TRACER TEST DESIGN FOR THE ROTORUA GEOTHERMAL FIELD

H.PAN[1], D.H. FREESTON[1] and M.J. O'SULLIVAN[2]

Geothermal Institute[1] and Department of Engineering Science[2]
University of Auckland, New Zealand

ABSTRACT - This paper describes a tracer test design which is part of an investigation into doublet systems within the Rotorua geothermal field. The overall project has been divided into three stages: the fist stage is a theoretical study which is aimed at finding better analytical and numerical methods for simulation of doublets (Pan et al 1990). The second stage is to carry out a tracer test in the Rotorua geothermal field. The third stage will be an analysis of the tracer test results and an assessment of doublet systems for the geothermal field The present paper discusses the tracer test design work. Tracer tests are being conducted at the Rotorua geothermal field, New Zealand, to detect possible high permeability flow paths connecting injection and production wells. Fluorescein Sodium and Rhodamine WT are selected as tracer materials for the tests since these materials are inexpensive, easy to use, and nontoxic. The major aspects of the work like the field investigation, selection of the tracers, quantity calculation of required tracers, tracer evaluation, choice of doublets for the tests, theoretical tracer test simulation and tracer injection and sampling methods are described in this paper.

1. INTRODUCTION

1.1 Test Principle

The main aim of the tracer test is able to define the likelihood of thermal breakthrough between an injection well and one or more production wells. The basis for the use of the tracer test is that the chemical transport is a precursor of the thermal transport. Thus if a tracer arrives quickly and in large quantities, the likelihood is that the thermal breakthrough will also be rapid and strong. If a tracer does not arrive at all, it may be presumed there are no direct flow connection exists between the injection and the production wells.

Some dye tracer tests to investigate shallow subterranean interconnections between several groups of springs around Roto-A-Tamaheke Fault in Whakarewarewa of Rotorua geothermal field (MOE 1985a) have been undertaken. However the operating doublet systems in Rotorua are located within the urban district, and there is very little information available about doublet connections between injection and production wells in this area. In order to obtain information for evaluating doublet system performance it was decided to *carry* out tracer tests at two or more doublet sites in the urban district of the geothermal field.

1.2 Objectives

The objectives in carrying out the tracer test are as follows: (See also Gulati, et al 1978)

(1). To determine if the reservoir is fractured or homogeneous.

(2). To determine if there are any fast paths along high permeability fractures from the injection to the production wells. (that is, at what speed most fluid travels through the reservoir.)

(3) To determine how the pressure and temperature will change with time at the production/observation wells.

(4) To determine the regional flow pattern of fluid in the reservoir.

(5) To supply data for computer simulations and future doublet system design.

(6) To evaluate which tracer materials would be the best for this kind of geothermal reservoir tracer work.

To achieve the objectives stated above a proper tracer test design is important.

1.3 Scope of the Paper

This paper is a summary of the tracer test design. Since the tracer test work is extremely labour intensive and the tracer materials are normally expensive, careful design of the tracer tests is necessary. The work described in this paper concerns the Rotorua geothermal field investigation, selection of the tracers, calculation of the quantity of tracers required, tracer evaluation, choosing doublet systems for the tests, theoretical tracer test simulation and tracer injection and sampling method.

2. ROTORUA GEOTHERMAL FIELD

2.1 Location of Rotorua geothermal field

The Rotorua geothermal field is located on the north-west margin of the Taupo Volcanic Zone, North Island, New Zealand, about 60 km north of Taupo and Wairakei. The field itself covers about 11 km^2 at the south of the Rotorua caldera which is 140,000 years old and is associated with the eruption of Mamaku Ignimbrite. Subsequent to caldera collapse, rhyolite domes have been extruded and the basin has been partially infilled by lake sediment and tephra. Today, the shallow lake occupies the floor and Rotorua city lies above the geothermal field, between the lake edge and the southern topographic expression of the caldera boundary (Simpson 1986).

2.2 Rotorua geothermal utilization

The geothermal resource in historic times was initially used by the Arawa Maori people where boiling springs were used for cooking, washing, food drying and processing of flax fibres, With Europeans arriving in the area, spa bathing increased in popularity and from about 1870 many bath houses and treatment centres were established in the Rotorua area. As the demand on the resource exceeded that which could be provided by the spring, shallow bores were drilled to increase supply (Gammon, 1986).

The first recorded geothermal well in Rotorua was drilled in 1936 and by the end of 1958 there were more than 150 wells drilled. In 1959 and the early 1960s there was a great increase in drilling and exploitation. A further upsurge in drilling activity occurred during the mid 1970s when once again severe energy shortages were experienced throughout New Zealand (Simpson 1983). To date (1990) 956 wells have been drilled into the resource in Rotorua (DSIR 1990). There are currently 430 production bores supplying the commercial and residential sectors. A typical well is double cased, 100 mm in diameter, going to a shallow depth, and 95% of all bores are less than 200 m deep and reach temperatures of 120-200 °C. The well heat output varies from 300 kW at just above the minimum flowrate, to between 600 kW and 6000 kW. All wells, even those with low well head pressure, can provide enough heat for space heating for 30 homes (MOE, 1985c). The bores are allowed to self-flow by boiling or flashing of the hot water to low quality steam-water mixtures, with steam fractions varying from 3% - 6% by weight at the well head (MOE 1985a).

For a century now, visitors have come from all around the world to enjoy the thermal activity in Rotorua, As well as the popular bathing in the hot pools, they admire and photograph the geysers playing at Whakarewarewa. Pohutu geyser, probably now the most famous, still erupts regularly in a tall column of water or steam well over 15 to 20 meter (50 to 70 ft) in height. Tourisms is an important industry in New Zealand, and Rotorua is one of the main centres. NZ$ 80 million was spent by visitors in 1985 (Drew, 1985).

2.3 Geothermal system

The movement of geothermal fluid in the exploited part of the Rotorua field is controlled largely by four geological formations. Mamaku Ignimbrite and Rotorua Rhyolite have good permeability and form the geothermal aquifer. The lower beds of an overlying sedimentary sequence are largely impermeable and act as an aquitard. Superficial sediments and tephras in the upper part of the sedimentary sequence contain permeable pumiceous layers which receive much geothermal effluent via shallow soakage holes. Fault structures, mostly associated with the margin of Rotorua Caldera, channel fluids and penetrate the aquitard allowing diluted alkaline chloride water to rise to the surface as hot springs (MOE 1985a).

From the data currently available, it appears that the main source of fluid and energy for the Rotorua-Whakarewarewa system is most likely to be in the zone underlying the Whakarewarewa and Arikikapakapa thermal reserves. As the geothermal fluid has a temperature of about 250°C neat the surface in this zone, it must boil under ground. Wells around, and to the immediate north of this area, do indicate two-phase conditions (Grant and Donaldson 1980). But wells just to the north of, Sophia Street (in the west) indicate a liquid water condition. We may thus assume a cut off near Sophia Street for the boiling.

A large scale conceptual model of the western section of the Rotorua geothermal field is thus that illustrated in Fig.2.1 (Donaldson & Grant 1981). Hot water comes from a deep reservoir through Ngapuna and Roto-a-Tamaheke faults which provide vertical permeability (Simpson 1983). Part of the geothermal water is mixed with cold water, and then flashed. The flashed two phase fluid discharges as springs, steaming ground and geysers. The remaining part of the hot water goes through a aquifer to the lake Rotorua. Rotorua city is located on top of this aquifer (MOE 1985c). Grant (1986) introduce a idealized model (Fig.2.2) of the Rotorua geothermal system, which is similar to the model of Donaldson and Grant. The system is modelled as a box filled with water. The geothermal aquifer is in two sections joined by a pipe representing how the Inner Caldra Boundary fault (ICBF) limits the fluid. Sources of hot and cold inflow are connected to the box through pipes. These waters mix inside the box and are discharged at hot spring areas.

From a small scale point of view, the movement of geothermal fluid in the aquifer is controlled by three main faults: the Ngapuna faults, Roto-a-Tamaheke fault and Inner Caldera Boundary fault (ICBF). The eastern boundary of the field coincides with the Ngapuna and Roto-a-Tamaheke faults (Simpson, 1986) which are presumed to provide vertical permeability connecting with a deep geothermal reservoir. This reservoir has never been penetrated by drilling but chemical geothermometer suggests a minimum reservoir temperature of 250 °C. Ngapuna and Roto-a-Tamaheke faults strike northeast parallel to the trend of the Taupo volcanic Zone. They may predate the caldera collapse as they are offset by a third structure. The ICBF which is related to caldera collapse trends roughly east-west and lies between Whakarewarewa and the rest of Rotorua city. Unlike the faults along the eastern field boundary, the ICBF appears to be a relatively shallow structure. Enthalpy and geochemical data show that it provides considerable lateral (east-west) permeability whereas Ngapuna and Roto-a-Tamaheke faults are clearly source areas for high enthalpy, high chloride fluid. Temperature gradients and a resistivity sounding south of the ICBF confirm a lateral flow in the geothermal aquifer and both geochemical and pressure observations are consistent with this being a southward flow. Thus all the hydrothermal features at Whakarewarewa appear to be fed from a tongue of fluid flowing south from the ICBF (MOE, 1985a). Fig 2.3 schematically presents the influence of these three faults on fluid flows within the geothermal aquifer.

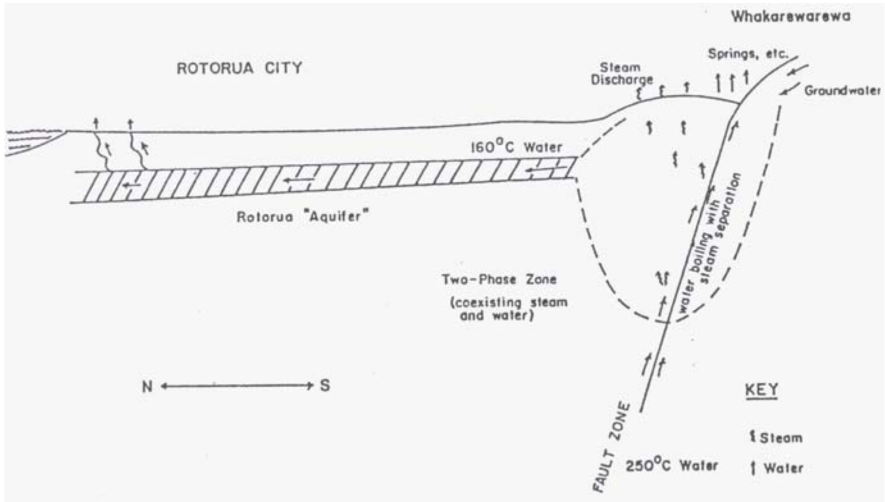

Fig. 2.1 The Rotorua geothermal reservoir flow system for the area to the west of Fenton Street (After Donaldson and Grant, 1981).

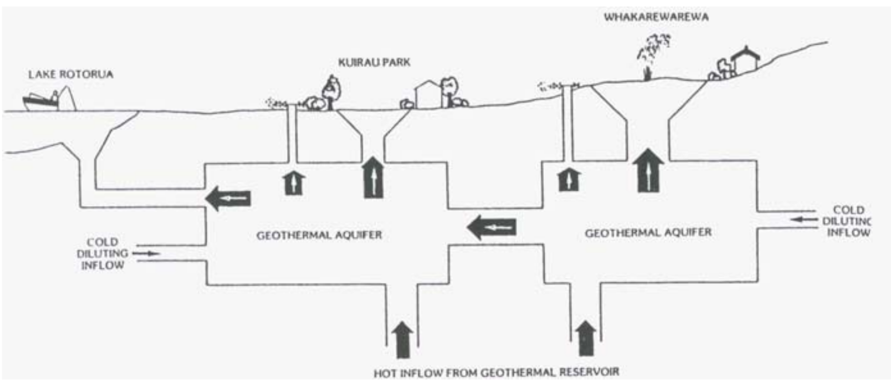

Fig. 2.2 The conceptualized Rotorua geothermal system (After MOE 1985c).

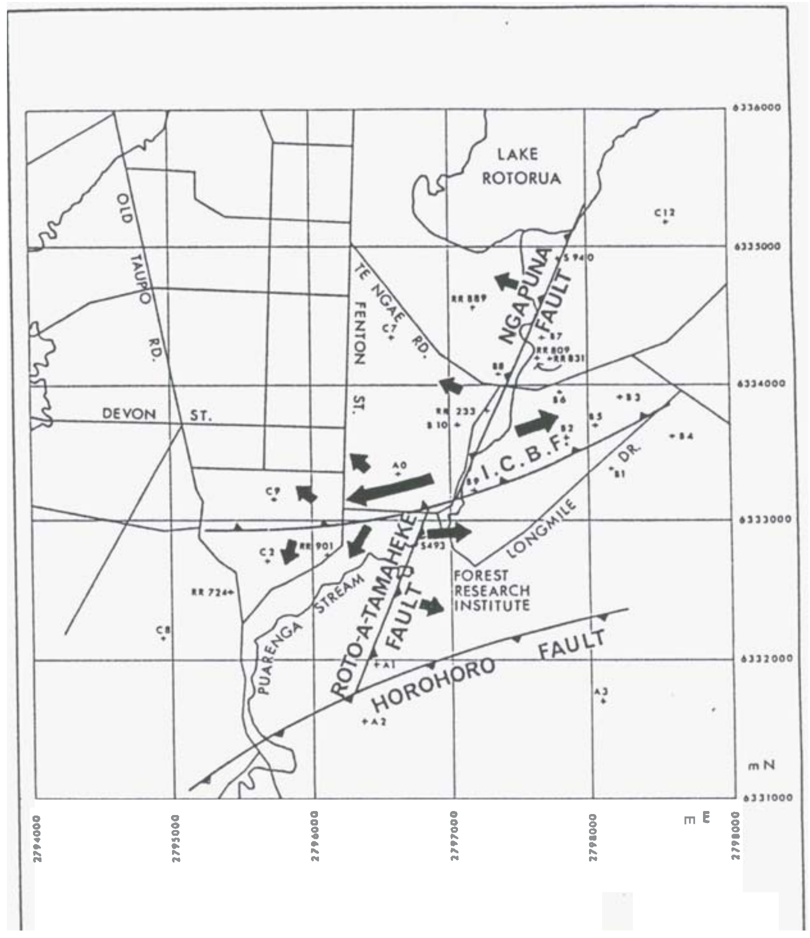

Fig. 2.3 Inferred influence of the three faul∞ ∞ fluid flows in the Rotorua geothermal aquifer (MOE, 1985a).

2.4 Reservoir Properties

In order to analyse and define and analyse the Rotorua geothermal field, its possible fluid and energy sources, and its hydrological and energy flow path, reservoir properties were collected from the information available and are summarized below.

(1) Thickness of the aquifer: The aquifer is reached at 70-130 m depth over much of the field (Grant 1986). The thickness of aquifer is between 10 and 50 m, that is it is a thin two dimensional body (MOE 1985a).

(2) Aquifer area: The geothermal field underlies the southern portion of the Rotorua caldera and covers an area of 11 km^2 under the business centre and southern suburbs of the city (Drew 1985). The field boundary is defined both by the water temperature of the wells (Grafer 1974) and by the resistivity data (Macdonald 1974).

(3) Well depth: 95% of all Rotorua drill holes are less than 200 m deep, and the average depth of currently producing wells is only about 110 m (MOE 1985a).

(4) Reservoir temperature: The temperature of the reservoir is about 130 - 180°C MOE (1985a).

(5) Aquifer permeabilities: A number of interference tests have been performed, all subject to some problems and all of fairly limited scale in time and space. These tests have been reported by Grant and Bradford (1983) and discussed by Simpson (1983) and MOE (1985a). The conclusion from these tests is that the permeability thickness (kh) is of the order of 100 Darcy-meter.

(7) Aquifer pressure: Pressure measured in wells indicate that the average aquifer pressure is about 10 bar (MOE 1985a).

2.5 Rotorua geothermal doublet system

Geothermal doublet systems have been used successfully in Paris Basin, France, (Coudert 1985) and Klamath Falls, USA (Sammel 1984).

Most of the geothermal drawoff in Rotorua field goes to either shallow soak holes, to storm water drains or directly into the lake and streams. However there are some deep (to production depth) soak bores which were either old production bores or were bores drilled intentionally for reinjection. A pair of wells with a production bore connected to a deep soak bore, which reaches the production aquifer, is defined as doublet system.

There are at least 28 doublet systems currently operating in Rotorua, (DSIR 1990). The flow of geothermal fluid used by these doublet system is estimated to be 1700 t/d in the winter. Even though no detail investigation has been carryed out on the doublets, they appear to work well and have very few problems.

3. TRACER MATERIALS

3.1 Selection of the tracer materials

There are three main classes of tracers: radioactive tracers, chemical tracers and fluorescent dyes.

Radioactive tracers are not subject to any chemical degradation and decay in a predetermine way. Detection is relatively simple and can be done continuously by monitoring the production outflow using a radiation counter. McCabe, Barry & Manning (1983) describe the injection, measurement and handing of radioactive tracer materials based on their experience in Wairakei and Broadlands geothermal fields in New Zealand. A similar arrangement was used for the radioactive tracer injection at Fenton Hill, New Mexico (Tester et al 1982). But the radioactive tracers normally are toxic radionuclides and some care is required in designing test procedures to comply with safety regulations.

Chemical tracer is dissolved in the injected water and detected by chemical analysis at the production well. The most common chemical tracers in geothermal applications have been the halides (bromide and iodide), although more recently research has investigated the suitability of fluorocarbon tracers (Adams, et al, 1986) and of reactive materials (Tester et al, 1986). Since iodide and bromide are usually both present in geothermal fluids, it is necessary to inject a large quantity of material to raise the concentration to detectable levels. So the material costs are significant and more complex facilities such as mixing tank, pumps, large diameter valves and high pressure piping are required.

Fluorescent dye tracers are a particular kind of chemical tracer recognizable by their colour or fluorescence. They are most commonly used tracers in groundwater and geothermal systems because of their low detection limits, ease of analysis and low cost (Adams and Davis 1991). Fluorescein was first used to trace surface waters in the early twentieth century (Dole, 1906). Subsequently, fluoresceins were used to measure flow magnitude, direction, and dispersion in tidal estuaries (Parnell, 1982 & 1986), karst (Jones 1984), water pollution studies (Aley 1984) and petroleum environments (Smart and Laidlaw, 1977). During the last decade, fluoresceins have been used to trace the direction and dilution of fluids injected into geothermal reservoirs at Klamath Falls, Oregon (Gudmundsson et al., 1984), Cornwall, England (Batchelor, 1986), Fenton Hill, New Mexico, USA (Tester et al., 1986), Hatchobaru, Japan (Yoshida, 1980), Palinpinon, Philippines (Urbino et al., 1986), and Dixie Valley, Nevada, USA (Adams et al., 1989).

Because of the licensing and safety complexities of radioactive tracers and cost and complex facilities of the chemical tracers, it is decided that fluorescing tracers, Fluorescein Sodium and Rhodamine WT, should be used in the Rotorua geothermal tracer test.

3.2 Kinetics of the tracers

The Fluorescein Sodium and rhodamine WT tracers are widely used in hydro-geology tracer tests (Smart and Laidlaw 1977). Rhodamine WT tends to absorb less on to soil and rocks than fluorescein (Timperley 1991). However rhodamine is not stable at high temperature (approximately 200°C) for periods of more than a few days. However rhodamine WT was used and breakthrough was obtained in Svartsengi, Iceland, geothermal field, which the reservoir temperature was in the range 235-240 °C (Gudmundsson and Hauksson 1985). Adams & Davis (1991) have reported that fluorescein will decay less than 10% during a one month tracer test in geothermal reservoirs with temperatures of approximately 210 °C. A laboratory test has indicated that after 98 days fluorescein decayed 10% at a temperature of 200 °C. The Rotorua geothermal reservoir temperature in urban district is between 120 - 170°C. It seems that the thermal stability of these two tracers means that they are suitable for the tracer test in this geothermal reservoir.

The concentration of fluorescein in a fluid sample is measured by fluorometer. The readings from fluorometers are sensitive to fluid temperature. Usually the higher the temperature the lower the reading that is obtained. Wilson (1968) suggested that all fluorometer readings must be either controlled at a common temperature base or adjusted to it. The temperature control is obtained by establishing room temperature as the base and allowing all field samples to stand long enough to attain room temperature. If a significant difference between the base and sample temperature is noted, correction factors given in Wilson (1968) should be applied.

3.3 Review of the toxicity of Fluorescein tracers

The literature was searched (Gudmundsson 1984) for data on possible health risks associated with the fluorescein and the rhodamine tracer materials. It was found that no ill effects would be likely to occur upon drinking the geothermal water during the tracer test.

Eight fluorescent dyes (amino G, photine CU, fluorescein, lissamine FF, pyranine, rhodamine B, rhodamine WT, and sulpho rhodamine B) were compared in laboratory and field experiments to assess their utility in quantitative tracing test work (Smart and Laidlaw 1977). The properties considered included sensitivity and minimum detectability, the effect of water chemistry on dye fluorescence, photochemical and biological decay rates, absorption losses on equipment and sediments, toxicity to man and aquatic organisms, and cost. Their study indicated that fluorescein sodium and rhodamine WT are generally the most satisfactory fluorescein dyes recommended for water tracing work. In addition, since rapid dilution occurs following injection in the tracer test, the dye will not cause any ill effects to aquatic life.

Smart (1984) reviewed toxicological information for twelve fluorescent dyes used in water tracing. Fluorescein sodium and rhodamine WT were demonstrated not to provide a carcinogenic or mutagenic hazard. Fluorescein dyes have been certified for use in externally applied drugs, lipsticks, and cosmetics in the United States by the Food and Drug Administration.

The biological effects of the dyes mentioned above is described in Wilson (1968). There is no danger of this kind of human intake resulting from water tracing work. Persons who has handled the dye solutions for many years, often immersing their hand and arms in the fluorescein dyes, have suffered no ill effects. It is also reported that fish survived in the laboratory for months in extremely high dye concentrations.

3.4 Quantity calculation

Several points were considered in deciding the quantity of tracer required for each doublet tracer test. (1) The tracer concentration must be sufficient to be recognizable above any background concentration of that material (or any other material that cannot be distinguished from it) in the reservoir. (2) The concentration of the tracer at the observation points must be sufficient that it can be accurately measured. (3) The quantity needs to be kept as small as possible to minimise the cost.

The determination of the likely minimum and maximum exit concentration is based on the two extremes of mixing mechanisms. In the minimum concentration calculation, the tracer is assumed to be mixed uniformly over the area swept by the tracer front between the injection well and the production well. The volume swept, V_{swept}, as given by (Home 1987) is:

$$V_{swept} = 1.076*D*h*n$$

where D is the distance separating the wells, h the reservoir thickness and n the porosity of the reservoir. If the volume of tracer material injected is V_{inj} (either continuously or as a spike), the concentration at breakthrough must be greater than

$$C_{min} = V_{inj}/V_{swept} = V_{inj}/(1.076*D*h*n)$$

In order to detect the tracer at the exit points, the minimum concentration C_{min} must be significantly higher (by at least a factor of ten) than both the background concentration and the lower detection limit of the device used to measure it. For example, if fluorescein is used as a tracer in a reservoir that has a background concentration of 1 bpm, then the test must be designed so that exit tracer concentration is at least 10 bpm. However, if the detection limit of the available measurement instrument is 10 bpm, then the test design must achieve an exit concentration of at least 100 bpm.

From per-tracer test samples in the Rotorua geothermal reservoir, the background concentration of Rhodamine - WT is nil, however sometimes the Fluorescein is about 0.1 ppm. The detection limit of measurement device, fluorometer, is very low (See Section 5.4). It is determined that C_{min} for Rhodamine is 0.01 ppm. Fluorescein is 1 ppm.

The maximum concentration at breakthrough will occur if the tracer follows a direct linear path, as might happen when the flow is in a single fracture or fault plane. In this case the maximum tracer concentration will occur at the mean arrival time of a tracer spike. At this time, the exit concentration is given by

$$C_{max} = (V_{inj}/Qt) * (Pe/3.14 1593)$$

Where in this case Qt is the total volume of injected fluid. The injection flow rate and breakthrough time are parameters that are unknown before the tracer test, but can be estimated from observations of tests in other fields. If the injection flow rate is about 1.0 kg/s, the breakthrough time can be a few days, and the Peclet number, Pe, is around 40.

The quantity of tracer for the test is dependent upon two factors. Firstly for each doublet system the distance between wells varies secondly the detection limit of the tracer materials varies. The tracer quantity requirement is calculated using the equations presented above. They have been programmed on a PC and the calculation results are shown in Table 3.1. The aquifer regional flow and the tracer absorption on to soil or rocks has not been considered here. In order to obtain a tracer breakthrough at production well(s), the amount of injection tracer material(s) should be at least twice of the calculated results.

Table 3.1 Calculated tracer requirement for individual doublet and different tracer material

Doublet.	Well spacing meter	Rhodamine kg	Fluorescein kg
1	112.0	0.243	0.675
2	7.9	0.00121	0.00336
3	28.0	0.0152	0.0422
4	37.0	0.0265	0.0737
5	58.0	0.06515	0.181
6	71.0	0.0976	0.271
7	39.0	0.0295	0.0818

4. TRACER TEST SIMULATION

4.1 Simulation method

The tracer test simulation was conducted using the RESSQ programme. This programme was developed at the Lawrence Berkeley Laboratory, University of California, USA (Javandel et al 1984). It is based on a solution procedure used by Gringarten and Sauty (1975). It can be applied to two dimensional contaminate transport by advection in a homogeneous, isotopic confined aquifer of uniform thickness when regional flow and sources and sinks create a steady flow field. It calculates the streamline pattern in the aquifer and tracer concentration at the production well versus time. The programme RESSQ is a semi-analytical method. The simulation results from this programme, an analytical method (2D-model) and a fully numerical method (MULKOM) have been compared. The details of the comparison are presented in Pan et al (1990).

4.2 Results

Fig 4.1 shows the effect of distance between the injection and production wells on the tracer arrival. It is assumed that the regional flow direction is from the injection well to the production well. The three curves are for a velocity of regional flow of 0, 100 and 200 meters per year respectively.

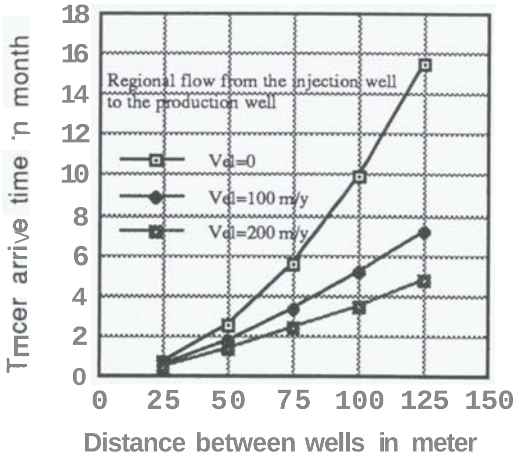

fig **4.1** Effect of doublet distance

The influence of regional flow direction on tracer arrival is shown in Fig 4.2. The angle is relative to an axis from the injection well to production well) The distance between the production and the injection wells is assumed to be 50 meters. The regional flow velocity is supposed to be 100 meters per year.

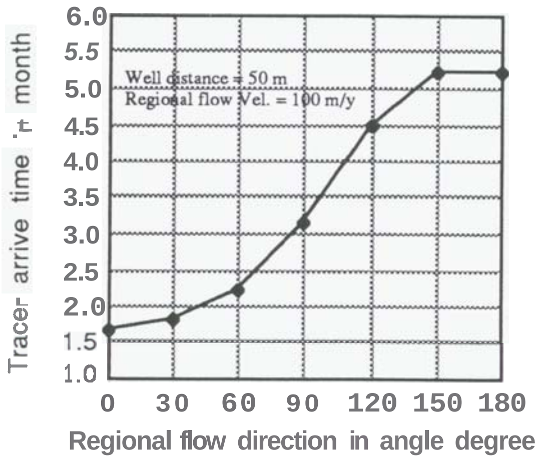

Fig **4.2** Influence of regional flow direction

Fig 4.3 indicates the effect of reservoir aquifer thickness on the tracer arrival. The distance between the production and the injection wells is again assumed to be 50 meters. Regional flow velocity is zero.

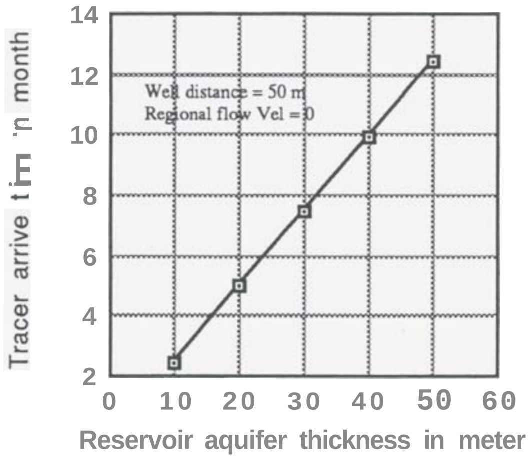

Fig 4.3 Effect of reservoir aquifer thickness

Fig **4.4** illustrates the effect of different aquifer porosities on tracer arrival time. The well distance is also assumed to be 50 meters, there is no regional flow and the aquifer thickness is 10 meters.

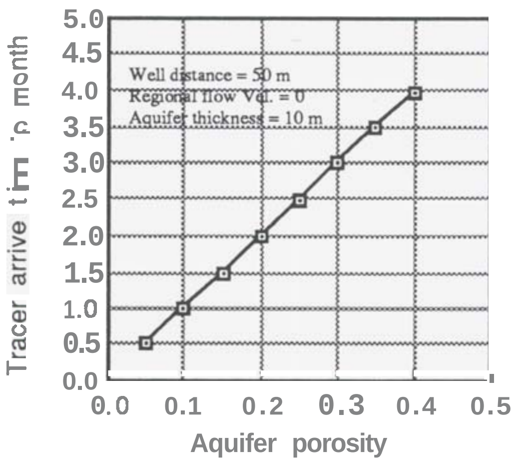

Fig 4.4 Influence of aquifer porosity

5. TEST PREPARATION

5.1 Selection of doublet

As mentioned above, there are 28 geothermal doublet systems that are currently operating in Rotorua. The doublets for the tracer tests were selected from these 28.

The selection was based on the following:

1) Both the production and the injection wells tend to be of similar depth. The depths of the wells are about 100 meters. Thus the production water comes from the geothermal aquifer rather than the shallow surface, and the water will return to the Same aquifer.

2) The direction of aquifer regional flow is from the injection to the production well with an angle of less than 90°, so that the tracer material injected into the injection well can be detected from the production well after a period of time.

3) There are no fault(s) so far identified between the production and injection wells. Therefore the tracer is not expected to be blocked.

The five doublet systems were selected as candidates for tracer testing. The final decision was made after contacting the owner of the well and the Energy and Resources Division, Ministry of Commerce.

5.2 Injection method

Tracer can be introduced into the geothermal reservoir either continuously or as a single "slug" or "spike". Since the slug injection results in a greater increase in the concentration of the tracer in the reservoir (although over a small volume), it is commonly used for artificial tracer tests for which amounts (and cost) need to be minimized.

For most of the **Rotorua** injection wells, the injected fluid can be introduced into the well by gravity. For a relatively high pressure (higher than 3 bar) doublet system, the injection well could turn into a production well if the pipeline is opened to the atmosphere. In this case, a dosing pump has to be used. With fluorescein and rhodamine tracers the quantity of the material will be less then 1.0 kg. The diluted solution can be 10 to 20 kg. The method used will depend on the particular wellhead design but it is anticipated that it will possible to bleed upstream of the wellhead valve and to inject the tracer as a slug.

5.3 Sampling

To take samples from the production well, a small valve installed at the well head is needed. Since the temperature of the geothermal fluid is normally over 110°C, a cooling coil is required to condense the fluid.

The injected tracer may arrive at a production well in less than an hour, or it may take weeks, even months to arrive. In order to confidently interpret the tracer arrival information, it is necessary to have samples both before and after the peak breakthrough concentration. The longer the peak concentration takes to arrive the more dispersed it is, thus frequency of sampling can be decreased with time.

To obtain samples both preceding and subsequent to the peak that may arrive within a few hours, sampling immediately following injection should be frequent, say every half hour or even every 15 minutes if the wells are closely spaced. After the first day sampling can be reduced to hourly, after the second day two hourly, and so on. After two weeks, sampling can be daily, and if the test is intended to be long, the samples can be eventually taken weekly (Home 1987).

If the samples have not been taken frequently enough, it is impossible to interpret the results accurately. Since the tracer materials, labours and test facilities are very expensive, it is expedient to take samples very frequently.

Sampling must begin several days before the injection of the tracer. This is to obtain information on the level and stability of the background concentration of the tracer or of materials indistinguishable from it.

5.4 Tracer detection

Although it is possible to determine the concentration of the fluorescent tracers in sample solution by using a spectrofluorometer, the expense, complexity, and delicacy of these instruments rule out their general application (Smart and Laidlaw 1977). Most water tracing work is carried out by means of filter fluorometers such as the Turner 111 and 112 or the Aminco Bowman fluoro/colorimeter. These machines are only moderately expensive, simple to use, and portable. Furthermore, their sensitivity is comparable to that of a spectrofluorometer.

The samples taken from the production wells will be analysed in a laboratory, using Turner 111 or Turner 112 fluorometer. The fluorometers have been calibrated with the tracer materials which will be used for the test. The following detection limits will be apply for these techniques and materials:

Rhodamine WT	0.001 mg/l
Fluorescein	0.01 mg/l

6. CONCLUSION

Fluorescent dye tracers are a particular kind of chemical tracer recognizable by their colour or fluorescence. It has been demonstrated that these dyes are not stable at very high temperatures (temperatures greater than 200°C) for periods of more than a few months. However, they are still useful in cases where breakthrough is expected to be rapid, or where the temperature is low.

The conclusions of this report are summarized as follows:

(1) Fluorescent dyes have the advantage of being cheap, easy to handle, and relatively easy to measure. The fluorescein sodium and rhodamine WT were selected as tracer materials for the first stage tracer test.

(2) The permission for running the tracer test has been obtained from The Energy and Resources Division, Ministry of Commerce.

(3) The maximum quantity of the tracer required will be 2.0 kg of fluorescein and 1.0 kg of rhodamine.

(4) There are no known hazards associated with the use of the proposed tracers.

The tracer tests are currently being carryed out in the Rotorua geothermal reservoir using three doublet systems. in the Holland Street doublet, 0.4 litre of 20% rhodamine WT (80 grammes) is being used as tracer material , while 1.0 kg fluorescein sodium is being used at both Boulevard Motel and Kingsgate Hotel. Samples are being taken, and some of them have been analysed. The detail of the test and the results will be published at a later data.

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