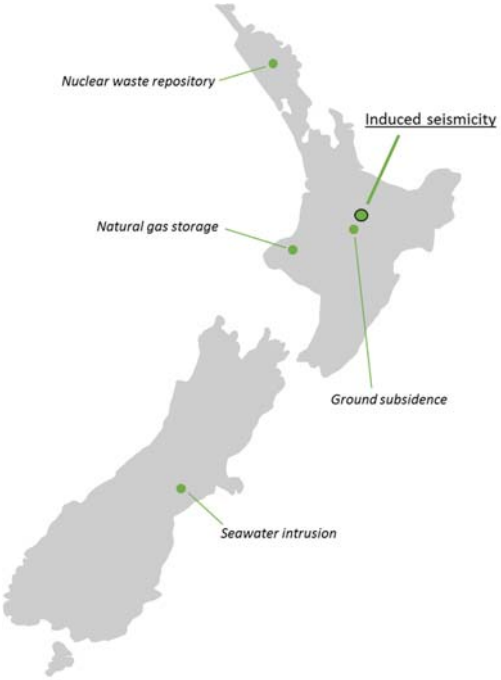
Induced seismicity at Ngatamariki geothermal field



Induced seismicity refers to earthquakes that are triggered by human-engineering activities. In the operation of a geothermal field, these will occur either as a result of reinjection of exhaust water from the power plant or wellbore stimulation. The intent of the latter is to create new pathways for fluid to flow underground, i.e., increase the size of a reservoir.

Induced earthquakes have not generally been large enough to cause concerns in New Zealand (most people won't notice events M<2.5, and won't worry about events M<4.0). This is in part due to the small scale of well stimulations in New Zealand, however, were these to increase, the problem could become more severe.

Recently, Mercury NZ Ltd., operator of the Ngatamariki geothermal power station, have been investigating wellbore stimulations with cold river water. They have detected about one hundred earthquakes associated with the most recent operation, a 35 day stimulation in which water was injected at up to 175 t/hr. The largest event was an M 2.1. Earthquake magnitudes are observed to scale according to a power law: if 100 events are triggered and the largest is a M 2, then if we were to trigger another 1000 events, we should expect the largest to be an M 3 (and the largest of 10 000 events an M 4, and so on).

Mercury have applied to the Waikato Regional Council (WRC) for resource consent to expand the size of the Ngatamariki geothermal field through a prolonged campaign of cold water stimulation. They propose to increase the present injection rate up to 250 t/hr and to maintain this for 6 months. This will undoubtedly trigger further earthquakes in the field. However, since Ngatamariki geothermal field is reasonably remote, nobody cares awfully much, except for one farmer who alleges his stock have been disturbed by the earthquakes. He opposes the consent vigorously. The consent is supported by Ngāti Tahu, who have a 35% stake in the geothermal plant. The WRC have indicated that consent is unlikely to be granted if the projected seismicity is likely to exceed a maximum value of M 4.5.

You have been retained by the applicant to undertake a computer modelling study of induced seismicity at Ngatamariki. To support your study, you have been provided the following data:

- Injection rates during the initial 35 day stimulation.
- Pressure changes in the reservoir during the stimulation.
- The total number of earthquakes triggered during the stimulation.

Project expectations:

You should undertake a computer modelling study that will assist the applicant in their resource consent application, in particular addressing the noted concerns of other stakeholders where they are relevant to the study. The model you develop should be defensible, reflective of reality, and take appropriate account of uncertainty. You will be required to communicate the model findings in both oral and written formats.

Recommended literature:

On the recent stimulation and seismicity at Ngatamariki.

Hopp, C, S Sewell, S Mroczek, M Savage, J Townend, (2019). Seismic response to injection well stimulation in a high-temperature, high-permeability reservoir. *Geochem, Geophys, Geosys.*

For a model linking fluid pressure to earthquake rate (see Section 2.3.4)

Dempsey D, J Riffault, (2019). Response of Induced Seismicity to Injection Rate Reduction: Models of Delay, Decay, Quiescence, Recovery, and Oklahoma. *Water Resour Res,* 55, doi: 10.1029/2018WR023587.

For a model of fluid pressure changes in a geothermal system due to mass changes (see Eq 15).

Fradkin, L. J., M L. Sorey, A. McNabb (1981), On Identification and Validation of Some Geothermal Models, *Water Resour Res,* 17: 929-936.