Bay of Plenty Regional Council

Community Report on the Sustainable Management of the Kawerau Geothermal System

Based on 2016 Annual Reports (reported in May 2017)

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 independent Peer Review Panel, consisting of three 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 2016 Annual Reports, which cover activities from 1 January to 31 December 2016, and were presented to Council in May 2017. 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 (formerly Mighty River Power) Ngati Tuwharetoa Geothermal Assets (NTGA) and Geothermal Developments Limited (GDL) together extracted a total of around 40 million tonnes[1] of geothermal fluid from the Kawerau reservoir during 2016, which equates to a total average daily take of around 109,000 tonnes and were in all cases in compliance with respective conditions of consent.. The total consented take for these Consent Holders (and te Ahi o Māui) is 174,680 tonnes per day.

The Role of Modelling In Management Computer modelling is the most advanced tool currently available for management of the reservoir. Numerical reservoir models, calibrated using key reservoir data, are used to gain an understanding as to how the reservoir is likely to respond to extraction and to evaluate potential reservoir responses to various extraction/injection strategies including adaptive management. This is done through periodic comparison of reservoir model predictions with measured changes in the reservoir that are obtained through monitoring programmes required in consents. A significant difference between what is predicted and what is observed serves as an alert that the model may need reviewing, or that, that an adaptive management response might be required or that changes to consented activities are needed.

[1] 1 tonne = 1000 litres

Summary of trends in the reservoir

Changes to Reservoir Pressure, Reservoir Temperature and Discharge Enthalpy

When fluid is extracted from a geothermal reservoir certain changes occur, the most immediate being a fall in pressure. Results for pressure tests conducted in Kawerau wells show that the reservoir is highly permeable[2] and well interconnected both laterally and vertically.

To date the fall in pressure within the Kawerau reservoir has been modest (of the order of 5 - 6 bar since 2008 when the KGL power station was commissioned. This is much less than pressure drops reported for some other New Zealand reservoirs, such as Wairakei. Monitoring data for recent years show that pressures in some reservoir monitor wells are approaching stability. The magnitude and trend of the pressure drop are in line with those predicted by numerical reservoir modelling.

The amount of geothermal fluid extracted is offset to some extent by injection which provides pressure support for the reservoir. Of the total amount of fluid extracted from the Kawerau reservoir during 2016, approximately 24.4 million tonnes, or about 63%, was returned to the reservoir. Of this amount an estimated 78% was injected deep, the remainder at depths of 300-400m, above the producing reservoir. The balance of rejected fluid was discharged to atmosphere from power stations and to the Tarawera River.

Injection of cooled geothermal fluid supplements the entry of cool water at the reservoir margins. Hot fluid entering at the base of the reservoir is believed to also contribute to recharge of the reservoir. Hence, an important goal of reservoir management at Kawerau is to ensure that recharge is managed in a manner that avoids higher than desirable rates of reservoir cooling.

The decrease in reservoir pressure at Kawerau has been accompanied by changes in reservoir fluid temperature which is estimated from chemistry of the fluid. Temperatures estimated in this way are generally consistent with periodic direct measurements of fluid temperature in the wells. Kawerau reservoir fluid temperatures estimated this way indicate that temperatures within the deep reservoir have cooled by an average of some 5 – 10^{0}C over the past 7 years. The decline in reservoir fluid temperature is reflected in changes to the enthalpy[3] of geothermal fluids discharged from production wells. Average enthalpy of fluid tapped by the Kawerau production wells has declined by some 1.5% per year.

Importantly, the discharge enthalpy trends, which continued during 2016, were largely as predicted by the current numerical reservoir model.

[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 equates approximately to change in fluid enthalpy.

Strategies to manage reservoir recharge

As mentioned above, a goal of reservoir management is to ensure that recharge is managed to ensure the long term sustainability of extraction. Current strategies include injecting the relatively cool geothermal water deep and close to the periphery of the reservoir in order to limit the entry of marginal fluid and to provide a less direct route for the return of injected water to the production wells, whilst providing pressure support for the reservoir. Spreading injection along the periphery reduces the risk that the injected cool fluid will find its way back to production wells too quickly and increases the efficiency with which heat is mined from the reservoir host rock. Potential effects of shallow colder fluids entering the field at the margins are likely mitigated by ensuring that the temperature of fluid injected into shallow in-field injection wells is kept as high as possible.

Trends in reservoir fluid chemistry

Processes that occur within the reservoir in response to fluid extraction, such as recharge by marginal fluid and injected reservoir brine, influence over time the chemical composition of the reservoir fluid discharged by the production wells. Knowledge of these chemical signatures (for example dilution in the case of marginal recharge and increased concentrations of chemicals such as chloride in the case of injected fluid) assists interpretation of reservoir processes. An understanding of reservoir processes is particularly important in situations where an adaptive management response is required to address an unanticipated reservoir response to extraction such as rapid cooling of the reservoir. Data for 2016 indicate a continuation of past trends. Whilst they vary across the field they are in general, consistent with marginal recharge, the return of injected brine to the production wells or a combination of the two.

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. Most are located within that part of the field where shallow injection occurs. Relatively minor physical and chemical changes reported for 2016 are of no concern. The chemical changes have been interpreted to reflect the effects of shallow injection and marginal recharge In this regard, it is noted that some of the shallow groundwater wells are to some extent influenced naturally by geothermal fluids present within the system. Groundwater level changes were due mainly to variations in rainfall and changes to the level of the Tarawera River.

Surface Thermal Features

Twenty-eight surface thermal features are monitored at Kawerau on a two yearly basis. They include hot pools, fumaroles, heated ground and seeps. Monitoring includes photographic surveys and temperature measurements. Whilst temperatures reported for some features in 2016 were higher and for others lower compared with those for the previous survey, they were nevertheless within historic ranges for these features. In some cases the variations were attributed to non-geothermal factors such as changes to river levels.

Two of the twenty eight thermal features monitored are non-flowing pools which are monitored six monthly for water chemistry and temperature. Both features have undergone temperature and chemical changes over a period of several years. It is considered possible that these changes reflect a reduction in the contribution of deep reservoir fluid to these features. Results for future monitoring should confirm or otherwise this pattern of activity.

Geothermal vegetation in the Parimahana Reserve is surveyed two yearly. The survey includes measurement of soil temperatures for two monitored plots as wells as vegetation mapping. Results for the 2016 surveys confirmed cooler average (by about 10^{0}C) soil temperatures than those reported for the previous survey (2014). They were not however, significantly different from measurements reported for earlier surveys. Temperatures measured at a depth of 1m within the same two plots were mostly similar to those measured in 2014.

The extent of geothermal vegetation within the reserve remained unchanged although changes in the height of geothermal kanuka were observed. It is considered possible that these changes relate to changes in soil temperature. Longer term monitoring should confirm any trends and their possible cause(s).

Subsidence

Extraction of fluid from New Zealand geothermal systems has usually resulted in downward movement of the ground surface above the reservoir and in some cases surrounding ground, due to changes in reservoir pressure and temperature of the reservoir rock. At Kawerau ground subsidence to date has been relatively modest. That said the Kawerau field hosts industrial plant which is sensitive to subsidence, particularly when it is non uniform (tilt).

Changes to ground levels within the Kawerau geothermal field and surrounding area are determined by measuring ground elevations at fixed locations (called benchmarks) in relation to a reference location which is beyond the area influenced by geothermal operations. Rates of ground subsidence are arrived at by comparing repeat elevation measurements for benchmarks within the network. Past surveys have shown a relatively large area of slowly subsiding ground above the reservoir. Within this broad area are four localised areas within which the ground is subsiding at higher yet still relatively modest rates. Data from the 2016 survey when compared with the 2015 survey data indicate lower rates of subsidence within most of these localised subsidence bowls compared with those reported for the previous surveys. The location of the maximum rate of subsidence at Kawerau has changed from year to year. The maximum rate reported for 2015-2016 was about 20% less than that for the previous period. Reported rates of tilt were slightly higher for some of these bowls and less for others.

A new localised area of subsidence was reported for the 2015-2016 levelling survey some 300m east of production well KA30, west of Spencer Avenue. It is possible that this area of recent subsidence reflects in part, localised cooling of the reservoir and its extent needs to be better understood.

Field Development

During 2016 access roads and well pads were constructed for two production wells, KGL’s KA56 and NTGA’s KA54 and one injection well, KGL’s KA55, all of which were successfully completed during the year. TAOM, the most recent operator on the Kawerau field was also active during 2016. Civil works for production and injection well pads were completed, together with bulk earthworks for the consent holder’s planned power station. Three wells, production well TP-1 and injection wells TI-1 and TI-2 were completed during the reporting period.

Numerical Reservoir Modelling

The Council approved numerical reservoir model is known as the Holt model (2012). Since it was approved a number of additional production and injection wells have been drilled. Data for these wells, particularly injection wells drilled along the periphery of the field, together with responses of certain production wells to extraction, have improved conceptual understanding of the reservoir.

On 22 November 2016, Mercury advised Council that it had, in conjunction with Dr John Burnell of GNS, developed a new numerical reservoir model for Kawerau. Mercury has requested that Council adopt this model in place of the Holt model. In 2017 Council requested the Kawerau Peer Review Panel review the Mercury model. The review is in progress.

Key recommendations of the PRP and actions required of consent holders

In summary the 2016 Annual reports did not identify any issues of concern regarding the overall sustainable management of the system. Reservoir cooling and discharge enthalpy trends were as anticipated by modelling and through consent processes. However the Peer Review Panel made a number of recommendations on the basis of Consent Holder 2016 Annual Reports. They included the need to repair/replace and reinstate some monitoring equipment in a timely manner, extension of the levelling benchmark network to enable delineation of the recently identified area of subsidence and matters concerning presentation of the Annual Reports. The Panel recommended that Consent Holders make further efforts to resolve the issue of access to some benchmarks used for the levelling surveys.