Proc. 7th NZ Geothermal Workshop 1985

NAIKE HOT SPRINGS: A HOT SPRING SYSTEM
(NORTH ISLAND, NEW ZEALAND)

S. SISWOJO, A.S. KASONTA, M.P. HOCHSTEIN

Geothermal Institute
University of Auckland

ABSTRACT

Thermal water (ab. 29 ℓ/s) is discharged near a greywacke basement–Tertiary sediment contact over a distance of 0.5 km by a few hot springs (T_{max} = 67°C) and by seepage along the Te Maire Stream near Naike (70 km S of Auckland, NZ). The springs discharge a dilute alkaline, NaCl-type water which shows affinity to the chemistry of other thermal springs in the greater area occurring in a similar geological setting. The hot springs at Naike are fed by two NE–striking fracture zones which are connected by subsidiary fractures and joints. No significant, concealed outflow has been observed, and the shallow reservoir of the system appears to be restricted to the fracture zones.

Minimum equilibrium temperatures of about 100°C are indicated for the deeper feeder system. It is postulated that an anomalous terrestrial heat flow supplies all the heat discharged by the system and that a collection network exists at depths greater than 3 km covering an area of the order of a few hundred km^2.

Introduction

Two km NW of Naike Village (NZMS 260 Sheet R13), thermal water discharges from two large springs and numerous smaller seepages for about 500m along the Te Maire Stream. Older chemical analyses of the thermal waters are cited in Petty (1972); a short description of the springs is also given by Waterhouse (1978). The total flowrate of the springs was estimated to be 10 ℓ/s, and their maximum temperatures were given as ranging from 65 to 93°C (Petty 1972).

The geological map of Waterhouse (1978) shows the springs to occur close to outcropping Early Jurassic basement rocks. Other hot springs within 30 km of Naike also occur near basement contacts, namely the hot springs at Lake Waikare (Hochstein 1978), or in the basement rocks themselves, i.e. the Waikorea and Waingaro hot springs (Petty 1972), south of Naike. From the available geochemical data it is inferred that all these springs discharge dilute alkaline NaCl-type thermal waters. It has been postulated that hot water discharged by these springs ascends along deeply penetrating basement fractures and that some of the springs derive their heat from magmatic sources (Petty 1972). Hochstein (1978) suggested that the heat source for these, and numerous other thermal springs in the Hauraki Depression, Northland, and the Coromandel Peninsula, is the anomalous terrestrial heatflux caused by hot Upper Mantle rocks which underlie most of the area.

The Te Maire hot springs, also referred to here as Naike hot springs, have been studed by students and staff of the Geothermal Institute during short field trips between 1983 and 1985; more detailed studies in the form of field projects were undertaken by Sulasdi (1983, geochemistry), Simandjuntak (1983, geophysics), Siswojo (1984, geology), and Kasonta (1984, geophysics). The aim of these studies was to establish a representative lithostratigraphic section, and to delineate the extent of fracture zones and their relation to any shallow reservoir present. In addition, the composition of all discharges was determined to assess their homogeneity. The total discharge rate of all known thermal waters and the natural heat loss rate was also estimated. A summary of these studies is given in this paper.

Not all the field work could be checked by staff of the Institute, and only the most salient features of the field projects have been summarized.

Geology

Mesozoic and Tertiary sedimentary rocks outcrop in the area surrounding the Te Maire hot springs (Waterhouse 1978). A low lying area forms the flood plain of the Te Maire Stream with an elevation between 16 and 20m above sea level; it is covered by a thin layer of alluvial swamp deposits. The flood plain is surrounded by hilly terrain reaching elevations of about 100m both in the S and NW part of the area shown in Fig. 1. In general, the S part of the hill country is formed by hard, sedimentary rocks of Early Jurassic age, the northern part by Tertiary sediments.

A geological map of the area based on field work by Siswojo (1984) is shown in Fig. 1; this covers an area of 6.5 km^2. The stratigraphic terms of Waterhouse (1978) were used in establishing the stratigraphic column in Table 1. The information (Table 1) is based on the study of 24 outcrops. The oldest sedimentary rocks exposed are of Early Jurassic age (New Castle Group of Waterhouse) that are referred to as basement rocks. Rare fossils, including Pseudaucella marshalli, occur in outcrops 300m S of Spring 1. These rocks are unconformably overlain by Tertiary rocks of the Te Kuiti Group consisting of claystones, limestones and sandstones (see Table 1). Resistivity soundings by Simandjuntak (1983) showed that the lower members of the Te Kuiti Group and the basement rocks exhibit significantly different resistivities; this information was used to clarify stratigraphic relations in areas with no outcrops or ambiguous appearance of weathered rocks. The maximum thickness of the Tertiary rocks (Table 1) was obtained from resistivity soundings and interpretation of residual Bouguer anomalies (Kasonta 1984).

Geological map

On the whole, the geological structure of the area shown in Fig. 1 is similar to that as mapped by Waterhouse (1978); however, several changes can be noticed if the map (Fig. 1) is compared with the smaller scale map of Waterhouse, namely:

Waikato Coal Measures (kh) are clearly exposed and occur at the surface to the SE of hot springs No. 1; these sediments are not shown in the Waterhouse map.

The location of the basement (np) contact in the southern area of Fig. 1 differs from that shown by Waterhouse where the basement was shown to occupy a large area in the SE extending northwards to the Waimai Fault.

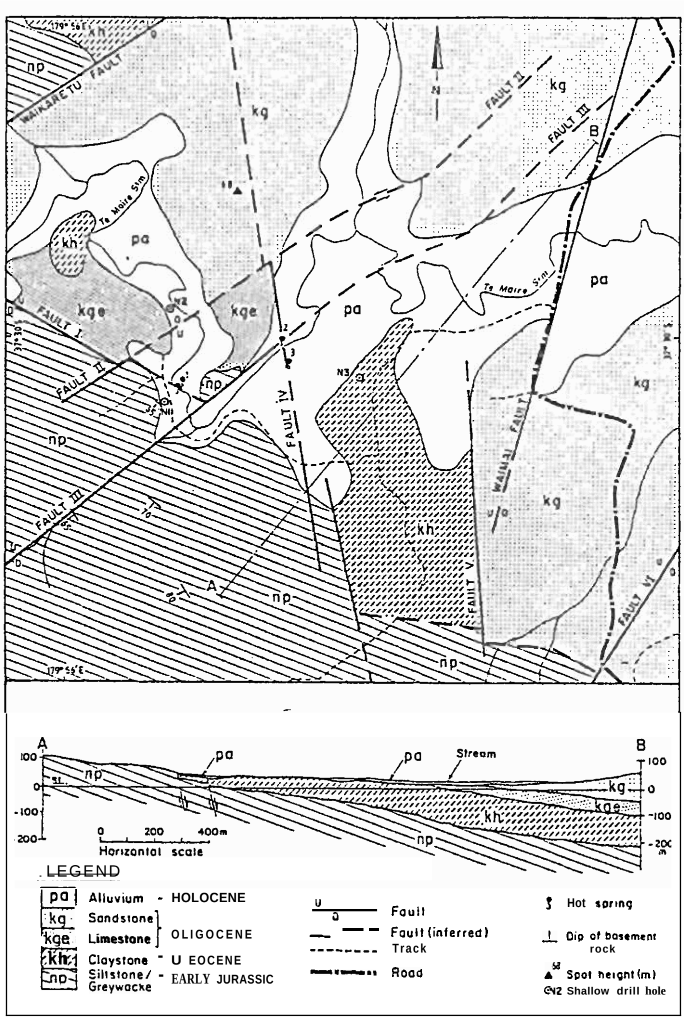


Fig. 1: Geological map and section of Naike Hot Springs area.

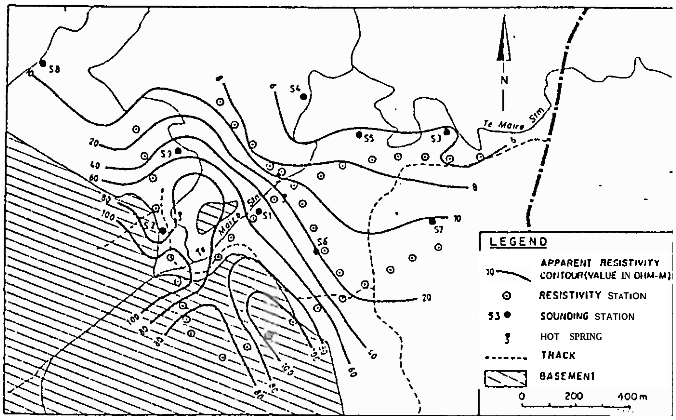
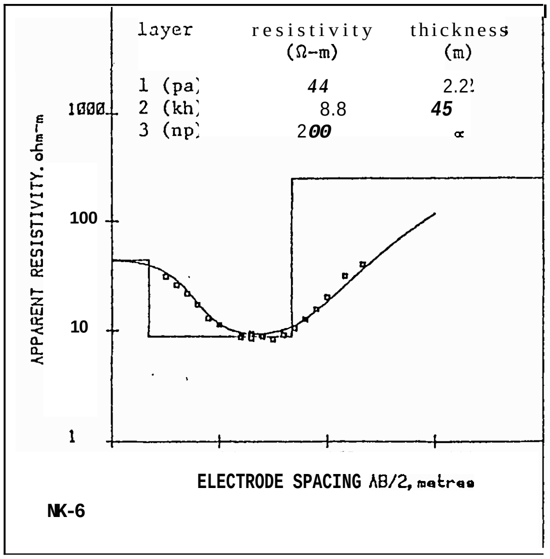


Fig. 2: Apparent resistivity map of Naike Hot Springs. (Schlumberger array AB/2 = 100m)



layer	resistivity (Ω-m)	thickness (m)
1 (pa)	44	2.2
2 (kh)	8.8	45
3 (np)	200	∝

Fig. 3: Resistivity sounding S6 near exposed claystones, Waikato Coal Measures (kh).

Minor differences were noted with respect to the actual extent of the Elgood Limestone (kge) in the W part of Fig. 1; Whaingaroa Siltstone could not be found.

Structural Geology

The Jurassic basement rocks are folded, jointed, and faulted whereas the Tertiary rocks lie sub-horizontal on top of the eroded basement; the latter exhibit only minor jointing. Folding of the basement rocks is indicated by dips between 60" and 80" of bedding planes which strike generally NW; these rocks are fractured and extensively jointed. A stereo-histogram plot of measured joints (n = 146) shows a dominance of joints in the direction of ***046"*** which is similar to that of lineaments visible on air photos of the greater area surrounding (Fig. 1).

Two faults were mapped in the area covered by Fig. 1 by Waterhouse (1978), namely the Waikaretu and the Waimai Faults. Although these faults can be recognized on air photos, other pronounced lineaments can also be seen; these are shown in Fig. 1 (Fault I to Fault VI). Fault I is associated with some vertical displacement of the less dense Tertiary sediments as indicated by gravity data; the fault appears itself to be displaced by Fault II and might extend through the westernmost hot springs (No. 1). Gravity data indicate that the concealed basement structure NW of spring No. 1 is complex; the structure of this area probably requires more work.

Faults II and III are parallel to the Waikaretu Fault and Maire Fault (outside Fig. 1) as mapped by Waterhouse. Fault III is probably the major feeder fracture along which thermal water ascends to the surface although temperature measurements in one shallow hole indicate that some thermal water also ascends in the W segment of Fault II. Both faults appear to be strike-slip features (sinistral) showing some flexure in the N part whereas Fault II is marked by an alignment of sinkholes in the Tertiary sediments. The lineaments shown as Faults IV and V trend NNW and are only visible on air photos; these lineaments are probably also strike-slip faults associated with vertical displacements too small to be recognized in the gravity anomaly.

Initially it was thought that both groups of hot springs, i.e. No. 1 and Nos. 2 and 3, were located over a single, NE trending fracture zone (Sulasdi 1983), but information shown in Fig. 1 indicates that only springs Nos. 2 and 3 lie over Fault 111, whose surface trace lies 120m south east from spring group No. 1. The finding that elevated temperatures (24") occur at a shallow depth (6.0m) in drillhole N1 to the SW of spring No. 1 and that a small minor outflow of thermal water occurred in hole N2 near Fault II can be explained by assuming that warm water is moving along these two NE trending faults (Faults II and III) and that spring No. 1 is fed either by a NW striking cross fault connecting the two or by a yet unknown NE trending fracture or NE trending joints between the two faults. The permeability of this network must be high since all major springs discharge at the same level (17.5m) as determined by tacheometric surveys. Both major springs (No. 1 and No. 2) discharge in an artesian mode; spring No. 1 stands about 0.2m and spring No. 2 about 1.0m above the usual flow level of the Te Maire Stream.

Geophysical structure

Resistivity soundings:

The resistivity structure of the area around the springs was investigated by Simandjuntak (1983) using resistivity soundings (Schlumberger array up to AB/2 = 315m). The location of the sounding stations is shown in Fig. 2. The aim of the survey was to detect the lateral extent of mineralized thermal fluids both within the Tertiary sediments and within the basement. However, it was found that the lower sequence of the Te Kuiti Group (Waikato Coal Measures) exhibits resistivities as low as 5 ohm-m, even away from the hot springs, and this prevented any detection of hot mineralized fluids at shallow depths within the Tertiary sequence.

The soundings, however, showed that the top and bottom of the Waikato Coal Measures can be clearly identified in the resistivity sections, and one of the soundings, S6 in Fig. 2, was made over outcropping claystones of this member (kh) in an area where it was thought that basement occurred near the surface. Sounding S6, shown in Fig. 3, led to the discovery of Waikato Coal Measures in the SE part of the area, and this was confirmed by field mapping.

Resistivity traverses:

To obtain a better understanding of the extent of the low resistivity rocks of the Te Kuiti Group, a resistivity traverse (AB/2 = 100m) was conducted in 1984. The results of this survey are shown in Fig. 3, taken from Kasonta (1984); the southernmost traverse line might contain an error (about 100m) in the NS direction. It can be seen that the apparent resistivity over the Tertiary sediments decreases towards the NE; resistivity soundings showed that this decrease is caused mainly by the increase in the thickness of the conductive claystones (kh); see also geological section in the lower part of Fig. 1. There is no evidence for any significant structural control of the resistivity pattern shown in Fig. 3 apart from that of the basement-Tertiary contact.

Gravity survey:

Because of equivalence, the exact thickness of the low resistivity claystone sequence (kh) could not be determined for all resistivity soundings; the large resistivity contrast between these sediments and the basement also prevented delineation of any vertical displacements of Tertiary sediments near the basement contact. To obtain an independent estimate of the total thickness of the Tertiary sediments and to check whether the basement contact is fault controlled, a gravity survey was made (Rasonta 1984); all station heights were determined by tacheometry. The residual Bouguer anomalies of this survey are shown in Fig. 4; these were computed using a standard density of 2.67 x 10^3 kg/m^3 for all terrain and by subtracting the effect of the regional field which, in turn, was obtained from DSIR gravity data of stations located on basement rocks in the greater area. The resulting residual anomalies are almost zero over the exposed basement (see Fig. *4)*.

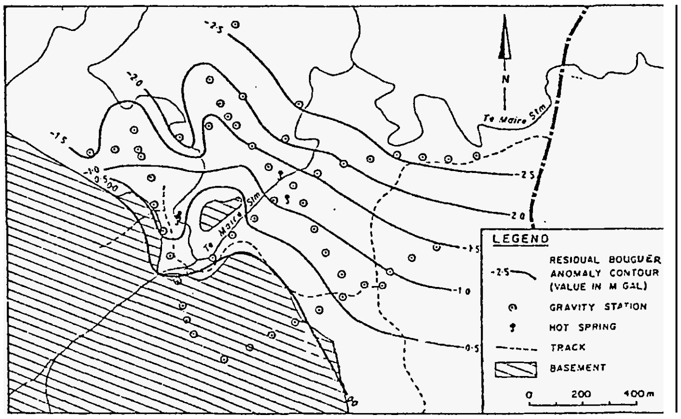


Fig. *4:* Residual Bouguer anomaly of Naike Hot Springs.

The approximate density of the Tertiary sequence was determined by using the Nettleton procedure over pronounced terrain features and incorporating basement depths at sounding stations where the effect of

TABLE 1: Stratigravhic column of sedimentary rocks in the Te Maire hot spring area (Naike)

Epoch	(Group) Member	Outcrops	Maximum thickness (m)	Average resistivity (ohm–m)	Lithologic description
Holocene	(Alluvium) (pa)	–	6	30–50	Swamp deposits
Oligocene	(Te Kuiti Gp) Glen Massey sandstone (kg)	**10**	90	***15-20***	Siltstone: white–grey, brittle, clayey, calc., tuffaceous, fossil–bearing Sandstone: grey, med.-hard, fine grained, calc., forams
	(Te Kuiti Gp) Elgood Lime–stone (kge)	3	***40***	10–20	Limestone: yellow–grey, hard, sandy
Upper Eocene	(Te Kuiti Gp) Waikato Coal Measures (kh)	3	120	3–8	Claystone: dark–grey, soft, non–calc., sandy, carbon., molluscs, limestone lenses Claystone: dark–grey, soft, non–calc., carbonaceous
Early Jurassic (Ururoan)	(New Castle Gp) Pongawhakatiki Siltstone (np)	*8*	1200	60–90	Siltstone: steel blue, very hard, well bedded, fractures filled by calcite, fossil–bearing (pseudaucella marshalli) Greywacke: steel blue, very hard, massive spheroidal weathering.

equivalence is small. The density of dry Tertiary rocks was found to be 1.7 x 10^3 kg/m^3, that of saturated rocks about 2.16 x 10^3 kg/m^3; these values are similar to average densities of Te Kuiti Group rocks as encountered in wells in the nearby Huntly Area (Fitzgerald ***1985).*** Depths to basement were then computed for the data shown in Fig. *4;* the cross-section shown in the lower half of Fig. 1 is based on this interpretation. It can be seen from this section that the Tertiary sediments attain a thickness of about 200m in the **NE** part of Fig. 1.

The horizontal gradient of these anomalies is rather small over the basement contact lying to the E of spring No. 1, thus indicating that downfaulting of Tertiary sediments is small; this inference was confirmed by computing the theoretical effect of 2–D models. Some vertical displacement of sediments, however, is indicated near the basement contact lying to the W of spring No. 1 (i.e. Fault I), although the control of gravity anomaly contours is poor in this area. The gravity anomaly pattern to the NW of spring No. 1 is irregular and is probably caused by an irregular basement subsurface.

Shallow temperature and SP surveys

Since the extent of conductive rocks saturated with thermal fluids could not be outlined by resistivity surveys, a ground temperature survey was made to find whether some thermal water occurs at shallow depths outside the inferred feeder fractures. A set of nine auger holes (2.5 to 4.1m deep) was drilled in ***1983*** near the resistivity sounding stations. The observed bottom temperatures were all between ***14.0*** and 15.0°C (mean annual temperature about 14.5°C) except for hole S2 (18.2°C at 2.5m) and hole S9 (16.0°C at 2.6m). To check these temperatures, two additional holes N1 and N2 were drilled in ***1984*** near site ***S2*** and S9 respectively; in addition, the temperatures in an existing non–producing farm well (N3 in Fig. 1) were measured. The bottom temperatures of these wells are listed in Table ***2.***

As can be seen from Table 2, higher temperatures exist near site S2 and in hole N1 which lies about 100m to the SW of hot spring No. 1, whereas normal temperatures (i.e. 15°C) occur at the bottom of hole **N2.** However, slightly elevated temperatures of about **17°C** were found at shallow depths in **N2** thus confirming the earlier measurements in nearby auger hole S9. Since hole N2 lies about 250m upstream from hot spring No. 1, it is unlikely that this temperature anomaly is caused by a shallow outflow from hot spring No. 1. On the other hand, Fault II lies near hole N2 and it is possible that minor flow of thermal water originates frcm this fracture.

To obtain some independent evidence for fluid movement in basement fractures away from the hot-springs, a survey of the natural self potential was made by Kasonta ***(1984)*** at most of the resistivity traverse stations shown in Fig. 2. The phenomenon of negative self potentials (SP) in the vicinity of thermal springs has been reported for hot springs over some high temperature hot water systems (Corwin 1975).

TABLE 2: Ground temperatures in selected shallow holes (Naike hot springs)

Hole No.	Depth (m)	Temperature (°C)	Date
s2	2.5	18.2	Sept. 1983
N1	2.5)	22.5	April 1985
N1	6.0)	24.2	
S9	2.6	16.0	Sept. 1983
N2	2.6)	16.8	April 1985
N2	9.0)	15.1	
N3	8.0	15.0	Sept. 1983

In the Naike prospect, reproducible negative potentials (about -10mV) were observed near hole N2, near Fault III to the SW of hot spring No. 1 and near hot spring No. 2. Unfortunately, the spacing between adjacent SP stations was too large (100m) to define the exact centre of these anomalies.

Chemistry of hot springs and natural heat loss

As mentioned in the introduction, the chemistry of the thermal waters discharged in the Te Maire hot springs shows some affinity to that of other thermal springs which can be found near greywacke basement contacts between South Auckland and Raglan. Analyses of these springs are listed in Table 3.1. It can be seen that these waters are alkaline NaCl-waters with a high concentration of boron and rather low concentrations of calcium and sulphate.

Chemical studies:

The chemistry of all major hot springs, i.e. springs Nos. 1, 2 and 3 in Fig. 1, was determined by Sulasdi (1983) who found that constituents do not vary significantly between springs, and that the springs are fed by the same body of hot water (see Table 3.2). There is no evidence for shallow mixing with groundwater between spring No. 1 and No. 2, which indicates that the feeder zone is sealed at shallow depths. If the SiO_2 concentration were controlled by conductive temperature losses, equilibrium temperatures at greater depths of about 120°C are indicated; if equilibration with chalcedony exists, equilibrium temperatures of 90°C can be inferred. The Na-K-Ca geothermometer points to deeper equilibrium temperatures of about 100°C although this value lies at the lower confidence range of this geothermometer.

Mass flow and heat loss:

To determine the total flowrate of thermal water which enters the Te Maire Stream, the upstream and downstream concentrations of boron and chloride were measured by Sulasdi (1983), i.e. upstream of spring No. 1 and downstream of spring No. 2. The flowrate of the Te Maire Stream was measured by a flowmeter near spring No. 2 (average flowrate was 970 ℓ/s in April 1985). The measurements were repeated in 1985 (see Table 3.3) when the sodium and chloride concentrations were checked. It can be seen from Table 3.3 that the thermal water entering the stream increases the concentration of these constituents significantly. Since the chemistry of all major springs listed in Table 3.2 is rather constant, the total mass flow rate of thermal water can be computed. It was found that in April 1985 the total flow rate of thermal water entering the stream was 29 ± 3 ℓ/s, which is significantly greater than the flow rates of springs No. 1 and No. 2 which were measured using a V-notch weir and which are 3 ℓ/s and 4.5 ± 0.5 ℓ/s respectively. These results indicate that most of the thermal water enters the stream by seepage and springs at the bottom of the stream. Some discharge of thermal water at the bottom of the stream occurs upstream from spring No. 1.

The temperature of the water discharged by seepage, however, night be less than 65°C; a seepage near spring No. 3 discharged water at a temperature of 39°C. Assuming that all thermal water discharged into the stream was originally at 65°C, the total heat loss can be computed from the total flow rate with respect to the temperature of the stream; it was found that the heat loss based on the chloride flux is about 6.1 ± 1.0 MW. A minimum heat loss of about 2.8 MW is indicated by the temperature rise of the stream; this figure does not allow for evaporative and other losses.

Discussion of results

The study of the Naike hot springs presented in this paper is one of the few studies made so far of low temperature prospects in the North Island. The study shows that a significant flow of thermal water ascends in fracture zones of the Jurassic basement; the ,thermal water is discharged by a few hot springs and numerous seepages over a distance of about 0.5 km in the direct vicinity of the basement- Tertiary contact. The feeders are most likely two NE striking fracture zones (Fault II and Fault III) which can be recognized in air photos and which are associated with some strike slip (sinistral) movement in the past; these feeders appear to be interconnected by subsidiary fractures and joints. The homogeneous chemistry of the waters indicates that no mixing with ground water occurs at shallow depth and that the fracture zones are well sealed, probably by calcite deposition.

There is no reliable information which can be used to estimate the width of the fracture zones saturated with thermal water. Temperature measurements taken in hole S1, about 30 to 50m away from one of the inferred fracture zones (Fault III), showed no anomalous bottom temperature and it is, likely that the width of the fracture zones is small.

The absence of a reservoir at shallow depths is a characteristic feature of the Naike hot spring system and in this aspect it differs from two other low temperature systems in the Auckland area which have already been studied in detail, namely the Parakai and Waiwera system. Temperature profiles in bores and resistivity surveys have shown that at Parakai and Waiwera, thermal water spreads laterally in thick permeable Tertiary sandstones of the Waitemata Group over distances of at least 0.5 to 1 km; this created a shallow reservoir which is at least 150m thick at Parakai (ARWB 1981) and probably thicker than 200m at Waiwera (ARWB 1980). The chemistry of the thermal waters is also different because of some mixing with diluted marine water; both systems lie at the coast. The natural output of the Parakai and Waiwera systems (about 10 to 15 ℓ/s each) is less than that of the Naike springs.

One can only speculate about the possible heat source of the Naike system. It can be safely assumed that a minimum temperature of about 100°C exists near the bottom of the feeder system. It can be inferred that the total heat (i.e. about 6 MW) transferred and discharged at the surface at Naike is a minimum value since some conductive losses occur in the feeder system. It can also be assumed that there is no magmatic input at source depth since volcanism in the area ceased at least 2 Mill years ago. This leaves the natural terrestrial heatflow as likely heat source.

An anomalous terrestrial heatflow of about 85 ± 10 mW/m^2 has been observed in most deep sedimentary basins of the Northland area (Pandey 1982) and an. anomalous flux has also been postulated to explain the development of the Hauraki Rift which has been active at least during the last 2 Mill yrs (Hochstein 1978). Using thermal rock parameters for basement rocks as cited in Pandey (1982) it can be inferred that the thermal waters at Naike can be heated to 100°C at depths of the order of 3 km; resource

Table 3.1: Chemistry of thermal waters associated with greywacke contacts between South Auckland and Raglan
(all constituents in mg/kg)

Locality	T(°C)	pH	Na	K	Li	Ca	Mg	B	Cl	SO4	HCO_3	SiO_2
Naike	65	9.15	150	'2.5	1.8	2.6	7.9	18.6	159	4.0	34	70
Lake Waikare	71	8.3	260	21	n.d.	6	0.1	17	370	n.d	0	110
Whitford	42	9.7	108	1.5	0.3	3	n.d.	16	39	14	0	85
Waikorea	54	n.d.	≈150	n.d.	n.d.	n.d.	n.d.	n.d.	≈185	"9	≈33	63

References:
Naike Springs (Waterhouse 1978);
Lake Waikare Springs (Hochstein 1978);
Whitford well (from unpublished ARA data);
Waikorea Springs (Petty 1972).

Table 3.2: Chemistry of the Te Maire hot springs (Naike) as determined by Sulasdi (1983) and students of the 1985 Geothermal Diploma Course
(all constituents in mg/kg)

Locality	Date	T(°C)	pH	Na	K	Li	Ca	Mg	B	Cl	SO4	HCO_3	SiO2
Spring 1	Aug. 1983	64	9.7	155	2.1	0.2	5.2	0.01	12.3	160	5.0	n.d.	48 (?)
Spring 2	Aug. 1983	60	9.7	150	2.2	0.2	4.7	0.02	12.8	163	7.0	n.d.	70
Spring 3	Aug. 1983	59	9.7	145	2.1	0.5	4.5	0.01	12.4	153	8.0	n.d.	72
Spring 2	Apr. 1985	65	9.1	143±1.5	2.0	n.d.	n.d.	n.d.	n.d.	154±7	6.7	47	67±4

Table 3.3: Chemistry of Te Maire Stream, upstream and downstream of the hot springs
(all constituents in mg/kg)

Locality	Date	T(°C)	pH	Na	K	Li	Ca	Mg	B	Cl	SO4	HCO_3	SiO2
Upstream	Aug. 1983	14.5	n.d.	x(1)	x	-	10.0	9.2	0.27	x	x	-	-
Downstream	Aug. 1983	15.0	n.d.	x	x	-	10.5	9.2	0.36	x	x	-	9
Upstream	Apr. 1985	13.3	n.d.	14.4±0.5	-	-	-	-	-	20.4±1.0	-	-	-
Downstream	Apr. 1985	14.0	n.d.	17.6±0.5	-	-	-	-	-	24.3±0.3	-	-	-

1) x indicates that results with too high an error were obtained.

depths would therefore be greater than 3 km. Since there is no evidence that the regional heatflux has been lowered to more than 65 mW/m^2 in other wells in the greater area (Huntly area, for example, Pandey 1982), it can be assumed that only a small portion of the heat transported by the terrestrial heat flux is transferred to the surface by deep, secular movement of fluids in the basement. If 20% of this flux (i.e. 17 mW/m^2) were transferred by deep fluids, a cross-section of at least 700 km^2 is indicated for the deep collection system which feeds the Naike hot springs, i.e. an area within a radius of about 15 km around these springs. These figures. appear to be rather large but hot spring systems in the greater area, including those in the Hauraki Depression which produce discharges of ≥5 MW, are indeed separated by distances between 15 and 25 km.

Such deep collection systems extending to resource depths greater than 3 km could explain the rather homogeneous chemistry of other hot spring systems which occur within 30 km distance of Naike, i.e. at Lake Waikare, Waikorea and Waingaro. Sulasdi (1983) suggested that the waters at Naike might contain some metamorphic waters which can be liberated at temperatures above 120°C.

Acknowledgenent

D. Larsen and N. Renner (Chemistry Dept., University of Auckland) helped with sampling and the analysis of the thermal waters. G. Caldwell and E. Pak (Geothermal Institute) participated in the field projects.

References:

ARWB (Auckland Regional Water Board) (1980): Waiwera Water Resource Survey. ARWB technical publication No. 17, 178 pp.

ARWB (Auckland Regional Water Board) (1981): Parakai Water Resource Survey and Management Proposals. ARWB technical publication No. 20, 121 pp.

CORWIN, R.F. (1975): Use of the self potential method for geothermal exploration. Lawrence Livermore Berkeley Lab. Report LBL-3235, 48 pp.

FITZGERALD, N.A. (1985): The application of geophysical prospecting in the Huntly Coal Basin. Unpublished MSc thesis lodged in the Library, University of Auckland.

HOCHSTEIN, M.P. (1978): Geothermal systems in the Hauraki Rift Zone, New Zealand - an example for geothermal systems over an inferred upper mantle swell. In: Alternative Energy Sources vol 6, 2599-2610. Hemisphere Publishing Corp., Washington, DC.

KASONTA, A.S. (1984): Self potential, resistivity and gravity surveys of Naike Hot Springs Area, Huntly, New Zealand. Geothermal Project Report No. 84.16, 71 pp, Geothermal Institute, University of Auckland.

PANDEY, O.M.P. (1982): ,Terrestrial heat flow in New Zealand. Unpublished PhD thesis lodged in the Library, Victoria University of Wellington.

PETTY, D.R. (1972): Springs in the Auckland Region. NZ Geological Survey Report NZGS 57, 56pp, DSIR Wellington.

SULASDI, D. (1983): Investigation of thermal springs at Te Maire, Huntly, New Zealand. Geothermal Project Report No. 83.22, 28 pp, Geothermal Institute, University of Auckland.

SIMANDJUNTAK, Y. (1983): Geochemical (data) and DC resistivity of Naike Hot Springs area, New Zealand. Geothermal Project Report No. 83.20, 37 pp, Geothermal Institute, University of Auckland.

SISWOJO, W. (1984): Geological mapping of Naike Area, Huntly, New Zealand. Geothermal Project Report No. 84.25, 32 pp, Geothermal Institute, University of Auckland.

WATERBOUSE, B.C. (1978): Onewhero, Sheet N51, 1:63 360, Geological Map of New Zealand, DSIR Wellington.