Metering geothermal takes in Rotorua – Project update

Mariana de P. S. Zuquim[1]*; Penny Doorman[1]; Jason Laurent[1]; Rithwik Danthala[2], Sadiq J. Zarrouk[2]

[1] Bay of Plenty Regional Council – 5 Quay Street, Whakatāne, 3120, New Zealand.

[2] Department of Engineering Science, The University of Auckland, Private Bag 92019, Auckland, New Zealand

* mariana.zuquim@boprc.govt.nz

Keywords: *Rotorua Geothermal System, metering, efficiency, flow loop, heat meter, surface features, conservation.*

ABSTRACT

As part of the review of the Rotorua Regional Geothermal Plan, the Bay of Plenty Regional Council (BOPRC) established a metering project team to develop and effectively implement metering of the geothermal takes for fluid and energy in Rotorua. Currently, data on the actual use of the geothermal takes is of low accuracy and does not reflect the use profile over time. Therefore, this data is not suitable for developing a finer understanding of how different patterns and use levels affect the geothermal system, including the vulnerable geothermal surface features. BOPRC is closing this gap by starting to require continuous metering of ~75% of the water and heat takes from the Rotorua system. To achieve that, BOPRC first developed, trialled and proved a flow loop system that can meter the geothermal water takes with reasonable accuracy. Lately, BOPRC has also identified heat meters as a suitable method for monitoring heat and water takes in Rotorua. Take size thresholds in which different metering requirements would be required (e.g. spot measurements, continuous metering) were defined, based on the distribution of take sizes, user profile and geographical coverage, to close spatial gaps, particularly on the 1.5 km mass abstraction exclusion zone, which protects the geyser flat. The analysis of the flow loop trial data showed that the actual use profile mirrored the expected profile for the different types of use (e.g. domestic, commercial). Cost estimates for implementing metering for each user affected by the new metering requirement were carried out to understand the financial implications of those measures to the consent holders. The results showed that the costs are considered reasonable and proportional to the different user profiles and the new metering requirements. This project is now in the stages of rolling out to the largest users.

1. INTRODUCTION

1.1 Background

The Bay of Plenty Regional Council (BOPRC) manages the Rotorua Geothermal System under the Resource Management Act 1991 (RMA)[1]. The system is managed to protect its unique natural surface features while allowing limited use where this does not cause adverse effects.

Currently, there are ≈110 consented takes for geothermal water and heat (thermal power) in the Rotorua Geothermal System. Those takes are mainly for space and water heating for homes, public facilities and commercial properties such as hotels and motels. Understanding the type of uses, their size, and the effect of these uses on the system and its surface features is key to sustainable management.

Resource consent must be obtained from the Council to take and use geothermal water and heat, except for certain customary uses by Maori (indigenous people of New Zealand). While all consents have conditions requiring monitoring of use, this is typically periodic bucket/stop-watch testing. Currently, data on the actual use of the geothermal takes is of limited quality and quantity and has been accepted upon compliance discretion due to the lack of suitable alternatives/methods. While this data gives BOPRC a broad understanding of patterns of use and the amount of energy being taken from the system, it is not adequate for developing a finer understanding of how different patterns and levels of use affect the vulnerable surface features and geothermal aquifer water levels.

Since 2014 BOPRC established a project team to develop and effectively implement metering of the geothermal takes in Rotorua. BOPRC has worked with external technical experts to identify and/or develop a metering method that will provide adequate data (Barber *et al*., 2017). The key stages of the project are outlined below:

- Assess our monitoring objectives.
- Research and prove the feasibility of the different options for metering systems.
- Assess the quantity, quality and geographic distribution of data required for the effective management of the Rotorua Geothermal System.
- Costing assessment to understand the financial implications to the users.
- Project roll-out: Define and implement a strategy to roll out metering based on a risks analysis, legal factors and a communication strategy.

This paper describes the outcomes of the first four stages of the project. The project roll-out (item 5) commenced in 2022, and is out of this paper's scope.

1.2.1 Objectives

The main purpose of gathering metering data on the use of geothermal water[2] and energy is to improve the management

[1] The RMA reforms currently underway are not expected to significantly change resource consents requirements to provide accurate data on resource use.

[2] The RMA uses the term 'geothermal water' (RMA Part 1 s.2). The authors acknowledge that the term 'fluid' is technically more appropriate to refer to the mass abstracted from the geothermal aquifer, and is used throughout the text

ISSN 2703-4275

of the Rotorua Geothermal System. The importance of this data thus goes beyond compliance processes (i.e. verifying whether the user's use is within the limits of the resource consent). This data will help to:

- Understand type and patterns of use, such as daily and seasonal trends and the end use of energy.
- Refine the understanding of the effects of use on the geothermal aquifer and surface features.
- Guide future policy direction, for example, system allocation and efficiency provisions.
- May improve future numerical model calibration.

1.2.2 Metering methods

Options to continuously meter geothermal takes are limited in Rotorua, mostly due to the lack of industry drive coupled with limitations on options for 'off-the-shelf' flow meters suitable for Rotorua takes (Barber *et al*., 2017). The standard consent condition for monitoring geothermal water and heat take in Rotorua currently requires five separate spot measurements on different days between April and August (colder months), twice in the lifetime of the consent (every five years in practice). One of the two methods below is applied to meet those consent conditions:

- Production-reinjection: Bucket/stop-watch.
- Downhole heat exchanger: Pump rate, in-line flow meter and temperature readings of the hot and cold legs.

While those methods have been accepted upon compliance discretion so far, it is of low accuracy and might not reflect the peak use. The methods also do not capture the actual take over time and are of limited use to inform the management of the Rotorua Geothermal System.

Around 2016, BOPRC started working to develop a robust, cost-effective method to fill the gap of a suitable methodology for continuous metering for Rotorua. Two methods were identified as appropriate for Rotorua settings: a flow loop installed in the reinjection line or a heat meter installed in the secondary fluid (town water) line (Figure 1). Temperature measurements must also be taken in the primary fluid line for doublet systems to derive the take for doublet systems using a heat meter in the secondary fluid line. For downhole heat exchanger (DHX) systems, a simple heat meter can be installed in the secondary fluid line to derive the thermal power use. A summary of methods identified so far that allows for the different monitoring levels for different production systems is presented in Table 1.

Table 1: Methods for different levels of metering requirements and production systems.

Level of monitoring	Method
Permanent continuous	Flow loop, permanent – Doublets
Permanent continuous	Heat meter – Doublets or DHX
Temporary continuous	Flow loop (movable 'rig') - Doublets
Spot-measurement	Bucket/stop-watch - Doublets
Spot-measurement	DHX readings

1.2.2.1 Flow loop design

The flow loop system consists of two parts, the flange-pipe bypass assembly and the portable system (Figure 2). This bypass assembly can be installed temporarily or left permanently on the reinjection line. The permanent option allows to bypass the fluid into a small-scale separator and then to the turbine hot water flow meter without taking the well off service.

As stated before, the flow loop system was trialled on 13 sites over the period of ~ two years between 2017-2019. Small adjustments were made as it moved from site to site to improve performance and accuracy until it landed in the final design for the trials (Figure 2). Nonetheless, the final design retained its core aspects/concepts throughout the trials. The main changes over time were (i) enlarging the separator from 4" to 6" and installing baffles to improve performance, (ii) changes to the design of the separator inlet, and (iii) removal of the gas venting system due to regulatory provisions in the Bay of Plenty Regional Air Plan (Section 5.6.1 Rule 16).

The assessment also identified financial and technical advantages of requiring the consent holder to have a permanent metering system, like the flow loop, rather than rotating a movable meter owned, managed and operated by BOPRC (Barber *et al*., 2017; Section 1.2.4). This change leads to further adjustments to the final design, particularly improving anchorage/fixing.

During the trial stages, output tests (total flow calorimeter test and bucket/stop-watch test; Zarrouk & McLean, 2019) were carried out simultaneously to the flow loop at the beginning and end of each of the 13 flow loop trials. The output tests were used to 'correct' the flow meter data on the assumption that the water meter would not be able to read the geothermal fluid flow with accuracy. Dantala (2021) recommended that output tests should not be used to correct the paddle turbine data due to the lack of accuracy of those methods *per se*, and that the discrepancies between the results are more likely associated with accuracy issues of the output test rather than lack of accuracy of the paddle meter.

As a result of those findings, the final engineering drawings and specifications for flow loop (and heat meter) systems provided to the consent holders allow for the removal of the user flow meter and temporary installation of a calibrated flow meter for verification of the data accuracy from the user system.

unless it is making direct reference to RMA processes, in this case, different types of consent (geothermal water or heat).

ISSN2703-4275

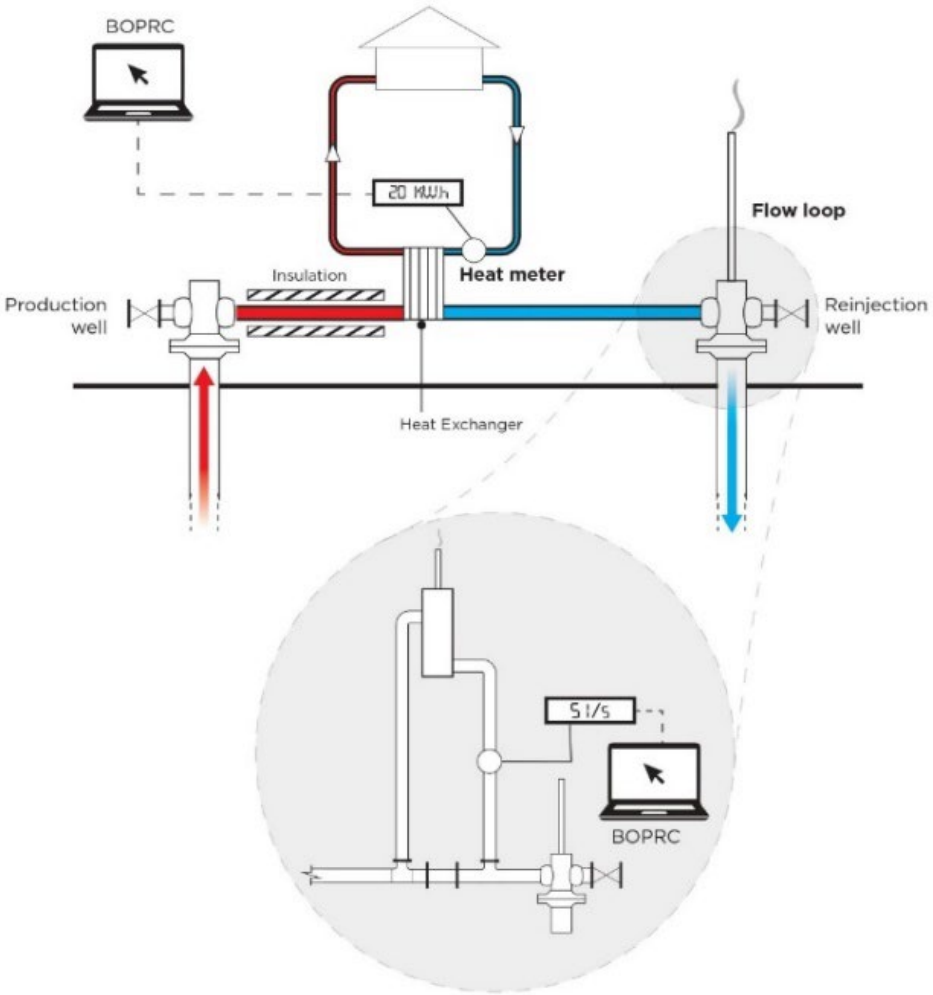

Figure 1: Flow loop rig and heat meter – Schematic diagram. The user shall install one system or another.



Figure 2. The BOPRC portable flow loop system. Flange-pipe bypass assembly (white circle) and portable system (yellow circle).

ISSN 2703-4275

1.2.2.2 Flow loop data review

A reasonable amount of usage data was obtained over the trialling stage. The flow meter system captured one reading per hour over 2-4 weeks for each of the 13 trial sites. Data was telemetered to HydroTel web server. A review of the flow loop data obtained during the trial stages was carried out by Dantala (2021) to verify whether the results showed a good agreement with what would be expected for the different end uses (e.g. domestic, commercial). The analysis showed that the data have a good correlation between the heat demand for the end use and the usage profile (daily, weekly use) over the trial period.

The Carnot Street domestic shared scheme is one of the best examples analysed by Dantala (2021). The geothermal heating system services thirty (30) domestic properties with geothermal energy for space and water heating. The results showed that the flow rate reflected the typical domestic use heat load profile (Figure 3). The highest flow rates are in the mornings and evenings, when heat load peaks and drops during the day.

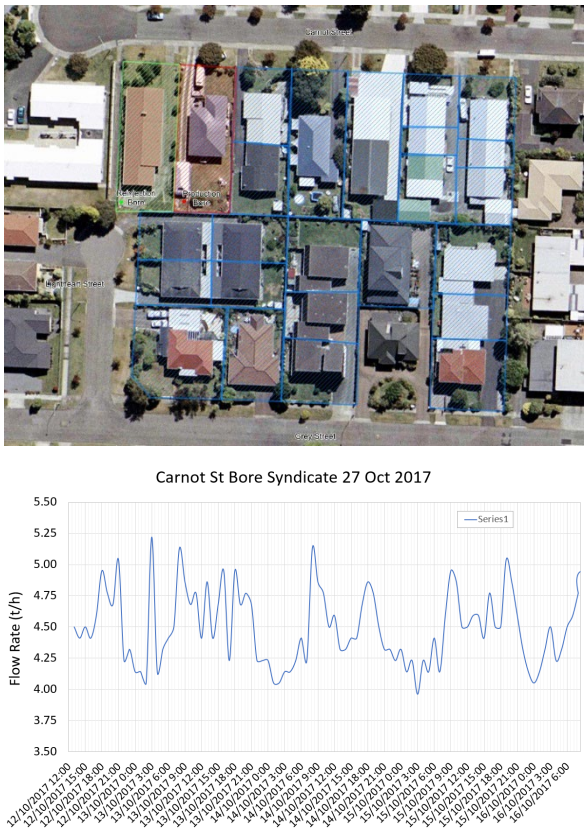

Figure 3: Carnot Street shared scheme. Map of the houses serviced by the geothermal system (top). Mass flow rate data (t/h) was obtained during flow loop trials (bottom)..

1.2.2.3 Heat meter design and the Aquatic centre heat meter

The use of heat meters in Rotorua has not been widely adopted so far, and has been identified as a suitable method for continuous monitoring of both production-reinjection and DHX systems (Peng & Moore, 2021). Currently, only one heat meter is installed in Rotorua, in a branch of a secondary fluid pipeline off the RLC Aquatic Centre system (Figure 4). There is an opportunity for the users to adopt an accurate and reliable technology that is available 'off-the-shelf', with requirements for continuous monitoring when applicable.

The use of heat meters was identified as the main method suited to meter DHX takes in Rotorua. However, it is acknowledged that consent holders may propose other methods to derive energy use over time, like adding a flow meter coupled with temperature monitoring of the hot and cold legs. The acceptance of proposed alternative metering methods will ultimately be accepted upon consents and compliance discretion.



Figure 4: Heat meter in secondary fluid line in a doublet system. The same arrangement can be used for DHXs. Display showing the actual heat take (kW_{th} per hour).

1.2.3 Data quantity, quality and geographic distribution

As stated, there are currently ≈110 consented takes for geothermal water and heat in the Rotorua Geothermal System. Around 70 takes are for geothermal water, and the remaining ≈40 are for heat take via DHX. These takes vary considerably in size, ranging from small takes (e.g. <30 tonnes per day) to heat a single home to large takes (e.g. >400 tonnes per day) to heat large hotel complexes or shared domestic schemes with 20-30 houses sharing the same geothermal production system.

A challenge for BOPRC was to define the monitoring requirements to effectively achieve the project's objectives (Section 1.2.1), particularly regarding data quantity and their geographic distribution across the system.

An assessment of the number of consents to be affected based on different scenarios of monitoring across the Rotorua system was carried out. This assessment is based on allocated resources as of 2020 (see below and figures 5 and 6). Consents have slightly changed since then, which affects the take size distributions (Figures 5 and 6). The main change was the take increase for the Queen Elizabeth Health Centre (RM20-0571), now allocated 800 tonnes per day, up from 600 tonnes per day. Requirements for continuous metering already exist as part of their consent conditions.

For water takes via production-reinjection systems, the following number of takes would need to be metered to achieve the different levels of monitoring:

- Monitoring of 50% of the water take (mass take) can be achieved by monitoring the large consent holders (12 takes).
- Monitoring of 75% of the water take can be achieved by monitoring the large and medium consent holders (28 takes).
- 4-5 additional consent holders would need to be monitored from ~100t/d to only add only 5% of monitoring.
- 100% of monitoring is achieved by metering the remaining 42 small consent holders.

For heat takes via DHX systems, the following number of consent holders and monitoring requirements apply:

- Monitoring 45% of the heat take can be achieved by monitoring the large consent holders (3 takes).
- Monitoring of 71% of the heat take can be achieved by monitoring the large and medium consent holders (7 takes).
- Monitoring all the large takes across the system plus all the medium takes within the 1.5km Mass Abstraction Exclusion Zone (MAEZ) will achieve 64% of heat take monitoring.

The geothermal takes in Rotorua were categorised into classes to define an appropriate strategy for consent monitoring for each group. The main criterion for the class limits was the take size on the assumption that larger takes, cumulatively and individually, have greater potential to cause adverse effects on the geothermal system and should be prioritised for monitoring. It also means that fewer consent holders would be affected by new metering requirements to achieve a high level (e.g. 50-75%) of monitoring than if targeting the smaller takes.

Different types of consents and user profiles were also considered to ensure that the impacts of increased metering costs on the consent holders can realistically be met (Figure 5). The same rationale was applied to users with DHX systems (Figure 6).

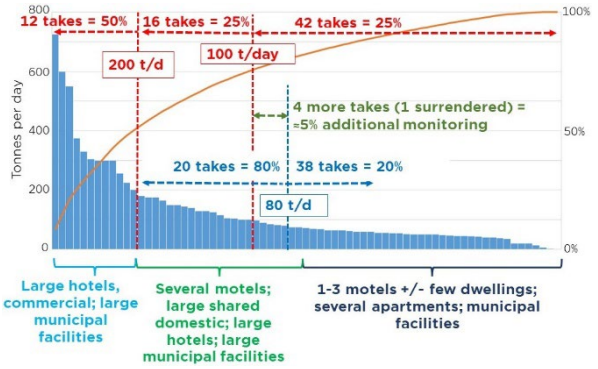

Figure 5: Take size classes for water takes. Orange line = cumulative takes of the Rotorua Geothermal System.

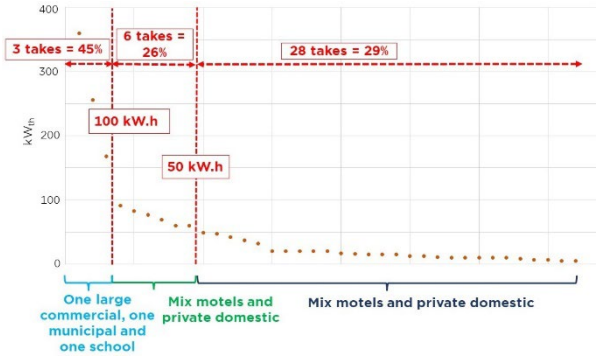

Figure 6: Take size classes for heat takes via downhole heat exchanger systems.

Based on the takes distribution curves and consents types of consents/users, the following classes were defined for production-reinjection and DHX systems:

Table 2: Take size classes for water and heat takes.

Take size class	Water - Doublet (tonnes per day)	Heat - DHX (kW_{th})
Large	≥ 200	≥ 100
Medium	< 200 and ≥ 100	< 100 and ≥ 50
Small	< 100	< 50

The take size classes were also checked against their geographical distribution to ensure that there is good geographical coverage across the system, particularly around the main outflows in Ngāpuna-Government Gardens, Whakarewarewa and Kuirau-Ōhinemutu, where the majority of the vulnerable surface features are located. The Whakarewarewa area is currently considered the most sensitive area of the geothermal system, as it includes the Geyser Flat, where all currently active geysers are located [Pohutu, Te Tohu (Prince of Wales Feathers) and Kereru].

ISSN2703-4275

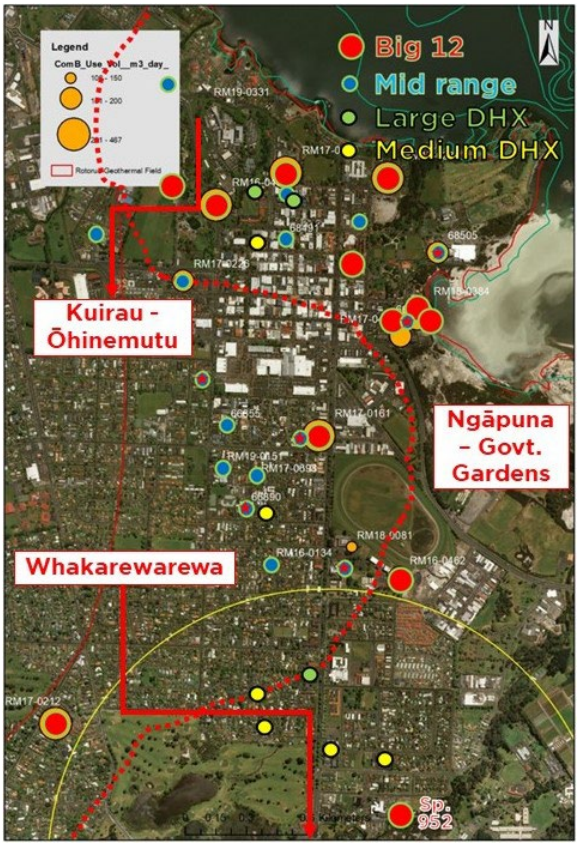

Figure 7: Geographic coverage of consent monitoring for large and mid-range users (doublets and DHX) in the Rotorua Geothermal System. Geothermal system approximate boundary (solid red line). Thermal areas are located approximately to the east of the dotted red line. Rotorua 1.5km MAEZ (yellow semi-circle)

Water takes with a production-reinjection system are likely to cause more adverse effects on the geothermal system than heat takes via DHX production systems (Clearwater & Franz, 2021; Burnell, 2022). Therefore, achieving a lower level of monitoring for heat takes via DHX (~50%) was considered satisfactory, as long as the 1.5 km MAEZ zone is adequately monitored.

DHX users are, by nature, small users (e.g. small motels, 1-3 shared homes), and it was anticipated that the costs for increased monitoring requirements would disproportionally affect them in relation to water takes (Section 1.2.3). However, by adopting the ~50% of monitoring target for DHX users, a monitoring gap would exist within the 1.5 km MAEZ (Figure 7). The planning controls are more rigorous in this area, with use limited to DHX production systems and no increase in heat take. Medium-size DHX takes within the 1.5km MAEZ were included in the group of consent holders to be required to continuously meter their use to fill this gap.

Another metering gap is in Ngāpuna (Figure 7), as there are effectively no consented geothermal takes in the area. Ngāpuna already has a substantial gap in environmental monitoring (surface features and geothermal aquifer monitoring programs; Scott *et. al.*, 2021), therefore, it is a substantial gap across various BOPRC monitoring programs, with no easy solutions identified so far.

For small water and heat takes, BOPRC approach was first to review the frequency, or schedule, for spot measurements (Table 1). This proposed schedule should be based on how often the peak use in winter is likely to change over the years across the lifetime of the consent (10 years). At least one measurement shall be obtained for each period to ensure that long-term changes in use can be determined for those smaller consent holders.

It is known that the difference between the cumulative deviation of the yearly rainfall from its long-term mean strongly controls the geothermal aquifer water levels (Scott *et al.*, 2021). It is likely that the geothermal aquifer water level is actually a summation of the takes and rainfall (which controls aquifer recharge).

Because the majority of the uses in Rotorua are for thermal energy, for space and water heating, lower outside air temperature increases the heat demand and, consequently, their takes. Because the cycles of air temperature in Rotorua vary between 4-8 years, biennial spot measurements will be required for the smaller users to ensure that at least one or two measurements occur for every climate cycle. This is effectively 2.5 times more data than it is currently obtained every 5 years (Section 1.2.2).

1.2.4 Costing

The cost implications of metering for consent holders has been closely considered by BOPRC, and ensuring costs are reasonable (as is required by the RMA) was a key driver in this project. There are already substantial costs to access geothermal energy in Rotorua, and BOPRC carefully considered the additional metering costs to resource consent holders to ensure that geothermal energy remains a viable option for the City. Any costs required of resource consent holders must also be reasonable and reflect the scale of the activity and potential effects of the activity on the environment.

Accessing geothermal energy in Rotorua has proven an economical option over decades, particularly for commercial and municipal users and shared domestic and mixed schemes. Most users have had their systems running for decades now. The high capital costs (CAPEX) associated with drilling and laying the geothermal heating system and operational costs (OPEX) for maintenance of assets and for meeting consents/compliance processes are offset by access to ‘free energy’. For hotels with thermal pools, for example, access to geothermal energy increases their revenue, and for other geothermal energy users is at the core of their business (e.g. Polynesian Spa) (Barns, 2022).

Small users (e.g. 1-3 homes, one small motel) generally opt for conventional DHX (i.e. without enhancements like promoter tube) for the production system (Peng & Moore, 2021). DHX in Rotorua generally does not suit larger users, as their output is typically low (<50kW$_{th}$). On the other hand, DHX has much lower maintenance requirements than doublet systems, requiring only one well to run (Peng & Moore, 2021).

The CAPEX and cumulative costs over the first ten years (CAPEX + OPEX + compliance costs) were estimated for the various metering methods and options. (Figure 9). The estimated costs were compared to how much the consent holders are paying to meet standard resource consent monitoring conditions (bucket/stop-watch and DHX readings).

ISSN2703-4275

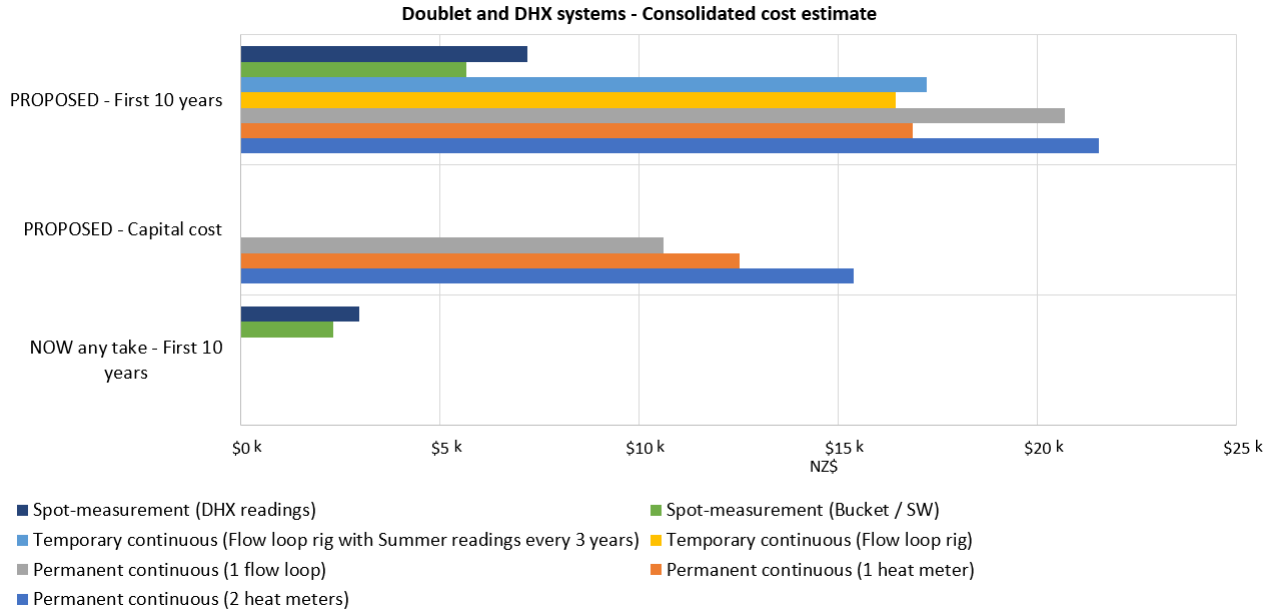

Figure 9: Consolidated costs for doublet and DHX systems.

The costs for the flow loop rig and permanent flow loop are considered accurate to ±10% as they were based on previous costs incurred to BOPRC to build the portable flow loop rig. The results are considered accurate for heat meter(s), DHX readings and bucket/stop-watch tests, given that it has been quoted with two suppliers and local service providers. Nonetheless, each consent holder's geothermal system is different; thus, the exact cost is site-specific.

BOPRC carried out a high-level cost estimate for each consent holder based on the geothermal system schematics supplied as part of their resource consent applications and compliance records. The results showed that all users could build metering systems with 1-2 flow loops or 1-2 heat meters, which would incur costs between $11k-16k (CAPEX) and 17k-22k over ten years (timeframe of the consent).

A key assumption for costing the movable flow loop metering program is that BOPRC would run it, and all costs are to be recovered through Section 36 RMA charges. This includes costs for moving the flow loop rig, maintenance and program administration charges. The main findings of the cost estimate analysis for doublet and DHX systems are outlined as follows:

- Overall, costs for continuous data acquisition and submission are 17k-22k over ten years (CAPEX + OPEX), which is not incommensurable compared to large warm/ freshwater takes in Tauranga (CAPEX ~10-35k and annual OPEX ~10k).
- Heat meters have a slightly higher CAPEX than a flow loop.
- The cumulative costs for one heat meter over ten years are lower than for one flow loop system. This is mostly due to the high maintenance costs anticipated for the flow loop.
- The costs for installing two heat meters are similar to one flow loop, cumulatively over ten years. Again, this is due to high maintenance costs anticipated for the flow loop.
- The user's heating systems can be upgraded to increase efficiency (e.g. reduce the number of heat exchangers). This would significantly reduce the costs to the users and would result in an indirect positive outcome for this project.
- Costs for monitoring with the movable flow loop rig, as originally developed by BOPRC, are of the same magnitude as a permanently installed flow loop and heat meter. This is because the OPEX of the flow loop rig (maintenance and program management) are high and will fall on the user (recovered through RMA Section 36).
- Increased costs on small users are due to changes in the schedule of spot measurements, from every five years to biennial. However, costs are still considered reasonable and justifiable, and in many cases can be done by the consent holder themselves.
- DHXs pay more than doublets for spot measurements now and will still pay more with the proposed changes. This is because DHX readings are more expensive than bucket/stopwatch tests at the local industry end.

2. DISCUSSION AND CONCLUSIONS

The lack of data on actual use for Rotorua has been a long standing issue for the management of the geothermal system. This has now been addressed through a cross-council, staged project, first initiated in 2014 and rolled out in 2022. This lengthy timeframe reflects the complexity of this project and the number of variables that needed to be carefully considered from project scoping to roll out.

The development of the flow loop as an accurate, repeatable and cost-effective method to continuously measure the use of geothermal takes was a major part of the project. It was initially developed to be a portable system to take continuous data from the larger users for a defined period of time (~6 weeks). However, the cost analysis showed that this was not the best option as (i) it would lead to similar costs to the user over time compared to a permanent metering system, and (ii) data would be continuous but for only a number of weeks every few years, only partially fulfilling BOPRC objectives for the project.

Once the methodology issue was overcome, the efforts were concentrated on defining the monitoring requirements while ensuring a balanced approach between an 'ideal' 100% monitoring target and what is reasonable for the complex Rotorua settings. This required first understanding the take size distribution, where the thresholds for take size classes would be, checking and closing monitoring gaps where possible by adjusting the monitoring requirements approach, how the different types of uses fit in this take size distribution and finally, what would be the financial implications to them.

The project is now under a staged implementation via reviewing consent clauses for large and medium water users, then DHX users and finally small users. The new monitoring requirement is expected to yield quality data across most of Rotorua, resulting in improved management of this geothermal system, its unique and vulnerable surface features and its precious resources.

ACKNOWLEDGEMENTS

Many BOPRC staff provided guidance and input on all elements of this body of work through workshops, field trials, technical assessments and robust debate. In particular, our thanks go to Danielle Petricevich and Mary Pappon (Senior Consents Officers), Ella Tennent (Principal Advisor Consents) and Adell Gilchrist (Senior Regulatory Project Officer) and Paul Scholes (Senior Environmental Scientist), all of who continue to be key players. Lilly (Qiija) Peng (University of Auckland; at Dobbie Engineers when involved in this project), and Greg Moore (Dobbie Engineers) contributed with various technical reports and were also in the early stages of project scoping and issues identification. Andrew Austin worked with BOPRC on the development and trial of the flow loop. Thanks to all the owners of the geothermal production systems who allowed for running the flow loop trials. Finally, thanks to Peter Brownbridge (RLC) for his contribution during the various stages of this project.

REFERENCES

Barber, J., Doorman, P and Laurent, J. (2017) Rotorua Geothermal Field - Exploring Methods to Measure Heat and Fluid Use. Proc. 39th New Zealand Geothermal Workshop, Rotorua, New Zealand.

Barns, S. The Economic Impacts and Benefits and Costs of Geothermal Resources in the Bay of Plenty Region. Bay of Plenty Regional Council, February 2022.

Burnell, J.G. (2022). Modelling the Rotorua Geothermal System. GNS Science Consultancy Report 2021/118. 92p.

Clearwater, J. & Franz, P. (2021). Effects of Downhole Heat Exchanger and Doublet Systems on Geothermal Reservoirs. Flow State Solutions Consultancy report - August 2021.

Dantala, R. (2021). Mass Flow Rate Measurement from Geothermal Wells Using Flow Loop Device - A case study from Rotorua, New Zealand. Research project for partial fulfilment of the Postgraduate Certificate in Geothermal Energy Technology, University of Auckland. 51p.

Peng, L. & Moore, G (2021). Geothermal Energy Productive Efficiency Review. Dobbie Engineers Consultancy report C2556. Available at https://www.boprc.govt.nz/your-council/documents-and-publications/publications

Scott, B.J., Kissling, W.M., Moreau, M., Sajkowski, L., Burnell, J.G., Brakenrig, T., Reeves, R.R. (2021). Assessing the Rotorua Geothermal System: a review of data sets. GNS Science Consultancy Report 2020/84. 101fp.

Zarrouk, S.J., & McLean, K. (2019). Geothermal well test analysis: fundamentals, applications and advanced techniques. Academic Press. 337p.