Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Injection Modeling Simulation in a Geothermal Exploitation Site in Korea

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Keywords: injection, geothermal, temperature distribution , FEFLOW

ABSTRACT

This study is to design injection well to recharge in a deep geothermal fluid supply. A borehole is drilled to the depth of 1,300m to use geothermal fluid in Pohang, Korea. The water table around the pumping well is at about 30m depth and the pump is located at 400m depth. After twenty-four hours' pumping test by 377 m^3/day the ground water table is lowered more than 200m and showed very low recovery rate. According to the well logging data obtained 72 hours after pumping shut down, bottom water temperature is about 55 degree Celsius and EC is 5,000 microS/cm. In order to maintain the insistent supply of the geothermal fluid, we planed to install injection well. By the ground water modeling between injection well and withdraw well, we simulated the temperature distribution according to pumping rate in transient and steady state condition by using FEFLOW model.

1. INTRODUCTION

Heat transport modeling is applied to a problem relating to the exploitation of geothermal heat as an energy source, in the form of hot water (70°C) from deep aquifers. Similarly the heat storage capacity of groundwater and aquifers are often utilized for heating and cooling in climates that have cold and hot seasons by cycling warm water (10°C - 40°C) for heating in winter and cold water in summer for cooling (5°C). This is referred to as Aquifer Thermal Energy Storages (ATES). In this example we developed a deep geothermal heat energy source and geothermal system with a temperature of 70°C would be extracted from a homogeneous deep aquifer using a well (Figure 1) at a geothermal direct-use facility. Also the wastewater has a temperature of 5°C and will be disposed of by reinjecting it into the deep aquifer at a well located 750m of the extraction well. The chosen location of wastewater injection well provides the maximum separation between the injection and extraction wells while locating the wells on the manufacturing facility property. For this study, twenty-four hours' pumping test was accomplished at the drilling depth of 1,300m. During the test, periodic water quality measurement, such as water temperature, EC, pH, Eh, and DO (Dissolved oxygen) coupled with pumping rate was made. We are to develop a model to determine whether the injected water will reach the extraction well within short periods and the injection well could be used to recharge for the extraction well.

2. HYDROGEOLOGICAL SETTINGS

The study area is located southeastern part of Korea peninsula (Figure. 1). The surficial geology is summarized as Cretaceous shale and sandstone, Tertiary rhyolite, tuff, and shale, and Quaternary unconsolidated mudstone and alluvium. Subsurface geology by drilling results of production well is as follows. The depth zone of -1300 m to -525 m is rhyolite, -525 m to -352 m is alternating zone of tuff and mudstone, and -352 m to surface is unconsolidated mudstone.

Except for the pumping and observation wells, four boreholes were already drilled in the area to use warm water in bathhouses (Fig. 1). The geothermal gradient of H1 and H4 is known as 55.2 °C/km and 46.8 °C/km, respectively (KIGAM, 1993 and 2000). The drilling depths of the boreholes range from 300-690 m and estimated total pumping rate is about 450 m^3/d (Table 1). DTW (Depth to water table) of the area is sharply declined due to pumping at three boreholes. DTW of H2 was just 10.17m when drilling was completed in December 1999, however, DTW of present time is about 30 m.

The production well depth at the time of pumping test was 1,030 m. 8" steel casing is installed to the depth of 420 m and 6.5" casing to the bottom of the borehole. Strainer was installed to the depth zone of 450-480 m, 500-510 m, 700-710 m, 715-725 m, 755-780 m, and 955-965 m on the basis of rock fragment recovered during drilling and borehole logging results.

The water from production well is a mixture of water from all permeable horizons within the cone of depression, in an unknown ratio (Gaona-Vizcayno et al., 1985). To see water quality variations of the geothermal water, 24 hours' of pumping test did on December 17th, 2003. For the pumping test, a 40 HP submersible pump was installed at the depth of 380 m. Pumping rate range was 296-377 m^3/d. Pumping rate was controlled at the early part of the test to prevent excessive drawdown which might cause shut out of the pump. After 70 minutes since pumping start, the discharge controlling valve was in full open state. As seen in Fig. 2, discharge rate is steadily increasing from 70 minutes possibly due to the release of bentonite material used for drilling.

3. METHOD

Heat transport simulations are numerically intensive. To reduce simulation time in this example, we can simulate the aquifer using a 2D plan-view model, and consequently density effects are neglected. This will allow us to focus on effects caused by viscosity changes due to varying temperature. However, the effects of density should not be neglected in real-world projects, and FEFLOW provides routines for simulating the non-linear relationship between temperature and fluid density.

The following two figures show the simulated groundwater table and the relative change in viscosity at reference temperatures of 70°C and 5°C. Reference temperature refers to the temperature at which the assigned hydraulic conductivity values were measured in the aquifer (e.g. from a pumping test).

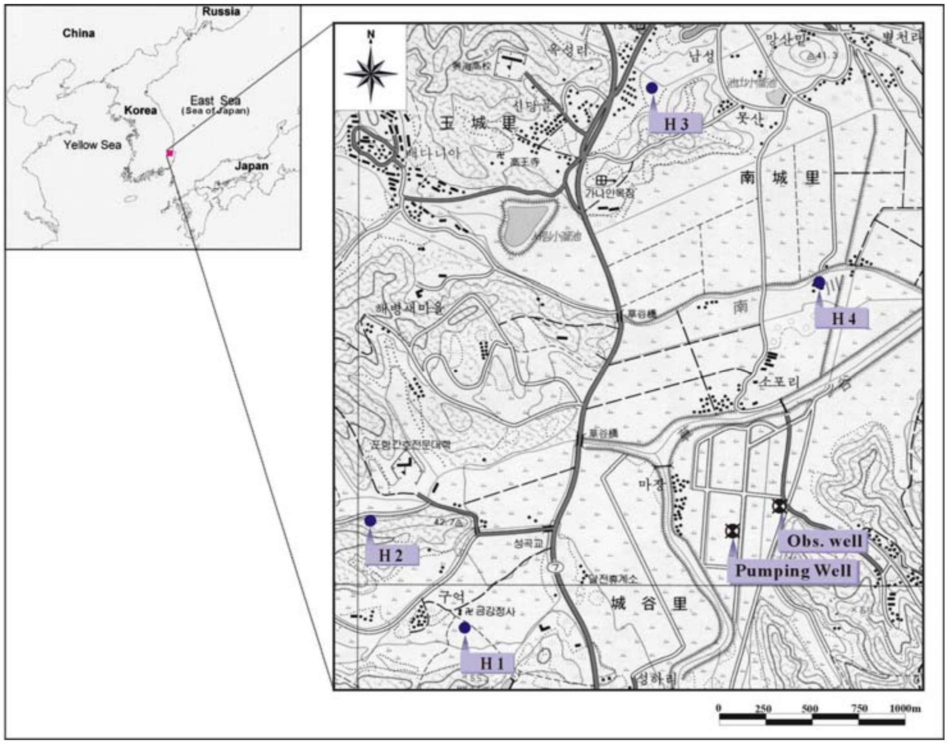

Figure 1: Location map of the study area.

Table 1. Hydrogeologic and geothermal parameters used in the simulation

Parameter	Unit	Assigned Value
aquifer thickness	m	40
porosity	1	0.25
volumetric heat capacity of the solid	10^6 J/m^3/K	2.52
heat conductivity of the solid	J/m/s/K	3.0
longitudinal dispersivity	m	0
transverse dispersivity	m	0
source(+)/sink(-) of fluid	J/m^2/d	0
source(+)/sink(-) of solid	J/m^2/d	0
In-transfer rate	J/m/d/K	0
Out-transfer rate	J/m/d/K	0

RESULTS AND CONCLUSION

Figure 2 shows that the groundwater table at the exploitation well is highly decreased and that at the recharge well is sharply increased after 10000 days pumping and recharging. According to the recharge of injection well the groundwater near exploitation well is compensated and the effect of pumping is constrained. However the water table of the southern area of exploitation is lowered in large area.

Figure 3 is the temperature distribution in the geothermal exploitation site. The simulation of temperature distributions indicate that the temperature of the water at the extraction well will decrease due to breakthrough from the injection wells beginning at about 10000 days. Any decrease in the temperature of the water at the extraction well will increase costs for electricity generation.

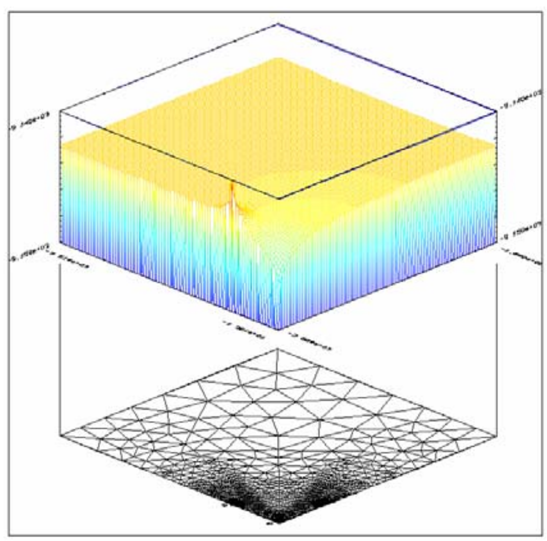

Figure 2: The groundwater table distribution after 10000 days pumping and recharging.

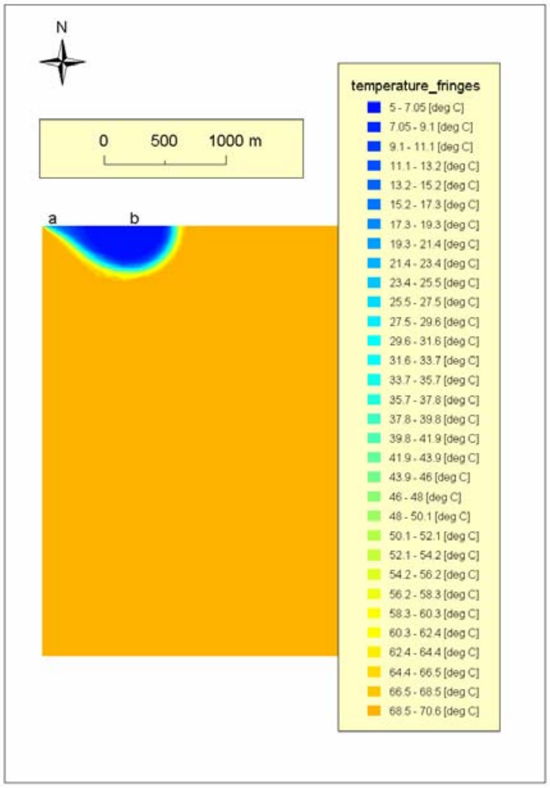

Figure 3: Temperature distribution in the aquifer after 10000 days pumping and recharging.

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