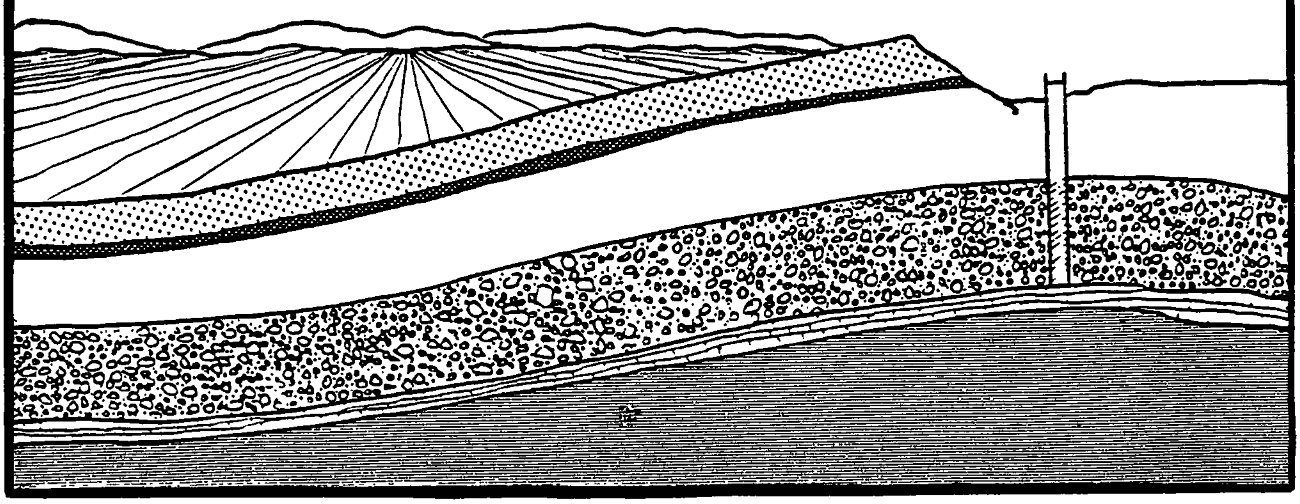
LOW TEMPERATURE HEAT UTILISATION – TAUHARA GEOTHERMAL FIELD, TAUPO

R.J. CURTIS

April 1988.

WAIKATO CATCHMENT BOARD

TECHNICAL REPORT No. 88/2



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LOW TEMPERATURE HEAT UTILISATION - TAUHARA GEOTHERMAL FIELD, TAUPO

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1.0 INTRODUCTION

The Tauhara Geothermal Field is located immediately east of, and beneath Taupo township. Associated with the deep geothermal reservoir is a hot, shallow ground water resource which is the most intensively used, low temperature hydrothermal resource in New Zealand. Over 400 users, both domestic and commercial, extract heat and mass from the shallow aquifers and springs around Taupo for domestic hot water, heating, spa pools, irrigation, agriculture and industry.

As part of the Upper Waikato River Management Plan, investigations are being undertaken into the size, and use, both existing and potential, of the shallow ground water resource and associated water and soil resources. In this respect, the Management Plan will examine the deep geothermal reservoir and cold ground water in addition to hot, shallow ground water, and consider the interaction between these resources, their potential for use, their discharge/recharge relationships, and the existing and potential conflicts in their uses.

Part of the larger study involves an assessment of heat utilisation by users of the shallow, low temperature energy source and it is the purpose of this report to examine energy consumption by domestic and commercial hot water users in Taupo. No attempt has been made in this report to assess the size of the shallow energy resource, other than to use existing figures, or to assess the size or use of ground water mass. Estimates of energy use have been based on two surveys; a questionnaire survey which examined the manner and purpose of thermal water use, and a telephone survey which examined comparative use of electrical and thermal energy consumption for home heating, spa pools and domestic hot water.

Prior to examining heat abstraction and heat use, it is appropriate to first outline the local geology, and to briefly examine the nature of the shallow ground water resource. Both factors are important in controlling the movement of geothermal energy to shallow ground water.

2.0 GEOLOGY

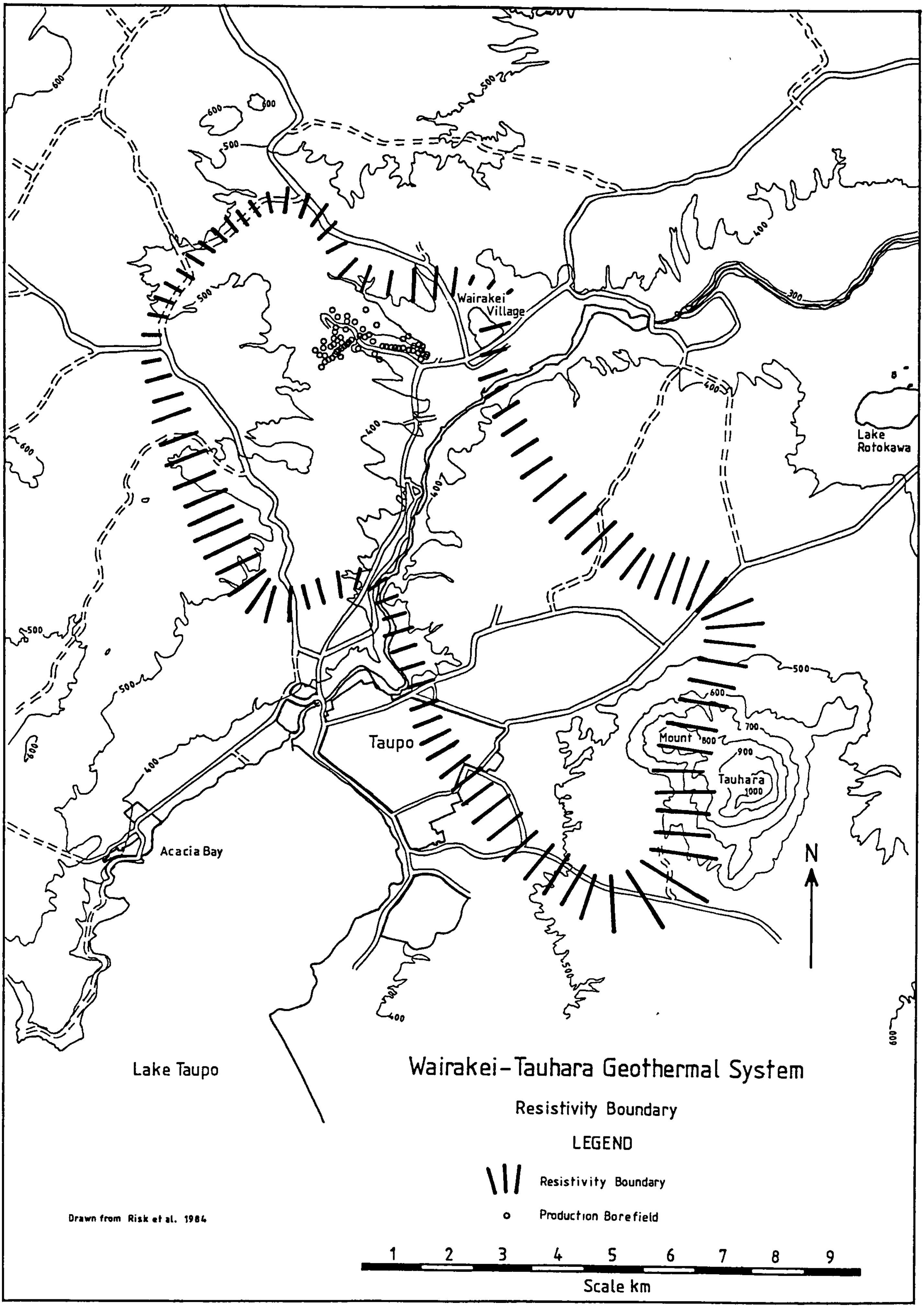
The Tauhara Geothermal Field is located at the SW end of the Taupo - Reporoa Basin, adjacent to the Wairakei Geothermal Field (see Figure 1). The geothermal reservoir is the lowest of three aquifers in the Tauhara Field, and is contained within highly permeable, pumiceous sandstones and siltstones, and pumiceous and rhyolitic breccias of the Waiora Formation (Figure 2). Impermeable Huka Falls Formation mudstones and siltstones form a thick cap (200-400 m) over the deep reservoir (Grindley, 1974). They in turn are overlain by more recent Pleistocene/Holocene pumice breccias and pumice alluvium. These recent sediments have infilled the Taupo-Reporoa Basin around Taupo to depths of up to 150 m.

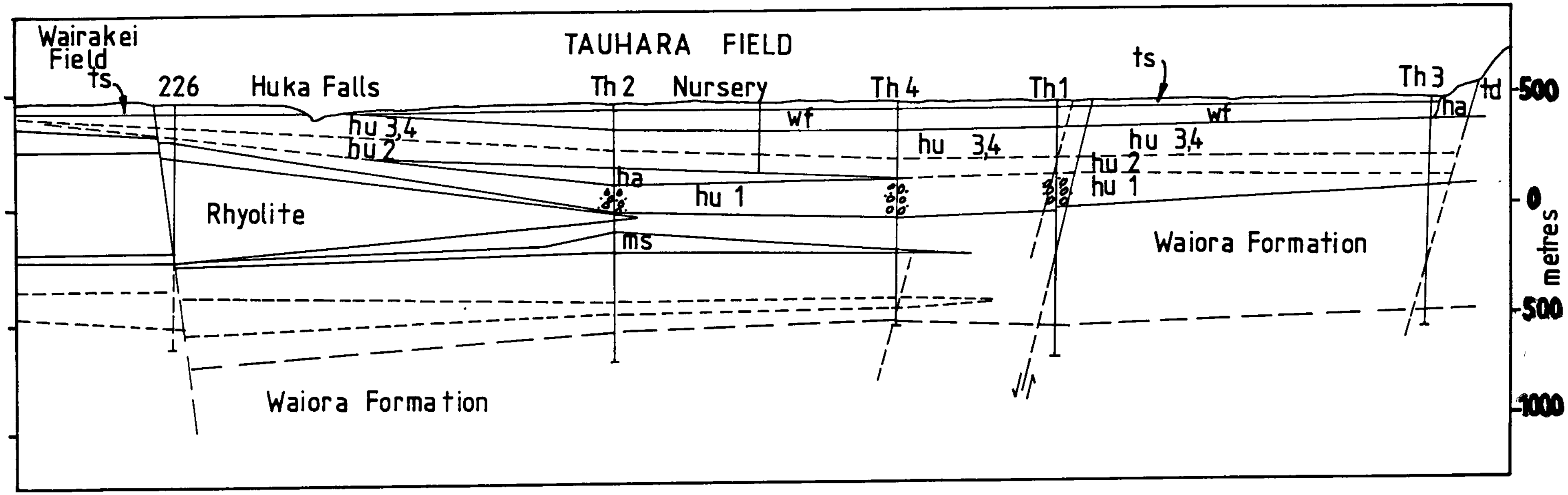
The sequence of pumiceous sediments and layered mudstone aquicludes forms a very shallow basin, thinning to the north, west and south, and extending to beneath the Mt Tauhara dacite-rhyolite centre to the east of Taupo. Notably less faulting exists in the Tauhara Field as compared with the adjacent Wairakei Geothermal Field although the geology of the two fields is similar. Tauhara is linked to Wairakei via the Waiora Formation and as a consequence has been affected by pressure losses resulting from drawdown in the Wairakei reservoir (Allis, 1983).

The surface Wairakei, aquifer associated with the Tauhara Field is within the surficial pumiceous alluvium and breccias. Ground water flows down a natural, shallow gradient to Lake Taupo. This aquifer is the primary source of hot water utilised by Taupo residents. It is separated from the underlying Huka aquifer by a layer of Huka Falls mudstone which forms an aquiclude between the two. The Huka aquifer is contained in a breccia layer within the Huka Falls Formation (hu_2 ; Figure 2) at a depth of around 200-300 m although in places near Lake Taupo the aquifer may be at less than 100 m and outflows to the lake (Allis, 1983).

3.0 THE HOT WATER RESOURCE

Hot water for domestic and commercial heating in Taupo is derived primarily from the shallow Wairakei aquifer. This aquifer contains fresh ground water which is recharged by rainfall and is heated by steam rising from the geothermal reservoir.


Wairakei Village
Lake Rotokawa
Taupo
Mount Tauhara
Acacia Bay
Lake Taupo
N
300
400
500
600
700
800
900
1000
Wairakei-Tauhara Geothermal System
Resistivity Boundary
LEGEND
Resistivity Boundary
Production Borefield
Drawn from Risk et al. 1984
1 2 3 4 5 6 7 8 9
Scale km



-4-

ts Taupo Subgroup
wf Wairakei Formation
ha Haparangi Rhyolite
td Tauhara Dacite
hu Huka Formation
ms Mudstone
Th4 Geothermal Well
eruption breccias

FIGURE 2: NW-SE simplified geological cross section through Tauhara Geothermal Field. Data from Grindley, 1965 and Grindley, et al., 1966.

Vertical and horizontal scales are equal.

Prior to the late 1950's, the Tauhara Field was in an undisturbed state with deep chloride water discharging as hot and boiling springs in the Spa and Terraces areas (Henley and Stewart, 1983) (see Figure 3). The upflow of this geothermal fluid may have occurred beneath Mt Tauhara (Allis, 1983) from where it flowed underground towards Lake Taupo. Allis suggests that the middle, Huka, aquifer carried most of the near-surface liquid outflow from Tauhara. However, deep drawdown in the Tauhara Field as a result of the drawdown in the Wairakei Field caused a loss of pressure and the formation of a steam zone immediately beneath the Huka Falls Formation over a large portion of the Tauhara Field.

The liquid drawdown beneath Tauhara led to the virtual cessation of deep fluid upflow and a substantial increase in steam, increasing the heat flow to the near-surface waters. This increased aquifer temperatures, and thermal activity around Taupo increased in intensity and expanded in area. As a result, the temperature of bore, well and spring waters around Taupo increased significantly in the late 1960's (Allis, 1983).

Thus, the existing resource used by residents comprises a shallow ground water aquifer which is steam heated from the deep reservoir. There is now minimal geothermal fluid upflow, so that recharge to the aquifer is likely to be largely from rainfall, and springs in the Spa, Terraces and Waipahihi areas are surface discharges from the aquifer. Evidence for this reduction in geothermal upflow, in the Spa area, exists from a decline in chloride concentrations, increasing sulphate and silica levels and enrichment of oxygen and deuterium isotopes in the water, all of which reflect an increase in steam heating of shallow ground water (Henley and Stewart, 1983). There has been little change in the water chemistry in the Waipahihi-Terraces area however, where deep upflow comprised dilute chloride water. This may be due to a chloride water component draining from rocks which originally hosted deep chloride water, and the silica content being controlled by the solubility of amorphous silica present in the pumiceous sediments. Henley and Stewart (1983) note that most of the waters around Taupo with temperatures less than 100°C are likely to be formed by dilution of hot, steam heated waters with cold ground water.

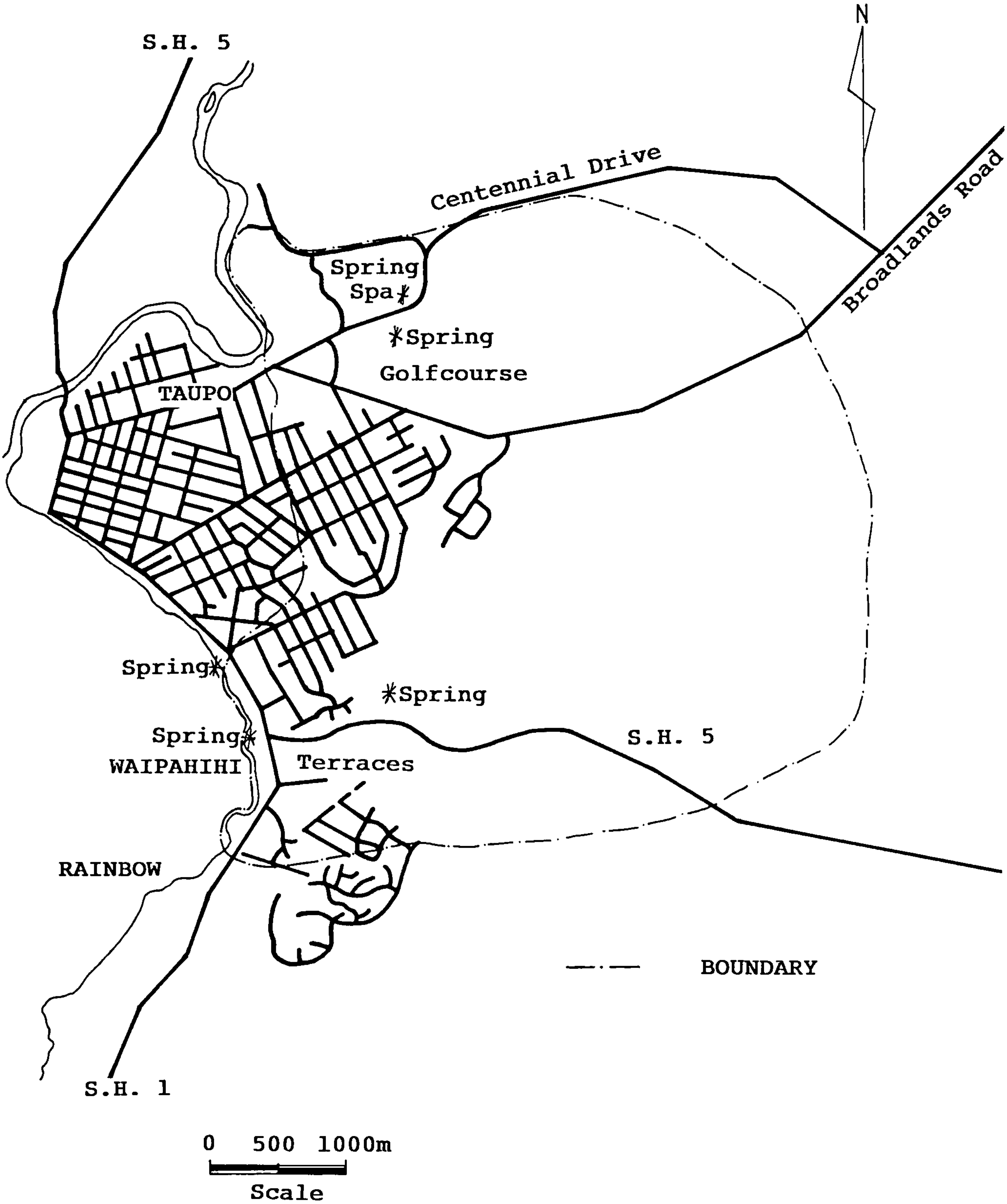


FIGURE 3: Approximate boundary of the area around Taupo containing hot, shallow ground water.

Of more importance to users of the resource was the effect of the increased steam flow in raising shallow water temperatures and increasing the available energy. Allis (1983) states that the magnitude of the increase in heat flow, while subject to debate, was at least 100MW.

4.0 RESOURCE USE

Use of the Taupo hot water resource is difficult to quantify or define because of a lack of information. To overcome this problem a house to house survey was conducted over the 1986/87 summer in the "hot" areas of Taupo to locate bores and resource users. The survey comprised a questionnaire which was designed to obtain information on the type of resource use (i.e. water abstraction or heat exchanger); the purpose of its use; the extent of its use; the quantity of mass abstracted; the manner in which water is discharged; and the temperature of the water being used. Completed questionnaires were received from 381 ground water users or bore owners. Additional bores were located at properties where owners were unable to be contacted (e.g. at holiday baches), and in such instances questionnaires were left to be returned by mail. Questionnaires were not returned for approximately 150 properties thought to have bores, and for these cases information on usage is not available. Results from the survey are given in Table 1 and discussed in the following sections. A copy of the questionnaire is included as an appendix.

4.1 TYPE AND PURPOSE OF RESOURCE USE

Primarily the hot water resource is used for domestic and commercial hot water, central heating and spas or pools. Other more minor uses include glasshouse heating, industrial heating and cleaning, and irrigation, although in the latter case the hot water is a hindrance and has to be cooled before use.

More than half the surveyed users utilise the resource for domestic hot water heating, with 41% using it to heat houses and spa pools (Table 1). Very few people use it directly to drink, wash or bathe in, although some motels use it directly in spas and pools.

TABLE 1: Ground water use in Taupo and immediate surrounds (Results from 1986/87 questionnaire - 381 users/bore owners).

TYPE OF RESOURCE USE	PERCENTAGE OF USERS
Heat Exchangers	45
Water Abstraction	48
Steam Bores	9
Cold Water Bores	3
Unused Bores	11
PURPOSE OF USE	
Domestic Hot Water	54
Central Heating	41
Spa/Pool Heating	41
Other (glasshouse, irrigation, industrial, etc).	4

The resource is used in several ways to draw off heat energy. As shown in Table 1, nearly half (48%) of the users abstract water which is then used directly, or passed through surface heat exchangers or building heating systems. Approximately the same number (45%) use heat exchangers alone, and extract heat only, by passing town supply water down the bore to be heated by hot water in the ground. These systems generally operate on a thermo-siphoning principle, driven by cold water mains pressure and hot and cold water temperature imbalances. Various levels of sophistication exist in such systems, ranging from downhole plate heat exchangers, to copper coils, piping with a simple u-bend at the bottom or, in some cases, merely PVC piping buried in hot ground. In the last example, town supply water is heated by ground heat rather than by hot water.

The use of downhole heat exchangers requires sufficient heat flow through the ground to enable cold town supply water to be heated. In some instances the natural heat flow is insufficient, and surface heat exchangers have to be used in conjunction with water abstraction to maintain a satisfactory heat flux.

To the east (Invergarry Road area) and north (Spa Hotel) of Taupo where the ground water resource is hotter, many users draw steam. The steam is passed through heat exchangers with excess steam being vented to the atmosphere.

A further category of ground water users around Taupo are those abstracting cold ground water (Table 1). Although cold groundwater lacks heat energy, it is considered to be part of the same water mass resource and was therefore included in the bore survey. However, since these users are in areas that do not have a heat flux through them, their use of the resource is not germane to this report.

4.2 EFFICIENCY OF USE

Downhole heat exchangers provide more efficient use of the low temperature resource than do heating systems based on abstracting mass and energy (e.g. systems with pumps). Heat exchangers heat only the water that is used, whereas there is frequently energy wasted where water is abstracted. For example, where there is direct use of hot water, such as in spas or pools, the water is often cooled before use by spraying it in the air. In addition, more water is sometimes pumped than is used, and the surplus may be discharged to drains or streams rather than to soak holes where it has potential to recharge the hot water resource.

It must be noted that the efficiency of use, or conversely the proportion of energy wasted, is far less of an issue in Taupo than at Rotorua, where the resource being used comes directly from the geothermal reservoir as steam under pressure. Because of the pressure, the simplest means of abstracting geothermal energy in Rotorua is to induce the bores to flow naturally, passing the steam through surface heat exchangers and venting the excess to the atmosphere. The problem with these bores is that they will not flow naturally below a certain discharge, which is usually substantially in excess of the requirements of small users. Therefore, unless bores are supplying a group heating scheme, there is considerable energy wasted, being discharged continually to the atmosphere in the form of steam. Such waste does not occur at Taupo, where energy or mass has to be abstracted and the quantity abstracted can be controlled. In those areas of Taupo where there is a shallow steam resource, wastage is minimal because the steam is 'secondary' steam derived from boiling shallow ground water. It is therefore under far less pressure than steam from the deep geothermal reservoir and discharges at a much reduced rate.

Although there is far more efficient use of the hot water resource at Taupo than at Rotorua, the resource is available without charge per unit consumption once a pump or heat exchanger has been installed. Thus, although many users incur considerable installation and maintenance costs, the resource is essentially free and tends to be used without further regard to efficiency.

4.3 QUANTITY OF THERMAL ENERGY USED

The data used in estimating energy consumption from the hot water resource have been taken largely from the survey in which 381 users specified the manner in which energy is abstracted and the purpose for which it is used. However, the survey provided only limited results in terms of quantity of energy used because few people know the temperature or volume of water that they use. Where heat exchangers are used, energy consumption cannot be determined without a meter being installed.

Calculation of the available energy in abstracted water involves obtaining an enthalpy (energy per unit mass) figure from steam tables for water at a given temperature. The quantity of energy being abstracted can be calculated by multiplying the volume of water abstracted by the enthalpy of the water. An energy consumption figure can then be calculated by subtracting the energy content of the cooler, discharged water.

Forty-three domestic users supplied water abstraction rates and temperatures and discharge temperature data, with use covering central heating, spa pools and hot water. The average daily take is 1,839 l, and the average energy consumption from that water is 50%. The remaining mass and energy is discharged to soak holes and streams, and returned to the aquifer or surface water system.

Six responses from commercial users allowed similar calculations. The average daily commercial take is 1,946,297 l with an average energy consumption of 36%. This large average take is influenced by several users such as the A.C. Baths, De Bretts, and the Taupo Golf Course which requires large volumes of water for irrigating.

In estimating energy consumption for all the users in Taupo, average figures for abstraction rates, energy consumption and water temperature were used because of the lack of information covering all the bores. An average temperature for all the Taupo hot areas was obtained by running temperature logs down 26 bores around Taupo and estimating the mean maximum downhole temperatures. A mean of 73.7°C was calculated, which compares closely with a mean of 72.9°C obtained using figures from Dawson and Thompson (1981). Water at 73.7°C has an enthalpy of 308 kJ/kg (Rogers and Mayhew, 1980).

The average figures for domestic use have been assumed to represent households where hot water, central heating and a pool are all thermally heated. In many cases however, only one or two of these uses will be thermally heated, and the average energy consumption figure needs to be separated into three components to estimate energy use by individual households. Energy use by the three components was estimated from the questionnaire, where people with only one or two uses supplied abstraction rates. Data from the telephone survey, which examined comparative use of electrical and thermal energy consumption, indicated that, on average, thermal central heating was used for 6.5 months of the year and pools were thermally heated for 6 months, in winter only. Based on these data, the annual percentage energy use from the three components is as follows: hot water heating 52%; pool heating 32%; and central heating 16%.

These figures were applied to the remaining users who had not supplied information on abstraction rates or water temperatures, including those using downhole heat exchangers. In this respect, it was assumed that the efficiency of a downhole heat exchanger would equate to that of a system abstracting hot water and the same averages were applied. However, the actual energy consumption is likely to be somewhat different between heating systems using pumps and those using heat exchangers, because of the manner in which the energy is utilised (see Table 2). From this table it is apparent that abstracted hot water is primarily used for pools, whereas heat exchanger systems have a greater use in home heating and domestic water heating.

TABLE 2: A breakdown of energy use versus the method of energy extraction.

Method of Energy Extraction	Number of Users *			Total Number Surveyed
	Central Heating	Spa Pools	Hot Water Heating	
Hot Water Abstracted	40	104	57	130
Heat Exchanger	117	52	129	167

* Excludes cases where a heat exchanger is being used in conjunction with a pump.

In addition to those users identified from the questionnaire, 150 bores were located at the time of the survey for which questionnaires were not obtained. The assumption was made that these bores would be used in accordance with percentage figures in Tables 1 and 2, and energy consumption was calculated for their use on this basis.

Table 3 shows annual energy use figures in four groups; domestic and commercial with water abstraction, and domestic and commercial with heat exchangers. From this table it is apparent that most energy utilised from the hot water resource is by a small number of commercial users, with those abstracting water accounting for 78.4% of the total energy use.

TABLE 3: Estimated annual energy use

TYPE OF USE	ENERGY CONSUMED (MJ)	PERCENTAGE OF TOTAL
Domestic - water abstracted	2.481×10^7	9.0
Domestic - heat exchanger	1.503×10^7	5.4
Commercial - water abstracted	2.1674×10^8	78.4
Commercial - heat exchanger	1.982×10^7	7.2
Total	2.7640×10^8	100.0

The total energy consumption of 2.764×10^8 MJ/y estimated for all users is small compared with the natural heat flow of the Tauhara Geothermal Field. Natural heat flow has been estimated for the Tauhara field as 105MW (3.3×10^9 MJ/y) (Mongillo and Clelland, 1984), and consists of the deep geothermal heat which flows to the surface in the form of hot springs, fumaroles, and hydrothermal ground.

The total energy consumption amounts to 8.4% of the natural heat flow, with commercial use being 7.2% and domestic use accounting for only 1.2% of energy at the surface. More recent estimates of natural heat flow are approximately 200-220MW (Mongillo, pers comm, DSIR, 1988). In this case, energy consumption would amount to only 4-4.4% of the natural heat flow.

5.0 DISCUSSION

The estimate of between 4 and 8% utilisation of the natural heat flow is, in practical terms, a sizeable energy consumption by a relatively small number of Taupo residents. Comparing the average domestic use of geothermal energy with electrical energy used for similar purposes suggests that considerably more thermal energy is used than electrical to achieve the same heating requirements. Based on this survey, more than twice as much energy is used in households using geothermal energy (85500 MJ annually) than in those households using solely electrical energy (39420 MJ annually). The most probable reason for this discrepancy is the absence of any unit charge on thermal energy when it is being used, although in fact many users incur large maintenance bills, particularly those using pumps.

However, from a resource management point of view there appears to be no requirement at present to impose restrictions on the use of the thermal energy. On the contrary, there is potential for greater exploitation of the resource than currently occurs. The effect of the existing energy consumption will be minimal on the total resource, which has an energy recharge far in excess of the energy drawoff. Furthermore, there is no indication that the available thermal energy is likely to reduce in the future. Shallow hot water users are not removing energy from its source, but are merely drawing off residual energy which is discharging naturally to the shallow aquifers from the deep geothermal reservoir. Even the potential exploitation of the deep reservoir for power generation should have minimal effect on the use of shallow energy because the shallow ground water is steam heated. This steam originates from a steam zone at the top of the deep reservoir, and the zone is expected to vary only slightly under a situation of field exploitation.

The main potential conflicts arising from continued and additional use of the shallow hot water are between individual users. Figure 4 shows the location of bores throughout the hot areas of Taupo. Should the density of bores increase significantly in some areas, localised cooling may occur between bores. It is this issue that should be emphasised in future management of the shallow energy resource.

FIGURE 4: Map of shallow bores and hot water users in Taupo.

6.0 CONCLUSIONS

This report has attempted to determine the amount of energy being taken from the shallow hot water resource at Tauhara Geothermal Field by bore and spring users. In so doing, many assumptions have been made because of the limited data available, and average figures from only a few known cases have been taken to represent all users. Therefore, the figures calculated should only be regarded as rough estimates, with a large margin of error. However, the assumptions made are probably conservative so that energy consumption is likely to be over estimated.

There is a natural heat flow from Tauhara geothermal field of 3.3×10^9 MJ/y. The results of this survey indicate that approximately 2.8×10^8 MJ/y (8.4%) of this heat flow is being utilized for commercial and domestic heating purposes. The majority of this use (86%) is for commercial requirements, notably heating pools and central heating in motels. Domestic use amounts to only 14% of the total use (1.2% of the total natural heat flow). The main domestic use of the hot water resource is for central heating, heating pools, and heating water.

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WAIKATO VALLEY AUTHORITY

TAUPO BOROUGH QUESTIONNAIRE

1. Name : ______________________

   Address and Telephone No.: ______________________

   ____

   ____

   ____

2. Bore/well Details

Is there a bore/well on your property?	Yes/No
Hot or Cold water	________
Bore depth (m)	________
Intake depth (m)	________
Base of casing (m)	________
Screen level (m)	________
Screen lengths (m)	________
Bore diameter (mm)	________
Water level: Average (m)	________
Water level: Winter (m)	________
Water level: Summer (m)	________
Water level after pumping (m)	________
Pump type	________
Pump capacity (gph or l/s)	________
Potential bore yield	________
Bore pressure	________
Driller	________
Date drilled	________

Location of bore on property ______________________
(Please provide sketch overleaf)

Distance from lake ______________________

Is it suitable for : Pump testing Yes/No
Water Quality sampling Yes/No
Water level measurements Yes/No

Has the bore ever been Monitored? Yes/No

who by? ____________________

when? ____________________

3. What type of resource is utilised? (circle)

Hot groundwater
Hot surface water
Steam/water mixture
Steam from dry bore
Ground heat only
Cold water

4. What is the resource used for? (circle)

Domestic hot water
Central heating
Thermal bath/spa
Glasshouse
Industrial
Other - Specify:

Are you the sole user from this source or do you supply several users? ____________________

How Many? ____________________

5. Water abstraction (circle)

Abstraction from: bore, stream, spring
Discharge to : injection bore - depth (m)
soak hole - depth (m)
Surface - drain, stream, lake

Average quantity abstracted/day : ____________________
Average number hours pumping/day : ____________________

Temperature prior to abstaction (°c) ____________________
Temperature when discharged (°c) ____________________

Is water: used directly? Yes/No

: Passed through heat exchanger Yes/No

If used directly : How is it cooled ? ________

: Are chemicals added? Yes/No

: If yes, what type? ________

6. Down - hole heat exchanger

Is it in hot water or hot ground? ________

Water temperature (°c) ________

Ground temperature (°c) ________

Depth below ground surface (m) ________

Does the bore require pumping to attain sufficient heat Yes/No

7. Steam bores

Temperature (°c) ________

How is it controlled? ________

8. Do you have any problems abstracting water or discharging it?

eg. silica scaling.
Specify: ________

9. Have you ever noticed any changes in water level or water/ground temperatures:

Specify: ________

10. Do you have any indications of geothermal activity on your property? eg. steaming ground, springs, etc.,

Specify: ________