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Poddebice Geothermal Area, Poland, Production Simulation Using Simple Lumped Parameter Modelling

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Data simulation

Axelsson (1989) presents the theoretical background of lumped parameter modelling of pressure change data from geothermal systems. During the last three decades such models have been used quite successfully to model, and manage, geothermal systems worldwide (Axelsson et al., 2005). Lumped parameter models consist of a few tanks and resistors, which simulate the fluid storage capacity and flow resistance, respectively, of geothermal systems. The pressure response of the models can, therefore, be used to simulate the pressure response of geothermal systems, as well as other hydrological systems underground.

It has become customary to simulate pressure or water level data from geothermal systems with both open and closed models, see Figure 1. The open models simulate systems where production and recharge eventually equilibrate, while closed models have no recharge. At a constant rate of production pressure declines continuously in the latter. Calculating future predictions with both model versions, therefore, provides conservative as well as optimistic predictions.

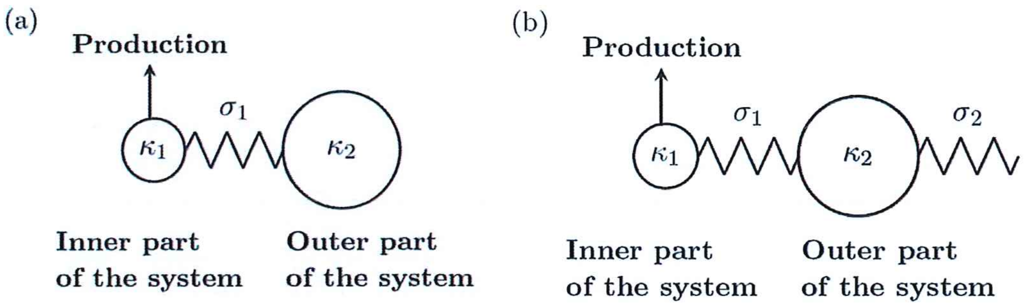

Figure 1. *Schematic pictures of (a) two closed tanks and (b) two open tanks which are used to model the reservoir system. Both systems are composed of two tanks, κ_1 and κ_2, that represents the inner and outer part of the geothermal system. The connection between the tanks is represented with a flow resistance σ_1. For the open two tank system the outer part is connected to an infinite reservoir with a flow resistance σ_2.*

The models were fitted via least square norm to the water level and production data. The result can be seen visually in Figure 2 for the open model and numerically for both in Table 1. There was little visual difference between the open and closed model. The residuals of the open model, or the difference between model and data can be seen in Figure 3. The data is rather noisy and the model does not follow the major jumps well but as we can see from Figure 2 it manages to roughly reproduce the gross trend of the water level data.

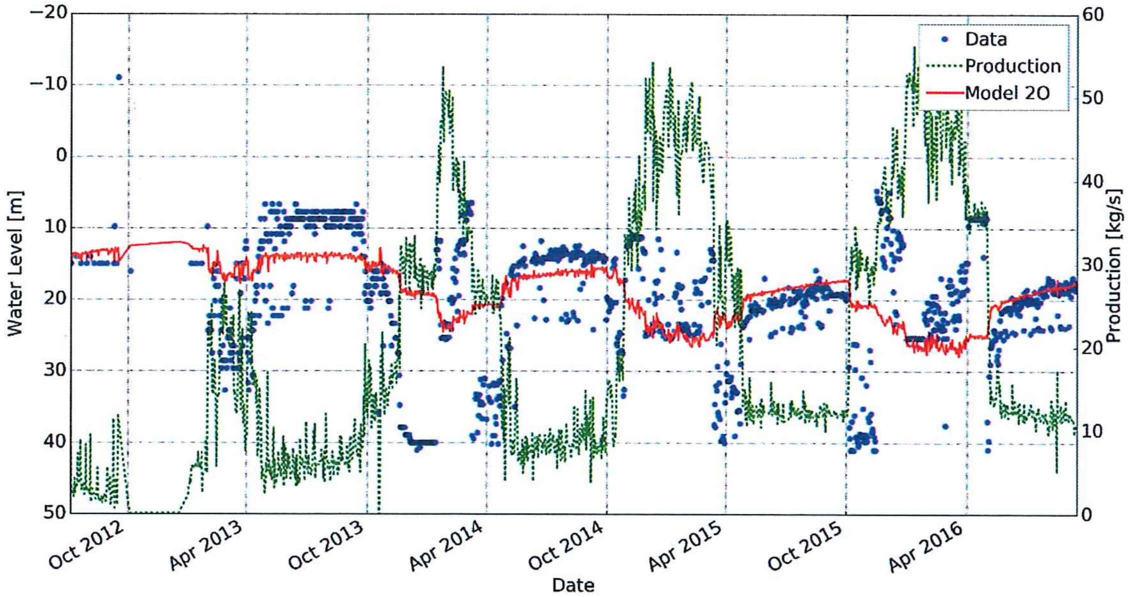

Figure 2. *Measured production and water level shown with a green dashed line and blue dots respectively. The model result for the water level is shown with a solid red line.*

Table 1. *Variables used and calculated in the two models.*

Variables used in model	Two Tanks Closed	Two Tanks Open
A_1	5.4×10^{-6}	7.3×10^{-6}
L_1	2.28×10^{-5}	3.95×10^{-5}
B	2.73×10^{-9}	
A_2		1.5×10^{-8}
L_2		7.09×10^{-8}
Variables calculated from A_i, V_i, and B		
$Kappa_1$ [kg/Pa]:	19.3	14.2
$Sigma_1$ [kg/s/Pa]:	4.39×10^{-4}	5.61×10^{-4}
$Kappa_2$ [kg/Pa]:	3.81×10^{4}	6.95×10^{3}
$Sigma_2$ [kg/s/Pa]:		4.94×10^{-4}
Statistic		
RMS deviation [m]	8.6	8.5
Secondary variables		
Storativity [kg/m^3/Pa]:	6.2×10^{-5}	6.2×10^{-5}
V_1 [km^3]:	0.313	0.231
V_2 [km^3]:	619	113
$Permeability_1$ [mDarcy]:	551	579
$Permeability_2$ [mDarcy]:		169

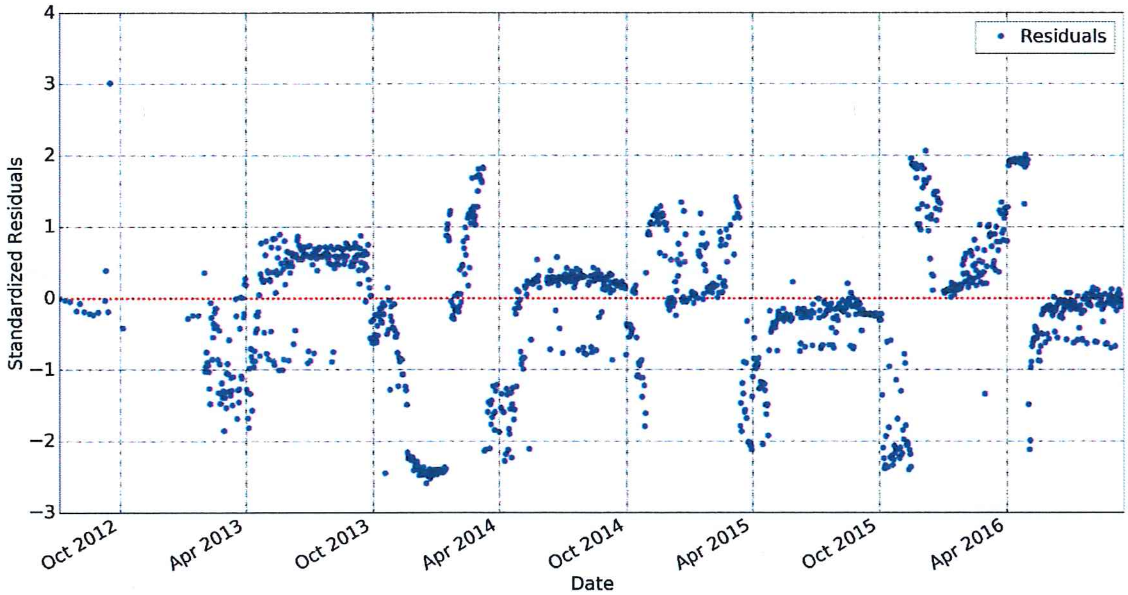

Figure 3. *Standardized residuals of the modeled water level compared to measured water level.*

The model that was produced from the fit is used to do five year projections for three different production scenarios. Both the open and closed systems are simulated and presented in Figures 3–6; the open system with a solid light blue line and the closed system with a solid black line. In all the scenarios the simulated production oscillates in a square like way between summer and winter with a 20 kg/s amplitude. In Figures 4–6 it is shown with a dashed light blue line.

The first production scenario is shown in Figure 4. There the yearly average production is set at 30 kg/s, which resembles the current production. We see that the open system settles to a water level close to the present one, while for the closed system the water level drops by roughly 5 m.

For the second scenario shown in Figure 5, the yearly average production is increased to 50 kg/s. For this scenario the average water level for the open system settles to around 35 m while the average water level for the closed system approaches 45 m.

In the final production scenario shown in Figure 6, the average production is ramped up to 70 kg/s. For this scenario the average water level for the open system quickly settles to 40 m, while the water level for the closed system is starting to go below 60 m in the winters.

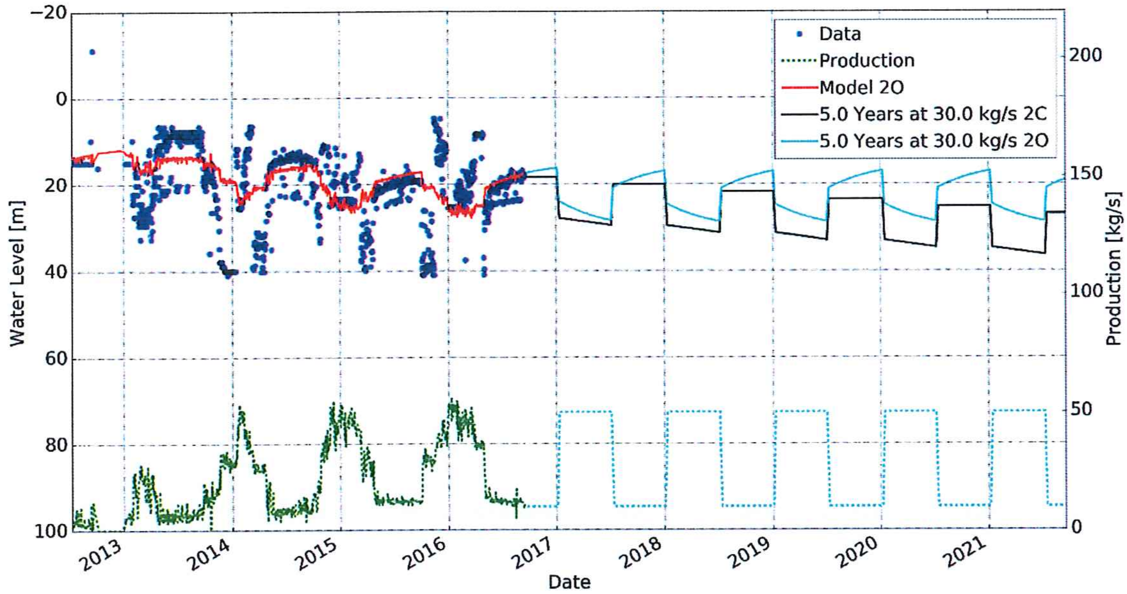

Figure 4. *Projection of the water level for the system in response to a periodic step like production. The production has yearly average of 30 kg/s and is shown with a dashed blue line. The projected water level is shown with a solid black line.*

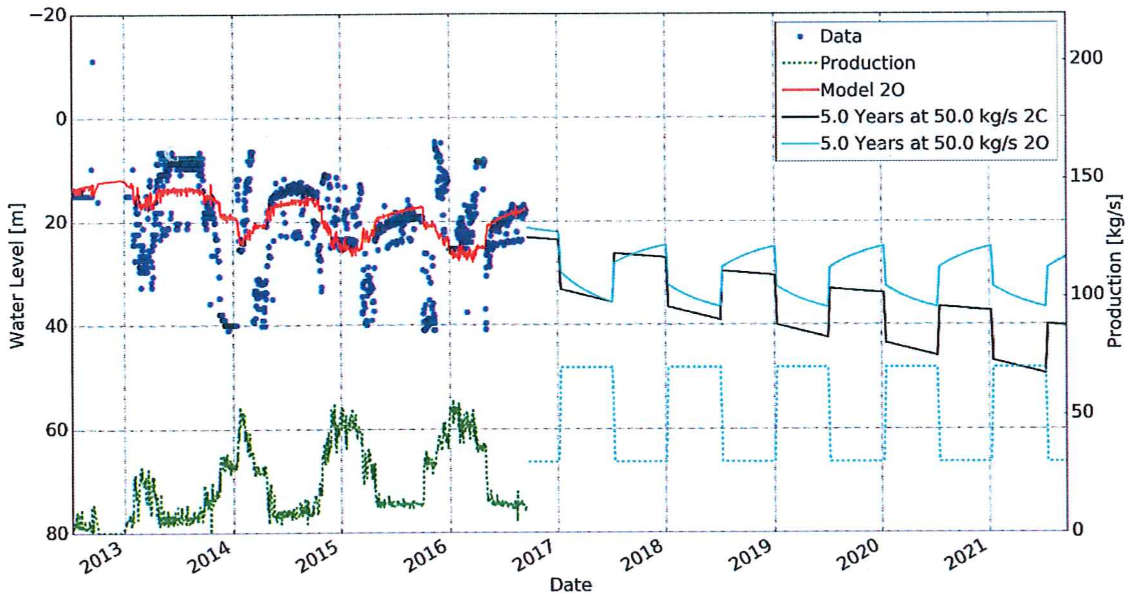

Figure 5. *Projection of the water level for the system in response to a periodic step like production. The production has yearly average of 50 kg/s and is shown with a dashed blue line. The projected water level is shown with a solid black line.*

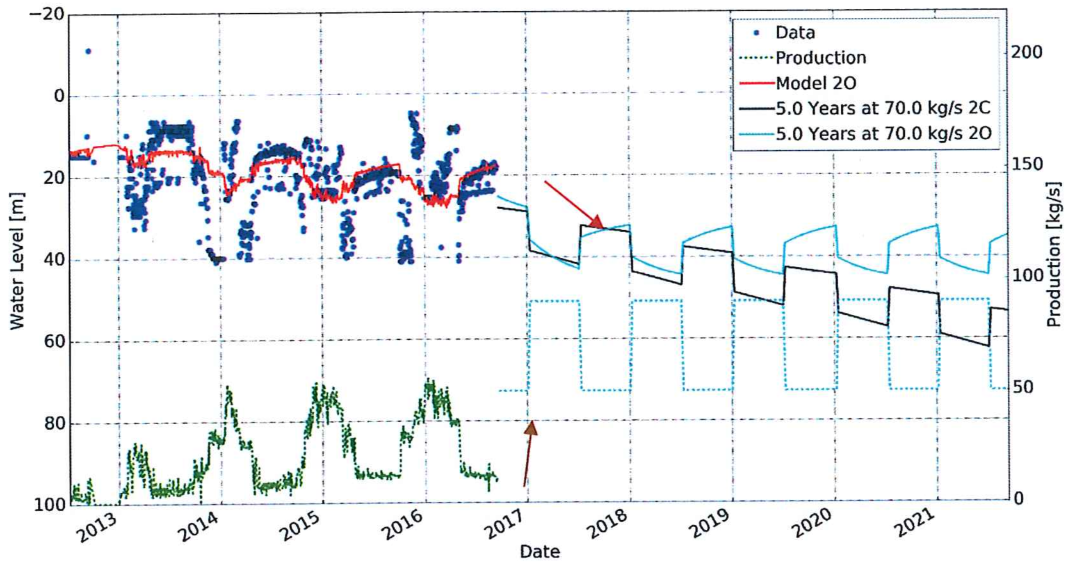

Figure 6. *Projection of the water level for the system in response to a periodic step like production. The production has yearly average of 70 kg/s and is shown with a dashed black line. The projected water level is shown with a solid black line.*

Conclusions and recommendations

The water level data is not very good as can be seen from the figures. The measured water level above the pump was used when the water was pumped from the well, but well head pressure (WHP) during the artesian flow period. Both data set show much scatter in the data. The measured flow rate data is much better. It would be great if there is a possibility to find out why there is so much scatter in the data and fix it if possible for future predictions.

The main conclusions that can be drawn for these simulations is that the current production is not aggressive and the water level is in not decreasing. Since the production is not aggressive it is difficult to predict the water level/pressure changes in the system, but these predictions shown here are indications of what can happen if the production is increased.

If the heating system will be enlarged and more water is needed, then at least one production well should be drilled and one or two injection wells also. It is very important to reinject the spent water into to geothermal system when more water is produced from the geothermal reservoir to make sure the water-level/pressure does not decrease too much. The effect could be that the pumps have to be lowered below the casing of the wells and the cost of pumping can become too big a portion of the management cost of the system.

Surface explorations such as magneto telluric (MT), shallow gradient wells, gravity or other methods are needed before further drilling is decided on. It is important to locate the production and injection wells carefully to make sure that the injected fluid does give pressure support to the system but minimize the cooling effect.

Well test and interference tests should be performed and further modeling.

References

Axelsson, G. (1989). Simulation of pressure response data from geothermal reservoirs by lumped parameter models. *Proceedings 14th Workshop on Geothermal Reservoir Engineering*, Stanford University, USA, 257–263.

Axelsson G., Björnsson, G., and Quijano, J. (2005). Reliability of lumped parameter modelling of pressure changes in geothermal reservoirs. *Proceedings of the World Geothermal Congress 2005, Antalya, Turkey*, April 2005, 8 pp.