WAIRAKEI POWERSTATION DISCHARGES

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ABSTRACT

Contact Energy's geothermal power station at Wairakei, located 10km north east of Taupo, has resource consent to extract up to 245,000 tonnes per day of geothermal fluid from the Wairakei geothermal fields. Disposal of this fluid after processing for power generation and heat extraction has potential to create a number of environmental effects.

The first generating station was constructed in the early 1950's. At that time all geothermal fluid was discharged either directly (steam condensate from the turbines) or indirectly (separated geothermal water from separators) via local hot streams to the Waikato River. As a result of the environmental and reservoir management impacts this practice became unacceptable. Over a number of years, processes to mitigate operational impact on the river have been continually investigated, developed and implemented. These processes include physical management techniques, such as disposal through reinjection, and water treatment, such as use of a tubular biofilm reactor that uses chemolithoautorophic microbes to reduce sulphide concentrations.

By combining these processes Contact Energy has significantly reduced the impact that operations at Wairakei have on the Waikato River.

KEYWORDS

Geothermal power, Environmental Monitoring, Water treatment

1 INTRODUCTION

Contact Energy and its predecessors have operated Geothermal Power Stations at Wairakei, on the banks of the Waikato River 10km north east of Taupo, for over 50 years. This location was selected because of two main factors. The first being geothermal surface expressions at Wairakei showed that the area potentially had one of the highest heat outflows of the Taupo Volcanic Zone (TVZ). The second being the proximity to a major water course, the Waikato River. The river provided a source of cold water for cooling the turbines and a receiving water body for unwanted and spent geothermal fluid.

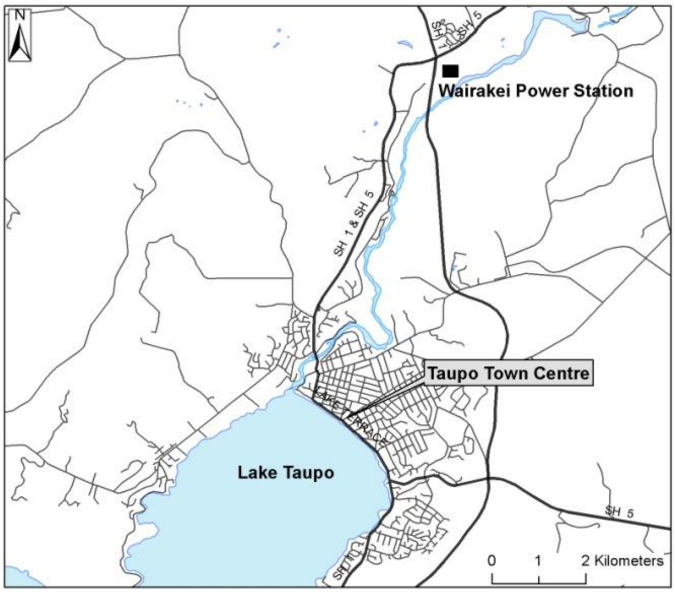

Figure 1: Location of Wairakei Power Station

At Wairakei up to 245,000 tonnes of geothermal fluid is extracted from the Wairakei and Te Mihi steam fields, via bores, typically 1000m to 2700m deep. When extracted, geothermal fluid is a mixture of water and steam (on average 80% water 20% steam) and contains dissolved minerals. This requires the fluid to be separated into its two phases, as any liquid entrained in steam supplying the turbine can have a detrimental effect and may result in turbine failure. When the power station was first constructed, the liquid phase, known as separated geothermal water (SGW), had no economical use and was disposed of into local hot streams and ultimately into the Waikato River.

Once the steam has passed through the turbines, it is condensed back into liquid known as steam condensate (SC), and disposed of directly into the Waikato River along with the cooling water.

2 POTENTIAL IMPACT ON THE WAIKATO RIVER

As early as 1974, it was realized that because of the chemical and physical properties of the waste geothermal fluids discharged to the river, there was a high potential for operations at Wairakei to have an impact on the Waikato River (Axtmann 1974).

2.1 PRIMARY IMPACTS

Discharging geothermal fluids to the Waikato River has a number of environmental effects and the most obvious is temperature. By definition, geothermal fluid is any fluid that is naturally heated to temperatures above 30 degrees Celsius.

At Wairakei, fluids discharged to the Waikato River are typically between 25 and 45 degrees Celsius. Until complete mixing is achieved, at approximately 1km downstream of the last discharge, temperatures down gradient of the station's operations are on average three degrees Celsius higher than up gradient (Ray et. al. 2001).

Photo 1: Warmer discharge water mixing with the Waikato River.

Lesser potential physical issues of discharging geothermal fluids to the Waikato River include changes to pH, turbidity, total suspended solid load and conductivity.

There are a number of different chemical species that naturally occur in geothermal fluids that have the potential to greatly impact the Waikato River. The most commonly known of these are arsenic, boron, hydrogen sulphide and mercury. In addition to these, there are other less commonly known species such as ammonia, dissolved carbon dioxide, chloride, gold, iron, silica and silver (Ray et. al. 2001).

2.2 SECONDARY IMPACTS

In addition to the impacts mentioned above, there are secondary impacts that may result from discharged geothermal fluids. These secondary impacts include.

i. Reduced Levels of Dissolved Oxygen.

The dissolved oxygen concentration may be reduced due to temperature increase or by equalization with low concentration discharge fluid.

ii. Increase In Bio-toxicity Of Heavy Metals and Ammonia.

The toxicity of heavy metals is greatly increased as temperature increases. The dissociation of ammonia into ammonium hydroxide (unionized ammonia) becomes more toxic to aquatic organisms as temperature and pH increase.

3 PROCESSES UTILIZED TO MITIGATE POTENTAL IMPACTS ON THE WAIKATO RIVER.

A number of processes have been employed by Contact Energy to reduce the impact of operations on the river.

The most effective method of reducing the impact of SGW has been to significantly reduce the volume of fluid being discharged to the Waikato River. This reduction was achieved through the development of reinjection areas at the periphery of the geothermal field. Reinjection is a simple concept whereby SGW is returned to the reservoir through reinjection wells. However in reality this practice is not simple. Reinjection areas require enough hydraulic conductivity to accept the fluid but not so much as to allow reinjection fluid return at a rate that would cool down the production area.

Investigations into the feasibility of reinjection areas at Wairakei began in 1978. Since that time three areas within the Wairakei field have been developed for reinjection, Aratiatia, Otupu and Karapiti. A fourth area Poihipi West is still under evaluation and testing. Of these, the Aratiatia area is no longer in use. Currently 5800 tons an hour of SGW is reinjected into 15 wells, which range in depths from 250 meters to 2900 meters (CEL 2014).

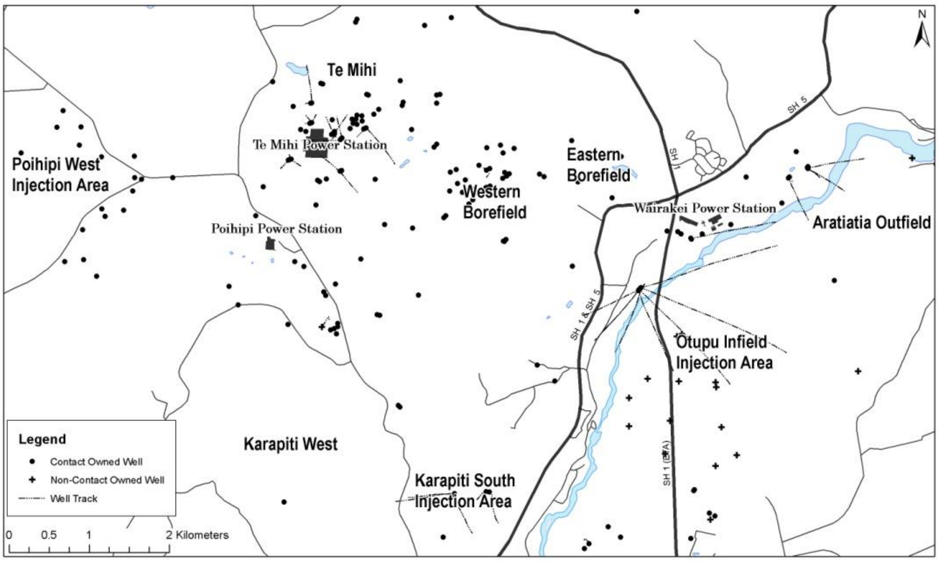

Figure 2: Different areas of the Wairakei geothermal field

3.1 PROCESSES EMPLOYED TO REDUCE THE IMPACT OF SGW DISCHARGED TO THE WAIKATO RIVER.

Contact Energy utilizes a number of different processes to reduce operational impact of SGW discharged to the Waikato River.

i. Wairakei Drop Structure

All SGW discharged from the production areas passes through these structures. The structures themselves consist of a series of waterfall like drops that disturb the flow through the drains resulting in an average temperature drop of five degrees Celsius. These structures also have an added benefit of raising the dissolved oxygen content of the fluid.

Photo 2: The main Wairakei Drop Structure.

ii. On-line Arsenic Load Monitoring

The monitoring is achieved through an on-line arsenic load calculator. The arsenic calculator is a computer program that produces a real time arsenic mass load value. This value is based on regular arsenic analysis of SGW samples taken at the discharge points and the current flow rate measured on-line through a SCADA system.

iii. Heat Exchangers

Heat can be extracted from SGW through heat exchangers for power generation or for direct use applications. At Wairakei heat exchangers are used to heat the working fluid (isopentane) of the binary plant for electricity generation and for local tourist venture. Both of these operations result in cooler fluid being discharged to the river.

iv. SGW Direct use

This is when fluid is used directly for heating applications. One tourist venture located close to the Wairakei station uses SGW to supply an artificial geyser, silica terrace and a recreational swimming pool. This operation helps to cool the fluid and reduce the silica concentration before it is discharged to the Waikato River.

3.1.2 PROCESSES EMPLOYED TO REDUCE THE IMPACT OF STEAM CONDENSATE (SC) DISCHARGED TO THE WAIKATO RIVER

Currently there is only one process employed to reduce the impact of SC on the river. In 2012, Contact Energy commissioned a tubular biofilm reactor to reduce the concentration of dissolved hydrogen sulphide contained in the SC.

The bioreactor primarily consists of a pipe field (cumulative length of over 350km) that provides an ideal habitat for filamentous sulphur oxidizing bacteria that naturally occur in the river (predominantly Thiothris sp.), to colonise and reproduce. These chemolithoautorophic bacteria metabolize reduced sulphur compounds. The majority of SC fluid discharged from the power station passes through this pipe field. Once it has completed the circuit, hydrogen sulphide concentration is on average 80% lower than fluid directly from the station (Bierre 2013).

Photo 3: Wairakei Bioreactor.

4 MONITORING

4.1 MONITORING CHALLENGES

As with any operation of this size, there is a considerable amount of monitoring involved with the processes above. This monitoring is primarily driven by the need to ensure that these processes are fully effective and can be separated into three main parameters; chemistry, pressure and temperature.

Because of the characteristics of a geothermal environment, a number of challenges to successful monitoring exist. Some of the most common challenges encountered are a result of working with fluid at temperatures considerably higher than ambient (typical temperatures encountered at Wairakei are between 65C and boiling); many off the shelf products are not suitable for use in this environment.

There are also challenges associated with the chemical composition of the fluid. The most common of these is scale build up. This occurs when geothermal fluid high in dissolved minerals cools resulting in some of these minerals precipitating and coating equipment submerged in the fluid. The chemical composition can also present challenges for analytical analysis. For some analyses, it is difficult to achieve low detection limits due to the high concentration of interference from other dissolved salts. For example the positive interference when analysing for oxidized nitrogen species caused by high sulphur concentrations.

Photo 4: Example of logging equipment coated in silica.

Further challenges are associated with the ambient atmospheric conditions. Hydrogen sulphide corrosion of exposed copper wires is very common in logging equipment used.

4.2 MONITORING SOLUTIONS

Monitoring staff at Wairakei have developed solutions to some of these challenges and are continuously investigating solutions to challenges that have not been overcome. Some of the solutions employed are very simple.

4.2.1 SOME SIMPLE SOLUTIONS EMPLOYED BY WAIRAKEI MONITORING STAFF INCLUDE:

1. The use of heat shielding fabric, such as that used by performance engine builders to wrap exhausts, to protect surface equipment from temperature extremes.

2. Placing temperature logging equipment inside a watertight container filled with ethylene glycol or tap water prior to submerging in geothermal fluid. This protects the logging equipment from silica precipitation while still effectively logging the temperature.

3. Coating exposed copper wire with nail polish or spray polyurethane to prevent hydrogen sulphide corrosion.

4. Constructing temporary monitoring equipment that can be easily be installed and removed. An example is the portable temporary weir plate. This is made up of a sheet of plastic connected to a stainless steel plate with a ‘v notch’. This weir is used to conduct flow measurements where a permanent structure cannot be constructed and the channel is too shallow to use a conventional gauging equipment (see photo below).

Photo 5: A temporary weir deployed at Taharepa Bath warm spring.

5 CONCLUSION

The impact of operations at Wairakei on the Waikato River has been significantly reduced. This has been achieved through a range of innovative and some simple solutions to address the challenges faced in monitoring in a geothermal environment, through the adoption of better management process and through the introduction of treatment processes over the decades of operation. Contact Energy is committed continuously improve and innovate methods of mitigation as new technologies become available.

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