

# UPDATED NUMERICAL SIMULATION OF THE MIRAVALLES GEOTHERMAL FIELD, COSTA RICA

Mainieri, A.<sup>1</sup>, Gonzalez, C.<sup>1</sup>, Moya, P.<sup>1</sup>, Sanchez, E.<sup>1</sup>, Yock, A.<sup>1</sup>, Pham, M.<sup>2</sup>,  
Granados, E.E.<sup>2</sup>, and Klein, C.W.<sup>2</sup>

<sup>1</sup>Instituto Costarricense de Electricidad (ICE) San José, Costa Rica

<sup>2</sup>GeothermEx, Inc., 5221 Central Avenue, Suite 201, Richmond, CA 94804-5829 USA

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*Costa Rica, numerical simulation*

## **ABSTRACT**

Numerical simulation techniques have been utilized by the Instituto Costarricense de Electricidad (ICE), to understand the evolution of the Miravalles Geothermal field throughout its production history, and the results from forecast have been recently used for optimizing field management. An initial modeling effort was conducted by ICE in 1998, when only the first 55 MW unit was installed. Since then, a second 55 MW Unit (Miravalles II) came on line in 1998, and a third unit of 27.5 MW (Miravalles III) came on line in 2000. These two additional units increased the installed generation capacity at Miravalles to 142.5 MW. With the large increase in capacity, and the additional data gathered from the field over the last three years, it was necessary to update the original numerical model so that it could continue to be effectively used as a tool for reservoir management. An update of the model was made in 2001, using the TOUGH2 simulation program. The data available for history matching consisted of downhole pressure from observation wells, and enthalpy and chloride concentration in the fluid from production wells. Detailed matching of the observed enthalpies was not considered, because the accuracy of the enthalpy measurements was considered to be low and minor enthalpy changes were obscured by the uncertainties in the measurements. However, excellent chloride content monitoring data were available from the production wells. Chloride concentration at the production wells had been tracked at Miravalles since the beginning of field operation, the initial chloride distribution in the reservoir was reasonably well known, and reliable chloride trends from the production wells were available. Because chloride does not participate in water-rock reactions in most volcanic environments, it is a good tracer for determining the pathways between injection and production zones. A three-dimensional simulation model was constructed based on the conceptual hydrogeological model of the field. The model included a "double porosity" formulation with two water components (one for the fluid phases and the other for the chloride content). The model was first calibrated by trial-and-error matching of the initial state and then further calibrated by history matching. Pressures derived from observed water levels and downhole measurements had been well matched, and excellent matches to measured chloride data were achieved for the majority of the production wells. Thus, the model was adequately calibrated for use in forecasting future reservoir behavior under various production and injection scenarios. Although a rigorous matching of the measured and calculated enthalpy histories was not attempted, the enthalpies calculated by the model agreed reasonably well within the error range of the measured data. The results of the modeling demonstrated that many of the wells at Miravalles are producing fluid that has been previously injected. So far, the returning

injection fluid has been adequately heated by the reservoir rock, so it has not caused a significant decline in the production enthalpy, but since the amount of heat available in the rock formations is limited, it is likely that cooling will accelerate in the future as the heat supply from the rock is diminished. The model has shown that, under the current scheme of production and injection, reservoir temperatures will decline in the production wells located closest to the injection areas, and additional pressure declines will occur during the next 25 years. The model was used to simulate different scenarios of production and injection. Through this trial and error process, it was found that by shifting a portion of the injected fluid from the injectors located at the south of the field to the western injection wells, the pressure and temperature declines rates were greatly improved. In 2002, ICE decided to modify the injection system to accommodate to this new scheme and avoid future deterioration of the field.

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