**Bay of Plenty Regional Council**

**Community Report on the Sustainable Management of the Kawerau Geothermal System**

**Based on 2017 Annual Reports (reported in May 2018)**

## *Background*

Bay of Plenty Regional Council (BOPRC) manages the Kawerau Geothermal System under the Resource Management Act 1991, through resource consents for the taking of geothermal water and heat, and geothermal discharges. Council is assisted in this role by an impartial Peer Review Panel, consisting of three independent technical experts.

In part fulfilment of its responsibilities for sustainable management of the Kawerau Geothermal System, and implementation of the Kawerau System Management Plan, the Council has undertaken to report annually to elected members and the community on the overall state of the Kawerau Geothermal System. This is the first report and for this reason includes some background information on the characteristics and behaviour of the geothermal system to better inform readers.

Detailed information on the Kawerau Geothermal System and its management can be found in the Kawerau System Management Plan on Council's website https://www.boprc.govt.nz.

### *Scope*

The report is based upon consolidation of data reported by all Consent Holders in their 2017 Annual Reports, which cover activities from 1 January to 31 December 2017, and were presented to Council in May 2018. It covers activities undertaken by the Consent Holders, changes to the reservoir, environmental effects and model development.

### *Geothermal Takes from the Kawerau Geothermal System*

Three Consent Holders, Mercury, Ngati Tuwharetoa Geothermal Assets (NTGA) and Geothermal Developments Limited (GDL), together extracted a total of around 43 million tonnes[1] of geothermal fluid from the Kawerau reservoir during 2017, which equates to a total average daily take of around 117,000 tonnes. The total consented take for all Consent Holders (including Te Ahi o Māui Limited Partnership (TAOM)) is 174,680 tonnes per day.

The total amount extracted from the reservoir for 2017 was in compliance with that specified in consents.

[1] 1 tonne ~ 1000 litres

## *Summary of Trends in the Reservoir*

### *Trends in Pressure*

When is extracted from a geothermal reservoir changes occur, including changes in pressure. Results from pressure tests and long-term reservoir pressure monitoring conducted in Kawerau wells show that the reservoir is highly permeable[2] and interconnected both horizontally and vertically. In 2017 the pressure drops field wide were comparable to recent years and well within modelled limits. The amount of geothermal extracted is offset to some extent by injection which provides pressure support for the reservoir and also natural recharge from various sources. Of the total amount of fluid extracted from the Kawerau reservoir during 2017, about 60% was returned to the reservoir via reinjection. The other 40% was discharged to atmosphere from power stations and directly to the Tarawera River.

### *Trends in Enthalpy*

The discharge enthalpies[3] of the individual production wells in Kawerau are mainly a function of the temperature of the reservoir encountered by the wells. It has been noted that the average enthalpy of taken by the Kawerau production wells has declined by some 0.75% per year since 2010. Importantly, the discharge enthalpy trends during 2017 were mostly as predicted by the current numerical reservoir model, with a number of wells showing stable conditions. In a small number of wells, enthalpies have declined at a higher rate and the reasons for this are being addressed by the Consent Holders by developing both short and long term strategies to mitigate the decline.

### *Trends in Chemistry*

When ground waters descend deep into the ground they become heated. This is especially so in the Kawerau area since the thermal gradients are very high (perhaps 100$^{o}$C per kilometre of depth). The hot water dissolves minerals in the rocks to produce reservoir fluids. At Kawerau these are low salinity[4] hot fluids with temperatures as high as 300$^{o}$C. These fluids enter the production wells at depths of up to 2km and flow to the surface where the steam and water are separated off to produce power and process steam for geothermal direct use. The separated geothermal fluids (most of which is reinjected back to the reservoir) becomes enriched in the dissolved minerals. By sampling and analysing these fluids we can learn a lot about the chemistry both at depth in the reservoir and at the surface which is an important part of geothermal field management.

The production wells are sampled and analysed four times a year while the reinjection well chemistry is analysed every 6 months. Processes of particular interest include the scaling potential of the fluids at the surface and in the reinjection wells and the fluid interactions occurring in the reservoir, particularly how reinjection and other sources of recharge (hot upflow, groundwater or inflows from the margins of the field) are affecting the reservoir and the production wells.

[2] Permeability is a measure of the ability of the reservoir rock to transmit fluids.

[3] Enthalpy is the sum of internal energy and work done by applied pressure. In a constant pressure system it can be viewed as "heat content". Work performed by a turbine, for example, equates approximately to the change in fluid enthalpy.

[4] Salinity is the saltiness or amount of salt dissolved in a body of water.

The chemical monitoring to date has shown that individual production wells are affected to varying degrees by the different sources of recharge and the major effect of this is the noted 0.75% average drop in enthalpy.

***Strategies to Manage Reservoir Recharge***

A major goal of reservoir management in Kawerau is to ensure that recharge is managed to ensure the long term sustainability of the system. Current strategies include:

a. Injecting the relatively cool separated geothermal fluid deep and along the edge of the reservoir.
b. To spread out production and distribute the pressure drawdown regions.
c. Maintaining the reinjection temperatures as high as possible.
d. Managing the effects of mixing reinjected fluids with both reservoir fluids and groundwater to mitigate enthalpy decline.

***Monitoring of Impacts on Groundwater***

Groundwater above the geothermal reservoir is monitored by means of a network of shallow bores in order to assess the potential effects of fluid extraction (and injection) on groundwater quality over time. The program includes continuous temperature and water level measurements and 6 monthly or yearly sampling for chemical analysis to determine whether the geothermal component of the groundwater is changing. Although there is variation in how the shallow bores are responding across the field, only relatively minor physical and chemical changes are reported for 2017 and are of no real concern as they reflect processes expected for a development system. Groundwater level changes were due mainly to variations in rainfall and changes to the level of the Tarawera River while temperatures remained relatively stable, with changes of less than 1°C.

***Monitoring of Surface Thermal Features and Vegetation***

Surface thermal features are monitored at Kawerau once every two years. They include hot pools, fumaroles[5], heated ground and seeps. Monitoring includes photographic surveys and temperature measurements and in 2017 indicates that at least one of the features is continuing the trend of waning over time.

Geothermal vegetation in the Parimahana Reserve was surveyed February and September 2017 and all results were normal for the area.

***Subsidence***

Extraction of fluid from New Zealand geothermal systems usually results in downward movement of the ground surface above the reservoir (subsidence). With the Kawerau field containing industrial equipment which is sensitive to subsidence, particularly when it is tilted Consent Holders are required to carry out surveys yearly.

Past surveys have shown a relatively large bowl of slowly subsiding ground above the reservoir. Within this bowl are four localised areas (with the fourth first identified in 2016) within which the ground is subsiding at higher yet still relatively modest rates. The 2017 survey indicates that tilt rates have decreased since previous surveys.

[5] an opening in geothermal ground which emits steam and gases

***Field Development***

Infrastructure for the development of the TAOM Power Station has been completed along with the drilling of two productions wells. None of the other users drilled new wells in the reporting period with only maintenance activities carried out on their current assets.

***Numerical Reservoir Modelling***

As of 15 March 2018, the Peer Review Panel (PRP) provided an interim report to Council approving the Kawerau Reservoir Model v3 (KRMv3) as the official replacement for the Holt model for the purpose of scenario forecasting. As stated in the report, full documentation relating to the review will follow once completed by the PRP. The new model will allow better sustainable management of the system, as it contains a greater range of data and a better ability to process the data.

The PRP also recommend "that, as a matter of priority, the Mercury model KRMv3 2015_07_17 be updated to reflect the additional production/injection history since 2014 and to include available data for the TAOM, Mercury and NTGA wells drilled since the Mercury model was developed".

***Key Recommendations of the PRP and Actions Required of Consent Holders***

Integration of data both in terms of downhole geology/geochemistry and baseline survey (subsidence and groundwater) from the TAOM area into the Kawerau Reservoir Model and field wide survey sets needs to be progressed before production from the TAOM program is initiated. Incorporating this data will ensure that sustainable management of the field as a whole is based on robust scientific processes. A whole system approach (as required by the System Management Plan) can also be better achieved from an annual report being submitted for the 2018 reporting period that contains data from all Consent Holders. This would extend on the joint presentation from Mercury/NTGA that was successfully introduced for the 2017 reporting period.

The PRP requested a detailed discussion concerning the potential for ongoing marginal recharge and associated cooling effects, particularly within the context of increased extraction rates. The PRP also requested pressure and enthalpy forecasts; the need to mitigate the enthalpy changes or not and if so the options available and likely timeframe for doing so. The PRP noted its view that the approach to mitigation of reservoir cooling and injection strategy generally should be supported by computer-based reservoir modelling (also termed reservoir simulation).

The Kawerau Geothermal System is the only geothermal field in New Zealand where there are three (soon to be four) different Consent Holders who are drawing and discharging geothermal fluids from the same resource. It is therefore critical that all four Consent Holders operate under a common System Management Plan, particularly as TAOM is in the final stages of commissioning their operation. The PRP acknowledges the various challenges in addressing these issues and that the overall field strategy is a 'work in progress'. In this regard, the PRP wishes to emphasise the importance of a coherent field wide injection strategy that is supported by reservoir simulation and requests that it be kept informed of developments.