Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

LOW TEMPERATURE GEOTHERMAL FIELDS UTILIZED FOR DISTRICT HEATING IN REYKJAVIK, ICELAND

Einar Gunnlaugsson[1], Gestur Gislason[1], Gretar Ivarsson[1], Snorri Pall Kjaran[2]
[1]Orkuveita Reykjavikur, Sudurlandsbraut 34, 108 Reykjavik, Iceland.
[2]Vatnaskil, Sudurlandsbraut 50, 108 Reykjavik, Iceland

Key Words: geothermal, district heating, monitoring, Reykjavik

ABSTRACT

The district heating in Reykjavik utilizes three low temperature geothermal fields two of which, Laugarnes and Ellidaar are located within the city limits, but the third, Reykir lies some 20 km northeast of Reykjavik. Exploitation of the Laugarnes field began in 1930 by pumping 14 l/s of 87°C water from wells and surface springs. Water from Reykir field was first piped to Reykjavik in 1943 and exploitation of the Ellidaar field began in 1968. Initially only artesian flow from springs and relatively shallow drill holes was used for district heating in Reykjavik but in the sixties and early seventies deep production wells were drilled in all the fields and downhole pumps installed, multiplying the flowrate from the fields. The pumping has lowered waterlevel and geothermal surface manifestations have disappeared. With reduced pumping in the later years the waterlevel rose again and equilibrium has been attained indicating that the geothermal energy is sustainable. The geological settings of these low temperature geothermal fields, their size and boundaries are described. Extensive monitoring programme of the exploitation has been carried out for the last decades and records have been kept on fluid production, fluid temperature, water level variation and fluid chemistry. The field data has been incorporated into numerical simulation models, which are used to predict changes in waterlevel and chemistry.

1. INTRODUCTION

Geothermal energy plays a crucial role in Iceland's energy economy. The dominant use is for space heating where almost 90 % of the houses are heated with geothermal water. The first district heating utility was in Reykjavik, which commenced operation in 1930. It is probably still the world's largest district heating system using geothermal water, serving the homes of about 157,000 people. The heating utility provides geothermal water not only for homes but also for commercial and industrial buildings in its area.

Four geothermal fields are exploited for district heating in Reykjavik: Laugarnes, Ellidaar, Reykir and Nesjavellir (Gunnlaugsson et al, 2000). The last one is a high-temperature area but the others are of the low-temperature type. This paper will be dealing with the three low-temperature fields.

2. GEOLOGY AND HYDROLOGY

The low-temperature geothermal areas in Iceland, characterized by water not exceeding 150°C in the uppermost 1 km, are situated in Plio-Pleistocene and Tertiary rock formations outside the main volcanic zones. The geothermal water in Iceland is mainly of meteoric origin and high pH and most often low content of dissolved solids characterize the low-temperature water. Two main hypotheses have been proposed to explain the flow path of the water and their heat source. The first was proposed by Einarsson (1942) which assumed that the precipitation falling in the highlands seeps down to deep levels in the crust where it is heated by elevated geothermal gradient. It returns to the surface through permeable structures in lowland areas. The second hypothesis (Bödvarsson, 1982, 1983) proposed that groundwater flow could also be at shallow level and percolate to deep levels along near-vertical fracture systems where it is heated locally by the hot crust before it returns to the surface.

Figure 1 shows the location of the geothermal fields utilized for district heating in Reykjavik. Three extinct central volcanos are located in the area with low temperature geothermal areas, characterized by high-grade alteration indicating former high-temperature areas. Fractures and faults with SW-NE direction cut through the area. Hot bedrock in these fissure swarms has initially caused convection. The low-temperature fields are located near junctions of the fissure swarm and the old caldera. The Laugarnes and Ellidaar fields lie close together but appear to be separated by hydrological barriers. Production in one field does not affect the groundwater level in the other and chemistry, isotopic compositions and temperature of the water differ between these areas. The northern end of the fissure swarm extends beyond the volcanic zone towards the Reykir geothermal field.

3. EXPLOITATION AND MONITORING

Extensive monitoring programme of the exploitation has been carried out for the last decades and records have been kept on water production, temperature, water level variation and fluid chemistry. The data has been incorporated into numerical simulation models, which are used to predict changes in waterlevel and chemistry.

3.1 The Laugarnes field

The exploitation of geothermal water from the Laugarnes field began in 1928-1930 with drilling of 14 shallow wells near the Þvottalaugar thermal springs. The deepest well was 246 m deep and the well field delivered 14 l/s of artesian water at a temperature of 87°C. This water was used for heating of schoolhouses, hospital, swimming pools and about 60 residential houses.

In 1958 further drilling in the Laugarnes area commenced with a new type of rotary drilling rig, which was able to drill deeper and wider wells than previously. Deepwell pumps pumped the

water from the wells, whereas the water previously extracted in the area had been free artesian flow from the wells. The yield increased to 330 l/s of 125 to 130°C water.

Now there are 10 production wells in the field, which covers about 0.28 km^2 and is located at a junction of a caldera and a fault-scarp. The temperature is 110 to 125°C at 400 to 500 m depth and increases with depth. The highest measured temperature is 163 °C at 2700 m depth. The main aquifers are at 1000 to 2000 m depth.

Prior to exploitation the hydrostatic pressure at the surface in the geothermal field was 6-7 bars corresponding to a free water level 60-70 m above the land surface. Exploitation has caused pressure drop in the field and water level has fallen (Figure 2). Consequently fresh and slightly saline groundwater has flown into the pressure depression and mixed with the thermal water. Slight decrease in silica and fluoride and in some wells also increase in chloride concentration were noticed but without changes in the fluid temperature. The mixing of different water types resulted in disequilibrium of calcite and formation of that mineral. Reduced pumping after 1990 has reduced the pressure drop and the mixing of groundwater.

3.2 The Reykir area

Prior to drilling in the Reykir area the artesian flow of thermal springs was estimated to be about 120 l/s of 70-83°C water. After drilling the water from this area was piped to Reykjavik and by the end of 1943 about 200 l/s of 86°C water were available for heating houses in Reykjavik.

After 1970 the deep rotary drilling of large diameter wells and installing pumps redeveloped the Reykir field. The yield from these wells was up to 2000 l/s of 85-100°C water.

The geothermal field, which is about 5.5 km^2, is geographically divided into sub-areas, Reykir and Reykjahlid. It is located between two calderas and the stratigraphy consists of lavas and hyaloclastite layers cut by numerous faults and fractures. Altogether 34 exploitation wells are in the field. The temperature is in the range of 65 – 100 °C.

Aquifers can be correlated to faults and fractures. Annual variation in production is reflected in the water level (Figure 3). The water level was steadily decreasing until 1990 when it became possible to reduce pumping from the field when a new power plant at Nesjavellir started operation. Immediately after the reduction of production the pressure built up and the water level rose again. Changes in chemistry and temperature of the fluid were only observed on the southeastern boundary of the field.

3.3 The Ellidaar field

The Ellidaar field had minor surface manifestations before drilling with maximum temperature of 25°C. Drilling began in the area in 1967 finding aquifers with 85-110°C. The exploitation area covers 0.08 km^2 but the manifestations cover 8 – 10 km^2. When exploitation started in the area the temperature was in the range of 95-110 °C. Production from the field caused pressure drop (Figure 4) and consequently cooling of the field. Cold groundwater from the surrounding mixed with the thermal water, reduced the temperature and affected the chemistry of the water by diluting the silica and the fluoride concentration (Figure 5). Reduction of production in 1990 resulted immediately in higher waterlevel in the area and decreasing of mixing with cold water.

4. SIMULATION

Two-dimensional simulation models of the geothermal areas have been developed. Individual model for the Ellidaar field was developed in 1982 followed by the Reykir field and Laugarnes field in 1985 and 1986 respectively. These models have now been merged in one model taking into account the geological structure and exploitation history of all the fields. The model is used to predict changes in reservoir pressure and waterlevel, cooling and changes in chemistry. Figure 6 shows an example of simulation of waterlevel in Reykir field and prediction of changes for next five years.

5. CONCLUSION

Utilization of geothermal activity for heating in Reykjavik began on small scale 70 years ago and has developed since. Monitoring of the thermal fields which are still in use have indicated overexploitation during some period of time. With reduction of production equilibrium between production and pressure decline has been reached indicating the sustainability of the energy source.

6. REFERENCES

Bödvarsson, G., (1982). Glaciation and geothermal processes in Iceland. Jökull. Vol. 32, pp. 21-28.

Bödvarsson, G., (1983). Temperature/flow statistics and thermo-mechanisms of low-temperature geothermal systems in Iceland. Journal of Volcanological and Geothermal Research. Vol. 19. pp. 255-280.

Einarsson, T., (1942). Über das Wesen der heissen Quellen Islands, Visindafélag Islendinga, No. 26, 91 pp.

Gunnlaugsson E., Frimannson, F. and Sverrisson, G.A., (2000). District heating in Reykjavik. – 70 years experience. (this issue).

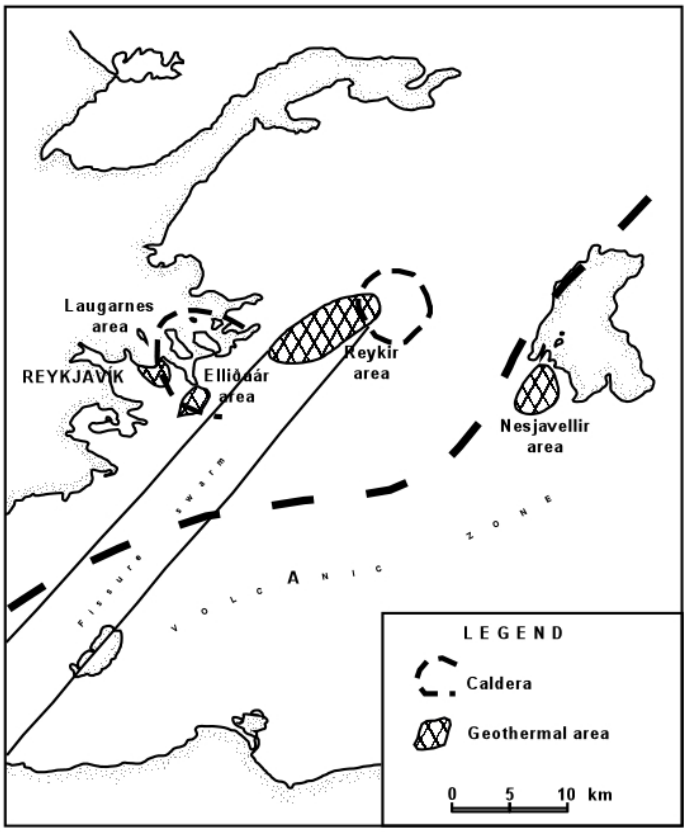

Figure 1. Location of geothermal fields utilized for district heating in Reykjavik.

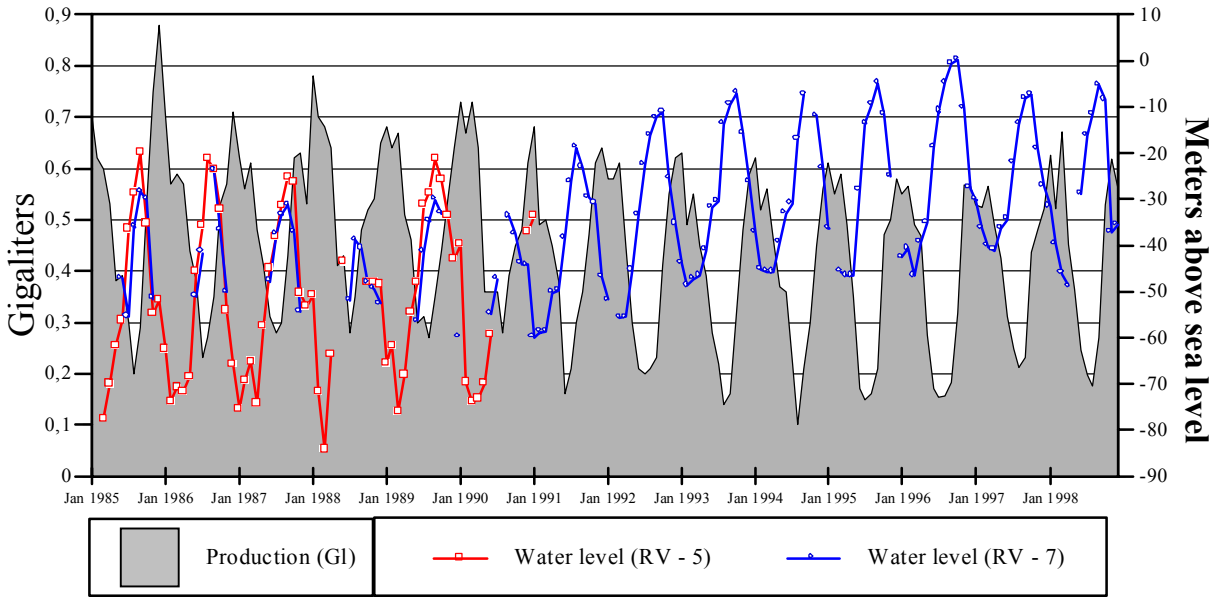

Figure 2. Production and water level at Laugarnes geothermal field

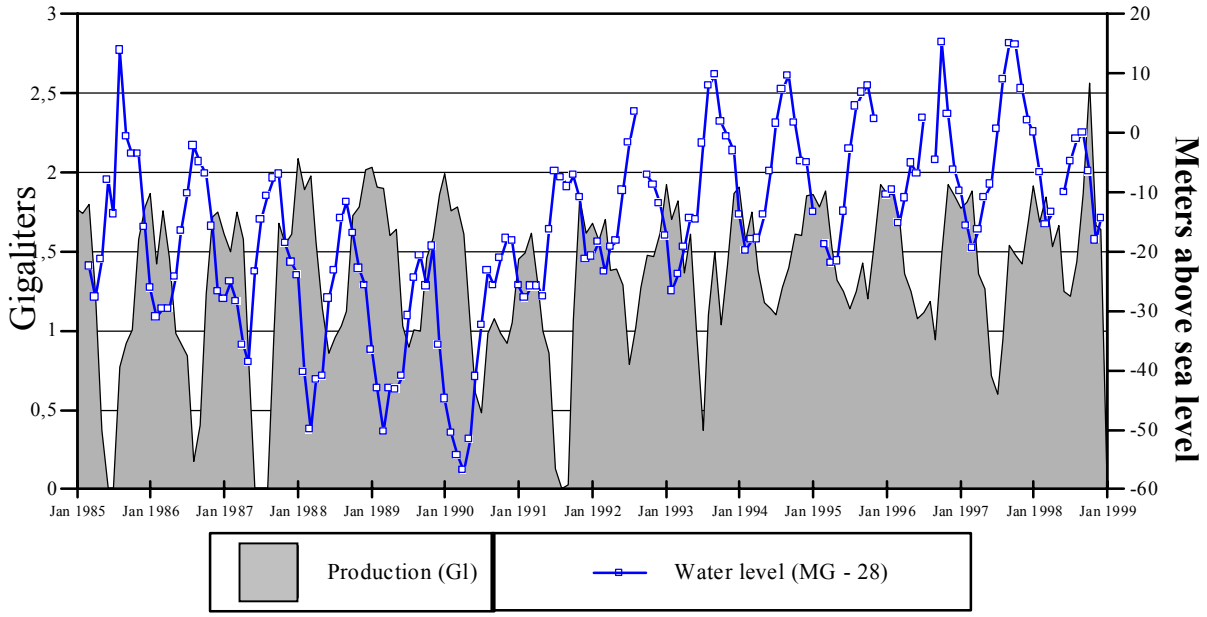

Figure 3. Production and water level at Reykir geothermal field.

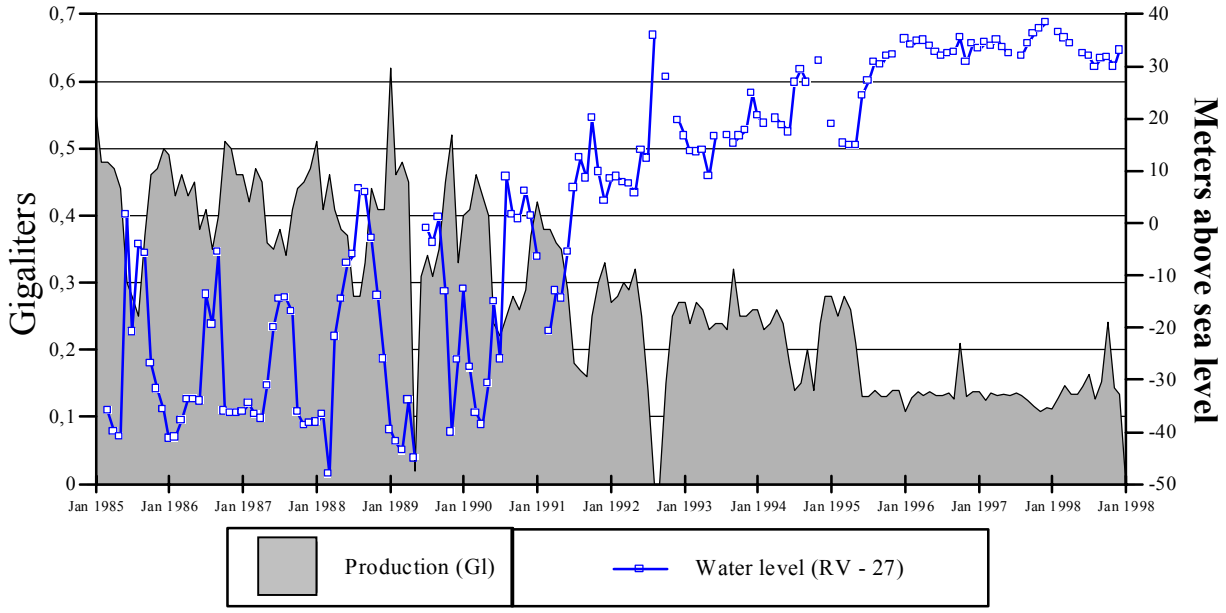

Figure 4. Production and water level at Ellidaar geothermal field.

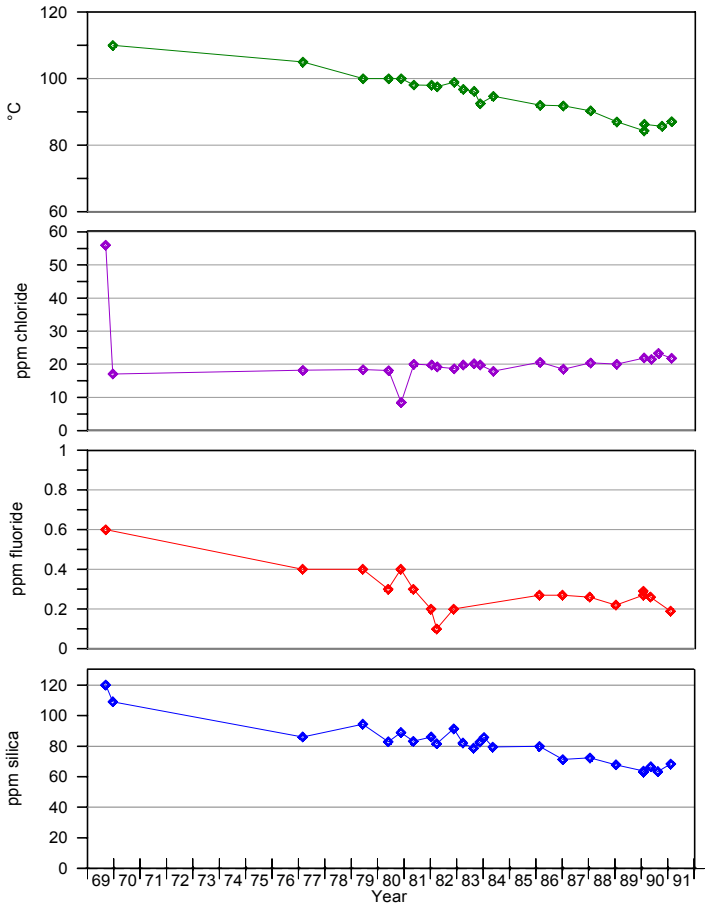

Figure 5. Changes intemperature, and chloride, fluoride and silica concentration for well RV-30 at Ellidaar.

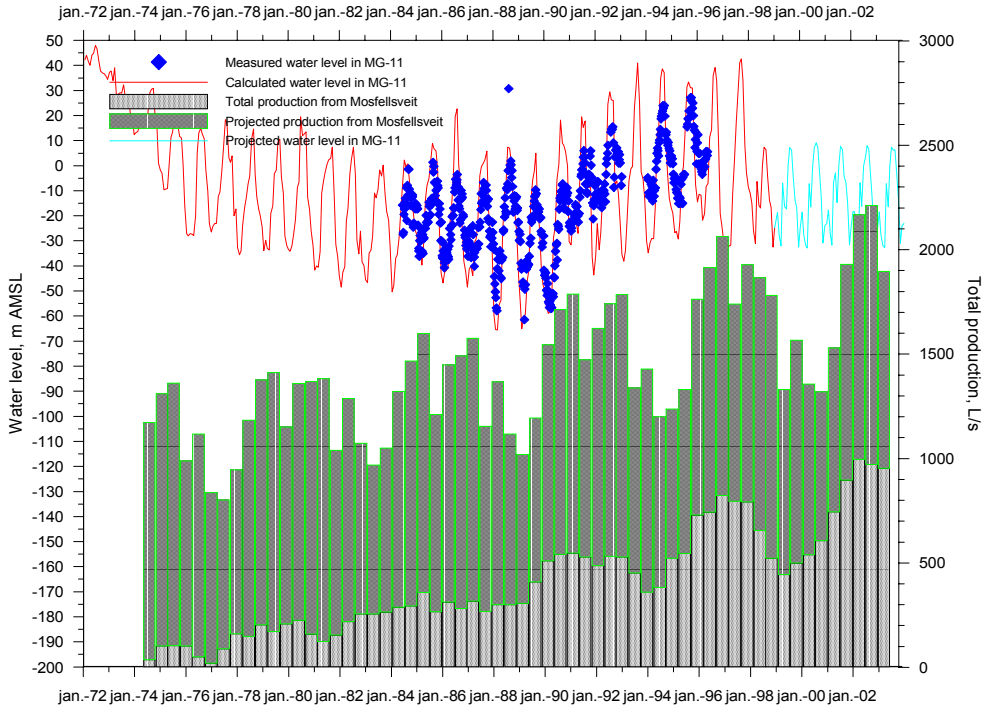

Figure 6. Changes in water level at Reykir, and predicted changes for next five years