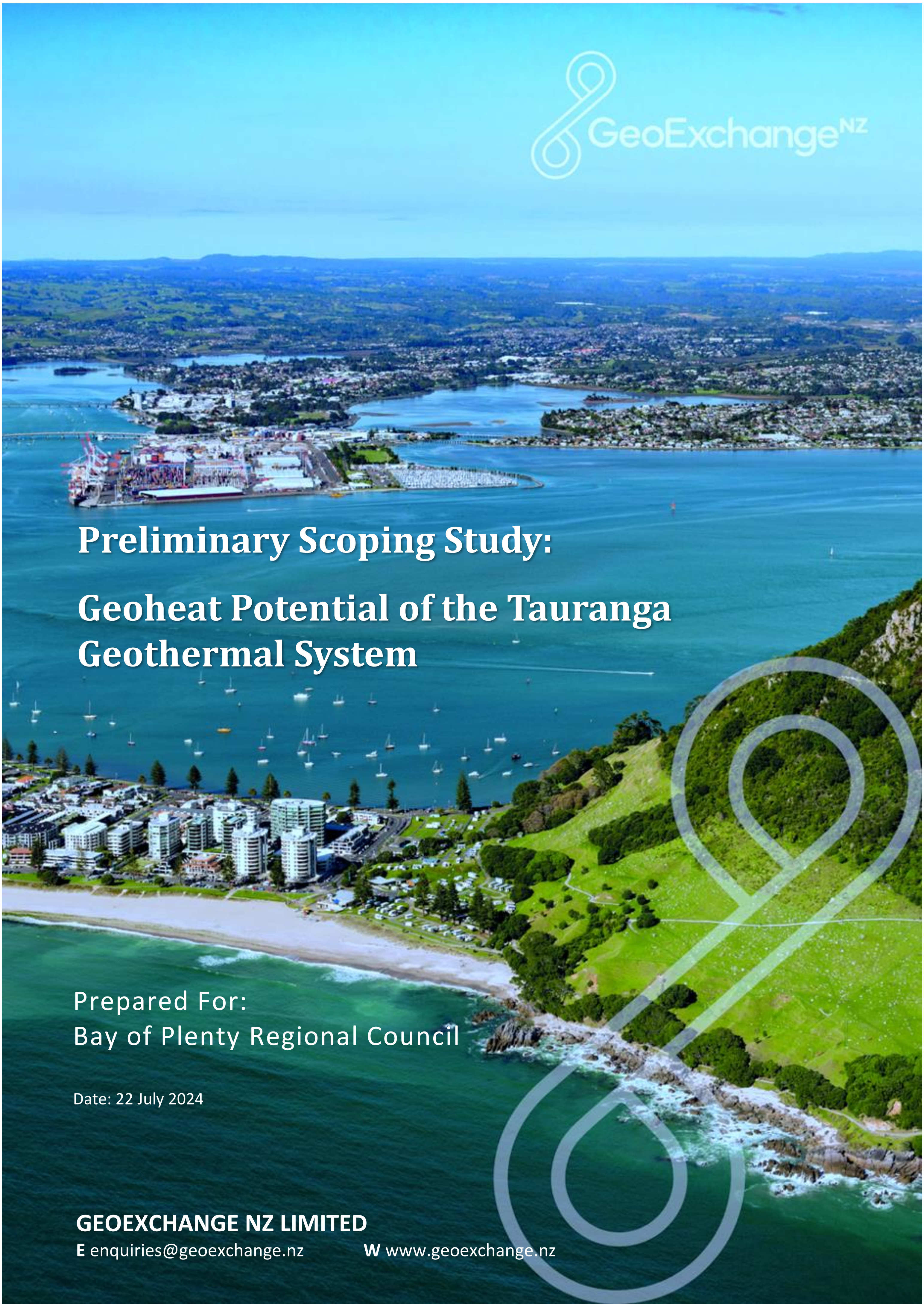

Preliminary Scoping Study:

Geoheat Potential of the Tauranga Geothermal System

Prepared For:
Bay of Plenty Regional Council

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PRELIMINARY SCOPING STUDY:
GEOHEAT POTENTIAL OF THE TAURANGA GEOTHERMAL SYSTEM

PREPARED FOR BAY OF PLENTY REGIONAL COUNCIL

EXECUTIVE SUMMARY

The Tauranga Geothermal System (TGS) covers an area of approximately 875 km^2 in the western Bay of Plenty[1] on the east coast of the North Island of New Zealand. It is classified as a low temperature geothermal system, or perhaps more accurately, as a groundwater system that is warmed by underlying geothermal influences. The groundwater temperatures in this area range from approximately 15°C in the absence of a geothermal influence up to a maximum recorded temperature of 70°C. Approximately 70% of consented wells are shallower than 200 metres and the deepest well is at 916m.

As geothermal waters ranging between 30°C and 70°C are not sufficiently high for electricity generation, the focus of this report is on how to extract value from this low temperature geothermal resource in the form of renewable and affordable heat. Using geothermal heat in this way is often referred to as 'geoheat' and this term is used throughout the report.

Existing uses of the TGS include heating of public and private pools, some space and water heating, and irrigation - where the heat of the water is of no additional value. By comparison, international applications access low temperature geoheat at depths of 2km-3km, often deeper, to replace gas heating for whole districts and light industry (Section 5.2). As such, **the renewable geoheat resource in the TGS is currently underutilised**, and thus, this report posed two questions:

- Could the western Bay of Plenty use its comparatively shallow low temperature geothermal resource to its strategic advantage as the region develops? and
- Importantly, how can this be done sustainably?

The report identified that a key factor contributing to the underutilisation of available geoheat is a lack of awareness of the presence and potential of the resource. By this we mean a lack of knowledge about different end uses of geoheat (covered crops, light industry, residential and commercial heating and cooling, or district schemes with multiple end-uses), different technology applications (direct use or heat pump assisted, closed or open loop), sustainable management practices, and even a lack of knowledge of the full breadth and depth of the TGS. This is symptomatic of a general lack of awareness of low temperature geothermal uses in New Zealand. There is clearly a need for increased communication on the geoheat opportunities, not just in the western Bay of Plenty but across New Zealand.

Most existing consent holders use the geoheat they access 'directly' (or not at all as per irrigators), meaning the heat they access matches or is higher than the end temperature needed. **This report presented that heat pump assisted geoheat installations (referred to as 'indirect' geoheat – Section 6.3) are well suited to the TGS.** Benefits of ground source heat pump (GSHP) use with geothermally enhanced groundwater are:

- A high efficiency system compared to other heating systems;

[1] Includes the area of Western Bay of Plenty District and Tauranga City Councils.

- More flexible and wider application as they do not rely on subsurface temperature. The GSHP will work with source temperature and deliver required temperature efficiently;
- Potential to access shallower groundwater which may reduce drilling depth requirements and thus expense;
- The GSHPs will maintain delivery temperature even if natural variation in the subsurface occurs;
- Can cool as well as heat;
- Industrial high-temperature GSHPs are technically advancing and now capable of delivering 150°C (see EECA, 2024 case study at Port of Tauranga); and
- A less extractive use of the resource and thus conducive to sustainable management.

To increase awareness of the TGS and to identify the most suitable and sustainable applications, Section 7 includes a series of maps that broadly characterise the potential of the TGS. Highlighted on these maps are key future development / growth areas that are outlined in SmartGrowth (2024) and an assessment of the geoheat potential for each development is summarised in Section 10.1.4. **The potential for district heating and cooling schemes is favourable for most of these future developments / growth areas, positively reflecting the available resource that is the TGS.**

The report also highlights potential for significant emissions reduction by utilising geoheat for commercial and industrial purposes, including at the Port of Tauranga and Rangiuru Business Park. **Being able to access clean and affordable heat for commercial and industrial purposes could be an attractive value proposition for economic development of the region.** Additionally, a favourable assessment was also made for a district scheme in Tauranga City centre that connects the remaining public buildings in Te Manawataki o Te Papa.

By building an understanding of these maps and their limitations, and of geoheat technology, this report can be used by stakeholders to better understand the geoheat potential of the TGS. It can also be used to strategize geoheat prospecting and development efforts for individual buildings or at a district level. **It is important that subsurface data collection improves and that these maps are regularly updated for public access**. As these maps improve, they will reduce the risk of investing in geoheat. Better data will improve understanding of the TGS from an extraction and management perspective.

Strategically using geoheat to the region's advantage can and must be done sustainably, in a way that is consistent with regional and district policy (Section 9). Adopting best practise principles is critical for balancing an increased uptake of geoheat systems within the TGS with its long-term sustainable management. The report outlines how important it is to ensure good system design, appropriate technology selection, and ensuring compliance of installation techniques (Section 9.4).

The majority of international examples of district geoheat schemes involve the public sector to some degree. Therefore, it is likely that in order to ignite a geoheat future for the western Bay of Plenty, where multiple residential and industrial district schemes operate**, support and leadership from local councils and central government will be required.**

In conclusion, the TGS is an accessible source of sustainable thermal energy that could provide significant energy, economic, environmental and health benefits to the region. However, it is relatively unknown as a resource and further research and data collection is essential to sustain the resource for the future.

PRELIMINARY SCOPING STUDY: GEOHEAT POTENTIAL OF THE TAURANGA GEOTHERMAL SYSTEM

PREPARED FOR BAY OF PLENTY REGIONAL COUNCIL

TABLE OF CONTENTS

1. INTRODUCTION 9

1.1 Focus of the Report 9

2. SCOPE OF WORKS 12

3. DEFINING GEOHEAT 13

4. THE TAURANGA GEOTHERMAL SYSTEM 15

4.1 Local Climate 15

4.2 Geological Setting 16

4.3 Low Temperature Geothermal 17

4.4 Current Uses of the Tauranga Geothermal System 17

5. THE CASE FOR GEOHEAT 19

5.1 Available Data for the Tauranga Geothermal System 19

5.2 International Trends in Geoheat 21

5.3 Proven Applications of Geoheat 23

6. ACCESSING GEOHEAT 25

6.1 Using the Ground and Groundwater for Thermal Energy 25

6.2 Direct Use 28

6.3 Indirect Use 30

6.4 Cooling with Geoheat 33

6.5 District Thermal Energy Systems 34

6.6 Hypothetical Geoheat Decision Schematics 35

7. TAURANGA GEOTHERMAL SYSTEM CHARACTERISATION 37

7.1 Data Gap Analysis 37

7.2 Differentiating Direct and Indirect Use Potential 38

7.3 Realising the Geoheat Potential 45

8. STRATEGIC RELEVANCE OF GEOHEAT FOR THE WESTERN BAY OF PLENTY 50

8.1 Tāngata Whenua Interests in Geoheat 50
8.2 Regional Economic Growth 51
8.3 Resilience and Stability of Energy Supply 53
9. THE REGULATORY FRAMEWORK AND RESOURCE MANAGEMENT 54
9.1 Geothermal Resource Management History in New Zealand 54
9.2 Regulatory Framework 54
9.3 Significant Geothermal Features 57
9.4 Environmental Best Practise 57
9.5 A Dynamic Resource 58
10. FUTURE OPPORTUNITIES 61
10.1 Existing Applications and Future Opportunities for Western Bay of Plenty 61
10.2 Investment, Ownership and Innovation 65
10.3 Initiatives to Enable Future Opportunities 67
11. CONCLUSIONS 71
12. RECOMMENDATIONS 72
13. REFERENCES 74
APPENDIX A: VALUING THE TAURANGA GEOTHERMAL SYSTEM – SEMISTRUCTURED INTERVIEWS WITH CONSENT HOLDERS. 77
APPENDIX B: DETAILED SCOPE OF WORKS 78
APPENDIX C: LITERATURE REVIEW LIST 80

FIGURES

Figure 1: Schematic of Earth's heat production from radioactive decay in the crust and solar radiation's thermal influence (left); Earth's crustal structure depth, based on Stober and Bucher (2014) (centre); solar/climatic and terrestrial influence areas (right). 13
Figure 2: Geographic Setting of the Tauranga Geothermal System (Source: Source: Topographic Basemap Land Information New Zealand (LINZ, Underlying topography NZ 8m Digital elevation model (2012). ... 15
Figure 3: Regional Geological map 1:250k (Source: GNS Science, geological units). 16
Figure 4: Left: end use of geothermal takes from the TGS, for 'geothermal uses' only. Right: type of users for 'geothermal uses' of the Tauranga Geothermal System (BOPRC, 2023) 18
Figure 5: Histogram distribution of well depths for available well data within the TGS. 20
Figure 6: Plot of well depth verses temperature for available well data within the TGS. 21
Figure 7: Installed capacity for geothermal heating projects, Source: Rystad Energy's Geothermal Solution (Rystad Energy, 2023) 22
Figure 8: Example of Connection Between Various Geoheat Sources and Above Ground Applications. Source: GNS Science from EECA (2024) 25
Figure 9: Potential uses of geothermal energy in the agriculture sector (IRENA, 2022) 29
Figure 10: Typical Schematic of a Heat Pump System 31
Figure 11: Schematic of a system with separate heating and cooling wells (Source: Schuppler, 2019) ... 34
Figure 12: Schematic showing a district thermal energy system using an open groundwater loop and closed loop GHX. 35
Figure 13: Example decision schematic for a tomato grower that requires 60°C water in their heating system to maintain optimal growing conditions year-round. It considers different subsurface conditions, different technology approaches and provides an estimated coefficient of performance (COP). 36
Figure 14: Example decision schematic for a commercial building / residential home requiring seasonal space heating and cooling. It considers different subsurface conditions, different technology approaches and provides an estimated COP. 36
Figure 15: Interpolated temperature at 150 m b.s.l across the TGS. 39
Figure 16: Depth distribution of temperatures greater than 30°C as a proxy of direct use potential. 40
Figure 17: Distribution of wells and depth with temperatures greater than 50°C. 41
Figure 18: Presence of 30°C temperature at depth for potential development zones. 43
Figure 19: Presence of wells with temperatures greater than 50°C temperature at depth for potential development zones. 44
Figure 20: Potential areas for closed loop geoheat systems. 47
Figure 21: Potential areas for open loop geoheat systems. 49

TABLES

Table 1: Summary of Potential Development Zones/Growth Areas 10
Table 2: Summary of Common and Proven Uses of Geoheat 23
Table 3: Summary of GeoHeat Extraction Options 26
Table 4: Direct Use Advantages and Disadvantages 28
Table 5: Indirect Use / Heat Pump Assisted Advantages and Disadvantages 30
Table 6: Impact of Source Temperature on Heat Pump Efficiency and Output 32
Table 7: Data Gap Analysis 37
Table 8: Depth Range of Ground Temperatures Underlying the Potential Development Zones 42
Table 9: Impediments to a Closed Loop Ground Heat Exchanger 46
Table 10: Regulatory Policies and Rules that are Relevant to Geoheat 56
Table 11: Geoheat Potential of the Future Development Zones/Growth Areas 64

ABBREVIATIONS

Acronym	**Term**
ASHP	Air Source Heat Pump
b.s.l	Below sea level
BOPRC	Bay of Plenty Regional Council
COP	Coefficient of Performance
DTES	District Thermal Energy System
EECA	Energy Efficiency and Conservation Authority
GSHP	Ground Source Heat Pump
IEA	International Energy Agency
MBIE	Ministry of Business, Innovation and Employment
NZGA	New Zealand Geothermal Association
RETA	Regional Energy Transition Accelerator
RMA	Resource Management Act
ROI	Return on Investment
RTE	Renewable Thermal Energy
TCC	Tauranga City Council
TGS	Tauranga Geothermal System
TVZ	Taupō Volcanic Zone
UTES	Underground Thermal Energy Storage
VRF	Variable Refrigerant Flow
VRV	Variable Refrigerant Volume
WBOPDC	Western Bay of Plenty District Council
WSHP	Water Source Heat Pump

PRELIMINARY SCOPING STUDY:
GEOHEAT POTENTIAL OF THE TAURANGA GEOTHERMAL SYSTEM

PREPARED FOR BAY OF PLENTY REGIONAL COUNCIL

1. INTRODUCTION

GeoExchange (GX) was engaged by the Bay of Plenty Regional Council (BOPRC) to assist with their understanding of the geothermal heating and cooling potential of the Tauranga Geothermal System (TGS).

The intention of the study was:

- To identify the potential of the TGS for sustainable heating and cooling applications;
- To outline innovative applications for use of the low temperature geothermal resource;
- To be a foundational report for broader stakeholder consultation on energy resilience and regional development planning, and the Tauranga System Management Plan (SMP); and
- To highlight opportunities and priority areas to further develop low temperature applications in Tauranga and the western Bay of Plenty.

In order to achieve the stated intent, a combination of technical groundwater and geothermal analysis was combined with stakeholder interviews as well as reviews of local planning, zoning and development strategies.

1.1 Focus of the Report

This report focusses on the sustainable use of geothermal for heat. It does not address geothermal electricity generation. It considers applications for businesses, industry, public facilities and homes for heating, hot water and even cooling.

Using geothermal heat in this way is often referred to as 'geoheat', henceforward the term geoheat will be used throughout this report. Geoheat is a globally accepted term when using geothermal energy for heating rather than to generate electricity. New Zealand has a GeoHeat strategy 2017-2030 and the 2024-25 Action Plan is a complementary document to this report. [2]

It is worth noting that emerging research is underway as to how to generate electricity from low temperature systems. However, it is too early to include as a viable option in this report and should be monitored as a future opportunity for the region.

1.1.1 Interviews With Current Users of the Tauranga Geothermal System

Interviews with a small number of current geothermal consent holders were conducted as research for this project. The findings and specific quotes from these interviews are woven through the report. Interviews and meetings were conducted with the following:

- Meetings with Tauranga City Council and Western Bay of Plenty District Council;
- A small, covered horticulture facility;

[2] Geoheat Action Plan 2024-25 https://www.nzgeothermal.org.nz/downloads/2024-2025-Geoheat-Action-Plan.pdf

- An apartment complex;
- A privately owned recreation/entertainment facility;
- A public education facility with swimming pools; and
- A kiwifruit orchardist.

The identities of these consent holders and the individuals from councils have been kept anonymous. The script used to guide the 30-45 minute semi-structured interviews can be found in Appendix A.

1.1.2 Key Development / Growth Zones in the Western Bay of Plenty

There are nine locations in the western Bay of Plenty which are highlighted on the maps and tables generated for this report. These nine locations are identified as planned growth areas and potential long-term growth areas within SmartGrowth (2024), the region's coordinated growth strategy. They include new residential and industrial corridors as well as existing neighbourhoods with planned intensification. We have chosen to include some of the long-term growth areas, however it is important to note that they have not yet been fully investigated and/or confirmed.

Table 1: Summary of Potential Development Zones/Growth Areas

Potential Development Zones	Land Use Zoning
Port of Tauranga[3]	Industrial
Tauranga City Centre[4]	Mixed Use: Residential / Commercial
Te Papa Peninsula	Mixed Use: Residential / Commercial
Tauriko[5]	Residential
	Industrial
Rangiuru Business Park[6]	Industrial
Eastern Centre	Residential
Ōmokoroa / Te Puna	Residential
	Industrial
Otūmoetai	Residential
Pāpāmoa East[7]	Residential

These key potential development locations / growth areas have been mapped and an assessment made about their geoheat potential. We have chosen to use geographic place names that are familiar to the region as some of the names used in SmartGrowth are specific to the strategy and not intended as long-term names, e.g. Tauriko is used rather than the Western Corridor. In Section 10 we identify how utilising

[3] Port of Tauranga is within the Mount Maunganui Connected Centre, highlighted here due to potential at that specific site.
[4] Tauranga City Centre is within the Te Papa Peninsula Connected Centre, highlighted here due to potential at that specific site.
[5] The Taurirko boundary shown in this report's maps makes up most of the Western Corridor Connected Centre.
[6] Rangiuru Business Park is adjacent to the western boundary of the Eastern Connected Centre, the Eastern Centre boundary is included in this report's maps.
[7] Pāpāmoa East includes territory from Wairakei to Te Tumu, as shown within SmartGrowth.

the available low temperature geoheat aligns with SmartGrowth's strategic vision for Tauranga City and the western Bay of Plenty region. Coordinated planning and investment from key regional players could catalyse a geoheat strategy for these areas.

2. SCOPE OF WORKS

This report was undertaken in accordance with the agreed Scope of Works, the following is a summary of the key elements specified in the scope. A full, detailed version of the Scope of Works can be found in Appendix B:

- Geothermal resource characterisation;
- Review of technologies suited to the Tauranga Geothermal System;
- Regional opportunities and constraints based on resource characterisation and socio-economic analysis;
- Stakeholder input as required;
- Resource management implications; and
- Recommendations.

3. DEFINING GEOHEAT

Geothermal heating systems, referred to as geoheat in this report, harness the earth's natural heat for various heating and cooling applications. To understand how this sustainable resource is extracted and utilised, an understanding of the underlying geological conditions is required and then an appropriate heat extraction technology needs to be identified.

Geoheat systems are either:

- Direct use: Systems that use available geoheat directly (e.g. a geothermal hot pool); or
- Indirect use: Systems that require a heat pump to modify the source temperatures.

For the purposes of this report, we will consider direct use heating systems possible from temperatures greater than 30°C, a value that aligns with the definition of geothermal water within the Resource Management Act (1991). Direct use cooling systems would typically require source temperatures that are less than 10°C.

However, in reality, whether a heating or cooling system is direct or indirect use is a function of the available source temperature and the temperatures required by the individual heating or cooling application, and thus, will be very site and application specific.

The Earth's thermal dynamics are driven by both external and internal energy sources (Figure 1). For example, the varying surface temperatures we experience are primarily shaped by external solar radiation. This same solar radiation, combined with thermal storage properties of the ground, provides relatively stable shallow ground temperatures that are independent of daily or seasonal fluctuations. As per Figure 1, ground temperatures, outside the influence of geothermal activity, become constant and stable beyond a depth of approximately 8-12m. These 'ambient' ground temperatures are a function of annual average air temperature for a given location, across New Zealand these range from nominally 10°C in the South Island or in alpine areas, to approximately 17°C in Northland.

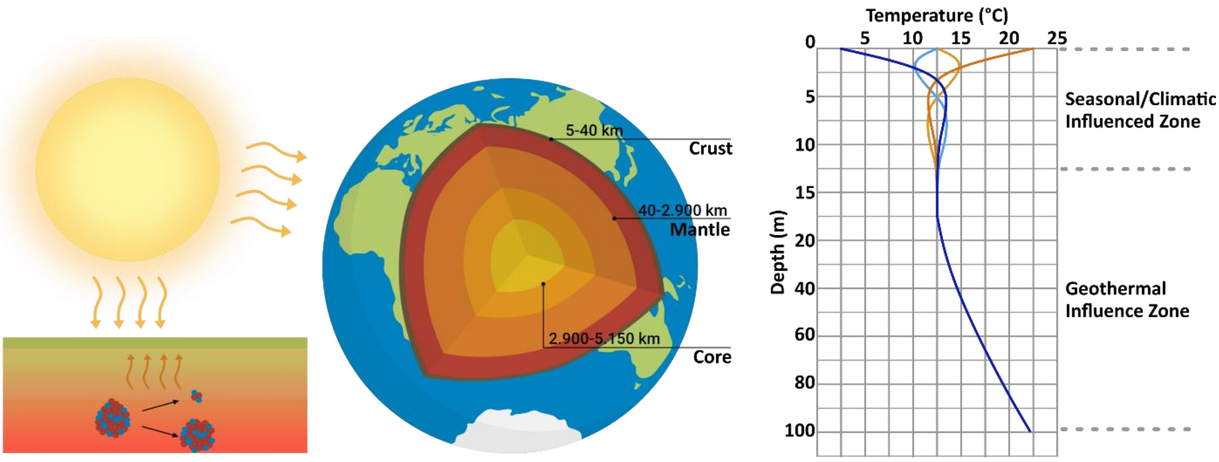


Figure 1: Schematic of Earth's heat production from radioactive decay in the crust and solar radiation's thermal influence (left); Earth's crustal structure depth, based on Stober and Bucher (2014) (centre); solar/climatic and terrestrial influence areas (right).

Beyond these comparatively shallow depths, the influence of external solar radiation is surpassed by the influence of internal energy sources – what is referred to as geothermal energy. The contrast between the high temperatures deep within the earth (up to 5000 °C at the inner solid core) and the cooler surface fosters a continual flow of heat from the core to the surface (Stober and Bucher, 2014). Various processes, including frictional heating, potential energy from crustal formation, and residual heat from planetary formation, contribute to subsurface heat production, with the majority stemming from the radioactive decay of elements. This temperature increase with depth is termed the geothermal gradient, which varies globally.

The following section addresses specific characteristics of the Tauranga Geothermal System (TGS).

4. THE TAURANGA GEOTHERMAL SYSTEM

The TGS covers an area of approximately 875 km^2 in the western Bay of Plenty , stretching from Waihi Beach in the north to Te Puke- Maketū in the south east (Figure 2) (BOPRC, 2023). To the northeast lies the Pacific Ocean, while the west and northwest are dominated by the Kaimai and Coromandel Ranges respectively.

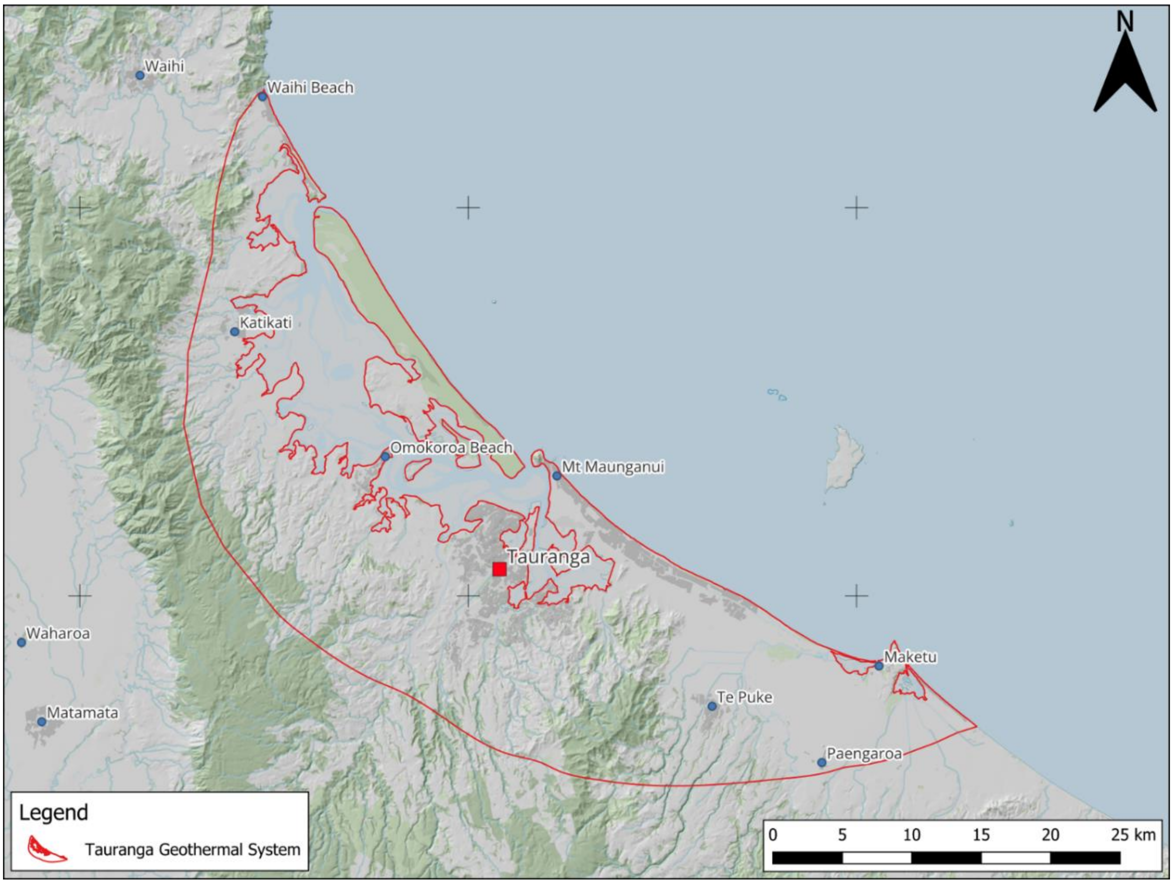


Figure 2: Geographic Setting of the Tauranga Geothermal System (Source: Source: Topographic Basemap Land Information New Zealand (LINZ, Underlying topography NZ 8m Digital elevation model (2012).

The landscape is the product of a complex interplay of volcanic activity, characterised by volcanic events that have resulted in ignimbrite plateaus, while effusive eruptions have formed lava domes and stratovolcanoes, as well as tectonic activity (Leonard et al., 2010).

4.1 Local Climate

The area has an oceanic or marine climate in accordance with the Koppen classification providing cool winters and mild summers. Average annual rainfall is 1202 mm with 111 rain days per year.

Average maximum temperatures range from 14.6°C in July through to 24.4°C in February for an average maximum of 19.4°C. Average minimum temperatures range from 6.3°C in July through to 15.8°C in February for an average minimum of 10.8°C (NIWA, 2024) and an annual average of 15.1°C.

The climate conditions indicate that both heating and cooling is required in residential and commercial buildings. The impacts of climate change will result in an increase in the requirement for cooling.

Depending on the application, heating for industrial processes is less, if at all, influenced by climate. In such applications, heating only may be required and no cooling.

4.2 Geological Setting

Sitting within the Tauranga Basin, the TGS was formed around 2 to 3 million years ago (Davis and Healy, 1993). The cityscape of Tauranga features notable volcanic landforms such as Mt Maunganui (Pearson, 2018). The Tauranga Group Sediments, around 6.5 thousand years old, are found on volcanic formations, along with intertidal sediments between 3.4 and 0.7 thousand years old (Pearson, 2018 after Davis and Healy, 1993). The sediment thickness increases towards the sea, reaching depths of up to 300 meters offshore and decreasing towards the west (White, 2009).

In the Tauranga area, there are no active mapped faults; only inactive, concealed faults are present. (BOPRC, 2023 after Briggs et. al., 2006).

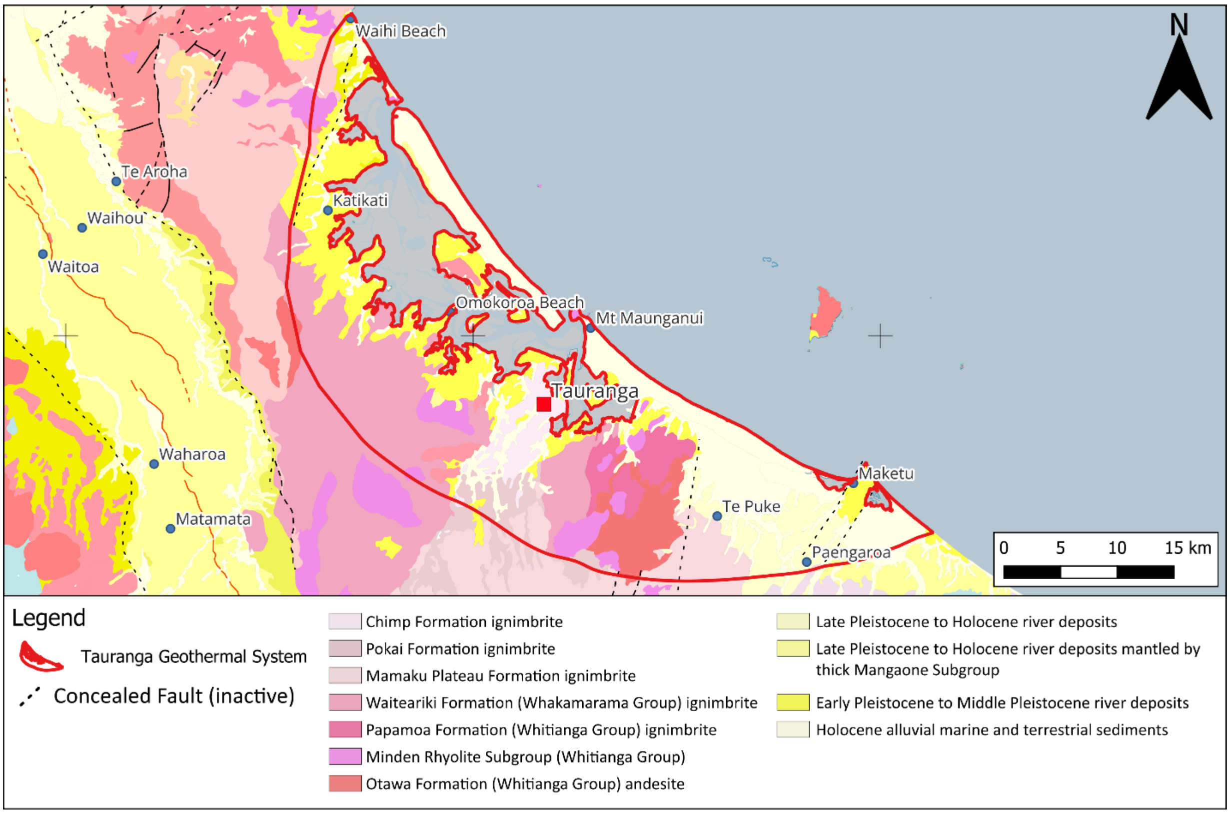


Figure 3: Regional Geological map 1:250k (Source: GNS Science, geological units).

Understanding the geological conditions is crucial for assessing the geothermal potential of an area. Geology influences the thermal and hydraulic properties of rock formations, which determine the viability of geothermal systems. Key factors such as rock permeability, water reservoirs, thermal gradients, rock composition and fault structures influence the efficiency and profitability of geothermal energy. Analysing these factors helps to estimate the sustainability of resources and assess economic feasibility.

Further discussion of the TGS can be found in Sections 7-8 of this report. See also Tauranga Geothermal System Science Summary Report, BOPRC Environmental Summary Report December 2023.[8]

[8] Tauranga Geothermal System Science Summary Report – https://atlas.boprc.govt.nz/api/v1/edms/document/A4581253/content

4.3 Low Temperature Geothermal

Geothermal water is designated by the Resource Management Act (RMA, 1991) as water with temperatures exceeding 30°C. In some cases, groundwater less than 30°C is geothermally influenced, and while not 'technically' geothermal, it may have elevated temperatures. The distinction between low and high-temperature geothermal systems is somewhat subjective. However, GNS Science commonly uses a threshold of 150°C and this will be adopted in this report. According to this classification, the TGS qualifies as a low-temperature geothermal system, with a maximum recorded temperature of approximately 70°C at a depth of 707 meters.

The groundwater aquifer system in the western Bay of Plenty consists of multiple hydrologically connected parts. The TGS covers the parts of this aquifer system where geothermally influenced groundwater, or water over 30°C is found. Therefore, it is more a groundwater system warmed by geothermal influences rather than a pure geothermal system as per the high temperature systems in nearby Rotorua, Kawerau and Taupō.

In a further point of difference to the regional high temperature geothermal systems, the mineral content of the thermal water in the TGS is relatively low and is more similar to that of ambient temperature groundwater. While in most cases it is suitable for irrigation, storage water or for frost protection, in certain places it may have slightly elevated levels of potentially harmful minerals such as arsenic and boron (BOPRC, 2023).

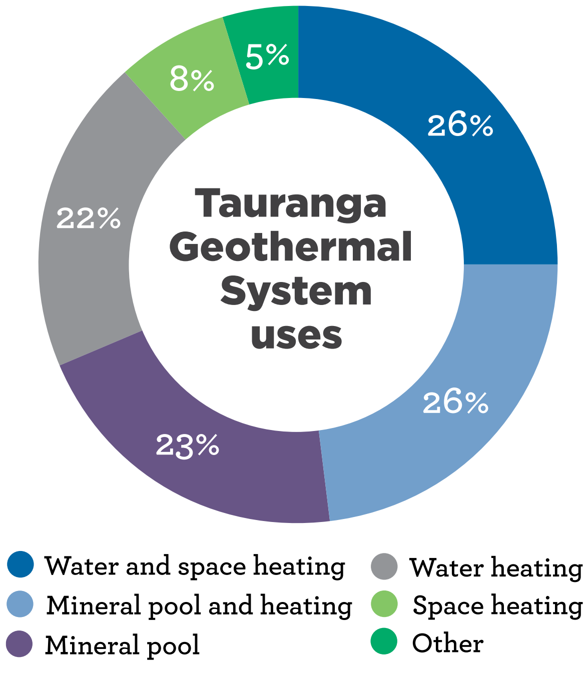
In the TGS, notably high gradient increases have been observed, ranging from of 4 to 22.5°C per 100 meters when descending from the surface. It is these high gradients, attributed to residual heat from past tectonic and magmatic activities, that provide the notably elevated near subsurface temperatures.

4.4 Current Uses of the Tauranga Geothermal System

9.5 million m^3 of geothermal water is currently consented for extraction from the TGS per year. In comparison, the total extraction of non-geothermal groundwater in the Tauranga-Kaituna-Waihi area is around 53 million m^3 per year, which is around 5.5 times the consented geothermal extraction volume (BOPRC, 2023).

The BOPRC categorise usage of extracted groundwater as 'geothermal uses' or 'non-geothermal uses' (Figure 4). Geothermal uses are those where the value of the resource use is intrinsically linked to the geothermal energy (heat) and/or the well-being associated with bathing in pure geothermal water. This accounts for 76% of the allocated geothermal water.

Non-geothermal uses, constituting 24% of the extraction, involve relatively warm water (>30°C) that does not necessitate geothermal energy or mineral properties for the end use. (BOPRC, 2023).



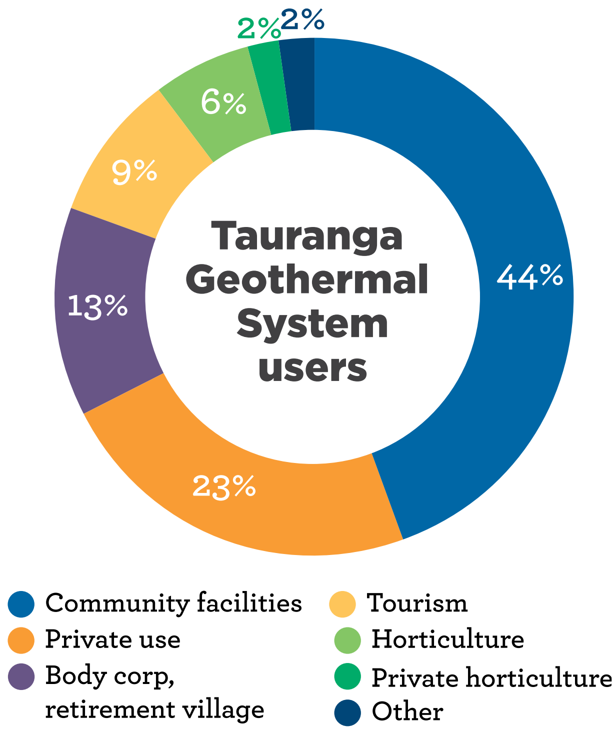


Figure 4: Left: end use of geothermal takes from the TGS, for 'geothermal uses' only. Right: type of users for 'geothermal uses' of the Tauranga Geothermal System (BOPRC, 2023)

5. THE CASE FOR GEOHEAT

Most New Zealanders are familiar with the very hot geothermal temperatures present in neighbouring Waikato Region, and Kawerau in the Bay of Plenty, and that these high temperature systems are extracted to generate almost 18% of New Zealand's national electricity (MBIE, 2023). Within the Taupō Volcanic Zone (TVZ), maximum temperatures of up to 337°C have been measured, significantly higher than the approximately 70°C recorded in the TGS, categorising it as a low-temperature geothermal system (Bibby et al., 1995).

Since these lower temperatures are generally not sufficient for electricity generation, the question arises: what can be done with low-temperature geothermal energy and is it properly valued?

Heating is a significant driver of global energy demand, both in buildings and in industrial processes. According to the International Energy Agency (IEA), heat accounted for almost half of total final energy consumption and 38% of energy-related CO_2 emissions in 2022. Global heating demand in the building sector is expected to remain steady from 2023 to 2028. However, the modern use of renewable energy sources for space heating, water heating and cooking is expected to increase by almost 40% over this period, with the share of renewables rising from 15% to 21% by 2028. Heat pumps, renewable electricity and bioenergy will be the main drivers of this growth. The share of renewable energy sources in global industrial heat consumption is anticipated to rise slowly, from 12% in 2022 to 15% in 2028 (IEA, 2024).

There is nothing more efficient than harnessing available heat directly for heating, thus the TGS is a heat resource that, managed sustainably, could contribute to decarbonising fossil fuel use and support sustainable growth of the region.

Geothermal is a renewable energy (as recognised by the RMA, 1991) that alongside solar, hydro, and wind generated electricity, as well as emerging fuels such as hydrogen and biofuels, will play a significant and interconnected role in New Zealand's journey to a zero-carbon future.

Geothermal's role in New Zealand as an electricity generator is well established but current use of geoheat is relatively modest, around 29 PJ (MBIE, 2023). Surprisingly, New Zealand's projected investment in geoheat is dwarfed by countries that have less favourable geological or geothermal conditions, notably Europe, the US and China. Section 5.2 addresses some of the reasons that geoheat is attractive to these countries and its various applications.

5.1 Available Data for the Tauranga Geothermal System

The data used in this study of the TGS came from a variety of sources, including literature reviews, geological studies, previous surveys and groundwater management units. Also integral to the analysis were datasets such as the 3D geological model of the western Bay of Plenty developed by White et al. (2009), which provides detailed geological information. In addition, well[9] data with temperature data and geothermal gradients were included to provide an understanding of the subsurface temperature distributions. The New Zealand Aquifer Potential Map (GNS Science, 2017) served as a foundational dataset that provided valuable insight into the potential of aquifers in the region.

[9] BOPRC practice is to use the term well, however, note that the term bore or borehole are also commonly used. It is not uncommon to hear people use well and borehole interchangeably.

The geothermal status and potential of the TGS has been intensively analysed in earlier studies. Investigations, especially by White et al. (2009) and Simpson (1987) have analysed the groundwater properties and temperature data in the western Bay of Plenty region in detail. White et al. (2009) conducted a comprehensive groundwater investigation and analysed well data that provided groundwater level measurements, chemical data, geological logs and temperature data. Simpson (1987) measured the thermal conductivity of volcanic rocks and well temperatures and assessed heat flow.

Furthermore, surface resistivity measurements were carried out by Stagpoole and Bibby (1998), which identified a zone of low resistivity between Maketū and Te Puke. Finally, Pearson et al. (2012 and 2018) developed the Tauranga Basin geothermal reservoir model. The aim of the modelling was to better understand the TGS, to assess its energy potential, to identify upwelling zones for drilling and to adequately inform management implications. Results from this modelling indicated that the current geoheat use of the TGS is sustainable and that this should be continued to be modelled to ensure this status is maintained (Pearson et al. 2018).

By bringing these datasets together, this study assessed the spatial resource characteristics by providing a solid foundation for informed decision making in geothermal resource management and development.

5.1.1 Well Data

The analysis of well data is of crucial importance for the assessment of geothermal potential. It provides direct insights into subsurface geological formations and thermal gradients, which are essential for assessing project feasibility, optimising drilling strategies and estimating energy potential. For the evaluation (Figure 5), a total of 2029 wells (geothermal and non-geothermal) within the TGS area are available. The average well depth is 152 meters, with a median depth of 123 meters. The maximum well depth recorded is 917 meters.

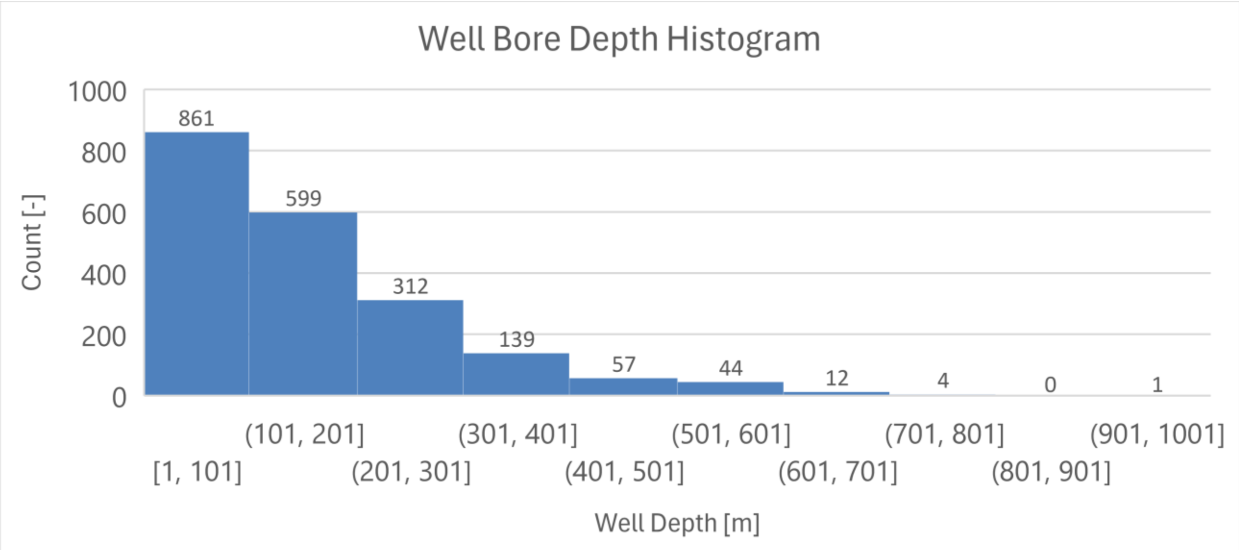


Figure 5: Histogram distribution of well depths for available well data within the TGS.

Consequently, over 70% of wells are shallower than 200 meters below ground level and with only 3% of all wells exceeding 500 meters in depth, significantly limiting knowledge of the deep subsurface within the TGS.

With respect to the relationship between well depth and temperature within the TGS, an interesting trend is presented in Figure 6. Based on the individually analysed wells, the geothermal gradient varies significantly between 4 and 22.5°C per 100 meters. The highest temperature measured is 68°C at a well depth of 707 meters. This indicates a variable distribution of temperature increase within the TGS, suggesting different hotspots in the subsurface. These variations emphasise the presence of significant localised temperature increases illustrating the complex thermal dynamics at play beneath the surface.

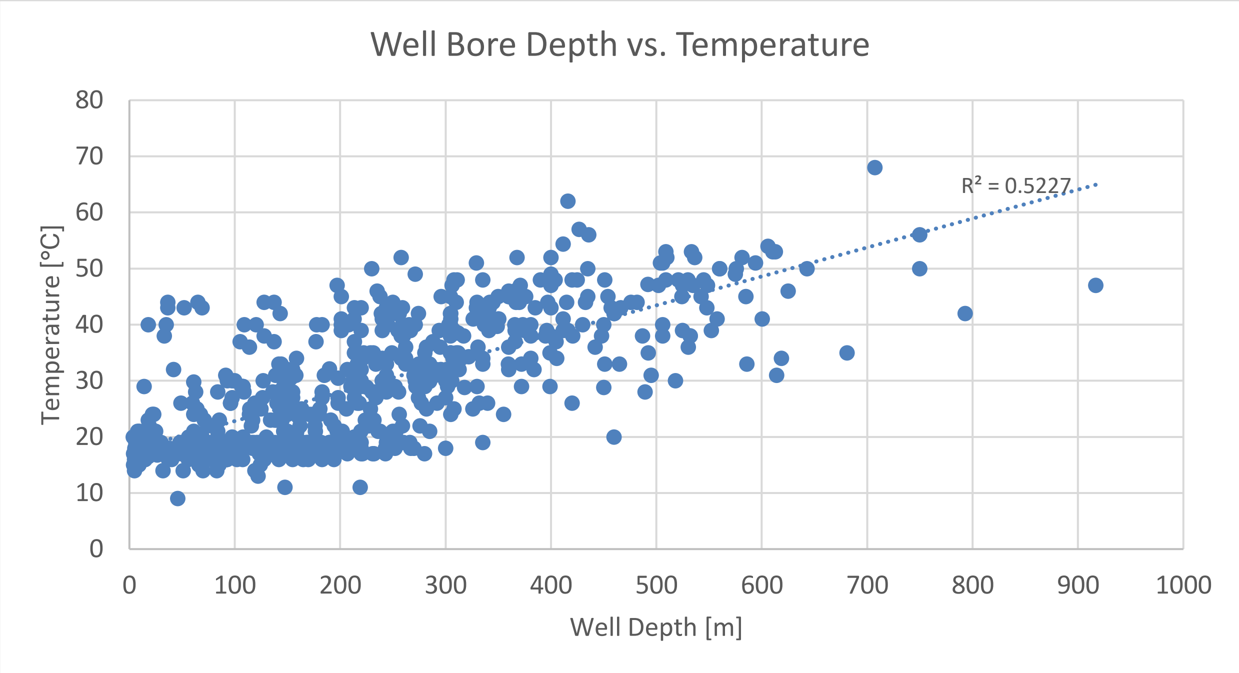


Figure 6: Plot of well depth verses temperature for available well data within the TGS.

This Section has presented a summary of the known information on the TGS. In Section 7, we provide further interpretation and characterisation of the TGS with respect to its potential for geoheat.

5.2 International Trends in Geoheat

Unlike other renewables, a major benefit of geoheat is that it is not weather dependent, it sustainably generates heat 24/7. For this reason, it is a logical and now attractive alternative to gas in district heating schemes. This is especially evident in Europe where cities are switching fuels to increase energy independence and achieve climate targets. Unlike biofuels and hydrogen, geoheat does not need to be transported, stored on site, nor is it subject to supply constraints and fluctuating costs.

There are currently 240 geothermal district heating schemes in Europe, ranging from 0.5 to 50 MW_{th} in capacity, these schemes are either for new housing developments or are successful retrofits of old gas systems. Project Aarhus in Denmark, consisting of 17 wells on seven sites, with a 110 MW_{th} capacity is under development targeting provision of 20% of the city's heating for its 336,000 residents by 2030 (NZGA, 2024). Also, the city of Munich has a target of being the first major German city to provide 100% of its district heating from renewable energies by 2040, with geothermal heat as the backbone of the heat supply. The target is the Jurassic Malm aquifer, for which a depth of approx. 2.5 km must be drilled north of Munich in order to reach a reservoir temperature of 60°C and a depth of approx. 5 km south of Munich in order to reach a reservoir temperature of 150°C (Farquharson N. et al., 2016).

In the horticulture sector, geoheat has become an increasingly attractive alternative to gas heating for covered crops that require year-round heat to maintain stable glasshouse growing temperatures. Gas prices soared in Europe with the start of Ukraine War and as a result, many covered crops shutdown over winter forcing produce price spikes for some vegetables. Divestment away from gas, already underway and being driven by regional carbon taxes, has accelerated investment in geoheat.

The Netherlands geothermal strategy specifically highlights the potential for their world leading covered crops industry. By 2030, approximately 40% of the industry is targeted for conversion to geoheat, producing approximately 2 million tonnes pa of produce for export. Their transition to 2030 is targeting 30 PJ pa of geoheat which will reduce emissions by approximately 1.6 million tonnes pa (DAGO, 2018).

Using geothermal heat directly requires drilling, pumps and pipes. As with solar and wind, the capital investment is higher, but it rewards with abundant 'free' energy, thus a favourable return on investment (ROI) is possible. However, geothermal infrastructure has less embodied carbon and rare earth minerals than solar and wind and it has a smaller geographic footprint on site, essentially some wells and a pumping station. Although maintenance is required and there is a risk of well failure, a properly constructed and maintained geothermal well can operate for decades (Violante et al., 2022), significantly outlasting solar and wind power plants, which typically have a lifespan of around 20 years (Piotrowska et al., 2022).

The abovementioned benefits have driven investment in Europe where it appears that the benefits of low temperature geoheat are well understood and now being extensively applied. However, this is comparatively poorly understood and underutilised in New Zealand (NZGA, 2024). Figure 7 highlights investment trends, noting strong growth from 2012, especially in Germany and the Netherlands.

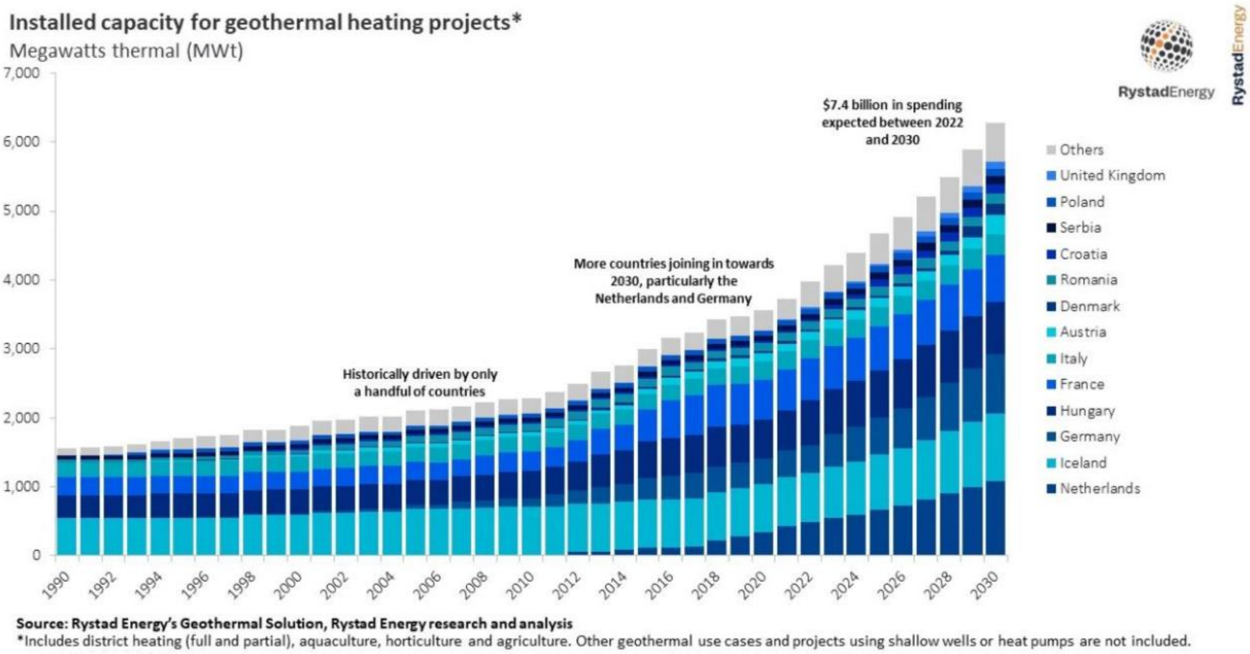


Figure 7: Installed capacity for geothermal heating projects, Source: Rystad Energy's Geothermal Solution (Rystad Energy, 2023)

Total installed capacity is projected to surpass 6.2 gigawatts thermal (GWt) in 2030, a 58% increase from today's total of 3.9 GWt, developments that are expected to cost an estimated $7.4 billion (USD).

The average drilling depth for European geothermal district heating projects is around 2,000 meters (Rystad Energy, 2023).

It is noted that numerous countries are drilling more than 8x the well depth, at significant expense, to access temperatures available at comparatively shallow depths in the TGS. While the social and political context in Europe differs significantly from that in New Zealand, the opportunity to sustainably utilise low temperature geothermal resources in New Zealand generally, and more specifically the TGS, should be considered more closely.

To this end, could the western Bay of Plenty use its comparatively shallow low temperature geothermal resource to its strategic advantage as the region develops? Importantly, how can this be done sustainably?

5.3 Proven Applications of Geoheat

As per the above examples, geoheat has proven itself in a number of applications and as such, where it is available, it should arguably be the first source of thermal energy considered in any design feasibility. The intention of this section is to highlight the most common and proven uses of geoheat globally (Table 2). In Section 10.1 these are specifically linked to known future development plans western Bay of Plenty .

Table 2: Summary of Common and Proven Uses of Geoheat

Geoheat Application	Description
Pools and Aquatic Centres	Geothermal spas or springs are a small component of the potential for geoheat. Public and private pools are typically heated to 26-28°C, therapy pools to 32-35°C and spas to 38-40°C. For many facility providers globally, pool heating is a significant operating cost and one that is getting more expensive. The use of geoheat enables these facilities to be heated directly for significantly lower cost as long as source temperatures are at least 5-10°C greater than what is required. Further, indirect use of geoheat using heat pumps is also a cost-effective option.
Covered crops/glasshouses	The stable and constant supply of geoheat, irrespective of external weather conditions or global resource prices, has proven highly suitable for maintaining the optimised temperatures required for year-round crop growth. Geoheat investments from the covered crop sector are advancing in Europe, especially with global horticulture leaders, the Netherlands. There, a typical geoheat installation requires drilling 2-3km to access temperatures of 80°C (DAGO, 2018). This is a major capital investment but an unparalleled supply of secure, affordable heat out into the future.
Public buildings	Many public buildings around the world utilise geoheat, some undergoing recent retrofits from fossil fuel boilers. Examples include Paris's Elysée Palace, Princeton University in New Jersey and the Christchurch Town Hall. For public spaces, an investment in geoheat for heating and cooling is attractive due to its efficiency and sustainability. Harnessing the stable temperatures found beneath the surface, reduces dependence on fossil fuels, lowering greenhouse gas emissions and operational costs over time. Additionally, geothermal systems have a longer lifespan and require

	less maintenance compared to traditional HVAC systems, further safeguarding the public investment in the future.
Residential	Geoheat has been used successfully in residential buildings for years. Numerous examples worldwide show that it can reliably heat and cool. These systems generally supply space heating energy and hot water at temperatures of 30-60 °C. In addition, they provide efficient cooling in the range of 5-20 °C, ensuring year-round climate control. Significantly reducing energy costs and emissions, this emphasises the efficiency and reliability of geoheat while enhancing well-being.
Industrial	Geoheat can also be used for a variety of industrial applications. Industrial processes require a wide range of temperatures, so that geothermal energy can be used directly in sectors such as food processing, paper manufacturing and drying processes, to name a few. These applications typically require temperatures between 60-150°C or higher. Geoheat is also potentially valuable for applications requiring higher peak temperatures. For these systems it can provide reliable base load, reducing operating costs and greenhouse gas emissions. This increases energy security and price stability and promotes a more sustainable industrial sector. Although industrial use is not yet widespread, its importance will increase as the drive for more efficient and sustainable processes continues.
District heating and cooling	When several systems are networked together, they form a district thermal energy system (DTES) that supplies buildings with heating, cooling and hot water. These systems can utilise individual or shared heat sources with heat pumps in buildings or central plants. Geoheat can play a central role in DTES by providing both base load and peak load heating and cooling. DTES offer advantages such as lower peak demand, better integration of renewable energy and higher efficiency through heat exchange and load redistribution. Modern DTES, now in their fifth generation, have ambient temperature circuits for more efficient and sustainable energy utilisation.

6. ACCESSING GEOHEAT

As shown in Figure 8, geoheat can be accessed in various ways depending on the requirements of the application and the subsurface characteristics present. Therefore, which geoheat extraction technology is most appropriate for a given application is determined on a case-by-case basis.

It is important to note that Figure 8 provides an example only of the temperatures and depths likely to be encountered and that these will vary for each location. The TGS is a great example of this. Further explanations, especially of the various geoheat extraction technologies, are provided in the following sections.

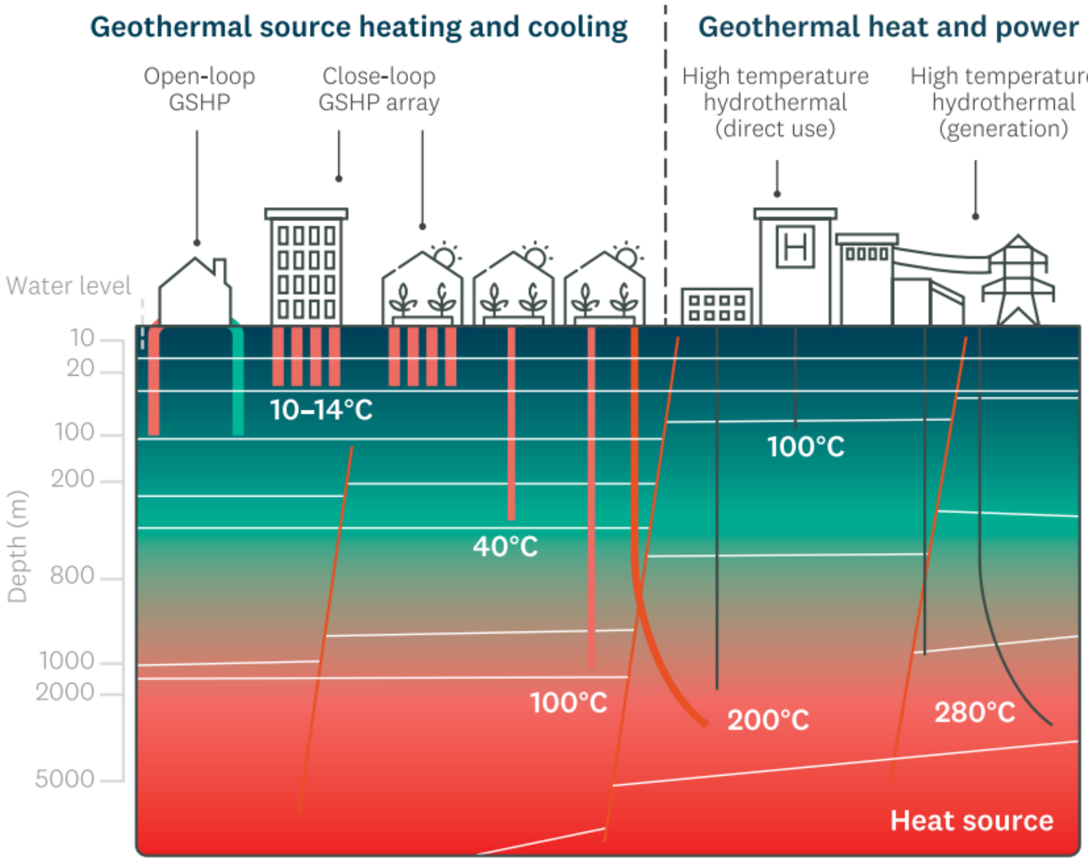
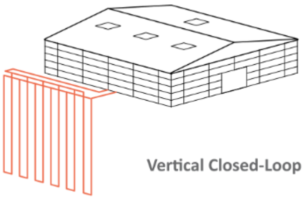
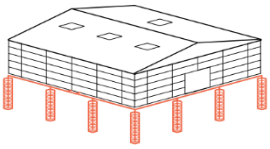
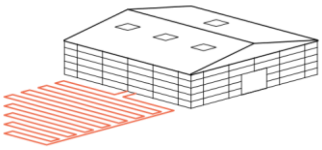
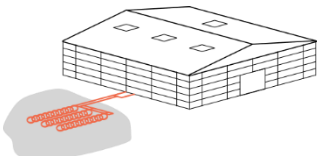


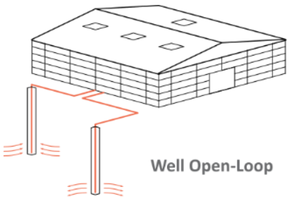
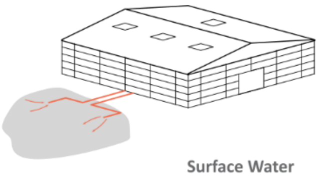
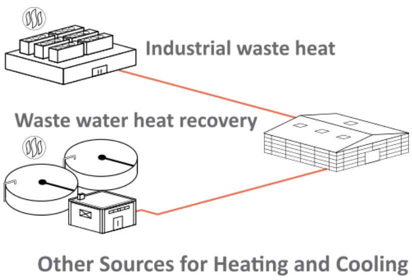
Figure 8: Example of Connection Between Various Geoheat Sources and Above Ground Applications. Source: GNS Science from EECA (2024)

6.1 Using the Ground and Groundwater for Thermal Energy

Table 3 summarises a selection of geoheat extraction technologies that use geothermal and non-geothermal water and briefly explains how they work. As a generic term, ground heat exchanger (GHX) applies to the infrastructure that is installed in the ground.

The following applies for 'direct' and 'indirect' geoheat systems, terms which are defined in detail following this table.

Table 3: Summary of GeoHeat Extraction Options		
Type	**Figure**	**Description**
Closed Loop	 Vertical Closed-Loop	Closed vertical GHXs are typically installed in wells 50 to 200 metres deep but could be deeper in certain applications. These systems use polyethylene (PE) pipe filled with a water-antifreeze (or brine) mixture that by circulating around either absorb heat from (heating) or reject heat to (cooling) the ground. A GSHP then delivers heating and/or cooling as required by the application. GHXs are highly efficient, suitable for various building sizes and types, including space-limited and different lithologies and can have high initial costs. They can be installed beneath buildings, are a form of thermal energy storage and perform best when they have a mix of heating and cooling.
	 Closed Loop Building Piles	Vertical closed-loop systems can also be installed in the existing building infrastructure and integrated into building piles. Often called energy piles, these systems are generally only able to cover some of the building's heating and cooling requirements. The performance of these systems is determined in particular by the soil moisture and whether the piles are located in the groundwater zone. The advantage of these systems is that they can be installed at relatively low additional cost if a foundation is required anyway. In addition to the building, the base plate and earth-covered side walls can also be thermally activated.
	 Horizontal Closed-Loop	A closed horizontal GHX is typically installed to a depth of 1-2 metres. Types include surface, trench and spiral collectors. They utilise the seasonal temperature fluctuations in the ground and are suitable for areas with plenty of space, such as rural residential areas. They work best in clayey, moisture-rich soils that allow for optimal heat transfer and regeneration. They can be a capital cost effective heating and cooling solution for rural residential properties that have suitable areas of land available.
	 Pond Closed-Loop	In areas with accessible bodies of water, a closed loop GHX can also be submerged and anchored to concrete supports to ensure proper positioning above the pond bottom. Installation is quicker and less costly compared to other types of closed loop GHX. Minimum water body depths of 2-3 metres are required while the water body needs to be sufficiently large (and permanent) for the heating and cooling requirements of the application. Installation can be relatively quick and easy using PE loops or purpose built plate heat exchangers.

Open Loop		Open loop groundwater systems require an aquifer of sufficient quality and capacity to sustainably supply groundwater to a heat pump, which then typically re-injects it into the aquifer. This process benefits from the stable temperatures of the groundwater (10°C to 14°C) and its high heat capacity, resulting in high COPs. Higher temperatures can be achieved in the TGS with an open loop system, as the local underground temperature can be elevated, leading to a higher heating COP. The drilling depth is determined by the aquifer and the water table. An appropriate distance between the extraction and reinjection wells is important to avoid recirculation of the heated or cooled water. A groundwater extraction permit is required in most areas and larger systems will require thermal-hydraulic modelling to ensure they operate efficiently and sustainably. In addition to quantity, groundwater quality is also important as poor quality groundwater will damage the installed infrastructure, leading to increased maintenance costs. Water analysis and specialised expertise are required for system design.
		If surface water is available, it can be used as a source via an open loop system with heat exchangers similar to those described above. Open surface water loops, usually require a secondary heat exchanger. The suitability of a surface water source depends on its availability, the source size and the sensitivity of the receiving ecosystem to temperature fluctuations and different water chemistry.
Other Sources		In addition to the sources already discussed, which can be used for heat exchange with the closed and open loop systems outlined above, other sources are available that can be integrated into the building's heating and cooling systems. These include, for example, heat recovery from industrial processes and heat recovery from waste water and sewage treatment plants. These processes contain a considerable amount of thermal energy that can be reused either directly or via heat pump systems. This requires the relevant sources to be located in the immediate vicinity of the end customer in order to reduce possible pipeline lengths. The overall goal is to find the most economical and ecologically sustainable way of utilizing thermal energy or other environmental heat.

In addition to each of the individual sources of thermal energy listed above, it is possible to develop a system that uses more than one. These are simply called hybrid systems and their ability to integrate multiple sources of thermal energy on site will typically enhance system efficiency and optimisation by taking advantage of the varying availability of different thermal energy sources during heating and cooling cycles. For example, they can utilise the ground temperature in extreme weather conditions and the ambient air on temperate days. By utilising a vertical closed loop GHX, hybrid systems achieve better thermal balancing, improving performance per unit and reducing the long-term cumulative effects of thermal load imbalances.

6.2 Direct Use

As per the terminology, direct use systems use the geoheat resource directly. For example, a nominal 50°C geoheat source could be used directly for heating applications that require temperatures of less than 50°C. This simple rule similarly applies to high temperature geoheat sources of 150°C and more.

If the geothermal waters themselves are not required (e.g. balneology / mineral baths) then a heat exchanger may be in place to physically separate the geothermal waters from the heating application. While potentially important for purposes of system maintenance (minerals in geothermal waters can cause maintenance issues), the use of this heat exchanger, combined with simple control of system flow rates, enables accurate system temperatures to be achieved. For example, a 27°C pool and a 38°C spa in a single facility could both be heated from a 50°C geoheat source simply by controlling system flow rates either side of the heat exchanger.

Table 4 summarises the advantages and disadvantages for considering a direct use geoheat system.

Table 4: Direct Use Advantages and Disadvantages

Advantages	Disadvantages
Very high system efficiencies are possible.	Limited to heating (or cooling only if a cold water source).
No requirement for heat pump.	Location specific - areas where the geoheat source temperature aligns with those required by the heating application.
Very low operating energy inputs (often just pumping costs).	The ground cannot be used for thermal storage or as a thermal battery.

Common applications for different primary industries are displayed in Figure 9. It shows what is typically feasible with different geoheat temperatures, specifically highlighting which type of industrial processes are compatible with geoheat.

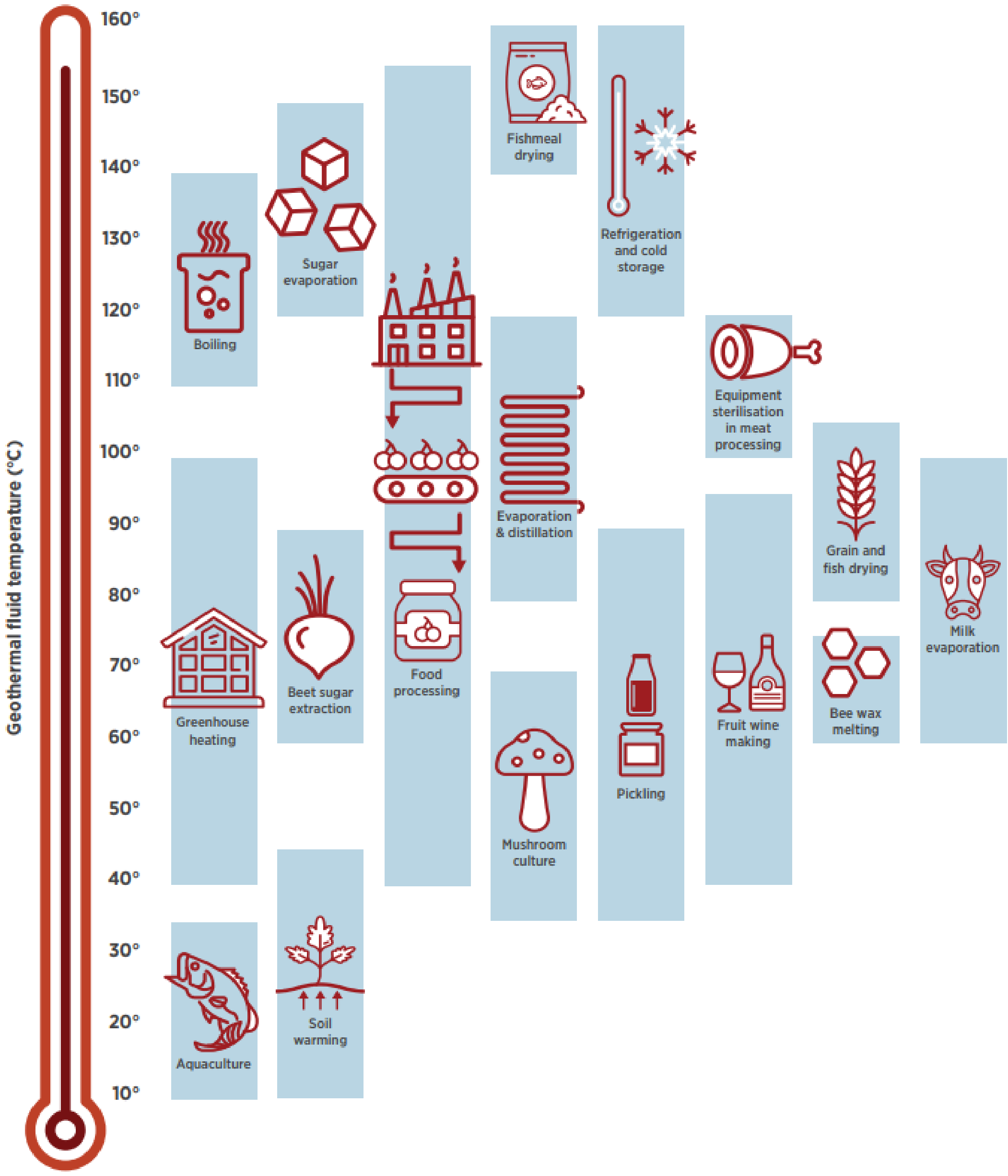


Figure 9: Potential uses of geothermal energy in the agriculture sector (IRENA, 2022)

As described in Section 3.2, the TGS is a low-temperature system[10] with temperatures <70 °C within several hundred metres below the earth's surface. Consequently, the direct utilisation potential is limited to lower temperature applications but still very useful, especially if favourable temperatures are available at relatively shallow depths.

6.2.1 Direct Use in the Tauranga Geothermal System

The process of utilising geoheat begins with the extraction of geothermal fluid from underground reservoirs. In New Zealand, wells have been drilled up to 3.5 kilometres deep into high-temperature geothermal fields. However, direct use wells in operation in the TGS are much shallower, with the deepest reaching 917m and most (~70%) being shallower than 200m.

[10] In the New Zealand context, low temperature geothermal systems are classified as <150 °C.

There are limitations for high temperature uses, such as industrial direct use applications in the TGS, due to it being a low temperature system.

However, there is still a wide range of direct use heating applications from the TGS that are suitable using the temperatures available. These include pools and spas, covered crops, commercial and residential buildings and some lower temperature industrial processes (see Figure 9). Further, industrial sites can use available heat for the parts of their operations which have lower temperature demand, in many instances, this will serve a majority of the energy use at site. In this pre-heating scenario, other energy sources will be needed for peak temperatures.

Low temperature indirect use applications that require heat pumps are an option for the region and addressed in the following.

6.3 Indirect Use

Indirect use systems use the geoheat resource as a starting point for heating and / or cooling. For example, a nominal 15°C geoheat source (groundwater) could be used by a ground source heat pump (GSHP) to heat or cool a building.

Similarly, a nominal 50°C geoheat source (geothermal water) could be used by a high temperature GSHP to produce higher temperatures, including steam, for an industrial process.[11] This example highlights the site and application specific nature of geoheat.

Table 5 summarises the advantages and disadvantages when considering an indirect use geoheat system.

Table 5: Indirect Use / Heat Pump Assisted Advantages and Disadvantages	
Advantages	**Disadvantages**
Can be applied almost anywhere.	The GSHP still requires electrical energy, although less than an air source heat pump.
The inclusion of the GSHP enables greater control over the application output temperatures.	Not as efficient as direct use systems.
Includes heating and cooling, often simultaneously.	
More efficient than air source heat pumps (ASHPs).	
More potential applications than direct use systems.	
Usually requires shallower wells than direct use systems.	

As a result of their wide ranging applicability, low temperature indirect use applications are increasingly generating interest as an alternative to conventional heating and cooling systems. Notably where fossil fuel boilers such as gas, diesel or coal are due for replacement.

[11] A high temperature GSHP was modelled for an industrial facility in the Port of Tauranga for EECA's RETA report for the Bay of Plenty. (EECA, 2024)

Given the historical prevalence of geothermal electricity and high temperature direct use in the geothermal sector in New Zealand, low-temperature applications of geoheat, now including cooling using heat pumps, are by comparison poorly understood and have not been developed to any great extent.

To better understand the potential of low temperature, indirect use systems, it is first necessary to explain in more detail how the heat pump works and what advantages it offers in combination with geothermal.

6.3.1 Heat Pumps: Ground Sourced or Air Sourced

A heat pump is a device that transfers heat from a source (such as the ground, water, air or other sources) to provide heating or cooling at a destination. It operates on the principle of the vapor-compression refrigeration cycle, which involves four main components: an evaporator, a compressor, a condenser, and an expansion valve.

In this cycle, a refrigerant absorbs heat at low pressure in the evaporator, causing it to vaporize. The vaporized refrigerant is then compressed by the compressor, which raises its temperature and pressure. This higher-pressure, higher-temperature vapor moves to the condenser, where it releases heat and condenses back into a liquid. The liquid refrigerant then passes through the expansion valve, reducing its pressure and temperature before returning to the evaporator to repeat the cycle.

This process is reversible, meaning that a heat pump can also function as an air conditioner. By reversing the direction of refrigerant flow, the evaporator and condenser switch roles, absorbing heat from the indoor environment and releasing it outside, providing cooling (see Figure 10 below).

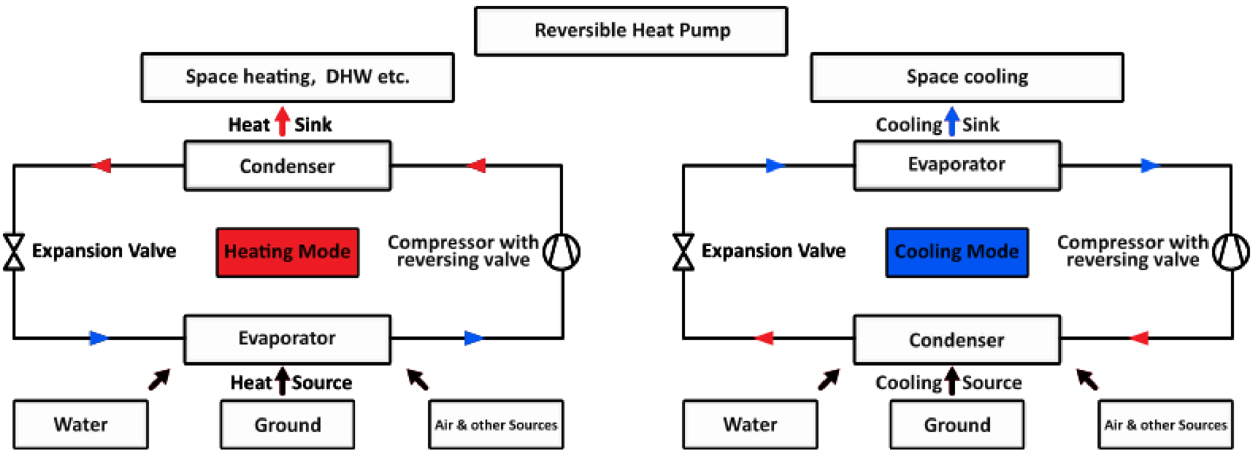


Figure 10: Typical Schematic of a Heat Pump System

Most people are familiar with ASHPs. A GSHP operates in much the same way with respect to the vapor compression refrigeration cycles described above. It just tends to do so with a higher Coefficient of Performance (COP) due to its source of thermal energy being geoheat rather than air.

Heat pump COP is defined as the quotient of the heat output and the supply of electrical energy. The electrical energy used is primarily required to operate the compressor and the circulation pumps. The amount of energy required is in turn a function of the source temperature and the sink temperature and therefore how large the difference between these two values is.

$$\text{COP} = \frac{Heat\ output\ (kW)}{Power\ input\ (kW)}$$

As a result, the higher the COP value, the more efficient the system.

In contrast to ASHPs, which are dependent on outside temperatures that can fluctuate greatly, GSHPs utilise the relatively constant, stable ground temperature that are sometimes even geothermally enhanced, as is the case in the TGS.

Table 6 has been developed to demonstrate the influence of source temperature on thermal efficiencies. It is based on a nominal 12 kW GSHP with all variables identical except the source temperature. Output temperature from the GSHP has been nominated as 45°C in heating mode and 12°C in cooling mode and a source flow of 0.5 L/s. Heat pumps lose their effectiveness as the source temperature approaches the output temperature. Hence, heating above 30°C is not shown and in this instance, a direct use application would apply. However, if heating output increases, as it would using a high temperature heat pump, then a higher source temperature is suitable.

Table 6: Impact of Source Temperature on Heat Pump Efficiency and Output

Source Temperature (°C)	Heating COP	Heating Output (kW)	Cooling COP	Cooling Output (kW)
10	4.15	13.7	9.4	17.3
15	4.6	15.2	8.0	16.7
20	5.0	16.7	6.5	16.0
25	5.15	17.7	5.7	15.2
30	5.3	18.6	4.8	14.3
35	Direct Use Zone*		4.4	13.6
40			3.9	12.9
45			3.4	12.2

*These temperatures are commonly used for direct use. However, as discussed in Section 6.3 they can be used with a high temperature GSHP to reach higher temperatures, including steam.

The main takeaway from Table 6 is the impact on system performance, in terms of both efficiency (COP) as well as the thermal output in kW, as source temperature approaches output temperature.

For the same heating requirement, COP increases from 4.15 to 5.3 (28%) and heating output from 13.7 to 18.6 kW (36%) as the source temperature increases from 10 to 30°C.

For the same cooling requirement, COP increases from 3.4 to 9.4 (176%) and cooling output from 12.2 to 17.3 kW (42%) as the source temperature decreases from 45 to 10°C.

Typically, a GSHP operates with COPs of 4 to 6, even during periods of extreme temperatures, whereas an ASHP typically has a COP of 2 to 4, that can reduce significantly during defrost cycles on cold mornings or in heatwave events. These efficiency benefits have implications for both annual energy costs and carbon emissions, as well as the capacity of connected electrical load. The latter being a significant consideration when sizing heating and cooling systems for peak loads, which is increasingly a critical issue as gas boilers are replaced by heat pumps as part of decarbonisation and electrification initiatives.

Further, compared to an ASHP, the underground component of an indirect geothermal system (the GHX) is protected from the elements, which reduces wear and tear, reducing maintenance costs and extending the life of the heat pump.

6.3.2 Indirect Use in the Tauranga Geothermal System

Due to data limitations, there are currently no known indirect use systems in the TGS. This is mainly because a GSHP that uses non-geothermal water does not require a resource consent and thus is not present in the data sources used for this report.

6.4 Cooling with Geoheat

As discussed in Section 4.1, the western Bay of Plenty has an oceanic or marine climate that requires both heating and cooling in residential and commercial buildings. Cooling (air conditioning) of spaces is already required for many months of the year and with all the discussion about 'heat', it must be made clear that cooling is also achievable from geothermal systems. In many cases, not only is it the most efficient cooling option but it can also make the total thermal energy system more efficient, thus enhancing the energy savings and the investment required.

The combination of an increased expectation of conditioned buildings and global warming requires cooling (air conditioning) in more buildings for more of the time and is recognised as a key driver of future energy planning. As such, cooling is something of a current reality that will increase in the future, and one that requires appropriate consideration in strategic planning for the western Bay of Plenty.

This section will consider cooling potential from the TGS. Geothermal cooling can be applied to buildings for air conditioning as well as for industrial / refrigeration processes (Alsagri, A.S., 2022).

In line with the discussions so far, cooling potential is as site specific as heating potential. For example, cooling using >50°C ground temperature is thermally inefficient and would not provide better efficiencies than conventional ASHPs. However, cooling from an ambient ground temperature of 15°C is very efficient and when combined with a heating system (thermal sharing) or using a closed loop GHX as a form of thermal storage, significant efficiencies are possible.

In this latter example, heat rejected from a building during air conditioning can either be used immediately, as many buildings heat and cool simultaneously, or it can be stored in the GHX and then made available hours or even months later when heating is required. This form of thermal energy conservation aligns thermal energy systems with the broader circular economy conversations that are becoming increasingly more prevalent.

In some instances, the geoheat system can be designed with separate heating and cooling wells (Figure 11). During winter, the system is in heating mode so that the ground gradually cools in the immediate vicinity of the rejection well. The rejection well is then utilised in summer so that these cooler temperatures becoming the source temperature now that the system is in cooling mode.

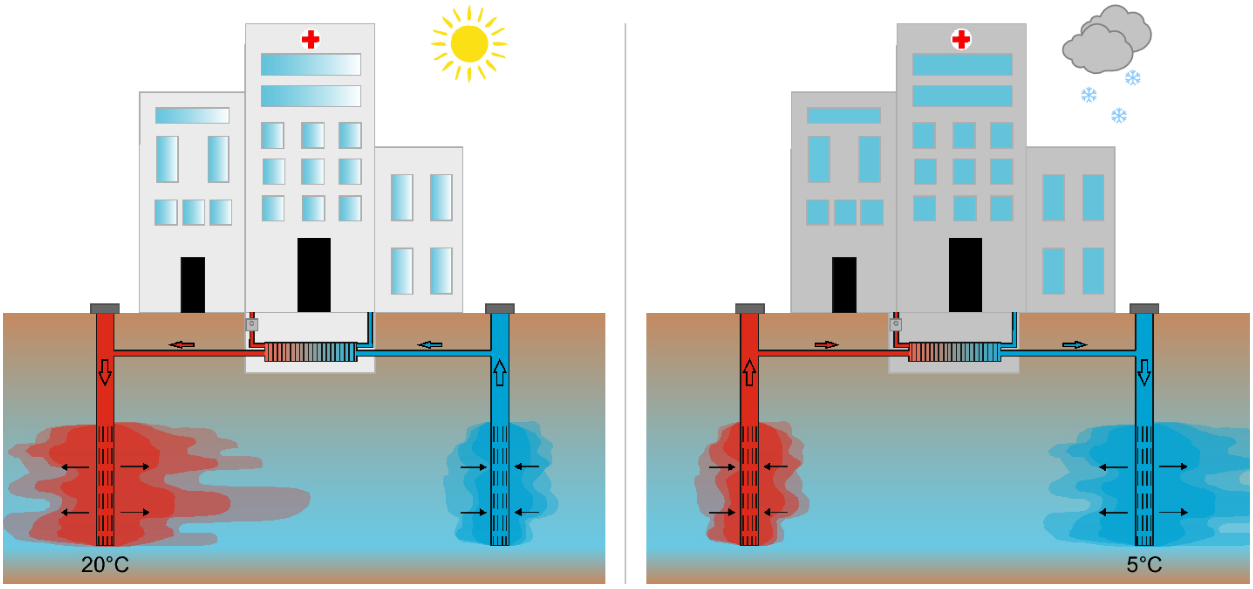


Figure 11: Schematic of a system with separate heating and cooling wells (Source: Schuppler, 2019)

In terms of the TGS, cooling will be easily and effectively applied in areas of ambient ground temperatures but may not be an opportunity in areas where ground temperatures are in excess of 45°C. 45°C has been adopted here as it is the highest data point available from Table 3. Note that even at 45°C, a cooling COP of 3.2 is still possible, which makes it at least comparative with ASHP efficiency.

As per the recurring theme in this report, suitability of any given application for a particular outcome or technology (e.g. heating, cooling, direct use, indirect use, open loop, closed loop, etc) is a function of the interplay between underlying ground conditions and the heating and cooling demands of the application. Site specific assessment is required.

6.5 District Thermal Energy Systems

Whether direct or indirect use, the descriptions provided above typically consider an individual building or application with its own individual geoheat system.

As per Section 5.2, district heating or district thermal energy systems (DTES) that include heating, cooling and hot water for multiple buildings are becoming increasingly common. Early first generation district heating systems typically used high temperature geothermal or waste heat from an industrial facility as a direct use application for heating only.

The most recent evolution are fifth generation systems with ambient temperature distribution loops between the buildings that are capable of both heating and cooling. In such systems, some buildings may heat from the distribution loop at the same time as some are cooling and thus the system conserves the thermal energy and shares it between the buildings. For example, a data centre could be rejecting heat to the distribution loop while the local public aquatic centre is heating from it.

Recent applications include education campuses (university or school), residential developments and industrial areas. These systems typically centralise or share their source of thermal energy in the form of a GHX, with GSHPs located either in individual buildings or as a central plant.

As per above, advantages of the multi-building or district approach over individual systems include diversity, heat sharing and thermal storage that reduce peak demands and enable smarter integration of renewable energy.

Diversification allows for a smaller GHX, while thermal sharing increases system efficiency by redistributing heat between zones with different demands. Load sharing occurs when excess cooling heat is redirected for heating purposes, increasing system efficiency. Thermal storage can be considered as deferred load sharing. For example, Underground Thermal Energy Storage (UTES) or sometimes referred to as Aquifer Thermal Energy Storage (ATES) is an example of thermal storage (Figure 11) as it stores heat rejected in summer in the ground prior to it being used for heating that evening or even in the following winter.

A DTES may also alleviate capital cost barriers to uptake as they can be operated as a thermal utility and thus installed and managed as an infrastructure investment.

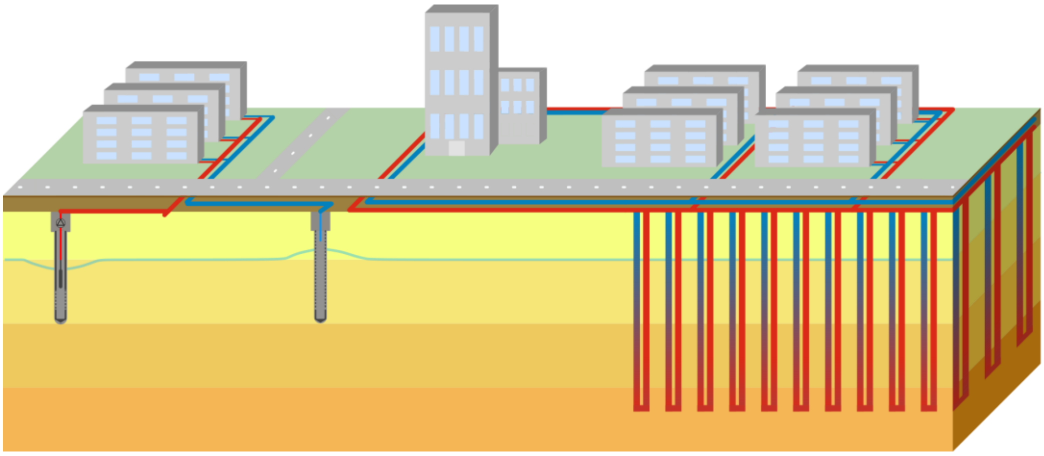


Figure 12: Schematic showing a district thermal energy system using an open groundwater loop and closed loop GHX.

6.6 Hypothetical Geoheat Decision Schematics

This section has been developed to assist with understanding the potential for a geoheat system for a given application. By providing these simplified decision schematics, it is intended to remove some of the complexity that needs to be understood before determining the best way to access geoheat. The range of variables for a preliminary analysis at a given site typically includes:

- What is the available subsurface temperature;
- What is the groundwater flowrate;
- Do different well depths provide different temperatures and flowrates; and
- What are the operational demands at site.

The information in this section is technical and to fully comprehend it is further hampered by the variables that need to be understood as to which technology is right for a specific application at a particular site.

To address the complexity of options listed above, Figure 13 and Figure 14 have been provided to summarise considerations at a high level with a hypothetical scenario involving a covered crop grower and space heating and cooling of a commercial building/residential home.

These diagrams include some 'rule of thumb' conclusions that could help in determining if it is warranted to explore the opportunity further in the form of a more detailed feasibility study. They do include a series of assumptions and design considerations such as pumping head, flow rate etc which influence the COP value presented.

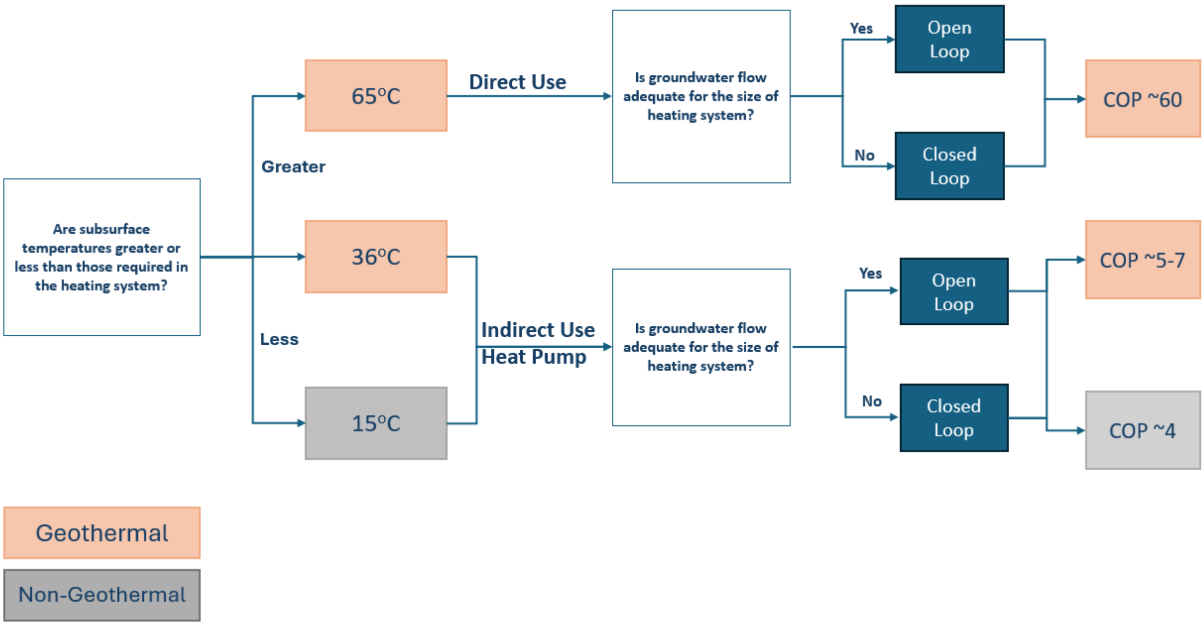


Figure 13: Example decision schematic for a tomato grower that requires 60°C water in their heating system to maintain optimal growing conditions year-round. It considers different subsurface conditions, different technology approaches and provides an estimated coefficient of performance (COP)[12].

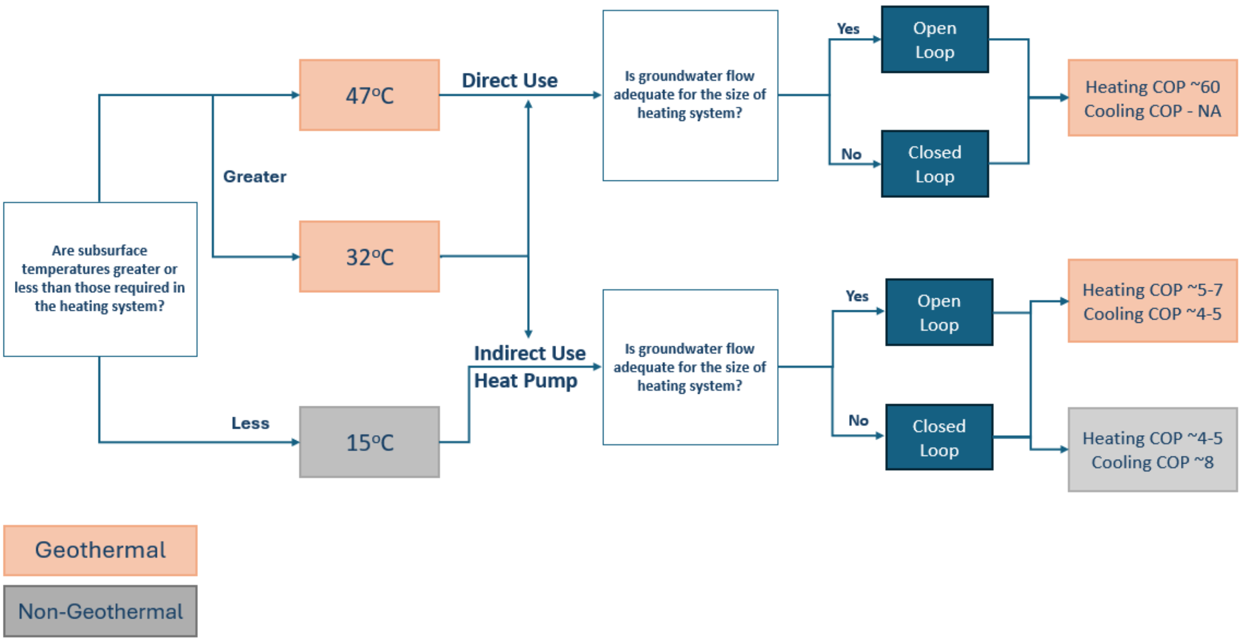


Figure 14: Example decision schematic for a commercial building / residential home requiring seasonal space heating and cooling. It considers different subsurface conditions, different technology approaches and provides an estimated COP.

[12] Coefficient of performance (COP) is a standard term used to benchmark energy efficiency; a more detailed explanation is provided in Section 6.2.2.

7. TAURANGA GEOTHERMAL SYSTEM CHARACTERISATION

The available scientific literature reviewed to characterise the TGS corresponds for the most part to the reading list of the Tauranga Geothermal System Science Summary Report (BOPRC, 2023). In addition, further literature was reviewed which was classified as relevant with regard to the intended objectives. A list of the literature analysed for the study is included in Appendix C.

7.1 Data Gap Analysis

Table 7 presents a data gap analysis that was conducted to enable a comprehensive assessment of the available data and to identify possible gaps that may assist with better characterisation or management of the TGS with respect to its sustainable geoheat potential. The data gap analysis only refers to the subsurface parameters that are considered significant for an assessment of the geothermal potential and for further exploration.

Table 7: Data Gap Analysis

Category	Subcategories	Existing Data Sources	Observations
Geological Data	Availability of geological maps and models Depth and distribution of geological formations Geological structures and faults	▪ GNS Geological map 1:250k ▪ New Zealand Aquifer Potential Map ▪ 3D Groundwater Model Tauranga ▪ Tauranga Basin Geothermal Reservoir Model	Geological maps and models appear comprehensive, yet their accuracy hinges on the quality of underlying data and may lack detail in certain locations. Although initially valuable, the available data's limited detail constrains its effectiveness and necessitates further refinement.
	Well data	▪ Well dataset BOPRC	Well data show variations in density and vertical resolution, which affects the accuracy of interpretation and modelling.
Hydrological Data	Aquifer characteristics (e.g., hydraulic conductivity, storativity, transmissivity) Groundwater Level	Summarized in the Tauranga Groundwater Model Calibration Report: ▪ Aquifer parameters, such as hydraulic conductivity and storage capacity, are derived from well data that included data from pumping tests from which the parameters were	Knowledge of the Tauranga aquifer system is based on current hydrogeological data, which is dense in the coastal areas but sparse at higher elevations. It is also based on insufficient long-term groundwater level data, limited measured groundwater withdrawals and regional recharge estimates from a single lysimeter station. These gaps and uncertainties in Tauranga's hydrogeological data require cautious

	Groundwater recharge	derived and include geological assumptions.	interpretation and emphasize the need for improved data collection.
Geothermal Data	Temperature gradients and distributions	Data are based on studies by White et al. (2009) and Simpson (1987), who analysed the thermal properties in the Tauranga region extensively. Simpson (1987) measured the thermal conductivity and temperatures in the wells, as well as performing heat flow calculations. White et al. (2009) created temperature profiles and modelled temperature data.	Despite earlier studies in which various reservoir parameters were recorded, the data density is still limited. Additional measurements, in particular temperature measurements in further wells and the systematic recording of thermal conductivity and permeability measurements on the interacting lithologies, combined with further geophysical investigations, is necessary.
	Geothermal reservoir properties		
	Heat flow measurements		

Upon thorough analysis of the available literature, data and documents, it is evident that further investigation is needed to build understanding of the geoheat potential of the TGS. Improvement of data quality is essential to predict subsurface temperatures, heat flow and the distribution of potential geothermal reservoirs for both system design as well as management and is further addressed in Section 9.4.

7.2 Differentiating Direct and Indirect Use Potential

With regard to the assessment of the direct heat potential in the TGS, the focus of the analysis was on the temperature values obtained from the available drilling data. It is important to note in advance that the interpolated temperature data was derived from a compilation of existing data sets. For the purposes of this report, it has been assumed to be reliable and has not been independently verified. In addition, due to the sparse distribution of local data, some interpolations had to be made over large distances.

To estimate the potential for direct use applications, a temperature threshold of 30 °C was adopted to align with the RMA definition of geothermal waters. This RMA definition aligns relatively well from an application perspective as there are limited heating applications below this temperature and as such it is not commonly used for direct use geoheat applications. Ambient groundwater temperatures (i.e. those at naturally occurring temperatures as a result of solar radiation and with no geothermal influence) are indicated as being 15°C.

To visually differentiate between areas of direct and indirect use potential, two maps have been developed. The first map (Figure 15) shows the temperature distribution in the subsurface at a reference depth of 150 metres below sea level (b.s.l). The reference depth of 150 m b.s.l was chosen because the highest population density is found near the coast, where the ground elevation is relatively shallow between 1-20 m above sea level. In terms of drilling depth, 150 metres also corresponds to the average depth of wells within the TGS and is also a common depth for closed loop GSHP systems. It should be noted that the drilling depth at which the specified temperatures can potentially be obtained corresponds to the local elevation.

It indicates that the probability of encountering geothermal water above 30°C (yellow to red) at a depth of 150 m b.s.l is most likely in and around the Tauranga City area and harbour, and to the south-east in the Maketū area.

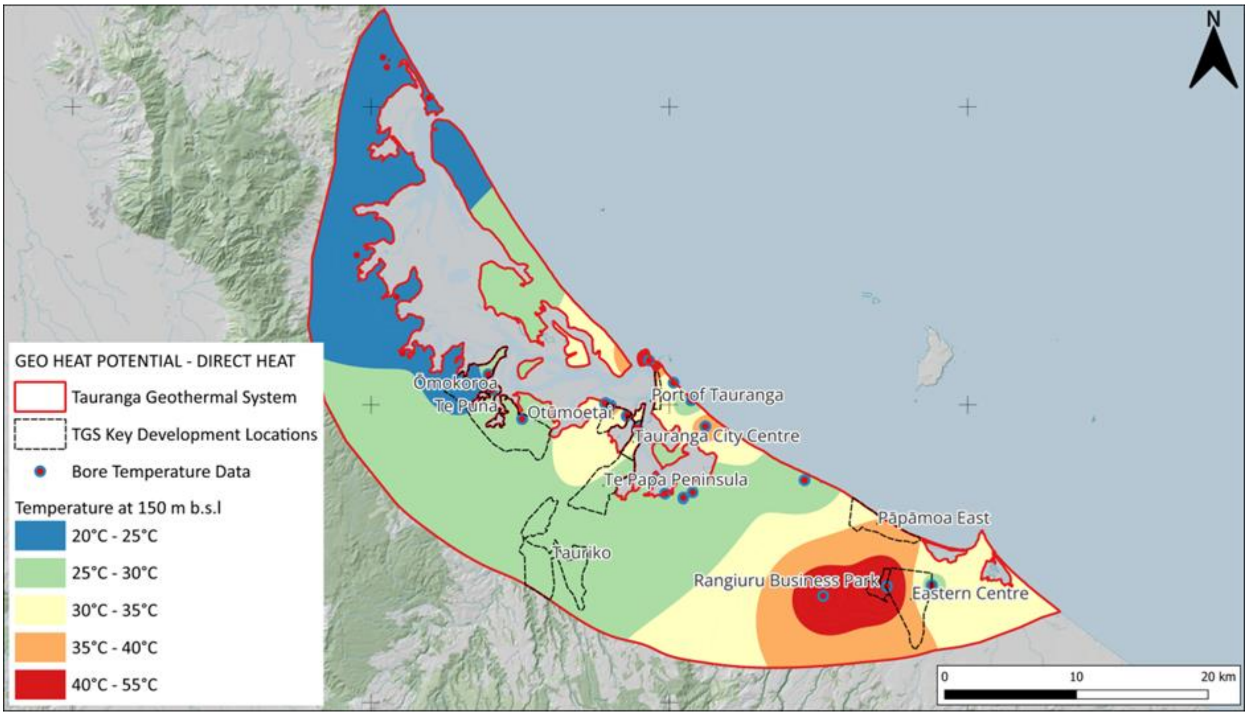


Figure 15: Interpolated temperature at 150 m b.s.l across the TGS.

Figure 16 presents the interpolated depth to metres below sea level at which a temperature of 30°C can be expected. It provides an estimate of the depth required for a well to have a higher probability of encountering this temperature. However, this depends on the local terrain elevation.

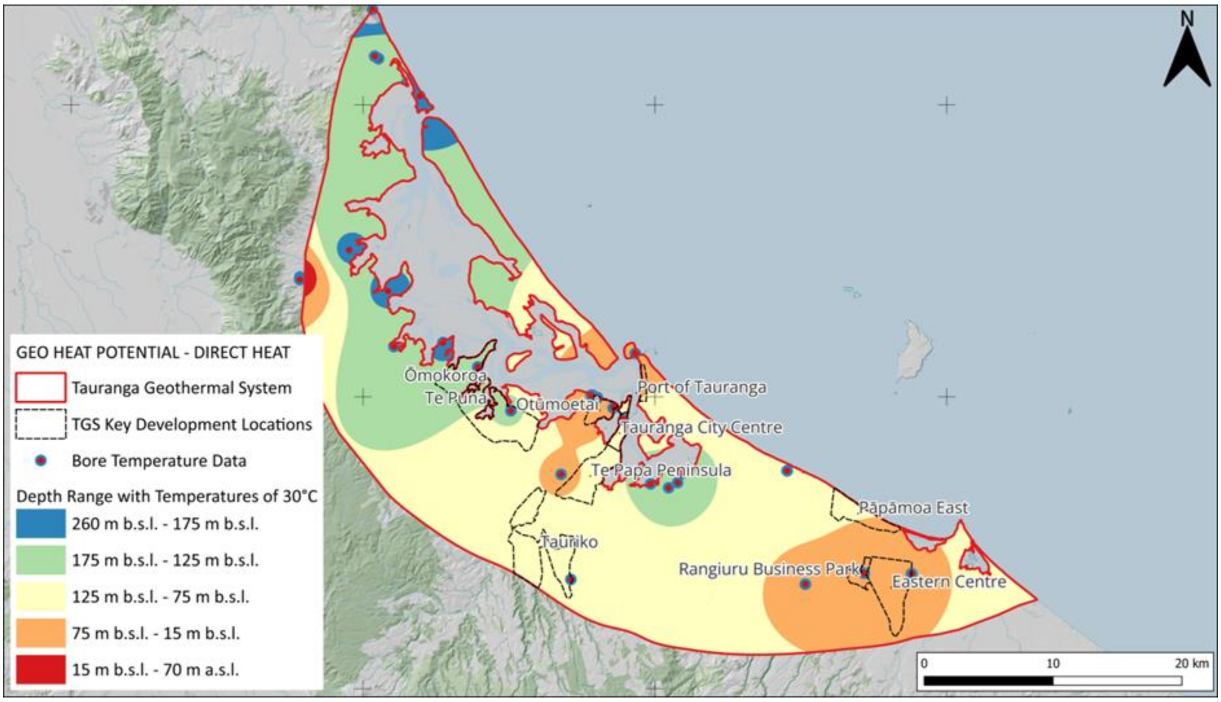


Figure 16: Depth distribution of temperatures greater than 30°C as a proxy of direct use potential.

It is important to emphasise that these interpolations are not a guarantee that the target temperature will be within the specified range at a given location and additional data may be available to inform more detailed site specific assessments. Further to this, the maps should also not be interpreted to mean that there is no potential in the areas labelled as less favourable. Rather, they indicate that deeper drilling may be required in these areas to encounter geothermal resources with temperatures above 30°C as per Figure 16. By understanding these maps and their limitations, stakeholders can better plan their geoheat prospecting and development efforts, ensuring a more efficient use of resources while maximising the likelihood of achieving the desired thermal results.

Figures 15 and 16 indicate that elevated subsurface temperatures are mostly present in the areas below Tauranga Harbour and in the Maketū area to the southeast, confirming the findings from the literature. Consequently, these areas are the most promising for the further development of direct use geoheat systems.

The drilling data also indicates that even higher temperatures can be encountered at relatively shallow depths, which increases the potential of direct geoheat utilisation in these locations.

Due to insufficient data, an interpolated spatial map of 50°C temperatures was not created. Rather, the areas in which wells have recorded a temperature higher than 50°C and the depth have been shown on Figure 17. The limited data means that further investigation is required for a more in-depth analysis to prepare the 50°C temperature map.

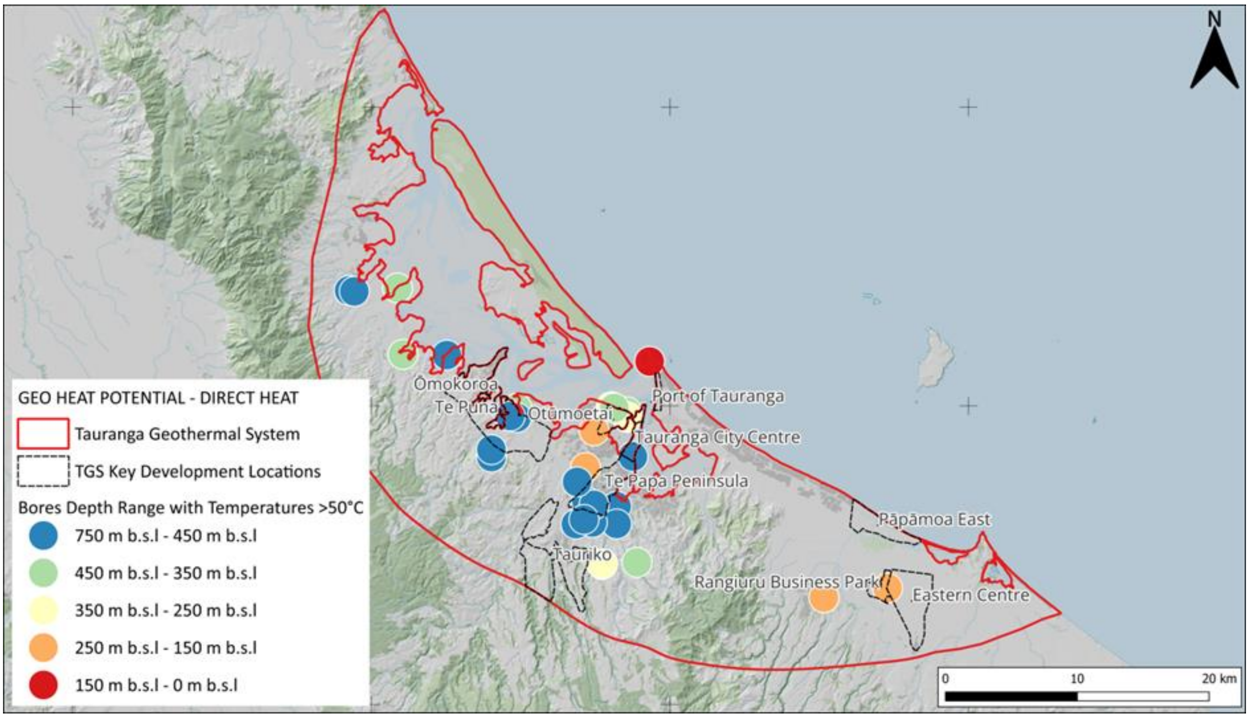


Figure 17: Distribution of wells and depth with temperatures greater than 50°C.

To assist with understanding geoheat potential of future development areas, a selection of zoomed in maps have been generated as Figures 18 and 19.

Table 8 has been developed to summarise the ground temperatures encountered at each potential development zone/ growth areas as identified in SmartGrowth (2024). Of note, the Port of Tauranga encounters higher temperatures at shallow depths which potentially aligns with industrial heating requirements in the industrial area. Rangiuru Business Park similarly encounters 30°C temperatures at a depth of less than 75 m b.s.l but does not encounter 50°C until a depth of 350m.

The mixed use developments of the Tauranga City Centre and Te Papa Peninsula do not encounter 30°C temperatures until beyond a depth of 150m and approaching 250m. A similar temperature profile occurs for residential developments at Tauriko, Ōmokoroa and Te Puna. The presence of lower temperatures for these areas potentially aligns with the mixed heating and cooling requirements that would be expected for these developments and thus the potential for indirect use systems using heat pumps.

Table 8: Depth Range of Ground Temperatures Underlying the Potential Development Zones			
Potential Development Zone	**Land Use Zoning**	**Depth Range Encountered**	
		30°C	**50°C**
Port of Tauranga	Industrial	<125 m b.s.l	<500 m b.s.l
City Centre	Mixed Use: Residential / Commercial	<125 m b.s.l	<500 m b.s.l
Te Papa Peninsula	Mixed Use: Residential / Commercial	<125 m b.s.l	<600 m b.s.l
Tauriko	Residential	<125 m b.s.l	<700 m b.s.l
	Industrial		
Rangiuru Business Park	Industrial	<75 m b.s.l	<200 m b.s.l
Eastern Centre	Residential	<75 m b.s.l	<200 m b.s.l
Ōmokoroa / Te Puna	Residential	<175 m b.s.l	<500 m b.s.l
	Industrial		
Otūmoetai	Residential	<75 m b.s.l	<450 m b.s.l
Pāpāmoa East	Residential	<125 m b.s.l	>150 m b.s.l
Note: Anticipated average depth range in which the temperature value was measured within the potential development zone.			

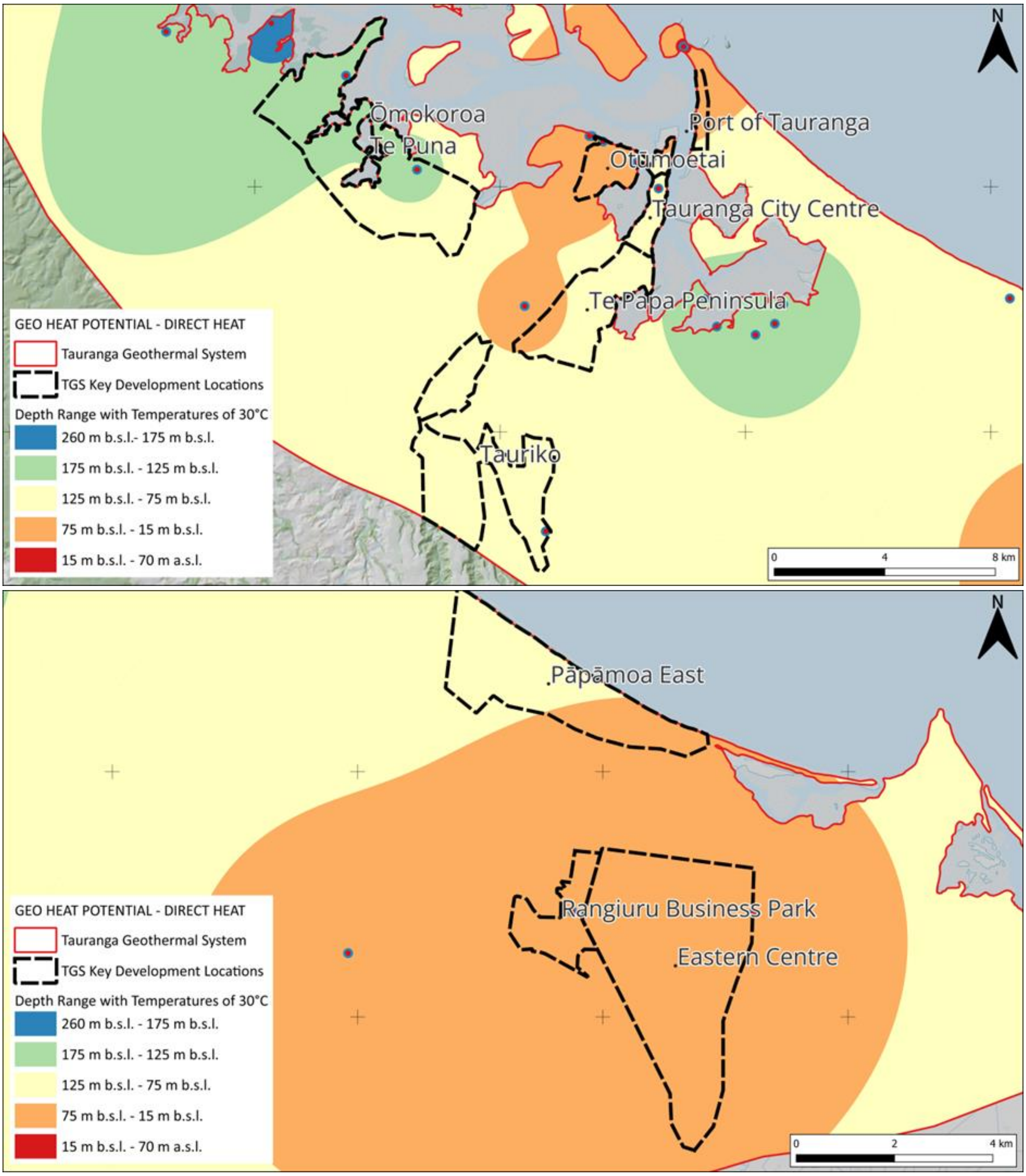


Figure 18: Presence of 30°C temperature at depth for potential development zones.

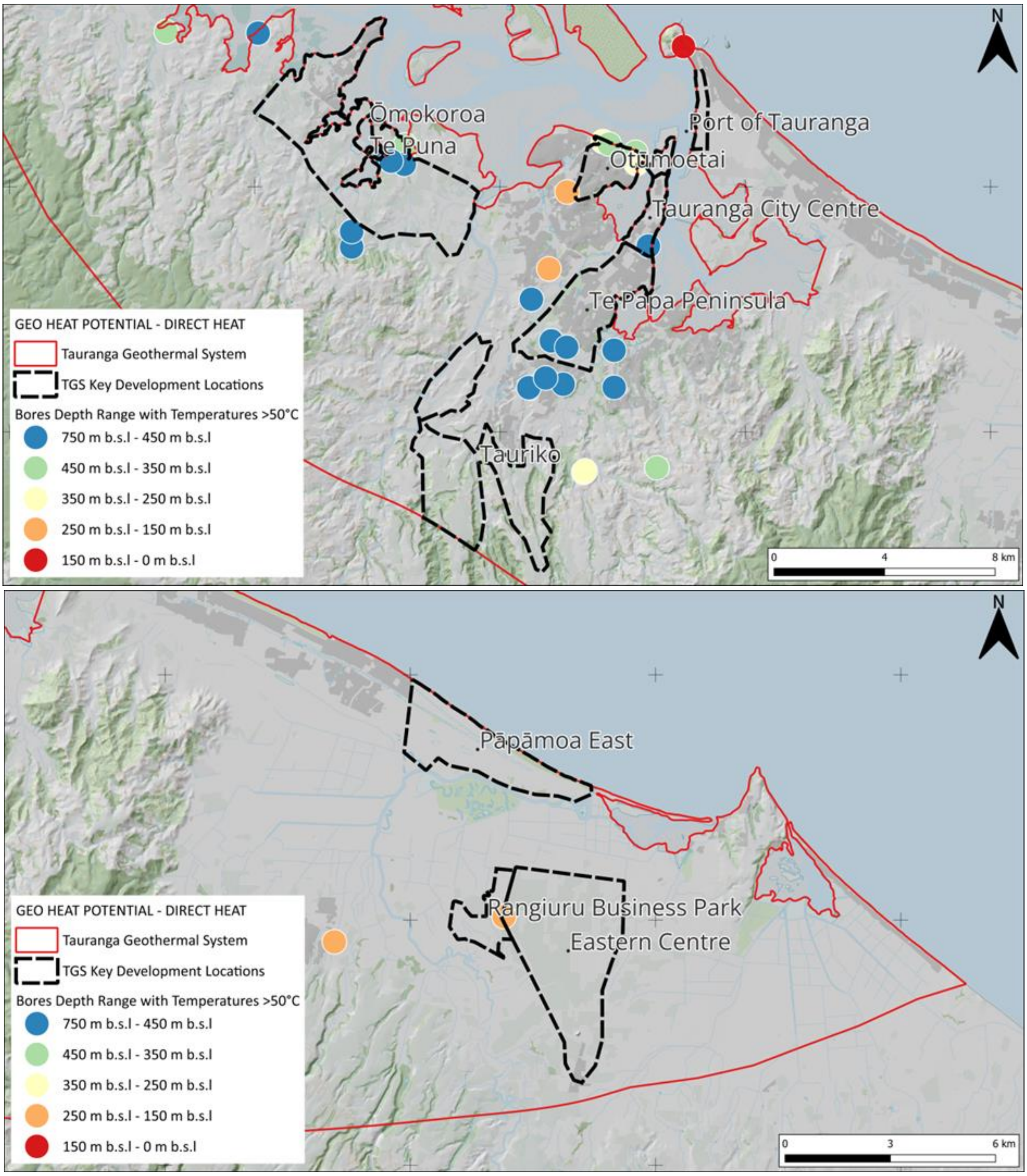


Figure 19: Presence of wells with temperatures greater than 50°C temperature at depth for potential development zones.

Due to a limited dataset, the data presented here is based on point data rather than the interpolation presented previously. Boreholes have shown that this method does not always adequately reflect the subsurface temperature distribution. Consequently, the temperatures in the indicated areas could potentially be achieved based on available evidence. With the availability of further data in the future, understanding can be expanded. However, this will not replace a site-specific investigation.

Having identified the presence of geoheat, how it is accessed and its potential realised, whether as a closed or open loop, is discussed in the following Sections.

7.3 Realising the Geoheat Potential

This section enhances the existing geothermal data with additional considerations on GHX requirements, providing information essential for understanding technologies that can harness the geoheat potential of a given location. An additional series of maps are presented below and they consider direct use, indirect use, open loop and closed loop systems as outlined in Section 6.

The maps make a distinction between favourable and less favourable areas based on chosen criteria, classification methods and assessment. In the following sections, the maps produced are presented, the data sets used in their creation and the factors considered in their development are explained in more detail.

The high degree of uniformity apparent in some maps is due to a relative degree of homogeneity of geological fabric and the single aquifer nature of the TGS. It is therefore a unique and favourable feature of the region with respect to geoheat potential. In most instances, reproducing this map outside the TGS with different settings and regulatory and structural features would result in a more diverse depiction.

Additional detail was added to the maps where appropriate, particularly in areas with restrictions that may impact potential resource management or have implications for geothermal resource utilisation. It is essential to recognise that local potential for specific geoheat applications is not solely determined by spatial conditions but also by local circumstances, requirements, heating and cooling loads, etc.

Hence, any proposed project must be evaluated on its individual merits. Careful planning and system design are crucial to ensure sustainable management of the geothermal resource and the longevity of system plant and equipment and thus the application itself. Improper design, as with any system, can lead to a shortened lifespan.

7.3.1 Closed Loop Potential

A closed loop GHX can be installed as either a direct or indirect application. However, they are most commonly installed as an indirect application with a GSHP that can provide heating and cooling.

They offer opportunities for adaptable, space efficient and seasonally stable heating and cooling solutions as they can be drilled to different depths depending on the specific site requirements. Installation and planning must be carried out by qualified professionals to ensure that the design is optimised for the thermal load to enable efficient and sustainable system operation.

Knowledge of the subsurface parameters, particularly thermal conductivity, is crucial. Although closed loop systems generally have a lower efficiency and higher investment costs than open loop systems, they are characterised by lower maintenance costs and a service life of more than 50 years. In addition, the thermal influence on the surroundings is typically significantly lower, which reduces potential conflicts in the management of the geothermal resource. Additional advantages of a closed loop vertical GHXs are that the subsurface can be used as a thermal storage medium that can be seasonally charged and discharged with heat / cold, especially in impermeable subsurface conditions. Therefore, closed loop systems in the TGS offer potential especially where an open loop system is not feasible due to subsurface conditions.

The assessment of the potential for closed loop GHXs was based on the geological conditions within the TGS and an evaluation of whether there are areas that constitute challenges for the installation of vertical wells. Compared to an open loop GHX, a vertical closed loop GHX is significantly less dependent on the geological conditions in the subsurface, as they do not rely on the availability of an aquifer. Therefore, these systems can be installed anywhere where the subsurface conditions allow.

Potential impediments to a vertical closed loop GHX are summarised in Table 9.

Table 9: Impediments to a Closed Loop Ground Heat Exchanger		
Potential Impediment	**Description**	**Assessment**
Sulfate bearing rocks	Different geological layers can be hydraulically connected, which can cause sulfide-bearing rock such as anhydrite to expand when it comes into contact with water. This expansion can lead to ground uplift, which can be felt on the surface and cause damage to buildings and infrastructure.	Not present
Water protection zones	Water protection zones may exist where critical water supplies for drinking or environmental protection are present.	Not present[13]
Artesian groundwater conditions	Pressurised groundwater aquifers that rise to the surface when drilled into. A drilling and management risk that could increase drilling costs.	Artesian conditions have been observed at various locations and depths within the TGS but without a clear trend. Therefore, they must be assessed more closely and appropriate precautions taken for each individual project.
Heritage or cultural significance	Areas to avoid due to heritage or cultural considerations. May or may not be legislated.	The cultural significance springs can only be determined by tāngata whenua. A spring at Maketū in the south east is a known culturally significant spring for Te Arawa iwi.

As per Figure 20, the implementation of closed loop GHXs within the TGS is not characterised by any perceptible restrictions. The entire TGS region can be considered favourable for their use. However, it is important to recognise that while a location may be favourable overall, the feasibility of individual projects will depend on factors such as heating and cooling demand and available installation space. These project specific considerations need to be carefully assessed.

[13] Under development.

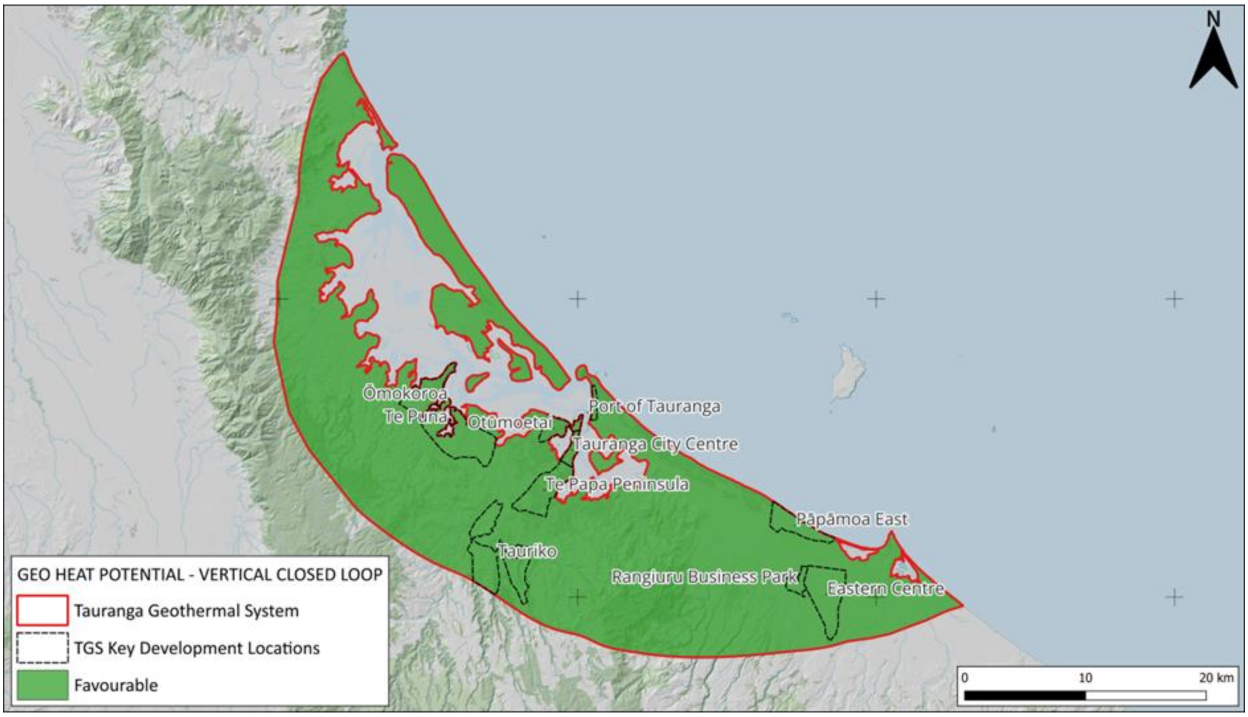


Figure 20: Potential areas for closed loop geoheat systems.

7.3.2 Open Loop Potential

An open loop GHX can be installed as both a direct use and indirect use application depending on the available temperature. They are typically more efficient and more readily scalable than closed loop systems and as such the investment required can be lower depending on the depths involved. Typically, the source temperature of groundwater is relatively stable throughout the year, leading to higher efficiency in heat exchange processes. Although operating and maintenance costs are higher compared to closed GHX systems, this can be offset by the higher efficiency.

Moreover, flexible water sources can be utilised, such as rivers, treated wastewater, and process water. However, it should be noted that open loop GHX systems are dependent on sufficiently good conditions of quantity and quality of groundwater, making them not universally applicable. The aquifer system, according to initial estimates, has a good distribution across its areal extent. In addition, this aquifer benefits from the high geothermal gradient of the TGS.

For the evaluation of the potential for open loop geothermal systems, various sources were used to assess the geological conditions within the TGS and policy regarding allocation was broadly evaluated. Unlike closed loop systems, open loop systems rely on sufficient groundwater conditions and require an aquifer that can provide water of sufficient quality and, most importantly, quantity for the geothermal heat exchange process.

Within the TGS, there are numerous geological formations that could be considered as a target for groundwater extraction. However, a precise assessment is only possible to a limited extent by analysing map material alone. The actual potential of a site can only be properly determined by drilling test wells and a subsequent aquifer investigation.

The New Zealand Aquifer Potential Map demonstrates a preliminary assessment of aquifer potential, based on the data described in Tschritter et al. (2017). It is important to recognise the inherent limitations and uncertainties of the data, with some boundaries remaining unchanged since 2001. Therefore, the accuracy of the maps may vary depending on specific conditions.

This map categorizes the potential of the aquifer in New Zealand into classes such as “poor”, “low”, “medium” and “high”. For creating the open loop map, the “poor” and “low” classes were combined into the “less favourable” category, while the “medium” and “high” classes were combined into the “favourable” category. It is important to note that even in areas classified as “less favourable”, underground conditions may be encountered that are suitable for the installation of open loop systems. As mentioned earlier and regularly repeated through the report, each site must be evaluated individually based on its potential.

The potential constraints mentioned for the closed loop system, which arise from the presence of sulfate-bearing rocks, artesian conditions and water protection zones, equally apply.

Additionally, the potential of open loop systems is also subject to the physical availability of sufficient groundwater flows as well as available allocation in accordance with the BOPRC policy for each groundwater allocation management unit. These units delineate areas which may include allocation limits for consumptive use of water.

Figure 21 includes a consideration of allocation limits as an additional layer in the potential map. The groundwater management units indicate the permissible quantity of groundwater that may be sustainably abstracted in a given area. However, groundwater allocation limits only affect the creation of an open loop to the extent that it may require the re-injection of water after heat extraction (i.e. the take and reinjection of water is likely to be considered a non-consumptive or zero net take). As is discussed in Section 9.1, this is a process that should be carried out from the perspective of the best practise management of the groundwater resource. Consequently, while existing or future allocation limits do not directly restrict geoheat potential, they may influence the type of geoheat system adopted.

In comparison to the closed loop map in Figure 20, the open loop map below (Figure 21) has a smaller favourable area due to areas where groundwater flows could be limited, either as a result of groundwater allocation limits or the underlying geology. However, as with the closed loop systems, there is significantly more favourable areas (green) than less favourable (yellow), again reflecting the unique conditions of the TGS.

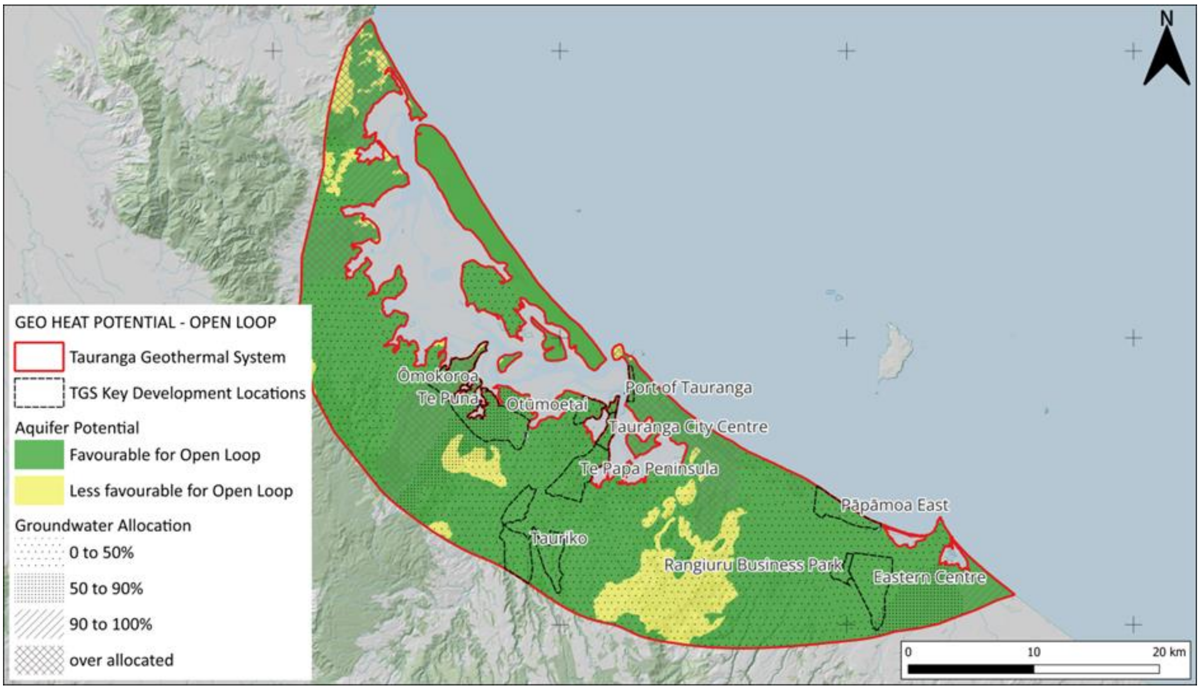


Figure 21: Potential areas for open loop geoheat systems.

The BOPRC is currently refining allocation limits through a plan change process. It is important to note that in areas where groundwater resources are limited, either presently or projected to be in the future, new net water takes will be carefully managed. This precautionary approach is aimed at preventing further depletion and ensuring the long-term viability of the region's groundwater supplies.

The method of discharge is also an important consideration for open loop systems. In some cases discharge may be to source, but not in all cases. Also, the quality and temperature of discharges needs to be considered in sensitive environments. Excessive cooling or heating of a source would be considered an adverse effect, especially in sensitive receiving water bodies like the coastal environment.

Council is also working to develop surface water risk management areas, within which risks to a drinking water supply intake from contaminant sources are managed. this could include risks from drilling activities.

At the time of writing this report, new allocation limits and surface water risk management areas were still under development, and this material will be updated when they are confirmed.

8. STRATEGIC RELEVANCE OF GEOHEAT FOR THE WESTERN BAY OF PLENTY

According to Transpower and PowerCo (2023), by 2030, the capacity of their electricity networks in the western Bay of Plenty will no longer be sufficient to meet growing demand. Decisions about investment are needed now as sustainable and reliable energy is fundamental to the strategic growth of Tauranga City and the western Bay of Plenty. This section outlines how geoheat aligns with important strategic goals for the region and could, in fact, be key to unlocking regional prosperity and resilience.

8.1 Tāngata Whenua Interests in Geoheat

As the Tauranga City Council's Long-term Plan 2024-2034 states "the future is exciting for Tauranga City and Tāngata Whenua, the key to achieving positive cultural and environmental outcomes is the ability to work productively together and participation lies at the heart of this" (TCC, 2024).

Tāngata whenua interests in the ownership and management of geothermal resources under Te Tiriti o Waitangi are multifaceted and complex, and beyond the scope of this report to address. However, in summary, current legislation makes clear the requirement for councils to engage with tāngata whenua when carrying out their functions, and for the sustainable management of natural and physical resources, while recognising and providing for the relationship of tāngata whenua with their taonga. The relationship of tāngata whenua with geothermal resources are described in Treaty claims relating to geothermal water and is outlined in many iwi and hapū management plans.

For tāngata whenua, environmental health, and social, cultural and economic wellbeing are all intimately linked. A key consideration is Te Taiao: that the health and wellbeing of our natural environment is not compromised further as a result of land use and development (SmartGrowth, 2024). So sustainable management is key. This is especially the case in areas where tāngata whenua have traditionally used geothermal or geothermally influenced springs, such as at Maketū.

The intention of this report is to communicate strategic opportunities geoheat can create for the region, including for iwi and hapu, any eventual development based on these recommendations will need thorough design and investigation to assess sustainable and appropriate use of the resource. This is especially relevant if developments are scaled across the region. Ensuring protection of Te Taiao is also a goal of this report, only technologies and techniques understood to be compatible with the environmental parameters of the TGS are suggested, and it is recommended that further research and case studies will build our understanding of what the resource can sustain. This report – and future related work – can educate and assist all parties involved in design and consenting processes, including iwi and hapu.

Geoheat is strategically relevant for Māori development, including the development of Māori land. For example, papakāinga (housing on Māori land) in the region is supported in the Tauranga City Council's Long-term Plan and SmartGrowth. Papakāinga would include homes, communal areas and in some cases co-location of hauora (health), employment and/or education facilities on multiple owned Māori land (TCC, 2024). The co-location of community facilities alongside homes is an excellent opportunity for district geoheat schemes, delivering affordable and sustainable heating and cooling with positive community outcomes. Overseas, district schemes are often owned by the community, and thus, for the community, this ownership model and its outcomes is compatible with the aspirations of papakāinga.

Te Keteparaha Mo Nga Papakāinga Māori Housing Toolkit[14] is a step-by-step guide designed to help Māori develop papakāinga proposals (development plans) on multiple owned Māori land. Tauranga City Council is part of a joint agency group that supports Māori land trusts to develop their proposals through the use of the toolkit (TCC, 2024). Future versions of this toolkit could include advice and guidance on considering geoheat for a papakāinga development and include guidance for a geothermal consent application.

8.2 Regional Economic Growth

The western Bay of Plenty is one of the fastest growing areas of the country, a further 43,000 homes are required to accommodate the 290,000 people who will live there by 2054. The challenges of this rapid growth are addressed by SmartGrowth. The SmartGrowth strategy provides a 50-year direction for housing, employment, and people's wellbeing in the face of rapid and sustained long term growth, while safeguarding what people value most about the region. It provides a framework to manage growth in an integrated and collaborative way in order to address complex planning issues, especially matters that cross over council boundaries (SmartGrowth, 2024).

Central government has an urban growth partnership with Tauranga – Western Bay of Plenty and in 2020 the Crown joined the region's existing and longstanding SmartGrowth partnership. The 'Urban Growth Agenda'[15] has three main national objectives: affordable housing, emissions reduction and liveable and resilient cities (Ministry of Housing and Urban Development, 2024). The following outlines how available geoheat in the region supports these objectives:

- **Affordable housing:** Homes connected to geoheat have low operating costs year-round. Modelling for a new housing development in Taupō (GXA, 2023) indicated that a geoheat system would provide 30-40% lower costs than an equivalent ASHP system. Geoheat systems can supply hot water, heating and even cooling. On balance, they deliver a higher standard of living that is more affordable than alternatives;
- **Emissions reduction:** Heat used in manufacturing and in the processing of primary products currently makes up around 25% of New Zealand's energy related emissions (EECA, 2024), these operators must move away from fossil fuel use and switch to renewable energy. Geoheat is an attractive decarbonisation option for existing industry in the western Bay of Plenty, as outlined in EECA's 2024 Regional Energy Transition Accelerator (RETA) report for the Bay of Plenty. Furthermore, available clean heat (used directly or heat pump assisted) could attract industry to the region, thus concurrently achieving national emissions reductions and regional development goals. With a favourable climate, connected transit routes to other markets, and a thriving port, the availability of clean heat makes the western Bay of Plenty an attractive sustainable industry hub; and
- **Liveable and resilient cities:** Central to SmartGrowth is the Connected Centres programme, this will require redevelopment and intensification of some existing neighbourhoods as well as greenfield development. The Connected Centres philosophy is to create liveable hubs with housing intensification that is integrated with community facilities that are within a 15 minute walk or cycle for most. The liveable hubs are ideal for district schemes connected to geoheat due to the close proximity of buildings and the economies of scale achieved from connecting multiple dwellings to well infrastructure. In comparison to multiple individual systems, district schemes are desirable from a resource management perspective (see Section 6.5), thus enhancing resource resilience with best practice management of the geothermal resource.

[14] https://www.westernbay.govt.nz/council/working-with-maori/te-keteparaha-mo-nga-papakainga
[15] Ministry of Housing and Urban Development https://www.hud.govt.nz/our-work/urban-growth-agenda

SmartGrowth (2024) lists cultural, environmental, economic and social objectives as being critical to the delivery of the long-term vision for the western Bay of Plenty. Those most aligned to sustainably using geoheat – as identified in this report – for regional development are:

- Encourage sustainable development and adaptive planning;
- Respond and adapt to climate change through building resilience, support the transition to lower carbon and improving biodiversity;
- Achieve an integrated approach and accommodate growth within the limits set through Ngā Wai ki Mauao me Maketu which:
    - Recognises the importance of the waters (coastal and freshwater bodies) that flow to Mauao and Maketu and the significance of these two places to tāngata whenua;
- Enable and support sufficient housing supply in existing and new urban areas to meet current and future needs, this includes a range of housing types, tenures and price points;
- Enable and support social infrastructure that is accessible and meets the needs of our community – where they can connect, socialise, learn and participate in a wide range of social, cultural, art, sporting and recreational activities, as well as broader support for community wellbeing;
- Support tāngata whenua values and aspirations, in particular papakāinga development on Māori land;
- Enable a sufficient supply of business land, support access to employment and foster a high-value, low carbon circular economy as the western Bay of Plenty grows;
- Ensure long-lasting economic, social, environmental and cultural benefits and value for money from the agreed strategy; and
- Enable and support the continued establishment, operation and maintenance of existing industrial activities that contribute to the regional and national economy, provided the health and wellbeing of people and the environment are safeguarded.

8.2.1 Potential Development Zones / Growth Areas

As introduced in Section 1.1.2, SmartGrowth identifies key growth areas within its Connected Centres programme. They include new residential and industrial corridors as well as existing neighbourhoods with planned intensification.

In Section 10, we identify how utilising the available low temperature geoheat aligns with SmartGrowth's strategic vision for Tauranga City and the western Bay of Plenty region. These locations are also identified on maps generated for this report in Section 7.

- Port of Tauranga
- Tauranga City Centre
- Te Papa Peninsula
- Tauriko
- Rangiuru Business Park
- Eastern Centre
- Ōmokoroa / Te Puna
- Otūmoetai
- Pāpāmoa East

8.3 Resilience and Stability of Energy Supply

Rapid growth in Tauranga City has put pressure on critical infrastructure. The electrical load in the western Bay of Plenty has approximately tripled over the last 25 years and is one of the highest load growth areas in New Zealand (SmartGrowth, 2024). Additional electrical demand is expected and thus a requirement for significant planning and investment in grid expansion, which is being driven by further population growth as well as decarbonisation/electrification of buildings, transport and industry.

Utilising geoheat in future developments has the potential to increase the resilience of the electrical grid by reducing peak demand and potentially reducing the required investment in supply infrastructure. A 2023 report funded by the US Department of Energy calculated that mass deployment of geothermal heat pumps for building heating and cooling electrification in the US would reduce national transmission expansion requirements by 33-38% (Liu, et al. 2023).

Electricity transmission and distribution companies will play a major role in enabling the reduction of GHG emissions and increasing energy resilience in the region. Arguably it is within their interests that geoheat is adopted as the western Bay of Plenty grows due to its potential to reduce electrical demand, particularly peak demand and adoption would assist to minimise over investment in grid infrastructure. Targeted investments in geoheat could be central to electricity supply and distribution companies’ strategic growth plans, alongside investment in other renewable energy sources like solar and regional battery solutions.

9. THE REGULATORY FRAMEWORK AND RESOURCE MANAGEMENT

9.1 Geothermal Resource Management History in New Zealand

New Zealand's geothermal systems are currently managed under the Resource Management Act of 1991 (RMA), which has the overall purpose of sustainable management of natural and physical resources.

The importance of robust geothermal management became most evident in the 1970s when resource failures in Rotorua, caused by uncontrolled extraction, highlighted the need for careful oversight. Culturally significant geysers like Waikite and Papakura stopped erupting, prompting a protection and recovery plan in the 1980s. Practices in other geothermal systems, such as Wairakei and Ohaaki also resulted in the loss of features, and in some cases unsustainable use of the energy resource. More careful management under the RMA, and industry best practice, has resulted in greater consideration of environmental impacts of geothermal use.

All geothermal systems are distinctly unique and have different management requirements. The regional council's policy framework provides overall direction about the sustainable management of geothermal systems within a regional context. This report aims to balance sustainable management of the TGS with opportunities for best practice geoheat extraction.

9.2 Regulatory Framework

9.2.1 Regional Policy Statement

Under the RMA, Bay of Plenty Regional Council has the responsibility of regulating the taking and use of geothermal water, heat and energy, and the discharges of geothermal water and geothermal discharges to air.

The Bay of Plenty Regional Policy Statement (RPS) provides the overall policy framework for management of geothermal, including sustainable and integrated management of geothermal

The RPS classifies all geothermal systems in the region, where the TGS is classified as a low temperature system. The RPS provides for extractive use of the geothermal system, where the adverse effects of the activity can be avoided, remedied or mitigated. Discharge of geothermal fluid must be managed to avoid significant adverse effects on surface water and stormwater.

The RPS also requires the protection of significant surface features and includes criteria to determine whether a feature is significant.

A system management plan is also required for the integrated management of the system. This is currently under development.

9.2.2 Rules That May Apply for Low Temperature Geoheat Systems

Table 10 provides a broad assessment of the type of regional resource consents that may be needed to install a geoheat system. Generally regional rules relate to drilling, take and use of geothermal or non-geothermal water, taking of heat and energy, and discharges. Where more than one type of resource consent is required, these will be dealt with as one application where possible.

While less likely, any disturbance of land or disturbance of contaminated land has potential to need consent for earthworks and would need to be confirmed on a case-by-case basis. Where structures are placed on the beds of water, consents may also be needed for structures in water bodies.

Consenting requirements will be site and system specific, so the information below is a guide only. For example, the sensitivity of the receiving environment will be considered when discharging water, groundwater allocation limits will be assessed when taking water, and the impact on other users or geothermal springs will be considered when taking heat. The size, flow rate, reinjection depth, and temperature will also determine consenting requirements.

The Regional Council is currently going through a regional plan change and our recommendations include looking at streamlining and clarifying some of these rules and developing an enabling consenting pathway.

Table 10: Regulatory Policies and Rules that are Relevant to Geoheat			
GHX Type	**Source Temperature**	**Resource Consents that may be Required**	**Note**
Closed Ground Loop (Horizontal)	Ambient ground temperature ~1.5m deep	None	Heat from surrounding substrate. Disturbance of ground would be assessed on case-by-case basis.
Closed Ground Loop (vertical) (heat take only)	Geothermal water (>=30°C)	Landuse consent for drilling[16] Consent to take heat from geothermal water	Heat only take, no take of geothermal water.
	Non-geothermal water (<30 °C)	Land use consent for drilling	Likely permitted where meets individual's reasonable domestic needs. Consent to take heat may be required for large takes to manage effects on the aquifer.
Open[17] Groundwater Loop (water and heat)	Geothermal water (>=30 °C)	Land use consent for drilling Consent for take and discharge of geothermal water	Discharges may be to land via soakage, to groundwater via reinjection, to surface water or to stormwater or wastewater network.
	Non-geothermal water (<30 °C)	Land use consent for drilling Consent for take/use/diversion and discharge of water	Permitted activity for water takes less than $35m^3$/day, and heat takes to meet reasonable domestic needs. Permitted activity rule and standards may apply for discharges.[18]
Open Surface Water (water and heat)	Non-geothermal water (<30 °C)	Consent for take/use/diversion and discharge of water	Permitted standards apply for takes <5 l/s and heat takes to meet reasonable domestic needs. Permitted rule and standards may apply for some discharges where receiving environment is not adversely impacted.
Closed Surface Water (including natural or artificial water body) (Heat take only)	Non-geothermal (<30 °C)	None	Likely permitted where meets individual's reasonable domestic needs. Consent to take heat may be required for large takes to manage effects on the surface water body.

16 New Zealand Environmental Standard for Drilling of Soil and Rock NZS 4411 apply for drilling a geothermal well <70 °C, or a non-geothermal bore. In some cases the deep drilling standards may be applied.

17 Can be a non-consumptive water take, where water is taken and discharged back to source aquifer; or a consumptive water take, where water is not discharged back to source.

18 Permitted activity where water is returned to source, and at the same or similar quality and in a matter not causing adverse effect (i.e.. not excessively cooled or heated).

Resource consents (permits for use) granted under this plan are likely to include conditions of resource consent, such as metering of use, monitoring of downhole or surface temperature etc.

9.2.3 Regulatory Matters to Consider

Matters likely to be considered include:

- Well testing costs (e.g. pump testing, chemistry analysis);
- Costs of resource consent application, including the costs of an assessment of environmental effects (e.g. cultural assessment, modelling);
- Metering requirements;
- Ongoing compliance costs;
- Costs of disposal (e.g. treatment of used geothermal water before disposal, discharge structures);
- Costs of reinjection; and
- Ongoing monitoring costs, temperature measurements.

9.3 Significant Geothermal Features

There are few surface geothermal features within the TGS, although there are a number of geothermally influenced springs. Some previously recorded springs are no longer present (BOPRC, pers comm). Although there has been no systematic assessment of their significance there is a well-known culturally significant spring present (although modified) at Maketū.

The potential impact of geothermal or other groundwater takes in proximity to springs, such as at Maketū, is being considered by Council as part of the development of the Tauranga System Management Plan. A development buffer zone around the spring at Maketū is tentatively recommended. The buffer zone will indicate the presence of the spring, and signal the need for appropriate setbacks, and assessments for allocation of groundwater or geothermal in that area. This has implications for other potential uses and will be confirmed through community engagement.

9.4 Environmental Best Practise

Adopting best practise principles is critical for balancing increased uptake of geoheat systems within the TGS with its long term sustainable management.

The UK Environment Agency (2016) has developed an 'Environmental good practice guide for ground source heating and cooling' that could serve as a useful tool for BOPRC in its ongoing management of the TGS with respect to enhanced uptake of geoheat systems. The Tauranga System Management Plan, under development, will include best practice principles.

A summary of recommendations to consider have been provided and centred around technology selection and system design, drilling implementation and ongoing management and data collection.

9.4.1 Technology Selection and System Design

Geoheat designs are considered on an individualised basis as they are an integration of the thermal requirements of the facility with what is available from the underground resource. As a sustainable technology solution, there is an expectation that any system design will select a technology that will:

- Supply the required heating and cooling demands;
- Be appropriate for the underlying subsurface conditions at the site; and
- Protect the environment, especially in the long term.

A staged approach that utilises desktop assessments and feasibilities prior to confirmation with test drilling is typical. All technologies listed in this document can be used sustainably, so long as they are used and managed appropriately. A few simple points that assist with best practise and to minimise impact of the environment are as follows:

- Net zero discharge systems such that all water extracted is returned to the aquifer, i.e. no discharge to stormwater / Harbour;
- Closed loops to be fully grouted to prevent mixing of aquifers and surface water infiltration; and
- Thermal modelling of any system design to ensure sustainability of long term operational performance as well as environmental protection.

9.4.2 Drilling Installation

The risk of environmental damage is elevated during the drilling process. As such, suitably qualified and experienced drilling professionals (SQEPs) are required for these types of installations, following best practice standards, including NZS4411 New Zealand Standard for Drilling Soil and Rock, as required through consenting. Licensed professionals should develop and construct the well to meet minimum requirements, especially with respect to durability and longevity. Consenting requirements should ensure that groundwater, drilling fluids and spoil do not enter sensitive receiving environments. In the event that an artesian aquifer may be encountered, appropriate measures are to be taken. We note that drilling in the TGS is a well established activity for which the BOPRC is currently applying regulatory oversight.

9.4.3 Data Collection

A theme of this report is the need for more data. Better data will improve understanding of the TGS from an extraction and management perspective. Thus, minimum data collection requirements during installation should be a requirement moving forward.

The lack of metering of water use was a legacy problem and the Freshwater Regulations 2010[19] now require metering with most water takes now being metered. The regulations do not specifically apply to geothermal water, however, the BOPRC now generally requires metering of geothermal water, with temperature measurements, on consent renewal. Data on use of geothermal within the TGS will therefore improve over time.

9.5 A Dynamic Resource

Geothermal systems are a dynamic natural system subject to spatial and temporal variability. Even with no utilisation and the highest standards of environmental best practices (like those outlined in Section 9.4), the dynamic nature of the resource is prone to change. With respect to geoheat systems, these dynamic forces could result in changes to system flow rates, temperature distribution, and water quality that could potentially result in system or well failure. Usually these are isolated instances, but regular well monitoring by BOPRC would indicate if there was any risk of a wider trend for the aquifer.

[19] National Regulations 2010 for measuring and reporting water takes require all water takes of 5L/s or more to be metered and to supply regular electronic water records to the BOPRC.

A good understanding of the resource in the form of good quality data and monitoring programmes that feed into an effective management model is one of the most effective tools to mitigate impacts on geoheat systems due to the dynamic nature of the resource. See previous Section 7.1 Data Gap Analysis.

To illustrate this with a real world example, a facilities manager of a public facility with pools, interviewed for this project, explained the localised issues he had to manage. He stated that in the 14 years he had been involved with managing the well the temperature had dropped approximately 10°C and the flow rate had dropped by 1.5L per second. As a result, the pool would no longer reach desired temperatures in colder months. Rather than consider drilling deeper or drilling a new well or upgrading the submersible pump, the public institution invested in a gas boiler to top up temperatures.

The decision to invest in a gas boiler rather than upgrade the existing geoheat system was driven by cost constraints and certainty, essentially the capital costs of a new gas boiler and its operating costs were known, whereas a geoheat solution had unknowns. Furthermore, they had certainty that pursuing the gas solution would fix the issue in in a timely manner, thus avoiding a lengthy pool shutdown. The following discusses management options if a well is affected by localised changes.

9.5.1 Temperature Variation

A direct use application that relies on the geoheat temperature is vulnerable to natural variations. While minor natural variations are considered in system design, if there is a significant reduction in temperature, system efficiency will decrease and thus operating costs increase. A significant change to temperature may be a result of poor design and thus be an operational issue. For example (in heating mode), extracting too much heat too quickly in a way that is beyond the natural replenishment rate or injecting the cooler return water too close to the extraction well may result in short cycling of the system.

A new, possibly deeper well may need to be drilled as a replacement or supplement to the original well or other heating systems may be required to replace or supplement the system. If an operational issue, the system would need to be reconfigured to be more sustainable before consideration of additional wells or heating systems.

An indirect use system is less reliant on geothermally enhanced temperatures and because of the associated heat pump, can work with different source temperatures and is less vulnerable to temperature changes.

9.5.2 Flow Rate Variation

In addition to temperature, thermal capacity from the aquifer is also a function of flow rate. Simply, an aquifer with a higher sustainable flow rate can serve a larger heating and cooling system for a given temperature.

Flow rate itself is a function of head pressure or water levels and formation characteristics. With the exception of a significant geological event, the formation itself is unlikely to change. However, head pressure on the system may change if water levels drop either from over extraction or in periods of reduced rainfall/drought.

When this occurs, the installed pump will not be able to deliver the same flow rate and thus the thermal capacity of the system could be impacted. This reduction in flow rate can lead to decreased efficiency and increased operational costs.

Over extraction may be localised by the system itself or a function of regional trends. Localized over-extraction of groundwater can lead to issues such as land subsidence and reduced water availability for other uses. Over extraction of heat can also lead to localised cooling of the aquifer. Exclusive consumptive abstraction for heating only purposes is not advisable, therefore, reinjection is recommended for sustainable management and to maintain water levels and formation pressures. Best practise design can ensure that a system doesn't cause its own over extraction issues while resource consent conditions are required to minimise local impacts, impacts on other users, manage the regional trends associated with cumulative impacts of multiple geoheat systems, and compliance with water allocation limits within freshwater management units. This process involves thorough assessment through the consent process, to ensure sustainable water and heat use.

It is noted that the Tauranga SMP will be addressing sustainable management practices for the system, including reinjection requirements and discharges to surface etc. Implementing these measures helps to maintain the thermal capacity of the aquifer and ensure reliable and efficient operation of the geothermal systems.

9.5.3 Installation Failure

The risk of an installation failure can be minimised with best practise design and installation (as above) and through ongoing maintenance. Geoheat systems should be considered as a long term infrastructure investment and designed and installed accordingly.

For open loop systems, this means adoption of best industry practices, and compliance with consent conditions requiring maintenance of geothermal wells in a fit for purpose state.

For closed loop systems, this means adoption of best practises from international bodies such as the UK Ground Source Heat Pump Association or the US based International Ground Source Heat Pump Association (IGSHPA, 2017) which has been encoded into North American Standard ANSI/CSA C448 (2016). A revision of this standard is planned for 2024 and is currently under review.

10. FUTURE OPPORTUNITIES

This section outlines geoheat opportunities that are worthy of discussion and further investigation for the western Bay of Plenty. Where possible, this section links geoheat to specific regional development zones. Barriers are also discussed with the aim of providing potential solutions, often drawing on overseas examples, with the perspective that every barrier can also present an opportunity.

10.1 Existing Applications and Future Opportunities for Western Bay of Plenty

Sections 4.4, 5.2 and 5.3 described the most common uses of geoheat due, in large part, due to proven returns on investment or other wellbeing gains. In the following, these proven geoheat uses have been applied to the western Bay of Plenty, outlining existing uses and future opportunities.

10.1.1 Pools

Heating of public and commercial pools is one of the most established and successful uses of geoheat in the western Bay of Plenty. There are six public run pools, including the iconic Mount Maunganui Hot Pools, that access the TGS, plus numerous small commercially run thermal mineral bathing facilities. While some facilities value the thermal minerals present, the main driver for public pools using geoheat are energy cost savings, according to Tauranga City Council, their larger facilities save between $200-330k annually on energy costs.

The new aquatic centre under construction at Memorial Park includes a deep-water eight-lane 25m indoor swimming pool, a hydrotherapy pool and spa, a learn to swim pool, and a leisure pool with a toddler pool. Outside, there will be a four-lane 25m lido pool, a splash pad, and a bombing pool. There will also be three hydroslides, a fitness centre, and a café that services the facility and the park. Current design is for two production wells (500-600m deep), to supply the pools via a heat exchanger, with two shallower wells for reinjection.

It is also understood that current design does not allow for the centre's building facilities to be heated and cooled via the same wells. It is recommended that to maximise the investment in wells, it should have multiple uses (e.g. space heating and cooling and hot water in addition to the pool heating) and multiple users (adjacent business or buildings) where possible. New community pool developments are listed in the 'Development Infrastructure' section of SmartGrowth. These include new public pools in Ōmokoroa and a new primary and secondary school[20], new pools near Te Puke at Wairakei, and a new indoor sports and community centre in Tauriko, plus relocation of the primary school and a new secondary school.

There are numerous homes in the region which heat their private pool with a geothermal well. For some this supplies pleasant bathing temperatures, thus extending their swimming season, and for others it supplies hot water bathing year round. In most cases, granted consents are for the swimming pool only. Only a handful of Tauranga home developments maximise the use of their geothermal well to also supply home heating (usually hydronic heating). It is possible for homeowners with an existing geothermal well for their pool to retrofit their home and connect home heating and hot water supply. Such a retrofit may be best timed with other home renovations and may require a consent change.

[20] It isn't clear if pools are within scope for new schools in the region. If not, it is worth noting that these types of developments could sit adjacent to new community pools and share the geothermal well(s), providing affordable and sustainable heating and cooling to the schools.

10.1.2 Horticulture

Geoheat is compatible with many industries, but its use in horticulture deserves dedicated discussion. Covered crops (glasshouses) require 24/7 heating during colder seasons to supply New Zealanders with capsicums, tomatoes, cucumbers and other produce year round. Most use gas for heating and have limited options when considering switching to renewables.

Solar thermal heating is typically not attractive as it can't go on a glasshouse roof and otherwise takes up land space. Further, it doesn't provide energy at night or on overcast days. Biomass is a viable alternative in some instances depending on location. However, concerns exist about supply constraints, onsite storage requirements and unpredictable supply costs. For reasons listed above, there is some enthusiasm for geoheat opportunities in New Zealand from covered crop growers (Seward et al, 2023).

Modelling conducted for EECA's Regional Energy Transition Accelerator (RETA) for the Bay of Plenty (Carey et al, 2024) demonstrated favourable economic outcomes if growers were to access elevated aquifer temperatures for a GSHP compared with standard aquifer temperatures. A 3.2 ha greenhouse located within the BOP region and outside the TGS was first modelled with up to 4.8 MWth GSHPs supplying 65°C water into the greenhouse from the 15°C Matahina formation near Whakatane.

To demonstrate the efficiency of higher source temperatures, the same greenhouse was modelled with source temperatures of up to 30°C, which reflects temperatures found in some shallow aquifers in the broader Tauranga area. It did not consider direct use options. The result was that a 25°C increase in aquifer water temperature resulted in both a 40% reduction in capital of the installation and of the annual electricity costs for the facility. The ambient GSHP installation which was used as a benchmark had a ROI of a few years, ROI periods reduced even further with access to higher subsurface temperatures. Although ambient and low temperature geoheat infrastructure case studies are often replicable over broader areas, a specific design feasibility will always be required. More information on the EECA RETA BOP geothermal workstream can be found in Carey et al (2024).[21]

A small (< 1ha) covered crop grower interviewed for this project stated that if they didn't have access to geoheat they would simply go without heat over winter, meaning no or low production and a loss of revenue. The fact they can grow over winter has meant securing loyal clients and being able to sell for "quite a premium" during that season. They described themselves as a "ma and pa business" comfortable with current scale of operations and with no intentions to expand. However, upon hearing about geoheat uses in the horticulture sector internationally, they felt that someone with more of a risk appetite could scale up the facilities they had on their land. They reflected that the existing geoheat well could add to the valuation of their business.

Not only does the western Bay of Plenty have available geoheat for covered crops, it has excellent sunshine hours, access to domestic and international freight routes and an existing horticulture labour market. There is an opportunity for the western Bay of Plenty public agencies to work with covered crop industry bodies to strategize how they can support new ventures in the region. For example, growers in the Netherlands have successfully installed covered crop facilities adjacent to new housing developments that are connected to a geoheat district scheme, enabling sharing of capital investment in well infrastructure, providing local jobs and increasing food security.

[21] https://www.eeca.govt.nz/assets/EECA-Resources/Co-funding/Bay-Of-Plenty-Geothermal-Assessment.pdf

10.1.3 Public Buildings

When public institutions adopt geothermal heating and cooling systems, they communicate the potential of geoheat within the region, educate about different technological applications, as well as demonstrate a commitment to environmental stewardship. Tauranga city centre is undergoing its biggest renovation project in recent memory with a number of significant public buildings designed for construction. This is known as Te Manawataki o Te Papa project, and it aims to deliver a transformative social infrastructure initiative in the heart of Tauranga. These large public spaces also sit above a known geoheat resource that has been assessed favourably for development (see Section 7).

One of the findings of stakeholder research for this report is that awareness of Tauranga's available geoheat and potential applications is relatively low, therefore public education efforts, such as this report, are recommended. This was also evident with Tauranga City Council and Western Bay of Plenty District Council staff. While they were well informed that geoheat is useful for pool facilities, they were less informed about other geoheat uses and international trends. The construction of the new Tauranga City Council building has commenced without a geoheat system and it is unclear whether the available geoheat at site was considered as an energy option in the design phase.

Furthermore, a stakeholder interviewed for this project similarly cited a lack of awareness within government agencies of geoheat. This stakeholder's facilities are on Crown leased land and the future of their business operations is subject to outcomes of a public consultation about future land use. They noted a general lack of awareness of the presence of geothermal waters from their irrigation bore and even though it was brought to the attention of consultation staff, the potential to utilise it in a future redevelopment or even the value it added to the site was absent in public documents. This is symptomatic of a general lack of awareness of low temperature geothermal uses in New Zealand. There is clearly a need for increased communication on the geoheat opportunities not just in the western Bay of Plenty but across New Zealand.

It is potentially not too late for the remaining public buildings in Tauranga's Te Manawataki o Te Papa project to design and install geo heating (and cooling) systems. Due to their close proximity to each other, they are well positioned for a geoheat district system which other city centre buildings / businesses could possibly connect to. Recommendations in Section 12 include a number of actions to address this.

10.1.4 Key Future Developments: Residential, Industrial and Mixed Use

As addressed in the introduction (and future discussed in Section 8.2), the SmartGrowth strategy identifies key growth areas within its Connected Centres programme, these are new residential and industrial corridors as well as existing neighbourhoods with planned intensification. An assessment of the geoheat potential for each development zone has been made in Table 11, this combines the planned land use, available geological and hydrogeological data and the application of different geoheat technologies determined to be compatible with the TGS.

Table 11: Geoheat Potential of the Future Development Zones/Growth Areas

Potential Development Zones	Geothermal Characterisation					Regulatory Status	Geothermal Application Suitability Assessment					
	Land Use Zoning	GNS Aquifer Potential[1]	Geology	Depth Range Encountered[2]		Consent for Groundwater Take for Consumptive Use[3]	Indirect Heating and Cooling			Direct Heating		
				>30°C	>50°C		Closed Loop System	Open Loop System	District Heating and Cooling	Closed Loop System	Open Loop System	District Heating
Port of Tauranga	Industrial	Good	Sediments over volcanites	<125 m b.s.l	<500 m b.s.l	May not be available reinjection may be required	✓	○	✓	○	○	✓
Tauranga City Centre	Mixed Use Residential/Commercial	Good	Sediments over volcanites	<125 m b.s.l	<500 m b.s.l	Available	✓	✓	✓	✓	✓	✓
Te Papa Peninsula	Mixed Use Residential/Commercial	Good	Sediments over volcanites	<125 m b.s.l	<600 m b.s.l	Available	✓	✓	✓	✓	✓	✓
Tauriko	Residential	Good	Volcanites	<125 m b.s.l	<700 m b.s.l	Available	✓	✓	✓	✓	✓	✓
	Industrial						✓	✓	✓	○	✓	✓
Rangiuru Business Park	Industrial	Good	Sediments over volcanites	<75 m b.s.l	<200 m b.s.l	Available	✓	✓	✓	○	✓	✓
Eastern Centre	Residential	Good	Sediments over volcanites	<75 m b.s.l	<200 m b.s.l	Available	✓	✓	✓	○	✓	✓
Ōmokoroa / Te Puna	Residential	Good	Sediments over volcanites	<175 m b.s.l	<500 m b.s.l	Available	✓	✓	✓	✓	✓	✓
	Industrial						✓	✓	✓	○	✓	✓
Otūmoetai	Residential	Good	Sediments over volcanites	<75 m b.s.l	<450 m b.s.l	Available	✓	✓	✓	✓	✓	✓
Pāpāmoa East	Residential	Good	Sediments	<125 m b.s.l	>150 m b.s.l	Available	✓	✓	✓	✓	✓	✓

[1]Note: New Zealand Aquifer Potential Map Version 1.0,https://www.gns.cri.nz/data-and-resources/new-zealand-aquifer-potential-map-version-1-0/
[2]Note: high uncertainty due to the limited data available, especially when localising the areas with temperatures above 50 °C.
[3]Note: BOPRC

✓ suitable ○ partly suitable

The desktop assessment results are largely positive for each development zone. For a developer interested in the geoheat potential for an individual site or district scheme in one of these zones, this information could act as a first pass review as to whether investment in a site specific feasibility study is warranted.

Of course, a table like this cannot stand alone as a decision-making tool, other values must be considered. For example, the drive to lower emissions of operators at the Port is of value to the region and for national emissions reduction targets. Due to constrained electrical infrastructure and a lack of available storage space for biomass at the Port, the geoheat potential for this area is attractive. Furthermore, at Rangiuru Business Park, the greenfield development makes the installation of geoheat technology more straightforward, and being able to offer clean and affordable heat for industrial purposes could be an attractive value proposition for the development.

Regional value for warm, dry and affordable homes is repeated throughout the SmartGrowth strategy as the "homes and communities we live in are the foundation of our wellbeing" (2024). A stakeholder interviewed for this project is a resident and bodycorp manager for an apartment building with five large apartments that each have underfloor heating and a spa pool connected to geoheat. These may sound like luxury features, however, the cost of achieving this high standard of home heating using geoheat is appealing when compared to the cost of achieving the same standard with electricity. In their role as bodycorp manager, he keeps a spreadsheet of costs, each apartment uses underfloor heating for six months of the year, which apparently "takes the chill off and does about 70% of required heating", they have an air source heat pump to top up indoor temperatures when it is very cold. It costs $340 a month to run the underfloor heating for all five apartments, divided by each apartment that is $75 a month for the majority of required home heating in winter. Unexpected maintenance repairs can be costly when divided between five homes. However, he reflected that doing geoheat at a larger scale must have benefits of reducing individual burden and sharing of costs.

Investment in geoheat systems is capital intensive and may not appeal to those developers that aim to build at lowest cost and sell with maximum profit. Well-drilling costs for low temperature geothermal range from $600 -1,300/m, so a 100 m well would cost about $60,000 - $130,000 (Rochelle Gardiner, BOPRC, Pers Comm). However, investment in geoheat systems delivers long term value with low operating costs (for residential, commercial and industrial), a higher standard of home heating and cooling and low emissions. These values align with regional and national policy directives and could be eligible for public funding or other forms of support. Even without public funding the business case is favourable, typical ROI is a few years (financial case studies are available in GXA, 2023 and EECA, 2024).

The majority of international examples of district energy schemes involve the public sector to some degree, whether it is with planning strategies, incentivising development, or in many cases, the public sector has partial or full ownership of the project (UN Energy Programme, 2016). Section 10.2 discusses different ownership and operating models for geoheat installations. In many cases it is a viable business opportunity to operate alongside a developer and install and own a geoheat system, generating long term revenue from selling thermal energy (i.e. heating and/or cooling) to users.

10.2 Investment, Ownership and Innovation

District schemes using geoheat are attractive as multiple households, businesses or public buildings benefit from receiving cost effective heating and cooling from shared infrastructure. However, how that materialises may not seem so straightforward; who pays for the well infrastructure? Who pays for maintenance? Are utility bills issued and by whom? District heating schemes have existed in the Northern Hemisphere for decades. Although not all are geoheat systems, often fossil fuels or waste heat, their investment and operating models are relevant and a summary provided in Table 11.

It is likely that in order to ignite a geoheat future for the western Bay of Plenty and Tauranga City, where multiple residential and industrial district schemes operate, it will need significant support and leadership from local councils and central government. For example, the development of a regional geoheat strategy and a commitment to geoheat project support initiatives like streamlined consenting, central government grants or even council led geoheat project tenders. It is also likely that projects will initially follow a public and private sector investment partnership model. However, as the concept matures, private investment could be expected to be more common.

These initiatives are well suited to ESG investors like New Zealand Green Investment Finance (NZGIF) and also superannuation funds. If local private sector investment is slow to get involved, there are multiple overseas investors that specialise in financing, developing, constructing, and operating large-scale geothermal heating plants for district heating companies. Therefore, it is not unforeseeable that international finance would take an interest in a geoheat strategy for the western Bay of Plenty.

Table 12: Summary of Investment and Operating Models

Model	Description	Case Study
Consumer Cooperative	A community-owned not-for-profit or cooperative business model. In this model, the local authority takes on a lot of risk initially in development and can underwrite any finance to the project. Maintenance costs are shared by consumers. At a small scale, this can be as simple as a body-corporate managing a geoheat system for an apartment complex.	Community ownership of renewable energy projects is somewhat common. Hepburn Energy (formerly Hepburn Wind), located in Victoria, was established in 2007 and has almost 2000 shareholding members. Australia's first community owned wind farm, it supplies 42% of Hepburn Shire's energy needs. As a sign of their success, they are currently expanding to include solar and batteries to their energy mix.
Public Owned Utility	The wholly public business model is the most common globally. The public sector, in its role as local authority or public utility, has full ownership of the system, which allows it to have complete control of the project and makes it possible to deliver broader social objectives, such as environmental outcomes and the alleviation of energy poverty through tariff control. This is not dissimilar to councils owning, servicing, and charging for water assets.	In London's Islington Borough, the local Council prioritised the development of a district heat network. The resulting district heat network uses a 1.9 MWel CHP plant with thermal storage and serves 850 apartments in addition to two leisure pool centres. The first phase of the project was fully funded by the Council in cash within a discretionary budget, plus some external grants, as it was felt that any debt on the project could raise heat tariffs outside the affordable warmth objectives.[1]
Hybrid Public and Private	These have a rate of return that will attract the private sector, but the public sector is still willing to invest in the project and retain some control to achieve public outcomes. A process may follow that a concession contract where the public sector is involved in the design and	Dubai has developed the world's biggest district cooling network, created through a public-private partnership between TECOM Investments, a real estate developer and the operator of Dubai's leading business parks, and the public utility Dubai Energy and

	development of a project, which is then developed, financed and operated by the private sector, and the city usually has the option to buy back the project in the future.	Water (DEWA). Meeting a demand equivalent to 1 million tons of refrigeration annually (3,510 MW), the network requires just half the energy of the air conditioning units it replaces, and thermal storage makes it possible to reduce electricity use during peak hours. This has enabled Dubai to limit growth in its electricity transmission network – a key objective of the district energy system. [2]
Private Owned Utility	Private organisation owns and operates assets, this could be local iwi, an existing electricity retailers or overseas investor. Private business models are pursued where there is a high rate of return for the private sector and require limited public sector support. They are developed as a wholly privately owned Special Purpose Vehicle but may benefit from guaranteed demand from the public sector or a subsidy or local incentives.	Tuwharetoa Geothermal supply heat and geothermal generated electricity to large process heat users at their industrial park in Kawerau. They purchased the steamfield assets from the Crown in 2005 to run the facility privately, they are the largest direct use steam supplier in the world. While it is a private and profit driven organisation, the business provides long-term socio-economic benefits for Ngati Tuwharetoa ki Kawerau and the wider Kawerau community.[3]
Notes / Source: 1. UN Energy Programme. (2016) 2. UN Energy Programme. (2016) 3. Tuwharetoa Geothermal. (2024)		

10.3 Initiatives to Enable Future Opportunities

10.3.1 Data Accuracy and Geoheat Maps

There is risk that once drilled a well may not perform as modelled in a detailed design or there is a temperature anomaly. Such risks are the reality of geoheat projects worldwide and this risk can be an obstacle to investment. To reduce risk and improve design accuracy, more collected data and updated maps should be made publicly available.

The temperature maps made for this report in Section 7 are based on data collected from 2029 wells made available from existing consents. In some areas, like Matua, the number of data points available in a contained geographic area increases the map accuracy there and reduces risk for future investments. However, in other areas and for certain depths, data availability is limited.

In Section 9, the value of good data, including system monitoring, was discussed in terms of understanding resource variations and their impact on management and operational performance. Good data is equally, arguably more important, in terms of the role it plays in derisking an initial investment into geoheat.

It is not the role of, nor expected that, publicly available data be of sufficient quality to completely derisk and design a specific application at a given location. However, enhancing the availability and quality of publicly available data can go a long way to encouraging investment into geoheat systems. A preliminary derisking process using publicly available data at a minimum provides a level of certainty to any investor that there is at least a known geoheat resource available and whether it may be applicable to their application. For example, even a simple understanding of what temperatures are available at what depth enables a project proponent to understand whether geoheat may be applicable and thus worth further site specific investigation.

10.3.2 Resource Consents

Resource consents for some geoheat installations are a necessary requirement. They are the main tool available to regional councils to manage the effects of the use of the resource, and appropriately manage it for the future. It is the BOPRC's legal requirement to manage the TGS as set out in the RMA.

Feedback from stakeholder interviews conducted for this report was that due to the uncertainty of outcome, unknown costs, and unknown time frames, consents are a perceived and/or real barrier.

Reconsenting of geothermal wells is required every 10 years by the BOPRC. One consent holder interviewed for this project described that approaching reconsenting was "daunting", another said it was "horrendous", and the third said it was an "awful process" with "hoops to jump through." All had gone through the reconsenting process within the last two years and had employed consultants to assist. For each site, the fee for reconsenting that included their consultants, council employed consultants, and the council reconsenting fees, totalled $15k and $16k. A third site spent $25k in total for their home heating and orchard irrigation reconsenting application, the majority of that total was also on consultant fees after their attempt to complete the application themselves was rejected. Unfortunately, reconsenting costs of this magnitude dilute the economic gains from having geoheat, especially for smaller installations.

In some cases, applicants must engage local iwi or hapū to assess the cultural effects of their application. This was something interviewees said they didn't know how to appropriately undertake without specialist assistance. Although employing external consultants is not a requirement, these parties were driven to this decision by fear of being bogged down in a red tape process and losing time by making mistakes.

One interviewee expressed that, in his opinion, the rigour required of the current reconsenting process seemed more appropriate for the initial application only. As metering of the well is now required and because BOPRC send someone to inspect the well annually, he said as long as those checks were OK, the reconsenting process should be streamlined and more like "rubber stamp process."

All parties were successful in the reconsenting process once consultants were employed and commented that all council staff they engaged with in the process were very helpful. Council staff have advised that, where possible, staff will assist applicants as much as possible through pre-application discussions. They also try to ensure that conditions do not place unreasonable costs on applicants.

There is no escaping that consents for some geoheat installations are necessary. However, if local government wants to support a geoheat strategy for the region, an evaluation of the current consenting and reconsenting process that engages a larger sample is recommended. Although difficult to predict the outcome of such an evaluation, it could include:

- Greater instructional material for the process;
- Fast tracking of projects that meet a high positive impact status;
- More dedicated council staff for support; and
- Streamlining parts of the process, especially for reconsents.

Through the Tauranga SMP process, and upcoming plan change, BOPRC are exploring ways to further enable geoheat use. This could also include permitted uses or more permissive activity status in the Regional Natural Resources Plan. Ideally, any such changes would appropriately re-balance expectations of a geoheat consent application and reduce unnecessary spending with consultants.

10.3.3 Developing an Industry Ecosystem

The SmartGrowth Strategy 2024-74 refers to the western Bay of Plenty 's economic development strategy which states: "Raising income levels within our communities through high-value job creation and ensuring local people develop the necessary skills for local jobs is a key objective."

Realising a geoheat strategy will assist to address this in two ways:

- By attracting new industry to the region that can access affordable, clean heat; and
- By requiring specific expertise for the installation of geoheat systems.

The former is an outcome of an energy transition that has a geoheat focus, while the latter is an important part of ensuring the success of the energy transition itself.

In terms of the knowledge sector, the delivery of a sustainable and optimally performing geoheat systems is the result of collaborative expertise as diverse as:

- Geologists;
- Hydrogeologists;
- Modellers;
- Mechanical engineers;
- Ecologically Sound Development (ESD) consultants;
- Drillers;
- Project managers;
- Excavators;
- Plumbers;
- Electricians;
- Refrigeration technicians;
- Architects;
- Tāngata whenua, experts in Te Ao Māori and Mātauranga Māori;
- Planners; and
- Investment / finance specialists.

Thus, developing a geoheat industry ecosystem is about refocussing these existing trades and skills. It is not about learning something completely novel. Fortunately, most of these are existing skillsets that already existing within, or within close proximity, of the TGS and the Bay of Plenty region.

To this end, a geoheat specialist should be viewed as both a niche technology expert and a systems or skills integrator. Those interested in geoheat should shop around for the right professionals, a stakeholder interviewed for this report that has domestic hot water supply, home heating, pool heating, and orchard irrigation from the same well, explained that engineers and trades were quick to dismiss his request for support of his proposed geoheat system. If it hadn't been for his own technical understanding and determination, he may not have ended up with the successful installation he enjoys.

In terms of suppliers, the local industry already includes suppliers of:

- Water bore equipment;
- Pipe, fittings, valves etc;
- Heat pumps;
- Submersible bore/well pumps;
- Heat exchangers;
- Circulating pumps; and
- Associated components.

The development and maturation of a local geoheat industry will strengthen these supply chains while assisting to decrease component costs through competition and economies of scale while encouraging innovation in supply chains and available products.

11. CONCLUSIONS

GeoExchange was engaged by the Bay of Plenty Regional Council (BOPRC) to assist with their understanding of the geothermal heating and cooling – or geoheat – potential of the TGS.

In developing the report, a wide range of elements associated with the TGS have been addressed. These have ranged from the technical to the regulatory, from the socio-economic to the geological, and from existing uses to consideration of potential future development zones.

The simple conclusion from the above works is that the TGS is a readily accessible source of sustainable thermal energy that could provide significant energy, economic, environmental and health benefits to the region. However, it is relatively unknown as a resource and further research will improve resource management and inform the potential benefits it may provide.

In Section 5.2 we compared the international experience with low temperature geothermal resources, especially in Europe, with that of the TGS. The comparison indicated that the TGS is up to 8x shallower for similar temperature conditions sought in Europe, thus making it easier and less costly to access.

In concluding this comparison in Section 5.2, the following questions were posed:

- Could the western Bay of Plenty use its comparatively shallow low temperature geothermal resource to its strategic advantage as the region develops? and
- Importantly, how can this be done sustainably?

All efforts to use the TGS to the region's strategic advantage can and must be done sustainably. Adopting best practise principles is critical for balancing increased uptake of geoheat systems within the TGS with its long term sustainable management. This report has outlined how important it is to ensure good system design, appropriate technology selection, and ensuring compliance of installation techniques.

A repeated theme of this report is the need for more data. Better data will improve understanding of the TGS from an extraction and management perspective. Enhancing the collection, availability and quality of publicly available data is important to manage and maintain the resource. However, it also increases knowledge of the geoheat systems and can go a long way to encourage further investment. Critically, these points about resource management and sustainability are captured in the following Recommendations section.

The intention of this report is to create a geoheat vision for the region that is based on the best available science and technological expertise. It is now up to key regional players to collaborate and turn this vision into reality. The following recommendations are made to aid the success of future work.

12. RECOMMENDATIONS

Building on the insights and findings detailed in the preceding conclusions, this Section presents a series of targeted recommendations designed to guide future actions and strategic initiatives.

1. A comprehensive geoheat vision is developed for the western Bay of Plenty. This will be a collaborative initiative led by local organisations such as councils, iwi, industry bodies and associated stakeholders. Collaboration is encouraged to identify key strategic opportunities, establish connections and partnerships with relevant community partners and provide clear investment pathways.

2. In addition to an overarching regional geoheat strategy, a specific geoheat for energy resilience strategy should be initiated that would involve key regional stakeholders, especially Transpower and PowerCo. Targeted investments in geoheat could be central to electricity supply and distribution companies' strategic growth plans, alongside investment in other renewable energy sources like solar and regional battery solutions.

3. Conduct further studies of the geoheat potential in the key development / growth zones (Section 10.1.4). The intent of this is to ensure a thorough evaluation and understanding of the potential and challenges, thus facilitating an informed decision-making and strategic planning process.

4. The potential for decarbonisation and regional economic growth from a geoheat district scheme is most evident at the Port of Tauranga and the Rangiuru Business Park, therefore these are recommended priority study areas. These studies will quantify the opportunities, paving the way for a strategic approach and attracting investment.

5. The remaining public buildings in Tauranga's Te Manawataki o Te Papa project will install geothermal heating and cooling systems to reduce future operational expenses and demonstrate a commitment to geoheat. These buildings will also serve as a demonstration case study of a geoheat district scheme.

6. The Memorial Park Aquatic Centre geoheat system is designed so multiple facilities are heated and cooled, rather than the wells being used for pool heating exclusively. Maximising use of the geoheat wells improves the ROI and a successful public geoheat system serves as a demonstration case study.

7. There is an opportunity for the western Bay of Plenty to collaborate with covered crop industry bodies to develop strategies supporting new ventures utilising geoheat. Additionally, economic agencies such as Priority One can identify and initiate other geoheat industry strategies to further regional development, e.g. aquaculture.

8. Future versions of Te Keteparaha Mo Nga Papakāinga Māori Housing Toolkit will provide advice and guidance on incorporating geoheat into papakāinga developments, including information on sustainable design, consent applications, installation, and ownership models.

9. Further science research of the TGS that includes additional monitoring of existing wells and new test well exploration. This will enable a greater understanding of the quantum of heat in the TGS

and how long it would last under differing geoheat use scenarios, informing sustainable resource management.

10. Systematic improvement of data quality and data collection from existing consent holders and all future consents. As a start, data for the whole TGS would be improved if all well/bore holes had a one off manual data collection to record depth and temperature profiles.

11. Similar public guidance, as outlined in the United Kingdom Environment Agency's Environmental good practise guide for ground source heating and cooling, is created for the New Zealand context with some recommendations being embedded into environmental law.

12. An evaluation of the current consenting and reconsenting process that engages a representative sample is undertaken to identify costs and time involved, common perceptions, and potential opportunities to streamline the process.

13. The Regional Council is currently going through a regional plan change, this is an opportunity to streamline and clarify some of these rules relating to low temperature geoheat use and to develop an enabling consenting pathway.

14. Public education efforts, such as this report, continue to be invested in to generate awareness of the geoheat opportunities and the associated broader societal benefits.

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APPENDIX A: VALUING THE TAURANGA GEOTHERMAL SYSTEM – SEMISTRUCTURED INTERVIEWS WITH CONSENT HOLDERS.

The Bay of Plenty Regional Council requested that primary research with geothermal consent holders from the western Bay of Plenty was obtained for this report. A range of consent activities and types of consent holders were selected for a semi-structured interview which was conducted via videoconference.

Each of the five interviews were 30-45 minutes in length and were conducted in May or June, 2024.

The semi-structured interview covered the following discussion points:

- Describe known history of well/bore and geothermal use at site;
- Describe general practices and uses and whether the full potential of heat is being used;
- Environmental practices e.g. describe daily/monthly use, maintenance, discharge, system design, metering, downstream uses;
- Does the geothermal well/bore save/cost money? Would you recommend?;
- Other activities/operations on site or neighbours. e.g. is there refrigeration, dehydration, multiple neighbours;
- If they have done an energy inventory/audit and have a decarb plan. Fossil fuel use on site?;
- Is heat valued (e.g. personal use, commercial use, irrigation)?;
- Are minerals in the geothermal water valued?;
- Gauge prior knowledge and general awareness of geothermal heat potential and GHSP use;
- Perceived or real obstacles / constraints from utilising heat to full potential;
- Any major development plans in the next 5 years?; and
- Any other anecdotal info or even reports done which they are willing to share.

The interviewees agreed to participate on the condition of anonymity. Therefore notes from the interviews are not included here. If of further interest, the authors can be contacted for anonymised versions of the interview notes.

APPENDIX B: DETAILED SCOPE OF WORKS

The following detailed Scope was developed in consultation with BOPRC and is as per the project agreement.

Resource Characterisation

- Reviewed existing studies provided by BOPRC that characterise the TGS;
- A data gap analysis was conducted to form recommendations for further investigations; and
- Based on existing data provided for the purposes of this study, map overlays were developed to spatially characterize the resource, where possible. These were interpreted, based on our experience of the potential applications. Map figures were created.

Review of Technologies Suited to the Tauranga Geothermal System

- Conducted a review of currently available low temperature geothermal technologies;
- Presented opportunities and constraints of low temperature geothermal technology applications in the TGS; and
- Provided commentary on existing industry ecosystem capabilities in terms of supply chain and skills transfer.

Thermal Opportunities and Constraints

- Identified existing known heating applications that utilise the TGS, considering both direct and indirect (with heat pump) applications;
- Provided commentary on trends identified with respect to consenting and management practices of existing heating applications;
- Identified opportunities and constraints of direct and indirect heating applications that are well suited to both the TGS as well as the Western BOP (e.g. climate, housing stock, housing density, current and future land use zoning, type of industry, rural production focus, reliance on fossil fuels etc); and
- Identified broad categories of applications from the perspective of short term ‘low hanging fruit’ opportunities as well as medium or longer term regional led opportunities.

Stakeholder Input as Required

The following were consulted or their public documentation reviewed as part of the scope:

- Tauranga City Council;
- Western Bay of Plenty District Council;
- A small number of resource consent holders (approximately 5);
- Review of SmartGrowth Bay of Plenty strategy; and
- Review of PowerCo and Transpower strategy documents to understand current electrification forecasts and grid investment planning with an additional scenario that considers the demand reduction potential of utilising a well-managed TGS.

Results from the stakeholder interviews and document reviews have been included within the text of the report as appropriate rather than as a standalone section.

Management Implications

- A qualitative analysis was conducted of the sustainability of the thermal resource, commensurate with the level of information available;
- Augmented the values assessment work carried out to date in the development of the draft Tauranga System Management Plan (BOPRC, 2024) on competing interests within the TGS (e.g. irrigation vs thermal, environmental, cultural, etc) from the perspective of economic opportunity, cost savings, carbon emissions, grid stability, etc;
- Identified where current zoning or land use policy obstruct or allow for potential development;
- Considered the role of the TGS with respect to climate adaptation;
- Commented on the status of existing consent / regulatory framework with respect to enabling economic development of the TGS from a strong foundation of sustainable development; and
- Identified opportunities for regional / economic development, job creation, etc.

Recommendations

Based on the findings of this report, identify recommendations for further work required to assist with the sustainable utilisation of the TGS. These should include but not be limited to:

- Additional aquifer characterisation work required (e.g. monitoring, more wells, geophysics, etc);
- Ongoing engagement strategy and workshops;
- Guidance documents for development of roadmaps for uptake of geothermal heating and cooling;
- Further regional economic development planning; and
- Application specific feasibility studies.

APPENDIX C: LITERATURE REVIEW LIST

Name	Year
ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Governments and Australian state and territory governments. Canberra ACT, Australia. Retrieved from www.waterquality.gov.au	2000
Barns, S. (2022). The Economic Impacts and Benefits and Costs of Geothermal Resources in the Bay of Plenty Region. Bay of Plenty Regional Council Strategic Policy Publication 2022/01.	2022
Bay of Plenty Regional Natural Resources Plan (RNRP) – available at https://www.boprc.govt.nz/yourcouncil/plans-and-policies/plans/regional-plans/regional-natural-resources-plan	2023
Bay of Plenty Regional Policy Statement – available at https://www.boprc.govt.nz/your-council/plansand-policies/policies/regional-policy-statement	-
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Leonard, G. S., Begg, J. G., Wilson, C. J. N., Leonard, G. S. (2010). Geology of the Rotorua area. Lower Hutt, New Zealand: GNS Science.	2010
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O'Shaughnessy, B.O. (1998). Issues Associated with the Management of a Low-Grade Geothermal Resource in the Bay of Plenty Region. Bay of Plenty Regional Council report	1998
Pearson-Grant, S.C., Burnell, J.G. (2018). Update of the Tauranga Basin geothermal reservoir model. GNS Science Consultancy Report 2018/102.	2018
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-andpublications/publications	2021
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Simpson, B., Stewart, M. K. (1987). Geochemical and isotope identification of warm groundwaters in coastal basins near Tauranga, New Zealand. Chemical Geology, 64(1-2), 67-77.	1987
Simpson, B. (1987). Heat flow measurements on the Bay of Plenty coast, New Zealand. Journal of volcanology and geothermal research, 34(1-2), 25-33.	1987
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