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Sinter-forming springs and geysers of the Waikato region

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Acknowledgement

This report is the work of several people over many years. David Speirs of Waikato Regional Council first commissioned it from Council's geothermal monitoring contractor Ashley Cody, and then it grew with the addition of photographs, more accurate map coordinates, spring numbers in various numbering systems, and recent commentary updates by subsequent observers. All the contributors have provided valuable enhancements.

We extend our many thanks to the land owners and occupiers who have allowed us access to the geothermal features on their land, and who act as kaitiaki and look after the features on a day-to-day basis. Thanks are also due to the many people in the geothermal community who have undertaken useful research and observation over many years in related topics, and those who have provided comments on the contents of this report.

There have been unavoidable delays in bringing this report to print, but now that it has been published, Waikato Regional Council staff hope that it will provide a useful statistical summary of the region's rarest and most vulnerable, and most highly prized, geothermal surface features.

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Abstract

Sinter-forming springs and geysers are among the rarest, the most vulnerable, the most spectacular and the most prized among the Waikato Region's geothermal surface features.
This report provides an inventory of sinter-forming springs and geysers in the Waikato Region, and provide notes on their location, activity, characteristics, and any threats that they face. It is hoped that this report will assist the preservation of these features by providing a guide to assist further monitoring.

There are 169 sinter-forming springs in the Waikato Region, down from 668 in the 1950s, and 51 geysers, down from 161. The greatest loss of features was caused by the inundation of many features at Orakei Korako when the Ohakuri Dam was constructed for hydroelectric electricity generation, and by the extinction of features on the Wairakei-Tauhara Geothermal System due to the large-scale extraction of deep geothermal fluid for the Wairakei Power Station.

Waikato Regional Council's policy framework under the Resource Management Act 1991 (New Zealand Government 1991) now protects these features and so there has been little change in numbers since the 1990s when the policy was formed.

1 INTRODUCTION

One of the Waikato Regional Council's statutory requirements, as set out in the Resource Management Act (1991) Section 35, is to describe the state of the regional environment. In conformity with that requirement this document aims to describe the current state ("condition") of all known sinter-forming hot springs and geysers in the Waikato Region.

Geothermal surface features are rare internationally, nationally, and regionally. Geysers and sinter-forming springs are among the rarest, and the most prized as a tourist and scientific resource. They are also the most vulnerable to adverse effects from both large-scale extraction of geothermal fluid and surface interference.

New Zealand has more geothermal resources than many nations, and a significant proportion of the world's geysers and sinter-forming springs are concentrated within the Waikato Region (Bryan, 2018). The number of geysers and sinter-forming springs within the Waikato Region dropped sharply in the mid- to late-20th century due to geothermal power developments and other human effects.

The Waikato Regional Policy Statement (RPS) classifies some types of geothermal features as Significant Geothermal Features and sets out issues, objectives, policies, implementation methods, and rules relating to their protection. Geysers, hot springs, recent sinter, and mud geysers are all listed as Significant Geothermal Features.

The RPS also classifies the Region's geothermal systems into five usage categories and sets out issues, objectives, policies, environmental results anticipated, and implementation methods including rules relating to the activities that may be carried out on each type of system.

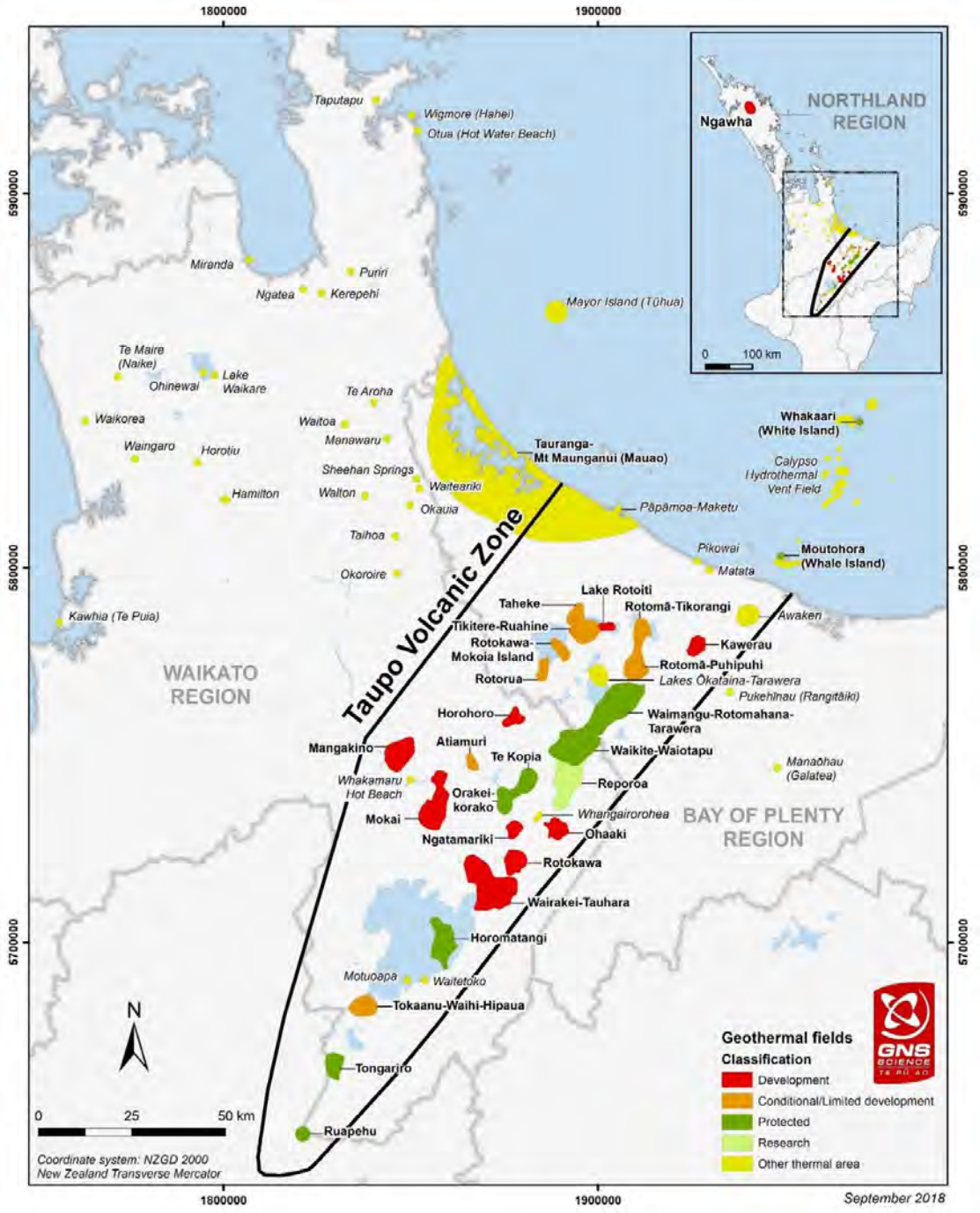
With human activity having caused many of the changes that have occurred within historical times and with Waikato Regional Council's responsibility to protect the environment within the Waikato Region, a key aspect of this report is an assessment of the vulnerability of each individual feature to artificial modification.

This document thus provides an inventory of geysers and sinter-forming hot springs in the Waikato Region, the changes that have occurred to their number and condition, and the threats that they face. It is hoped that this report will provide practical information for the purposes of policy development and public education, act as a baseline for further reports, and be a useful resource for researchers in the field.

Each feature is listed under the geothermal system in which it is found, it is briefly described, its location is detailed, some historical details are provided, and references to further information about it are given. Those features that have become inactive or have been inundated recently are also noted, although, in general, fewer details are provided in these cases.

There may be springs in existence that do not appear in this report. The authors therefore welcome any corrections or additions, details of which should be addressed to Katherine Luketina at Waikato Regional Council (katherine.luketina@waikatoregion.govt.nz).

Map 1: Geothermal Resources of the Waikato and Bay of Plenty Regions (Courtesy of New Zealand Geothermal Association and GNS Science Ltd)



2 EXPLANATORY NOTES

2.1 Spatial hierarchy of geothermal manifestations

A geothermal **system** is an individual body of geothermal energy (including geothermal water), material containing heat or energy surrounding any geothermal water, and all plants, animals, micro-organisms and other characteristics dependent on the geothermal energy. There are fifteen such systems in the Waikato Region (Map 1).

A geothermal system may contain more than one geothermal field. A geothermal field is an area of separate upflow with its own set of surface features, for example the Wairakei and Tauhara fields in the Wairakei-Tauhara geothermal system.

The term 'field' is sometimes used by others to denote an area of geothermal surface features. For example, the Tokaanu, Waihi and Hipaua 'fields' on the Tokaanu-Waihi-Hipaua geothermal system are separate sets of features but they are all fed by the same upflow. That meaning is not used in this document.

Geothermal features are the surface manifestations of a deep geothermal resource. They include hot or steaming ground, hot springs and pools, deposits of silica (sinter), sulphur, and other minerals, mud pool, and fumaroles. A feature or geographical group of features usually has a thermophilic or thermotolerant ecosystem associated with it. A field may contain many groups of such features, which in turn may be logically divided into several subgroups depending on the geography of the area.

The listing of springs in this document follows the hierarchy of field, group, subgroup and then spring. Within each group, the springs are listed according to their geographical location rather than in numerical sequence of the spring numbers.

2.2 Waikato Regional Council Policy Considerations

The RPS identifies five types of geothermal system and sets outs the uses of geothermal resources that may be undertaken in each system. There are 15 large systems within four categories and numerous isolated sets of warm springs in the Small Geothermal System category. There is only one spring in a Small Geothermal System that is listed in this document.

The RPS lists Protected Geothermal Systems. The remaining large geothermal systems are identified in the Waikato Regional Plan. The categories are:

- In **Development Geothermal Systems**, development may occur, and any adverse effects on geothermal features must be avoided, remedied and mitigated. There are seven Development Geothermal Systems: Horohoro, Mangakino, Mokai, Ngatamariki, Ohaaki, Rotokawa and Wairakei-Tauhara.
- In **Limited Development Geothermal Systems**, only development that does not affect geothermal features may take place. The two systems in this category are Atiamuri and Tokaanu.
- **Research Geothermal Systems** are those for which there is insufficient information to classify them otherwise. In these systems only small takes for general uses and larger takes for research may occur. The only system in this category is Reporoa.
- **Protected Geothermal Systems** are those which have a large number of Significant Geothermal Features that are to be protected by an almost absolute restriction on takes. The five systems in this category are: Horomatangi, Orakei Korako, Te Kopia, Tongariro, and Waikite-Waiotapu-Waimangu.

- In **Small Geothermal Systems** takes are permitted as long as they are at a sustainable level and do not adversely affect any geothermal features. There are approximately 30 small systems in the Waikato Region. Their names and indicative locations are found on Map 1 above.

These classifications affect the level of protection and the degree of threat that each geothermal feature listed in this document faces.

2.3 Sinter-forming Springs

As near-neutral, alkali-chloride[1], hot spring water discharges at the surface, it cools to temperatures of less than 100 °C and silica precipitates to form a rock type known as sinter, mediated by microbial communities that thrive in the discharging thermal fluid (archaea, cyanobacteria, diatoms, etc.). Over time, the depositing silica coats, entombs and silicifies all the components within the spring channel, fossilising them within the sinter.

Discharging alkali-chloride fluids are of deep geothermal origin and are chemically distinct from the water of other hot springs, which is either steam heated ground water, or a mixture of geothermal fluid and ground water. Some springs discharge near-neutral, alkaline chloride water but form an acidic pool. This occurs when sulphur is distributed throughout the water and the pool has a large surface area which allows the sulphur to oxidise at the surface and form sulphuric acid. Although these pools appear to be acidic, the deep thermal fluid feeding the pool is in fact, near-neutral alkaline chloride fluid. Therefore, pH alone is not a reliable indicator of deep fluid input. The key indicator of the proportion of deep geothermal fluid present is the chloride concentration in the spring water compared with neighbouring springs.

Deposits of silica can also accumulate at the surface of geothermal fields by the reaction with silicate country rocks by steam condensate acidified by sulphuric acid, derived from oxidation of H_2S (White *et al.,* 1956; Rodgers *et al.,* 2002).

2.4 Geysers

The RPS defines a geyser as:

> "Any naturally occurring geothermal spring that occasionally or frequently erupts producing an intermittent or continuous discharge by the evolution of a phase dominated by steam or other gases, vigorous enough to eject forcefully liquid water by surging, boiling, throwing, splashing, or jetting it into the air above a static water level or vent opening. This includes hot water geysers, perpetual spouters, soda geysers, and crypto-geysers. The area of a geyser comprises that of the spring basin and the area covered (perhaps intermittently) by surface water composed of the undiluted discharge from the geyser, and by any sinter deposits created by that discharge."

The intervals between geyser eruptions can vary over minutes to hours or days, as can the duration of eruptions. However, there is often some regularity or predictability involved in their

[1] Mineral waters have been traditionally named (in short hand) by their dominant dissolved cation (Na, K, Ca, etc.) and dominant anion (chloride, bicarbonate, sulphate, carbonate, etc.). Since there are fewer anions than cations to compete for dominance, the shorthand name often just includes the anion. "Alkali-chloride" is a shorthand term for a water name otherwise based upon the full chemical analysis. "Alkali-chloride" names the dominant cations (the alkali metals Na, K, Mg, Ca, Li, etc) with the anion. In the Waikato Region, many sinter-forming chloride waters come out at higher pH than neutral, and can be referred to as "alkaline" waters.

behaviour. Worldwide, geysers are rare and appear to be short-lived phenomena on a geological timescale.

Inactivity of geysers may be due to natural conditions such as the self-sealing of vents due to sinter deposits or a change in the fluid pathway that feeds the geyser. Alternatively their inactivity may be due to human interference with the parent geothermal systems, e.g. by reducing feed pressure and water levels until geysers and sinter-forming springs can no longer discharge. Wairakei-Tauhara, Tokaanu, and Ohaaki have all lost geysers in such a manner. In addition Ohaaki, Mangakino, Atiamuri, Ngatamariki, Mokai, Rotokawa, and Orakei Korako have lost sinter-forming springs due to inundation of springs when hydro-electric lakes were created. Tokaanu-Waihi and Rotokawa have non-sinter-forming springs that are affected by lake and river level management.

This document uses the term mud geyser for a naturally occurring geothermal mud pool that intermittently or continuously ejects liquid mud by surging, boiling, throwing, splashing, or jetting, more than two metres into the air above a static liquid level.

Mud geysers erupt in a geyser action, but they do not constitute hot springs in that there is little or no input of deep geothermal fluid. Therefore, they do not fall under the RPS definition of a geyser. As with all mud features, the heat is supplied by steam, and the bulk of the water is supplied by rain. Eruptions from mud geysers are bigger by several orders of magnitude in terms of height reached and volume of mud ejected than the plopping action normally observed in a bubbling mud pool.

There are only three mud geysers known in the Waikato Region, one at each of the Wairakei, Mokai, and Te Kopia fields. They are listed in this document because of their rarity, but are not included in the table of geysers at the end.

Most geysers are **sinter-forming springs** and are surrounded by a sinter apron. Sinter acts as a sealant in the near-surface plumbing of the spring, assisting the build-up of steam and other gases necessary to initiate and power an eruption.

Soda geysers are different in that the rock surrounding them consists of calcium carbonate and is referred to as **travertine**. The eruptive gas is dominantly carbon dioxide rather than steam, with the erupted water often being well below boiling temperature. The Waikato Region has one **soda geyser**, Mokena Geyser at Te Aroha. This is an artificial geyser, as it is actually an erupting well.

Another subset of the geyser genre is the **acid geysers**. These generally do not form sinter or travertine, so the necessary gas-impermeability of their conduits must be a natural characteristic of the type or structural integrity of the surrounding rock matrix. Acid geysers exist at White Island in the Bay of Plenty Region and at Ketetahi and Waiotapu in the Waikato Region. The Ketetahi geysers do not deposit silica whereas the Waiotapu geyser deposits minimal silica.

Crypto-geysers are underground hot springs periodically erupting so far below the surface that they do not eject a column of steam and water above the surface. They can be divided into two sub-groups, as described below.

Submerged geysers have an overlying body of water. The site of eruption is so far below the water surface that the steam produced becomes condensed before reaching the surface, and so there is no two-phase ejection of fluid above the surface of the overlying pool. There is an increased flow from the pool as a result of the steam produced displacing water upwards, and because reduced pressure at the bottom of the steam column allows a greater inflow.

Subterranean geysers erupt into underground open spaces at such depths that the eruptive column has insufficient upward thrust to reach the surface, and the only evidence of the eruption is a mixture of acoustic and seismic signals and an increased discharge from overlying steam features.

Submerged geysers in the Waikato Region include but are not limited to Taumatapuhipuhi at Tokaanu, the northern Whangapoa Spring at Atiamuri (Graham 2006) and the Map of Australia at Orakei Korako. In the Bay of Plenty Region, Inferno Crater at Waimangu is a very large submerged geyser, with its water level ranging approximately 7 metres and sometimes as much as 12 metres from overflow to its lowest point over a cycle of six or seven weeks (Keam, 2002). Parekohoru is one of several examples at Rotorua geothermal system, also in the Bay of Plenty Region.

2.5 Condition and Threats

This document classifies springs into six categories depending on their condition. A spring may be:

- **Unaltered**: pristine or nearly pristine,
- **Largely intact:** a moderate degree of alteration that could be readily remedied,
- **Recoverable:** altered but with its unaltered state able to be substantially recovered,
- **Unrecoverable:** altered with its unaltered state unrecoverable, or
- **Extinct**: no longer flowing, but it may still exist as a sinter formation with or without steam discharge.

There is an additional category of:

- **Inundated:** now underwater due to management of Lake Taupō or the Waikato River for hydroelectric generation. Such springs still exist and could be recovered if water levels were reduced to expose the springs.

In addition, springs are classified according to whether their existence or characteristics are **severely threatened, moderately threatened, slightly threatened** or **hardly threatened** from anthropogenic interference. Due to the unpredictable and wide-ranging nature of anthropogenic influences, it is not possible to have a feature that is completely protected from human influence. The nearest you can get is the 'hardly threatened category. Natural influences are not considered in the threat category.

An extinct spring may still hold the classification of 'threatened'. This is because sinter deposits and subsurface plumbing may have their own aesthetic, scientific, cultural or intrinsic value. Thus an extinct spring may be vulnerable to alteration if the sinter or other characteristics risk being degraded or destroyed. The document makes clear when discussing such features that it is the remnant sinter that the threat classification refers to.

Several geothermal systems have had geysers and sinter-forming springs inundated when hydroelectric lakes were created. This document does not classify the inundated springs as extinct, as they would be likely to recover their activity if the Waikato River were returned to its pre-dams water level at that point. Such springs are considered 'recoverable'.

Flows from the springs at Orakei Korako that remain above lake level following inundation have increased due to the rise in aquifer pressure caused by the rise in lake level. Therefore, unless there is some other form of interference, this document considers the remaining above-lake springs as 'largely intact' because the increase in their activity would be quickly remedied by lowering of lake levels to natural levels.

On the Wairakei-Tauhara and Ohaaki geothermal systems, geysers and sinter-forming springs have become inactive due to their flow being diverted to geothermal wells. The springs have stopped flowing and cannot be recovered, probably for hundreds of years at least following closure of the wells. They are essentially 'extinct'. Remaining sinter deposits and steam-fed features are threatened by human activity.

At Tokaanu the geysers and sinter-forming springs have been depleted due to several factors, including the continued discharge from an uncapped government exploration well drilled in 1942, and a well drilled more recently to provide steam to the Department of Conservation baths (Hochstein, 2007). However, if these takes were discontinued the springs might return to their previous eruptive behaviour, and so they are classed as 'recoverable'.

Natural occurrences that may affect a spring's behaviour or existence are not considered as 'threats' in this document. Such occurrences include naturally fluctuating river levels and rainfall recharge rates, natural ground instability, weathering of sinter whose regenerating flow has ceased naturally, and natural changes in spring flow. The weathering of sinters that are no longer regenerating due to human interference is considered a human interference, and therefore a 'threat'.

Some springs are located on land owned by the New Zealand Government and administered by the Department of Conservation for conservation purposes, and therefore some legal protection is afforded them. Other land may be legally protected in other ways such as through covenants. In addition, the RPS and the Proposed Waikato Regional Plan give protection to all sinter-forming springs and geysers by classifying them as Significant Geothermal Features and providing rules for their protection. However, in geothermal systems classified as Development Geothermal Systems, protection for extractive uses is not required, and instead, remediation or mitigation of such adverse effects is allowed.

There are some situations where legally occurring human activities may unintentionally affect springs and other situations where activities that affect springs have been authorised under the Resource Management Act (1991) or other relevant legislation. In addition, there are cases where springs are altered without legal authorisation. The legal protection status of the springs in this document has been considered when assigning 'threatened' or 'safe' status, but the primary factor in assigning status is the practical situation of what human-induced effects are occurring, are likely to occur, or could reasonably occur.

2.6 Spring Location Identification

One problem when seeking information on a particular spring from such references is that there is often inconsistency between documents regarding the names used for a particular feature. Most references were written before the widespread use of GPS readings, which can now easily be taken to an accuracy of a few metres or better. In order to minimise future confusion, the known name(s) of each spring, its precise location to within metres, and a verbal description of the spring's location and appearance, are provided for most features where known.

Those seeking maps and aerial photos of the sites are referred to Wildlands (2014).

2.7 Chemical Analyses

Chemical analyses given are for indicative purposes. In some cases, analyses that are more complete are referenced, but there may be other sources. Recent detailed chemical analysis of many geothermal features is given by Webster-Brown and Brown (2010). Hampton et al. (2001) provides a comprehensive list of geo-scientific references for each geothermal field.

GNS Wairakei, hold much information in paper records and an online database. Waikato Regional Council holds monitoring records for some springs in an electronic database, and paper records of water analyses received from resource consent holders. It is planned that in time these records will be available electronically.

3 ATIAMURI

3.1 Atiamuri Springs

The Waikato Regional Plan classifies Atiamuri as a Limited Development Geothermal System, meaning that development may proceed as long as there is no significant adverse effect on the geothermal features. Mercury Ltd was granted resource consents for exploratory drilling in the early 2000s; however, no drilling occurred.

Several hot springs are known in the Atiamuri system but only the two main springs, the Whangapoa Springs, are forming sinter at present. These are located in a small Department of Conservation (DOC) reserve near the intersections of Ohakuri, Matapan, and Ngautuku Roads and are listed below. They have extensive historic sinter deposits around them. Until recent years they both had artificial channels dug to contain the outflow. The southern spring has a regenerated sinter terrace following restoration work by DOC in 2002 that included blocking the discharge channel and channelling the discharge to the west of the pool, creating a new sinter terrace. The discharge channel of the northern feature was originally dug to supply a large swimming pool, which no longer exists. Sinter deposits have formed in and around the discharge channel depositing silica wherever the water flows.

West of the Whangapoa Springs is a sinter-lined extinct spring vent of a similar size to them. It is about 20 m in diameter and about 10 m deep. It had a warm pool in the bottom with algae growing in it. However, its vent was filled in by the landowner in 2003.

The extinct spring vent and the Whangapoa Springs are found in an area that was previously in pine. In 2002, the forestry company Carter Holt Harvey Limited (CHH) sold the land to a private owner and it was cleared for farming. CHH gifted the land surrounding the Whangapoa Springs to DOC, who have fenced it off. DOC is undertaking an ongoing programme to re-establish native plants on the margins, replacing first pines then blackberry. On the farm track leading from the Whangapoa Springs to the extinct spring vent, altered earth can be seen.

Also on the farm property is a boiling mud pool about 6 m in diameter and a warm pool filled with clear water of about 45 °C and neutral pH. The pool is in a vent that is lined with thick sinter. It is clear that in historic times the pool was once an overflowing silica-forming spring, but now the nearby stream undercuts it and it may discharge through the ground into the stream.

In an arm of Lake Atiamuri about 0.5 km west of the two main hot springs there is a small hot spring, which was flooded by the filling of the lake in January 1961. This was a silica-forming spring. It still produces hot water and bubbles, and dead fish can sometimes be found near it. It is not known why the fish die but thermal stress is a likely cause.

Figure 3-1: Matapan Rd Spring

There are several springs in the vicinity that are considered not to be part of the Atiamuri system. These include springs in the stream immediately north of the intersection of Ohakuri and Parsons Roads, and near the stream-bed north-east of Matapan Road.

At the north end of Matapan Road a hot spring produces clear water of about 70 °C that flows at about 0.2 litres per second (L/s) from a fissure in the ignimbrite cliff, but no sinter deposits occur here. It has a

growth in its outflow of a cream-coloured, gelatinous mass measuring approximately 20 cm by 30 cm in area, and 2 to 3 cm in depth. It has a spongy consistency and resembles a brain.

Approximately 1 km upstream of the Ohakuri dam, on the western bank of the river, a hot spring discharges from a cliff face. This spring has not been investigated by Waikato Regional Council at the time of writing. It can be accessed only by water.

In 2019 a warm spring was discovered during road maintenance on the Mangaharakeke Bridge on State Highway One near the settlement of Atiamuri.

3.1.1.1 Feature Name: Southern Whangapoa Spring (Scalding Pool) [ATF3]

Type: Hot spring actively depositing silica to form sinter.

Condition: Recoverable. Affected by past forestry operations and current game-processing uses.

Threats: Slightly threatened. In an actively managed DOC reserve, but use by locals for processing game has some adverse effect.

Location: NZMS-260 U16: 277605 E, 6311078 N +/- 5 m. Location measured from GPS (+/- 5 m).

Figure 3-2: Southern Spring, Whangapoa

Description: The spring lies about 100 m south of Ohakuri Road, beside the farm access drive. The spring is sub-circular, about 12 m in diameter, with vertical walls visible beneath the surface. The water is clear, has no odour, and occasionally produces bubble swarms, probably caused by the evolution of CO_2. Since Waikato Regional Council started monitoring the spring in 1995, the water temperature has ranged between 55 and 70 °C.

Sinters and coloured microbial mats grow along an outflow channel heading due west that is about 1 m wide at the pool outlet, and about 10 m wide at the fence that serves as its boundary about 20 m downstream. It then flows into a wetland tributary of the Whangapoa Stream.

The spring is often used for scalding fur and feathers off game, and wooden pallets and other temporary structures can sometimes be found around the shallows of the pool edge. Litter and feathers, hair, bones, and other animal remains are also occasionally left around the pool margins.

When the surrounding pines were cleared in 2002, logs and branches were left on the sinter flat and became cemented in by silica deposition. DOC removed as much as they could without damaging the sinter, but many branches still remain.

This pool and the northern pool are called by some authors the eastern and western pools respectively, even though they are on an axis aligned almost exactly north-south, and the scalding pool is marginally to the west rather than to the east.

History: There is no known Māori name or legend associated with the spring.

The outflow was artificially constrained to a narrow channel at some unknown time, probably in the 1970s. This was successfully sandbagged by DOC in the early 2000s to encourage regeneration of the sinter apron. The spring has been fenced off by DOC and warning signs have been erected.

3.1.1.2 Feature Name: Northern Whangapoa Spring (Trough Pool) [ATF2]

Type: Hot spring actively depositing silica to form sinter.

Condition: Recoverable. The spring's natural head has been decreased several metres by an artificial channel.

Threats: Slightly threatened. In an actively managed DOC reserve, but the artificial channel and use of the outflow by locals for bathing has some adverse effect.

Location: NZMS-260 U16: 2776600 E, 6311132 N. Location estimated as 40 m north of Spring 1.

Description: The pool is oval, about 10 m long and 7 m wide with overhanging vertical walls about 1.5 m high above water level. It has clear, lime green waters, no odour, a constant strong bubble plume, and a strong convection. Surface sinters are exposed in the walls of the pool, and there is very minor sinter growth along the channel. The flow is measured to be between 0.2 and 0.5 L/s. The pool temperature in January 2008 was 67 °C.

The pool fills a crater which may have been of hydrothermal eruption origin. Geothermal ferns inhabit the steep sides of the crater.

Figure 3-3: Northern Pool, Whangapoa

Monthly monitoring by Mercury throughout most of 2005 revealed that the spring has at least two cycles – a four minute cycle in which flow approximately range from 0.47 L/s to 0.67 L/s, and a cycle of the order of months in which flow ranges at least as low as 0.32 L/s and at least as high as 1.05 L/s. More frequent monitoring on a daily or weekly interval would be needed to determine the full range of the variation. Temperature ranged from 65 to 72 °C (Graham, 2006).

History: There is no known Māori name or legend associated with this spring. Grange (1937) records a bath there.

Exposed sinters show that extensive sinter sheets once grew here. Fencing and land clearance has exposed sinters right down to the wetland, covering an area of approximately 2 hectares. This would have been similar in appearance to the sinter apron of Ohaaki Ngawha. It is not known when the sinter became covered with top soil, but it is presumed to be due to a pre-historic event such as a volcanic eruption. This must have occurred after the flow from the spring waned, otherwise the outflow from the spring would have either washed the volcanic ash away or deposited sinter on top.

The outflow was channelled to supply a concrete open-air swimming pool in the 1970s. According to a local farmer, it was used and maintained by the local people, but after it was repeatedly vandalised by other parties, it fell into disuse. The swimming pool was demolished by CHH when the previous pine crop was logged in c. 1992. The spring outlet was then excavated to form a trench about 1 m wide and about 1.5 m deep to divert flows down the hill until they were sufficiently cool to be safe. A concrete trough has been installed in the outflow to be used as a bath.

3.1.1.3 Feature Name: "Berg's Crater" [ATF6]

Type: Large extinct spring vent with sinter and stone sides.

Condition: Recoverable. The vent has been filled in with logs and earth.

Threats: Severely threatened as it is at risk of further interference by the land owner. The feature, not being a 'recent sinter' has no protection in the Waikato Regional Plan.

Location: NZMS-260 U16: 2776278 E, 6311069 N +/- 5 m. Location estimated as 425 m west of Southern Whangapoa Spring.

Description: On top of flat spur, south of the farm access drive and due west of the southern Whangapoa Spring. In approximately 2003, the spring vent was filled in by the farmer using tree stumps and dirt, because it was a risk to cattle. Before it was filled in, the crater was circular, about 15 m in diameter at the top with near-vertical walls narrowing to a diameter of about 5 m at the bottom, which was approximately 20 m down. There was a non-flowing pool at the bottom, possibly geothermal, with water plants floating on the surface. The water was stagnant, with no steam or gas evolution.

The sinter-lined vent provided a rare opportunity to see the near-surface dimensions of a large spring. The digging of posts for fencing has shown that there is sinter under the flat ground around the top of the crater. The surrounding land has been cleared of pine and the crater fenced off. The fill has started to degrade and slumping has occurred, so if the fill is not topped up, at least the upper part of the vent should become visible again.

History: There is no known Māori name or legend associated with the crater.

3.1.1.4 Feature Name: No name known

Type: Inundated hot spring, no longer forming sinter.

Condition: Recoverable. The spring has been inundated by the creation of Lake Ohakuri.

Threats: Moderately threatened. The feature could be affected by development of the system for geothermal electricity.

Location: NZMS-260 U16: 277600 E, 631170 N. Location measured from map sheet.

Description: In an arm of Lake Atiamuri about 0.5 km west of the two main hot springs there is another small hot spring, which was flooded by the filling of the lake in January 1961. This was a sinter-forming spring.

History: There is no known Māori name or legend associated with this spring.

3.2 Chemistry of Atiamuri System:

See also Hedenquist (1984) and Allis (1987), which give geothermometry source temperatures of about 180 – 200 °C.

Southern Spring initially showed transitional water chemistry between mature and peripheral water in 1978, but showed mature compositions during later sampling programmes (1993 – 2009). Northern Spring also experienced water type maturation, initially being sampled as a peripheral water in 2005, but samples from 2009 show a mature water composition.

Table 1: Chemistry of Atiamuri hot springs

(Webster-Brown, 2012)

Spring	Located ID	Other ID	Date	Temp.	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Southern Spring (ATF3)	3058_3	Historical: 72_4387	15/03/78	69	8.7	328	41	565	280
			8/07/93	66	7.4	354	49	589	262
			11/05/94	70	7.3	362	49	620	272
			17/08/09	60.3	7.6	300	38	19	140
Northern Spring (ATF2)	3058_2	Historical: 72_3004	4/10/05	56	8.4	343	45	267	280
			17/08/09	60.2	7.7	370	50	18	130

4 HOROHORO

Horohoro is a waning geothermal system, with very extensive extinct sinters, dried up spring basins, and big hydrothermal eruption craters (Hedenquist, 1984). In recent historical time there has been no boiling or geysering recorded here. Presently there are two hot springs depositing insignificant sinters (Allis, 1987). The Waikato Regional Plan classifies Horohoro as a Development Geothermal System. A glass house operation draws steam from a bore to heat the glasshouse.

4.1 Horohoro Springs

4.1.1.1 Feature Name: Waipupumahana; Spring 1 [HHF1]

Type: Hot spring actively depositing silica to form sinter.

Condition: Recoverable. Altered by channelling and stock grazing the margins.

Threats: Moderately threatened by current land use practices.

Location: NZMS-260 U16: 2788383 E, 6323144 N +/- 10 m. Location measured from GPS (+/- 10 m).

Description: This is the largest active feature remaining in Horohoro. It is a circular pool about 12 m in diameter with vertical sinter walls on the eastern half of its circumference. It has clear, blue water with a temperature around 50 °C, no odour, and occasional bubble swarms, most likely caused by evolution of CO_2. Since Waikato Regional Council started monitoring the spring in 1995, the water temperature has ranged between 48 and 56 °C. The outflow is about 0.5 to 1.0 l s^{-1}.

Figure 4-1: Waipupumahana

The pool is on Māori land. A channel about 0.25 m wide x 0.3 m deep has been excavated through the sinter wall to provide a single concentrated channel outflow for filling a bath. Consequently, there is no longer the dispersed outflow necessary for sinter accumulation. The owners have told Ashley Cody that they have considered blocking the channel to restore the pool to its natural condition. However, this has yet to occur. The pool would also benefit from fencing off from stock, and planting the margins with native species. The steep bank surrounding some of the pool is prone to erosion and slumping into the pool.

History: There is a Māori legend associated with the pool; and a log lying across its northern end is considered to be a taniwha named Korowhakatipua.

4.1.1.2 Feature Name: Un-named Gully Spring; Spring 2 [HHF2]

Type: Hot spring weakly depositing silica to form sinter.

Figure 4-2: Gully spring

Condition: Unaltered.

Threats: Moderately threatened by land use practices in surrounding farmland. Drainage of the swampy gully would modify the spring.

Location: NZMS-260 U16: 2788066 E, 6322908 N +/- 10 m. Location measured from GPS (+/- 10 m).

Description: This shallow pool is sub-circular with a diameter of about 2 m, and in 2008 had a temperature of 90 °C. It has peaty walls and substrate. It produces clear water with occasional bubbles, and has an outflow of about 0.1 L/s. It lies at the base of a steep slope in a swampy gully about 200 m south of an old homestead. It has white sinters deposited as thin, sparse rinds; thick or massive sinter deposits are absent. The wooden boxing around it is evident in the above photo (Figure 4-2), which was taken in the early 2000s, and has since largely rotted away.

History: No known Māori name or legends. No known European history.

4.2 Chemistry of Horohoro System

See also Hedenquist (1984) and Allis (1987). Geothermometry gives source temperatures of approximately 165 °C.

Water samples taken from 1980 to 2005 (excluding 1963 and 1985 due to absence of HCO_3 data) from Waipupumahana spring show water chemistry progressing from peripheral waters with 70% HCO_3, to more mature compositions with over 55% Cl composition. The spring chemistry is observed to return to a more transitional chloride-bicarbonate composition in 2009.

Table 2: Chemistry of Horohoro hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp. (°C)	pH	Cl (parts per million)	SO_4 (parts per million)	HCO_3 (parts per million)	SiO_2 (parts per million)
Waipupumahana (HHF1)	3059_1	Historical: 72_3006	6/11/63	47	8.7	155	40		152
			4/02/80	55	8.5	168	45	285	149
			17/04/84	50	8.4	169	41	244	
			4/02/85	52	8.3	172	42		152
			8/07/93	44	8.3	150	37	159	140
			11/05/94	47	8.4	168	41	177	150
			4/10/05	48	8.4	143	38	85	155
			22/07/09	45	8.4	150	36	150	150

5 MANGAKINO

There were seven known hot springs, including one sinter-forming spring, on the Mangakino system, in what is now the bed of the Waikato River and an arm of the river just south-west of the well MA1, between about T16: 535-110 and T16: 545-130 (G. Risk, pers. comm, 2002). These were inundated by the creation of Lake Maraetai for hydroelectric generation.

Mangakino is a Development Geothermal System. The resource has been subject to investigation over the last few decades. In 1986, the Crown drilled an investigation well (MA1) to a depth of approximately 600 metres. Carter Holt Harvey conducted some further shallow drilling during the 1990s. Mercury drilled four deeper wells in 2005, but did not obtain good permeability for production.

5.1.1.1 Feature Name: Unknown

Type: Inundated hot spring previously depositing silica to form sinter.

Condition: Inundated.

Threats: Severely threatened. If development occurred, the spring would probably cease flowing.

Location: NZMS-260 T16: 530 110. Location approximate only, from Mongillo and Clelland 1984.

Description: A boiling, sinter-forming spring near the Mangakino township, now inundated by Lake Maraetai (G. Risk, pers. comm.).

History: None known.

Figure 5-1: Sinter springs discharge on the bed of Lake Maraetai

6 MOKAI

There are hot springs scattered around various parts of the Mokai geothermal system, but most of the activity is found in three main sets of features (Glover & Klyen, 1989). Most of the springs in the South Paerata Rd area of the system are steam-fed which includes a mud geyser. Another set of springs along the Waipapa Stream is depositing minimal sinter. There is a set of springs due north of these, on the banks of the Waikato River, but these are generally underwater. Hot springs, steam and sinter were recorded in the Ongaroto Gorge prior to the filling of Lake Whakamaru in 1956, built for hydroelectric purposes (Cave *et al.* 1993, Glover & Klyen, 1989). There was a hydrothermal blow-out near these springs when the railway was being constructed across the Waikato River (Grange, 1937, p. 97). Mokai is a Development Geothermal System and supports a 100 MW geothermal power station, a 12 hectare geothermally heated glasshouse operation growing tomatoes and capsicums, and a geothermally heated milk powder plant.

6.1 Waipapa

6.1.1.1 Feature Name: Waipapa Stream Springs (Mulberry Road)

Type: Approximately five hot springs depositing minimal silica to form sinter.

Condition: Unaltered, not threatened.

Threats: Moderately threatened. The springs are protected by the Waikato Regional Plan. However, land-use activities could cause damage at the surface. Most of the springs are in a deep gorge and are fairly inaccessible, and therefore safe from structural interference. The outflows could possibly be affected by large-scale fluid draw-down by the Tuaropaki geothermal power station, and shallow reinjection of that fluid in the future, but at the current rate of extraction this is unlikely.

Location: NZMS-260 T17, a line along the stream bed from: 2767784 E, 6300470 N to 2767902 E, 9301297 N. Location from GPS (+/- 5 m).

Description: A group of hot, clear springs discharging through boulders and hill slope colluvium into the Waipapa Stream, in the bottom of a steep gorge. Some have very minor, thin sinter margins a few millimetres wide at the water edges, but there is neither conspicuous accumulation of any sinters nor any historic deposits. The outflows, several flowing at up to 0.5 L/s, mingle into the cold stream and swampy margins.

History: No Māori names or legends are known. A Māori rock drawing in ancient style (B. Jones, pers. comm.) is situated in the area (Merrett et al., 1999), and was drawn in recent years (Robin Black, pers. comm.). The surrounding land use has changed in recent years from forestry to dairy pasture.

6.2 Ongaroto

6.2.1.1 Feature Name: Ongaroto Springs

Type: Sinter-forming springs.

Condition: Inundated.

Threats: Hardly threatened. The outflows could possibly be affected by large scale fluid draw-down by the Tuaropaki geothermal power station and shallow reinjection of that fluid, in the future but at the current rate of extraction this is unlikely.

Location: NZMS-260 T17: 2769000 E, 6305300 N. Location approximate only, taken from map.

Description: No details have been found.

History: No Māori names or legends are known. Inundated by the creation of Lake Whakamaru in 1956 for hydroelectric purposes.

6.3 Paerata

6.3.1.1 Feature Name: Mokai Mud Geyser

Type: Intermittently geysering mud pool.

Condition: Recoverable.

Threats: Moderately threatened. This site is heavily grazed and trampled by cattle. Blackberry is extensive in the areas not accessed by cattle. There is graffiti on the sides of the mud geyser and refuse in a nearby fumarole. The area surrounding the features should be fenced and planted with appropriate native plants.

Location: NZMS-260 T17: 2765570 E, 6295100 N. Location from GPS (+/- 5 m).

Description: East of Paerata Rd about 1.5 km north of Forest Rd. Three km north-east of Mokai.

History: No history is known for this spring.

6.4 Chemistry of Mokai System

See also Henley and Glover (1980), whose results give geothermometry source temperatures of 150-180 °C.

The chemistry of water samples from Waipapa Spring steadily show mature water compositions between 1978 and 2009. Parekiri Pool has a very bicarbonate-rich peripheral water chemistry typically observed in outflow areas. West Mokai Bath Spring has a transitional mature-volcanic water chemistry, with a higher proportion of chloride to acid sulphate.

Table 3: Chemistry of Mokai hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp	pH	Cl	SO_4	SiO_2	HCO_3
				(°C)		(parts per million)			
Waipapa Spring (North Mokai)	3062_42	Historical: 72_4386	3/05/78	58	7.0	370	7	130	90
			8/04/80	58	6.4	370	8	137	155
			14/06/82	59	6.3	371	4		139
			19/10/83	58	6.6	362	9	144	119
			15/07/93	60	6.5	380	8	130	119
			3/05/94	61	6.5	371	7	129	152
			17/08/09	54.5	7.2	480	5.4	160	120
Parekiri Pool (MKF1) Mistakenly called South Mokai	3062_17	Historical: 68_729	8/04/80		6.1	39	9	118	
			14/06/82		6.1	35	5		
			19/10/83	49	9.1	29.1	20	139	
			15/07/93	49	6.3	31.2	5	117	961
			3/05/94	52	6.3	34	<5	116	1043
West Mokai Bath Spring (MKF17) Mistakenly called Parekiri			22/07/09	41	3.2	360	300	200	19

7 NGATAMARIKI

The Ngatamariki system is classified as a Development Geothermal System in the Waikato Regional Plan. The 110 MW Ngatamariki geothermal power station has been operating since 2013. There are currently five sets of features actively depositing calcium carbonate and forming travertine, and one actively depositing silica to form sinter. One set of springs was partially inundated by the creation of Lake Ohakuri in 1961. The area is highly dynamic, with new features appearing from time to time. In about 1948 a significant hydrothermal eruption occurred at Ngatamariki. The noise was heard by the resident guide at Orakei Korako, and the Waikato River was discoloured for several days. Another large hydrothermal eruption occurred in April 2005 at the southern Orakonui Springs (Cody 2005bb).

7.1 Southern Orakonui Springs

7.1.1.1 Feature Name: Southern Spring (Eruption Crater) [NMF1]

Type: Hot spring weakly depositing calcium carbonate to form travertine.

Condition: Unaltered.

Threats: Moderately threatened. It is vulnerable to pine plantation logging works damaging it. Future geothermal extractions could affect the feature. In addition, stream flooding or scouring could modify the spring.

Location: NZMS-260 U17: 2786600 E, 6291800 N. Location from GPS (+/- 5 m).

Description: When Waikato Regional Council started monitoring the Ngatamariki Springs in 1995, this was a neutral, hot, clear, bubbling spring about 7 m in diameter. It had very thin, 5 mm wide margins of carbonate-silica precipitates around the edges and on branches dipping into the pool. The outflow was concentrated into a narrow channel. There are no significant travertine or sinter accumulations present. The temperature ranged from 69 to 91 °C, and the approximate flow from 0.25 L/s to 3 L/s. Over the years to 2005, the activity of this spring increased and several new hot springs broke out around it.

On 19 April 2005, this spring was the site of a large hydrothermal eruption which led to the formation of a crater pool. A mud pool also formed on the east side of the crater. Intense rain events have scoured and deposited pumice gravels from proximal slopes and crater walls into the lake. This causes the pool to be completely infilled by sediments such as in 1999 (Cody 2000), or partially infilled as observed in 2020, turning the water colour into dark brown.

Figure 7-1: Southern Spring partially covered by cyanobacterial mats and pumiceous debris

History: No name, use, or legend known.

7.1.1.2 Feature Name: New Southern Geyser

Type: A boiling spring, actively depositing calcium carbonate to form travertine, formerly a geyser.

Condition: Unaltered.

Threats: Moderately threatened. Future geothermal extractions could affect the feature.

Location: NZMS-260 U17: 2786610 E, 6291715 N. Location from GPS (+/- 10 m). About 20 m south from the main southern spring pool (Cody, 2000).

Description: A boiling and flowing spring in a marshy, soft ground beneath a vertical bank of pumice gravels. This spring was formed in December 1999, when a fresh bank collapsed, blocked an upflow, which then filled a cavity behind the landfill and overflowed 0.5 m above the marshy pool alongside. The new spring against the wall is about 0.8 m long x 0.5 m wide, and produces clear alkaline water, with a conspicuous white sinter rind forming on the bank at the surface. For many months this pool had a true geysering action when it would begin boiling and geyser between 0.1 m to 0.3 mm, high with an outflow of between 0.2 L/s to 0.5 L/s lasting up to one minute. It would then stop flowing for about 10 minutes or more, before commencing the next eruption. By March 2000, the surrounding ground collapsed to leave a big open pool that does not geyser, but is still warm and depositing a sinter rim (Cody, 2000).

7.2 Central Orakonui Springs

7.2.1.1 Feature Name: Calcite Spring [NMF5]

Type: Hot spring that formerly actively deposited calcium carbonate to form travertine.

Condition: Extinct.

Threats: Moderately threatened. Being on a low bank close to Orakonui Stream the spring and its calcite formations are at risk of flood damage. The surrounding vertical bank is composed of unstable weak alluvium.

Location: NZMS-260 U17: 2786625 E, 6291876 N. Location from GPS (+/- 5 m).

Figure 7-2: Outlet from Calcite Spring in 1995. Copyright Shaun Barnett.

Description: This spring is situated on the west bank approximately 10 m from the Orakonui Stream. It had its genesis sometime between 1986 when Glover visited the area (Glover 1986) and 1995 when Waikato Regional Council started monitoring the Ngatamariki Springs. It was a neutral, hot (approximately 85 °C), clear and calm spring approximately 1.5 m in diameter. It had 10 to 50 mm wide margins of calcium carbonate around the vent and non-porous, broad, brilliant white travertine on the outflow channel spillway, covering and area of approximately 2 m width and 5 m in length. The outflow was approximately 1 L/s with filamentous and gelatinous microbial masses. It stopped flowing in mid-2003 (Cody, 2003c) although its vent still held hot water. It produced a trickling flow in early 2004 but ceased flowing again in mid-2004 (Cody, 2004a). In 2007, the pool was dry.

History: No name or legend is known. The spring may be of very recent origin as there is no record of this spring by Glover (1986) or in earlier surveys of the area.

7.3 Northern Orakonui Springs

7.3.1.1 Feature Name: Northern Springs

Type: Approximately five hot springs actively depositing silica to form sinter.

Condition: Unaltered.

Threats: Moderately threatened. Logging of the pine plantation could damage the sinter terraces. Future geothermal extractions could affect the features.

Location: NZMS-260 U17: 2786773 E, 6292177 N. Location measured from map sheet.

Description: Several hot clear, alkaline springs, approximately 0.5 m in diameter. These are all in an area of approximately 10 m diameter, with the outflows spilling across an area 30 m long and 15 m wide. Outflow from the springs form a sinter terrace, which cascades across an area approximately 15 m wide by 5 m long down to the Orakonui Stream. The outflow of approximately 5 L/s is concentrated into a narrow channel. The sinter terrace consists of non-porous, massive sinter sheets with abundant, well-established coloured microbial mats and gelatinous masses. Since Waikato Regional Council started monitoring the springs in 2003, the temperature of one of the spring, known as the Boiling Spring, has been steady at 94 °C, and the flow is about 0.5 L/s.

History: No Māori name or legend is known.

7.3.1.2 Feature Name: New Northern Spring [NMF16]

Type: Hot spring actively depositing calcium carbonate to form travertine.

Condition: Unaltered.

Threats: Moderately threatened. Future geothermal extractions could affect the feature. The greatest potential threat is collapse of the soft alluvial, vertical bank above the spring.

Location: NZMS-260 U17: 2786730 E, 6292215 N. Location from GPS (+/- 5 m).

Description: This spring formed around 1993 or 1994. It is a boiling, flowing, neutral spring 1.5 m in diameter, located approximately on the eastern bank of Orakonui Stream. There is a vertical bank approximately 2 m high above the east side of the spring. The pool has a silica sinter rind 10 - 20 mm wide at the surface. Silica is deposited on the walls and on sticks and vegetation etc. hanging into pool. The outflow is approximately 0.3 L/s.

History: No Māori name or legend is known. The spring was probably formed in 1993 when a conspicuous steam plume was first noticed above it, as previous workers describing these northern springs did not mentioned it. It was found by Ashley Cody during an ecological survey in 1994-95, and the spring was visited again in 2000 for a GPS survey.

7.4 Waikato River Springs

7.4.1.1 Feature Name: Waikato River Spring [3063_3]

Type: Hot spring actively depositing silica to form sinter.

Condition: Altered and threatened by river level management.

Threats: Moderately threatened. Future geothermal extractions could affect the feature.

Location: NZMS-260 U17: 2788030 E, 6293410 N. Location from GPS (+/- 5 m).

Description: The spring lies on the south margin of the Waikato River approximately 0.5 km upstream from its confluence with the Orakonui Stream, which flows northwards from the Ngatamariki geothermal area. This spring is now beneath the water level of the Waikato River. However, during 1993, 1994 and 1995 it was exposed by low river levels, at which time it formed an ochre red-brown sinter. The sinter extends over an area of approximately 10 m x 15 m. In 1999 – 2000, it was concealed under approximately 0.5 m of river water, silt, and aquatic vegetation build-up. According to Brotheridge (1995), the feature was largely destroyed or

drowned when the river was dammed in 1961 for the creation of Lake Ohakuri, and what remains today is only a remnant of the original spring.

7.5 Chemistry of Ngatamariki system

See also Healy (1974), Glover (1986), and Brotheridge (1995).

The Ngatamariki Main Pool and Biodiversity Pool are observed to have chloride-rich mature water chemistry, while the Blue Pool is observed to have transitional chloride-bicarbonate water chemistry, but with higher chlorine concentrations for all samples. The New North Spring was initially observed to have a similar chemistry to the Blue Pool in 1993 and 1994, but progressed towards a more mature composition when sampled in 2005.

Table 4: Chemistry of Ngatamariki hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp	pH	Cl	SO_4	SiO_2	HCO_3
				(°C)		(parts per million)			
New North Spring (NMF16)	3063_16	72_2990	21/05/93	89	7.3	605	49	241	479
			11/05/94	90	7.2	613	55	251	496
			20/09/05	94	7.5	327	12	187	162
North Stream Source (NMF17)	3063_17	72_2991	20/09/05	70	7.2	216	13	153	114
Waikato River/Harvey's North1 (NMF6)	3063_6	Historical: 72_2992	20/09/05	75	7.0	171	1	262	192
Biodiversity Pool/Southern Spring/Harvey's South2 (NMF4)	3063_4	72_2997	29/09/05	72	7.6	646	50	237	222
Ngatamariki Main Pool/Hydrothermal Eruption Crater/South1 (NMF1)	3063_1	72_2098 673_1	1/10/74	89	8.0	579	36	235	343
			1/03/60		7.3	461	99	250	
Blue Pool			9/01/87	71	7.8	639	65	270	437
			16/07/86	71	7.8	638	70	270	443
			28/05/86	71	7.7	634	68	280	456
			18/12/84	78	7.7	628	69	244	450
			24/07/79		7.8	597	40	245	458
Flowing Spring (Blue)			7/06/83	82	8.6	630	48	261	408

8 OHAAKI

Ohaaki is a Development Geothermal System, and the Ohaaki geothermal power station has been operating since 1988. All of the flowing geothermal features at Ohaaki have been irreparably damaged by development of the geothermal system for power generation, and some have also been damaged by related subsidence, and the increased water levels of the Waikato River due to creation of Lake Ohakuri. Only steam features now remain.

8.1 Ohaaki Springs

8.1.1.1 Feature Name: Ohaaki Pool [OHF1]

Type: Artificially fed but previously naturally-occurring large hot pool, actively depositing silica to form sinter. It has a large sinter terrace leading down to the Waikato River.

Condition: The natural flow of the pool is extinct. The sinter is recoverable by artificial means.

Threats: Severely threatened. The sinter is threatened by current management of the pool outflow, and by subsidence.

Location: NZMS-260 U17: 2798733 E, 6293201 N. Location from GPS (+/- 50 m).

Description: This is a large pool, 15 m wide x 45 m long, surrounded by approximately 2 hectares of silica sinter sheets that are now being broken apart due to subsidence and weathering. They are also being covered by vegetation. The spring ceased flowing when a nearby well was test discharged and later when the Ohaaki power station was commissioned (Glover *et al.*, 2000).

The bottom of the pool was first cemented in 1988 by the power station operator to prevent drainage down its original vent. Subsequent cementing on multiple occasions have been required to maintain the water level. Water flow is maintained by discharge from a well (Contact Energy, 1988).

The outflow has been re-routed away from the silica terrace down a channel dug through the sinters to provide hot water to a bath house for the Ohaaki Marae. The pool waters are chemically altered and therefore the silica deposition is different from that of the original boiling alkaline upflow. The outflow is approximately 5 L/s.

Figure 8-1: Ohaaki Pool before it was affected by extraction. Copyright Ron Keam.

If the channelled outflow were blocked and the overflow dispersed, sinter accumulation would resume across the terraces. The pool is within the Ohaaki power station's central subsidence basin and is within the area protected by a bund to prevent inundation by the Waikato River.

8.1.1.2 Feature Name: May include the spring known as Konukukehu (Stokes 1987)

Type: Now inundated group of four or more sinter-forming springs, including one that was known to geyser occasionally.

Condition: Inundated, presumably extinct from field depletion.

Threats: Hardly threatened. The springs are both inundated by altered river level and subsidence, and presumably rendered dormant by field extraction, so the likely further subsidence is not an issue.

Location: NZMS-260 U17: 2798700 E, 6292500 N. Location from GPS (+/- 50 m).

Description: On Thursday 18 April 1957, Lloyd (Lloyd 1957) visited the springs to observe recently commenced unusual behaviour of the Ohaaki springs:

> "The group of springs several chains south of Ohaaki were all overflowing and one was geysering. This spring has an elongated opening and is surrounded by a grey sinter terrace. Geyser action occurred approximately once every hour and a considerable volume of water was ejected, almost emptying the basin".

The mentioned geyser was active on other occasions and it played to a height of 2 to 3 metres. Its surrounding sinter deposits had nodular geyserite typical of very splashy water flows as usually only seen around geysers (E.F. Lloyd, pers. comm.).

The springs were inundated when Lake Ohakuri was created. Subsidence associated with fluid draw-off from the system for the Ohaaki Power Station has further submerged the springs. It is presumed that like Ohaaki Ngawha, the springs are now extinct due to the Ohaaki power station taking their fluids.

8.2 Chemistry of Ohaaki System

Discussion of recent and historical chemistry together with references to further articles is given by Glover *et al.* (1996). Mahon *et al.* (1972) also gives chemistry.

Between natural state conditions and post-commission conditions since 1988, the water chemistry of Ohaaki Pool has changed from mature composition to almost 100% peripheral composition. This is greatly influenced by a drastic decrease of Cl concentrations from 1040 ppm in 1965 to 54 ppm in 1994, accompanied by an increase of HCO_3 concentrations from 680 to 847 ppm during the same period.

Table 5: Chemistry of Ohaaki Pool, Broadlands

(Mahon and Finlayson, 1972) & (Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp.	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Ohaaki Pool (OHF1)	3064_1	GF101	16/06/1965	98	7	1040	100	680	338
			27/04/94	33	6.6	54	<5	847	133

9 ORAKEI KORAKO

Orakei Korako is listed in the Waikato Regional Policy Statement as a Protected Geothermal System. This means that no new extractions, large or small, may commence, and that the geothermal features are to be protected from any interference.

In January 1961, Lake Ohakuri was formed when the water level was allowed to rise behind Ohakuri dam for hydro power generation. The Waikato River was raised by 18 m at Orakei Korako (Lloyd, 1972), from approximately 271 metres above sea level (masl) to 289.6 masl.

The most comprehensive published study of surface thermal activity and geology in this area is by Lloyd (1972), who gives a detailed account of the springs of the system prior to, during, and immediately after the 1961 flooding. He lists 1007 springs, 87 of which were known to carry sufficient cultural significance to be given names by either Māori or Pakeha. More than 105 were geysers. An estimated 75% of the springs were drowned by the creation of Lake Ohakuri, including approximately 70 geysers and 200 alkaline hot springs.

There were eight distinct areas of geothermal activity at Orakei Korako listed by Lloyd (1972). These were Papakainga, Matangiwaikato, Te Kapua, Red Hill, Whakaheke, Hokopuku, Akatarewa, and Waihunuhunu. There were sinter-forming springs at all of these locations. Hokopuku Springs and Whakaheke Rapids Springs, downstream of Te Kapua, have been completely inundated. At Akatarewa, Waihunuhunu (downstream), and Matangiwaikato (upstream), there are very few springs left above lake level. Most of the geothermal activities above lake level are now confined to Papakainga, Te Kapua, and Red Hill.

Those that remain above the water level generally exhibit greater activity because of the increase in hydrostatic pressure. If the water level were allowed to fall to its pre-dam level the entire system would probably return its previous strength of activity, although individual springs would not necessarily exhibit their pre-inundation behaviour.

Most of the present day geothermal features can be viewed or accessed only by boat along the Waikato River on Lake Ohakuri. The topography is of steep hills with no road access to all but one thermal area. Presently there are approximately 100 springs depositing silica and forming sinter, and approximately 35 have been active geysers in the past decade. During the twelve months to March 2001, approximately 25 geysers were active. The area has not been thoroughly described in recent decades due to poor access and dense bush vegetation over many deeply incised gullies and streams. Hamlin (2001) documented the surface features on the main terrace areas as they were in 2000. Only 50 of the hundred sinter-forming springs are listed here, being those accessed by Ashley Cody in 2001. The remainder are those listed by Lloyd (1972) and remain above the river level.

The land is owned by the Tutukau Trust. Orakei Korako has a long history of Māori settlement and some old photographs exist, depicting meeting houses and people there.

9.1 Waihunuhunu Valley

This is also known as Paradise Inlet by water skiers, who boat into the eastern arm of the lake to bathe in the hot water where the springs discharge into the lake. In March 2008, the temperatures of two spring discharges were 53 °C and 42.1 °C. There may be some alkaline flowing springs still present here, but most were drowned by the flooding of Lake Ohakuri in January 1961. The remaining springs are in a deeply incised gully that has not been explored due to bad access; so any remaining silica-forming springs are presently uninspected.

9.2 Papakainga

This is the area along the west side of the river near the main tourist reception and accommodation. Some hot springs are situated along the base of the alluvial terrace. The area is swampy and generally not easily accessible.

9.2.1.1 Feature Name: Map of Australia Spring [OKF0025]

Type: Hot spring actively depositing silica to form sinter, formerly a crypto-geyser.

Condition: Recoverable. Altered by river level increase.

Threats: Moderately threatened. The spring outflow is channelled to a bath house and the spring is used for processing game.

Location: NZMS-260 U17: 2784264 E, 6298543 N. Location from GPS (+/- 15 m).

Description: This is a clear, alkaline flowing spring approximately 9 m long x 4 m wide. It is situated at the western end of the car park, and its flow supplies a bathing pool. It has thick sinter walls and outflow channel. This spring is also used for processing game. Since Waikato Regional Council started monitoring the spring in 1995, the temperature has ranged from 76 to 85 °C, and the approximate flow between 0.25 L/s and 2 L/s.

Figure 9-1: Map of Australia on 11 February 2020. Copyright Jesse Ledwin Lebe.

History: Before Lake Ohakuri was formed in January 1961 this spring exhibited crypto-geyser behaviour. It is not known if it still behaves in this manner.

9.3 Te Kapua (Waipapa Valley)

Location: NZMS-260, Sheet U17: approximately at 2784700 E, 6298550 N. Location from GPS (+/- 15 m).

Description: This is a small valley approximately 0.5 km long by 0.2 km wide on the eastern bank of the Waikato River. It is the main tourist area and includes hot flowing springs and geysers. Access across the river is by boat. At least three fault scarps cross the valley with many springs near to the fault traces. Many of the springs exhibit variable activities, including intermittent flows and sometimes geysering (Lloyd, 1972).

The site is crossed by several prominent transcurrent, normal faults (Golden Fleece, Rainbow and Wainui Faults). A large area of sinter covered in coloured microbial mats forms Rainbow Terrace, which is located beneath and to the west of Rainbow Fault scarp. Above it and adjoining the south-eastern corner, is Golden Fleece Terrace which is located beneath and to the west of Golden Fleece fault scarp. Most of the terrace is usually dry, but intermittent spring activity results in discharge channel flow paths occurring from time to time on the western side of the boardwalk. The Artist's Palette Terrace is above and to the east of Golden Fleece Fault scarp. The majority of the Golden Fleece Terrace is dry but this is determined by the fluctuating water levels of the pools on the Palette.

The springs of Te Kapua are described below, grouped within each of these three terraces.

9.3.1 Rainbow Terrace

9.3.1.1 Feature Name: Diamond Geyser [OKF0095]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: The western base of Rainbow Fault scarp. NZMS-260 U17: 2784618 E, 6298509 N. Location from GPS (+/- 15 m).

Figure 9-2: Diamond Geyser Erupting in 2004.

Description: An active geyser, which during the years 1995 to 2005 was observed by Ashley Cody to erupt 3 to 8 m high in pulsating jets for several hours, with approximately 1 L/s overflow. The frequency and duration of eruptions were less before Lake Ohakuri was formed. However, no eruptions were witnessed during 2007 and April 2008. During this time, only a trickle of water constantly flowed over the vent rim and down the slopes of the geyser mound. The vent is approximately 1 m in diameter, and about 3 m above the level of the path that passes across the outflow. The water temperature in the pool at the top of the geyser mound measured 93 °C in March 2008. The geyser has an apron of hard creamy-white sinters, covering approximately 7 m x 15 m in spatial extent. Nodular and spicular geyserite textures occur in the splash zone around the vent and down the 3 m high vent slope. The outflow fans across the south-east portion of Rainbow terrace, where coloured microbial mats flourish.

9.3.1.2 Feature Name: Bush Geyser [OKF0096]


Figure 9-3: Bush geyser in 2004.

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: The western base of Rainbow Fault scarp. NZMS-260 U17: 2784646 E, 6298511 N. Location from GPS (+/- 15 m).

Description: An active geyser, about 5 m from the path and approximately 15 m from Diamond geyser. It is hidden in manuka shrubs. The geyser plays approximately 1 m high for several minutes every 20 or more minutes, but with very little outflow. The vent and its surrounding surfaces to a diameter of approximately 0.5 m are covered in sinter. The vent is surrounded by a semi-circular brick or stone collar, the origin of which is not known, but it appears to be tens of years old.

9.3.1.3 Feature Name: Cascade Geyser [OKF0097]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Western base of Rainbow Fault scarp. NZMS-260 U17: 2784649 E, 6298511 N. Location from GPS (+/- 15 m).

Description: An active geyser, which, when in an eruptive phase, typically boils and has minimal outflows for approximately 30 seconds every 5-10 minutes. Sometimes it becomes dormant for several months or years. This erratic behaviour has been observed since Waikato Regional Council started monitoring the spring in 1995. Its vent, which is approximately 0.5 m in diameter, is halfway up Rainbow Fault scarp and about 5 m from Sapphire geyser. White sinters extend downslope from the vent and form Rainbow Terrace. In 2007, extensive orange and brown coloured microbial mats became established in the discharge water on Rainbow Terrace.

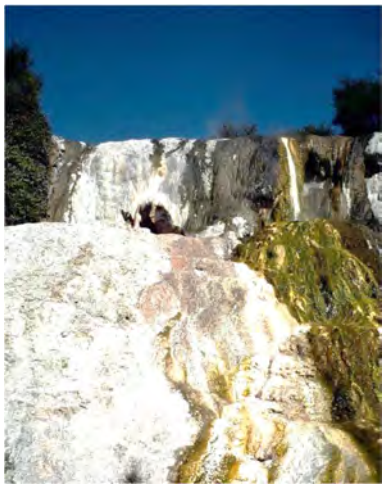


Figure 9-4: Cascade geyser in 2004.

9.3.1.4 Feature Name: Sapphire Geyser, S106, S107 [OKF0106-0107]

Figure 9-5: Sapphire geyser in 2004.

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: The base of Rainbow Fault scarp. NZMS-260 U17: 2784675 E, 6298560 N. Location from GPS (+/- 15 m).

Description: An active geyser, which since early 1995 has played 2 - 3 m high for 30 to 45 seconds every 20 - 30 minutes, apart from several months of dormancy in late 1995. The outflow of about 1 to 2 L/s flows across a creamy-white, massive sinter terrace. This behaviour has been observed since Waikato Regional Council started monitoring the spring in 1995. There are two vents about 2 m apart, with the northern-most vent named Sapphire.

9.3.1.5 Feature Name: S108, 109, 110 [OKF0108-0110]

Type: Three hot springs, two of which have been observed erupting (Cody, 2000), all actively depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: The central mid-level terrace on Rainbow Fault scarp. NZMS-260 U17: 2784654 E, 6298521 N. Location from GPS (+/- 15 m). About 50 m from Sapphire geyser.

Description: Several small vents about 0.3 m diameter with constantly boiling overflows, producing white sinters. One was seen to be erupting in October 2000 (Cody, 2000e).

9.3.1.6 Feature Name: Devil's Throat [OKF118]

Type: Constantly boiling and overflowing alkaline spring.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: The central mid-level terrace on Rainbow Fault scarp. NZMS-260 U17: 2784703 E, 6298564 N. Location measured by GPS, +/- 15 m. About 10 m from Sapphire geyser.

Description: Devil's Throat flows at a rate of up to 1 L/s. lt had true geysering, with flows from nil to ~0.5 L/s and eruptions ~0.5m high, occurring every few minutes from May 2003 to mid-2004 (Cody, 2004e).

9.3.1.7 Feature Name: My Lady's Lace/Soda Fountain, S111 [OKF0111]

Type: Cyclically boiling hot spring actively depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Top of Rainbow Fault scarp. NZMS-260 U17: 2784670 E, 6298530 N. (2784658 E, 6298492 N). Location measured by GPS, +/- 15 m.

Description: This is an intermittently boiling spring with a temperature around 99 °C. Since 1995 it has been typically boiling with the height of ebullition about 0.5 m and flow rate around 0.5 L/s. The overflow passes through an artificial channel across a narrow sinter terrace which spills down the scarp of Rainbow Fault above S108-110. It boils for several days or weeks at a time, then stops boiling and the vent basin dries out for a period of time. On December 5th 2007 the pool drained overnight and had not refilled by April 25th 2008. The vent is a basin about 2.5 m in diameter surrounded by manuka scrub. There appears to be a sympathetic action with Diamond Geyser (described above), as data-logger records show that S111's boiling episodes frequently occur at the same time as eruptions from Diamond Geyser (Cody, 1996).

Figure 9-6: My Lady's Lace with a high water level.

9.3.1.8 Feature Name: Aorangi Geyser, S1004, S1005

Type: A dormant geyser.

Condition: Altered by river level increase, no longer flowing.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: 40 m NNW of Hochstetter Pool. On the left of the path walking up past Sapphire Geyser. NZMS-260 U17: 2784615 E, 6298566 N. Location extrapolated from GPS reading for S118.

Description: This geyser was formed from a hydrothermal eruption that occurred following the filling of Lake Ohakuri (Lloyd, 1972, p. 130; Keam, 1961). It flowed for several years but has not been known to flow since the 1960s. The water level is now about 0.3 m below overflow. Its

pool contains two vents located just less than 2 m apart. The water in it is clear and constantly bubbling, with a temperature ranging between 98 °C and 100 °C.

9.3.1.9 Feature Name: Dante's Pool, S105

Type: Flowing sinter-forming spring.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Five metres west of Aorangi Geyser. NZMS-260 U17: 2784623 E, 6298544 N. Location measured by GPS, +/- 15 m.

Description: According to Lloyd (1972):

> "The pool measures 2.2 m by 4 m at the surface and 4.6 m deep. From 1952 to 1954 this was an insignificant pool, but increased activity during late 1954 and 1955 caused a strong gas flow, which gave the appearance of boiling though the water temperature was only about 80 °C. In April 1959 its temperature was 34 °C, and there was no overflow until after Lake Ohakuri was filled."

On 13 May 1961 during the outbreak of Aorangi Geyser, Dante's Pool discharged water at 45 °C and much gas escaped from it (Lloyd, 1972).

On 25 January 2001, a new boiling and flowing spring was formed in Dante's Pool following a hydrothermal eruption (Cody, 2001a). It constantly boils with the height of ebullition about 0.2 m with a flow rate of about 1 L/s.

9.3.1.10 Feature Name: Hochstetter Pool, S98

Type: Sinter-forming spring, formerly a geyser.

Condition: Altered by river level increase and by channelling of its outflow, recoverable, not further threatened.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: At the base of Rainbow Scarp. NZMS-260 U17: 2784656 E, 6298539 N. Location measured by GPS, +/- 15 m.

Description: This geyser ceased erupting sometime after Lake Ohakuri was formed. It has since flowed at a stable rate of 2 L/s, producing water between 67 and 70 °C. It has large green microbial rafts around the margins and in the outlet channel that has been cut to direct the water onto Rainbow Terrace.

History: According to Lloyd (1972), this may be the spring known as Puia Tuhitarata.

9.3.1.11 Feature Name: S100, S101, S102, S103

Type: Hot springs actively depositing silica to form sinter.

Condition: Altered by river level increase, recoverable, not further threatened.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: NZMS-260 U17: 2784666 E, 6298539 N. Location measured by GPS, +/- 15 m.

Description: Several hot, clear, flowing springs along the northern end of the base of Rainbow Fault scarp. They are found on the northern side of Hochstetter Pool (S98). All are forming silica sinters and contribute to a coalescing mass of sinter terracing.

9.3.1.12 Feature Name: S114, S115, S117

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: On the middle level terrace (known by some as Coronation Terrace) against Rainbow Fault scarp. NZMS-260 U17: 27846900 E, 6298570 N. Location measured from map.

Description: Three small boiling hot springs that occasionally geyser to about 0.5 m high. All contribute to continuous sinter terrace formations.

9.3.1.13 Feature Name: S1007

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: In base of Rainbow Fault scarp, about 30 m NE of Hochstetter Pool.

Description: A noisily boiling and flowing spring that occasionally geysers about 1 m high. It lies within an area along the fault scarp where there is recent crumbling and collapse of the scarp face.

9.3.2 Golden Fleece Terrace

In September 2002 Golden Fleece Terrace commenced a period of intense activity, with many springs that had not been very active for the past twenty years or so, boiling and overflowing (Cody email to Luketina, 10/10/2002). During 2005 to 2008 spring activity has been variable.

9.3.2.1 Feature Name: Fred and Maggie pools, S119 [OKF0119]

Type: A pair of boiling flowing springs, actively depositing silica to form sinter.

Location: Middle of Golden Fleece terrace, approximately 60 m northeast of Manganese Pool. NZMS-260 U17: 2784751 E, 6298549 N. Location measured by GPS, +/- 15 m.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Description: The basin is about 2 m in diameter, and irregular in shape. From the mid-1990s to 2008 the temperature of the pool has been constant around 98 °C with a flow of approximately 0.1 L/s. Smooth, massive sinters coat the walls and the outflow channel. Discharge from the springs deposit silica and contribute to build up of the sinter terrace.

Figure 9-7: Fred and Maggie pools in 2003.

9.3.2.2 Feature Name: Manganese Pool, S120

Figure 9-8: An overflown Manganese Pool with visible conophyton stromatolite growths in February 2020. Copyright Jesse Ledwin Lebe.

Type: Hot spring actively depositing silica to from sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Western end of Golden Fleece terrace. NZMS-260 U17: 2784749 E, 6298522 N. Location measured by GPS, +/- 15 m.

Description: A clear, calm spring in a basin about 2 m in diameter. Usually the water level is below overflow but it occasionally flows, and from September 2002 it has been boiling steadily to a height of about 0.3 m and overflowing at a rate of about 1 L/s (Cody, 2002e). Massive, thick sinters coat the walls and the surrounding terrace.

9.3.2.3 Feature Name: Petrifying Pool, S121 [OKF0121] and Scarp Geyser, S122 [OKF0122]

Type: A hot spring and a geyser, both actively depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: On Golden Fleece terrace at base of fault scarp. NZMS-260 U17: 2784750 E, 6298522 N. Location measured by GPS, +/- 15 m.

Description: These are clear, hot springs that since monitoring began in 1995 have usually been calm and below overflow with massive sinter walls and surrounds. One of them commenced a period of geysering to a height of about 1.5 metres for several minutes during September 2002 (Cody email to Luketina, 7/10/2002).

9.3.2.4 Feature Name: Cauldron Geyser, S124 [OKF0124]

Type: Hot spring actively depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: NZMS-260 U17: 2784761 E, 6298517 N. Location measued by GPS, +/- 15 m.

Figure 9-9: Cauldron geyser in 2003.

Description: A calm, clear hot spring about 4 m in diameter at the base of Golden Fleece fault scarp, with massive sinter walls and surrounds. Since monitoring began in 1995, the spring remained below overflow for most of the time, but recommenced overflowing intermittently in September 2002. It had a period of geysering in the late 1940s.

9.3.2.5 Feature Name: Dreadnought Geyser [OKF0125]

Figure 9-10: Dreadnought geyser in 2004.

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Western base of Golden Fleece fault scarp. NZMS-260 U17: 2784765 E, 6298512 N. Location measured by GPS, +/- 15 m.

Description: An active geyser, in a vent of about 1 m diameter, located beneath a scarp face. It had episodes of geysering in the late 1940s, in September 2000 and again in October 2000 (Cody, 2000e) and September 2002 (Cody email to Luketina, 10/10/2002). The water is usually below boiling temperature and without any flows. It has thick creamy-coloured sinter walls and surrounds. Eruptions are at heights of up to 2 m.

9.3.2.6 Feature Name: Wairiri Geyser [OKF0126]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Western base of Golden Fleece fault scarp. Approximately 10 m west of Cauldron. NZMS-260 U17: 2784746 E, 6298519 N. Location measured by GPS, +/- 15 m.

Figure 9-11: Wairiri Geyser erupting in 2004.

Description: This feature had a period of eruptive activity from November 1982 to June 1983 (Cody, 2002c). It also erupted in 1996. In September 2002 it resumed overflowing, and then began erupting approximately seven times per day for 17 minutes at a time. Eruptions consisted of multiple spurts 5 to 8 m high in all directions and lasted for about 8 minutes, producing a flow of approximately 10 L/s (A.D.Cody, emails to Katherine Luketina, 19/11/2002 and 5/12/2002). This lasted until early 2003, when it continued boiling but ceased erupting (Cody, 2003a). During 2007 and April 2008, the water level of the pool varied considerably, rising and falling up to 1 m but remaining at least 0.5 m below the rim. In 2008, the water temperature was 93 °C, clear and calm.

9.3.2.7 Feature Name: Kurapai (Bendix) Geyser [OKF0708]

Type: Modified hot spring actively geysering, depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: In scrub and bush about 250 m west of Artist's Palette terrace. NZMS-260 U17: 2784662 E, 6298404 N. Location measured by GPS, +/- 15 m.

Figure 9-12: Dry Kurapai Geyser in 2004.

Description: A sinter-forming spring that has been modified to make an active geyser, which plays to about 20 m high for minutes or hours continuously, although typically dormant for weeks or months at a time. The vent is a steel pipe about 150 mm in diameter with a hole about 2 - 3 m wide and about 10 m long. In late 2002, Kurapai was erupting approximately 7 times per day for 8 minutes at a time (A.D.Cody, email to Katherine Luketina dated 5 December 2002). During 2007 to April 2008, eruptive periods increased from once a day to four times per day, with eruptions lasting about 20 minutes. The surrounding vegetation is coated with silica.

History: Bendix was the name given by either the Hamiltons (Charlie Hamilton was the resident guide from about 1948 to 1952) or the Wensors (Stan was resident guide from about 1952 to about 1956) (Lloyd, 1972). In its unmodified form, Bendix was the long basin evident today and it had periods of activity when it surged making a sound very like that of the old-style oscillatory washing-machine for which it was named. Only the occasional splash of water rose above the level of the surrounding ground.

The geyser was renamed Kurapai by Eileen Pascoe, resident at Orakei Korako from about 1956 until about 1970, in honour of the last Māori woman to leave Orakei Korako after the flooding. After leaving Ohakuri, Mrs Kurapai lived at Ohaaki until her death in 2001 at the age of 99 years (R.F. Keam, Ashley Cody, pers. comm).

Ted Lloyd cemented a 100 mm diameter pipe vertically into the vent in Bendix sometime about 1970-72. The pipe is several metres long. Ted considered that by confining the water to a pipe he could produce a geyser that might go a considerable height. The pipe remained in place for many years, although corrosion formed a hole in the side near its base. Most of the pipe was removed by the new proprietor, Craig Gibson, in 2002. Only the base of the pipe remains which is cemented in place by the formation of a small sinter mound that has formed around it. The removal of the rest of the pipe has had no apparent effect on eruptive behaviour of Kurapai (Cody, 2002c).

9.3.3 Artist's Palette Terrace

From time to time, the Artist's Palette Terrace has had intense activities, with many vents erupting and flowing. In July 1995, Palette Pool (S741) had a period of intense geysering to heights of 20 m, with overflows and progressive filling of adjacent vents in a steady outwards radiating migration of activity over several months. This resumption in boiling and overflowing of previously dry vents, was often accompanied by geysering action. However, some of those geysers have subsequently become quenched by overflows and merging of water levels from surrounding vents. Others have exploded and broken up their sinter margins which appear to have destroyed their geyser chambers. At least five such geysers blew apart the sinter in the first half of 1996 and then ceased erupting (Cody, 1996).

9.3.3.1 Feature Name: Palette Pool [OKF0741]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Centre of Artist's Palette silica sinter terrace. NZMS-260 U17: 2784850 E, 6298500 N. Location measured by GPS, +/- 15 m.

Figure 9-13: An overflowing Palette Pool on February 2020. Copyright Jesse Ledwin Lebe.

Description: An active pool geyser with hard white sinters and surrounds. The geyser plays 1 - 5 m high for a minute or so, with intervals of an hour or more. Eruptions sometimes are as high as 20 m. Since Waikato Regional Council monitoring began in 1995, the water level has varied greatly through the seasons, sometimes overflowing and sometimes up to five metres below overflow. The water level was well below overflow, and not erupting in the early 1990s and in 2004 (Cody, 2004c). The spring sometimes overflows gently without geyser action. Sometimes vents near the edge and inside the Palette Pool basin will geyser (see S1012 below).

9.3.3.2 Feature Name: Psyche's Bath, Gordon's Geyser [OKF0704]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: South-west side of Artist's Palette terrace. NZMS-260 U17: 2784776 E, 6298440 N. Location measured by GPS, +/- 15 m.

Description: An active geyser in a sinter lined basin about 5 m in diameter within kanuka scrub at the side of the terrace. Since monitoring began in 1995, its water has been generally boiling and about 3 m below overflow. The spring erupts to heights of about 5 - 8 m and floods over the surrounding ground. In 2001, its activity killed nearby shrubs.

For a time it was called Gordon's Geyser, after Gordon Bruce Scott who published an illustrated booklet about Orakei Korako in 1958 (Scott, 1958).

9.3.3.3 Feature Name: OKF0735

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: North-eastern side of Artist's Palette terrace and about 5 m west of a decomposing old pine tree lying on the terrace. NZMS-260 U17: 2784850 E, 6298500 N. Location measured by GPS, +/- 15 m.

Description: An active geyser with hard white sinter and surrounds. Since Waikato Regional Council monitoring began in 1995 the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of 3 - 5 m for 30 to 45 seconds, but intervals vary from less than one hour up to many hours. The surrounding wet terrace indicates when the geyser is active.

9.3.3.4 Feature Name: [OKF0738]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: North-eastern side of Artist's Palette terrace about 5 m south from an old pine tree lying out onto the terrace. NZMS-260 U17: 2784870 E, 6298510 N. Location measured by GPS, +/- 15 m.

Description: An active geyser with hard white sinters and surrounds. The vent is a small hole about 0.8 m in diameter. Since Waikato Regional Council monitoring began in 1995 the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of 1 - 2 m for a minute or so, but intervals vary from less than one hour up to many hours. The surrounding wet terrace indicates when the geyser is active.

9.3.3.5 Feature Name: [OKF1012]

Type: Several small active geysers depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Within the south end of the main Palette Pool. NZMS-260 U17: 2784855 E, 6298495 N. Location measured by GPS, +/- 15 m.

Description: Geysers within the hard white sinters in the south-eastern end of Palette Pool. The vent of one is about 0.5 m in diameter. Since Waikato Regional Council monitoring began in 1995, the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 5 to 10 m for a minute or less, with intervals of half an hour or more.

9.3.3.6 Feature Name: Square Pool [OKF0742]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: About 10 m west of Palette Pool. NZMS-260 U17: 2784840 E, 6298505 N. Location measured by GPS, +/- 15 m.

Description: An active geyser with hard white sinters and surrounds. It has a conspicuous straight side and is about 5 m wide x 7 m long. Since Waikato Regional Council monitoring began in 1995 the geyser has been active, either boiling or erupting. The geyser plays about 1 m high for several minutes, with intervals varying from one hour or less up to many hours. The surrounding wet terrace indicates when the geyser has been overflowing or erupting.

9.3.3.7 Feature Name: [OKF0764]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: West side of Artist's Palette terrace about 30 m north of Psyche's Bath. NZMS-260 U17: 2784810 E, 6298490 N. Location measured by GPS, +/- 15 m.

Description: An active geyser with hard thin grey sinters and surrounds. The pool is about 1.5 m in diameter. The geyser plays 3 - 5 m high for 30 seconds or more, but intervals vary from one hour or less up to many hours. The surrounding wet terrace indicates when the geyser has been active.

History: Lloyd (1972) did not describe this spring as a geyser, and there has been no record of it having erupted before October 2000 (Cody, 2000d).

9.3.3.8 Feature Name: [OKF0766]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: South-west side of Artist's Palette terrace about 10 m north of Psyche's Bath. NZMS-260 U17: 2784800 E, 6298480 N. Location estimated relative to Palette Pool.

Description: An active geyser with hard sinters and surrounds. There are two vents within a deep basin about 5 m in diameter, with manuka scrub edges. From December 2001 to June 2001 this geyser was erupting to heights of up to 5 metres every few hours (Cody, 2001a).

9.3.3.9 Feature Name: [OKF0772]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: South-west side of Artist's Palette terrace halfway between Palette Pool and Psyche's Bath. NZMS-260 U17: 2784820 E, 6298500 N. Location estimated relative to Palette Pool.

Description: An active geyser with hard grey sinters and surrounds. The vent is about 2 m in diameter. Since Waikato Regional Council monitoring began in 1995 the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of 3 - 8 m for 30 - 180 seconds, but intervals vary from one hour or less up to many hours. The surrounding wet terrace indicates when the geyser has been active. Sometimes its discharge flows into SOKF0773.

9.3.3.10 Feature Name: [OKF0760/1]

Figure 9-14: OKF0760/1 erupting in 2004.

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: 10 m north-east of S772. Location estimated from map.

Description: An active geyser that broke out in November 2001 beside a previously dormant vent (OKF0760). Eruptions last a few minutes and occur every few hours (Cody, 2001a).

History: OKF0760 spring has had alternating periods of dormancy and flowing activities lasting several years (Lloyd, 1972).

9.3.3.11 Feature Name: [OKF0773]

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Figure 9-15: OKF0774 (left) and OKF0773 (right) in 2003.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: West side of Artist's Palette terrace between Palette Pool and Psyche's Bath. NZMS-260 U17: 2784830 E, 6298495 N. Location estimated relative to Palette Pool.

Description: An active geyser with hard grey sinters and surrounds. The pool is about 20 m long and is oval in shape. Sometimes the run-off from OKF0772 flow into it. The run-off from OKF0773 flows into OKF0774. At high water levels OKF0773 and OKF0774 merge into one large pool that also contains the two unnamed springs below. Since Waikato Regional Council began monitoring in 1995, the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 3 m for about 30 seconds, with intervals of many hours or days. The surrounding wet terrace indicates when the geyser has been active.

9.3.3.12 Feature Name: two un-named small vents around OKF0773

Type: Active geysers depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: Near OKF0773.

Description: These geysers were active in February 2002. They erupt to height of up to 8 metres for several minutes, with a period of a few hours (Cody, 2002c).

9.3.3.13 Feature Name: OKF0774

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: West side of Artist's Palette terrace between Palette Pool and Psyche's Bath. NZMS-260 U17: 2784830 E, 6298495 N. Location estimated relative to Palette Pool.

Description: An active geyser with hard grey sinters and surrounds. The pool is about 20 m long, oval shaped, and is located within a larger depression that also contains OKF0773. At high water levels OKF0773 and OKF0774 merge into one large pool that also contains the two un-named springs above. Since Waikato Regional Council monitoring began in 1995 the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 3 m high for about 30 seconds or less, with intervals of many hours or days.

9.3.3.14 Feature Name: OKF0770

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: South-west side of Artist's Palette terrace about 20 m east of Psyche's Bath. NZMS-260 U17: 2784800 E, 6298475 N. Location estimated relative to Palette Pool.

Description: An active geyser with hard grey sinters and surrounds. The pool is about 1 m in diameter, about 20 m long, and oval shaped. It is surrounded by kanuka shrubs at the margin of the terrace. Since Waikato Regional Council monitoring began in 1995, the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 0.5 m high for several minutes, with intervals of many hours. It flows onto the terrace when active.

9.3.3.15 Feature Name: OKF0782

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: West side of Artist's Palette terrace at the base of the bank below the lookout shelter. NZMS-260 U17: 2784810 E, 6298470 N. Location estimated relative to Palette Pool.

Description: An active geyser with hard grey sinters and surrounds. The pool is about 1 m in diameter. Since Waikato Regional Council monitoring began in 1995 the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 0.5 to 1 m high for a few minutes, with intervals of many hours or days. The surrounding wet terrace indicates when the geyser has been active.

9.3.3.16 Feature Name: OKF0783

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: South-western side of Artist's Palette terrace directly beneath the tourist lookout shelter and about 10 m east of S782. NZMS-260 U17: 2784820 E, 6298470 N. Location estimated relative to Palette Pool.

Description: Hard grey sinters and surrounds. The pool is about 1 m in diameter. Since Waikato Regional Council monitoring began in 1995 the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 1 m high for a minute or less, with intervals of many hours or days. The surrounding wet terrace indicates when the geyser has been active.

9.3.3.17 Feature Name: OKF0795

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: East side of Artist's Palette terrace between Palette Pool and Pyramid of Geysers. NZMS-260 U17: 2784875 E, 6298500 N. Location estimated relative to Palette Pool.

Description: Hard grey sinters and surrounds. The vent is an irregular hole with a diameter of roughly 1 m, and is surrounded by broken, collapsed sinter sheets. The geyser erupts to heights of up to 3 m for several minutes (Cody 2001b), with intervals ranging from about 20 minutes to several hours. The geyser is unusual in that analysis of the frequency of eruptions recorded by data logger suggest this is actually two different geysers sharing one common vent to erupt through.

9.3.3.18 Feature Name: OKF0806

Type: An active geyser depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: East side of Artist's Palette terrace between the Pyramid of Geysers and a rotten pine tree lying on the north-east side of the terrace. NZMS-260 U17: 2784849 E, 6298500 N. Location measured by GPS, +/- 15 m.

Figure 9-16: OKF0806 in 2004.

Description: An active geyser with flaky, grey laminated sinters and surrounds. The vent is about 0.5 m in diameter in a shallow depression on the east side of a rotting old pine tree. Since Waikato Regional Council monitoring began in 1995, the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 0.5 m high for a minute or so, with intervals of half an hour or more. Several small vents around the geyser sometimes boil vigorously.

9.3.3.19 Feature Name: Pyramid of Geysers [OKF0812, OKF0824]

Type: Two active geysers depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Inaccessible to the public due to hazardous nature of the terrain.

Location: Up the slope on the east side of Artist's Palette terrace, at the base of the Pyramid of Geysers. NZMS-260 U17: 2784886 E, 6298486 N. Location measured by GPS, +/- 15 m.

Description: Two intermittently active geysers with massive creamy, white sinters that cascade down the slope. The vent of S812 is about 1.5 m in diameter and about 2 m up from the terrace level. Since Waikato Regional Council monitoring began in 1995 the geyser has exhibited periods

Figure 9-17: Pyramid of Geyser on February 2020. Copyright Jesse Ledwin Lebe.

of activity interspersed with periods of dormancy, both lasting months. When active, it plays for many minutes when active to a height of about 0.5 m.

9.3.3.20 Feature Name: Pyramid of Geysers [OKF0817- OKF0819]

Type: Active geysers depositing silica to from sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Inaccessible to the public due to hazardous nature of the terrain.

Location: East side of Artist's Palette terrace up the hill slope. NZMS-260 U17: 2784886 E, 6298486 N. Location measured by GPS, +/- 15 m.

Description: Three active geysers with hard white sinters and surrounds that cascade down the slope. The vents are about 0.5 m in diameter on a hillside above terrace level. Since Waikato Regional Council monitoring began in 1995, the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 0.5 m high for many minutes, with intervals of many hours.

History: The first published reference to the Pyramid of Geysers was in Allen (1894).

9.3.3.21 Feature Name: OKF0834

Type: An active geyser depositing silica to from sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: At extreme south-eastern end of Artist's Palette terrace. NZMS-260 U17: 2784900 E, 6298440 N. Location estimated relative to Palette Pool.

Description: An active geyser with crumbly, grey laminated sinters and a vent of about 1 m diameter. Since Waikato Regional Council monitoring began in 1995, the geyser has exhibited

periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 0.5 m high for several minutes, with intervals of unknown duration.

9.3.3.22 Feature Name: OKF0844

Type: An active geyser depositing silica to from sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: At south-east end of Artist's Palette about 15 m north of S834. NZMS-260 U17: 2784915 E, 6298440 N. Location estimated relative to Palette Pool.

Description: An active geyser in a vent about 1 m in diameter, surrounded by collapsed laminated grey sinters. Since Waikato Regional Council monitoring began in 1995, the geyser has exhibited periods of activity interspersed with periods of dormancy. When active, it erupts to heights of about 0.5 m high for several minutes, with intervals of hours or days.

9.4 Red Hills

This area is up-river and south of the main tourist area. There are boiling springs along the riverbanks that are forming sinters. The site has not been visited recently and its features not properly identified. There are probably more springs forming sinter yet to be described.

9.4.1.1 Feature Name: Springs [OKF0350-OKF0351]

Type: Two boiling springs actively depositing silica to form sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Not readily accessible to the public.

Location: NZMS-260 U17: 2784750 E, 6297250 N. Location measured from map sheet. Approximate only.

Description: There are two boiling springs alongside the east bank of the Waikato River. Both flow down the slope to produce creamy-white sinter aprons about 5 m wide x 10 m long or more. The area is inaccessible by foot and visible only from the lake. The springs have not been properly located or described.

9.4.1.2 Feature Names: [OKF0487-OKF0488]

Type: Active geysers depositing silica to from sinter.

Condition: Recoverable. Altered by river level increase.

Threats: Hardly threatened. Accessible to the public, with slight risk of vandalism.

Location: About 0.5 km upriver of Red Hills. A freshwater stream valley enters the east side of the river and alongside the stream there are several boiling flowing and sinter-forming springs. This area is known as Akatarewa.

Description: OKF0487 and OKF0488 are geysers, which are seen erupting by people who use the stream for hot bathing. Each has a vent pool about 1 - 2 m in diameter. They are perched on banks about 10 m above the river. They are not accessible by foot.

9.5 Chemistry of Orakei Korako System

See also Lloyd (1972), and Lyon & Sheppard (1981).

The waters from Waihunuhunu have a peripheral or bicarbonate-rich water chemistry, different from the more chloride-rich waters from Map of Australia. Sapphire Geyser has a chemistry type in between the two aforementioned features, having a mixed chloride-bicarbonate chemistry.

Table 6: Chemistry of Orakei Korako hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Waihunuhunu [OKF0674]	72_2995		1965	80	7.9	106	16	271	130
			8/07/93	58	7.6	54.2	20	196	105
			27/04/94	59	7.1	57	21	237	105
			18/10/95	52	7.2	57	19	229	118
			21/09/05	81	7.4	93.2	28	207	148
Map Of Australia [OKF0025]	3065_1	Historical: 72_2998	27/04/94	86	7.9	312	65	317	254
			29/09/05	82	8.1	309	66	148	252
			23/07/09	81	7.8	310	63	20	140
Sapphire S106 [OKF0106, OKF0107]	3065_17, 3065_18	Historical: 72_2999	29/09/05	98	8.9	336	83	138	306

10 REPOROA

Reporoa geothermal system is classified in the Waikato Regional Plan as a Research Geothermal System. The system may be connected to the protected Waikite-Waiotapu-Waimangu system, which adjoins it. It has hot springs and pools, steaming ground, mud pools, and seepages. There are large numbers of the rare fern *Christella* sp. *thermal* at Golden Springs. Springs in two locations are still depositing silica. There are no sinters at Golden Springs. Land drainage for farming is ongoing and has lowered the water table, stopping other springs from continuing to build up sinter deposits. The cones of extinct geysers on drained farmland were bulldozed in 2004 (Cody 2004a).

10.1 Opaheke Springs (a.k.a. Opateketeke)

10.1.1.1 Feature Name: Māori (North) Spring [RPF21]

Type: Boiling spring actively depositing silica to form sinter.

Condition: Unaltered.

Threats: Moderately threatened. If the Reporoa geothermal system classification were changed to Development, the spring would be highly vulnerable to any geothermal well production reducing aquifer pressure and stopping all flows. It is also at risk from any human activities such as diversion of outflow into a narrow channel, which would stop sinter formation.

Figure 10-1: Māori Spring in 2004.

Location: NZMS-260 U17: 2800898 E, 6304602 N. Location measured by GPS, +/- 50 m.

Description: A clear, constantly vigorously boiling and overflowing alkaline spring within Māori land known variously as Opaheke (the official LINZ name) or Opateketeke. It is situated about 1 km east of S.H.5 and about 1 km south of Wharepapa Road. The spring has marshy surrounds with large microbial mats and sinters and peripheral manuka scrub. The sinter deposits around the spring are raised hard, crenulated masses, with thick flat laminar deposits along the outflow zone for about 10 m. Beyond there, cooler waters allow the growth of algae and microbes. The outflow is about 0.5 L/s. (Glover and Ellis, 1967; Newson, 1993; Mahon, 1966).

History: The area is Māori land.

10.2 South-east Springs

10.2.1.1 Feature Name: South Spring, Hot Pool 3 [RPF9]

Type: Hot spring actively depositing silica to form sinter.

Condition: Recoverable. The spring is in a paddock. Its muddy margins are trampled by cattle, and the spring is altered by channelling and land drainage.

Threats: Severely threatened. The surrounding landscape has been extensively drained to allow pastoral development. The spring once naturally flowed into marshy peats and swamps and

there are thin sinter sheet deposits in this area. It is vulnerable to further lowering of the groundwater table, which would reduce the flow. Any geothermal power development on the system would lower the geothermal aquifer pressure and water level. Cattle trample the surrounds and margins.

Location: NZMS-260 U17: 2800959 E, 6304325 N. Location measured by GPS, +/- 15 m.

Description: A large, circular hot spring about 8 m in diameter with clear, calm alkaline water. In 1999, a channel was dug to contain the outflow of about 1 L/s. In clear sunlight the view down the vent shows vertical to overhanging walls to a depth of more than 6 m. There is no present silica deposition in the surrounding area due to the outflow being directed into an artificial channel.

Figure 10-2: South Spring in February 2020.

History: No Māori name or legend known.

10.3 Longview Road Springs

10.3.1.1 Feature Name: Longview Road Springs

Figure 10-3: Longview Road features in 2003.

Type: Three or more hot springs no longer depositing silica.

Condition: Recoverable. Altered by land drainage.

Threats: Severely threatened. These springs were significant for the types of silica deposition occurring (Jones *et al.*, 1998), but sinter is no longer actively forming due to the surrounding land having been drained by the owner for farming purposes. There is ongoing destruction of hot spring habitats.

Location: NZMS-260 U17: 2803591 E, 6304521 N. Location from GPS (+/- 15 m).

Description: An area of thermal ground with springs in the centre, a sinter apron and prostrate kanuka and associated vegetation on the margins. The area is surrounded by farmland and the springs are not fenced from cattle, which trample the sinter.

History: No Māori name or legend known.

10.4 Chemistry of Reporoa Hot Springs

See also Mahon (1966), Glover and Ellis (1967), and Newson (1993).

Hot Pool 3 shows a mature chloride water chemistry, similar to waters typically observed on upflows of geothermal systems. Māori Spring has a transitional chloride-bicarbonate chemistry when sampled by Waikato Regional Council in 1993, but progressively show changes in water chemistry of the hot spring into very mature chloride compositions in 2005 and 2009.

Table 7: Chemistry of Reporoa hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp	pH	Cl	SO_4	SiO_2	HCO_3
				(°C)		(parts per million)			
Hot Pool 3 [RPF9]	3066_9	72_3001	29/09/05	97	8.1	588	14	242	262
			23/07/09	93	7.7	580	12	170	17
Māori Spring [RPF21]	3066_21	72_3002 72_4220	8/07/93	95	7.2	746	30	268	601
			27/04/94	97	7.3	744	29	274	571
			29/09/05	98	7.4	818	26	274	276
			23/07/09	53	6.7	770	48	250	18

11 ROTOKAWA

Rotokawa geothermal system is listed in the Waikato Regional Plan as a Development Geothermal System, and it supports two geothermal power stations, the 30 MW Rotokawa Power Station and the 140 MW Nga Awa Purua station. The system is located only a few kilometres northeast of the Tauhara field. The most notable geothermal surface feature of the system is Lake Rotokawa, a cold shallow lake with a pH of 2.3. The lake has formed in a hydrothermal eruption crater (Browne, 1988; Krupp et al., 1986). Occupying approximately 0.6 km^2, it is New Zealand's largest geothermal lake.

Lake-edge springs deposit sinter into a lagoon on the northern shore of the lake, known as the Western Lagoon. The Western Lagoon discharges into the lake at a rate of approximately 5 L/s. The lake drains from the eastern side into Parariki stream at a flow rate of ~100 L/s (Forsyth, 1978). The Parariki Stream has non-sinter-forming geothermal springs along most of its length. The stream discharges to the Waikato River.

On the banks of the Waikato River, upstream from the Parariki Stream outlet, there are numerous hot springs discharging directly into the bed of the river. There are two isolated hot springs north of the lake, on the farm land near the power station. Immediately to the north of the lake is a large expanse of altered soil and geothermal vegetation of approximately two square kilometres. This area includes mud pools in deep collapse craters.

Lynne (2008) describes many of the surface features at Rotokawa and includes detailed maps and descriptions by Lloyd (1951). Due to resourcing constraints, this information is not repeated here.

11.1 Lagoon Springs

11.1.1.1 Feature Name: RKF3

Type: Cold to warm acid spring.

Condition: Unaltered. Minimal adverse effects observed from geothermal extraction.

Threats: Slightly threatened. Future geothermal extractions could affect the feature.

Location: NZMS-260 U17: 2787821 E, 6281347 N. Location measured by GPS, +/- 50 m.

Figure 11-1: RKF3 on February 2020. Copyright Jesse Ledwin Lebe.

Description: A large spring on a mud flat approximately 25 – 30 m in diameter with turbid, cloudy yellow-green, acid sulphate water. The level of ebullition is observed to change from only small gas discharge around pool margins, to a constant discharge between January 2015 and January 2016. The presence of sulphur slimes are observed in the pool. There are smaller springs and sulphur-depositing steam vents around the pool margins.

History: No Māori name or legend known.

11.1.1.2 Feature Name: RKF4

Type: Hot acid spring.

Condition: Unaltered. Minimal adverse effects observed from geothermal extraction.

Threats: Slightly threatened. Future geothermal extractions could affect the feature.

Location: NZMS-260 U17: 2787821 E, 6281347 N. Location measured by GPS, +/- 50 m.

Description: A small sub-circular next to RKF3 with turbid, cloudy yellow-green, acid sulphate water. Constant ebullience and gas discharge is observed. In 2016, the spring colour was observed as being slightly blue.

History: No Māori name or legend known.

11.2 Chemistry of Rotokawa hot springs

The features sampled in Rotokawa are divided into two main groups, mature neutral-chloride waters (RKF4 and RKF10), or low pH acid sulphate waters (RKF4A, RKF22). Feature RKF4A is observed to have become more sulphide-rich from 1994 to 2009, while other springs are also observed to have more minor increases in acid sulphate concentrations.

Table 8: Chemistry of Rotokawa hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Date	Temp.	pH	Cl	SO_4	SiO_2	HCO_3
			(°C)		(parts per million)			
Rotokawa #4 [RKF4]	3067_4	14/06/94	94	6.8	538	99	198	155
		28/01/94	80	7.8	496	112	218	115
Rotokawa #4A	72_4392	14/06/94	78	2.6	447	685	238	
		28/01/94	75	2.4	418	932	246	
		1/9/09	78.4	2.3	350	1100	270	20
Rotokawa #22 [RKF22]	3067_22	14/06/94	90	2.3	454	980	313	
		28/01/94	80	2.1	450	1038	319	
Rotokawa #10 [RKF10]	3067_10	14/06/94	75	2.6	629	803	352	290
		01/02/94	73	2.4	635	898	355	110

12 TAUHARA

Wairakei-Tauhara geothermal system is listed in the Waikato Regional Plan as a Development Geothermal System, because it has already been developed and its sinter-forming springs destroyed by that development. The Wairakei-Tauhara system had many geysers and sinter-forming springs in its pre-development state, but these are all extinct following the commencement of large-scale extraction for the Wairakei geothermal power station in 1958. The system is identified as having two fields, with the Waikato River forming the boundary between them. The Wairakei field in the west had many sinter-forming springs in the area known as Geyser Valley, at the northern part of the field, as well as steam features in the Waiora, Te Kiri O Hinekai, and Karapiti areas.

The Tauhara field in the east is recognised has having two separate upflows, one producing springs in the Waipahihi Valley, and the other producing springs in the AC and Spa Sights areas, in addition to many steam features to the north of the town.

Most of the features on the Wairakei-Tauhara system, with the possible exception of the Waipahihi features, were adversely affected by the development and operation of the Wairakei Power Station. At Wairakei none of the sinter-forming springs currently discharge at the surface. However, there is some discharge of condensed steam. The activity of the steam-fed features of the Wairakei-Tauhara system has been enhanced by the reduction in field pressure due to exploitation of the field for electricity.

At Tauhara, the riverside geysers and sinter-forming springs are extinct. This is due to the effect of the Wairakei Power Station, and the combined effect of the construction of a gate at the outlet of Lake Taupō which controls the lake level, river flow, attendant permanent diversion of the start of the Waikato River, and river level management. There has been a considerable decline in the activities of sinter-forming springs around the Otumuheke Stream. This may be due to either the Wairakei Power Station, or local rainfall and ground water fluctuations. Declines in activity of the Waipahihi springs appear to be related to low rainfall or draw-off by local bores, although there is some evidence that it may also be a late result of the draw-off for the Wairakei Power Station.

12.1 Tauhara Springs

Name: Waipahihi Source Spring, Terraces Spring No. 6, Terraces, Top Spring [THF6]
Type: Inactive geyser with minimal silica deposition.

Condition: Unrecoverable.

Threats: Severely threatened. Nearby wells supply the baths of Taupō Hot Springs and heating for DeBretts Hotel. Further use, new wells, or increased extraction will reduce supply to this spring. It is the only remaining sinter-forming spring along this valley, although in the 1890s-1900s several more pools existed. It is fenced off from stock but the fence could fail.

Location: NZMS-260 U18: 2779884 E, 6273259 N. Location measured from GPS (+/- 15 m).

Description: A hot, flowing, clear spring about 2.5 m in diameter in the bottom of the deep Waipahihi gully east of Taupō Hot Springs public swimming complex (previously DeBretts). In 1964 and in 1985, it had a flow of at least 5 L/s (Fisher, 1964; Allis, 1985). It was known to geyser in the 1970s. In 2005 it was documented to flow at a rate of about 2 L/s. By 2008 it was only flowing at 0.2 l/s. It has thin sinter margins on a soft marshy substrate. In 2008, the water temperature was 74 °C with a flow rate of 0.1 L/s.

History: No Māori name or legend known.

12.1.1.1 Feature Name: Iron Bath Spring [THF1]

Type: Extinct sinter-forming spring.

Condition: Unrecoverable.

Threats: Severely threatened. The remaining sinter and spring vent is threatened by human uses.

Location: NZMS-260 U18: 2779839 E, 6273199 N. Location measured from GPS (+/- 50 m).

Description: The Iron Bath Spring is so named because of its black sinter surrounds. It is now covered in blackberry and has not discharged since the late 1980s.

History: No Māori name or legend known. It had a large multi-coloured sinter terrace (Cody, 1993). In 1964 it had a discharge of 4 L/s (Fisher, 1964). Much of the sinter was excavated and a pump installed in the 1970s to provide water to the nearby De Bretts Hotel (Allis *et al.*, 1989). However its flow became insufficient to meet the heat demand and pumping ceased in mid-1985 when a 35 m well was drilled 20 m from the spring to replace the flow (Allis, 1985).

The Waipahihi springs had a chloride content of ~ 300 ppm in 1962 (Sarbutt, 1964) and there has been little change in the spring chemistry over time, although individual springs have changed their behaviour (Glover, 2000).

12.1.1.2 Feature Name: Kathleen Spring [THF91]

Type: Spring, now dormant, of mixed chloride water that weakly deposited silica

Condition: Altered by steam drawdown

Threats: Moderately threatened. The dry sinter is at risk from land use practices.

Location: NZMS-260 U18: 2779566 E, 6276024 N. Location measured from GPS (+/- 50 m).

Description: This spring, like those surrounding it in the Otumuheke area, is sensitive to rainfall. In early 1993 it stopped flowing but recommenced in mid-October 1995 with a discharge of about 0.8 L/s at 82 °C, which was similar to its previous flow (Bromley 1995). It has not flowed since 1997. There are several potential reasons why the springs have failed; rainfall variations, natural variation in the geothermal resource, drawdown from Wairakei, and extraction from the shallow aquifer by nearby.

History: No Māori name or legend known.

12.2 Extinct Geysers and Hot Springs of Tauhara:

Several geysers were present at The Spa in the Wairakei-Tauhara field at Taupō, but ceased erupting due to the lowering of water level in the Waikato River for the installation and operation of the Taupō Control Gates prior to 1950 (Henley and Stewart, 1983). Like the Wairakei chloride springs, these springs were also subsequently affected by the operation of the Wairakei Power station, and had ceased flowing by 1962 (Glover, 2000). The remnant sinter from the extinct geysers can now be seen along the bank of the Waikato River downstream of Taupō township.

As with the Wairakei extinct springs, a recovery of the reservoir may cause new chloride outflows and the creation of new features. The sinter remains, and is under threat from weathering and human activities such as vandalism.

Grange (1937) describes the geysers at Taupō township:

> "A track from the Spa Hotel leads to hot springs near the Waikato River, the most conspicuous being the Crow's Nest Geyser, which has built a mound of sinter 7 ft. high and 5 ft. in diameter at the top… The vent 7 ft. below the surface is about 15 in. The base of the mound, which is 3 ft. above the river, has a hole about 1 ft. in diameter. It is inactive for about four hours; the period of rest, according to the proprietor of the Spa, depending on the height of the river, being less when the river is high. When in action it plays to a height of about 60 ft., sending up as many as thirty shots at intervals of two minutes. Nearby, Waipikirangi Geyser (98 °C) overflows at the rate of about 10 gallons per minute and erupts when the outlet is blocked. Hazel Geyser, a grey, turbid, acid sulphate spring (98 °C), upstream from the geysers, boils up occasionally to a height of 4 ft or 5 ft."

Keam (1959) mentions three other geysers; a small unnamed geyser "that splashes up every few minutes", Satan's Laundry, "which splashes unceasingly", and Eunice Geyser, with "eruptions reaching twenty feet".

12.3 Chemistry of Tauhara hot springs

See also Henley (1979), Allis (1982) and Bromley and Glover (1996) for geochemical data. Glover (2000) gives a list of sources, summarises their content, and provides updated data.

The water chemistry of features which are sources to commercial bathing uses, including the A.C. Bath Spring and Waipahihi Source Spring, show mixed water and transitional chloride-bicarbonate water compositions respectively, which are both very high in bicarbonate concentrations. The Lake Front Spring, situated at the shore of Lake Taupō, has a strongly mixed water chemistry, but could be affected by mixing of freshwater from the lake.

Table 9: Chemistry of Tauhara hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp.	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Rocky Point Spring [THF12]	3068_17	72_2988	9/06/94		6.6	115	131	377	232
			20/09/05	66	7.1	104	131	109	276
			23/07/09	66	7	160	100	18	250
Lake Front (Taharepa) [THF16]	3068_16	1197_1 Policeman's Bath	9/06/94		6.5	156	107	509	240
Spa Spring			9/06/94	92	6.3	9.7	410	49	331
Primary Spring			9/06/94	78	6.5	7.4	211	95	290
A.C. Bath Spring [THF92]	3068_92		9/06/94		6.7	7.2	146	126	258
Waipahihi Source Spring [THF6]	3068_6	72_2989	9/06/94		7.0	332	70	371	239
			20/09/05	67	7.0	331	74	138	262
			23/07/09	68	6.8	330	75	340	260

13 TE AROHA

Te Aroha geothermal system is considered a Small Geothermal System by the Waikato Regional Plan. It is a waning geothermal system related to Miocene to early Pliocene age Coromandel volcanism (18 to 4 million years old) (Adams et al., 1994), and is associated with prominent regional faulting. The Te Aroha area consists of 3 - 5 million year old geothermal activity but has since been deeply eroded and uplifted. No sinter deposits exist but one drilled "spring" presently deposits very minor calcite.

13.1 Te Aroha Springs and Bores

13.1.1.1 Feature Name: Mokena Geyser

Type: Modified hot spring, actively geysering and depositing calcium carbonate to form travertine.

Condition: Recoverable.

Figure 13-1: Mokena Geyser erupting to ~1.5 m high in 2012.

Threats: Hardly threatened. This is an artificial feature with values for its tourism uses, so its activity is likely to be maintained by the owner.

Location: Within Te Aroha Domain, which is between Boundary and Wilson Streets east of Whitaker Street. NZMS-260 T13: 2750244 E, 6402898 N. Location measured from GPS (+/- 25 m).

Description: Mokena Geyser is actually a bore drilled in 1936 (Rockel, 1986). It erupts periodically with a geyser action. In 2001, it was spouting around 4 m into the air every 40 minutes. Its surrounding wet splash zone has a thin coating of white calcium carbonate. This occurs in the splash zone to a radius about 1 m around the wellhead. The deposit is 2 to 10 mm thick. The outflow is diverted to the nearby bathing complex.

Although this is not a natural feature, it has developed significant tourist appeal and scientific value as New Zealand's only soda geyser. Because of its cultural value as a tourist attraction, it has been included in the table of features at the end of this report.

Mokena geyser was named after a chief (who also went under the name Morgan) living at Te Aroha who is believed to have gifted the Te Aroha domain, in which the hot springs are situated, to the nation (Rockel, 1986).

13.2 Chemistry

Water analyses can be found also in Henderson (1938) and Petty (1972), Lancet Correspondent (1893), Grange (1937), Healy (1956), and Waikato Regional Council records.

The chemistry of Mokena Geyser is mixed water, with very high bicarbonate concentrations relative to chloride and sulphate.

Table 10: Chemistry of Te Aroha Springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Date	Temp.	pH	Cl	SO_4	HCO_3	SiO_2
			(^oC)		(parts per million)			
Mokena Geyser	72_2227	01/01/38			581	388	6860	
		01/01/56			596		5960	
		01/01/58		7.5	582	321	7000	120
		01/01/79		7.8	540	472	6830	138
		29/01/81		8.7	575	417	6880	114
		01/01/86		8.4	567	1260	7100	123
		05/08/93	73	8.2	571	394	6300	116
		20/04/94	77	8.2	570	374	6450	118
		20/07/09	94	7.8	580	390	18	120

14 TE KOPIA

Te Kopia geothermal system is listed in the Waikato Regional Plan as a Protected Geothermal System. It is contiguous with the protected Orakei Korako geothermal system, which lies immediately to the southwest. Geothermal activity occurs at the base and on the face of the Paeroa Scarp, which rises 600 m from its base at 380 m to its highest point at 980 m. Several super-heated fumaroles pump steam out in an impressive display from part-way up the scarp. The features at the base of the scarp consist of boiling mud pools of various colours including dark grey, bright red, and cream, smaller fumaroles, a mud volcano and an unusual mud geyser. Some geothermal springs can be found in farmland immediately west of the geothermal features, and from time to time areas of farmland become steaming ground, killing grass and trees, with the occasional small hydrothermal eruption.

14.1 Murphy's Gully Springs

14.1.1.1 Feature Name: Murphy's Gully Springs [TKF100]

Type: Three hot springs with minimal sinter.

Condition: Recoverable.

Threats: Severely threatened. The sinters are continually damaged by stock crushing them. Pine trees have been planted around the area and logging work could damage the springs.

Location: NZMS-260 U17: 2790849 E, 6307341 N. Location measured from GPS (+/- 100 m).

Description: Three weakly flowing, hot, clear springs on the north wall of the gully about 1 km north-west from the house. They are alkaline, sinter-forming springs, although the sinters are very insignificant in extent and mass.

History: No Māori name or legend known. The springs may be very young, due to the very minor extent of the sinter deposits.

Chemistry: See Sheppard and Klyen (1992) and Bromley (1998) for a discussion of work and chemistry of waters.

14.2 Te Kopia Springs

14.2.1.1 Feature Name: Te Kopia Mud Geyser [TKF1, TKF2]

Type: Intermittently erupting mud geyser.

Condition: Unaltered.

Threats: Hardly threatened.

Location: NZMS-260 U17: 2790866 E, 6306251 N. Location measured from GPS (+/- 15 m). It is located within the Department of Conservation (DOC) Scenic Reserve on the east side of Te Kopia Road.

Description: This geyser is possibly unique in that its discharge is muddy water, erupted from a narrow vent in the side of a large mud pool. Since Waikato Regional Council started monitoring the geyser in 1995, it has exhibited three types of activities. It has periods of dormancy, interspersed with infrequent large eruptions that may take place only every few months. These eruptions coat the surrounding vegetation with mud. The geyser also has periods in which it has smaller, more frequent eruptions, ejecting a column of grey, muddy water 3 to 10 m high as a single shot accompanied by a loud detonation. These eruptions occur every 10 to 30 minutes when the geyser is active. Its vent is an oval slot about 0.8 m x 0.5 m in area in the west wall of a large hot muddy pool about 30 m in diameter. Successive eruptions of muddy water have built up a long mud bank along the wall surrounding the vent. When active, the Te Kopia Mud Geyser plasters surrounding vegetation in a thick layer of pale grey mud. In very wet weather or prolonged high rainfall, the neighbouring pool becomes flooded, quenching the geyser. The geyser played frequently from September 2000 to March 2001 and manuka and kanuka shrubs to about 20 m radius were bent over under the weight of the mud coating.

Figure 14-1: Te Kopia Mud Geyser erupting in 2009.

In July 2008 it was erupting to a height of 2 m within the vent every three minutes. The vent had become enlarged to about one metre in diameter, and the frequent eruptions had carved an extension of the vent into the side of the mud bank. The interior of this vent was fluted with streams of dried mud. Recent heavy rain had failed to destroy evidence of a recent large eruption, with mud deposits on nearby vegetation.

A similar feature at Te Kopia was visited and described by the Austrian geologist Hochstetter in the early 1860s. He clearly describes its size and activity, and its position at the bottom of the steep hillside (p.150 in 1959 Fleming translation of Hochstetter, 1864). It is not clear whether this feature is the same as today's mud geyser.

14.2.1.2 Feature Name: Unnamed acid spring, gully spring [TKF5]

Type: Mixed acid-sulphate-chloride spring, actively depositing silica to form sinter.

Condition: Unaltered.

Threats: Hardly threatened.

Location: NZMS-260 U17: 2790855 E, 6306431 N. Location measured from GPS (+/- 25 m). It is ~70 m west from Te Kopia Road in a gully just ~100 m north from the Scenic Reserve on the east side of the road.

Description: It is very acidic, with a pH of 3. Since Waikato Regional Council started monitoring the spring in 1995, it has been ~90 °C, constantly flowing, clear, with no odours. All around is hard, dark brown, well-indurated sinter banks and terraces, although only ~5 m x 3 m in spatial extent. At present, the spring is not forming sinter on the terrace but black sinter is forming in the pool.

14.3 Chemistry

Many springs in the eastern side of Te Kopia along the fault scarp are diluted by mud, so their geochemistry data are not very reliable. Murphy's Farm NW Spring, on the west of Te Kopia Rd,

shows near-neutral transitional chloride waters, but with significant bicarbonate compositions. However, their chlorine compositions are relatively low for the TVZ.

Table 11: Chemistry of Te Kopia Springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp.	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Murphy's Farm NW [TKF100]	3069_43	72 _3003	05/03/92	62	7.5	89	18	56	140
			21/05/93	61	8.0	83	22	27	134
			11/05/94	53	7.5	79	21	48	119
			18/10/95	61	7.6	82	19	52	139
			30/09/05	60	7.5	95	20	25	137

15 TOKAANU

The Tokaanu features are a field within the Tokaanu-Waihi-Hipaua Geothermal System, which the Waikato Regional Plan classifies as a Limited Development Geothermal System.

Various researchers have published their own maps of the hot springs at Tokaanu but without any continuity or standardisation on the use of Māori names. Earlier published maps gave names but without any explanation of where those names came from, nor why they did not use those already published by previous authors. This problem is discussed more thoroughly by Severne (1995), who wrote her University of Auckland MSc and PhD theses on this geothermal system. Those names used here are as given by Severne (1995).

The natural outflow of the Tokaanu field has been affected by several factors. There is extensive small-scale draw-off from the system for heating and bathing by homes, motels, a hotel, a lodge, and a swimming complex. In addition a government-owned bore known as the Healy No. 2 bore has been openly discharging since the 1940s, and currently is responsible for approximately 15 percent of the total discharge from the system.

Sometime before May 2003, the Healy No. 1 bore, which had been properly closed blew out, sending ejecta ~2m to the north, and leaving a steaming crater ~2m deep, with big blocks of concrete exposed. No casing could be seen and it was assumed that it had fallen downwards. Shrubs and plants in the immediate vicinity were all dead (Cody, 2003c).

The local ground water level has been affected by drainage of the surrounding swamp land, and several re-routings of the Tokaanu Stream.

In addition, there is significant tectonic tilting in the Taupō Volcanic Zone that gives Lake Taupō an effective water level rise of 1 mm per year at Tokaanu compared with the lake level at Taupō township (Blick and Otway, 1995). The lake level is also artificially controlled for hydroelectric purposes. As well as affecting the outflow from springs, increases in lake water level have caused inundation of non-sinter-forming springs on the Waihi foreshore.

Almost all of the geysers and sinter-forming springs at Tokaanu have drainage channels dug or been otherwise modified in order to use their heat or water for traditional uses, or to protect the DOC scenic path that passes through the Tokaanu features.

Much of the information provided in this section has been taken from Severne (1999).

15.1.1.1 Feature Name: Te Korokoro A Te Poinga (Severne), S15 (Mahon) [TOF15]

Type: Warm pool, no longer depositing silica to form sinter, previously a geyser.

Condition: Recoverable.

Threats: Moderately threatened. The spring appears to have been affected by well draw off from the system lowering supply pressures. Surface overflow no longer occurs.

Figure 15-1: Te Korokoro A Te Poinga in 2000. Copyright Ashley D Cody.

Location: NZMS-260 T19: 2749524 E, 6245014 N. Location measured from GPS (+/- 50 m).

Description: A hot, clear spring about 2 m in diameter, found in the bush downstream of the Tokaanu domain, close to the Atakorereke Stream. The spring has sinter

walls and surfaces but no surface outflow. It was described by Grange (1937) as a strongly boiling (above boiling temperature) clear spring. Grange measured temperatures in 1928 of 100.5 °C at the surface and 103.5 °C at 2 m depth and 106 °C at 4.6 m depth. In 1952, it was still boiling vigorously (R.F. Keam, pers comm. 2000). The spring is now significantly cooler with a maximum measured temperature of 45 °C.

History: Māori name and occupation of the site for 100s of years.

15.1.1.2 Feature Name: Tuwhare Spring (Severne), S23 (Mahon) [TOF23]

Type: Inactive geyser actively depositing silica to form sinter.

Condition: Recoverable.

Threats: Moderately threatened. The spring is vulnerable to increased well draw off from the system lowering supply pressures.

Location: NZMS-260 T19: 2749696 E, 6244935 N. Location measured from GPS (+/- 50 m).

Description: A hot, clear spring about 6 m long and with a maximum width of 2 m. It is surrounded by a flat sinter apron at the south-east end of the marae grounds, which is across the road from the public baths. It is about 30 m north from the roadside and surrounded by a high fence covered in Japanese honeysuckle.

Figure 15-2: Tuwhare Spring in 2005.

The pool's water is steadily convecting, with occasional bubble plumes. The temperature and pH of the major zone of upwelling have been measured at 98 °C and 7.8 respectively (Severne, 1999). Sinter has formed in layers at various water levels, resulting in a series of uneven steps around the edge of the spring. The upflow occurs at the eastern end, close to where a heat exchanger has been installed to heat the wharepuni. The spring overflows at the western end of the pool into a series of smaller pools (Severne, 1999).

History: According to Severne (1999):

> "In the early part of the century Tuwhare geysered, playing regularly every four hours and erupting water to a height of 18 m until 1906 when the activity ceased (Mahon and Klyen 1968). After the Napier earthquake (1931) activity began again but ceased 18 months later. In 1966 the geyser activity started again with eruptions of muddy water up to 12 m height for periods of up to 90 minutes, this activity lasted for about 24 hrs (NZ Herald 19th January 1966). There are oral reports of the Tuwhare erupting at the Marae in January 1990 (Bob Severne pers comm. 1992)."

In 2005, the cold pool at the southern margin of Tuwhare heated up and the surrounding vegetation started to die, in a progressively increasing radius, reaching 10 m by September (Cody 2005c). In 2007, the area of newly heated ground extended across the road, and through some house sections as far as the Tokaanu Stream. A previously warm swamp dried up and the ground started steaming.

15.1.1.3 Feature Name: Taumatapuhipuhi Geyser (Severne), S13 (Mahon) [TOF13]

Type: 3 springs including two that discharge through one geyser vent, cyclically boiling (crypto-geyser), actively depositing silica to form sinter.

Condition: Recoverable.

Threats: Severely threatened. Taumatapuhipuhi is vulnerable to increased well draw off lowering supply pressures. The surface overflow is now confined to splashes around the vent and a dug channel to supply an open-air bath. Consequently, the sinter terrace is weathered and degraded by foot traffic, and no longer provides a steam-impermeable barrier. Steam now escapes from many points on the apron, and assuming that these discharges are connected to the geyser, this reduces the internal pressure and heat retention, which in turn reduce the geyser's ability to erupt. Plugging the outflow channel would allow surface overflows to restore natural sinter sheet formation.

Figure 15-3: Taumatapuhipuhi Geyser in 2005.

Location: NZMS-260 T19: 2749625 E, 6244803 N. Location measured from GPS (+/- 50 m). At the north-east end of Tokaanu Domain, off to the north of the thermal walkway administered by DOC, and situated on the south banks of Tokaanu stream.

Description: According to Severne (1999):

> "The geyser basin of Taumatapuhipuhi appears to have two vents from which boiling water emanates. The basin is 1.45 m long, 0.39 m wide and 0.98 m deep with fissures in the floor and sides of the basin. The geyser has formed a wide sinter platform 15 x 20 m that slopes towards the Tokaanu Stream. Around the rim of the basin close to the most active area, spicular geyserite occurs.
> "Visual observations by the author and Katherine Luketina in November 1996 showed the following patterns: first the side vent boils furiously and the water level rises several centimetres in the geyser, with a correspondingly increase in outflow. Then the boiling from that vent subsides after about 30 seconds, and is replaced by similar activity from the end vent, accompanied by a decrease in water level and flow. After another 30 seconds a hole in the sinter platform close to the geyser overflows for 20 seconds then its flow subsides. The boiling stops and is replaced by boiling in the end vent, completing the geysers 2-minute cycle"

A dug channel drains the outflow into two concrete open-air baths. Approximately 2 m from the main vent is another cyclically boiling spring that also forms sinter. It too has a channel draining it. In March 2008, the water temperature reached 102.6 °C during boiling cycles.

History: Observations in 1928 indicated that the geyser played regularly to a height of 6 m (Grange 1937). Grange revisited the geyser in December 1936 and found that the geyser was playing every six minutes, with the eruption column reaching a height of 3 m (Severne, 1999).

According to Keam (1959), in the 1950s Taumatapuhipuhi was erupting every 25 minutes or so, but was considered a relatively new geyser as it had not been mentioned in the guide books of the previous century. Its recent genesis was also indicated by the thinness of the buff-coloured sinter encrusting the adjacent reddish ground. He described its activity thus:

> "When playing, the geyser throws water thirty or forty feet into the air in an initial burst lasting about half a minute. A minute later a second display of smaller duration occurs, and often a third display follows this again."

The last record of this geyser continually playing was in May 1966 (Mahon and Klyen, 1968). It now erupts no more than several times per year. However since Waikato Regional Council started monitoring the spring in 1995 it has been cyclically boiling to heights of up to 1 m every few minutes.

15.1.1.4 Feature Name: Matewai (Severne), 31D (Mahon), 48 (Grange) [TOF31]

Figure 15-4: Matewai Spring in 2005.

Type: Boiling spring actively depositing silica to form sinter, occasionally erupts.

Condition: Recoverable.

Threats: Moderately threatened. Matewai is vulnerable to increased well draw-off lowering supply pressures. Surface overflow no longer occurs due to urbanisation effects of draining swampy land and drilling hot wells.

Location: NZMS-260 T19: 2749664 E, 6244782 N. Location measured from GPS (+/- 50 m). At the north-east end of Tokaanu Domain, about 30 m SW from Taumatapuhipuhi geyser.

Description: Matewai spring has sinter walls and surfaces. The water is steadily convecting, with occasional bubble plumes. Silica deposits as highly porous, coral-like masses.

According to Severne (1999):

> "Matewai is one of four pools located on a large sinter platform, probably formed in response to fluctuations in the water level of the springs. It is a boiling spring (maximum temperature 100 °C) of neutral pH and is approximately 3 m long and 2 m wide at its widest point, the depth is unknown. This group of springs was referred to in Mahon and Klyen (1968) as spring 31 system; they misnamed the Matewai as Teretere. Matewai and the adjacent spring Hoani are linked by an overflow channel, which allows flow in both directions. On occasion, neither feature is overflowing but there is obvious inflow of hot water into both pools, which indicates that there is subsurface drainage from these springs.
>
> "From 6th August 1998 to the 2nd February 1999 the pool erupted every 8-12 hrs for periods upwards of 8 hours, the eruption column was up to 3 m high but was usually between 1-2 m. During the cycle, the water level in Hoani was very high and the water from Matewai was not draining away. The pool has a history of geyser eruptions; it was last reported to have discharged in 1952 (Taranaki Daily News 8th December 1952)."

Keam (1959) states that eruptions can reach heights of several hundred feet. Eruptions are more likely to occur when the level of nearby Lake Taupō, is high.

In December 2002 Matewai commenced a period of eruptive behaviour lasting several months, erupting 1 - 1.5 m high for up to ~1 hour, with large overflows (~20 L/s). The outwash flooded over the adjacent road and along the viewing path. The Department of Conservation had a drain cut through the gravel road to direct the outflow but it nevertheless spilled water onto the walkways and nearby picnic area. After eruption, a large volume of water back flowed down the vent and the water level retreated to ~ -2 m. The eruptive cycle was ~7 - 10 hours (A.D. Cody, email to Katherine Luketina dated 18 February 2003). In 2008 the water temperature was around 75 °C.

15.1.1.5 Feature Name: Hoani springs (Severne), 31B (Mahon) [TOF31]

Figure 15-5: One of the three Hoani Springs in 2004.

Type: Three near-boiling springs actively depositing silica to form sinter.

Condition: Recoverable.

Threats: Moderately threatened. The springs are vulnerable to increased well draw-off lowering supply pressures. Surface overflow no longer occurs due to urbanisation effects such as draining swampy land and drilling hot wells.

Location: NZMS-260 T19: 2749588 E, 6244783 N. Location measured from GPS (+/- 50 m).

Description: According to Severne (1999):

> "Hoani is a large (~4 x 3 m of unknown depth), near boiling, chloride spring with a feature except into the adjacent Matewai spring. A wide sinter platform surrounds this feature and Matewai. The sinter is very porous and is dominated by layered textures that may be microbial. The water level in this spring appears to be very sensitive to local groundwater conditions, much more so than Matewai. When there is little surface water in the Domain, after a dry period, the water level is as low as 500 mm below the sinter platform. When there is a large amount of surface water around, the pools overflow and form a large lagoon".

In March 2008, Hoani A was a clear, green coloured pool with steep sides and a temperature around 89 °C. The pool was surrounded by a thin sinter lip.

In March 2008, Hoani B was a clear, blue pool with a temperature of 85 °C and was a rimmed with sinter. Both Hoani A and B pools are surrounded by a sinter platform indicating that in the past these pools have overflowed, although in during 2007 to March 2008 neither pool water levels remained below the pool lip.

History: Hoani has been known to erupt.

15.1.1.6 Feature Name: Takarea [TOF5] - Te Paenga springs (Severne), S4, 5 (Mahon) [TOF4]

Figure 15-6: Te Paenga Springs in 2004.

Type: Three hot springs actively depositing silica to form sinter.

Condition: Recoverable.

Threats: Moderately threatened. The springs are vulnerable to increased well draw-off lowering supply pressures, or modification of the spring. Surface overflows probably vary due to swampy ground and water runoff effects from rainfall.

Location: (Takarea) NZMS-260 T19: 2749460 E, 6244725 N – (Te Paenga) NZMS-260 T19: 2749449 E, 6244723 N. Location measured from GPS (+/- 50 m).

Description: Three hot, clear springs 3-5 m in diameter in the central area of Tokaanu Domain. A fenced boardwalk passes between and alongside these pools. An old changing shed stands alongside and tall kanuka scrub surrounds the area. The springs have sinter walls and margins. They have minimal flow to the north. There are abundant photosynthetic microbial mats in the outflow.

According to Severne (1999):

> "Takarea and Te Paenga are large hot pools with maximum temperatures of 87 °C and 68 °C respectively. Both pools are surrounded by sinter forming a siliceous overhang that has a fine frittered texture. Sinter is actively forming around Takarea but not in the cooler pool that is surrounded by dark green algae. The pool complex utilizes the overflow from both features for bathing. Takarea has an upflow close to the centre of the pool, where a continuous column of gas rises to the surface. Takarea and Te Paenga are located in an extensive sinter platform (25 x 15 m), which also contains smaller hotter pools (maximum temperature 97 °C) and small gas vents."

In March 2008, the water temperature of two of these pools was 61 and 64 °C, while the third pool was 48 °C. Well-established orange-coloured microbial mats were thriving in the shallow outflow region of Takarea Pool where the water temperature was around 34 °C.

History: Māori names for hot springs and occupation of the site for many 100s of years.

15.1.1.7 Feature Name: Toretiti (Severne), 3A (Mahon) [TOF3]

Type: Hot spring no longer depositing silica to form sinter.

Condition: Recoverable.

Threats: Moderately threatened. The springs are vulnerable to increased well draw-off lowering supply pressures. Surface overflows probably vary due to swampy ground and water runoff effects from rainfall. The spring is also vulnerable to modification of its channels.

Location: NZMS-260 T19: 2749426 E, 6244714 N. Location measured by GPS (+/- 50 m).

Description: A large warm pool with temperatures ranging from 37 °C to 70 °C (Severne 1999). The warmer, central upflow area is clear with occasional gas discharges. Algae surround the edges of the pool but there is evidence of an extensive sinter platform, which was still very obvious in the 1950s, when it was used as a communal dancing place. The sinter platform is now submerged and covered in reeds.

History: Photographic evidence suggests the spring was warmer in the past. The pool was renowned around the district for its curative properties (Severne 1999). According to Keam (pers. comm.), Toretiti used to supply the public baths.

15.1.1.8 Feature Name: Teretere (Severne), S27, 31D (Mahon) [TOF31]

Type: Warm pool that has been known to erupt.

Condition: Recoverable, threatened by further draw-off from the system or modification of the spring.

Threats: Moderately threatened. The spring is vulnerable to increased well draw off from the system lowering supply pressures.

Location: NZMS-260 T19: 2749367 E, 6244749 N. Location measured by GPS (+/- 50 m).

Description: An algae-covered warm pool at the edge of the swamp, on the northern side of the return part of the path. The pool is about 5 m wide and 7 m long, with calm water. Since Waikato Regional Council started monitoring the spring in 2001, the water, which is generally approximately 0.21 m below overflow level, has maintained a pH of about 6, and a temperature range from 23 °C to 45 °C.

Figure 15-7: Teretere Spring in 2004.

However, on Friday 23 and Saturday 24 November 2001, the pool erupted repeatedly and boiling overflows flooded surrounding manuka shrubs, rushes, and sedges, leaving those within a 3 metre radius of the pool, flattened and dead (Cody, 2002c).

15.1.1.9 Feature Name: Healy's Bore No. 2

Type: Uncapped well, producing boiling water and actively depositing silica to form sinter.

Condition: Recoverable.

Threats: Hardly threatened. The feature is artificial**.**

Location: NZMS-260 T19: 2749170 E, 6244665 N. Location measured by GPS (+/- 50 m).

Description: A well was drilled in 1942 and left open to discharge at the surface. It was capped at least once but the cap eventually corroded. Most of the time since 1942 it has discharged at the surface. It is situated about 200 m west from Paureni spring, on the northern foot of a hillside an d in an area of tall kanuka scrub. The vegetation gives way to the north onto swampy raupo wetland. The drill hole has built up silica sinter terrace surrounds (Severne, 1995; Mahon and Klyen, 1968). This bore is not a natural feature, and should be closed, as its existence is detrimental to natural features. It is not represented in the table of features at the end of this report.

Figure 15-8: Healy's Bore No.2 in 2004.

Threats: Existing and continued discharge from this well may have an adverse effect on the natural hot springs in the Tokaanu Domain. So rather than considering potential impacts on this well, it must be considered as an impact on all neighbouring natural springs.

15.1.1.10 Feature Name: Te Waihoto [TOF12]

Type: Hot pool, no longer discharging, previously a sinter-forming spring.

Condition: Recoverable.

Threats: Moderately threatened. The spring is vulnerable to increased well draw off from the system lowering supply pressures.

Location: NZMS-260 T19: 2749579 E, 6244823 N. Location measured by GPS (+/- 50 m).

Description: According to Severne (1999):

> "This is a small hot pool ~5 m diameter with a maximum temperature of 75 °C and pH 6.5. The pool is surrounded by flat area of altered clay. There are several small seeps around the edge of the pool, but no major upflow area. In the past, the

feature was obviously hot and overflowing, as there are remnants of an old sinter platform around the feature."

15.1.1.11 Feature Name: Atakororeke Stream Seeps

Type: Numerous (more than 10) chloride seeps and small boiling springs.

Condition: Largely intact. Largely unaltered at the surface but possibly affected by artificial changes to the local ground water and extraction from the geothermal aquifer.

Threats: Moderately threatened. The springs are vulnerable to increased well draw off from the system lowering supply pressures.

Location: NZMS-260 T19: 2747000 E, 6246222 N. Note that this co-ordinate is an estimate from map, not a GPS reading. Thirty metres downstream from the domain.

Description: According to Severne (1999):

> "Downstream from the Domain, close to the Atakororeke Stream, is an extensive thermal area on the flanks of the Tokaanu Stream that is characterised by chloride seeps and small boiling springs. The ground is very unstable at this part of the stream, as the sinter crust is not thick or continuous over the area…There are many small springs and pools, which are utilised by locals. Temperature and pH were measured and ranged from 62 to 98 °C and 7.6 to 8.3 respectively. The exposed platey sinter resembles fine-grained concrete in texture and colour with ripple marks, and is broken and uneven in many places. Sinter is actively depositing in isolated spots throughout this area. Cracks in the platey sinter show that the sinter is inter-layered with fine silt and clay due to flooding from the stream."

15.2 Chemistry of Tokaanu hot springs

Hot spring analyses have been made by several workers over many decades. See Severne (1995 and 1999), who also refers to earlier papers and work. A thorough water sampling and analysis was done in 1966 (Mahon and Klyen, 1968). See also Healy (1942) and Paterson (1974).

The dominant water type observed in Tokaanu are mature chloride waters, with high chlorine concentrations more than 3000 parts per million (ppm). Taumatapuhipuhi Spring [TOF13] consistently has high chlorine levels and near-boiling temperatures, which are typical of upflow areas.

Table 12: Chemistry of Tokaanu hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Bathhouse Spr.			18/10/93	66	6.2	3258	82	134	306
			04/05/94	66	6.4	3165	76	132	309
Tuwhare No.23A [TOF23]	3070_23	72_2983	16/09/05	79	7.5	2570	50	101	285
Taumatapuhipuhi [TOF13]	3070_13	72_2984	28/11/02	98	7.5	3056	63	64	248
			16/09/05	98	7.8	3220	62	34	243
			23/07/09	98	7.6	3200	61	19	150
Takarea No.5 [TOF5]	3070_5	72_2985	16/09/05	60	6.5	3710	78	24	330
			23/07/09	57	6.3	3200	78	16	310
Healy Bore No.2		72_2986	03/05/66	67	6.9	2936	69	22	320
			16/09/05	91	7.9	1810	47	24	145
#31D Spring (Teretere)			28/11/02	72	7.1	3117	77	60	316
			01/12/03	86	7.6	3128	66	67	324
			22/12/04	85	7.3	3116	66	102	296
			19/12/05	86	7.5	3099	66	107	307
			17/04/06	86	7.0	3182	64	128	312
#5 Pool			28/11/02	32	6.3	3147	64	74	322
			01/12/03	62	6.6	3157	78	47	316
			22/12/04	63	6.7	3053	70	44	281
			19/12/05	62	6.5	3121	75	50	299
			17/04/06	59	6.1	3226	77	86	313

16 TONGARIRO

The Tongariro geothermal system is classified by the Waikato Regional Plan as a Protected Geothermal System. It covers the summit and northern slopes of the active volcano Mt. Tongariro, which is located just north of the apex of the Taupō Volcanic Zone. The geothermal field derives its heat from the volcano's magma (Hochstein, 1985). There is thermal activity at Ketetahi, the Upper Te Maari Craters and at Red Crater and Central Crater. However, the only hot springs are at Ketetahi. The Ketetahi geothermal activity consists of many steam features and acid springs that feed into a warm stream. The land is privately-owned Māori land and access is restricted.

16.1 Ketetahi Springs

16.1.1.1 Feature Name: Unknown

Type: Two non-sinter-forming acid geysers.

Condition: Unaltered.

Threats: Hardly threatened. Littering occurs but more permanent vandalism by tourists is not likely.

Location: NZMS-260 T19: 390 294. Easting and northing coordinates unknown. Location approximate only, from map sheet.

Description: These springs have been observed by Cody (1978c, 1983c, 2000). On the first two visits, they behaved as true cyclical geysers, each playing every few minutes to a height of about 2 m. In 2000 only one was seen to be active, engaging in a steady constant eruption, 1-2 m high.

History: None known.

16.2 Chemistry

Table 13: Chemistry of Tongariro Springs

(Webster-Brown and Brown, 2012)

Spring	Date	Temp	pH	Cl	SO_4	HCO_3	SiO_2
		(°C)		(parts per million)			
Ketatahi Stream	11/06/98	67	3.8	1.27	648		223
Ketatahi Stream (Lower)	01/12/05	54	3.5	84	230	10.4	0.01
Ketetahi Stream Headwaters	01/12/05	66	7.1	1.1	216	<0.1	0.024
Black Cauldron	27/11/98	90	6.4	2.9	1638		267
	01/12/05	90	6.8	224	275	<0.1	0.59
	14/09/94	81	6.7	0.71	1135	192	148
	30/08/90		3.3	5.85	1980	82	230
	04/04/89	79	2.7	29	1600	102	245
Iron Spring	14/09/94	62	6.3	1.4	564	225	243
	28/08/90		7.3	1.17	310	63	201
	23/04/89	69		3	141		164
Ketatahi Stream at track crossing	22/05/07	25	2.9	135	271	<0.01	30

17 WAIHI

The Waihi features are a field within the Tokaanu-Waihi-Hipaua Geothermal System, which is classified in the Waikato Regional Plan as a Limited Development Geothermal System. It is located at the southern end of Lake Taupō. For further details on the history and characteristics of this system, see the introduction to the Tauhara Field above. Geothermal manifestations consist of numerous springs and seeps along the lake edge, discharging water with temperatures up to 80 °C. There are three groups of springs (Mahon and Klyen, 1968) but only one spring that is capable of actively forming silica sinter.

17.1.1.1 Whakatara Bath Spring [TOF147]

Type: Sinter-forming spring.

Condition: Recoverable.

Threats: Severely threatened. Continued use of this spring for traditional bathing means that the sinter apron cannot regenerate.

Location: NZMS-260 T19: 2747885 E, 6246873 N. Location measured from GPS (+/- 50 m).

Description: According to Severne (1999):

> "This is now the hottest spring at the Waihi foreshore. Before the bath diverted the flow, this spring had formed an expansive sinter platform dipping into the lake. The flow from this spring was measured at 0.11 l/s and the temperature was 84 °C when the lake level was significantly above its median. As the lake level was lowered below the median the measured flow rate and temperature decreased to 0.07 l/s and 72 °C."

17.2 Chemistry

The water chemistry analysis for samples from Whakatara bath shows near-neutral mixed water chemistry. However, this spring is situated proximal to lake level, and may be influenced by water from Lake Taupō.

Table 14: Chemistry of Waihi Springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Date	Temp	pH	Cl	SO_4	HCO_3	SiO_2
			(°C)		(parts per million)			
Whakatara Bath [TOF147]	3070_47	09/06/94			469		551	
		04/05/94	76	6.9	470	28	455	224
		18/10/93	76	6.6	477	30	539	214
		16/09/05	75	7.0	467	27	155	248
		19/04/66	75	6.6	440	27	468	212

18 WAIKITE

The Waikite Geothermal Field is part of the Waiotapu-Waikite-Waimangu system, which is classified in the Waikato Regional Plan as a Protected Geothermal System. Hot to boiling springs occur along the base of the Paeroa Fault scarp. Active sinter formations still occur, but was much more widespread before farm development and extensive drainage of low-lying ground occurred. The spring deposits contain some calcite and one spring (active in the late 1980s) deposited only calcite. No geysers have been active in recent years although WAF5651 used to geyser many times daily 5 - 8 m high during the early 1980s. Chemistry is given in Glover *et al.* (1992), with some partial analyses given at the end of this section.

18.1 Waikite Springs

18.1.1.1 Feature Name: WE 1001, HT Geyser [WAF5651]

Type: Inactive geyser, actively depositing silica to form sinter, clear spring, with sinter along outflow and around pool margins.

Condition: Largely intact

Threats: Severely threatened. The springs are vulnerable to drainage of surrounding soft marshy ground by farmers; or cattle crushing the weak crumbly ground at pool sides. They are presently just within a DOC reserve.

Figure 18-1: HT Geyser in 2003.

Location: NZMS-260 U16: 2799801 E, 6315008 N. Location measured from GPS (+/- 50 m).

Description: A boiling clear spring, 9 m x 6 m oval in shape, on farmland in the base of an amphitheatre in the Paeroa Fault scarp. Close by are overhead high tension power lines, hence the description “HT Geyser”. It is now a constantly boiling and flowing spring.

History: This spring formed in the early 1980s, beginning as a small outbreak of hot ground, then a flowing spring and explosively formed a large crater that geysered 5 - 8 m high many times daily during the early 1980s until abruptly ceasing in the late 1980s. Jim McLeod, while researching for his PhD, witnessed a hydrothermal eruption that signalled the death of this geyser. The eruption was much bigger than its normal eruptions, and could be seen level with the road above, a height of tens of metres.

18.1.1.2 Feature Name: Scalding Spring, WE 1008 [WAF5664]

Type: Hot spring actively depositing silica to form sinter.

Condition: Recoverable

Threats: Severely threatened. The spring probably once flowed across the land surface to form extensive sinters (now covered in grass). The outflow is now confined to a narrow channel, perhaps dug when the farm was developed in the 1950s.

Location: NZMS-260 U16: 2799917 E, 6315382 N. Location measured from GPS (+/- 50 m).

Figure 18-2: Scalding Spring in 2009.

Description: This is a hot, clear spring about 3 m in diameter in a grassed paddock on the flat of the valley floor. It is fenced off and is used occasionally by hunters for scalding game. It was visited in 2003 and recorded a temperature of 88 °C, a pH of 8, and an outflow of about 0.05 L/s. It discharges to the nearby Otamakokore stream via a dug channel. Small sinter margins surround the pool and the edges of the stream. The surrounding grassland has extensive sinters now overgrown by grass.

18.1.1.3 Feature Name: Waikite Scarp Swamp Spring, WE 1019, [WAF5670]

Type: Hot spring actively depositing silica to form sinter.

Condition: Recoverable

Threats: Severely threatened. The spring is vulnerable to further drainage of the swampy land and clearing of blackberries, which would then allow stock to crush the sinter deposits.

Location: NZMS-260 U16,: 799636 E, 6314831 N. Location measured from GPS (+/- 50 m).

Description: This is a hot, clear spring about 1 m in diameter in a swampy blackberry thicket south-east from HT Geyser. Sinters occur around many small, hot seep flows.

History: No Māori name or legend known.

18.1.1.4 Feature Name: North Gully Spring (Top Gully Spring), WE 1026 [WAF5580]

Type: A boiling spring actively depositing silica to form sinter.

Condition: Recoverable

Threats: Moderately threatened. The spring is downslope from the road and already contains cobbles of rhyolite road base and old bottles, etc. It is highly vulnerable to damage from any road works.

Location: NZMS-260 U16: 2799058 E, 6314267 N. Location measured from GPS (+/- 50 m).

Description: A boiling, clear spring about 5 m x 3 m in size. It is located on the eastern or left side of the stream gully. The spring is about 10 m west of Waikite Valley Road edge and about 5 m lower in elevation than the road. It is in a deeply incised gully, about 30 m - 50 m wide and about 200 m long, which leads downstream to a carpark and public swimming baths complex. Waikato Regional Council started monitoring the spring in 1995, and the monitoring contractor, Ashley Cody had been observing the spring since about 1980. During that time its behaviour had been quite steady. The pH was around 7, and the outflow remained stable at about 2 L/s, until early 2003 when the pH increased to 8. In late 2003, the pool increased in size at its northern

end and the steady flow changed to a strong noisy oscillating boiling. Vegetation to the north of the feature was killed. The spring discharge increased to 5 L/s, and sometimes as high as 7 L/s (Cody 2003c). This surging behaviour lasted about two months, and flow stabilised in early 2004 at about 3 L/s, with stronger boiling to a height of about 0.3 m. Further vegetation die-back also occurred in early 2004 (Cody 2004a).

The spring has mammillary nodular masses of sinters growing out over the water edges. Hard, creamy sinter masses coat the two outflow channels.

History: No Māori name or legend known.

18.1.1.5 Feature Name: Left Bank Spring, WE 1029, [WAF5583]

Type: Boiling spring actively depositing silica to form sinter.

Condition: Recoverable.

Threats: Moderately threatened. Road works could adversely affect this spring.

Location: NZMS-260 U16: 2799046 E, 6314270 N. Location measured from GPS (+/- 50 m).

Description: A boiling, clear spring about 1.5 m in diameter on the left bank wall of a gully about 15 m downstream of North Gully Spring [WAF55880]. The sinters are a mixture of silica and calcite. The flow was about 1 L/s in 1995. Massive, creamy sinters coat the pool margins and outflow channel.

History: No Māori name or legend known.

18.1.1.6 Feature Name: Te Manaroa Spring, WE 1031 [WAF5586]

Figure 18-3: Te Manaroa Spring with travertine in 2013.

Type: A boiling spring actively depositing calcite to form travertine.

Condition: Largely intact.

Threats: Hardly threatened. The proprietors of the Waikite Hot Pools have built a track to the pool and a viewing platform with good guard rails, and erected some interpretative signage. Now that Manaroa is a valued tourist attraction that people can view without getting close to it, its condition can be easily monitored and degradation is likely to be actively resisted.

Location: NZMS-260 U16: 27990192 E, 6314276 N. Location measured from GPS (+/- 50 m).

Description: Boiling, clear spring about 10 m in diameter, in a circular basin on the right side of the hot springs gully and upstream from the public swimming pool complex. Powerful, continuous, explosive boiling occurs and the height of ebullition varies between 0.3 m to 1.5 m. The outflow is usually about 20 L/s but since Waikato Regional Council started monitoring the spring in 1995 it has ranged between 15 L/s and about 30 L/s. It is believed that this spring has the greatest outflow of all boiling springs in New Zealand.

Massive, mammillary travertine less than 1 m wide coat the pool edges and form thick deposits in the outflow channel. A photograph taken in the 1890s by Josiah Martin can be aligned to appear virtually identical with the present day appearance.

History: Māori name of Manaroa is given as the label on a 1890s photograph.

18.1.1.7 Feature Name: Resurgence Spring, WE 1033 [WAF5589]

Type: A boiling spring actively depositing calcite to form travertine.

Condition: Largely intact.

Threats: Moderately threatened. The spring is vulnerable to vegetation clearing or any earthworks along the stream way.

Location: NZMS-260 U16: 2798982 E, 6314287 N. Location measured from GPS (+/- 50 m).

Description: This is a clear spring about 2 m in diameter. It is located in a shallow circular basin on the left side of the hot springs gully. It is just upstream from the public swimming pool complex and about 15 m downstream from Manaroa. Since Waikato Regional Council started monitoring the spring in 1995, it has had a strong upflow of about 10 L/s from beneath a vertical bank. The travertines are black beneath the water level and snow white above. The spring may be simply an underground resurgent flow from springs upslope to the south.

History: Unknown

18.1.1.8 Feature Name: Waikite Group, WE 1039 [WAF5595]

Type: Two hot springs actively depositing silica to form sinter.

Condition: Largely intact

Threats: Moderately threatened. The springs are vulnerable to vegetation clearing or any earthworks along Waikite Valley Road, which is upslope about 20 m to the south-east. The springs are hidden from view by tall kanuka.

Location: NZMS-260 U16: 2799002 E, 6314252 N. Location measured from GPS (+/- 50 m).

Description: Two boiling, clear springs about 0.2 m in diameter, among others of similar size; all about 10 m north of the Squash Club supply spring. Thick, white sinters surround the walls and outflows. When measured in 2001, total flow was less than 1 L/s.

History: No known name or history. “Waikite Group” is the general locality.

18.1.1.9 Feature Name: Stream bank, WE 1037 [WAF5591]

Type: Hot spring actively depositing silica to form sinter.

Condition: Largely intact.

Threats: Moderately threatened. The spring is vulnerable to vegetation clearing or any earthworks along the stream way and gully. Road works could threaten the whole gully.

Location: NZMS-260 U16: 2799009 E, 6314277 N. Location measured from GPS (+/- 50 m).

Description: A calm, clear spring forming a triangular shaped pool about 2 m long x 2 m wide at maximum length and width, with a turbulent outflow through hard sinters. When measured in 2001, the outflow was less than 1 L/s. The spring is situated within a few metres of the left bank of the main stream, opposite Te Manaroa Spring [WAF5586].

History: No known name or history.

18.2 Chemistry of Waikite Valley hot springs

Glover *et al.*, 1992 provides a comprehensive analysis.

The waters of Te Manaroa Spring are of mixed-water chemistry, boiling at atmospheric conditions, and with a near-neutral pH. The water sample from HT Geyser shows a similarly high bicarbonate concentration, but with a more transitional chloride-bicarbonate chemistry, and a higher silica concentration.

Table 15: Chemistry of Waikite Valley hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Te Manaroa Spring [WAF5586]	3073_32	WE1031	21/01/92	100	7.8	145	39	338	167
			21/05/93	100	7.8	143	37	342	161
			11/05/94	101	7.4	143	36	366	162
			21/09/05	98	7.8	127	35	169	173
HT Geyser [WAF5651]	3073_10	WE1002	21/09/05	98	7.9	174	41	225	249

19 WAIOTAPU

The Waiotapu Geothermal Field is part of the Waiotapu-Waikite-Waimangu system, which is classified in the Waikato Regional Plan as a Protected Geothermal System. For further details on the history and characteristics of this system, see the introduction to the Waikite Field above. It may be hydrologically linked to the contiguous Reporoa System directly to its south.

The area in which the main geothermal activity occurs at Waiotapu is a scenic reserve. Waiotapu has five known active geysers but may have two more, in an inaccessible blackberry infested stream valley. Water chemistry is given at the end of this section.

Several hot springs deposit silica to form sinter, two of which are unique in NZ for very different reasons. Firstly, Champagne Pool is a large spring about 65 m in diameter within a hydrothermal eruption crater. The overflow from the pool deposits silica to form a sinter terrace about two hectares in extent. Secondly, Hakareteke geyser is a mixed acid-sulphate-chloride pool whose discharge forms sinter deposits, although these are sparse and very minor. However, it is unusual because it is presently the only geyser in New Zealand that forms sinter deposits and has acid waters. A collation and summary of many publications about Waiotapu geothermal field is given in Hunt and Glover (1994).

19.1 Waiotapu Springs

19.1.1.1 Feature Name: Unknown Geysers [WTF1133, 1134]

Type: Two active geysers actively depositing silica to form sinter.

Condition: Unaltered

Threats: Slightly threatened. The remote location of these geysers protects them from damage, but the infestation of blackberry adversely affects the surrounding thermo-tolerant vegetation.

Location: [WTF1133] NZMS-260 U16: 2804134, 6311097; [WTF1134] NZMS-260 U16: 2804119. 6311116. Location measured from GPS (+/- 50 m). Located in an inaccessible blackberry-infested stream valley.

Description: Two boiling clear alkaline springs were described by Lloyd (1959) as being geysers each with a vent of 0.1 m - 0.2 m in diameter, and have actively growing grey-white sinters. Keam saw one of these springs erupt to about 1 m high in 1952 and concluded that the other spring was a geyser from evidence of the distinctive geyserite sinter deposits (R.F. Keam, pers. comm.).

History: No known name or history.

Chemistry: See Lloyd (1959) and also Giggenbach *et al.* (1994). Data in Table at end of this section.

19.1.1.2 Feature Name: Champagne Pool [WTF1064]

Type: Hot spring actively depositing silica to form sinter.

Condition: Largely intact

Threats: Moderately threatened. The spring is at risk of its western wall collapsing through erosion of the soft muds and weakly laminated sinters. Tourist foot traffic has down-cut the ground alongside the pool to form a raised wall. Ideally, the path needs boardwalks past the pool. Any geothermal exploitation of the Waiotapu field would probably stop the spring flow. Concerns exist about fluid connections with Reporoa and the possibility of that adjoining system being utilised for steam generation.

Location: NZMS-260 U16: 2804468 E, 6310529 N. Location measured from GPS (+/- 15 m).

Figure 19-1: Champagne Pool in 2019.

Description: The largest flowing hot spring in the Waiotapu area, about 70 m in diameter and 60 m deep, occupying a 900-year-old hydrothermal eruption crater (Hedenquist and Henley, 1985). Since Waikato Regional Council started monitoring the spring in 1995, the water temperature has stayed constant at around 77 °C. Constant bubble swarms of CO_2 evolve. The overflow of the pool is up to about 17 L/s (Hedenquist, 1991) and deposits silica to form extensive sinter terraces that cover about two hectares in spatial extent. The terrace hosts a diverse microbial community (Pope *et al.*, 2004). Outflow from the pool follows very irregular flow directions and prolonged drying episodes occur on the terrace. The sinters that are found within the spring margins are spectacularly coloured bright orange due to the presence of arsenic and antimony sulphides.

History: No Māori name or legend known.

19.1.1.3 Feature Name: Waiotapu Geyser (Four Foot Geyser) [WTF1070]

Type: Hot spring actively depositing silica to form sinter.

Condition: Largely intact.

Threats: Slightly threatened. It is now fenced off with low wooden railings but is still easily accessible to the public.

Location: NZMS-260 U16: 2804491 E, 6310255 N. Location measured from GPS (+/- 50 m).

Figure 19-2: Waiotapu Geyser in 2004.

Description: This is a small geyser on the valley floor about 30 m downstream from Bridal Veil Falls. The vent is about 0.5 m wide x 0.8 m long. Surrounding the vent are several shallow pools that become filled with alkaline chloride water when the pool erupts. Silica sinter has formed around the rims of the pools. Sinter with nodular geyserite texture is visible around the rim of Waiotapu Geyser. The geyser erupts to heights of 1 m to 2 m with eruptions lasting about 10 to 15 minutes. It is dormant for several hours between eruptions. In the early 1990s it did not play at all for about 5 years or more, and its vent became partially filled with silt and gravel washed in from the nearby stream. It recommenced regular eruptions in late 1995. In late 2002, it was erupting daily for approximately 13 minutes (A.D. Cody email to Katherine Luketina, 5/12/2002). Data loggers placed in this geyser during 2007 to April 2008 show that the geyser is very active although eruptions are irregularly spaced and the pool temperature is generally between 85 and 90 °C during non-eruptive episodes. During these eruptions it overflows at a rate of about 2 to 3 L/s. It is also known amongst older staff as “Four Foot” geyser because of the height to which it plays.

The spring may respond to years of low rainfall by ceasing all activity. It is also vulnerable to the cold stream overtopping it when in flood and filling the vent with alluvium.

History: Māori legend of name unknown.

19.1.1.4 Feature Name: Lady Knox Geyser [WTF1052]

Type: Modified hot spring, actively geysering, actively depositing silica to form sinter.

Condition: Recoverable. This is a natural feature that has been heavily modified.

Threats: Moderately threatened. Continued soaping affects the cone structure and composition. The feature and its sinter surrounds are easily accessed by the public.

Figure 19-3: Lady Knox Geyser on February 2020. Copyright Jesse Ledwin Lebe.

Location: NZMS-260 U16: 2805213 E, 6311402 N. Location measured from GPS (+/- 15 m).

Description: Lady Knox Geyser is soaped daily at 10:15 a.m. for the benefit of tourists. The eruption plays about 10 m high for a few minutes, then continues at about 3 to 5 m high for 1 to 1.5 hours (Cody, 2001). It does erupt naturally when left alone, but at very erratic intervals of 48 to 72 hours. The sinters are of unusual silica stearate composition due to the soap powder.

The geyser seems to be highly vulnerable to low rainfall periods when lowered groundwater may influence eruptions. Some years it will play about 10 m high for 2 - 5 minutes and then continuing at 5 - 8 m high for up to 2 hours. In 1999 and 2000 this high eruption state only lasted about 30 seconds or so, with a following 3 - 5 m high play continuing for about 1-1.5 hours.

History: According to Keam (1961):

> "…In the first few years of this century Waiotapu was made an open prison settlement and the prisoners there were engaged in planting the pine-forests. The geyser was no doubt discovered by the convicts. The warder, Mr Scanlon, had a length of piping sunk into the spring, and held in place with stones and mud. Eruptions were induced then, as now, by soaping, and the deposit of silica over the years has obliterated almost all signs of the cone's artificial structure.
>
> "On the night of May 5th - 6th 1903, the Earl of Ranfurly, the Governor of New Zealand, and his entourage broke their journey at Waiotapu. Lady Constance Knox, a member of the party, christened the new attraction "Northland Geyser", after Lord Northland, the Governor's eldest son. Although this name persisted for a few years the present one has now become firmly established."

The soaping tradition continues, albeit by a different type of person for a different reason. See also p. 152 in Lloyd (1959).

19.1.1.5 Feature Name: Postmistress Spring [WTF1020]

Type: Inactive geyser, actively depositing silica to form sinter.

Condition: Largely intact

Threats: Moderately threatened. The spring is vulnerable to damage from vegetation clearing or collapse of steep soft banks. It appears to be unchanged since the 1950s.

Location: NZMS-260 U16: 2803773 E, 6311236 N. Location measured from GPS (+/- 50 m).

Description: A boiling, clear spring about 7 m in diameter located in the bottom of a deep gully at the west side of S.H.5, opposite the Waiotapu Road junction. It has a steady flow of about 2 L/s and has thin sinter margins on a soft marshy substrate. It was known to geyser in the 1970s and earlier.

History: No Māori name or legend known.

19.1.1.6 Feature Name: Jean Batten Geyser [WTF1069]

Type: Inactive geyser.

Condition: Largely intact

Threats: Moderately threatened. The spring is vulnerable to damage from vegetation clearing or collapse of steep soft banks. It appears to be unchanged since the 1950s.

Location: NZMS-260 U16: 2804548, 6310482. Location measured from GPS (+/- 50 m).

Figure 19-4: Jean Batten Geyser in 2004.

Description: It has not been known to geyser since there was a sinter collapse that formed a new hole 5 m to the north-east (WTF2069, "Pool N of Jean Batten Geyser") in 1994 (Cody, 1996), and does not overflow, although there is boiling in its pool. The water level is about 2 m below the ground surface. It used to erupt for approximately a minute to a height of 5 m (Cody, 2000).

History: No Māori name or legend known.

19.1.1.7 Feature Name: Venus Bath [WTF1047]

Figure 19-5: Venus Bath in 2004.

Type: Hot spring with minimal sinter.

Condition: Largely intact

Threats: Slightly threatened. Road works could possibly influence the cold stream and hence the Venus Bath.

Location: NZMS-260 U16: 2804555 E, 6311400 N. Location measured from GPS (+/- 50 m).

Description: A hot spring about 15 m in diameter, with a sinter outflow channel and wall linings. It lies approximately 30 m west of the roadside and alongside a cold stream. It has a small bath dug in its outlet. Presently it does not appear to be forming sinters. (Lloyd, 1959).

History: No Māori name or legend known.

19.1.1.8 Feature Name: NW Boardwalk Geyser [WTF1066]

Type: Geyser actively depositing silica to form sinter.

Condition: Unaltered

Threats: Hardly threatened.

Location: NZMS-260 U16: 2804554 E, 6310526 N. Location measured from GPS (+/- 50 m).

Figure 19-6: NW Boardwalk Geyser 2004.

Description: A boiling, turbid grey, mildly acidic spring about 0.7 m in diameter on the north side of Primrose Terrace, and about 30 m north east of Champagne Pool. The vent area is surrounded by grey sinter fragments and blocks about 5 mm in radius. It occasionally has true geyser action and in the mid-1990s it played 2 - 3 m high for about 5 minutes with a periodicity of about 20 - 30 minutes and surface outflows. During 1999 to 2001 it constantly boiled without erupting, but was active in January 2002 (Cody, 2002c).

The spring appears vulnerable to rainfall and possibly air pressure. Most likely to erupt during very wet months.

History: This spring appeared newly formed in 1951 (R. Keam, pers. comm).

19.1.1.9 Feature Name: Hakareteke Geyser [WTF49]

Type: An active acidic geyser actively depositing silica to form sinter

Condition: Unaltered

Threats: Hardly threatened.

Figure 19-7: Hakareteke Geyser in 2004.

Location: NZMS-260 U16: 2805525 E, 6313309 N. Location measured from GPS (+/- 50 m).

Description: A boiling, clear acid (pH 3) spring on the east bank of Hakareteke stream. The vent is about 0.5 m in diameter with thin sinter deposits covering an area about 5 m wide x 8 m long. The sinters are unusual, with a dark grey to black sulphide-rich halo to about 2 m radius of the vent, then changing to brick red ochre colour further from the vent, probably due to iron oxidation. About 1 m from the vent is an unusual spicular, white silica deposit about 0.3 m in diameter, that looks somewhat like a hedgehog coat of spines, and is quite different from the rounded, nodular geyserite that indicates the extent of the splash-zone of a geyser. Bridget to check in field

The geyser is rarely visited due to difficult access. It was reported as geysering in 1950s and again in the early 1990s (Lloyd, 1959; Klyen, pers. comm. ADC). It was visited many times in 2000 by ADC, who took SAPAC records of eruptions. In January 2002 it was having up to 27 eruptions per day, but in February had only one eruption (Cody, 2002a, 2002b). It erupts for up to 10 minutes at a time, at intervals of up to 30 minutes. Flow rate during eruptions is up to 10 L/s (Cody, 2000e).

Hakareteke Stream could flood across the geyser and modify the vent area; although the geyser appears unchanged since about the 1950s.

History: No Māori name or legend known.

19.2 Chemistry of Waiotapu Hot Springs

See p.606 in Giggenbach *et al.* (1994), Lloyd (1959) and Pope *et al.*, 2004. Note that data from Giggenbach is actually analyses from 1978.

Table 16: Chemistry of Waiotapu hot springs

(Webster-Brown and Brown, 2012)

Spring	Located ID	Other ID	Date	Temp.	pH	Cl	SO_4	HCO_3	SiO_2
				(°C)		(parts per million)			
Waiotapu [WTF1024]	3074_149		27/04/94	92	2.0	475	1370		319
			08/07/93	91	2.0	428	1659		319
			1978	81	2.5	614	530		412
Waiotapu Geyser [WTF1070]	3074_195		30/09/05	87	7.0	332	90	54	377
Postmistress [WTF1020]	3074_145		30/09/05	96	8.6	699	78	39	204
Champagne Pool [WTF1064]	3074_189 3074_283 3074_284	72_4217 72_4218 72_4219	27/04/94	76	5.5	1905	90	237	426
			21/01/94	76	5.7	1929			
			08/07/93	75	5.6	1858	91	220	427
			07/06/86	74	5.5	1814	68	393	438
			14/04/84	76	6.1	1807	64	424	380
			03/04/84	75	6.0	1813	57	290	410
			31/01/84	74	6.2	1839	39	188.9	433
			10/01/84	76	5.9	1835	43	344	410
			15/12/83	74	6.0	1817	64	416	418
			08/12/83	75	5.5	1845	37	250	440
			23/11/83	76	7.1	1825	62		420
			27/10/83		5.6	1820	65	170	435
			03/08/83	73	5.2	1816	63	331	429
			19/05/83	75		1820	54	220	420
			17/03/83	75	5.6	1898	53	345	443
			18/05/82	73	7.8	1912	108		468
			24/07/58			1961	143		
			27/06/55		6.5	1879	99	366	170
			1926		4.9	1990	119	43	448

20 WAIRAKEI

The Wairakei Geothermal Field is part of the Wairakei-Tauhara Geothermal System, which is classified in the Waikato Regional Plan as a Development Geothermal System. For further details on the history and characteristics of this system, see the introduction to the Tauhara Field above.

20.1 Wairakei Springs

20.1.1.1 Feature Name: Wairakei Mud Geyser [WKF421]

Type: Intermittently geysering mud pool.

Condition: Unrecoverable. The impervious layer underlying this and other mud pools and lakelets in the Waiora Lakes area was cracked by subsidence caused by geothermal draw-off and all the features drained over a period of several years, becoming mostly completely empty in the early 2000s.

Threats: Moderately threatened. Subject to continued effects from draw-off by electricity companies.

Location: NZMS-260 U18: 2776612 E, 6282402 N. Location measured from GPS (+/- 1000 m).

Description: This was a mud geyser in a crater about 20 metres deep and 20 metres in diameter. There were several boiling mud pools in the base of the crater, one of which had a ferocious geysering action. Usually it erupted to a height of about 10 metres, but sometimes went much higher than the top of the crater, coating surrounding mature pines in mud.

History: No Māori name or legend known.

20.2 Extinct Geysers and Hot Springs of Wairakei

Figure 20-1: Great Wairakei Geyser in 1929. Copyright B Dickie.

Many geysers were present in Geyser Valley. Gregg and Laing (1951) described 270 flowing springs in Geyser Valley, of which 132 were neutral to alkaline; and of these 30 were true geysers. These had all ceased flowing by 1965 as a result of the operation of the Wairakei Power Station, which started production in 1958. By 1966 discharge of chloride water from Geyser Valley had virtually ceased (Glover, 2000).

It is expected that it would take several hundred years for the surface chloride flows to re-establish after electricity production from the field stops (Pritchett 1998, Rybach 2003, Sanyal 2004, O'Sullivan and Mannington 2005, and Axelsson *et al.* 2005), and that in most cases new features would come into being in such a process, rather than the old features regenerating.

Most of the remaining surface features are steam-fed. The remnant sinter from the extinct geysers can now be seen among areas of hot springs and mud pools.

Grange, in his 1937 Bulletin "The Geology of the Rotorua-Taupō Subdivision", describes Geyser Valley thus:

> "The springs in the Wairakei Valley - also known as Geyser Valley – rise on both banks of the stream over a distance of about 30 chains. The valley is noteworthy on account of its numerous geysers which play at fairly regular intervals; the

> eruption of some can be predicted to within a minute. The chloride waters of the geysers and clear springs are alkaline and most of them deposit buff-coloured sinter, whereas boiling mud-pots located at the western end of the valley are acid. The pumice-beds along the valley-sides are being altered to red and yellow clays.
> "Champagne Pool, about 60 ft. in diameter and partly surrounded by steep cliffs, is the most active centre in the group. At intervals of a few minutes the superheated water boils up vigorously at certain points, the column of water reaching at times to 9 ft. Following this activity, bubbles of steam rise over the whole surface. Champagne Pool has a large overflow, which runs over a beautiful cream-coloured sinter terrace called Tuhuatahia…
> "Great Wairakei Geyser has a vent about 10 ft. in diameter and at a depth of 15 ft. suddenly narrows to an irregular vent 3 ft. in greatest length. A fracture crosses the vent. Up till about three years ago it played every ten minutes, but since that time the period has gradually increased; now it is in action every ten hours for ten minutes, sending a column of water about 60 ft. Between eruptions boiling water can be seen at the point where the vent narrows considerably. Black Geyser, within a few yards of the stream, is the only geyser surrounded by black sinter. The sinter is black only where wetted by boiling water; farther away it is buff coloured. It plays to a height of a few feet for forty-five seconds at forty second intervals. The Dragon's Mouth Geyser, near the Black Geyser, has a rugged sinter vent about 3 ft. in diameter with a conspicuous spine of sinter projecting over its mouth. At a depth of 5 ft. the vent narrows to an inclined vent about 18 in. in diameter. The geyser plays for about three minutes, and during that time most of the over-flow is through a small vent at the base of the cone. Below it is Lightning Pool, in which large bubbles of steam shoot swiftly to the surface. Opal and Sulphur springs, both of which are turbid, have a small overflow which has encrusted the steep slope to the stream with sinter, coloured orange and green by the algae that grow on it. The Eagle's Nest Geyser has two vents close together, 3 ft. and 5 ft. in diameter, which at depths similar to their diameters narrow to 9 in. A series of eruptions commences every half-hour. The Prince of Wales Feathers, on a sloping surface of sinter, erupts from a narrow crevice, playing fifteen minutes after the water from a spring higher up is diverted from it. The Twin Geysers (Nga Mahanga) are in a pool about 15 ft. in diameter. The main geyser plays from near the centre of the pool every three minutes to four minutes for thirty-five seconds, to a height of 15 ft., and after every third shot the Paddle Wheel Geyser plays for a few seconds at the margin. The pool overflows just before and during the eruption of the main geyser. Te Rerereke Geyser (The Giant's Heels), across the stream from the Twin Geysers, is a deep, wide, boiling spring which erupts at irregular intervals. Red Coral Geyser, 3 ft. in diameter at the top, plays every two hours and a half, and its waters cascade down a steep slope about 50 ft. high and coated with pink sinter."

Keam (1958) also mentions "the gently-bubbling **Waitangi Pool** [WKF55]**,** with droplets of water constantly falling into it from some overhanging green stalactites, **Donkey Engine** [WKF54]**,** the **Mirror** pools (or Kuiwai pools or Fairy Baths) [WKF48-51], Heron's **Nest** (or Haematite Pool) [WKF65], **Dancing Rock Geyser**, and **Bridal Veil Geyser** [WKF199], which "sprays water over a beautiful pink coral-like sinter slope. It plays for about 15 minutes every two hours".

Keam (1961) also describes the **Devil's Inkpot** [WKF217], "which plays every two minutes" and **Satan's Toll-gate** [WKF180] and a smaller adjacent springs which "occasionally splash across the path and bar the way – hence the name". In the same publication Keam also mentions **Satan's Punchbowl** [WKF185], ("actively terrace building"), **Crystal Pool** [WKF186], the Indicator, and the **Menagerie.**

Figure 20-2: Pink Terrace, Wairakei, in 1929. Copyright B Dickie.

20.3 Chemistry of Wairakei Hot Springs

Totara Gut, located at the south-eastern part of Wairakei, shows mixed water chemistry when sampled in 1993 and 1994.

Table 17: Chemistry of Wairakei hot springs

(Webster-Brown and Brown, 2012)

Spring	Date	Temp.	pH	Cl	SO_4	HCO_3	SiO_2
		(°C)		(parts per million)			
WK Totara Gut	15/07/93	32	6.7	9.2	27	64	116
	04/05/94	34	6.6	8.5	26	94	117

21 SUMMARY OF GEYSERS AND SINTER-FORMING SPRINGS

The table below gives the total numbers of springs and geysers by geothermal field and area, using counts of the existing features known to the authors and described above. Historically active springs and geysers are also included, although some of these numbers are estimates only, with all counts and estimates derived from the references provided above. Note also that Orakei Korako is probably under-represented for the total number of sinter-forming springs and geysers due to much of that geothermal field being difficult to access and rarely visited by anyone. To avoid double-counting, the number of sinter-forming springs does not include geysers on the same field.

Table 18: Summary of sinter-forming hot springs and geysers

Geothermal Field	Sinter-forming Springs		Geysers	
	Active	Historical	Active	Historical
Atiamuri	2	3	0	0
Horohoro	2	2	0	0
Ketetahi	0	0	2	2
Mangakino	0	1	0	0
Mokai	5+	6+	1	1
Ngatamariki	10+	8+	0	1
Ohaaki	0	5	0	1
Orakei Korako	100+	450+	35+	105+
Reporoa	2	5+	0	0
Tauhara	3	10+	0	7+
Te Aroha	1	1	1	0
Te Kopia	3	3	1	1
Tokaanu	21	23	4	5
Waihi	1	1	0	0
Waikite	10+	9+	1	0
Waiotapu	9+	9+	6	8
Wairakei	0	132	0	30
Totals:	**169+**	**668+**	**51+**	**161+**

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