

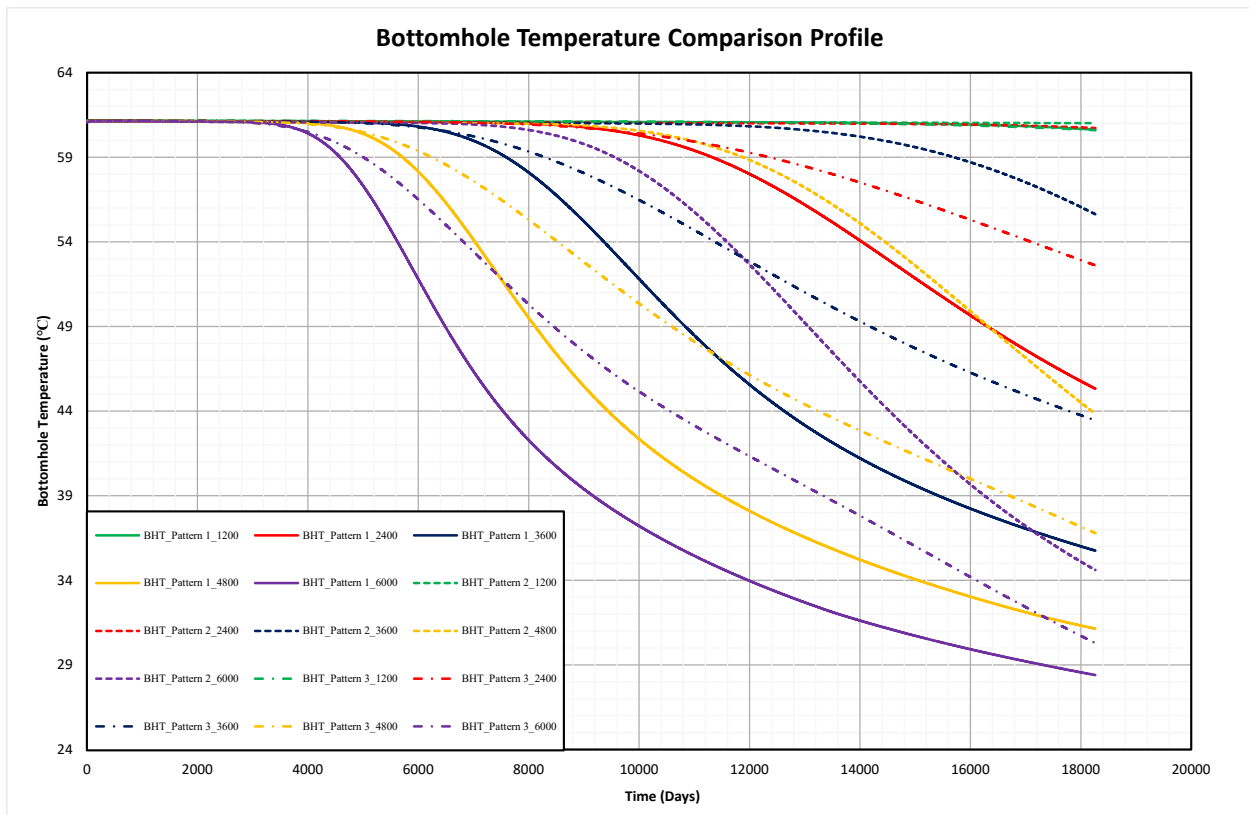
## Exploitation of Geothermal Reservoir in Regina Area by Designing and Optimizing Multiple-well Arrangements

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### Summary

Considering the limited sources of fossil fuels and the goal of achieving net zero carbon emissions by 2050 (IEA, 2023), humanity needs to develop new methods and technologies to meet energy demands. Therefore, renewable energy, namely geothermal, solar, wind, etc., has significant opportunities in these circumstances. In contrast to solar or wind, geothermal provides a constant, reliable and more efficient energy source, regardless of the weather conditions. However, fully understanding the characteristics of geothermal reservoirs, the thermal coupling mechanisms, and how to extract energy efficiently and economically from the resources have always been challenges in geothermal reservoir development. The aims of this paper are not only to evaluate the performance of different types of multiple-well configurations for industry operational scale effective geothermal energy extraction from a low-temperature geothermal reservoir in Regina Area (Jessop and Vigrass 1989), but also have a better understanding of the thermal coupling mechanisms of multiple-well patterns. A detailed reservoir model is constructed with horizontal dimension of 1 mile by 1 mile and vertical targeted thickness of 2111m (Brunskill, Dale, and Vigrass 2019). With three types of multiple-well configurations, two-spot, regular five-spot and regular nine-spot, including various operation rates, the bottomhole temperature and energy extraction for the geothermal reservoir were simulated and analyzed. Moreover, the sensitive analysis of grid direction, the thickness of the basement layer under the geothermal reservoir, and the thermal conductivity of the reservoir fluid and reservoir rock are also being investigated.

The bottomhole temperature profiles among three types of multiple-well patterns with various operation rates are presented in Figure 1. The bottomhole temperature increases slightly at the beginning of the production period, and then, as the injected cold water reaches the production well, the bottomhole temperature decreases. So, a turning point can be investigated from the bottomhole temperature curves; this point also helps us indicate the thermal breakthrough phenomenon.



**Figure 1. Bottomhole Temperature (BHT) profile, under three multiple-well patterns with same rate at 10 °C, with temperature gradient is 24.76 °C/km, with surface temperature 10 °C,  $T_i=60.634^{\circ}\text{C}$ .**

### Theory / Method / Workflow

The reservoir models were built using CMG Builder, and STARS simulator was used to conduct the simulation study (CMG, 2023). The geology model is 1 mile by 1 mile in horizontal direction, and the total depth of this model targets at 2111m. A geothermal reservoir is at a depth of 2000m, and the net interval of this geothermal reservoir is 111m. There is a rock layer over this geothermal reservoir, and the thickness of this rock layer is 2000m. This geothermal reservoir's boundary condition is assumed to be a closed boundary with no heat and fluid flow to generate a conservative scenario. Another simulation software, COMSOL multiphysics (COMSOL multiphysics V6.1, 2023), also was used for the simulation study. The parameters and values of the reservoir model built from COMSOL multiphysics are the same as those in CMG. The boundary conditions in COMSOL multiphysics is also assumed to be a closed boundary with no heat and fluid flow.

### Results, Observations, Conclusions

Compared with the different operation rates for the same multiple-well pattern, the larger the operation rate, the faster and more the bottomhole temperature drops, because the injected cold water flows faster and takes less time to reach the production well with a larger amount under

higher operation rate. And comparing the three types of multiple-well patterns at the same operation rate, i.e., the same total injection and production rate, the regular five-spot provides the highest bottomhole temperature. In the two-spot and regular five-spot patterns, the distance between the production well and the injection well is postulated the same. Heat transfer is taking place in more flooded areas due to the addition of more injection wells in regular five-spot, so that the corresponding bottomhole temperature is higher in the regular five-spot pattern. Moreover, the bottomhole temperature of the regular nine-spot is lower than that of regular five-spot. The reason is that there are always four injection wells that are relatively closer to the production wells under the condition of the same coverage area compared with regular five-spot. Therefore, by comparing the temperature of three types of multiple-well configuration, the regular five-spot could provide the highest bottomhole temperature for the geothermal development.

### Novel/Additive Information

Many research efforts have focused on the development of geothermal reservoirs. However, at present, there is only a few applications for geothermal reservoirs in Canada. There is currently no electricity being generated from geothermal reservoir in Canada (Grasby et al. 2011), even though Canada is one of the major countries in the Pacific Ring. Geothermal reservoirs, especially the low- and medium-temperature geothermal resources, are considered as a marginal resource, which needs to be developed more efficiently and economically with technical support. The thermal coupling mechanisms for various multiple-well patterns need to be fully understood and investigated, and this can be challenging as geothermal reservoir heterogeneity is encountered. However, most research focuses on geothermal recovery using closed-loop well which have both advantages and disadvantages, investigate the effect of the distance between injection well and production well, and few research focuses on the multiple-well patterns with industry operational scale for effective geothermal energy extraction in geothermal resource development (Chong, Wang, and Gates 2021; Jiang et al. 2016; Liu et al. 2022; Zhang et al. 2021).

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