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SOME POSSIBLE RESTRAINTS ON GEOTHERMAL DEVELOPMENT IN NEW ZEALAND

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Introduction Using the Wairakei field as a model, Donaldson & Grant (1978) recently suggested that if all the major New Zealand geothermal fields, except Whakarewarewa, were exploited for electric power production, we might anticipate a total generating capacity of as much as 2500 MWe. Their field-by-field breakdown is given in Table 1. While about half of this total is speculative, their figures are also conservative. Being based on the Wairakei system, the power station generating capacities are controlled by the acceptable pressure drawdown in the reservoirs, rather than any lifetime factor. Thus, the power generation capability of these fields may continue through several plant amortization periods. Both Thain (1980) and Donaldson and Grant (1981) consider that Wairakei could continue to produce power at near the present rate for a very long time. Alternatively, the successful maintenance of pressure in the reservoir, as, for example, by reinjection, could allow a shorter term, higher generating capacity.

Field	Proven	Inferred	Speculative
Wairakei	150		
Tauhara	100		80
Broadlands	120	30	
Kawerau	100		30
Waiotapu-Reporoa		150	100
Orakeikorako		50	50
Rotokaua		50	100
Tikitere-Taheke		75	75
Waimangu		50	100
Te Kopia		20	20
Mokai			170
Atiamuri			30
Tokaanu-Waihi			100
Ketetahi			25
Ngawha		200	500
Totals	470	625	1380

Table 1: Estimated potential power station output (MWe) for New Zealand geothermal fields if these were exploited in the same manner as Wairakei is currently (from Donaldson & Grant, 1978)

Not only do we appear to have this generating capacity available, we also have proven, operating systems in Wairakei and Kawerau. As Thain (1980) has pointed out, power from the Wairakei power station first flowed into the New Zealand national electricity grid on November, 15, 1958 and the full coupling of the system was completed in October, 1964. Since that time this plant has had one of the best records for reliability of any power station in New Zealand. The annual station load factor has consistently been between 85% and 90% and the availability factor in excess of 85% for most of the past decade. Thain (1980) also indicates that the plant has not been expensive to operate, the operating costs being some 16.5% less than the average costs of the hydroelectric plants in the North Island (on a per unit generated basis).

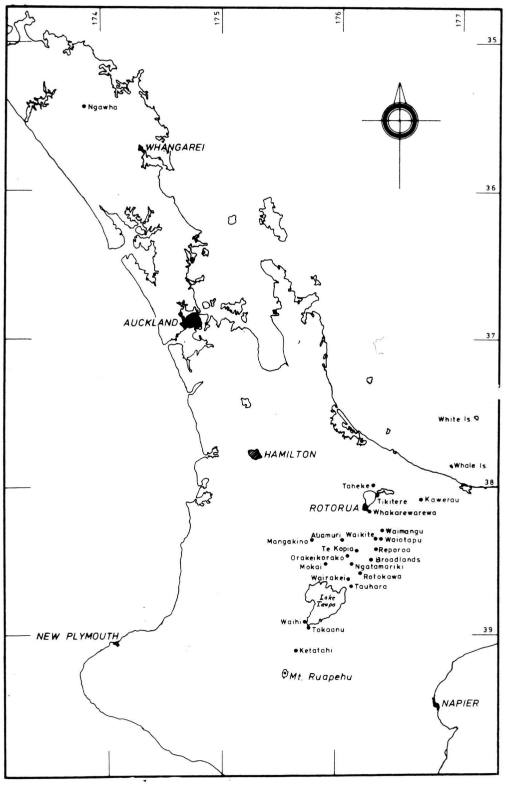

Fig. 1: New Zealand Geothermal Fields

At Kawerau, a field that has been exploited commercially since the early/mid-1960's, the output is still being expanded. Since 1978, three new wells have been drilled and another deepened. With the connection into the system of the very large producer KA21, the steam supply to the Tasman Pulp & Paper Company mill has been increased from 120 tonne/hr to 200 tonne/hr (Denton, 1980). Denton (1980) anticipates a further increase to 270 tonne/hr in the very near future.

In the light of this considerable power generation potential and the success of our current plants, why has our progress in development of our resources been so slow? I should like to look here at what I think may be some of the background reasons. I will separate these into two categories: those related directly to the exploitation process, and those, associated with other aspects of energy development in New Zealand or with environmental concerns, that may have had a less direct influence.

Current Status of New Zealand Geothermal Projects Before I discuss the problems of geothermal development in New Zealand, let me first indicate the present status of our program. I will not touch on Wairakei as Thain (1980) discussed this field in some detail in his presentation last year.

Broadlands, due to its imminent exploitation for power production, is currently the site of the majority of the field testing. Over the past two to three years the number of investigation/production wells has been increased to 37. The latest of these, BR37, was drilled outside the hot primary field area, the aim being to find permeability for reinjection external to the main reservoir. No good permeability horizens were, however, found in this 1400m hole. The bottom hole temperature was close to 200°C.

Most of the other tests carried out recently in this field have been detailed by Denton (1980). He indicates that reinjection tests have now been carried out in four wells (BR7, BR34, BR28, and BR13) with varying degrees of success. In the long term test using BR7 which began in April, 1976, 665 tonne of separated geothermal water had been injected to March 1980 without apparent adverse effects (Bixley & Grant, 1979). This well is of moderate permeability and accepted 21.5 tonne/hr at 180°C and WHP 10.1 bg, 27 tonne/hr at 140°C and 7.4 bg, and 27.6 tonne/hr at 112°C and 3.3 bg.

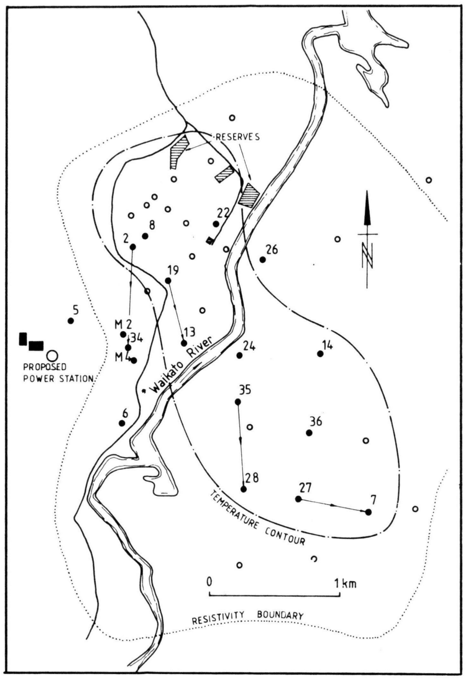

Fig. 2: Injection Tests
At Broadlands, New Zealand

In the test using BR34, 3.6×10^5 tonne of separated water were injected at temperatures between 80°C and 95°C over a total period of 1960 hours. This well initially accepted the water at up to 200 tonne/hr but its capacity to accept this water decreased to about one third during the test. Silica deposition took place in the transmission pipeline, in the injection well, and in the formation away from the well (Denton, 1980).

Late last year, 1980, the remaining two tests were still in progress. Temperature/pressure fluctuations and mechanical problems were delaying the test using BR28. During operation a flow of 160 tonne/hr at 150°C and 3.1 bg WHP was achieved. The fourth test was only just underway.

Other tests being carried out at Broadlands and discussed by Denton (1980) include a study of silica deposition and an attempt to stimulate well BR14 by use of injection/discharge cycling. This technique had previously resulted in significant improvements in output of wells BR13 and BR23 (Bixley & Grant, 1979). It appears that in the formations around BR14 existing fractures in the rock open during the injection cycle when the pressure is high enough but close again when the pressure drops. Further tests with higher injection flows and propant injection are proposed (Denton, 1980).

Current plans are for the first 50 MW unit at Broadlands (Ohaki Power Station) to be commissioned in October, 1986; the second, one year later. Should the field be capable of supporting the extra draw-off, a further 50 MW unit will be added at a later date.

At Ngawha, on the North Auckland peninsula, wells have now been drilled. The first six three of these (NG2, NG5, and NG7) encountered little permeability and may have suffered from mud damage. The remaining three wells (NG3, NG4, and NG9) are all good producers, NG4 and NG9 having multiple feeds. To stop the interzonal flow in NG9 and yet get the benefit of both feeds, an internal pipe has been lowered down from the surface and sealed to the casing between the two feed zones. The double completion is apparently successful. The internal pipe expanded some 3 m on warm-up.

Electricity Supply and Demand in New Zealand

Currently some 6% of New Zealand's electrical energy is produced from its geothermal resources; 85% comes from hydro-power, and 8% comes, or is planned to come, from natural gas. Although this latter supply has a limited lifetime, at an estimated 35 years its decline should have no effect on the short term figures quoted here. New Zealand geology also suggests that other offshore oil and gas fields are likely.

At these current levels New Zealand still has plenty of untapped energy reserves. I have already indicated a geothermal electrical energy potential of from 10 to 25 times that currently generated; for our water-power we have a factor of about 3; and we have barely touched our coal. The reserves of the latter are conservatively estimated at somewhat in excess of 3 billion tonnes.

Euromoney, in a recent survey on New Zealand (September, 1980), titled its energy chapter "A Thousand Years of Energy Reserves." The subtitle read "New Zealand is an energy planner's dream: it has more coal and hydro-electric potential than it needs for a century or more. It also possesses the Maui field, the fourteenth largest gas field in the world."

Currently, in a dry year, New Zealand can produce some 25,000 GWh of electricity. The demand is about 22,000 GWh. Thus, even under these worst conditions, there is a significant surplus. With the planned electrical development, by 1985, the generating capacity will be about 32-33,000 Gwh (dry year).

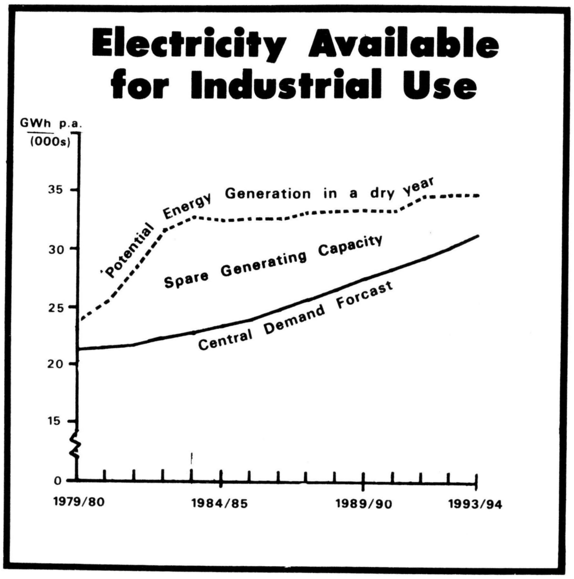

Fig. 3: New Zealand electrical energy supply and demand for the next 15 years (Plot does not include planned industrial expansion of 6,500 GWh p.a. by the late 1980's)

Obviously, there must be plans to utilize this surplus energy. New Zealand is, in fact, just now entering into a period of energy-intensive industrial development. I list some of the scheduled projects (by category) and their estimated annual energy requirements in Table II. These projects are virtually all scheduled for completion by the mid-to-late 1980's. Thus, by the end of this decade the total power requirement of 6500 GWh for these projects will be part of our electric load. There will be no dry year surplus at that time.

Table II

Plant	Power Required GWh/yr	Construction Period
Energy Sector		
Oil Refinery Expansion	1000	1981-83
Synthetic Gasoline	700	1983-86
Chemical Methanol	300	1982-84
Ammonia/Urea	300	1980-81

Table II cont.

Plant	Power Required GWh/yr	Construction Period
Aluminum		
Comaleo Expansion	400	1980-83
New Plant	1250	1981-88
Steel		
NZ Steel	1000	1981-85
Ferro-silicon	200	1981-83
Cement		
Whangerei	150	1980-82
Oamaru	250	1981-83
Pulp & Paper		
NZ Forest Products	450	1982-85
Fletcher/Carter or Northern Pulp	210	
CSR Baigents	300	1982-84
Total	6500	(1980-88)

Possible Reasons for Slow Development of our Geothermal Resources - (1) Directly Related to Exploitation Although the Wairakei reservoir was exploited on a try-and-see basis and we have made a few mistakes, its development as an energy resource has been a successful exercise. We have also learned a lot by carrying it out. Several effects that have shown up are, however, of some concern and these, together with changing public attitudes and increasing technical regulation, must play a role in our decision making concerning future development.

a. Pressure Drawdown As Thain (1980) pointed out one of our main concerns with regard to the Wairakei reservoir is the pressure drawdown that has occurred due to the exploitation. Not only does this drawdown place a restraint on the amount of energy that we can extract from this reservoir, it has also altered some of the characteristics of the field. It extends not only throughout the Wairakei reservoir, but also, although to a lessening degree as we get further away, right through the adjacent, connected, Tauhara reservoir. It is also believed to be having side effects on activity as far away as the Taupo lakeshore (5 to 6 miles).

This drawdown is by no means unique to Wairakei. The Ohaki section of the Broadlands reservoir was showing some effect in the late 1960's, towards the end of some significant test discharge. There are also indications that there has been some drawdown in the Rotorua area due to the exploitation there (Donaldson, 1980).

While the limitation on the rate of withdrawal of energy may have engineering and economic consequences, the total amount of energy that may be extracted from the field may not be greatly altered. Theoretically, using an ideal model, it is only the time-scale that is changed. The potential side effects may be more important. Let us, therefore, look briefly at some of the effects of this drawdown.

Using the current model of Wairakei, a hot core of fluid, surrounded by, and in reasonable hydrologic contact with, cold water, the drawdown implies the development of a pressure gradient from outside to within the reservoir. This induces the inflow of the cold water. This inflow will (a) tend to stabilize the drawdown once a new mass balance is achieved, a situation we may be approaching today; and (b) extract heat from outer edges of the reservoir and sweep it in towards the production wells (Donaldson & Grant, 1981).

The above are both positive effects. The drawdown will, however, also be differential in the vertical and hence we will induce changes in the pressure profile and flow in any shallow two-phase zone. Grant & Horne (1980) show the change in pressure profile for Wairakei from approximately hydrostatic to approximately vapostatic in one zone due to the exploitation. The consequential effect of this is the commencement of flow down of cooler water. Thain (1980) remarked on this. Downward interzonal flows, of 150°C water, occurred in some production wells when they were temporarily shut in. They are probably occurring, undetected, in cracks and fractures in the formations. Drainage of water in the two-phase zone is now taken into account in some models of Wairakei (Fradkin et al., 1981).

This change in near surface flow due to the drawdown has two effects. First, cool water sinks to the liquid-water/steam-water interface in the system. If this were a general percolation this water would pick up heat on the way and thus sweep some of the heat from the upper layers of the reservoir. The indications are, however, that this flow may be channelled. In that event, the heat swept out would be limited and cooling would take place at depth.

The second consequence of the change of flow is at the surface. As has occurred in Wairakei, liquid-controlled surface manifestations will cease and steam-heated ones change. At the time of development of Wairakei, environmental changes of this nature were accepted with relatively little protest. Such is no longer the case today. Nor were the extent of the effects, now showing in Taupo, foreseen at the time Wairakei was developed.

b. Reinjection It is widely considered that reinjection of the cooled geothermal fluid may be the answer to the pressure drawdown problem. With good production-injection management it is thought that pressures may be maintained and the heat swept out of the rock more efficiently. In New Zealand reinjection is still regarded primarily as a waste disposal technique, although any side effects, such as pressure maintenance, would be very acceptable. The experience so far with reinjection in Japan (Horne, 1981) and our own experience with direct in-reservoir injection at Broadlands, suggests that return periods of the injected fluid are much less than the idealized theory would suggest. Energy recovery factors with in-reservoir reinjection may thus be much lower than those attainable by just allowing the cold fluid to flow in from outside the reservoir. Unfortunately, in the Broadlands area, we are having difficulty in finding sufficiently good permeability outside the reservoir.

There may also be other problems with reinjection in some fields. In a recent study, Grant (1981) has shown that reinjection of cool fluid into a hot two-phase zone may result in an additional drop in pressure, rather than a pressure recovery. The cool fluid must extract heat from the fluid in place and thus condense some of the steam. If the injected fluid temperature is below some "neutral" value the injected fluid volume will not make up the steam volume lost. Heat must then come from the rock and the temperature and pressure drop. In most real situations, the injected fluid temperature will be below the neutral temperature. Even with relatively poor mixing of the injected fluid, a proportion may, for example, move out along channels and hence not heat up in the two-phase zone, a pressure drop is likely.

c. Environmental Constraints When Wairakei was developed the waste water was discharged into the Waikato River and the gas fraction vented to the atmosphere. It was fortunate that the effects of this direct disposal of the geothermal effluents were as little as they have been.

Since that time the environmental regulations in New Zealand have been tightened considerably and to meet these we obviously have significant additional costs. Broadlands has been particularly bothersome in this regard due to the high non-condensible gas content of the fluid discharged. The H_2S is probably the most problematic fraction of this gas.

We have already discussed the environmental consequences of the pressure drawdown, i.e. the decay and modification of the surface activity.

d. Other Field Problems Exploratory/investigation wells were drilled in some of the other larger fields relatively early in our geothermal program. In both Waiotapu and Orakeikorako these investigation wells were not particularly successful. Donaldson & Grant (1978), for example, downgraded the potential of Orakeikorako due to the poor permeability found in the two wells drilled there. Nowadays, with our greater experience, we might choose different drilling sites, drill to different depths, or try stimulation. The low permeability of the first three wells at Ngawha did not deter us from continuing investigation.

Possible Reasons for Slow Development of our Geothermal Resources - (2) External Factors

There is no doubt that New Zealand's current energy surplus is a good reason for keeping the rate of geothermal electrical energy development down. The possibility of a restricted supply by the end of this decade, cannot, however, be disregarded. Obviously if a geothermal plant is to be a viable proposition in the early 1990's a field will need to be proven within the next few years. Only Broadlands, to be brought on line in the mid-to-late 1980's, is in that state at the moment.

Choosing the next site may not, however, be easy as, apart from the direct field development problems we have already discussed, there are other considerations that may need to be taken into account.

a. Tourism Tourism is now one of New Zealand's major industries. At the beginning of this decade about half a million visitors from overseas passed through our resorts. Current forecasts are for the figure to exceed 800,000 by the late 1980's. A large proportion of these tourists visit at least some of our thermal areas.

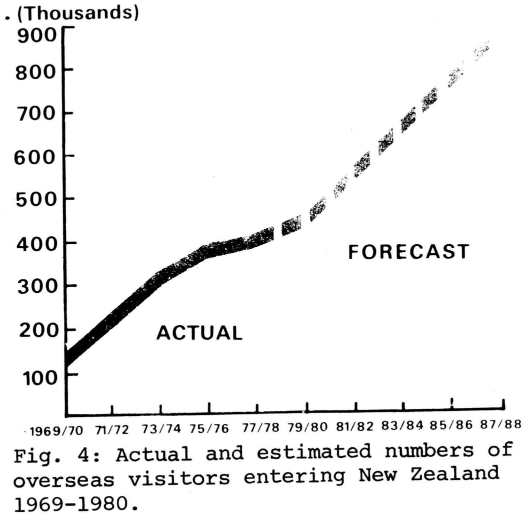

Fig. 4: Actual and estimated numbers of overseas visitors entering New Zealand 1969-1980.

In the Wairakei area, the development of the geothermal field quickly closed down the Geyser Valley tourist area, a water-controlled manifestation area adjacent to the Wairakei field, and ultimately resulted in the shutting down of the Karapiti blowhole area. It is to be expected that surface manifestations associated with any other exploited field would also ultimately deteriorate and die. Thus, tourism and energy development are in conflict.

The long term effect of this conflict is difficult to forecast. The major problem is that fields that are regarded as being the best tourist areas are also top of the list for energy. A high heat flow generally means more extensive (and interesting) surface manifestations. Low heat flow areas are naturally of less interest to the energy developers.

For development to date the conflicts have as yet been limited. Wairakei was spawned before we recognized the likely effects or their extent, and neither Broadlands nor Kawerau were sensitive areas. The investigation wells in both Orakeikorako and Waiotapu were also drilled early in the New Zealand geothermal development period, before water and other legal rights were required. In neither Ngawha, where the major attraction is a swimming pool complex, nor Mokai, an isolated area with little obvious activity, has there been problems getting these rights. In contrast, an investigation well at Ruahine Springs (Tikitere-Taheke) has been discussed for some time, but not yet scheduled, and a right was refused for a well some distance from Waimangu because there might be some effect. There is also considerable concern that withdrawal of water (and energy) in the Rotorua area for direct (non-electrical) use may be affecting features in Whakarewarewa Thermal Reserve, New Zealand's premier thermal tourist area.

b. Non-Electrical Uses of Geothermal Energy
For electricity production it is advantageous to have the fluid as hot as possible; for direct building and water heating cooler water will suffice. Thus, hot water in shallow aquifers and in areas of lower temperature is being tapped for such non-electrical uses. This water is also being used for tourism (swimming and spa pools), for agriculture and silviculture (drying, heated beds), and for industry. Higher temperature fluid, from deep wells, is also being used for industry. At Kawerau the steam is used in the pulp and paper processing; at Broadlands, for drying lucerne; and at Rotokaua, for extracting and processing sulphur.

It may be argued that such direct use of geothermal fluids is more efficient than the electricity production process and that, where this heat is available, it is bad energy policy to use electricity purely to produce heat. Non-electric uses of geothermal energy are, therefore, continually being sought. The low population base of the thermal area and the high cost of transportation of goods to our major centers do, however, work against these uses to some extent.

Conclusion The future of geothermal energy development in New Zealand is difficult to forecast. New Zealand is currently in an energy-rich state as far as electricity is concerned and it is anticipated that, even with the commissioning of several energy-intensive industrial plants, the demand will not catch up with the supply until the end of the present decade. Even then, geothermal energy will be competing with water-power as the source of supply of additional energy. While this water-power potential is still great, future development must take place in more difficult sites and be increasingly subject to consideration of protection of scenic areas, wild river sections, and other public domains.

As I have pointed out in this paper, geothermal energy development also has its problems: the drawdown of the reservoir and its side effects, the uncertainty of the benefits of reinjection, the necessity of cleanliness of the environment and the unproven production potential of undeveloped fields. These are all, however, scientific or engineering problems. Currently they are a challenge. Ultimately we will have the answers. The option between water- and geothermal-power may rest on the cost of the solutions at any time rather than whether there is a solution. It is my opinion that these problems and their solution will not restrain geothermal development in New Zealand in the long term.

It is also my opinion that the conflict between tourism and energy development for each field will also be resolved. In some cases there will be no problem, energy development will affect very little, or total protection for tourism (or for the unique nature of the area or something in it) is essential. In other cases a "political" choice must be made. In a few cases, and I am hopeful that Rotorua may be in this category, it may be possible to extract some energy and still protect the manifestations in the tourist park.

Ever since the first moves were made to study Wairakei with the serious objective of development (in the early 1950's), New Zealand has maintained its geothermal team of scientists and engineers. I am confident that it will continue to do so. I am also confident that development of our resources will continue, although I cannot guarantee that they will all be used for the production of electric power.

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