IDENTIFYING AND DESIGNING FOR GEOTHERMAL HAZARDS

GUIDELINES FOR BUILDINGS AND ASSOCIATED SITE WORKS IN ROTORUA DISTRICT

VERSION 2 APRIL 2025

ROTORUA LAKES COUNCIL
Te Kaunihera o ngā Roto o Rotorua

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Ngā mihi nui kia koutou

1. INTRODUCTION

1.1 PURPOSE OF THESE GUIDELINES

The purpose of these guidelines (the Guidelines) is to assist those planning and designing building projects and associated site works in the Rotorua district to manage potential geothermal hazard risks.

The Guidelines are intended to encourage development that:

- keeps people safe, healthy and comfortable;
- doesn't exacerbate the geothermal risks to neighbours;
- is appropriately durable to geothermal environments.

The Guidelines also provide information to assist those planning and designing building projects and associated site works to comply with regulatory requirements. The Guidelines focus principally on the Building Act 2004 (Building Act), Building Regulations 1992 (Building Code) and a requirement in the Rotorua District Plan (Rotorua Plan) relating to provision of assessments of geothermal hazards and mitigation when undertaking building work in the Rotorua Geothermal System. The Guidelines may also be of assistance to other processes under the Resource Management Act 1991 (RMA) and the Rotorua Geothermal Bylaw.

1.2 WHEN TO USE THE GUIDELINES

The Guidelines are intended for any person involved in planning or designing buildings and associated site works in the Rotorua district.

1.3 OUTLINE OF THE GUIDELINES

The Guidelines provide information about the hazards and risks associated with building in geothermal areas and how to identify and manage the risks.

Sections 2 and 3 provide the context and background for understanding why building works need to address the geothermal context:

- **Section 2** provides an overview of geothermal systems in the Rotorua district and the associated geothermal hazards, risks and durability issues for buildings.
- **Section 3** summarises key provisions in statutory and regulatory instruments and compliance matters when undertaking building works.

Sections 4, 5 and 6 provide guidance about assessing and responding to the geothermal context at a site-specific level:

- **Section 4** describes steps for identifying geothermal hazards and durability issues affecting a site. A flow chart is included with accompanying detail on each step.
- **Section 5** introduces example design responses to the geothermal hazards identified through the process outlined in section 4.
- **Section 6** provides broad guidance for addressing durability issues.

1.4 LIMITATIONS

The focus of the Guidelines is building work involving roofed structures intended for occupation by people and/or their property and associated site work. The Guidelines do not address geothermal risks associated with other types of structures and activities (despite that they may be within the definition of building under statute or regulation). For example, the Guidelines do not address the construction of geothermal pools, geothermal bores, other geothermal infrastructure, structures for viewing geothermal areas and structures for excluding people from geothermal areas.

The risks considered are those relating to the ongoing use and occupation of the building and building site; and the potential impact of the building work on the geothermal risks to neighbouring sites. The Guidelines do not address management of risks during the site investigation and construction. Nor do the Guidelines address mitigation of issues identified with existing buildings, or remediation actions in the event that an issue arises.

The Guidelines contain guidance on specific geothermal hazards and do not address all potential geothermal hazards that may affect a site. For example, the Guidelines do not address harmful substances in the soil, ground instability or earthquakes associated with geothermal areas.

The document provides general guidance only and does not provide definitive or site specific information. There may also be unique circumstances that were not considered in the preparation of the Guidelines that warrant a different approach.

The Guidelines do not replace or override the statutory and regulatory requirements regardless of whether there is a conflict or not. If there is no conflict, the provisions of lawfully enacted statute or regulation apply rather than any equivalent statement in the guidelines. Requirements may also vary between the RMA, Building Act and Council bylaws.

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2. CONTEXT

2.1 INTRODUCTION TO THE GEOTHERMAL SYSTEMS OF ROTORUA DISTRICT

The Rotorua district includes various geothermal systems that are a result of volcanic activity. These systems vary in size and have a diverse array of natural surface features, including hot crater lakes, bubbling springs, geysers, small springs, warm pools, steam vents (also known as fumaroles), and streams. Additionally, these geothermal systems may cause heated ground at or near the surface and may release various gases into the atmosphere.

Council is aware of around twenty distinct geothermal systems or isolated geothermal occurrences[1] identified in the Rotorua district:

- **Tāheke:** a moderate-sized geothermal area, featuring hot ground, fumaroles, and warm to hot springs. Potentially under development for electricity production. Potentially linked to Tikitere.
- **Tikitere:** expansive territory of hot ground, fumaroles, mud pools, and springs, this site has experienced small-scale hydrothermal eruptions. Several shallow local drill holes have been established in the vicinity, contributing to ongoing geothermal exploration and tourist activities.
- **Lake Rotoiti Centre basin:** Area with thermal activity at the bottom of the eastern part of Lake Rotoiti, potentially linked with Tāheke and Tikitere.
- **West Lake Rotorua:** A potential low temperature system located at the lakebed, to the west of Mokoia Island.
- **Lake Rotokawa – Mokoia Island:** Includes group of small warm springs, which supports a local bath and several shallow boreholes. Potentially connected with Rotorua City system at depth.
- **Rotorua City:** extends from Whakarewarewa Valley in the south, northward under the city into the south western portion of Lake Rotorua. Three areas of significant surface activity include Whakarewarewa-Arikikapakapa, Ngāpuna-Government Gardens and Kuirau-Ōhinemutu. This system is remarkable for its size, its large number and wide variety of surface features and the extent to which natural geothermal processes and development coincide. See Scott et al. 2016 for a discussion of this.
- **Makatiti Dome:** Potential system identified through geological surveys east of Lake Ōkataina.

[1] Warm springs/bores where there is a lack of information to connect these to more extensive geothermal resources at depth (Zuquim & Box, 2023).

- **Rotomā - Tikorangi:** warm to hot ground and springs extending north to include lakeside seeps in Lake Rotoehu.
- **Rotomā/Puhipuhi:** located north and west of Lake Tarawera, but primarily in the Whakatāne district.
- **Lake Tarawera and Lake Ōkataina - Kanaehepa Bay, Humphries Bay and Ōtangimoana Bay:** Three occurrences each with warm seeps that flow in the lakes. Possibly a result of circulation of meteoric (rain) water through permeable rhyolitic rocks driven by gravity, discharging at the lakes shore where it intersects the water table, and not associated with a wider geothermal system.
- **Mount Tarawera:** Geothermal occurrences identified within the crater.
- **Waimangu-Rotomahana-Tarawera:** Extends from Rainbow Mountain to Lake Tarawera and includes Waimangu Valley and the collection of hot springs, fumaroles and warm seeps situated at Te Rātā Bay (Hot Water Beach), Lake Tarawera.
- **Ātiamuri:** small-scale geothermal system, characterised by high-temperature overflowing pools situated within a rural area. The system remains predominantly undisturbed.
- **Horohoro:** a small-scale system showcasing a series of small springs within a rural landscape approximately 15 kilometres southwest of Rotorua.
- **Ngātamariki:** Surface thermal features including hot springs, sinter in a rural area. The system is used extensively for electricity production.
- **Ohākī-Broadlands:** expansive geothermal system used extensively for electricity production.
- **Ōrākeikōrako:** an extensive area featuring an array of hot springs and sinter terraces. Many features lie under Lake Ōhakuri.
- **Reporoa:** high-temperature springs located within a rural setting. Additionally, it encompasses minor warm springs such as Golden Springs and Butchers Pool.
- **Te Kopia:** an extensive area showcasing hot ground, fumaroles, mud pools, and springs situated on the Paeroa range, approximately 20 kilometres south of Rotorua. Minor hydrothermal eruptions have been recorded within this area.
- **Waikite Valley:** diverse range of hot and boiling springs, along with warm lakelets and ground in a rural environment.
- **Waimangu-Rotomahana:** large hot crater lakes, hot springs, and ground, having witnessed moderate-sized hydrothermal eruptions. This site stands as a prominent hub for tourism activities. This region was the epicentre of significant large-scale eruptions in 1886, triggered by the intrusion of magmatic material from Mt Tarawera into the geothermal system.
- **Waiōtapu:** an array of geothermal features, including numerous explosion and collapse craters, hot springs, steam vents, and warm ground. Developed for tourism.
- **Whāngairorohea:** collection of warm to hot springs situated in proximity to the Waikato River within the rural environment.

The identified geothermal systems are depicted in Figures 1 to 3, based on Scott B., 2010 and Zuquim & Box 2023. Figures 1 and 3 correspond to the extents from 2010, which are adopted in the Rotorua District Plan maps. The extents presented in Figure 2 for the Bay of Plenty part of the district come from the 2023 study. This more recent study does not form part of the current District Plan or Bay of Plenty Regional Council policy but may ultimately inform an update to the extents mapped in district and regional plans. In the meantime, the Guidelines refer to the extents identified in both studies.

There may also be geothermal processes occurring in other areas that have not been identified as systems or occurrences. Furthermore, some hazards can also be associated with relic geothermal systems that are no longer active.

While the mapping identifies distinct systems, they are connected many kilometres below the surface as part of the Taupō Volcanic Zone (“TVZ”). The TVZ has a high heat flow and a high density of faulting present, which supports the large extent of active geothermal systems within the district (Scott, 2010).

GEOTHERMAL FIELDS IN THE ROTORUA DISTRICT WITHIN THE BAY OF PLENTY (2010)

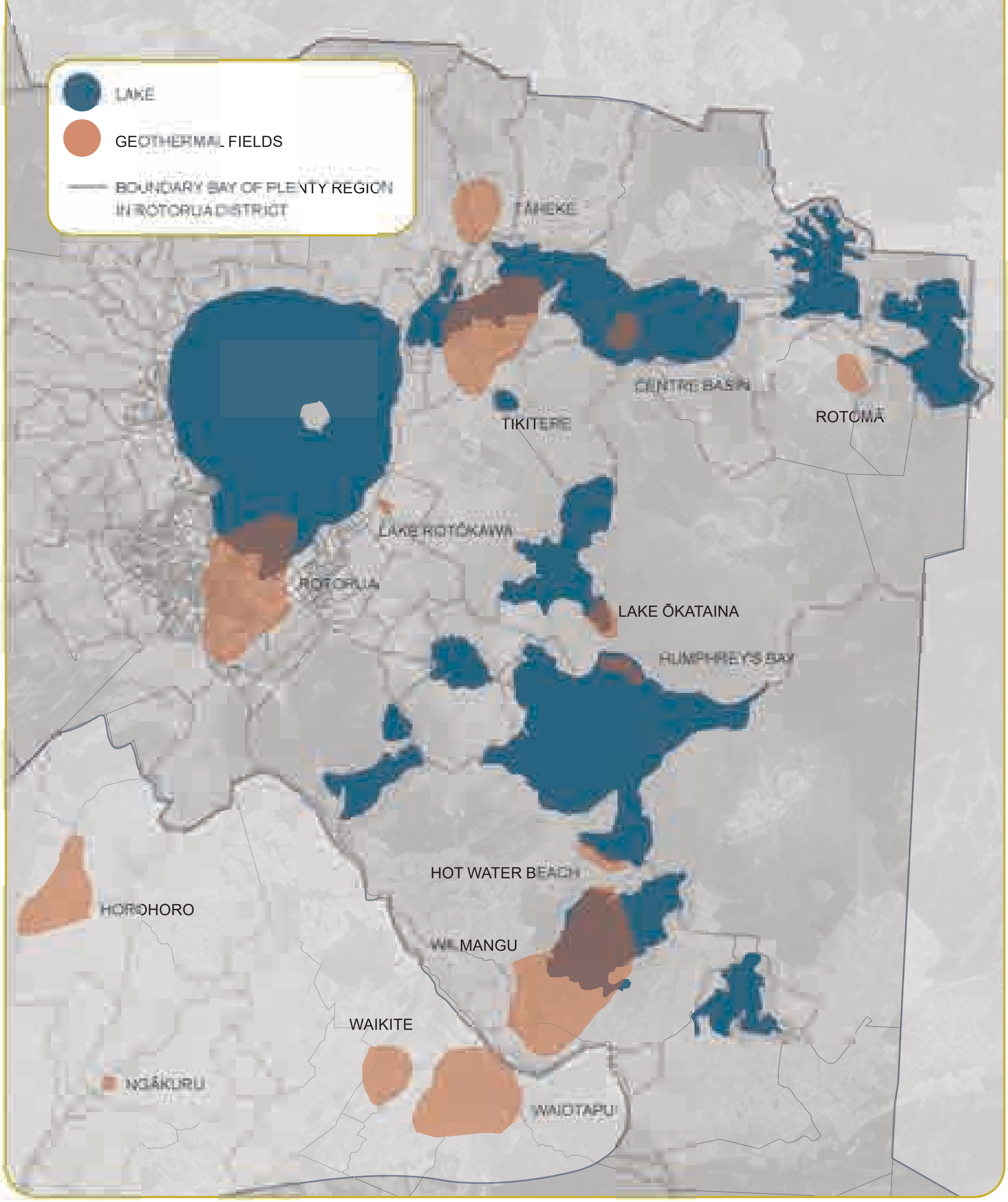


Figure 1 Geothermal Fields (Systems) in the Rotorua District within the Bay of Plenty Region (source: Scott, 2010).

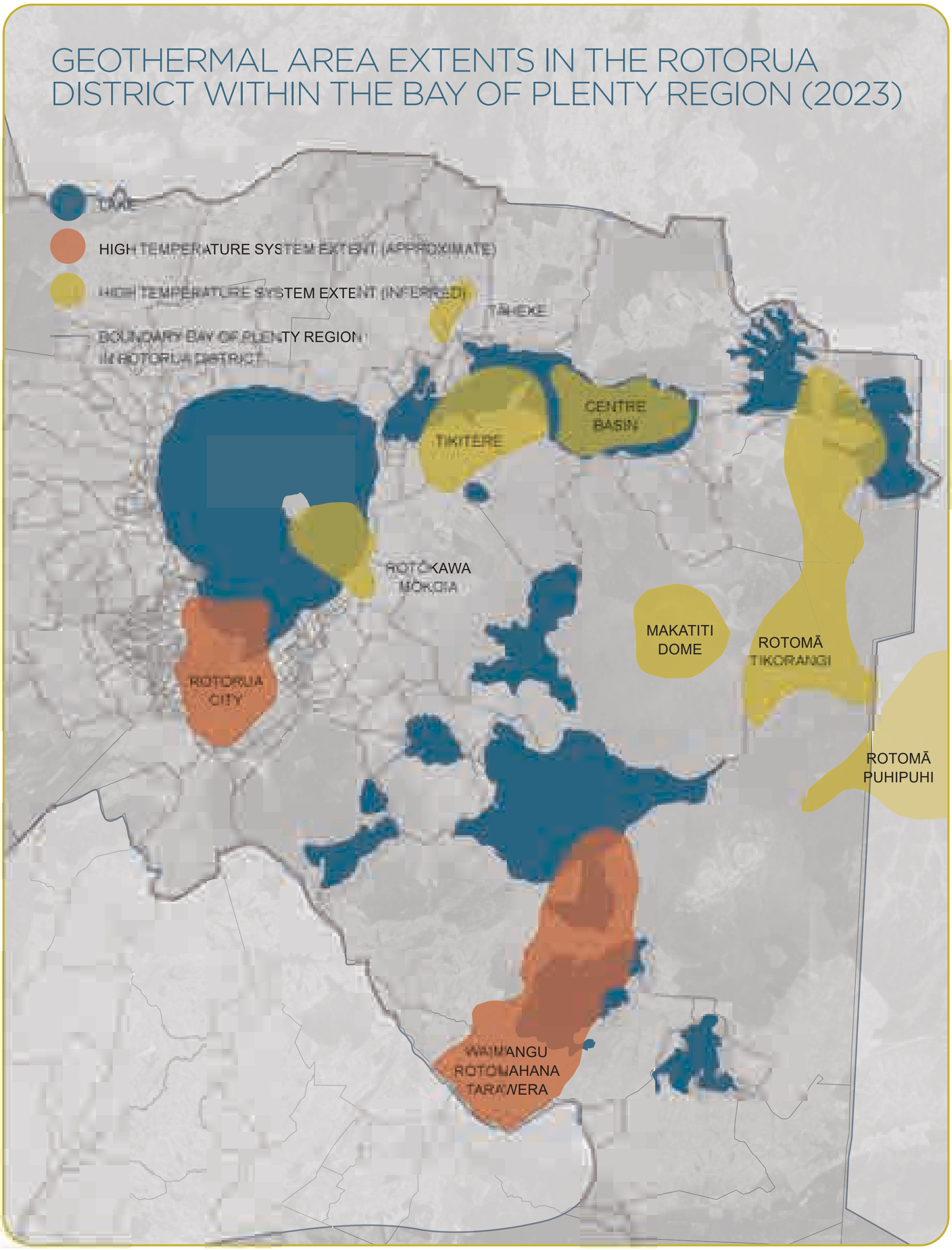


Figure 2 Geothermal System High Temperature (Approximate and Inferred) Extents in the Rotorua District within the Bay of Plenty Region (source: Zuquim & Box, 2023).

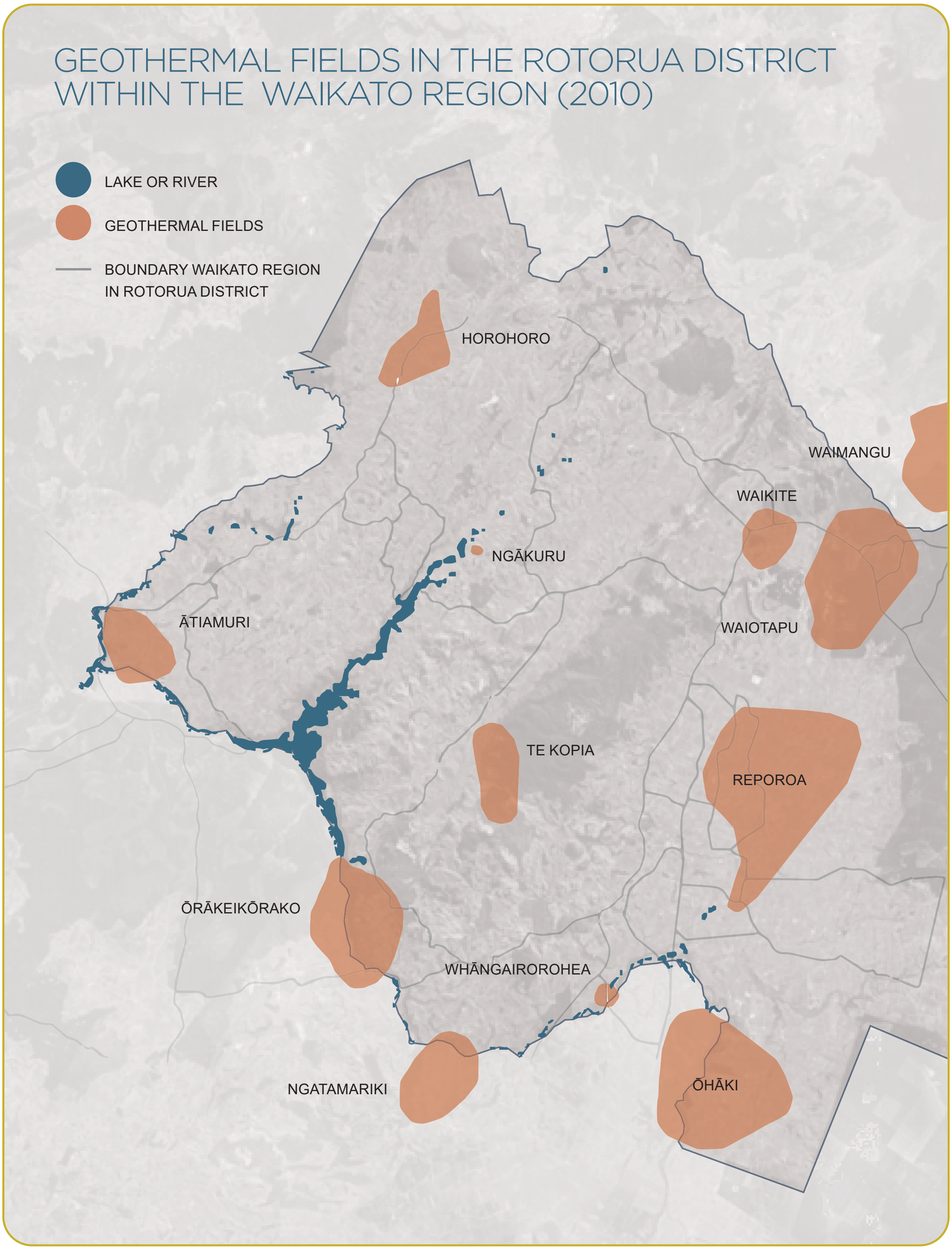


Figure 3 Geothermal Fields (Systems) in the Rotorua District within the Waikato Region (source: Scott, 2010) [2].

[2] Ngakuru was previously recognised as a geothermal occurrence based on elevated temperature in a now-closed well and no other geothermal expression has been found. On this basis, it has been removed from Waikato Regional Council maps (comms, K Luketina, Waikato Regional Council, February 2024). Consideration may also need to be given to removing it from the Rotorua District Plan

Further background information can be found in:

- The publication prepared jointly by GNS Science and Bay of Plenty Regional Council (BOPRC), 'Ngā pūnaha ngāwhā o Te Moana-ā-Toitehuatahi, Bay of Plenty Geothermal Systems: The Science Story' (Scott & Scholes, 2021)

2.2 INTRODUCTION TO GEOTHERMAL HAZARDS AND RISKS

The geothermal context in the Rotorua district presents unique hazards for development. Information about various hazards and the associated risks is summarised below.

Geothermal Surface Features

Geothermal surface features such as fumaroles, hot springs, mud pools and pots can be close to or at boiling temperatures. Geothermal surface features can also cause injury and damage through the ejection of hot water, mud and steam, sometimes many metres from the source (Tonkin & Taylor, 2022). The general distribution of surface features tends to be relatively stable over long periods of time. However, their behaviour can be unpredictable, with surface features often exhibiting periods of relative reduced and increased activity, occasionally leading to minor explosive activity (Scott B. , 2010). Issues have also been experienced in Rotorua where old features have reactivated.

Surface features are also a source of geothermal gases and their presence indicates high heat flow and greater probability of other hazards including geothermal eruptions and land instability.

Heated ground

Heated ground can occur across substantial portions of geothermal systems. Ground temperature within the geothermal systems varies, ranging from areas where temperatures are only slightly above ambient to boiling conditions at shallow depths (Scott B. , 2010). Geothermal hot ground, due to the high temperatures as well as the potential for fluctuations, can pose risks to foundations and structures including through thermal stress and material degradation (Tonkin & Taylor, 2022). In addition, areas of heated ground are associated with land instability, as discussed further below. Heated ground can also affect building internal temperature and, therefore, the quality of living environments.

Development, by increasing surface coverage, can influence the hazard by reducing the cooling effect of rainwater percolation and creating a barrier to reducing heat radiation to the air (Tonkin & Taylor, 2022).

Geothermal Gases

Geothermal fluids are a source of various dissolved gases released into the atmosphere. Two key geothermal gas species that can be harmful in sufficient concentrations are (International Volcanic Health Hazard Network, 2023):

- **CARBON DIOXIDE (CO_2)** is a common geothermal gas, which has effects at high concentrations ranging from shortness of breath to headaches, vertigo and even death if concentrations are sufficient.

- **HYDROGEN SULPHIDE (H_2S)** is a toxic gas with varying health effects depending on the concentration and duration of exposure. Humans can begin to perceive H_2S presence at extremely low concentrations of 0.008 to 0.2 parts per million (depending on the individual) because of its distinctive 'rotten eggs' odour, for which Rotorua is renowned. However, sense of smell of H_2S is lost as concentrations increase, so people can have little warning of the presence of gas at dangerous concentrations. At lower concentrations, it irritates the eyes and respiratory tract and can result in headache, fatigue, dizziness, diarrhoea, followed by bronchitis. Large concentrations result in paralysis of the respiratory centre, causing breathing to stop and potentially death.

Geothermal areas are also associated with other harmful gases, including carbon monoxide, methane, radon, elevated levels of radioactive isotopes and heavy metals (Luketina, 2007) (Tonkin & Taylor, 2022) (Ellis, 1977).

Geothermal surface features, such as springs and fumaroles, are key point sources of potential harmful gases. However, it is important to understand that gas can also be emitted diffusely through the soil. Gas is normally concentrated in areas of surface features (Fitzgerald, et. al., 2022) and there is a relationship between diffuse gas emissions and hot ground, however these hazards do not correlate exactly (Tonkin & Taylor, 2022). The Guidelines assume that areas with high gas emissions are fairly stable over long periods of time, determined by the underlying faults, which act as a pathway to the surface (Hollingworth, 2016). It is noted, however, that changes in the areas that are affected are possible, for example after a significant earthquake.

Deteriorating bores and excavations also present a risk for gas emissions.

The rate of emissions from the ground (flux) can be influenced by inhibiting emissions nearby (for example, by covering the ground with buildings or other hard surfaces). In some cases (for example, around geothermal bores) gases are purposely collected and vented and these venting exhausts can also present a hazard if not correctly positioned with respect to nearby buildings and other confined spaces (Tonkin & Taylor, 2022).

In Rotorua fourteen deaths have been attributed to H_2S exposure since 1946 (Collins, 2003; Bassingdale, Hosking, 2011; Garcia, 2023)

Rotorua is also recognised as having the largest population in the world with long-term chronic exposure to low concentrations of H_2S. The overall impacts of this exposure are uncertain, with some studies suggesting an association with adverse health effects, while others suggesting no relationship to the health issues investigated or even potential benefits (Hinz, 2011) (Bates, et. al., 2002) (Reed, et. al., 2014) (Bates, et. al., 2015).

Figure 4 Bore Failure, 2016 (photo: Andrew Austin).

In addition to potential health impacts, geothermal gases can also cause corrosion and damage to structures over time, leading to potential structural weaknesses (refer to further discussion of material durability below).

Bores and Geothermal Infrastructure

Geothermal bores have been constructed throughout Rotorua city to utilise the geothermal resource. They serve different purposes, including extraction and disposal of geothermal fluid, facilitating heat exchange, geotechnical ground investigations and technical operations, such as monitoring. The bores and associated infrastructure can present a risk to human health and structures. Deterioration and 'failure' of these bores is the main concern, which can give rise to several consequential hazards, including the emergence of warm-hot ground, heightened emissions of geothermal gases and the development of surface features (Tonkin & Taylor, 2022) (Figures 4 and 5).

Although rare, during a drilling operation or maintenance of a bore, failure can occur with a blowout around the drill rig (Fitzgerald, et. al., 2022).

Failures can also occur in distribution pipe networks or in re-injection bore casings (Scott, 2010), resulting in flows of hot water/steam.

Vehicle and machinery access to bores is very important for monitoring and maintenance, emergency works in the event of a bore failure and to allow the works are needed to decommission bores.

Figure 5 Bore Casing Failure (photo: Rotorua Lakes Council).

Many bores have been closed in line with standards that reduce potential risks (filling the cavity with cement, capping and sealing). However, even with proper decommissioning, risks cannot be completely ruled out. The Guidelines recommend that future development be designed to reduce potential risks by not building over locations of closed bores.

Hydrothermal Eruptions

Two primary types of eruptions are found in geothermal systems, both of which are driven by steam. These are hydrothermal eruptions (which have varying definitions but are usually considered not to have direct magmatic heat or fluid involvement) and phreatic (which, also have varying definitions but, put simply, can be described as explosive expansion of steam, water or gas due to magmatic activity heating rock under a water body) (Fitzgerald, et. al., 2022).

Hydrothermal eruptions from existing geothermal systems are more common than phreatic eruptions. They also range significantly in size from splashes of muddy water a few metres from the feature to eruptions that have created 2km wide craters and ejected material 4km away from the crater (Cody, 2003).

The geological record suggests that major eruptions are very infrequent, with major events in a geothermal field separated by thousands of years. Much more likely are smaller, short-lived eruptions, as depicted in Figure 6. Most are likely to eject material only several metres from the source but ejections further than 100 metres are possible. Geothermal eruptions have occurred in the geothermal systems of the Rotorua district in the recent past and should be expected to recur in any of the high-temperature geothermal fields of the district. They have the potential to cause serious injuries and damage to property but are most likely to occur where the geothermal heat flow is very high. In other words, areas where there are existing boiling springs or high flows of steam (Scott, 2010).

Figure 6 Aerial view of the area in Kuirau Park, Rotorua impacted by the 27 January 2001 hydrothermal eruption of Spring 721 (photo: Rotorua Daily Post).

Building Material Deterioration (Durability)

Geothermal systems can contribute to the deterioration of building materials and a decrease in building durability through processes inherent to the geothermal environment, which can also lead to structural instability. These durability issues could potentially be described as an additional risk associated with geothermal hazards.

The high temperatures associated with geothermal areas can induce thermal stress, causing certain materials to weaken and deform over time. This thermal stress can particularly affect materials with lower heat resistance.

Additionally, the chemical composition of geothermal fluids, including their high mineral content and acidity, can facilitate the corrosion of metals and the degradation of various construction materials (Nogara & Zarrouk, 2018) (Figure 7).

Geothermal gases can also be corrosive due to their chemical composition and their interaction with various elements present in the surrounding environment. Sulphur containing gases are common in geothermal areas and contribute significantly to corrosion (Figures 8 and 9). Enhanced corrosion has been identified some distance from geothermal gas sources, with researchers suggesting that the large number of geothermal sources in the district could combine to affect a much larger area than a single isolated geothermal source, possibly through synergistic effects (Li, 2021).

The cumulative effects of these geothermal factors necessitate consideration of the use of specialised building materials that can withstand the harsh conditions of geothermal environments to ensure long-term durability and structural integrity of buildings. Regular maintenance and proactive measures are also crucial to mitigate the impact of geothermal activity on building materials and to sustain the longevity of structures within geothermal areas.

Figure 7 Concrete core showing effects of geothermal corrosion (Photo: Ash Bowtell)

Figure 8 Accelerated corrosion on a building near Sulphur Bay (Photo: Kim Smith, January 2024).

Figure 9 Accelerated corrosion on a Rotorua vehicle (Photo: Kim Smith, January 2024).

Ground Instability

Chemical and physical processes associated with geothermal systems can also weaken soil and rock, and erode subsurface materials (Figure 10). These 'hydrothermal alteration' processes and products present risks to people and structures by decreasing the ability for the earth to hold loads and potentially causing ground collapse (Fitzgerald, et. al., 2022).

Ground instability due to hydrothermal alteration is most likely to occur in areas with high ground temperatures and gas flux. Stormwater soakage and drainage, which concentrates water, can also accelerate the processes. Overlying sinter sheets, hardened bare ground surfaces and surface treatments such as paths and driveways can sometimes conceal collapse holes (Tonkin & Taylor, 2022).

Figure 10 A collapse hole developing at Whakarewarewa Village over eight days in September 2012. Roof-fed stormwater disposal to shallow depth drove the creation of the feature (these images were originally published in Fitzgerald, 2022)

Land sliding is also another form of land instability found in geothermal areas. Fortunately, most geothermal areas in the Rotorua district where development occurs are in areas with gentle slopes where this hazard is less likely (Scott, 2010).

Shallow earthquakes can also be associated with land instability in geothermal systems but are typically small and few are reported as felt. If larger earthquakes occur, the consequences are the same as elsewhere in New Zealand (Fitzgerald, et. al., 2022).

The primary approach to addressing potential ground instability issues associated with geothermal areas and relict geothermal soils when building is through site-specific investigation and advice from geo-professionals; and this is not further addressed in the Guidelines. Ground conditions may preclude development on some sites.

Harmful Substances in the Soil

In addition, there are potential hazards associated with the substances in the soil in currently active and historically active geothermal areas. This is because geothermal fluids can contain and carry elevated concentrations of harmful substances, particularly arsenic, but also other substances such as mercury, boron and lithium (Fitzgerald, et. al., 2022), which can build up in the soil. The Guidelines do not address this hazard.

3. REGULATORY FRAMEWORK FOR MANAGING GEOTHERMAL RISKS TO DEVELOPMENT

3.1 INTRODUCTION

This section provides a summary of key provisions in statutory and regulatory instruments that relate to building work in geothermal areas. A detailed review of the instruments themselves is necessary and reliance on the summary in this section is not sufficient to ensure full compliance with the statutory and regulatory instruments. There could also be additional instruments that come into force before the Guideline is reviewed.

3.2 BUILDING ACT AND BUILDING CODE

The Building Act sets out rules, standards and procedures for people involved in building work. It covers how building work can be done, who can do it and what approvals are needed. Its overarching purpose includes the following relevant to the Guidelines (section 3):

> *to provide for the regulation of building work, the establishment of a licensing regime for building practitioners, and the setting of performance standards for buildings to ensure that:*
>
> *i. people can use buildings safely without endangering their health;*
>
> *ii. buildings have attributes that contribute to their users' health, physical independence and wellbeing; and*
>
> *iii. people who use a building can escape from the building if it is on fire; and*
>
> *iv. buildings are designed, constructed and able to be used in ways that promote sustainable development.*

The Building Code sets out the performance standard.. Importantly, buildings must comply with the Building Code even if a building consent is not required (section 17). Failure to comply can result in compliance actions, such as a notice to fix (section 164). Compliance with the code can be established by various methods including compliance with an acceptable solution or verification method.

Summarised below are the parts of the Building Code that are of particular relevance to building in geothermal areas and the hazards addressed in the Guidelines. This is only a selection of clauses and other parts of the Building Code may be relevant to geothermal hazards, depending on the circumstances.

i. Clause B1 Structure
The objective of this provision is to (clause B1.1):

> *a) safeguard people from injury caused by structural failure,*
>
> *b) safeguard people from loss of amenity caused by structural behaviour, and*
>
> *c) protect other property from physical damage caused by structural failure.*

It is the functional requirement of Clause B1 that buildings, building elements and site work withstand the combination of loads likely to experience during construction or alteration and throughout their lives (clause B1.2).

The performance requirements include relevant to geothermal hazards and risks (clause B1.3):

- Buildings, building elements and site work have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during construction or alteration and throughout their lives;
- Buildings, building elements and site work shall have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during construction or alteration when the building is in use;
- Account be taken of all physical conditions likely to affect the stability of buildings, building elements and site work. A non-exhaustive list of conditions is provided, which includes conditions relevant to geothermal hazards and risks such as temperature, water and other liquids, adverse effects due to insufficient separation from other buildings.

The common method of compliance is through application of various standards referred to in the acceptable solutions. However, key standards (NZS 3604:2011 for timber framed buildings and NZS 4229:2013 for masonry buildings) do not apply to sites that are not on 'good ground', defined to exclude ground that is potentially compressible or could foreseeably experience movement of 25mm of greater for any reason. Therefore, the potential for geothermal processes to cause land instability on some sites could exclude application of standard means of compliance; and specific engineering design will be required.

ii. Clause B2 Durability

The objective of this provision is to ensure that a building will continue to satisfy the other objectives of this code throughout its life (clause B2.1).

The functional requirement of Clause B2 is that all building materials, components and construction methods are sufficiently durable to ensure that the building, without reconstruction or major renovation, satisfies the other functional requirements of the Building Code throughout the life of the building (clause B2.2).

The performance requirement in clause B2.3.1, in summary, requires that each individual building element, with only normal maintenance, continues to satisfy the performance requirements of the Building Code for a specified minimum period. The minimum period varies from five to 50 years, depending on the function of the building element in the structure and ease of maintenance and replacement (unless the building has a shorter specified life).

Once again, the acceptable solutions refer to various standards that often require specific engineering design or assessment for geothermal issues. For example, NZS 3604:2011 on timber framed buildings divides the country into exposure zones for defining the quality required for steel fixings and fastenings; but also requires consideration of local environmental effects (microclimates). It specifically mentions geothermal hot spots (within 50m of a bore, mud pool, steam vent or other source), stating that in these areas specific engineering design is required. SNZ TS 3404:2018 for steel structures and components uses similar maps to define requirements for material quality but also states microclimates should be considered and a site specific corrosivity test is required if the building is within 500m of a geothermal source or if the smell of H_2S is noted.

The alternative verification method of compliance (B2/VM1), in summary, requires evidence of the performance of the products in the conditions to which it will be exposed. The evidence must be based on history of performance, laboratory testing and/or comparable performance of similar building elements. This information can sometimes be found in the manufacturer's product information (now required under recent building regulation changes) or in the certificates approved under the CodeMark scheme. However, geothermal conditions are often not considered and specific information needs to be sought.

iii. Clause F1 Hazardous Agents on Site

The objective of this provision is to safeguard people from injury or illness caused by hazardous agents or contaminants on a site (clause F1.1)
The functional requirements require buildings to be constructed to avoid the likelihood of people within the building being adversely affected by hazardous agents or contaminants on the site (clause F1.2).

The term 'contaminant' under the Building Code has the same meaning as in the Resource Management Act 1991 (RMA), (section 2 RMA 1991, clause A2 of the Building Code):

> *Contaminant includes any substance (including gases, odorous compounds, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat -*
>
> *(a) when discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or*
>
> *(b) when discharged onto or into land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged.*

The term 'hazardous', in turn, is defined in the Building Code as "creating an unreasonable risk to people of bodily injury or deterioration of health" (clause A2). Geothermal gases clearly fall within the ambit of clause F1; and heat is potentially a hazardous agent and/or contaminant.

The performance requirements of clause F1 include that:

- sites must be assessed to determine the presence and potential threat of any hazardous agents or contaminants; and
- the likely effect of any agent or contaminant on people must be determined taking account of:
    - the intended use of the building;
    - the nature, potency or toxicity of the hazardous agent or contaminant; and
    - the protection afforded by the building envelope and building systems.

The compliance document for F1 provides no acceptable solutions so compliance will generally be through the verification method (F1/VM1). This, in summary, requires that where information suggests there may be contaminants and hazardous agents, a site-specific assessment is undertaken, the acceptability of potential exposure levels is considered and appropriate remedial work or building design is included.

It is noted that the verification method (F1/VM1) specifically mentions hazards to building elements and gives the example of sulphates (which form from sulphur containing geothermal gases) attacking concrete. It requires that such hazards are assessed at each site and appropriate preventative measures taken (2.7.1). Thus, there is an overlap between clause F1 and clause B2 durability.

3.3 DISTRICT PLAN

The Rotorua District Plan contains the following provisions that are relevant to managing the risks associated with building in geothermal areas:

a) Requirement to assess geothermal hazards and mitigation at building

With the adoption of Plan Change 9, the District Plan now includes a requirement for most types of buildings in the Rotorua Geothermal System (as mapped in the District Plan, Figure 1) to submit to council, at the same time as a building consent application, an assessment of geothermal hazards and mitigation (Rule NH-R8). The assessment is to be prepared by a suitably qualified and experienced person. The intention is that this assessment will encourage broad consideration of how to manage geothermal hazards. Completing the assessment should also assist to address the requirements of the Building Code.

The Guidelines are intended to support the preparation of these assessments, providing guidance on key matters including how to identify hazards and potential options for mitigation and who should be involved.

b) Setbacks

Buildings within 5 metres of a geothermal surface feature or bore require resource consent as a restricted discretionary activity and Council's discretion on considering these applications includes 'adverse effects from natural hazards or the worsening of any hazard identified on the planning maps are managed' (Rule NH-R6).

c) Impervious surface limits

The District Plan restricts the percentage of a site that can be covered by impervious surfaces in many zones (for example, performance standard RESZ-S3 in Residential Zones limits impervious surfaces for permitted activities to 70% in Residential 1 Zone and 80% in Residential 2 Zone). Council has discretion to consider natural hazard issues if a resource consent is sought for exceeding the limits (for example, under Rule RESZ-R3(2) for residential units in Residential 1 or 2 Zones where site coverage is exceeded). However, the Guidelines caution against assuming it will always be appropriate to build to the maximum impervious surface standard on all sites.

There are also requirements to assess geothermal hazards at subdivision. Conditions of subdivision consent may provide site-specific requirements that may then be included in a consent notice registered on a property title that apply to future development (sections 220 and 221 of the RMA).

3.4 REGIONAL POLICY STATEMENTS

Regional policy statements provide overall direction for geothermal management and guide the development of the rules in regional and district plans, which must give effect to the regional policy statements (sections 67(3) and 75(3) of the RMA).

The northern part of the Rotorua district is located within the Bay of Plenty region, while the southern and eastern parts of the district are within the Waikato region. Refer to Figures 1, 2 and 3 above for information about which region each geothermal system is located in and, therefore, which regional policy statements and plans are relevant.

Bay of Plenty Regional Policy Statement

The Bay of Plenty Regional Policy Statement (BOPRPS) requires classification of geothermal systems into management groups based on their unique values, current uses and development potential (Policy GR 1A). Some systems, such as the Waimangu system, are managed to protect their unique geothermal surface features, while others such as Kawerau are used for electricity generation and industrial use. The Rotorua System is classified as its own management group in recognition of the unique situation where a city has been built on what otherwise would have been a completely protected system (Group 2, Policy GR 1A).

The BOPRPS has policies directing how the geothermal resource should be managed, such as:

- Managing hazards (Policy GR 11B);
- Development of System Management Plans for certain systems (Policy GR 2A);
- Getting and using the right information (Policy GR 5B);
- Managing takes and discharges, for example, through a discharge strategy (Policies GR 6B, GR 8B);
- Assessing and protecting significant surface features (Policies GR 4A, GR 9B); and
- Recognising and providing for the relationship of tangata whenua with their resources and taonga (Policy GR 4A).

Waikato Regional Policy Statement

The objectives and policies of the WRPS recognise that a range of uses including energy, extraction, research and the protection of geothermal features should be provided for, whilst ensuring any potential adverse effects are recognised and addressed (GEO-O1, GEO-P1).

Similar to the BOPRPS, The WRPS requires the regional plan to classify geothermal systems to determine the most suitable management approach for each system (GEO-P1).

Geothermal activity is also included within the definition of a 'natural hazard' under the WRPS (where it may adversely affect human life, property or other aspects of the environment) (Interpretation - 1.6). This means that hazard risks are to be managed using an integrated and holistic approach that ensures risk does not exceed an acceptable level and seeks to use the best available information/ best practice, amongst other things (HAZ-P1). Subdivision, use and development is to be managed to reduce risks to an acceptable or tolerable level, including by ensuring risk is assessed for proposed activities on land subject to natural hazards (HAZ-P2).

3.5 REGIONAL PLANS

Regional plans include objectives, policies, rules and matters that must be considered where resource consents are required.

Bay of Plenty Regional Plan

Geothermal policies and rules for all geothermal systems in the Bay of Plenty Region are currently included in the Bay of Plenty Regional Natural Resources Plan, while the Rotorua Geothermal Regional Plan only covers the Rotorua System.

A plan change is underway (Plan Change 11) to review the geothermal provisions in both of these regional plans, which will then be combined into a single geothermal chapter in the Bay of Plenty Regional Natural Resources Plan.

Of most relevance to the Guidelines is that the Bay of Plenty Natural Resources Regional Plan seeks avoid or mitigate the effects of natural geothermal hazards (GR O7), with policies addressing, amongst other matters:

- Increasing community awareness about the geothermal systems and their inherent hazards (GR P10); and
- Working with city and district councils to avoid or mitigate the effects of geothermal hazards by encouraging land use and development to avoid areas with a high risk of geothermal hazard and requiring land users and developers to take effective measures to remedy or mitigate the adverse effects of geothermal hazards (GR P14);

Also of relevance is that the regional plans contain several rules relating to the interference with geothermal surface features (GR R8 Natural Resources Regional Plan; 13.5.3(b)(i) Rotorua Geothermal Regional Plan).

For updates on Plan Change 11 please see www.boprc.govt.nz/environment/geothermal/geothermal-plan-change

Waikato Regional Plan

In response to the WRPS, the Waikato Regional Plan classifies the geothermal systems in the region based on their size, vulnerability, and existing uses (7.4, Policy 1). For example, Te Kopia and Waikite-Waiotapu-Waimangu are classified as 'protected' geothermal systems due to their unique and vulnerable features. Other geothermal systems in the region are classified as 'development' systems and contribute to New Zealand's electricity supply. Different rules for use/extraction of resources apply under the plan, depending on the classification (7.6).

In terms of what is most relevant to building and the Guidelines, the Regional Plan seeks to regulate certain activities in and within the vicinity of significant geothermal features, to avoid, remedy or mitigate their impact on the significant geothermal features. Importantly, most vegetation clearance and soil disturbance activities (including for construction of a building) within 20m of a Significant Geothermal Feature are a discretionary activity so require resource consent (Rule 7.6.6.3).

3.6 ROTORUA GEOTHERMAL BYLAW

The core focus of the Rotorua Geothermal Bylaw 2016 (Bylaw) is to ensure public safety near geothermal bores, geothermal infrastructure, and natural geothermal features and from H_2S gas. The following bylaw requirements are most relevant to the subject matter of the Guidelines (building and associated site works):

- Site access to any well [bore] shall be maintained in such a condition as to allow access to the well by a drilling rig at all times (clause 5.12);
- No person shall erect a structure or building within 5 metres of either an existing well, or a closed well, except with the express written approval of the council, and subject to any conditions it may impose (clause 5.18); and
- Developers, owners and occupiers of every building are required to take all reasonably practical steps to incorporate acceptable barriers to the ingress or egress of hydrogen sulphide, into or from, new or upgraded buildings developments (clause 7.3).

For information, it is noted that the bylaw also contains the following clauses relating to the ongoing use of buildings, but these are of less relevance to the subject matter of the Guidelines:

- hydrogen sulphide (H_2S) exposure limits for commercial and work premises (clause 7.2); and
- a requirement to mitigate defects in buildings that permit or are likely to permit the ingress or egress of hydrogen sulphide gas, in such concentrations as to be injurious or dangerous to the health of any person (clause 7.4).

Much of the remaining content of the Bylaw (relating to pools, bore maintenance and inspection) is not within the scope of the Guidelines. However, you should familiarise yourself with these requirements if there are bores/other geothermal infrastructure, geothermal pools or surface features in or near your property.

4. HAZARD IDENTIFICATION

4.1 INTRODUCTION

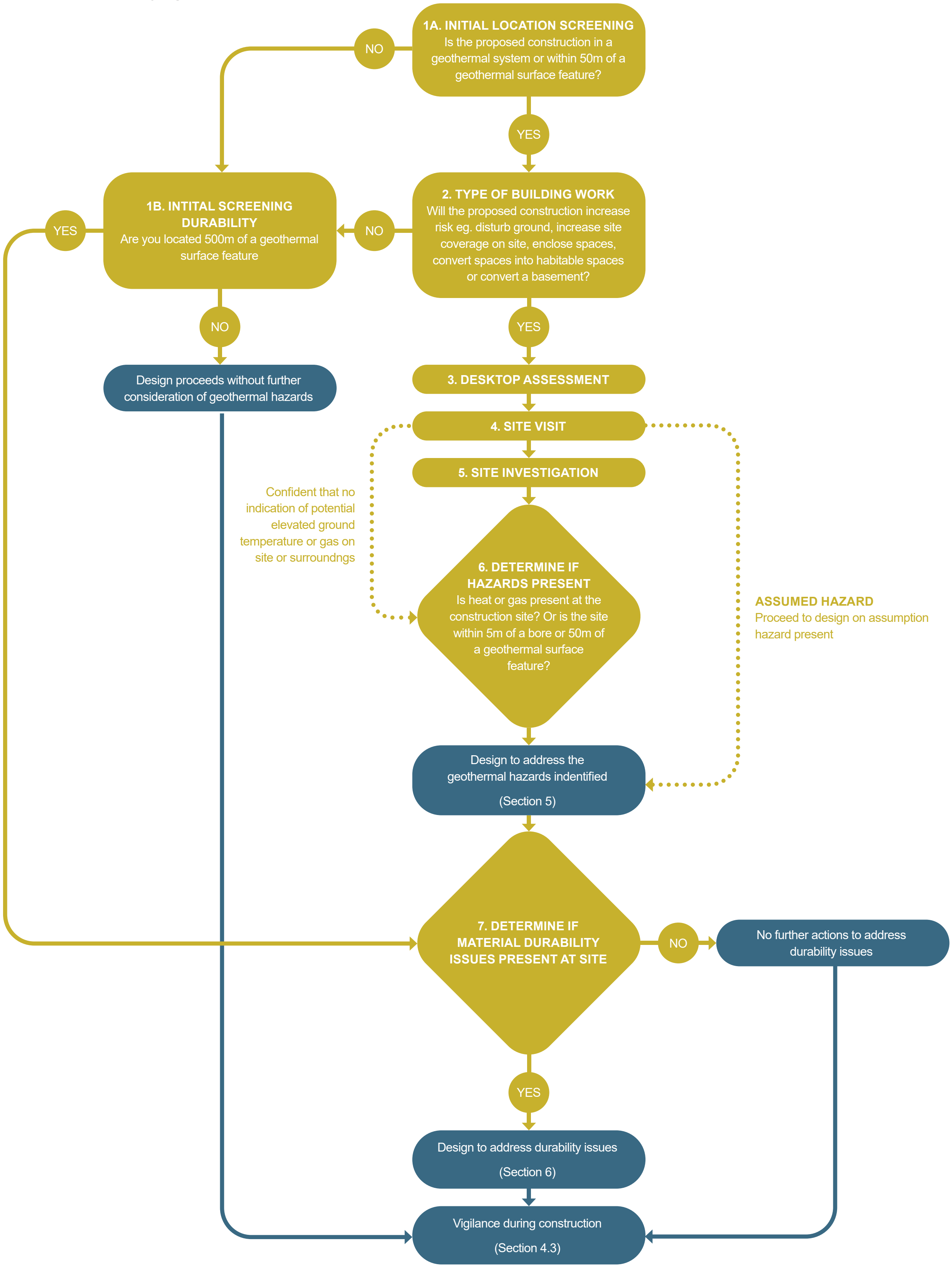
Geothermal hazards pose unique challenges and considerations for developing within geothermal areas. Understanding and effectively managing these hazards is critical for ensuring safety, liveability and longevity of development.

Identifying the potential geothermal hazards is the foundation to managing the risks. Section 4.2 provides a flow chart of steps for identifying potential geothermal hazards and then explains each of the steps.

The Guidelines recommend this process for hazard identification be followed when planning any building and/or associated site works in the Rotorua district, regardless of whether any building consent is required or RMA plan rules require the hazard assessment. Completing this process should also assist to meet the requirements of the Building Code, RMA plans and Bylaw.

4.2 STEPS FOR IDENTIFYING GEOTHERMAL HAZARDS

Geothermal Hazards & Building Works
Guidance for Identifying Hazards



STEP 1A Initial Location Screening for Geothermal Hazards

Before planning any building and/or and associated site works in the district an initial screening for the potential for geothermal hazards in that location should be completed. Generally, geothermal hazards are more likely to be present if the site is within a defined geothermal system or near a geothermal surface feature or bore; so this provides the basis for the initial screening. However, it should be noted that there remains a possibility that geothermal hazards exist outside of these areas.

Specific expertise to complete the initial screening is not needed as it relies on previous studies and mapping.

i. Is the Development in a Geothermal System?
A key tool for the initial screening for potential geothermal hazards is to check whether your site is in an identified geothermal system extent as explained below by region.

- For all of the district check the system extents identified in the District Plan (Figures 1 and 3 above), which is also available in the Rotorua Lake Council's online mapping tool Geyserview, under Planning and Development > Hazards and Risks > Geothermal Systems *DP*
- For the part of the Rotorua district in the Bay of Plenty region also check whether the site is in the high temperature (both approximate and inferred) extents identified in the more recent 2023 study (Figure 2 above) (Zuquim & Box, 2023). These extents are also available in the Bay of Plenty Regional Council's online mapping tool BayExplorer under Environment > Geothermal > Geothermal Systems Indicative Extents (2023). Note: this mapping is indicative only and has not been adopted into BOPRC policy.

ii. Is the Development near a Geothermal Surface Feature?
For the initial screening, further consideration of geothermal hazards is recommended when the building or site works are within 50 metres of a geothermal surface feature, at a minimum. (Most sites near geothermal surface features would also be flagged for further consideration under (i) on the basis that they are located with the mapped geothermal systems, but there is the possibility that some sites near geothermal surface features are located outside the mapped systems.)

The following tools can be used to identify whether the development is close to geothermal surface feature:

- In the Bay of Plenty region use the mapping of surface features in the BOPRC's online mapping tool BayExplorer under Environment > Geothermal > Geothermal Inventory (for the Bay of Plenty).
- In the Waikato region use mapping of geothermal habitat (vegetation) as a proxy for the location of surface features, which is available on Colab's open data portal.

iii. Is the Development near a Geothermal Bore?
Proximity to bores should also be a signal for further consideration of geothermal hazards. All the relevant sources of bore location information for the region in which your site is located should be checked:

- Rotorua Lakes Council's online mapping tool Geyserview under Planning and Development > Hazards and Risks > Geothermal Bores.
- For the Bay of Plenty, the Bay of Plenty Regional Council's online mapping tool BayExplorer under Water > Well/Bore Locations (for the Bay of Plenty).
- The Wells Aotearoa database: Wells Aotearoa New Zealand (teurukahika.nz)

STEP 1B Initial Location Screening – Durability

Whether or not the initial screening in Step 1A indicates that further consideration of geothermal hazards is needed, geothermal conditions could cause material durability issues on the site. In the Rotorua district, even sites outside of mapped geothermal systems and located some distance from any geothermal surface feature may be affected by airborne aerosols (gas and steam) that form 'acid rain'. A distance of 500 metres from a geothermal surface feature is suggested as a guide for further consideration of durability issues.

Refer to Step 1A(ii) above for where to find information about the location of geothermal surface features and Step 7 for further consideration of durability.

STEP 2 Type of Building or Site Work

If the initial location screening (Step 1A) suggests you should further consider geothermal hazards, the next step is to consider whether the type of building or associated site works could potentially increase the associated risks, for example by:

i. disturbing the ground;

ii. increasing site coverage (expanding the footprint of the building and/or laying hard surfaces with the associated site works);

iii. enclosing spaces (for example, enclosing a porch to form a room);

iv. converting spaces into habitable spaces (for example, converting a garage to a sleepout); or

v. constructing and/or converting a basement.

If any of these types of building works are involved, a desktop assessment of the geothermal hazards should be undertaken (Step 3). Even where the above types of building works are not be undertaken, material durability may still be an issue to address (refer to Steps 1B and 7).

STEP 3 Desktop Assessment

If the initial location screening indicates the potential for geothermal hazards (step 1A) and the type of building works is identified as potentially increasing risk (step 2), a desktop assessment of geothermal hazards should be undertaken.

If the building works require building consent, a summary of what has been considered in the assessment and findings should be included with the application.

If there is any suggestion of a geothermal hazard, then involvement of a geo-professional is recommended. In any case, a geotechnical report will often be required to support building consent applications and, if so, a desktop assessment is a routine step in any geotechnical assessment and the council would expect the geotechnical report to discuss the results.

Set out below are key sources of information for the desktop assessment, but the assessment may also draw on other key sources of information, such as the New Zealand Geological Database (www.nzgd.org.nz).

i. District and Regional Council Maps - Bores and Surface Features
A check should be of whether there are any recorded bores or surface features affecting the site or neighbouring sites (refer above in Step 1A (ii) and (iii) for where to access the information).

ii. Previous Applications
Previous building consent and resource consent applications may potentially contain information about geothermal hazards, for example, in geotechnical reports submitted to support the applications. You can identify previous consent applications by requesting a property file or LIM (see below) then request the associated applications in full.

iii. Records of Title
In some instances, records of title contain relevant information, for example, about geothermal pipe infrastructure. Titles can be purchased online directly from LINZ or other websites.

iv. Previous Studies
Previous studies may suggest areas subject to geothermal hazards.

For Rotorua city, the following figures are of assistance in identifying areas of potential heated ground and/or geothermal gas: [3]

- Figure 11 shows areas with potential elevated heat and/or geothermal gas emissions in the Rotorua Geothermal System compiled by Tonkin & Taylor using a previous study (Tonkin & Taylor, 2022) (Finlayson, 1992). While the map broadly indicates where gas and/or heat issues may be present, as the source data was limited in coverage, the possibility that geothermal gas is present in other areas cannot be ruled out.

[3] Other studies relevant to Rotorua City include further soil gas surveys (Hollingworth, 2016; Werner & Cardellini, 2006) and thermal imaging (Reeves & Rae, 2016).

- Figure 12 shows Sensitive Management Areas (blue, pink and yellow areas) adopted by the Bay of Plenty Regional Council in the Ngā Wai Ariki o Rotorua He Mahere Wahahaere Pūnaha - Rotorua Geothermal System Management Plan (Bay of Plenty Regional Council, 2024). These Sesitive Management Areas were developed to minimise the localised and cumulative effects of heat and fluid extraction on the geothermal area, rather than for hazard management purposes. Nonetheless, the information sources used (distance from significant geothermal surface features and geothermal vegetation, resistivity contour and aquifer temperature) are also relevant for geothermal hazard identification.

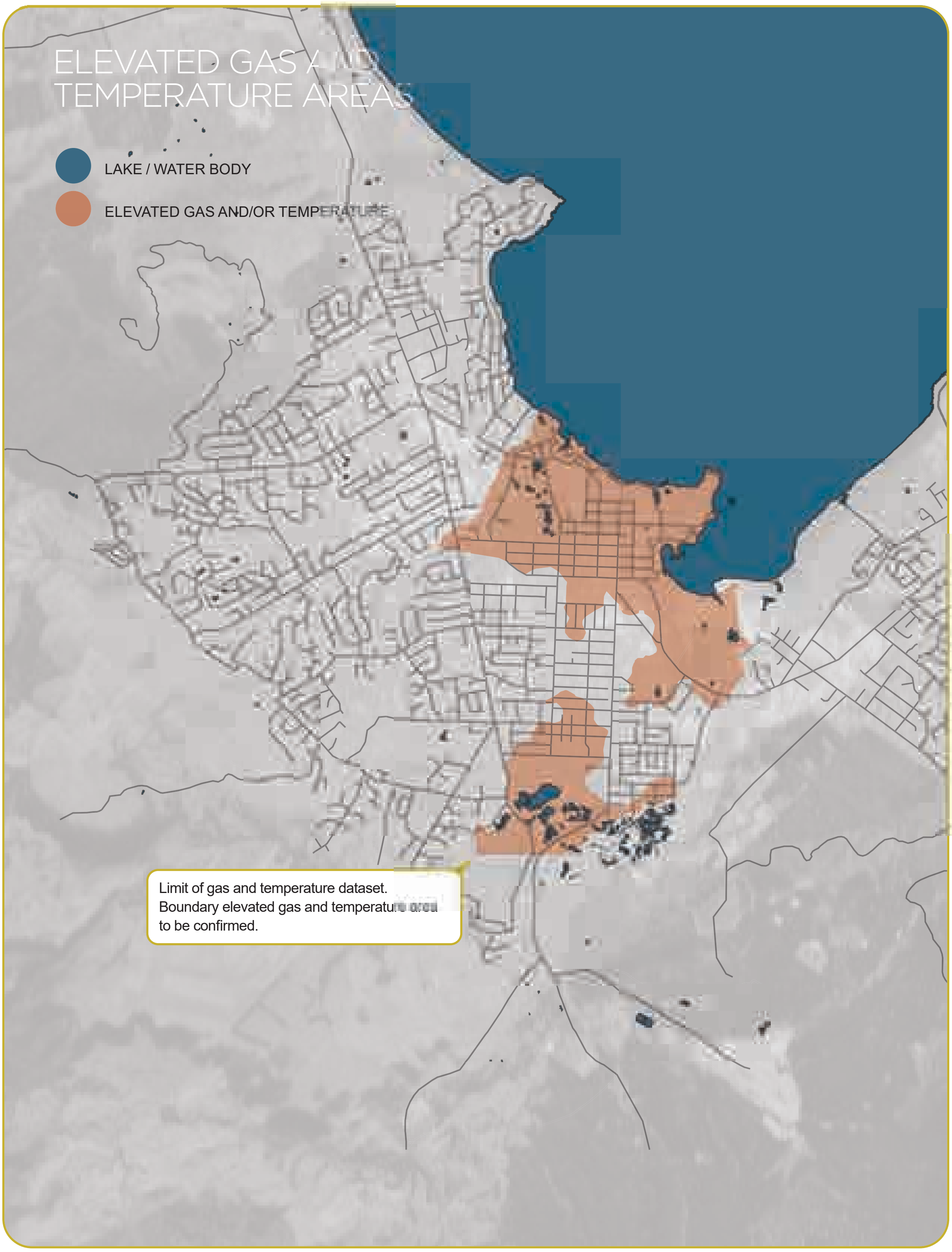


Figure 11 Elevated Gas and Temperature Areas Compiled from Previous Study (source: Tonkin and Taylor, 2022)

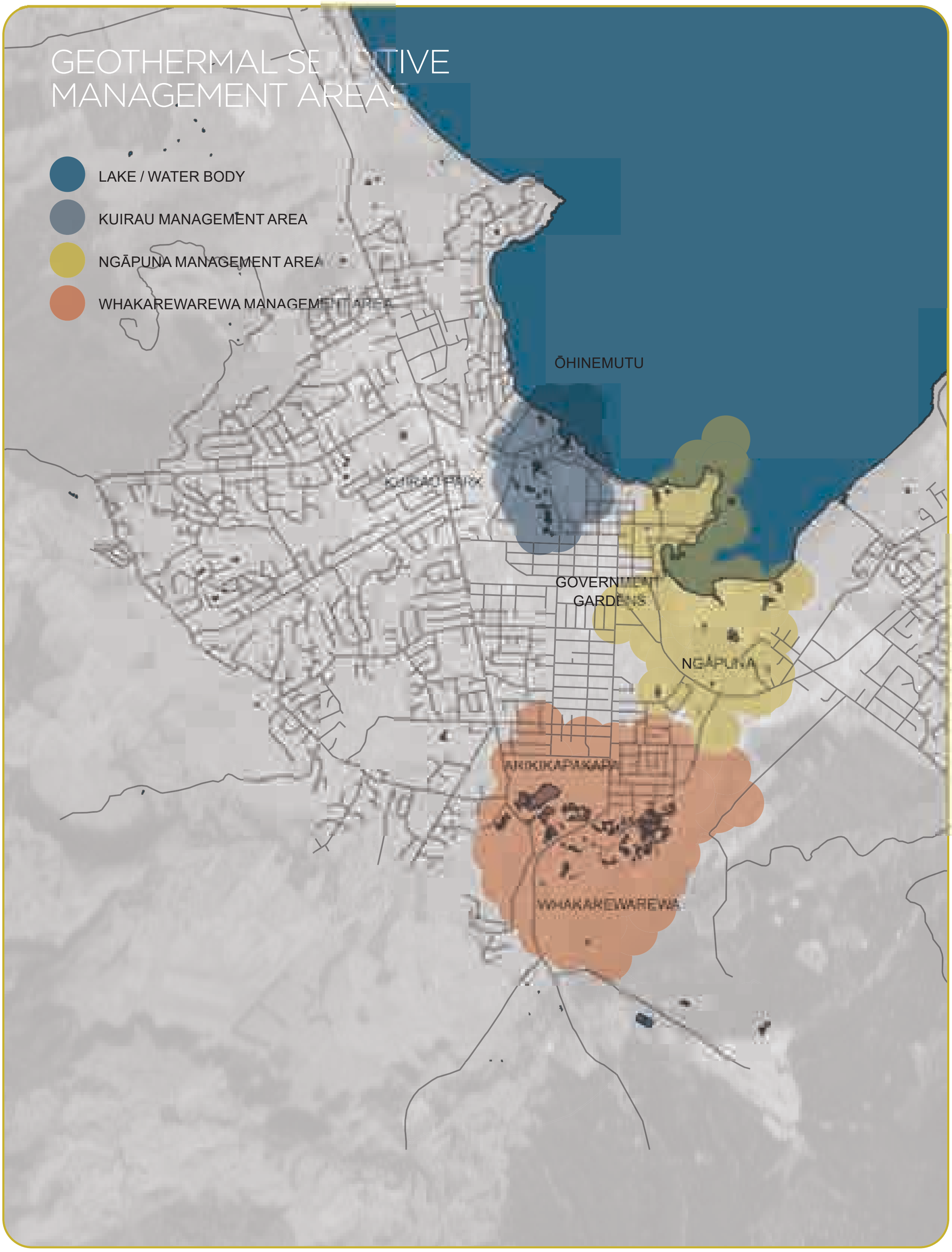


Figure 12 Bay of Plenty Regional Council Geothermal Sensitive Management Areas (source: Ngā Wai Ariki o Rotorua - He Mahere Whakahaere Pūnaha – Rotorua Geothermal System Management Plan, 2024)

v. Historic Aerial Photos

Historic aerial photos can serve as valuable tools for identifying geothermal hazards by providing a visual record of the evolution and changes in geothermal areas over time. These photos offer insights into the historical distribution and extent of geothermal features, such as hot springs, fumaroles, geysers and less obvious signs of geothermal activity including land subsidence, surface deformation or vegetation pattern changes that may indicate underlying geothermal activity or potential hazards. Historical aerial imagery can be found on Google Earth and the Retrolens website.

vi. Council Property Files and LIMs

Property files may potentially contain information of assistance, such as notations about bores or hazards and decisions on consent applications. Property files can be required through the Rotorua Lakes Council's website. Previous geotechnical reports submitted to support consent applications should be requested.

A Land Information Memorandum ("LIM") report is a summary of information that council holds on a property. Council compiles LIMs using its property file information as well as other information. Therefore, they are a useful way of obtaining some of the information for a desktop assessment. A LIM can be requested through the Rotorua Lakes Council's website.

vii. Local Knowledge and Experience

The site and surroundings should be discussed with site occupants and owners to understand if they have identified any potential signs of geothermal hazards or know any relevant history.

Broader local knowledge of the environment may also be of assistance. For example, areas like Ōhinemutu, Ngāpuna, Whakarewarewa and Kuirau Park are known areas with geothermal activity; there may be accounts from neighbours of geothermal issues; or there may be previous experience with nearby sites.

Step 4 Site Visit

Once a desktop assessment of the site is complete, a site visit should be undertaken to confirm the information found in the desktop assessment and look for any additional signs of geothermal hazards and/or geothermal infrastructure.

If the building works require building consent, a summary of the results of the site visit should be included with the application.
If there are any indications of a hazard, then involvement of a geo-professional is recommended. In any case, a geotechnical report may be required to support the building consent and, if required, the results of the site visit should be included in the geotechnical report. The site visit should include consideration of the matters below.

CAUTION: HEALTH & SAFETY

Site visits can be hazardous, for example:

- **Gas emission exposure:** Potentially harmful gases including hydrogen sulphide (H_2S) and carbon dioxide (CO_2) can accumulate to high concentrations in low lying and/or unventilated areas. Gases can also be released unexpectedly by releasing gases that have accumulated (for example, lifting a manhole).
- **Unstable ground conditions and heated ground:** Geothermal processes can lead to unstable ground and high temperature environments.

Advice on how to manage the risks present during a site visit is not within the scope of the Guidelines. Advice should be sought on appropriate procedures, including any relevant guidance from Worksafe. Independent companies can provide gas measurement and safety equipment, equipment calibration and advice.

i. Geothermal Surface Features

Geothermal surface feature data may not be accurate with respect to the type of features or their location. So the actual location and type of geothermal surface features, both on the site and on nearby sites should be confirmed.

ii. Geothermal Bore Locations

The site visit should confirm the existence and location of bores and other geothermal infrastructure on the site and nearby sites (within 50 metres), such as those illustrated in Figure 13. It is possible that the site will contain unrecorded open or closed/decommissioned bores, or that the recorded location of bores is incorrect.

Bores may have been cut off below the surface. A metal detector may assist in locating a bore.

Whether the bore is recorded on the council maps or not, compliance with regulatory requirements is required. Rotorua Lakes Council should be informed if an unmapped bore or inaccuracies in the information are discovered.

Figure 13 Bore examples. To the left is a typical heat exchange bore. In the example to the right the lower part of a gas vent can be seen at the top of the well (photos: Rotorua Well Drillers)

iii. Geothermally Altered Soils

The presence of geothermal fluids and gases can result in alterations in soil colour and composition (such as those shown in Figure 14 and Figure 15). Unusual or distinct colours, such as reddish-brown, yellow, white or even blue hues can indicate the presence of specific minerals or chemical compounds associated with past or present geothermal activity.

Soil discolouration from geothermal activity at the ground surface as well as in any exposed soil layers (strata) including layers exposed during soil/ground investigations (such as from hand auger or CPT cores) should be identified.

Figure 14 Relict geothermal soil in the Coromandel with unusual bright blue subsoil. (Photo: Matthew Taylor)

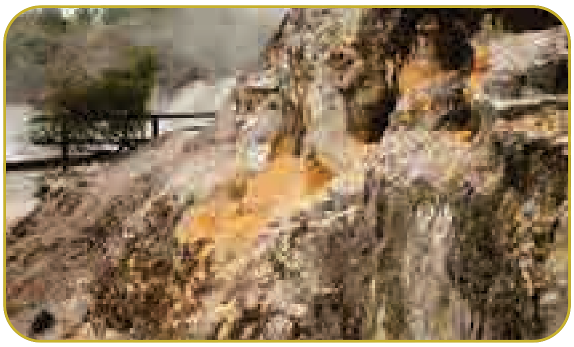


Figure 15 Soil in active geothermal area (Source: GNS Visual Media Library, 128471)

iv. Vegetation Changes

Geothermal conditions, including elevated ground temperatures, altered soil composition, and the presence of specific gases, can significantly influence the growth and distribution of vegetation. Key ways in which vegetation changes can signal geothermal hazards include:

- Stunted or discoloured vegetation;
- Areas of no vegetation growth;
- Altered vegetation patterns; and
- Damage to vegetation.

Geothermal kānuka (Kunzea tenuicaulis, formerly known as prostrate kānuka) is only found in geothermal habitats. There are also plants that are normally only found in geothermal sites, such as the ferns Nephrolepis flexuosa, Dicranopteris linearis and Christella aff. dentata. There are also common plants that are tolerant to geothermal conditions but may also be common in nearby areas such as mānuka (Leptospermum scoparium), turutu / NZ blueberry (Dianella nigra), bracken (Pteridium esculentum) and mingimigi (Leucopogon fasciculatus) (Wildland Consultants Limited, 2014).

v. Depressions in the Land

Depressions in the land can result from various geological processes related to the underlying geothermal activity and, therefore, can indicate potential geothermal hazards such as elevated heat and gas. These variations in the land can be difficult to see but would often be noted by a geo-professional.

vi. Venting of Steam through Pipe Networks

Note should also be taken of any steam venting into the surrounding environment (for example, discharges from piped networks), as this can indicate geothermal heat and/or gas.

vii. Deterioration, Corrosion or Discolouration of Building Materials

Signs of deterioration, corrosion and discolouration of any existing buildings or structures on the site and surroundings should be identified, as these may indicate elevated ground temperatures, geothermal fluids and/or gas emitting on site. Such signs may include:

- Corrosion of metals (which may include rusting and pitting), such as to:
    - structural elements;
    - surfaces (e.g. steel cladding systems, cut edges of flashings or steel cladding);
    - fasteners; or
    - fixtures (e.g. fixings visible through exterior coating systems, fixings of exterior to subfloor structures).
- Deterioration of masonry and concrete, such as:
    - concrete spalling due to corrosion of reinforcing close to the surface; or
    - deterioration of concrete in close proximity to the ground (Figures 16 and Figure 24);
- Discolouration and erosion of materials, such as:
    - discolouration in timber treated with copper-bearing preservatives (typically turned dark blue or brown) (Figure 17);
    - deterioration of the structural integrity of timber member encased in concrete (typically where the timber meets the concrete and moisture is present); or
    - discolouration of electrical or other wire casing (typically brown, grey or black).

- Effects on roofing materials: degradation, premature aging, or corrosion of iron, shingles, tiles or membranes.

Depending on the severity of these signs, the deterioration could indicate airborne gas affecting the wider environment, rather than hazards originating from the site. Regardless of the severity, the findings should be noted, as they may also inform consideration of durability (see Step 7).

Figure 16 Concrete edging at ground level affected by geothermal conditions (photo: Kim Smith, January 2024).

Figure 17 Timber affected by geothermal conditions (photo: (Kim Smith, January 2024).

viii. Presence of Hydrogen Sulphide Odour

Whoever undertakes the site visit should be careful not to expose themselves to potentially dangerous concentrations of gas (for example, in confined spaces, or releasing trapped gases) and purposefully seeking out olfactory signs of gas is not promoted. Note that olfactory thresholds for H_2S vary markedly between individuals and, at lethal levels, H_2S is odourless. Nonetheless, if a smell of H_2S with its distinctive 'rotten eggs' odour is identified during the course of a site visit it should be noted. H_2S can be detected by smell at very low levels. It may indicate emissions of geothermal gas onsite, although the source could also be some distance away.

ix. Deposits of Salts on Surfaces

Salts accumulated on surfaces for example masonry walls, pipes, existing building foundations, paving and nearby manholes should be identified (Figure 18).

Figure 18 Deposit of salts on paving (photo: Kim Smith, January 2024).

Such deposits can indicate the presence of geothermal fluids (including aerosol vapor), which carry the dissolved minerals that then precipitate and accumulate on exposed surfaces. Note that the porous pavement in Figure 18 is allowing the geothermal gases to escape to the atmosphere, as promoted in this guidance (see section 5).

STEP 5 Site Investigations

If the planned building works are in a location identified for further consideration of geothermal hazards (Step 1A) and the building works could increase the risks (Step 2), supplementing the desktop assessment and site visit with further site investigations for heat and gas should be considered. The Guidelines recommend a precautionary approach: if the desktop assessment or site visit suggest any possibility of elevated ground temperature or geothermal gas emissions, then further site investigation should be undertaken.

However, in some circumstances, it may be appropriate to assume a hazard is present and proceed to design to address the hazard without undertaking site investigation. This option should be discussed first with the council's building consent team and will likely require expert advice.

Investigations should be logged in accordance with New Zealand Geological Society Guidelines for the Field Description of Soil and Rock (Williams, et. al., 2005).

If the building works require building consent, a summary of the method and results of the site investigations should be included with the application, even if the site investigations do not indicate gas or heated ground. This will usually be provided within a geotechnical report to support a proposal.

In the absence of a NZ standard or guideline for the investigation of ground gas, the Guidelines support the use of the BS 8576:2013 and the CIRIA guidance on assessing risks posed by hazardous ground gases to buildings (CIRIA, 2007) as a basis for geothermal investigation good practice. This involves measuring gas concentrations and flows within installed gas monitoring wells as an indication of the presence of gas on a site. If elevated concentrations are encountered, mitigation measures should be employed. Where significant flow rates are recorded, or there are obvious signs of gas flux on site, more robust forms of mitigation should be employed. Additional gas flux measurements can also be incorporated into the investigation to provide justification for the design of mitigation measures.

Set out below is further guidance on methods for undertaking the investigations with reference to these standards/guidance. Other approaches to site investigation may be appropriate if supported by expert advice.

CAUTION: HEALTH AND SAFETY

Site investigation in geothermal areas can itself be hazardous, posing potential health and safety risks, for example.

- **Gas emission exposure:** Potentially harmful gases including hydrogen sulphide (H_2S) and carbon dioxide (CO_2), can be released during testing or ground disturbance.
- **Unstable ground conditions:** Geothermal processes can lead to unstable ground, which presents a hazard for drilling and excavation (particularly with heavy machinery).
- **Hot ground:** Testing activities can involve working in high-temperature environments.
- **Geothermal surface features:** Springs and mud pools are hot.

Advice on how to manage the risks present during site investigation is not within the scope of the Guidelines. You should ensure you have sought advice and implemented appropriate procedures, including any relevant guidance from Worksafe. Independent companies that can provide advice, gas measurement safety equipment and equipment calibration.

Geotechnical investigations on geothermal sites may require supervision by a specialist drilling contractor who is familiar with drilling in these conditions. A geotechnical engineer will be able to advise on whether or not this is required based on the risks identified and the likely depth of investigations.

Supervision

The investigations should be completed under the supervision of a geo-professional or a chartered engineer, using appropriate equipment that has been recently calibrated. Most investigations are expected to be undertaken as part of a wider geotechnical investigation for the proposal. Supervision by a specialist driller may be required in high risk areas. A geo-professional will be able to determine if this is necessary.

Types of investigation

Standard ground investigation techniques will be suitable if they provide a large and deep enough hole in which to install a gas monitoring well. Suitable current commonly used investigation methods in New Zealand include hand augers, machine augers and machine boreholes. Gas monitoring wells should be constructed within geotechnical investigations as explained further below.

- Any soil cores should also be examined for soil discolouration (see Step 4 (ii) above).

Location and depth of investigations

The location of monitoring installations should be determined by the development proposal and the nature of the site itself. BS8576:2013 provides further detail on the location of monitoring installations. The depth of the investigations and installations is dependent on the nature of the development plans. Investigations should be undertaken to a depth sufficient to characterise all the soils that may affect the design of foundations. This is normally determined by the geotechnical engineer and should be not less than 2m.

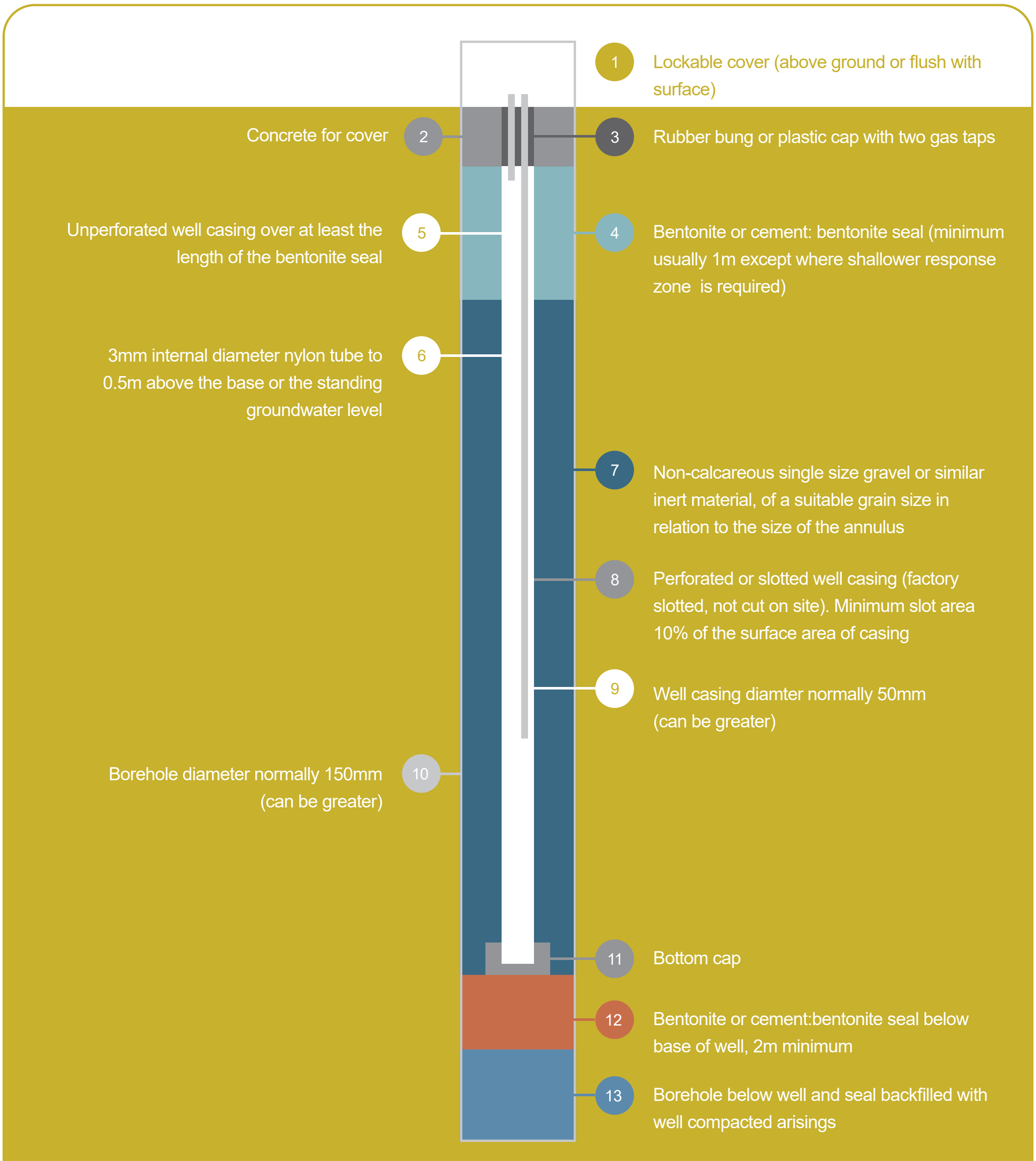
Timing and frequency of monitoring

As discussed in BS 8576:2013 and CIRIA C665, the timing and frequency of the monitoring should be sufficient to allow for the prediction of worst-case conditions. This would typically involve undertaking monitoring over different barometric pressure and pressure trends. Readings should be taken at least three days after the last rainfall event because gas flux and temperature is highly affected by rainfall (Yang, et al., 2024). Rainfall records should be included in the submitted information.
A minimum of three rounds of monitoring is recommended.

Construction of gas monitoring wells.

Construction of a gas-monitoring standpipe is illustrated in Figure 19 and full details are given in BS8576:2013. The following minimum requirements should be considered when planning installations:

- 50mm diameter HDPE pipe installed to full target depth
- Pipe should be slotted to 0.5 metres from the surface
- Slotted section to be surrounded by a filter medium such as gravel.
- Top 0.5 metres to be sealed using hydrated bentonite pellets or bentonite/cement grout
- The pipe should be capped with a removable plastic cap or rubber bung a ball gas valve.
- A flush fitting lid to prevent damage should cover the gas cap.



Well installed partway into borehole

Note 1: Oversize covers are required with certain high-frequency monitors that are installed in the well head space
Note 2: Bentonite or cement:bentonite pellets require hydrating and compacting

Figure 19 Typical well design (Based on the diagram in BS 8576:2013).

The full standard can be obtained from BSI Knowledge: knowledge.bsigroup.com.

Gas measurement methodology

Gas concentration, borehole flow rates and pressure, should be undertaken in general accordance with BS 8576:2013. As per the recommendations of BC8576:2013, the following site measurements should be taken:

- Pressure in the well
- Gas flow
- Background gas concentrations, atmospheric pressure and temperature
- Gas concentrations (hydrogen sulphide, carbon dioxide and methane). Initial value, and at 1 minute intervals for 5 minutes.
- Well temperature
- Depth to ground water
- Depth to base

In addition to this, the following information should be collected during each round of monitoring:

- Weather conditions (temperature, atmospheric pressure, wind, rainfall) for a minimum of three days prior to and post each monitoring round
- The condition of the ground surface around the well (dry, wet, signs of settlement or distress, etc.)
- Condition of the well
- Any strong or unusual odours
- Visible or audible indication of gas migration
- Any relevant site activities that could affect results
- Evidence of condensation in the well.

Measured gas concentrations and flows can be compared against the following suggested values as an indication of the presence of a gas issue. Flow rates may be used as further justification for the adoption of different mitigation options using a quantitative risk assessment approach.

Parameter	Guideline level	Reference
Hydrogen Sulphide	1 ppm	NZ WorkSafe 8-hour time weighted average is 5ppm. Common background H_2S levels in Rotorua are 0.03 ppm. 1 ppm is indicative of elevated gas.
Carbon dioxide	5000 ppm	NZ WorkSafe 8-hour time weighted average
Methane	1000 ppm	USEPA 1995: Air Emissions from Municipal Solid Waste Landfills – Background Information for Final Standard and Guidelines. EPA 453/R-94-021.

Ground Temperature Methodology

- Soil temperature readings shall be measured at depths of 0.2m, 1m and 2m below ground (for example, inside hand or machine auger boreholes used for broader geotechnical site investigations or using CPT temperature readings). Temperature readings may also be needed to a greater depth depending on the nature of the development.
- A temperature 10° C or more above ambient is suggested as a suitable threshold to identify heated ground hazard for most proposals.
- Determination of ambient ground temperature should ideally be established from a site known to not be affected by hot ground. However, ground temperature at depths of up to 2 metres is generally within the range of 15-20° C. Therefore, a value as low as 25° C could indicate geothermally heated ground.

Lodging of data gathered

Council encourages all ground investigation data eligible for inclusion in the New Zealand Geotechnical Database (completed by professional geotechnical and structural engineers) to be uploaded into the database. Council supports this national initiative for its wide potential benefits, including informing future developments and broader hazard mapping and planning.

Step 6A Determine if Hazards are Present

A determination should then be made, using the information gathered in the desktop assessment, site visit and site investigation, about whether geothermal hazards are present on the site, such as:

i. Presence of geothermal bores or other infrastructure (such as pipes or vents) on the site or adjacent sites.

ii. Proximity to geothermal surface features or historic surface features.

iii. Heated ground.

iv. Corrosive ground or potential ground instability.

v. Point source or diffuse geothermal gas emissions from the site.

The conclusions should be included with any building consent application.

If there is any indication that there may be a hazard, involvement of a geo-professional is recommended in this determination. In any case, a geotechnical report will often be required to support a building consent application. If a geotechnical report is required, the person submitting that report should include their conclusions on the presence of geothermal hazards, along with the summary of the assessments undertaken.

If it is determined that geothermal hazards are present, the building and associated site works should be designed to address these hazards (see section 5).

Regardless of whether it is determined that a hazard to be present, it is necessary to consider whether there are durability issues on the site (see Step 7 below).

Step 7 Determine if Durability Issues are Present at the Site

Buildings in some areas of the Rotorua district need special design to ensure their materials are durable to the deterioration caused by geothermal processes (see section 2.2). The Guidelines suggest that, in the absence of other information or expert advice, if the site is within 500m of a geothermal surface feature, consideration should be given as to whether there is any evidence of durability issues in the local environment (microclimate) to address.

Refer to Section 4.2, Step 4 (vii) above for signs of durability issues in the microclimate.

4.3 VIGILANCE DURING PREPARATORY WORKS AND CONSTRUCTION

Once the preparatory works (including any supporting ground improvements) and construction starts, those undertaking the works should remain vigilant for any signs of geothermal hazards, even if no indication of geothermal hazards had been found previously. Things to look for include:

- Indications of geothermal activity in excavated or exposed earth layers (see description above in section 4.2, Step 4 (iii);
- Sulphur smell when excavating;
- Signs of material damage or corrosion that may have been missed in the initial assessment such as blackened timber, eroded concrete and masonry;
- Ground cavities/tomos;

- Elevated ground temperature or warm ground; and
- Suspicious bird or other animal deaths.

If such indications of geothermal hazards are found, professional advice should be sought. The design may need changing as well as a formal amendment to a building consent.

CAUTION: HEALTH AND SAFETY

Advice on how to manage the risks during construction in geothermal areas is not within the scope of the Guidelines. However, a precautionary approach should be used, even if no geothermal hazards were previously identified. For example, in relation ro entering excavations.

5. DESIGNING TO ADDRESS GEOTHERMAL HAZARDS

5.1 INTRODUCTION

This section provides high-level guidance on how to design buildings and associated site works to reduce the risks from the potential geothermal hazards identified (refer to Section 4 – Hazard Identification, above).

The Guidance is intended only as a starting point to be supplemented by expert advice.

The presentation of the risk reduction options here does not imply that all geothermal hazards risks can be reduced to an appropriate level of on every site. Those planning building works should also consider whether the development they are contemplating is appropriate on the site in the context of the hazards identified and any residual risks that would remain if steps were taken to reduce the risks.

5.2 SITE LAYOUT

Set out in the table below are potential options and considerations for site layout to reduce the risk on sites potentially affected by specific geothermal hazards. These site layout options may sit alongside building design responses discussed in the subsequent sections.

SITE LAYOUT

Possible Options and Considerations	Explanation	Where to get more info / advice
1 Set buildings, structures and site works (including impervious surfaces) away from geothermal surface features.	The further away buildings, structures and site works can be located from surface features, the less the risk to people and property. Setting buildings and other activities away from surface features also assists to protect the important biodiversity and natural values. The Rotorua District Plan requires that buildings are setback at least 5m from a geothermal surface feature, otherwise resource consent is required. However, this may not be sufficient to manage the hazard in the particular circumstances or to meet the relevant regional plan requirements. Within the Rotorua Geothermal System, the Bay of Plenty Regional Council's 'Rotorua Geothermal Plan' does not contain a specific setback but requires resource consent for any interference with the natural geothermal fluid outflow from a surface feature, and interference with the physical structure of a surface feature, including any destruction, excavation, or placement of any substance within a surface feature. In the Waikato region, the regional plan requires resource consent for most soil disturbance and vegetation clearance (including for most building works) within 20m of a significant geothermal feature. An appropriate setback should consider both the type of surface feature and the planned works.	A suitably qualified and experienced geo-professional for advice on a suitable setback. Rotorua Lake Council's and Bay of Plenty or Waikato Regional Council's planning team regarding plan requirements.
2 Maintain areas around bores free from buildings and other obstructions (even if the bores are closed or on a neighbouring site).	The Rotorua District Plan and Rotorua Geothermal Bylaw require that buildings and structures are located at least 5m away from a bore, otherwise consent is required. This is to enable machinery to access the bore for remedial works in the event of uncontrolled emissions of gas, steam, mud etc. (Figure 21). Maintaining the area around a bore free from obstructions also allows access for regular maintenance and decommissioning of bores. Furthermore, locating buildings and other structures away from active and closed bores also reduces the risks of damage to property and health risks to occupants should uncontrolled emissions occur. Bore headworks can appear unsightly; but avoid pergolas or other screening structures that hinder access in the event of an emergency. (See also below regarding maintaining heavy vehicle access from the road to bores on a site).	Rotorua Lake Council's duty planner regarding the District Plan requirements. Rotorua Lakes Council's bylaw compliance team if you are considering locating a building or a structure within 5m of a bore. Local well drillers may also be able to provide advice about designing the site for ease of access to bores.

3 Maintain access for heavy vehicles and machinery from the road to any bores on a site (including to any closed bores).

The Rotorua Geothermal Bylaw requires that sites maintain access for a drilling rig to bores. This is to allow the ability to respond to uncontrolled emissions, maintain and decommission bores.

This can be achieved with a 3m wide heavy vehicle access corridor from the road to the bore and a 5m radius machinery operating area around the bore (see also above). This access should be unobstructed by buildings or other structures, of a reasonable gradient, be suitably surfaced and have appropriate turning circles for a heavy vehicle.

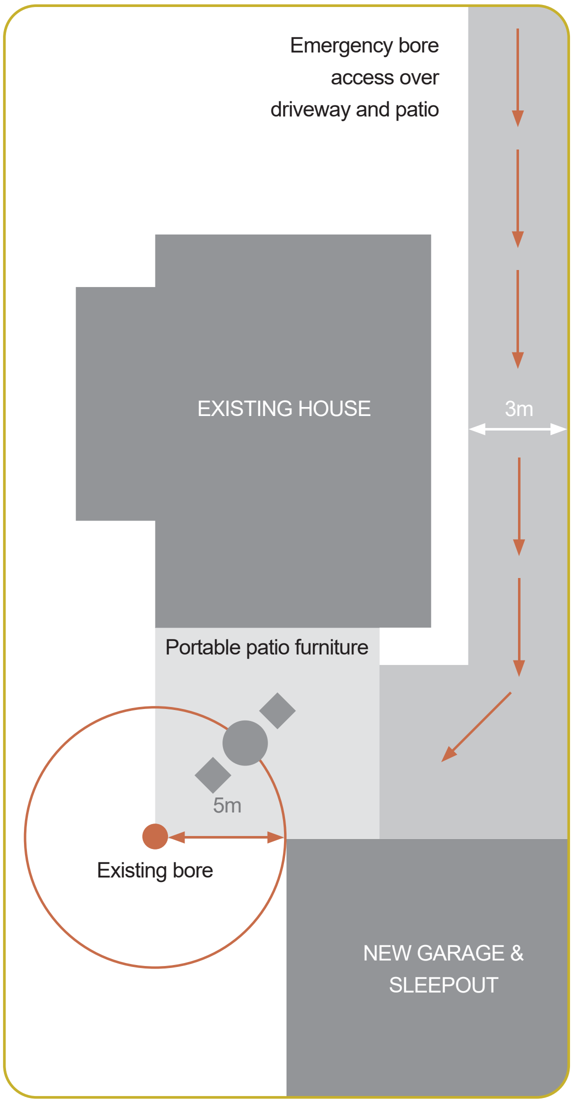


Figure 20 Conceptual example of site layout to maintain access to an existing bore with development of new garage and sleepout.

Rotorua Lakes Council's bylaw compliance team if you may have an issue maintaining access to a bore.

4 Avoid enclosed or partially enclosed outdoor spaces if diffuse geothermal gases emissions may be present on a site.	Avoid creating enclosed or partially enclosed outdoor spaces with low natural ventilation, inside which harmful geothermal gases (that are heavy and displace air) could build up to dangerous concentrations. For example, semi-enclosed areas between buildings and solid fences, or in depressions. Consider how the development may create confined spaces not just on the subject site but also on neighbouring sites.	Suitably qualified and experienced design professional
5 Ensure surface treatment allows natural gas venting and ground cooling to occur if diffuse geothermal gas emissions or elevated ground temperatures may be present on site.	Hard surfaces such as concrete slab buildings, concrete driveways and sealed parking areas that restrict the natural 'venting' of gases can mean that gas emissions become concentrated into unwanted areas, such as neighbouring properties. These hard surfaces also create a barrier to natural ground cooling processes including rainwater percolation. Find opportunities to substitute hard impervious surfaces with alternatives that allow venting and cooling. For example, substitute concrete paths with permeable pavers.	Suitably qualified and experienced design professional
6 Take into account the location of any existing gas venting structures	Geothermal bores and associated infrastructure often include gas vents. Some building designs also collect gas from under the building footprint and vent the gas through a structure. Any activities located near these venting structures need to consider the risks associated with the concentrated emissions of gases from the vents.	Environmental engineer or other suitably qualified and experienced design professional.

Figure 21 Geothermal venting structure (photo: Kim Smith, January 2024).

Figure 22 Example of space required around a bore for a drilling rig and plant (photo: Rotorua Well Drillers).

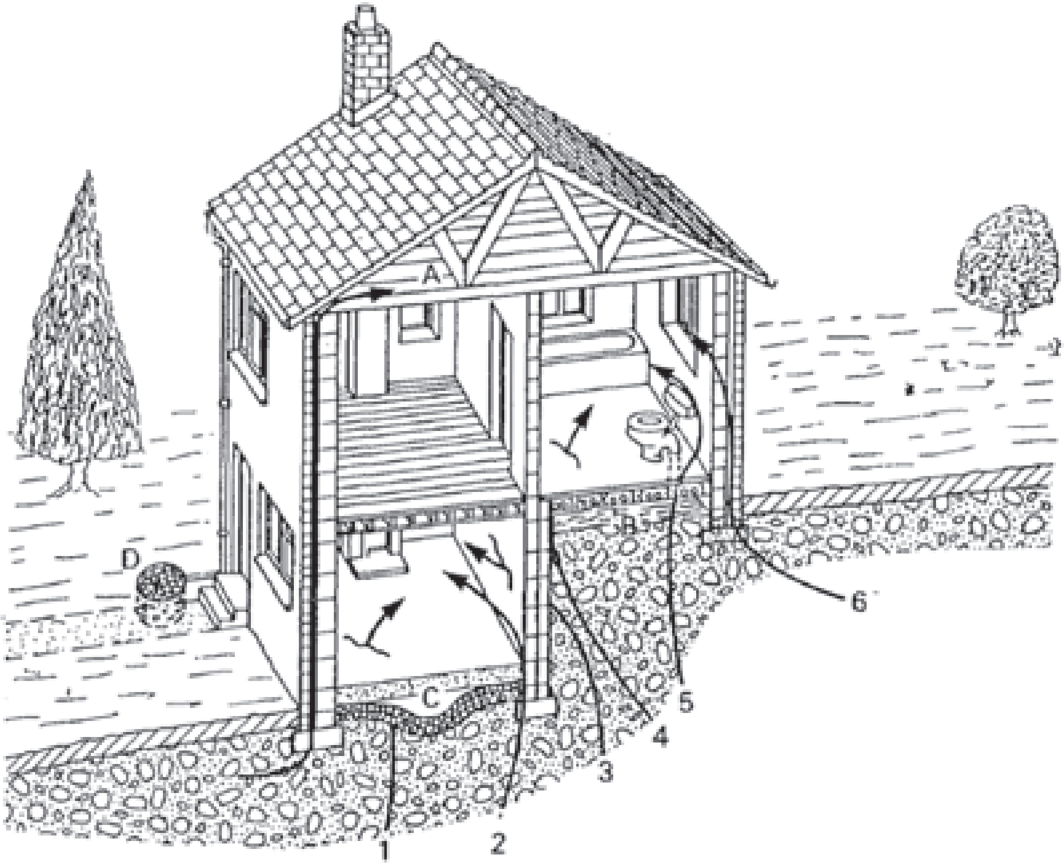
5.3 BUILDING DESIGN FOR MANAGEMENT OF GAS

The following table provides information on potential building design options and considerations for sites affected by diffuse geothermal gas emissions. This is only an introduction to the options and expert advice should be sought. Sites affected by geothermal gas emissions are often also affected by elevated ground temperature, which is discussed separately in the next section.

DESIGNING BUILDINGS ON SITES WITH POTENTIAL GEOTHERMAL GAS EMISSIONS

POSSIBLE OPTIONS AND CONSIDERATIONS	EXPLANATION	WHERE TO GET MORE INFO /ADVICE
1 **Raised floors**	Raising building floors above the ground and allowing ventilation underneath is a key approach to reduce the risk of geothermal gas entering buildings. This approach has less vulnerability with respect to the integrity of materials, installation and vulnerable points such as junctions and floor penetrations than the barrier (membrane) option. Therefore, it can reduce residual risk and the risks as the building ages beyond its design life. On the other hand, it relies on maintaining sufficient passive ventilation to prevent the concentration of gases under the building, which also presents a risk and may not be suitable for high-risk sites without further protection from gas ingress. Potential considerations include: › Designing of the subfloor space to ensure additional ventilation above that specified in NZS 3604: 2011 › Locating services outside the building footprint instead of underneath the building to avoid service penetrations from below and the need to access the subfloor. › Providing additional subfloor access points near services to reduce risks associated with accessing the subfloor. › Use of easy clean traps to showers to avoid the need to access the subfloor. › Avoiding siting buildings in depressions	Suitably qualified and experienced design professional supported by geo-professional advice on appropriateness of option. CIRIA guidance document C735

2 Slab on ground with barrier	The other main approach to reduce the risk of geothermal gas entering a building is to install a gas-proof barrier under the floor (membrane). Potential considerations include: - Key gas ingress routes such as between the floor and walls or through cracks in walls (Figure 23). - Qualifications and experience of installers. - Good work practices to avoid damage to membrane during installation and construction. - Suitability of the membrane and welds to site conditions (such as temperature, pH and groundwater). - Avoiding stresses in the membrane such as from right angles. - Design and location of penetrations for services. - Avoiding un-trapped wastes without a water seal (such as a floor waste or from a water cylinder safe tray), which could increase the risk of gas entry. - Additional ground treatment adjacent to doors and low-level windows to reduce the risk of gas intrusion, for example, extending the membrane past the perimeter of the building in these locations. - Undertaking integrity testing prior to foundation construction. - Avoiding siting buildikngs in depressions. Some buildings on high-risk sites include structures to collect gas in the ground under the building and vent it in a controlled way. If this approach is used, consider the location and design of the vents to avoid risks to people using the site and neighbouring sites.	Suitably qualified and experienced local design professional. Product manufactures/product certification/specifications. CIRIA guidance document C735.
3 Internal ventilation	While not considered a primary design option to reduce risks, internal ventilation may still have a role in reducing residual risk (that is, used in addition to other options) or respond to existing issues. This could include forced pressurised ventilation systems.	Suitably qualified and experienced ventilation expert and/or engineer.
4 Internal air quality monitoring	Monitoring of gas concentrations inside buildings is another option to reduce residual risk or potentially respond to existing health and safety issues. However, this is not considered a primary design option for new building works.	Suitably qualified and experienced engineer.



KEY TO INGRESS ROUTES

1. Through cracks and openings in solid concrete ground slabs due to shrinkage/curing cracks.
2. Through construction joints/openings at wall/foundations interfere with ground slab.
3. Through cracks in walls below ground level possibly due to shrinkage /curing cracks or movement from soil pressures.
4. Through gaps and openings in suspended concrete or timber floors.
5. Through gaps around service pipes/duct.
6. Through cavity walls.

LOCATIONS OF GAS ACCUMULATIONS:

- A Roof voids.
- B Beneath suspended floors.
- C Within settlement voids.
- D Drains and soakaways.

Figure 23 Key ground gas ingress routes and accumulation areas within unprotected conventional residential buildings (based on Figure 3 in CIRIA Report 149 (CIRIA, 1995), reproduced with the kind permission of CIRIA).

5.4 BUILDING DESIGN FOR ELEVATED GROUND TEMPERATURES

There is little national guidance on overheating in buildings and an absence of detailed building performance expectations. Nonetheless, it can still present a compliance issue in terms of F1 of the Building code (see Section 3.2) and impact the quality of living environments.

International standards suggest temperature in bedrooms is particularly important for health (and, therefore, compliance with F1 of the Building code) due to the impact on sleep. The United Kingdom standard CIBSE TM59, for example, provides the following performance expectations:

1. In a naturally ventilated home, TM59 prioritises getting a good night's sleep by stating that bedrooms may only be warmer than 26°C for 1% of the year's sleeping hours (10pm-7am). The allowable temperature in the rest of the home - which includes the bedrooms between 7am and 10pm - involves a more complex calculation of the percentage of the year these rooms spend above the 'comfort temperature'. The comfort temperature, in turn, varies throughout the year.

2. In a mechanically ventilated home TM59 uses the simpler criteria that the temperature may only exceed 26°C for 3% of the annual occupied hours. 6This is calculated separately for each room.

The above UK guidance is not for optimum temperatures for comfort and a quality living environment, but rather a 'minimum' standard. Optimum temperatures are subjective, but the UK standard states that sleep quality is likely to be compromised above 24°C, so a reasonable target for a home is to stay below that temperature.

The table below discusses possible building design options and considerations to address overheating on sites with elevated ambient ground temperatures. The appropriate response will depend on the measured site temperatures and the plans for the site.

DESIGNING BUILDINGS ON SITES WITH ELEVATED GROUND TEMPERATURE

Possible Options and Considerations	Explanation	Where to get more info / advice
1 **Raised floors and insulation**	Raising building floors above ground level to provide ventilation, combined with underfloor insulation to create a thermal barrier, is one potential approach to managing heated ground (see above also for the use of this option for managing gas). Potential considerations include: › Design of the baseboards on the subfloor space to ensure additional ventilation than that specified in NZS 3604:2011. For example, through the use of slatted baseboards. › Design of insulation/thermal barrier. › Heat conduction through the foundations.	Suitably qualified and experienced engineer.
2 **Ground improvements**	Ground improvements could be considered to re-direct heat in the subsurface away from the building. However, there is a lack of known examples of this practice being purposely used to reduce overheating.	Suitably qualified and experienced engineer and/or geo-professional.
3 **Insulation of slab-on-ground buildings**	Conceivably slab-on-ground buildings could be designed with a thermal barrier/insulation to reduce heating of the building or insulating aggregates could be incorporated within the concrete. However, there is a lack of known examples of this practice being purposely used to reduce heat transfer from the ground.	Suitably qualified and experienced engineer.
4 **Alternative buildings/ structures that are less \ vulnerable to heat**	In areas affected by high ambient ground temperatures, alternative types of buildings/structures may be able to be used to meet the building project outcomes, while also reducing the risk of problems associated with heat. For example, building an open carport instead of an enclosed garage.	Suitably qualified and experienced engineer.
5 **Internal ventilation and cooling systems**	Even if the potential temperature of a building may not be significant enough to identify a Building Code compliance issue, consideration should still be given to supporting the comfort of occupants through options such as mechanical or passive ventilation and cooling systems.	Suitably qualified and experienced design professional.

6. DESIGNING TO ADDRESS DURABILITY ISSUES

Geothermal conditions (with elevated ground temperatures, different soil substances, geothermal gases and aerosols) can affect the durability of a wide variety of materials in a building and in the associated infrastructure and site works. Due to the aerosols and air-borne gases, these durability issues can affect the areas some distance from the sources of steam and geothermal gas emissions.

Careful selection of materials is required to address the durability issues identified. If the product manufacturer information does not address the suitability of the product to the specific conditions on your site then you should seek additional information from the manufacturer or an expert statement.

General guidance for durability is:

1 Choose materials with a focus on durability

This guidance encourages a focus on product selection for durability. Actively seek product information.

2 Design for reasonably expected lifetime

When choosing products you are encouraged to think beyond the minimum life requirements for building elements in the Building Code to what is reasonably expected for each building element.

CONCRETE REQUIREMENTS

NZS 3101.1:2006, which is used by structural engineers to design concrete structures, provides information on concrete constituents/additives appropriate to attack from aggressive soil and groundwater conditions (such as from geothermal conditions).

It requires sulphate and pH testing.

3 Design for ease of replacement

The enhanced deterioration caused by geothermal conditions means that building elements may need to be replaced more often than normal (notwithstanding that the minimum requirements of the Building Code may be met). Consider how to design the building to minimise inconvenience and expense during replacement. For example, site electrical wiring to reduce costs and disruption of replacement.

4 Materials used for services should also be durable

Consideration of appropriate building materials should also extend to choice of materials for services. For example, common stormwater piping materials deteriorate in high ground temperatures.

5 Give particular attention to materials in the ground or located just above ground level.

Durability issues are particularly evident in materials located in the ground or just above ground level because of the soil conditions in geothermal areas, potentially elevated temperatures and the interaction of geothermal gases with groundwater (Figure 24).

Figure 24 Deterioration of building materials at ground level (photo: Kim Smith, January 2024).

GLOSSARY

DESIGN PROFESSIONAL

Those professionals that are involved in designing building work: Licensed Building Practitioners in the design class, New Zealand Registered Architects or Chartered Professional Engineers.

GEO-PROFESSIONAL

A professional advisor with expertise and specialisation in the field of geology, geotechnical engineering, or related earth sciences. These professionals possess knowledge of natural processes, allowing them to assess and analyse various geological features, materials, and formations. Geo-professionals often work in diverse areas such as environmental assessment, geotechnical engineering, geological surveys, natural resource exploration, and hazard mitigation. Geo-professionals play a critical role in ensuring the sustainable and safe development of projects in areas influenced by geothermal factors.

It is expected that the level of expertise and experience of geo-professionals supervising site investigations or providing geotechnical advice to support consent applications will correspond to the level of complexity of the land involved, as follows:

Level of Complexity	Land Description	Level of expertise expected for supervising site investigations and for geotechnical reporting
Level 1	Land is located in the geothermal field and the desktop investigation and site visit have not identified any indication of geothermal hazards	Supervision of investigation and reporting to be verified by a Chartered Professional Engineer (CPEng) with a working knowledge of geotechnical and geothermal issues within the Rotorua District.
Level 2	Land is located in the geothermal field and the desktop investigation or site visit has identified the potential for geothermal gas emissions or elevated ground temperature.	Supervision of investigation and reporting to be undertaken by a geo-professional with a sound knowledge of geothermal hazards. Reporting may also be undertaken by a CPEng and peer reviewed by a geo-professional with a sound knowledge of geothermal hazards.
Level 3	Land contains or is adjacent to a geothermal surface feature.	Supervision of investigation and reporting to be undertaken by a geo-professional with an expert level of competency in geotechnical engineering and detailed knowledge of local geothermal conditions.

GEOTHERMAL AREA

An area affected by geothermal processes without formal defined boundaries. The use of this term as an alternative to geothermal system in the Guidelines reflects that the mapping of the extent of geothermal systems is dependent on the definition, criteria chosen and data available and that areas affected by geothermal processes (such as airborne geothermal gas and steam) may extend outside formal mapped geothermal systems.

GEOTHERMAL SYSTEM

For the purpose of the Guidelines, a geothermal system is a body of geothermal energy and geothermal water with an extent mapped by scientific investigation. Such a system also includes materials containing heat or energy surrounding any geothermal water and plants, animals and other characteristics dependent on the body of geothermal energy and geothermal water.

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DOCUMENT HISTORY

Version 1	June 2024	
Version 2	April 2025	Update to the definition of geo-professional

ROTORUA
LAKES COUNCIL
Te Kaunihera o ngā Roto o Rotorua