# Mighty River Power's Resource and Development Strategy at Kawerau Geothermal Field, New Zealand

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## ABSTRACT

The Kawerau power station was commissioned beginning in June 2008. The dual-flash plant is fed by six 2000m deep production wells in a 300°C reservoir and disposes spent brine and condensate into four 2500m deep injection wells.

The development of the Kawerau geothermal field and design of the new 106 MW(Net) power station incorporated many innovations reflecting a strategy of best practices in many areas of sustainable development and energy efficiency, from sustainable geothermal reservoir management, steamfield design, distributed generation configuration, engineering design and construction, to environmental management and community participation.

## 1. INTRODUCTION

New Zealand's largest single geothermal development in more than 20 years, the Kawerau power station is an essential element in Mighty River Power's geothermal development strategy. The project reflects a strategic commitment to energy efficiency and sustainable development from initial concept through to detailed engineering design. The 106 Megawatt (MW) output from the Kawerau station is sufficient to meet about one-third of residential and industrial demand across the Eastern Bay of Plenty. It also provides electricity price certainty for Kawerau's major industry, the Norske Skog Tasman paper mill, and reduces the region's dependence on electricity supplied from elsewhere, lowering both the transmission losses and the cost of new transmission infrastructure associated with relying on importing energy over long transmission distances.

## 2. DEVELOPMENT STRATEGY

The Kawerau Geothermal Power Station is New Zealand's largest geothermal development in 20 years and increased New Zealand's geothermal energy production by approximately 20%. The new Kawerau plant generates around 840GWh of electricity annually and its design and construction introduced a number of significant innovations.

At the initial design stage, it was recognised that a high efficiency outcome would be best achieved by taking an integrated approach to geothermal reservoir development, requiring negotiations with the Crown, two neighbouring iwi (Tuwharetoa ki Kawerau and Ngati Awa) and local land owners including Putauaki Trust, and the industrial companies Norske Skog Tasman, Carter Holt Harvey, and SCA Hygiene. At the same time the Crown was negotiating a Treaty of Waitangi settlement with Tuwharetoa ki Kawerau. This was concluded in 2005, facilitated by contemporaneous transaction between Mighty River Power, the Crown, and Tuwharetoa ki Kawerau for the crown's existing geothermal direct heat business at Kawerau. A critical element in this project was acquiring the Crown's interest in the Kawerau Geothermal Field, and on-selling the asset and steam supply agreement to Ngati Tuwharetoa Geothermal Assets Ltd (NTGA) benefiting the local Tuwharetoa ki Kawerau people.

## 3. TIMELINE

Investigation by Mighty River Power began in 2003 following agreement for the development of the Kawerau geothermal resource with the Putauaki Trust. Mighty River Power began exploration drilling in January 2004 and lodged a resource consent application in August 2005. Resource consent was granted in September 2006 and the 100 week power station construction project began in January 2007. Production and injection well drilling was completed in November 2007 and station commissioning began in June 2008 with handover from construction in September 2008. Construction of the Kawerau station was completed more than a month ahead of schedule, under budget, and with a plant capable of generating 10% more electricity than originally specified.

## 4. THE GEOTHERMAL RESOURCE AT KAWERAU

The Kawerau geothermal field is the northernmost high-temperature (up to 300°C) geothermal system in the Taupo Volcanic Zone (Figure 1). Kawerau represents an extended case of staged development, with exploration and development continuing over more than 50 years. Development of the shallow (<1000m) reservoir at Kawerau was started in the 1950's by the Tasman Pulp & Paper company with the assistance of the New Zealand Government, and has supplied steam to the paper mill operations at Kawerau for process heat since 1957.

The pulp and paper mill was originally located in Kawerau to make use of the local steam supply and the adjacent forests, and the location of a now large industrial complex overlying the geothermal field has posed challenges to the expansion of geothermal development in the field. The six production wells for the new development are within or directly adjacent to the mill complex, providing challenges for the drilling and testing of wells and pipeline construction. Subsidence at geothermal fields is a key issue in acquiring regulatory authority consent for new and expanding geothermal developments in New Zealand and has been an issue at Kawerau due to the paper mill complex overlying the field.

Kawerau follows the pattern of most geothermal fields where subsidence is about 1 or 2 cm per year, far less than the more than 30 cm per year observed at Wairakei. Because induced subsidence related to geothermal operations was relatively small during the 50 year history of geothermal development at Kawerau, other causes of subsidence were given more attention. For example, short term natural deformation associated with the 1987 Edgecumbe earthquake produced about 30% of the maximum 90 cm subsidence detected at Kawerau since 1973.

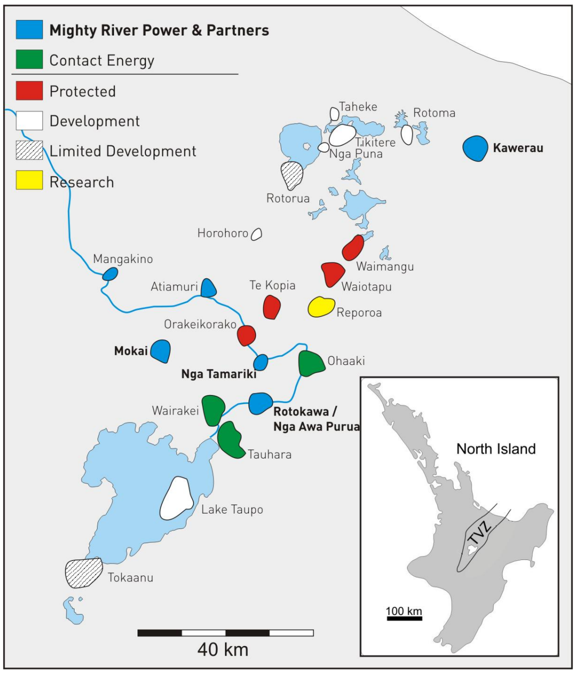


**Figure 1: Taupo Volcanic Zone, North Island, New Zealand.**

Many of the wells drilled in the 1950's encountered high temperatures at shallow depths (~300-600m) within highly permeable volcanic rocks (figure 2), and discharged with significant excess enthalpy. Production severely declined over less than a decade, plagued by scaling, shallow casing problems, and cold water incursion. A shallow two-phase region that initially existed within permeable rhyolite lavas was suppressed during early production by cooler surface waters connected with the surface and down wells with broken casing. Subsequent wells were drilled and cased deeper to produce sustainably from deeper volcanic rocks overlying the greywacke basement. Production at Kawerau has increased since original commissioning in 1957, with withdrawal rates in 2008 of around 32,000 tonnes per day (t/day).

Mighty River Power began deep exploration drilling at Kawerau in 2004, and the new 106 MW(net) Kawerau power station produces from a high temperature (300°C) reservoir in greywacke basement rock between 1200m and 2000m deep, which is below and laterally offset from production in the existing part of the field (Figure 2). The new development extracts an additional 45,000 t/day (annualised average) of geothermal fluid, with full injection of spent fluids (~78% of total produced fluid) in 2500m deep injection wells at the NE margin of the field. The deep Kawerau reservoir exhibits uniform and very high permeability throughout. The station is fed by six production wells with a maximum depth of ~2000m. Spent brine is discharged to three 2500m deep wells to the northwest of the field and condensate to a dedicated condensate injection well.

Well-bore simulation of well output in three of the first four standard diameter (7" liner) production wells drilled by Mighty River Power indicated that production was well-bore limited. The subsequent two production wells were drilled as big bore (9-5/8" liner diameter) wells which increased production by ~200% (Bush & Siega, *this volume*), reducing the number of wells needed at station start-up, and delaying the need for make-up production wells. Two big-bore brine injection wells were also drilled with one well achieving an injection capacity in excess of 1000 t/hr.

Analyses of the expanded resource development predicted that the planned deep injection would provide sufficient pressure support in the geothermal reservoir, minimising further pressure decline and resulting in relatively low subsidence rates, comparable to previous experience at Kawerau.

## 5. THE NEW 106 MW GEOTHERMAL POWER PLANT

The Kawerau plant tendering process was structured to encourage vendors to optimise plant for minimum life-cycle costs, thereby optimising the selection of power plant, including the steam turbine design. Customising the supplier's standard steam turbine design to more closely match the specific characteristics of the Kawerau geothermal team resulted in a 10% gain in station output (Gray, *this volume*). This additional output was realised without significant changes to the engineering, procurement, and construction contracts and costs.

The power plant facility incorporates several innovations that were designed to achieve a high-efficiency outcome. The design of the plant provided significant flexibility to cater for changes in geothermal fluids during the life of the project. The turbine and fluid handling system was optimised for reservoir fluids with an enthalpy between 1260 kJ/kg and 1300 kJ/kg. The gas extraction system used to remove non condensable gases (NCG) from the condenser includes three separate trains. The trains are sized to handle 40%, 60%, and 80% of the design NCG flow of the plant. A combination of these trains is used to efficiently match the NCG extraction required and reduce energy consumption. Injection pumps are driven by variable speed drives to reduce parasitic loads compared with more standard methods (such as throttle valves).

Silica scale can be a significant operational problem for geothermal plant, and can be difficult to control. A research project developed a test rig to simulate power plant cycles thereby enabling the chemical behaviour of geothermal fluids to be observed under simulated conditions. This allowed the testing of various chemical treatments to prevent the onset of silica scale. The results of the tests allowed the selection of a lower injection temperature without significant scaling risk, increasing the available energy per ton of fluid extraction by maximising the temperature differential between the fluid extracted from the field and injected and injected into the field. The acid injection system is adjustable to cater for operational or chemistry changes.

## 6. RESOURCE MONITORING

Kawerau is an important centre for the region's Tangata whenua, and local iwi regard the geothermal resource as a taonga. Understanding and respecting their concerns and embracing iwi and landowners in a partnership was critical to success. The Kawerau geothermal resource area involves a large number of landowners and Mighty River Power employed a strategy of engaging all interested parties in discussion at an early stage, which played a significant part in the clarification and identification of solutions. Without the support of the pulp, paper, and tissue manufacturers operating on the land sitting above the geothermal resource, development of the highly significant resource would have been impossible. The land around Kawerau is geothermally and seismically active. As well as imposing additional design constraints to ensure protection of Mighty River Power's plant and equipment, this required extra consideration be given to minimising disruption to activities at the mill.

### 6.1 Reservoir Monitoring

The performance of wells while online to the plant is monitored using Tracer Flow Testing (TFT), which measures steam and brine flow rates while the well is on production, conducted at three-month intervals. Geochemical sampling of the wells is conducted in tandem with TFT flow measurements to monitor the individual well chemistry and correlate with the observed changes in physical characteristics (well head pressure, mass flow, enthalpy etc) to obtain a holistic assessment of well performance.

Continuous reservoir pressure monitoring, using downhole capillary tubing, is conducted at various levels within and above the geothermal reservoir. A network of groundwater monitoring wells is also used to monitor temperature, pressure and chemistry of shallow groundwater aquifers.

### 6.2 Thermal Feature Monitoring

Monitoring of surface thermal features in Kawerau includes photographic and sampling survey of all thermal features, geochemical analysis of accessible flowing springs, ground temperature surveys and vegetation surveys. A scenic reserve in the southwest of the field containing natural surface features required a specific monitoring program. A purpose-designed monitoring well was installed adjacent to the thermal area to monitor temperature, water level, and allow chemical analysis of fluids from the shallow thermal aquifer. Springs are sampled at six-monthly intervals, with biennial photographic and vegetation surveys.

### 6.3 Ground-Level Monitoring

As the operation of both the power station and the adjacent pulp/paper and tissue manufacturing plants are extremely sensitive to ground movement, Mighty River Power needed to be able to guarantee exceedingly precise management of ground subsidence during geothermal fluid extraction. Precision levelling surveys are conducted annually at Kawerau, covering the requirements of the resource consent. The survey covers more than 22 $km^2$ with over 400 benchmarks.

### 6.4 Seismic Monitoring Network

Although not a resource consent requirement, Mighty River Power has installed a network of five seismographs and a central data hub to monitor micro-seismicity in the Kawerau geothermal field. The principal objectives are to monitor any micro-seismicity that might be associated with deep geothermal injection, and to map the flow of injection fluids using micro-earthquake locations. Data are relayed from the seismograph to the hub site via digital radio link. They are then forwarded to GNS Science in Wellington using Mighty River Power optical fibre cable. GNS Science archives continuous data (ground velocity in three orthogonal directions digitised at 200 samples per second) from all five sites on secure servers in both Wellington and Taupo.

On behalf of Mighty River Power, GNS Science runs several automatic checking and analysis procedures. Site health is monitored via a web page the shows the most recent data received in Wellington and the site battery voltage. Summary data plots are produced every 10 minutes and are displayed on a web page. These plots can be used to identify earthquakes that may originate in Kawerau. An automatic location program is applied to the data, supplemented with data from some nearby seismographs operated by GNS Science for the nationwide GeoNet project.

Since the network was installed, prior to commissioning, seismicity at Kawerau has been low. Forty-one earthquakes have been located by GNS Science within about 12 km of the Kawerau power station. The largest earthquake located close to Kawerau occurred on 30 October 2008, several km northwest of the geothermal field, with a magnitude 2.4 and depth of 5 km.

### 6.5 Reservoir Performance

The Kawerau reservoir has shown minimal response to the first 12 months of operation (to June 2009). A pressure decline of ~3 bar is observed in all monitoring wells across the field, from the southwest of the deep production field to the deep injection field in the northwest. The consistent pressure decline across the reservoir indicates a large, distributed, and permeable reservoir. The observed pressure decline compares favourably with the numerical model simulation which showed between 4 and 8 bar of pressure decline in the production zone after the same period.

## REFERENCES

Bush, J., and Siega, C.: Big bore well drilling in New Zealand – a case study. Proceedings World Geothermal Congress 2010 (this volume).

Gray, T.: Power Plant Selection in Mighty River Power Development Projects. Proceedings World Geothermal Congress 2010 (this volume).

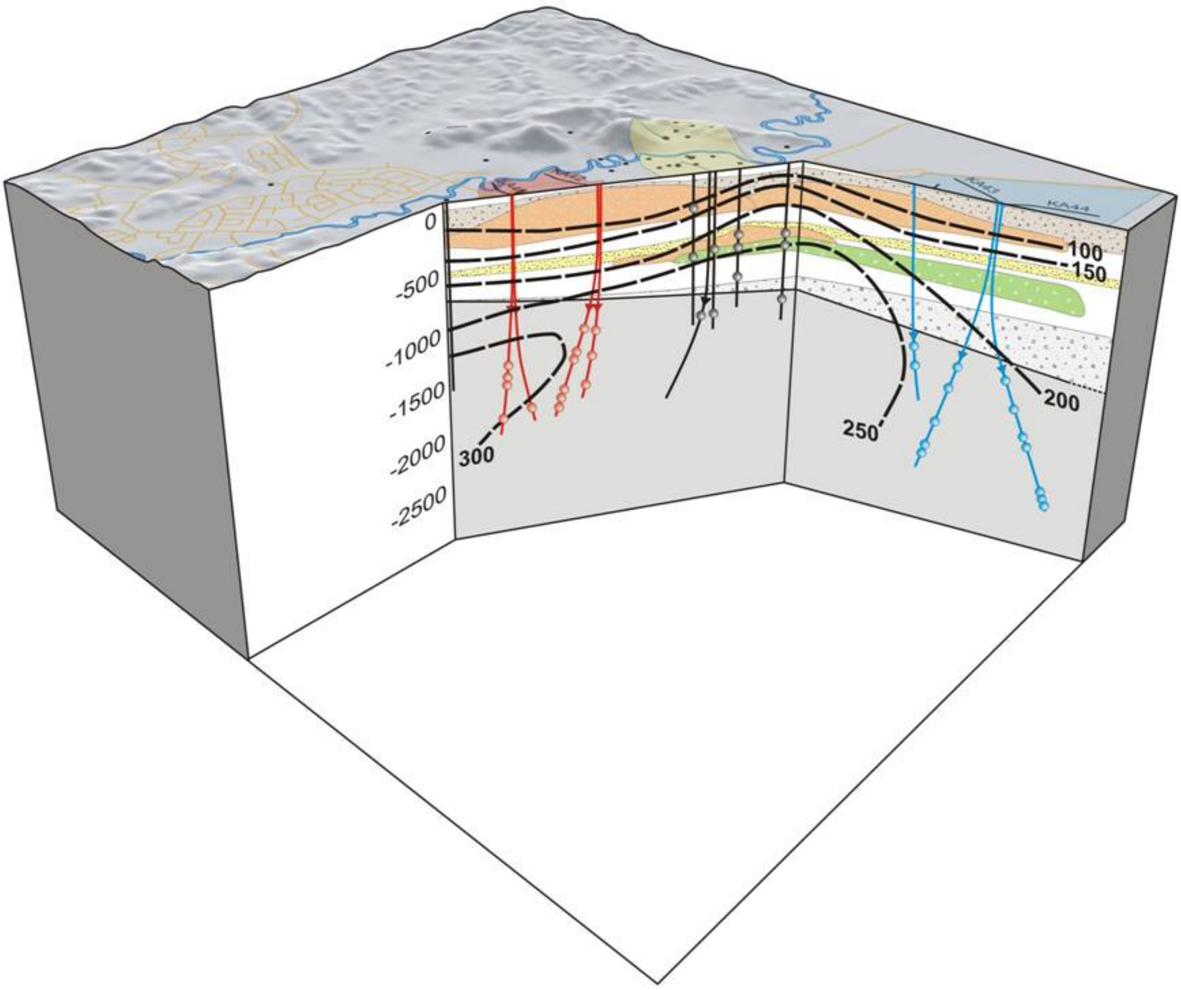


**Figure 2: Block diagram showing the Kawerau geothermal resource.**