TWENTY-FIVE YEARS OF GEOTHERMAL MONITORING BY WAIKATO REGIONAL COUNCIL: EMBRACING CHANGE, COLLABORATION, AND INNOVATION

Katherine Luketina[1] and Jim McLeod[1]

[1]Waikato Regional Council, 401 Grey St, Hamilton, New Zealand

katherine.luketina@waikatoregion.govt.nz

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ABSTRACT

Waikato Regional Council (WRC) has a statutory obligation under the Resource Management Act 1991 to monitor the state of the regional geothermal environment, keep records, and make those records available to the public. Therefore, WRC undertakes geophysical, geochemical, and ecological monitoring of the region's geothermal environment, stores the data in a variety of databases depending on the data type, interprets the data and publishes reports in several media for different audiences. The WRC website provides environmental articles for a lay audience, Technical Reports, environmental indicators, and downloadable data. Papers are publicly available through the International Geothermal Association (IGA) papers database and through other open-access journals.

Monitoring is undertaken to determine the natural state of the regional geothermal resource, its variability, any trends and to identify any anthropogenic changes. This informs the policy development, resource allocation and organisation decision making processes to ensure that the resource is managed sustainably.

Monitoring is funded through resource consent holder annual charges and the general rate levied on regional landowners. This small income stream is augmented by collaboration with and support of other research bodies such as Crown Research Institutes (CRIs) and universities who have central government research grants.

WRC researchers have had significant success in developing or supporting the development of new monitoring techniques including remote sensing technology to provide system-wide and multi-system monitoring as well as interaction with groundwater and surface water, geothermal ecologies and the gradation from geothermal to non-geothermal environment.

Change is constant in our monitoring programmes as we embrace new information-gathering technologies, data collection, storage, retrieval, analysis and interpretation applications, and communication media. Collaboration with tangata whenua on Matauranga Maori physical and meta-physical monitoring is becoming more and more a part of what we do.

1. MONITORING THE WAIKATO REGIONAL GEOTHERMAL RESOURCE

1.1 Geothermal resources of the Waikato Region

The Waikato Region stretches from the northern slopes of Mt Ruapehu to the southern slopes of Maungakakaramea (Rainbow Mountain) and encompasses much of the Taupō Volcanic Zone (TVZ). It also covers the Coromandel Peninsula and the west coast of the North Island from Mokau to Waiuku. The Region contains about 70% of New Zealand's geothermal resources. As well as 15 high-temperature geothermal systems in the TVZ it also holds about 30 low-temperature systems scattered throughout the region except for the south-west (See Figure 1).

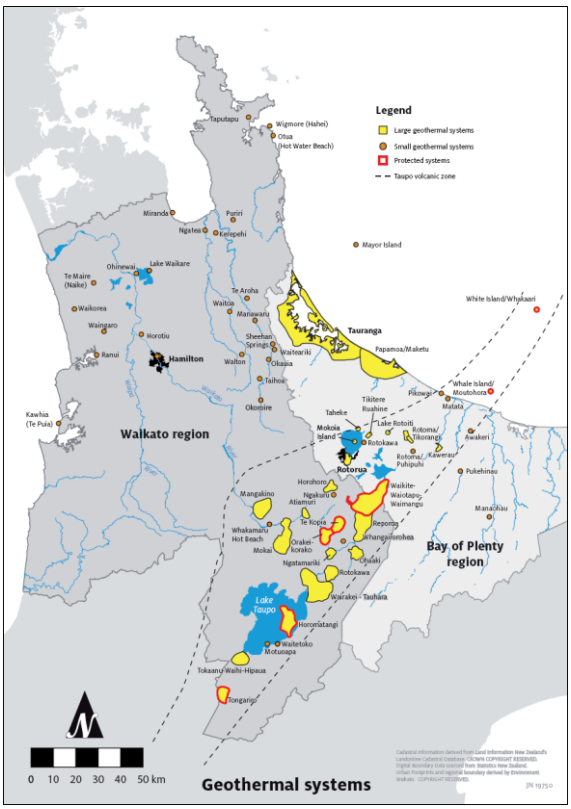

Figure 1: Map of the Waikato Regional Geothermal Resource

The high-temperature systems are divided into four categories depending on existing uses and the vulnerability of surface features to extractive uses. Five systems are set aside for protection of the features for scientific, cultural, tourism and ecological purposes. One system is a research system, two are for limited development and in seven systems, large-scale development is enabled. To date, six of the development systems have been developed for electricity generation and extractive large-scale direct uses such as timber drying, wood product processing, milk powder production and the growing of flowers, capsicums and tomatoes (Waikato Regional Council 2016).

Several high-temperature and low-temperature geothermal systems have geothermal tourism facilities ranging from bathing to nature and health tourism and industrial tourism.

All the active uses of geothermal resources provide employment and economic activity to the regional economy. Cultural, social, scientific, and ecological uses such as biodiversity and ecosystem services are also important.

1.2 Statutory requirement to monitor

Most of the environmental functions, powers and duties of the regional councils are outlined in the Resource Management Act 1991 (RMA). Section 30 gives regional councils control over the taking or use of geothermal energy and water, and control of discharges of contaminants into or onto land, air, or water and discharges of water into water. RMA s30 also requires regional councils to manage indigenous biological diversity.

The Maori tribes inhabiting the TVZ tell in legend how the ancestor Ngatotoirangi called his sisters from their original homeland north of Aotearoa to bring him geothermal and volcanic heat to sustain him when he was dying of cold. The story provides insights into the cultural, spiritual, historical, ceremonial, and practical relationships between tangata whenua and this valuable resource, which is regarded as a taonga in all its many aspects and uses. Within the Waikato region the main iwi (tribes) that hold tangata whenua (land association) status over the geothermal resources include Waikato-Tainui, Te Arawa, Ngati Tuwharetoa, Ngati Tahu, Ngati Whaoa, Ngati Raukawa, and their hapu (sub-tribes).

Since the Resource Management Act 1991 (RMA) was enacted in 1991, Waikato Regional Council and other research organisations have advanced our knowledge of the regional geothermal resource, through routine monitoring and innovative research into all aspects of the resource. Research topics can be roughly divided into those that look at the underground resource and those that look above ground, including into ecological matters.

We have developed an increasing understanding of the delicate and fragile nature of geothermal features and their dependent ecosystems (Parkyn and Boothroyd, 2000; Duggan and Boothroyd, 2001; Duggan and Boothroyd, 2002; Stevens *et al.*, 2003; Wildland Consultants Ltd., 2004, 2006a, 2006b, 2007a, 2007b; 2014, 2015,Cody 2007; Keam *et al.*, 2005, Willoughby and Beard, 2013, Willoughby et al., 2015). This resonates with the increasing awareness in society generally of the importance of biodiversity for the future of the planet and of the need to preserve rare ecosystems and organisms. (Department of Conservation, 2000, McQueen-Watton et al, 2018, Power et al., 2018).

In recent years pre-Covid-19, New Zealand has rapidly increased its tourism industry to the point where tourism was one of the top four export providers. The geothermal tourism industry has played a significant part in this tourism growth. (APR Consultants, 1994; Bay of Plenty Regional Council, 1999; Chrzanowski, 1997; McDermott Fairgray *et al*, 1996; Luketina, 2002; Barns and Luketina, 2011; Luketina, Olubode, and Phillips 2017).

Environmental legislation including the RMA is increasingly requiring the application of the 'polluter pays' principle, which requires that the adverse effects on resource use do not fall on society but on the resource user. This is true of geothermal uses, where the unintended adverse effects such as subsidence have sometimes taken many years to manifest after the first pioneering large-scale geothermal developments were initiated.

Since the 1990s, issues of sustainability of natural and physical resources are becoming more vital to the international community and the hearts and minds of the people (UNCED, 1992, Pintér et al., 2012, Shortall & Kharrazi 2017).

Sound and effective environmental policy for allocating resources and protecting the environment must be grounded in defensible scientific fact and principles.

RMA s35 requires regional councils to monitor, keep records, interpret data and report on the state of the environment resource. Therefore, WRC monitors the extent, variety and condition of the regional geothermal resource, and the way that the many different uses of the resource affect its sustainability.

Since WRC's inception under the Local Government Act 1989 it has continued the geothermal monitoring initiated by its predecessors such as the Waikato Valley Authority.

As well as the monitoring that WRC undertakes, the resource users are required to monitor the effects of their activities on the geothermal resource and on other resources. For large-scale users such as electricity developers, the effect of their operation on the geothermal resource is overseen by expert peer reviewers appointed by WRC with skills in such disciplines as geothermal reservoir modelling, reservoir engineering, geophysics, geology and geochemistry. Data and interpretations are made public to enable open scrutiny and healthy debate.

This paper brings together a public record of what we monitor, why we monitor it, how we monitor it, and discusses trends in data and monitoring.

1.3 Structure and strategy of the Regional Geothermal Monitoring Programme

There are approximately 3,000 geothermal features in the Waikato Region, ranging in characteristics from warm seeps through to fumaroles and geysers Their geographical range traverses 400 km in a N-S direction from the shores of Whitianga to the summit of Mt Ruapehu, and East-West from coast to coast. We cannot monitor all features regularly, but we can monitor selected features to give an overall picture of trends in physical characteristics such as energy and mass output, cyclical activity, and ecological parameters. This provides us with a baseline for what is the normal range of activity of these indicator features across the region.

WRC requires consent holders for large-scale extractive uses to monitor the effects of their activities, but the data and information from such monitoring programmes is not always received by WRC, and not always in a form that is compatible with WRC databases and analytical and modelling tools. It is hoped that ongoing refinement of consent monitoring requirements, WRC internal data transfer processes and storage protocols and resources will lead to better data capture, analysis, interpretation and reporting on the regional resource.

WRC undertakes some monitoring of geothermal features in Development Geothermal Systems, as some features are vulnerable to adverse effects from other uses of the features by other parties. Also, WRC's monitoring ensures consistency of approach and full regional spread.

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1.4 Innovation and filling knowledge gaps

Although such parameters as spring outflow and chemistry are well-understood, there are many ecological aspects of geothermal environments that remain unstudied. The geothermal monitoring programme includes a push to learn more about the ecosystems that depend on geothermal outputs. WRC undertook the first ever survey of soil-dwelling invertebrates in geothermal soil (citation), has done some studies on beetles, and hopes to extend these preliminary studies to a greater number of geothermal areas. Current acknowledged gaps in our information include data on the incidence of spiders, lizards, and birds in geothermal habitats, and the roles they play in ecosystem dynamics.

For aquatic habitats, the recently developed survey method of DNA analysis of water will shed new light on aquatic communities, to update and provide more detail than previous studies. WRC actively supported the use of this method in the GNS 1000 Springs project. (Power et al., 2018).

Innovation is vital to improving our monitoring techniques. With the expertise of contractor Mark Harvey, WRC pioneered the use of drones to undertake high-resolution visual and thermal infrared surveys of geothermal areas. Such uses have now become common throughout the world. Using drone, plane and satellite data, WRC has been able to undertake heat-mapping and quantify the heat-output of a geothermal area, locate and describe geothermal features in dangerous or remote locations, develop 3-d point cloud images of geothermal areas, identify volumetric differences over time and create virtual reality images.

WRC recently conducted surface change analysis in the Taupō area (Harvey et al., 2019), using Sentinel-1 satellite Synthetic Aperture Radar (SAR) data. The analysis used the Persistent Scatterer Interferometric Synthetic Aperture Radar (PSInSAR) method, and results showed i) Wairakei-Tauhara and Rotokawa geothermal systems are associated with zones of subsidence, and ii) subsidence bowls in the same locations as previously identified by levelling surveys. This provided confirmation of the PSInSAR method over a 400 km^2 area.

WRC has also used this method to observe vegetation changes in geothermal areas, and the method is being extended to identify sites of other regional environmental issues such as forest clearance and wetland drainage.

In a national first, WRC has recently devolved the responsibility of monitoring fresh water quality around Lake Taupō to the Tūwharetoa Māori Trust Board. It is likely that further such monitoring responsibilities will be taken up by tangata whenua groups, including for monitoring geothermal resources.

1.5. Funding for monitoring

WRC has two main sources from which funding for monitoring is derived: a portion of the general rate levied on all properties in the region and a portion of the annual charges on consent holders. The amounts to be gathered from all sources for all council purposes including geothermal monitoring are determined every three years in the Long Term Plan (LTP), which sets out in detail the overall council direction for the next three years, and in less detail, for the next ten years. Each LTP is developed with community consultation through public submissions. The current LTP runs from July 1 2018 to June 30 2021. WRC is currently preparing the 2021 – 2024 LTP.

In the current LTP budget for the 2020-2021 year, direct expenses for geothermal monitoring (consultants, lab costs, equipment replacement etc.) were allocated $491,000, which equated to 8.8% of the Science monitoring budget. The actual geothermal monitoring budget subsequently received funding for direct costs of $59,480, or 1.8% of the Science monitoring budget. The figures for the previous two years are similar. The printed LTP document does not provide the level of detail to show this and instead reports financial matters at a higher level.

As a result of the budget cuts, the geothermal monitoring programme shelved some long-standing monitoring projects and decline the opportunity to work with others to extend geothermal investigations to the benefit of the regional community. For example, the two-yearly geochemistry sampling programme has not occurred since 2018 (Wilson, 2018), and the five-yearly geothermal vegetation survey has not occurred since 2014 (Wildlands, 2015). WRC did not have sufficient funding to extend into the Waikato Region the study undertaken by a partnership between Bay of Plenty Regional Council, GNS and the SCRIPPS Institute of Oceanography, USA, which undertook a lake-bed magneto-telluric survey of geothermal system boundaries.

2. MONITORING AND INVESTIGATION OUTPUTS

2.1 Technical Reports and Internal Reports

WRC produces two types of scientific reports (known as Technical Reports and Internal Reports). The primary means of publishing WRC environmental information is through Technical Reports. A Technical Report is a registered document that includes the analysis or evaluation of primary data or field data collected by or on behalf of Waikato Regional Council, or the synthesis, re-analysis or appraisal of secondary data for research and monitoring purposes. The work presented should be relevant to the Waikato region and Waikato Regional Council's statutory functions and responsibilities. A technical report has a strong analytical focus; that is, it seeks to understand or evaluate or assess the issue being investigated through the application of appropriate research design and methodology. It also demonstrates the quality of science capability available for policy development and decision making. All published Technical Reports are listed in the Publications section of Waikato Regional Council's website and appear on the website as downloadable PDF files.

In the last five years the management approach to the publishing of geothermal technical reports has been in a state of flux and so a reduced number of Technical Reports have been published. For example, in 2015 eight geothermal Technical Reports were published, but since then, only six. Publishing processes have since been streamlined and facilitated, although some draft Technical Reports will remain as drafts until adequate funding can be obtained to add the necessary components for completion.

An Internal Report is a scientific report that does not meet the criteria of a Technical Report. It is available to WRC staff, and may in some cases be made available to external parties on request. Internal Reports are not listed with the Legal Deposit Office.

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2.2 Student reports, dissertations and theses

WRC works with universities and other tertiary education providers, in particular but not limited to The University of Auckland Geothermal Institute, to support student geothermal investigations. Depending on course requirements, these investigations may yield diploma project reports, dissertations and theses, which may or may not be available publicly depending on the university's policy. WRC encourages the public dissemination of all such suitable student works through such means as conference or open-access journal papers.

2.3. Conference and open-access journal papers

WRC geothermal scientists frequently report their monitoring data, analyses and interpretations through conference and journal papers. Such papers may be co-authored with students, consultants, CRIs or other collaborators. The NZ Geothermal Workshop and World Geothermal Congress are the primary outlets used, and therefore the papers are publicly available online through the International Geothermal Association papers database. Any journal paper written by WRC geothermal scientists is made open-access, and WRC encourages other authors using WRC resources to make their paper open-access.

2.4 Book chapters

From time to time WRC may publish a book, with contributions from WRC scientists. A WRC geothermal scientist may author or co-author a book chapter or segment (Luketina 2010, Luketina and Parson, 2019).

2.5 Online Environmental Data, Information, and Indicators

2.5.1 Environmental Data

Much of WRC's data is available publicly and can be obtained through WRC's online data portal. Depending on the data type, some of this data can be downloaded directly from the portal, and other data must be requested. Data can take the form of time series, drilling logs, GIS layers, etc.

The range of data available is listed online in the WRC Data Catalogue, which holds metadata (data about data) in an ANZLIC-compliant format, for spatial datasets and non-spatial data owned or jointly owned by WRC. https://www.waikatoregion.govt.nz/services/data-catalogue/

The Data Catalogue provides to the public the ability to:

- Search for and view metadata for spatial datasets and non-spatial data owned and jointly owned by Waikato Regional Council
- Download Data when available
- Request data via the 'Data Request' form
- Download metadata in XML format

Data can also be requested through an online Request for Service: https://bps.waikatoregion.govt.nz/online-services/new/RequestForService/step/1

The Environmental Data Hub provides online direct access to a range of live data feeds. As yet, there are no geothermal data feeds available. https://www.waikatoregion.govt.nz/environment/environmental-information/

2.5.2 Online Environmental Information

The WRC website's Environment pages show several pages about the Regional Geothermal Resource. https://www.waikatoregion.govt.nz/environment/geothermal/

2.5.3 Online Environmental Indicators

In addition, there are two geothermal environmental indicators, which should be updated every few years. These indicators are under review to ensure they are timely and provide the most useful information about the changing state of the regional geothermal environment. The Number of Geysers indicator is more-or-less static now that regional policy protects geysers, and so there are plans to replace it with an indicator tracking the extent and condition of geothermal vegetation.

The geothermal environmental indicators can be found here: https://www.waikatoregion.govt.nz/Environment/Environmental-information/Environmental-indicators/Geothermal/

3. MONITORING REGIMES

Monitoring the regional geothermal resource requires multiple scientific disciplines, an eye for innovation and cross-pollination of ideas, a readiness to engage in collaborative projects at short notice, as well as the ability, capacity and dedication to plod on with long-running data collection projects.

The range of projects to date includes the following categories:

3.1 Ecology

3.1.1 Microbial biodiversity

WRC supported the GNS 1000 springs project, which identified 28,000 taxonomic units in thermophilic microorganisms in TVZ geothermal pools (Power et al., 2018).

3.1.2 Aquatic biodiversity and habitat characterization

WRC commissioned NIWA to report on the distribution of biota in geothermally-influenced flowing and standing waters (Duggan and Boothroyd 2001, 2002). Waikato University studied a range of aquatic geothermal habitats in the Region and described the important habitat parameters of each site (Stevens, Cody and Hogg, 2003). WRC staff studied in details the water quality and biodiversity of three Waiotapu geothermal lakes (Catlin et al., 2017)

3.1.3 Terrestrial plant ecology

WRC undertakes a five-yearly inventory of geothermal vegetation in the Waikato Region. This maps changes in the extent and condition of all 64 geothermal vegetation sites in the Region, using a combination of field assessment and revision of boundaries using aerial photos. It is timed to follow the WRAPS (Waikato Regional Aerial Photography Syndicate) acquisition of high-resolution aerial photography across the entire region. The report is used extensively by WRC and other agencies working on geothermal vegetation protection such as Department of Conservation, geothermal power developers, district councils and landowners. It provides the basis for several subsidiary reports providing concentrated detail on such things as priorities for fencing and pest control, priorities for field assessments, and a set of indicators for State of The Environment Monitoring. An up-

to-date report will be needed for the current review of the Waikato Regional Plan, which contains statutory maps showing the boundaries and buffer zones for Significant Geothermal Features in Development Geothermal Systems and Limited Development Geothermal Systems. The most recent reporting cycle was completed in 2014 (Wildland 2014, 2015). The 2019 vegetation report timed to follow the 2017 WRAPS flyover has been deferred indefinitely due to budget constraints.

In 2016, WRC commissioned a study to determine whether Thermal Infrared emissions from heated ground and Near Infrared reflections from thermotolerant vegetation could be used to assess the heat-stress levels of the vegetation (Lloyd et al, 2016.).

3.1.4 Soil-dwelling invertebrates

In 2013, WRC undertook the first-ever investigation into the biodiversity of soil-dwelling invertebrates in pasture surrounding geothermal features, and the environmental factors that influenced the communities. A subsequent study (Willoughby and Beard, 2013, Willoughby, Beard and Luketina 2015) compared this with the biodiversity in soil under geothermal vegetation. These were preliminary investigations to test the method at a few representative sites. The project, which can now be expanded across the TVZ, has been shelved indefinitely due to budget constraints.

3.1.5 Ecosystem dynamics and biodiversity management: GEORGA

In 2015 a study was undertaken to determine the drivers of biodiversity in terrestrial geothermal vegetation, including soil dwelling, crawling and flying invertebrates, and vegetation secession. A biodiversity assessment tool was developed that is applicable for all ecosystem types, including geothermal (Willoughby and Beard, 2015).

3.1.6 Ecosystem Services

Desktop assessment of selected ecosystem services provided by terrestrial geothermal sites in the Waikato Region was undertaken (McQueen-Watton et al., 2018).

3.2 High-temperature system assessment

3.2.1 System boundaries

In 2000 WRC commissioned the mapping of the system boundaries for all Protected and Research high-temperature geothermal systems in the Waikato region. Council policies and rules relating to use of geothermal resources apply within these boundaries, which are conservatively based on resistivity measurements to 500 and 1000 metres depth, drilling results, location of springs, geology, and all other available geochemical and geophysical data. (Risk 2000a, 2000b, 2003). The mapping of Development and Limited Development Geothermal Systems for the Regional Policy Statement is described in (Luketina 2000).

Now that much of the TVZ has been surveyed using magneto-telluric remote sensing, mainly by GNS, the extra information provided by this technique, particularly regarding the deeper resource and upflows, should be used to refine the boundaries. The Ruapehu Geothermal System has been identified (Jones et al., 2008). Deep drilling, particularly at Ngatamariki, has also provided information on the extent of some geothermal systems. Statutory system boundary maps will need to be revised for the current review of the Regional Plan. This update project is currently unfunded.

3.2.2 Resource Capacity

Resource Capacity Estimates for High Temperature Geothermal Systems in the Waikato Region uses stored heat calculations to estimate the amount of available energy in each of the 15 large geothermal systems in the Waikato region (Sinclair Knight Merz 2002)

Since then, the United Nations Framework Classification engaged the International Geothermal Association to develop a framework for classifying geothermal reserves, which was published in 2016. This framework is likely to be suitable for defining the resource capacity of the geothermal systems of the Waikato Region, which may be used to set development limits for Development and Limited Development Geothermal Systems in the review of the Waikato Regional Plan. This proposed resource capacity project is currently unfunded within WRC, although it will be needed for the review of the Regional Plan.

3.2.3 Mangakino

A 2016 collaboration between the Geothermal Institute and WRC enabled a geological study to determine the likely upflows and permeable regions of the Mangakino Geothermal System (Rustandi et al., 2016)

3.3 Geophysics

3.3.1 Significant Geothermal Features

Definition and Listing of Significant Geothermal Features in the Waikato Region (Keam et al., 2005) defines and identifies the type of Significant Geothermal Features in the Waikato region and determines the significance of each type based on rarity and vulnerability.

3.3.2 Spring characteristics

From 1995 to the present and ongoing, WRC has monitored the behaviour and condition of geothermal springs in the Waikato region and produced quarterly and annual reports. Until 2013 these were not published but were available on request. From 2013 to 2015 the annual reports were published as Technical Reports and the quarterly reports were printed as Internal Reports. The data is still being collected and written up annually, and efforts are being made to make reports available in published form again.

3.3.3 Geyser eruptive cycle: what influences it?

The time series temperatures records of selected geothermal springs were analysed in the light of local meteorological conditions and nearby earthquakes to determine what external natural phenomena affected. (Nikrou, 2013, Nikrou et al., 2013).

3.3.4 Ground-penetrating radar

In 2016 ground-penetrating radar (GPR) was used to determine the depth below the ground, overall thickness, and spatial extent of sinter buried below a layer of sediment in the Waipahihi Valley, Taupō. Although GPR has been used elsewhere to investigate sinter, this project in particular proved the method for use by WRC (Lynne et al., 2016).

3.3.5 Tauhara

Part of Tauhara geothermal field underlies Taupō town, where it is used for domestic heating and spa bathing in

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motels and swimming complexes. The geothermal surface features and shallow geothermal resource have been affected by lateral draw-off by the Wairakei geothermal power station. There is also large-scale extraction itself by the Te Huka geothermal power station and the Tenon wood processing plant. Curtis (1989) surveyed the hundreds of small geothermal bores in Taupō and characterised the aquifers. Lebe (2020) updates and expands upon that work.

3.3.5 Hydrothermal eruption craters

Lynne (2007a) reports on field examinations of eruption breccia within the Horohoro Thermal Area and Tauhara to determine the true nature of landforms previously identified as hydrothermal eruption craters.

3.4 Geochemistry

A geothermal geochemical monitoring programme (REGEMP) for the Waikato region was developed and commenced in 1996 (Huser and Jenkinson, 1996). In 2007 it was revived (Luketina, 2007), with a two-yearly sampling period (Webster-Brown and Brown, 2008; Webster-Brown & Brown 2012; Golder 2014; Wilson and Allen, 2018).

3.5 Low-temperature system assessment

WRC has collaborated over many years with the Geothermal Institute in providing resources for Institute students to undertake resource assessment surveys of the region's low-temperature geothermal systems.

3.6 Socio-economic assessments

Following a report commissioned by WRC to examine WRC's social information needs for the management of geothermal resources and a survey of tourists' experience of geothermal attractions (Chrzanowski, 1997), WRC surveyed the numbers of visitors to Waikato geothermal attractions (Luketina, 2002). The survey was repeated in 2011 and expanded to include an assessment of the economic effect of the three categories of geothermal uses – tourism, direct heat applications and electricity production (Barns and Luketina, 2011). In 2017, a joint study with BOPRC used off-market valuation techniques to further investigate the numbers of visitors and the value of tourism spending to the economies of both regions (Luketina et al. 2017) These economic assessments have been informed by analyses of the environmental costs of electricity generation including geothermal generation (Denne 2007, Denne 2012)

4. CONCLUSION

The more we know, the more we realise how much we don't know. The complex thermodynamics of geothermal resources, and of their dependent ecosystems become more and more apparent as we seek to understand them. New monitoring, investigation, surveillance, modelling, and change-detection methods enable greater understanding of the regional geothermal resource, and the natural and anthropogenic changes in its nature and characteristics. Intensification of land use and the use of geothermal resources call for greater monitoring at a time when severe constraints are placed on the monitoring budget. Good resource management policy that provides certainty to resource users and the community relies on comprehensive scientific understanding of the resource and the effects of its use. Much monitoring and investigation information and data are required to inform the current policy review process and to satisfy the requirements of the RMA.

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