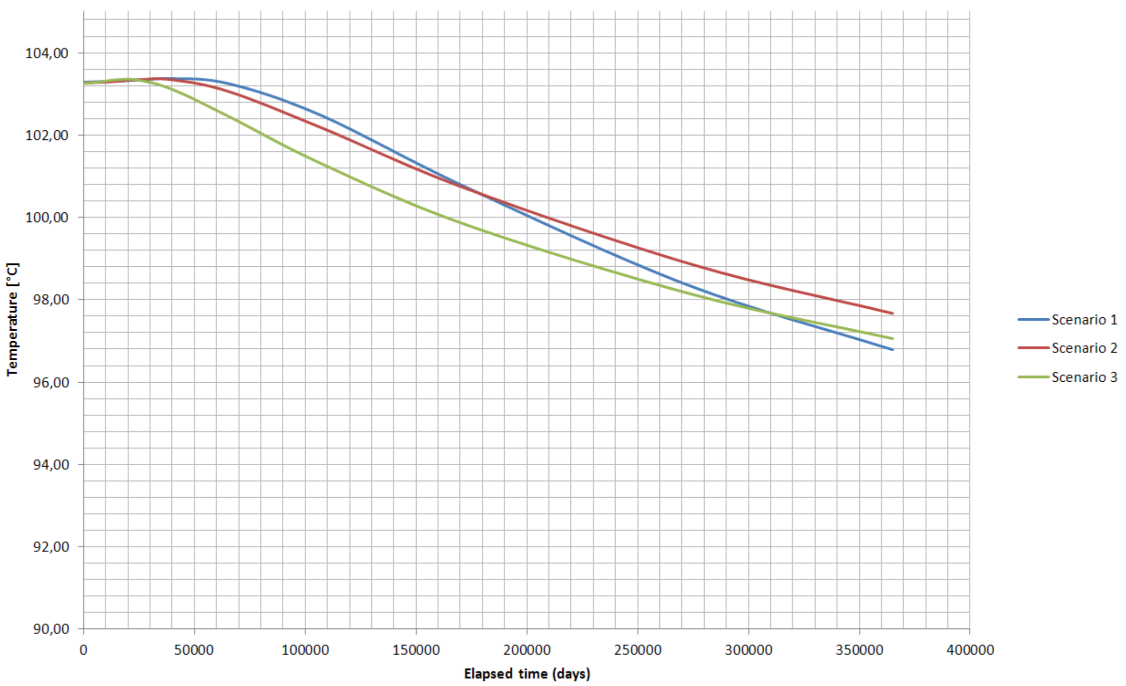

Figure 13. Modelled temperature decrease in observation point 2 – scenarios 1, 2 and 3.

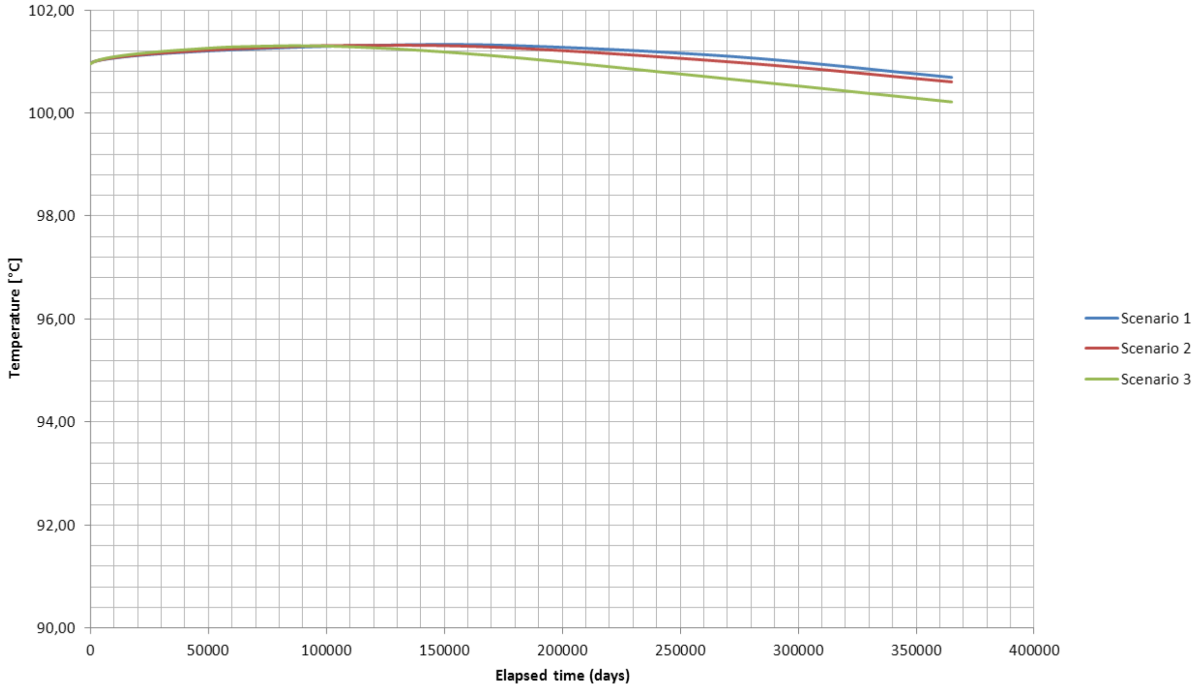

Figure 14. Modelled temperature decrease in observation point 3 (production borehole) – scenarios 1, 2 and 3.

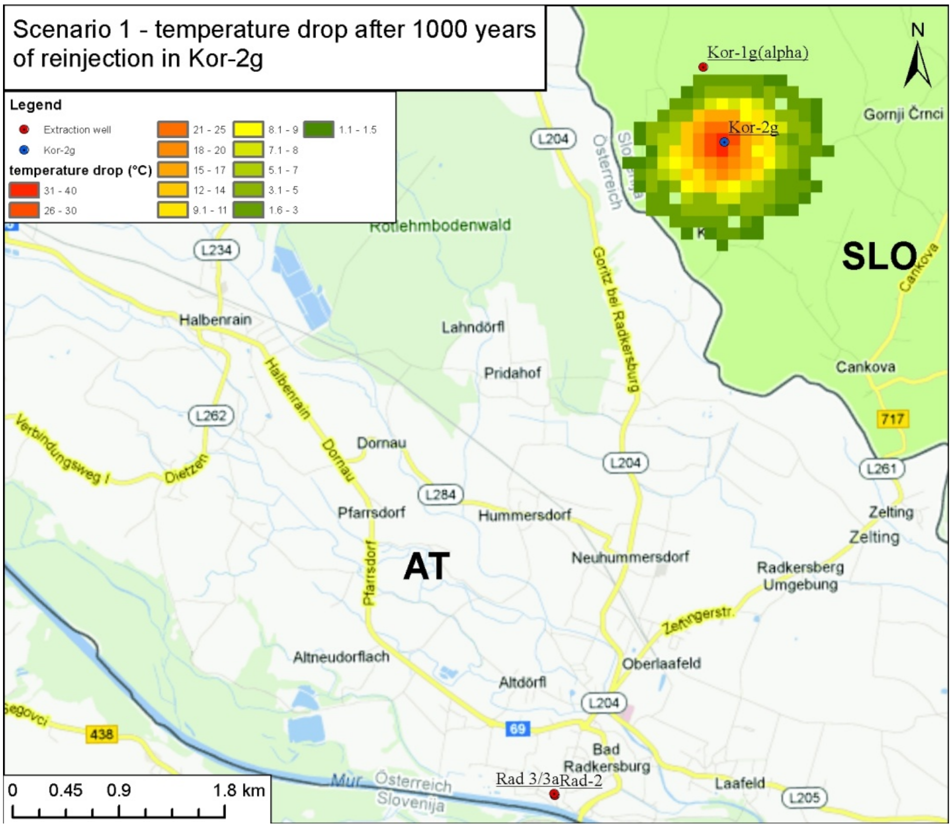

Figure 15. Scenario 1 – modelled temperature decrease and extend of the thermal plume after 1000 years of reinjection in Korovci.

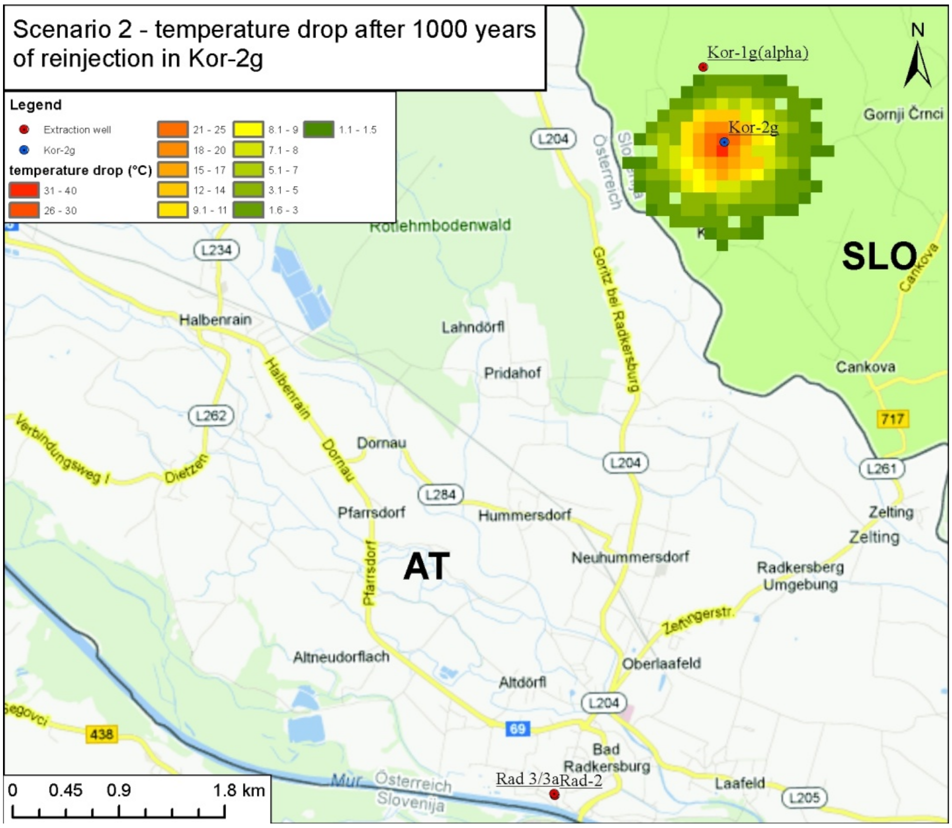

Figure 16. Scenario 2 – modelled temperature decrease and extend of the thermal plume after 1000 years of reinjection in Korovci.

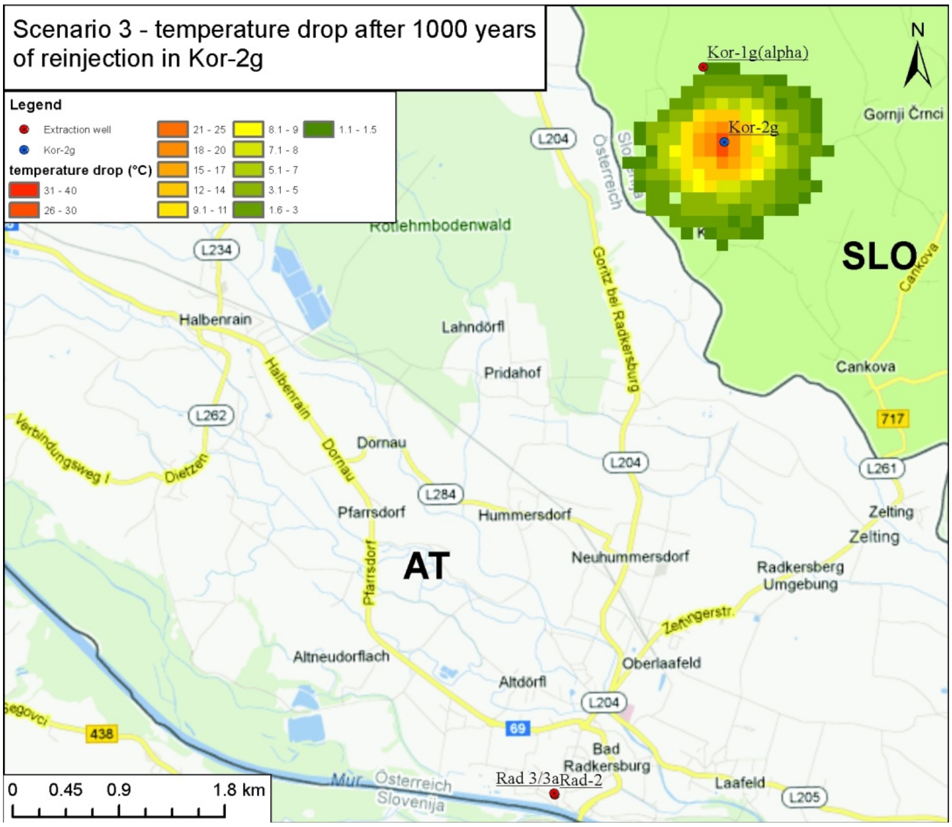

Figure 17. Scenario 3 – modelled temperature decrease and the extend of the thermal plume after 1000 years of reinjection in Korovci.

Figures 18 to 20 show the temperature decrease in scenarios 4 and 5. In those scenarios conductivity values have been set to higher values at 1×10^{-5} m/s. After the simulation time of 100 years effects of reinjected water are detected in the production borehole in both cases. In scenario 4, the decrease is very small (less than 1 °C) and occurs after 50 years of simulation. In the case of scenario 5, the reinjection rate was doubled to 40 l/s. The temperature decrease in the production borehole is detected in less than 30 years of reinjection. The temperature decrease after 100 years of simulation is around 4 °C.

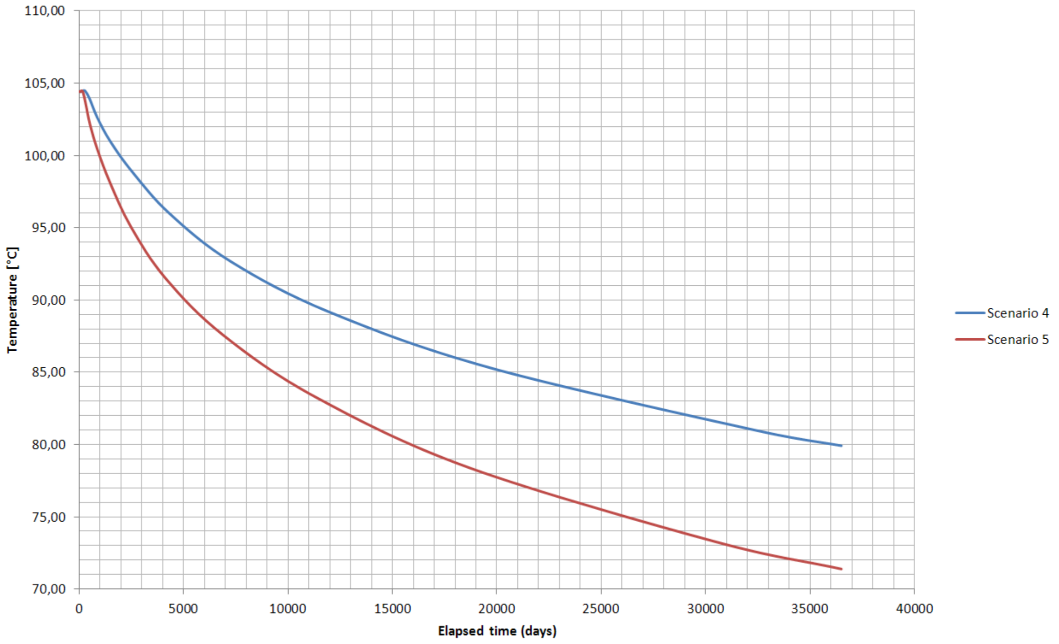

Figure 18. Modelled temperature decrease in observation point 1 – scenarios 4 and 5.

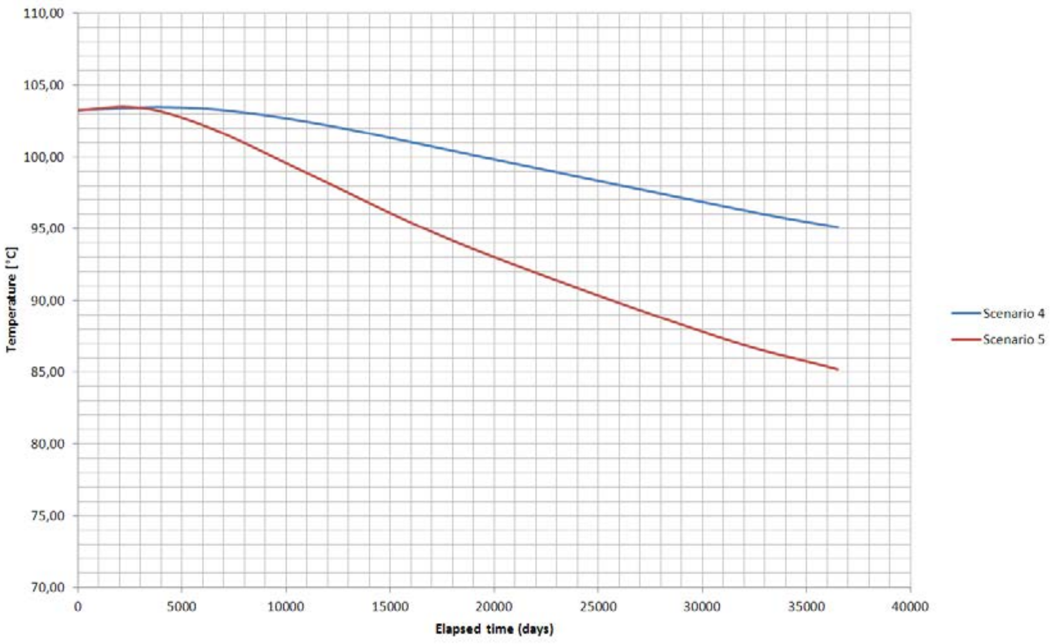

Figure 19. Modelled temperature decrease in observation point 2 – scenarios 4 and 5.

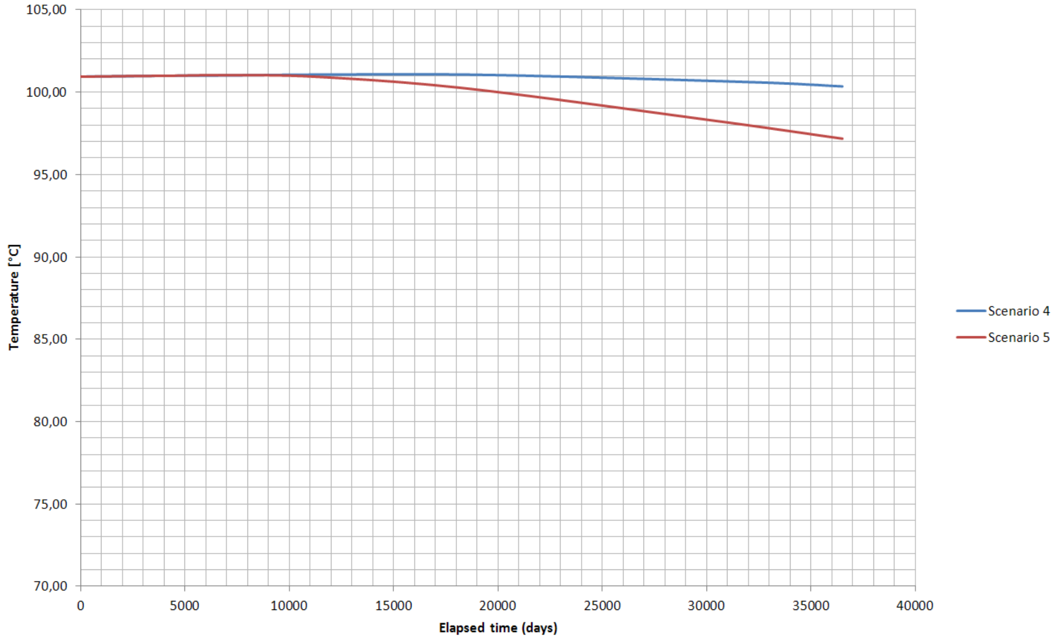

Figure 20. Modelled temperature decrease in observation point 3 (production borehole) – scenarios 4 and 5.

Figure 21 shows extend of the thermal plume after 100 years of simulation for the scenario 4. Temperature decrease in the production borehole does not exceed 1 °C.

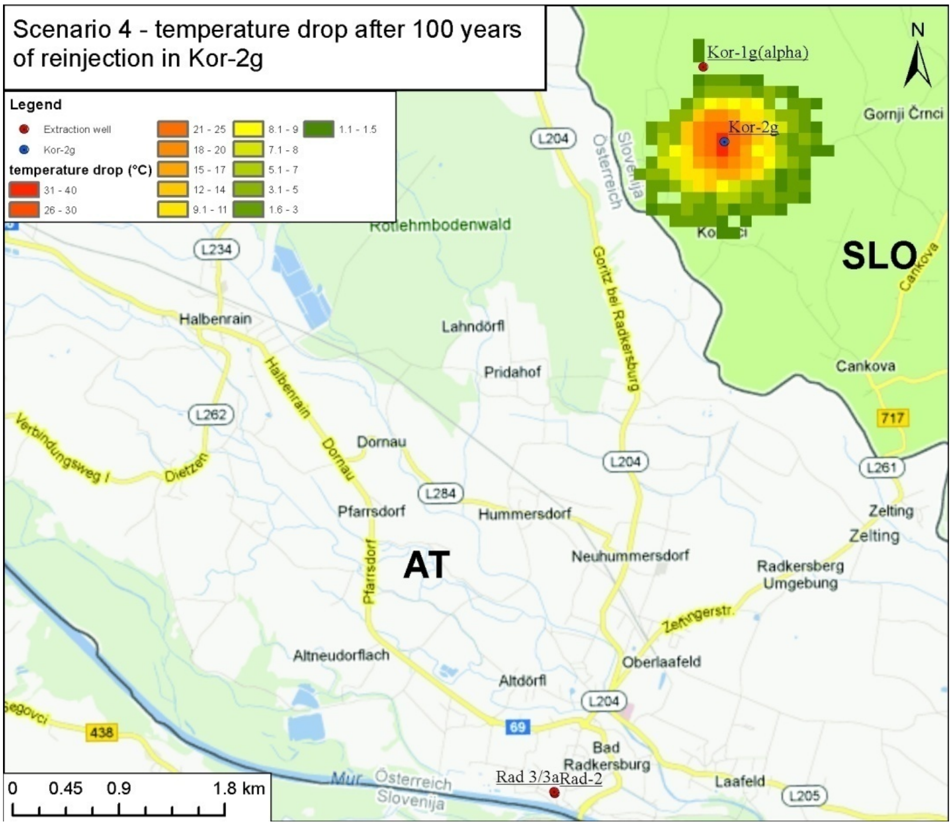

Figure 21. Scenario 4 – modelled temperature decrease and extend of the thermal plume after 100 years of reinjection in Korovci.

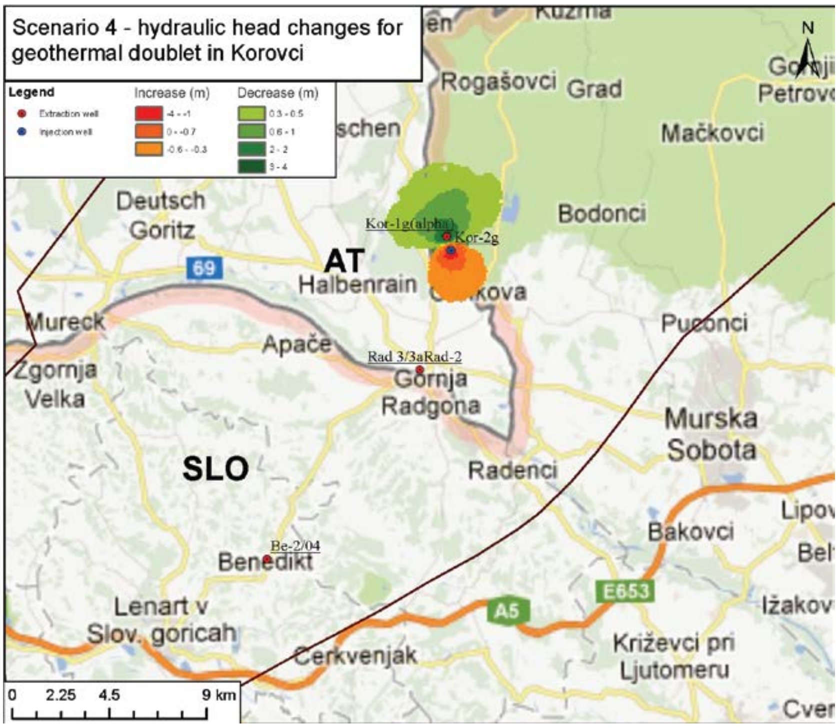

Figure 22. Modelled hydraulic head changes for geothermal doublet in Korovci after 100 years of simulation.

Figure 23 shows extend of the thermal plume after 100 years of simulation for the scenario 5. The thermal plume reaches the production borehole in this case and the temperature decrease exceeds 1 °C after 100 years of reinjection.

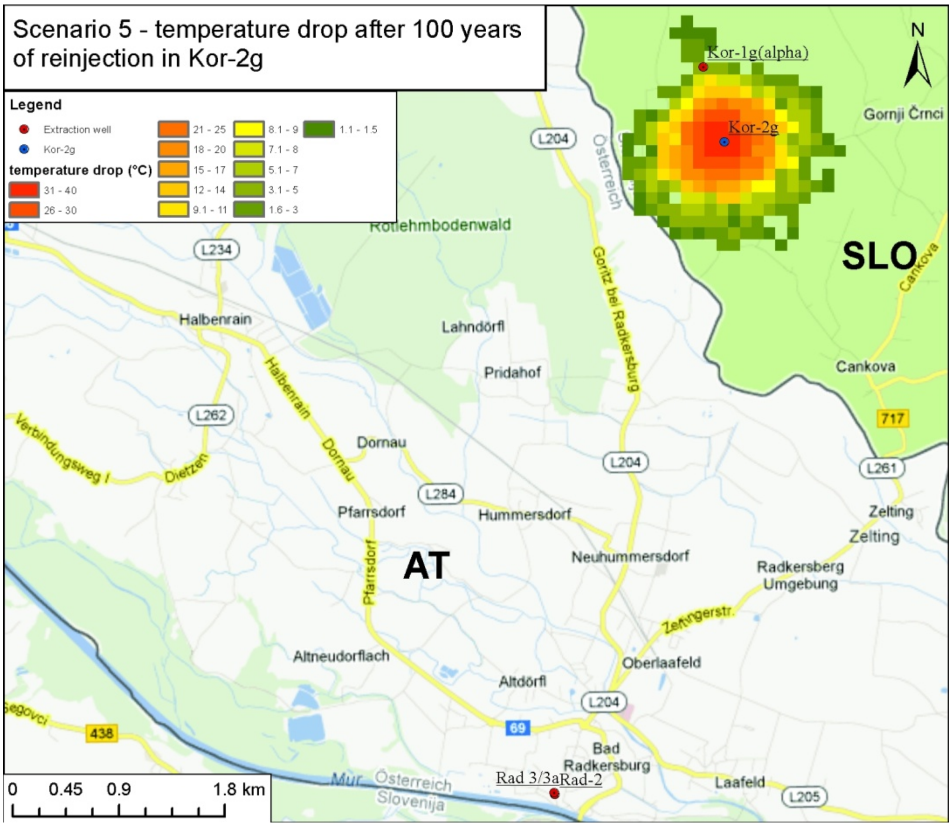

Figure 23. Scenario 5 – modelled temperature decrease and extend of the thermal plume after 100 years of reinjection in Korovci.

4 CONCLUSIONS

The main issue addressed in this study was assessment of the impact of planned utilisation of geothermal energy in Korovci. For this purpose scenarios taking into account different utilisation strategies and range of model parameter values were performed. Simulations showed no impact of abstraction in Korovci on Benedikt. The impact on Bad Radkersburg was simulated with and without reinjection well. When no reinjection is applied the expected hydraulic depression reaches Bad Radkersburg only if higher than expected hydraulic conductivity or abstraction rate are implemented in the model. The simulated drawdown in the Korovci production well after 50 years of 20 l/s abstraction is between 11 and 15 m. Five reinjection scenarios imply that thermal breakthrough is expected only if very high hydraulic conductivity is used in the model, in this case is noticeable after 50 years. Higher abstraction and injection rates in the model cause the breakthrough after 30 years already.

5 LITERATURE

Gosar, A., 1995: Modelling of seismic reflection data for underground gas storage in the Pečarovci in Dankovci structures – Mura Depression. - Geologija 37, 38, 483 – 549 (1994/95), Geological Survey of Slovenia, Ljubljana.

Kraljić, M. and Lugomer-Pohajda, R.: Rudarski projekt izvedenih del raziskovalne vrtine Kor-1g v Korovcih, 1A-08/MK-RLP (2008a).

Kraljić, M. and Lugomer-Pohajda, R.: Rudarski projekt izvedenih del raziskovalne vrtine Kor-1gα v Korovcih, 08/09MK-RLP (2008b).

Lapanje, A., Fuks, T. et al., 2012: Hidrogeološke strokovne podlage za pridobitev vodne pravice za izkoriščanje termomineralne vode v Korovcih. Archive of the Geological Survey of Slovenia, Ljubljana.