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GEOTHERMAL VEGETATION OF THE WAIKATO REGION, 2014

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GEOTHERMAL VEGETATION OF THE WAIKATO REGION, 2014

Contract Report No. 3330

November 2014

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SUMMARY

This study provides an updated inventory of the current distribution and extent of geothermal vegetation in the Waikato Region, and includes an assessment of the relative significance of each assessed site based on 2012 aerial photographs and field survey of selected sites during 2014. Approximately 74% of the extent of New Zealand's geothermal vegetation occurs within the Waikato Region. The remaining 26% is located within the Bay of Plenty Region. Geothermal feaures are present elsewhere in New Zealand (in Northland, the Hauraki Gulf, and scattered hot springs in the North and South Islands), but there is little to no associated geothermal vegetation at these localities. Vegetation associated with geothermal sites contains characteristic plant species and vegetation types, including species capable of surviving high soil temperatures, disjunct populations of plants that are usually confined to warmer climates, and locally endemic species and distinct genetic forms arising where ground temperatures are sufficiently stable. Many geothermal sites are dynamic and unstable and changes in surface geothermal activity are often reflected in changes in the extent and composition of geothermal vegetation. The geothermal vegetation of the Waikato Region includes populations of several plant species that have been classified as 'Threatened' or 'At Risk' at a national level.

Sixty-four sites, located within fifteen geothermal fields have been described, mapped, and assessed for significance using existing information, information collected during field surveys of 25 sites, and assessment of 2012 aerial photographs. The Waikato Region contains *c.*750 ha of mapped geothermal vegetation (including nonvegetated raw-soilfield) and *c.*113 ha of mapped geothermal water where it was an integral part of a geothermal site. There are likely to be some small areas of geothermal vegetation on hillslopes above Tokaanu and elsewhere that have not been mapped in this report. Three broad categories of geothermal vegetation and habitats were mapped: nonvegetated raw-soilfield (*c.*90 ha), emergent wetland vegetation (*c.*86 ha), and terrestrial vegetation (*c.*575 ha). Terrestrial vegetation is vegetation that was not mapped as geothermal wetland or nonvegetated raw-soilfield and includes (but is not limited to) forest, scrub, shrubland, fernland, and mossfield.

The vegetation of each site has been described and classified using predefined vegetation structural classes based on Atkinson (1985) and a protocol for assigning type names based on the dominant plant species. Site condition, current threats, modifications, and vulnerability were assessed, and management requirements identified.

Each site was assessed for significance and then assigned a relative significance level of International, National, Regional, or Local using the criteria in the Waikato Regional Policy Statement (updated in accordance with the revised threat classification lists). Four entire sites, and part of one other site, were assessed as being of International Significance encompassing *c.*214 ha or 25% percent of the geothermal habitat in the Waikato Region. Ten entire sites were of National significance, with one site being partly of National significance and partly of Local significance, areas of National significance encompass *c.*386 ha or 45% of geothermal habitat in the Waikato Region. Twenty-two sites were identified as being of Regional significance, with an additional four sites being partly of Regional and partly Local significance. In total, *c.*246 ha or 29% of geothermal habitat in the Waikato Region was identified as being Regionally Significant. The remaining sites (23 sites) were identified as being of Local Significance (*c.*18 ha or *c.*2% of geothermal habitat in the Waikato Region).

Sites are presented and discussed in this report in relation to the geothermal field within which they occur. Using geothermal fields as a framework for presenting site information is more likely to show differences in character between geothermal sites than ecological districts, as sites within the same geothermal field are thought to be sourced from the same geothermal reservoir, which is the source of water and heat in geothermal surface manifestations. The character of 17 geothermal fields is described in this report. The following areas of geothermal vegetation were mapped in each geothermal field: Waiotapu (*c.*221 ha), Wairakei-Tauhara (*c.*145 ha), Rotokawa (*c.*115 ha), Tokaanu-Waihi-Hipaua (*c.*59 ha), Te Kopia (*c.*65 ha), Orakeikorako (*c.*64 ha), Tongariro (*c.*29 ha), Waikite (*c.*20 ha), Ohaaki (*c.*18 ha), Reporoa (*c.*10 ha), Mokai (*c.*3 ha), and Ngatamariki (*c.*1 ha); three fields have less than one hectare of geothermal vegetation (Atiamuri, Horohoro, and Whangairorohea), and two fields have no known geothermal vegetation (Mangakino and Horomatangi).

The majority of geothermal vegetation in the Waikato Region occurs in Atiamuri Ecological District (*c.*81%), while Taupō and Tongariro Ecological Districts contain *c.*13% and *c.*7% of the vegetation of the region respectively, and Rotorua Lakes Ecological District contains <0.1% of the geothermal vegetation of the Waikato Region. Geothermal vegetation in the Waikato Region is distributed relatively evenly between two local authorities: Rotorua District (50.5%) and Taupō District (*c.*49.4%).

In the Atiamuri Ecological District there has been a significant decline in the extent of geothermal vegetation since European settlement (estimated to be approximately 30%). However there has been an estimated gain of approximately 4% in the Taupō Ecological District. The overall decline in geothermal vegetation is the result of a number of factors. These include energy and hot water draw-off from the geothermal fields, damming of the Waikato River to form Lake Ohakuri, clearance and burning of vegetation, weed invasion, livestock grazing, modification of groundwater tables, dumping of rubbish, and other activities associated with forestry, farming, tourism, urbanisation, and recreation. The ecological sustainability of geothermal vegetation in the Waikato Region is under ongoing threat from plant and animal pests and from the activities of humans, particularly on private land. Monitoring, protection, and restoration, wherever possible, are essential to halt the decline of these fragile and unique ecosystems.

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1. INTRODUCTION

This study provides an inventory of the current distribution, extent, and character of geothermal vegetation in the Waikato Region, and includes an assessment of the relative significance of each site based on criteria defined in the Waikato Regional Policy Statement (2002). This information will enable management of the varied characteristics of the geothermal resource, as required by the Waikato Regional Policy Statement. This report collates information from a number of previous reports undertaken by Wildland Consultants for Waikato Regional Council between 2000 and 2012 (Wildland Consultants 2000, 2003, 2004c, 2006, 2007a&b, and 2012), as well as updated information based on site inspections of selected sites, improved knowledge about sites from other studies, and inspection of recent better quality aerial photographs (2012 WRAPS[1]) than were previously available.

The Waikato Region is located in the upper part of the central North Island. It extends from Coromandel-Colville in the north to Mount Ruapehu in the south, as far west as Mokau, and east to include part of Kaingaroa Forest (refer to Figure 1). The Waikato Region comprises part or all of 34 ecological districts, three of which - Atiamuri Ecological District, Taupō Ecological District, and Tongariro Ecological District - contain all areas of geothermal vegetation in the Waikato Region larger than 1 hectare. Isolated surface geothermal expressions occur elsewhere in the Waikato Region, but they are generally very small (usually small surface springs) and are not known to contain any geothermal vegetation of ecological significance. Many of these small geothermal expressions have been converted into bathing pools, while others are hot springs amongst sand on the ocean edge and do not support any vegetation.

Geothermal fields are used as the framework for presenting site information (rather than ecological districts). This is more likely to show differences in character between geothermal sites, as sites within the same geothermal field are thought to be sourced from the same geothermal reservoir, which is the source of water and heat in geothermal surface manifestations. It also avoids splitting geothermal fields that extend across two ecological districts, for example the Tokaanu-Waihi-Hipaua geothermal field (which spans Tongariro and Taupō Ecological Districts) and the Wairakei-Tauhara Geothermal Field (which spans Atiamuri and Taupō Ecological Districts).

Almost 80% of New Zealand's geothermal systems occur within the Waikato Region (Environment Waikato 1998). Geothermal areas are appreciated for their historical, amenity, cultural, spiritual, conservation, tourism, and scientific values (Waikato Regional Council 2007; Merrett & Clarkson 1999). Threats to these values include exploitative resource use such as thermal energy extraction and the utilisation of mineralised fluids, pest plants. pest animals, and tourism operations. If these threats are not monitored and controlled, ecological values of sites are likely to decline. The Waikato Regional Council management objectives, which are derived from consideration of these issues, are to maintain the extent and variety of geothermal

[1] WRAPS = Waikato Region Aerial Photograph Syndicate.

characteristics within the region, and to achieve protection and efficient take of the regional geothermal resource (Waikato Regional Council 2007).

Geothermal areas are often characterised by unusual assemblages of plants, including species that are normally found in climates warmer than that of the surrounding region, species capable of surviving high soil temperatures or hydrothermally altered soils (Given 1980), and local genetic forms arising where ground temperatures are sufficiently stable.

This report updates the 2012 geothermal vegetation report (Wildland Consultants 2012) using information collected from a 2014 survey of selected sites (listed in Appendix 2). Twenty-five sites were resurveyed in 2014 and two sites that had not been included in previous studies were added (THV08-Mountain Road and THV09-Kathleen Springs). The resurveyed sites included one entire site, parts of three other sites which previously had not been surveyed in detail, and parts or all of 21 sites which had previously been surveyed. Vegetation maps and descriptions have been updated. Vegetation types present in each site were identified, mapped, and described, and have been assigned to one of seventeen broad vegetation classes. Threatened species rankings have been updated using de Lange *et al.* (2013) for plants and Robertson *et al.* (2013) for birds. Information included in the 2012 report has been updated where possible, including information on site changes (generally either since the last field survey, or within the last ten years, if known), historical site changes, and incorporation of more fauna information where available. Historical site change assessments undertaken in 2012 have been carried over to this report, but new comparisons using 2012 aerial photographs have not been undertaken.

The ecological significance of each site was reassessed as being of international, national, regional, or local significance as determined by the updated criteria defined in the Waikato Regional Policy Statement (2002). These criteria have been revised to reflect changes to the New Zealand Threat Classification Lists undertaken in 2008 (refer to Appendices 10 and 11). Ecosystem Ranking assessments were completed for all sites (see Wildland Consultants 2014).

The objectives of the current project were to identify, map, and classify known areas of geothermally-influenced terrestrial and emergent wetland vegetation in the Waikato Region. Relevant existing information was collated, and field investigations have been carried out for most sites (see Appendix 1) between 2003 and 2014. The exceptions are Hipaua, Ketetahi Springs, Maunganamu North, and parts of Tokaanu Lakeshore Wetland, where field survey was not undertaken because access permission was withheld. A total of 64 sites are reported on in detail in this report. All sites have been remapped using 2012 aerial photography and all boundaries have been checked at high resolution. Any parts of sites that were unsafe to access due to geothermal hazards were assessed based on vegetation pattern and appearance inferred from aerial photographs and information collected elsewhere at the site. Threats, modifications, vulnerabilities, and the relative significance of each site have been assessed in a regional context.

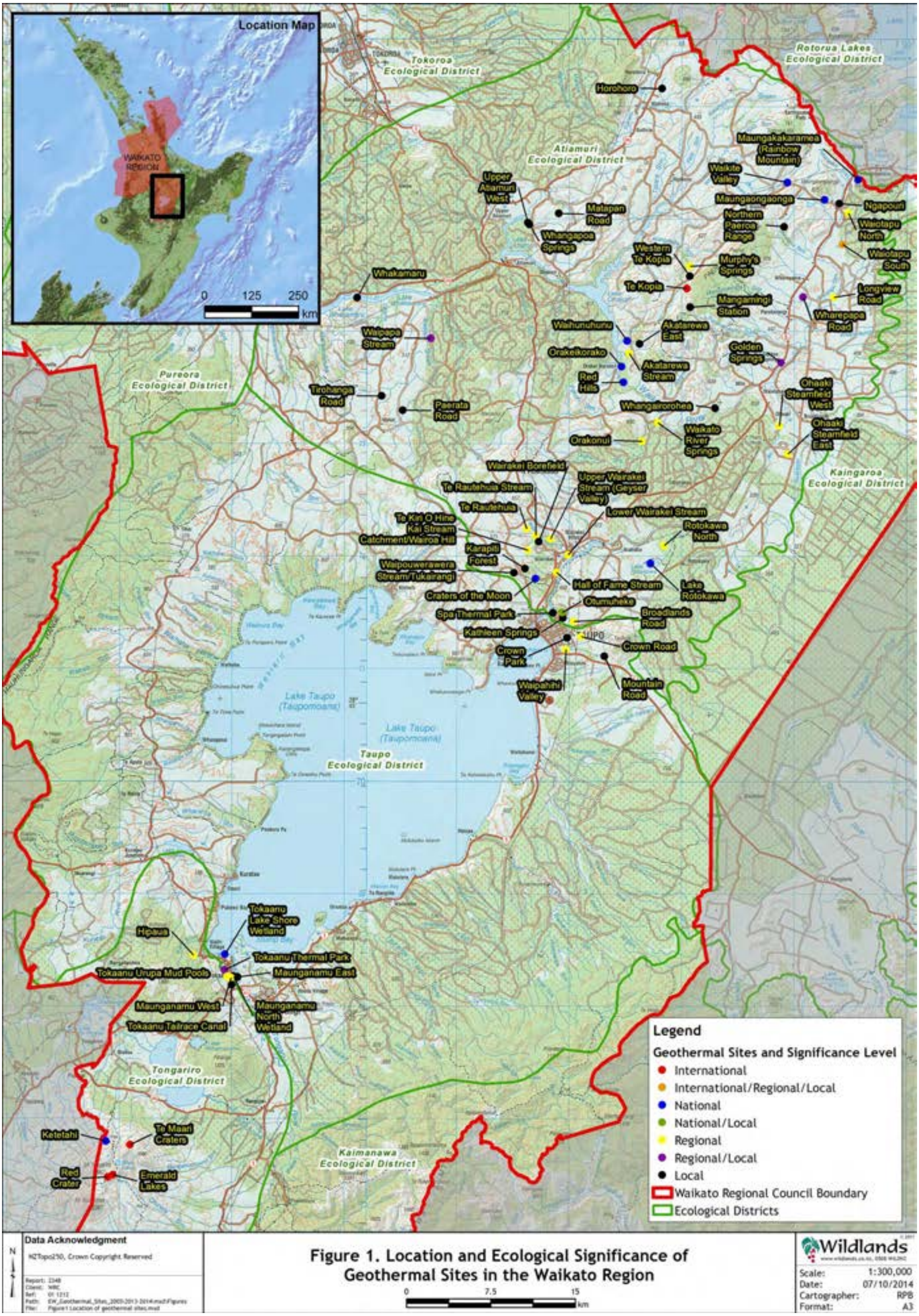

Figure 1. Location and Ecological Significance of Geothermal Sites in the Waikato Region

This report includes an index of the geothermal sites, and the appendices include information on sites for which field work was undertaken, a description of vegetation classes, a glossary of technical terms including threatened and uncommon plant classifications, and notes on notable vascular plants found within geothermal areas.

A list of 20 additional sites in the Waikato Region with known geothermal surface expressions, but which have not been assessed in any detail, is presented in Appendix 3. These sites have not been investigated in detail for this report because they are not known to contain any significant geothermal vegetation. Generally these sites are small and many have been altered for recreational uses such as swimming, or have been altered for farming or commercial use. Several are also located on the coastal margin in sand and contain no vegetation.

2. PREVIOUS WORK

The botany of many of the geothermal areas of the central North Island has been surveyed, documented and assessed in numerous reports (see Bibliography). The relative scientific or conservation significance of some sites containing geothermal vegetation and flora was assessed in Given (1978 & 1980a), Clarkson (1987), and various other reports. Given (1989a & 1996) assessed the relative botanical significance of geothermal sites in the Central Volcanic Plateau Ecological Region within the Waikato Region.

Merrett and Clarkson (1999) compiled an annotated bibliography of reports relevant to geothermal vegetation occurring within the boundaries of the Waikato Region. Wildland Consultants (2000) provided the first major inventory and assessment of geothermal sites in the Waikato Region. This was updated in 2003, based on field survey between November 1999 and February 2000 and in May 2003 and existing information on 34 sites (Wildland Consultants 2003). A further update was completed in 2004, based on field survey of 35 sites undertaken between April 2003 and August 2004 and assessment of 2002 aerial photographs (Wildland Consultants 2004c).

Several additional geothermal sites were resurveyed between 2006 and 2007 and their information updated (Wildland Consultants 2006, 2007a, and 2007b). In 2012, a full update of the geothermal vegetation of the Waikato Region was undertaken based on field survey of 37 sites undertaken between June 2010 and June 2011 and assessment of 2007 aerial photographs (Wildland Consultants 2012).

3. METHODS

3.1 Existing information

Existing information on the distribution and botanical values of geothermal areas in the Waikato Region was compiled from published and unpublished sources (see Bibliography). Geothermal sites containing, or likely to contain, geothermal vegetation were identified from Cave *et al*. (1993), Mongillo and Clelland (1984), Leathwick *et al*. (1995), Given (1989a & 1995), Spring-Rice (1996), Department of

Conservation (1997), and personal knowledge. Department of Conservation staff provided some additional information on geothermal sites for this 2014 study.

For each geothermal site, existing information was compiled for the following categories: grid references, site names, local authority, ecological district, geothermal field (from Merrett and Clarkson 1999), bioclimatic zone (from Leathwick *et al*. 1995), tenure, altitude, notable indigenous flora, fauna, threats/modification/ vulnerability, management requirements, significance/justification, and significance ranking (botanical rank from Given 1996, and ecological significance from Wildland Consultants 2003, 2004c, 2006, 2007a&b, and 2012).

3.2 Ecological districts

Four ecological districts in the Waikato Region contain sites with geothermal vegetation. These are Atiamuri Ecological District, Taupō Ecological District (both of which occur within the Central Volcanic Plateau Ecological Region), Tongariro Ecological District (within the Tongariro Ecological Region), and Rotorua Lakes Ecological District (within the Northern Volcanic Plateau Ecological Region). Only a tiny portion (*c.*1 ha[1]) of Maungakakaramea occurs within the part of Rotorua Lakes Ecological District that lies within the Waikato Region.

3.3 Bioclimatic zones

Bioclimatic zones refer to the broad distribution of vegetation zones along both altitudinal and coastal to inland gradients where a particular climatic regime dictates the character of the natural ecosystem. Bioclimatic zones used were based on the published definitions of Meurk (1984), but with one further subdivision, and with the addition of a coastal zone to delineate those environments that are typified by frequent windblown salt and a marked reduction in the severity of frost.

The coastal bioclimatic zone includes areas less than 1 km from the coast, and with an altitude of less than 300 m. The lowland bioclimatic zone extends from the coastal zone up to an altitude of 300 m. The submontane bioclimatic zone extends from 300 m to 800 m and the montane bioclimatic zone from 800 m to 1300 m. The subalpine bioclimatic zone includes all land between 1,300 m and 1,800 m altitude. The alpine bioclimatic zone includes all areas above 1,800 m.

(Source: Leathwick *et al*. 1995)

3.4 Field survey

Field survey of 25 sites was carried out between January and July 2014 using a survey team of two people for safety reasons.

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[1] Leathwick *et al.* (1995) placed 2 ha of geothermal vegetation in the Waikato Region in the Rotorua Lakes Ecological District. However following refinement of the Rotorua Lakes Ecological District boundary as part of the Rotorua Lakes Ecological District PNAP survey (Beadel *et al.* 1998), only a very small area of geothermal vegetation now lies within the Rotorua Lakes Ecological District in the Waikato Region.

Geothermal vegetation types were described for each site, and the extent of each type was mapped onto colour printouts of digital aerial photographs (2012) (scale *c.*1:5,000). Field assessments addressed the following components: the extent and types of vegetation and habitats; indigenous flora and fauna (including threatened species); current condition of vegetation and habitats; invasive exotic plants; human impacts; grazing; adjoining land use, and management requirements.

The year of the most recent field survey for each site is provided in Appendix 2. Known geothermal sites that were not field surveyed are listed in Appendix 3.

3.5 Kānuka identification and taxonomy

Recent revision of the *Kunzea ericoides* complex (including taxa identified as kānuka and prostrate kānuka in this report) has split this complex into ten species, seven of which are newly described taxa (de Lange 2014). Following this revision, seven species of *Kunzea* occur in the North Island. Four[1] of the seven species are present in geothermal vegetation and habitats, with three of these species (*Kunzea robusta*, *Kunzea serotina*, and prostrate kānuka (*Kunzea tenuicaulis*))[2] present within the Waikato Region. Hybrids of *K. robusta* × *K. tenuicaulis, K. serotina* × *K. tenuicaulis*, and potentially *K. robusta* × *K. serotina*[3] may also be present within geothermal habitats in the Waikato Region. Field surveys of the geothermal habitats described in this report were completed prior to the revision of the *Kunzea ericoides* complex being published. Adopting the taxonomy of de Lange (2014) in the current report would require kānuka entities from each site to be reassessed against the revised descriptions, which would require extensive additional field and desktop assessment. As a result, the revised taxonomy for kānuka has not been adopted within this report.

3.6 Geophysical properties

In 2007 and 2010, geophysical assessments were undertaken for all or parts of 19 geothermal sites within the Waikato Region (see Table 1). Specific methods for these assessments varied slightly between the geophysical consultants, but generally the following methods were used:

- Locations of each feature were recorded using a GPS.
- Direct temperature measurements were made with a thermocouple on a 4 m long wire, or a 100 mm long rigid probe, connected to a Fluke multimeter. If the surface to be measured was not accessible, a Fluke infrared (IR) thermometer was used; however this has limited accuracy, particularly where steam blocks a clear view of the feature.
- The pH was measured with a Hanna Instruments pH meter with a maximum operating temperature of 50 °C; if the spring temperature was >50 °C the water

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1 *Kunzea robusta*, *Kunzea salterae*, *Kunzea serotina*, and *Kunzea tenuicaulis*.

2 *Kunzea salterae* has only been recorded from Moutohora (Whale Island) in the Bay of Plenty Region.

3 Hybrids of *Kunzea robusta* × *K. serotina* also occur (see de Lange 2014), but it is not known whether any occur in geothermal vegetation/habitats.

was cooled to less than 50 °C before the pH measurement was taken or a pH paper strip was used. Further details are provided on each site sheet.

Table 1: Geothermal sites where geophysical assessments have been undertaken.

Site Number	Site Name	Date of Assessment
WAV02	Northern Paeora Range	29 & 30 June 2010
WTV03	Waiotapu North	26 & 29 July 2010
WTV05	Waiotapu South	27, 29 & 31 July 2010 (*c.*30% of site)
WTV04	Maungakakaramea (Rainbow Mountain)	26 July 2010 (about 1/2 of site)
MKV03	Tirohanga Road	5 February 2007
ATV01	Upper Atiamuri West	5 February 2007
ATV02	Whangapoa Springs	5 February 2007
TKV03	Western Te Kopia[1]	29 June 2010
TKV02	Murphy's Springs	29 June 2010
TKV06	Mangamingi Station	28 June 2010
OKV03	Orakeikorako	1 August 2010 (*c.*50% of site)
RPV02	Wharepapa Road	30 July 2010
TOV10	Maunganamu East	7 February 2007
TOV07	Maunganamu West	13 February 2007
TOV14	Tokaanu Tailrace Canal	7 February 2007
TOV08	Tokaanu Thermal Park	7 February 2007 (*c.*50% of site)
TOV09	Tokaanu Urupā Mud Pools	7 February 2007

Details of the assessments are presented in Appendix 4.

3.7 Geothermal vegetation and habitat classes, and vegetation and habitat types

For the purposes of this report, geothermal vegetation and habitats are defined as all geothermal habitat that includes vegetation dominated by vascular plants, non-vascular plants, nonvegetated raw-soilfield (which often contain scattered patches of non-vascular and vascular plants), and emergent wetland vegetation. It does not include open geothermal water. Geothermal water was only mapped if it was an integral part of a geothermal site. In the site descriptions (Appendix 1), open geothermal water is included in "extent of geothermal habitat", but not in "extent of geothermal vegetation".

Vegetation types within previous editions of this report (e.g. Wildland Consultants 2003, 2004, 2007a&b, and 2012) were based on field work and types described in Merrett and Clarkson (1999), with additional types based on Atkinson (1987) vegetation structural classes identified during field inspections. In 2014, the vegetation types identified and mapped in 2012 were refined, similar types were combined, and geothermal vegetation types not represented in geothermal habitats in the Waikato Region were deleted. These 173 detailed vegetation and habitat types were then grouped together based on dominant species (e.g. prostrate kānuka) and

[1] The Western Te Kopia site includes three sites previously known as Te Kopia Northwest, Te Kopia Red Stream, and Te Kopia West Mud Pools.

structural class (e.g. shrubland) into 17 broad vegetation/habitat classes (c.f. 14 in 2012), within which 173 vegetation types are mapped and described within the detailed individual site descriptions and maps. A summary of the vegetation and habitat classes and types is presented in Tables 2 and 3 below. The vegetation classes have also been mapped (scale 1:2,000-1:25,000), and these maps are presented in Appendix 14. The extent of each vegetation class in the Region is given in Table 2.

Table 2: Geothermal vegetation and habitat classes.

Overview	Geothermal Vegetation/Habitat Class	Extent (ha)
Indigenous dominant vegetation	Indigenous forest and treeland	5.93
	Prostrate kānuka-dominant vegetation	428.05
	Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland	141.77
	Fernland	3.28
	Wetland vegetation	56.80
	Mossfield[1]	Not mapped[2]
	Bare ground[3]	89.83
	Geothermal water	113.39
Exotic dominant vegetation	Exotic forest and treeland	7.99
	Exotic vineland	0.33
	Exotic species-dominant scrub and shrubland	7.32
	Exotic grassland	2.23
	Exotic sedgeland	0.03
	Exotic herbfield	0.03
Mixed indigenous-exotic woody vegetation	Mixed exotic-indigenous species forest	0.02
	Mixed exotic-indigenous species scrub	7.15
	Mixed indigenous-exotic shrubland	1.69

1 Including *Campylopus* and other mosses, and indigenous liverworts.
2 Present, but extent at individual sites too small to map.
3 Including loamfield, sinter, boulderfield, and sandfield.

Table 3: Geothermal vegetation and habitat types within each geothermal/habitat class.

Geothermal Vegetation/ Habitat Class	Geothermal Vegetation/Habitat Type
Indigenous forest and treeland	Kānuka forest
	Kānuka forest⇔kānuka shrubland
	Prostrate kānuka forest
	Rautāwhiri/rank exotic grass treeland
	Mixed indigenous trees/blackberry-rank exotic grasses treeland
	Mixed indigenous-exotic trees/blackberry-rank exotic grasses-*Hypolepis ambigua* treeland
	Mixed indigenous-exotic trees/rank exotic grasses-exotic shrubs treeland
Prostrate kānuka-dominant vegetation	Prostrate kānuka scrub
	Tasmanian blackwood/prostrate kānuka scrub
	Exotic pine/prostrate kānuka scrub
	Burnt prostrate kānuka scrub
	Prostrate kānuka-mingimingi scrub
	Prostrate kānuka-monoao scrub
	Prostrate kānuka-mānuka scrub
	(Kāmahi)/prostrate kānuka-(monoao) scrub
	(Whauwhaupaku)/prostrate kānuka-mānuka/blackberry scrub
	Exotic pine/prostrate kānuka-mingimingi-mānuka scrub
	Prostrate kānuka-mingimingi scrub[1]

1 Recorded under mingimingi-dominant scrub in 2011.

Geothermal Vegetation/ Habitat Class	Geothermal Vegetation/Habitat Type
	Prostrate kānuka-mingimingi-mānuka scrub1
	Wilding pine/prostrate kānuka-mingimingi scrub
	(Exotic pine)/prostrate kānuka-mingimingi-mānuka scrub
	Prostrate kānuka shrubland
	Wilding pine/prostrate kānuka-mingimingi shrubland
	Prostrate kānuka-broom-blackberry shrubland
	Wilding pine/prostrate kānuka shrubland
	Prostrate kānuka-mingimingi-mānuka shrubland
	Prostrate kānuka-kāmahi-whekī-whauwhaupaku/blackberry shrubland
	Prostrate kānuka/nonvegetated raw-soilfield shrubland
	Prostrate kānuka/felled radiata pine-mingimingi shrubland
	Burnt prostrate kānuka shrubland
Mingimingi/mānuka/ monoao/kānuka dominant scrub and shrubland	Kānuka shrubland
	Kānuka-mānuka/oioi shrubland
	Kānuka-prostrate kānuka scrub
	Mingimingi scrub
	Exotic pine/mingimingi scrub
	Mingimingi-kānuka-mānuka-karamū/bracken scrub
	Mingimingi-mānuka-blackberry-indigenous broadleaved species scrub
	(Mānuka)/mingimingi scrub
	(Silver birch)/mingimingi-(prostrate kānuka) scrub
	Mānuka scrub
	Mānuka-mingimingi scrub
	(Exotic pine)/mānuka-mingimingi scrub
	Mānuka-prostrate kānuka-exotic species scrub
	Mānuka-mingimingi-blackberry-bracken scrub
	Mānuka-mingimingi-prostrate kānuka scrub
	Whauwhaupaku scrub
	Prickly mingimingi scrub
	Mānuka-prostrate kānuka-mingimingi/water fern-bracken scrub
	Whauwhaupaku-kāmahi-kōhūhū scrub
	Rewarewa-kāmahi/prostrate kānuka-mingimingi scrub
	Mingimingi-water fern shrubland
	Mingimingi-mānuka shrubland
	Mānuka-mingimingi shrubland
	Mānuka shrubland
	Mānuka/bracken-blackberry shrubland
	(Maritime pine)/mānuka-broom-blackberry-Himalayan honeysuckle shrubland
	Mānuka/water fern-*Carex secta* shrubland
	Mānuka-prostrate kānuka-mingimingi shrubland
	Mānuka/bracken shrubland
	Monoao shrubland
	Mixed indigenous shrubs/mixed fern species shrubland
	Planted indigenous species/rank grass shrubland
	Mixed indigenous species/Yorkshire fog shrubland
	Mānuka-mingimingi/lichen-bare ground lichenfield
Fernland	*Dicranopteris linearis* fernland
	Bracken-mingimingi-blackberry fernland
	Water fern fernland
	Ring fern-exotic grasses fernland
	Water fern-bracken-whekī fernland
	Bracken-*Cyclosorus interruptus*-blackberry-pampas/raw-soilfield fernland
	Mixed fernland
	Christella aff. *dentata* (“thermal”) fernland
	Christella aff. *dentata* ("thermal”)-*Nephrolepis flexuosa*-blackberry fernland
	Nephrolepis flexuosa fernland
	Ring fern fernland

Geothermal Vegetation/ Habitat Class	Geothermal Vegetation/Habitat Type
	Deparia fernland
	Cheilanthes sieberi-mixed exotic grass fernland
	Dicranopteris linearis-water fern-*Lycopodiella cernua* fernland
	Lycopodiella cernua fernland
	Kōhūhū-mānuka/bracken fernland
	Cyclosorus fernland
	Whekī fernland
	Bracken fernland
	Whekī/water fern fernland
	Hypolepis ambigua-water fern fernland
Wetland vegetation	(Mānuka)/harakeke-*Cyperus ustulatus* flaxland
	Cyperus ustulatus-raupō sedgeland
	Oioi sedgeland
	Mānuka/*Machaerina rubiginosa*-swamp kiokio-blackberry-*Carex secta* sedgeland
	Carex geminata-Yorkshire fog-(*Carex secta*) sedgeland
	Bracken-*Machaerina rubiginosa*-mixed fern sedgeland
	Lake clubrush/water pepper-*Persicaria decipiens* sedgeland
	Lake clubrush-(*Cyperus involucratus*) sedgeland
	Haraheke/lake clubrush sedgeland
	Machaerina juncea-M. arthrophylla sedgeland
	Carex secta-raupo-lake clubrush-*Hypolepis ambigua-Cyclosorus interruptus* sedgeland
	Raupō reedland
	(Grey willow)-(silver birch)-(tī kōuka)/raupō-blackberry reedland
	(Crack willow)/raupō reedland
	(Tī kōuka)-(mānuka)/raupō-*Cyperus ustulatus*-lake clubrush reedland
	Grey willow/raupō reedland
	Raupō-harakeke reedland ⇔ Carex secta-*Machaerina rubiginosa-M. juncea* sedgeland
	(Mānuka)/raupō-(harakeke) reeedland
	Glossostigma elatinoides and *G. diandrum* herbfield
Mossfield	*Campylopus clavatus* mossfield
	Campylopus sp. mossfield
Exotic forest and treeland	Grey willow forest
	Tasmanian blackwood-mānuka-kānuka-whauwhaupaku-kāmahi-tī kōuka/blackberry-rank exotic grasses forest
	Exotic pine/mingimingi-prostrate kānuka forest
	Exotic pine/prostrate kānuka-mānuka-mingimingi forest
	Grey willow/harakeke-*Cyperus ustulatus* treeland
	Mixed exotic-indigenous trees/Yorkshire fog-*Hypolepis ambigua* treeland
Exotic vineland	Mixed exotic vineland
	Grape vineland
	Japanese honeysuckle-(*Cyperus ustulatus*) vineland
Exotic species-dominant scrub and shrubland	Blackberry scrub
	Silver birch-Chinese privet/blackberry-(prostrate kānuka) scrub
	Chinese privet scrub
	Spanish heath-blackberry-bracken scrub
	Blackberry-bracken scrub
	Arrow bamboo scrub[1]
	Chinese privet-(mānuka)-(prostrate kānuka) scrub
	Exotic pine/blackberry-prostrate kānuka shrubland
	Blackberry (dead) shrubland
	Blackberry-broom/Yorkshire fog shrubland
	Blackberry shrubland
	Blackberry-mingimingi-Nephrolepis flexuosa shrubland
	Chinese privet/*Cyperus ustulatus*-tūrutu shrubland and sedgeland

[1] Mapped as bambooland in 2011.

Geothermal Vegetation/ Habitat Class	Geothermal Vegetation/Habitat Type
	Blackberry-mixed exotic grasses shrubland
	(Crack willow)/blackberry-broom-bracken-rank exotic grasses shrubland
	Blackberry/buffalo grass shrubland
	Blackberry-broom-water fern-bracken shrubland
Exotic grassland	Yorkshire fog grassland
	Prostrate kānuka/Yorkshire fog grassland
	Mercer grass grassland
	Mercer grass-*Cyclosorus interruptus-Hypolepis ambigua* grassland
	Sweet vernal-browntop grassland
	(Mānuka)-(prostrate kānuka)-harakeke/narrow-leaved carpet grass-Yorkshire fog grassland
	Indian doab grassland
	(Prostrate kānuka)/rank exotic grasses grassland
	(*Machaerina arthrophylla*)/mixed exotic grasses-raw soilfield grassland
	Reed sweetgrass-raupō-lake clubrush grassland
	Raupō/reed sweetgrass- lake clubrush-swamp millet grassland
	Paspalum-sweet vernal grassland
	Tall fescue-*Cyperus ustulatus-Carex virgata*-blackberry grassland
	Paspalum-Indian doab grassland
	Mixed exotic grassland
	Planted indigenous and exotic species/exotic grassland
Exotic sedgeland	Soft rush-paspalum sedgeland
	Cyperus involucratus-Cyperus ustulatus sedgeland
Herbfield	*Polygonum maculosa* herbfield
	Mixed exotic species herbfield
Mixed exotic-indigenous species forest	Mixed exotic-indigenous species forest
Mixed exotic-indigenous species scrub	Prostrate kānuka-blackberry-pampas scrub
	Mixed exotic-indigenous species scrub
	Whekī-Montpellier broom-Himalayan honeysuckle scrub
	Black wattle/mānuka-blackberry-bracken scrub
Mixed indigenous-exotic shrubland	(Whekī-kōhūhū-tī kōuka)/whekī-kiokio-blackberry shrubland
	(Maritime pine)/kiokio-blackberry-bracken-buddleia shrubland
	(Whekī-mingimingi)/blackberry-bracken-kiokio shrubland
	Spanish heath-prostrate kānuka shrubland
	(Exotic pine)/prostrate kānuka-exotic species shrubland
	(Wilding pine)/(Chinese privet)/prostrate kānuka-blackberry-water fern-*Hypolepis ambigua*-bracken shrubland
	Blackberry-bracken shrubland
Bare ground	Geothermal sands
	Nonvegetated raw-soilfield
	Nonvegetated raw-soilfield (mining operations)
	Bare ground
	Sinter
Geothermal water	Geothermal water
	Mud pools
	Geothermal springs and stream
	Geothermal springs, mudpools, geothermal stream, and sinter

3.8 Threats/modification/vulnerability

For each site, current threats, modification, and vulnerability were evaluated under four categories:

- Invasive exotic plant species;
- Human threats;
- Grazing;
- Adjoining land use.

Invasive exotic plant species were assessed in terms of their abundance. In field surveys undertaken prior to 2014, a cover class index based on Allen (1992) was used to indicate the relative abundance of weeds at each site (see Table 4). Field assessment of exotic plant species cover in 2014 was recorded as an absolute cover percentage over the entire site.

Table 4: Cover class index (from Allen 1992).

Percentage Cover	Cover Class
<1	1
1-5	2
6-25	3
26-50	4
51-75	5
76-100	6

3.9 Site mapping

This study is based on both field survey and assessment of vegetation cover in aerial photographs. At many sites, particularly large ones, not all units of vegetation and habitats could be viewed in the field. In these instances, the appearance of vegetation and habitat types were inferred or extrapolated based on the appearance of areas that have been visited.

Vegetation type boundaries for each site were digitised onto 2012 aerial photographs (WRAPs) in ArcView (V.9.3) at a scale of 1:5,000 with the following data fields:

- Site Name
- Site Number
- NZTM Eastings and Northings
- Geothermal Field
- Ecological District
- Territorial Local Authority
- Area (ha)
- Ecological Significance Ranking
- Vegetation Code
- Broad Vegetation Class
- Vegetation Description
- Hydroclass
- Structural Class Code
- Broad Class Code
- Ecological Significance Ranking 2003
- Botanical Rank 1996

Definitions of data fields are presented in Appendix 13.

3.9.1 Mapping geothermal wetland habitat

Wetland habitat boundaries have been mapped as accurately as possible given the time limitations, issues with safe access, and difficulties of mapping very small areas. Examples of difficulties that may be encountered when mapping geothermal wetland include:

- Heated wet air (steam) from fumaroles and hot pools can extend for a considerable distance from the surface geothermal activity, making geothermal vegetation and habitats generally difficult to map.

- Heated water flowing over waterfalls produces graduations of habitats affected by water flow, splash, and spray (Johnson and Gerbeaux 2004), and seepages and associated increased air and soil temperatures provide habitat for plant species typical of geothermal activity. These types were too small to map separately.

- The presence of surface geothermal activity can fluctuate at a particular location and across a landscape making access and mapping difficult.

- Access to all parts of a geothermally active area is difficult in some locations, particularly in geothermal wetlands where isolated geothermal seepages and immediate geothermal plants can be surrounded by cold water species (e.g. raupō (*Typha orientalis*) wetland). In this situation the vegetation is mapped as one broad class. Generally the water present will have geothermal derived chemical inputs.

3.9.2 Mapping of nonvegetated raw-soilfield

Occasional scattered vascular and non-vascular plants are included in mapping of nonvegetated raw-soilfield, particularly in areas that appear as bare ground on aerial photographs, and in areas that could not be viewed during the field survey. Small mud pools amongst nonvegetated raw-soilfield have also been mapped as nonvegetated raw-soilfield (large areas with open water and abundant mud pools were mapped as open geothermal water). On this basis, nonvegetated raw-soilfield is included in calculations of the area covered by terrestrial geothermal habitats.

3.10 Historical site changes

In 2011, assessment of historic changes in extent of geothermal vegetation and habitats at the sites included in this report was undertaken by comparing 2007 aerial photographs with aerial photographs held by Waikato Regional Council from 1940-1960. Due to the nature of the historic aerial photographs (differing scales, black and white colour), interpretation of change was subjectively carried out by an ecologist familiar with geothermal vegetation and the individual sites. A literature search was also carried out to provide supplementary information on historic site condition. Where possible, change was quantified using broad percent ranges of hectares lost or gained. This information is summarised within the site information sheets for each site (presented in Appendix 1) and a summary of gross change over the Region is presented in Appendix 5.

3.11 Ecological evaluation

The relative significance of each geothermal site (see Figure 1) was assessed as part of the current study using the criteria specified in Waikato Regional Council Regional Policy Statement (2002). These criteria have recently been updated to reflect more recent changes to the New Zealand Threat Classification Lists (refer to Appendices 11 and 12). Using these criteria, each site was assigned to one of four levels of relative significance: Internationally Significant, Nationally Significant, Regionally Significant, or Locally Significant.

3.12 Data analysis

The extent (in hectares) of each geothermal vegetation type in each site was calculated using GIS. The extent of geothermal vegetation (but not geothermal water) was also calculated for each ecological district, geothermal field, and administrative district (see Tables 7, 10, and 11). The extent of geothermal water and terrestrial and emergent geothermal wetland habitats is provided for each site (Appendix 1).

3.13 Presentation of results

Geothermal Fields

Site information is presented in order of geothermal field, generally following a north to south alignment.

The following information is presented for each geothermal field within the Waikato Region.

1. A list of geothermal sites within the part of the field located in the Waikato Region.

2. A separate site information sheet and map for each geothermal site.
   - Maps include a topographic map showing the location of each geothermal site (scale 1:20,000) and a vegetation map of sites overlain on aerial photographs (vegetation map scales vary from 1:5,000 to 1:10,500 depending on the size of the site).
   - Site information sheets include information on the extent and composition of vegetation and habitat types present, the presence of threatened plant or animal species within a site, threats to the vegetation and habitats at the site, and an assessment of the significance of the site (see Section 3.10 above).

3. A summary of all geothermal sites located within the Waikato Region for which site assessments have been undertaken are listed in Table 6 (see Section 6), ordered by the geothermal field within which they are located. A summary of the total area (ha) of geothermal vegetation at each site and the significance ranking assigned to the site are provided in Table 8 (see Section 6).

4. DEFINING AND DELINEATING GEOTHERMALLY INFLUENCED VEGETATION

> *Geothermally influenced terrestrial and emergent wetland vegetation are plant communities that have compositional, structural, and/or growth rate characteristics determined by current or former inputs of geothermally-derived energy* (*heat*) *or material* (*solid, fluid, or gas*).
>
> Merrett & Clarkson 1999

Compositional, structural, and/or growth rate characteristics of geothermally influenced terrestrial and emergent wetland vegetation include the unexpected presence of species usually found in warmer climates or at lower altitudes or latitudes

(disjunct populations), prostrate or stunted growth forms, and reduced growth rates. Merrett & Clarkson (1999) classified geothermal habitats into four broad categories:

- heated ground.
- geothermal wetlands.
- cooled hydrothermally altered soils.
- atmospheric influence from regular toxic gas emissions, or warm micro-climates created by hot-springs discharge.

In this report, the 'cooled hydrothermally altered soils' and 'heated ground' categories of Merrett and Clarkson (1999) have been included in the category 'nonvegetated raw-soilfield'. Explanations of these categories are provided below.

4.1 Geothermal wetlands

Adapted from Wildland Consultants (2005).

The definition of geothermal wetland for this study follows Clarkson *et al*. (2004) and Johnson and Gerbeaux (2004).

"A wetland hydrosystem where the dominant function is **geothermally heated water.** The RMA91 specifies geothermal waters as those heated by natural phenomena to 30 degrees [C] or above. Geothermal wetlands may have water temperatures below this, but must be considered geothermal due to the chemical composition of the water. Geothermal wetlands are permanently or intermittently wet areas, shallow water, or land water margins that support a natural ecosystem of plants that have compositional, structural, and/or growth rate characteristics determined by current or former inputs of geothermally derived water." (Clarkson *et al*. 2004)

"A hydrosystem where volcanic activity produces hot surface waters, or heated soils (30 °C or more) or where geothermal chemistry affects wetland habitats." (Johnson and Gerbeaux 2004).

Geothermal wetlands provide habitat for threatened fern species such as *Thelypteris confluens* at Waikite and *Cyclosorus interruptus* at Waiotapu South.

4.2 Nonvegetated raw-soilfield

Nonvegetated raw-soilfield includes Merrett and Clarkson's (1999) 'heated ground' and 'cooled hydrothermally altered soils' categories of geothermal habitat.

Nonvegetated raw-soilfield is defined as areas that are bare of vegetation and that are either too hot to support plant life, are cooled by hydrothermally altered sinter pavements, or are subjected to regular mud ejection or gas emission that prevent colonisation and established plants. These areas are often small, and may not be visible on aerial photographs (Merrett and Clarkson 1999)

Heated ground comprises geothermally heated soils that generally have temperatures above 20 °C at 10 cm depth and increasing temperature with depth. Vegetation growing on heated ground comprises terrestrial geothermal vegetation.

Very hot soils are often associated with steam vents and/or boiling mud craters, and soil temperatures at 10 cm depth are usually >90 °C.

Vigorously boiling mud pools and craters that regularly eject hot mud around margins effectively prevent plant colonisation. Where toxic gas is emitted, vegetation is either absent, or if present, killed.

Hydrothermally altered soils often occur where geothermal expression has ceased, e.g. dried mud craters, which result in soils with unusual chemical composition. Cooled hydrothermally altered soils comprise habitats where geothermal heating has ceased, but the chemically altered soils restrict plant colonization and diversity. These habitats include inactive craters and solfataras, old sinter pavements, and dried mud pools.

4.3 Atmospheric influence

Habitats subject to (a) regular toxic gas emissions to the extent that vegetation growth is negatively influenced (e.g. White Island), or (b) a warm micro-climate created by hot-springs discharge (e.g. the fern *Christella* aff. *dentata* ("thermal") occurs along the margins of hot streams where the atmosphere is influenced by steam) (Merrett & Clarkson 1999).

5. ECOLOGICAL CONTEXT

Geothermal vegetation (as defined in Section 4) is naturally rare in New Zealand (Williams *et al*. 2007) and internationally. In New Zealand, four types of geothermal ecosystems (fumaroles, geothermal stream sides, geothermal heated ground, and geothermal hydrothermally altered ground) have been classified as Critically Endangered (Holdaway *et al*. 2012). Approximately 74% (750 ha) of the total extent of New Zealand's geothermal vegetation occurs within the Waikato Region, with the remainder in the Bay of Plenty Region (267 ha) (Fitzgerald and Smale 2010), largely focused around the Rotorua Lakes. This is all within the Taupō Volcanic Zone. Few other examples of geothermal vegetation are known from elsewhere in New Zealand. The Ngāwhā geothermal field in Northland (near Kaikohe) is the only high temperature geothermal field in New Zealand outside of the Taupō Volcanic Zone (Northland Regional Council 2007), but does not contain any geothermal vegetation. Other geothermal features occur in the Hauraki Gulf and in scattered hot springs in the North Island and South Island, but there is little to no associated geothermal vegetation at these sites. There is some geothermal vegetation present on the Kermadec Islands (Sykes 1977).

The varied nature of geothermal surface manifestations, due to varying combinations of temperature (Burns 1997b, Given 1980 & 1989, Wildland Consultants 2012), chemistry, hydrology, and localised protection from frosts, produces rare and unusual habitats for plants. These habitats include plants capable of surviving high soil temperatures, disjunct populations found a considerable distance from other sites of the same species which are usually confined to warmer climates, and local endemic species and distinct genetic forms arising where ground temperatures are sufficiently

stable (Given 1989). Many geothermal sites are dynamic and unstable and changes in surface geothermal activity are reflected in relatively rapid changes in the extent and composition of geothermal vegetation. Species present in geothermal habitats can be divided into three groups:

(i) Relatively common indigenous plant species able to tolerate conditions within geothermal habitats, and which may also occur in neighbouring non-geothermal vegetation. Examples of such species include mānuka (*Leptospermum scoparium*), mingimingi (*Leucopogon fasciculatus*), monoao (*Dracophyllum subulatum*), and tūrutu (*Dianella nigra*).

(ii) Plant species that are relatively uncommon, either at other sites in New Zealand or outside of New Zealand. Geothermal sites mimic aspects of these species' usual habitats (Given 1995) outside of their normal latitudinal and/or altitudinal ranges. These include species that occur in warmer climates outside New Zealand, but within New Zealand only occur at geothermal sites. Examples are the ferns *Nephrolepis flexuosa*, *Dicranopteris linearis*, and *Christella* aff. *dentata* ("thermal"). Other species occur in geothermal areas at higher altitudes than in their normal range, including the ferns *Thelypteris confluens* and *Cyclosorus interruptus*, and the fern allies *Lycopodiella cernua* and *Psilotum nudum.* Many of these species are frost-intolerant and conditions such as steam and heated soils protect them from these cold events.

(iii) Species endemic to New Zealand geothermal habitats. One of the most interesting is the shrub, prostrate kānuka (*Kunzea ericoides* var. *microflora*)[1], which is endemic to New Zealand and only occurs in geothermal habitats. Its form varies in relation to soil temperatures, becoming shorter as soil temperatures increase. Prostrate kānuka has an ectomycorrhizal association with the fungus *Pisolithus* (Moyersoen & Beever 2004).

Vegetation and habitats present at geothermal sites include lichenfield, mossfield, herbfield, fernland, scrub, shrubland, rushland, sedgeland, reedland, forest, wetland, open water, and geothermally-influenced bare ground. The vegetation is highly variable, reflecting soil temperatures, the presence of permanent water and ephemeral wetlands, acidity and other chemical aspects of soil and water, altitude, and the age of the geothermal activity at a particular site. Sites occur over a wide range of altitudes, from sea level to the summits of the central North Island volcanoes. Soil chemistry and temperature (environmental gradients) strongly influence vegetation at geothermal sites (c.f. Given 1980, Burns and Leathwick 1995).

Seventeen nationally 'Threatened' or 'At Risk' vascular plant species (as per de Lange *et al*. 2013) are known from geothermal sites in New Zealand, as listed in Table 5. Fifteen of these occur in geothermal habitats in the Waikato Region, which contains the largest populations of prostrate kānuka in New Zealand, and key populations of six other 'At Risk' species. Some populations are presumed to have become extinct, for example *Cyclosorus interruptus* is thought to have become extinct at three geothermal sites (Upper Wairakei Stream (Geyser Valley), Kathleen Springs, Tokaanu Thermal Park) in the last 40 years, and *Christella* aff. *dentata* ("thermal") is

[1] See Section 3.4 of this report for a discussion of the recent revision of *Kunzea* taxonomy (de Lange 2014).

now presumed extinct at four sites in the Taupo Volcanic Zone for which historic records are available (Te Kiri O Hine Kai Stream Catchment/Wairoa Hill, Kathleen Spring, Tokaanu Thermal Park, and Upper Wairakei Stream Geyser Valley) (Bycroft & Beadel 2007). The cause of extinction at most of these sites is due to changes in the character of the sites where these species occurred; these species require specialised habitat and changes to conditions caused by any factor or a combination of factors, including hydrological processes (including energy development and wetland drainage), pest plant competition and pest animal impacts, vegetation clearance, and other land development can alter the habitat so that it is no longer suitable for *Cyclosorus* or *Christella*. Some extinctions (particularly of very small populations) may be as a result of natural changes in population size, as well as natural changes to the characteristics of surface geothermal features (e.g. extent of geothermal activity and changes in chemical characteristics of the feature) and volcanic eruption.

Table 5: Nationally 'Threatened' and 'At Risk' vascular plant species[1] of geothermal habitats in the Waikato Region[2].

Scientific Name	Threat Ranking
Cyclosorus interruptus+	At Risk-Declining
Nephrolepis flexuosa+	At Risk-Declining
Calochilus paludosus	At Risk-Naturally Uncommon
Calochilus robertsonii+	At Risk-Naturally Uncommon
Christella aff.*dentata* ("thermal")+	At Risk-Naturally Uncommon
Corunastylis pumila	At Risk-Naturally Uncommon
Dicranopteris linearis var. *linearis*+	At Risk-Naturally Uncommon
Fimbristylis velata	At Risk-Naturally Uncommon
Hypolepis dicksonioides+	At Risk-Naturally Uncommon
Korthalsella salicornioides	At Risk-Naturally Uncommon
Kunzea ericoides var. *microflora*+	At Risk-Naturally Uncommon
Petalochilus alatus	At Risk-Naturally Uncommon
Schizaea dichotoma+	At Risk-Naturally Uncommon
Stegostyla atradenia	At Risk-Naturally Uncommon
Thelypteris confluens	At Risk-Naturally Uncommon

+ Key populations of these species are present in the Waikato Region and thus survival of these populations is very important for conservation of the species in New Zealand.

The Waikato Region contains *c.*426.7 ha of prostrate kānuka-dominant vegetation and seven sites with over 20 ha of prostrate kānuka scrub and shrubland. Key populations for seven other threatened species also occur in geothermal areas in the Waikato Region, with large populations of *Schizaea dichotoma* (at Te Kopia), *Dicranopteris linearis* var. *linearis* (Orakeikorako, Te Kopia, Te Kiri O Hine Kai Stream Catchment/Wairoa Hill, and Red Hills), *Cyclosorus interruptus* (Otumuheke and Waikite Valley), *Hypolepis dicksonioides* (Waikite Valley), *Christella* aff. *dentata* ("thermal") (Waipapa Stream, Waikite Valley, Red Hills, and Waihunuhunu), and *Calochilus robertsonii* (Lake Rotokawa and Maungakakaramea (Rainbow Mountain)).

1 As per de Lange *et al.* (2013).

2 Two other species - *Paracaleana minor* (Threatened-Nationally Critical) and *Machaerina complanata* (Threatened-Nationally Vulnerable) - have been recorded in geothermal habitats in the Bay of Plenty and Northland regions, respectively.

6. GEOTHERMAL SITES AND VEGETATION IN THE WAIKATO REGION

Sixty-four sites within fifteen geothermal fields are identified, mapped, and described, and their significance assessed in this report (Table 6). For each site, the vegetation and its condition are described, the significance assessed, and the vegetation types, site boundaries, and location relative to other sites mapped (see Appendix 1). The areas of geothermal habitats/vegetation on the hillslopes above Tokaanu are mapped and described in this report. This is based on earlier information and inspection of the 2012 aerial photographs, as survey and mapping of this area has not been undertaken recently as landowner pemission to access the site has been withheld, however this location is likely to contain other areas of geothermal habitat. While areas omitted or changes to mapped areas are likely to be relatively small, field survey should be a high priority if access can be arranged.

Table 6: List of geothermal sites in the Waikato Region.

Geothermal Field	Site Name
Horohoro	Horohoro
Waikite	Waikite Valley (including Upper Paeroa Scarp) Northern Paeroa Range
Waiotapu	Maungaongaonga Ngapouri Waiotapu North Maungakakaramea (Rainbow Mountain) Waiotapu South
Mokai	Whakamaru Waipapa Stream Tirohanga Road Paerata Road
Atiamuri	Upper Atiamuri West Whangapoa Springs Matapan Road
Te Kopia	Te Kopia Murphy's Springs Western Te Kopia[1] Mangamingi Station
Orakeikorako	Waihunuhunu Akatarewa Stream Orakeikorako Red Hills Akatarewa East
Ngatamariki	Waikato River Springs Orakonui[2]
Whangairorohea	Whangairorohea
Reporoa	Longview Road Wharepapa Road Golden Springs
Ohaaki	Ohaaki Steamfield West Ohaaki Steamfield East

[1] Includes the sites mapped and described as Te Kopia Northwest, Te Kopia West Mud Pools, and Te Kopia Red Stream in Wildland Consultants (2012).

[2] Referred to in previous reports as Ngatamariki.

Geothermal Field	Site Name
Wairakei-Tauhara	Otumuheke Stream
	Spa Thermal Park
	Broadlands Road
	Crown Park
	Crown Road
	Waipahihi Valley
	Mountain Road
	Kathleen Springs
	Te Rautehuia
	Te Rautehuia Stream
	Upper Wairakei Stream (Geyser Valley)
	Wairakei Borefield
	Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
	Lower Wairakei Stream
	Karapiti Forest
	Hall of Fame Stream
	Waipouwerawera Stream/Tukairangi
	Craters of the Moon
Rotokawa	Rotokawa North
	Lake Rotokawa
Tokaanu-Waihi-Hipaua	Hipaua
	Tokaanu Lake Shore Wetland
	Maunganamu West
	Tokaanu Thermal Park
	Tokaanu Urupā Mud Pools
	Maunganamu East
	Maunganamu North Wetland
	Tokaanu Tailrace Canal
Tongariro	Te Maari Craters
	Ketetahi
	Emerald Lakes
	Red Crater

These sixty-four sites contain *c.*863 ha of geothermal habitat, which comprises *c.*750 ha of geothermal vegetation (including nonvegetated raw-soilfield) and *c.*113 ha of geothermal water. Broad groupings of geothermal vegetation and habitats within the Waikato Region include nonvegetated raw-soilfield (*c.*90 ha), emergent wetland vegetation (*c.*86 ha), and terrestrial vegetation (*c.*575 ha) (see Table 7). Terrestrial vegetation includes all vegetation that was not mapped as geothermal wetland and nonvegetated raw-soilfield; this category includes (but is not limited to) forest, scrub, shrubland, fernland, and mossfield.

Each of the 64 sites meets one or more of the criteria for ecological significance in the Waikato Regional Policy Statement (refer to Appendix 10). Four entire sites, and part of one other site encompassing *c.*214 ha or 25% of geothermal habitat in the Waikato Region (see Table 8), were identified as being of International significance. Ten entire sites, and part of two other sites encompassing *c.*386 ha or 45% of geothermal habitat in the Waikato Region, were identified as being of National significance. Twenty-two entire sites, and part of three other sites encompassing *c.*245 ha or 29% of geothermal habitat in the Waikato Region, were identified as being of Regional significance. The remainder of the sites (23 entire sites, and parts of six other sites encompassing *c.*18 ha, or *c.*2% of geothermal habitat in the Waikato Region) were identified as being of Local significance. Parts of one site (Waiotapu South) were identified as being of International, Regional, and Local significance.

Table 7: Area (ha) of each habitat type within geothermal sites in the Waikato Region. Geothermal fields are also ranked by the area of geothermal vegetation present within the Waikato Region.

Site Name	Site Number	Ecological District	Geothermal Habitats					Total Site Area[1]	Ranking (Size Rank by Geothermal Field)
			Geothermal Water	Geothermal Vegetation					
				Terrestrial Vegetation	Nonvegetated raw-soilfield	Emergent Wetland	Total		
Horohoro Geothermal Field									
Horohoro	HHV01	Atiamuri	<0.1	<0.1			<0.1	<0.1	14=
		Total	**<0.1**	**<0.1**			**<0.1**	**<0.1**	
Waikite Geothermal Field									
Waikite Valley	WAV01	Atiamuri	0.8	10.6	0.6	8.7	19.9	20.7	8
Northern Paeroa Range	WAV02	Atiamuri			0.3		0.3	0.3	
		Total	**0.8**	**10.6**	**0.9**	**8.7**	**20.2**	**21.0**	
Waiotapu Geothermal Field									
Maungaongaonga	WTV01	Atiamuri	0.1	8.3	0.4		8.7	8.7	1
Ngapouri	WTV02	Atiamuri	1.1	6.4	0.1		6.5	7.6	
Waiotapu North	WTV03	Atiamuri	3.1	41.5	1.3		42.8	45.9	
Maungakakaramea (Rainbow Mountain)	WTV04	Atiamuri/ Rotorua Lakes	3.5	48.6	3.0		51.6	55.1	
Waiotapu South	WTV05	Atiamuri	21.0	76.7	8.4	26.4	111.5	132.5	
		Total	**28.7**	**181.5**	**13.2**	**26.4**	**221.1**	**249.8**	
Mokai Geothermal Field									
Whakamaru	MKV01	Atiamuri			<0.1		<0.1	<0.1	11
Waipapa Stream	MKV02	Atiamuri		1.2			1.2	1.2	
Tirohanga Road	MKV03	Atiamuri	0.3	0.1	0.1		0.2	0.5	
Paerata Road	MKV04	Atiamuri	0.2	1.3	0.4		1.7	1.8	
		Total	**0.5**	**2.6**	**0.5**		**3.1**	**3.6**	
Atiamuri Geothermal Field									
Upper Atiamuri West	ATV01	Atiamuri		<0.1			<0.1	<0.1	13
Whangapoa Springs	ATV02	Atiamuri	<0.1	0.1	<0.1		0.1	0.1	
Matapan Road	ATV03	Atiamuri		<0.1			<0.1	<0.1	
		Total	**<0.1**	**<0.1**	**<0.1**		**0.1**	**0.1**	
Te Kopia Geothermal Field									
Te Kopia	TKV01	Atiamuri	0.8	53.6	4.6	6.1	64.3	65.1	4
Murphy's Springs	TKV02	Atiamuri		0.2			0.2	0.2	
Western Te Kopia	TKV03	Atiamuri		0.3			0.3	0.3	
Mangamingi Station	TKV06	Atiamuri		0.4	0.1		0.5	0.5	
		Total	**0.8**	**54.5**	**4.7**	**6.1**	**65.3**	**66.1**	

[1] Includes geothermal vegetation and geothermal water.

Site Name	Site Number	Ecological District	Geothermal Habitats					Total Site Area[1]	Ranking (Size Rank by Geothermal Field)
			Geothermal Water	Geothermal Vegetation					
				Terrestrial Vegetation	Nonvegetated raw-soilfield	Emergent Wetland	Total		
Orakeikorako Geothermal Field									
Waihunuhunu	OKV01	Atiamuri	2.6	0.4		2.4	2.8	5.4	5
Akatarewa Stream	OKV02	Atiamuri	<0.1	1.4			1.4	1.4	
Orakeikorako	OKV03	Atiamuri	<0.1	44.7	2.1	0.1	46.8	46.8	
Red Hills	OKV04	Atiamuri	0.2	12.8	0.3		13.1	13.3	
Akatarewa East	OKV05	Atiamuri		0.1	<0.1		0.1	0.1	
		Total	**2.8**	**59.3**	**2.4**	**2.5**	**64.1**	**66.9**	
Ngatamariki Geothermal Field									
Waikato River Springs	NMV01	Atiamuri	0.2		<0.1	0.4	0.4	0.6	12
Orakonui	NMV02	Atiamuri	0.1	0.5	0.3	<0.1	0.9	1.0	
		Total	**0.3**	**0.5**	**0.3**	**0.4**	**1.3**	**1.6**	
Whangairorohea Geothermal Field									
Whangairorohea	WGV01	Atiamuri	<0.1	<0.1			<0.1	<0.1	14=
		Total	**<0.1**	**<0.1**			**<0.1**	**<0.1**	
Reporoa Geothermal Field									
Longview Road	RPV01	Atiamuri	0.3	4.6	1.3		5.9	6.2	10
Wharepapa Road	RPV02	Atiamuri	0.2	2.3	1.1		3.4	3.6	
Golden Springs	RPV03	Atiamuri	0.1	0.3		0.4	0.7	0.8	
		Total	**0.6**	**7.1**	**2.5**	**0.4**	**10.0**	**10.6**	
Ohaaki Geothermal Field									
Ohaaki Steamfield West	OHV01	Atiamuri	0.1	9.2	2.4		11.6	11.7	9
Ohaaki Steamfield East	OHV02	Atiamuri		4.3	2.2		6.4	6.4	
		Total	**0.1**	**13.5**	**4.6**		**18.0**	**18.1**	
Wairakei-Tauhara Geothermal Field									
Otumuheke Stream	THV01	Atiamuri	<0.1	1.4	0.2	0.7	2.3	2.3	2
Spa Thermal Park	THV03	Atiamuri		1.3	0.1		1.4	1.4	
Broadlands Road	THV04	Atiamuri	0.1	25.5	4.6		30.1	30.2	
Crown Park	THV05	Taupō		0.7	0.2		0.9	0.9	
Crown Road	THV06	Taupō/Atiamuri		17.1	3.3		20.4	20.4	
Waipahihi Valley	THV07	Taupō	0.1	0.2		<0.1	0.3	0.4	
Mountain Road	THV08	Taupō		<0.1	0.1		0.1	0.1	
Kathleen Springs	THV09	Taupō		0.1			0.1	0.1	
Te Rautehuia	WKV01	Atiamuri		7.2	0.6		7.8	7.8	
Te Rautehuia Stream	WKV02	Atiamuri		1.5	0.4		1.9	1.9	
Upper Wairakei Stream (Geyser Valley)	WKV03	Atiamuri		4.8	0.1		4.9	4.9	
Wairakei Borefield	WKV04	Atiamuri		<0.1			<0.1	<0.1	

Site Name	Site Number	Ecological District	Geothermal Habitats					Total Site Area[1]	Ranking (Size Rank by Geothermal Field)
			Geothermal Water	Geothermal Vegetation					
				Terrestrial Vegetation	Nonvegetated raw-soilfield	Emergent Wetland	Total		
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill	WKV05	Atiamuri	0.1	33.7	1.8		35.6	35.7	
Lower Wairakei Stream	WKV06	Atiamuri	0.1	0.1			0.1	0.2	
Karapiti Forest	WKV07	Atiamuri		0.4			0.4	0.4	
Hall of Fame Stream	WKV08	Atiamuri	0.1	0.3			0.3	0.4	
Waipouwerawera Stream/Tukairangi	WKV09	Atiamuri		0.1	<0.1		0.1	0.1	
Craters of the Moon	WKV10	Atiamuri		36.9	1.2		38.1	38.1	
		Total	**0.5**	**131.5**	**12.5**	**0.7**	**144.7**	**145.2**	
Rotokawa Geothermal Field									
Rotokawa North	RKV01	Atiamuri	0.6	37.3	2.7	0.1	40.1	40.7	3
Lake Rotokawa	RKV02	Atiamuri	70.8	58.1	16.6		74.7	145.4	
		Total	**71.4**	**94.1**	**20.6**	**0.1**	**114.8**	**186.1**	
Tokaanu-Waihi-Hipaua Geothermal Field									
Hipaua	TOV02	Tongariro		11.7	0.4		12.1	12.1	6
Tokaanu Lake Shore Wetland	TOV05	Taupō/ Tongariro	4.6			37.7	37.7	42.3	
Maunganamu West	TOV07	Taupō/ Tongariro				0.6	0.6	0.6	
Tokaanu Thermal Park	TOV08	Tongariro	0.2	6.4	0.1	0.7	7.2	7.5	
Tokaanu Urupā Mud Pools	TOV09	Taupō		<0.1			<0.1	<0.1	
Maunganamu East	TOV10	Taupō				<0.1	<0.1	<0.1	
Maunganamu North Wetland	TOV11	Taupō				1.4	1.4	1.4	
Tokaanu Tailrace Canal	TOV14	Tongariro				<0.1	<0.1	<0.1	
		Total	**4.8**	**18.2**	**0.5**	**40.4**	**59.2**	**64.0**	
Tongariro Geothermal Field									
Te Maari Craters	TGV01	Tongariro	1.1		8.4		8.4	9.5	7
Ketetahi	TGV02	Tongariro			8.2		8.2	8.2	
Emerald Lakes	TGV03	Tongariro	0.9		11.2		11.2	12.1	
Red Crater	TGV04	Tongariro			0.8		0.8	0.8	
		Total	**2.0**		**28.6**		**28.6**	**30.6**	
Grand Total			**113.4**	**574.7**	**89.8**	**85.8**	**750.3**	**863.7**	

Table 8: Area (ha) of geothermal sites of International, National, Regional, and Local significance in the Waikato Region.

Site Name (Site Number)	Ecological District	Ecological Significance Ranking (ha)			
		International	National	Regional	Local
Horohoro Geothermal Field					
Horohoro (HHV01)	Atiamuri				<0.1
	Total				**<0.1**
Waikite Geothermal Field					
Waikite Valley (WAV01)	Atiamuri		20.7		
Northern Paeroa Range (WAV02)	Atiamuri				0.3
	Total		**20.7**		**0.3**
Waiotapu Geothermal Field					
Maungaongaonga (WTV01)	Atiamuri		8.7		
Ngapouri (WTV02)	Atiamuri				7.6
Waiotapu North (WTV03)	Atiamuri			45.9	
Maungakakaramea (Rainbow Mountain) (WTV04)	Atiamuri/Rotorua Lakes		55.1		
Waiotapu South (WTV05)	Atiamuri	126.8		5.2	0.4
	Total	**126.8**	**63.8**	**51.1**	**8.0**
Mokai Geothermal Field					
Whakamaru (MKV01)	Atiamuri				<0.1
Waipapa Stream (MKV02)	Atiamuri		0.9		0.3
Tirohanga Road (MKV03)	Atiamuri				0.5
Paerata Road (MKV04)	Atiamuri				1.8
	Total		**0.9**		**2.6**
Atiamuri Geothermal Field					
Upper Atiamuri West (ATV01)	Atiamuri				<0.1
Whangapoa Springs (ATV02)	Atiamuri			0.1	
Matapan Road (ATV03)	Atiamuri				<0.1
	Total			**0.1**	**<0.1**
Te Kopia Geothermal Field					
Te Kopia (TKV01)	Atiamuri	65.1			
Murphy's Springs (TKV02)	Atiamuri			0.2	
Western Te Kopia (TKV03)	Atiamuri				0.3
Mangamingi Station (TKV06)	Atiamuri				0.5
	Total	**65.1**		**0.2**	**0.8**
Orakeikorako Geothermal Field					
Waihunuhunu (OKV01)	Atiamuri		5.4		
Akatarewa Stream (OKV02)	Atiamuri			1.4	
Orakeikorako (OKV03)	Atiamuri		46.8		
Red Hills (OKV04)	Atiamuri		13.3		
Akatarewa East (OKV05)	Atiamuri				0.1
	Total		**65.5**	**1.4**	**0.1**
Ngatamariki Geothermal Field					
Waikato River Springs (NMV01)	Atiamuri			0.6	
Orakonui (NMV02)	Atiamuri			1.0	
	Total			**1.6**	
Whangairorohea Geothermal Field					
Whangairorohea (WGV01)	Atiamuri				0.1
	Total				**0.1**

Site Name (Site Number)	Ecological District	Ecological Significance Ranking (ha)			
		International	National	Regional	Local
Reporoa Geothermal Field					
Longview Road (RPV01)	Atiamuri			6.2	
Wharepapa Road (RPV02)	Atiamuri			3.3	0.3
Golden Springs (RPV03)	Atiamuri			0.5	0.3
	Total			**10.0**	**0.6**
Ohaaki Geothermal Field					
Ohaaki Steamfield West (OHV01)	Atiamuri			11.7	
Ohaaki Steamfield East (OHV02)	Atiamuri			6.4	
	Total			**18.1**	
Wairakei-Tauhara Geothermal Field					
Otumuheke Stream (THV01)	Atiamuri		1.9		0.4
Spa Thermal Park (THV03)	Atiamuri				1.4
Broadlands Road (THV04)	Atiamuri			30.1	
Crown Park (THV05)	Taupō				0.9
Crown Road (THV06)	Taupō/ Atiamuri			20.4	
Waipahihi Valley (THV07)	Taupō			0.4	
Mountain Road (THV08)	Taupō				0.1
Kathleen Springs (THV09)	Taupō				0.1
Te Rautehuia (WKV01)	Atiamuri			7.8	
Te Rautehuia Stream (WKV02)	Atiamuri			1.9	
Upper Wairakei Stream (Geyser Valley) (WKV03)	Atiamuri			4.9	
Wairakei Borefield (WKV04)	Atiamuri				<0.1
Te Kiri O Hine Kai Stream Catchment/ Wairoa Hill (WKV05)	Atiamuri			35.7	
Lower Wairakei Stream (WKV06)	Atiamuri			0.2	
Karapiti Forest (WKV07)	Atiamuri				0.4
Hall of Fame Stream (WKV08)	Atiamuri			0.4	
Waipouwerawera Stream/Tukairangi (WKV09)	Atiamuri				0.1
Craters of the Moon (WKV10)	Atiamuri		38.1		
	Total		**40.0**	**101.8**	**3.4**
Rotokawa Geothermal Field					
Rotokawa North (RKV01)	Atiamuri			40.7	
Lake Rotokawa (RKV02)	Atiamuri		145.4		
	Total		**145.4**	**40.7**	
Tokaanu-Waihi-Hipaua Geothermal Field					
Hipaua (TOV02)	Tongariro			12.1	
Tokaanu Lake Shore Wetland (TOV05)	Taupō/ Tongariro		42.3		
Maunganamu West (TOV07)	Taupō/ Tongariro			0.6	
Tokaanu Thermal Park (TOV08)	Tongariro/ Taupō			7.5	<0.1
Tokaanu Urupā Mud Pools (TOV09)	Tongariro			<0.1	
Maunganamu East (TOV10)	Taupō				<0.1

Site Name (Site Number)	Ecological District	Ecological Significance Ranking (ha)			
		International	National	Regional	Local
Maunganamu North Wetland (TOV11)	Taupō				1.4
Tokaanu Tailrace Canal (TOV14)	Tongariro/ Taupō				<0.1
	Total		**42.3**	**20.2**	**1.4**
Tongariro Geothermal Field					
Te Maari Craters (TGV01)	Tongariro	9.5			
Ketetahi (TGV02)	Tongariro		8.2		
Emerald Lakes (TGV03)	Tongariro	12.1			
Red Crater (TGV04)	Tongariro	0.8			
	Total	**22.4**	**8.2**		
Grand Total		**214.4**	**386.0**	**245.1**	**17.5**

The significance ranking has not changed for any sites assessed in previous versions of this report (Wildland Consultants 2004c, 2007, and 2012). Two new sites (Mountain Road and Kathleen Springs) have been described in this report; both of these sites have been ranked as of Local significance. These sites do not represent new areas of geothermal activity, but geothermal vegetation and habitats previously not known to occur at these sites.

6.1 Changes in geothermal site extent since 2012

There has been a net gain (*c.*16 ha or 2%) in mapped area of geothermal vegetation (including nonvegetated raw-soilfield) across all sites in the Waikato Region between 2012 and 2014 (Table 9). A total of *c.*750 ha of geothermal vegetation was mapped in the Waikato Region in 2014 compared with *c.*734 ha of geothermal vegetation mapped in Wildland Consultants (2012). Part of the change in the mapped extent of geothermal vegetation was due to an improvement in the quality of aerial photographs between 2007 and 2012, which allowed a more accurate delineation of geothermal vegetation boundaries. The change in extent of geothermal vegetation as a result of more accurate vegetation mapping, and a better understanding of where geothermal features are present at sites, was <1 ha at each of 22 sites, 1-5 ha at six sites, and >5 ha at two sites.

Table 9: Changes in the area (ha) of geothermal vegetation mapped at each site between 2012 and 2014 based on assessment of 2007 and 2012 aerial photographs. Reasons for any change are noted in the comments column. Other changes observed at these sites since 2011 are also noted.

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
Horohoro Geothermal Field							
Horohoro	HHV01	Atiamuri	19 February 2014	<0.1	<0.1	No real change	This site has not changed noticeably since 2004.
		Total		**<0.1**	**<0.1**		
Waikite Geothermal Field							
Waikite Valley	WAV01	Atiamuri	23 July 2014	24.6	19.9	Unlikely	Some areas included as geothermal vegetation in previous reports did not comprise geothermal or geothermally influenced vegetation. These areas were removed from the site in 2014.
Northern Paeroa Range	WAV02	Atiamuri	29 and 30 June 2010	0.3	0.3	No real change	No field assessment in 2014. Inspection of 2012 aerial photographs does not indicate any change since 2010.
		Total		**24.9**	**20.2**		
Waiotapu Geothermal Field							
Maungaongaonga	WTV01	Atiamuri	7 and 16 May 2014	9.1	8.7	No real change	Changes to vegetation extent are as a result of higher resolution aerial photographs being available in 2014.
Ngapouri	WTV02	Atiamuri	7 May and 24 July 2014	3.1	6.5	No real change	The increase in vegetation extent at this site is not the result of new geothermal activity within this site. The increased area is as a result of geothermal areas previously not known to the authors being added to the site as a result of new information.
Waiotapu North	WTV03	Atiamuri	26-29 July 2011	45.8	42.8	No real change	Change relates to vegetation and site boundaries being better defined on better quality 2014 aerial photographs. The authors do not consider that the extent of geothermal vegetation has decreased at this site between the 2011 and 2014 studies.

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
Maungakakaramea (Rainbow Mountain)	WTV04	Atiamuri/ Rotorua Lakes	26 July 2010	50.6	51.6	No real change	No field assessment in 2014. Change related to boundaries being better defined on better quality 2012 aerial photographs. The authors do not consider that the extent of geothermal vegetation has increased at this site between the 2011 and 2014 studies.
Waiotapu South	WTV05	Atiamuri	9 December 2010, 10 July 2011	112.4	111.5	No real change	No field assessment in 2014. Change related to boundaries being better defined on better quality 2012 aerial photographs. The authors of this report do not consider that the overall extent of vegetation at this site has increased between the 2011 and 2014 studies.
		Total		**221.0**	**221.1**		
Mokai Geothermal Field							
Whakamaru	MKV01	Atiamuri	17 February 2008	<0.1	<0.1	Unlikely	No field assessment in 2014. Significant change unlikely.
Waipapa Stream	MKV02	Atiamuri	30 March 2011	1.1	1.2	Unlikely	No field assessment in 2014. Change related to boundaries being better defined on better quality 2012 aerial photographs. The authors of this report do not consider that the overall extent of vegetation at this site has increased between the 2011 and 2014 studies.
Tirohanga Road	MKV03	Atiamuri	2 March 2011	0.2	0.2	Unlikely	No field assessment in 2014. Significant change unlikely.
Paerata Road	MKV04	Atiamuri	2 March 2011	1.7	1.7	Unlikely	No field assessment in 2014. Significant change unlikely.
		Total		**2.9**	**3.1**		
Atiamuri Geothermal Field							
Upper Atiamuri West	ATV01	Atiamuri	5 February 2007	<0.1	<0.1	Unlikely	No field assessment in 2014. No change likely.
Whangapoa Springs	ATV02	Atiamuri	2 February 2011	0.1	0.1	Unlikely	No field assessment in 2014. No change likely.
Matapan Road	ATV03	Atiamuri	2 February 2011	<0.1	<0.1	Unlikely	Not previously included in study. Significant change unlikely.
		Total		**0.1**	**0.1**		

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
Te Kopia Geothermal Field							
Te Kopia	TKV01	Atiamuri	9 and 16 May 2014	58.8	64.3	No real change	The increase in area of this site is not the result of new geothermal manifestations at this site. Rather change is as a result of vegetation boundaries being clearer on better quality aerial photographs and additional areas being identified through inspection of 2012 aerial photographs.
Murphy's Springs	TKV02	Atiamuri	29 June 2010	0.2	0.2	Unlikely	No field assessment in 2014. No change likely.
Western Te Kopia	TKV	Atiamuri	29 June 2010	0.2	0.3	Unlikely	No field assessment in 2014. No change likely.
Mangamingi Station	TKV06	Atiamuri	28 June 2010	0.5	0.5	Unlikely	No field assessment in 2014. No change likely.
		Total		**59.8**	**65.3**		
Orakeikorako Geothermal Field							
Waihunuhunu	OKV01	Atiamuri	18 February 2014	3.0	2.8	No real change	Slight reduction in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Akatarewa Stream	OKV02	Atiamuri	13 February 2014	1.4	1.4	No real change	No change in extent of geothermal vegetation noted during 2014 field survey.
Orakeikorako	OKV03	Atiamuri	1 August 2010 (east side of Lake Ohakuri), 2 February 2011 (west side of Lake Ohakuri), 13 February 2014 (new part)	42.4	46.8	No real change	Additional areas added to the site based on new information. The new areas are not the result of new geothermal manifestations but rather represent existing areas that have not previously been mapped.
Red Hills	OKV04	Atiamuri	18 February 2014	11.4	13.1	No real change	Slight increase in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Akatarewa East	OKV05	Atiamuri	3 February 2011	<0.1	0.1	Unlikely	No field assessment in 2014. No change likely.
		Total		**58.2**	**64.1**		
Ngatamariki Geothermal Field							
Waikato River Springs	NMV01	Atiamuri	2-3 February 2011	0.4	0.4	No real change	No field assessment in 2014. No change likely.

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
Orakonui	NMV02	Atiamuri	2 February 2011	1.5	0.9	No real change	The decrease in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
		Total		**1.9**	**1.3**		
Whangairorohea Geothermal Field							
Whangairorohea	WGV01	Atiamuri	13 February 2014	<0.1	<0.1	No real change	No change.
		Total		**<0.1**	**<0.1**		
Reporoa Geothermal Field							
Longview Road	RPV01	Atiamuri	23 January 2014	3.4	5.9	No real change	Additional areas added to the site based on identification as a result of better quality aerial photographs. The new areas are not the result of new geothermal manifestations but rather represent existing areas that have not previously been mapped.
Wharepapa Road	RPV02	Atiamuri	30 July 2010	3.3	3.4	Unlikely	No field assessment in 2014. Slight increase in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Golden Springs	RPV03	Atiamuri	14 May 2007	0.5	0.7	No real change	Additional areas added to the site based on new information. The new areas are not the result of new geothermal manifestations but rather represent existing areas that have not previously been mapped.
		Total		**7.4**	**10.0**		
Ohaaki Geothermal Field							
Ohaaki Steamfield West	OHV01	Atiamuri	28 January 2011	11.7	11.6	No real change	The slight decrease in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Ohaaki Steamfield East	OHV02	Atiamuri	28 January 2011	6.8	6.4	Decrease	Inspection of aerial photographs in 2014 indicates that some geothermal vegetation has been destroyed since the 2007 aerial photographs were flown.
		Total		**18.5**	**18.0**		
Wairakei-Tauhara Geothermal Field							
Otumuheke Stream	THV01	Atiamuri	10 December 2010	2.3	2.3	No real change	No change in the extent of geothermal vegetation at this site.
Spa Thermal Park	THV03	Atiamuri	17 July 2014	0.1	1.4	No real change	Additional areas added to the site based on

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
							new information. The new areas are not the result of new geothermal manifestations but rather represent existing areas that have not previously been mapped.
Broadlands Road	THV04	Atiamuri	3 March 2011	29.8	30.1	Slight decrease	Slight change in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014. Two very small areas of geothermal vegetation appear (in 2012 aerial photographs) to have been cleared.
Crown Park	THV05	Taupō	16 July 2014	0.7	0.9	No real change	One small area has been added to the site as a result of being visible on better quality aerial photographs in 2014. Additionally, a small area of vegetation has been cleared. Overall extent of geothermal vegetation is probably stable.
Crown Road	THV06	Taupō	3 March 2011	17.5	20.4	No real change	Minor changes to vegetation boundaries as a result of better quality aerial photographs in 2014.
Waipahihi Valley	THV07	Taupō	16 July 2014	0.3	0.3	No real change	Minor changes to vegetation boundaries as a result of better quality aerial photographs in 2014.
Mountain Road	THV08	Taupō	16 July 2014	N/A	0.1	Unlikely	Not assessed in previous versions of this report. Significant change unlikely.
Kathleen Springs	THV09	Taupō	17 July 2014	N/A	0.1	Unlikely	Not assessed in previous versions of this report. Significant change unlikely.
Te Rautehuia	WKV01	Atiamuri	27 January 2011	7.7	7.8	No real change	Minor changes vegetation boundaries as a result of better quality aerial photographs in 2014.
Te Rautehuia Stream	WKV02	Atiamuri	27 January 2011	2.1	1.9	No real change	Minor changes vegetation boundaries as a result of better quality aerial photographs in 2014.
Upper Wairakei Stream (Geyser Valley)	WKV03	Atiamuri	31 January 2014	4.7	4.9	No real change	Minor changes vegetation boundaries as a result of better quality aerial photographs in 2014.
Wairakei Borefield	WKV04	Atiamuri	11 February 2014	<0.1	<0.1	Increase	Very small site. Geothermal vegetation extent has increased by approximately 45 m^2 since the 2007 field survey.

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
Te Kiri O Hine Kai Stream Catchment/ Wairoa Hill	WKV05	Atiamuri	11 February 2014	40.1	35.6	No real change	The decrease in vegetation extent at this site is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Lower Wairakei Stream	WKV06	Atiamuri	11 February 2014	<0.1	0.1	No real change	Minor changes vegetation boundaries as a result of better quality aerial photographs in 2014.
Karapiti Forest	WKV07	Atiamuri	31 January 2014	0.6	0.4	No real change	Slight change in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Hall of Fame Stream	WKV08	Atiamuri	16 July 2014	0.1	0.3	No real change	Most change within this site is a result of improved vegetation boundary mapping as a result of better quality aerial photographs in 2014. A new small area of springs alongside the Waikato River was added to the site in 2014 but is not the result of new geothermal manifestations but probably represents an existing spring that had not previously been mapped.
Waipouwerawera Stream/Tukairangi	WKV09	Atiamuri	3 March 2011	0.1	0.1	No real change	No field assessment in 2014. No change likely.
Craters of the Moon	WKV10	Atiamuri	31 January 2014	44.6	38.1	No real change	The decrease in vegetation extent at this site is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
		Total		**150.7**	**144.7**		
Rotokawa Geothermal Field							
Rotokawa North	RKV01	Atiamuri	13 May 2014	34.3	40.1	No real change	Additional areas added to the site based on new information. The new areas are not the result of new geothermal manifestations but rather represent existing areas that have not previously been mapped.
Lake Rotokawa	RKV02	Atiamuri	15 July 2014	69.4	74.7	No real change	The increase in vegetation extent at this site is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
		Total		**103.7**	**114.8**		

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
Tokaanu-Waihi-Hipaua Geothermal Field							
Hipaua	TOV02	Tongariro	No survey. Observed from main road on 19 October 1999	11.3	12.1	No real change	No field assessment in 2014. Minor changes vegetation boundaries as a result of better quality aerial photographs in 2014.
Tokaanu Lake Shore Wetland	TOV05	Tongariro/ Taupō	13 February 2007	39.1	37.7	No real change	No field assessment in 2014. Minor changes vegetation boundaries as a result of better quality aerial photographs in 2014.
Maunganamu West	TOV07	Tongariro/ Taupō	13 February 2007	0.6	0.6	Unlikely	No field assessment in 2014. No change likely.
Tokaanu Thermal Park	TOV08	Tongariro	23 August 2004 (partly updated in February 2007)	7.6	7.2	No real change	Slight change in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Tokaanu Urupā Mud Pools	TOV09	Taupō	7 February 2007	<0.1	<0.1	Unlikely	No field assessment in 2014. No change likely.
Maunganamu East	TOV10	Taupō	7 February 2007	<0.1	<0.1	Unlikely	No field assessment in 2014. No change likely.
Maunganamu North Wetland	TOV11	Taupō	February 2007	0.9	1.4	No real change	Slight change in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
Tokaanu Tailrace Canal	TOV14	Tongariro	7 February 2007	<0.1	<0.1	Unlikely	No field assessment in 2014. No change likely.
		Total		**59.5**	**59.2**		
Tongariro Geothermal Field							
Te Maari Craters	TGV01	Tongariro	14 June 2011	4.9	8.4	Increase	No field assessment in 2014. The 2012 eruptions from these craters appears to have resulted in a significant increase in geothermal habitat within this site.
Ketetahi	TGV02	Tongariro	No field survey undertaken. Mapping is based on aerial photograph and descriptions in Given (1995 & 1996).	8.2	8.2	Unlikely	No field assessment in 2014. No change likely.
Emerald Lakes	TGV03	Tongariro	14 June 2011	11.3	11.2	Unlikely	Slight change in vegetation extent is as a

Site Name	Site Number	Ecological District	Date of Field Survey	Area of Mapped Geothermal Vegetation (ha)		Overall Real Change	Comments
				2011	2014		
							result of more accurate mapping enabled by better quality aerial photographs in 2014.
Red Crater	TGV04	Tongariro	14 June 2011	0.7	0.8	Unlikely	Slight change in vegetation extent is as a result of more accurate mapping enabled by better quality aerial photographs in 2014.
		Total		**25.1**	**28.6**		
Grand Total				**733.6**	**750.3**		

The mapped extent of nine sites increased as a result of field survey (new parts of the site were found that were not previously known to the authors; none of these areas were new geothermal surface manifestations). Examples of such sites include Rotokawa North, Orakeikorako, and Te Kopia. A 'decrease' in the mapped extent of geothermal vegetation (*c.*4.7 ha) at Waikite Valley is as a result of inaccurate mapping of the geothermal wetland vegetation during the field survey in 2011.

There was a real increase in extent of geothermal habitat at one site (Te Maari Craters) and a slight increase at another (Wairakei Borefield). There was a real decrease in the extent of geothermal vegetation at two sites (Broadlands Road and Ohaaki Steamfield East). Detailed notes on changes at each site are presented in the site information sheets located within (Appendix 1).

Horohoro Geothermal Field

This field has <0.1 ha of geothermal vegetation, surrounding hot springs. The geothermal features (an overflowing pool and a seepage) are mapped as one site - Horohoro (HHV01). The site is currently surrounded by pasture, and values could be enhanced if the site were fenced to exclude stock. Species typical of geothermal habitat recorded in 2014 were *Lycopodiella cernua* and *Gleichenia microphylla*. *Nephrolepis flexuosa* (At Risk-Declining; de Lange *et al.* 2013) has been recorded from this site in the past (Given 1995), but is presumed extinct at this site (Bycroft and Beadel 2007). The Horohoro Geothermal Field is classified as a 'Development Geothermal System' by Waikato Regional Council[1].

Waikite Geothermal Field

The geothermal features of this field are mapped within two sites: Waikite Valley (WAV01) and Northern Paeroa Range (WAV02). The Northern Paeroa Range site was included for the first time in the 2012 report.

A total of *c.*20.2 ha of geothermal vegetation has been mapped in the Waikite Geothermal Field, which comprises about 2.7% of the geothermal vegetation in the Waikato Region. The mapped vegetation in this field comprises *c.*8.7 ha of geothermal wetland, *c.*0.9 ha of nonvegetated raw-soilfield, and *c.*10.6 ha of terrestrial geothermal vegetation. In addition to the above, *c.*0.8 ha of geothermal water has also been mapped. A total of *c.*6.5 ha of this field was mapped as terrestrial indigenous-dominated vegetation, and of this *c.*4.8 ha was mapped as being dominated by prostrate kānuka (*c.*1.1 % of the area of vegetation dominated by this species in the Waikato Region).

Most of the vegetation mapped within the Waikite Geothermal Field is contained within the Waikite Valley site (19.9 ha) which includes several disjunct areas of geothermal activity near several small bodies of open water in the north of the site, and hot springs, heated soils, sinter pavements, geothermal wetlands, and plants present on the margins of heated geothermal streams. Surface water draw-off to supply a public swimming pool complex is the only extractive use of the geothermal

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

resource. Since 2011, most of the areas north of the Waikite Swimming Baths that were farmed have been fenced to exclude stock. However, stock still have access to some areas in the northernmost part of the site. Vegetation along most stream margins and geothermal wetlands has been subjected to grazing by domestic stock in the past. Most of the wetlands and stream margins are now fenced to exclude stock. Work is underway to restore a large geothermal wetland in the part of the site that is on the Waikite Landcorp Farm. Some restoration planting has been undertaken on the margins of the stream in two separate parts of the site. The stream below the Corbett Road Bridge is dominated by weed species, and the geothermal areas on the Waikite Scarp are surrounded by dense areas of blackberry (*Rubus fruticosus* agg.) scrub. The Waikite Valley site contains important habitat for a number of 'At Risk' plant species including the second largest population of *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon; de Lange *et al.* 2013) in New Zealand. Five other 'At Risk' species (as per de Lange *et al.* 2013) are known from this site: prostrate kānuka, *Cyclosorus interruptus*, *Thelypteris confluens*, *Nephrolepis flexuosa*, *Dicranopteris linearis*, and *Hypolepis dicksonioides*. Other species of interest are *Lycopodiella cernua* and *Psilotum nudum.*

Northern Paeroa Range is a relatively small site of *c.*0.3 ha and comprises four disjunct relatively small areas of geothermally influenced bare ground. A few plants of prostrate kanuka are present at this site. The site is surrounded by farmland, plantation, and shelter belts, Most of the site is fenced, but stock had recently had access to most parts of the site when field survey in 2011.

The Waikite Geothermal Field is classified as a 'Protected Geothermal System' by Waikato Regional Council[1].

Waiotapu Geothermal Field

The Waiotapu Geothermal Field contains the largest area of surface geothermal activity in New Zealand (Cave *et al.* 1993). The geothermal vegetation of this field is mapped over five sites, although the boundaries between some of these sites are somewhat arbitrary, with geothermal vegetation being almost continuous between the five sites. A total of *c.*221.1 ha of geothermal vegetation was mapped, which comprises almost a third (*c.*29.3%) of the geothermal vegetation of the Waikato Region. Based on 2014 mapping, Waiotapu South is the largest site in this field containing *c.*111.5 ha of geothermal vegetation, followed by Maungakakaramea (Rainbow Mountain) (*c.*51.6 ha of geothermal vegetation), Waiotapu North (*c.*42.8 ha of geothermal vegetation), Maungaongaonga (*c.*8.7 ha of geothermal vegetation), and Ngapouri (*c.*6.5 ha of geothermal vegetation). Most or all of Maungakakaramea (Rainbow Mountain), Maungaongaonga, and Waiotapu South are protected and administered by the Department of Conservation. Other sites and parts of these sites within the geothermal field are in private ownership and are surrounded by farmland and plantation forests.

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

The area mapped in the Waiotapu Geothermal Field comprises *c.*181.5 ha of terrestrial vegetation, *c.*13.2 ha of nonvegetated raw-soilfield, and *c.*26.4 ha of geothermal wetland. The geothermal wetland is completely located in the Waitopu South site in the southern part of the geothermal field. This is the best geothermal wetland vegetation in the Waikato Region and it is contiguous with non-geothermal wetland (the entire wetland including geothermal and non-geothermal habitat is known as Orutu Wetland). The geothermal portion of this wetland comprises *c.*30.9% of the geothermal wetland vegetation mapped in the Waikato Region. While the wetlands present at Tokaanu are larger, they do not contain the diversity of habitat types, or the diversity of geothermal features of the Orutu Wetland at Waiotapu South. Nonvegetated raw-soilfield within the Waiotapu Geothermal Field comprises *c.*14.7% of this type in the Waikato Region and includes some of the largest areas of sinter terraces remaining in New Zealand, as well as extensive areas of geothermally heated bare ground. The field contains *c.*207.4 ha of indigenous geothermal scrub and shrubland (this includes some extensive areas of geothermal wetland mapped as mānuka scrub), of which *c.*207.4 ha is mapped as indigenous geothermal scrub and shrubland, and *c.*162.1 ha is dominated by prostrate kānuka scrub and shrubland (comprising 38.1% of the area dominated by this species in the Waikato Region), making this the most important field for this species and vegetation type in the Waikato Region.

Ten vascular plant taxa present in this geothermal field are classed as 'At Risk' in de Lange *et al*. (2013): prostrate kānuka, *Cyclosorus interruptus*, *Schizaea dichotoma*, *Nephrolepis flexuosa*, *Dicranopteris linearis*, *Calochilus paludosus*, *C. robertsonii*, *Petalochilus alatus, Stegostyla atradenia*, and *Korthalsella salicornioides.* The population of *Cyclosorus interruptus* in Orutu Wetland is the largest population of this species at any geothermal site in New Zealand. Other species of interest are *Lycopodiella cernua, Schizaea fistulosa* and *S. bifida*, *Psilotum nudum*, *Caladenia atradenia*, *Thelymitra carnea, T. decora*, and *T. ixioides.*

Management of pest plants, particularly wilding pines (*Pinus* spp.) is a priority in protected areas, and some control of these species has been undertaken by land managers and the Department of Conservation. Extensive pig damage to geothermal wetland vegetation through trampling and making tracks was observed in the Orutu Wetland of Waiotapu South in 2011. The Waiotapu Geothermal Field is classified as a 'Protected Geothermal System' by Waikato Regional Council[1].

Parts of the geothermal vegetation and habitats that are not protected within this field are subject to grazing and extensive areas are dominated by pest plants. These unprotected areas provide important linkages between the protected areas of geothermal habitat, and regular management of pest plants, particularly wilding pine trees should be undertaken. These areas should be monitored regularly for management issues and formal protection and a restoration plan to enhance and/or protect the highly significant ecological values of this field should be considered.

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

Mangakino Geothermal Field

No terrestrial geothermal vegetation is currently known to be present within this geothermal field. At least one boiling spring was previously known at Mangakino, but this was drowned during the formation of Lake Maraetai (Cave *et al.* 1993) and is not included in the current study. The Mangakino Geothermal Field is classified as a 'Development Geothermal System' by Waikato Regional Council[1].

Mokai Geothermal Field

Four sites within the Mokai Geothermal Field were described in this study. These comprise small areas of steam-heated activity and a small (*c.*3.5 ha) area of associated geothermal vegetation. This comprises *c.*0.4% of the geothermal vegetation in the Waikato Region. An additional *c.*0.5 ha was mapped as geothermal water. The northern part of the Waipapa Stream site includes the third largest population of the fern, *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon; de Lange *et al*. 2013) in New Zealand. Prostrate kānuka (another 'At Risk' plant species) occurs at Paerata Road and Tirohanga Road. Other plant species characteristic of geothermal sites that are present within this field include *Psilotum nudum*, *Lycopodiella cernua*, and *Campylopus capillaceus*.

Geothermal electricity production commenced at Mokai in 1999 and currently 113 MW is generated from two adjoining stations (http://www.nzgeothermal.org.nz/nz_geo_fields.html#Mokai accessed 15 December 2014). After evaporative losses, all geothermal fluid used in the power plant is being reinjected up to 4 km from the site (Stretch 2000 cited in Merrett and Fitzgerald 2004). Monitoring of the sites within this field is recommended to assess the impacts of energy extraction on geothermal features. This field is classified as a 'Development Geothermal System' by Waikato Regional Council[1].

Other key management issues include:

- Some geothermal features at Paerata Road are grazed by stock, and values would be enhanced by fencing. Fences should be checked regularly at Tirohanga Road to ensure stock continue to be excluded from the site.
- Wildling pines are an issue at Waipapa Stream and Paerata Road. Future plantation pine planting adjacent to the site should allow a buffer (10 metres minimum width) between the plantation and geothermal features, and wilding trees should be removed regularly from the site.

Atiamuri Geothermal Field

Several hot springs and pools occur at the Whangapoa Springs and the Matapan Road Geothermal sites, and hot springs and fumaroles are present at Upper Atiamuri West. Past records indicate that the area once had hotter temperatures (Cave *et al.* 1993), and two pools were submerged when Lake Atiamuri was formed. There are

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

similarities between the geothermal characteristics of the Atiamuri and Horohoro Geothermal Fields and the two fields may be connected (Cave *et al.* 1993). A small population of *Nephrolepis flexuosa* is present by one hot pool at Whangapoa Springs. This and the neighbouring pool at Whangapoa Springs have been fenced, and considerable weed control and planting of indigenous tree species has been undertaken at this site since 2004. The other two sites in this field are located within farmland, or in fenced gullies adjacent to farmland, with no significant ecological values found. This field contains *c.*0.1 ha of geothermal vegetation and is classified as a 'Limited Development Geothermal System' by Waikato Regional Council[1].

Te Kopia Geothermal Field

Geothermal vegetation mapped within Te Kopia Geothermal Field comprises *c.*8.7% (*c.*65.3 ha) of the geothermal vegetation within the Waikato Region, which is the fourth largest area of geothermal vegetation within a geothermal field in the Waikato Region. This vegetation has been mapped over four sites, with most of the vegetation being present at Te Kopia (TKV01) (*c.*64.3 ha). Most of the Te Kopia site is located within Te Kopia Scenic Reserve and is contiguous with a much larger area of non-geothermal indigenous vegetation (mainly forest within the Te Kopia Scenic Reserve). The geothermal vegetation of Te Kopia (TKV01) is in good condition, and this site is of International significance. The geothermal activity of this area is thought to result from steam boiling off deep chloride water. All the features result from steam heating, although chloride springs are thought to have occurred here in the past (Cave *et al.* 1993).

The vegetation at Te Kopia Geothermal Field is made up of *c.*53.6 ha of terrestrial geothermal vegetation, *c.*4.6 ha of nonvegetated raw-soilfield, and *c.*6.1 ha of emergent wetland vegetation. An additional *c.*0.8 ha was mapped as geothermal water. The field has *c.*7.1% of the geothermal wetland and 9.5% of the geothermal terrestrial vegetation in the Waikato Region. Approximately 54.5 ha was mapped as indigenous terrestrial geothermal vegetation, of which *c.*47.3 ha was mapped as prostrate kānuka dominated vegetation, which is about 11.1% of the total area of prostrate kānuka dominated vegetation in the Waikato Region.

The Te Kopia site contains very high quality examples of geothermal vegetation, including habitat for one of the largest populations of the fern *Dicranopteris linearis* (At Risk-Naturally Uncommon; de Lange *et al*. 2013) in New Zealand. *D. linearis* is known from *c.*23 sites in New Zealand. Murphy's Springs contains a good sized population of *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon) with about 100 plants present. Other 'At Risk' species known from the Te Kopia field include *Schizaea dichotoma*, *Calochilus paludosus*, *C. robertsonii*, *Korthalsella salicornioides*, and *Nephrolepis flexuosa*.

Key management issues in Te Kopia Geothermal Field include fencing to exclude stock from geothermal habitat where stock may have access to 'At Risk' fern populations outside Te Kopia Scenic Reserve (e.g. Mangamingi Station and Murphy's Springs). Pest plant monitoring and control, particularly of wilding pines, should continue within Te Kopia Scenic Reserve. Formal protection (e.g. covenant) should be considered for geothermal areas outside Te Kopia Scenic Reserve. The Te Kopia

Geothermal Field is classified as a 'Protected Geothermal System' by Waikato Regional Council[1].

Orakeikorako Geothermal Field

Geothermal vegetation within Orakeikorako Geothermal Field comprises *c.*8.5% (*c.*64.1 ha) of the geothermal vegetation of Waikato Region, and is the fifth largest area of geothermal vegetation in the Waikato Region. An additional 2.8 ha was mapped as geothermal water. The 64.1 ha of mapped geothermal vegetation within the Orakeikorako Geothermal Field includes *c.*2.4 ha of nonvegetated raw-soilfield, *c.*2.5 ha of geothermal wetland, and the remainder (59.3 ha) as terrestrial geothermal vegetation. In this field, *c.*55.9 ha of vegetation has been mapped as indigenous geothermally influenced vegetation, of which *c.*10.1 ha has been mapped as prostrate kānuka dominant vegetation (*c.*2.4% of the prostate kānuka dominated vegetation in the Waikato Region). The vegetation has been mapped over five sites with the largest areas of geothermal vegetation present at two sites: Orakeikorako (*c.*46.8 ha) and Red Hills (*c.*13.1 ha).

Present-day geothermal features and vegetation within the Orakeikorako Geothermal Field represent only part of what was once a spectacular geyser field (Cave *et al.* 1993). About three quarters of the geothermal features were lost when the Waikato River was dammed and Lake Ohakuri was created in 1961 (Cave *et al.* 1993). Cave *et al.* (1993) noted that any development of the Te Kopia and Ngatamariki fields would need to be investigated to establish the nature and extent of possible connections with the Orakeikorako Geothermal Field. An 82MW geothermal power plant was commissioned at Ngatamariki in 2013. Most of the geothermal fluid used for production is reinjected back into the field, and regular monitoring of the vegetation at this site is undertaken. Orakeikorako is classified as a 'Protected Geothermal System' by Waikato Regional Council[2].

The two largest sites in the Orakeikorako Geothermal Field, Red Hills and Orakeikorako, contain large areas of good quality geothermal vegetation, are nationally significant sites, and are notable for large populations of the 'At Risk' fern, *Dicranopteris linearis* (At Risk-Naturally Uncommon; de Lange *et al*. 2013). As well as *D. linearis*, there are a relatively high number of other 'At Risk' species including the orchids *Calochilus robertsonii* and *Corunastylis pumila* (Given 1989) and good populations of several 'At Risk' ferns: *Christella* aff. *dentata* ('thermal'), *Schizaea dichotoma*, *Nephrolepis flexuosa*, *Thelypteris confluens*, and *Cyclosorus interruptus.* Other notable species present include *Lycopodiella cernua*, arrow grass (*Triglochin striata*), *Schizea bifida*, sea rush (*Juncus kraussii* var. *australiensis*), *Psilotum nudum,* and the moss *Campylopus capillaceus.*

The key management issue in this field is the management of pest plants, particularly wilding pines, Chinese privet (*Ligustrum sinense*), and black wattle (*Acacia mearnsii*). Blackberry should be controlled where present on the eastern side of Lake

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

[2] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

Whakamaru where it is currently rare. Recent control of wilding pines at Orakeikorako and Red Hills has improved the long-term viability of these sites; follow-up pine control is planned for Red Hills in 2015. Some pampas (*Cortaderia selloana*) control has been undertaken at Orakeikorako and Red Hills; this species should be controlled around any geothermal features. Royal fern in wetlands should be controlled. Willows should be controlled in the geothermal wetland at Orakeikorako. Geothermal vegetation at Akatarewa East should be fenced to exclude stock.

Ngatamariki Geothermal Field

There is *c.*1.3 ha of geothermal vegetation in the Ngatamariki Geothermal Field which contains small areas of nonvegetated raw-soilfield, terrestrial vegetation, and geothermal wetland. The vegetation has been mapped over two sites. A high proportion of Orakonui (NMV02) is surrounded by pine plantation. The key geothermal features at this site are the Orakonui Hot Springs, which are mostly protected in a DOC reserve. The Waikato River Springs are a series of springs located on each side of the Waikato River along *c.*200 m of river.

About 38 plants of *Cyclosorus interruptus* (At Risk-Declining; de Lange *et al*. 2013) are present at the Orakonui[1] site. Other species characteristic of geothermal sites that are present within the field include prostrate kānuka, *Campylopus*, arrow grass, *Lycopodiella cernua*, and *Psilotum nudum*. A small population of *Christella* aff. *dentata* ("thermal") was recorded from Waikato River Springs in 2006 (Wildland Consultants 2006), but has not been recorded in subsequent surveys.

The Ngatamariki Geothermal Field is classified as a 'Development Geothermal System' by Waikato Regional Council[2]. An 82MW geothermal power plant was commissioned at Ngatamariki in 2013. Most of the geothermal fluid used for production is reinjected back into the field, and regular monitoring of the vegetation at this site is undertaken.

Other key management issues in this geothermal field are the monitoring and control of pest plants, and good practice in the management of surrounding pine plantations. Extensive wilding pine control work has been undertaken within the Orakonui site since 2011. Whilst this control work has resulted in improved geothermal vegetation condition and appearance, it has also created an avenue for invasion and expansion of other pest plant species within the site. Chinese privet, blackberry, pampas, and Montpellier broom (*Genista monspessulana*) have expanded in extent at the Orakonui site since 2011. Control of Chinese privet, blackberry, and pampas, and ongoing control of wilding pines should be undertaken within this site.

Whangairorohea Geothermal Field

This geothermal field has a *c.*10 × 15 m wide geothermal spring and pool surrounded by sedges, reeds, and exotic terrestrial vegetation. Scattered pest plants such as

[1] Referred to as 'Ngatamariki' in previous reports.

[2] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

Spanish heath (*Erica lusitanica*), blackberry, and buddleia (*Buddleja davidii*) occur around the pool and these should be removed.

Reporoa Geothermal Field

Reporoa Geothermal Field contains *c.*10 ha of geothermal vegetation spread over three sites (*c.*1.3% of the geothermal vegetation in the Waikato Region). Several areas of surface geothermal activity are also present in this field (e.g. Butchers' Pool), but are not known to contain any geothermal vegetation and therefore are not mapped in this report. Mapped vegetation comprises *c.*7.1 ha of terrestrial vegetation, *c.*0.4 ha of emergent wetland vegetation, and *c.*2.5 ha of nonvegetated raw-soilfield.

Small populations of *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon; de Lange *et al*. 2013) and prostrate kānuka (At Risk-Naturally Uncommon; de Lange *et al*. 2013) are present within the Golden Springs site.

Parts of the site at Wharepapa Road are unfenced and grazed by stock, and values within the site would improve if these areas were fenced. Geothermal features have been adversely affected by drainage at all sites within this geothermal field. No further drainage of geothermal wetlands and features should be undertaken at any of the sites in the Reporoa Geothermal Field. The Reporoa Geothermal Field is classified as a 'Research Geothermal System' by Waikato Regional Council[1].

Ohaaki Geothermal Field

The Ohaaki Geothermal Field has about 18.0 ha of geothermal vegetation which comprises *c*.2.4% of the geothermal vegetation in the Waikato Region. The vegetation comprises *c.*4.6 ha of nonvegetated raw-soilfield, and *c.*13.5 ha of terrestrial geothermal vegetation. About 10.4 ha is dominated by prostrate kānuka dominant vegetation, which equates to *c.*2.4% of the prostrate kānuka dominant vegetation in the Waikato Region. The vegetation has been mapped over two sites on either side of the Waikato River.

Small areas of relatively undisturbed geothermal vegetation dominated by prostrate kānuka are present. Scattered areas of monoao are a feature of this geothermal field. Other species typical of geothermal habitat include *Lycopodiella cernua*, *Campylopus capillaceus* (a moss), and *Dicranopteris linearis* (known from *c.*23 sites in New Zealand). Arrow grass (Burns 1997a) and *Psiloum nudum* (Merrett *et al*. 2003) have also been recorded in this geothermal field.

The Ohaaki Geothermal Field is classified as a 'Development Geothermal System' by Waikato Regional Council[2]. From 1989, Ohaaki Geothermal Power Station supplied electricity to the national grid, and this exploitation has affected the geothermal features of both sites described in this report. All geothermally-influenced pools in this area are now dry. Ground temperatures have decreased in places and increased in

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

[2] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/. Accessed 1 October 2014.

others, resulting in an overall increase in the extent of geothermal vegetation (Merrett and Burns 1998a). Merrett *et al.* (2003) found no apparent evidence of any negative impacts of geothermal fluid extraction on geothermal vegetation overlying the Ohaaki Geothermal field between December 1997 and July 2003.

Other threats to geothermal vegetation in this field include the ongoing subsidence of land and subsequent inundation of existing geothermal vegetation by the Waikato River, and the establishment and spread of wilding pines from surrounding plantation forest into geothermal habitat. Some ongoing pest plant control is being undertaken within this field (pampas and wilding pines by Contact Energy, other species near Ohaaki marae by WRC). The values of these sites could be further enhanced through restoration, additional pest plant control and appropriate planting to maintain and enhance the ecological values present.

Wairakei-Tauhara Geothermal Field

The Wairakei-Tauhara Geothermal Field contains *c.*144.7 ha of geothermal vegetation, which comprises *c.*19.3% of the mapped geothermal vegetation in the Waikato Region. The vegetation has been mapped over 18 sites, with the largest sites being Craters of the Moon (38.1 ha), Te Kiri O Hine Kai Stream Catchment/Wairoa Hill (35.6 ha), Broadlands Road (30.1 ha), and Crown Road (20.4 ha). A total of *c.*131.5 ha was mapped as terrestrial geothermal vegetation and *c*.12.5 ha as nonvegetated raw-soilfield. Vegetation dominated by prostrate kānuka covers *c.*108.0 ha, which represents 25.4% of the prostate kānuka dominant vegetation within the Waikato Region.

Geothermal features associated with the Wairakei-Tauhara Geothermal Field occur in both the Atiamuri and Taupō Ecological Districts. This field is classified as a Development Geothermal System by Waikato Regional Council[1]. Exploitation from the Wairakei Geothermal Power Station has resulted in the decline of chloride water springs and geysers, shallow aquifers, and change in the extent of hot ground. The result of this is that some sites are cooling, while others are becoming hotter, affecting the vegetation growing on the sites (Cave *et al.* 1993). The extent, distribution, and composition of the geothermal vegetation of this field are continuing to change. The extent and quality of geothermal vegetation at sites within this field was similar between 2011 and 2014.

Other key threats to geothermal sites in the Wairakei Geothermal field are:

- The recent loss of vegetation to both road and industrial development, particularly near Taupō township at Crown Road and Broadlands Road sites. The sites near Taupō are also particularly vulnerable to fire due to recreational use. A fire occurred recently at the Upper Wairakei Stream (Geyser Valley site) in late 2012.
- Grazing occurs at several sites in Wairakei Geothermal Field (e.g. parts of Te Rautehuia and Te Rautehuia Stream). These areas should be fenced to exclude stock.
- Pine plantation forest is present on the margins of many sites in this field. Plantation forests provide a source of wilding pines, and all sites should be

monitored for their spread. Pine trees should be felled away from geothermal areas when harvesting, and a buffer of at least 10 m should be established around geothermal sites when replanting. Other pest plant species should be controlled in geothermal sites, e.g. pampas at Otumuheke Stream and grape (*Vitis vinifera*) vine at Upper Wairakei Stream (Geyser Valley).

At Broadlands Road, Craters of the Moon, Te Kiri O Hine Kai Stream Catchment/Wairoa Hill, and Crown Road there are relatively large areas of prostrate kānuka (At Risk-Naturally Uncommon; de Lange *et al*. 2013). Good populations of two ferns, *Cyclosorus interruptus* (At Risk-Declining; de Lange *et al*. 2013) and *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon; de Lange *et al*. 2013), are present at Otumuheke Stream. A small population of *Christella* aff. *dentata* ("thermal") is also known from Hall of Fame Stream, and a small population of *Cyclosorus interruptus* is present at Waipahihi Valley. Relatively large populations of *Nephrolepis flexuosa* and *Dicranopteris linearis* are present within sites in this geothermal field (populations of these species are present at Te Kiri O Hine Kai Stream Catchment/Wairoa Hill, Te Rautehuia Stream, and Craters of the Moon). Other taxa present in the Wairakei-Tauhara Geothermal field include *Hypolepis dicksonioides*, *Campylopus capillaceus*, *Psilotum nudum*, *Lycopodiella cernua*, and rock fern (*Cheilanthes sieberi*). Historic records of *Asplenium flabellifolium* and *Fimbristylis velata* exist for sites within this field (Given 1989a), but have not been recorded in recent surveys.

Waikato Regional Council is undertaking pest plant control at several sites within the Wairakei-Tauhara geothermal field. An extensive restoration plan is being implemented at Otumuheke Stream as a joint project with the landowners and the Waikato Regional Council, with the help of some volunteer groups; currently wilding pines, pampas, exotic woody shrubs, and climbers have been controlled in parts of this site. Wilding pines and broom are subject to ongoing control at Crown Park and Crown Road; geothermal vegetation within Crown Road continues to be at risk of clearance for development by adjoining landowners. Waikato Regional Council has undertaken aerial pampas control in recent years at Craters of the Moon, and some additional pest plant control is undertaken by the Craters of the Moon Trust.

Rotokawa Geothermal Field

The Rotokawa Geothermal Field contains *c.*114.8 ha of geothermal vegetation, which comprises *c.*15.3% of the mapped geothermal vegetation in the Waikato Region. An additional 71.4 ha (most of this comprising Lake Rotokawa) has been mapped as geothermal water. Of the *c.*114.8 ha mapped geothermal vegetation in this field, *c.*20.6 ha was mapped as nonvegetated raw-soilfield; the extent of this type may reduce over time as the site recovers from past disturbances. The vegetation has been mapped over two sites: Lake Rotokawa (74.7 ha of geothermal vegetation) and Rotokawa North (40.1 ha of geothermal vegetation). The vegetation between parts of the two sites is continuous with the boundaries between them being arbitrary. Most of the Lake Rotokawa site is administered by the Department of Conservation as Lake Rotokawa Conservation Area. Approximately 70.6 ha was mapped as prostrate kānuka dominant vegetation, over both sites, which represents 16.6% of the mapped prostate kānuka dominant vegetation within the Waikato Region.

This field is characterised by collapse pits and eruption craters, one of which is filled by Lake Rotokawa. Large deposits of sulphur lie under and around the edge of the lake, and the surrounding area has been modified by sulphur mining. Further modification has occurred from harvesting operations in the surrounding pine plantation forest which dominates the northern end of this field (Cave *et al.* 1993). Considerable control of pest plants (particularly wilding pines) has been undertaken by the Department of Conservation in the Lake Rotokawa Conservation Area in recent years. Ongoing control of pest plants in this reserve is recommended.

The large area of prostrate kānuka scrub and shrubland is a key feature of this geothermal field. Large areas of mānuka scrub and shrubland are also present. Three 'At Risk' plant species (as per de Lange *et al.* 2013) have been recorded from this geothermal field: small populations of *Nephrolepis flexuosa* and *Dicanopteris linearis* were recorded near one spring in 2004, and; a relatively large population of *Calochilus robertsonii* was recorded from the Lake Rotokawa site in November 2006. Within Lake Rotokawa, two species of flagellate algae (*Euglena anabaena* and *Chlamydomonas* sp.), a leech (*Helobdella* sp.), and larvae of a chironomid (*Chironomus zealandicus*), have been recorded (Burns 2007). The blue-green alga *Cyanidium caldarum* has been recorded in and around hot springs and their outflows around the lake and the Parariki Stream. Larvae of the thermal mosquito *Culex rotoruae* and the thermal fly *Ephydrella thermarum* have been recorded associated with the blue-green alga (Burns 2007).

This field is classified as a Development Geothermal System by Waikato Regional Council[1]. The 29 MW Rotokawa power station was commissioned in 1997 (and subsequently expanded to 34 MW in 2003). Further development of the Rotokawa field has since taken place with commissioning of the 140 MW Nga Awa Purua power station in 2010, which includes the largest single geothermal turbine in the world[2]. The impacts of this energy extraction on the vegetation and features in this geothermal field should be monitored to assist with future management of the field.

Horomatangi Geothermal Field

This geothermal field occurs on the bed of Lake Taupō. It comprises sinter-depositing springs on the bed of the lake, sinter tubes, and associated specialised ecosystems[1]. The Horomatangi Geothermal Field is classified as a 'Protected Geothermal System' by the Waikato Regional Council[1]. As this geothermal field is under Lake Taupō, no terrestrial or emergent wetland geothermal vegetation is present, and no sites are mapped and described in this report and analysis.

Tokaanu-Waihi-Hipaua Geothermal Field

The Tokaanu-Waihi-Hipaua Geothermal Field contains *c.*59.2 ha of geothermal vegetation, which is *c.*7.9% of the geothermal vegetation in the Waikato Region. An additional *c.*4.8 ha has been mapped as geothermal water. This field contains an estimated 40.4 ha of geothermal wetland habitat; which equates to about 47% of the

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/, Accessed 1 October 2014.

[2] http://www.nzgeothermal.org.nz/nz_geo_fields.html#Rotokawa, Accessed 24 July 2011.

geothermal wetland vegetation in the Waikato Region. The boundaries of geothermal wetlands are somewhat difficult to map, so the boundaries identified in this report may require updating in the future if more information becomes available. Regardless of the exact size of the geothermal wetland in this field, it is of considerable ecological significance. Most of the area mapped as geothermal wetland was present at Tokaanu Lakeshore Wetland (*c.*37.7 ha). A small area within this field was mapped as nonvegetated raw-soilfield (0.5 ha). About 11.8 ha of this field was mapped as prostrate kānuka dominant vegetation, which comprises about 2.8% of this vegetation type in the Waikato Region.

Geothermal activity at Tokaanu has changed over time and, historically, this site was more extensive and spectacular than it is now. The cause of this decrease in activity is unknown, but may have been related to changes in the water level of Lake Taupō (Cave *et al.* 1993).

The geothermal vegetation, most of which has developed during the last few decades, is of relatively good quality, with few weeds. A moderate-sized population of the naturally uncommon, semi-parasitic mistletoe, *Korthalsella salicornioides* (At Risk-Naturally Uncommon; de Lange *et al*. 2013), occurs at the Tokaanu Thermal Park site. *Schizaea dichotoma* (At Risk-Naturally Uncommon; de Lange *et al*. 2013) is also present at the Tokaanu Thermal Park site and there are historical records of the fern *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon; de Lange *et al*. 2013) and *Nephrolepis flexuosa* (At Risk-Declining; de Lange *et al*. 2013) from this site (Given 1995). Oioi (*Apodasmia similis*) also occurs at Tokaanu Thermal Park, outside its normal coastal distribution. Tokaanu Lakeshore Wetland contains an extensive area of wetland, with steam seen rising through raupō at regular intervals throughout much of the mapped site. Most of the prostrate kānuka dominant vegetation within this geothermal field occurs at the Hipaua site; however while it is presumed to be of high quality, there has been no botanical survey here since 1995 (Given 1995). Hipaua was ranked highly by Given (1995) due to a high diversity of edaphic factors, and for the overall integrity and maintenance of ecological processes.

Tongariro Geothermal Field

Mount Tongariro has four areas of geothermal vegetation covering *c.*28.6 ha, or 3.8% of the geothermal vegetation in the Waikato Region. The Ketetahi site has not been field surveyed by the authors and the site description and asssessment are based on the information provided in Given (1995), aerial photographs, and viewing from a distance in 2011. The other three sites (Red Crater, Emerald Lakes, and Te Maari Craters) were included in this project for the first time in 2012. This field contains the only subalpine geothermal vegetation mapped in this study. Geothermal habitat within this field has increased since the 2012 study due to the eruption of the Te Maari Craters in late 2012; based on inspection of aerial photographs, the extent of geothermal habitat at this site has almost doubled. The three sites in Tongariro National Park (Te Maari, Emerald Lakes, and Red Crater) are protected, and Ketetahi is protected by the Māori owners as private land. Most of the geothermal sites are bare ground, with scattered *Rytidiosperma setifolium* in cooler areas. A small population of *Lycopodiella cernua* was found in Te Maari Crater in 2011; the continued presence of this species at this site following the crater eruptions is unknown. The nearest known population of this species is at Tokaanu Thermal Park.

6.2 Assessment by Local Authority District

Geothermal vegetation in the Waikato Region is distributed relatively evenly between the Rotorua and Taupō Districts with *c.*50.6% in the Rotorua District and 49.4% in the Taupō District (see Table 10).

Table 10: Area (ha) of geothermal vegetation[1] for each administrative district in the Waikato Region.

Administrative District	Area (ha)[1]	Area (%)
Rotorua	380.0	50.6
Taupō	370.3	49.4
Total	**750.3**	**100**

6.3 Assessment by Ecological District

Most (79%) of geothermal vegetation in the Waikato Region occurs in sites that lie solely within the Atiamuri Ecological District (see Table 11). Sites located solely in the Taupō Ecological District and solely in the Tongariro Ecological District contain *c.*12.4% and 6.6% of the vegetation in the Waikato Region respectively. The remaining geothermal vegetation is located in sites that straddle two ecological districts, with 2.1% of geothermal vegetation in the Waikato Region occurring in a site that spans the Atiamuri and Rotorua Lakes Ecological Districts, and <0.1% occurring in a site that spans the Taupō and Atiamuri Ecological Districts.

Table 11: Area (ha) of geothermal vegetation[1] and geothermal water for each Ecological District in the Waikato Region.

Ecological District	No. of Sites	Habitats					Total Geothermal Habitats[2]
		Geothermal Water	Geothermal Vegetation			Total Geothermal Vegetation[1]	
			Nonvegetated Raw-Soilfield	Terrestrial	Emergent Wetland		
Atiamuri	43	105.7	52.0	494.8	44.7	591.3	697.0
Atiamuri/ Rotorua Lakes	1	0.6	0.6	15.4	0.0	16.0	16.4
Taupō	10	4.2	8.3	46.3	38.5	93.1	97.3
Tongariro	9	3.0	29.0	18.2	2.7	49.8	52.8
Taupō/ Atiamuri	1			0.1		0.1	0.1
Grand Total	**64**	**113.4**	**89.8**	**574.7**	**85.8**	**750.3**	**863.7**

The change in extent of geothermal vegetation from the time of European settlement to the present day was estimated for each Ecological District. Estimations are based on existing data and anecdotal evidence, and are only a rough indication of the changes that have occurred. Within Atiamuri Ecological District, an overall loss of *c.*30% of the geothermal vegetation has been estimated, compared with an estimated gain of *c.*4% within the Taupō Ecological District (Wildland Consultants 2004a).

[1] Total area (ha) of geothermal vegetation (not the area of the site). Geothermal vegetation includes terrestrial vegetation, nonvegetated raw-soilfield, and emergent wetland vegetation, but not geothermal water.

[2] Total area (ha) of geothermal water and geothermal vegetation.

There has probably been little change in the extent of geothermal vegetation in the Tongariro Ecological District.

7. NATURAL DYNAMICS

Many geothermal sites are very active and dynamic, and their habitats are therefore somewhat unstable. This dynamic nature is illustrated by the recent (2012) eruption of the Te Maari Craters and a hydrothermal eruption at Orakonui in 2005. Changes in geothermal activity tend to be reflected in changes in the extent and composition of geothermal vegetation. Local increases in heat, steam production, and eruptions of mud and hot water often damage or kill surrounding vegetation; conversely, cooling ground may lead to increased weed invasion and the decline of heat tolerant species. These changes are an integral part of the natural dynamics of geothermal sites.

8. HUMAN DISTURBANCE AND ASSOCIATED THREATS

Human disturbance and associated threats to the geothermal vegetation in the Waikato Region include a range of activities, as set out below:

Exploitation of Geothermal Fields for Energy Production

This is one of the greatest threats to the viability and sustainability of geothermal vegetation and associated flora. Exploitation can cause changes to the underground geothermal system that have the potential to change both the character of geothermal sites, and the distribution of species within them. Exploitation can result in increases in temperature and subsequent extent of geothermal habitat, or decreases in temperature which result in the disappearance of geothermally tolerant species and increased risk of invasion by pest plant species. For example, exploitation of the Wairakei-Tauhara Geothermal Field for electricity generation has resulted in a lowering of the water table and consequent loss of hot springs and geysers. Past collections indicate that Geyser Valley at Wairakei supported colonies of nearly all the tropical ferns and fern allies associated with thermal areas in New Zealand (Given 1989b). Most of these species are now either completely absent or much reduced in abundance and distribution at this site. The cooler ground at this site has also provided avenues for pest plant invasion and establishment. Conversely, at nearby Karapiti (Craters of the Moon in this report), a ten-fold increase in heat output occurred following development of the Wairakei field (Huser 1989).

Large scale energy development has been undertaken in the Wairakei-Tauhara, Mokai, Ohaaki, Ngatamariki, and Rotokawa geothermal fields. These fields have been classified as Development Geothermal Systems by Waikato Regional Council[1]. The Waikato Regional Council allows large-scale use of the energy resources within these fields as long as they are undertaken in a sustainable and environmentally responsible manner. Horohoro and Mangakino geothermal fields are also classified as Development Geothermal Systems, but no large scale developments have been

[1] http://www.waikatoregion.govt.nz/Environment/Natural-resources/Geothermal-resources/Classifying-geothermal-systems/ Accessed 3 September 2014.

undertaken within these fields to date. A total of *c.*281.9 ha of geothermal vegetation was mapped in fields classified as Development Geothermal Systems, comprising *c.*38% of the mapped geothermal in the Waikato Region.

Two geothermal fields (Atiamuri and Tokaanu-Waihi-Hipaua) are classified as Limited Development Geothermal Systems. The Waikato Regional Council allows resource take that will not damage surface features[1] within these fields. A total of *c.*59.2 ha of geothermal vegetation was mapped in Limited Development Geothermal Systems, comprising *c.*8% of the geothermal vegetation in the Waikato Region.

The Reporoa Geothermal Field is classified as a Research Geothermal System, because the Waikato Regional Council considers that not enough is known about the system to classify it as either Development, Limited Development, or Protected. In these systems, only small resource takes and those undertaken for scientific research into the system are allowed[1]. A total of 10.0 ha of geothermal vegetation was mapped in the Reporoa geothermal field, which represents *c.*1% of the geothermal vegetation in the Waikato Region.

Five geothermal fields are protected from development and classified as Protected Geothermal Systems by Waikato Regional Council. These are Horomatangi, Orakeikorako, Te Kopia, Tongariro, and Waikite-Waiotapu-Waimangu geothermal fields. These fields contain vulnerable geothermal features valued for their cultural and scientific characteristics. Their protected status ensures that their underground geothermal water source cannot be extracted and that the surface features are not damaged. A total of *c.*399.3 ha of geothermal vegetation was mapped in Protected Geothermal Systems, representing *c.*53% of the geothermal vegetation in the Waikato Region.

Tourism and Recreation

Considerable damage can result from the construction of facilities such as tracks, roads, and buildings, and from the combined effects of large numbers of visitors, particularly to popular tourist sites such as Waiotapu, Wairakei, Maungakakaramea (Rainbow Mountain), Craters of the Moon, Orakeikorako, and Upper Wairakei Stream (Geyser Valley). Some sites, such as Craters of the Moon, have produced a management plan to reduce the impacts of tourists, by discouraging visitors from walking off formed tracks. This plan is being implemented successfully, although it will take some time for vegetation to recover due to soil compaction. Geothermal sites are particularly vulnerable to trampling damage, particularly populations of threatened ferns and prostrate kānuka dominant vegetation.

Attempts to 'tidy' or otherwise 'enhance' areas for tourism and recreation can also degrade the geothermal vegetation. Mowing or slashing geothermal vegetation, the indiscriminate use of herbicides for weed control, replacement of 'scruffy' geothermal vegetation with grass or other introduced plants, and the application of fertiliser to promote growth of non-thermal vegetation all threaten the viability of geothermal vegetation. This practice is still continuing at some sites, such as Golden Springs. Better communication with land managers/owners will be required to change these practices.

Vegetation and features at Crown Road were destroyed for motorcross track construction, suggesting that public perception of the value of geothermal vegetation needs to change.

Mountain bikers are discouraged from riding in vegetation and features at Craters of the Moon, other Wairakei sites, and Maungakakaramea (Rainbow Mountain), and this protection strategy should continue to be emphasised at these sites.

Dumping of Rubbish

Dumping of garden refuse leads to the establishment of garden escapees and other weeds. Dumping of other types of rubbish is a problem at some sites, e.g. Wharepapa Road, Crown Park, Otumuheke, and Ngapouri, where it threatens the viability of geothermal vegetation, as well as being unsightly.

Pest Plants

Invasive exotic plants, particularly blackberry and wilding pines, are the most obvious threat to most sites. The scale of the problem is large: in 2008 we calculated that within 125 ha (or 17% of all geothermal vegetation), pest plants covered greater than 25% of the area and, furthermore, that pest plants covered between 5-25% of a further *c.*272 ha or 37% of geothermal vegetation. More than 111 exotic plant species have been recorded from geothermal habitats in the Waikato Region, of which 42 are considered to be serious plant pests. While weeds will generally not survive on hotter sites, species such as blackberry, wilding pines, silver birch (*Betula pendula*), buffalo grass (*Stenotaphrum secundatum*), Montpellier broom, tree lucerne (*Chamaecytisus palmensis*), Himalayan honeysuckle (*Leycesteria formosa*), broom (*Cytisus scoparius*), Spanish heath, cotoneaster (*Cotoneaster glaucophyllus*), and pampas (mainly *Cortaderia selloana*) readily invade cooler ground around the margins of geothermal sites, e.g. Maungakakaramea (Rainbow Mountain), Te Kopia, Lake Rotokawa, and Waiotapu.

Wilding pines (particularly maritime pine (*Pinus pinaster*) and radiata pine (*Pinus radiata*)) are the most common pest plants in geothermal areas. For example, seven species of wilding pines were present at Maungakakaramea (Rainbow Mountain), and earlier reports (prior to pine control work which began in the 1980s) noted pines covering 6-20% of the geothermal vegetation at the site. However, considerable pine control work has been undertaken at this site by the Department of Conservation, with a dramatic improvement in vegetation condition. Pine control has also taken place at Waipapa Stream, Ohaaki, Waiotapu, Te Kopia, Orakeikorako, Orakonui, Rotokawa North, and several sites near Wairakei and Taupō.

Other pest plant tree and shrub species recorded from geothermal habitats include flowering cherry (*Prunus* sp.), Chinese privet, Khasia berry (*Cotoneaster simonsii*), false acacia (*Robinia pseudoacacia*), eucalyptus (*Eucalyptus* sp.), Tasmanian blackwood (*Acacia melanoxylon*), crack willow (*Salix fragilis*), grey willow (*Salix cinerea*), and tree lucerne.

Blackberry, broom, buddleia, Himalayan honeysuckle, gorse (*Ulex europaeus*), Spanish heath, and exotic grasses are common on cooler geothermal soils and on the

margins of sites, but are difficult to manage in most situations. Where they are present in low abundance, they should be controlled to prevent them from spreading or, if possible, they should be eradicated.

Some pest plants are site specific and require urgent management, for example *Cyperus involucratus* and ivy (*Hedera helix*) are a significant threat to populations of *Nephrolepis flexuosa* and geothermal vegetation at Waikite. Weed control methods need to avoid or minimise risk to geothermal vegetation. For example, removal of pest plants may make geothermal ferns more susceptible to damage during frosts if the canopy providing shelter is removed. Pest plant control can also threaten 'At Risk' ferns alongside stream margins by making stream banks more vulnerable to erosion. Where pest plant management within a site could damage habitat of 'Threatened' and 'At Risk' plant species, implementation of a management plan written by an appropriately qualified person should be undertaken (particularly for sites larger than 10 hectares).

Domestic Livestock Damage

Where livestock have access to geothermal vegetation e.g. in the northeastern part of Waikite Valley, they are a major threat to its viability, and stock-proof fencing is a high priority. Livestock cause damage to vegetation by grazing, trampling and pugging of the ground surface and open up sites for weed invasion. Stock can cause considerable damage to sites by congregating in the warm areas during cold weather. Deer (*Cervus* sp.) were noted to have caused considerable damage to some units by trampling in prostrate kānuka shrubland at Te Rautehuia Stream in 2006. An area within the Golden Springs site has been fenced since it was last surveyed in 2007. Management of pest plants will be required here.

Plantation Forestry and Shelterbelts

A number of geothermal sites in the Waikato Region are located adjacent to plantation forest and wilding pines are invading the geothermal vegetation, particularly around the margins. Where geothermal areas adjoin plantation forests, management and harvesting operations need to be undertaken with care to avoid damaging the geothermal vegetation or associated buffer vegetation. Such damage can provide avenues for weed invasion and wind access, and threaten the viability of geothermal vegetation. The adverse effects of plantation forestry on geothermal sites needs to be addressed, as recommended by Given (1995), who emphasised the importance of buffer zones for indigenous vegetation, of which there are currently few. For example, a protection buffer was not established around the relevant geothermal habitats at Karapiti Forest when plantation pines were recently replaced.

Some sites (e.g. Northern Paeroa Range) are surrounded by shelter belts. Adjacent shelterbelts should be managed to ensure that trees are not felled into geothermal sites.

Introduced Pest Animals

Animal pests such as possums (*Trichosurus vulpecula*), deer, and pigs (*Sus scrofa*) can threaten the viability of indigenous vegetation associated with geothermal sites. Control is required where pest animals are causing problems. Significant damage by

pigs was noted at Waiotapu South in Orutu Wetland. This is the best quality geothermal wetland in New Zealand, and control of pigs should be undertaken to reduce their impacts on this site.

Fire

Geothermal vegetation is frequently dominated by flammable species such as prostrate kānuka and monoao, and great care needs to be taken with fire in the vicinity of geothermal sites. Fires have occurred at several sites in the Waikato Region, including Crown Road. A fire in late 2012 at Upper Wairakei Stream (Geyser Valley) (started as a result of a discarded cigarette butt) has resulted in degradation of the site through weed invasion of the burnt area. Smoking should be discouraged at all geothermal sites.

Genetic Pollution

The planting of indigenous species around geothermal areas using plants sourced from other parts of New Zealand can result in genetic mixing of different ecotypes (e.g. see Wassilief and Timmins 1984, Simpson 1992). When restoration or amenity plantings are undertaken within or adjacent to geothermal areas, only locally-sourced plants from within the same ecological region or district should be used and, where possible (particularly for sites of Regional/National/International significance), plant stock should be sourced from the site (or from within the geothermal field).

Wetland Infilling and Drainage

Some geothermal activity is associated with freshwater wetlands, and these sites are vulnerable to infilling and drainage, which are common threats to wetlands. Wetlands have been much reduced in the Waikato Region and remaining wetlands deserve a high level of protection.

Industrial/Residential/Recreational/Roading Development

Sites near urban areas have been destroyed by replacing vegetation for industrial, residential, recreational, and roading developments. This is particularly prominent at sites near Taupō where the new State Highway 1 bypass around Taupō has passed through the Crown Road site, and areas to the south of the site have recently been converted to industrial land use.

9. FUTURE MANAGEMENT

9.1 Regulatory controls

All areas of geothermal vegetation assessed as being significant are worthy of formal protection and management to protect them from the threats identified and discussed above. Some sites that have been assessed as locally significant or regionally significant may improve in condition over time if protected, and could warrant a higher ranking in the future.

9.2 Buffers and connections

Protective buffers enhance the viability of natural areas by buffering sensitive ecosystems from external modifying influences such as plantation forest harvesting, wind, and weed invasion. Geothermal habitats were previously surrounded by non-geothermal indigenous vegetation, which also provided connective links or corridors to other geothermal sites. Connections need to be protected or enhanced wherever possible. Many geothermal sites are relatively small and currently have inadequate buffers.

Buffers around geothermal sites are also important due to natural fluctuations in surface geothermal activity at a particular location and across the landscape. Creating and maintaining good buffers around geothermal sites would allow greater protection of sites as a result of this variability.

9.3 Land status and protection

Private Land

Many sites containing geothermal vegetation with significant conservation values are located on private land. Formal legal protection (e.g. by covenant) would be warranted for these sites. The current management of some privately-owned sites is ecologically unsustainable, and land management agencies need to consider opportunities to promote and fund physical protection and restoration works (e.g. fencing) for geothermal features in private ownership. Better engagement with private landowners/managers is warranted as management issues at some sites have changed little since the last survey several years previously, indicating that key messages are not being acknowledged or implemented.

Protected Sites

Some legally protected sites (e.g. reserves administered by District Councils or the Department of Conservation) require physical protection works, e.g. control of wilding pines. Change of management and/or ownership of some Department of Conservation land to Iwi has already provided opportunities for new restoration initiatives.

9.4 Ecological restoration

Ecological restoration of degraded geothermal sites would enhance the conservation values and viability of many areas - particularly the smaller areas. Restoration works have been undertaken in at least 18 sites in the Waikato Region, including Waikite Valley, Maungakakaramea (Rainbow Mountain), Waiotapu South, Waiotapu North, Waipapa Stream, Whangapoa Springs, Te Kopia, Orakeikorako, Red Hills, Orakonui, Craters of the Moon, Otumuheke Stream, Broadlands Road, Crown Road, Crown Park, Waipahihi, Rotokawa North, and Lake Rotokawa.

Successful restoration requires a sound ecological basis and an achievable vision. Examples of restoration works being undertaken include weed control at several sites, including radiata pine control over about 39 ha at Orakeikorako, radiata pine and

pampas control at Otumuheke Stream, control of pampas and planting of "closed" informal tracks to restore vegetation cover at Craters of the Moon, and local removal of fill previously placed on geothermal features (Crown Road).

Ecological restoration and pest plant control works are a high priority at 27 sites, as summarised in Table 12 below:

Table 12: High priority geothermal sites for restoration within the Waikato Region.

Geothermal Field	Site Name	Notes
Mokai	Waipapa Stream	Ongoing pest plant control.
Ngatamariki	Orakonui[1]	Ongoing pest plant control.
Ohaaki	Ohaaki Steamfield West	Ongoing pest plant control.
Orakeikorako	Waihunuhunu	Pest plant control.
	Orakeikorako	Ongoing pest plant control.
	Red Hills	Ongoing pest plant control.
Reporoa	Longview Road	Fencing, drainage, pest plant management.
Rotokawa	Rotokawa North	Wilding pines.
	Lake Rotokawa	Ongoing pest plant control.
Te Kopia	Te Kopia	Ongoing pest plant control.
	Murphy's Springs	Fencing and management of pest plants.
Tokaanu-Waihī-Hipaua	Hipaua	Pest plant control and surveillance.
	Tokaanu Thermal Park	Ornamental plants.
	Tokaanu Lakeshore Wetland	Pest plant control.
Waikite	Waikite Valley (including Upper Paeroa Scarp)	Ongoing. Particularly pest plants downstream of Te Manaroa Spring.
Waiotapu	Waiotapu North	Ongoing pest plant control.
	Waiotapu South	Wilding pine control is required. Control of pest plant and pest animal controls in wetlands.
	Maungaongaonga	Pest plant control.
	Maungakakaramea	Pest plant control.
Wairakei-Tauhara	Otumuheke Stream	Ongoing pest plant control.
	Crown Road	Pest plants, habitat loss.
	Te Rautehuia	Fencing, wilding pines.
	Te Rautehuia Stream	Fencing, wilding pines.
	Upper Wairakei Stream (Geyser Valley)	Pest plants.
	Te Kiri O Hine Kai Stream Catchment/ Wairoa Hill	Wilding pines and other pest plants.
	Waipahihi Stream/Valley	Pest plants.
	Craters of the Moon	Ongoing pest plant control.

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[1] Previously referred to as Ngatamariki.

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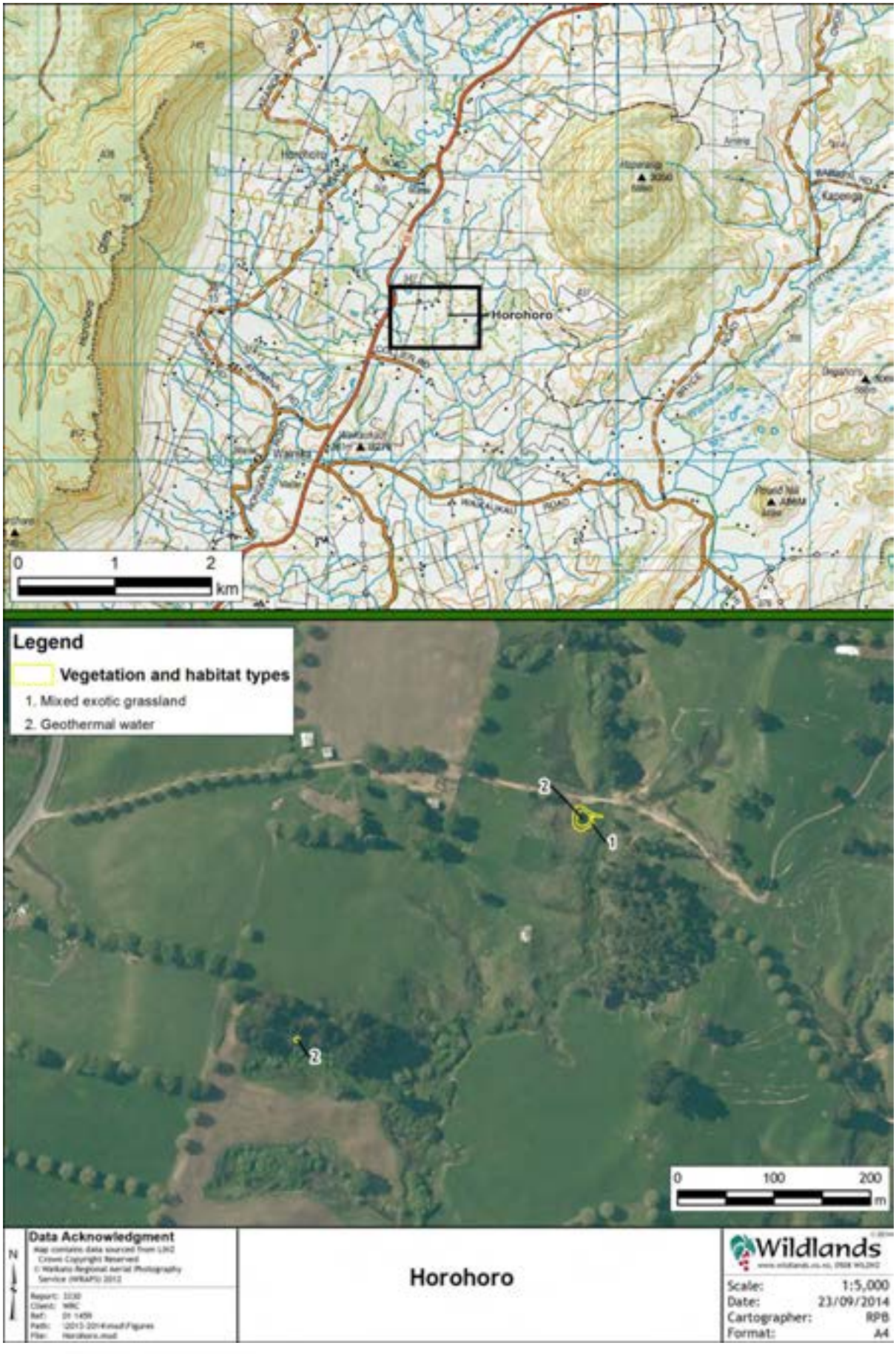
APPENDIX 1

SITE DESCRIPTIONS

HOROHORO GEOTHERMAL FIELD


Horohoro
0 1 2 km
Legend
Vegetation and habitat types
1. Mixed exotic grassland
2. Geothermal water
0 100 200 m
Data Acknowledgment
Horohoro
Wildlands
Scale: 1:5,000
Date: 23/09/2014
Cartographer: RPB
Format: A4

HOROHORO

Site Number: HHV01[1] **Grid Reference:** NZTopo50 BF37 782 616
Ecological District: Atiamuri **GPS Reference:** NZTM E1878243 N5761598
Geothermal Field: Horohoro **Local Authority:** Rotorua
Bioclimatic Zone: Submontane **Altitude:** 340 m
Tenure: Unprotected private land (Waipupumahana C - Maori freehold land)
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Most Recent Field Survey: 19 February 2014

VEGETATION TYPE	LANDFORM	EXTENT
Exotic grassland (08.01) **Mixed exotic grassland (08.01.15)** Exotic grassland dominated by narrow-leaved carpet grass (*Axonopus fissifolius*), Mercer grass (*Paspalum distichum*), Yorkshire fog (*Holcus lanatus*), browntop (*Agrostis capillaris*), and sweet vernal (*Anthoxanthum odoratum*), with scattered catsear (*Hypochaeris radicata*), white clover (*Trifolium repens*), red clover (*Trifolium pratense*), yarrow (*Achillea millefolium*), selfheal (*Prunella vulgaris*), and narrow-leaved plantain (*Plantago lanceolata*), surrounds a geothermal pool (*c.*10 × 10 m). Occasional emergent blackberry and Spanish heath are also present, along with scattered *Leucopogon fraseri* and *Blechnum penna-marina*. Harakeke (*Phormium tenax*) has been planted on banks above a small wetland. A few small patches of fernland dominated by *Gleichenia microphylla* are present near the water edge, along with patches of *Lycopodiella cernua* and *Campylopus clavatus*. Occasional kiokio (*Blechnum novae-zelandiae*), whekī-ponga (*Dicksonia fibrosa*) seedlings, and *Paesia scaberula* are present on banks above the pool. A small wetland dominated by *Eleocharis acuta*, track rush (*Juncus tenuis*), jointed rush (*Juncus articulatus*), soft rush (*Juncus effusus*), and water purslane (*Ludwigia palustris*) is present on the southern and western sides of the pool.	Hillslopes	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** Two geothermal pools are present. Pool 1: A round pool (*c.*10 × 10 m) located at NZTM E1878248 N5761608. This pool had abundant orange and green algae present. The maximum surface temperature was 48°C in 2014. Sinter is present in the pool at the pool outlet, and sinter deposits are present in the outflow stream. Pool 2 (NZTM E1877948 N5761370): A 2 m × 5 m pool is located *c.*400 m to the southwest of Pool 1. The maximum measured surface temperature was 55°C. The pool is located under a canopy	Open water	<0.1 ha

[1] Site number in 2004 was U16/9 (Wildland Consultants 2004c).

of maritime pine and grey willow. Scattered emergent grey willow and whekī-ponga over blackberry scrub are present on the southern margin of the pool. Exotic grassland occurs on the northern boundary. Only a narrow band of vegetation on pool margins appears to be geothermally influenced, with scattered kiokio, water fern (*Histiopteris incisa*) and *Carex virgata* present.		

Indigenous Flora: *Lycopodiella cernua*, a plant that is characteristic of geothermal areas, is present. Occasional *Leucopogon fraseri*, *Gleichenia microphylla*, and *Campylopus clavatus* are also present. *Nephrolepis flexuosa* (At Risk-Declining[1]) was recorded by Given in 1995 but was not present in 2003 or in 2014 and is presumed to be extinct at this site.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including spur-winged plover, silvereye, grey warbler, myna, goldfinch, and Eastern rosella. Cicadas and crickets were abundant, one dragonfly was seen.

Current Condition (2014 Assessment): Pool 1: The vegetation is highly modified with only occasional indigenous species present. Drains have been dug to control the pool outlet for bathing. An overflow drain is also present. Cattle sign was observed near pool margins.

Pool 2: Cattle sign was observed near pool margins.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): The geothermal pools are mostly surrounded by exotic pasture species. Pool 1: Blackberry (2% cover) and Spanish heath (2% cover). Pool 2: Maritime pine forms a canopy over the pool. Dense blackberry is present to the south of the pool with scattered emergent grey willow.

Human impacts (*2014 Assessment*): Pool 1: Modified outlet trench with concrete platform and temporary pool for bathing facilities. An overflow trench is also present. Site has lost most of its ecological values because pastoral farming operations have resulted in the disappearance of indigenous vegetation cover. Pool 2 is mostly surrounded by exotic species.

Grazing (*2014 Assessment*): Both pools are unfenced. Livestock grazing and trampling has modified the vegetation composition around the hot pools.

Adjoining land use (*2014 Assessment*): Farmland.

Site Change:

Recent change (2014 Assessment): Overall, sites appeared similar in both the 2003 and 2014 surveys.

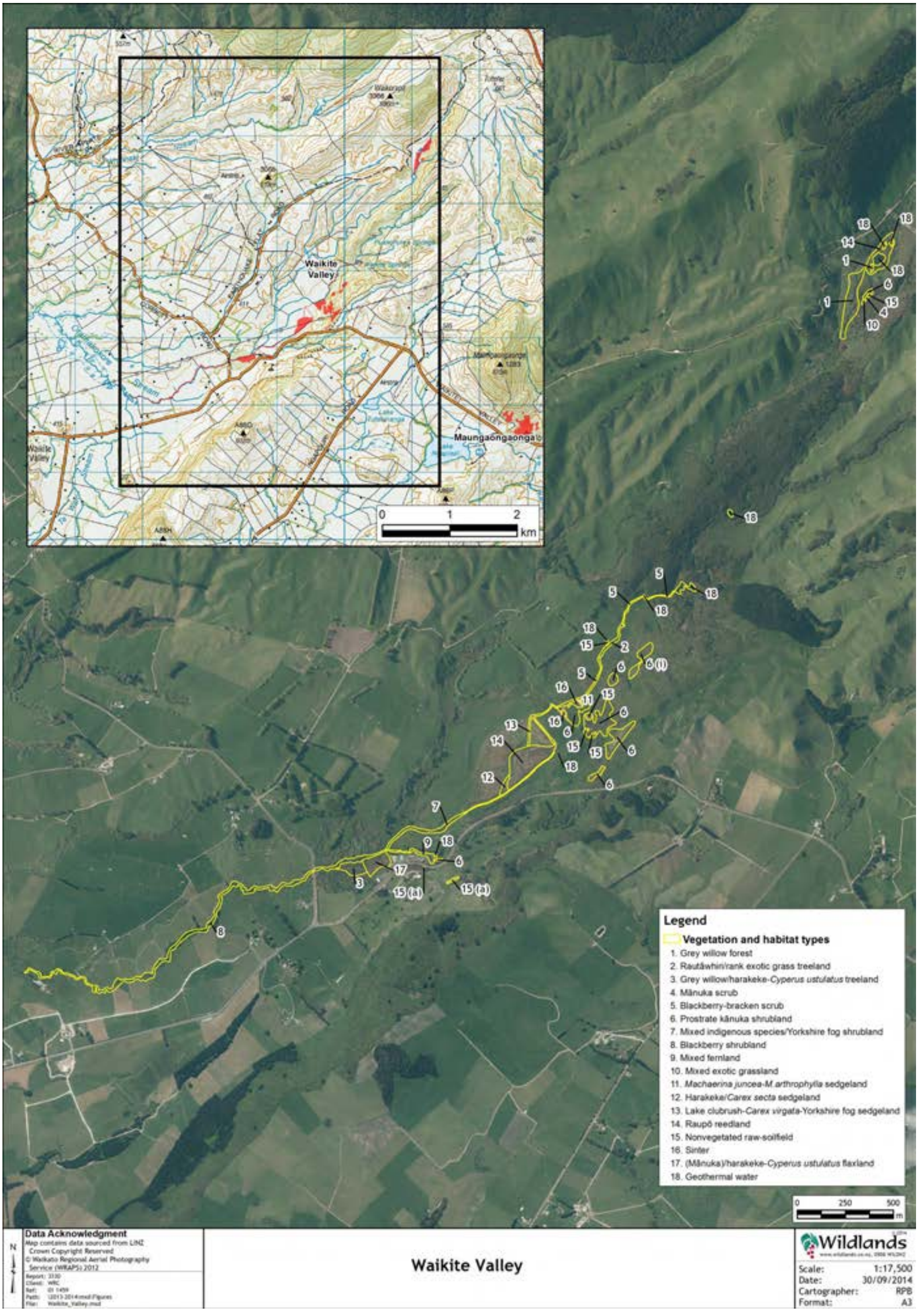
Historical This site is too small to identify any evidence of change since 1948[2].

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] Historical photo SN 255 Run 715 Photo 69, 1948.

(*Assessed in 2011*):

Management Requirements:	Indigenous values could be restored by fencing the pools to exclude grazing animals, and undertaking restoration planting around the pools. If the main pool (Pool 1) is fenced to exclude stock, *Nephrolepis flexuosa* could be reintroduced to the pool margins at this site.
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19).
Significance Justification:	The site is of local significance because it comprises a small example of geothermal habitat, a nationally uncommon habitat type.
Notes:	The small geothermal pools and small areas of geothermal substrate have potential for restoration if stock are excluded. Given (1995 & 1996) assessed the botanical value of many of the geothermal sites in the Waikato Region. In these studies, this site was ranked as 'D' in 1995 and 'C' in 1996 (an A ranking was given to the most significant sites). Waikato Regional Council (unpublished) named this site as Waipupumahana. It is used for recreational bathing; water in the larger pool is 40-50ºC.
References:	Given 1995 & 1996; Spring-Rice 1996; Waikato Regional Council unpublished; Wildland Consultants 2004c & 2012.

WAIKITE GEOTHERMAL FIELD


Waikite Valley
Maungaongaonga
0 1 2 km
0 250 500 m
Legend
Vegetation and habitat types
1. Grey willow forest
2. Rautāwhiri/rank exotic grass treeland
3. Grey willow/harakeke-Cyperus ustulatus treeland
4. Mānuka scrub
5. Blackberry-bracken scrub
6. Prostrate kānuka shrubland
7. Mixed indigenous species/Yorkshire fog shrubland
8. Blackberry shrubland
9. Mixed fernland
10. Mixed exotic grassland
11. Machaerina juncea-M. arthrophylla sedgeland
12. Harakeke/Carex secta sedgeland
13. Lake clubrush-Carex virgata-Yorkshire fog sedgeland
14. Raupō reedland
15. Nonvegetated raw-soilfield
16. Sinter
17. (Mānuka)/harakeke-Cyperus ustulatus flaxland
18. Geothermal water
Data Acknowledgment
Map contains data sourced from LINZ
Crown Copyright Reserved
© Waikato Regional Aerial Photography Service (WRAPS) 2012
Waikite Valley
Wildlands
Scale: 1:17,500
Date: 30/09/2014
Cartographer: RPB
Format: A3

WAIKITE VALLEY

Site Number: WAV01[1] **Grid Reference:** NZTopo50 BF37 890 529
Ecological District: Atiamuri **GPS Reference:** NZTM E1889034 N5752934
Geothermal Field: Waikite **Local Authority:** Rotorua
Bioclimatic Zone: Submontane **Altitude:** *c.*380-440 m
Tenure: Protected (Waikite Valley Scenic Reserve; Otamakokore Stream Marginal Strip; Waikite Wildlife Management Reserve) and unprotected private land.
Extent of Geothermal Habitat: *c.*20.7 ha
Extent of Geothermal Vegetation: *c.*19.9 ha
Date of Most Recent Field Survey: 23-25 July 2014

VEGETATION TYPE	LANDFORM	EXTENT
Exotic forest (01.02) **Grey willow forest (01.02.03)** Grey willow forms a canopy over *Carex secta* with local patches of raupō (*Typha orientalis*), *Machaerina rubiginosa*, and lake clubrush (*Schoenoplectus tabernaemontani*). Swamp kiokio (*Blechnum minus*), swamp millet (*Isachne globosa*), bracken (*Pteridium esculentum*), and harakeke are common. Areas of open water within this type support *Lemna minor* and water purslane. Where the willow canopy is less dense (or absent) scattered mānuka are present over *Machaerina rubiginosa* and *Carex secta* sedgeland or raupō and *Machaerina rubiginosa* reedland with local patches of lake clubrush. Other species common within these areas are swamp millet, kiokio, harakeke, and *Machaerina articulata*. Several areas with elevated water temperatures (up to 24 °C in 2014) are present. In one of these areas, *Cyclosorus interruptus* was common. A small population of *Thelypteris confluens* was present in this type in 2007 but was not observed in 2014.	Wetland	*c.*1.9 ha
Indigenous treeland (02.01) **Rautāwhiri/rank exotic grass treeland (02.01.01)** An incomplete canopy of planted rautāwhiri (*Pittosporum colensoi*) *c.*1.5 m height is present over rank grassland dominated by Yorkshire fog on the margins of a stream. *Christella* aff. *dentata* ("thermal") is abundant on the banks of the stream with locally common ring fern (*Paesia scaberula*), and occasional *Cyperus ustulatus*, *Carex secta*, and *C. virgata*.	Stream margin	*c.*0.3 ha
Exotic treeland (02.02) **Grey willow/harakeke-*Cyperus ustulatus* treeland (02.02.01)** Grey willow forms a discontinuous canopy over harakeke, and *Cyperus ustulatus*. Swamp kiokio, *Carex secta,* and *C. virgata* are also present. (This area was viewed from the margins as it was not safe to enter.)	Wetland	*c.*0.7 ha

[1] Site number in 2004 was U16/6 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
Mānuka-dominant scrub (04.04) **Mānuka scrub (04.04.01)** Mānuka forms a canopy up to *c.*2 m height. Occasional tūrutu are present in the groundcover.	Flat	<0.1 ha
Exotic species-dominant scrub (04.10) **Blackberry-bracken scrub (04.10.05)** Dense scrub dominated by blackberry and bracken is present along the margins of the main stream within the site. Kiokio and *Hypolepis ambigua* are common within this type with occasional *Cyperus ustulatus* and karamū (*Coprosma robusta*). There are local patches of kōhūhū and occasional emergent barberry (*Berberis glaucocarpa*). Scattered plants of *Christella* aff. *dentata* ("thermal") and occasional *Cyclosorus interruptus* are also present.	Stream margins	*c.*0.4 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka forms a canopy 0.5-1.5 m height around loamfields, fumaroles, and boiling mud. Scattered mingimingi and occasional Spanish heath are also present. Mats of moss (*Campylopus* sp. and *Sphagnum cristatum*) with local patches of *Nephrolepis flexuosa* and wild portulaca (*Portulaca oleracea*) form a sparse groundcover. A few patches of *Cheilanthes sieberi* are present in one part of this type. Parts of this type are surrounded by pasture and are grazed by domestic stock.	Flat, gentle slopes, scarp	*c.*4.8 ha
Mixed indigeous species shrubland (05.07) **Mixed indigenous species/Yorkshire fog shrubland (05.07.03)** Planted woody indigenous species form an incomplete canopy over rank Yorkshire fog grassland on the margins of the Otamakokore Stream. The stream banks have local patches of water fern and *Hypolepis ambigua*, and scattered patches of *Christella* aff. *dentata* ("thermal"). Planted indigenous tree species include tī kōuka (*Cordyline australis*), kōhūhū (*Pittosporum tenuifolium*), tarata (*Pittosporum eugenioides*), rautāwhiri, mānuka, and harakeke. Occasional patches of naturally occurring prostrate kānuka and whekī are also present within this type.	Riparian margin	*c.*1.1 ha
Exotic-dominant shrubland (05.09) **Blackberry shrubland (05.09.04)** West of the Corbett Road Bridge, the margins of Otamakokore Stream are dominated by blackberry, with bracken and cocksfoot (*Dactylis glomerata*) common. Patches of *Carex geminata*, ring fern, kiokio, *Muehlenbeckia australis*, *Deparia petersenii*, and swamp millet are locally common. Clumps of mature *Christella* aff. *dentata* ("thermal") are scattered along the stream margins with local patches of *Nephrolepis flexuosa*. Other species occurring along the stream margin include *Hypolepis distans, H. ambigua,* water fern, ivy, feijoa (*Feijoa sellowiana*), Lawson's cypress, Lombardy poplar (*Populus nigra* 'Italica'), and pampas, with local barberry, kōhūhū, karamū, and tī kōuka. The site margins are fenced and a small section has been planted in indigenous species, predominantly tī kōuka, kōhūhū, and	Stream margins	*c.*3.6 ha

VEGETATION TYPE	LANDFORM	EXTENT
harakeke. Small areas of Yorkshire fog-cocksfoot grassland are present within this type but are too small to map separately.		
Indigenous fernland (07.01) **Mixed fernland (07.01.07)** A mosaic of several fern species, including *Nephrolepis flexuosa*, *Dicranopteris linearis*, *Deparia petersenii*, and water fern surround the Te-Manaroa Hot Spring and the margins of the stream that flows from the spring. Scattered *Christella* aff. *dentata* ("thermal") are present downstream of the spring. Local patches of *Lycopodiella cernua*, bracken, kiokio, and *Hypolepis ambigua* are also present in this area, with occasional kōhūhū, karamū, whauwhaupaku (*Pseudopanax arboreus*), and kāmahi (*Weinmannia racemosa*) on higher, cooler areas. Blackberry and bracken become more abundant along stream margins downstream of the Waikite Pools. In places along the stream margins *Cyperus involucratus* and ivy have spread into indigenous geothermal vegetation.	Stream gully	*c.*0.3 ha
Exotic grassland (08.01) **Mixed exotic grassland (08.01.15)** Grassland dominated by narrow-leaved carpet grass with local Mercer grass. Small areas of nonvegetated raw-soilfield are present.	Flat areas and gentle slopes at the foot of scarp	<0.1 ha
Indigenous sedgeland (09.01) ***Machaerina juncea-M.arthrophylla* sedgeland (09.01.09)** Scattered emergent mānuka are present over sedgeland dominated by *Machaerina juncea* and *M. arthrophylla*. Local patches of lake clubrush are present. *Cyclosorus interruptus* is scattered along the stream margin. Seepages on terraces within this type have arrow grass grassland, fringed by narrow-leaved carpet grass on dry edges. Blackberry is common on drier, raised areas within this type. **Harakeke/*Carex secta* sedgeland (09.01.10)** Harakeke is emergent over sedgeland dominated by *Carex secta*. Occasional emergent mānuka are present. **Lake clubrush-*Carex virgata*-Yorkshire fog sedgeland (09.01.12)** Lake clubrush and *Carex virgata* sedgeland is present on the margins of a geothermally influenced stream. Yorkshire fog is common.	Riparian wetland Riparian margin Riparian margin	*c.*0.3 ha *c.*0.2 ha *c.*0.4 ha
Raupō-dominant reedland (11.01) **Raupō reedland (11.01.01)** Occasional emergent mānuka are present over raupō with harakeke locally common. *Carex secta*, *Cyperus ustulatus,* lake clubrush, and *Machaerina rubiginosa* are common within this type. Blackberry and bracken are common around the margins. *Nephrolepis flexuosa* and *Christella* aff. *dentata* ("thermal") occur locally where hot water flows into the reedland.	Flat/wetland	*c.*4.1 ha

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Thermally altered clay and fumaroles. Occasional prostrate kānuka, *Cyperus ustulatus*, *Lycopodiella cernua*, and mosses are present in parts of this type. Narrow-leaved carpet grass and Yorkshire fog are common on the cooler margins in parts of this type. In Area A, occasional *Cheilanthes sieberi* and wild portulaca are present on the non-vegetated raw-soilfield, and *Nephrolepis flexuosa* is present beneath Spanish heath on the upper margins. **Sinter (20.01.01)** Sinter terrace	Hillslopes, gentle slope Flat	*c.*0.3 ha *c.*0.3 ha
Flaxland (21.01) **(Mānuka)/harakeke-*Cyperus ustulatus* flaxland (21.01.01)** Scattered mānuka are present over harakeke, and *Cyperus ustulatus*, with local patches of raupō, *Machaerina juncea,* and lake clubrush. Swamp kiokio, *Carex secta,* and *C. virgata* are also present. Grey willow is common on the southern margin of this type. Blackberry, bracken, *Hypolepis ambigua*, creeping buttercup (*Ranunculus repens*), and exotic grasses occur on dryer, cooler soils. Seepages of hot water are scattered throughout. *Christella* aff. *dentata* ("thermal") occurs near several of these seepages. *Cyperus involucratus* is locally common on the southern margin of this area.	Wetland	*c.*1.0 ha
Water (22.01) **Geothermal water (22.01.01)** Hot springs, geothermally influenced ponds and streams.	Flat, gully	*c.*0.8 ha

Indigenous Flora:

Seven 'At Risk' indigenous plant species[1] are present within this site: *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon), *Cyclosorus interruptus* (At Risk-Declining), *Dicranopteris linearis* (At Risk-Naturally Uncommon), *Hypolepis dicksonioides* (At Risk-Naturally Uncommon), prostrate kānuka (At Risk-Naturally Uncommon), *Nephrolepis flexuosa* (At Risk-Declining), and *Thelypteris confluens* (At Risk-Naturally Uncommon).

A large population of *Christella* aff. *dentata* ("thermal") is present at this site. Bycroft and Beadel (2007) estimated that there were *c.*400 plants at this site in 2007. One hundred and sixty-two clumps of *Christella* aff. *dentata* ("thermal") were noted at this site in 2014 but this does not represent the entire extent of the population at the site as undertaking a detailed inventory of the population was outside of the scope of the current project.

Scattered populations of *Nephrolepis flexuosa* are present alongside stream margins, Waikite scarp, within prostrate kānuka shrubland, and beside geothermal wetlands at the site. Bycroft and Beadel (2007) estimated that there were *c.*100 clumps of *N. flexuosa* at the Waikite site. In 2014,

[1] All flora threat rankings are from de Lange *et al.* 2013.

N. flexuosa was particularly abundant around the Te Manaroa hot spring and on stream margins near E1889533, N5753311. The stream margin population of *N. flexuosa* mentioned previously has increased significantly since a fence has been erected along the stream margins to exclude domestic stock.

Also present within the site are small populations of *Dicranopteris linearis* and *Hypolepis dicksonioides*. Bycroft and Beadel (2007) recorded ten plants of *H. dicksonioides* from this site in 2007 and nine were recorded in 2014. All plants recorded were located downstream of the Corbett Road Bridge. Bycroft and Beadel (2007) also estimated that there were about 20 clumps of *D. linearis* spread between Te Manaroa Hot Spring and Waikite Scarp. *D. linearis* is known from only *c.*23 sites in New Zealand.

Several populations of *Cyclosorus interruptus* and *Thelypteris confluens* are present. Generally these populations cover small areas but are often relatively healthy within those areas, e.g. over 800 fronds of *Thelypteris confluens* occurred in over two distinct areas of *c.*10 m^2 (Bycroft and Beadel 2007). Although the populations of *T. confluens* were not found in 2014, they are likely to still be present, as this species is inconspicuous or not visible after dieback in winter. Some of the *Cyclosorus interruptus* plants are threatened by stock. Bycroft and Beadel (2007) identified two distinct populations of *C. interruptus* at this site: sixteen clumps were recorded in Waikite Wildlife Management Reserve, while another eight clumps were recorded on Waikite Landcorp Farm. The Landcorp Farm plants were threatened by grazing, but more recently stock have been excluded from most of this area, protecting most of these plants from grazing by stock.

Prostrate kānuka and *Campylopus clavatus*, which are both endemic and restricted to geothermal areas, occur at this site.

One *Psilotum nudum* plant was observed in an area of prostrate kānuka shrubland in the northeast of the site (Waikite Wildlife Management Reserve) in 2014; *P. nudum* had previously only been recorded from this site historically (Ecroyd and Coham 1976). *Lycopodiella cernua*, *Cheilanthes sieberi*, *Machaerina juncea*, *M. arthrophylla,* arrow grass, wīwī, and *Doodia australis* also occur here.

Fauna:

North Island fernbird (At Risk-Declining[1]) were recorded from the site in 2014 along with several common indigenous and introduced bird species including tomtit, whitehead, welcome swallow, bellbird, pukeko, grey warbler, Australasian harrier, paradise shelduck, fantail, spur-winged plover, common pheasant, Australian magpie, and mallard. Based on the 2014 survey, the population of North Island fernbird appeared healthy in the wetland and scrub upstream of the Corbett Road Bridge. Other bird species previously recorded at the site include spotless crake (At Risk-Relict), pied stilt (At Risk-Declining), grey duck (Threatened-Nationally Critical), silvereye, greenfinch, yellowhammer, and Eurasian blackbird.

Pig sign (scat and rooting), rabbit sign (scat), hares (observed), and goat sign (scat) were observed within the site.

[1] All avifauna threat rankings are from Robertson *et al.* 2013.

Current Condition (2014 Assessment):

The geothermal vegetation ranges from very high ecological quality to moderately poor quality. The areas where vegetation quality is poor is predominantly due to a high density of adventive species. The geothermal vegetation is discontinuous and is often surrounded by vegetation dominated by adventive species. Although many key geothermal areas are fenced, the margins are heavily infested with blackberry. Some populations of thermal ferns are open to stock access.

Part of the fenced paddock adjacent to the rediverted geothermal stream is reverting to predominantly indigenous-dominated vegetation. Invasive pest plant species are present in this area but are currently present at low density and cover. The vegetation composition of this area is likely to continue to change over the next five to ten years. The location of the stream rediversion is thought to reflect the original location of the stream prior to human modification.

Blackberry is locally invading geothermal habitat around some drains, and competing for habitat with 'At Risk' ferns. The entire length of the main geothermal stream that passes through the site has been fenced to exclude stock. Some restoration planting with indigenous species has been undertaken. As a result of fencing of the stream margins, many areas of 'At Risk' ferns previously threatened by stock grazing and tramping on stream margins are now recovering and are in good health.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*):

Invasive exotic plants are common within the site. Estimates of the percentage of cover of invasive pest plants given here are an average cover for the entire site. Locally, covers may therefore be much larger than what is represented here. Blackberry is common to locally abundant throughout (*c.*20% cover) and grey willow is locally dominant (*c.*2% cover). Other invasive pest plant species present include broom (<1% cover), barberry (*c.*1% cover), Chinese privet (<1% cover), common alder (*Alnus glutinosa*) (*c.*1% cover), *Cyperus involucratus* (*c.*2% cover), elephant's ear (*Alocasia brisbanensis*) (<1% cover), ivy (*c.*2% cover), Japanese honeysuckle (*Lonicera japonica*) (<1% cover), Khasia berry (<1% cover), Lombardy poplar (2% cover), pampas (<1% cover), Spanish heath (*c.*1% cover), and tradescantia (*Tradescantia fluminensis*) (<1% cover).

The *Cyperus involucratus* population near the Te Manaroa spring has spread noticeably since 2011, and reaches 90% cover on some stream banks within the site. However the geothermal stream may be acting as a barrier to the further spread of this species, as *C. involucratus* does not appear to have spread to the opposite bank of the stream; this indicates that this species is spreading vegetatively at the site. Ivy has also spread noticeably within this area since 2007.

Human impacts (*2014 Assessment*):

Human impacts associated with the public thermal baths are the responsibility of the Rotorua District Council who has specific management policies for its biological features (Rotorua District Council 1994). Geothermal water is used in the swimming and bathing pools at the site.

A path is present from the public thermal baths to Te-Manaroa Spring. A small amount of rubbish was present around this path.

A portion of the thermal stream has been rediverted and some restoration planting has occurred on the margins (see above). Vegetation composition change is likely to occur in this area over time.

Grazing (*2014 Assessment*): The entire length of the main geothermal section of Otamakokore Stream within this site has been fenced to exclude domestic stock. Most of this fencing has taken place since 2007. The central wetland north and north-east of the pool complex is also fenced.

Stock are excluded from most parts of Waikite Scarp.

The wetland near the pool complex and Te Manaroa Hot Springs are not grazed by stock.

The northernmost parts of the site are not fenced and many geothermal features are grazed to the margins.

Adjoining land use (*2014 Assessments*): Farmland and public thermal baths.

Site Change:

Recent change (2014 Assessment): Indigenous species are starting to re-establish and become dominant in the wetland and adjacent damp paddock in the centre of the site as a result of stream diversion, management to raise water tables (to negate impacts of drains), restoration planting, and fencing to exclude stock. The main wetland is now dominated by harakeke rather than raupō, and indigenous and exotic rushes and indigenous sedges have colonised and established within the adjacent paddock. The restoration works within this part of the site have been funded by the Wairakei Environmental Mitigation Charitable Trust. The entire length of the main stream that passes through the site has been fenced to exclude stock, and some restoration planting with indigenous species has been undertaken. The vegetative character of these areas is likely to change over the next five to ten years as vegetation is released from grazing pressure.

Other than natural fluctuations in vegetation composition, most changes to the mapped vegetation extent within the site since 2011 are a result of better quality aerial photographs being available in 2014. A small area of geothermal habitat within the Waikite Valley golf course has been added to the southern side of the site. This area has been overlooked during previous studies and does not represent new geothermal activity.

Historical (*Assessed in 2011*): It appears that the extent of geothermal vegetation and habitats has been reduced since 1961[1]. Geothermal vegetation/habitats have been removed to construct the commercial pool complex and in paces have been replaced with farmland. Semi-heated nonvegetated raw-soilfield on Waikite Scarp has been invaded by blackberry and broom scrub. It is difficult to make out the boundaries between geothermally-influenced scrub and other scrub habitats on Waikite Scarp in 1961 photographs. The wetlands on the Landcorp Farm, north of Waikite Valley Road, and the pool complex were

[1] Historical photo: SN 1394 Run 3170 Photos 18-20, 1961.

grazed, with an extensive drain network similar to those observed in the field surveys undertaken. The wetland above the Corbett Road bridge and the vegetation around Te Manaroa Hot Spring appear similar in extent to the current day. Below the Corbett Road bridge there has probably been little change to the extent of the geothermal vegetation between 1961 and the present day. It is likely that the stream margins have been fenced at some locations, however the buffer of scrub around the stream was wider in other locations in 1961 than it is today. Only the upstream section of Otamakokore Stream was viewed on the 1961 aerial photographs.

Management Requirements:

Blackberry is well established along stream margins in some places and will be difficult to control without damaging the indigenous vegetation. Regular surveillance and control of pest plant species (particularly blackberry) within recently fenced stream margins would be beneficial to ensure unwanted exotic species do not get established in these areas. Unfenced geothermal vegetation and habitats should be fenced to exclude domestic stock.

Pest plants have become a major management issue downstream of Te Manaroa Spring. Ivy is smothering populations of *Nephrolepis flexuosa*, and banks above the stream have become locally dominated by *Cyperus involucratus*. Both of these species require urgent control before they spread further within this site and potentially into other nearby geothermal sites. An ecological restoration plan (including an implementation plan) should be prepared for the highest priority areas of geothermal vegetation at the site. High priority areas include vegetation surrounding Te Manaroa Spring downstream to the pool facilities, the wetland on the old Landcorp farm to the north of Te Manaroa Spring, Waikate Wildlife Management Reserve, and *Christella* aff. *dentata* ("thermal") habitat near, and downstream, of Corbett Road Bridge.

Significance Level:

National (Table 1 - Criteria 1, 3, 5, 7, 9; Table 2 - Factor 8).

Significance Justification:

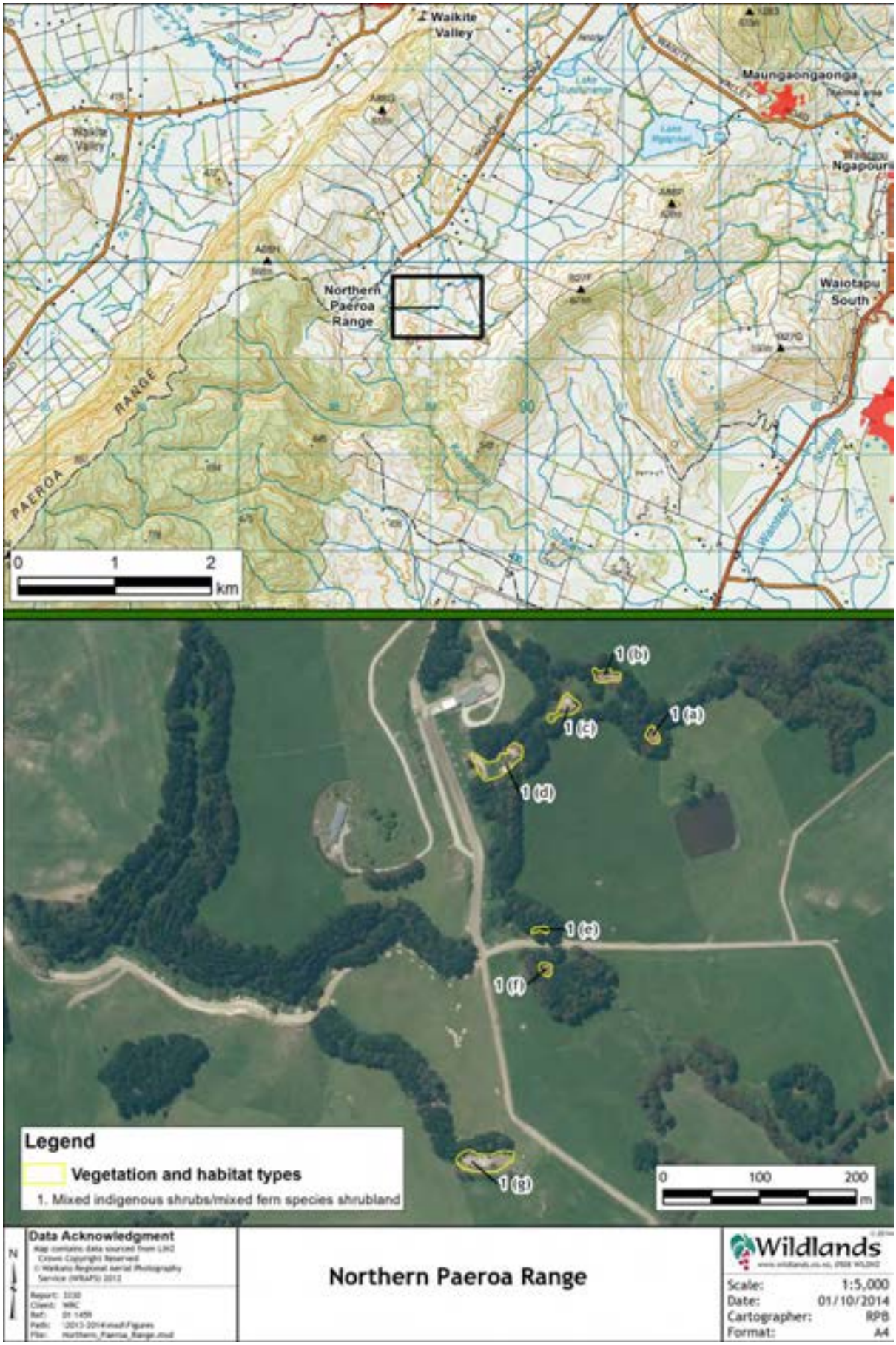
This site is nationally significant because it contains good quality, high diversity, and representative examples of geothermal habitat types that are nationally uncommon (fumaroles, geothermal streamsides, geothermally heated dry ground) (Williams *et al*. 2007; Holdaway *et al.* 2012). The site also contains a large population of an 'At Risk' plant species (*Christella* aff. *dentata* ("thermal") that is known at only 15 sites in the North Island. Six other 'At Risk' plant species are also present. Three 'At Risk' indigenous bird species are also present at the site: Spotless crake, North Island fernbird, and pied stilt.

Notes:

This site comprises three areas ranked in Given (1996): "Waikite Valley", "Paeroa Scarp", and "Otamakokore Stream";, these sites were ranked as Category A, Category B, and Category B respectively.

References:

Beadel 1995b; Beadel and Bill 2000; Bycroft and Beadel 2007; Ecroyd and Coham 1976; Given 1996; Miller and Ecroyd 1993; Rotorua District Council 1994; Wildland Consultants 2004c, 2007b, & 2012.


Waikite Valley
Maungaongaonga
Ngapouri
Waiotapu South
Northern Paeroa Range
PAEROA RANGE
0 1 2 km
1 (b)
1 (e)
1 (a)
1 (d)
1 (c)
1 (f)
1 (g)
Legend
Vegetation and habitat types
1. Mixed indigenous shrubs/mixed fern species shrubland
0 100 200 m
Data Acknowledgment
Northern Paeroa Range
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

NORTHERN PAEROA RANGE

Site Number:	WAV02[1]	**Grid Reference:**	NZTopo50 BF37 891 497
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1889118, N5749700
Geothermal Field:	Waikite	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	520 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*0.3 ha		
Extent of Geothermal Vegetation:	*c.*0.3 ha		
Date of Most Recent Field Survey:	29 and 30 June 2010		

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** This site comprises seven areas of nonvegetated raw-soilfield located within gullies housing a tributary of the Kawaunui Stream. Area A: Nonvegetated raw-soilfield surrounded by plantation pines with an understorey of mānuka shrubland and small patches of Yorkshire fog. While this area has been active in the recent past, no steaming was evident during the 2010 site visit. This area was viewed with binoculars from across the creek. Area B: Nonvegetated raw-soilfield with abundant pine needles, several prostrate kānuka plants, and occasional browntop. A concrete pipe is present in the hottest area of geothermal activity. The loamfield is surrounded by maritime pine forest with a mānuka subcanopy to *c.*3 m, and occasional mingimingi, grey willow, and blackberry. Area C: Nonvegetated raw-soilfield. The site is surrounded by pine plantation and mānuka-mingimingi scrub with occasional blackberry, broom, and bracken, and several small patches of Yorkshire fog grassland. Area D: This area is predominantly exposed geothermal clays surrounded by plantation forest. There has been geothermal activity previously within this are, although no geothermal activity was evident during the 2010 inspection. Occasional mānuka to 3 m height, water fern, and mingimingi are present on the margins. A small wetland <5 × 5 m is also present within this area, with *Juncus edgariae* and rank exotic grasses, including Yorkshire fog and browntop. Area E: A small area of nonvegetated raw-soilfield surrounded by pine plantation with mānuka and mingimingi, and occasional water fern and bracken, in the understorey, with occasional Yorkshire fog, sweet vernal, mānuka seedlings, and prostrate kānuka. Area F: Nonvegetated raw-soilfield surrounded by pine and eucalyptus plantation. One monoao plant and five prostrate kānuka	Gully (Area D is gully and wetland)	*c.*0.3 ha

[1] Site number in 2004 was U17/36 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
plants are present on the loamfield. Area G: Nonvegetated raw-soilfield. Occasional mānuka and prostrate kānuka are present on the margins of the raw-soilfield, and occasional sweet vernal and browntop are present on cooler parts of raw-soilfield. *Juncus prismatocarpus* is present by a warm spring. This area is surrounded by plantation pine and planted eucalyptus to *c.*12 m tall, with an understorey of mānuka with broom and bracken and common.		

Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]) is present as occasional scattered plants within parts of the site. Other species typical of geothermal habitats present include mānuka, bracken, mingimingi, and water fern.

Fauna: Common indigenous and exotic bird species are present including grey warbler, Australian magpie, and spur-winged plover. Cattle sign and rabbits were also present.

Current Condition (2011 Assessment): In a moderate condition. Most features have had some impact from stock and are surrounded by exotic plantation forest. A concrete pipe has been constructed within one geothermal feature.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Most areas of geothermally-altered soils are largely devoid of vegetation. Blackberry and grey willow are locally common on margins. Management of pest plants at this site is of lower priority compared with other geothermal sites in the Waikato Region.

Human impacts (*2011 Assessment*): A concrete pipe is present in Area B.

Grazing (*2011 Assessment*): While all sites are fenced, stock sign was present in most sites.

Adjoining land use (*2011 Assessment*): Exotic plantation forest, farming, riparian margin vegetation.

Site Change:

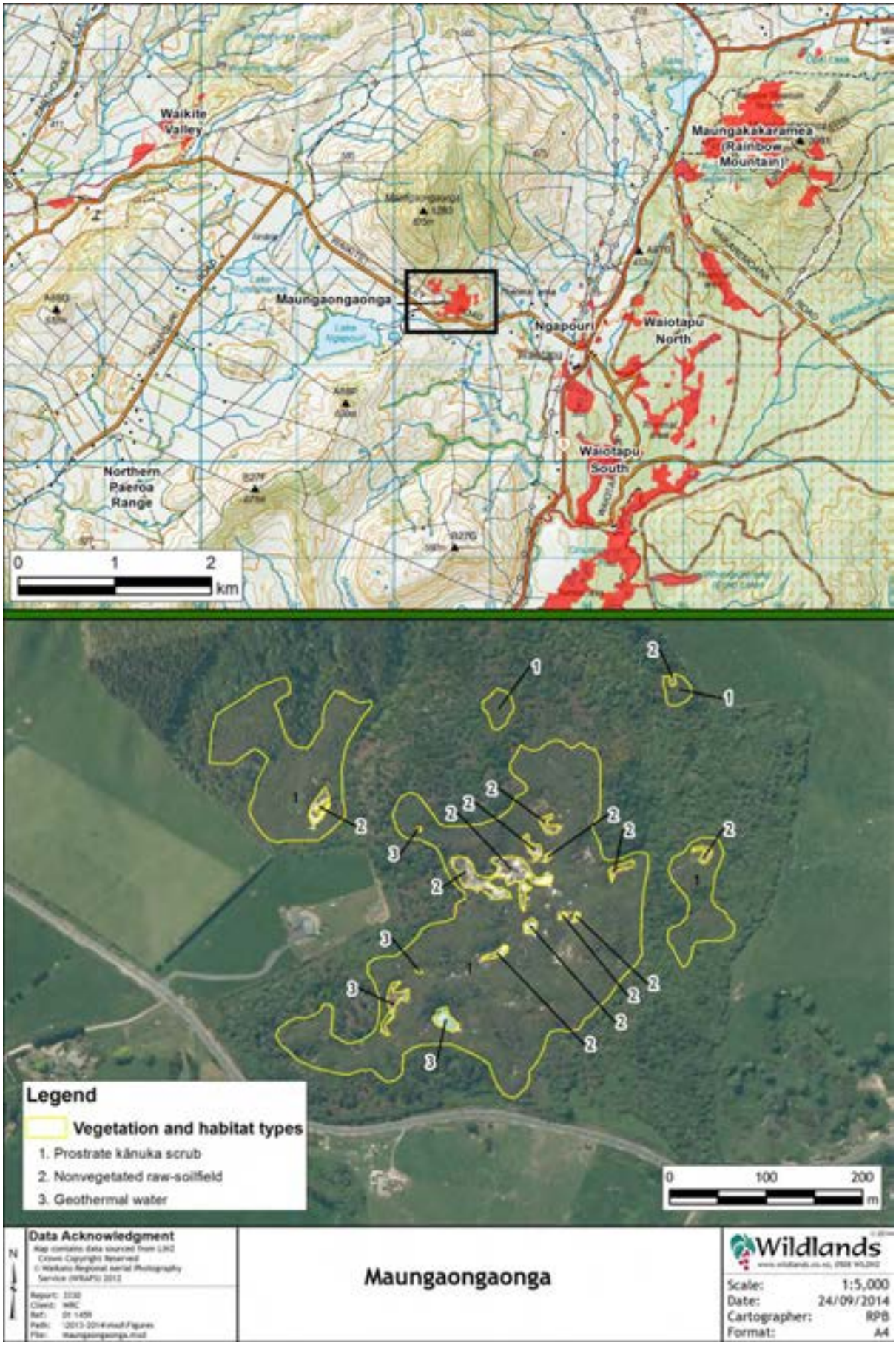
Recent change (2014 Assessment): This site was not visited during the 2014 geothermal survey of geothermal vegetation in the Waikato Region, however the site appears similar in extent when comparing 2007 and 2012 aerial photographs.

Historical (*Assessed in 2011*): Site not assessed, no historical photos found. The surrounding land use was previously pastoral and is currently plantation forestry. As most sites are in gullies and relatively small it is unlikely that changes will be visible on black and white aerial photographs.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Management Requirements:	Fences should be maintained to ensure stock cannot access site. Consider management of pest plants (e.g. willows). This site is a lower priority for pest plant control than most other geothermal sites in the Waikato Region. Care should be undertaken when felling the pine trees that surround some of the site to not damage geothermal features or indigenous geothermal vegetation.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19)
Significance Justification:	Northern Paeroa Range is locally significant because it comprises several small examples of a nationally uncommon habitat type (geothermally heated dry ground, hydrothermally altered ground; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also provides habitat for a very small population of an At Risk plant species (prostrate kānuka) but does not represent habitat of considerable importance for the conservation of this species.
Notes:	A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010 (University of Auckland).
References:	Wildland Consultants 2004c & 2012.

WAIOTAPU GEOTHERMAL FIELD


Waikite Valley
Maungakakaramea (Rainbow Mountain)
Maungaongaonga
Ngapouri
Waiotapu North
Waiotapu South
Northern Paeroa Range
0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Nonvegetated raw-soilfield
3. Geothermal water
0 100 200 m
Data Acknowledgment
Maungaongaonga
Wildlands
Scale: 1:5,000
Date: 24/09/2014
Cartographer: RPB
Format: A4

MAUNGAONGAONGA

Site Number:	WTV01[1]	**Grid Reference:**	NZTopo50 BF37 926 516
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1892615 N5751642
Geothermal Field:	Waiotapu	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*540 m
Tenure:	Protected (Maungaongaonga Scenic Reserve)		
Extent of Geothermal Habitat:	*c* 8.7 ha		
Extent of Geothermal Vegetation:	*c* 8.7 ha		
Date of Most Recent Field Survey:	7 and 16 May 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** A dense canopy of prostrate kānuka with an average height of 1 m (but up to 2 m high) dominates this area, in association with locally scattered mānuka, mingimingi, and local patches of monoao (up to 50% cover in places). The groundcover is dominated by mosses (*Dicranoloma billardierei* and *Sphagnum cristatum*) with local scattered tūrutu and hound's tongue fern (*Microsorum pustulatum*). Mānuka and monoao form a dense scrub up to 2 m high, in association with prickly mingimingi (*Leptecophylla juniperina* subsp. *juniperina*) and locally scattered whauwhaupaku. Kāmahi and toru (*Toronia toru*) occur on several rocky outcrops. The groundcover associated with these outcrops comprises scattered tūrutu with local *Gleichenia microphylla* and occasional hound's tongue fern. Small patches of *Nephrolepis flexuosa* and *Dicranopteris linearis* are present beneath the prostrate kānuka canopy.	Hillslope and rocky outcrops	*c.*8.3 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01[2])** Prostrate kānuka forms a low discontinuous canopy (*c.*0.1-1.0 m high) in association with scattered monoao and mingimingi. The groundcover comprises dense cushions of mosses with *Campylopus* spp. (including *C. clavatus*) covering *c.*30% of the area. *Dicranoloma billardierei, Sphagnum cristatum,* and lichens (e.g. *Cladonia* sp. and *Cladia* sp.) are also present. *Lycopodiella cernua* is locally present in areas of relatively high geothermal activity. Water fern is common near steam vents. This vegetation type occurs sporadically amongst the prostrate kānuka scrub. The orange algae *Trentepohlia* is abundant on prostrate kānuka and monoao branches.	Hillslope	Not mapped
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Geothermal clays, mud pools, geothermally altered soils, and fumaroles.	Hillslope	*c.*0.4 ha

[1] Site number in 2004 was U16/11 (Wildland Consultants 2004c).

[2] Small areas of this vegetation type also occur within the area mapped as 04.01.01, however these were too small to be mapped separately.

VEGETATION TYPE	LANDFORM	EXTENT
Water (22.01) **Geothermal water (22.01.01)** Geothermal water, mudpools	Flat	<0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Declining[1]), a species endemic to geothermal areas, is present. A population of *Korthalsella salicornioides*, a semi-parasitic mistletoe (At Risk-Naturally Uncommon), is also present.

A few patches of *Nephrolepis flexuosa* (At Risk-Declining), a species confined to geothermal areas in the North Island in New Zealand, and at least 50 plants of *Dicranopteris linearis* (At Risk-Naturally Uncommon), are also present at this site (population numbers based on 2004 field assessment). *D. linearis* is known from only *c.*23 sites in New Zealand).

Other species of interest present are *Schizaea bifida* (recorded by Beadel 1995a) and *Lycopodiella cernua*. *S. bifida* was not recorded in the 2004 or 2014 surveys.

Fauna: Common indigenous and introduced bird species typical of the habitat present include tūī, silvereye, fantail, Australasian harrier, Australian magpie, Eurasian blackbird, and goldfinch.

Current Condition (2014 Assessment): The geothermal vegetation is largely unmodified. It is relatively untracked (by humans), and adventive species are not common.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Weeds are present at low density and extent at this site. The main weed species present are blackberry (1% cover), radiata pine (<1% cover), Douglas fir (*Pseudotsuga menziesii*) (<1% cover), Spanish heath (<1% cover), gorse (<1% cover), and narrow-leaved carpet grass (<1% cover). The distribution of pest plants in Maungaongaonga Scenic Reserve in 1998 was mapped and described in Bibby *et al.* (1998).

Human impacts (*2014 Assessment*): This site is vulnerable to damage from human trampling, as can be seen from the vegetation destruction associated with an informal track (Beadel 1995a). Informal tracks are used occasionally be local residents and hunters.

Grazing (*2014 Assessment*): Livestock are not a threat to this area.

Adjoining land use (*2014 Assessment*): Farmland, indigenous forest and scrub.

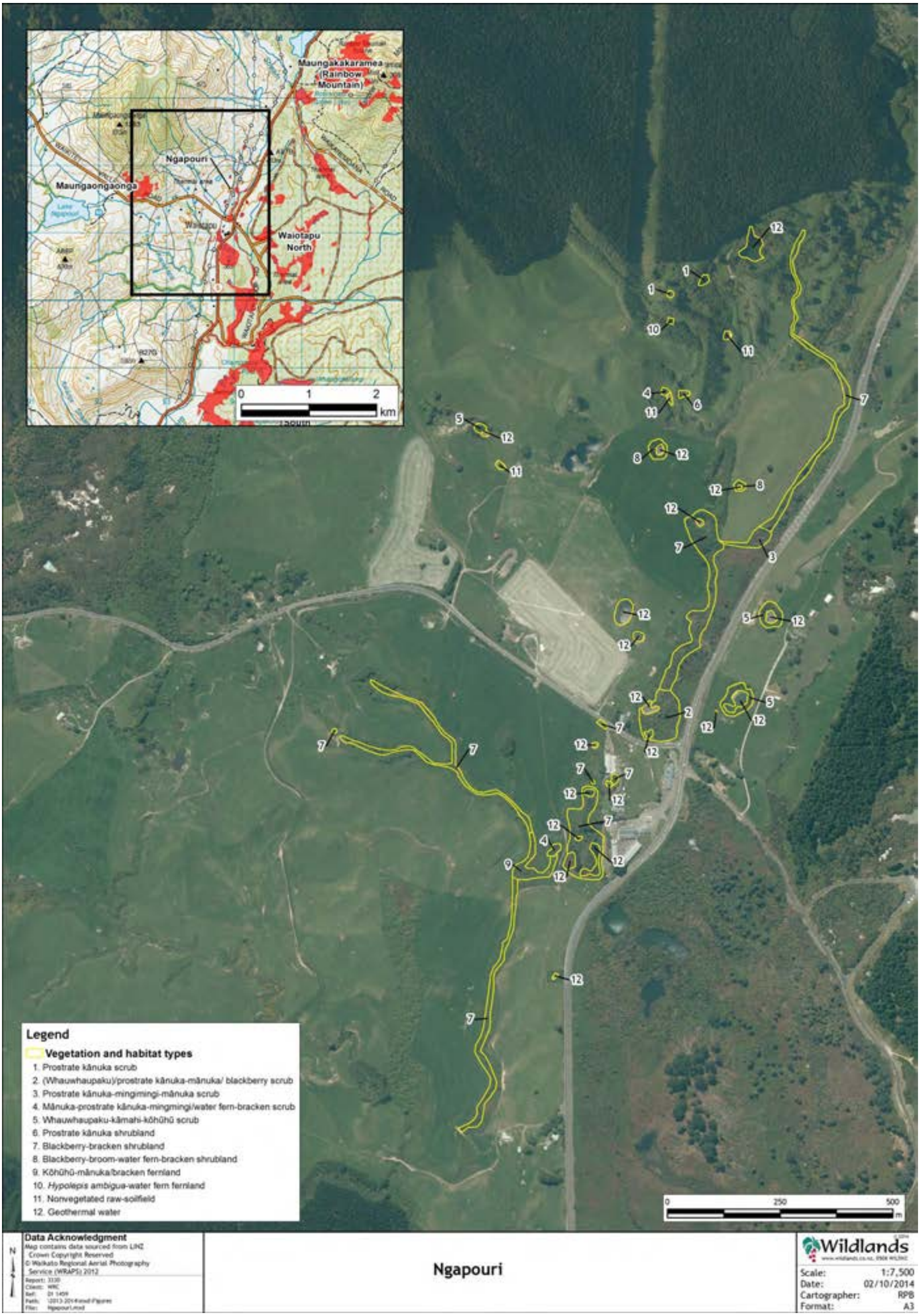
Site Change:

Recent change (2014 Assessment): Any changes to the area mapped since the 2011 report are based on better quality aerial photographs rather than any real site change.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Historical (*Assessed in 2011*):	It is difficult to determine the difference between "geothermal" and "non-geothermal" scrub on the historic black and white photos[1]. However, the vegetation surrounding the geothermal areas has developed from scrub in 1941 to secondary forest. Within the geothermal areas the historic photographs show considerably more bare ground, and it is likely that the "cooler" geothermal soils have been invaded by blackberry in recent years. Overall, based on the above assessment, we consider that no real change can be proven in the extent of geothermal vegetation and habitats at this site, although invasion of pest plants on less active geothermal soils may have taken place.
Management Requirements:	Further use and establishment of informal tracks should be discouraged. Ongoing weed control, particularly of wilding pines, is needed.
Significance Level:	National (Table 1 - Criteria 1, 3, 5, 9, 10; Table 2 - Factor 8).
Significance Justification:	This site is of national significance because it comprises a very high quality example of geothermal vegetation and habitat, which includes nationally uncommon habitat types (fumaroles, geothermally heated dry soil) (Williams *et al*. 2007; Holdaway *et al.* 2012). The site is part of an indigenous ecological sequence that extends from geothermal vegetation to tall forest (see Nicholls 1974; Clarkson 1981b; Beadel 1995a). The vegetation is of good quality and is relatively unmodified. Four 'At Risk' plant species (prostrate kānuka, *Korthalsella salicornioides*, *Nephrolepis flexuosa*, and *Dicranopteris linearis*), are present, as well as several species which, within the central North Island, are limited to geothermal areas. The site is protected as a Scenic Reserve.
Notes:	This site has been previously surveyed and mapped in 1995 (Beadel 1995a). Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in this survey this site was classed as Category A - the highest category.
References:	Beadel 1995a; Beadel and Bill 2000; Bibby *et al.* 1998; Clarkson 1981b; Nicholls 1974; Wildland Consultants 2004c & 2012.

[1] Historical photo: SN 172 Run 1158 Photos 2-4, 1941.


Maungakakaramea
(Rainbow
Mountain)
Ngapouri
Maungaongaonga
Waiotapu
Waiotapu
North
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1
2
km
0
250
500
m
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. (Whauwhaupaku)/prostrate kānuka-mānuka/ blackberry scrub
3. Prostrate kānuka-mingimingi-mānuka scrub
4. Mānuka-prostrate kānuka-mingmingi/water fern-bracken scrub
5. Whauwhaupaku-kāmahi-kōhūhū scrub
6. Prostrate kānuka shrubland
7. Blackberry-bracken shrubland
8. Blackberry-broom-water fern-bracken shrubland
9. Kōhūhū-mānuka/bracken fernland
10. Hypolepis ambigua-water fern fernland
11. Nonvegetated raw-soilfield
12. Geothermal water
Data Acknowledgment
Map contains data sourced from LINZ
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© Waikato Regional Aerial Photography
Service (WRAPS) 2012
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Ngapouri
Wildlands
Scale: 1:7,500
Date: 02/10/2014
Cartographer: RPB
Format: A3

NGAPOURI

Site Number:	WTV02[1]	**Grid Reference:**	NZTopo50 BF37 934 511
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1893493 N5751107
Geothermal Field:	Waiotapu	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*400 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*7.6 ha		
Extent of Geothermal Vegetation:	*c.*6.5 ha		
Date of Most Recent Field Survey:	7 May 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01)		
Prostrate kānuka scrub (04.01.01) Prostrate kānuka scrub with occasional emergent kāmahi or local whekī and occasional mingimingi located in steep-sided gullies surrounded by dense blackberry. Steam was observed rising through the prostrate kānuka but these areas could not be accessed safely. Viewed from a distance. A small area of geothermal water was observed at the base of one of the gullies within this type but could not be accessed safely to inspect further.	Gully	*c.*0.1 ha
(Whauwhaupaku)/prostrate kānuka-mānuka/ blackberry scrub (04.01.09) Scattered whauwhaupuaku are emergent above a dense canopy dominated by prostrate kānuka and mānuka with locally common mingimingi on the margins of the Waiotapu Stream. Blackberry is common to locally abundant in canopy gaps within this type. Local patches of *Hypolepis ambigua* are present, and patches of grassland dominated by paspalum and Mercer grass are present around the margins of mud pools within this type. A number of dead emergent kāmahi are scattered throughout.	Riparian margins	*c.*0.7 ha
Prostrate kānuka-mingimingi scrub (04.02) **Prostrate kānuka-mingimingi-mānuka scrub (04.02.02)** Prostrate kānuka and mānuka form a canopy up to *c.*4 m tall with locally common mingimingi over an understorey dominated by blackberry and bracken.	Riparian margins	*c.*0.2 ha
Mixed indigenous species scrub (04.08)		
Mānuka-prostrate kānuka-mingmingi/water fern-bracken scrub (04.08.01) Mānuka, prostrate kānuka, and mingmingi form a canopy over water fern and bracken scrub, with tūrutu scattered throughout.	Riparian margin	*c.*0.1 ha
Whauwhaupaku-kāmahi-kōhūhū scrub (04.08.02) Indigenous species dominated scrub located on steep crater sides and riparian margins. The canopy is dominated by either whauwhaupaku	Crater and riparian margins	*c.*0.5 ha

[1] Site number in 2004 was U16/7 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
or kāmahi, with kōhūhū, prostrate kānuka, and mānuka common, and scattered to locally common whekī, mingimingi, and blackberry. Where this type occurs on the margins of craters, indigenous dominated scrub grades into blackberry and bracken scrub on very steep sides, with *Hypolepis ambigua* common to locally abundant close to the mud pools that are often present in the crater bases.		
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka up to *c.*3.5 m height with local mingimingi over bare ground. Local patches of *Hypolepis ambigua* and water fern are present.	Flat	<0.1 ha
Mixed indigenous and exotic shrubland (05.08) **Blackberry-bracken shrubland (05.08.07)** Dense blackberry with bracken and locally common broom and mānuka. Occasional emergent whauwhaupaku, karamū, whekī (*Dicksonia squarrosa*), and kānuka (*Kunzea ericoides*) are present throughout. Local patches of *Hypolepis ambigua*, and scattered *Carex secta* and *Carex virgata* are present where the blackberry is less dense. Where this type occurs near geothermal ponds, *Machaerina articulata* is common with scattered harakeke. Emergent Tasmanian blackwood are locally common in one part of this type. This type is highly variable - in places there is often dense blackberry and there are local patches of fernland around small wetlands and geothermal pools.	Riparian margin, flat	*c.*4.4 ha
Exotic shrubland (05.09) **Blackberry-broom-water fern-bracken shrubland (05.09.10)** Shrubland dominated by blackberry and broom with locally common water fern and bracken is present on the walls of a steep-sided crater surrounding a mudpool.	Crater margin	*c.*0.2 ha
Indigenous fernland (07.01) **Kōhūhū-mānuka/bracken fernland (07.01.16)** Kōhūhū and mānuka are emergent over dense bracken fernland with scattered mingimingi. ***Hypolepis ambigua*-water fern fernland (07.01.21)** Two areas of this type are present within the site. One is located in the base of a steep-sided gully containing a geothermal spring, which flows into a small stream. Scattered emergent mingimingi are present above fernland dominated by *Hypolepis ambigua* and water fern. The other comprises a small area of *Hypolepis ambigua* and water fern above a steam vent on a steep hillslope and is surrounded by blackberry scrub.	Riparian margin Riparian margin, hillslope	*c.*0.3 ha <0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Heated soils and sinter with patches of narrow-leaved carpet grass, paspalum (*Paspalum dilatatum*), and browntop, and occasional	Crater, flat	*c.*0.1 ha

VEGETATION TYPE	LANDFORM	EXTENT
Lycopodiella cernua. Steam vents are present (surface temperature up to *c.*76 °C in 2014). Grassland dominated by narrow-leaved carpet grass is common around areas of this type within the site.		
Water (22.01) **Geothermal water and mudpools (22.01.01)** Heated pools/ponds. A small lake is present at the base of a steep-sided gully in the north of the site. Fog obscured the view of the lake but it appears to be geothermal in nature. Patches of water fern are present on the margin.	Flat	*c.*1.1 ha

Indigenous Flora: Small areas of prostrate kānuka (At Risk-Naturally Uncommon[1]) are present within the site. A small population of *Lycopodiella cernua*, a characteristic feature of geothermal areas, is also present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including grey warbler, tūī, fantail, welcome swallow, spur-winged plover, paradise shelduck, Eurasian blackbird, goldfinch, and Australian magpie.

Current Condition (2014 Assessment): The vegetation is highly modified. Adventive plants are common and some areas in the northern part of the site are grazed.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Large parts of this site are dominated by invasive exotic plants. Invasive pest plant species present include: apple (*Malus ×domestica*) (<1% cover), barberry (<1% cover), blackberry (50% cover), broom (1% cover), cotoneaster (<1% cover), crack willow (1% cover), false acacia (<1% cover), flowering cherry (<1% cover), grey willow (<1% cover), ivy (<1% cover), Khasia berry (<1% cover), montbretia (*Crocosmia ×crocosmiiflora*) (<1% cover), pampas (<1% cover), poplar (*Populus* sp.) (<1% cover), Spanish heath (<1% cover), Tasmanian blackwood (<1% cover), and wilding pines (radiata pine (2% cover) and maritime pine (<1% cover)).

Human impacts (*2014 Assessment*): Herbicide drift, and run-off from State Highway 5 and farmland affect this site. Building refuse has been dumped in a fumarole and it appears that some surface water is drawn off for use in the nearby Arataki Honey factory.

Grazing (*2014 Assessment*): Most of the site is fenced to exclude domestic stock. However small areas in the northernmost part of the site are not fenced and the margins are grazed. Nonvegetated raw-soilfield in these areas is trampled by domestic stock.

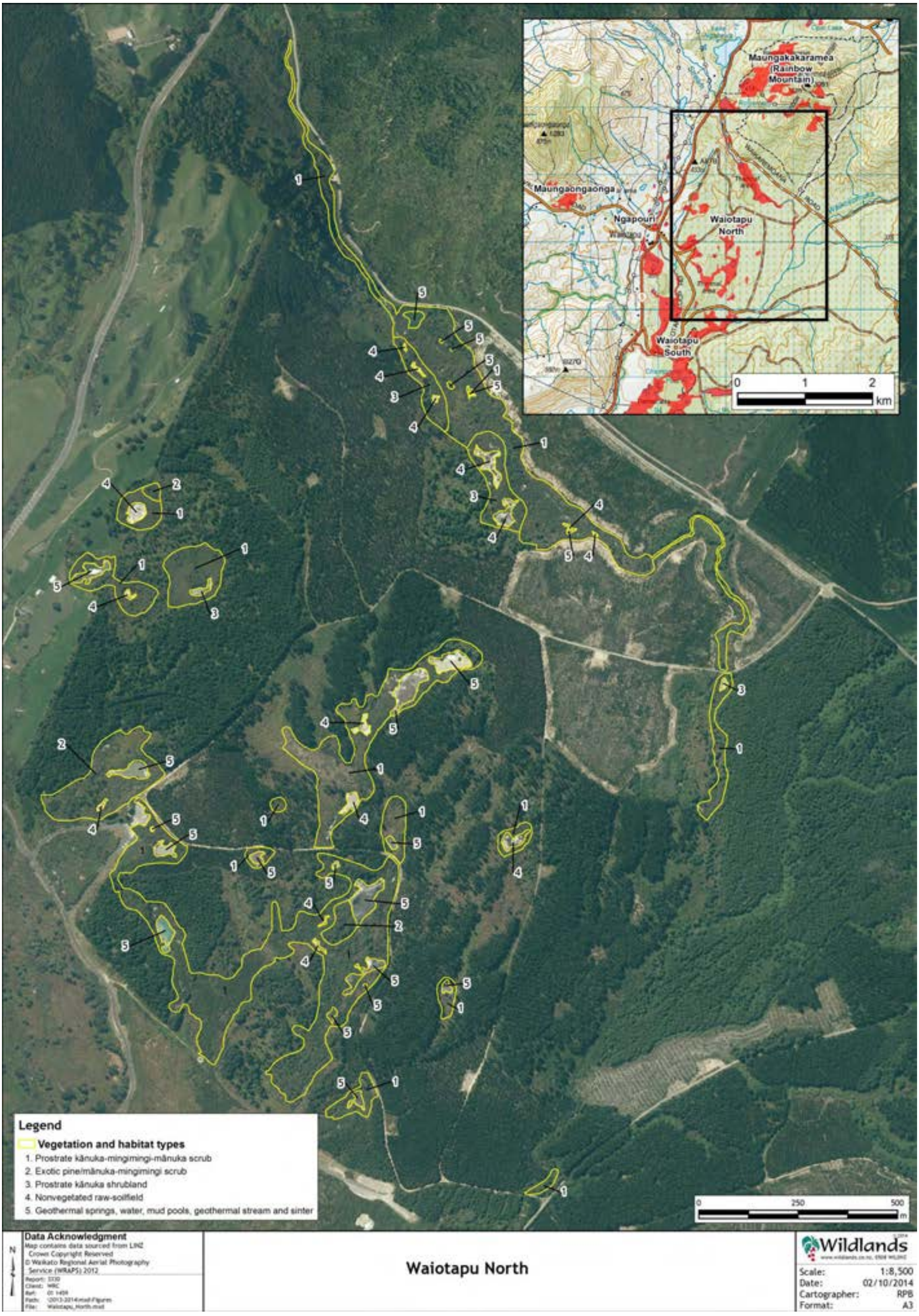
Adjoining land use (*2014 Assessment*): Farmland, Arataki Honey factory.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Site Change:

Recent change (2014 Assessment):	Additional areas that were previously not known from the existing literature were added to the site in 2014. This is as a result of new information rather than any new surface manifestations of geothermal activity becoming apparent since the previous survey in August 2004. All of the geothermal areas surrounded by farmland south of Waikite Valley Road have been fenced to exclude stock. Otherwise, little change was noted in this area in 2014, which is well known to the authors.
Historical (*Assessed in 2011*):	Based on historic aerial photographs[1], it appears geothermal vegetation and habitat may have been more extensive, particularly west of the Waiotapu Hotel. Several pools evident on the 1941 aerial photographs are no longer present; this may be a result of wetland drainage in order to modify the land for farming. It also appears that there were unvegetated bare areas in what is now farmland on the north side of Waikite Valley Road, particularly upslope toward Maungaongaonga. These may have been geothermal habitat which has been destroyed during land modification. However, most areas of geothermal vegetation at this site are unlikely to be visible in the 1941 aerial photographs as geothermal areas are either in gullies or covered in vegetation that appears similar to other adjacent vegetation in the 1941 aerial photographs.
Management Requirements:	Pest plant control, particularly of blackberry, wilding pines, and wattle species would enhance the ecological and amenity values of this site. Rubbish should be removed from geothermal features, and future rubbish dumping should be avoided. The small areas that are not currently fenced should be fenced to exclude domestic stock.
Significance Level:	Local (Table 1 - Criteria 3, 4, 5; Table 2 - Factor 19).
Significance Justification:	This site is locally significant because it contains small examples of geothermal habitat (some of which are degraded) and which include nationally uncommon habitats (geothermal stream margins, geothermally heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also provides habitat for a very small population of an At Risk plant species (prostrate kānuka) but does not represent habitat of considerable importance for the conservation of this species.
Notes:	Parts of the geothermal vegetation and habitats are subject to grazing and extensive areas are dominated by pest plant species. Although these areas are degraded, they provide important links between the protected areas of geothermal habitat. Regular management of pest plants, particularly wilding trees should be undertaken. A restoration plan should be prepared and implemented to enhance the ecological values of this site. Formal protection is recommended.
References:	Beadel 1995b; Beadel and Bill 2000; Wildland Consultants 2004c & 2012.

[1] Historical photos: SN172 Run 1158, Photo 4, 5 - 1941.


Maungakakaramea (Rainbow Mountain)
Maungaongaonga
Ngapouri
Waiotapu North
Waiotapu South
0 1 2 km
0 250 500 m
Legend
Vegetation and habitat types
1. Prostrate kānuka-mingimingi-mānuka scrub
2. Exotic pine/mānuka-mingimingi scrub
3. Prostrate kānuka shrubland
4. Nonvegetated raw-soilfield
5. Geothermal springs, water, mud pools, geothermal stream and sinter
Data Acknowledgment
Map contains data sourced from LINZ
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Waiotapu North
Wildlands
Scale: 1:8,500
Date: 02/10/2014
Cartographer: RPB
Format: A3

WAIOTAPU NORTH[1]

Site Number:	WTV03[2]	**Grid Reference:**	NZTopo50 BF37 949 502
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1894927 N5750233
Geothermal Field:	Waiotapu	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*380-420 m
Tenure:	Unprotected private land and protected (Waiotapu Scenic Reserve)		
Extent of Geothermal Habitat:	*c.*45.9 ha		
Extent of Geothermal Vegetation:	*c.*42.8 ha		
Date of Most Recent Field Survey:	26-29 July 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-mingimingi scrub (04.02) **Prostrate kānuka-mingimingi-mānuka scrub (04.02.02)** Prostrate kānuka (*c.*0.3-3 m tall) forms a dense cover with mingimingi locally co-dominant, mānuka and kānuka common throughout and occasional emergent kāmahi and wilding pines. Mānuka is common to dominant in wet areas and along stream margins. The groundcover comprises scattered bracken and water fern. Wilding pines, Japanese cedar (*Cryptomeria japonica*), broom, and blackberry are common on the margins of this area. Pine control has been undertaken in parts of this vegetation type.	Sides of crater, flat, riparian margins, and lake margins	*c.*34.7 ha
Mānuka-dominant scrub (04.04) **Exotic pine/mānuka-mingimingi scrub (04.04.03)** Mānuka and mingimingi (2-4 m high) dominate the canopy within these areas. Emergent wilding pines (radiata pine and black pine (*Pinus nigra*)) are generally scattered throughout but form small groves in places. Black wattle, prickly mingimingi, whekī, whekī-ponga, and broom are also scattered throughout. The groundcover is sparse, with scattered *Gleichenia microphylla*, tūrutu, and *Hypolepis distans*, and several *Dicranopteris linearis* plants. Several heated pools, seepages, boiling mud, and heated ground patches are present.	River terraces, flat, and gently undulating	*c.*0.8 ha
Exotic species dominated scrub (04.10) **Blackberry scrub (04.10.01)** Located about 30 m north of the bridge in the northeast of the site (*c.*E1896462 N5751308). Steam was seen rising from an area of blackberry scrub.		Not mapped
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Dense prostrate kānuka forms a canopy ranging from 0.3-4 m high with mingimingi scattered throughout. Locally scattered prickly mingimingi, monoao, wilding pines, and occasional patches of *Lycopodiella cernua* are present.	Hillslope, gently rolling	*c.*2.6 ha

[1] Site name was Waiotapu 2 in Beadel & Bill (2000).
[2] Site number in 2004 was U16/1 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** This includes heated ground, sinter pavements, hot water springs and seepages, boiling mud, and steaming ground.	River terraces, flat, and gently undulating	*c.*4.7 ha
Water (22.01) **Geothermal springs, water, mud pools, geothermal stream and sinter (22.01.04)** Geothermally-influenced lakes and pools, mud pools, mud pools surrounded by raw-soilfield, occasional hot springs.	Flat and craters	*c.* 3.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Dicranopteris linearis* (At Risk-Naturally Uncommon) are present. A small population of *Lycopodiella cernua*, a species which is characteristic of geothermal areas, is also present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present, including tūī, grey warbler, fantail, pied tit, silvereye, Australasian harrier, bellbird, and welcome swallow. Pied stilt (At Risk-Declining[2]) were observed nesting at the site in Beadel and Bill 2000. Possum and pig sign was evident in 2004.

Current Condition (2011 Assessment): Small to moderate sized areas of geothermal vegetation, many with impressive geothermal features, separated by plantation forest, exotic scrub, and farmland. The site links the geothermal habitats of Waiotapu South with the Maungakakaramea (Rainbow Mountain) and Ngapouri sites. A diverse range of geothermal habitats are present at this site.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Invasive exotic plants dominate the margins of these areas. Although extensive wilding pine control has been undertaken since 2004, wilding pines are still common (5-25% cover). Other pest plant species present include apple (<1% cover), blackberry (1-5% cover), broom (5-25% cover), climbing rose (*Rosa* sp.) (<1% cover), cotoneaster (<1% cover), grey willow (1-5% cover), and Spanish heath (1-5% cover). Blackberry and grey willow are often common on geothermal stream margins.

Human impacts (*2011 Assessment*): This site has well maintained roads, and Kerosene Creek is a popular bathing area for tourists and locals, however the larger areas of geothermal vegetation are seldom visited as most can not be seen from a main road.

Grazing (*2011 Assessment*): Livestock have no access to these areas and are only a potential threat to the Landcorp Protective Covenant; however the fencing of this area is currently sufficient to exclude domestic stock.

Adjoining land use (*2011 Assessment*): Plantation forest, farmland, Waiotapu Scenic Reserve.

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1 All flora threat rankings are from de Lange *et al.* 2013.
2 All avifauna threat rankings are from Robertson *et al.* 2013.

Site Change:

Recent change (2011 Assessment):

Several previously unmapped areas were mapped in 2011, however these were mostly found due to increased visibility through recently cleared pine plantation and better quality/higher resolution aerial photographs. Minor loss of geothermal vegetation has occurred in places following harvesting of pine trees; however in most instances it appears that the land manager(s) has taken reasonable care to avoid damage to geothermal sites. Replanting of plantation trees has generally taken place outside of geothermal habitats. Some minor updates were made to boundaries based on the higher resolution 2012 aerial photographs.

Historical (*Assessed in 2011*):

Historic aerial photographs[1] were compared with 2007 aerial photographs. The boundaries between geothermal vegetation and non-geothermal vegetation, particularly scrub and shrubland, is difficult to determine on aerial photographs for this site. In the area identified as A on the aerial photograph, the southern part of the site is now in plantation forest. The extent of the site in 2007 is only approximately two-thirds the site extent evidenced in 1941. Some of the bare ground evident in 1941 has been invaded by shrubs and pine trees. These areas are probably areas of lower geothermal activity.

It is difficult to determine change (if any) in the area marked C. Wilding pines have established in parts of the site, but otherwise the geothermal vegetation in these areas appears similar in 1941 and 2007 photos.

The areas identified as D on the accompanying map were in a poor condition in 1941. It appears that stock had access to the western and southern parts of these areas and vegetation had been cleared through part of the site, possibly for power lines. The extent of raw geothermal soilfield within Area D in 1941 was about 10-15% greater than current extent, and pines and shrubs have since colonised some areas that were raw-soilfield habitat in 1941. There has also been a 25-50% reduction of shrubland habitats because of plantation forestry, and wilding pine establishment. Few wilding pines were present in the southern part of Area D in 1941.

Little change was evident in the area marked E.

Overall, a crude estimate of loss of geothermal vegetation at this site since 1941 would be in the order of 25%. It is likely that some geothermal vegetation would have already been cleared prior to 1941.

Management Requirements:

Wilding pines in core geothermal areas, particularly those in the prostrate kānuka scrub, need to be removed. An infestation of African feather grass (*Cenchrus macrourus*) was present near the mud pools in the southwest of this site in 2011. This infestation was reported to the landowner and the Waikato Regional Council, and it has since been controlled by the Council.

Care needs to be taken during plantation management and harvesting in adjacent plantation forests. The forest managers have taken steps to address these issues (see Beadel and Bishop 1997; Wildland Consultants 2004c).

[1] Historical photos: SN 172 Run 1158 Photos 6-7, 1941.

Significance Level: Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factors 12, 14).

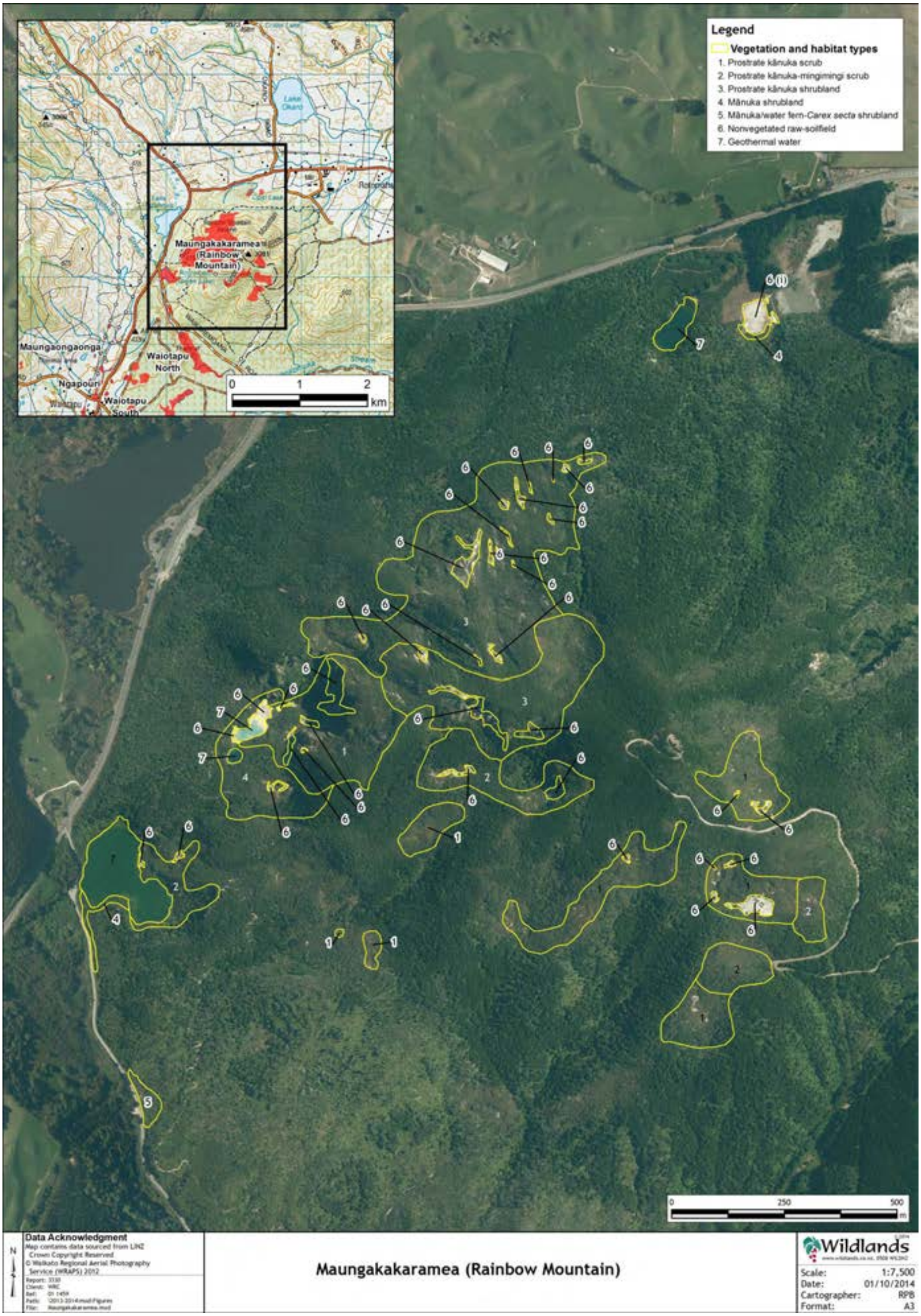
Significance Justification: Waiotapu North is of regional significance because, in association with 'Waiotapu South' and 'Maungakakaramea (Rainbow Mountain)', it comprises a relatively large example of geothermal habitat, which includes nationally uncommon habitats (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012), and provides important habitat for two 'At Risk' plant species: prostrate kānuka and *Dicranopteris lineraris*. If protected from the adverse effects of plant and animal pests and of adjacent land use (e.g. discharges, erosion) the site will maintain its ecological sustainability over time.

Notes: Ecological surveys and assessments were undertaken of the parts of this site managed by Kaingaroa Timberlands in April 2004 (see Wildland Consultants 2004a). These areas were identified as "high conservation value forest" using the Forest Stewardship Council criteria for assessment of high conservation value forests.

Parts of the geothermal vegetation and habitats are not protected and are subject to grazing; extensive areas are also dominated by pest plants. The unprotected areas provide important linkages between the protected areas of geothermal habitat and regular management of pest plants, particularly wilding trees, should be undertaken. These areas should be monitored regularly. A restoration plan should be prepared and implemented to enhance the highly significant ecological values of this site. Formal protection is recommended.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.

References: Beadel and Bishop 1997; Beadel and Bill 2000; Given 1995; Wildland Consultants 2004a&c, & 2012.


Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Prostrate kānuka-mingimingi scrub
3. Prostrate kānuka shrubland
4. Mānuka shrubland
5. Mānuka/water fern-Carex secta shrubland
6. Nonvegetated raw-soilfield
7. Geothermal water
Maungakakaramea (Rainbow Mountain)
Maungaongaonga
Waiotapu North
Ngapouri
Waiotapu South
0 1 2 km
0 250 500 m
Data Acknowledgment
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Maungakakaramea (Rainbow Mountain)
Wildlands
Scale: 1:7,500
Date: 01/10/2014
Cartographer: RPB
Format: A3

MAUNGAKAKARAMEA (RAINBOW MOUNTAIN)

Site Number:	WTV04[1]	**Grid Reference:**	NZTopo50 BF37 956 534
Ecological District:	Atiamuri; Rotorua Lakes	**GPS Reference:**	NZTM E1895633 N5753443
		Local Authority:	Rotorua
Geothermal Field:	Waiotapu	**Altitude:**	*c*.400-740 m

Bioclimatic Zone: Lowland - submontane
Tenure: Protected (Rainbow Mountain Scenic Reserve) and unprotected private land
Extent of Geothermal Habitat: *c*.55.1 ha
Extent of Geothermal Vegetation: *c*.51.6 ha
Date of Most Recent Field Survey: 26 July 2010

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01)		
Prostrate kānuka scrub (04.01.01) Prostrate kānuka dominates the canopy (0.3-3 m high) with kāmahi and kānuka scattered throughout, and locally scattered mingimingi, prickly mingimingi, tāwiniwini (*Gaultheria antipoda*), toru, rewarewa (*Knightia excelsa*), and toatoa (*Phyllocladus toatoa*). The groundcover comprises bracken, *Gleichenia microphylla*, and tūrutu.	Hillslope and road escarpment	*c*.15.3 ha
Prostrate kānuka-mingimingi scrub (04.02.01) The vegetation in this area comprises a mosaic of prostrate kānuka scrub (described above) and scrub dominated by mingimingi. Within the mingimingi scrub, mingimingi is dominant in association with tūrutu, *Gleichenia microphylla*, and tāwiniwini. Kāmahi, rewarewa, mānuka, and karamū occur over mingimingi , with bracken where soil temperatures are cooler. Fumaroles are abundant throughout. Wilding pines, particularly radiata pine, are establishing in places. Monoao is locally common within prostrate kānuka scrub.	Hillslope and shallow basin	*c*.6.7 ha
Prostrate kānuka-dominant shrubland (05.01)		
Prostrate kānuka shrubland (05.01.01) Prostrate kānuka shrubland (0.3-0.75 m high) is common in areas with high substrate temperatures, with patches of mossfield interspersed with areas of nonvegetated heated ground and steaming ground. Monoao, mingimingi, and the lichen *Cladia retipora* are locally scattered in these areas. Other vascular species present include tūrutu, toru, *Lycopodiella cernua*, kānuka, mānuka, and prickly mingimingi. Kāmahi occurs at the margins of the areas of high substrate temperatures, and local populations of *Dicranopteris linearis* and *Nephrolepis flexuosa* are present. Wilding pines are establishing within this vegetation type.	Hillslope, spur tops and cliffs	*c*.22.7 ha
Mānuka-dominant shrubland (05.04)		
Mānuka shrubland (05.04.01) Mānuka forms a canopy over an understorey of mingimingi, bracken, tūrutu, and kiokio, with prostrate kānuka in more geothermally active areas. *Sphagnum cristatum* often forms the ground cover where there is a high water table. Water fern and *Carex geminata* occur locally	Hillslope	*c*.3.5 ha

[1] Site number in 2004 was U16/2 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
near areas of hot water in poorly drained areas. Occasional whekī and kāmahi are present. **Mānuka/water fern-*Carex secta* shrubland (05.04.04)** Mānuka forms a canopy *c.*2-4 m high with prostrate kānuka and mingimingi scattered throughout. Other species present include whekī-ponga, whekī, karamū, broom, and grey willow. The groundcover is dominated by water fern and *Carex secta*, with local patches of raupō where there is a high water table. Whauwhaupaku, kōhūhū, and kāmahi occur around the margins of this type, and locally throughout. Several crack willow are present.	Wetland at toeslope	*c.*0.4 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Geothermally-altered soil, mud, sinter, explosion craters, and fumaroles.	Flat, hill, hillslope	*c.*3.0 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermally influenced lakes.	Basins	*c.*3.5 ha

Indigenous Flora: The following species characteristic of geothermal vegetation occur here: prostrate kānuka (At Risk-Naturally Uncommon[1]), *Schizaea dichotoma* (At Risk-Naturally Uncommon), *Dicranopteris linearis* (At Risk-Naturally Uncommon), a small population of *Nephrolepis flexuosa* (At Risk-Declining), and *Schizaea* sp. (cf. *S. fistulosa*). *D. linearis* is known from only *c.*23 sites in New Zealand. Four orchid species - *Calochilus paludosus*, *C. robertsonii*, *Petalochilus alatus*[2], and *Stegostyla atradenia*[3] (all At Risk-Naturally Uncommon) - have been recorded at the site (Rotorua Botanical Society 2006) but were not recorded in 2004 or 2010.

Other species typical of geothermal habitats present include mānuka, tūrutu, *Lycopodiella cernua*, *Morelotia affinis*, monoao, and bracken.

Other species of interest present in the wider reserve area are *Ileostylus micranthus*, *Thelymitra carnea, T. nervosa, T. ixioides, T. pulchella, T pauciflora*, and *Psilotum nudum* (see species list, Rotorua Botanical Society 2006), however these species may not be present in the areas of geothermal vegetation and habitats.

Fauna: Common indigenous bird species typical of the habitat are present, including North Island robin, spur-winged plover, grey warbler, welcome swallow, fantail, bellbird, Eurasian blackbird, and Australian magpie. New Zealand Dabchick (Threatened-Nationally Vulnerable[4]) were recorded at Feature 2 (F2 on site map).

Current Condition (2011 Assessment): The geothermal vegetation in this site is surrounded by a relatively large area of indigenous vegetation within Rainbow Mountain Scenic Reserve.

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1 All flora threat rankings are from de Lange *et al.* 2013.
2 Previously *Caladenia alata.*
3 Previously*Caladenia atradenia* .
4 All avifauna threat rankings are from Robertson *et al.* 2013.

There are public access tracks to some of the geothermal areas, and these tracks appear to be well maintained and adhered to. However, stock have access to a small area of geothermal activity found in 2010 by the authors in the north of the site. This small area was in poor condition and should be fenced to exclude stock.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*):

Wilding pines are the key invasive plant species in areas of geothermal vegetation. Whilst geothermal hot spots appear to be resistant to weed invasion, wilding conifers[1] are a threat to some areas of prostrate kānuka scrub which occurs on cooler soils, particularly on the eastern side of the site. Considerable pine control has been undertaken by Department of Conservation in recent years, and the current population of pines in geothermal areas is now very low (<1% cover of the area in which geothermal vegetation occurs).

Crack willow (<1%) and grey willow (<1%) are present alongside stream margins. Gorse (<1%) and Spanish heath (<1%) are present in geothermal areas alongside Kerosene Creek Road and site margins. Willow-leaved hakea (*Hakea salicifolia*) (1-5% cover) has become more common on the north faces of the reserve. Chinese privet (<1%) is also present on the north-facing slopes.

Human impacts (*2011 Assessment*):

Human impacts are minimal and are mainly associated with recreational use restricted to clearly defined tracks. In the past, orchid collectors have been a major threat to the orchid populations, however there have been no recent reports of collecting.

Grazing (*2011 Assessment*):

Domestic livestock are not a threat to most of this area, however horses and sheep have access to the northern part of the site near SH38 (see F1 on site map).

Adjoining land use (*2011 Assessment*):

Surrounded by indigenous vegetation in Rainbow Mountain Scenic Reserve. Farmland, roads, plantation forest.

Site Change:

Recent change (2010 Assessment):

The ongoing control of wilding pines within the site has markedly improved the condition of the geothermal vegetation. Additional areas of geothermal vegetation were found in 2010 as a result of better quality aerial photographs (2007 photos).

Historical (*Assessed in 2011*):

A series of historic photographs[2] were compared with 2007 photographs. In most places it is difficult to determine the differences between geothermal and non-geothermal scrub and shrubland however the following observations were made:

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[1] Conifers previously recorded in the reserve prior to control works being undertaken include bishop pine (*Pinus muricata*), lodgepole pine, European larch (*Larix decidua*), black pine, maritime pine, radiata pine, and strobus pine (*Pinus strobus*) (Rotorua Botanical Society 2006).

[2] Historical photos: SN 172 Run 1157 Photos 7-12, 1941; SN 172 Run 1158 Photos 7-8, 1941.

- A small lake, which may have been geothermal, is no longer present to the south-west of Lake Rotowhero (approximately E1894870 N5752800). The extent of bare ground in the southern portion of the site was also greater on the 1941 photographs (c.f. 2007); weed invasion and establishment of plantation forests on historically geothermal soils are the likely cause of the decrease in extent of bare ground since 1941.

- The extent of bare ground visible on the eastern and northern slopes of Maungakakaramea has decreased significantly since 1941. This is partly as a result of cooling geothermal soils, and establishment of shrubs and exotic pines.

- More bare ground was evident on the margins of Lake Rotowhero, but not markedly so.

- The extent of geothermal vegetation and habitat in the north of the site, near SH38, appears significantly reduced since 1941, likely as a result of land being converted for industrial and farm use. A geothermal lake and surrounding vegetated and nonvegetated raw-soilfield have been converted to pasture. The lake at F3 on the site map may have also been more active in 1941, with bare ground on northern and southern margins of the lake.

Taking into account the fact that many areas that were historically bare geothermal sites have been invaded by indigenous shrubs and wilding pines, an estimated loss of geothermal activity at this site is likely to be in the order of 5-20% since 1941.

Management Requirements: Ongoing management of pest plants should continue. Domestic stock have access to geothermal features in this part of the site and fencing of geothermal features to the north of the site near SH38 to exclude domestic stock should be considered.

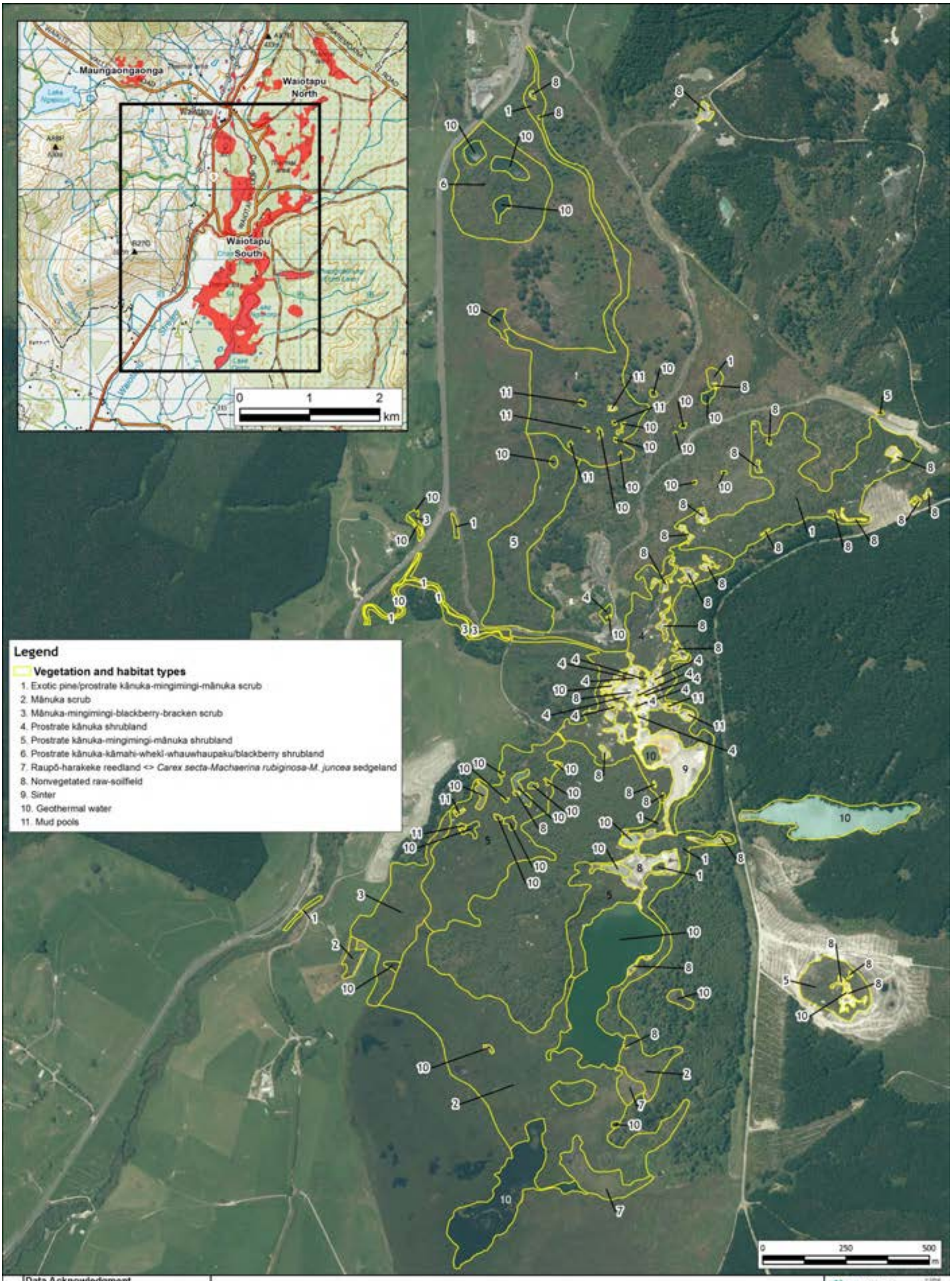
Significance Level: National (Table 1 - Criteria 1, 3, 5, 7, 9; Table 2 - Factor 8).

Significance Justification: This site is of national significance because it is a good quality, relatively large example of geothermal vegetation and includes nationally uncommon habitat types (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also contains a good quality representative example of an ecological sequence grading from geothermal vegetation to tall forest over an elevation gradient of 380-743 m (see Nicholls 1974; Clarkson 1981b; Beadel 1995a).

The site has a high diversity of vegetation types related to thermal activity, subsequent cooling, and succession after periodic burning (Watt 1986). The geothermal vegetation is a good example of the distinctive vegetation zones which progress over increasingly cool ground into indigenous scrub and forest. The variety of vegetation types is matched by few other reserves in the South Auckland Land District (Clarkson 1981a).

Eight plant species classed as 'At Risk' have been recorded at the site: prostrate kānuka, *Schizaea dichotoma*, *Nephrolepis flexuosa*, *Dicranopteris linearis*, *Calochilus paludosus*, *C. robertsonii*, *Caladenia alata*, and *C. atradenia*.

Notes:	A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.
References:	Beadel and Bill 2000; Bycroft 2006; Clarkson 1981a & 1982b; Rotorua Botanical Society 2006; Watt 1986; Wildland Consultants 1998, 2004c, & 2012.



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WAIOTAPU SOUTH[1]

Site Number:	WTV05[2]	**Grid Reference:**	NZTopo50 BF37 945 487
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1894491 N5748676
Geothermal Field:	Waiotapu	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*320-380 m
Tenure:	Protected (Waiotapu Stewardship Area, Waiotapu Scenic Reserve)		
Extent of Geothermal Habitat:	*c.*132.5 ha		
Extent of Geothermal Vegetation:	*c.*111.5 ha		
Date of Most Recent Field Survey:	9 December 2010, 10 July 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Exotic pine/prostrate kānuka-mingimingi-mānuka scrub (04.01.10)** Wilding radiata pine and maritime pine occur over prostrate kānuka, mingimingi, mānuka, broom, prickly mingimingi, *Coprosma lucida*, blackberry, and whauwhaupaku, with occasional black wattle, kāmahi, and whauwhaupaku. Groundcover components include bracken, *Carex secta*, tūrutu, *Hypolepis ambigua*, kiokio, swamp kiokio and ring fern. Along the margins of heated streams, pines are scattered above a canopy dominated by prostrate kānuka, with local small areas of steaming ground. Tūrutu, water fern, broom, harakeke, and Yorkshire fog are also common within these areas. Other notable species within this type include *Lycopodiella cernua* and *Gleichenia microphylla*. Boiling mud pools are scattered throughout this area. Blackberry and mingimingi dominate less geothermally active areas within this type.	Flat areas, stream margins and wetland Flat area and gently rolling hills	*c.*28.8 ha
Mānuka-dominant scrub (04.04) **Mānuka scrub (04.04.01)** This vegetation type is part of an extensive wetland in the south of the site. Mānuka forms a canopy *c.*2-4 m tall over a dense groundcover of *Machaerina rubiginosa*, kiokio, *Carex secta*, *Hypolepis distans*, and exotic grasses such as Yorkshire fog in drier areas. Prostrate kānuka and mingimingi are common around sinter and hot springs within this type, with local arrow grass. Raupō reedland occurs locally, and there are patches of lake clubrush, *Carex secta*, and *Carex virgata* are present. Arrow grass occurs in several locations on sinter. Pig sign was abundant throughout. **Mānuka-mingimingi-blackberry-bracken scrub (04.04.05)** A highly diverse vegetation type with areas of mānuka scrub, mingimingi scrub, blackberry scrub, and bracken fernland, and scattered emergent wilding maritime pines. Broom is common in places, and whekī and whekī-ponga occur in wet areas. Mud pools and hot springs are common, with sinter present near many of the hot springs.	Wetland Flat, rolling hills, gently undulating, stream margins	*c.*24.0 ha *c.*5.9 ha

[1] Site name was Waiotapu 1 in Beadel & Bill (2000).
[2] Site number in 2004 was U17/1 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
Along stream margins mingimingi, mānuka, water fern, tūrutu, and bracken are common. Blackberry becomes dominant on cooler soils, although steam is common within the blackberry. Vegetation within this type along the stream margins was viewed from a distance		
Prostrate kānuka shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka forms a discontinuous canopy *c.*0.1-1.0 m high in association with scattered mingimingi, and local *Lycopodiella cernua*. **Prostrate kānuka-mingimingi-mānuka shrubland (05.01.05)** A dense canopy of prostrate kānuka, mingimingi, and mānuka, with locally dominant kānuka and local monoao. Maritime pine is locally common on cooler soils along the margins of these areas. **Prostrate kānuka-kāmahi-whekī-whauwhaupaku/blackberry shrubland (05.01.06)** Prostrate kānuka, kāmahi, whekī, and whauwhaupaku comprise the canopy over blackberry with *Hypolepis ambigua* and ring fern locally common around steam vents.	 Gently undulating, flat Flat area , gently rolling hills Stream margin	 *c.*11.8 ha *c.*23.3 ha *c.*6.8 ha
Reedland (11.01) **Raupō-harakeke reedland⇔*Carex secta-Machaerina rubiginosa-M. juncea* sedgeland (11.01.06)** This area comprises a mosaic of raupō-harakeke reedland and *Carex secta-Machaerina rubiginosa-M. juncea* sedgeland with patches of mānuka shrubland throughout. Raupō and harakeke are locally dominant in association with *Austroderia toetoe*, koromiko (*Hebe stricta* var. *stricta*), *Coprosma propinqua,* karamū, and kiokio. *Carex secta, Carex virgata,* lake clubrush, *Machaerina rubiginosa*, and *M. juncea* dominate the sedgeland, in association with *Juncus* species and *Eleocharis acuta*. Geothermal activity is evident in areas throughout this vegetation type with occasional *Cyclosorus interruptus* present. Blackberry is common in dry areas.	Wetland	*c.*2.4 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Includes craters, steaming ground, boiling mud, hot pools, and sinter terraces. **Sinter (20.01.04)** A large sinter terrace.	 Flat, gently rolling Flat	 *c.*6.4 ha *c.*2.0 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermally influenced pools and lakes. **Mudpools (22.01.02)**	 Open water Mud pools, craters	 *c.*20.8 ha *c.*0.2 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]), which is endemic and restricted to geothermal areas, occurs here.

A large population of *Cyclosorus interruptus* (At Risk-Declining), is present in the wetland in the south of the reserve. Hobbs (2002) recorded >300 *C. interruptus* plants in Orutu Wetland (in the south part of this site), however the total population is likely to be considerably larger than this, as large parts of the site are inaccessible. One *Dicranopteris linearis* frond (At Risk-Naturally Uncommon) was observed near 'Twin Rivers' geothermal stream (Paul Cashmore pers. comm. 2007). *D. linearis* is known from only *c*.23 sites in New Zealand.

Fauna: Spotless crake (At Risk-Relict[2]) and North Island fernbird (At Risk-Declining) are present in the wetland at the southern end of the site. New Zealand dabchick (Threatened-Nationally Vulnerable) are present on Lake Orutu. Other species present include shining cuckoo, grey warbler, bellbird, tūī, fantail, Australasian shoveler, grey duck, mallard, pied tit, North Island robin, greenfinch, house sparrow, and Australian magpie.

Current Condition (2011 Assessment): Some management of wilding pines has taken place in recent years, improving the vegetation quality of the site, however exotic pines continue to be a major threat, particularly in the area between Waiotapu Loop Road and State Highway 5. Few other invasive exotic plants are present. In the tourist area, the habitats around the key geothermal features are well maintained for public viewing, except for the presence of maritime pine. Pigs have had a major negative impact on understorey vegetation in the wetlands to the south and southwest of the site. Despite the impacts of pigs, and the presence of pines, large areas of the site are in excellent condition, with a wide diversity of features and vegetation types present.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Wilding pines comprise *c*.6-25% cover. Several species are present, the most common of which is maritime pine with local radiata pine, black pine, and strobus pine. However, the density of pines in the northern part of the site has been significantly reduced through control between the 2004 and 2011 surveys. Other invasive exotic plant species present are blackberry (5-25% cover), black wattle (<1% cover), broom (1-5% cover), gorse, and Spanish heath (<1% cover). Chinese privet is common in the western wetland. The distribution of environmental weeds at the site was mapped and described in Wildland Consultants (1998).

Human impacts (*2011 Assessment*): The central portion of this area is managed as a tourism venture, which focuses on the geothermal features (e.g. the Champagne Pool and extensive sinter terraces). The tracks are well maintained and generally adhered to, and the overall impact is probably low. In most other areas human impacts are low as they are rarely visited.

Grazing (*2011 Assessment*): Domestic livestock have no access to most of this site, although sheep have had access to the wetland in the southwestern portion of the site due to

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] All avifauna threat rankings are from Robertson *et al.* 2013.

broken fences. These fences have recently been replaced. Feral pigs have caused extensive damage in the southern and western wetlands, with abundant tracks observed. Feral possum sign was also abundant and feral deer are also likely to graze the site. The small part of this site within Ngapouri Station is grazed by domestic stock.

Adjoining land use (*2011 Assessment*): Plantation forest, farming, road, tourism.

Site Change:

Recent change (2011 Assessment): Several small areas in the eastern part of the site have been destroyed as a result of plantation pine harvest and replanting. Most of the other change to site mapping since 2004 is related to parts of the site only becoming known to the authors in 2011, and improved quality of aerial photographs. Pest pines continue to degrade parts of the site where control has not taken place. In areas where pines have been controlled, particularly to the northeast of the site, the quality of the habitat present is greatly improved, and it is now dominated by indigenous vegetation. Overall, the extent of geothermal habitat at Waiotapu South is considered to be similar to the 2004 study.

Historical (*Assessed in 2011*): An assessment was made comparing 1941[1] to 2007 aerial photographs. The most significant change since 1941 is the establishment of wilding pines since1941. In the south of the site, the wetland extended most of the way to State Highway 5 and the wetland may have been approximately one-third larger than it is today. However, it is unlikely that much of this wetland would have been geothermal. There was also a wider buffer between geothermal features and plantation forest in many parts of the site.

A considerable change in geothermal vegetation and habitat has occurred in the area marked as Whangaioterangi South on the accompanying map. This area may now be only approximately half the size it was in 1941. The area of raw-soilfield is also reduced by about half.

Approximately 5-15% of the geothermal vegetation at this site has been lost since 1941, and wilding pines have caused degradation to 25% of the site, however some of these pines have been controlled in recent years.

Management Requirements: Pest plant spread should continue to be controlled, particularly within the main area of geothermal activity within the reserve. Given (1995) recommended a 50 m buffer zone of indigenous forest should be established around the major geothermal area to counter pine invasion. This should be implemented. An area of high priority for exotic tree control is between Waiotapu Loop Road and State Highway 5 (some pine control work has been done in this area since the 2011 survey). Fences should be checked on a regular basis where the site adjoins farmland. Pigs should be controlled in the wetlands in the southern part of the site.

[1] Historical photos: SN 172 Run 1158 Photo 6, 1941; SN 172 Run 1159 Photos 1-4, 1941; SN 172 Run 1160 Photos 2-5, 1941.

Significance Level: A: International (Table 1 - Criteria 1, 3, 5, 9, 10; Table 2 - Factor 5).
B: Regional (Table 1 - Criteria 1, 5; Table 2 - Factor 9).
C: Local (Table 1 - Criterion 5; Table 2 - Factor 19).

Significance Justification: This site has been divided into three parts, A, B, and C (see site map).

A: This part of the site (which includes most of Waiotapu South) contains the best representative example of geothermal wetland and one of the best areas of terrestrial geothermal vegetation in New Zealand.

B: Most of the remaining parts of this site are of regional significance because they are within a scenic reserve protected under the Reserves Act (1977), or are relatively large good quality examples of geothermal vegetation and habitats (e.g. Whangioterangi South).

C: This area is of local significance because it contains a small degraded example of geothermal wetland. Wetlands are under-represented regionally and national (<10% of wetlands remain nationally; Ministry for the Environment 1997).

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category A - the highest category.

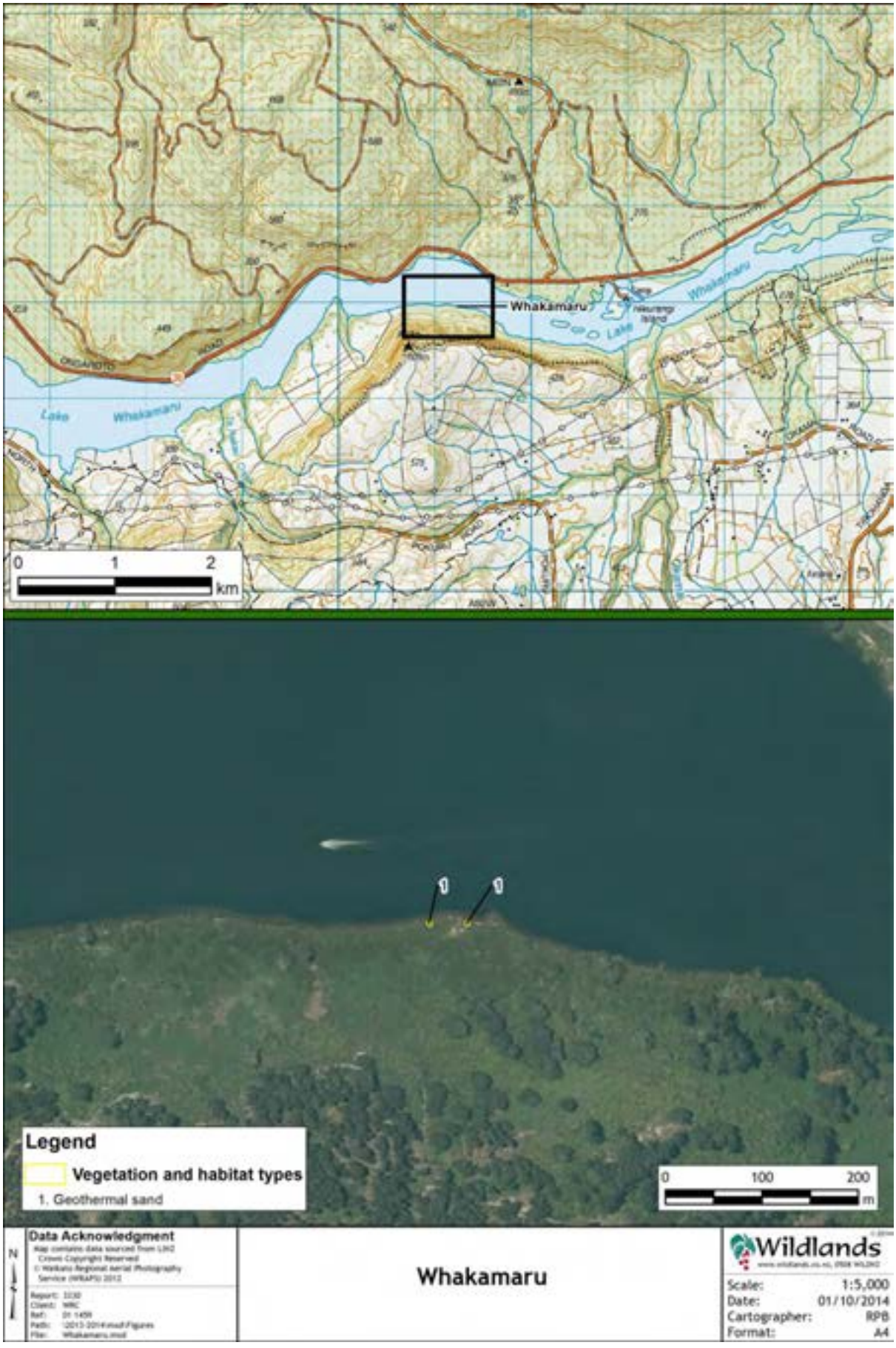
Some parts of this site are too dangerous to access on foot. The exact extent of geothermal habitat is difficult to safely determine in both the wetland to the south near Lake Orutu, and in the area between Waiotapu Loop Road and State Highway 5.

Parts of the geothermal vegetation and habitats that are not in reserves are subject to grazing, and also extensive parts are dominated by pest plants. These unprotected areas are important linkages between the protected areas of geothermal habitat, and regular management of pest plants, particularly wilding trees should be undertaken. These unprotected areas should be monitored regularly and formal protection and implementation of ecological restoration in these areas would enhance and/or protect the highly significant ecological values of this field.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010 .

References: Beadel and Bill 2000; Clarkson 1982a; Given 1995 & 1996; Hobbs 2002; Miller and Miller 1983; Rasch 1989; Spring-Rice 1996; Wildland Consultants 2000, 2004c & 2012.

MOKAI GEOTHERMAL FIELD


Whakamaru
Lake Whakamaru
0 1 2 km
Legend
Vegetation and habitat types
1. Geothermal sand
0 100 200 m
Data Acknowledgment
Whakamaru
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

WHAKAMARU

Site Number:	MKV01[1]	**Grid Reference:**	NZTopo50 BF35 511 429
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1851114 N5742958
Geothermal Field:	Whakamaru	**Local Authority:**	Taupō
Bioclimatic Zone:	Lowland	**Altitude:**	*c.*220 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	17 February 2008		

VEGETATION TYPE	LANDFORM	EXTENT
Sandfield (19.01) **Geothermal sand (19.01.01)** Two hot pools in lakeshore sands on the margins of Lake Whakamaru.with temperatures of 45.7°C and 46.2°C recorded in 2008. More geothermal pools are likely to be present. The pools are surrounded by occasional mānuka seedlings and *Morelotia affinis*. Kānuka scrub is present a few meters from the pool edge.	Beach	<0.1 ha

Indigenous Flora: Species typical of geothermal habitats are present near the geothermal springs including kānuka, mānuka, *Morelotia affinis*, and *Cyperus ustualtus*.

Fauna: No fauna was noted.

Current Condition (2008 Assessment): The site is small and is used recreationally by boat users. Geothermal vegetation values are not significant.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2008 Assessment*): No serious pest plant issues noted.

Human impacts (*2008 Assessment*): Holes are often dug in the sand to create small hot water pools for bathing by people who access the site by boat.

Grazing (*2008 Assessment*): This site is not grazed by stock.

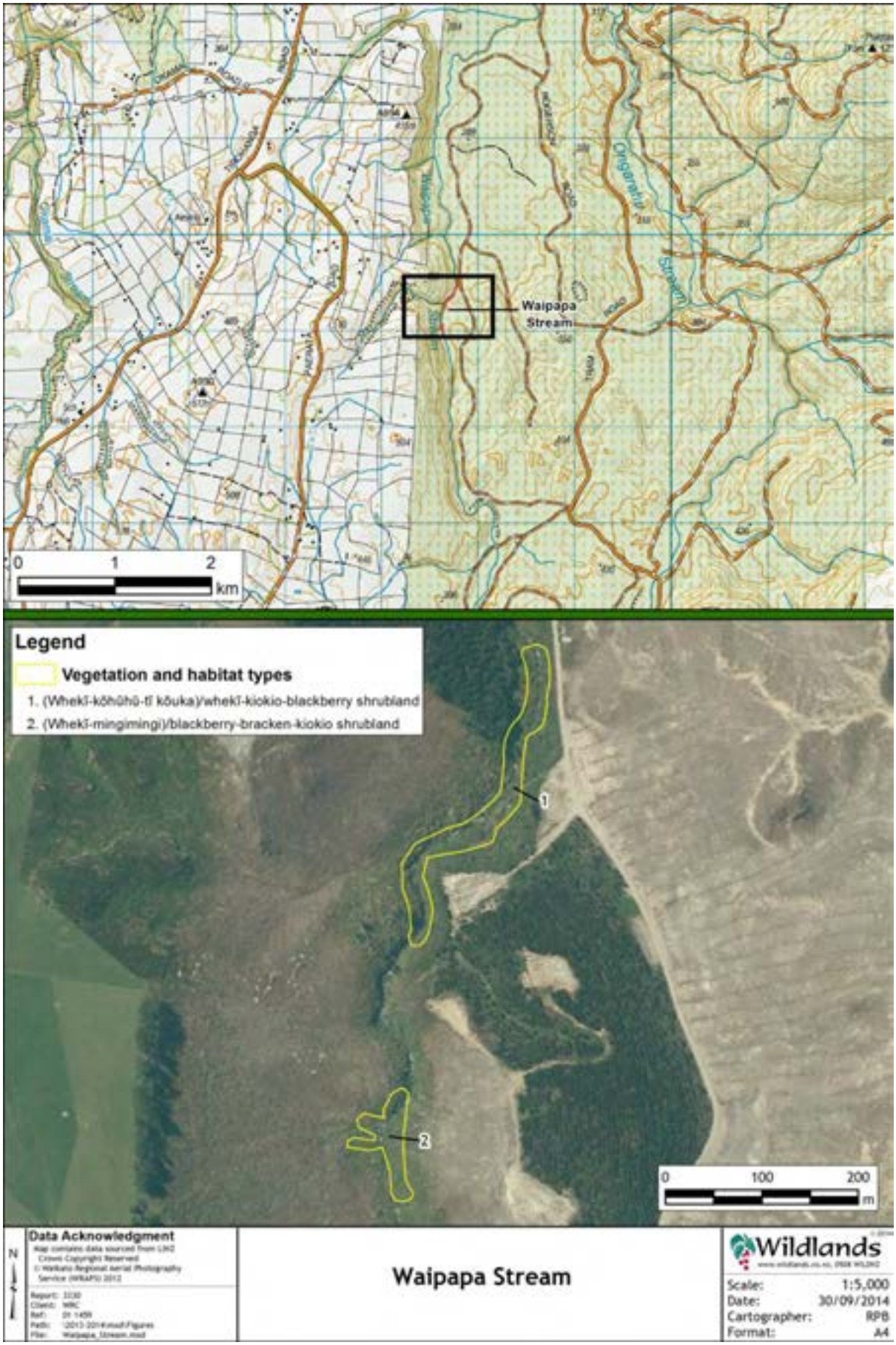
Adjoining land use (*2008 Assessment*): Lake Whakamaru, indigenous forest and scrub.

[1] Site number in 2004 was T17/7 (Wildland Consultants 2004c).

Site Change:

Recent change (*2008 Assessment*):	Unknown; this site was surveyed for the first time in 2008.
Historical (*Assessed in 2011*):	Part of the site is likely to have been drowned when the Whakamaru Dam became operational in 1956 (http://www.mightyriverpower.co.nz/Generation/AboutUs/HydroStations/Whakamaru/Technical.aspx; Accessed 27 June 2010). This site is too small to see any evidence of change since 1949[1].
Management Requirements:	None noted
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19)
Significance Justification:	Whakamaru is a locally significant site because it comprises a small example of a nationally uncommon habitat type (lake margin wetlands; Williams *et al*. 2007; Holdaway *et al.* 2012).
Notes:	The above information is based on a site visit with the Rotorua Botanical Society on 17 February 2008.
References:	Department of Conservation 1998; Spring-Rice 1996; Wildland Consultants 2004c & 2012.

[1] Historical photos: SN 258 Run 1071 Photos 72-73, 1949.


Waipapa Stream
0 1 2 km
Legend
Vegetation and habitat types
1. (Whekī-kōhūhū-tī kōuka)/whekī-kiokio-blackberry shrubland
2. (Whekī-mingimingi)/blackberry-bracken-kiokio shrubland
1
2
0 100 200 m
Data Acknowledgment
Waipapa Stream
Wildlands
Scale: 1:5,000
Date: 30/09/2014
Cartographer: RPB
Format: A4

WAIPAPA STREAM

Site Number:	MKV02[1]	**Grid Reference:**	NZTopo50 BF36 577 393
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1857719 N5739348
Geothermal Field:	Mokai	**Local Authority:**	Taupō
Bioclimatic Zone:	Lowland	**Altitude:**	286 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*1.2 ha		
Extent of Geothermal Vegetation:	*c.*1.2 ha		
Date of Most Recent Field Survey:	30 March 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Mixed indigenous and exotic shrubland (05.08) **(Whekī-kōhūhū-tī kōuka)/whekī-kiokio-blackberry shrubland (05.08.01)** Whekī (*c.*2-3 m tall), kōhūhū, and tī kōuka are emergent over kiokio, whekī, whauwhaupaku, blackberry, and bracken along the stream margins. Tutu (*Coriaria arborea* var. *arborea*), koromiko, māhoe (*Melicytus ramiflorus* subsp. *ramiflorus*), *Austroderia fulvida*, buddleia, and broad-leaved fleabane (*Conyza sumatrensis*) are scattered throughout. There is also local *Cyperus ustulatus* and ring fern. Occasional pampas and grey willow are present. At least two geothermally heated tributary streams flow into the main stream through recently harvested plantation forest. Vegetation around these streams includes the above species, but the canopy cover is younger and lower, and there are dead and fallen radiata pine and local patches of greater bindweed (*Calystegia silvatica*). Occasional radiata pine seedlings occur on the outer margins of this vegetation type. *Christella* aff. *dentata* ("thermal") occurs on the margins of springs, hot steam vents, and both sides of the Waipapa stream (over a distance of *c.*1 km), in the northern part of the site, with one plant in the southern part of the site.	Alluvial terrace	*c.*0.9 ha
Mixed indigenous and exotic shrubland (05.08) **(Whekī-mingimingi)/blackberry-bracken-kiokio shrubland (05.08.03)** Blackberry is dominant in association with bracken and kiokio, on the margins of a small, heated pool. Green and yellow algae are present on the pool surface. Fern species on the margins include *Gleichenia microphylla*, whekī, ring fern, and *Christella* aff. *dentata* ("thermal") (two plants). Karamū, kānuka, harakeke, koromiko, mingimingi, and *Cyperus ustulatus* are scattered throughout, with local patches of *Lycopodiella cernua*.	Stream gully	*c.*0.3 ha

Indigenous Flora: A large population (*c.*400 plants) of *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon[2]) was recorded in 2004, and *c.*200-300 plants were recorded during other surveys (Beadel and Clarkson 1986, Beadel and

[1] Site number in 2004 was T17/1 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

Bill 2000, Merrett and Fitzgerald 2004). *Christella* aff. *dentata* ("thermal") populations appear to be stable in 2011 (current study) although the number of plants was not counted. *Lycopodiella cernua* and *Psilotum nudum* (Beadel and Clarkson 1986), both characteristic species of geothermal areas, occur at this site.

Fauna: Common indigenous and introduced bird species, including fantail, whitehead, North Island robin, Californian quail, Australasian harrier, Australian magpie, Eurasian blackbird, and other species typical of these habitats are present.

Current Condition (2011 Assessment): Several areas of geothermal vegetation occur in association with hot springs and seepages. Recent harvesting has disturbed the indigenous vegetation that provides a buffer between the plantation forest and the threatened fern populations on the stream margins. There is one log jam in the stream.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Blackberry is locally abundant (local patches have 6-25% cover) but cover is relatively low overall (1-5% cover). Radiata pine, buddleia, Himalayan honeysuckle, and Japanese honeysuckle all have a cover of less than 1%. Waikato Regional Council undertook control of pines, broom, and buddleia at this site in 2010/2011.

Human impacts (*2011 Assessment*): Following harvesting of surrounding pine plantation in the 1970s, the populations of *Christella* aff. *dentata* ("thermal") took several years to recover (Beadel and Clarkson 1986). Recent harvesting to the west of the stream may also have impacted the *Christella* aff. *dentata* ("thermal") population as only one plant was located in the southern part of the site during this survey. Elsewhere the population appears to be stable.

It is unclear if the Mokai geothermal field extraction continues to have any effect on the seepages and springs of this site as reported by Merrett and Smale (1999). There is a well used track leading to the key geothermal sites.

Wilding pines in the northern part of the site have been controlled. However, the site should be inspected regularly to identify threats and management requirements, and further control of pest plant species should be undertaken in the future, if required.

Tracks were created by an adjoining landowner through vegetation adjacent to the hot pool. Subsequently, the Waikato Regional Council has constructed rails around the hot pool.

Grazing (*2011 Assessment*): Domestic livestock are not a threat to this site but feral goats have been recorded in the past (Beadel and Bill 2000).

Adjoining land use (*2011 Assessment*): Plantation forest surrounds this site.

Site Change:

Recent change (2011 Assessment): Recent harvesting operations adjacent to the southern part of the site have negatively impacted stream and adjacent vegetation; tree falls have altered natural water flows and damaged the stream banks. Populations of *Christella* aff. *dentata* ("thermal") may have been negatively affected by the damage to the vegetation on the stream banks as a result of the recent harvest. The narrow indigenous vegetation buffer will allow habitat for this species to remain, and recovery of the population is likely to occur (as was observed and discussed in 1986; Beadel and Clarkson 1986). Management of wilding pines at the site has been undertaken by the landowner since 2004. Geothermal pools on the eastern side of the stream in the northern part of the site have been partly damaged by floods and sediment deposition. The condition of the southern part of the site prior to the 2011 survey is unknown, as this part of the site had not been assessed previously.

Historical (*Assessed in 2011*): Site not assessed, no historical photos found. It is unlikely that any changes would be evident on historic black and white photographs, as the geothermal features at this site are located in a steep sided gully.

Management Requirements: Greater care needs to be taken during harvesting operations and subsequent management of the surrounding plantation forest to ensure the geothermal features and vegetation of this site do not continue to be disturbed. Monitoring of impacts relating to power draw-off from the Mokai geothermal field should continue. Protection of *Christella* aff. *dentata* ("thermal") populations from the potential impacts of wilding and planted radiata pine trees (outlined in Wildland Consultants 2004b) will assist in maintaining the ongoing survival and good health of this species at the site. The management requirements of *Christella* aff. *dentata* ("thermal") should be reassessed and updated within the next few years.

Significance Level:

A: National (Table 1 - Criteria 3, 5, 9; Table 2 - Factor 7).
B: Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).

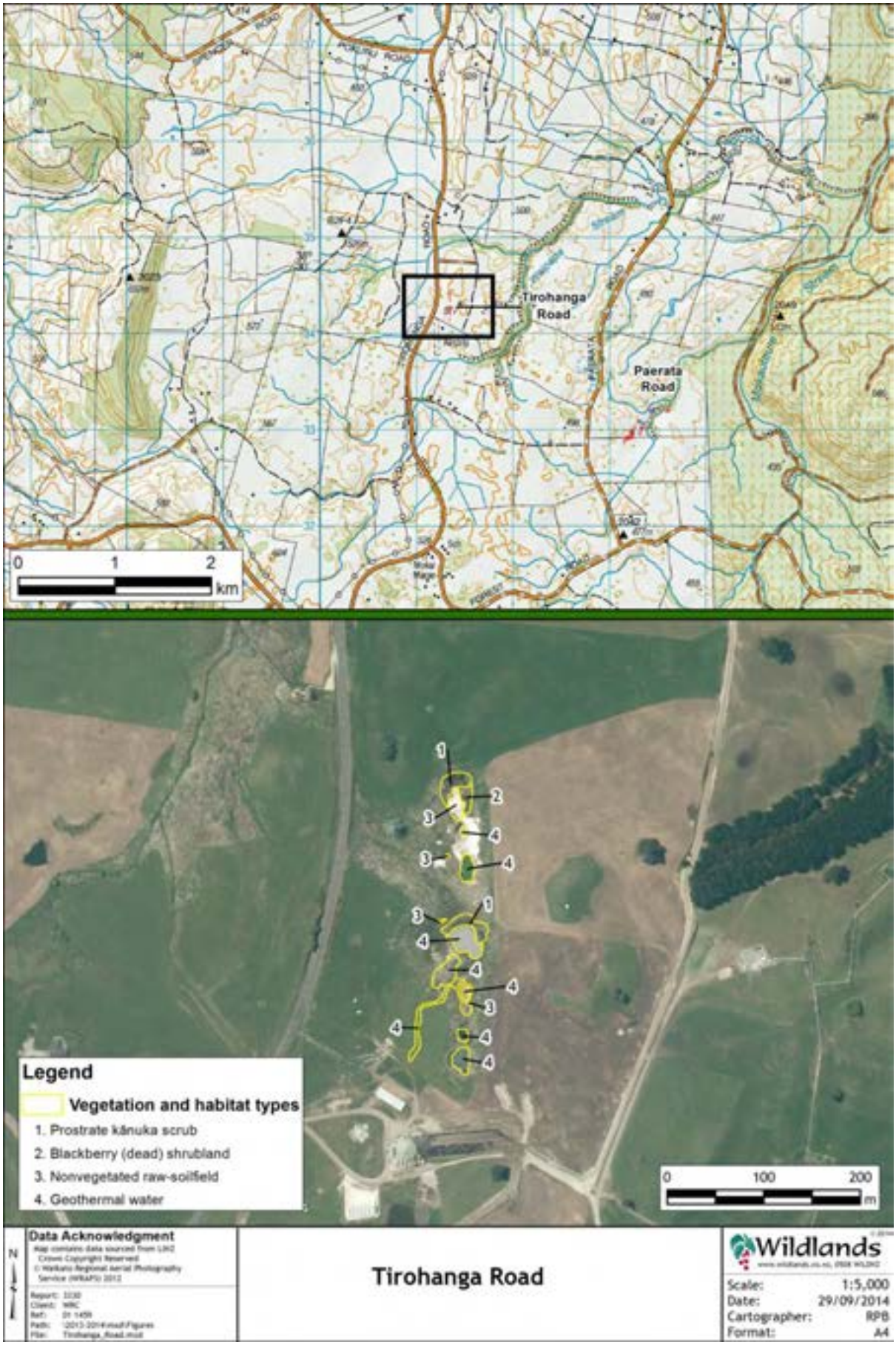
Significance Justification:

A: The part of the site identified as A on the map is of national significance as it contains the third largest population of *Christella* aff. *dentata* ("thermal") (an At Risk species) in New Zealand. This species is known from only 15 other sites in New Zealand.

B: The part of the site identified as B is of local significance as it comprises a small example of geothermal stream habitat - a nationally uncommon vegetation type (Williams *et al*. 2007; Holdaway *et al.* 2012).

References:

Beadel and Bill 2000; Beadel and Clarkson 1986; Given 1989a & 1996; Merrett 2001a & 2001b; Merrett and Fitzgerald 2004; Merrett and Smale 1999; Merrett *et al*. 1999; Spring-Rice 1996; Wildland Consultants 2004a,b&c & 2012.


Tirohanga Road
Paerata Road
0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Blackberry (dead) shrubland
3. Nonvegetated raw-soilfield
4. Geothermal water
0 100 200 m
Data Acknowledgment
Tirohanga Road
Wildlands
Scale: 1:5,000
Date: 29/09/2014
Cartographer: RPB
Format: A4

TIROHANGA ROAD

Site Number:	MKV03[1]	**Grid Reference:**	NZTopo50 BF36 533 342
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1853319 N5734204
Geothermal Field:	Mokai	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	498 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*0.5 ha		
Extent of Geothermal Vegetation:	*c.*0.2 ha		
Date of Most Recent Field Survey:	2 March 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Occasional mānuka, mingimingi, and kāmahi (less than 5 m tall) are emergent over prostrate kānuka scrub (to *c.*1 m tall) surrounded by rank exotic grasses (e.g. Yorkshire fog, brown top, and Indian doab (*Cynodon dactylon*)) with occasional patches of ring fern. Patches of blackberry (both alive and dead from herbicide spray) are present on the margins. Small areas of nonvegetated raw-soilfield are present within this vegetation type.	Crater rim	*c.*0.1 ha
Exotic shrubland (05.09) **Blackberry (dead) shrubland (05.09.02)** An area of sprayed, dead blackberry occurs around the northern-most geothermal pool.	Crater rim	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Heated soil, vents, and mud pools occur throughout the site. Indian doab, paspalum, browntop, Yorkshire fog, sheep's sorrel (*Rumex acetosella*), broad-leaved fleabane, and bracken occur on the margins of these areas.	Crater; gently sloping; geothermal hole	*c.*0.1 ha
Water (22.01) **Geothermal water (22.01.01)** A series of geothermal pools, oriented in a north-south series, surrounded by browntop grassland with patches of blackberry (alive, sprayed, and dead), bracken, and Californian thistle (*Cirsium arvense*). Occasional patches of water fern and Yorkshire fog, and some small isolated patches of nonvegetated raw-soilfield are also present.	Base of craters	*c.*0.5 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[2]) is present on the crater rims.

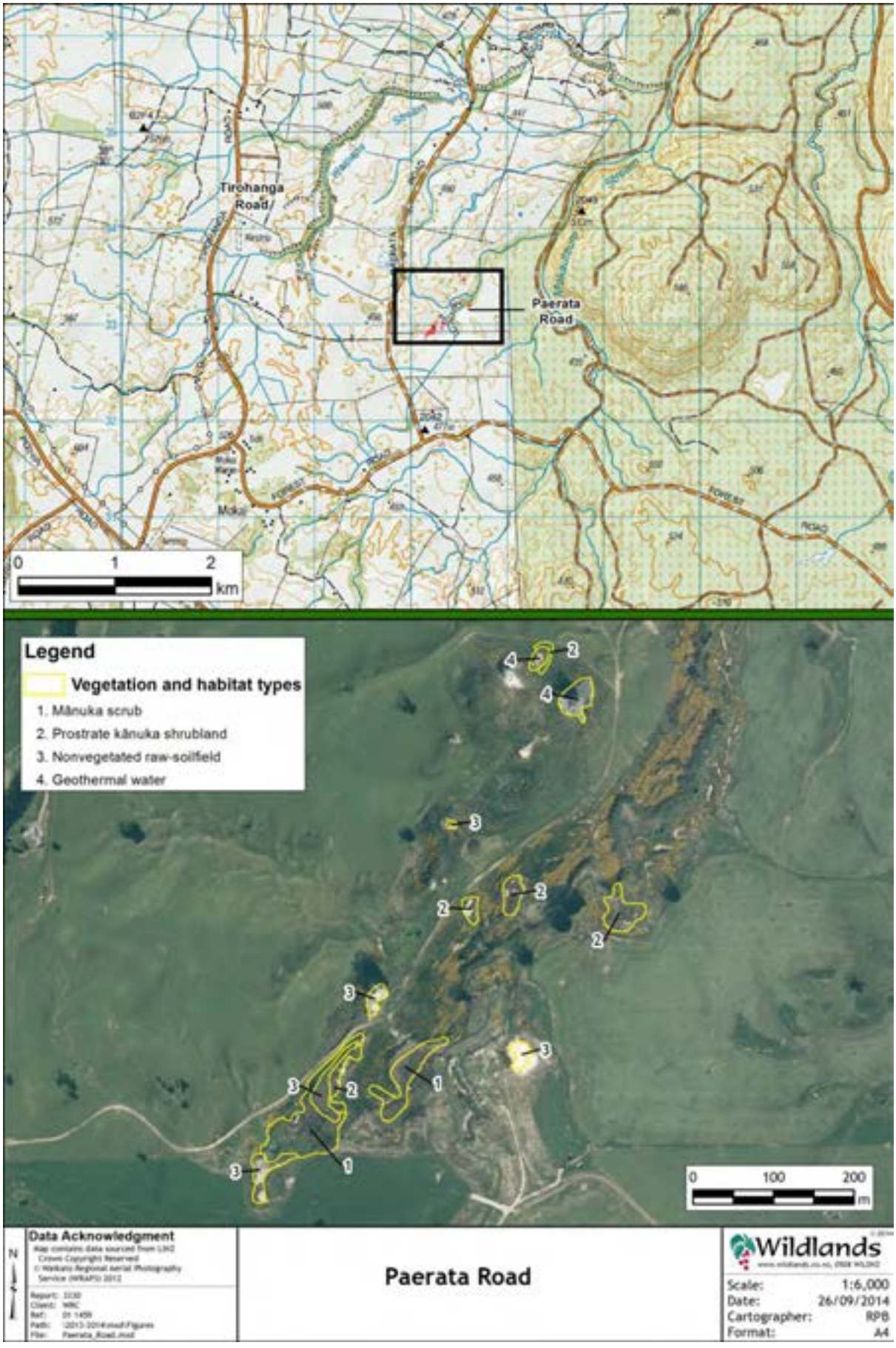
Fauna: Common indigenous and introduced bird species are present, including Australian magpie, yellowhammer, and goldfinch.

Current Condition Geothermal habitat is surrounded by rank exotic grasses and blackberry,

[1] Site number in 2004 was T17/4 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

(2011 Assessment):	some of which has been sprayed. The entire geothermal area has been fenced to exclude stock, and there is potential for restoration plantings.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2011 Assessment*):	Recent spraying of blackberry has been partially successful, and ongoing control is recommended.
Human impacts (*2011 Assessment*):	A small amount of rubbish was present at this site during the 2011 survey. This site is vulnerable to draw-off associated with the operation of the Mokai Geothermal Power Station. Large changes occurred to the geothermal features and vegetation following the commissioning of the Mokai Geothermal Power Station. Parts of the site have been used as a rubbish dump in the past, and some of this material was still present in 2007 (Wildland Consultants 2007a) but had been removed prior to the 2011 inspection. A cooking pit (umu) is present in the north of the site.
Grazing (*2011 Assessment*):	Domestic stock did not have access to this site in 2011, however, stock have gained access to the site in the past (see Wildland Consultants 2007a).
Adjoining land use (*2011 Assessment*):	This site is surrounded by pastoral land.
Site Change:	
Recent change (2011 Assessment):	The fence excluding stock appears to have been relocated further away from the geothermal expressions (parts of the old fence remain). Recent herbicide spraying has killed large areas of blackberry as well as prostrate kānuka scrub and mānuka (and possibly water fern). Rank brown top-Yorkshire fog-paspalum grassland is present between the geothermal expressions and the fence. Waste material that had been dumped into geothermal features, noted in 2007, appears to have been removed from site.
Historical (*Assessed in 2011*):	Site not assessed, no historical photos found. As most features are small, changes are unlikely to be evident on historical photographs.
Management Requirements:	Changes to geothermal vegetation that appear to be associated with draw-off associated with the extraction of geothermal energy in the Mokai Geothermal field should be monitored. Major fluctuations have been evident in geothermal features over the last ten years (Chris Bycroft pers. comm.). A management plan for restoration of this site should be developed by an ecologist with an understanding of the ecological values and management issues of this site and the plan should be implemented.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).
Significance Justification:	Tirohanga Road is of local significance because it contains small examples of nationally uncommon habitat types (geothermally heated dry soils, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012). It also contains a small population of an 'At Risk' plant species (prostrate kānuka), but does not represent habitat of considerable importance for the conservation of this species.

Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. Assessment of 2012 aerial photographs indicates that this site has undergone considerable change.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and in this study, this site was classed as Category C - the third highest category. A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.
References:	Beadel and Bill 2000; Beadel and Clarkson 1986; Department of Conservation 1998; Given 1996; Hochstein 2006 & 2007a; Merrett and Fitzgerald 2004; Wildland Consultants 2004c, 2007a, & 2012.


Tirohanga Road
Paerata Road
0 1 2 km
Legend
Vegetation and habitat types
1. Mānuka scrub
2. Prostrate kānuka shrubland
3. Nonvegetated raw-soilfield
4. Geothermal water
0 100 200 m
Data Acknowledgment
Paerata Road
Wildlands
Scale: 1:6,000
Date: 26/09/2014
Cartographer: RPB
Format: A4

PAERATA ROAD

Site Number:	MKV04[1]	**Grid Reference:**	NZTopo50 BF36 552 329
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1855210 N5732941
Geothermal Field:	Mokai	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	447 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitats:	*c.*1.8 ha		
Extent of Geothermal Vegetation:	*c.*1.6 ha		
Date of Most Recent Field Survey:	2 March 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Mānuka-dominant scrub (04.04) **Mānuka scrub (04.04.01)** A discontinuous canopy of mānuka of varying height (*c.*0.5-1.5 m high), with mingimingi, blackberry, and broom scattered throughout, and occasional grey willow. The understorey contains water fern, bracken, and blackberry with local tūrutu and kiokio, and small patches of sedges, rushes, ferns, and prostrate kānuka.	Flat to undulating farmland; small gullies	*c.*0.8 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka dominates the depression faces around small geothermal mud pools[2], with scattered blackberry, broom, mingimingi, mānuka, bracken, and water fern.	Geothermal depressions	*c.*0.4 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** These areas comprise mainly bare ground and hot water pools. Introduced grasses (mainly Yorkshire fog, browntop, and Indian doab), *Gonocarpus micranthus* subsp. *micranthus*, and the moss *Campylopus clavatus* occur around the margins of these areas with scattered mānuka, koromiko, mingimingi, prostrate kānuka, broom, bracken, water fern, ring fern, and blackberry on cooler sites.	Flat to undulating farmland	*c.*0.4 ha
Water (22.01) **Geothermal water (22.01.01)** An area of geothermal water. Nonvegetated raw-soilfield, and patches of prostrate kānuka, mingimingi, and exotic grasses (including Yorkshire fog and browntop) are present on the margins.	Flat to undulating farmland	*c.*0.2 ha

Indigenous Flora: A small population of prostrate kānuka (At Risk-Naturally Uncommon[3]), an endemic plant species restricted to geothermal areas, is present. *Lycopodiella cernua* is present at the site. *Psilotum nudum*, another species characteristic of geothermal areas, has been previously recorded at the site but has not been seen since 1986 (see Beadel and Clarkson 1986).

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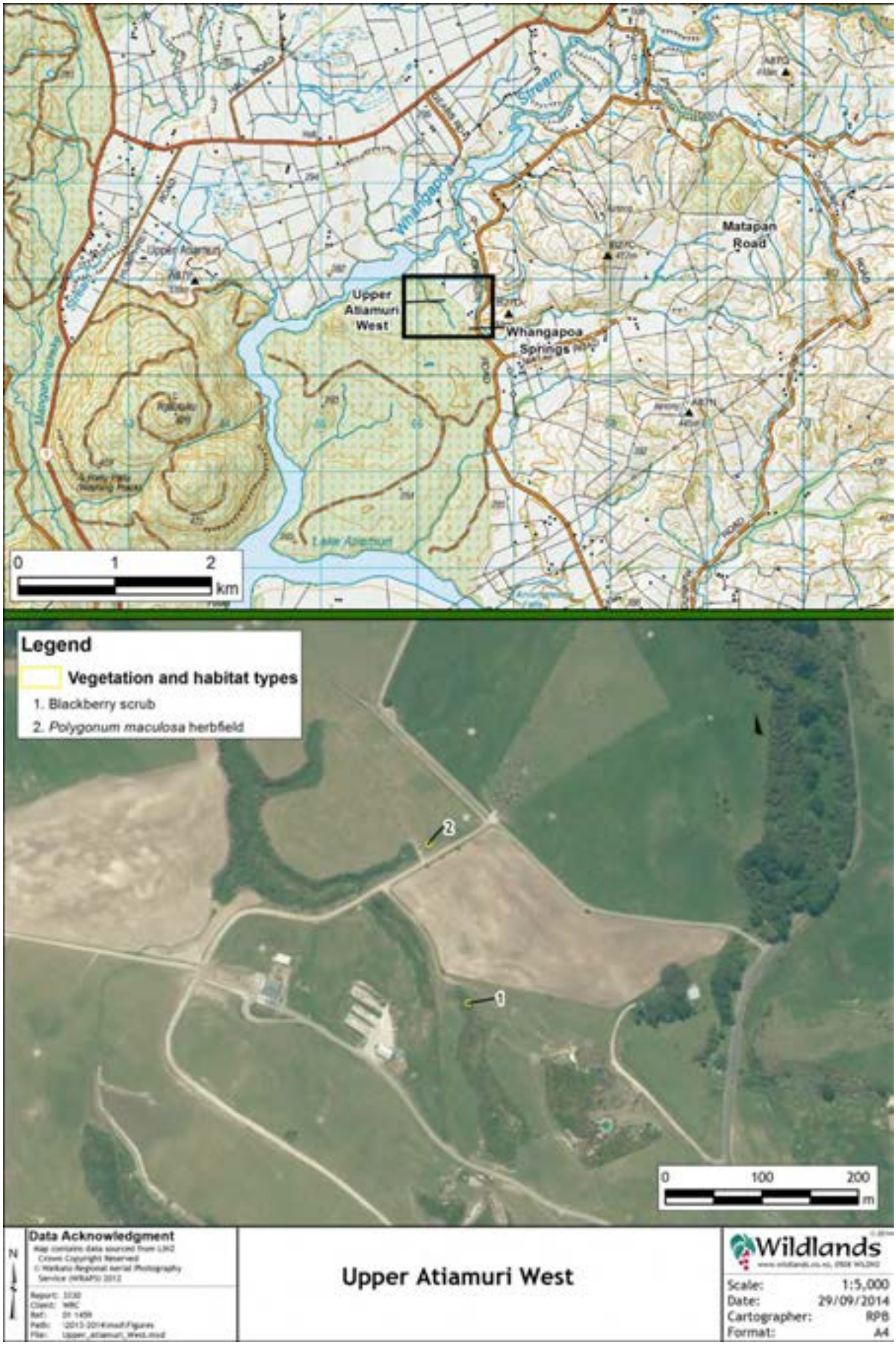
1 Site number in 2004 was T17/3 (Wildland Consultants 2004c).
2 Note the mud pools and hot water pools within these areas are too small to map out separately.
3 All flora threat rankings are from de Lange *et al.* 2013.

Fauna:	Common indigenous and introduced birds typical of the habitat are present, including Australasian harrier, spur-winged plover, fantail, and paradise shelduck.
Current Condition (2011 Assessment):	Most of the site is in poor ecological condition, with much of the site farmed and common pest plant species present. Vegetation clearance has occurred in the vicinity of some of the geothermal features. Blackberry on a steep bank above a geothermally-influenced stream has been sprayed with herbicide, which has also been applied to the mānuka around the fringes of the blackberry. Rubbish has been dumped down the bank and into the stream/geothermal vegetation margin. In 2011 radiata pines had recently been planted on the margins of some of the features and future shading by these pines is likely to adversely affect indigenous vegetation. Some geothermal features have been fenced to exclude stock, however a sheep was grazing within a fenced area during the site inspection.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2011 Assessment*):	Blackberry control has occurred over a large part of this area, however blackberry still comprises 1-5% cover of the site. Several large wilding pines have been killed. Planted radiata pine seedlings may shade geothermal vegetation in the future and prostrate kānuka is not tolerant of complete canopy closure. These planted radiata pine trees should be removed.
Human impacts (*2011 Assessment*):	Radiata pine were planted within 5 m of some geothermal features in 2010/2011. In preparation for planting, large areas of blackberry were sprayed and, in some cases, adjacent mānuka (and possibly other indigenous plant species) have died as a result of herbicide application. Parts of this site have been used as a rubbish dump, with refuse present adjacent to, and encroaching into, geothermal areas. Large wilding radiata pines have been felled into areas of prostrate kānuka.
Grazing (*2011 Assessment*):	Geothermal features between the stock race and the eastern stream edge are fenced to exclude stock, although one sheep was grazing within the fenced area in 2011. All other areas (to the west of the stock race) are not fenced and are grazed.
Adjoining land use (*2011 Assessment*):	This site occurs within farmland and a large part of the site has recently been planted with radiata pine (to the east of the farm race).
Site Change:	
Recent Change (2011 Assessment):	Blackberry has been sprayed and radiata pine has been planted into some areas. Some geothermal vegetation has been cleared and some has been sprayed with herbicide.
Historical (*Assessed in 2011*):	Site not assessed, no historical photos found. As most features are small, changes are unlikely to be evident on historical photographs.
Management Requirements:	The planted radiata pine should be set back at least 10 m from the outside margin of all geothermal areas. All pine trees in geothermal areas should be controlled.

	Unfenced areas require fencing to prevent further damage from stock. Ecological restoration actions at these sites would be beneficial.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19)
Significance Justification:	Paerata Road is of local significance because it contains geothermally heated dry soils, a nationally uncommon habitat type (Williams *et al*. 2007; Holdaway *et al.* 2012). It also includes a small population of an 'At Risk' species (prostrate kānuka), but does not represent habitat of considerable importance for the conservation of this species.
Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. Inspection of 2012 aerial photographs indicates that additional areas of geothermal habitat, which have not been mapped, may be present.
Notes:	This site was identified as a recommended area for protection (RAP) under the Protected Natural Areas Programme (Spring-Rice 1996). Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and in this study, this site was classed as Category C - the third category. This site contains the largest area of prostrate kānuka shrubland in the Mokai geothermal field.
References:	Beadel and Bill 2000; Beadel and Clarkson 1986; Given 1989a & 1996; Merrett 2001b; Merrett and Fitzgerald 2004; Spring-Rice 1996; Wildland Consultants 2004c & 2012.

ATIAMURI GEOTHERMAL FIELD


Upper Atiamuri West
Whangapoa Stream
Matapan Road
Whangapoa Springs
Lake Atiamuri
0 1 2 km
Legend
Vegetation and habitat types
1. Blackberry scrub
2. Polygonum maculosa herbfield
0 100 200 m
Data Acknowledgment
Upper Atiamuri West
Wildlands
Scale: 1:5,000
Date: 29/09/2014
Cartographer: RPB
Format: A4

UPPER ATIAMURI WEST

Site Number:	ATV01[1]	**Grid Reference:**	NZTopo50 BF36 663 497; BF36 663 496
Ecological District:	Atiamuri		
Geothermal Field:	Atiamuri	**GPS Reference:**	NZTM E1866297 N5749798; E1866338 N5749636
Bioclimatic Zone:	Lowland		
Local Authority:	Rotorua	**Altitude:**	*c.*240 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	5 February 2007		

VEGETATION TYPE	LANDFORM	EXTENT
Exotic species-dominant scrub (04.10) **Blackberry scrub (04.10.01)** This area comprises a tomo with a geothermal spring at the base (2 m wide and 2.5 m deep). Dense blackberry in association with Himalayan honeysuckle and broom surround the tomo, and scattered *Hypolepis distans* occurs on the sides of the tomo. A sinter deposit which extends *c.*1 m into the tomo is also present.	Geothermal pit	<0.1 ha
Herbfield (13.01) ***Polygonum maculosa* herbfield (13.01.01)** A small fumarole (0.3 m diameter) surrounded by a dense patch of *Polygonum maculosa*, with smaller patches of black nightshade (*Solanum nigrum*) and occasional Yorkshire fog.	Quenched fumarole; Geothermal pit	<0.1 ha

Indigenous Flora: No threatened species are present, however *Hypolepis distans*, a characteristic species of geothermal wetlands is present.

Fauna: Common indigenous and introduced bird species typical of the habitat are likely to be present.

Current Condition (2007 Assessment): The geothermal sites are fenced, but are dominated by exotic plant species.

Threats/Modification/ Vulnerability:

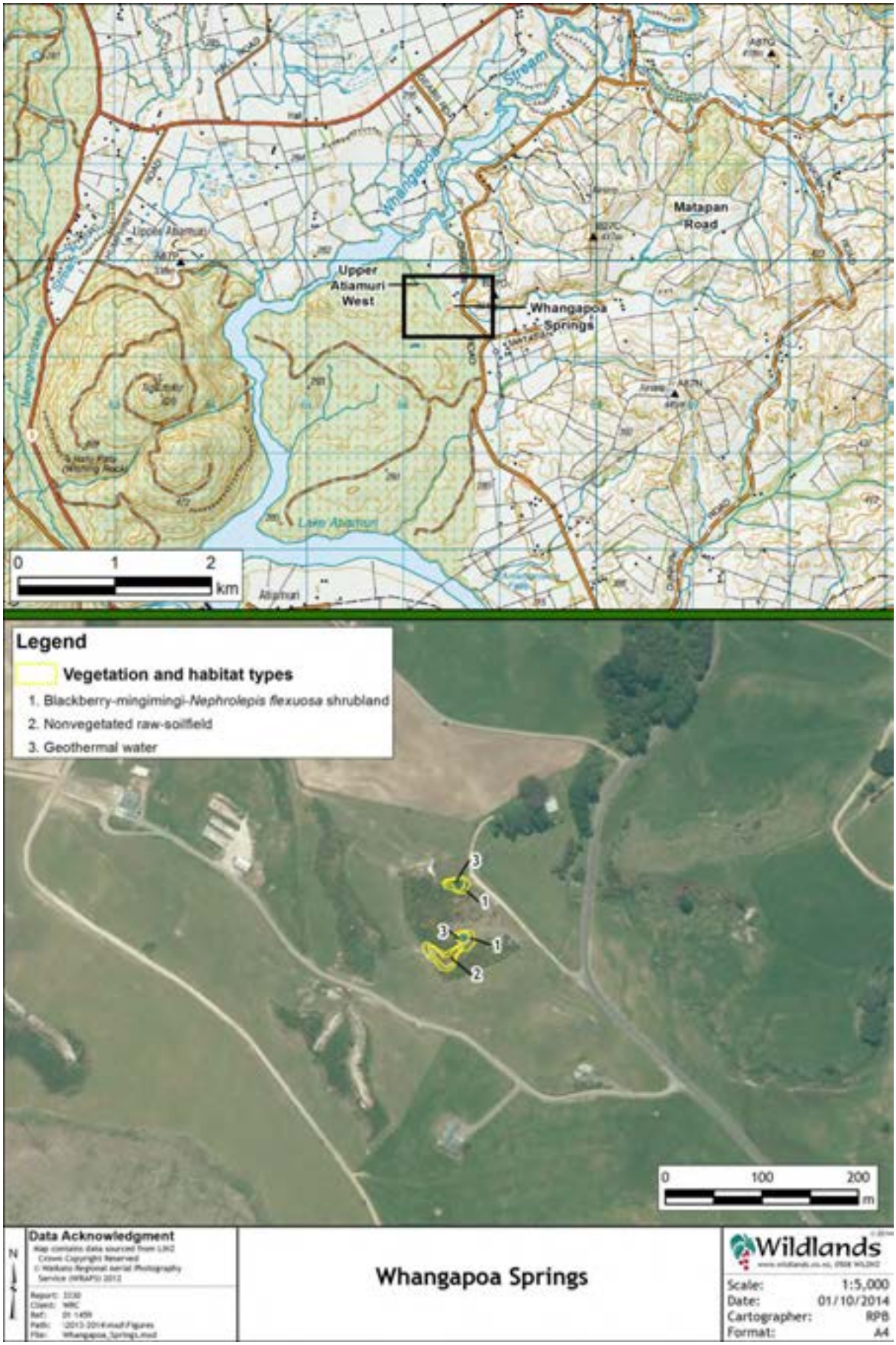
Invasive pest plants (*2007 Assessment*): Blackberry, Himalayan honeysuckle, and broom dominate the site, together comprising over 90% of the vegetation cover.

Human impacts (*2007 Assessment*): The site is surrounded by farmland.

Grazing (*2007 Assessment*): The geothermal areas are fenced from stock.

[1] Site number in 2004 was U16/10 (Wildland Consultants 2004c and 2007a).

Adjoining land use (*2007 Assessment*):	Farmland
Site Change:	
Recent change (2014 Assessment):	This site has not been revisited by the authors since 2007, but is unlikely to have undergone significant change over this timeframe. A new geothermal pool may be present in the gully west/northwest of the mapped area (based on inspection of 2012 aerial photographs); this gully should be surveyed in the future.
Historical (*Assessed in 2011*):	Site not assessed, as it is too small to be assessed based on historical photographs.
Management Requirements:	Restoration of the adjacent gully margins, which support geothermal and non-geothermal habitat and features, could be considered. There is the potential to link any restoration works with the nearby Whangapoa Springs site.
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19)
Significance Justification:	Upper Atiamuri West is of local significance because it contains a nationally uncommon habitat type (fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012). However the geothermal features are very small and highly modified, with few indigenous species present.
Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. Inspection of 2012 aerial photographs indicates that additional areas of geothermal activity may be present in the gully west/northwest of the mapped area.
Notes:	A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.
References:	Hochstein 2007a; Wildland Consultants 2004c, 2007a & 2012.


Matapan Road
Upper Atiamuri West
Whangapoa Springs
Lake Atiamuri
0 1 2 km
Legend
Vegetation and habitat types
1. Blackberry-mingimingi-Nephrolepis flexuosa shrubland
2. Nonvegetated raw-soilfield
3. Geothermal water
0 100 200 m
Data Acknowledgment
Whangapoa Springs
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

WHANGAPOA SPRINGS[1]

Site Number:	ATV02	**Grid Reference:**	NZTopo50 BF36 665 495
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1866465 N5749485
Geothermal Field:	Atiamuri	**Local Authority:**	Rotorua
Bioclimatic Zone:	Lowland	**Altitude:**	*c.*240 m
Tenure:	Protected (Whangapoa Springs Scientific Reserve) and unprotected private land		
Extent of Geothermal Habitat:	*c.*0.1 ha		
Extent of Geothermal Vegetation:	*c.*0.1 ha		
Date of Most Recent Field Survey:	2 February 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Exotic shrubland (05.09) **Blackberry-mingimingi-*Nephrolepis flexuosa* shrubland (05.09.05)** Blackberry, bracken, and broom with occasional Spanish heath, buddleia, ring fern, and toetoe (*Austroderia fulvida*) are present around geothermal pools within this site. *Nephrolepis flexuosa* is common amongst the shrubs. This vegetation type also surrounds the spring outlet.	Hillslope terrace	*c.*0.1 ha
Indigenous fernland (07.01) ***Nephrolepis flexuosa* fernland (07.01.10)** Several small patches[2] of *Nephrolepis flexuosa* occur around Pool 1 on steep banks above the hot spring. The *N. flexuosa* was viewed through the fence in 2011 and the population size appeared relatively unchanged since previous surveys, however some of the population was obscured from view.	Steep bank	Not mapped
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Pool 2 is surrounded by silica deposits with occasional toetoe (*Austroderia fulvida*), tūrutu, kiokio, and several prostrate kānuka plants. A small sinter terrace occurs downslope of Pool 2.	Hillslope terrace	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)**	Hot spring	<0.1 ha

Indigenous Flora: *Nephrolepis flexuosa* (At Risk-Declining[3]) and prostrate kānuka (At Risk-Naturally Uncommon), occur around the margins of these two hot springs. The 2011 population of *Nephrolepis flexuosa* was bigger than the population recorded in 1979 (see Ecroyd 1979a)[4]. Therefore the population has increased in size over the last 20 years. Because of fencing, not all of the population could be viewed in 2011, however the part of the population viewed appeared to be similar to the 2004 site visit (Chris Bycoft *pers obs.*). The *Nephrolepis flexuosa* population at this site is quite some distance from other populations of this species, with the nearest populations being at Waihunuhunu and Waikite Valley.

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1 Previously named Upper Atiamuri (site U16/8) in Wildland Consultants (2004c)
2 Population sizes: (1) 3×0.2 m; (2) 7×2 m; and (3) 2×1 m (based on 2003 survey).
3 All flora threat rankings are from de Lange *et al.* 2013.
4 1979 population size: 0.3×0.3 m and 1.5×0.5 m.

Lycopodiella cernua, another species characteristic of geothermal areas, is also present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present.

Current Condition (2011 Assessment): The condition of the vegetation surrounding these pools has greatly improved since 2003. Blackberry and broom infestations have been controlled and indigenous tree species have been planted. The cover of an 'At Risk-Declining' species (*Nephrolepis flexuosa*) has increased since 1979.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Scattered blackberry (5-25% cover) is present around the northern pool.

Human impacts (*2011 Assessment*): A 2 m tall fence surrounds Pool 1. The natural outlet of Pool 1 has been lowered and reformed as a drain, and there was a small concrete trough present at the outlet.

In the past there was a small wooden platform in Pool 2 that was used for cooking food, however this had been removed.

Grazing (*2011 Assessment*): The pools are fenced to exclude grazing.

Adjoining land use (*2011 Assessment*): Reserve (planted indigenous shrubs), farmland.

Site Change:

Recent change (2011 Assessment): The pools themselves are unchanged since 2003. However, the site is now securely fenced, and has been planted with indigenous tree species.

Historical (*Assessed in 2011*): Site not assessed, no historical photos found.

Management Requirements: The area of blackberry shrubland has potential for ecological restoration (e.g. control and planting of indigenous species).

Significance Level: Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 9).

Significance Justification: This site has been ranked as being of regional significance because of the physical geothermal features and because it is a scientific reserve. There are also small populations of two 'At Risk' species (prostrate kānuka and *Nephrolepis flexuosa*), but the site does not represent habitat of considerable importance for the conservation of these species.

The classification as a scientific reserve under the Reserves Act is because of the high value of the "hot flowing neutral springs" that are present. The springs were ranked C2 in Cody (1995) using the NZ Geopreservation Inventory Ranking System where C stands for "Regional - site of regional scientific, education or aesthetic importance" and 2 stands for "moderately vulnerable to modification by humans" (defined in Kenny and Hayward

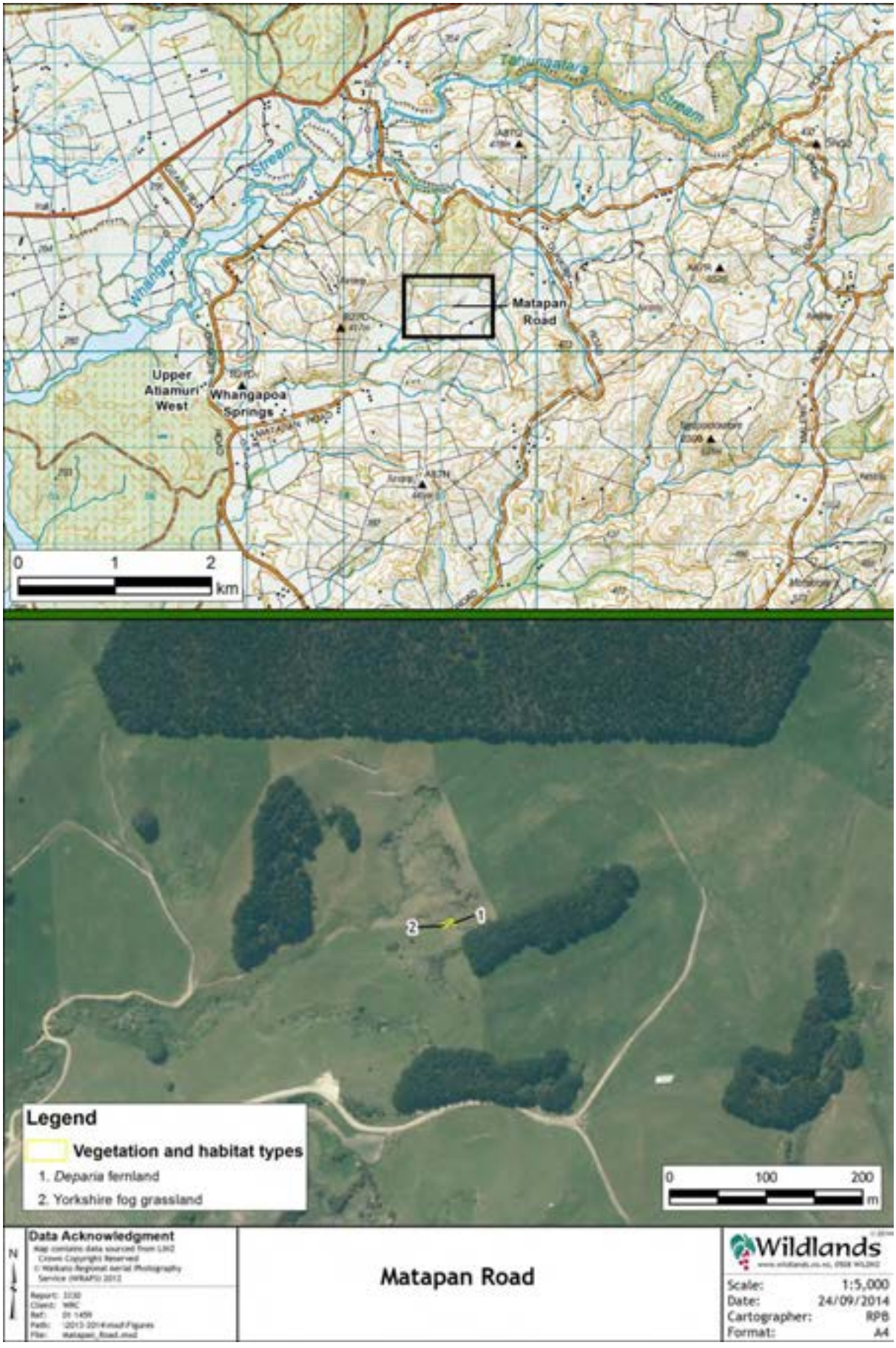
1993).

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and in this study, this site was classed as Category C - the third highest category.

In earlier assessments (e.g. Wildland Consultants 2004c & 2007a) the site name was "Upper Atiamuri".

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.

References: Ecroyd 1979a; Given 1996; Hochstein 2007a; Spring-Rice 1996; Wildland Consultants 2004c, 2007a, & 2012.


Matapan Road
Upper Atiamuri West
Whangapoa Springs
Whangapoa Stream
Stream
0 1 2 km
2
0
Legend
Vegetation and habitat types
1. Deparia fernland
2. Yorkshire fog grassland
0 100 200 m
N
Data Acknowledgment
Matapan Road
Wildlands
Scale: 1:5,000
Date: 24/09/2014
Cartographer: RPB
Format: A4

MATAPAN ROAD

Site Number:	ATV03	**Grid Reference:**	NZTopo50 BF36 691 505
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1869082 N5750467
Geothermal Field:	Atiamuri	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	333 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	2 February 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Indigenous fernland (07.01) ***Deparia* fernland (07.01.12)** *Deparia petersenii* occurs around a geothermal spring and on stream margins within the site. Green, orange, and red algae are present on the substrate behind the waterfall below the spring. Ring fern, whekī, *Asplenium oblongifolium*, and tall willow herb (*Epilobium ciliatum*), occur on the cooler margins.	Hillslope	<0.1 ha
Exotic grassland (08.01) **Yorkshire fog grassland (08.01.01)** Pasture along the margins of the warm water stream includes Yorkshire fog, tall fescue (*Schedonorus arundinaceus*), and creeping bent (*Agrostis stolonifera*).	Hillslope	<0.1 ha

Indigenous Flora: No 'Threatened' or 'At Risk' plant species have been recorded from this site.

Fauna: Yellowhammer was heard during the 2011 survey and other common pasture bird species are likely to be present.

Current Condition (2011 Assessment): This small (*c.*10 m × 3 m) geothermal spring on a hillslope is unfenced and the margins are grazed. The water temperature of the spring at the time of survey (2011) was 69.1 °C. The thermal stream flows into a small (cold) stream *c.*20 m below the spring.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): None evident, surrounded by pasture grasses.

Human impacts (*2011 Assessment*): Surrounded by farmland.

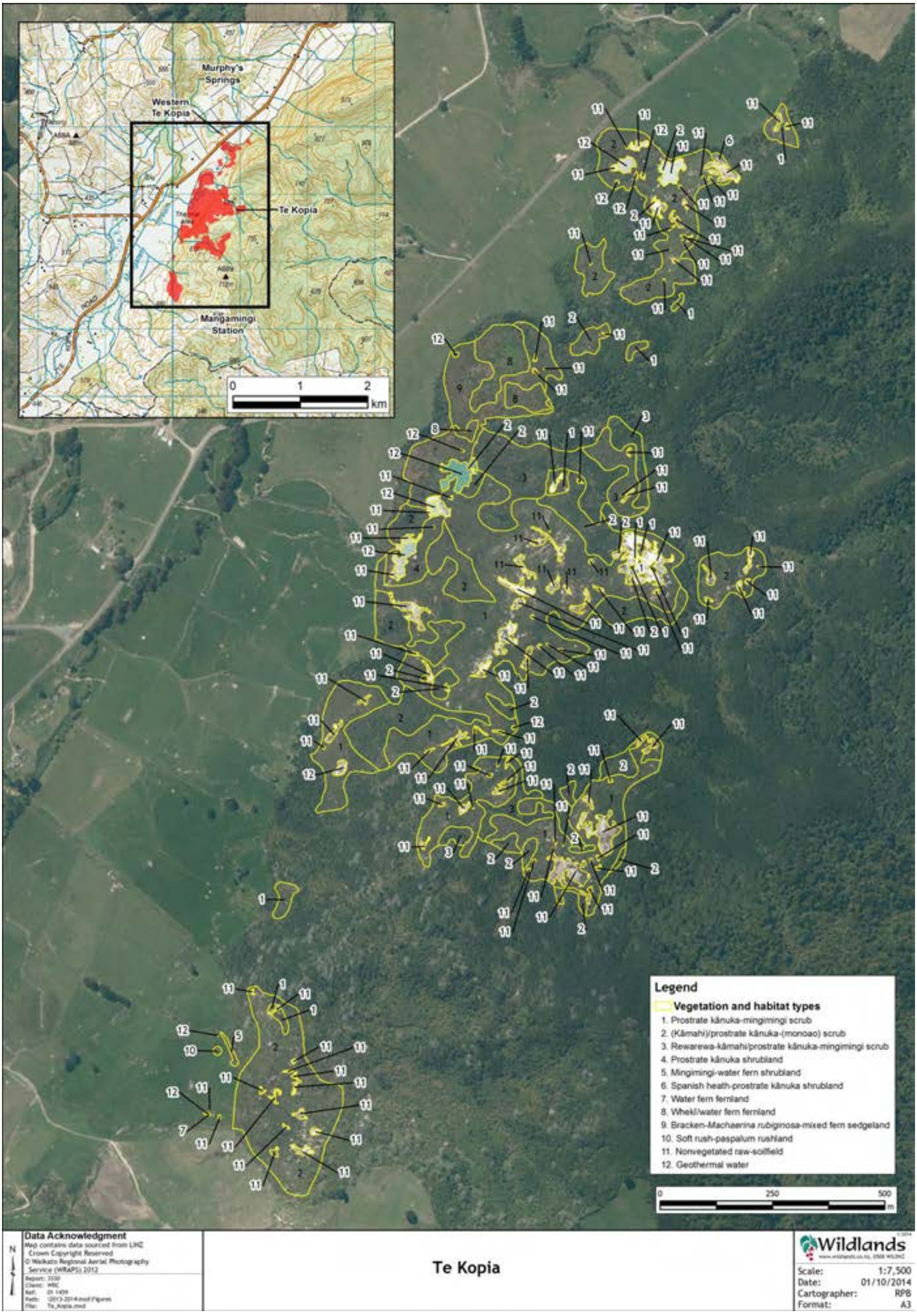
Grazing (*2011 Assessment*): This spring is unfenced and within grazed pasture.

Adjoining land use (*2011 Assessment*): Farming, pine plantation nearby.

Site Change:

Recent change (2011 Assessment):	Site has not been assessed previously, but is unlikely to have undergone significant recent change.
Historical (*Assessed in 2011*):	Site not assessed, no historical photos found.
Management Requirements:	This site should be fenced to exclude domestic animals and ecological restoration planting on the margins should be considered.
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19).
Significance Justification:	Matapan Road is locally significant because it comprises a very small example of geothermal vegetation and habitat, a feature that is nationally uncommon.
Notes:	A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.
References:	Newson 2010.

TE KOPIA GEOTHERMAL FIELD


Murphy's Springs
Western Te Kopia
Te Kopia
Mangamingi Station
0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka-mingimingi scrub
2. (Kāmahi)/prostrate kānuka-(monoao) scrub
3. Rewarewa-kāmahi/prostrate kānuka-mingimingi scrub
4. Prostrate kānuka shrubland
5. Mingimingi-water fern shrubland
6. Spanish heath-prostrate kānuka shrubland
7. Water fern fernland
8. Wheki/water fern fernland
9. Bracken-Machaerina rubiginosa-mixed fern sedgeland
10. Soft rush-paspalum rushland
11. Nonvegetated raw-soilfield
12. Geothermal water
0 250 500 m
Data Acknowledgment
Map contains data sourced from LINZ
Crown Copyright Reserved
© Waikato Regional Aerial Photography Service (WRAPS) 2012
Te Kopia
Wildlands
Scale: 1:7,500
Date: 01/10/2014
Cartographer: RPB
Format: A3

TE KOPIA

Site Number:	TKV01[1]	**Grid Reference:**	NZTopo50 BF37 805 434
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1880502 N5743445
Geothermal Field:	Te Kopia	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*440-620 m
Tenure:	Protected (Te Kopia Scenic Reserve) and unprotected private land		
Extent of Geothermal Habitat:	*c.*65.1 ha		
Extent of Geothermal Vegetation:	*c.*64.3 ha		
Date of Most Recent Field Survey:	9 and 16 May 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka scrub (04.01) **Prostrate kānuka-mingimingi scrub (04.01.05)** A variable type dominated by either prostrate kānuka, or mingimingi, or both. Areas with more prostrate kānuka occur on warmer soils, whilst areas on cooler soils contain a higher proportion of mingimingi. The canopy is up to *c.*2.5 m height with occasional emergent kōhūhū, kāmahi, mānuka, and dead wilding pines and local water fern. Large patches of the moss *Campylopus* are present in the understorey. Where mingimingi is dominant, mānuka often occurs in association with occasional kāmahi, and locally common radiata pine. The subcanopy comprises the above species as well as prickly mingimingi, monoao, *Dicranopteris linearis*, and bracken. The groundcover is dominated by tūrutu, and a moss and liverwort mat on which *Schizaea dichotoma* and *Schizaea fistulosa* occur.	Hillslopes	*c.*24.9 ha
(Kāmahi)/prostrate kānuka-(monoao) scrub (04.01.08) Local kāmahi are emergent over a dense prostrate kānuka canopy (0.5-3 m height) with monoao locally common. Minigminigi, prickly mingimingi, *Gleichenia microphylla*, and tūrutu are scattered throughout. Local patches of mānuka, *Dicranopteris linearis*, and the moss *Chiloscyphus semiteres* are also present. Patches of kāmahi/mingimingi-prostrate kānuka scrub and kāmahi-rewarewa scrub are present within this vegetation type but are too small to map separately.	Foot of scarp, hillslopes	*c.*21.6 ha
Mixed indigenous species scrub (04.08) **Rewarewa-kāmahi/prostrate kānuka-mingimingi scrub (04.08.03)** Rewarewa and kāmahi form a patchy canopy over prostrate kānuka and mingimingi with scattered māpou (*Myrsine australis*) and whekī. Local patches of water fern, *Dicranopteris linearis*, and tūrutu are present. Steam vents are present throughout.	Hillslopes	*c.*6.2 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** This vegetation type occurs around the most active geothermal features, and comprises a sparse low canopy of prostrate kānuka (0.3-1 m high) with occasional mingimingi and monoao. The groundcover	Foot of scarp; hillslopes	*c.*0.8 ha

[1] Site number in 2004 was U17/13 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
is dominated by *Campylopus* and *Dicranoloma* (mosses), with lichens, liverworts, and *Lycopodiella cernua* also present. Unvegetated areas occur locally throughout this vegetation type. Mānuka-kāmahi/prickly mingimingi scrub is locally common around the margins. Scattered radiata pine and emergent rewarewa saplings are present. *Dicranopteris linearis* is abundant throughout this habitat type, while a small population of *Nephrolepis flexuosa* is present at the north end of geothermal activity.		
Mingimingi-dominant shrubland (05.02) **Mingimingi-water fern shrubland (05.02.01)** Mingimingi and water fern form an incomplete canopy over bare ground with local patches of *Lycopodiella cernua*. Several patches of *Dicranopteris linearis* are present. Boiling hot springs are present within this type.	Hillslope	<0.1 ha
Mixed indigenous and exotic shrubland (05.08) **Spanish heath-prostrate kānuka shrubland (05.08.04)** Scattered Spanish heath and prostrate kānuka with occasional toetoe and tūrutu on a recent landslide scar.	Hillslope	<0.1 ha
Indigenous fernland (07.01) **Water fern fernland (07.01.03)** Water fern fernland surrounds a bubbling mudpool/spring within farmland in the southern part of the site. Soil temperatures of up to 100.4 °C were recorded at *c.*40 cm depth on the northern margin of this type. The fernland is fringed by pasture dominated by browntop, Yorkshire fog, and paspalum. Domestic stock have access. **Whekī/*Hypolepis ambigua*-water fern fernland (07.01.20)** Occurs on an alluvial fan with raised soil temperatures. Whekī and scattered mānuka are present over a dense fernland of *Hypolepis ambigua* and water fern, with local patches of dense *Carex geminata*. Small patches of *Machaerina teretifolia*, local prostrate kānuka, and occasional emergent whauwhaupaku are also present.	Hillslope Alluvial fan	<0.1 ha *c.*2.0 ha
Indigenous sedgeland (09.01) **Bracken-*Machaerina rubiginosa*-mixed fern sedgeland (09.01.05)** A wetland in the base of an old explosion crater where whekī, harakeke, toetoe, and mānuka are emergent over a dense cover of bracken, *Machaerina rubiginosa*, and *Hypolepis distans*. Locally common species include *Gleichenia microphylla, Machaerina tenax, Hypolepis ambigua,* water fern, swamp kiokio, and kiokio. Occasional patches of *Carex geminata* and scattered emergent whekī-ponga are also present.	Old explosion crater	*c.*4.1 ha
Exotic sedgeland (09.02) **Soft rush-paspalum sedgeland (09.02.01)** Soft rush and paspalum sedgeland with water purslane, sweet vernal, and narrow-leaved plantain occurs around the margins of small hot springs and small areas of bubbling mud.	Hillslopes	<0.1 ha

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Thermally altered clay, mud, and sinter (Burns and Leathwick 1995). Patches of raw-soilfield located within farmland support scattered patches of browntop.	Foot of the Paeroa fault scarp; hillslopes	*c*.4.6 ha
Water (22.01) **Geothermal water (22.01.01)** Hot springs, hot pools, and mud pools. Mudpools and springs within farmland are often surrounded by pasture dominated by exotic species including browntop, Yorkshire fog, and paspalum with scattered soft rush and water fern.	Foot of scarp; hillslopes	*c*.0.8 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]) dominates a large percentage of the geothermal vegetation present.

Dicranopteris linearis (At Risk-Naturally Uncommon, and known from only *c.*23 sites in New Zealand) is common throughout the site. *Schizaea dichotoma* (At Risk-Naturally Uncommon) is known from this site. A small population of *Nephrolepis flexuosa* (At Risk-Declining) is present and two 'At Risk' orchids - *Calochilus paludosus* (At Risk-Naturally Uncommon) and *C. robertsonii* (At Risk-Naturally Uncommon) - are also well represented here. *Schizaea fistulosa* has been recorded here in the past (Clarkson 1984; Burns and Leathwick 1995).

A survey of *Korthalsella salicornioides* (dwarf mistletoe; At Risk-Naturally Uncommon) in 2000 estimated the population at this site to comprise 100-200 plants (Anon 2000). There appeared to be at least this many plants at the site during the 2014 survey.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including fantail, tomtit, tūī, kereru, North Island robin, welcome swallow, grey warbler, bellbird, goldfinch, skylark, common pheasant, magpie, and Eastern rosella.

Current Condition (2014 Assessment): The geothermal vegetation is virtually unchanged since 1948 (Burns 1996b) and the area is relatively free from adventive species, although pines were invading the mingimingi scrub until recently. The Department of Conservation has undertaken control of wilding pines at this site in recent years, and it is significantly improved in condition. It is the most intact remaining example of natural vegetation zonation (extending over *c.*579 m in altitude) that includes geothermal vegetation, ranging from tall kāmahi-dominated forest through to prostrate kānuka shrubland and geothermal wetland (see also Clarkson 1984).

[1] All flora threat rankings are from de Lange *et al.* 2013.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Pine control has been ongoing in the reserve over recent years. The invasion of pines (previously *c.*6-25% cover, but now only *c.*1-5% cover) will be a continuing problem withinthe geothermal areas, and there is potential for ongoing weed invasion along the walking tracks. Blackberry (*c.*1% cover internally, *c.*5% cover on margins), Spanish heath (*c.*1% cover), grey willow (<1% cover), flowering cherry (<1%), buddleia (<1%), gorse (<1% cover), Himalaya fairy grass (*Miscanthus nepalensis*) (<1%), and pampas (<1%) are also present.

Human impacts (*2014 Assessment*): There are few walking tracks and human impact is low. A new walking track has been constructed near the northern end of the reserve.

Grazing (*2014 Assessment*): The reserve is fenced, and appeared to be in good condition in all areas inspected in 2014. Parts of this site are located in farmland and are unfenced. These areas are grazed and unfenced geothermal features are damaged by stock trampling.

Adjoining land use (*2014 Assessment*): Indigenous forest and scrub, farmland.

Site Change:

Recent change (2014 Assessment): Most changes to vegetation type boundaries are as a result of better quality aerial photographs available for the current study, rather than real change. A few additional areas, located in farmland, were added to this site in 2014. These areas are not new geothermal manifestations but have been located because of the better quality aerial photographs.

Historical (*Assessed in 2011*): Previous geological investigations of the field included the drilling of two temporary wells (drilled 1965-67, plugged 1973) (Burns 1997b).

Burns (1996b) carried out an in-depth assessment of vegetation changes at Te Kopia using historical photos from 1948, 1963, 1975, and 1991. He found that areas of bare sinter or mud occur in the same relative locations in all photographs, but change in extent. There was a marked increase in bare areas between 1948 and 1963 on steep slopes (probably as a result of earthquake or an extreme storm event), but bare areas decreased from 1963 to 1975 and essentially remained unchanged in character. Areas with vegetation dominated by prostrate kānuka did not change in obvious extent, structure, or composition since 1948 suggesting that this vegetation type is stable for long periods. Wilding pines are not present in 1948, but can be seen in the 1968 photos onwards. These have been controlled in recent years.

Management Requirements: Ongoing control of wilding pines should be undertaken and the geothermal area kept as weed free as possible. Fences should be checked regularly and maintained. Fencing of the geothermal features within private farmland should be considered.

Significance Level: International (Table 1 - Criteria 1, 3, 5, 6, 7, 9, 10; Table 2 - Factor 5).

Significance Justification:

This site is of international significance because it forms the best quality example of a relatively intact area of geothermal vegetation which is part of a high quality ecological sequence. The site is within Te Kopia Scenic Reserve which comprises an ecological sequence extending from geothermal vegetation through to tall forest, including a small geothermal wetland area. The Te Kopia Scenic Reserve has an elevation range of 400 to 979 m. This site is also an excellent, high quality example of geothermal vegetation with few weeds and little human-related disturbance.

One of the largest populations of *Dicranopteris linearis* (At Risk-Naturally Uncommon; de Lange *et al.* 2013) in New Zealand occurs here. This site also contains one of the largest populations of prostrate kānuka (At Risk-Naturally Uncommon), as well as good populations of four other 'At Risk' species (*Nephrolepis flexuosa*, *Calochilus paludosus, C. robertsonii*, and *Korthasella salicornioides*).

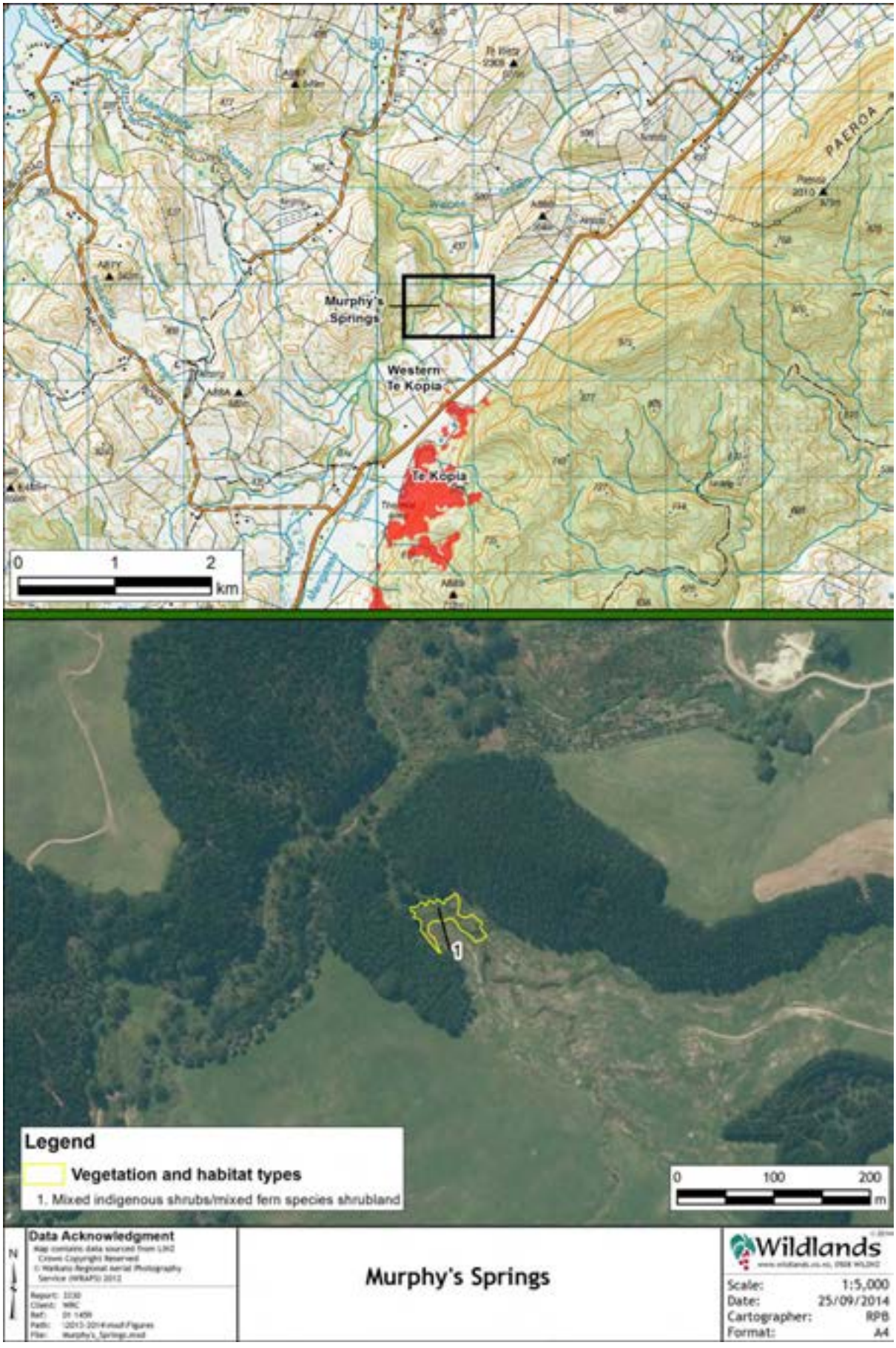
Notes:

Te Kopia Scenic Reserve was ranked as the protected natural area of highest conservation significance in the Atiamuri Ecological District (Spring-Rice 1996).

Given (1996) assessed the botanical value of many geothermal sites in the Waikato Region, and in this survey this site was classed as Category A - the highest category.

References:

Anon 2000; Beadel and Bill 2000; Burns 1996b & 1997b; Burns and Leathwick 1995; Clarkson 1984; Spring-Rice 1996; Wildland Consultants 2004c & 2012.


Murphy's Springs
Western Te Kopia
Te Kopia
PAEROA
0 1 2 km
1
Legend
Vegetation and habitat types
1. Mixed indigenous shrubs/mixed fern species shrubland
0 100 200 m
Data Acknowledgment
N
Murphy's Springs
Wildlands
Scale: 1:5,000
Date: 25/09/2014
Cartographer: RPB
Format: A4

MURPHY'S SPRINGS

Site Number:	TKV02[1]	**Grid Reference:**	NZTM BF37 807 458
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1880740 N5745787
Geothermal Field:	Te Kopia	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*370-390 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*0.2 ha		
Extent of Geothermal Vegetation:	*c.*0.2 ha		
Date of Most Recent Field Survey:	29 June 2010		

VEGETATION TYPE	LANDFORM	EXTENT
Mixed indigenous shrubland (05.07) **Mixed indigenous shrubs/mixed fern species shrubland (05.07.01)** A few plantation pines are emergent over mixed broadleaved and shrubland species including kōhūhū, karamū, mānuka, whekī, and *Coprosma propinqua* over an understorey of ferns dominated by bracken, kiokio, and *Deparia petersenii* subsp. *congrua*, and tūrutu. *Carex geminata* and *C. secta* are common on stream margins. In 2010 pines had recently been felled into the site, and black nightshade, exotic grasses (particularly Yorkshire fog), and lotus (*Lotus pedunculatus*) were common in recently disturbed areas. *Christella* aff. *dentata* ("thermal") is common in steam alongside geothermal springs and stream margins.	Gully	*c.*0.2 ha

Indigenous Flora: *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon[2]), is common alongside geothermally heated stream margins. An estimated 100 plants are present. Other species typical of geothermal habitats present include mānuka, bracken, and tūrutu.

Fauna: Common indigenous and exotic species typical of the habitats are present. Fantails were recorded during the 2010 survey.

Possum sign. Cattle have had access to site, and damage from cattle is particularly notable on site margins.

Current Condition (2011 Assessment): The site is currently in a poor ecological condition, pine plantation trees have been recently felled into the site and stock have access to site. The site has the potential to recover well if it is fenced.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): None noted.

Human impacts (*2011 Assessment*) : Trees had been felled into the site in 2010. The site is not fenced and cattle were recorded at the site.

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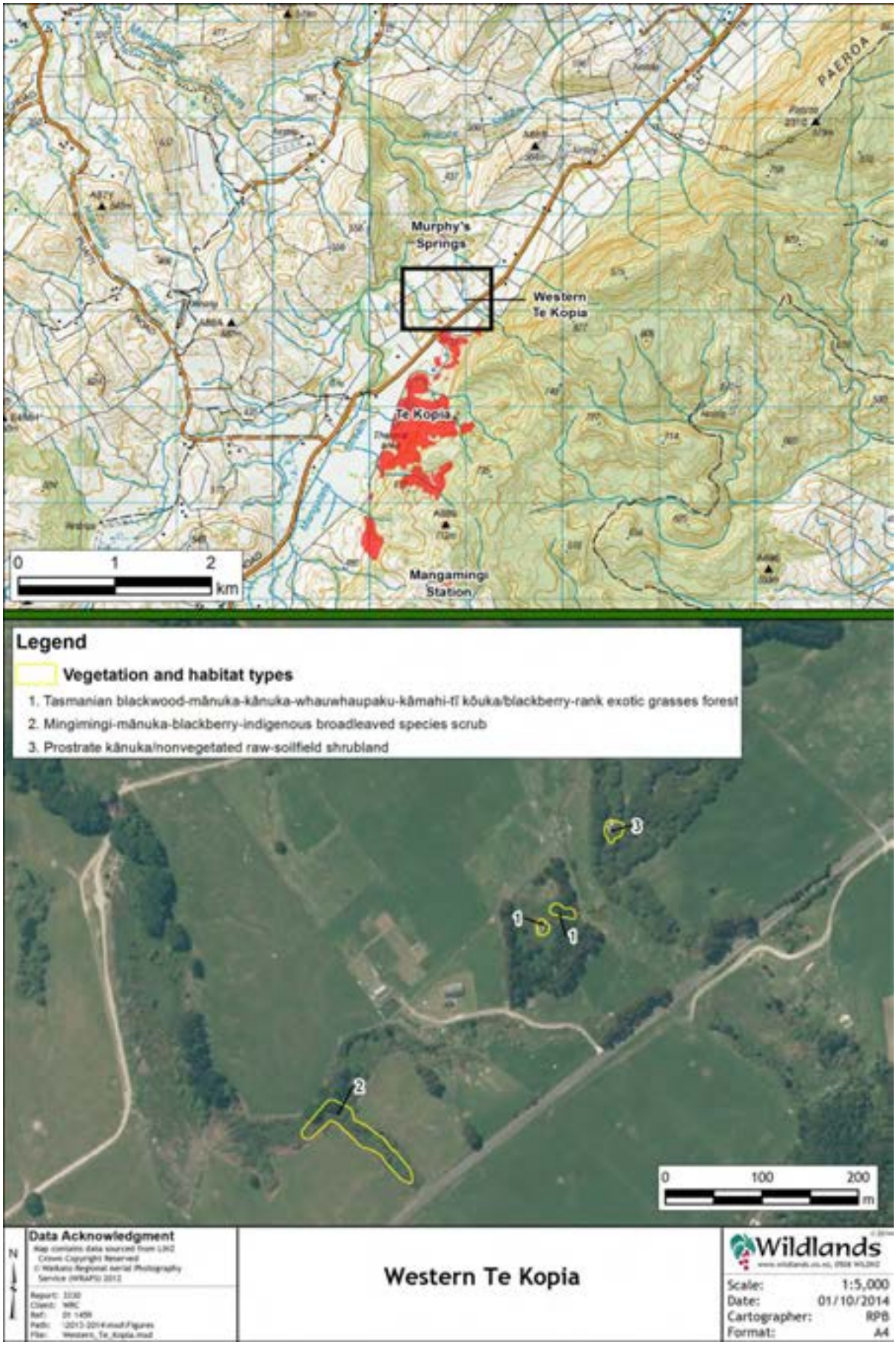
[1] Site number in 2004 was U17/38 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

Grazing (*2011 Assessment*):	The site is not fenced, and cattle have had access to the site following tree felling in 2010, and conversion of neighbouring land to pasture.
Adjoining land use (*2014 Assessment*):	Plantation forest and pasture.
Site Change:	
Recent change (*2010 Assessment*):	Unknown. Pine trees felled into geothermal areas in 2010 may have damaged some vegetation within the site.
Historical (*Assessed in 2011*):	Site not assessed, no historical photos found. The surrounding margins have previously been plantation forest and geothermal features are in a steep sided gully that is unlikely to be visible on historical black and white aerial photographs.
Management Requirements:	The site should be fenced to exclude stock. Adjacent trees should be felled away from geothermal vegetation and habitats. A small scale management plan should be prepared for the riparian margins around the springs and the thermal stream.
Significance Level:	Regional (Table 1 - Criteria 3, 5; Table 2 - Factor 12)
Significance Justification:	Murphy's Springs is a regionally significant site because it is a habitat of importance for an 'At Risk' species, *Christella* aff. *dentata* ("thermal"), known from only 15 other sites in New Zealand.
Notes:	In 2010 the pine plantation around the site had been harvested, and the adjacent land was in the process of being converted into pasture. Mapping is based on GPS waypoints obtained during the 2010 field survey. A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.


Murphy's Springs
Western Te Kopia
Te Kopia
Mangaming Station
PAEROA
0 1 2 km
Legend
Vegetation and habitat types
1. Tasmanian blackwood-mānuka-kānuka-whauwhaupaku-kāmahi-tī kōuka/blackberry-rank exotic grasses forest
2. Mingimingi-mānuka-blackberry-indigenous broadleaved species scrub
3. Prostrate kānuka/nonvegetated raw-soilfield shrubland
0 100 200 m
Data Acknowledgment
Western Te Kopia
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

WESTERN TE KOPIA

Site Number:	TKV03[1,2]	**Grid Reference:**	NZTopo50 BF37 810 452, BF37 809 451, BF37 807 449
Ecological District:	Atiamuri		
Geothermal Field:	Te Kopia	**GPS Reference:**	NZTM E1880972 N5745221, E1880919 N5745136, E1880706 N5744908
Bioclimatic Zone:	Submontane		
Local Authority:	Rotorua		
Altitude:	*c.*400 m		
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	0.3 ha		
Extent of Geothermal Vegetation:	0.3 ha		
Date of Most Recent Field Survey:	29 June 2010		

VEGETATION TYPE	LANDFORM	EXTENT
Exotic species forest (01.02) **Tasmanian blackwood-mānuka-kānuka-whauwhaupaku-kāmahi-tī kōuka/blackberry-rank exotic grasses forest (01.02.04)** Three mud pools (previously known as the Te Kopia Mud Pools) surrounded by a mostly failed Tasmanian blackwood plantation, with brush wattle (*Paraserianthes lophantha*) and indigenous tree species, including kānuka, whauwhaupaku, kāmahi, and tī kōuka. Tūrutu, *Hypolepis ambigua*, and bracken are common in the understorey. A notable feature of the kāmahi beside the eastern pool is the burnt foliage in the line of steam from the pool. A thin layer of mud from mud pool activity coats many of the trees around the hot pools. Creeping bent is common on heated soils to the south of the southern pool. There are elevated soil temperatures in the upper 10 cm of soil. Dead blackberry present here indicates a recent increase in surface geothermal activity in this area.	Mud pools	<0.1 ha
Mingimingi-dominant scrub (04.03) **Mingimingi-mānuka-blackberry-indigenous broadleaved species scrub (04.03.04)** Vegetation surrounding a small geothermal stream. Ferns (including *Deparia petersenii* subsp. *congrua*, water fern, *Gleichenia microphylla*, and bracken), *Carex secta*, mingimingi, mānuka, and whekī are common on upper stream margins with raised soil temperatures. Downstream on cooler stream margins kiokio, *Carex geminata*, and blackberry become more common. Further upslope, away from the geothermal stream, indigenous broadleaved species are common including kāmahi, whauwhaupaku, kōhūhū, karamū, horoeka (*Pseudopanax crassifolius*), with occasional common alder and cotoneaster. Scattered lianes of *Rubus schmidelioides* var. *schmidelioides* are present, and tūrutu is common in the understorey. Blackberry becomes increasingly dense away from geothermal stream margins until it is the dominant cover. The gully is steep-sided with unsafe access over much of the site, so	Gully	0.2 ha

[1] Includes the site numbered U17/39 in 2004 (Wildland Consultants 2004c).

[2] Includes "TKV03-Te Kopia Northwest", "TKV04-Te Kopia West mud pools", and "TKV05-Te Kopia Red Stream" from Wildland Consultants 2012.

VEGETATION TYPE	LANDFORM	EXTENT
only small parts of the stream were viewed.		
Prostrate kānuka shrubland (05.01) **Prostrate kānuka/nonvegetated raw-soilfield shrubland (05.01.07)** A small geothermal manifestation in a gully north of Te Kopia Mud Pools. Much of the site is unstable bare ground with an extensive network of springs present. The bare ground contains areas of *Campylopus* mossfield, and scattered plants of Mercer grass and creeping bent. In one place there are a few scattered macrocarpa (*Cupressus macrocarpa*) emergent over prostrate kānuka scrub with occasional blackberry. Three plants of *Nephrolepis flexuosa*, and occasional *Lycopodiella cernua* are also present. Tūrutu and *Rubus schmidelioides* var. *schmidelioides* are common on the margins. A stream flowing through the southern corner is surrounded by kāmahi, whauwhaupaku, karamū, makomako (*Aristotelia serrata*), whekī, kōhūhū, and macrocarpa forest.	Gully	<0.1 ha

Indigenous Flora: Three plants of *Nephrolepis flexuosa* (At Risk-Declining[1]) are present. A small area of vegetation dominated by prostrate kānuka (At Risk-Naturally Uncommon) is also present. Other species typical of geothermal habitats are also present including mānuka, mingimingi, *Deparia petersenii* subsp. *congrua*, water fern, *Gleichenia microphylla*, *Lycopodiella cernua*, tūrutu, and bracken.

Fauna: None noted. Common indigenous and exotic species typical of the habitats present are likely to be present. Possum sign was recorded in part of the site.

Current Condition (2010 Assessment): Most of the geothermal features within the site are in good condition, and an 'At Risk' fern species is present, however the vegetation within the site includes a high proportion of exotic plant species.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2010 Assessment*): Blackberry is common at the margins of the geothermal stream and on cooler soils (5-25% cover). Other pest plant species present include common alder (<1% cover) and cotoneaster (<1% cover). Although Tasmanian blackwood and brush wattle are present in part of the site, these species are not having a significant impact on geothermal features at the site.

Human impacts (*2010 Assessment*): Macrocarpa and Tasmanian blackwood have been planted close to parts of this site. A track has been cut through blackberry to the southern of the two mudpools within the site.

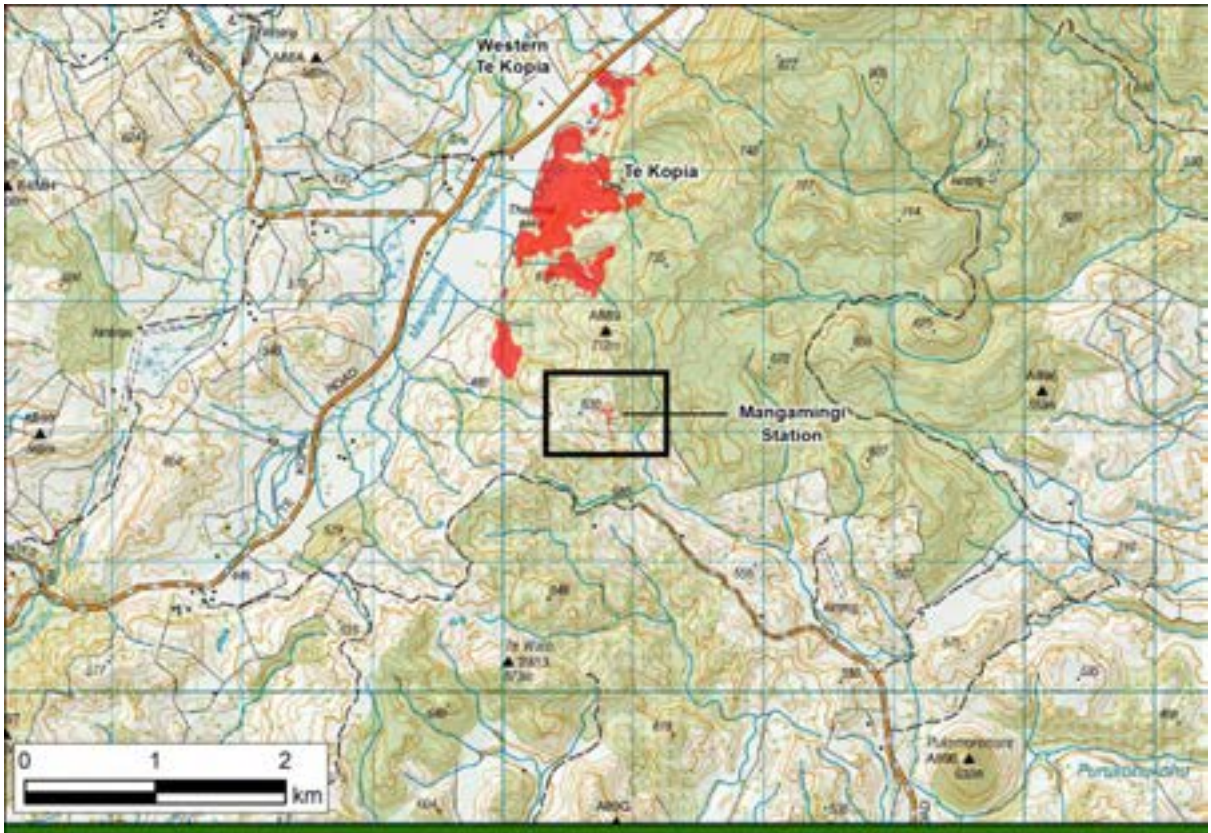
Grazing (*2010 Assessment*): The site has been fenced to exclude domestic stock.

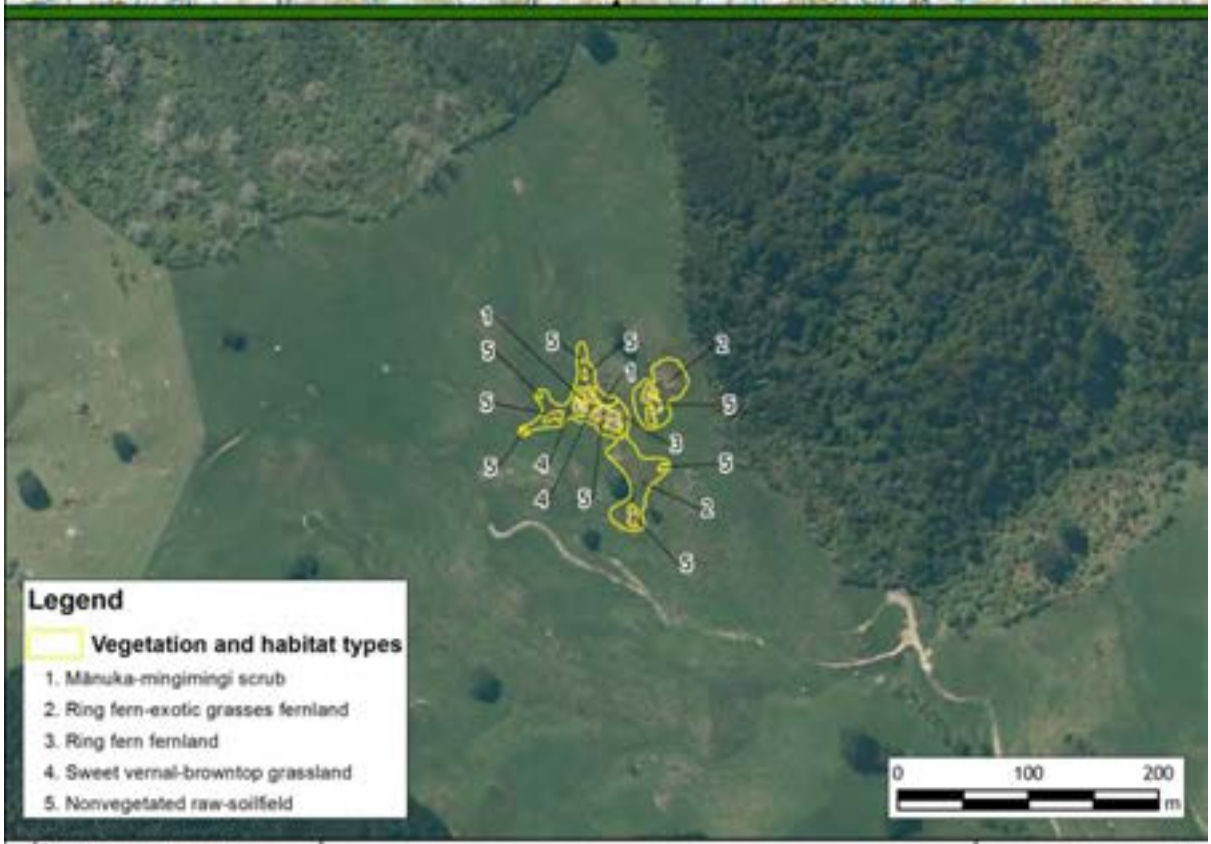
Adjoining land use (*2010 Assessment*): Macrocarpa plantation, Tasmanian blackwood plantation, mixed indigenous and exotic species scrub, farmland.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Site Change:

Recent change (2010 Assessment):	The site had not been inspected by Wildland Consultants prior to the 2010 survey. The farmer advised that the southern of the two mud pools has become more active in recent years.
Historical (*Assessed in 2011*):	Site not assessed, no historical photos found. As most of the vegetation is in a gully and the site is small, changes are unlikely to be visible on historical black and white photographs. Blackberry and other pest plant species are likely to have changed the character of the site, and reduced the extent of indigenous dominant vegetation in association with geothermal features.
Management Requirements:	Fences should be maintained to ensure continuing exclusion of stock. The spread of pest plant species should be monitored at regular intervals (e.g. five-yearly). Cotoneaster and common alder should be removed from the site.
Significance Level:	Local (Table 1 - Criteria 3, 5 ; Table 2 - Factor 19)
Significance Justification:	Western Te Kopia is a locally significant site because it contains two nationally uncommon habitat types (geothermally heated dry ground, geothermal stream; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also supports small populations of two 'At Risk' species (prostrate kānuka and *Nephrolepis flexuosa*), but does not represent habitat of considerable importance for the conservation of these species.
Notes:	Background information on these sites was provided by Paul Cashmore and Pete Corson (Deparment of Consevation, Rotorua). The area of geothermal habitat alongside the stream was referred to as 'Road Spring' in Hochstein (2007b). A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. The geophysical assessment is presented as three separate sites - Te Kopia Northwest, Te Kopia West Mudpools, and Te Kopia Red Stream.
References:	Hochstein 2005 & 2007b; Wildland Consultants 2004c & 2012.





Data Acknowledgment

Map contains data sourced from LINZ
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Mangamingi Station

Wildlands
www.wildlands.co.nz, 0508 WILDNZ

Scale:	1:5,000
Date:	18/09/2014
Cartographer:	RPB
Format:	A4

MANGAMINGI STATION

Site Number:	TKV06[1]	**Grid Reference:**	NZTopo50 BF37 808 422
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1880782 N5742165
Geothermal Field:	Te Kopia	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	600-630 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*0.5 ha		
Extent of Geothermal Vegetation:	*c.*0.5 ha		
Date of Most Recent Field Survey:	28 June 2010		

VEGETATION TYPE	LANDFORM	EXTENT
Mānuka-dominant scrub (04.04) **Mānuka-mingimingi scrub (04.04.02)** A small area of mānuka and mingimingi scrub above an area of geothermal activity. Other species present include kōhūhū, whekī, horoeka, and tāwiniwini. One rimu (*Dacrydium cupressinum*) seedling was also recorded. *Pyrrosia eleagnifolia* was epiphytic in this vegetation type. Lower banks are covered with non-vascular species and occasional *Asplenium flaccidum*. Sheep tracks are evident through the understorey and exotic grasses are common.	Hillslope	<0.1 ha
Indigenous fernland (07.01) **Ring fern-exotic grasses fernland (07.01.04)** This vegetation type is a mosaic of ring fern fernland and sweet vernal-browntop grassland. Several patches of kiokio and *Doodia australis* are also present.	Hillslope	*c.*0.3 ha
Ring fern fernland (07.01.11) Ring fern fernland, with common patches of *Lycopodiella cernua* and *Hypolepis ambigua*, and scattered mingimingi, tūrutu, and prostrate kānuka. There are local patches of pasture dominated by sweet vernal, browntop, white clover, and sheep's sorrel. Three juvenile plants of *Dicranopteris linearis* were recorded at one location in this vegetation type.	Hillslope	<0.1 ha
Exotic grassland (08.01) **Sweet vernal-browntop grassland (08.01.05)** Well grazed pasture. Common species present include sweet vernal, browntop, white clover, and sheep's sorrel with occasional Scotch thistle (*Cirsium vulgare*), cocksfoot, and *Gonocarpus micranthus*. Patches of ring fern are common.	Hillslope, gully	*c.*0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Bare geothermally influenced clays and silicified rocks and several pools of geothermally influenced water. Mostly bare ground, but scattered areas of mossfield and exotic grasses are present. Non-vascular plant species present include the mosses *Campylopus clavatus* and *Wijkia extenuata*, and the liverwort *Monoclea fosteri*; however a	Hillslope, gully	*c.*0.1 ha

[1] Site number in 2004 was U17/37 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
detailed non-vascular plant survey was not undertaken. Scattered plants of the following species are also present: prostrate kānuka, *Lycopodiella cernua,* ring fern, water fern, mingimingi, prickly mingimingi, *Blechnum fluviatile,* and Spanish heath.		

Flora: *Dicranopteris linearis* (At Risk-Naturally Uncommon[1]) and prostrate kānuka (At Risk-Naturally Uncommon) are present within the site. Prostrate kānuka is scattered throughout the site, and three juvenile plants of *D. linearis* were recorded at NZTM E1880808 N6303706. *D. linearis* is known from only *c.*23 sites in New Zealand. Other species typical of geothermal habitats recorded were *Lycopodiella cernua*, tūrutu, *Campylopus clavatus*, *Paesia scaberula*, mānuka, mingimingi, prickly mingimingi, tāwiniwini, *Blechnum penna-marina* subsp. *alpina*, *Doodia australis, Hypolepis ambigua, Gonocarpus micranthus*, and water fern.

Fauna: No 'Threatened' or 'At Risk' bird species are known from this site. Common bird species recorded were goldfinch, paradise shelduck, and Australian magpie. The site is grazed by sheep.

Current Condition (2011 Assessment): The site is currently grazed by sheep and is in a poor condition with trampling and grazed vegetation present throughout the site. Despite this the site contains populations of two at risk plant species and has relatively few pest plants. If fenced to exclude sheep, and major pest plants such as blackberry and Spanish heath are controlled, it is likely that the populations of prostrate kānuka and *Dicranopteris linearis* will expand in size.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Several Spanish heath plants are present.

Human impacts (*2011 Assessment*): The site is farmed.

Grazing (*2011 Assessment*): The site is within a farm paddock which is currently grazed by sheep.

Adjoining land use (*2011 Assessment*): Farmland.

Site Change:

Recent change (2010 Assessment): Unknown. The site has not previously been assessed but it is unlikely to have undergone significant recent change.

Historical (*Assessed in 2011*): Possible historic extent is difficult to determine because of the small size of the site. Geothermal features on site suggest that the most significant change has been the conversion of land to farming. There are no obvious areas near this site that could previously have been geothermal areas, but at which geothermal activity has ceased. The site is too small to locate on

[1] All flora threat rankings are from de Lange *et al.* 2013.

historical aerial photographs.

Management Requirements: The ecological condition of this site will improve markedly if it is fenced to exclude stock. If fenced, monitoring and control of pest plants (particularly blackberry, wilding pines, and Spanish heath) should be undertaken.

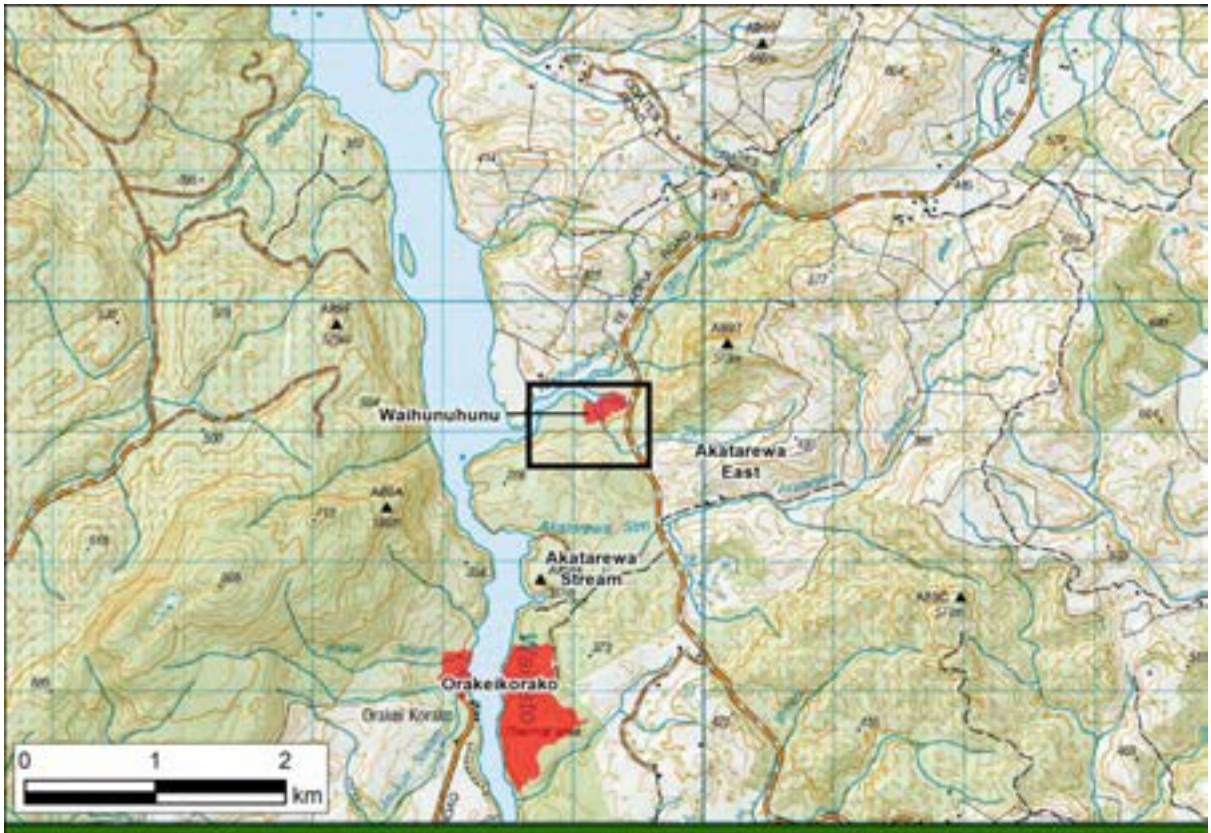
Significance Level: Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).

Significance Justification: Mangamingi Station is locally significant because it is a small example of a habitat type that is nationally uncommon (geothermally heated dry soils; Williams *et al*. 2007; Holdaway *et al.* 2012). It also supports small populations of two 'At Risk' species (prostrate kānuka and *Dicranopteris linearis*), but does not represent habitat of considerable importance to the conservation of these species. If fenced to exclude stock, the indigenous vegetation of the site is likely to improve markedly, and the ecological values of the site would increase. Prostrate kānuka and *Dicranopteris linearis* populations would be likely to increase in size.

Notes: The site is about 700 m to the east of other patches of geothermal vegetation mapped at Te Kopia (TKV01). It is on the Landcorp-owned Mangamingi Station and has only recently become known to ecologists and geologists. Paul Cashmore (Department of Conservation, Rotorua) provided background information on this site.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.

ORAKEIKORAKO GEOTHERMAL FIELD



Data Acknowledgment

Waihunuhunu

Wildlands

Scale: 1:5,000
Date: 07/10/2014
Cartographer: RPB
Format: A4

WAIHUNUHUNU

Site Number:	OKV01[1]	**Grid Reference:**	NZTopo50 BF36 752 390
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1875248 N5738978
Geothermal Field:	Orakeikorako	**Local Authority:**	Rotorua
Bioclimatic Zone:	Lowland - Submontane	**Altitude:**	300 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*5.4 ha		
Extent of Geothermal Vegetation:	*c.*2.8 ha		
Date of Most Recent Field Survey:	18 February 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Indigenous fernland (07.01)		
Bracken-mingimingi-blackberry fernland (07.01.02) Scattered emergent karamū, kōhūhū, mamaku, and whekī are present over bracken, mingimingi, and blackberry. On lake margins patches of *Machaerina articulata*, *M. rubiginosa*, lake clubrush, swamp kiokio, *Christella* aff. *dentata* ("thermal"), *Carex virgata*, and kiokio are common. A geothermal stream flows though this vegetation type.	Wetland, terrace	<0.1 ha
***Christella* aff. *dentata* ("thermal")-*Nephrolepis flexuosa*-blackberry fernland (07.01.09)** A narrow band of indigenous fernland is present on each side of an unnamed hot water stream that flows into the Waihunuhunu Arm of Lake Ohakuri. Immediately above the stream, the banks are dominated by *Christella* aff. *dentata* ("thermal") and *Nephrolepis flexuosa*. *Cyperus ustulatus* is common. Upslope, blackberry and bracken shrubland fringes the *Christella* and *Nephrolepis*. Karamū, kōhūhū, whekī, and other indigenous shrubs locally form a canopy over the ferns. Although access to the stream is very difficult due to the steep sides and very hot stream temperatures, the stream was viewed at several points along its length. This type is also located on the banks above Lake Ohakuri where hot geothermal water from a geothermal stream discharges into the lake. Here, patches of *Nephrolepis flexuosa* and bracken are common. *Christella* aff. *dentata* ("thermal"), blackberry, and mingimingi are also common, with scattered *Dicranopteris linearis,* Spanish heath, whekī, karamū, kōhūhū, and swamp kiokio.	Stream margins	*c.*0.1 ha
***Nephrolepis flexuosa* fernland (07.01.10)** Around the hot springs that feed into the unnamed hot water stream, the vegetation is dominated by *Nephrolepis flexuosa* with several patches of *Dicranopteris linearis*. Other scattered indigenous and exotic species also present within this area include *Carex virgata*, blackberry, mingimingi, *Hypolepis ambigua*, whekī, buddleia, *Christella* aff. *dentata* ("thermal"), Spanish heath, bracken, tī kōuka, Yorkshire fog, and *Cyperus ustulatus*.	River margins	<0.1 ha
Exotic grassland (08.01) **Mercer grass-*Cyclosorus interruptus*-*Hypolepis ambigua* grassland**	Ephemeral wetland	*c.*0.2 ha

[1] Site number in 2004 was U17/31 (Wildland Consultants 2004c and 2007b).

VEGETATION TYPE	LANDFORM	EXTENT
(08.01.04) Several hot springs are present within an area of grassland dominated by mercer grass in association with *Cyclosorus interruptus* and *Hypolepis ambigua.* Narrow-leaved plantain, blackberry, lotus, Spanish heath, Scotch thistle, broad-leaved fleabane, kōhūhū, water fern, *Cyperus ustulatus*, mānuka, and bracken are scattered throughout.		
Reedland (11.01) **Raupō reedland (11.01.01)** Raupō reedland is dominant with patches of *Carex virgata* and *Carex secta* common, and occasional grey willow, marsh bedstraw (*Galium palustre*), *Centella uniflora*, *Carex maorica,* lotus*, Eleocharis acuta,* whekī, swamp kiokio, *Juncus edgariae,* and *Machaerina articulata*.	Wetland	*c.*0.2 ha
(Tī kōuka)-(mānuka)/raupō-*Cyperus ustulatus*-lake clubrush reedland (11.01.04) Scattered emergent tī kōuka and local patches of mānuka are present over raupō reedland. In places, *Cyperus ustulatus*, lake clubrush, and *Eleocharis acuta* replace raupō as the dominant species. Small areas of bare soil are also present around hot springs. *Carex virgata*, whekī, swamp kiokio, and *Machaerina articulata* are locally common.	Wetland	*c.*1.6 ha
Grey willow/raupō reedland (11.01.05) Grey willow is common over raupō reedland.	Wetland	*c.*0.6 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermally heated waters of the Waihunuhunu Arm of Lake Ohakuri. Several hot springs feed this area, along with input from several hot streams.	Open water	*c.*2.6 ha

Indigenous Flora:

Nephrolepis flexuosa (At Risk-Declining[1]) is common and *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon) is scattered to locally common along stream margins throughout this site, and on lake margins.

One large population of *Cyclosorus interruptus* (At Risk-Declining) is present within the raupō reedland in the southern half of the site. This population comprises 52 large patches over *c.*60 m^2.

Two small populations of *Dicranopteris linearis* (At Risk-Naturally Uncommon) were present near the hot springs along the unnamed hot water stream, and another population occurs near the outlet of this stream into Lake Ohakuri. *D. linearis* known from only *c.*23 sites in New Zealand.

Other species present that are typical of geothermal habitat include *Cyperus ustulatus*, tūrutu, water fern, raupō, mingimingi, and mānuka.

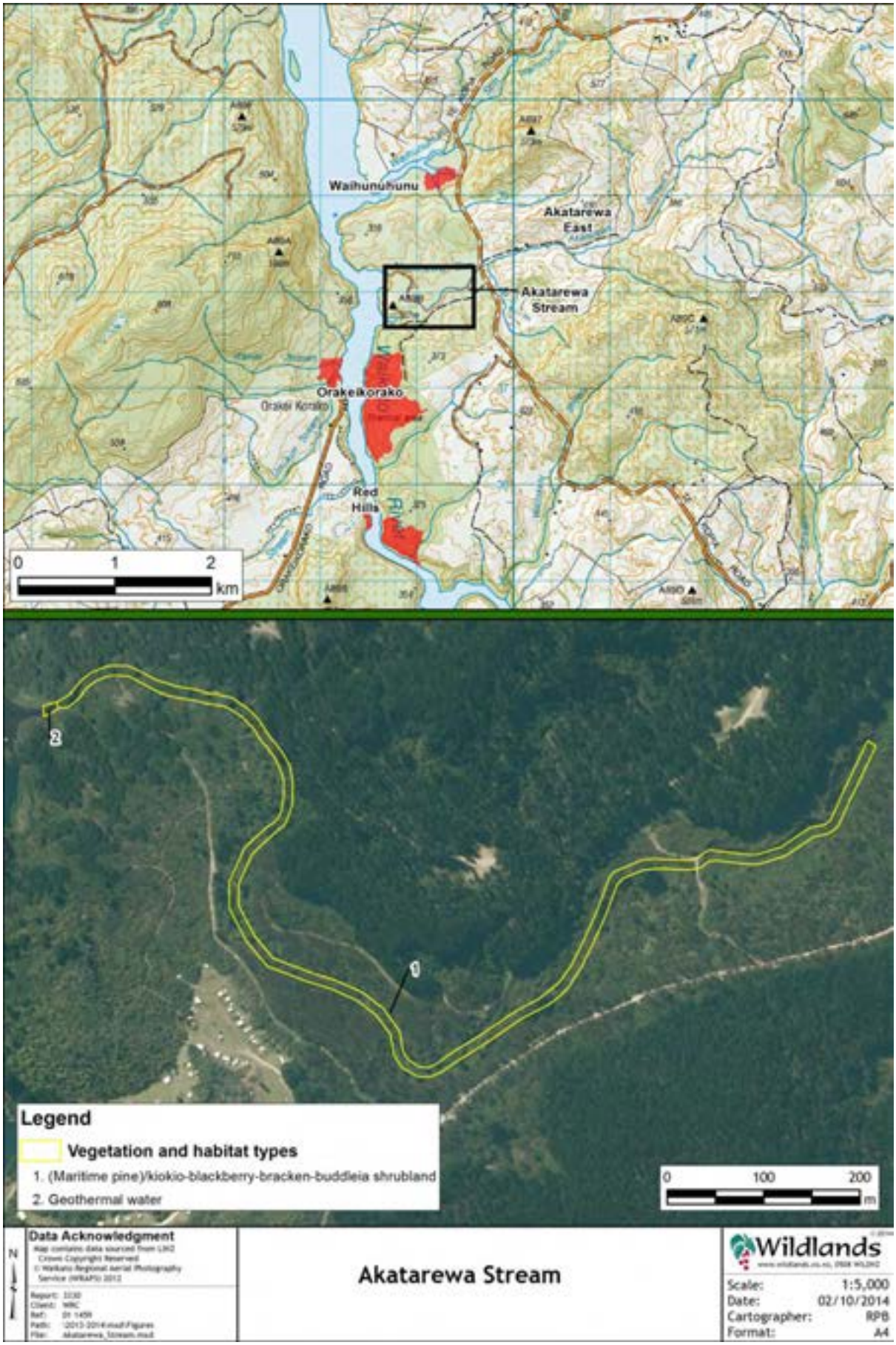
Thelypteris confluens (At Risk-Naturally Uncommon) has previously been recorded from this site (E. Miller pers. comm. in Hobbs 2002) but was not recorded in 2007 or 2014.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Fauna:	North Island fernbird (At Risk-Declining[1]), grey warbler, bellbird, and tūī are present. Spotless crake (At Risk-Relict), spur-winged plover, pukeko, and little shag have previously been recorded from the site (Wildland Consultants 2007b). Other common indigenous and introduced bird species typical of the habitat are likely to be present.
Current Condition (2014 Assessment):	This site is mainly in good ecological condition and provides good habitat for four threatened fern species. However, pest plants (e.g. grey willow, blackberry, and wilding radiata pines) are common within the site.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2014 Assessment*):	Blackberry (15% cover), grey willow (2% cover), crack willow (1% cover), Spanish heath (<1% cover), Himalayan honeysuckle (<1% cover), Japanese honeysuckle (<1% cover), and buddleia (<1% cover) are present.
Human impacts (*2014 Assessment*):	Some tracks near geothermal streams near road access to the Waihunuhunu Arm of Lake Ohakuri. Several pools have been used for swimming, and some features have been altered by pool users. The water to one hot pool has been piped to the site.
Grazing (*2014 Assessment*):	The site is not farmed. Some feral pig sign was evident.
Adjoining land use (*2014 Assessment*):	Surrounded by indigenous vegetation. Northwestern side adjacent to Lake Ohakuri.
Site Change:	
Recent change (2014 Assessment):	There has been little obvious change to the geothermal vegetation since 2007, though the density of blackberry has increased around the margins of the stream making access to the upper reaches and hot springs difficult.
Historical (*Assessed in 2011*):	The lower parts of the site were flooded when the Waikato River was dammed to form Lake Ohakuri in 1961, and features were destroyed by flooding. The loss of terrestrial geothermal vegetation and habitats at this site since the raising of Lake Ohakuri is likely to have been substantial. The geothermal activity in Waihunuhunu is now in the head of a bay that was previously a long valley (*c.*1 km in length)[2]. Heated water in this arm of the lake indicates that continues to be considerable geothermal activity beneath the lake. (Surface temperatures up to 25 °C were measured *c.*1 km from the Waihunuhunu site in 2014). Although significant terrestrial geothermal habitat was lost to flooding, the higher lake level may have expanded the area of geothermal wetland. The terrestrial part of the site has probably changed little over time, although wilding and plantation pines occur close to the site margins. We estimate that a loss of *c.*75% of terrestrial geothermal habitats occurred with the raising of Lake Ohakuri, of which about 25% became geothermal wetland, resulting in a total loss of geothermal habitats of *c.*50% since between 1961 and 2007.

[1] All avifauna threat rankings are from Robertson *et al.* 2013.
[2] Historical photograph: SN358 Run 1074 1944-49.

Management Requirements:	This site has high potential for ecological restoration through management of pest plants (e.g. grey willow and crack willow, and blackberry in wetland areas).
Significance Level:	National (Table 1 - Criteria 3, 5, 6, 9; Table 2 - Factor 8).
Significance Justification:	This site is of national significance because it is a good quality, representative example of geothermal habitat, which includes nationally uncommon ecosystems (geothermal stream margins, lakeshore wetland; Williams *et al*. 2007; Holdaway *et al.* 2012). It also contains good populations of four 'At Risk' species: *Cyclosorus interruptus*, *Christella* aff. *dentata* ("thermal"), *Dicranopteris linearis*, and *Nephrolepis flexuosa*. It contains one of the largest populations of *N. flexuosa* and *C. interruptus* in New Zealand.
References:	Beadel and Bill 2000; Given 1989, 1995 & 1996; Hobbs 2002; Merrett and Burns 1999; Smith-Dodsworth 1993; Wildland Consultants 2004c, 2007b, & 2012.


Waihunuhunu
Akatarewa East
Akatarewa Stream
Orakeikorako
Red Hills
0 1 2 km
Legend
Vegetation and habitat types
1. (Maritime pine)/kiokio-blackberry-bracken-buddleia shrubland
2. Geothermal water
0 100 200 m
Data Acknowledgment
Akatarewa Stream
Wildlands
Scale: 1:5,000
Date: 02/10/2014
Cartographer: RPB
Format: A4

AKATAREWA STREAM

Site Number:	OKV02[1]	**Grid Reference:**	NZTopo50 BF36 751 378
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1875142 N5737819
Geothermal Field:	Orakeikorako	**Local Authority:**	Rotorua
Bioclimatic Zone:	Lowland Submontane	**Altitude:**	*c.*300 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*1.4 ha		
Extent of Geothermal Vegetation:	*c.*1.4 ha		
Date of Most Recent Field Survey:	13 February 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Mixed indigenous and exotic shrubland (05.08) **(Maritime pine)/kiokio-blackberry-bracken-buddleia shrubland (05.08.02)** Kiokio, blackberry, bracken, and *Cyperus ustulatus* are common along stream margins, with scattered emergent maritime pine, tī kōuka, whauwhaupaku, kōhūhū, buddleia, harakeke, karamū, and whekī. Creeping bent, Yorkshire fog, *Deparia petersenii*, water fern, ring fern, *Hypolepis ambigua*, creeping buttercup, paku (*Pneumatopteris pennigera*), *Carex secta*, and lotus are also common. There are scattered *Christella* aff. *dentata* ("thermal") plants along the stream.	Stream margins	*c.*1.4 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermal stream. Springs, seepages, and occasional sinter are present along the entire length of the stream that has been mapped within this site (not mapped separately). Water temperatures of up to 63.8 °C were recorded from the stream in 2014 (range 38.9 °C-63.8 °C).	Stream	<0.1 ha

Indigenous Flora:

The population of *Christella* aff. *dentata* ("thermal") (At Risk-Declining[2]) appears to have decreased within the site compared with 2007, with only six plants recorded in 2014 compared with 47 mature plants in 2007. This may be related to the timing of the survey.

Cyclosorus interruptus (At Risk-Declining) was recorded at this site in 2002 (Hobbs 2002) but was not observed in either 2007 or 2014 in spite of extensive searching. *C. interruptus* is a seasonal species in the central North Island and is not always visible during all seasons, so this species could still be present at this site.

Dicranopteris linearis (At Risk-Naturally Uncommon, and known from only *c.*23 sites in New Zealand) was also been recorded from this site in 2002 (Hobbs 2002), but was not recorded in the 2007 or 2014 survey.

Other species typical of geothermal sites present include water fern,

[1] Site number in 2004 was U17/30 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

bracken, and *Cyperus ustulatus*.

Fauna: Common indigenous and introduced bird species typical of the habitat were present including North Island robin, grey warbler, North Island fantail, bellbird, pied tit, tūī, kōtare (sacred kingfisher), and California quail.

Current Condition: Much of the site is in a poor to moderate ecological condition with plantation forestry occurring close to stream margins. The site provides good habitat for at least one 'At Risk' fern species.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Blackberry (25% cover), pampas (5% cover), buddleia (5% cover), Himalayan honeysuckle (5% cover), grey willow (<1% cover), cotoneaster (<1% cover), black wattle (<1% cover), Spanish heath (<1% cover), wild kiwifruit (*Actinidia deliciosa*) (<1% cover), and Montpellier broom (<1% cover) are present.

Human impacts (*2014 Assessment*): Several bridges and culverts. Bathing pools. Plantation forest harvesting operations nearby.

Grazing (*2014 Assessment*): Livestock have no access to the area.

Adjoining land use (*2014 Assessment*): Plantation forestry, indigenous vegetation. Stream flows into Lake Ohakuri. A camp ground is present near the stream at one point.

Site Change:

Recent change (2014 Assessment): No significant change was observable at this site since 2007 other than the apparent decline in the *Christella* population.

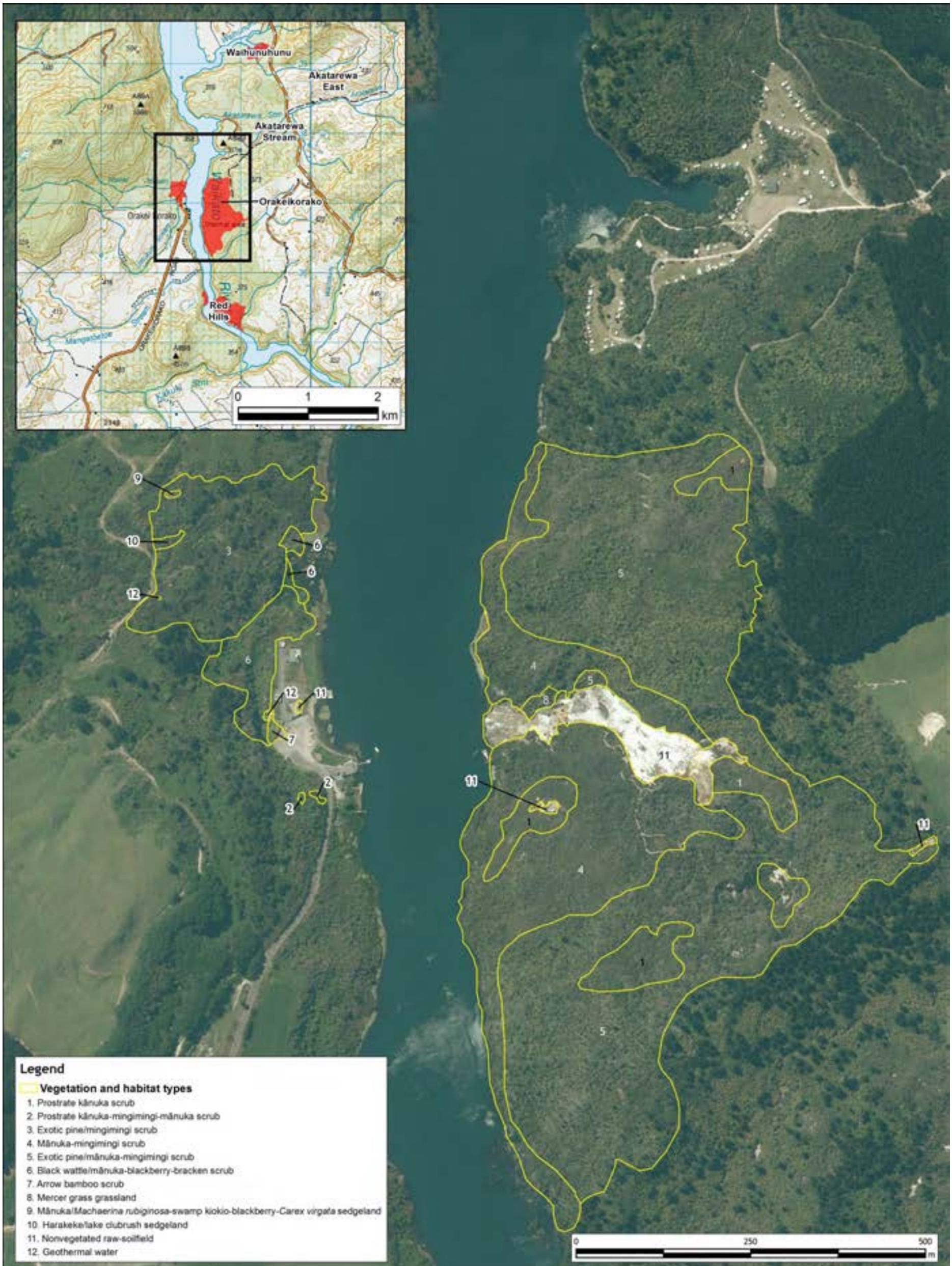
Historical (*Assessed in 2011*): In 2011 the 2007 aerial photographs were compared with those from 1949[1]. It appears that the lower portion of the stream (in the order of *c.*50 m) was inundated when Lake Ohakuri was raised. This is likely to have reduced habitat for fern species such as *Christella* aff. *dentata* ("thermal"). An area of raw-soilfield appears to be present in the upper stream catchment in 1949; this area is now in plantation forest. Overall, there was at least a 25% loss of geothermal vegetation and habitats at this site since between 1949 and 2007.

Management Requirements: The stream margins are potential ecological restoration sites. Management should include the control of pest plant species (e.g. patches of dense blackberry scrub) and planting of suitable, locally-sourced indigenous species. Establishing a buffer of indigenous vegetation between the stream and plantation forestry would reduce the possibility of harvesting operations impacting on the *Christella* aff. *dentata* ("thermal") populations.

Significance Level: Regional (Table 1 - Criteria 3, 5; Table 2 - Factor 12).

[1] Historical photos: SN 358 Run 1074 Photos 92-94, 1949.

Significance Justification:	This site is of regional significance because it contains an important population of an 'At Risk' species *Christella* aff. *dentata* ("thermal"). This is one of only 15 known sites of *Christella* aff. *dentata* ("thermal") in the North Island.
References:	Beadel and Bill 2000; Given 1989a, 1995, & 1996; Hobbs 2002; Merrett and Burns 1999; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004c, 2007b, & 2012.


Waihunuhunu
Akatarewa East
Akatarewa Stream
Orakeikorako
Red Hills
0 1 2 km
0 250 500 m
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Prostrate kānuka-mingimingi-mānuka scrub
3. Exotic pine/mingimingi scrub
4. Mānuka-mingimingi scrub
5. Exotic pine/mānuka-mingimingi scrub
6. Black wattle/mānuka-blackberry-bracken scrub
7. Arrow bamboo scrub
8. Mercer grass grassland
9. Mānuka/Machaerina rubiginosa-swamp kiokio-blackberry-Carex virgata sedgeland
10. Harakeke/lake clubrush sedgeland
11. Nonvegetated raw-soilfield
12. Geothermal water
Data Acknowledgment
Map contains data sourced from LINZ
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© Waikato Regional Aerial Photography Service (WRAPS) 2012
Orakeikorako
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A3

ORAKEIKORAKO

Site Number:	OKV03[1]	**Grid Reference:**	NZTopo50 BF36 747 369
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1874726 N5736937
Geothermal Field:	Orakeikorako	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*300-340m
Tenure:	Protected (Whirinaki Stream Marginal Strip administered by DOC) and unprotected private land		

Extent of Geothermal Habitat: *c.*46.8 ha
Extent of Geothermal Vegetation: *c.*46.8 ha
Date of Most Recent Field Survey: 1 August 2010 (east side of Lake Ohakuri)
2 February 2011 (west side of Lake Ohakuri)
13 February 2014 (new area on west side of Lake Ohakuri)

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka (1-3 m high) forms a dense canopy with mingimingi and mānuka scattered throughout. Prickly mingimingi and karamū are also present. The groundcover comprises local *Lycopodiella cernua, Dicranopteris linearis*, Indian doab, and bracken, with tūrutu and *Dicranoloma* sp. scattered throughout. Fumaroles occur throughout. Wilding pine control has recently been carried out in most of this area and some felled pine trees were observed.	Hillslopes	*c.*3.0 ha
Prostrate kānuka-mingimingi scrub (04.02) **Prostrate kānuka-mingimingi-mānuka scrub (04.02.02)** Small areas of heated soils (up to 30 °C in 2011) with prostrate kānuka, mingimingi, and mānuka occur near the road. Other species in this area include bracken, maritime pine, broad-leaved fleabane, Japanese honeysuckle, silver birch, and Spanish heath.	Hillslope	<0.1 ha
Mingimingi-dominant scrub (04.03) **Exotic pine/mingimingi scrub (04.03.02)** Emergent radiata pine and maritime pine up to *c.*8 m tall are scattered to locally common over mingimingi and mānuka with occasional mamaku and māpou. Frequent boiling mud pools occur within depressions in this area. Water fern, tūrutu, and occasional prostrate kānuka and blackberry are present on the margins of the mud pools. Patches of prostrate kānuka and mānuka scrub are present within this type but are too small to map out separately. In these areas, prostrate kānuka and mānuka form a moderately dense canopy up to *c.*4 m tall over a ground cover dominated by mosses, principally *Chiloschyphus semiteres* and *Dicranoloma billarderei*, with local patches of *Leucobryum javense*. Ferns (e.g. *Hypolepis ambigua*, *Asplenium flaccidum*, *A. polyodon*, hound's tongue fern) and indigenous broadleaved species are scattered throughout. Steam vents and *Dicranopteris linearis* occur throughout this area. *Trentepohlia*, an algae, is abundant on prostrate kānuka branches.	Hillslopes	*c.*4.4 ha

[1] Site number in 2004 was U17/11 (Wildland Consultants 2004c and 2007b).

VEGETATION TYPE	LANDFORM	EXTENT
Mānuka-dominant scrub (04.04) **Mānuka-mingimingi scrub (04.04.02)** Mānuka and mingimingi in association with scattered kānuka and prostrate kānuka and occasional karamū and kōhūhū. *Gleichenia microphylla,* bracken, ring fern, water fern, kiokio, and tūrutu are also present. There are large local patches of *Dicranopteris linearis,* and small local patches of Indian doab. Fumaroles are scattered throughout and there are seepages adjacent to Lake Ohakuri. Scattered populations of *Christella* aff. *dentata* ("thermal") occur near heated water on lake margins.	Hillslopes and alluvial terrace	*c.*10.8 ha
(Exotic pine)/mānuka-mingimingi scrub (04.04.03) This area comprises a mosaic of mānuka-mingimingi scrub and karamū-whekī-mamaku scrub, where mānuka-mingimingi scrub is the predominant vegetation type. Occasional rimu are present. Broadleaved species and tree ferns are common including rewarewa, kōhūhū, ponga (*Cyathea dealbata*), and *Cyathea smithii*. *Morelotia affinis,* kiokio, and tūrutu are common in the understorey. Fumaroles occur throughout, and prostrate kānuka is associated with areas of heated soil. Mingimingi, prostrate kānuka, water fern, kiokio, and whekī are common around mud pools. Wilding pine control has been recently undertaken, and whilst patches of wilding pine remain at some localities, the cover is greatly reduced compared with previous surveys.	Hillslopes and alluvial terraces	*c.*24.7 ha
Mixed exotic and indigenous species scrub (04.09) **Black wattle/mānuka-blackberry-bracken scrub (04.09.04)** Emergent black wattle and maritime pine occur in association with mānuka, blackberry, bracken and Japanese honeysuckle with small patches of raupō, mingimingi, and prostrate kānuka (up to *c.*3 m tall). Blackberry occurs in large swathes and in places is the dominant canopy cover. Other species that commonly occur in this area include *Lycopodiella cernua*, ring fern, swamp millet*, Machaerina rubiginosa,* karamū, whekī, tūrutu, *Gleichenia microphylla*, greater bindweed, *Cyperus ustulatus*, buddleia, Mercer grass, and *Hypolepis* sp. Large clumps of *Christella* aff. *dentata* ("thermal") (with a total population of *c.*40 plants), *Cyclosorus interruptus* (*c.*50 plants), and *Dicranopteris linearis* are also present. Mud pools occur throughout this type.	Wetland, gently sloping.	*c.*1.6 ha
Exotic species-dominant scrub (04.10) **Arrow bamboo scrub (04.10.06)** An area of arrow bamboo (*Pseudosasa japonica*) with occasional maritime pine, black wattle, cotoneaster, and Japanese honeysuckle is present near the visitor carpark	Hillslope	<0.1 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01[1])** Prostrate kānuka forms a sparse, low canopy (<0.5 m height) in local areas around the margin of the sinter terrace and other areas of		<0.1 ha

[1] Areas of this vegetation type occur within the area mapped as 04.01.01 but were too small to be mapped separately.

VEGETATION TYPE	LANDFORM	EXTENT
nonvegetated raw-soilfield. Mingimingi is common on margins. In poorly drained areas mānuka is common with occasional *Machaerina juncea*, wīwī, and oioi (*Apodasmia similis*).		
Indigenous fernland (07.01) ***Dicranopteris* fernland (07.01.01) (not mapped)** Small areas dominated by *Dicranopteris linearis* occur locally. These areas were too small to identify on the aerial photograph, but are scattered amongst prostrate kānuka scrub and shrubland.	Hillslope	<0.1 ha
Exotic grassland (08.01) **Mercer grass grassland (08.01.03)** A small area of grassland dominated by Mercer grass with local *Gleichenia microphylla,* water fern and ring fern. *Cyperus ustulatus* and *Machaerina juncea* occur around a small thermal seepage.	Alluvial terrace	*c*.0.1 ha
Indigenous sedgeland (09.01) **Mānuka/*Machaerina rubiginosa*-swamp kiokio-blackberry-*Carex virgata* sedgeland (09.01.03)** A small patch of geothermally influenced wetland dominated by *Machaerina rubiginosa* is present on the western side of the farm track that bisects the site. Mānuka is scattered to common over sedgeland dominated by *M. rubiginosa* with locally common swamp kiokio, blackberry, and *Carex virgata*. Scattered emergent maritime pine and kōhūhū are also present. **Harakeke/lake clubrush sedgeland (09.01.08)** A small patch of geothermally influenced wetland dominated by lake clubrush occurs beside the farm track that bisects the northwestern part of this site. Harakeke is common with local patches of raupō. A geothermally influenced stream flows through this area. Other species present include swamp millet, lotus, swamp kiokio, and Japanese honeysuckle. This wetland area is surrounded by exotic shrub species (including Spanish heath and blackberry) and bracken, which then grade into prostrate kānuka-mānuka scrub.	Flat Flat	<0.1 ha <0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** A large sinter deposit terrace on the eastern side of the river is the most prominent geothermal feature of the site (mapped as (i) on the vegetation map). Mineral pools and hot springs occur throughout this feature, with some geysers along its edge. There are also patches of bare ground, steaming fumaroles, and mud pools throughout the site, which were too small to map separately. Occasional wīwī, mānuka, and patches of exotic grasses are present.	Hillslopes and alluvial terrace	*c*.2.1 ha
Water (22.01) **Geothermal water (22.01.01)** Hot seepage and hot springs surrounded by blackberry. A few plants (<5 plants of each) of each of *Cyclosorus interruptus* and *Christella* aff. *dentata* ("thermal") are present along the warm margins.	Alluvial terrace	<0.1 ha

Indigenous Flora: Extensive areas of prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Dicranopteris linearis* (At Risk-Naturally Uncommon) are present within this site. *D. linearis* is known from only *c.*23 sites in New Zealand.

At least 50 plants of *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon) are located on the eastern margins of Lake Ohakuri. None are known inland of the lake edge on the eastern side. At least another 40 plants are located in the wetland behind the accommodation facilities on the western side of the lake, along with several small populations of *Cyclosorus interruptus* (At Risk-Declining), some of which were immature in 2011 and may not survive.

Schizaea dichotoma (At Risk-Naturally Uncommon), *Calochilus robertsonii* (At Risk-Naturally Uncommon), *Psilotum nudum*, *Lycopodiella cernua*, arrow grass, *Schizaea bifida*, sea rush, mānuka, tūrutu, and *Campylopus clavatus*, which are characteristic of geothermal areas, are also present.

Nephrolepis flexuosa (At Risk-Declining) and *Corunastylis pumila*[2] (At Risk-Naturally Uncommon) have been recorded from this site in previous surveys but were not observed in 2004, 2011, or 2014.

Other species of interest that occur at Orakeikorako include *Microtis parviflora, Thelymitra carnea* (Bellingham 1985), sea rush, *Limosella lineata*, and *Drosera binata* (Wildland Consultants 2009a).

Fauna: Common indigenous and introduced bird species typical of the habitat are present, including grey warbler, silvereye, Australasian coot, fantail, Australasian harrier, tūī, New Zealand scaup, North Island robin, spur-winged plover, Eurasian blackbird, wild turkey, mallard, yellowhammer, and Australian magpie. One New Zealand bush falcon (Threatened-Nationally Vulnerable[3]) was recorded flying over the eastern side of the site in February 2011. Grey duck (Threatened-Nationally Critical) and black shag (At Risk-Naturally Uncommon) have also been recorded on geothermal waters of Lake Ohakuri near this site. Wasps were recorded from the western wetland.

A small population of long-tailed bats (Threatened-Nationally Vulnerable) have been recorded in Ruatapu thermal cave (http://related.springerprotocols.com/lp/de-gruyter/observations-of-a-cave-colony-of-the-long-tailed-bat-chalinolobus-sjZI2WehC4; accessed 12 September 2011). Long-tailed bats have also been recorded from Tutukau Forest, adjacent to the northwestern part of this site.

Pig and possum sign (scat) were observed within the site. Deer are also likely to utilise this site.

Current Condition (2011 Assessment): Overall, most of the site is in excellent ecological condition. Removal of wilding pines in 2008/2009 improved the quality of the geothermal vegetation on the western side of this site markedly since 2004, with most

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1 All flora threat rankings are from de Lange *et al.* 2013.
2 Formerly *Genoplesium pumilum*
3 All avifauna threat rankings are from Robertson *et al.* 2013.

tree stumps not visible to the naked eye from the car park on the eastern side in 2011. However, pampas has become established in places following pine control. Some pampas control has been undertaken within the site since 2011 but was not completed due to time and weather constraints. Some small areas of wilding pines on the site are still to be controlled.

Invasive pest plant species are common within vegetation in the northwestern part of the site, and local patches of adventive weed species are present on the western side of the river. Control of maritime pine, radiata pine, black wattle, blackberry, Japanese honeysuckle, and arrow bamboo should be undertaken.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*):

Wilding pines (maritime pine and radiata pine) have been removed from large parts of the site but are still still present at *c.*1-5% cover in the main body of the site and up to 25% cover in part of the northwestern part of this site. Other invasive pest plant species present include grey willow (<1% cover), Spanish heath (1-5% cover), blackberry (1-5% cover), black wattle (1-5% cover), broom (<1% cover), Montpellier broom (<1% cover), buddleia (<1% cover), Himalayan honeysuckle (<1% cover), Japanese honeysuckle (1-5% cover), arrow bamboo (<1% cover), and narrow-leaved carpet grass (1% cover). Pampas has increased in cover since wilding pine control was undertaken and is now present at 1-5% cover. Arrow bamboo and blackberry were only recorded as common on the western side of the river. Blackberry is very uncommon on the eastern side of the river; an uncommon features of geothermal sites.

Waikato Regional Council has undertaken pampas control within this site in 2011 and 2014; further pampas control is still required as control operations were not completed in 2014 due to weather and time constraints.

Human impacts (*2011 Assessment*):

Two royal fern plants were found at Orakeikorako on 11 March 2009 (Wildland Consultants 2009a), and these were removed. This area is managed as a tourist facility and the geothermal features of the area are valued, with well maintained tracks and viewing sites keeping further human impacts to a minimum. Most vegetation away from the tourist area is rarely visited.

Farm tracks are present within the northwestern part of this site.

Grazing (*2011 Assessment*):

The northwestern part of the site is farmed and geothermal features and vegetation are not currently fenced to exclude stock. Stock sign was present within some areas of geothermal vegetation.

The main part of the site is not farmed and domestic stock do not have access to the site.

Adjoining land use (*2011 Assessment*):

Plantation forest, indigenous forest, Lake Ohakuri (on the Waikato River), accommodation facilities, tourism, and farmland.

Site Change:

Recent change (2014 Assessment):

An additional area has been added to this site, north of the existing area on the western side of Lake Ohakuri. The addition of this area is not the result of new geothermal manifestations but is the result of new information since the previous survey of the site.

The boundaries of the site have been updated following wilding pine control, and better quality aerial photographs provided in 2007 and 2012. The most significant real change to the site is the removal of pine trees on the eastern side of Lake Ohakuri which has greatly improved the ecological condition of the site.

Historical (*Assessed in 2011*):

In 1961 the Waikato River was artificially dammed to form Lake Ohakuri and *c*.75% of the geothermal features were destroyed by flooding (Lloyd 1972).

Comparison of 1949[1] and 2007 aerial photographs indicates a considerable reduction in the extent of geothermal vegetation and habitats at this site, particularly on the western side of Lake Ohakuri. Extensive areas of raw-soilfield were evident in 1949. A large proportion of these areas of bare ground were presumably geothermal, however this is virtually non-existent in 2007 aerial photographs. The advance of wilding pines into some areas on the eastern side of the river is evident in 1941 photographs. Large areas of indigenous vegetation on the western side of Lake Ohakuri have been converted to farmland since 1941.

Considerable loss of geothermal habitat with the construction of Lake Ohakuri is evident. Due to the steep nature of the landforms present an accurate measure of loss is impossible, however the previous estimates of 75% loss by Lloyd (1972) seems accurate. When assessing the areas not flooded in 1961, there was more bare ground present in the 1949 photographs in these areas than there was in 2007. Increased vegetation cover could be due to a number of factors including reduced heat from geothermal systems. Changes to the site since the 1949 photos also include a tourist operation and associated tracks.

Management Requirements:

Ongoing wilding pine and black wattle control work on the western side of the site will further enhance biodiversity values. Blackberry, Japanese honeysuckle, and arrow bamboo control at the site would allow geothermal species such as prostrate kānuka, mingimingi, *Cyclosorus interruptus*, and *Christella* aff. *dentata* ("thermal") populations to expand their range. On the eastern side of the river further pampas control should be undertaken along with follow-up monitoring and control as necessary. Follow-up control of pines should also be undertaken on a regular basis. The site should be regularly checked for new pest plant species invasions, and when small populations of invasive pest plants such as royal fern are found, they should be promptly controlled.

Geothermal vegetation and features in the northwestern part of the site should be fenced to exclude domestic stock.

[1] Historical photos: SN 358 Run 1074 Photos 92-94, 1949.

Significance Level: National (Table 1 - Criteria 1, 2, 3, 5, 7, 9; Table 2 - Factor 8).

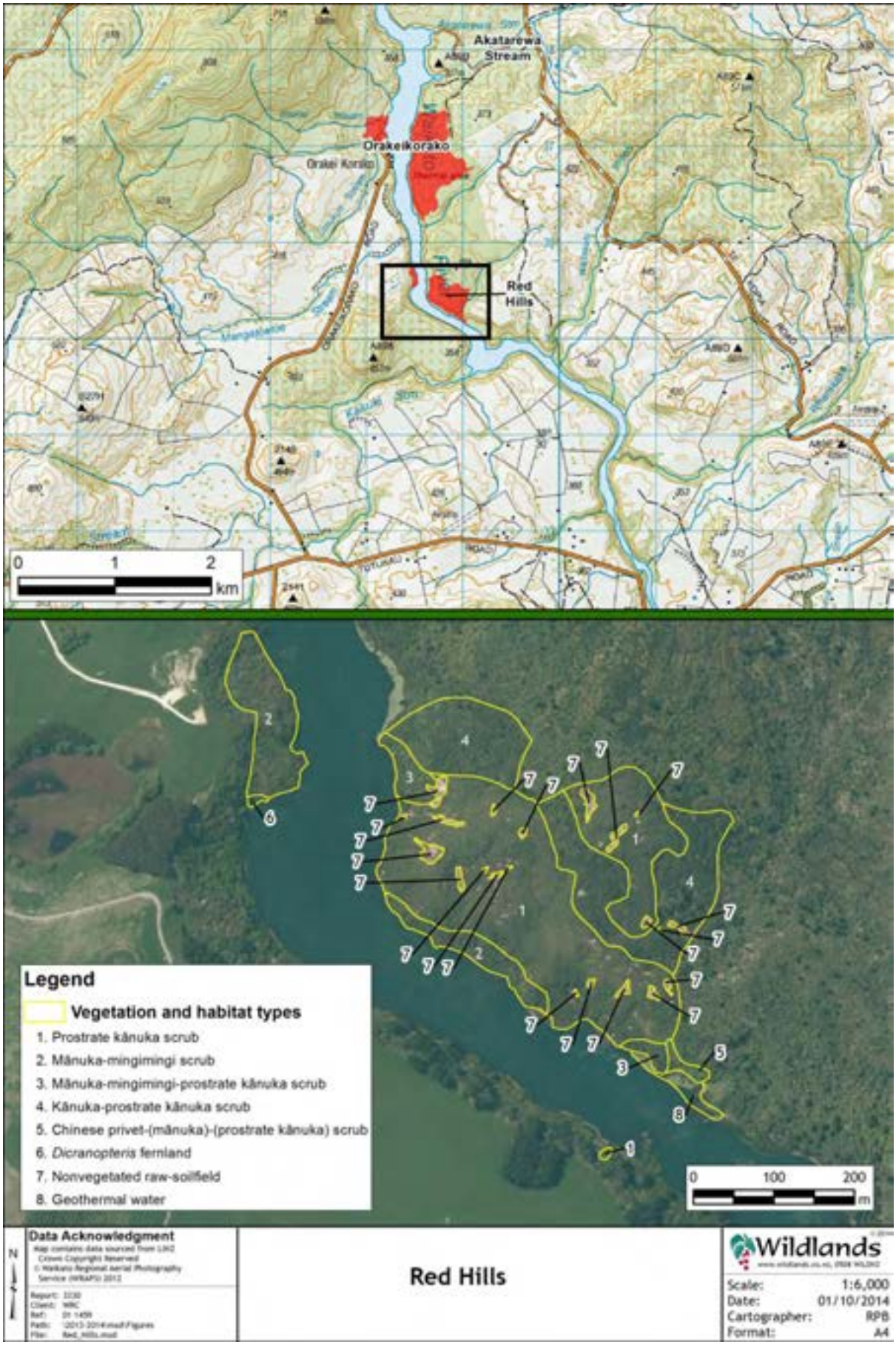
Significance Justification: This site is of national significance because it contains good quality examples of geothermal vegetation, some of which include nationally uncommon habitat types (fumaroles, geothermally heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012). The geothermal vegetation within the site includes one of the best examples in the Waikato Region. The site also includes populations of eight 'At Risk' species including prostrate kānuka, *Christella* aff. *dentata* ("thermal"), and one of the largest populations of *Dicranopteris linearis* in New Zealand. It supports a relatively high number of other notable geothermal plant species including sea rush and *Psilotum nudum*, and has a high diversity of geothermal features including steamfields, mud pools, fumaroles, geysers, hot springs, and sinter terraces. One 'Threatened' and one 'At Risk' indigenous bird species have also been recorded at the site.

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category A - the highest category.

Surface tempatures within the mudpools in the northwestern part of the site range from 45.6 to 87.4 °C in 2014. Soil temperatures within geothermal vegetation in the northwestern part of the site at approximately 10 cm depth range from 29.4 to 49.5 °C in 2014.

A geophysical assessment of the surface geothermal manifestations within the main part of this site is presented in Appendix 4.

References: Beadel 1995b; Beadel and Bill 2000; Ecroyd 1986; Given 1989a & 1995; Spring-Rice 1996; Wildland Consultants 2004c, 2007b, 2009a&b, 2012, & 2013b.


Akatarewa Stream
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0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Mānuka-mingimingi scrub
3. Mānuka-mingimingi-prostrate kānuka scrub
4. Kānuka-prostrate kānuka scrub
5. Chinese privet-(mānuka)-(prostrate kānuka) scrub
6. Dicranopteris fernland
7. Nonvegetated raw-soilfield
8. Geothermal water
0 100 200 m
Data Acknowledgment
N
Red Hills
Wildlands
Scale: 1:6,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

RED HILLS

Site Number:	OKV04[1]	**Grid Reference:**	NZTopo50 BF36 748 354
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1874822 N5735404
Geothermal Field:	Orakeikorako	**Local Authority:**	Rotorua/Taupo
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*300-340 m
Tenure:	Protected Private Land (Orakeikorako Conservation Covenant)		
Extent of Geothermal Habitat:	*c.*13.3 ha		
Extent of Geothermal Vegetation:	*c.*13.1 ha		
Date of Most Recent Field Survey:	17 February 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka forms a canopy up to *c.*0.5 m high with locally common mingimingi and scattered monoao and patches of bare ground. The groundcover comprises local patches of moss, predominantly *Dicranoloma billiardieri*, though *Campylopus clavatus*, *Leucobryum javense*, and *Sphagnum* are also present. Tūrutu and *Dicranopteris linearis* are scattered throughout. Patches of bare ground have scattered individuals of prostrate kānuka, mingimingi, and monoao. Scattered old wilding pines (radiata pine and maritime pine) within this type have been controlled, though occasional seedlings are still present. Average soil temperature within this vegetation type was 33.1 °C in 2014 (three readings). A small wetland is present in the base of a gully within this type and comprises a muddy geothermal pond surrounded by mingimingi with islands of prostrate kānuka in the pond. Water fern is abundant on the margin with occasional patches of *Gleichenia microphylla* and *Hypolepis ambigua*, and a patch of Vasey grass (*Paspalum urvillei*) is also present. Other small wetlands may be present within gullies within this type. Also within this type is a steep-sided gully with a small geothermal stream. Vegetation along the stream margins has occasional Chinese privet and whekī with scattered kiokio and occasional *Coprosma lucida* and *Austroderia fulvida*. *Cyperus ustulatus* is present around steam vents near the stream. Surface water temperatures within the stream of up to *c.*50 °C were recorded in 2014. Fumaroles are scattered throughout this type with soil temperatures around fumaroles up to 84.3 °C were measured in 2014. The moss *Racomitrium* is abundant around many fumaroles.	Hillslopes	*c.*7.2 ha
Mānuka-dominant scrub (04.04) **Mānuka-mingimingi scrub (04.04.02)** Mānuka and mingimingi form a dense scrub cover in the western part of this site, with scattered kānuka and prostrate kānuka, and occasional karamū and kōhūhū. The groundcover comprises *Gleichenia microphylla*, bracken, ring fern, water fern, kiokio, and tūrutu with large local patches of *Dicranopteris linearis*, and abundant	Hillslopes and alluvial terraces	*c.*1.7 ha

[1] Site number in 2004 was U17/10 (Wildland Consultants 2004).

VEGETATION TYPE	LANDFORM	EXTENT
Dicranoloma sp. Fumaroles are scattered throughout and there are a number of seepages that flow directly into Lake Ohakuri. Occasional emergent wilding pines (maritime pine and radiata pine) are present throughout, though most of the pines that were present in 2007 have been controlled and are dead or dying. Occasional Spanish heath and Chinese privet plants are present on the margins. **Manuka-mingimingi-prostrate kānuka scrub (04.04.06)** Occasional emergent maritime pines are present over scrub dominated by mānuka and mingimingi with local patches of prostrate kānuka shrubland. This vegetation type occurs around a small example of sinter terrace, a geyser, and an outflow of hot water into the lake. A slip exposing bright red substrate is also present. Occasional *Christella* aff. *dentata* ("thermal") are present on the lake margins.	Alluvial terrace, hillslopes	*c*.0.4 ha
Kānuka scrub (04.06) **Kānuka-prostrate kānuka scrub (04.06.01)** Kānuka forms a canopy with prostrate kānuka up to *c*.6 m high over a shrub tier dominated by mingimingi and prickly mingimingi. Groundcover within this area contains whekī-ponga and tūrutu, with local patches *of Dicranopteris linearis* and *Gleichenia microphylla*, and locally common *Chiloscyphus semiteres* (a moss).	Hillslopes	*c*.3.5 ha
Exotic species-dominant scrub (04.10) **Chinese privet-(mānuka)-(prostrate kānuka) scrub (04.10.07)** Chinese privet forms a canopy to c.2 m height with scattered mānuka and prostrate kānuka.	Lake margins	*c*.0.1 ha
Mānuka-dominant shrubland (05.04) **Mānuka shrubland (05.04.01) (not mapped)** Scattered mānuka over rank exotic grassland species (e.g. tall fescue, creeping bent, and ragwort (*Jacobaea vulgaris*)) with occasional Spanish heath and prostrate kānuka. Several areas of sandfield that has been altered by geothermal activity are present.	Lake margins	<0.1 ha
***Dicranopteris*-dominant fernland (07.01)** ***Dicranopteris* fernland (07.01.01)** A small south-facing section on the western bank of the lake with a steaming fumarole. *Dicranopteris linearis* forms the cover in this area. There are many small areas of *Dicranopteris* fernland within 04.04.02 which were almost completely dominated by *Dicranopteris linearis*, however were too small to be mapped spearately	Alluvial terrace, hillslopes	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Sinter deposits and mineral pools occur throughout this feature, with some geysers along the lake edge. There are patches of bare ground, craters, steaming fumaroles, and mud pools. Surface temperatures of up to 84 °C were recorded from fumaroles in 2014.	Flat, hillslopes	*c*.0.3 ha

VEGETATION TYPE	LANDFORM	EXTENT
Water (22.01) **Geothermal water (22.01.01)** A small area of open, geothermal water on the margin of Lake Ohakuri surrounding an island of mānuka shrubland with recorded water temperatures of up to 69ºC.	Open water	*c.*0.2 ha

Indigenous Flora: Extensive areas of prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Dicranopteris linearis* (At Risk-Naturally Uncommon) are present at this site. *D. linearis* is known from only *c.*23 sites in New Zealand. *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon) is also present. Many *Christella* plants are present near a hot stream in the south of the site[2]. *Campylopus clavatus*, a characteristic feature of geothermal areas, is also present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including grey warbler, silvereye, North Island fantail, tūī, whitehead, Australasian harrier, welcome swallow, common redpoll, chaffinch, spur-winged plover and Australian magpie.

Current Condition (2014 Assessment): Generally the site is in excellent condition with large areas of indigenous geothermal vegetation with no pest plants present. Whilst most of the wilding radiata pines within the site have been controlled, maritime pines seem to have been overlooked in the control. In addition, occasional pine seedlings are present. Few other pest plant species are present.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Scattered mature wilding radiata pines are dead or dying, though occasional seedlings of this species are still present (<1%). Maritime pine seem to have been overlooked for control and are locally common (5% cover). Chinese privet (1% cover) is present at the camp/picnic area adjacent to the southern side of the site, and is beginning to invade the mānuka-mingimingi scrub. It could spread rapidly if it is not controlled. Other pest plant species present include Spanish heath (<1%), buddleia (<1%), and Himalayan honeysuckle (<1%). Wilding pines (Ngati Tah-Ngati Whaoa) and pampas (Waikato Regional Council) have recently been controlled within this site.

Pig sign (rooting, rubbing, and scat) was locally common in the northeastern part of the site, and possum runs were also noted.

Human impacts (*2014 Assessment*): Direct human impact is low, as the site is relatively inaccessible. A bath has been constructed near the south end of the site, and some litter is present in this area. Some wilding pine control has been undertaken at the site. The vegetation at this site is very susceptible to damage by trampling.

Grazing (*2014 Assessment*): Livestock do not have access to this area.

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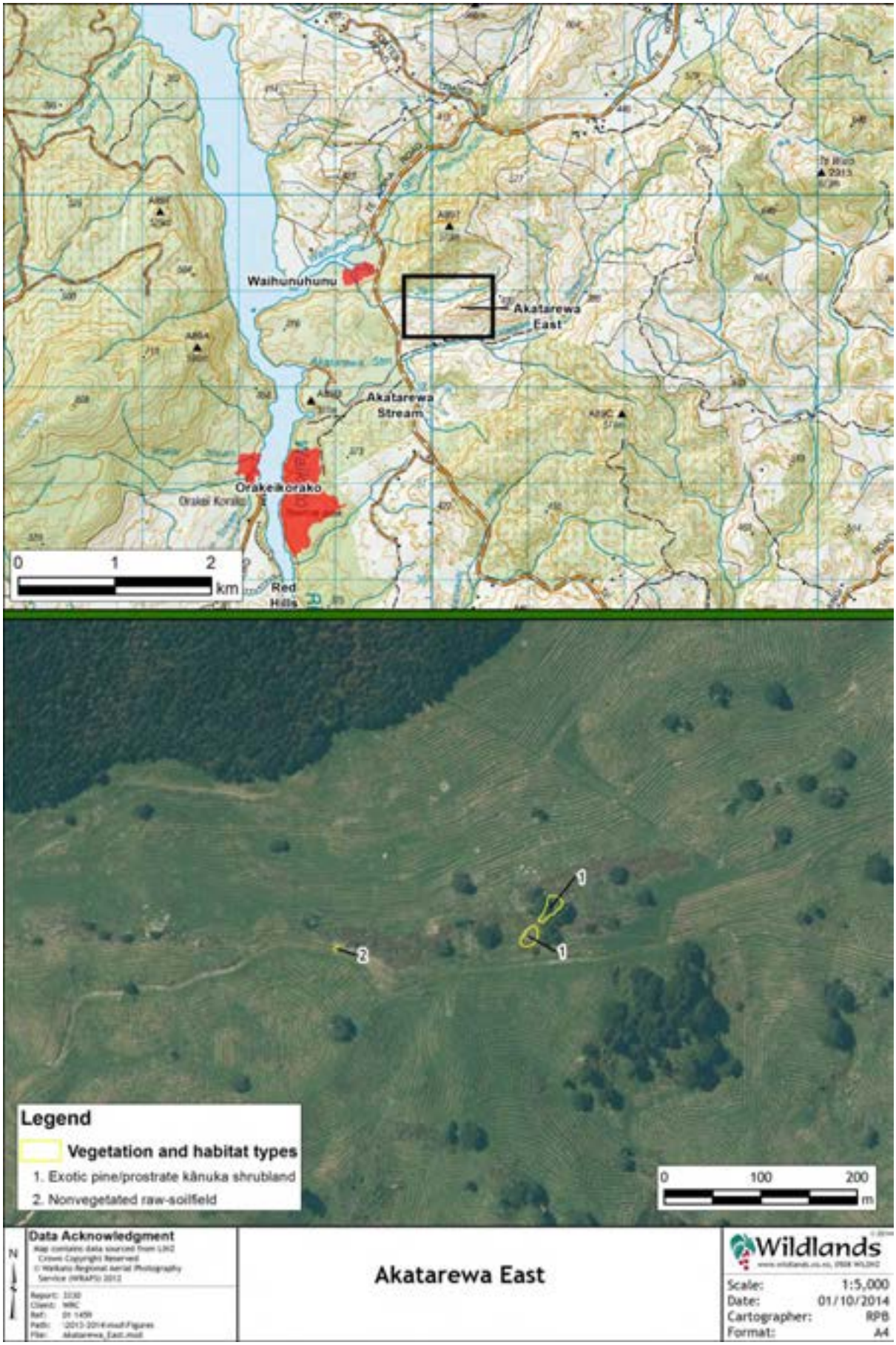
1 All flora threat rankings are from de Lange *et al.* 2013.
2 GPS reference: E1874474 N5735523 (50 plants present in 2007).

Adjoining land use (*2014 Assessment*):	Indigenous vegetation and the Waikato River.
Site Change:	
Recent change (2014 Assessment):	Some control of wilding pines and other pest plants has been undertaken at this site in the last ten years. No other changes to the extent and quality of geothermal activity are known to have occurred at this site. Any changes made to site boundaries are based on higher quality aerial photographs, rather than any real change to geothermal extent.
Historical (*Assessed in 2011*):	The extent of geothermal vegetation and habitats within the site were considerably reduced in size since dam construction on the Waikato River in 1961 resulted in the formation of Lake Ohakuri. An assessment of aerial photographs taken in 1949[1] showed significantly more bare soil on both sides of the Waikato River. The lower reaches of these were drowned when the river was dammed. The steep nature of bank margins means that the overall loss of geothermal habitat is difficult to determine, however it could be as high as 10-20%.
Management Requirements:	Some wilding pine control has been undertaken by Ngati Tahu-Ngati Whaoa in 2013 and follow-up control is planned for 2015. Pampas control has also been undertaken and regular follow-up monitoring and control of this species is advisable. Chinese privet should also be controlled.
Significance Level:	National (Table 12 - Criteria 1, 3, 5, 7, 9; Table 2 - Factors 7 & 8).
Significance Justification:	This site is nationally significant because it comprises a very good quality example of geothermal habitat, which includes nationally uncommon ecosystems (fumaroles, geothermally heated dry ground; Williams *et al.* 2007, Holdaway *et al.* 2012). Together with Orakeikorako (Site OKV03, *c.*1 km to the north) it comprises one of the best examples of geothermal vegetation in the Waikato Region. Red Hills has an extensive area of prostrate kānuka shrubland, and stable, relatively large, populations of *Christella* aff. *dentata* ("thermal"), and *Dicranopteris linearis* (both 'At Risk' species).
Notes:	Land that includes this geothermal area has been returned to Ngati Tahu-Ngati Whaoa as part of their Treaty of Waitangi settlement.
References:	Beadel 1995b; Beadel and Bill 2000; Given 1996; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004c, 2007b, & 2012.

[1] Historical photographs: SN 358 Run 1074 Photos 92-94, 1949.


Waihunuhunu
Akatarewa East
Akatarewa Stream
Orakeikorako
Red Hills
0 1 2 km
Legend
Vegetation and habitat types
1. Exotic pine/prostrate kānuka shrubland
2. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Akatarewa East
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

AKATAREWA EAST

Site Number:	OKV05	**Grid Reference:**	NZTopo50 BF37 763 389
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1876276 N5738860
Geothermal Field:	Orakeikorako	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	390 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*0.1 ha		
Extent of Geothermal Vegetation:	*c.*0.1 ha		
Date of Most Recent Field Survey:	3 February 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant shrubland (05.01) **Exotic pine/prostrate kānuka shrubland (05.01.04)** One tall (*c.*20 m height) radiata pine is emergent over prostrate kānuka, with scattered Spanish heath, buddleia, paspalum, and sweet vernal. Other species present include blackberry, bracken, mānuka, *Cheilanthes sieberi*, and occasional patches of *Dicranopteris linearis*.	Steep hillslope	*c.*0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** A small (*c.*0.5 × 0.2 m) fumarole alongside the cattle race is surrounded by pasture, which is dominated by sweet vernal and browntop. Ring fern and Spanish heath seedlings are also present.	Hillslope	<0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Dicranopteris linearis* (At Risk-Naturally Uncommon) are present. *Dicranopteris linearis* is present in small patches.

Fauna: Greenfinch and yellowhammer were recorded. Other common pasture birds are likely to be present.

Current Condition (2011 Assessment): This site comprises geothermal features and vegetation surrounded by farmland and pine plantations. Whilst domestic stock have access to this site, parts of the site are on a steep hill-face that is largely inaccessible to stock.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Radiata pine (5-25% cover) is present on the margins of the site with Spanish heath (1-5% cover) scattered throughout. Buddleia (1-5% cover) and blackberry (<1% cover) are also present.

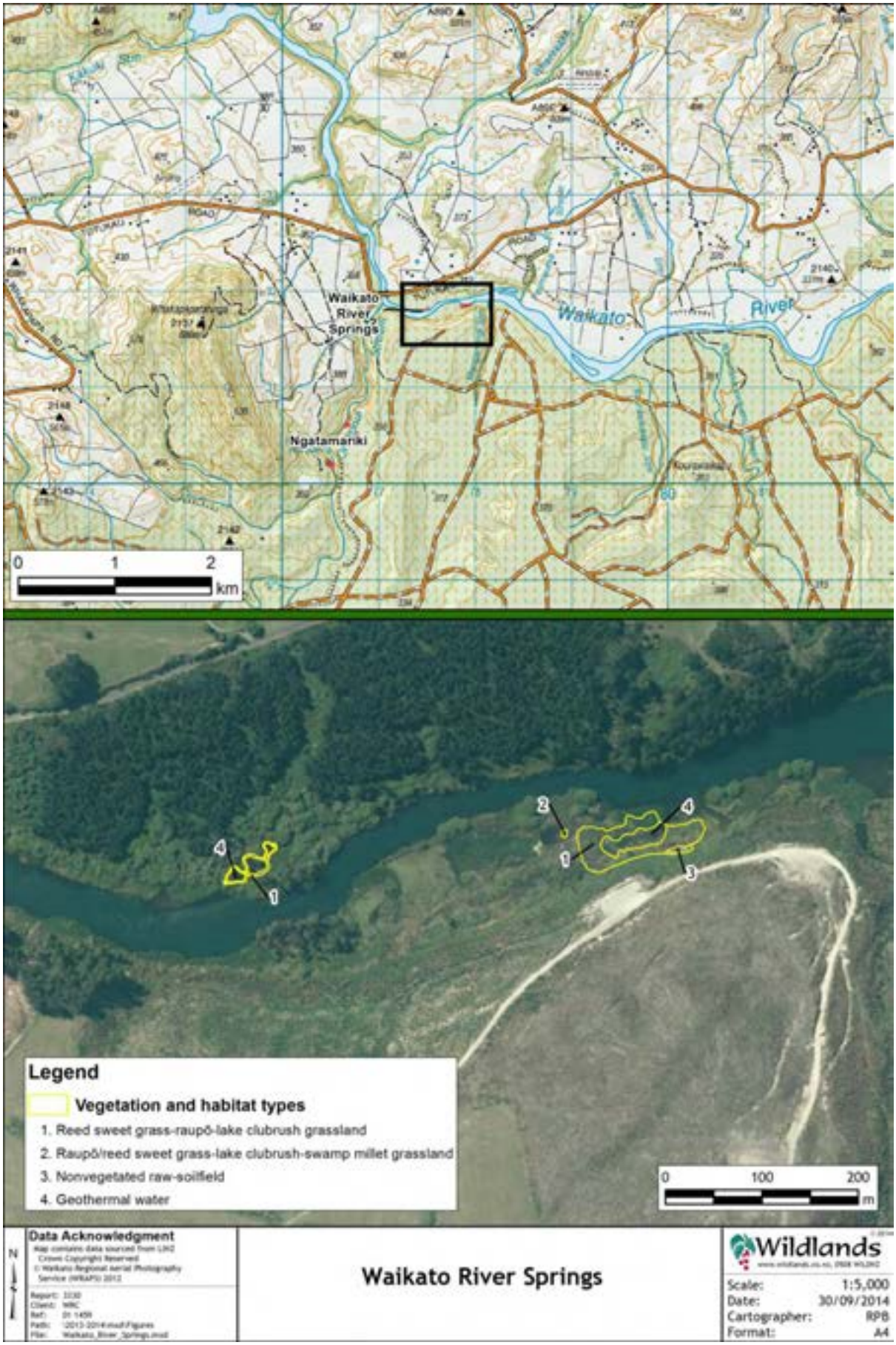
Human impacts (*2011 Assessment*): Site adjacent to farmland.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Grazing (*20011 Assessment*):	This site is unfenced and grazed. Some parts of the site are steep and domestic stock are unlikely to be a threat in these areas.
Adjoining land use (*2014 Assessment*):	Farming and pine plantation.
Site Change:	
Recent change (2011 Assessment):	Not assessed. There is no known ecological information for this site prior to the 2011 study.
Historical (*Assessed in 2011*):	Site not assessed, no historical aerial photos found. Because the site is small and is in a gully it is unlikely that change would be able to be identified at this site through comparing historic and recent aerial photographs.
Management Requirements:	The radiata pine should be removed, and the site fenced and retired from grazing. The *Dicranopteris linearis* population should be monitored.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2- Factor 19)
Significance Justification:	Akatarewa East is locally significant because it coontains a small example of geothermally heated dry soils, a nationally uncommon habitat type (Williams *et al*. 2007; Holdaway *et al.* 2012). It also provides habitat for two 'At Risk' plant species (prostrate kānuka and *Dicranopteris linearis*), but does not represent habitat of considerable importance for the conservation of these species.
Priority for Field Survey (2014 Assessment):	This site is a medium priority for field survey.
Notes:	There may be more features and small geothermal areas on the vertical face but access to this area for assessment was difficult and unsafe. This site was identified based on a summary of known geothermal features in Hochstein (2007b)[1]. The Hochstein study was based on summaries of geothermal features in the Orakeikorako and Te Kopia geothermal fields from Lloyd (1974) and Bignell (1994).
References:	Bignell 1994; Hochstein 2007b; Lloyd 1974; Wildland Consultants 2012.

[1] Figure 4.1, Page 92.

NGATAMARIKI GEOTHERMAL FIELD


Waikato River Springs
Waikato River
Ngatamariki
0 1 2 km
Legend
Vegetation and habitat types
1. Reed sweet grass-raupō-lake clubrush grassland
2. Raupō/reed sweet grass-lake clubrush-swamp millet grassland
3. Nonvegetated raw-soilfield
4. Geothermal water
0 100 200 m
Data Acknowledgment
Waikato River Springs
Wildlands
Scale: 1:5,000
Date: 30/09/2014
Cartographer: RPB
Format: A4

WAIKATO RIVER SPRINGS

Site Number:	NMV01[1]	**Grid Reference:**	NZTopo50 BF37 779 319
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1877904 N5731853
Geothermal Field:	Ngatamariki	**Local Authority:**	Rotorua
Bioclimatic Zone:	Lowland	**Altitude:**	295 m
Tenure:	Protected (Ngatamariki Hot Springs Scenic Reserve administered by DOC)		
Extent of Geothermal Habitat:	*c.*0.6 ha		
Extent of Geothermal Vegetation:	*c.*0.4 ha		
Date of Most Recent Field Survey:	2-3 February 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Exotic grassland (08.01) **Reed sweet grass-raupō-lake clubrush grassland (08.01.10)** Reed sweet grass (*Glyceria maxima*), raupō, and lake clubrush dominate the margins of a geothermally influenced pool (temperatures up to 45 °C in the northern pools in 2011), with emergent grey willow, blackberry, harakeke, Chinese privet, bracken, and radiata pine on the drier margins. Other species present include *Cyperus ustulatus*, and mercer grass.	Stream margins, pond margins	*c.*0.4 ha
Raupō/reed sweetgrass-lake clubrush-swamp millet grassland (08.01.11) Occasional raupō is emergent over reed sweetgrass, lake clubrush, and swamp millet. Other species present include *Carex maorica,* lotus, *Cyperus ustulatus*, peppermint (*Mentha ×piperita*), and pōhue (*Calystegia sepium* subsp. *roseata*).	Wetland	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Geothermally-heated soil.	Terraces	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** Hot spring, hot stream, pools. In cooler water, water lily (*Nymphaea alba*) is common.	Stream, pools	*c.*0.2 ha

Indigenous Flora: *Christella* aff. *dentata* ("thermal") (At Risk-Declining[2]) has previously been recorded at this site (Wildland Consultants 2006). No specimens were located during the 2011 survey but the entire site could not be inspected due to high river conditions so the population is still likely to be present.

Fauna: North Island fernbird (At Risk-Declining[3]) were present in 2006 (Wildland Consultants 2006). Common indigenous and exotic species including tūī, fantail, California quail, greenfinch, Eurasian blackbird, yellowhammer, and goldfinch are also present.

[1] Site number in 2004 was U17/29 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.
[3] All avifauna threat rankings are from Robertson *et al.* 2013.

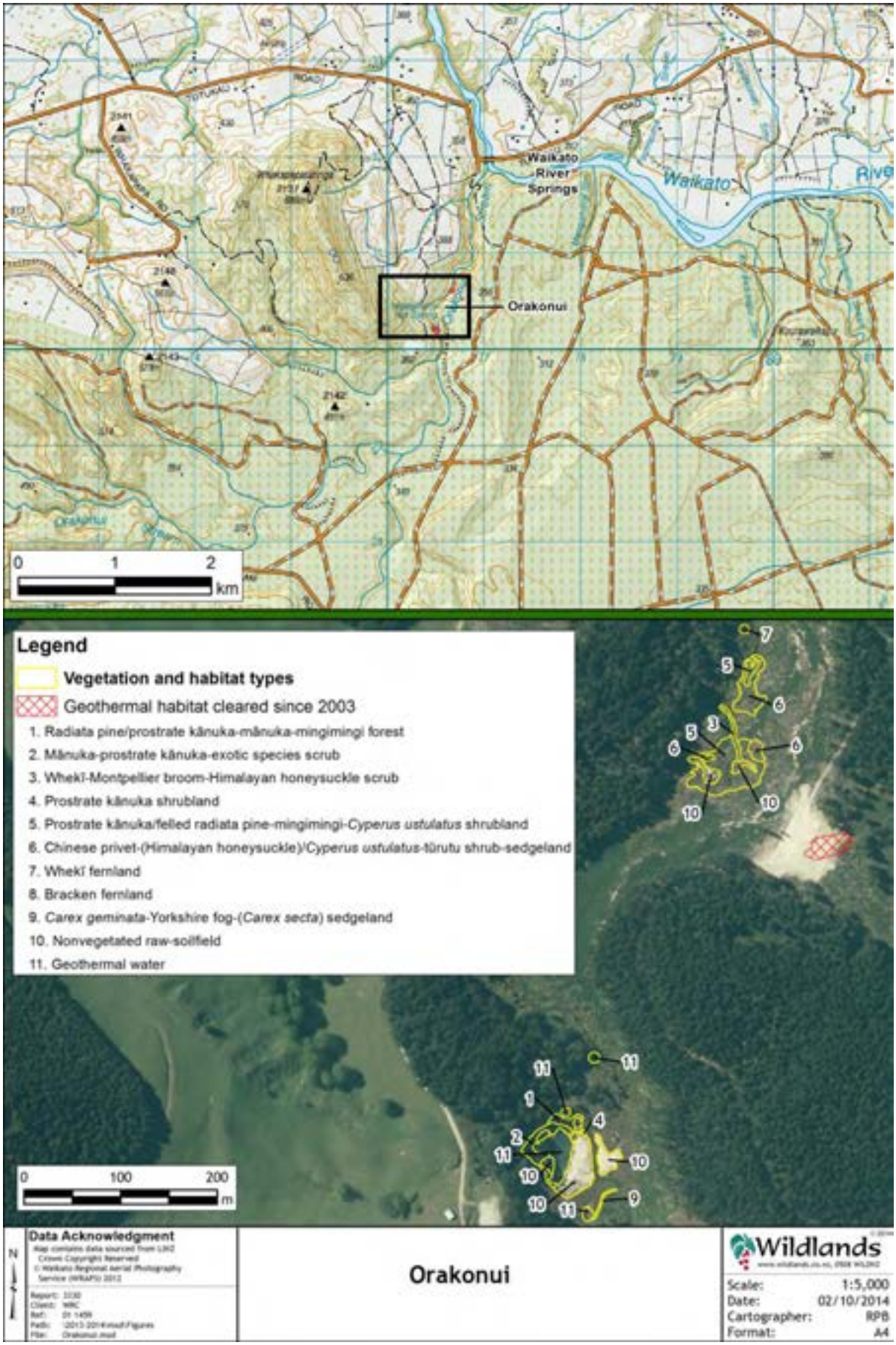
Current Condition (2011 Assessment):	Weed species such as reed sweetgrass dominate the wetland areas of this site.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2011 Assessment*):	Reed sweetgrass is the dominant vegetation within this site (75-100% cover). Chinese privet (1-5% cover), radiata pine <1% cover), grey willow (1-5% cover), buddleia (1-5% cover), and blackberry (1-5% cover) are also present.
Human impacts (*2011 Assessment*):	Radiata pine plantations border the southern area of this site and forestry operations (silt and sediment runoff, harvesting and replanting) may result in further degradation of its ecological values.
Grazing (*2011 Assessment*):	Site is not accessible to stock.
Adjoining land use (*2014 Assessment*):	Waikato River, mixed indigenous and exotic scrub, plantation forest.
Site Change:	
Recent change (2011 Assessment):	The water levels of the river were high during the 2011 field survey, so overall change is difficult to assess. However the site appeared similar to earlier surveys.
Historical (*Assessed in 2011*):	This site is too small to see any evidence of change since 1941[1], however the site is subject to water level fluctuations in the Waikato River, and it is likely that the vegetation cover has changed since 1941.
Management Requirements:	Chinese privet (on the southern side of the river), grey willow, and radiata pine should be removed from this site before weed management becomes an issue. The pest plant reed sweetgrass dominates this site but its control may be insurmountable as infestations are extensive along this section of the Waikato River.
Significance Level:	Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factors 9 & 12)
Significance Justification:	This site is regionally significant because is protected under the Reserves Act 1977 as a Scenic Reserve. The site also contains a small population of an 'At Risk' plant species (*Christella* aff. *dentata* ("thermal")); *Christella* is only known from 15 sites in New Zealand, therefore this site is important for the conservation of this species.
Priority for Field Survey (2014 Assessment):	This site is a medium priority for field survey.
Notes:	Part of this site was recorded as Lake Ohakuri/Tainui Road in Beadel and Bill 2000 and Wildland Consultants 2004c. The water temperature in one spring was 65 °C with a flow rate of

[1] Historical photos: SN 172 Run 1168 Photos 15-16, 1941.

1 m/second. The spring was depositing small amounts of sinter. The water temperature in one stream was 54ºC, with a water flow of *c.*2 m/second (Wildland Consultants 2006).

This site was formerly identified as being of national significance (Wildland Consultants 2006) due to the presence of *Christella* aff. *dentata* ("thermal") which, at that time, was classified as 'Chronically Threatened' (de Lange *et al.* 2004).

References: Beadel and Bill 2000; Wildland Consultants 2004c, 2006, & 2012.


Waikato River Springs
Waikato
Orakonui
0 1 2 km
Legend
Vegetation and habitat types
Geothermal habitat cleared since 2003
1. Radiata pine/prostrate kānuka-mānuka-mingimingi forest
2. Mānuka-prostrate kānuka-exotic species scrub
3. Whekī-Montpellier broom-Himalayan honeysuckle scrub
4. Prostrate kānuka shrubland
5. Prostrate kānuka/felled radiata pine-mingimingi-Cyperus ustulatus shrubland
6. Chinese privet-(Himalayan honeysuckle)/Cyperus ustulatus-tūrutu shrub-sedgeland
7. Whekī fernland
8. Bracken fernland
9. Carex geminata-Yorkshire fog-(Carex secta) sedgeland
10. Nonvegetated raw-soilfield
11. Geothermal water
0 100 200 m
Data Acknowledgment
Orakonui
Wildlands
Scale: 1:5,000
Date: 02/10/2014
Cartographer: RPB
Format: A4

ORAKONUI[1]

Site Number:	NMV02 [2]	**Grid Reference:**	NZTopo50 BF37 767 306
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1876675 N5730627
Geothermal Field:	Ngatamariki	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	310 m
Tenure:	Protected (Ngatamariki Hot Springs Scenic Reserve) and unprotected private land.		

Extent of Geothermal Habitat: *c.*1.1 ha
Extent of Geothermal Vegetation: *c.*0.9 ha
Date of Most Recent Field Survey: October-November 2013

VEGETATION TYPE	LANDFORM	EXTENT
Exotic pine forest (01.02) **Radiata pine/prostrate kānuka-mānuka-mingimingi forest (01.02.06)** A small area of plantation radiata pine forest with a subcanopy dominated by prostrate kānuka, mānuka, and mingimingi. Tāwiniwini and prickly mingimingi are common in the shrub tier over mosses and liverworts (dominated by *Chiloscyphus semiteres*, *Telaranea praenitens*, and *Campylopus clavatus*), with scattered *Drosera auriculata*.	Hillslope	<0.1 ha
Mānuka-dominant scrub (04.04) **Mānuka-prostrate kānuka-exotic species scrub (04.04.04)** Mānuka (up to *c.*2 m tall) and prostrate kānuka (up to *c.*0.25 m tall) with common blackberry forms a dense scrub on the scarp faces north of the moderate-sized geothermal pool in the southern part of this site. Bracken, mingimingi, and whekī are also common components in the western end of this vegetation type above the geothermal pool.	Scarp	*c.*0.1 ha
Mixed exotic and indigenous species scrub (04.09) **Whekī-Montpellier broom-Himalayan honeysuckle scrub (04.09.03)** A geothermal stream drains a spring from one of the southern areas of sinter in the northern part of the site and passes along a shallow gully system into Orakonui Stream. The slopes above the stream are dominated by whekī to *c.*3 m tall, Montpellier broom, and Himalayan honeysuckle over prostrate kānuka and ring fern. Occasional radiata pine seedlings are present. A small population of *Lycopodiella cernua* and *Dicranopteris linearis* is present alongside the stream.	Riparian margin	<0.1 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** A small area of short stature (up to *c.*0.8 m tall) prostrate kānuka shrubland with occasional mānuka and soft rush located near the confluence of the Orakonui Stream and the hot stream outflow that drains the medium-sized geothermal pool located in the southern part of the site. Prostrate kānuka does not form a complete canopy within	Alluvial terraces	*c.*0.1 ha

[1] Previously called Ngatamariki in earlier reports (Wildlands Consultants 2004c and 2012).
[2] Identified as U17/15 in Wildland Consultants (2004c).

VEGETATION TYPE	LANDFORM	EXTENT
this vegetation type, with approximately 60% bare ground present. Other species present include pampas, radiata pine, prickly mingimingi, minigmingi, *Juncus articulatus*, and *Campylopus clavatus*.		
Prostrate kānuka/felled radiata pine-mingimingi-*Cyperus ustulatus* shrubland (05.01.08) Prostrate kānuka (1-5 m tall) occurs in the northern part of the site with occasional to locally common whekī, whekī-ponga, and harakeke in the canopy. Mingimingi and bracken are common, with occasional Spanish heath. Tūrutu, *Cyclosorus interruptus,* and lotus are present in the understorey, with local *Hypolepis ambigua*. The groundcover comprises dense mosses and liverworts. *Cyperus ustulatus* sedgeland is present between patches of prostrate kānuka, and also where the prostrate kānuka canopy is less dense, particularly in wetter areas. Felled radiata pine are common throughout. Occasional karamū and toetoe are also present, and dense Montpellier broom is present on dry sites and non-geothermal margins.	Alluvial terraces	0.3 ha
Exotic shrubland (05.09) **Chinese privet-(Himalayan honeysuckle)/*Cyperus ustulatus*-tūrutu shrub-sedgeland (05.09.06)** Chinese privet with locally common Himalayan honeysuckle forms an incomplete canopy over *Cyperus ustulatus* sedgeland on poorly drained sites. Abundant felled pines are present in this vegetation type, along with emergent whekī and radiata pine saplings. Patches of tūrutu, *Hypolepis ambigua*, and *Hypolepis distans* are common, particularly in drier areas. Montpellier broom and Spanish heath are common on the margins of geothermal vegetation. Occasional harakeke, toetoe, foxglove (*Digitalis purpurea*), ring fern, and water fern are present, along with scattered prostrate kānuka. Scattered clumps of *Cyclosorus interruptus* are also present, particularly in taller *Cyperus ustulatus* sedgeland, but also occasionally under prostrate kānuka.	Alluvial terraces	*c*.0.1 ha
Indigenous fernland (07.01) **Whekī fernland (07.01.18)** A small geothermal seepage occurs beneath several whekī. Temperatures of up to 31 °C were recorded in the seepage in 2013. A small population of *Psilotum nudum* was found in the groundcover growing amongst *Nertera depressa*. The seepage "seeps" through a small area of kiokio fernland before draining into Orakonui Stream. *Juncus edgariae* is common amongst the kiokio. **Bracken fernland (07.01.19)** Bracken fernland dominates a small area near the outlet of the medium-sized geothermal pool located in the southern part of this site. No other species are present.	Hot spring margins Alluvial terraces	<0.1 ha <0.1 ha
Indigenous sedgeland (09.01) ***Carex geminata*-Yorkshire fog-(*Carex secta*) sedgeland (09.01.04)** Riparian vegetation surrounding a small, warm stream, which appears to originate from the small spring located in the southern part of the	Alluvial terraces	<0.1 ha

VEGETATION TYPE	LANDFORM	EXTENT
southern area of this site. The riparian margins are dominated by *Carex geminata* and Yorkshire fog, with occasional patches of *Carex secta*, *Cyperus ustulatus*, and harakeke. A single patch of *Leersia oryzoides* is present on the margins of the stream.		
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Sinter with hot pools, mud pools, springs, and seepages. Patches of prostrate kānuka, creeping bent, *Lachnagrostis*, and *Cyperus ustulatus* are present on sinter in parts of the northern site. Arrow grass is also present. Scattered plants of prostrate kānuka, mānuka, Spanish heath, bracken, water fern, and *Lycopodiella cernua* are present. Recent (2005) geothermal activity in the southern part of the site has resulted in mainly unvegetated geothermal are on both sides of a small stream that discharges from a moderate-sized geothermal pool. Pampas, Yorkshire fog, and prostrate kānuka are currently colonising the bare ground.	Alluvial terraces	*c.*0.3 ha
Water (22.01) **Geothermal water (22.01.01)** Several small to moderate-sized geothermal pools are present. Vegetation on the margins of the pools includes kiokio, *Cyperus ustulatus*, *Hypolepis distans*, bracken, mingimingi, raupō, water fern, whekī, blackberry, prostrate kānuka, pampas, buddleia, grey willow, Yorkshire fog, karamū, koromiko, and radiata pine. *Lemna disperma* is present on the surface of one pool, and red and green algae are present in another pool.	Flat	*c.*0.1 ha

Indigenous Flora:

Thirty-eight clumps of *Cyclosorus interruptus* (At Risk-Declining[1]) were recorded in the northern part of this site in 2013. Previous estimates of the *Cyclosorus interruptus* population at Orakonui indicate that the population size fluctuates naturally between seasons and years, with 30 plants recorded in 1979 (Ecroyd 1979b), 18 clumps recorded in 1999 (Merrett and Burns 1999), 16 clumps recorded in 2007 (Bycroft and Beadel 2007), and 50 clumps recorded in 2012 (Wildland Consultants 2012).

Dicranopteris linearis (At Risk-Naturally Uncommon) is present alongside a geothermal stream in the northern part of the site. Another population, which was found under radiata pine trees in the northern part of the site in 2007, was not relocated in 2012 or 2013 and may have been affected by control and harvest of the pine trees. *D. linearis* is known from only *c.*23 sites in New Zealand.

Prostrate kānuka (At Risk-Naturally Uncommon) and the moss *Campylopus capillaceous*, which are both endemic species restricted to geothermal areas, occurs in both the northern and southern parts of the site. *Lycopodiella cernua*, which is characteristic of geothermal areas, is also present, in both the northern and southern parts of the site.

Psilotum nudum, a plant restricted to geothermal and northern coastal areas,

[1] All flora threat rankings are from de Lange *et al.* 2013.

is also present at the site. Two small populations of *Psilotum nudum* were recorded during the 2012 survey. Both of these populations, as well as an additional population, were recorded in 2013. One population is located in the southern part of the site; the other two populations are located in the northern part of the site. All populations are small and vulnerable to both natural and human-induced disturbance. A population recorded below a waterfall in 1979 (Ecroyd 1979b) has not been recorded in recent surveys; this may reflect the inaccessibility of the site rather than a population decline.

Fauna:

Long-tailed cuckoo (At Risk-Naturally Uncommon[1]) were recorded from the site in 2013 and North Island fernbird (At Risk-Declining) have been recorded here in the past (Mitchell Partnerships 2009). Whitehead, fantail, grey warbler, kōtare (sacred kingfisher), tūī, greenfinch, yellowhammer, Australian magpie, and North Island robin are also present. The introduced green bell frog (*Litoria aurea*) was recorded near the northern population of *Psilotum nudum* in the northern part of the site in 2012.

Possum sign (scat), ungulate sign (footprints and grazing of grasses), and other animal disturbance (species unidentified) was observed at the site in 2013.

Current Condition (2013 Assessment):

The site comprises two areas of geothermal features and vegetation that contain several plant species of note. Natural changes in geothermal activity have been an ongoing feature at Orakonui (Milicich and Reeves 2009), and are likely to continue to exert a strong influence on any patterns observed. The southern end of the site has changed significantly as a result of a hydrothermal eruption, which resulted in the creation of a geothermal pond and a large area of debris. Indigenous vegetation condition in the northern part of the site has improved significantly following radiata pine control, with a noticeable expansion of prostrate kānuka. However other exotic pest plant species are expanding to fill the areas vacated by radiata pine trees.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2013 Assessment*):

Radiata pine plantation is in close proximity to parts of the site, and some trees have fallen into geothermal vegetation and features. Although extensive control of radiata pines within the geothermal vegetation in the northern part of the site has been undertaken, pines have been felled into significant geothermal features, particularly sinter fans and terraces. Live pines, comprising local saplings and scattered seedlings, now have a cover of <5% in the geothermal vegetation in the northern part of the site. In the southern part, plantation and wilding radiata pines are present surrounding most geothermal features.

Chinese privet has expanded significantly within the site to become a co-dominant feature of a small area of vegetation within the northern part of the site; overall the cover of Chinese privet is still relatively low (*c.*2% cover). Other adventive plant species present include buddleia (1% cover),

[1] All avifauna threat rankings are from Robertson *et al.* 2013.

pampas (2% cover), blackberry (5% cover), Himalayan honeysuckle (1% cover), arrow grass (<1% cover), Tasmanian blackwood (<1% cover), grey willow (<1% cover), Montpellier broom (1% cover), and Spanish heath (1% cover). Some control work on radiata pine has been undertaken by the Department of Conservation.

Human impacts (*2013 Assessment*): Informal access tracks are present within the site and pose a threat to the ecological values of geothermal vegetation. Although current visitor numbers to Ngatamariki are low due its isolation, access is more common now than historically due to monitoring associated with consents for the Orakonui Geothermal power station which was commissioned in September 2013. No changes associated with drawoff have been observerved to date.

Grazing (*2013 Assessment*): Livestock are not a threat to the site.

Adjoining land use (*2013 Assessment*): Pine plantation, farmland.

Site Change:

Recent change (2014 Assessment): Geothermal activity has changed the landforms and species composition of the southern end of this site. A hydrothermal eruption in 2005 has formed a new geothermal lake and mud pools, and deposited hydrothermal eruption debris. Changes in the mapped extent of vegetation and habitat types within the site is likely to be the result of better quality resolution of aerial photographs available in 2014. Some noticeable change has occurred in the composition of vegetation types within the site. These changes are mostly the result of expansion of invasive pest plant species associated with radiata pine control within the site.

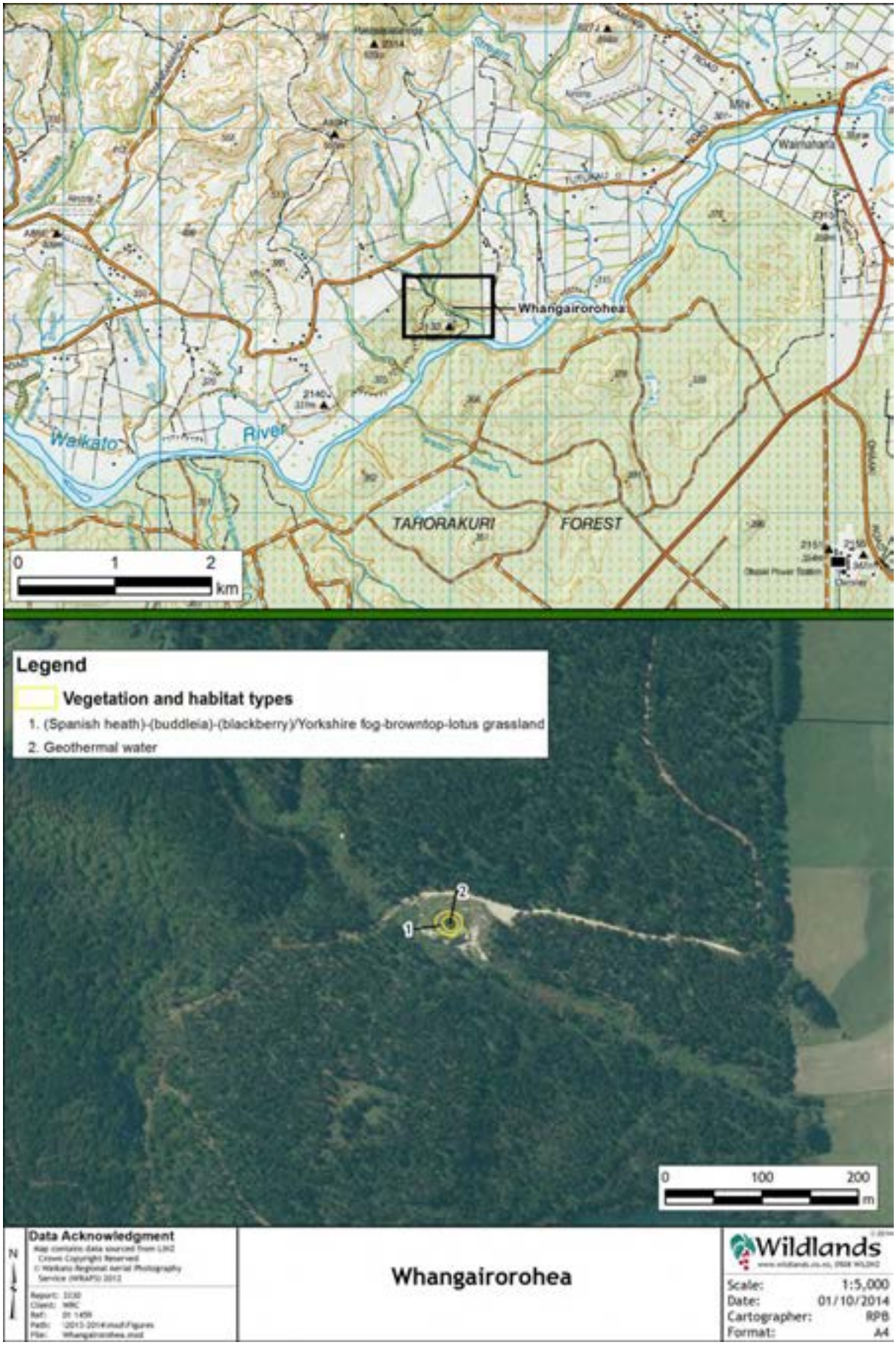
Historical (*Assessed in 2011*): Comparisons were made of 1941 aerial photographs[1] and 2007 aerial photographs in 2011. There is a larger buffer between geothermal features and forestry operations in 1941 compared with 2007, particularly around the southern part of the site. Bare ground is more extensive in 1941 (than 2007). The location/extent of the northern area of geothermal vegetation cannot be identified on the 1941 aerial photographs, but there is a greater buffer between geothermal features and plantation forests in 1941. The extent of geothermal vegetation and habitats is likely to have declined by 10-25%, but this decline may be mostly related to weed invasion, and change of land use to plantation forestry.

Management Requirements: Remaining radiata pines within geothermal areas and on the margins of the site should be removed, and felled away from geothermal features/vegetation where possible. Damage during plantation forest harvesting operations surrounding the site is a potential threat. Control of Chinese privet, Tasmanian blackwood, and pampas should also be undertaken. Ongoing monitoring of geothermal vegetation and threatened species should continue at this site to assess the impacts of energy extraction in the Ngatamariki Geothermal Field, and natural variation of features and vegetation within the site.

[1] Historical photo: SN 172 Run 1168 Photo 14, 1941.

Significance Level:	Regional (Table 1 - Criteria 1, 3, 5, 6, 9; Table 2 - Factors 9, 12)
Significance Justification:	Orakonui is of regional significance because it is protected as a Scenic Reserve, provides important habitat for three 'At Risk' plant species: *Cyclosorus interruptus, Dicranopteris linearis,* and prostrate kānuka, and contains a nationally uncommon habitat type (geothermally heated dry ground; Williams *et al.* 2007; Holdaway *et al.* 2012).
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category B - the second highest category. Orakonui is the best quality area of geothermal vegetation in the Ngatamariki Geothermal Field.
References:	Beadel and Bill 2000; Bycroft and Beadel 2007; Department of Conservation 1997; Ecroyd 1979b; Given 1989a, 1995, & 1996; Merrett and Burns 1999; Milicich and Reeves 2009; Spring-Rice 1996; Wildland Consultants 2004c, 2007b, & 2012.

WHANGAIROROHEA GEOTHERMAL FIELD


Whangairorohea
Waikato River
TAHORAKURI FOREST
0 1 2 km
Legend
Vegetation and habitat types
1. (Spanish heath)-(buddleia)-(blackberry)/Yorkshire fog-browntop-lotus grassland
2. Geothermal water
0 100 200 m
Data Acknowledgment
Whangairorohea
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

WHANGAIROROHEA

Site Number:	WGV01[1]	**Grid Reference:**	NZTopo50 BF37 830 331
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1882987 N5733149
Geothermal Field:	Whangairorohea	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	310 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	13 February 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Exotic grassland (08.01) **(Spanish heath)-(buddleia)-(blackberry)/Yorkshire fog-browntop-lotus grassland (08.01.06)** Mixed exotic species grassland is present on the dry terrace around the geothermal pool and is dominated by Yorkshire fog, browntop, and lotus with locally common cocksfoot. Also around the margins are local patches of exotic woody species including Spanish heath, buddleia, and blackberry, and occasional whekī and whekī-ponga. Bracken and creeping buttercup are common. Harakeke has been planted into the grassland around most of the margin. *Blechnum penna-marina* subsp. *alpina* is present at the northern side of the pool. There was no evidence of heated geothermal soils surrounding the pool.	Flat	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** A pool measuring *c.*10 × 15 m within a shallow depression. The water within this pool was clear and *c.*36 °C in 2014. Immediately on the margins of the pool patches of Mercer grass, *Carex secta*, and a small patch of lake clubrush are present.	Steep hillslope	<0.1 ha

Indigenous Flora: *Blechnum penna-marina* subsp. *alpina* is present amongst the exotic grassland on the northern side of the pool. This species is not common in Atiamuri Ecological District. *Pimelea prostrata* subsp. *prostrata* was present in 2010 but was not observed in 2014.

Fauna: Common indigenous and exotic bird species typical of the habitats at the site were present including silvereye, tūī, grey warbler, goldfinch, Eurasian blackbird, Eastern rosella, and Australian magpie.

Current Condition (2014 Assessment): This site comprises a geothermal pool located in a radiata pine plantation. There is a 20-50 m buffer zone around the spring which is not planted in pine. The vegetation in the buffer zone comprises mainly exotic grassland with a small gully dominated by blackberry and Himalayan honeysuckle. The pool is used for bathing, with a constructed jetty built towards the centre for easy access.

[1] Identified as U17/33 in Wildland Consultants (2004c).

Threats/Modification/ Vulnerability:

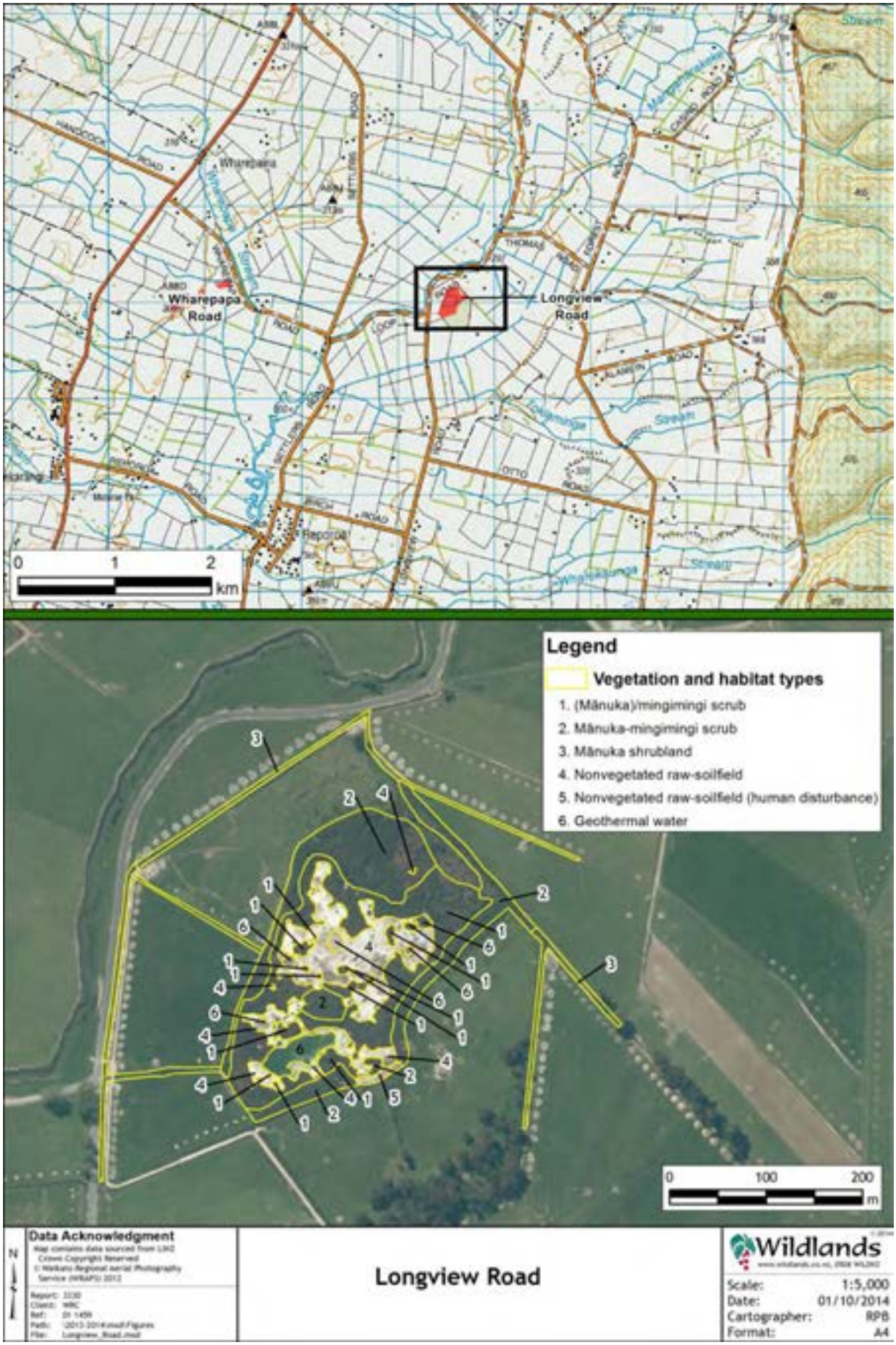
Invasive pest plants (*2014 Assessment*):	Spanish heath (*c.*5% cover), Mercer grass (*c.*2% cover), buddleia (*c.*1% cover), and blackberry (c.1% cover) are present.
Human impacts (*2014 Assessment*):	Impacts of adjacent forestry operations can be excluded from this site because there is a 20-50 m buffer between the geothermal pool and the plantation forest. A bund has been created on the southern side of the pool recently (<5 years ago). The earthworks associated with this bund may have slightly reduced the size of the pool (Evelyn Forrest pers. comm.) and some vegetation clearance was undertaken during the creation of the bund. There is a permanent wooden structure that provides access into the pool for bathers. Litter was noted within the pool and around its margins in 2011 but no litter was noted in 2014. A small shed has been built within 5 metres of the pool of the pool.
Grazing (*2014 Assessment*):	Stock do not have access to this site.
Adjoining land use (*2014 Assessment*):	Radiata pine plantation.

Site Change:

Recent change (2014 Assessment):	Vegetation has been cleared from part of the site since 2010 and the area of lake clubrush has reduced in size. The remainder of the site appears similar in extent to that described in 2010.
Historical (*Assessed in 2011*):	The geothermal lake is visible on the 1941 aerial photograph[1] and appears to be of a similar size to that observed in the 2011 survey. In 1941, plantation forestry did not completely surround this site.
Management Requirements:	Control of pest plants near spring is recommended.
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19)
Significance Justification:	This site is locally significant because it comprises a small example of a nationally uncommon habitat type (geothermal habitat).
Notes:	The stream to the south of the site is eroding and undercutting the steep stream bank to the south of the pool. This could eventually result in the pool disappearing, althoughbank stabilisation works have been undertaken in the last five years in an attempt to reduce the risk of undercutting the stream banks. These works are likely to be successful in delaying erosion of the stream bank in the short term. A sign identifies this site as 'Taahunaa tapu Waiariki o Toa'.
References:	Wildland Consultants 2004c & 2012.

[1] Historical photo: SN 172 Run 1167 Photo 2, 1941.

REPOROA GEOTHERMAL FIELD


Wharepapa Road
Longview Road
0 1 2 km
Legend
Vegetation and habitat types
1. (Mānuka)/mingimingi scrub
2. Mānuka-mingimingi scrub
3. Mānuka shrubland
4. Nonvegetated raw-soilfield
5. Nonvegetated raw-soilfield (human disturbance)
6. Geothermal water
0 100 200 m
Data Acknowledgment
Longview Road
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

LONGVIEW ROAD

Site Number:	RPV01[1]	**Grid Reference:**	NZTopo50 BF37 935 430
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1893489 N5742976
Geothermal Field:	Reporoa	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*300 m
Tenure:	Protected (Molloy Conservation Covenant)		
Extent of Geothermal Habitat:	*c.*6.2 ha		
Extent of Geothermal Vegetation:	*c.*5.9 ha		
Date of Most Recent Field Survey:	23 January 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Mingimingi-dominant scrub (04.03) **(Mānuka)/mingimingi scrub (04.03.05)** Occasional emergent mānuka (up to 4 m tall) are present over mingimingi between 0.3 and 1.5 m tall with occasional blackberry, tūrutu, and bracken present in the understorey. A dense cover of non-vascular plants dominates much of the groundcover with the liverwort *Chiloscyphus semiteres* common to abundant, and the mosses *Campylopus clavatus* and *Leucobryum javense* also common. Occasional water fern occurs on banks above steaming hot springs. The algae *Trentepohlia* is common in its orange form on mānuka and mingimingi stems throughout.	Flat	*c.*2.0 ha
Mānuka-dominant scrub (04.04) **Mānuka/mingimingi scrub (04.04.02)** Most of the area mapped as this type comprises dense mānuka scrub with occasional tūrutu and bracken in the understorey. Mānuka forms a canopy up to 8 m tall, but in most areas the height is 2-4 m tall. Areas with a dense mānuka canopy contain very few other species, with dense mānuka litter on the ground. In the northwest corner of this vegetation type blackberry becomes common in the understorey; elsewhere the blackberry is mostly present on margins with a cover of <1%. The most common non-vascular species is the liverwort *Chiloscyphus semiteres.* Small patches of mingimingi scrub are present within this type but are too small to map out separately.	Flat	*c.*1.9 ha
Mānuka-dominant shrubland (05.04) **Mānuka shrubland (05.04.01)** Narrow bands of mānuka shrubland are present alongside a stream, drains, and geothermal springs. Mānuka forms a canopy up to *c.*3 m tall over rank grasses and pasture dominated by Yorkshire fog. Scattered blackberry is present within the rank grass and pasture. Geothermal springs are present in some of the drains that are bordered by this type, with the surface water temperature of one spring (NZTM E1893741 N5742957) measuring 57 °C in 2014. In most areas the surface water temperature in drains range from 30 °C to 40 °C (temperatures measured in 2014); these drains are located outside the covenant boundary. Many of the sides of drains comprise bare soil.	Flat	*c.*0.7 ha

[1] Site number in 2004 was U17/18 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01)		
Nonvegetated raw-soilfield (20.01.01) Bare ground with scattered branches of mingimingi and mānuka present. Contains many hot springs too small to map out separately. The surface is often pumiceous rock, and brittle silicified gravelly soils and clays. Mud sediments are common on the surface, indicating higher water levels in the recent past.	Flat	*c.*1.3 ha
Nonvegetated raw-soilfield (human disturbance) (20.01.02) An area of disturbed bare ground occurs in the southern part of the site. This area contains flattened ground following earthworks (probably bulldozed). These earthworks are not recent (i.e. at least five years old, probably greater than ten years old).	Flat	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** Small geothermal lakes and hot springs. The maximum surface temperature recorded was 65.9 °C (NZTM E1893625 N5743064) however temperatures were only recorded from safe vantage points and surface temperatures are likely to exceed this measurement in other parts of the site.	Open water	*c.*0.3 ha

Indigenous Flora: No Threatened or At Risk indigenous plant species (as per de Lange *et al.* 2013) were recorded from this site.

Fauna: In 2011 a pair of pied stilt (At Risk-Declining[1]) were displaying territorially. Other bird species present include welcome swallow, pukeko, Australasian harrier (flying over), white-faced heron (flying over), and California quail.

Possum sign was present.

Current Condition *(2014 Assessment)***:** Overall the covenanted part of the site is in good condition. The most significant geothermal features are well buffered with indigenous vegetation, and few weeds are present[2]. The site is small in size and has a long history of disturbance from fire, cattle grazing, and drainage channel development (see Spring-Rice 1996). The drains and geothermal springs outside the covenanted area are vulnerable to farming activities.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Blackberry (15% cover on site margins and <1% cover in the site interior) was the only significant pest plant found at the site. In comparison to the May 2004 field survey of the site, blackberry does not appear to have increased in cover (Chris Bycroft pers. obs. 2014).

[1] All avifauna threat rankings are from Robertson *et al.* 2013.
[2] Apart from in the narrow bands of mānuka shrubland alongside drains outside the protected area.

Human impacts (*2014 Assessment*):	The site is vulnerable to the further development of drainage channels on neighbouring farmland which would further lower the water table and alter ground temperatures. No evidence was found of recent drain excavation at the site. Trampling damage to vegetation is currently low at the site, but the vegetation and features present are susceptible to recreational use (e.g. trampling of geothermal vegetation and use of the site during duck shooting season).
Grazing (*2014 Assessment*):	While no stock (or stock sign) were recorded from the covenanted area, the fencing in many places is poor or completely ineffective. Repair of the covenant fence should be a high priority.
Adjoining land use (*2014 Assessment*):	Farmland.

Site Change:

Recent change (2014 Assessment):	The quality of fencing surrounding the site has declined since the 2004 survey, although stock impacts within the site are minimal. The cover of pest plants (mostly blackberry) appears similar to the May 2004 assessment (Chris Bycroft pers. obs.). The geothermal vegetation present at this site appears to be similar in condition and overall extent as in 2004. Additional geothermal vegetation and habitat was found in the 2014 survey as a result of better quality aerial photographs.
Historical (*Assessed in 2011*):	It appears that the surrounding land use (farming) has intensified since 1941[1]. It also appears that the site was unfenced in 1941 and stock had access to the site. The size of the site has been approximately halved since 1941, with what is likely to have been geothermal wetland, having been converted to pasture, and drained. Some of the raw-soilfield vegetation to the south of the site has been converted to pasture. In 1941, the scrub (probably dominated by mānuka) is more than double the size of the current area, based on 2007 aerial photographs. Most of the change to this site appears to be the result of land drainage and development into pasture.
Management Requirements:	Fencing is in a poor condition around most of the covenanted site. Repair of these fences is recommended. While the current state of the fences is ineffective, the drains on the boundaries of the covenanted area are keeping most stock out of this site. Drains are likely to have lowered water tables within parts of this site (both within the covenanted area and in adjacent farmland). The decreased water table may have provided suitable habitat for blackberry to establish at this site. No further drainage channels should be created. It is also recommended that the margins of the geothermal creeks and drains in neighbouring farmland are fenced to exclude stock. Possum control in the covenanted area is recommended. Trampling of vegetation and geothermal features should be kept to a minimum.
Significance Level:	Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 10).
Significance Justification:	This site is of regional significance because it is protected by a conservation covenant and contains a nationally uncommon habitat type (geothermally heated dry ground; Williams *et al.* 2007; Holdaway *et al.* 2012). It is also

[1] Historical photos: SN 172 Run 1162 Photos 5-6, 1941.

the best example of geothermal vegetation associated with the Reporoa Geothermal Field. A feature of this site is that the site interior has a relatively low pest plant cover compared with most mānuka and mingimingi-dominant geothermal sites in the Waikato Region.

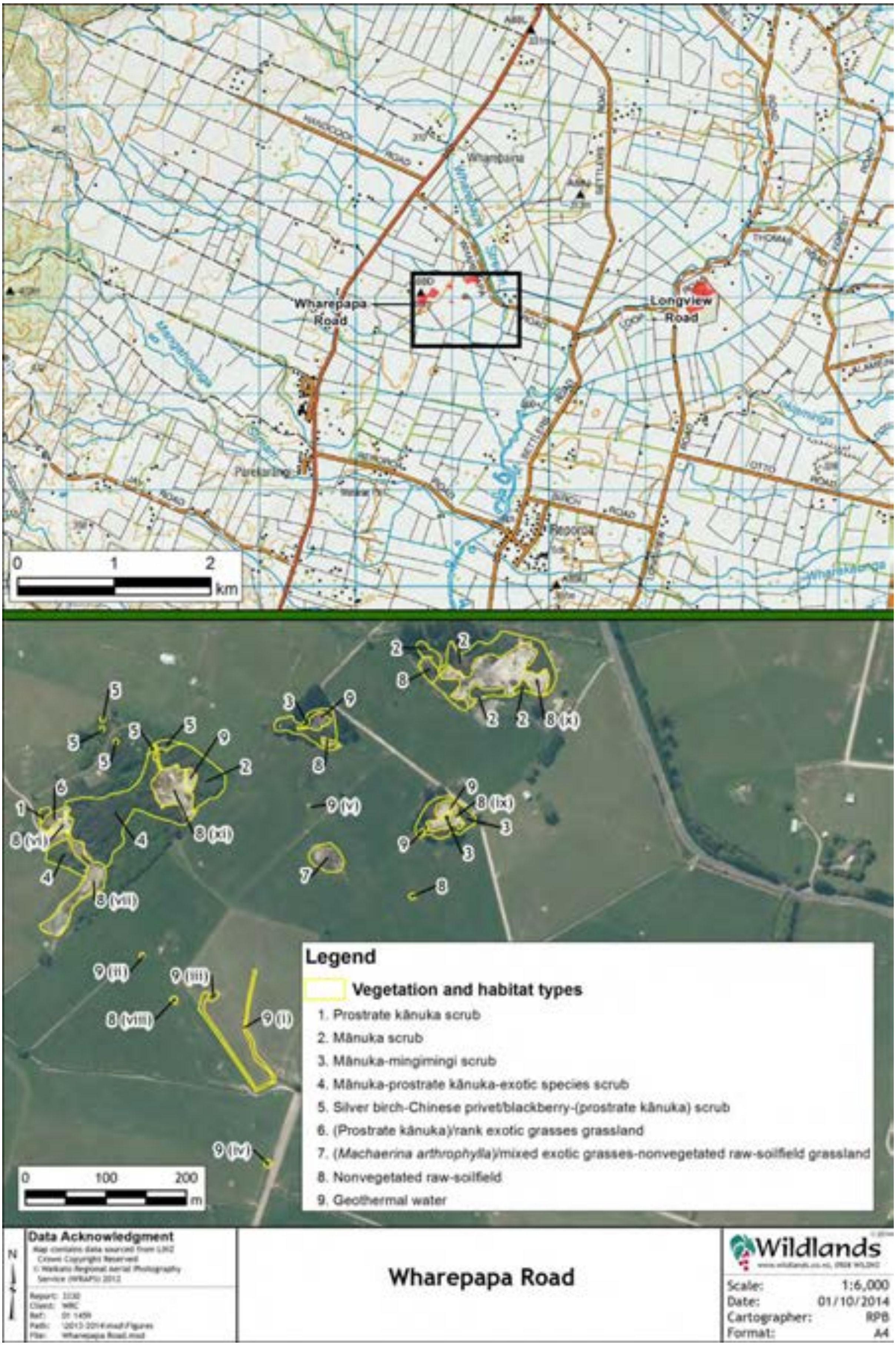
Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and classed Longview Road as Category C - the third category.

Much of this site is very unstable with very thin crusts and scorching water temperatures. Care should be taken during site inspections. It is not safe to access parts of the site on foot.

References:

Beadel and Bill 2000; Given 1995 & 1996; Spring-Rice 1996; Wildland Consultants 2004c & 2012.


Wharepapa Road
Longview Road
0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Mānuka scrub
3. Mānuka-mingimingi scrub
4. Mānuka-prostrate kānuka-exotic species scrub
5. Silver birch-Chinese privet/blackberry-(prostrate kānuka) scrub
6. (Prostrate kānuka)/rank exotic grasses grassland
7. (Machaerina arthrophylla)/mixed exotic grasses-nonvegetated raw-soilfield grassland
8. Nonvegetated raw-soilfield
9. Geothermal water
0 100 200 m
Data Acknowledgment
Wharepapa Road
Wildlands
Scale: 1:6,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

WHAREPAPA ROAD

Site Number:	RPV02[1]	**Grid Reference:**	NZTopo50 BF37 907 430
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1890738 N5743011
Geothermal Field:	Reporoa	**Local Authority:**	Rotorua
Bioclimatic Zone:	Lowland - Submontane	**Altitude:**	*c.*300 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*3.6 ha		
Extent of Geothermal Vegetation:	*c.*3.4 ha		
Date of Most Recent Field Survey:	30 July 2010		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** A small area of prostrate kānuka scrub to 3 m tall. Occasional blackberry, Mercer grass, Chinese privet seedlings, and sheep's sorrel in the understorey.	Gentle slope	<0.1 ha
Mānuka-dominant scrub (04.04) **Mānuka scrub (04.04.01)** Mānuka-dominant scrub (1-4 m tall) surrounds geothermal features, with scattered blackberry and occasional prostrate kānuka.	Flat	*c.*0.8 ha
Mānuka-mingimingi scrub (04.04.02) Mānuka (2-5 m tall) with mingimingi, patches of mingimingi-bracken scrub, and occasional prostrate kānuka. Scattered to local emergent radiata pine are present in parts of the site. Radiata pine, several oaks (*Quercus* sp.), and silver birch are present on the margins.	Flat	*c.*0.3 ha
Mānuka-prostrate kānuka-exotic species scrub (04.04.04) Mānuka, prostrate kānuka, and Chinese privet scrub to 7 m tall. Open areas dominated by mingimingi. Common understorey species include Yorkshire fog, Himalayan honeysuckle, blackberry, Chinese privet seedlings, and Khasia berry.	Flat	*c.*0.9 ha
Exotic species dominated scrub (04.10) **Silver birch-Chinese privet/blackberry-(prostrate kānuka) scrub (04.10.02)** Occasional to local silver birch and Chinese privet are emergent over blackberry scrub, with scattered broom and patches of prostrate kānuka. Browntop and Yorkshire fog present in the understorey. Fumaroles and small mud pools present in parts of this type.	Flat/gently rolling	<0.1 ha
Exotic grassland (08.01) **(Prostrate kānuka)/rank exotic grasses grassland (08.01.08)** Occasional prostrate kānuka over mixed exotic grassland species, including Indian doab, wild seradella (*Ornithopus perpusillus*), hawksbeard (*Crepis capillaris*), browntop, Mercer grass, catsear, and lotus. Soil temperature was 15 °C at 5 cm depth on a winter morning	Flat	<0.1 ha

[1] Identified as U17/32 in Wildland Consultants (2004c).

VEGETATION TYPE	LANDFORM	EXTENT
in 2010. **(*Machaerina arthrophylla*)/mixed exotic grasses-nonvegetated raw-soilfield grassland (08.01.09)** Emergent *Machaerina arthrophylla* is present over rank exotic grasses and herbs, including browntop, catsear, white clover, sheep's sorrel, sweet vernal, and *Gonocarpus micranthus*. Approximately 25 × 50 m of geothermal activity, including fumaroles, mud pools, and heated bare soils is present. Scattered pumice rocks are common.	Gently sloping/flat	*c.*0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** (vi) Sinter terrace, hot pools, occasional prostrate kānuka and mānuka. Scattered patches of Indian doab and hawksbeard. (vii) Patches of arrow grass on sediments from geothermal springs. Overflow from geothermal springs, 98 °C during field survey in 2010. (viii) Steaming ground. Five fumaroles. Occasional sheep's sorrel, Yorkshire fog, and annual poa (*Poa annua*). Small patch of sinter present. (ix) Occasional mingimingi on margins with scattered oaks and overhanging silver birch. (x) Nonvegetated raw-soilfield, including a mud pool. Scattered arrow grass, Yorkshire fog, and *Machaerina arthrophylla* are present on downstream overflow margins of the mud pool. (xi) Bare ground, geothermal water. Occasional prostrate kānuka to 3 m tall, mānuka seedlings, arrow grass, and *Lachnagrostis* sp.	Flat	*c.*1.1 ha
Water (22.01) **Geothermal water (22.01.01)** Several features are present. These are briefly described below with their location shown on the map. (i) Geothermal water in a drain, surrounded by exotic grasses, including reed sweet grass, Yorkshire fog, and curled dock (*Rumex crispus)*. (ii) Hot pool. (iii) Geothermal pool surrounded by mossfield. *Gonocarpus micranthus* on margins. Spring is surrounded by exotic grasses. (iv) Geothermal spring in ditch surrounded by rank exotic grasses, particularly reed sweetgrass and Yorkshire fog. The temperature was *c.*47°C in 2010 with green and orange algae present near spring outflow and drainage channel. (v) A mud pool surrounded by sheep's sorrel and grazed pasture grasses. Timber has been thrown into the mud pool.	Open water	*c.*0.2 ha

Indigenous Flora: Small populations of both prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Campylopus* sp. are present; both are endemic species restricted to geothermal areas. Other species characteristic of geothermal habitat include mingimingi, mānuka, and water fern. The presence of

[1] All flora threat rankings are from de Lange *et al.* 2013.

Machaerina arthrophylla at this site is of botanical interest.

Fauna: Pied stilt (At Risk-Declining[1]) use habitats at this site from time to time (observed at the site in 2010), though it does not represent habitat of considerable importance for the conservation of this species. Common indigenous and introduced bird species typical of the habitats are likely to be present, including Australasian harrier, spur-winged plover, grey warbler, Australian magpie, pukeko, fantail, welcome swallow, house sparrow, Eurasian blackbird, goldfinch, and skylark. Mosquitofish were recorded in drains.

Current Condition (2010 Assessment): Most of the site comprises small and isolated geothermal areas surrounded by farmland. The geothermal areas have been highly modified by dairy farming and the dumping of rubbish and are in poor condition. Parts of the site are fenced to exclude stock and have geological features of high significance (see Appendix 4 for a geophysical assessment of features at this site). Pest plants are common, but there is good potential habitat for indigenous geothermal plants to increase their cover and diversity in these areas with appropriate management. The values of the site are likely to improve if geothermal features are fenced to exclude stock.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2010 Assessment*): Several exotic species occur within the site and are likely to increase in extent under current management. Key weed species present are rank pasture grasses (26-50% cover), Khasia berry (1-5% cover), blackberry (6-25% cover), oaks (1-5% cover), silver birch (1-5% cover), and pine species (including radiata pine, maritime pine, lodgepole pine) (5-25% cover). Silver birch and pines could damage geothermal features if they fall into them.

Human impacts (*2010 Assessment*): Rubbish disposal is the main human-related threat to these areas. Rubbish, which includes litter, fencing material, white-ware, and garden refuse, has been dumped on the sinter terraces and geothermal sediments. Several drainage channels from the hot pools extend across the farmland, and these have lowered the water table and altered ground temperatures. Several geothermal baths are present at the site. Until recently, one of the pools was also used by pig hunters to clean their pigs. Harvesting of trees has caused considerable damage to geothermal features at one location. Many features are threatened by farming activities (see below).

Grazing (*2010 Assessment*): Most of the areas are currently fenced but the fences are in poor condition in places, allowing livestock access.

Adjoining land use (*2014 Assessment*): Farmland.

Site Change:

Recent change (2011 Assessment): More features were found in the 2010 survey than earlier surveys. These would have been present during earlier surveys, but not located on the

[1] All avifauna threat rankings are from Robertson *et al.* 2013.

ground due to dense vegetation.

Historical (*Assessed in 2011*): Historical photos of the site from 1941[1] were compared with 2007 aerial photographs to assess long-term change at this site. The development of farmland around these geothermal sites was less intense in 1941, with areas of shrubland linking most of the features. The geothermal activity in the northeast of the site appears to have become more active. The area that currently comprises mud pools and bare ground appears to have been dominated by shrubland in 1941 (there may have been geothermal features), and the area of bare ground present in 2010 is about five times the size it was in 1941. The large area of geothermal habitat in the southwest of the site appears to comprise a larger area of bare ground in 1941 than in 2007. Taking into account shrubland masking geothermal surface features in the 1941 photographs and the subsequent conversion of the site to pasture, a best estimate is that geothermal habitat in 1941 would have been about three times larger than that currently present (and mapped) at Wharepapa Road.

Management Requirements: Stock access to some areas and dumping of rubbish should be prevented. Planting of exotic species around geothermal features should be discontinued, and the impacts of the drainage channels should be monitored. Consideration should be given to fencing to exclude stock from all geothermal features within this site. Pest plants (particularly trees that could fall into features) should be controlled.

Significance Level: A: Regional (Table 1 - Criteria 3, 5; Table 2 - Factor 14)
B: Local (Table 1 - Criterion 5; Table 2 - Factor 19)

Significance Justification: This site has been divided into two parts, A and B (see site map).

A: These areas are of regional significance because, when considered together, they form a moderate-sized area of geothermal habitat that includes nationally uncommon ecosystems (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012). These areas also contain small populations of an 'At Risk' plant species (prostrate kānuka), but do not represent habitat of considerable importance for the conservation of this species.

B: These areas are of local significance because they contain small, disjointed, degraded examples of nationally uncommon habitat types (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012).

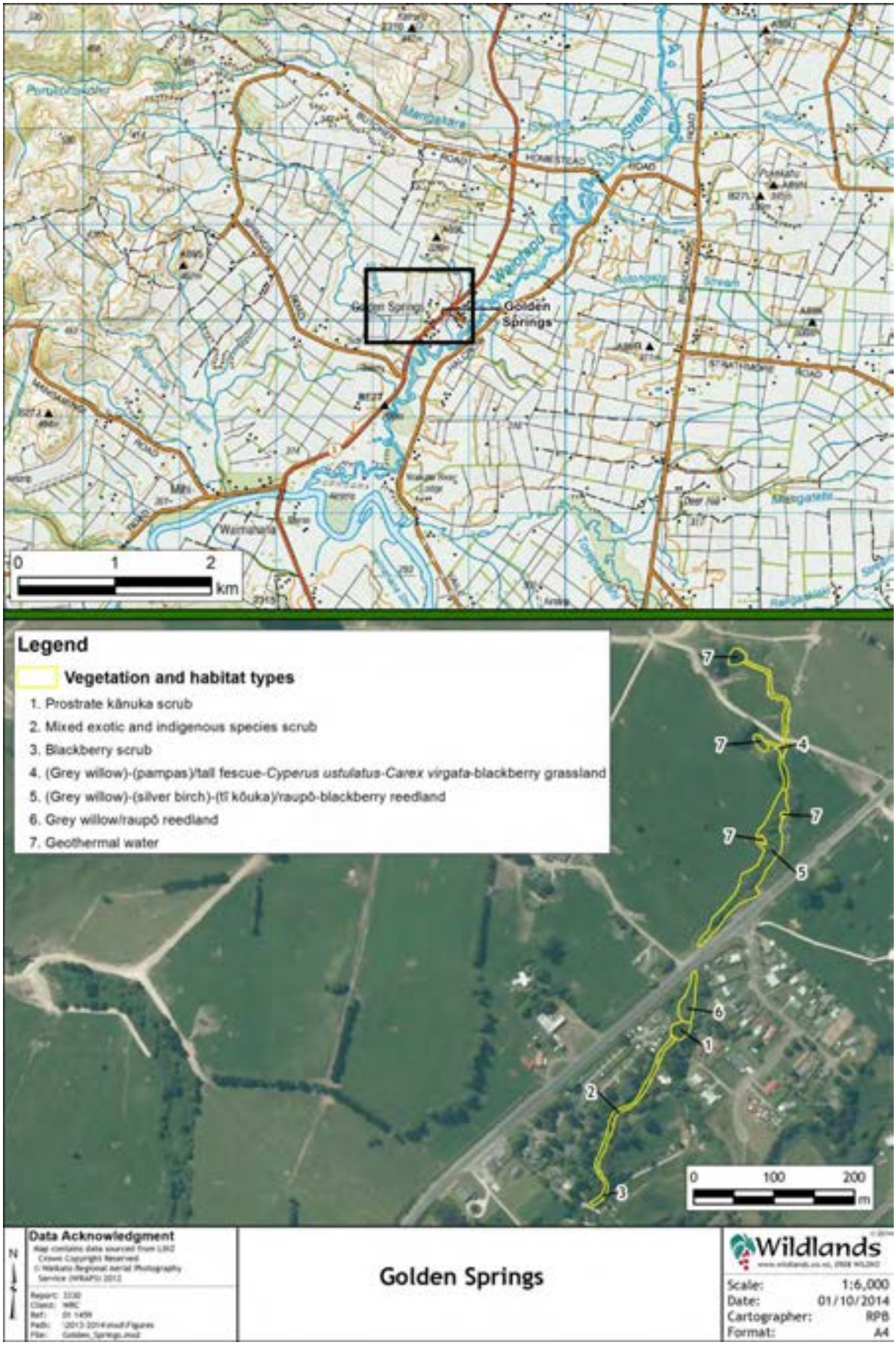
Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category B - the second highest category.

Features 2 and 12 are listed in Waikato Regional Council (undated) as "South (SE) Spring" and "Opaheke Spring" respectively.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4.

[1] Historical photos: SN 172 Run 1162 Photos 2-3, 1941.

References: Beadel and Bill 2000; Given 1995 & 1996; Spring-Rice 1996; Waikato Regional Council (undated); Wildland Consultants 2004c & 2012.


Golden Springs
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Mixed exotic and indigenous species scrub
3. Blackberry scrub
4. (Grey willow)-(pampas)/tall fescue-Cyperus ustulatus-Carex virgata-blackberry grassland
5. (Grey willow)-(silver birch)-(tī kōuka)/raupō-blackberry reedland
6. Grey willow/raupō reedland
7. Geothermal water
0 1 2 km
0 100 200 m
Data Acknowledgment
Golden Springs
Wildlands
Scale: 1:6,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

GOLDEN SPRINGS

Site Number:	RPV03[1]	**Grid Reference:**	NZTopo50 BF37 889 372
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1888850 N5737187
Geothermal Field:	Reporoa	**Local Authority:**	Rotorua
Bioclimatic Zone:	Lowland	**Altitude:**	300 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*0.8 ha		
Extent of Geothermal Vegetation:	*c.*0.7 ha		
Date of Most Recent Field Survey:	23 January 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka scrub (04.01) **Prostrate kānuka scrub (04.01.01)** A small area of prostrate kānuka to 8 m tall. Occasional Chinese privet and blackberry present.	Gully	<0.1 ha
Mixed exotic and indigenous species scrub (04.09) **Mixed exotic and indigenous species scrub (04.09.02)** A diverse range of vegetation occurs as a narrow band alongside the stream that flows through the Golden Springs camp ground. The heated stream creates suitable habitat for *Christella* aff. *dentata* ("thermal") with *c.*28 clumps observed during the 2014 survey. Other fern species common along the stream margin include kiokio, *Hypolepis ambigua*, *Deparia petersenii*, bracken, and water fern. Scattered planted and ornamental garden plant species are common in places (e.g. *Abelia grandiflora*, *Carex testacea*, various *Hebe* species, hydrangea (*Hydrangea macrophylla*), and *Begonia* 'semperflorens-cultorum hybrids'). Blackberry, ivy, periwinkle (*Vinca major*), and *Selaginella kraussiana*, are locally common particularly under shrubs and trees, while mown and rank grasses are common in other areas. Several prostrate kānuka plants are present. Scattered karamū, whekī, Chinese privet, silver birch, crack willow, ornamental cherry, and Douglas fir are locally emergent over the stream. *Cyperus ustulatus, Carex secta, Cyperus eragrostis,* harakeke, and lake clubrush are present on damp margins. The stream has been extensively altered in places with a diversion for water wheels, several dams, and excavations for swimming holes; channels have also been dug. There is local grassland dominated by sweet vernal, annual poa, and white clover, in association with black nightshade, broad-leaved fleabane, Scotch thistle, agapanthus (*Agapanthus praecox*), Spanish heath, Japanese honeysuckle, Chinese privet, arrow bamboo, shaking brake (*Pteris tremula*), *Hypolepis ambigua*, and swamp kiokio. One patch of *Pteris comans* was present (NZTM E1888176 N5736849).	Stream margins	*c.*0.1 ha
Exotic species dominated scrub (04.10) **Blackberry scrub (04.10.01)** Chinese privet and whekī are locally emergent over stream margins dominated by blackberry scrub on the true right of the stream. A few scattered *Christella* aff. *dentata* ("thermal") are present in the upstream	Stream margins	<0.1 ha

[1] Site number in 2004 was U17/27 (Wildlands 2004c and 2007b).

VEGETATION TYPE	LANDFORM	EXTENT
part of this vegetation type. Rank grasses (including Yorkshire fog, sweet vernal, and ryegrass (*Lolium perenne*)) are common on the true left. Some exotic vegetation on the true left has been cleared since 2007.		
Exotic grassland (08.01) **(Grey willow)-(pampas)/tall fescue-*Cyperus ustulatus*-*Carex virgata*-blackberry grassland (08.01.13)** Scattered emergent pampas and grey willow are present over grassland alongside geothermal streams/drains in the northeastern part of the site. The grassland is dominated by tall fescue with common Yorkshire fog, Mercer grass, and sweet vernal. Sedges are abundant on stream margins (*Carex virgata* and *Cyperus ustulatus*), and blackberry is locally abundant. Occasional creeping buttercup, broad-leaved fleabane, ring fern, and water purslane are also present. These habitats have been fenced since 2007.	Wetland	*c.*0.1 ha
Raupō-dominant reedland (11.01) **(Grey willow)-(silver birch)-(tī kōuka)/raupō-blackberry reedland (11.01.02)** A raupō and blackberry-dominated geothermal drain and wetland is located between State Highway 5 and farmland. Emergent grey willow, Chinese privet, hawthorn (*Crataegus monogyna*), cotoneaster, silver birch, tī kōuka, kōhūhū, and whekī are present. Several *Christella* aff. *dentata* ("thermal") plants were present at the south end of the drain in 2007, however none were seen in 2014. The western margin of this wetland has been fenced to exclude stock since 2007. Other species present include *Cyperus ustulatus*, Japanese honeysuckle, kiokio, pampas, and *Carex virgata*. The temperature in the drain at the southern end of this vegetation type was 40°C in 2014.	Roadside drain and wetland	*c.*0.4 ha
Grey willow/raupō reedland (11.01.05) A small geothermal wetland is located on the eastern side of State Highway 5. Scattered grey willow are emergent over raupō-dominant reedland with local patches of *Carex virgata*, *Carex secta*, and *Hypolepis ambigua*. Blackberry is common on the margins.	Wetland	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermal hot springs and open water habitats surrounded by rank grassland species and sedgeland species. The surface temperature of the pool in the northern part of the site (NZTM E18888848 N5737470) was 40°C in 2014.	Open water	*c.*0.1 ha

Indigenous Flora: *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon[1]) is scattered along stream margins throughout the eastern part of this site. A few plants of *Christella* aff. *dentata* ("thermal") were present in a roadside ditch on the western side of state highway in 2007 (Bycroft and Beadel 2007), but none were found during the 2014 survey. Bycroft and Beadel (2007) estimated that there were 45 mature plants present at this site in 2007, but only 28 clumps were recorded in the current survey. However,

[1] All flora threat rankings are from de Lange *et al.* 2013.

the cover and distribution of *Christella* aff. *dentata* ("thermal") at this site appears similar between the 2007 and 2014 surveys (Chris Bycroft pers. obs.).

A small population of prostrate kānuka (At Risk-Naturally Uncommon) is present along stream margins on the eastern side of State Highway 5. Prostrate kānuka is endemic to geothermal habitat in New Zealand.

Fauna:

Indigenous birds recorded from the site include North Island fantail, silvereye, bellbird, spur-winged plover, and pukeko. Introduced species recorded from the site include Eurasian blackbird, mallard, house sparrow, and yellowhammer. An indigenous butterfly, the red admiral butterfly, was also recorded from the site.

Current Condition (2014 Assessment):

This site is generally in a poor ecological condition, and pest plants are common on both sides of State Highway 5. The condition on the western side of State Highway 5 has improved since the 2007 survey - the geothermal springs and wetland areas have been fenced to exclude stock. The parts on the eastern side of the road are within a camping ground, and their condition is directly affected by management of recreational activities and aesthetic plantings. The downstream (southern) end of the site is overrun with blackberry and is partly grazed by stock. Exotic plantings are common along the length of the stream.

Threats/Modification/ Vulnerability:

Invasive pest plants (2014 Assessment):

Western side of State Highway 5: Grey willow (25% cover), Chinese privet (15% cover), blackberry (25% cover), cotoneaster (1% cover), pampas (1% cover), and Japanese honeysuckle (1% cover).

Eastern side of State Highway 5: Blackberry (35% cover), Chinese privet (15% cover), ivy (5% cover), periwinkle (2% cover), *Clemetis flammula* (1% cover), *Selaginella kraussiana* (2% cover), Japanese honeysuckle (1% cover), ornamental cherry (1% cover), arrow bamboo (2% cover), crack willow (1% cover), Himalayan honeysuckle (1% cover), grey willow (1% cover), *Calystegia silvatica* subsp. *disjuncta* (<1% cover), Douglas fir (<1% cover), silver birch (<1% cover), *Cyperus eragrostis* (<1% cover), agapanthus (2% cover), elephants ear (<1% cover), and *Pteris comans* (<1% cover).

Human impacts (2014 Assessment):

Western Part

Although the western part of the site is farmed, the geothermal features have recently been fenced to exclude stock. Some pools on the western side are used for swimming, but the impacts on vegetation from recreational use are minor. Drains have been dug in the western part of the site and alongside State Highway 5.

Eastern Part

The eastern part is negatively impacted by recreation use and aesthetic plantings. Impacts on the stream and margins include concreted sections, water wheels, and damming of stream for swimming holes. Exotic plantings are abundant on stream margins, and mowing has occurred close

to stream margins in some sections.

Grazing (2014 Assessment):

Western Part

The western part of the site is surrounded by farmland, however the geothermal features have recently been fenced to exclude stock, and stock are now having no direct grazing impacts on geothermal vegetation.

Eastern Part

The eastern part of the site is a camping ground. The manager occasionally lightly grazes this part with goats.

Adjoining land use (2014 Assessment): Farmland, camping ground, state highway, residential.

Site Change:

Recent change (2014 Assessment): On the western side of State Highway 5 all of the geothermal pools and associated streams and drains have been fenced since the previous survey in 2007 (Chris Bycroft pers. obs.). An additional geothermal spring and pond was found in the 2014 survey, this would have been present in 2007.

Overall, the eastern part of the site (Area A) appears similar to 2007. Some plantings (mainly exotic species)have been undertaken along steam margins. A swimming pond has been created by damming a small part of the creek.

Historical (*Assessed in 2011*): This site is too small for any evidence of change to be identified on aerial photographs (Historical photos: SN 172 Run 1165 Photos 3-4, 1941).

Management Requirements: The fences should be inspected and maintained regularly on the eastern side of State Highway 5. A management plan should be prepared to provide guidelines for the manager(s) of the camping ground to maintain and enhance the population of *Christella* aff. *dentata* ("thermal"). Abundant weeds are present alongside stream margins which threaten both the *Christella* aff. *dentata* ("thermal") populations at the site as well as the remaining indigenous components of stream margins. Occasionally the camp ground manager has tried to control weeds at the site by using goats, however this may threaten *Christella* populations. Pest plants should be controlled in the wetland on the western side of State Highway 5, including grey willow, pampas, and Chinese privet. There are significant opportunities for ecological restoration around stream margins, in areas of open geothermal water, and within geothermal wetlands.

Significance Level: This site has been divided into two parts for ranking - A and B.

A: Regional (Table 1 - Criterion 3, 5, 9; Table 2 - Factor 12).
B: Local (Table 1 - Criterion 5; Table 2 - Factor 19).

Significance Justification:

A: This part of the site is of regional significance as it is an important site for the conservation of an 'At Risk' species - *Christella* aff. *dentata* ("thermal"). This species is only known from 15 sites in the North Island, and many populations are threatened by grazing, human induced changes to geothermal fields (e.g. energy

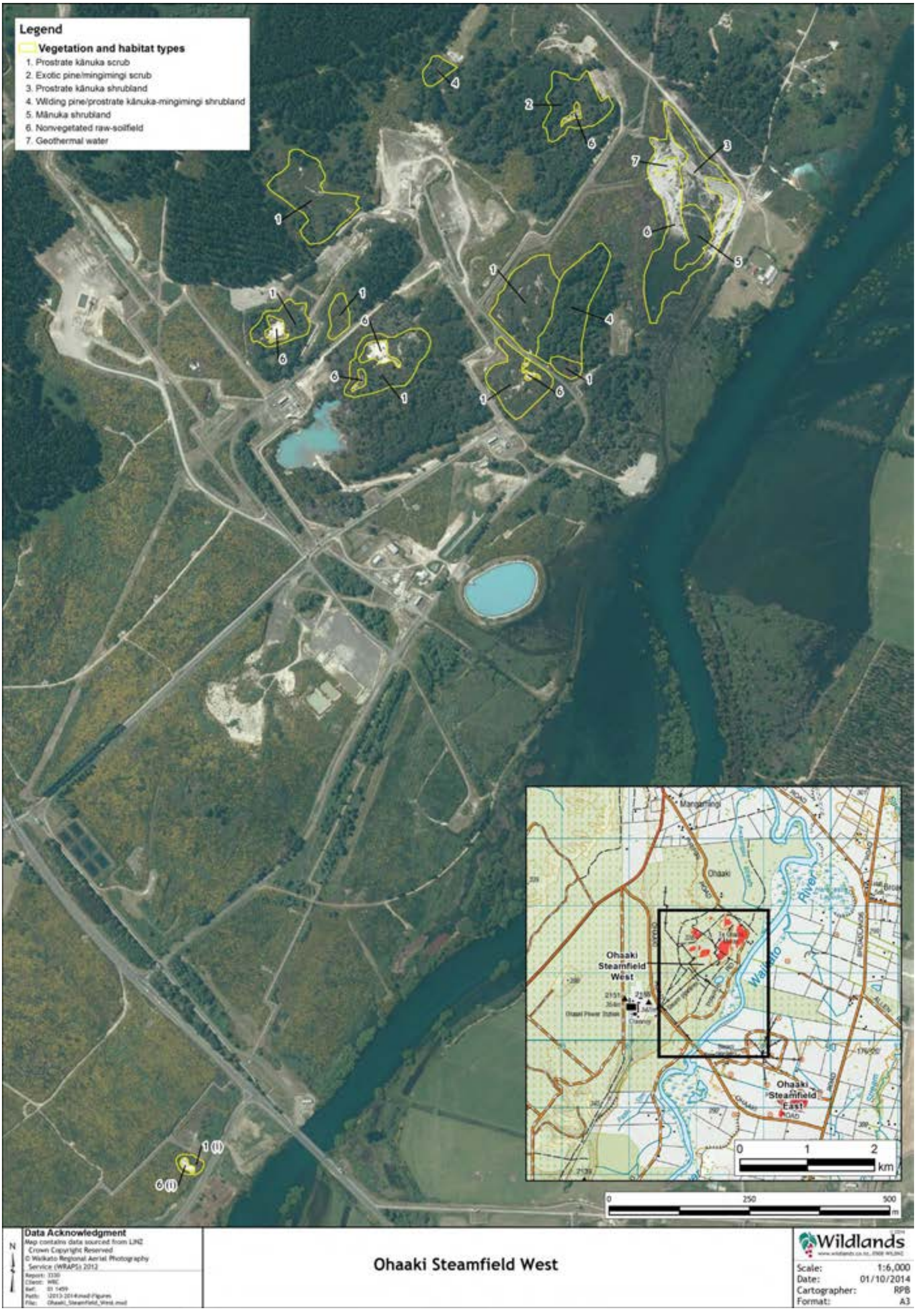
production), and vegetation clearance. It has become extinct at four sites.

B: This part of the site is of local significance because it contains geothermal stream margin habitat - a nationally uncommon habitat (Williams *et al.* 2007, Holdaway *et al.* 2012).

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region classed Golden Springs as Category B - the second highest category.

References: Beadel and Bill 2000; Bycroft and Beadel 2007; Given 1989a, 1995 & 1996; Spring-Rice 1996; Wildland Consultants 2004c, 2007b, & 2012.

OHAAKI GEOTHERMAL FIELD


Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Exotic pine/mingimingi scrub
3. Prostrate kānuka shrubland
4. Wilding pine/prostrate kānuka-mingimingi shrubland
5. Mānuka shrubland
6. Nonvegetated raw-soilfield
7. Geothermal water
Mangamingi
Ohaaki
Waikato River
Ohaaki Steamfield West
Ohaaki Steamfield East
0 1 2 km
0 250 500 m
Data Acknowledgment
Map contains data sourced from LINZ
Crown Copyright Reserved
© Waikato Regional Aerial Photography Service (WRAPS) 2012
N
Ohaaki Steamfield West
Wildlands
Scale: 1:6,000
Date: 01/10/2014
Cartographer: RPB
Format: A3

OHAAKI STEAMFIELD WEST

Site Number:	OHV01[1]	**Grid Reference:**	NZTopo50 BF37 887 316
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1888672 N5731579
Geothermal Field:	Ohaaki	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*300-320 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*11.7 ha		
Extent of Geothermal Vegetation:	*c.*11.6 ha		
Date of Most Recent Field Survey:	28 January 2011		

TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01[2])** Prostrate kānuka up to *c.*1.5 m tall forms a dense cover with scattered mingimingi and mānuka, and frequent emergent radiata pine and maritime pine up to *c.*10 m tall. Bracken, tūrutu, *Gleichenia microphylla*, ring fern, kiokio, and water fern are also present. Small patches of nonvegetated raw-soilfield occur amongst this vegetation type which supports scattered *Lycopodiella cernua*, Spanish heath, broad-leaved fleabane, gorse, buddleia, and broom.	Low hills; hillslopes and alluvial terrace	*c.*5.4 ha
Mingimingi-dominant scrub (04.03) **Exotic pine/mingimingi scrub (04.03.02)** Mingimingi dominates the canopy with scattered patches of kānuka, and scattered emergent radiata pine and maritime pine. Bracken, *Dicranopteris linearis*, buddleia, whauwhaupaku, kōhūhū, and whekī are also present.	Hillslope	*c.*0.9 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** This area comprises prostrate kānuka up *c.*0.75 m height, and areas of bare soil. Occasional pampas are present. **Wilding pine/prostrate kānuka-mingimingi shrubland (05.01.02)** Maritime pine is emergent over prostrate kānuka with patches of mingimingi.	Alluvial flat Alluvial flat	*c.*0.9 ha *c.*1.5 ha
Mānuka-dominant shrubland (05.04) **Mānuka shrubland (05.04.01)** Mānuka dominated shrubland with scattered prostrate kānuka, Spanish heath, blackberry, buddleia, and occasional maritime pine saplings.	Low hills, alluvial flat	*c.*0.5 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Sinter clay, small sinter terraces (unmapped), and steaming fumaroles, fissures, and bare ground with areas of prostrate kānuka, *Lycopodiella cernua,* the moss *Campylopus capillaceus*, and exotic grasses	Alluvial terrace	*c.*2.4 ha

[1] Identified as U17/25 in Wildland Consultants (2004c).

[2] The area of this type noted as (i) has not been inspected and requires field survey. Inspection of Google maps street view pictures indicates the presence of geothermal features.

TYPE	LANDFORM	EXTENT
(including narrow-leaved carpet grass and tall fescue). Around Ohaaki Pool there are local patches of kānuka in association with mānuka and scattered Spanish heath, pampas, and blackberry with small, isolated areas of *Machaerina juncea*.[1]		
Water (22.01) **Geothermal water (22.01.01)** Geothermal pool (Ohaaki Pool).	Alluvial terrace	*c.*0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[2]), *Dicranopteris linearis* (5-10 plants) (At Risk-Naturally Uncommon), *Campylopus clavatus*, and *Lycopodiella cernua* are present at this site; these species are characteristic of geothermal sites. *D. linearis* is known from only *c.*23 sites in New Zealand.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including fantail, kōtare (sacred kingfisher), tūī, grey warbler, North Island robin, and pheasant. Rabbits were also recorded at the site.

Current Condition (2011 Assessment): Major changes to the vegetation and landform within this site have occurred over several years due to land subsidence as a result of draw-off associated with the geothermal power station. This site has been fragmented by industrial activities and road works, with additional clearance recorded since the 2007 survey (a small area of prostrate kānuka appears to have been removed to construct a road). Small areas of geothermal vegetation remain. Overall this site comprises a relatively large area of geothermal vegetation and habitat with significant human-induced disturbance and major pest plant infestations. However, the site still has significant ecological values.

Wilding pines have been controlled in some areas but they remain prominent in other parts of the site.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Assessment of exotic plant species at this site concurs with previous survey results. Wilding pines are the most prominent invasive species, with a cover of 5-25%. Other invasive pest plant species present are blackberry, broom, pampas, and gorse (each with 1-5% cover). Temperatures are cooling at this site (D. Bowden, Contact Energy, pers. comm. 2011), which is resulting in increased opportunities for exotic species to invade. Over the last four years some of the larger infestations of wilding pines and pampas have been controlled in and around the borefield by the Waikato Regional Council. Ongoing pest plant control is being undertaken within this site by Contact Energy (wilding pines and pampas) and Waikato Regional Council.

Human impacts (*2011 Assessment*): Geothermal extraction and related earthwork operations present ongoing threats to the geothermal features and vegetation of this site. Temperatures

[1] At the time of the field survey in 2011 the southern parts of this site (E1888564 N5731359) were flooded by water from the Waikato River.

[2] All flora threat rankings are from de Lange *et al.* 2013.

are cooling (D. Bowden, Contact Energy, pers. comm. 2011), wilding pines are continuing to establish, and geothermal vegetation has been cleared to make way for roads and infrastructure. Plantation management and harvesting operations are a potential threat to geothermal vegetation adjacent to pine plantations.

Grazing (*2011 Assessment*): Grazing is not an issue at this site.

Adjoining land use (*2014 Assessment*): Geothermal power plant operations, plantation forestry, Waikato River.

Site Change:

Recent change (2014 Assessment): A small area in the south of the site (near NZTM E1887772 N5729858; labelled 'i' on the site map) has been added to the site. This is not a new manifestation, but has been found through incidental observation of the site. This area is a high priority for field survey. Vegetation change as a result of land subsidence within the site has occurred but the full extent of change is not known. Some wilding pine control has been undertaken at the site since 2004, however wilding pine encroachment is continuing in many areas.

An area of prostrate kānuka has been cleared for access tracks and laying of pipes associated with the Geothermal power plant. A population of prostrate kānuka has established on bare ground near the marae, in an area that was previously mapped as nonvegetated raw-soilfield.

Historical (*Assessed in 2011*): In 1941[1] there was a larger area of bare ground and low shrubland in the vicinity of this site, which may have been geothermal vegetation and habitat, however these areas are now non-geothermal. Merrett and Burns (1998a) compared and interpreted aerial photographs from 1941 to 1996 and found that the total area of geothermal vegetation reduced between 1941 and 1981, with many areas colonised by wilding pines. In 1996, there was an increase in the extent of geothermal vegetation, probably as a consequence of fallen pines and recolonisation by prostrate kānuka. The density of weed species has steadily increased at this site over the lst few decades.

The Ohaaki Power Station was commissioned in 1989. Prior to the development of field, the large boiling pool in the northeast of the site (Ohaaki Ngāwhā) was the most significant feature of the field, with its turquoise-blue water and extensive sinter terrace (Vaile 1939). When development commenced, the extraction of geothermal fluid made the water level at Ohaaki Ngāwhā drop. The change in water level within Ohaaki Ngāwhā changed the quality of the sinter terrace and allowed vegetation to establish on it. Most other features at Ohaaki have dried up because of the extraction of geothermal fluid. Before development, several types of geothermal features were present at Ohaaki including:

Several mud pools heated by steam;
Hot pools isolated from ground water by a layer of mineralised earth, also heated by steam;

[1] Historical photos: SN 172 Run 1167 Photos 7-9, 1941.

Hot springs producing chloride water and depositing sinter.

Most of these features have dried up and are now hot dry ground, however the area of steaming ground has expanded. There is steam rising through the graves in the urupā to the northwest of the site, and the ground has opened up in places (http://www.waikatoregion.govt.nz/Environment/Natural-resources/Geothermal-resources/Geothermal-systems-map/Ohaaki/; Accessed 9 July 2014).

Other management activities have also had significant impacts at the site, and some features are threatened by flooding of, and inundation by, the Waikato River (http://www.nzgeothermal.org.nz/nz_geo_fields.html#Ohaaki_Broadlands; Accessed 30 June 2011).

Environmental monitoring of this area over ten years prior to, and during, the development of the Ohaaki power project shows that significant changes to geothermal features have occurred in response to water draw-off for geothermal power generation. In the northwestern thermal area, all pools are now dry (other than Ohaaki Ngawha where the water level is artificially maintained) and geothermal vegetation is establishing on the exposed ground (Bromley *et al.* 1997). In some areas ground temperatures have decreased, but in others ground temperatures have increased, resulting in an increase in the extent of thermotolerant vegetation (Merrett and Burns 1998a).

Management Requirements:

Contact Energy is undertaking ongoing control of wilding pines and pampas within this site. Waikato Regional Council has mainted the area next to the Ohaaki marae free from pest plants since wilding pines were removed in 2011. Other pest plant species control should also be undertaken.

Monitoring of steamfield management, and the vegetation response to changing temperatures should be ongoing, including monitoring the *Dicranopteris linearis* population. The impacts of land subsidence on geothermal vegetation should also be monitored.

Future infrastructure developments on the site should aim to avoid destroying remaining areas of geothermal vegetation.

Significance Level:

Regional (Table 1 - Criteria 3, 5, 9; Table 2 - Factors 12, 14).

Significance Justification:

This site is of regional significance because it is a relatively large example geothermal vegetation, which includes nationally uncommon ecosystem types (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also contains a large population of an 'At Risk' plant species (prostrate kānuka), and a small population of *Dicranopteris linearis*, another 'At Risk' plant species.

Priority for Field Survey (2014 Assessment):

This site is a high priority for field survey. One new area has been added to the site but has not been field surveyed (near NZTM E1887772 N5729858), and a small bay on the margins of the Waikato River at E1888850 N5731630 is also of interest for survey. Changes are also likely to have occurred to the vegetation as a result of land subsidence. Management requirements and priorities require updating.

Notes:

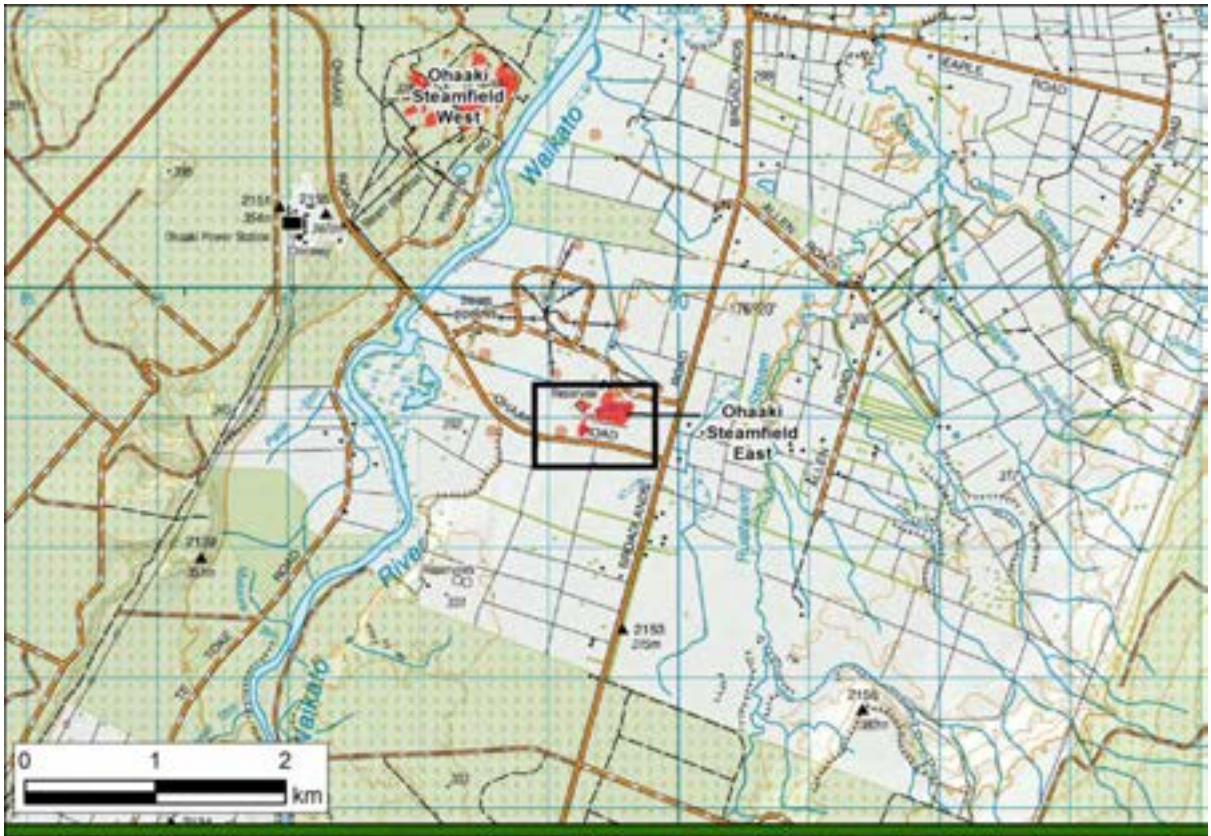
Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region. He ranked Ohaaki Ngawha, which occurs in this site, as Category C - the third highest category.

Merrett and Burns (1998a) suggest that the study area would rank in the Protected Natural Areas Programme as a level 2 priority for protection, and commented that "the conservation of thermotolerant vegetation at Ohaaki is moderately significant to the goal of maintaining adequate representative examples of the full range of natural vegetation present in the Atiamuri Ecological District."

Site name was Ohaaki Steamfield 1 in Beadel and Bill 2000.

References:

Beadel and Bill 2000; Bromley *et al.* 1997; Given 1996; Merrett and Burns 1998a; Merrett *et al*. 2003; Vaile 1939; Wildland Consultants 2004c & 2012.



Data Acknowledgment

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Ohaaki Steamfield East

Wildlands
www.wildlands.co.nz, 0508 WILDNZ

Scale:	1:5,000
Date:	02/10/2014
Cartographer:	RPB
Format:	A4

OHAAKI STEAMFIELD EAST

Site Number:	OHV02[1]	**Grid Reference:**	NZTopo50 BG37 895 291
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1889483 N5729076
Geothermal Field:	Ohaaki	**Local Authority:**	Rotorua
Bioclimatic Zone:	Submontane	**Altitude:**	305 m
Tenure:	Part unprotected private land, part protected (QEII)		
Extent of Geothermal Habitat:	*c.*6.4 ha		
Extent of Geothermal Vegetation:	*c.*6.4 ha		
Date of Most Recent Field Survey:	28 January 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka scrub with occasional patches of mānuka scrub. Mingimingi, monoao, Spanish heath, broom, and bracken are present on the margins with scattered emergent radiata pine and maritime pine. Small areas of raw-soilfield and moss patches are also present.	Geothermal basin	*c.*0.5 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka-broom-blackberry shrubland (05.01.03)** Occasional maritime pine and radiata pine are emergent over prostrate kānuka, broom, and blackberry. Yorkshire fog, lotus, broad-leaved fleabane, and gorse are also present.	Geothermal basin	*c.*2.1 ha
Exotic shrubland (05.09) **Exotic pine/blackberry-prostrate kānuka shrubland (05.09.01)** Scattered maritime pine and radiata pine occur over blackberry, broom, Spanish heath, gorse, and mānuka, with patches of prostrate kānuka in thermal areas.	Geothermal basin	*c.*1.1 ha
Exotic grassland (08.01) **Prostrate kānuka/Yorkshire fog grassland (08.01.02)** Scattered patches of prostrate kānuka occur throughout Yorkshire fog grassland. Broad-leaved fleabane, grey willow, and bracken are present on the margins.	Geothermal basin	*c.*0.5 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** In the south of this site, geothermal bare ground is surrounded by Indian doab. Within the portion of this site that is protected by a QEII covenant, geothermal clays support scattered plants of prostrate kānuka, broad-leaved fleabane, lotus, and Yorkshire fog.	Low hills	*c.*2.2 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[2]) is present at this site. Arrow grass, generally a coastal species which occasionally occurs inland, has been recorded at the site in the past (Burns 1997a).

Fauna: Common indigenous and introduced bird species typical of the habitat are

[1] Site number in 2004 was U17/14 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

present including spur-winged plover, chaffinch, Californian quail, house sparrow, and fantail.

Cat sign was noted during the 2011 survey of this site.

Current Condition (2011 Assessment):

The site is currently in relatively poor condition, with abundant pest plants and recent human disturbance, however values are likely to improve if management of site threats is undertaken. Based on inspection of the 2012 aerial photographs (WRAPS 2012), blackberry control has been undertaken in parts of the site. New roads are also evident within the site.

Given (1989) and Burns (1997a) noted that the quality of this site had deteriorated due to rubbish disposal, effluent from the lucerne drying plant polluting the ponds, and an increase in adventive weeds. Geothermal wastewater is no longer discharged into this site from the former lucerne-drying plant but the landowner is investigating options for reinjection. There is no longer open geothermal water here.

In 2011, the landowner had mulched a track through the blackberry and had started felling wilding pines. An area of pines (outside of the site) has been felled and cleared and this area will be part of a site-wide restoration/planting programme the landowner wishes to undertake. To ensure that this will successfully protect and enhance the natural values of the site the landowner will require some advice and/or assistance. A restoration plan to guide this process should be prepared by an ecologist with experience in restoration of geothermal areas.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*):

Weeds are abundant. Particularly blackberry, pines, Spanish heath, and broom, which together cover *c.*50% of the site. Hot spots appear to be resistant to weed invasion as long as the indigenous vegetation remains free from disturbance. A single mature lodgepole pine is present in this site. Contact Energy is undertaking ongoing control of wilding pines and pampas within this site.

Human impacts (*2011 Assessment*):

Ohaaki Power Station draws water from the underlying geothermal resources and this may affect geothermal features dependent on geothermal heat. To date there is no evidence of cooling or heating of the site (Burns 1997a; Merrett and Burns 1998a).

Geothermal wastewater dumping into this site has ceased in the last four or five years, but reinjection options are being considered.

Tracks cut through the site to gain access for weed control have, on the whole, been located through blackberry, but prostrate kānuka seedlings were noted along the newly formed track and may continue to establish on disturbed sites.

Grazing (*2011 Assessment*):

Most of this site is fenced to exclude domestic livestock but one area of nonvegetated raw-soilfield is located in a grazed paddock.

Adjoining land use (*2014 Assessment*):

This site is mainly surrounded by farmland with the Ohaaki Thermal Kiln operation on the northern margin.

Site Change:

Recent change (2014 Assessment):

Based on inspection of the 2012 aerial photographs (WRAPS 2012), blackberry control has been undertaken in parts of the site. Extensive earthworks in the northwest of the site are evident, and new roads are also present. The extent of geothermal vegetation is therefore likely to have changed since 2011. With no geothermal wastewater entering the centre of this site, and no geothermal water present, the vegetation is likely to continue to change over time. Prostrate kānuka has become established on part of what was previously nonvegetated raw-soilfield.

Blackberry appears to have increased in dominance, particularly in the southern half of the site (the fenced portion).

Historical (*Assessed in 2011*):

In 1941[1] the site appeared to be in better ecological condition. The western part of the site was not farmed and appears to be in shrubland. Exotic trees were not a major component of the site in 1941, and there were no impacts from the industrial site to the north. The eastern part of the site appeared to be in pasture, whereas part of this area is now fenced to exclude stock. The scrub vegetation appears very similar in character to geothermal and non-geothermal habitat, so the exact reduction in extent of geothermal vegetation at the site is difficult to determine. The vegetation present was likely to be significantly higher quality in 1941 due to the absence of pest plants and industrial waste. There was *c.*10-25% more geothermal vegetation and habitats at this site in 1941 than in 2007. The extent of nonvegetated raw-soilfield was also greater.

Management Requirements:

Contact Energy is undertaking ongoing control of wilding pines and pampas within this site. Other species that need to be controlled at this site include blackberry, Spanish heath, and gorse. The existing, recently-formed tracks could be used for access for weed control and planting, but they should be allowed to naturally revert as prostrate kānuka re-establishes.
Ideally, the site requires a long term restoration implementation plan to ensure that weed control and planting operations are appropriate, and that the ecological values of the site are protected and enhanced. Monitoring of vegetation to assess the impacts of geothermal energy extraction and its management should be implemented.

Options for injecting geothermal water will probably also need to be assessed by engineers and geologists.

Significance Level:

Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factors 1, 14.

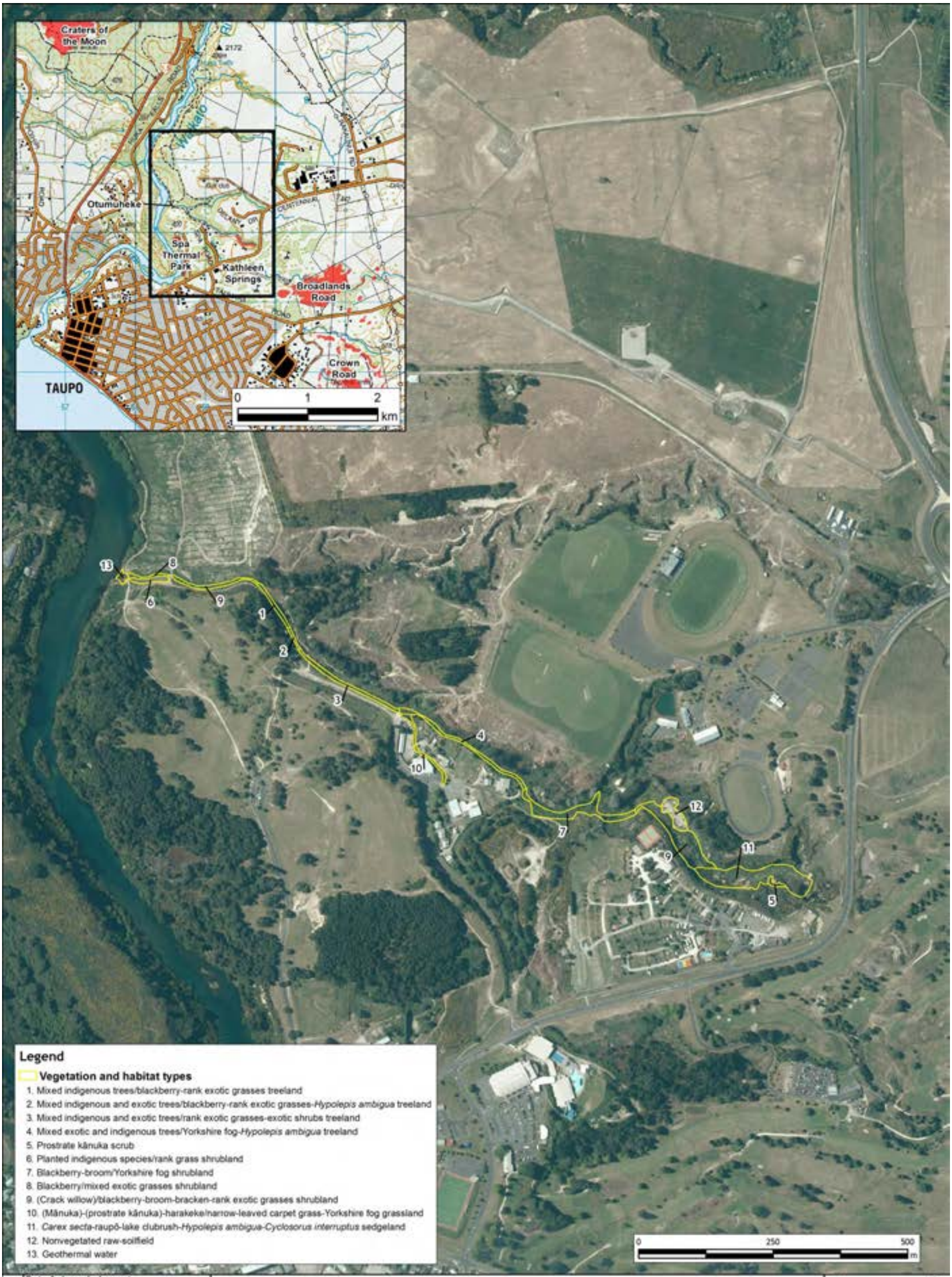
Significance Justification:

Ohaaki Steamfield East is of regional significance because it is partially protected by a QEII National Trust covenant and is a relatively large example of geothermal habitat, which includes a nationally uncommon ecosystem type (geothermally heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also contains a good population of an 'At Risk' plant species (prostrate kānuka), but does not contain habitat of considerable importance for the conservation of this species.

[1] Historical photos: SN 172 Run 1169 Photos 27-29, 1941.

Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. Inspection of 2012 aerial photographs indicates that some geothermal vegetation has been destroyed since the 2007 aerial photographs were flown. Management requirements and priorities require updating.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study, this site was classed as Category B - the second highest category. Site name was Ohaaki Steamfield 2 in Beadel and Bill 2000.
References:	Beadel 1986; Beadel and Bill 2000; Burns 1997a; Given 1989a & 1996; Merrett and Burns 1998a; Merrett *et al*. 2003; Wildland Consultants 2004c & 2012.

WAIRAKEI-TAUHARA GEOTHERMAL FIELD


Craters of the Moon
Wikato R
Otumuheke
Spa Thermal Park
Kathleen Springs
Broadlands Road
Crown Road
TAUPO
0 1 2 km
13
8
6
9
1
2
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10
12
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5
0 250 500 m
Legend
Vegetation and habitat types
1. Mixed indigenous trees/blackberry-rank exotic grasses treeland
2. Mixed indigenous and exotic trees/blackberry-rank exotic grasses-Hypolepis ambigua treeland
3. Mixed indigenous and exotic trees/rank exotic grasses-exotic shrubs treeland
4. Mixed exotic and indigenous trees/Yorkshire fog-Hypolepis ambigua treeland
5. Prostrate kānuka scrub
6. Planted indigenous species/rank grass shrubland
7. Blackberry-broom/Yorkshire fog shrubland
8. Blackberry/mixed exotic grasses shrubland
9. (Crack willow)/blackberry-broom-bracken-rank exotic grasses shrubland
10. (Mānuka)-(prostrate kānuka)-harakeke/narrow-leaved carpet grass-Yorkshire fog grassland
11. Carex secta-raupō-lake clubrush-Hypolepis ambigua-Cyclosorus interruptus sedgeland
12. Nonvegetated raw-soilfield
13. Geothermal water
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Scale: 1:6,500
Date: 07/10/2014
Cartographer: RPB
Format: A3

OTUMUHEKE

Site Number:	THV01[1]	**Grid Reference:**	NZTopo50 BG36 691 151
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1869068 N5715075
Geothermal Field:	Wairakei-Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*380-400 m
Tenure:	Protected (Patuiwi Marginal Strip) and unprotected private land		
Extent of Geothermal Habitat:	*c.*2.3 ha		
Extent of Geothermal Vegetation:	*c.*2.3 ha		
Date of Most Recent Field Survey:	10 December 2010		

VEGETATION TYPE	LANDFORM	EXTENT
Indigenous treeland (02.01)		
Mixed indigenous trees/blackberry-rank exotic grasses treeland (02.01.02) Scattered trees, including whekī, whekī-ponga, false acacia (live and dead), and kānuka, occur over rank exotic grassland, with patches of blackberry alongside much of the stream bank edge. The rank exotic grassland is dominated by Yorkshire fog, cocksfoot, and tall fescue, with occasional harakeke (planted) and gorse. The stream margins support patches of rank exotic grasses, blackberry scrub, and scattered *Muehlenbeckia australis,* pōhue*, Hypolepis ambigua,* and bracken. Tradescantia is locally common on stream banks. Some of the best quality populations of *Christella* aff. *dentata* ("thermal") at Otumuheke are present within this vegetation type along stream banks. *C.* aff. *dentata* is most vigorous at this site where it occurs beneath a treefern canopy. In the downstream part of this type, a terrace above the true right bank has been cleared of woody species and contains scattered planted harakeke within rank exotic grasses. The stream margins are as described above.	Riparian margin	<0.1 ha
Mixed indigenous and exotic trees/blackberry-rank exotic grasses-*Hypolepis ambigua* treeland (02.01.03) Scattered kānuka, whekī, false acacia (live and dead), dead crack willow, and sycamore maple (*Acer pseudoplatanus*) occur over grassland and blackberry scrub. The rank exotic grassland is dominated by Yorkshire fog, cocksfoot, and tall fescue. *Hypolepis ambigua*, and *Deparia petersenii* subsp. *congrua* are common on stream margins, with occasional montbretia and Chinese privet. Scattered *Christella* aff. *dentata* ("thermal") are present on stream banks.	Riparian margin	<0.1 ha
Mixed indigenous and exotic trees/rank exotic grasses-exotic shrubs treeland (02.01.04) Scattered trees and small shrubs occur over rank exotic grassland and exotic shrubland. The most common tree and shrub species are	Riparian margin	*c.*0.1 ha

[1] Site number in 2004 was U18/3 (Otumuheke Stream) (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
kānuka and kōhūhū, with occasional false acacia, silver birch, flowering cherry, and Tasmanian blackwood. Stream margins are dominated by blackberry and bracken, with locally common *Hypolepis ambigua* and tradescantia. Several patches of montbretia and periwinkle are also present on stream margins. Khasia berry and Japanese honeysuckle become common on steep faces above the stream in the eastern part of this type. A small population of *Christella* aff. *dentata* ("thermal") is present along stream margins.		
Exotic treeland (02.02) **Mixed exotic and indigenous trees/Yorkshire fog-*Hypolepis ambigua* treeland (02.02.02)** This area comprises scattered exotic and indigenous trees over Yorkshire fog and *Hypolepis ambigua* alongside Otumuheke Stream in the middle of the site. Tree species that are common within this area include feijoa, plum (*Prunus* × *domestica*), kānuka, Tasmanian blackwood, and silver birch. Occasional Lawson's cypress, rimu (planted), totara (planted), blackberry, and Japanese honeysuckle are also present. Blackberry and broom are common alongside stream margins. Khasia berry is common on banks above the side stream, and flowering cherry are common on steep banks on the true left of the side stream amongst blackberry shrubland. A small population of *Christella* aff. *dentata* ("thermal") is present at the downstream end of this type, however the entire length of the stream margin within this type appears suitable for this species.	Riparian margin	*c.*0.2 ha
Prostrate kānuka scrub (04.01) **Prostrate kānuka scrub (04.01.01)** A small area of prostrate kanuka scrub to *c.*3 m tall. Tūrutu and hound's tongue fern are common in the understorey. The groundcover is a dense mossfield.	Gully	<0.1 ha
Mixed indigenous shrubland (05.07) **Planted indigenous species/rank grass shrubland (05.07.02)** This vegetation type is located on the true left of the Otumuheke Stream downstream of a footbridge to the confluence of Otumuheke Stream and the Waikato River. Most of the type comprises indigenous species including tarata, harakeke, koromiko, kōwhai (*Sophora microphylla*), prostrate kānuka, *Coprosma dumosa*, and totara (*Podocarpus totara* var. *totara*) over bare ground and scattered exotic species including ripgut brome (*Bromus diandrus*), vetch (*Vicia sativa*), broad-leaved fleabane, and Yorkshire fog. The remainder of this area is dominated by blackberry and rank exotic grasses along the stream margins. A small population of *Nephrolepis flexuosa* is present at the upstream end of this vegetation type, and there are scattered populations of *Christella* aff. *dentata* ("thermal") along the length of this section of stream.	Riparian margin	<0.1 ha
Exotic species dominated shrubland (05.09) **Blackberry-broom/Yorkshire fog shrubland (05.09.03)** A geothermal stream flows through a flat valley floor covered with dense blackberry scrub and scattered areas of exotic grassland. The grassland is dominated by Yorkshire fog, but patches of *Hypolepis*	Valley	*c.*0.3 ha

VEGETATION TYPE	LANDFORM	EXTENT
ambigua fernland are also present. Buddleia, broom, and lupin (*Lupinus arboreus*) are common, with occasional grey willow. Occasional patches of Tasmanian blackwood are present in the western part of this area. Water fern and wetland species (e.g. *Carex secta*) become more common at the eastern end of this vegetation type. Some small areas of raupo reedland are also present.		
Blackberry/mixed exotic grasses shrubland (05.09.07) This vegetation type is located on the true right of the Otumuheke Stream downstream of a footbridge to the confluence of Otumuheke Stream and the Waikato River. Blackberry with occasional buddleia, broom, lupin, and karamū dominates the stream margins along the lower section of the stream. Grasses (particularly Yorkshire fog, tall fescue, and Vasey grass) have established on disturbed areas (e.g. lower edge of river scarp and on small islands within the stream). *Christella* aff. *dentata* ("thermal") and *Nephrolepis flexuosa* are scattered along the stream margins and on small islands in the stream. Other ferns present include occasional kiokio, *Hypolpis ambigua,* and water fern. Several patches of tradescantia are also present.	Riparian margin	<0.1 ha
(Crack willow)/blackberry-broom-bracken-rank exotic grasses shrubland (05.09.08) Occasional crack willow (*c.*5% cover) occurs over rank exotic grasses, including Yorkshire fog, tall fescue, ripgut brome, cocksfoot, and Vasey grass. Blackberry and bracken are dominant in small areas, with blackberry more common on the true right of the stream. Other species present include broom, lotus, pōhue*,* buddleia, Himalayan honeysuckle, and lupin.	Riparian margin	*c.*0.5 ha
Exotic grassland (08.01) **(Mānuka)-(prostrate kānuka)-harakeke/narrow-leaved carpet grass-Yorkshire fog grassland (08.01.06)** Within the grounds of the Spa Hotel the stream margins comprise bare ground and exotic grasses (including narrow-leaved carpet grass and Yorkshire fog), which, in places, are mown to the stream edge. Scattered shrubs present on the stream edge include mānuka, prostrate kānuka, Tasmanian blackwood, and whekī-ponga; some of these shrubs have been planted. Planted harakeke is also common. Other species present include tūrutu, water fern, and *Cyperus eragrostis*. In 2004, this area comprised dense blackberry but the blackberry has since been cleared. Historically this side stream was fed by Kathleen Spring and surrounding geothermal springs. No geothermal activity is currently evident above NZTM E1869032 N57115018. Stream temperatures increase from 22°C at the small bridge at this point, to temperatures of 48°C at the stream junction near the walking bridge at the end of Spa Road. Hot seepages are present in the stream.	Stream margin	<0.1 ha

VEGETATION TYPE	LANDFORM	EXTENT
Indigenous sedgeland (09.01) ***Carex secta*-raupo-lake clubrush-*Hypolepis ambigua-Cyclosorus interruptus* sedgeland (09.01.11)** This area contains a diverse variety of vegetation types surrounding geothermal springs, sinter, and associated sediments in the eastern end of Otumuheke Stream valley. This area contains most of the *Cyclosorus interruptus* population in the site, with 200-300 plants present. Sinter is widespread. There are small examples of raupo reedland, *Cyperus ustulatus* sedgeland, *Hypolepis ambigua* fernland, water fern fernland, and lake clubrush reedland, all of which are too small to map separately. Most of the naturally occurring prostrate kānuka and *Lycopodiella cernua* within the site is present in this area. Occasional mānuka, inkweed (*Phytolacca octandra*), buddleia, sweet vernal, Chinese privet, American fireweed (*Erechtites hieraciifolia*), silky cudweed (*Gamochaeta calviceps*), Spanish heath, and whekī are present. In areas with less geothermal influence, blackberry becomes common with scattered patches of *Cyclosorus interruptus* amongst the blackberry. Some pampas control has been undertaken in this area however juvenile plants are still present. Patches of water fern and tūrutu are common on the margins of geothermal areas. A temperature reading of 73^{o}C was taken from the edge of the stream.	Valley floor	*c.*0.7 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Debris (sediments) has eroded into the valley downslope of Owen Delany Park. Buddleia and fleabane are common, with occasional foxglove and pampas, surrounded by bare ground (pumice sediments). This area was viewed from the far side of the valley through binoculars due to the hazards associated with crossing geothermal wetlands.	Gully	*c.*0.2 ha
Water (22.01) **Geothermal water (22.01.01)**	Stream	<0.1 ha

Indigenous Flora:

Forty-seven indigenous vascular plant species and 76 exotic vascular plant species have been recorded from this site. Populations of five 'At Risk' indigenous plant species (as per de Lange *et al.* 2013) are present within the site: *Nephrolepis flexuosa* (At Risk-Declining), *Cyclosorus interruptus* (At Risk-Declining), *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon), *Hypolepis dicksonioides* (At Risk-Naturally Uncommon), and prostrate kānuka (At Risk-Naturally Uncommon).

There are an estimated 75-100 clumps of *Christella* aff. *dentata* ("thermal") in the site, the majority of which occur in the western half of the site. These clumps vary in size from a few centimetres to *c.*0.75 cm in length. Large parts of the stream cannot easily be viewed in the lower section due to high temperatures of the stream and dense blackberry to the stream margins, so this number is likely to be a conservative estimate.

Cyclosorus interruptus is abundant in the eastern part of the site in Vegetation Type 09.01.11 with *c,*200-300 clumps present. This is a very broad esitimate as large parts of the lower section of the stream cannot be

viewed easily due to high water temperatures combined with dense blackberry. Plants vary from a few centimetres high to *c.*50 cm tall. This site supports the largest population of *C. interruptus* in or near Taupō township.

Two small populations, each comprising *c.*0.5 × 0.5 m, of *Nephrolepis flexuosa* are present immediately downstream of the bridge that is second closest to the Waikato River. *N. flexuosa* is growing amongst blackberry scrub on the true right side, and rank exotic grassland on the true left.

A small population of prostrate kānuka is present in the eastern part of this site. Some prostrate kānuka has been planted in the western part of the site alongside the Otumuheke Stream. *Lycopodiella cernua* (a species characteristic of geothermal areas) is abundant at the eastern end of the site in Vegetation Type 09.01.11.

Hypolepis dicksonioides has been recorded from the site in the past (most recently in 2004(Wildland Consultants 2004c), but was not seen in 2012.

Fauna:

Common indigenous and introduced bird species typical of the habitat are present including fantail, shining cuckoo, kōtare (sacred kingfisher), grey warbler, tūī, silvereye, chaffinch, myna, California quail, yellowhammer, house sparrow, Eurasian blackbird, and song thrush.

Current Condition (2012 Assessment):

The geothermal wetland in the upper reaches of the site is in relatively good condition, and is one of few areas of sinter wetland remaining around Taupō. The remainder of the stream gully is highly modified and is dominated by invasive exotic plants. Some pest plant control has been undertaken within parts of the site. Some modification of the stream channel downstream from the Spa Hotel has occurred in the past and a geothermal wetland once occurred at the site of the Spa Hotel (Given 1989a).

Threats/Modification/ Vulnerability:

Invasive pest plants (*2012 assessment*):

Blackberry (50% cover) dominates the stream margins in parts of the site. Other invasive pest plant species present include Himalayan honeysuckle (<1% cover), grey willow (<1% cover), strawberry tree (*Arbutus unedo*) (<1% cover), false acacia (2% cover), tradescantia (5% cover), periwinkle (<1% cover), holly (*Ilex aquifolium*) (<1% cover), crack willow (<1% cover), sycamore maple (<1% cover), Tasmanian blackwood (1% cover), Khasia berry (<1% cover), cotoneaster (1% cover), Chinese privet (5% cover), silver birch (1% cover), montbretia (<1% cover), flowering cherry (<1% cover), Japanese honeysuckle (2% cover), buddleia (2% cover), lupin (<1% cover), and broom (1% cover). Control of grey willow, strawberry tree, and ongoing control of pampas is a priority for this site to contain the spread of these species.

Human impacts (*2012 assessment*):

Most of the lower part of this site has been highly modified through human use, with a wide walking track adjacent to most of the stream and leading to a popular bathing spot where Otumuheke Stream flows into the Waikato River. Other tracks and bridges and ornamental trees are present in the western part of the site.

Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) (www.nzgeothermal.org.nz; site accessed 28 June 2011) and this may further alter the composition and extent of the geothermal vegetation present.

Grazing (*2012 assessment*): Domestic livestock are not a current threat to this area.

Adjoining land use (*2012 assessment*): Scrub comprising adventive and indigenous species, accommodation, recreation grounds.

Site Change:

Recent change (2011 Assessment): Since 2009, vegetation clearance works near the stream mouth have destroyed a large portion of the *Nephrolepis flexuosa* population and a few plants of *Christella* aff. *dentata* ("thermal"). Some additional infill planting has been undertaken in this area. The *Nephrolepis flexuosa* population has become particulary vulnerable to destruction because of increased erosion, and exposure to frosts.

Flooding has caused dieback of blackberry on stream margins and has probably washed out some fern plants recorded during earlier surveys. This may provide new habitat for establishment of 'At Risk' fern species. Control work by the Waikato Regional Council, particularly in the upper stream gully (Waikato Regional Council 2011b), includes removal of pines from gully walls and pampas control.

Some weed control has also been undertaken in parts of the valley, but overall changes here are minor. Fresh sediments from erosion in the small gully system that drains from Owen Delany Park into geothermal wetland were also noted.

Historical (*Assessed in 2011*): This site is too small to see any evidence of change since 1946[1]. However, it is known that a geothermal wetland once occurred at the site of the Spa Hotel (Given 1989a).

Management Requirements: A restoration plan, which includes a detailed assessment of invasive pest plant distribution and abundance, has been prepared for this site. Some pest plant control, as a joint a project with the landowners and Waikato Regional Council, with volunteer group help, has been undertaken within this site in accordance with the restoration plan. The geothermal wetland, and the stream and its margins should be managed to ensure that the ecological sequences present are preserved. Weed control efforts should focus on preventing the establishment of blackberry, pampas, and wilding pines within the geothermal wetland.

Any restoration of the site or its margins needs to be planned and undertaken to minimise disturbance of threatened plant species. Specifically, herbicide should not be applied to the area near the stream mouth where *Nephrolepis flexuosa* and *Christella* aff. *dentata* ("thermal") are present. A conservative approach should be taken to the restoration of vegetation around the geothermal springs, wetlands, and *Christella* aff.

[1] Historical photos: SN 172 Run 1176 Photo 4, 1946.

dentata ("thermal"), and *Nephrolepis flexuosa* populations on stream margins in the lower part of the gully system. Initially, no more than 25% of the total area of geothermal vegetation should be cleared of blackberry or other dense infestation of pest plants at any one time.

Given (1989a) suggested that this site could be restored as it is an "interesting geothermal site on a walkway route down the Waikato River and is highly accessible". Restoration of this site would enhance and sustain its ecological values and would be valuable for educational purposes.

Changes in vegetation cover composition and extent associated with draw-off from the geothermal field should be monitored.

Significance Level:

A: National (Table 1 - Criteria 3, 4, 5, 6, 9; Table 2 - Factor 8).
B: Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).

Significance Justification:

The part of the site identified on the site map as A is of national significance because it is a good quality example of geothermal habitat, which includes nationally uncommon ecosystem types (geothermal stream margins, geothermally heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012). The thermal swamp at the head of the Otumuheke Stream remains in excellent condition. With its close proximity to Centennial Drive, it is one of few such areas close to Taupō.

This site also contains sizeable populations of *Christella* aff. *dentata* ("thermal") and *Cyclosorus interruptus*, and small populations of two other At Risk fern species: *Hypolepis dicksonioides* and *Nephrolepis flexuosa*.

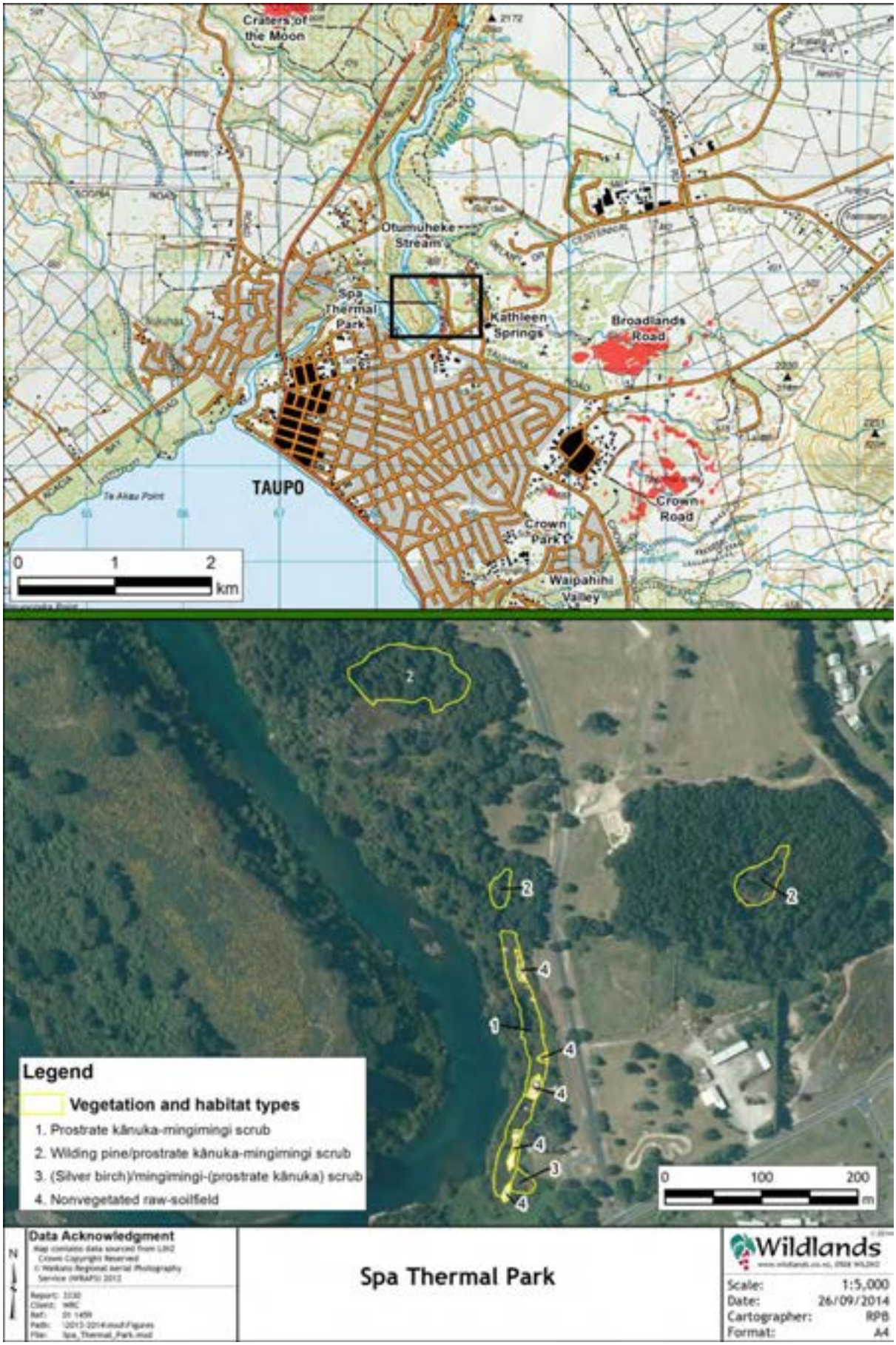
The part of the site identified on the site map as B is of local significance because it is a modified example of geothermal vegetation and habitat, which includes geothermal stream margins, a nationally rare habitat type (Williams *et al*. 2007; Holdaway *et al.* 2012). It also contains a small population of *Christella* aff. *dentata* ("thermal").

Notes:

This site comprises two areas ranked in Given (1996): "Upper Spa Stream" and "Lower Spa Stream" ranked as Category B and C sites respectively.

References:

Beadel and Bill 2000; Given 1989a & 1996; Waikato Regional Council 2011b; Wildland Consultants 2004c& 2012.


Craters of the Moon
Waikato
Otumuheke Stream
Spa Thermal Park
Kathleen Springs
Broadlands Road
TAUPO
Te Ahau Point
Crown Road
Crown Park
Waipahihi Valley
0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka-mingimingi scrub
2. Wilding pine/prostrate kānuka-mingimingi scrub
3. (Silver birch)/mingimingi-(prostrate kānuka) scrub
4. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Spa Thermal Park
Wildlands
Scale: 1:5,000
Date: 26/09/2014
Cartographer: RPB
Format: A4

SPA THERMAL PARK[1]

Site Number:	**THV03**[2]	**Grid Reference:**	NZTopo50 BG36 687 144
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1868685 N5714383
Geothermal Field:	Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*400 m
Tenure:	Protected (Taupō District Council Reserve)		
Extent of Geothermal Habitat:	*c.*1.4 ha		
Extent of Geothermal Vegetation:	*c.*1.4 ha		
Date of Most Recent Field Survey:	17 July 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-mingimingi scrub (04.02)		
Prostrate kānuka-mingimingi scrub (04.02.01) Prostrate kānuka scrub forms a canopy to *c.*2 m height with locally common mingimingi and occasional broom and gorse. There are a few emergent radiata pines.	Steep slopes	*c.*0.4 ha
Wilding pine/prostrate kānuka-mingimingi scrub (04.02.03) Scattered wilding maritime pine with occasional radiata pine is present over mingimingi and prostrate kānuka. Bracken is common in the understorey and *Hypolepis ambigua*, tūrutu, and whekī are occasionally present. This vegetation type is located around historically active geothermal craters and is surrounded by pine forest. The vegetation within this area is recovering following a fire in 2012.	Crater margins and sides	*c.*0.8 ha
Mingimingi-dominant scrub (04.03) **(Silver birch)/mingimingi-(prostrate kānuka) scrub (04.03.06)** Scattered emergent silver birch is present over scrub dominated by mingimingi with locally common prostrate kānuka. Patches of ivy and German ivy (*Delairea odorata*) are present on the western margin.	Steep slopes	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Bare geothermal soils occur on a cliff near the Waikato River. Occasional prostrate kānuka and mingimingi seedlings are present in parts of this area.	Steep slopes	*c.*0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[3]), which is characteristic of geothermal habitats, is present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present.

Current Condition: There is little sign of current geothermal activity, but the presence of nonvegetated raw-soilfield and prostrate kānuka indicate geothermal activity in recent times. Non-geothermal vegetation appears to be

[1] This site is called Broadlands Road/Wairakei Park in Beadel & Bill (2000).
[2] Site number in 2004 was U18/11 (Wildlands 2004c and 2006).
[3] All flora threat rankings are from de Lange *et al.* 2013.

encroaching downslope, and this is likely to increase in extent if geothermal activity at the site does not increase.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 assessment*): Silver birch (2% cover), broom (<1% cover), blackberry (<1% cover), gorse (1% cover), ivy (<1% cover), German ivy (<1% cover), buddleia (<1% cover), Himalayan honeysuckle (<1% cover), and wilding pine trees (3% cover) are present. Silver birch cover has increased since 2011, and ivy and German ivy are encroaching onto areas of nonvegetated raw-soilfield.

Human impacts (*2014 assessment*): Rubbish is present within the site, particularly within the old craters in the east of the site. The area in the east of the site appears to be regularly used for recreation with a small hut and a lot of litter present at the base of a shallow crater.

Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) but the proposed power plant has not yet been built or commissioned (http://www.contactenergy.co.nz/aboutus/our projects/ tauhara-phase-two?vert=au; accessed 8 October 2014) and this may further alter the composition of the geothermal vegetation.

Grazing (*2014 assessment*): No threat from grazing.

Adjoining land use (*2014 assessment*): Riparian margin scrub and shrubland, cliff faces, recreational park, plantation forest. Most of the site is located about 20 m above the Waikato River.

Site Change:

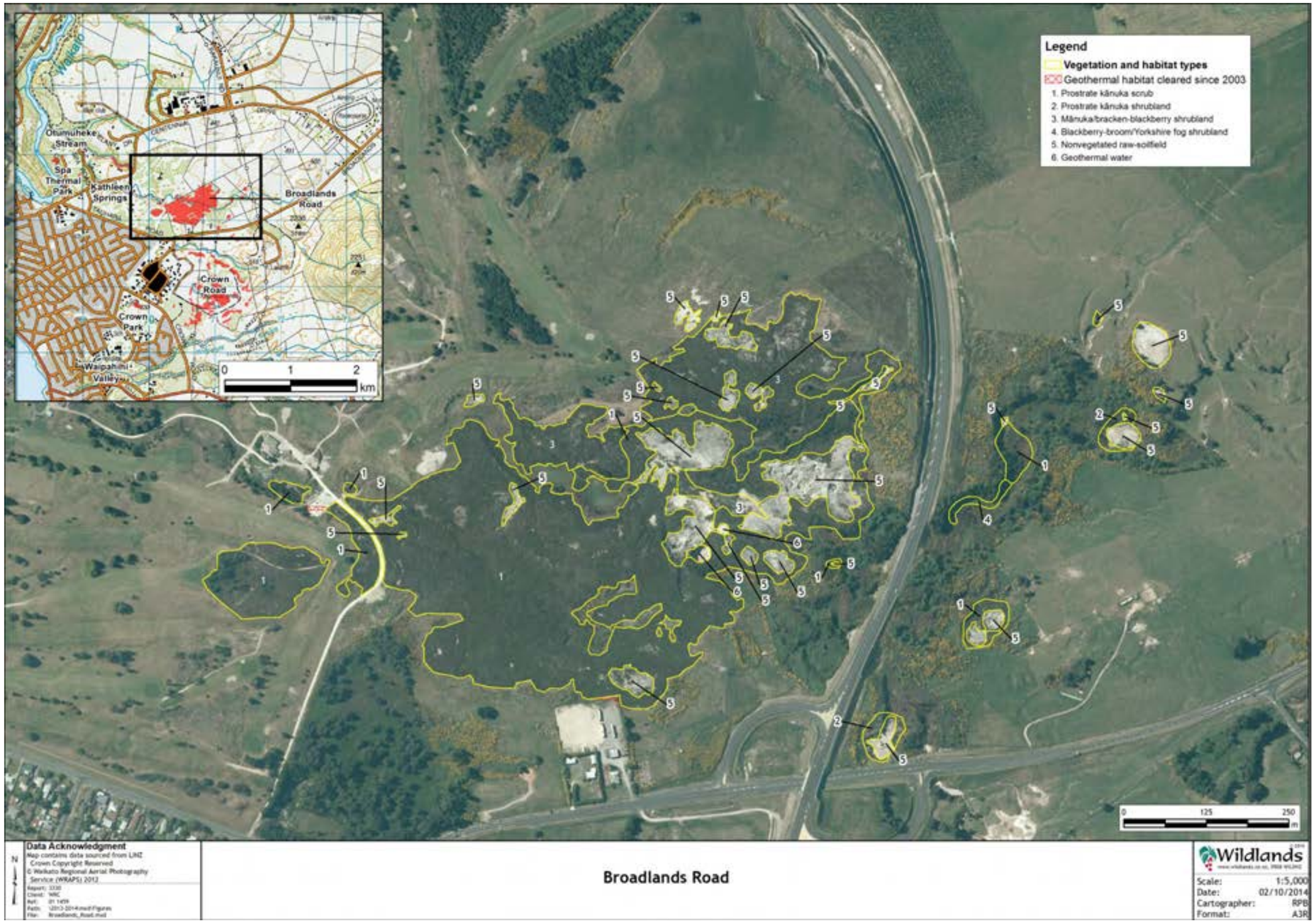
Recent change (2014 Assessment): Prostrate kānuka and mingimingi within the main part of the site below the river cliffs has grown in stature since 2011. Additional areas have been added to the site. These were found during vegetation surveys undertaken in 2013. Soil temperatures within the site have decreased significantly since 2006 (measured soil temperature ranged between 5.4 and 8.9 °C in 2014 compared with measrements taken in 2006 which ranged from 19.4 to 74.3 °C (Merret and Fitzgerald 2006).

Historical (*Assessed in 2011*): This site is too small to see any evidence of change since 1946[1]. According to Bromley *et al.* (2010), Spa Park was historically geothermally active, but has now "cooled off" resulting in areas of previously heated unvegetated ground being covered in prostrate kānuka. According to Burns *et al.* (1995), in 1938 there was an area of prostrate kānuka comprising *c.*10 ha within Spa Park (c.f. the present day population which only covers *c.*1.3 ha). Soil temperatures under the prostrate kānuka are lower than those usually found, suggesting that the remaining prostrate kānuka is a relict population from when soil temperatures were higher.

Management Requirements: Changes in vegetation cover associated with draw-off from the geothermal field should be monitored. This site is a low priority for management.

[1] Historical photos: SN 172 Run 1176 Photos 3-4, 1946.

Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19)
Significance Justification:	This site is of local significance because it contains small examples of a nationally uncommon habitat type (geothermal heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also contains a small population of a species classed as 'At Risk' (prostrate kānuka), but does not contain habitat of considerable importance for the conservation of this species.
Notes:	Proposed future development of the geothermal field is not expected to significantly affect this trend (Bromley *et al.* 2010).
References:	Beadel and Bill 2000; Bromley *et al.* 2010; Burns *et al.* 1995; Given 1996; Wildland Consultants 2004c, 2006, & 2012.


Legend
Vegetation and habitat types
Geothermal habitat cleared since 2003
1. Prostrate kānuka scrub
2. Prostrate kānuka shrubland
3. Mānuka/bracken-blackberry shrubland
4. Blackberry-broom/Yorkshire fog shrubland
5. Nonvegetated raw-soilfield
6. Geothermal water
Waikato
Otumuheke Stream
Spa Thermal Park
Kathleen Springs
Broadlands Road
Crown Road
Crown Park
Waipahihi Valley
0 1 2 km
0 125 250 m
Data Acknowledgment
Map contains data sourced from LINZ
Crown Copyright Reserved
© Waikato Regional Aerial Photography Service (WRAPS) 2012
Broadlands Road
Wildlands
Scale: 1:5,000
Date: 02/10/2014
Cartographer: RPB
Format: A3R

BROADLANDS ROAD

Site Number:	THV04[1]	**Grid Reference:**	NZTopo50 BG36 706 140
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1870625 N5713977
Geothermal Field:	Wairakei-Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	455 m
Tenure:	Protected (Broadlands Road Geothermal Scenic Reserve) and unprotected private land		

Extent of Geothermal Habitat: *c*.30.2 ha
Extent of Geothermal Vegetation: *c*.30.1 ha
Date of Most Recent Field Survey: 3 March 2011

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** A dense canopy of prostrate kānuka (up to *c*.1 m high) with occasional monoao. The ground cover comprises a mixture of lichens, mosses (including *Campylopus* sp.), and liverworts, with occasional *Lycopodiella cernua*. There are occasional emergent maritime pine and radiata pine (more common on the western side of this site).	Undulating plateau	*c*.19.2 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka scrub to 0.5 m tall. Patches of *Lycopodiella cernua* and narrow-leaved carpet grass are common. Broom, exotic grasses (including paspalum, browntop, Indian doab, and Yorkshire fog), and blackberry are common on margins.	Explosion crater; undulating plateau	*c*.0.3 ha
Mānuka-dominant shrubland (05.04) **Mānuka/bracken-blackberry shrubland (05.04.02)** A large area dominated by exotic shrubs (broom and blackberry) with occasional emergent mānuka and maritime pine. Small areas of prostrate kānuka shrubland (too small to map) are present within this area. Bracken and kiokio are abundant throughout, and Mercer grass and Indian doab are dominant in open areas.	Undulating plateau	*c*.5.8 ha
Exotic shrubland (05.09) **Blackberry-broom/Yorkshire fog shrubland (05.09.03)** This type is dominated by blackberry, broom, Himalayan honeysuckle, and Yorkshire fog along a narrow strip on a valley floor. Scattered prostrate kānuka are present. Small wetland areas are present and are dominated by *Carex virgata* and *Machaerina rubiginosa,* and are surrounded by Yorkshire fog.	Gully	*c*.0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Steaming ground, mud pools, explosion craters, and fumaroles. Small patches of prostrate kānuka occur on the margins. No sinter was recorded from this site.	Plateau	*c*.4.6 ha

[1] Site number in 2004 was U18/7 (Wildland Consultants 2004c & 2006)

VEGETATION TYPE	LANDFORM	EXTENT
Water (22.01) **Geothermal water (22.01.01)** Geothermal pond.	Explosion crater	*c.*0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Campylopus* sp., which are restricted to geothermal areas, are present at this site. *Lycopodiella cernua* and *Psilotum nudum*, which are both characteristic of geothermal areas, are also present.

Fauna: New Zealand pipit (At Risk-Declining[2]) have been recorded at this site. Common indigenous and introduced bird species typical of the habitat, including spur-winged plover, fantail, Eurasian blackbird, and Australian magpie have also been recorded at this site.

Current Condition (2011 Assessment): Two small areas have been cleared of vegetation within this site. In the western part of the site, adjacent to the Tauhara Golf Course, a small area has been cleared of vegetation and appears to be utilised for cut tree log storage (Google maps 2014). A small area in the southern part of the site associated with a commercial site, has also been cleared of vegetation (Google maps 2014). The State Highway 1 bypass around Taupō has been constructed over part of the site, however no geothermal vegetation or habitat was lost as a result of this construction.

This site contains a relatively large area of prostrate kānuka shrubland and scrub. Whilst adventive species are common in the reserve, the areas of prostrate kānuka are relatively free of invasive pest plants, except for wilding maritime pines and occasional blackberry on margins.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Invasive pest plant species at the site include blackberry (25-50% cover), wilding pines (including radiata and maritime pine, 5-25% cover), occasional gorse (1-5% cover), broom (5-25% cover), poplars (<1%), grey willow (<1%), and strawberry tree (one recorded in 2007).

Human impacts (*2011 Assessment*): A small area in the western part of the site has been cleared of vegetation. The new State Highway 1 bypass around Taupō was constructed over part of the site. Although no geothermal vegetation or habitat has been affected by the highway construction, the construction has made part of the site more accessible to people. This may increase the likelihood of dumping of litter, informal tracks, weed invasion, and vegetation trampling at this site. The site is still vulnerable to further degradation from farming activities and golf course expansion. A fire was recorded near the site on 7 June 2007.

This site is also vulnerable to the impacts of draw-off from the geothermal field and the vegetation and geothermal features underwent large changes with the establishment of Wairakei Power Station (Burns 1996a).

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] All avifauna threat rankings are from Robertson *et al.* 2013.

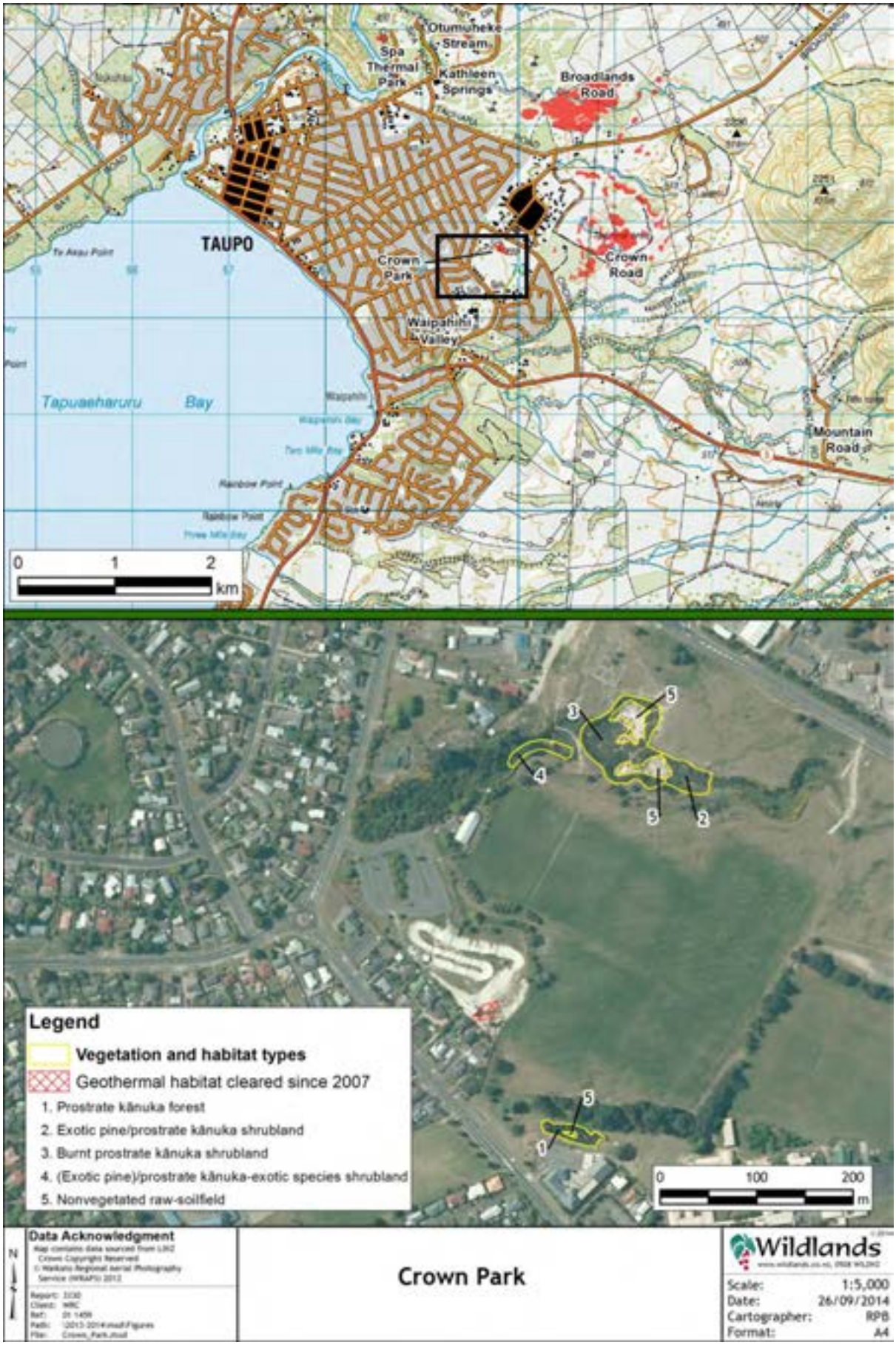
	Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) but the proposed power plant has not yet been built or commissioned (http://www.contactenergy.co.nz/aboutus/ourprojects/tauhara-phase-two?vert=au; accessed 8 October 2014). Additional draw-off from this field may further alter the composition, character, and extent of the geothermal vegetation and habitats present.
Grazing (*2011 Assessment*):	Small areas to the east of the reserve are accessible to stock. Pest animals, including rabbits, hares, and possums, are also likely to impact geothermal sites by grazing and browse.
Adjoining land use (*2011 Assessment*):	Golf course, farming, state highway.
Site Change:	
Recent change (2011 Assessment):	A small area in the western part of the site has been cleared of vegetation. Other changes to the site map are as a result of better quality aerial photographs. The new State Highway 1 bypass around Taupō now dissects the site (see above). Otherwise, the site is similar to earlier surveys. Some pest plant control (e.g. wilding pine) has been undertaken by Department of Conservation.
Historical (*Assessed in 2011*):	In 1946[1] there was bare ground in the vicinity of the site. Burns *et al.* (1995) noted that the 1938 and 1963 photographs showed that "no" and "little" geothermal shrubland was present, although two bare sinter areas with pools suggest some geothermal activity. Urban, road, and farming development have all reduced the size of this site. Two hydrothermal eruption craters formed in 1974 and 1981 (Bromley *et al.* 2010).
Management Requirements:	Wilding pines and other pest plants should continue to be monitored and removed from areas where prostrate kānuka is dominant. Changes in vegetation associated with draw-off from the geothermal field should be monitored.
Significance Level:	Regional (Table 1 - Criteria 1, 3, 5, 7, 9; Table 2 - Factors 9, 12, 14).
Significance Justification:	Broadlands Road is of regional significance because it is protected under the Reserves Act (1977) as a Scenic Reserve, contains a large population of prostrate kānuka (an 'At Risk' species), and comprises a relatively large example of geothermal habitat, which includes nationally uncommon habitat types (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012).
Priority for Field Survey (2014 Assessment):	This site is a medium priority for field survey. Inspection of 2012 aerial photographs indicates that some geothermal vegetation has been destroyed since the 2007 aerial photographs were flown.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as a Category B site - the second highest category.

[1] Historical photos: SN 172 Run 1176 Photos 5-6, 1946.

Several small areas of nonvegetated raw-soilfield amongst pasture to the northeast of the site have been excluded from the significant geothermal vegetation mapped at this site. They were included as part of this site in the report Wildland Consultants 2004c.

References:

Beadel and Bill 2000; Bromley *et al.* 2010; Burns 1995 & 1996a; Given 1989a & 1996; Grove *et al*. 1999; Wildland Consultants 2004c, 2006 2007c, & 2012.


Otumuheke Stream
Spa Thermal Park
Kathleen Springs
Broadlands Road
TAUPO
Crown Park
Crown Road
Waipahihi Valley
Tapuaeharuru Bay
Mountain Road
Rainbow Point
0 1 2 km
Legend
Vegetation and habitat types
Geothermal habitat cleared since 2007
1. Prostrate kānuka forest
2. Exotic pine/prostrate kānuka shrubland
3. Burnt prostrate kānuka shrubland
4. (Exotic pine)/prostrate kānuka-exotic species shrubland
5. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Crown Park
Wildlands
Scale: 1:5,000
Date: 26/09/2014
Cartographer: RPB
Format: A4

CROWN PARK

Site Number:	THV05[1]	**Grid Reference:**	NZTopo50 BG36 698 127
Ecological District:	Taupō	**GPS Reference:**	NZTM E1869808 N5712732
Geothermal Field:	Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*440 m
Tenure:	Protected (Taupō District Council Reserve)		
Extent of Geothermal Habitat:	0.9 ha		
Extent of Geothermal Vegetation:	0.9 ha		
Date of Most Recent Field Survey:	16 July 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Indigenous forest (01.01) **Prostrate kānuka forest (01.01.03)** Prostrate kānuka forms a canopy up to *c.*5 m height with occasional blackberry, *Hypolepis ambigua*, and broom on the margins. Scattered indigenous and exotic species are present in the understorey of this type including whauwhaupaku, mānuka, karamū, flowering cherry, *Lycopodiella cernua*, and tūrutu. Occasional banksia (*Banksia* sp.), eucalyptus, and silver birch are also present.	Flat	<0.1 ha
Prostrate kānuka-dominant shrubland (05.01) **Exotic pine/prostrate kānuka shrubland (05.01.04)** Occasional emergent maritime pine are present over prostrate kānuka shrubland to *c.*2 m height on the slopes and floor of a shallow gully. Other species present include occasional *Lycopodiella cernua*, tūrutu, and mingimingi, and scattered broom, banksia, eucalyptus, and tāwiniwini. Small areas of bare ground are present. These areas of bare ground support exotic grassland dominated by narrow-leaved carpet grass and cocksfoot, with narrow-leaved plantain common.	Shallow gully	*c.*0.1 ha
Burnt prostrate kānuka shrubland (05.01.09) This area contains patches of prostrate kānuka interspersed with areas of bare ground dominated by indigenous and exotic pioneer species including bracken, broom, and broad-leaved fleabane, with scattered prostrate kānuka seedlings. Occasional patches of narrow-leaved carpet grass and moss are also present.	Plateau, shallow gully	*c.*0.4 ha
Mixed indigenous and exotic species shrubland (05.08) **(Exotic pine)/prostrate kānuka-exotic species shrubland (05.08.05)** Scattered emergent maritime pine, radiata pine, and eucalyptus, are present above shrubland dominated by prostrate kānuka and exotic species including broom, blackberry, and Japanese honeysuckle.	Shallow gully	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Heated soils and fumaroles with small patches of prostrate kānuka.	Shallow gullies	*c.*0.2 ha

Indigenous Flora: The site supports small areas of prostrate kānuka (At Risk-Naturally Uncommon[1]) shrubland. *Lycopodiella cernua*, a species characteristic of

[1] Site number in 2004 was U18/12 (Wildland Consultants 2006).

geothermal areas, is also present.

Fauna: No 'Threatened' or 'At Risk' species (as listed in Robertson *et al.* 2013) are known from this site. Common indigenous and introduced bird species typical of the habitat present include grey warbler, fantail, bellbird, tūī, house sparrow, yellowhammer, and Eurasian blackbird.

Current Condition (2014 Assessment): The site is in poor condition with a large number of pest plants present amongst the prostrate kānuka. A recent fire in the site has burnt *c.*30% of the prostrate kānuka shrubland and scrub within the site. Rubbish is common within the site, and walking tracks dissect areas of prostrate kānuka.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Pest plant cover within the site has decreased significantly since 2006 as a result of pest plant control by Waikato Regional Council, and a wild fire burning vegetation in parts of the site. Control of wilding pines by Waikato Regional Council has reduced cover to <5%. Ongoing pest plant control (particularly pine seedlings and broom) has been carried out by Waikato Regional Council following pine control. Other pest plant species present include blackberry (1% cover), banksia (<1% cover), flowering cherry (<1% cover), eucalyptus (<1% cover), pampas (<1% cover), broom (1% cover), Montpellier broom (<1% cover), Chinese privet (<1% cover), silver birch (<1% cover), Japanese honeysuckle (<1% cover), Khasia berry (<1% cover), and Himalayan honeysuckle (<1% cover).

Human impacts (*2014 Assessment*): Approximately 30% of the prostrate kānuka shrubland and scrub within the site has been burnt. The site has been modified through rubbish dumping, and tracks created by people wandering through the geothermal area. It is surrounded by a recreational park. A small area of prostrate kāuka scrub that was present next to the BMX track has been cleared for construction of a building associated with the BMX track.

Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) but the proposed power plant has not yet been built or commissioned (http://www.contactenergy.co.nz/aboutus/ourprojects/tauhara-phase-two?vert=au; accessed 8 October 2014). Additional draw-off associated with the proposed power plant may result in further changes to the geothermal vegetation cover.

Grazing (*2014 Assessment*): Livestock are not a threat to this area.

Adjoining land use (*2014 Assessment*): Recreation reserve.

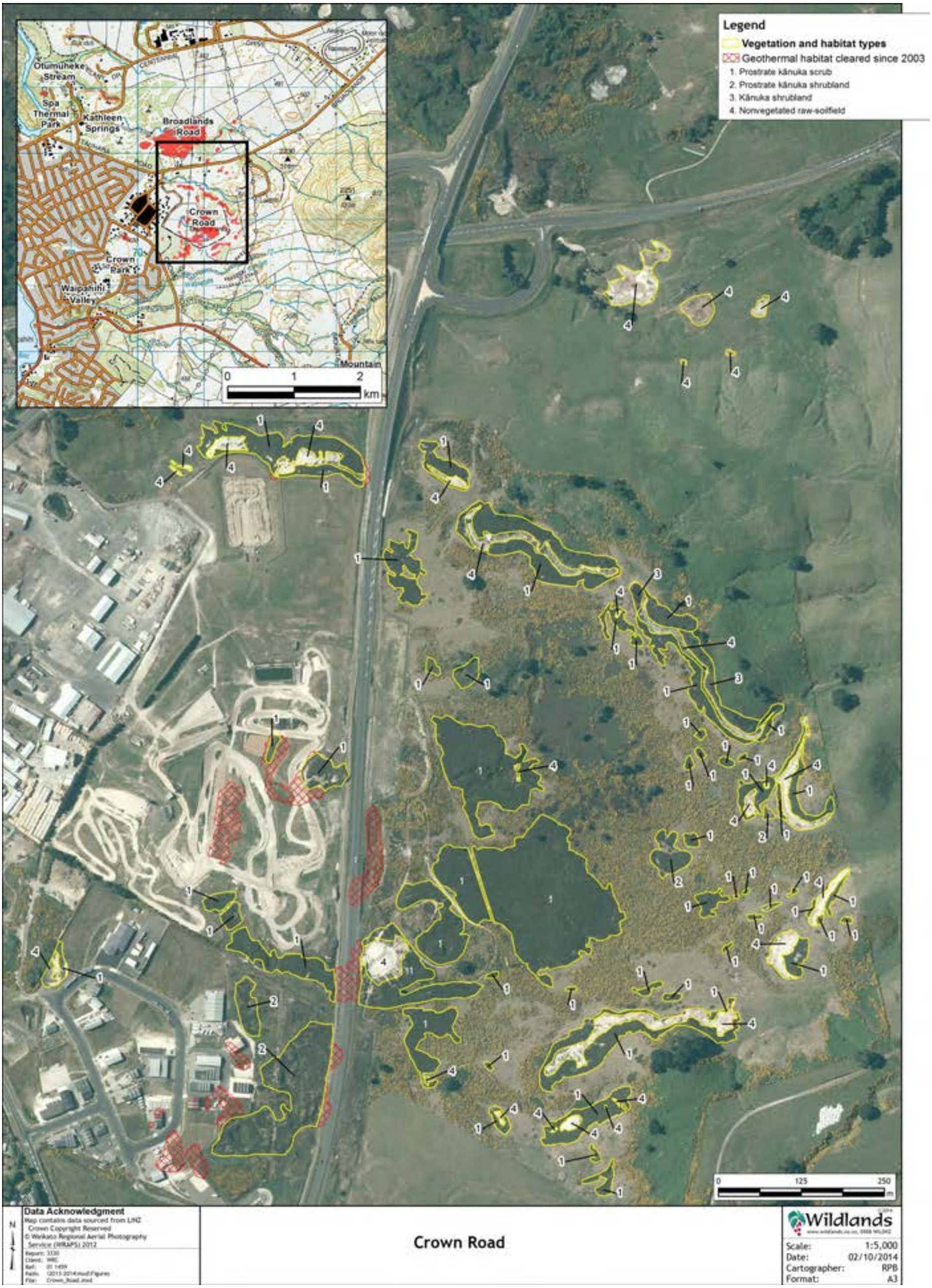
Site Changes:

Recent change (2014 Assessment): Pest plant control undertaken by Waikato Regional Council has reduced the extent of pest plants at the site since 2006. One area of prostrate kānuka

[1] All flora threat rankings are from de Lange *et al.* 2013.

	shrubland has been destroyed due to clearance associated with construction of a building within the BMX track area in the southwest corner of the site (see map). In addition, the current extent of prostrate kānuka has decreased as a result of a fire within the site since 2012; however the prostrate kānuka that remains has increased in height significantly since 2006.
Historical (*Assessed in 2011*):	This site is too small to see any evidence of change when comparing the 1946[1] aerial photographs with the 2007 digital aerials. Burns *et al.* (1995) found that 1963 aerial photos showed a 10-20% loss of the gully area due to infilling.
Management Requirements:	Ongoing monitoring and control of pest plants within the site should be undertaken, particularly control of wilding pines and blackberry. Monitoring of vegetation changes as a result of geothermal draw-off should be undertaken. The effects of fire on vegetation should be monitored, and if any weed issues arise undertake control.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).
Significance Justification:	This site is of local significance because it contains examples of nationally uncommon ecosystem types (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012). It also contains a small population of an 'At Risk' species (prostrate kānuka), but does not represent habitat of considerable importance for the conservation of this species.
References:	Burns *et al.* 1995; Wildland Consultants 2004c, 2006, & 2012.

[1] Historical photos: SN 172 Run 1176 Photos 4-5, 1946.


Legend
Vegetation and habitat types
Geothermal habitat cleared since 2003
1. Prostrate kānuka scrub
2. Prostrate kānuka shrubland
3. Kānuka shrubland
4. Nonvegetated raw-soilfield
Otumuheke Stream
Spa Thermal Park
Kathleen Springs
Broadlands Road
Crown Road
Crown Park
Waipahihi Valley
Mountain
0 1 2 km
0 125 250 m
Data Acknowledgment
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Crown Road
Wildlands
Scale: 1:5,000
Date: 02/10/2014
Cartographer: RPB
Format: A3

CROWN ROAD

Site Number:	THV06[1]	**Grid Reference:**	NZTopo50 BG36 711 128
Ecological District:	Taupō; Atiamuri	**GPS Reference:**	NZTM E1871212 N5712890
Geothermal Field:	Wairakei-Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	460 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*20.4 ha		
Extent of Geothermal Vegetation:	*c.*20.4 ha		
Date of Most Recent Field Survey:	3 March 2011		

TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka is abundant in association with occasional mingimingi. Occasional broom and emergent wilding pines (maritime pine and radiata pine) are scattered throughout and there are local patches of blackberry. Mosses and patches of *Lycopodiella cernua* are present locally, particularly around steam vents.	Shallow gullies and flat plateau	*c.*14.5 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka is common with scattered broom, blackberry and exotic grasses. An area of prostrate kānuka that had previously been burned (in 2002) has now re-established as prostrate kānuka shrubland. Broom, buddleia, and blackberry occur locally.	Flat plateau	*c.*2.2 ha
Kānuka-dominant shrubland (05.06) **Kānuka shrubland (05.06.01)** Kānuka shrubs dominate the margins of several geothermal areas in association with mingimingi. Broom, blackberry, and occasional emergent maritime pine are also present.	Hillslope	*c.*0.4 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Fumaroles and geothermally heated bare ground with small patches of prostrate kānuka and exotic grasses.	Shallow gullies	*c.*3.3 ha

Indigenous Flora: The site supports sizeable areas of prostrate kānuka (At Risk-Naturally Uncommon[2]) scrub and shrubland. The area of prostrate kānuka scrub and shrubland burnt in 2002 (*c.*1 ha) is recovering well. *Lycopodiella cernua*, a species characteristic of geothermal areas, is also present.

Dicranopteris linearis (1-2 plants) (At Risk-Naturally Uncommon) and *Psilotum nudum* have historically been recorded from the southeast corner of this site but have not been observed for over 10 years.

[1] Site number in 2004 was U18/2 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

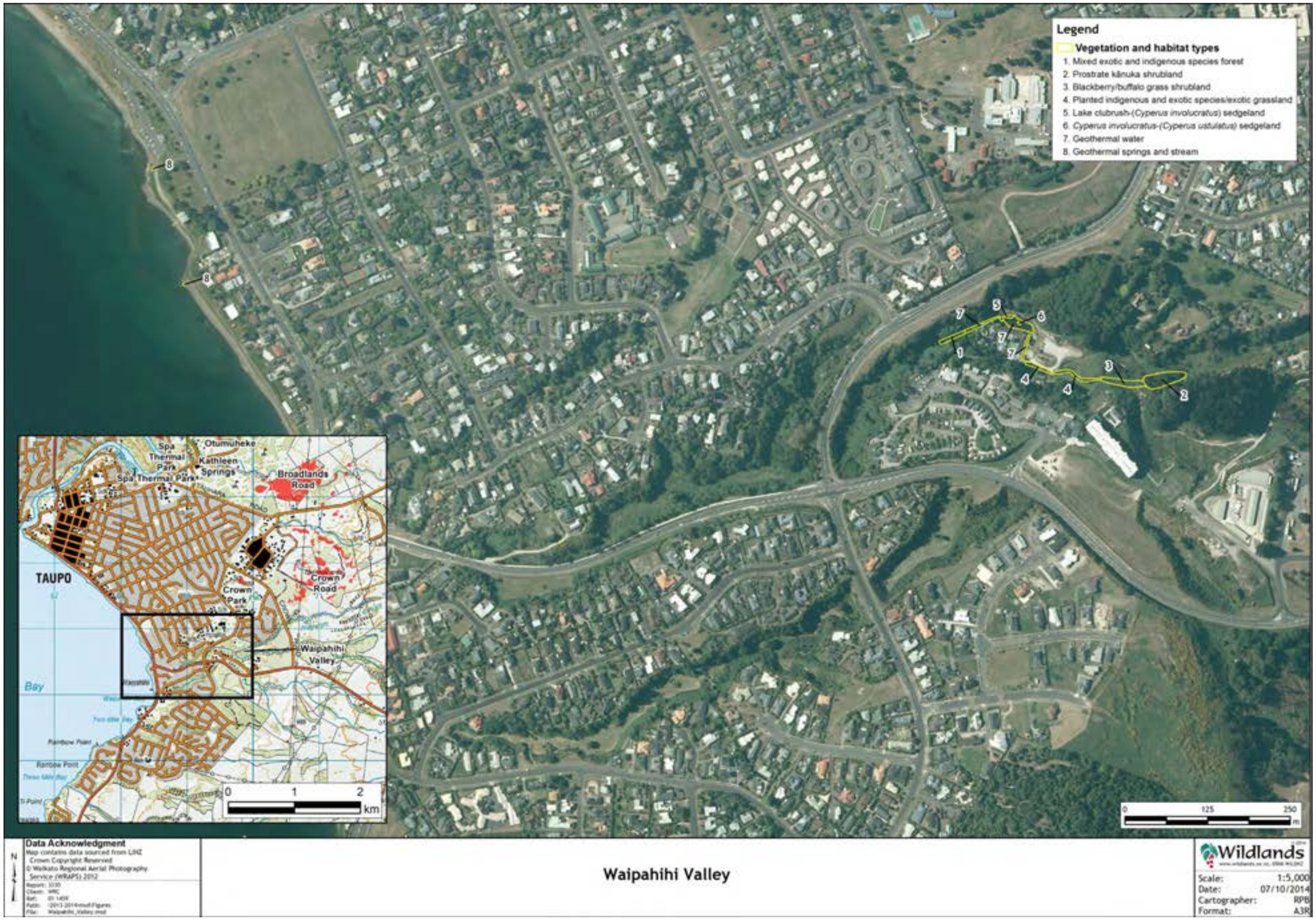
Fauna:	New Zealand pipit (At Risk-Declining[1]), tūī, bellbird, Australasian harrier, grey warbler, black-backed gull, fantail, paradise shelduck, and spur-winged plover have been recorded at the site.
Current Condition (2014 Assessment):	Vegetation clearance associated with residential development, State Highway construction, and motocross track construction has been undertaken within three parts of the site. The new State Highway 1 bypass around Taupō has been constructed through the middle of this site, resulting in destruction of some geothermal vegetation. Other areas of vegetation were destroyed as part of the Ashwood Park retail development to the south of the site. The site includes more than 20 separate areas of prostrate kānuka scrub and shrubland, with the development and use of a motorcross track having caused considerable fragmentation within the site.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2011 Assessment*):	The most abundant pest plants at the site are broom and blackberry, which occur both as scattered shrubs and dense scrub, and cover 1-5% of the site. Chinese privet and wilding pines, both with 1-5% cover, are also present. Buddleia covers <1%. This site is vulnerable to further weed invasion because of continual disturbance, particularly in the southwestern part of the site (motocross track and neighbouring industrial area). Recent control of broom and wilding pines in areas adjoining the new highway has been carried out by the Waikato Regional Council, particularly within areas of prostrate kānuka scrub and shrubland.
Human impacts (*2011 Assessment*):	The site has been bisected by the new State Highway 1 bypass around Taupō and is vulnerable to further degradation by farming, motorcycles, and further development for industrial and residential use. A fire in the southwestern part of the site in March 2002 greatly reduced the cover of prostrate kānuka scrub; however this vegetation type is recovering. Geothermal prospecting and field development for energy use have the potential to impact surface geothermal features and their character, and should be monitored for change. Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) but the proposed power plant has not yet been built or commissioned (http://www.contactenergy.co.nz/aboutus/ourprojects/tauhara-phase-two?vert=au; site accessed 8 October 2014). Additional draw-off associated with the proposed power plant may further alter the geothermal vegetation.
Grazing (*2011 Assessment*):	The eastern part of the site is farmed and has not been fenced to exclude domestic stock.
Adjoining land use (*2011 Assessment*):	Farmland, motocross track, state highway, industrial area.

[1] All avifauna threat rankings are from Robertson *et al.* 2013.

Site Change:

Recent change (2011 Assessment):	Approximately 1.9 ha of geothermal vegetation has been lost since 2004 (see the site map). The loss was due, in part, to roading development and construction of an industrial subdivision. Prostrate kānuka shrubland has mostly recovered since a fire in 2002. Parts of the western side of the site next to the new highway are now fenced to exclude domestic stock. The Waikato Regional Council has recently carried out control of pest plants in areas of prostrate kānuka scrub and shrubland adjoining the new highway. Additional vegetation clearance has been undertaken as a result of residential subdivision and expansion of the motocross track.
Historical (*Assessed in 2011*):	Burns *et al*. (1995), following a study of aerial photographs taken in 1963, indicate that this site had declined in size due to the establishment of a motorcross track and encroachment of the adjacent industrial land uses. Geothermal activity at this site probably increased briefly following the Wairakei power development, and then has steadily declined in intensity (Bromley *et al.* 2010). Photos from 1946[1] show more bare ground than is currently present.
Management Requirements:	Development and implementation of a restoration and management plan for this site should be considered to ensure no futher loss of geothermal habitat and to implement effective control of pest plant species. Parts of the site contain good examples of prostrate kānuka shrubland and associated areas of hydrothermally altered soils and heated soilfield. The restoration plan should consider management of the transition zone between geothermally influenced and non-geothermally influenced soils. Broom, wilding pines, and blackberry should be controlled. Changes in vegetation cover associated with draw-off from the geothermal field and the response of vegetation following fire should be monitored. Currently most of the site is not grazed. The parts of the site that are currently gazed should be fenced, and fencing should be checked regularly at other parts of his site.
Significance Level:	Regional (Table 1 - Criteria 3, 5, 9; Table 2 - Factors 12, 14).
Significance Justification:	This site is of regional significance because it comprises a relatively large example of geothermal habitat, which includes nationally uncommon habitat types (geothermally heated dry ground, fumaroles; Williams *et al*. 2007; Holdaway *et al.* 2012). It provides habitat for prostrate kānuka, an 'At Risk' species. Areas of hydrothermally altered soils and heated soilfield are also present.
Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. Inspection of 2012 aerial photographs indicates that some geothermal vegetation has been destroyed since the 2007 aerial photographs were flown.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category B - the second highest category for protection.
References:	Beadel and Bill 2000; Bromley *et al.* 2010; Burns *et al.* 1995; Given 1989a & 1996; Grove *et al.* 1999; Wildland Consultants 2004c & 2012.

[1] Historical photos: SN 172 Run 1176 Photos 5-6, 1946.



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Waipahihi Valley

Wildlands
Scale: 1:5,000
Date: 07/10/2014
Cartographer: RPB
Format: A3R

WAIPAHIHI VALLEY[1]

Site Number:	THV07[2]	**Grid Reference:**	NZTopo50 BG36 697 116
Ecological District:	Taupō	**GPS Reference:**	NZTM E1869718 N5711647
Geothermal Field:	Wairakei-Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	420 m
Tenure:	Protected (Waipahihi Stream Conservation Area) and unprotected private land.		

Extent of Geothermal Habitat: *c.*0.3 ha
Extent of Geothermal Vegetation: *c.*0.2 ha
Date of Most Recent Field Survey: 16 July 2014

VEGETATION TYPE	LANDFORM	EXTENT
Mixed exotic and indigenous species forest (01.03) **Mixed exotic and indigenous species forest (01.03.01)** Canopy species include flowering cherry, kōhūhū, houhere (*Hoheria sexstylosa*), tree lucerne (*Chamaecytisus palmensis*), olive (*Olea europaea*), and whekī. Groundcover is dominated locally by tradescantia and blackberry. Other ground cover and understorey species include Himalayan honeysuckle, montbretia, Cretan brake, and ivy. Occasional *Carex secta* are also present.	Riparian margins	<0.1 ha
Prostrate kānuka shrubland (05.01) **Prostrate kānuka-dominant shrubland (05.01.01)** Prostrate kānuka to *c.*5 m height is present over exotic grasses and *Cyperus ustulatus* with patches of blackberry. Planted eucalyptus, olives, and flowering cherry are present at the eastern end of this type within exotic grassland. Exotic grass species present include tall fescue, Yorkshire fog, browntop, and buffalo grass, with buffalo grass dominating in the downstream part of this vegetation type. A geothermal spring is present in the eastern part of this type.	Riparian margin	*c.*0.1 ha
Exotic species-dominant shrubland (05.09) **Blackberry/buffalo grass shrubland (05.09.09)** Dense blackberry with locally common *Cyperus ustulatus* and pampas, and locally abundant buffalo grass dominates the true right stream edge below a geothermal spring. *Cyclosorus interruptus* is locally scattered along stream margins amongst buffalo grass. Local patches of bracken are present amongst the blackberry, and occasional patches of lake clubrush are present on the stream margins.	Riparian margin	<0.1 ha
Exotic grassland (08.01) **Planted indigenous and exotic species/exotic grassland (08.01.16)** A variable type with a mixture of indigenous and exotic woody species over mixed exotic grassland. Surface temperature of the stream in this vegetation type was *c.*39 °C in 2014. The eastern part of this type comprises scattered patches of prostrate kānuka (1.5-5 m tall) on the margins of the stream. There are local areas of grassland dominated by buffalo grass, browntop, and creeping bent. Also located within this type is an area of *Cyperus ustulatus* and	Riparian margin	*c.*0.1 ha

[1] Previously named Waipahihi Stream (De Bretts Thermal Pool) in Beadel & Bill 2000.
[2] Site number in 2004 was U18/5 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
buffalo grass sedge-grassland. The grass is mown to within half a meter of the stream margin. The western part of this type comprises mown grass to the edge of the true left of the stream. The true right has a mixture of indigenous and exotic shrubs and trees over *Cyperus eragrostis*. Woody species present include prostrate kānuka, flowering cherry, birch, māhoe, and houhere. Groundcover species include agapanthus, Cretan brake, and locally abundant tradescantia.		
Indigenous sedgeland (09.01) **Lake clubrush-(*Cyperus involucratus*) sedgeland (09.01.07)** Lake clubrush sedgeland with local *Cyperus involucratus* and occasional *Carex secta* is located near the outflow of the pond.	Lake margin	<0.1 ha
Exotic sedgeland (09.01) ***Cyperus involucratus*-(*Cyperus ustulatus)* sedgeland (09.01.01)** A small island in the middle of the pond is dominated by *Cyperus involucratus* with some *Cyperus ustulatus*.	Island	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** West of vegetation type 08.01.16, Waipahihi Stream is channelised by earthworks and stone walls. The rocky stream margins within this area are planted with ornamental garden plants including *Choysia ternata*, rose, rhododendron (*Rhododendron* sp.), variegated flax, and flowering cherry. Scattered kānuka and whekī are also present. Some *Cyperus ustulatus* has established near the waters' edge. At the northwestern end of the diverted stream, a large pond is present. Patches of raupō and lake clubrush are present where the stream flows into the pond. Raupō extends around the southern margin of the pond and grades into *Cyperus involucratus*. The northern pond margin is raised and lined with boulders upon which ornamental garden species have been planted. Below the pond described below, the stream is bordered by mown grassland.	Stream, pond	<0.1 ha
Geothermal springs and stream (22.01.03) Two springs present on the margins of Lake Taupō: - A small spring bubbling out of a crevice in a rock stack with temperatures of up to 67.2 °C recorded in 2014. The rocks surrounding the spring support a sparse cover of herbaceous species including toatoa (*Haloragis erecta*), Mexican daisy (*Erigeron karvinskianus*), and kiokio. - Hot water (*c.*62 °C in 2014) flows from a spring in the side of a grassy bank into a small pool measuring *c.*5 × 3 m in sand on the margin of the lake. The vegetation on the bank surrounding the spring comprises a mixture of fern, herbaceous, and grass species including *Blechnum penna-marina*, *Christella* aff. *dentata* ("thermal"), shaking brake, narrow-leaved plantain, lotus, creeping bent, and broad-leaved fleabane.	Springs	<0.1 ha

Indigenous Flora: A small population of *Cyclosorus interruptus* (At Risk-Declining[1]) is present near the spring on the stream margins in the eastern part of the site. Fewer plants were observed in 2014 compared with 2009, possibly as a result of competition by buffalo grass along the stream margins. Three juvenile *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon) were recorded from around a spring on the margin of Lake Taupō for the first time in 2014. Prostrate kānuka (At Risk-Naturally Uncommon) and *Hypolepis dicksonioides* (At Risk-Naturally Uncommon) are also present.

Fauna: Common indigenous and introduced species, typical of the habitat are present including tūī, fantail, chaffinch, mallard, and Eurasian blackbird.

Current Condition (2014 Assessment): The spring is fenced to exclude domestic stock, and is surrounded by exotic grasses and planted exotic trees including olive, eucalyptus, and ornamental cherry. Blackberry and buffalo grass are dense close to the stream margins in places but some hand control of blackberry has been undertaken. The Waipahihi Stream has been diverted and partially chanellised within the de Bretts outdoor pool area but is more natural in the western part of the site. Planted exotic ornamental species are common along the margins of the stream throughout the site and in some cases may have naturalised within the site (*Cyperus involucratus*).

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Blackberry (10% total cover) and buffalo grass (10% total cover) are locally common along the stream margins. Buffalo grass poses a serious risk to the *Cyclosorus interruptus* population at the site and needs to be monitored and controlled. Exotic species are prevalent throughout the site. Other pest plant species include pampas (*c.*5% cover), tradescantia (*c.*2% cover), *Cyperus involucratus* (*c.*1% cover), radiata pine (<1% cover), black pine (<1% cover), ivy (*c.*2% cover), ornamental cherry (<1% cover), Spanish heath (<1% cover), Himalayan honeysuckle (<1% cover), Montpellier broom (<1% cover), Cretan brake (<1% cover), Khasia berry (<1% cover), Japanese honeysuckle (<1% cover), agapantus (<1% cover), and periwinkle (<1% cover).

Human impacts (*2014 Assessment*): Vegetation clearance and other site modifications (surface water draw off, pool complex development) have altered natural geothermal expressions and vegetation composition. Lawn mowing may reduce the likelihood of natural regeneration of prostrate kānuka and *Cyclosorus interruptus* populations. In 2011, the adjoining landowner damaged geothermal sinter and surrounding geothermal and non-geothermal vegetation by undertaking earthworks downstream of the geothermal spring.

Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) but the proposed power plant has not yet been built or commissioned (http://www.contactenergy.co.nz/aboutus/ourprojects/tauhara-phase-two?vert=au; accessed 8 October 2014). Additional draw-off associated with the proposed power plant may further alter the geothermal vegetation.

[1] All flora threat rankings are from de Lange *et al.* 2013.

The spring and small pool on the margin of Lake Taupō are utilised on a regular basis by bathers. The pool is modified regularly by creation of dams and channels within the sand. The *Christella* population beside the spring at this location is vulnerable to human disturbance associated with maintenance of the walking track and grassy margins of the lake in this area.

Grazing (*2014 Assessment*): Grazing occurs in fenced area above spring, but stock are excluded from the spring area.

Adjoining land use (*2014 Assessment*): Grazing occurs to the north of this site. Parking, recreational areas, and the spa pool complex west of the site. A mosaic of indigenous and exotic forest and restoration plantings occur on the gully sides. Residential dwellings, subdivision, and accommodation occur on the valley terraces.

Site Change:

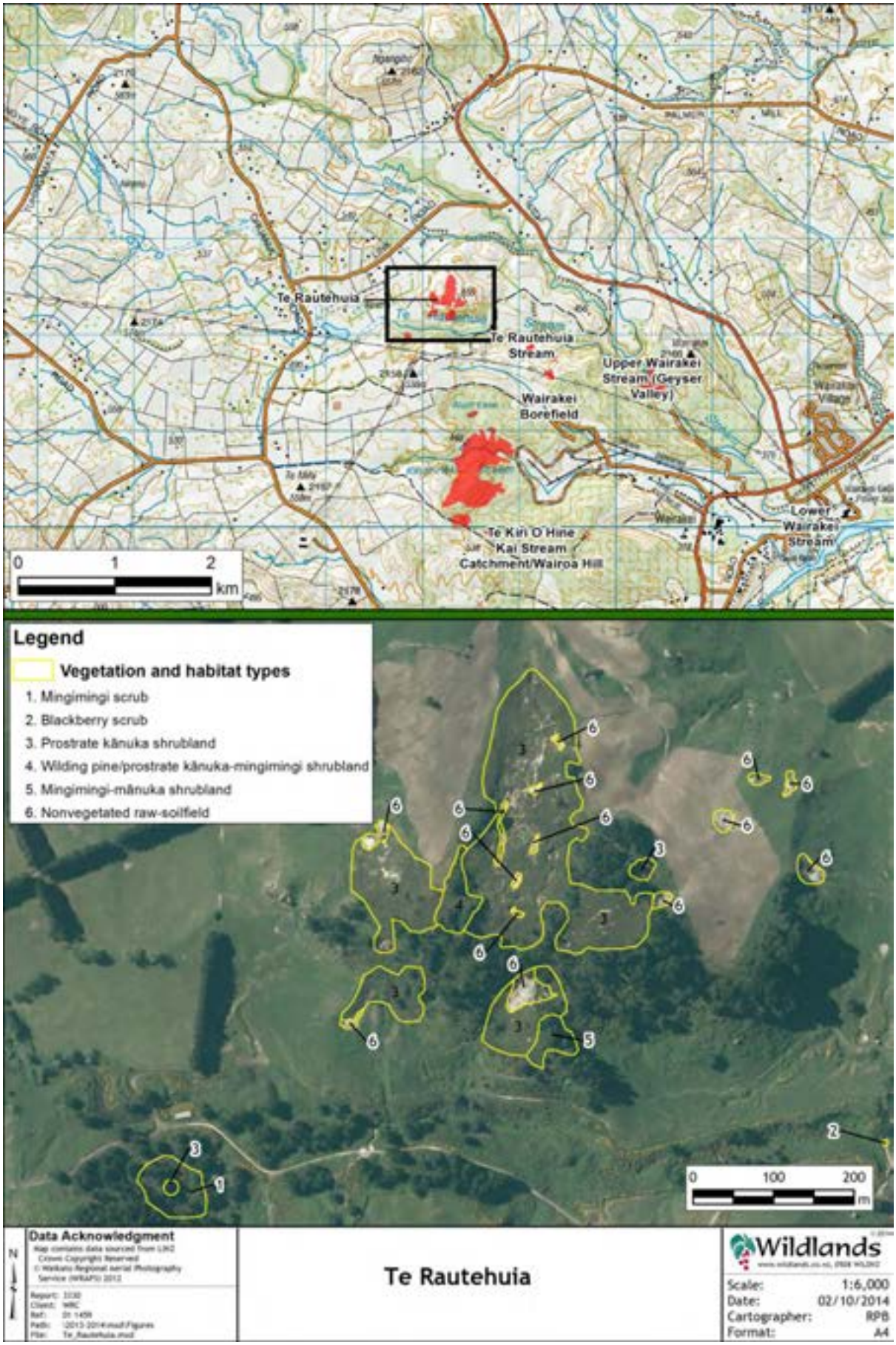
Recent change (*2014 Assessment*): Blackberry has expanded in cover since 2010 to become abundant in part of the site. Tracks have been cut through the blackberry in places. Buffalo grass has colonised and expanded into parts of the site and, in places, forms a dense grassland on the margins of the stream. Of particular note, buffalo grass cover has increased markedly within the areas of highest natural geothermal quality in the site since 2010. This may be a threat to *Cyclosorus interruptus* populations at this site. Pampas cover has also expanded within the site. The population of *Cyclosorus interruptus* appears to have decreased slightly in size since 2010 although no population census was carried out as access to the stream margins was unsafe (c.f. 2010 survey).

Historical (*Assessed in 2011*): Comparison of the extent and character of geothermal vegetation in 1946[1] and 2007 was undertaken. In 1946 there was substantially less urban and commercial development surrounding this site than exists presently, and the cliffs surrounding the site were less densely covered with vegetation. There appears to be a more extensive area of wetland and open water at the site, in 2007 than there was in 2014, although the composition of the vegetation in the gully floor is unclear in places. The site was probably significantly larger in the 1940s, and may have been at least five to ten times larger than it is today (i.e. in 2014). The stream below the site is likely to have been more geothermal in character in 1941.

The first recorded history of the physical features of the Waipahihi Spring reports a temperature of up to *c*.31 °C in the stream as it flowed towards Lake Taupō (Hochstetter 1864 in Cody 1993). Heated pools near the spring head, as large as *c*.50 × 30 m, and a stream 1-2 m across, were present in the 1870s (Fox 1874, Skey 1878, and Harris 1878 in Cody 1993). The pools were described as having raupō and rushes on the margins (Cody 1993). The Terraces Hotel was built in 1889 above the upper reaches of the stream at the top of 'a black sinter slope', and utilised the heated water in the valley below as swimming baths for their guests. These pools were renowned as the 'finest natural hot swimming baths in the Thermal District', ranging in temperature from 36.7 to 76.7 °C (ibid).

[1] Historical photo: SN 172 Run 1177 Photo 5, 1946.

Management Requirements:	Blackberry and buffalo grass should be controlled around the stream margins in the east of the site to manage *Cyclosorus interruptus* populations. However a conservative approach to the management of these species should be undertaken to protect the *Cyclosorus* from the heat of summer or winter frost (i.e. no more than 25% of the total area of the site should be cleared of blackberry or other pest plants at one time). The *Christella* population should be monitored. The site should be monitored to identify any potential changes in vegetation cover associated with draw-off from the geothermal field. The owner of DeBretts intends to restore the stream margins and the site of the old bathing pools. Development and implementation of an ecological management plan for this area would ensure sustainable management of geothermal features and vegetation.
Significance Level:	Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 9)
Significance Justification:	Waipahihi Valley is of regional significance because parts of the site are protected as a Conservation Area. It also provides habitat for four 'At Risk' species (prostrate kānuka, *Hypolepis dicksonioides, Christella* aff. *dentata* ("thermal"), and *Cyclosorus interruptus*) but does not represent habitat of considerable importance to the conservation of these species.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category C - the third highest category for protection.
References:	Beadel and Bill 2000; Cody 1993; Given 1996; Wildland Consultants 2004c & 2012.


Te Rautehuia
Te Rautehuia Stream
Upper Wairakei Stream (Geyser Valley)
Wairakei Borefield
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Lower Wairakei Stream
0 1 2 km
Legend
Vegetation and habitat types
1. Mingimingi scrub
2. Blackberry scrub
3. Prostrate kānuka shrubland
4. Wilding pine/prostrate kānuka-mingimingi shrubland
5. Mingimingi-mānuka shrubland
6. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Te Rautehuia
Wildlands
Scale: 1:6,000
Date: 02/10/2014
Cartographer: RPB
Format: A4

TE RAUTEHUIA

Site Number:	WKV01[1]	**Grid Reference:**	NZTopo50 BG36 663 225
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1866262 N5722450
Geothermal Field:	Wairakei	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	427 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*7.8 ha		
Extent of Geothermal Vegetation:	*c.*7.8 ha		
Date of Most Recent Field Survey:	27 January 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Mingimingi-dominant scrub (04.03) **Mingimingi scrub (04.03.01)** Scattered emergent wilding pines are present over a canopy dominated by mingimingi. Kānuka, mānuka, and whekī are common throughout.	Hillslope	*c.*0.5 ha
Exotic species-dominant scrub (04.10) **Blackberry scrub (04.10.01)** A small heated spring (73 °C in 2011) is surrounded by blackberry and pōhue with lesser amounts of broom and lotus. Water purslane is present on the cooler margins of the pool.	Shallow gully	<0.1 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka forms a low, discontinuous canopy *c.*0.3-0.75 m high, with mingimingi scattered around the outer margins. Groundcover includes moss cushions (mainly *Campylopus* sp.) and *Lycopodiella cernua*. Grasses, including Indian doab, sweet vernal, browntop, and paspalum occur locally on cooler and disturbed ground. There are scattered emergent radiata pine and maritime pine. Patches of blackberry and Spanish heath, and small areas of bare, steaming ground occur throughout.	Plateau and hillslope	*c.*6.2 ha
Wilding pine/prostrate kānuka-mingimingi shrubland (05.01.02) Radiata pine and maritime pine occur over prostrate kānuka and mingimingi shrubland.	Hillslope	*c.*0.3 ha
Mingimingi-mānuka shrubland (05.03) **Mingimingi-mānuka shrubland (05.03.01)** Occasional maritime pine occur over scrub dominated by mingimingi and mānuka. Prostrate kānuka occurs on heated soils near the margins of this type where it adjoins prostrate kānuka shrubland.	Hillslope	*c.*0.2 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Heated clays, fumaroles, and mud pools. Occasional prostrate kānuka and *Lycopodiella cernua*. Heated fumaroles present in open pasture have Indian doab on the margins.	Shallow gullies, crater, hillslope	*c.*0.6 ha

[1] Site number in 2004 was U17/22 (Wildland Consultants 2004c and 2006).

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]) is the dominant species at this site. *Lycopodiella cernua*, a species characteristic of geothermal areas, is also present. *Dicranopteris linearis* (At Risk-Naturally Uncommon) and *Nephrolepis flexuosa* (At Risk-Declining) were recorded at this site in 2006. *D. linearis* is known from only *c.*23 sites in New Zealand.

Fauna: Common indigenous and introduced bird species typical of the habitat have been recorded at this site including Australasian harrier, paradise shelduck, Australian magpie, tūī, yellowhammer, chaffinch, green finch, Californian quail, and Eurasian blackbird. New Zealand pipit (At Risk-Declining[2]) is also present.

Deer graze parts of the prostrate kānuka shrubland and fumaroles within pasture.

Current Condition (2014 Assessment): This site comprises several small geothermal areas surrounded by pine plantation forest and farmland. Domestic livestock, particularly deer, have access to some geothermal areas, although parts have been fenced off to exclude stock. The overall condition is very good with few weeds; however areas that are grazed are more degraded. Based on inspection of 2012 aerial photographs, the mingimingi scrub in the south of the site appears to have declined in condition, and no longer appears to comprise mingimingi scrub. Field survey is required to ground-truth this assessment.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Pine plantation is contiguous with the site and wilding pines are a key threat to this site. Broom and blackberry are present at low density (each at <1% cover). Exotic grasses occur in cooler areas and on margins (particularly Indian doab, sweet vernal, browntop, and paspalum).

Human impacts (*2011 Assessment*): This site is on private property and is seldom visited, so direct human impact is low.

Grazing (*2011 Assessment*): The site is mostly fenced, however deer graze some areas.

Adjoining land use (*2014 Assessment*): Pine plantation and farmland.

Site Change:

Recent change (2011 Assessment): Radiata pine and maritime pine continue to invade geothermal vegetation, particularly prostrate kānuka scrub and shrubland. Prostrate kānuka does not tolerate shading well. Feral deer access the fenced prostrate kānuka shrubland; tracks and signs of trampling are present throughout. Based on inspection of 2012 aerial photographs, the mingimingi scrub in the south of the site appears to have declined in condition, and no longer appears to comprise mingimingi scrub. Field survey is required to ground-truth this

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] All avifauna threat rankings are from Robertson *et al.* 2013.

assessment.

Historical (*Assessed in 2011*): Burns *et al.* (1996) assessed vegetation change at this site using aerial photographs from 1945 to 1993. In an area that includes Te Rautehuia Stream (site WKV02), they found that geothermal vegetation decreased by at least 23% between 1945 and 1993.

Comparison of 1961 aerial photographs[1] with 2007 aerial photographs (2007 WRAPS) was undertaken. The estimate of approximately one-quarter decline in geothermal vegetation by Burns *et al.* (1996) seems reasonable when viewing historical photos for this site, although some of this decline would have already taken place by the 1960s. The area to the southwest labelled as A on the site map appears considerably larger in 1961 aerial photographs then it does in the 2007 aerial photographs. While it is difficult to determine the boundaries of geothermal and non-geothermal scrub on black and white aerial photographs, the site could have been at least twice the current (2007) size. In the 1961 photos, there is an unvegetated area to the south that is no longer present; this may have been geothermal loamfield or it could have been unvegetated as a result of farming activities. The areas labelled as B are in shadow in the historic photos, so it is hard to determine boundaries, but these areas are probably similar in size to the current day. The area labelled as C appears very similar in 1961 and 2007 photographs, with pines having a very similar distribution on margins. Stock may have had access to this area in the early 1960s.

Management Requirements: Domestic livestock should be removed from all geothermal areas, and geothermal features (particularly fumaroles) in open pasture should be fenced to exclude stock. Wilding pines should be controlled within prostrate kānuka shrubland. Blackberry and other pest plants should be controlled before they out-compete indigenous geothermal vegetation.

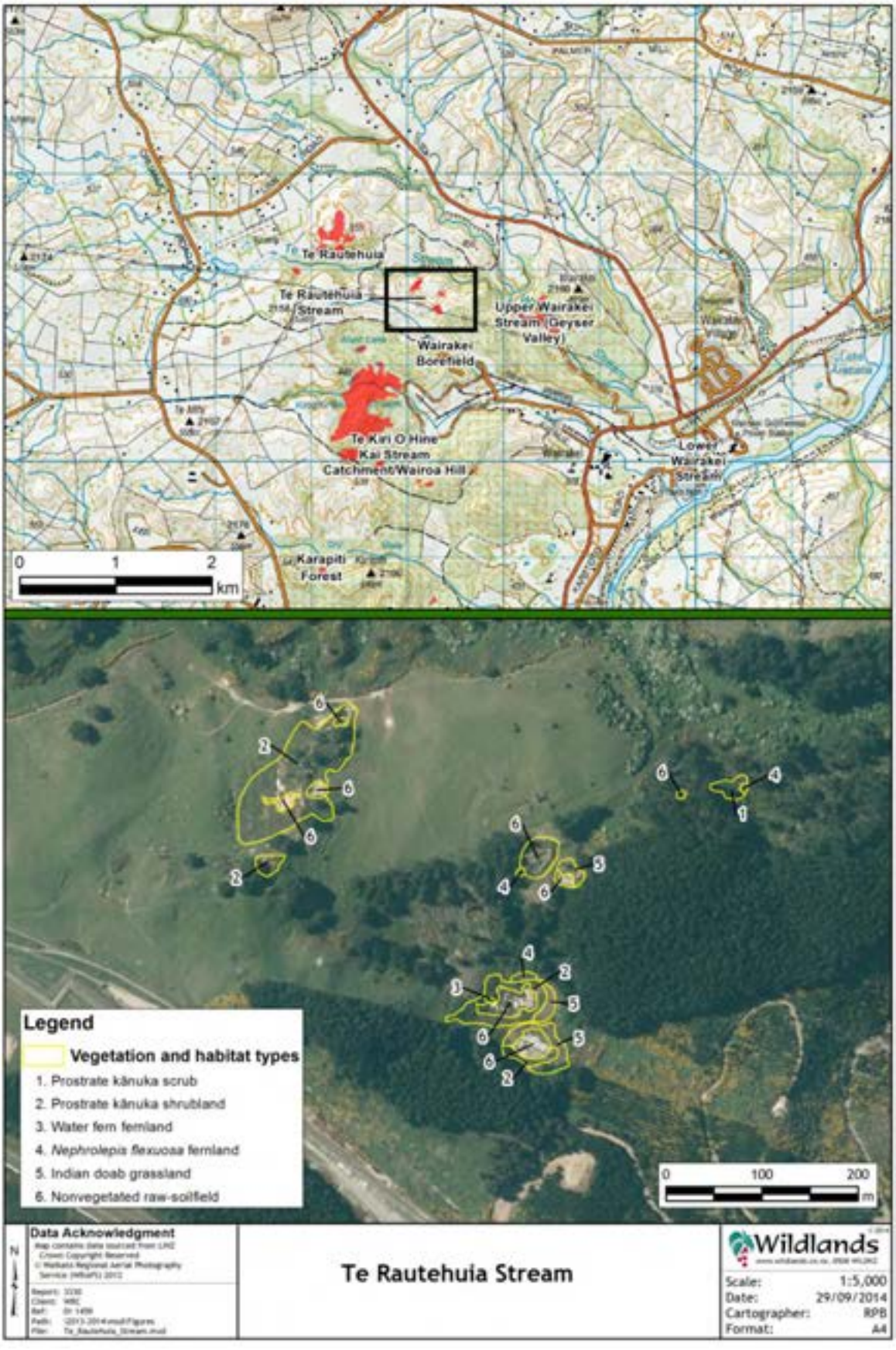
Significance Level: Regional (Table 1 - Criteria 3, 5, 9; Table 2 - Factor 14).

Significance Justification: This site is of regional significance because it is a relatively large example of geothermal habitat, which includes nationally uncommon ecosystem types (geothermally heated dry ground, fumarloes; Williams *et al*. 2007; Holdaway *et al.* 2012). It also contains populations of three 'At Risk' species (*Dicranopteris linearis*, *Nephrolepis flexuosa*, and prostrate kānuka).

Notes: This site is to the west of Te Rautehuia Stream site and is considered part of the same site in some studies (e.g. Burns *et al.* 1996).

References: Beadel and Bill 2000; Burns *et al*. 1996; Merrett and Burns 1998b & 1998c; Wildland Consultants 2004c, 2006, & 2012.

[1] Historical photos: SN 1394 Run 3187 Photos 22-23, 1961.


Te Rautehuia
Te Rautehuia Stream
Upper Wairakei Stream (Geyser Valley)
Wairakei Borefield
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Lower Wairakei Stream
Karapiti Forest
0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Prostrate kānuka shrubland
3. Water fern fernland
4. Nephrolepis flexuosa fernland
5. Indian doab grassland
6. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Te Rautehuia Stream
Wildlands
Scale: 1:5,000
Date: 29/09/2014
Cartographer: RPB
Format: A4

TE RAUTEHUIA STREAM

Site Number: WKV02[1] **Grid Reference:** NZTopo50 BG36 671 218
Ecological District: Atiamuri **GPS Reference:** NZTM E1867084 N5721842
Geothermal Field: Wairakei-Tauhara **Local Authority:** Taupō
Bioclimatic Zone: Submontane **Altitude:** 430 m
Tenure: Unprotected private land, Wairakei Tourist Park, Riparian marginal strip.
Extent of Geothermal Habitat: *c.*1.9 ha
Extent of Geothermal Vegetation: *c.*1.9 ha
Date of Most Recent Field Survey: 27 January 2011

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka up to *c.*1 m high dominates this vegetation type, with local patches of *Lycopodiella cernua* and *Nephrolepis flexuosa.*	Valley sides	*c.*0.1 ha
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka with scattered mingimingi forms a low canopy (up to *c.*1 m tall) with abundant *Lycopodiella cernua* and the moss *Campylopus capillaceus*, and occasional emergent maritime pine and radiata pine. Some geothermally-influenced bare ground is present. There is scattered bracken, water fern, Spanish heath, monoao, mānuka, broom, blackberry, karamū, prickly mingimingi, mānuka, and tūrutu throughout. Occasional patches of paspalum, Indian doab, narrow-leaved carpet grass, radiata pine seedlings, and pampas are also present within this vegetation type.	Hillslope, gentle hillslope	*c.*1.3 ha
Indigenous fernland (07.01) **Water fern fernland (07.01.03)** Water fern fernland occurs on a hillslope above a steaming fumarole. ***Nephrolepis flexuosa* fernland (07.01.10)** These areas comprise small patches of *Nephrolepis flexuosa* fernland surrounded by exotic grasses (e.g. Indian doab and paspalum). Bracken, prostrate kānuka, and *Lycopodiella cernua* occur throughout. Blackberry is encroaching from the margins.	Hillslope Hillslope	<0.1 ha <0.1 ha
Exotic grassland (08.01) **Indian doab grassland (08.01.07)** Indian doab occurs around the margins of areas of heated soils.	Shallow gullies, hillslopes	*c.*0.2 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Fumaroles, a geothermal crater (with boiling mud), and heated sinter clays. Prostrate kānuka, mingimingi, water fern, *Hypolepis ambigua*, maritime pine, radiata pine, pampas, blackberry, Spanish heath, and *Lycopodiella cernua* are present on the margins.	Shallow gullies, crater, hillslope	*c.*0.5 ha

[1] Site number in 2004 was U17/20 (Wildland Consultants 2004c).

Indigenous Flora: *Nephrolepis flexuosa* (At Risk-Declining[1]) and prostrate kānuka (At Risk-Naturally Uncommon) are present at this site. *Lycopodiella cernua*, which is typical of geothermal sites, is also present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including Australian magpie, tūī, yellowhammer, chaffinch, green finch, Californian quail, and Eurasian blackbird.

Current Condition (2011 Assessment): This site comprises several areas of geothermal expressions. It is surrounded by pine plantation forest and farmland. Stock access and trampling is occurring within the western portion of this site. Blackberry and scattered wildling pines are present. If the site is fenced and stock were excluded, the quality of geothermal vegetation is likely to improve markedly.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Wilding radiata pines occur locally within the geothermal vegetation (<1% cover). Occasional blackberry and broom are also present (1-5% cover).

Human impacts (*2011 Assessment*): Ongoing farming and plantation operations are having a negative impact within some parts of this site.

Grazing (*2011 Assessment*): The western part of this site is grazed and disturbance of vegetation within the area is significant.

Adjoining land use (*2014 Assessment*): Farmland and pine plantation.

Site Change:

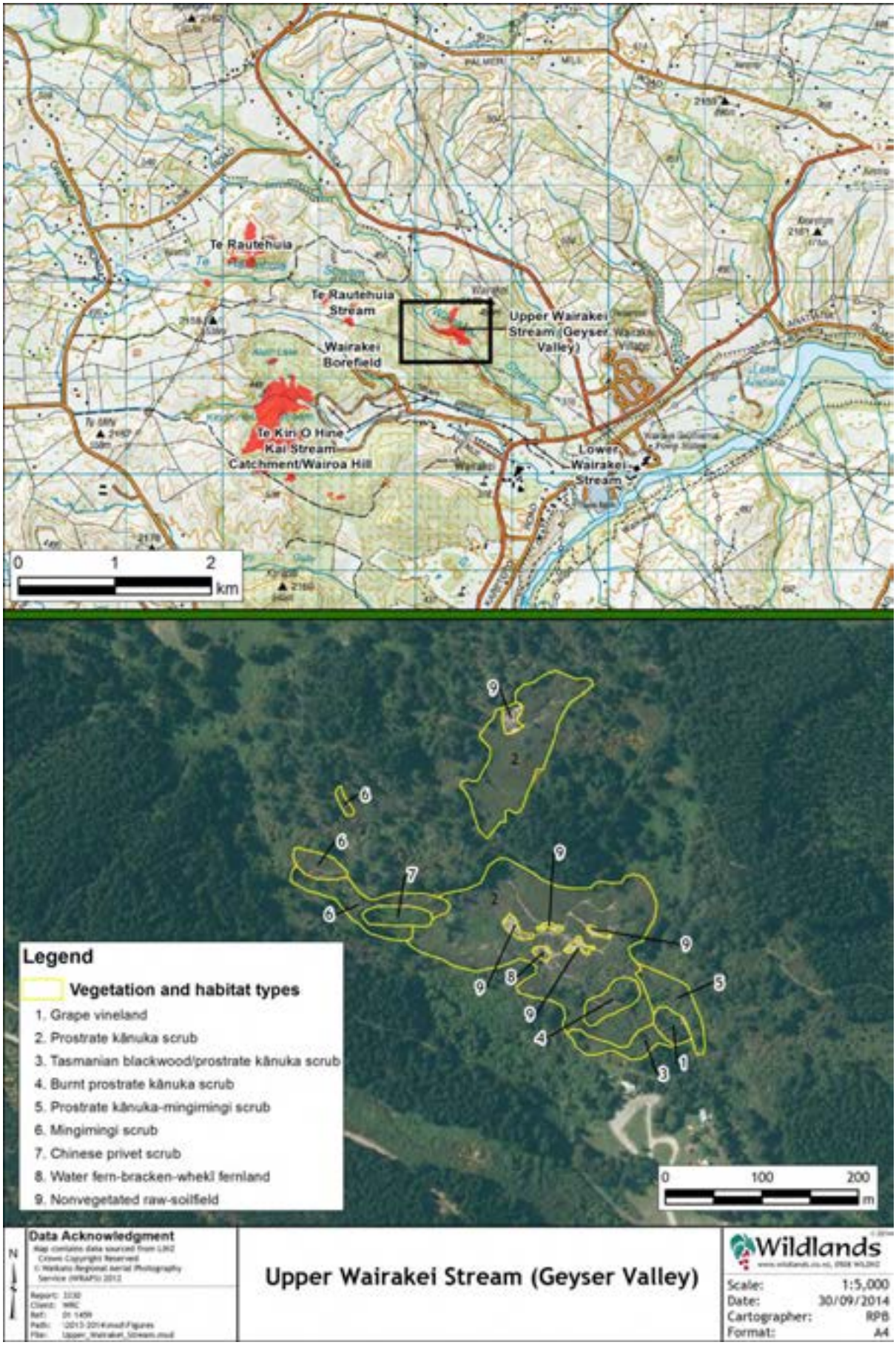
Recent change (2011 Assessment): The mixed fernland recorded on the walls of the geothermal crater (NZTM E1867136 N5721902) in 2006 (Wildland Consultants 2006) is no longer present and this area now comprises predominantly nonvegetated raw-soilfield with prostrate kānuka, mānuka, mingimingi, blackberry, broom, *Lycopodiella cernua*, and bracken scattered around the margins. Otherwise the site is similar to previous surveys.

Historical (*Assessed in 2011*): Burns *et al.* (1996) assessed vegetation change between 1945 and 1993 at this site using aerial photographs. Based on that study, in an area that includes Te Rautehuia (site WKV01), geothermal vegetation decreased by at least 23% between 1945 and 1993.

This estimate seems reasonable when viewing historical photos for this site from 1961[2]. The area labelled as A on the site map has been converted to pasture since 1961 and appears to be about half the size of earlier surveys. This part of the site extended further to the south in 1961. It was more difficult to assess site change at other areas. In 2011 the area labelled B had fewer pines than in 1961, but overall there is no strong evidence of change in site area since 1961. Area C was likely in a better condition in 1961 as it

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] Historic Photos: SN 1394 Run 3187 Photo 23, 1961.

	was surrounded by pine plantation and may not have been heavily browsed. The exact location of Area D is difficult to determine within the nongeothermal and geothermal scrub amongst scattered emergent pines. There are more areas of raw-soilfield alongside the stream to the north of the site in 1961. This may be indicative of more geothermal surface activity alongside stream margins in the past.
Management Requirements:	Where stock have access, geothermal features and vegetation should be fenced. Wilding pines should be removed from geothermal areas. Blackberry requires control.
Significance Level:	Regional (Table 1 - Criteria 3, 5; Table 2 - Factor 12).
Significance Justification:	This site is of regional significance because it is an important habitat for an 'At Risk' species, *Nephrolepis flexuosa*, and contains moderate-sized areas of prostrate kānuka scrub and shrubland (also an 'At Risk' species).
Priority for Field Survey (2014 Assessment):	This site is a medium priority for field survey.
References:	Burns *et al.* 1996; Department of Conservation 1997; Merrett and Burns 1998a; Wildland Consultants 2004c, 2006, & 2012.


Te Rautehuia
Te Rautehuia Stream
Wairakei Borefield
Upper Wairakei Stream (Geyser Valley)
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Lower Wairakei Stream
0 1 2 km
Legend
Vegetation and habitat types
1. Grape vineland
2. Prostrate kānuka scrub
3. Tasmanian blackwood/prostrate kānuka scrub
4. Burnt prostrate kānuka scrub
5. Prostrate kānuka-mingimingi scrub
6. Mingimingi scrub
7. Chinese privet scrub
8. Water fern-bracken-wheki fernland
9. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Upper Wairakei Stream (Geyser Valley)
Wildlands
Scale: 1:5,000
Date: 30/09/2014
Cartographer: RPB
Format: A4

UPPER WAIRAKEI STREAM (GEYSER VALLEY)

Site Number:	WKV03[1]	**Grid Reference:**	NZTopo50 BG36 684 214
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1868407 N5721446
Geothermal Field:	Wairakei-Tauhara	**Local Authority:**	Taupo
Bioclimatic Zone:	Submontane	**Altitude:**	386 m
Tenure:	Protected (Wairakei Thermal Park)		
Extent of Geothermal Habitat:	*c.*4.9 ha		
Extent of Geothermal Vegetation:	*c.*4.9 ha		
Date of Most Recent Field Survey:	31 January 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Exotic vineland (03.01) **Grape vineland (03.01.02)** A large grape vine is present in the southwestern corner of the site on the true right of Wairakei Stream. It has smothered the prostrate kānuka shrubland that was previously present. Chinese privet, Himalayan honeysuckle, and whekī can be seen beneath small gaps in the grape vine canopy. *Muehlenbeckia australis* is also present locally in the canopy.	Hillslope	*c.*0.1 ha
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka forms a canopy averaging *c.*1.0 m height with local mingimingi, and local patches of *Lycopodiella cernua* and *Dicranopteris linearis*. Around the margins, tūrutu is locally common and hound's tongue fern is occasionally present. Fumaroles and dried mud pools occur throughout. Blackberry, watercress (*Nasturtium officinale*), water fern, and *Carex secta* are common along geothermal stream margins within this vegetation type.	Terrace, hillslope	*c.*3.4 ha
Tasmanian blackwood/prostrate kānuka scrub (04.01.02) Tasmanian blackwood forms a patchy canopy over prostrate kānuka, with mingimingi and māpou common in the shrub tier. The groundcover is dominated by *Doodia australis* and tūrutu, with occasional *Asplenium polyodon*. Narrow-leaved carpet grass is common on the track margins. Brush wattle seedlings and saplings are scattered throughout.	Hillslope; gully	*c.*0.2 ha
Burnt prostrate kānuka scrub (04.01.04) A recent fire through part of the site has left burnt, standing dead prostrate kānuka (up to *c.*2.0 m high) over a ground cover dominated by exotic herbs and grasses, with *c.*25% bare ground. Broad-leaved fleabane is the dominant ground cover species, with locally abundant purple pampas (*Cortaderia jubata*). Black nightshade, acrid lettuce (*Lactuca virosa*), lotus, and Spanish heath are common. Vasey grass and narrow-leaved carpet grass are common on the track margins. Prostrate kānuka is re-establishing in places.	Terrace, hillslope	*c.*0.2 ha

[1] Site number in 2004 was U17/3 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-mingimingi scrub (04.01.05) Prostrate kānuka (up to *c.*3.0 m high) occurs with scattered mingimingi, māpou, wilding pine, Chinese privet, and Tasmanian blackwood. Occasional pampas, Spanish heath, blackberry, and tūrutu are present on the track margins. *Dicranopteris linearis* and *Nephrolepis flexuosa* occur locally.	Terrace, hillslope	*c.*0.2 ha
Mingimingi-dominant scrub (04.03) **Mingimingi scrub (04.03.01)** Mingimingi forms a canopy *c.*2.5 m in height with common Chinese privet and prostrate kānuka, locally common Spanish heath, and scattered karamū, whauwhaupaku, kōhūhū, and broom. Bracken is common in the understorey. Vasey grass and narrow-leaved carpet grass are common on the track margins. Blackberry is present on the margins of this vegetation type, particularly alongside the stream.	Hillslope	*c.*0.5 ha
Exotic species-dominated scrub (04.10) **Chinese privet scrub (04.10.03)** Chinese privet dominates a small area (*c.*40 × 15 m) north of the thermal stream in the west of the site.	Hillsope	*c.*0.1 ha
Indigenous fernland (07.01) **Water fern-bracken-whekī fernland (07.01.05)** Water fern, bracken, and whekī form the dominant cover on the steep face of a large steaming vent (named 'Witches Cauldron'). Blackberry, inkweed, tūrutu, mingimingi, *Gleichenia microphylla*, prostrate kānuka, *Dicranopteris linearis,* pampas, and māpou are also present.	Steaming vent	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Bare ground, clay soils, and areas of old and recent sinter. Occasional small areas of *Lycopodiella cernua*, prostrate kānuka, tūrutu, and the mosses *Racomitrium* sp. and *Campylopus* sp. are present (too small to map out separately).	Scarp	*c.*0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]), *Dicranopteris linearis* (At Risk-Naturally Uncommon), *Nephrolepis flexuosa* (At Risk-Declining), *Lycopodiella cernua*, and *Campylopus* sp., are all plants characteristic of geothermal areas which occur at this site. *D. linearis* is known from only *c.*23 sites in New Zealand.

Given (1976) recorded *Christella* aff. *dentata* ("thermal") (At Risk-Declining) from this site in the early 1970s, but it has not been recorded from this site in recent surveys (Wildland Consultants 2012, Bycroft and Beadel 2007, Merrett and Burns 1998).

Fauna: Common indigenous and introduced bird species typical of this type of habitat are present including whitehead, bellbird, tūī, North Island robin, grey warbler, fantail, yellowhammer, shining cuckoo, house sparrow, and song thrush.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Current Condition (2014 Assessment): Ongoing pest plant invasion and a fire in late 2012 have resulted in a reduction in the extent of geothermal vegetation since 2011, and degradation in quality of the remaining geothermal vegetation. Grape, Chinese privet, and blackberry are the dominant invasive weed species within the site, and purple pampas and Spanish heath are increasing in extent within the site since the 2012 fire. It appears that some geothermal features have become less active since 2011. Some areas of geothermal vegetation and habitats remain relatively intact.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Parts of this site are highly modified by invasive pest plants, particularly on cooler ground at the southwestern end of the valley. A grape vine covers a large area along the side of the gully (20% cover). Tasmanian blackwood (20% cover) and Chinese privet (15% cover) are also significant threats to the site. Other invasive pest plants present within the site include: wilding pines (radiata pine and lodgepole pine) (10% cover), brush wattle (2% cover), broom (1% cover), purple pampas (1% cover), tradescantia (<1% cover), Spanish heath (3% cover), cotoneaster (<1% cover), blackberry (5% cover), and buddleia (<1% cover).

Human impacts (*2014 Assessment*): The geothermal valley is run as a tourism venture with a circuit walking track; no evidence of visitors creating informal tracks in the vegetation was observed. Some geothermal features described as part of the tourist venture (and for which this valley was once renowned) have become quiescent due to the continued field drawdown for geothermal power generation (Given 1989a). Lowered soil temperatures have enabled the establishment of many adventive plant species, although in some areas the soil temperatures are increasing (Merrett and Burns 1998c).

A small part of the site has been negatively affected by a fire that resulted from a discarded cigarette butt in late 2012. Geothermal vegetation was burnt in the fire and the resultant bare ground has provided opportunities for weed invasion, particularly Spanish heath and purple pampas. Chickens and other domesticated fowl from the tea rooms have free access to the site, but are unlikely to have significant negative impacts on the site.

Grazing (*2014 Assessment*): Livestock do not have access to the site.

Adjoining land use (*2014 Assessment*): Plantation forest; scrub dominated by woody exotic species; indigenous scrub.

Site Change:

Recent change (2014 Assessment): The fire in 2012 has reduced the area of intact geothermal vegetation and resulted in avenues for weed invasion. However, regeneration of prostrate kānuka and bracken was noted in some areas. Chinese privet, blackberry, and grape have continued to increase in cover at the site since the last site visit in 2004 (Chris Bycroft pers. obs.).

Historical (*Assessed in 2011*): Burns *et al.* (1996) assessed vegetation change at this site using aerial photographs from 1945 to 1993 (named Wairakei Thermal Valley) and found that the extent of geothermal vegetation at this site decreased by at

least 74% between 1945 and 1993.

A 1961 aerial photograph was located for this site (Historical photo: SN 1394 Run 3187 Photos 25, 1961). The geothermal vegetation in this photo appears more extensive to the north, west, and to the east of the site. The geothermal vegetation is significantly wider in the middle of the site in 1961. Invasion of wilding pines into geothermal habitat occurred between 1961 and the present day, and the area of geothermal vegetation has become significantly more fragmented.

Management Requirements: Most parts of the site require some weed control. In particular, the grape vine, wilding pines, Tasmanian blackwood, Chinese privet, purple pampas, blackberry, and tradescantia require control. Education on ecological values and issues could be enhanced by the placement of signs explaining geothermal features, vegetation, and the changes which occurred as an impact of energy drawdown. The area affected by fire should be reinspected in 2017 to assess any pest plant control requirements. A management plan should be prepared to provide guidelines for the manager(s) of this site to address weed issues, and to enhance the ecological values of the site.

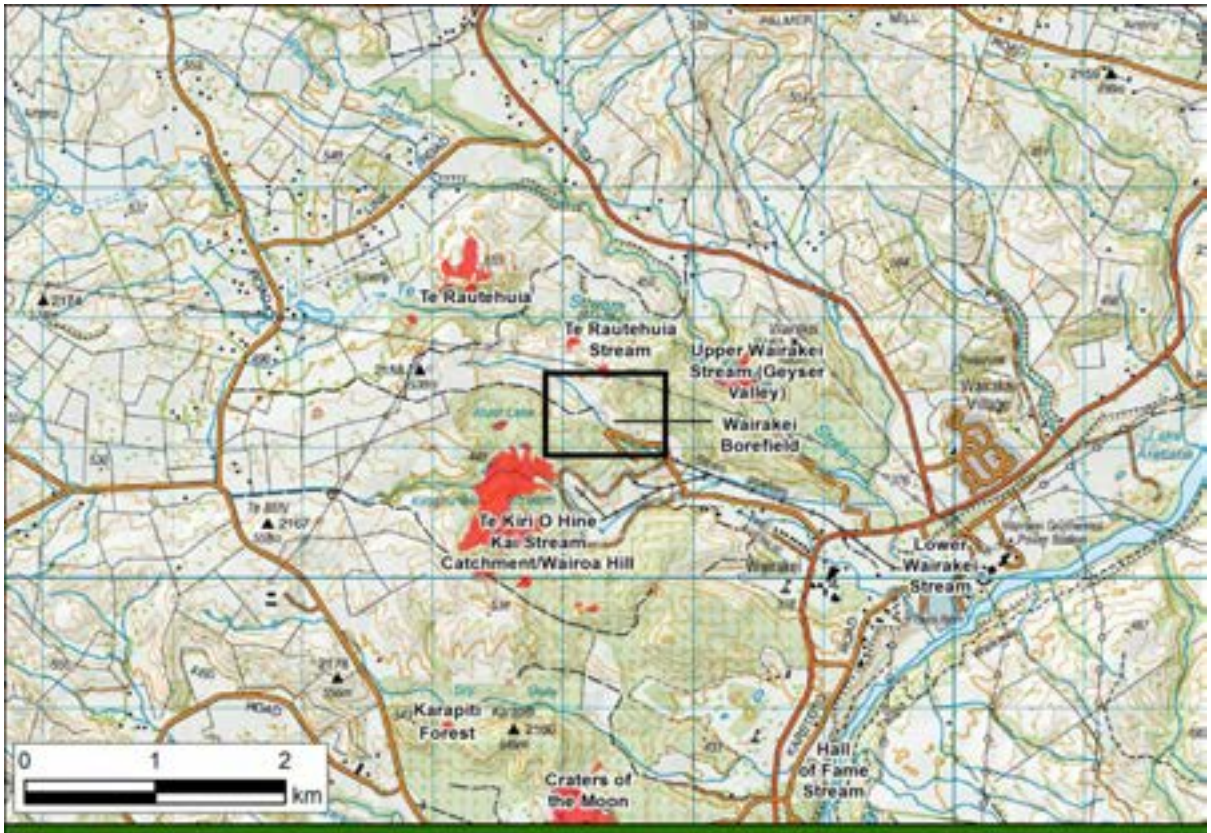
Significance Level: Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 9).

Significance Justification: This site is of regional significance because it is protected under the Reserves Act (1977) and contains stable populations of three 'At Risk' species: prostrate kānuka, *Dicranopteris linearis*, and *Nephrolepis flexuosa.*

Priority for Field Survey (2014 Assessment): This site is a medium priority for field survey. Spread of pest plant species within the area affected by fire should be monitored regularly.

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and classed this site as Category B - the second highest category.

References: Beadel and Bill 2000; Burns *et al*. 1996; Bycroft *et al*. 2007; Given 1976, 1989a & 1996; Merrett and Burns 1998c; Wildland Consultants 2004c & 2012.



Data Acknowledgment

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Wairakei Borefield

Wildlands
www.wildlands.co.nz, 0508 WILDNZ

Scale:	1:5,000
Date:	01/10/2014
Cartographer:	RPB
Format:	A4

WAIRAKEI BOREFIELD

Site Number:	WKV04[1]	**Grid Reference:**	NZTopo50 BG36 672 212; BG36 673 212
Ecological District:	Atiamuri		
Geothermal Field:	Wairakei	**GPS Reference:**	NZTM E1867298 N5721272; E1867314 N5721248
Bioclimatic Zone:	Submontane		
Local Authority:	Taupo	**Altitude:**	*c.*440 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	11 February 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Two areas of prostrate kānuka scrub (one up to *c.*1.5 m high and one up to *c.*0.75 m high) with occasional emergent broom separated by a strip of exotic grassland dominated by narrow-leaved carpet grass. Gaps in the prostrate kānuka canopy support the moss *Chiloscyphus semiteres* and scattered *Lycopodiella cernua*. Lotus, broom, and blackberry are common around the margins. Average soil temperature at 10 cm depth was 52.8 °C in 2014 (three measurements). Each area of scrub covers *c.*15 × 7 m (to give a total area of 170 m^2).	Hillslope	<0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[2]) is present. *Lycopodiella cernua*, a species typical of geothermal habitat, is also present.

Fauna: Common indigenous and introduced bird species typical of the habitat are likely to be present.

Current Condition (2014 Assessment): Two small patches of prostrate kānuka surrounded by an industrial site and separated by blackberry and rank grassland.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Broom (5% cover), buddleia (<1% cover), purple pampas (<1% cover), and blackberry (on margins).

Human impacts (*2014 Assessment*): This site is an operational industrial site and the vegetation is likely to be regularly disturbed - either cleared or damaged as part of the ongoing maintenance associated with the operational use of the site.

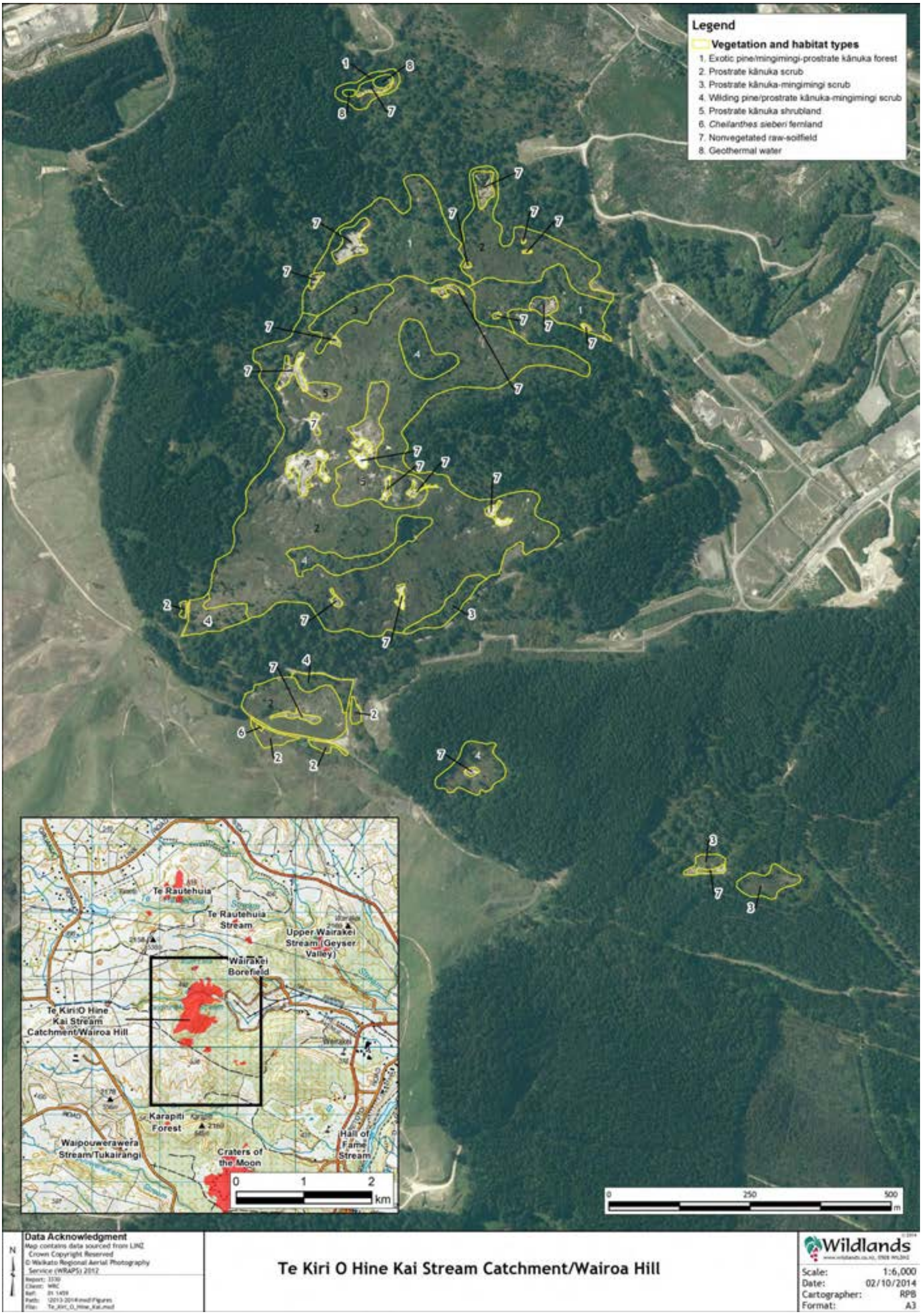
Grazing (*2014 Assessment*): The site is not grazed by stock.

Adjoining land use (*2014 Assessment*): Industrial.

[1] Site number in 2004 was U17/35 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

Site Change:

Recent change (2014 Assessment):	The geothermal vegetation (prostrate kānuka scrub) has expanded in area from *c.*125 m^2 in 2007 to *c.*170 m^2 in 2014. The canopy height of the prostrate kānuka has also increased and there are fewer canopy gaps within one of the patches.
Historical (*Assessed in 2011*):	This site is too small to be assessed on the historical aerial photographs that could be located.
Management Requirements:	None noted.
Significance Level:	Local (Table 1 - Criteria 3 & 5; Table 2 - Factor 19).
Significance Justification:	This site is of local significance because it is a small example of a nationally uncommon habitat type (geothermally habitat). It also contains a small population of an 'At Risk' plant species (prostrate kānuka) but does not represent habitat of considerable importance for the conservation of this species.
References:	Wildland Consultants 2004c, 2007a, & 2012.


Legend
Vegetation and habitat types
1. Exotic pine/mingimingi-prostrate kānuka forest
2. Prostrate kānuka scrub
3. Prostrate kānuka-mingimingi scrub
4. Wilding pine/prostrate kānuka-mingimingi scrub
5. Prostrate kānuka shrubland
6. Cheilanthes sieberi fernland
7. Nonvegetated raw-soilfield
8. Geothermal water
Te Rautehuia
Te Rautehuia Stream
Upper Wairakei Stream (Geyser Valley)
Wairakei Borefield
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Karapiti Forest
Waipouwerawera Stream/Tukairangi
Craters of the Moon
Hall of Fame Stream
0 1 2 km
0 250 500 m
Data Acknowledgment
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Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Wildlands
Scale: 1:6,000
Date: 02/10/2014
Cartographer: RPB
Format: A3

TE KIRI O HINE KAI STREAM CATCHMENT/WAIROA HILL

Site Number:	WKV05[1]	**Grid Reference:**	NZTopo50 BG36 666 206
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1866576 N5720644
Geothermal Field:	Wairakei-Tauhara	**Local Authority:**	Taupo
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*460-520 m
Tenure:	Unprotected private land (Unallocated Crown Land administered by Contact Energy)		

Extent of Geothermal Habitat: *c.*35.7 ha
Extent of Geothermal Vegetation: *c.*35.6 ha
Date of Most Recent Field Survey: 11 February 2014

VEGETATION TYPE	LANDFORM	EXTENT
Exotic forest (01.02) **Exotic pine/mingimingi-prostrate kānuka forest (01.02.05)** Radiata pine and scattered maritime pine are emergent and, in some areas, dominant over mingimingi, prostrate kānuka, tāwiniwini, and bracken. Patches of *Dicranopteris linearis* are present.	Hillslopes	*c.*5.1 ha
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka forms a dense canopy up to *c.*1 m high, with the mosses *Sphagnum* sp., *Campylopus introflexus*, and *Dicranoloma* sp. and the liverwort *Chiloscyphus semiteres* comprising the groundcover. Scattered lichen is also present. Monoao and local patches of mingimingi occur on rocky outcrops throughout, with monoao becoming more common in the scrub on the eastern side of a deep and geothermally active gully. Small fumaroles are scattered throughout the area. Patches of *Dicranopteris linearis, Nephrolepis flexuosa*, *Lycopodiella cernua*, and *Cheilanthes sieberi* are present. Exotic species are abundant throughout, particularly in cooler areas, including Spanish heath, buddleia, pampas, Himalayan honeysuckle, and blackberry.	Undulating plateau	*c.*22.7 ha
Prostrate kānuka-mingimingi scrub (04.02) **Prostrate kānuka-mingimingi scrub (04.02.01)** Prostrate kānuka forms the canopy in association with mingimingi. There is locally scattered monoao and emergent wilding radiata pine, false acacia, and maritime pine. The groundcover includes local *Campylopus* sp. and *Lycopodiella cernua*. Small patches of *Dicranopteris linearis* and *Nephrolepis flexuosa* are also present. **Wilding pine/ prostrate kānuka-mingimingi scrub (04.02.03)** Emergent radiata pine and maritime pine are scattered to locally common over an understorey dominated by mingimingi and prostrate kānuka. *Dicranopteris linearis*, *Nephrolepis flexuosa*, and tūrutu are scattered throughout, and *Lycopodiella cernua* is locally common. Patches of bare ground within this type supports a cover of the moss *Racomitrium* sp. Other species present include bracken, blackberry, buddleia, Spanish heath, whekī, whauwhaupaku, karamū, and	Hillslopes, gully Hillslopes	*c.*1.6 ha *c.*2.9 ha

[1] Site number in 2004 was U17/5 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
Himalayan honeysuckle. Emergent false acacia were recorded as locally common within part of this vegetation type in 2008 (Beadel and Bill 2008) but were not observed during the 2014 field survey.		
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka forms a low canopy up to *c.*0.5 m high over abundant *Lycopodiella cernua* and *Campylopus* sp. Local patches of mature, wilding, maritime pine and radiata pine (up to *c.*10 m tall) occur within this type, with an understorey of mingimingi, prickly mingimingi, karamū, tūrutu, and *Gleichenia microphylla*. At the southern end of the site prostrate kānuka occurs in association with *Dicranopteris linearis*, local patches of *Nephrolepis flexuosa*, and adventive species such as Himalayan honeysuckle, broad-leaved fleabane, foxglove, Yorkshire fog, wild portulaca, and occasional aloe (*Aloe* sp.).	Undulating plateau; valley floor, hillslopes	*c.*1.4 ha
Indigenous fernland (07.01) ***Cheilanthes sieberi* fernland (07.01.13)** A small area (*c.*5 × 2 m) of *Cheilanthes sieberi* fernland is present on the edge of prostrate kānuka scrub near the southwestern boundary of the site (NZTM E1866341, N5720032). *Lachnagrostis*, *Racomitrium*, and browntop are also present within this area.	Flat	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Geothermal clays, mud pools, and fumaroles with patches of prostrate kānuka shrubland scattered throughout. Pampas, kiokio, water fern, radiata pine seedlings, and bracken also occur in these areas.	Hillslopes, undulating plateau, crater	*c.*1.8 ha
Water (22.01) **Geothermal water (22.01.01)** Hot water and mud lakes, including Alum Lake. The two northernmost lakes are located within a steep sided depression. Pampas, *Carex secta*, raupō, and water fern occur on the margins, with *Lemna minor* present on the surface of cooler water.	Lakes	*c.*0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]), *Dicranopteris linearis* (At Risk-Naturally Uncommon), and *Nephrolepis flexuosa* (At Risk-Declining) occur at this site. The site supports the largest populations of both *Nephrolepis flexuosa* and *Dicranopteris linearis* of any of the geothermal sites in the Wairakei-Tauhara Geothermal field. *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon) was recorded near geothermal lakes at this site in 2001 (Nick Singers pers. comm. 2007) but has not been recorded since.

D. linearis is known from only *c.*23 sites in New Zealand.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including tūī, Australasian harrier, shining cuckoo, kōtare (sacred kingfisher), grey warbler, fantail, bellbird, chaffinch, Eurasian blackbird,

[1] All flora threat rankings are from de Lange *et al.* 2013.

pheasant, and California quail. New Zealand pipit (At Risk-Declining[1]) is also present at this site. Skink and gecko have also been reported from this site (Spring-Rice 1996).

Current Condition (2014 Assessment): A large and mostly contiguous area of geothermal features and vegetation surrounded by pine plantation and geothermal extraction operations. The site interior contains extensive areas of prostrate kānuka scrub and other geothermal vegetation types, but is vulnerable to, and is being compromised by, pest plant invasion, particularly wilding pines. Weeds are common on the margins of the site and the geothermal vegetation condition is likely being altered by geothermal extraction, which is ongoing.

An old asbestos dump is located within the site (near E1866417, N5720060) and is reverting to prostrate kānuka shrubland.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Wilding radiata pine (25% cover) and maritime pine (15% cover) threaten geothermal vegetation at this site. Other adventive species present include blackberry (<5% cover), pampas (1% cover), Himalayan honeysuckle (<1% cover), Montpellier broom (<1% cover), broom (<1% cover), and Spanish heath (<1% cover).

Human impacts (*2014 Assessment*): Access tracks, vehicle tracks, logging, and geothermal extraction infrastructure all occur along the boundaries of this site.

Grazing (*2014 Assessment*): The surrounding land is not farmed.

Adjoining land use (*2014 Assessment*): Pine plantation, industrial geothermal gas extraction plant, farmland.

Site Change:

Recent change: Wilding pine cover has increased significantly since 2007 as evidenced by the change of the mingimingi scrub at the southern end of the site to exotic pine/mingimingi-prostrate kānuka forest between 2007 and 2014. In the middle of this site an area mapped as prostrate kānuka-mingimingi scrub in 2007 now comprises radiata pine/mingimingi-prostrate kānuka forest.

Historical (*Assessed in 2011*): Burns *et al.* (1996) assessed vegetation change at this site using aerial photographs from 1945 to 1993 and found that geothermal vegetation in extent decreased by 20% between 1945 and 1993. In addition, an assessment of aerial photos from 1961[2] compared with more recent aerial photographs indicate a marked increase in wilding pines in the site.

Management Requirements: Wilding pines should be controlled as most threatened geothermal species do not tolerate high shade. Blackberry and pampas should be controlled within geothermal habitat to prevent further spread of these species. A management plan should be prepared to provide guidelines for pest plant

[1] All avifauna threat rankings are from Robertson *et al.* 2013.
[2] Historical photos: SN 1394 Run 3187 Photos 22, 23, 1961; SN 1394 Run 3188 Photos 23, 24, 1961.

control and to maintain ecological values.

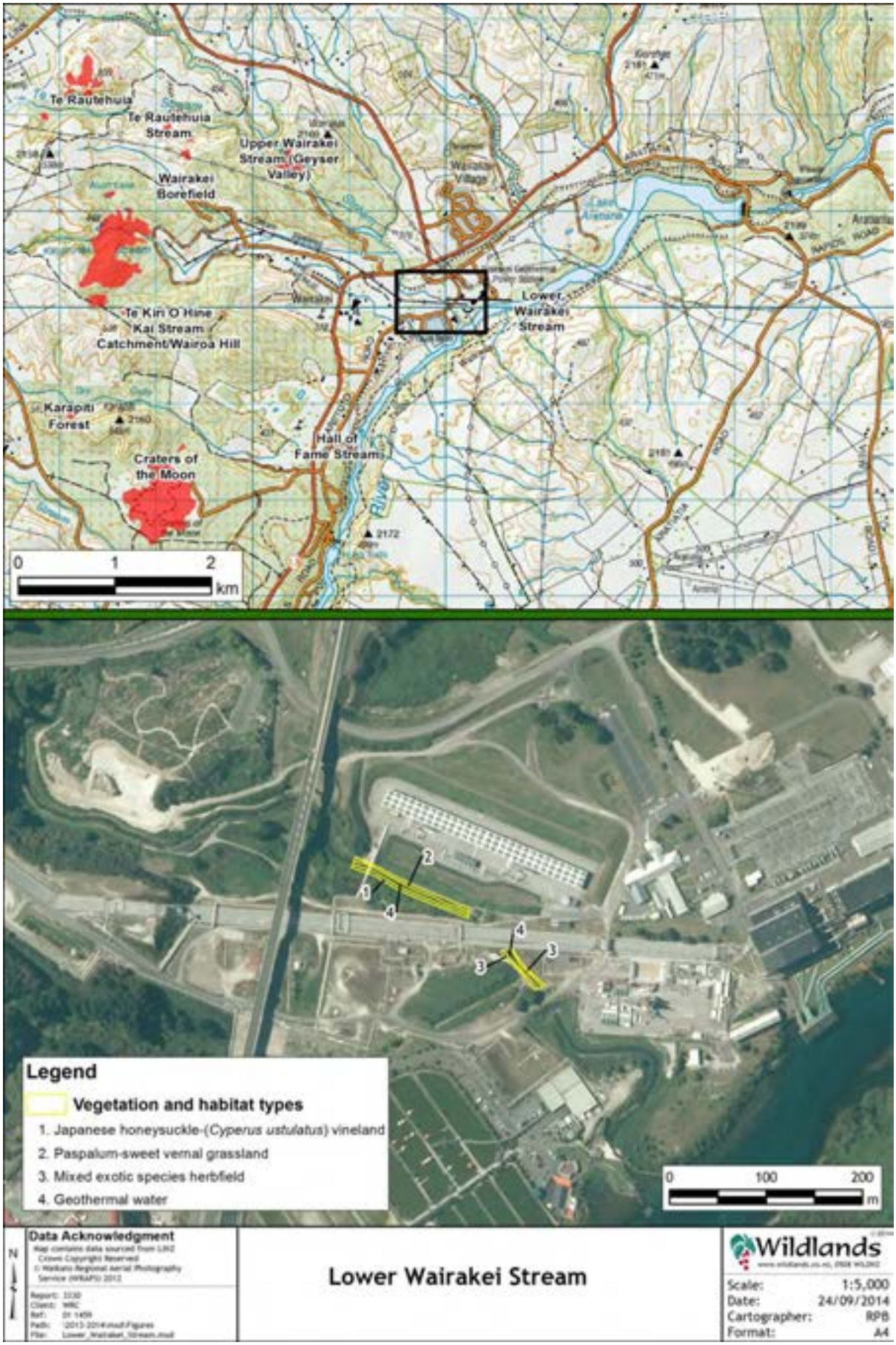
Significance Level: Regional (Table 1 - Criteria 3, 5, 7; Table 2 - Factors 12, 14).

Significance Justification: This site is of regional significance because it comprises a relatively large area of geothermal vegetation, which includes nationally uncommon habitat types (fumaroles, geothermally heated dry ground; Williams *et al.* 2007, Holdaway *et al.* 2012). The site also contains relatively large populations of three 'At Risk' species (prostrate kānuka, *Dicranopteris linearis*, and *Nephrolepis flexuosa*). The site is somewhat degraded in quality, with adventive plant species common.

Notes: This site comprises two areas ranked in Given (1996) as Category A (the highest category) - "Wairakei: Waiora Hill" and "Wairakei: Upper Wairakei Stream".

A large part of this site is very dangerous to walk around, and the assessment of some areas is based on inference of vegetation types based on assessment of aerial photographs.

References: Anon 1990; Beadel and Bill 2000; Burns *et al.* 1996; Given 1989a; Spring-Rice 1996; Wildland Consultants 2004c, 2007b, & 2012.


Te Rautehuia
Te Rautehuia Stream
Upper Wairakei Stream (Geyser Valley)
Wairakei Borefield
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Karapiti Forest
Craters of the Moon
Hall of Fame Stream
Lower Wairakei Stream
0 1 2 km
0 100 200 m
Legend
Vegetation and habitat types
1. Japanese honeysuckle-(Cyperus ustulatus) vineland
2. Paspalum-sweet vernal grassland
3. Mixed exotic species herbfield
4. Geothermal water
Data Acknowledgment
Lower Wairakei Stream
Wildlands
Scale: 1:5,000
Date: 24/09/2014
Cartographer: RPB
Format: A4

LOWER WAIRAKEI STREAM

Site Number:	WKV06[1]	**Grid Reference:**	NZTopo50 BG36 699 201
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1869918 N5720089
Geothermal Field:	Wairakei	**Local Authority:**	Taupo
Bioclimatic Zone:	Submontane	**Altitude:**	350 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	0.2 ha		
Extent of Geothermal Vegetation:	0.1 ha		
Date of Most Recent Field Survey:	11 February 2014		

TYPE	LANDFORM	EXTENT
Exotic vineland (03.01) **Japanese honeysuckle-(*Cyperus ustulatus)* vineland (03.01.03)** The stream margins (true right) in the northwest of the site comprise Japanese honeysuckle vineland with locally common *Cyperus ustulatus*, and local Montpellier broom, gorse, blackberry, and buddleia. Occasional *Christella* aff. *dentata* ("thermal") (six clumps) are present between the outlet of geothermal water into the Wairakei Stream and where the stream enters a culvert.	Stream margins	<0.1 ha
Exotic grassland (08.01) **Paspalum-sweet vernal grassland (08.01.12)** The stream margins (true left) in the northwest of the site comprise rank grassland dominated by paspalum and sweet vernal with abundant narrow-leaved plantain, and common yarrow and blackberry. Montbretia, fennel (*Foeniculum vulgare*), lotus, and cocksfoot are locally common.	Stream margins	<0.1 ha
Herbfield (13.01) **Mixed exotic species herbfield (13.01.02)** Stream margins with mixed exotic species herbfield and grassland dominated by broad-leaved fleabane, Yorkshire fog, and Indian doab with common lupin and pōhue. Scattered clumps of *Cyperus ustulatus* and blackberry, and occasional gorse are present.	Stream margins	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermal stream with a surface water temperature of 32.8°C at one location. The surface water temperature at an outflow into the stream at E1869871N5720120 measured 78.2°C in 2014.	Stream	*c.*0.1 ha

Indigenous Flora: Six clumps of *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon[2]) were found in 2014, compared to 47 clumps recorded at this site in 2007 (Wildland Consultants 2012), and seven clumps recorded in 1998 (Merrett and Burns 1999).

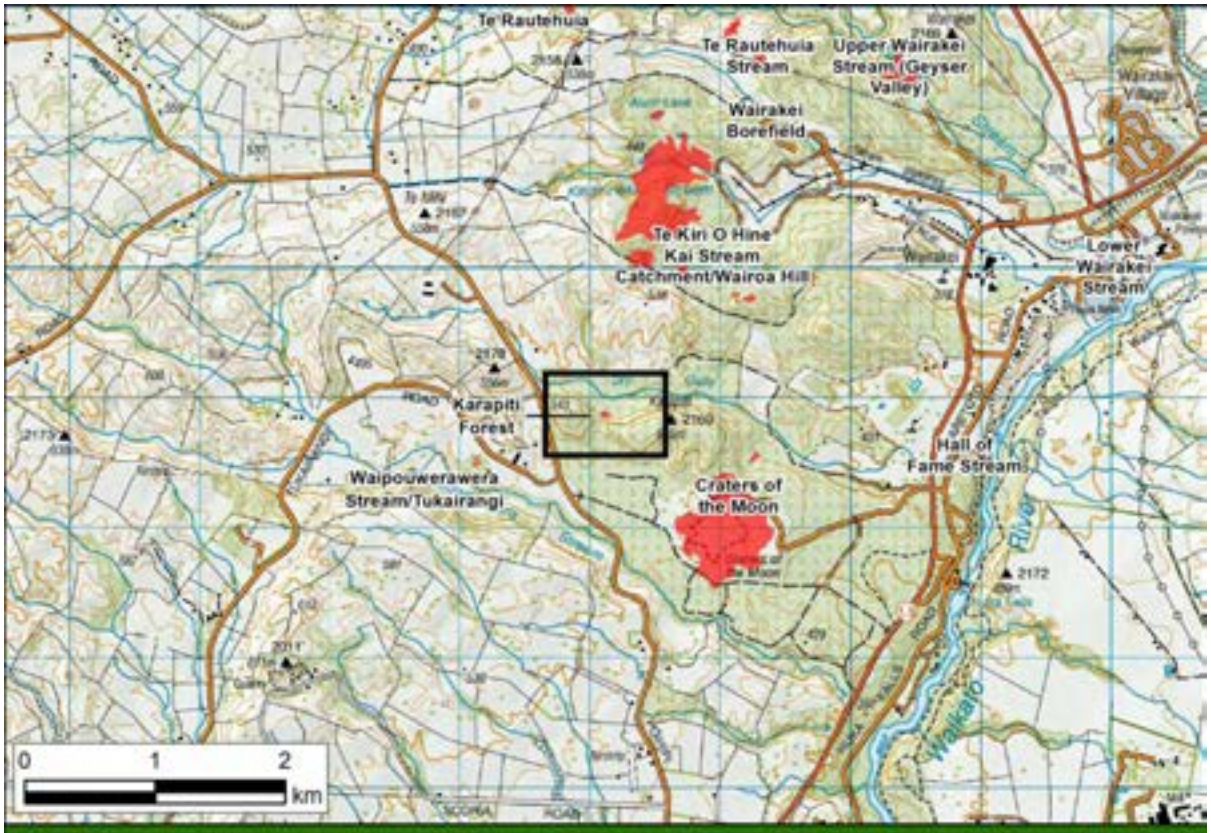
Two plants of *Hypolepis dicksonioides* (At Risk-Naturally Uncommon) were recorded from the true left stream bank in 2014. *H. dicksonioides* had

[1] Site number in 2004 was U17/2 (Wildland Consultants 2004c & 2007a).
[2] All flora threat rankings are from de Lange *et al.* 2013.

	previously been recorded from this site in the past (Merrett and Burns 1998b), but was not recorded in 2007.
Fauna:	Mallard, silvereye, chaffinch and Indian myna were recorded during the site visit. Other common indigenous and introduced bird species typical of the habitat are also likely to be present.
Current Condition (2014 Assessment):	This site is in a poor condition and pest plants are common. However, the site provides habitat for two threatened plant species and comprises geothermal habitat.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2014 Assessment*):	Japanese honeysuckle (35% cover), blackberry (25% cover), gorse (1% cover), buddleia (1% cover), montbretia (1% cover), Montpellier broom (<1% cover), lupin (<1% cover), and tree lucerne (<1% cover) are present.
Human impacts (*2014 Assessment*):	The geothermal vegetation occurs alongside a stream which has been modified as part of the ongoing management of the Wairakei Power Station.
Grazing (*2014 Assessment*):	Not a threat to this site.
Adjoining land use (*2014 Assessment*):	Industrial site.
Site Change:	
Recent change (2014 Assessment):	The gorse shrubland that was present in the southeastern part of the site in 2007 appears to have been sprayed. This area now comprises mixed exotic grassland and herbfield. This section of the site has also been fenced. The two clumps of *Christella* aff. *dentata* ("thermal") that were present in this area in 2007 were not observed in 2014 and there has been a significant reduction in the number of *Christella* clumps in the northwestern section of the site (from 47 clumps in 2007 to six in 2014). Japanese honeysuckle has expanded in cover and now smothers the blackberry shrubland on the true right of the stream in the northwestern part of the site.
Historical (*Assessed in 2011*):	This site is too small to see any evidence of change since 1941[1]. However, changes are likely to have been significant with the construction of the Wairakei Power Station in close proximity to this site. The stream has been channelised, which will have altered the extent of geothermal vegetation. It is likely that draw-down of geothermal water for power generation will have changed the vegetation composition of the site through water table and temperature changes.
Management Requirements:	The population of *Christella* aff. *dentata* ("thermal") should be monitored at regular intervals. It is threatened by dense infestations of exotic pest plants (e.g. blackberry and Japanese honeysuckle), and the ongoing maintenance of the stream margins as part of an operational industrial site (e.g. spraying of gorse).

[1] Historical photo: SN 172 Run 1173 Photo 3, 1941.

Significance Level:	Regional (Table 1 - Criterion 3, 5; Table 2 - Factor 12)
Significance Justification:	This site is of regional significance because it contains a small population of an 'At Risk' species - *Christella* aff. *dentata* ("thermal"). This species is currently only known from 15 sites in New Zealand (Bycroft and Beadel 2007).
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and classed this site as Category B - the second highest category.
References:	Bycroft and Beadel 2007; Given 1989a & 1996; Merrett and Burns 1998b & 1999; Wildland Consultants 2004c, 2007a, & 2012.



Data Acknowledgment

Karapiti Forest

Wildlands

Scale: 1:5,000
Date: 23/09/2014
Cartographer: RPB
Format: A4

KARAPITI FOREST

Site Number:	WKV07[1]	**Grid Reference:**	NZTopo50 BG36 661 189
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1866117 N5718870
Geothermal Field:	Wairakei	**Local Authority:**	Taupo
Bioclimatic Zone:	Submontane	**Altitude:**	***c.*480 m**
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*0.4 ha		
Extent of Geothermal Vegetation:	*c.*0.4 ha		
Date of Most Recent Field Survey:	31 January 2014		

TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka-monoao scrub (04.01.06)** Scattered radiata pine and lodgepole pine are emergent over a canopy dominated by prostrate kānuka and monoao up to *c.*1 m high, with locally common mingimingi. The groundcover comprises patches of the mosses *Campylopus semiteres* and *Racomitrium* sp. with occasional kiokio. Bracken fernland is present on the margins, with scattered emergent prickly mingimingi, broom and blackberry are common, and Himalayan honeysuckle is locally common.	Toe slope	*c.*0.4 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[2]) is present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present, including bellbird, fantail, silvereye, and Australian magpie.

Current Condition (2014 Assessment): Prostrate kānuka has grown in stature, but decreased in cover within the site, while monoao and prickly mingimingi have increased in cover, indicating reduced thermal activity within the site. No obvious steaming ground was observed within the site, which also supports the assessment of reduced thermal activity. Although thermal activity within the site appears reduced compared with 2004, weeds have not become more prominent.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): The site is surrounded by plantation pine forest. Although the thermal activity within the site appears reduced compared with 2004, wilding pine cover does not appear to have increased since 2004, remaining at *c.*5% cover within the site. However it is likely that wilding pine cover will increase over time if reduced thermal activity within the site continues. Blackberry and broom are also present within the geothermal area (*c.*5% cover), and Himalayan honeysuckle is present on the margins (*c.*1% cover).

Human impacts (*2014 Assessment*): The site is located within the Wairakei Geothermal Field and is showing a reduction in thermal activity since 2004. Whilst geothermal activity fluctuates naturally, the power station draw-off may be exacerbating this natural fluctuation. Soil temperatures within the site ranged from 15.8 °C to 20 °C in 2014.

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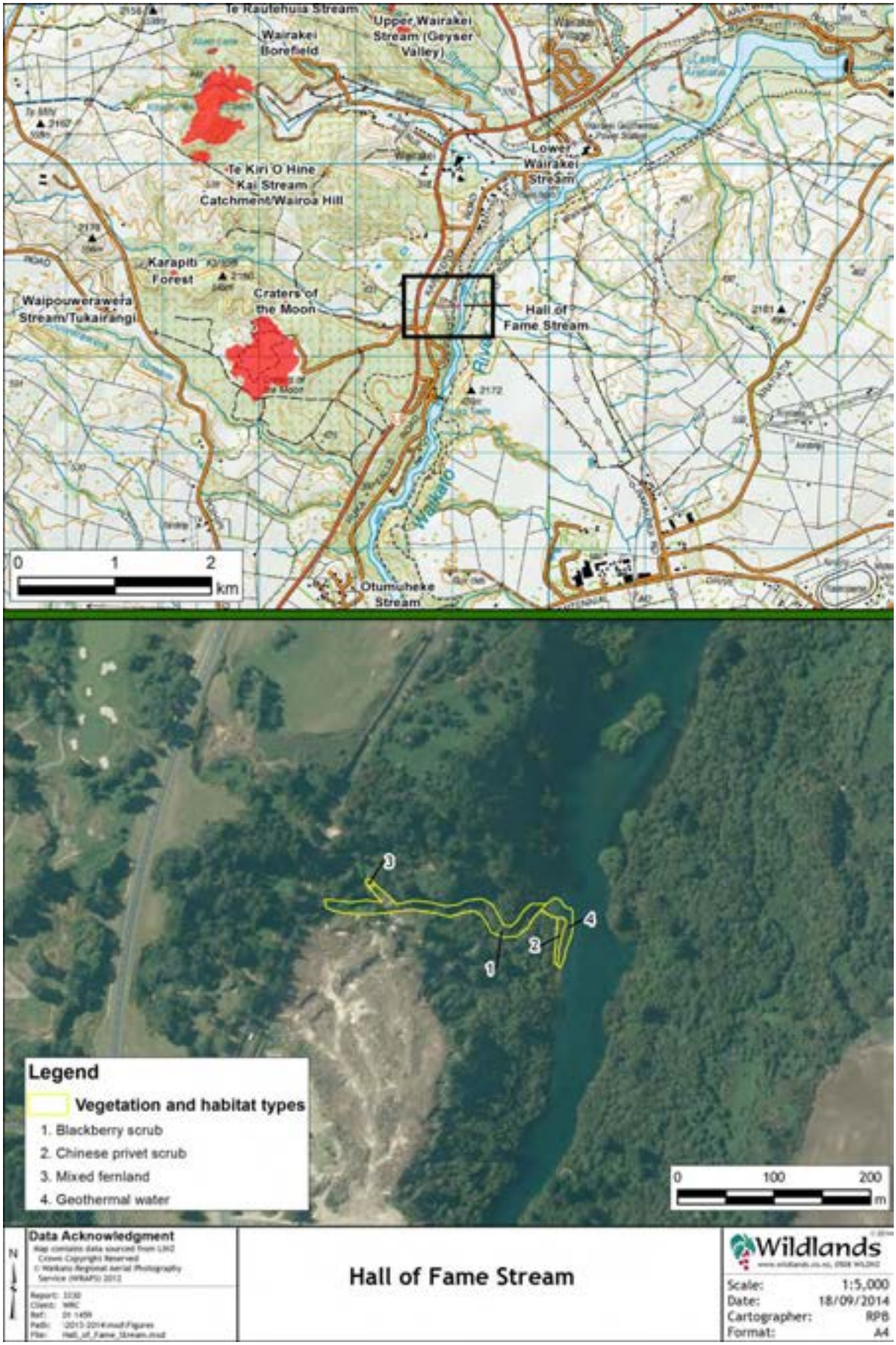
1 Site number in 2004 was U17/19 (Wildland Consultants 2004c).
2 All flora threat rankings are from de Lange *et al.* 2013.

Grazing (*2014 Assessment*):	Livestock are not a threat to this area.
Adjoining land use (*2014 Assessment*):	Harvesting and ongoing management operations of the surrounding pine plantation could result in ongoing damage to the geothermal vegetation. The mountain-biking tracks that have been established within the adjoining pine plantation are unlikely to affect the geothermal vegetation within this site.

Site Change:

Recent change (2014 Assessment):	Geothermal activity at this site appears to have declined since 2004. This is evidenced by the significant increase in height and cover of monoao and mingimingi, the reduced dominance of prostrate kānuka, the absence of obvious steaming ground, and the colonisation and growth of bracken on areas of previously bare ground. The extent of the site appears similar on 2012 aerial photographs compared with the 2004 assessment. Plantation trees near the site are markedly taller than they were at the time of the 2004 survey.
Historical: *(Assessed in 2011)*	An assessment was made between 1961 aerial photographs[1] and 2007 aerial photographs. There is a more extensive area of scrub around the site in 1961, although most of this is unlikely to be geothermal. There is also more disturbance around the site and it is difficult to assess whether some of the bare ground is geothermal or human-induced disturbance. There has probably been a small reduction of size of this site since 1961, with the establishment of pine plantation right to its margin. A broad estimate of reduction of geothermal habitat would be *c.*10-20% since 1961.
Management Requirements:	A buffer zone around the geothermal area should be created to avoid damage to the site during harvesting and ongoing management of the surrounding pine plantation. No buffer has been allowed for in recent plantings. Wilding pines should be controlled at this site on a regular basis. This site should be monitored to assess the impact of geothermal power extraction.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).
Significance Justification:	Karapiti Forest is of local significance because it is a small example of a nationally uncommon habitat type (geothermally heated dry ground; Williams *et al.* 2007, Holdaway *et al.* 2012). The site also provides habitat for two 'At Risk' species (prostrate kānuka and *Dicranopteris linearis*) but does not represent habitat of considerable importance for the conservation of these species. This site is a small, highly active, geothermal area, relatively undisturbed and currently has very low densities of invasive exotic plants.
References:	Beadel and Bill 2000; Burns *et al.* 1996; Department of Conservation 1998; Merrett and Burns 1998b, 1998c; Wildland Consultants 2004c & 2012.

[1] Historical photos: SN 1394 Run 3188 Photos 22-23, 1961.


Te Rautehuia Stream
Upper Wairakei Stream (Geyser Valley)
Wairakei Borefield
Wairakei Village
Lower Wairakei Stream
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Karapiti Forest
Craters of the Moon
Waipouwerawera Stream/Tukairangi
Hall of Fame Stream
Waikato River
Otumuheke Stream
0 1 2 km
Legend
Vegetation and habitat types
1. Blackberry scrub
2. Chinese privet scrub
3. Mixed fernland
4. Geothermal water
0 100 200 m
Data Acknowledgment
Hall of Fame Stream
Wildlands
Scale: 1:5,000
Date: 18/09/2014
Cartographer: RPB
Format: A4

HALL OF FAME STREAM

Site Number:	WKV08[1]	**Grid Reference:**	NZTopo50 BG36 689 186
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1868965 N5718516
Geothermal Field:	Wairakei	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*360 m
Tenure:	Protected (Huka Falls Scenic Reserve)		
Extent of Geothermal Habitat:	*c.*0.4 ha		
Extent of Geothermal Vegetation:	*c.*0.4 ha		
Date of Most Recent Field Survey:	16 July 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Exotic species-dominant scrub (04.10) **Blackberry scrub (04.10.01)** Scrub dominated by blackberry, Himalayan honeysuckle, and radiata pine with local emergent whekī is located on the margins of a stream within a steep-sided gully in which there are several hot springs. Māhoe, *Deparia petersenii*, and *Pneumatopteris pennigera* are locally common. There is occasional Chinese privet, kōtukutuku, *Carex geminata*, kiokio, and bracken. Local areas dominated by māhoe and kiokio are present in the mid-reaches of this type. Chinese privet is common near the confluence with the Waikato River. Water temperatures within the stream in 2014 ranged from *c.*23-27 °C. Steam was visible at the western end of the site but could not be accessed for temperature measurement.	Gully	*c.*0.3 ha
Chinese privet scrub (04.10.03) Chinese privet scrub with scattered blackberry and karamū forms a dense canopy *c.*2 m height. Five clumps of *Christella* aff. *dentata* ("thermal") plants were counted in this type though more are likely to be present.	Riparian margin	<0.1 ha
Indigenous fernland (07.01) **Mixed fernland (07.01.07)** A warm seepage (*c.*28.2 °C in 2014) surrounded by bare ground is present recessed into the base of a cliff. On the cliff face above the seepage, scattered ferns are present, predominantly *Blechnum vulcanicum* and kiokio, with occasional whekī and *Adiantum cunninghamii*. The bare ground south of the spring supports scattered woody species including makomako, blackberry, and rangiora. *Urtica incisa* and wall lettuce are also present. The *Christella* aff. *dentata* ("thermal") that was observed in this location in 2004 was not observed in 2014.	Steep hillslope	<0.1 ha
Water (22.01) **Geothermal water (22.01.01)** A geothermal spring on the margin of the Waikato River. *Glossostigma* is common submerged in the water around the spring. Water temperature at the spring is *c.*74.9 °C (2014 measurement).	River margin	<0.1 ha

[1] Site number in 2004 was U17/6 (Wildland Consultants 2004c).

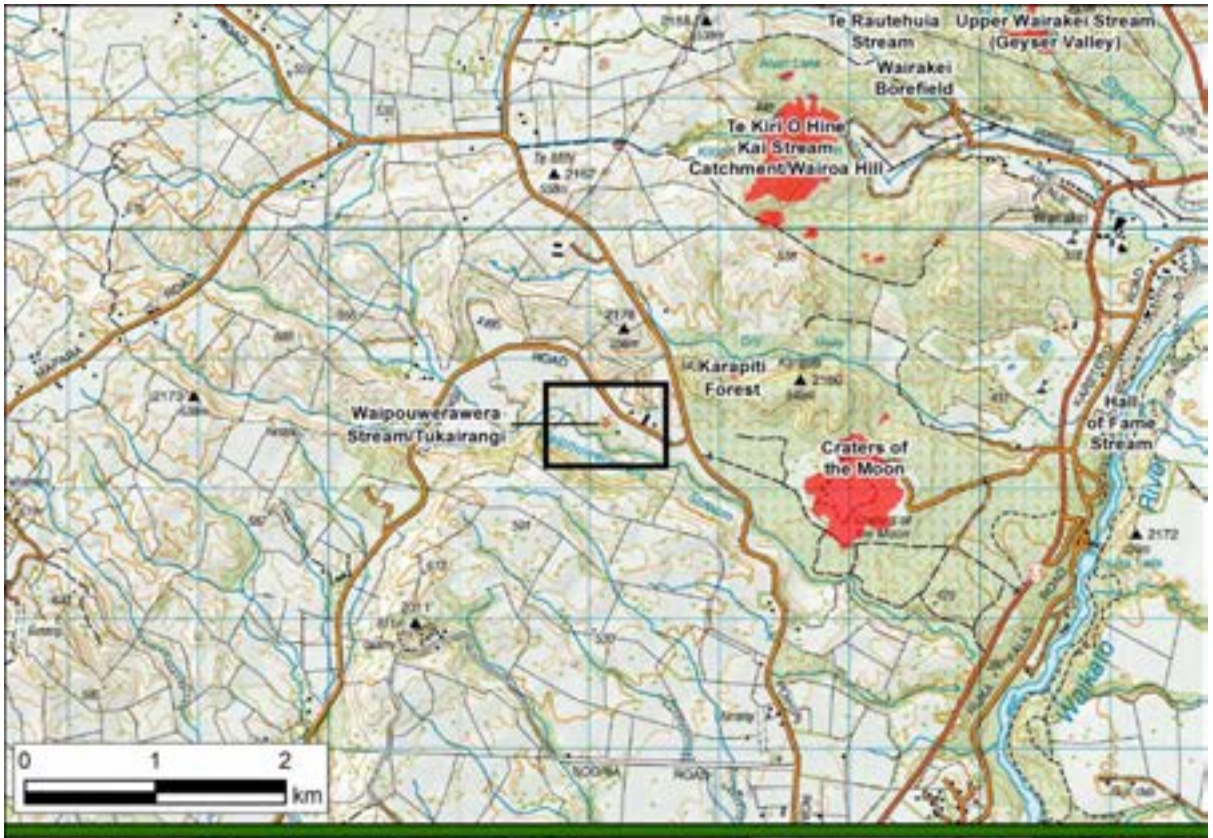
Indigenous Flora:	A small population of *Christella* aff. *dentata* ("thermal") (At Risk-Declining[1]) is present around a series of hot springs on the margins of the Waikato River, south of the confluence of Hall of Fame Stream and the Waikato River.
Fauna:	Common indigenous and introduced bird species typical of the habitat are present.
Current Condition (2014 Assessment):	Most of the site is dominated by blackberry and radiata pine. Some pine control work has been undertaken. Parts of the site have been cleared of exotic vegetation along the track within the gully.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2014 Assessment*):	Exotic pest plant species are common to dominant within this site. Blackberry is abundant (50% cover). Other pest plant species present include Himalayan honeysuckle (2% cover), Chinese privet (2% cover), and broom (<1% cover).
Human impacts (*2014 Assessment*):	A track is present within the gully. Track maintenance has not adversely affected geothermal vegetation or features within the site. This site is in the Wairakei geothermal field and is vulnerable to changes in ground temperature associated with power station draw-off (refer to Burns *et al.* 1996; Merrett and Burns 1998b&c), however the impacts to this area of draw-off are not currently known.
Grazing (*2014 Assessment*):	Livestock are not a threat to this area.
Adjoining land use (*2014 Assessment*):	Scenic Reserve administered by Department of Conservation. A walking track passes through the site.
Site Change:	
Recent change (2014 Assessment):	The site extent has increased slightly due to greater visibility in the gully in 2014. This does not represent a real change in geothermal manifestations within the site. A new spring on the margin of the Waikato River was also added to the site. This spring is likely to have been present in 2004 but was not surveyed at that time.
Historical (*Assessed in 2011*):	This site is too small to see any evidence of change since 1941[2].
Management Requirements:	Control of Chinese privet should be considered near the hot springs on the margin of the Waikato River.
Significance Level:	Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factors 9, 12).
Significance Justification:	This site is of regional significance because it is within a Scenic Reserve. It also contains a small population of an 'At Risk' plant species (*Christella*

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] Historical photos: SN 172 Run 1174 Photos 2, 3, 1941.

aff. *dentata* “thermal”).

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category C - the third highest category.

References: Given 1989a & 1996; Merrett and Burns 1998b&c; Wildland Consultants 2004c & 2012.



Data Acknowledgment

Waipouwerawera Stream/Tukairangi

Wildlands

Scale: 1:5,000
Date: 30/09/2014
Cartographer: RPB
Format: A4

WAIPOUWERAWERA STREAM/TUKAIRANGI

Site Number:	WKV09[1]	**Grid Reference:**	NZTopo50 BG36 651 185
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1865128 N5718488
Geothermal Field:	Wairakei-Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	468 m
Tenure:	Protected (Waipouwerawera Stream Conservation Area)		
Extent of Geothermal Habitat:	*c.*0.1 ha		
Extent of Geothermal Vegetation:	*c.*0.1 ha		
Date of Most Recent Field Survey:	3 March 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Mānuka-dominant shrubland (05.04) **(Maritime pine)/mānuka-broom-blackberry-Himalayan honeysuckle shrubland (05.04.03)** This vegetation type covers most of the side walls of the explosion craters and appears to be expanding downslope as the ground cools. Occasional maritime pine are emergent over a mixed shrub layer of mānuka, prostrate kānuka, broom, blackberry, and Himalayan honeysuckle. Tāwiniwini, tūrutu, and small patches of ring fern and *Gleichenia microphylla* are also present. Small areas of nonvegetated raw-soilfield occur on the crater floor, and also amongst the larger areas of mānuka and mingimingi. On the cooler crater rim whauwhaupaku is emergent over mānuka, broom, and a thick margin of blackberry.	Crater walls	*c.*0.1 ha
Monoao-dominant shrubland (05.05) **Monoao shrubland (05.05.01)** A patch of monoao shrubland occurs on crater walls in the northeast corner of the explosion craters. There are occasional emergent maritime pines and radiata pines. Prostrate kānuka, kānuka, mingimingi, bracken, *Lycopodium volubile*, and broom are scattered throughout, and whauwhaupaku occurs on the upper margins of this area.	Crater floor, steep crater walls	*c.*0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Patches of geothermally-influenced bare soil are present. No elevated temperatures were found, although access within the site is very hazardous.	Crater floor and walls	<0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[2]) is present. *Dicranopteris linearis* (At Risk-Naturally Uncommon) and *Lycopodiella cernua* have been recorded at the site in the past (Given 1989a), but were not seen in 2003 or 2011, and are unlikely to still be present.

Fauna: Common bird species typical of the habitat (including Australian magpie

[1] Site number in 2004 was U18/10 and U17/9 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

and Eurasian blackbird) are present.

Current Condition (2011 Assessment): The extent of geothermal vegetation and habitat appears to be declining at this site. No evidence of the fumaroles or hot ground recorded in 1989 (Given 1989a) has been observed in the 2003 or 2011 surveys. Since 1989, vegetation cover comprising a mixture of species typical of geothermal and non-geothermal habitats on the crater floor appears to have increased and only small areas of nonvegetated raw-soilfield remain scattered amongst monoao shrubland. Weeds are a problem on the margins with broom, Himalayan honeysuckle, blackberry, and wilding maritime pine on the crater walls and rim terrace.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Wilding pines (maritime pine and radiata pine) (1-5% cover), blackberry (25-50% cover), Himalayan honeysuckle (5-25% cover), poplar (<1%), and broom (25-50% cover) are spreading down the crater sides.

Human impacts (*2011 Assessment*): None observed.

Grazing (*2011 Assessment*): This area is fenced and domestic stock do not have access.

Adjoining land use (*2014 Assessment*): This site is surrounded by farmland.

Site Change:

Recent change (2011 Assessment): An increase in vegetation cover in the crater and a reduction in nonvegetated raw-soilfield suggests that the site has experienced reduced geothermal activity and that soil temperatures have decreased since Given surveyed the site in 1989.

Historical (*Assessed in 2011*): Comparison of 2007 aerial photographs with historical (1961) photographs[1] indicates that a greater extent of bare ground was present in 1961 compared with what is visible in the 2007 photos (i.e. there is an increase in the extent of vegetation in the 2007 aerials). Increased extent of vegetation (including non-geothermal vegetation) could be due to a number of factors including reduced heat from geothermal systems. The extent of geothermal vegetation and habitat appears to be declining at this site (see current condition above).

Management Requirements: Maritime pine and radiata pine wildings should be removed and weed species such as broom and blackberry should be controlled on the rim terrace and crater walls. The landowner proposes to undertake restoration plantings along the stream margins in the near future. Because of the declining geothermal activity at this site, this site is a lower priority for management than other sites in the Wairakei Geothermal Field.

Significance Level: Local (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 19)

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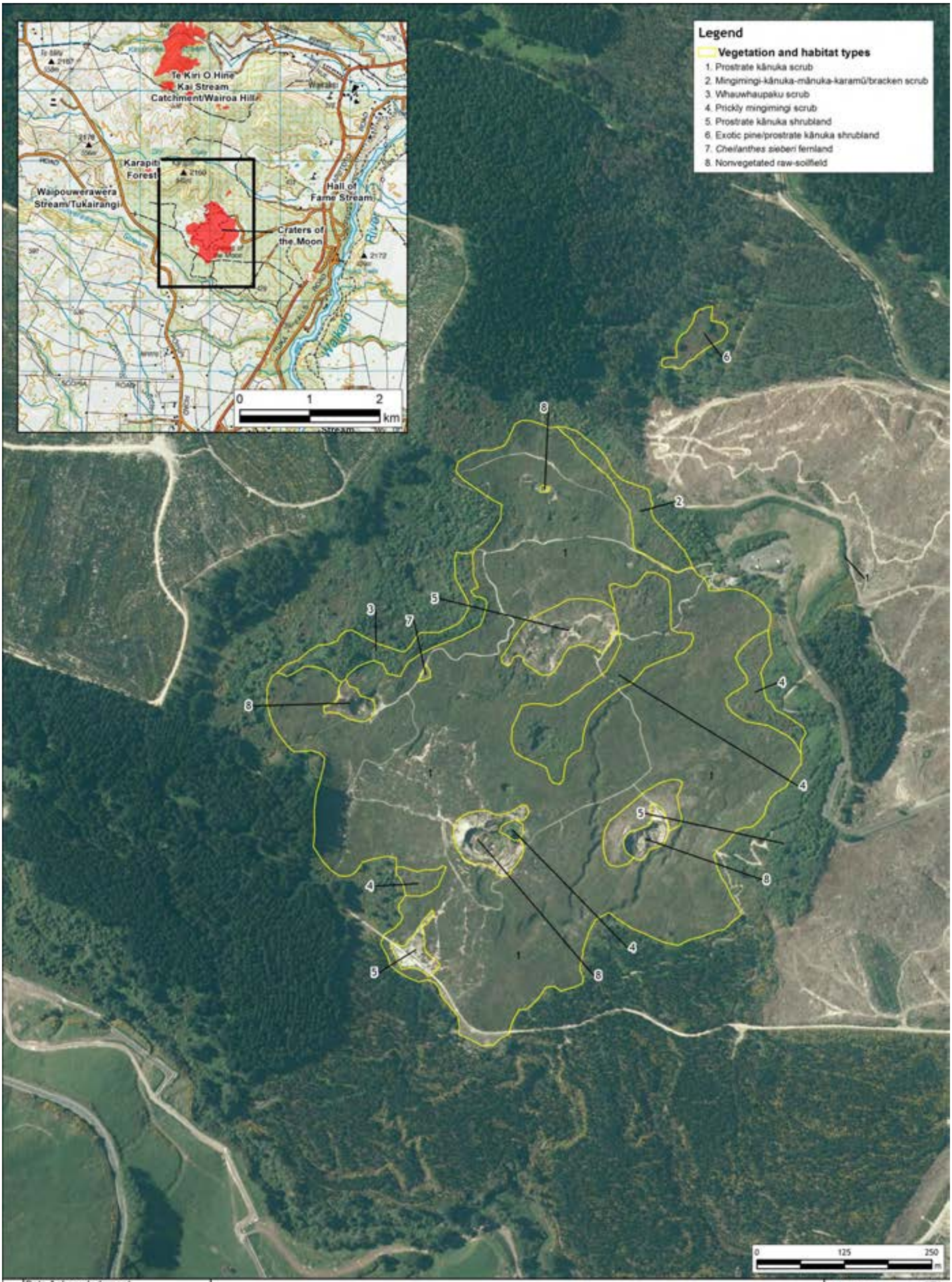
[1] Historical photos: SN 1394 Run 3188 Photos 22-23, 1961.

Significance Justification:	This site is of local significance because it contains a small example of a 'nationally uncommon' habitat (geothermally heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012), and a small population of an 'At Risk' species (prostrate kānuka).
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category B - the second highest category.
References:	Department of Conservation 1997; Given 1989a & 1996; Merrett and Burns 1998a; Wildland Consultants 2004c & 2012.


Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Mingimingi-kānuka-mānuka-karamū/bracken scrub
3. Whauwhaupaku scrub
4. Prickly mingimingi scrub
5. Prostrate kānuka shrubland
6. Exotic pine/prostrate kānuka shrubland
7. Cheilanthes sieberi fernland
8. Nonvegetated raw-soilfield
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Karapiti Forest
Waipouwerawera Stream/Tukairangi
Craters of the Moon
Hall of Fame Stream
Waikato River
0 1 2 km
0 125 250 m
Data Acknowledgment
Map contains data sourced from LINZ
Crown Copyright Reserved
© Waikato Regional Aerial Photography Service (WRAPS) 2012
Craters of the Moon
Wildlands
Scale: 1:5,000
Date: 02/10/2014
Cartographer: RPB
Format: A3

CRATERS OF THE MOON[1]

Site Number:	WKV10[2]	**Grid Reference:**	NZTopo50 BG36 671 180
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1867064 N5718041
Geothermal Field:	Wairakei	**Local Authority:**	Taupo
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*440-460 m
Tenure:	Protected (Ministry of Tourism Reserve)		
Extent of Geothermal Habitat:	*c.*38.1 ha		
Extent of Geothermal Vegetation:	*c.*38.1 ha		
Date of Most Recent Field Survey:	31 January 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Patches of prostrate kānuka up to *c.*2 m high are present throughout the site with scattered minigmingi and monoao and patches of *Lycopodiella cernua* and *Dicranopteris linearis*. Patches of *Campylopus clavatus* are common, and *Trentepholia* is common on prostrate kānuka branches. Occasional wilding pines are present throughout.	Flat	*c.*29.7 ha
Mingimingi-dominant scrub (04.03) **Mingimingi-kānuka-mānuka-karamū/bracken scrub (04.03.03)** A mixture of mingimingi, prostrate kānuka, mānuka and karamū forms a dense scrub cover, with small patches of bracken, blackberry, Himalayan honeysuckle and *Dicranopteris linearis* around the margins. Near the main entrance of the Reserve, Himalayan honeysuckle and bracken dominate a recently cleared hillslope, with broom and mingimingi scattered throughout and patches of *Dicranopteris linearis* on steep banks at the base of the hillslope.	Flat	*c.*0.7 ha
Whauwhaupaku-dominant scrub (04.05) **Whauwhaupaku scrub (04.05.01)** Occasional wilding radiata pine up to *c.*10 m tall are emergent over abundant whauwhaupaku up to *c.*8 m tall. Karamū and blackberry are common within this vegetation type, and Himalayan honeysuckle, koromiko, mingimingi, and bracken dominate the understorey. *Nephrolepis flexuosa* occurs locally on the margins, and *Dicranopteris linearis* is abundant on small banks at the edge of the crater. Near the main entrance of the Reserve, mamaku (*Cyathea medullaris*), in association with māhoe and young kāmahi, dominates a recently cleared hillslope.	Hillslope	*c.*1.1 ha
Prickly mingimingi-dominant scrub (04.07) **Prickly mingimingi scrub (04.07.01)** Occasional emergent mānuka up to *c.*4.5 m tall are present over a canopy dominated by prickly mingimingi up to *c.*3.5 m height with common whawhaupaku, karamū, and kōhūhū, and broom scattered to locally common throughout. Bracken, *Asplenium polyodon*,	Flat	*c.*3.1 ha

[1] This site was called Karapiti (Craters of the Moon) in Beadel & Bill (2000).
[2] Site number in 2004 was U18/4 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
blackberry, tūrutu, and *Lycopodium volubile* are scattered throughout the understory, and patches of *Dicranopteris linearis* are common.		
Prostrate kānuka-dominant shrubland (05.01)		
Prostrate kānuka shrubland (05.01.01) Prostrate kānuka to a height of *c.*0.3-0.5 m covers most of the site. There are local patches of *Lycopodiella cernua* and *Dicranopteris linearis*, and areas of nonvegetated raw-soilfield. The moss *Racomitrium* is locally common.	Flat	*c.*1.9 ha
Exotic pine/prostrate kānuka shrubland (05.01.04) Occasional emergent lodgepole pine and radiata pine are present over prostrate kānuka shrubland in the north of the site. Occasional mingimingi, Spanish heath, and Chinese privet are present. This area of shrubland is fringed by mixed indigenous and exotic species scrub dominated by mingimingi, Chinese privet, and broom over bracken with scattered tūrutu.	Flat	*c.*0.4 ha
Indigenous fernland (07.01)		
***Dicranopteris linearis* fernland (07.01.01)** Scattered emergent prostrate kānuka, tūrutu and mānuka are present over fernland dominated by *Dicranopteris linearis*, in association with *Lycopodiella cernua,* and occasional monoao and water fern. This vegetation type occurs amongst prostrate kānuka scrub and shrubland but is too small to map separately.	Flat and hillslope	Not mapped
***Cheilanthes sieberi* fernland (07.01.13)** A small area dominated by *Cheilanthes sieberi* and dead mixed exotic grasses, mainly annual poa and bay grass (*Eragrostis brownii*). It is near a walking track and appears to have developed following disturbance. This area appears to have been sprayed with herbicide and is in poor health.	Flat	<0.1 ha
***Dicranopteris linearis*-water fern-*Lycopodiella cernua* fernland (07.01.14)** Occasional emergent buddleia are present over fernland dominated by *Dicranopteris linearis,* water fern, and *Lycopodiella cernua* on the walls of an active fumarole. There are local patches of ring fern, bracken, monoao, and the mosses *Campylopus clavatus* and *Sphagnum cristatum*. The margins of the crater support narrow-leaved carpet grass. This type occurs amongst prostrate kānuka scrub and shrubland but areas are too small to map separately.	Fumarole	Not mapped
***Lycopodiella cernua* fernland (07.01.15)** A discontinuous cover of *Lycopodiella cernua* over dense mats of the moss *Campylopus clavatus* occurs in association with heated loamfield. Occurs amongst prostrate kānuka scrub and shrubland but is too small to map separately.	Flat	Not mapped
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Sinter pavement. Small patches of *Campylopus clavatus* mossfield with occasional *Lycopodiella cernua* are present.	Flat	*c.*1.2 ha

Indigenous Flora:

Prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Campylopus clavatus*, which are both endemic and restricted to geothermal areas, are common throughout this site.

Other 'At Risk' species present include *Dicranopteris linearis* (At Risk-Naturally Uncommon), *Hypolepis dicksonioides* (At Risk-Naturally Uncommon), and *Nephrolepis flexuosa* (At Risk-Declining). *D. linearis* is known from only *c.*23 sites in New Zealand. *Lycopodiella cernua* and *Psilotum nudum*, both of which are characteristic of geothermal areas, are also present.

Other species of interest present include *Cheilanthes sieberi*. Given (1989a) recorded *Asplenium flabellifolium* growing on hot siliceous soil (which is not its usual habitat) and *Fimbristylis velata*, which was reported to be at its southern limit. *A. flabellifolium* and *F. velata* have not been recorded from this site since 1989.

Fauna:

Common indigenous and introduced bird species typical of the habitat are present including tūī, New Zealand pipit, grey warbler, spur-winged plover, Eurasian blackbird, and goldfinch.

Current Condition (2014 Assessment):

This is a large site and is in good condition. There is clear vegetation zonation in response to different levels of heat flux (Given 1980). Commissioning of the Wairakei geothermal power station resulted in an increase in steam-heated activity at Karapiti which has increased the size of the site and the extent of geothermal vegetation present (Burns *et al*. 1996; Cave *et al*. 1993).

The site is threatened by wilding pine and other weed species. Control of these species will be necessary to maintain the high quality geothermal vegetation at the site.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*):

Several wilding pines (particularly radiata pine and maritime pine), and eucalyptus are scattered through the site, despite some recent wilding pine control. Other invasive plant species present include blackberry (3% cover), Chinese privet (<1% cover), lupin (<1% cover), cotoneaster (<1% cover), Kahsia berry (<1% cover), black wattle (<1% cover), grey willow (<1% cover), lodgepole pine (<1% cover), Himalayan honeysuckle (<1% cover), broom (3% cover), Montpellier broom (<1% cover), ornamental cherry (<1% cover), buddleia (2% cover), pampas (1% cover), Spanish heath (<1% cover), narrow-leaved carpet grass (3% cover), and Mercer grass (<1% cover). Where present, these species are having a negative impact on the indigenous character of the site. The Waikato Regional Council has recently undertaken aerial control of pampas at this site.

Human impacts (*2014 Assessment*):

The extent of heated ground around Craters of the Moon increased significantly following the development of the Wairakei geothermal field for electricity generation and there have been many changes in geothermal

[1] All flora threat rankings are from de Lange *et al.* 2013.

activity. The vegetation and geothermal features of this site continue to respond to the heating and cooling of soils, remaining vulnerable to the management of the geothermal power plant (Given 1989a).

This area is a popular spot for visitors. It is riddled with walking tracks (many disused), but visitors are now encouraged to keep to the main path which is maintained by the Craters of the Moon Trust. The site caretaker is utilising a variety of techniques to discourage people from walking off the main path.

The substrate of the network of informal tracks created by visitors trying to get closer to geothermal features is compacted. This limits the potential for indigenous plants to recolonise these areas. In addition, there may be a significant effect of compaction on soil micro-organisms.

The removal of some wilding pines from the reserve has improved the long-term viability of the site. Spraying of some areas with herbicide has adversely affected some indigenous communities (e.g. *Cheilanthes* fernalnd).

Grazing (*2014 Assessment*): Livestock are not a threat to this site, however brushtail possum, hares, and rabbit are present and are browsing the vegetation.

Adjoining land use (*2014 Assessment*): Plantation forest, recreational cycling, and horse trekking.

Site Changes:

Recent change (2014 Assessment): Some pest plant control work has been undertaken recently by site managers. Techniques to discourage use of informal tracks have been implemented by the Craters of the Moon Trust. The Waikato Regional Council undertook control of patches of pampas at this site in April 2011 by the aerial application of herbicide.

Historical (*Assessed in 2011*): Burns *et al.* (1996) have assessed vegetation change at this site using aerial photographs from 1945 to 1993 and found that there has been an eight-fold increase in geothermal vegetation at this site. However, there is no information on changes of structure or composition of this vegetation.

Management Requirements: Control of wilding pines and other pest plants needs to continue. Continued monitoring of this area will be invaluable for assessing the impacts of geothermal power extraction (refer to Burns *et al.* 1996; Merrett and Burns 1998b&c). The practice of discouraging the use of informal tracks should be continued.

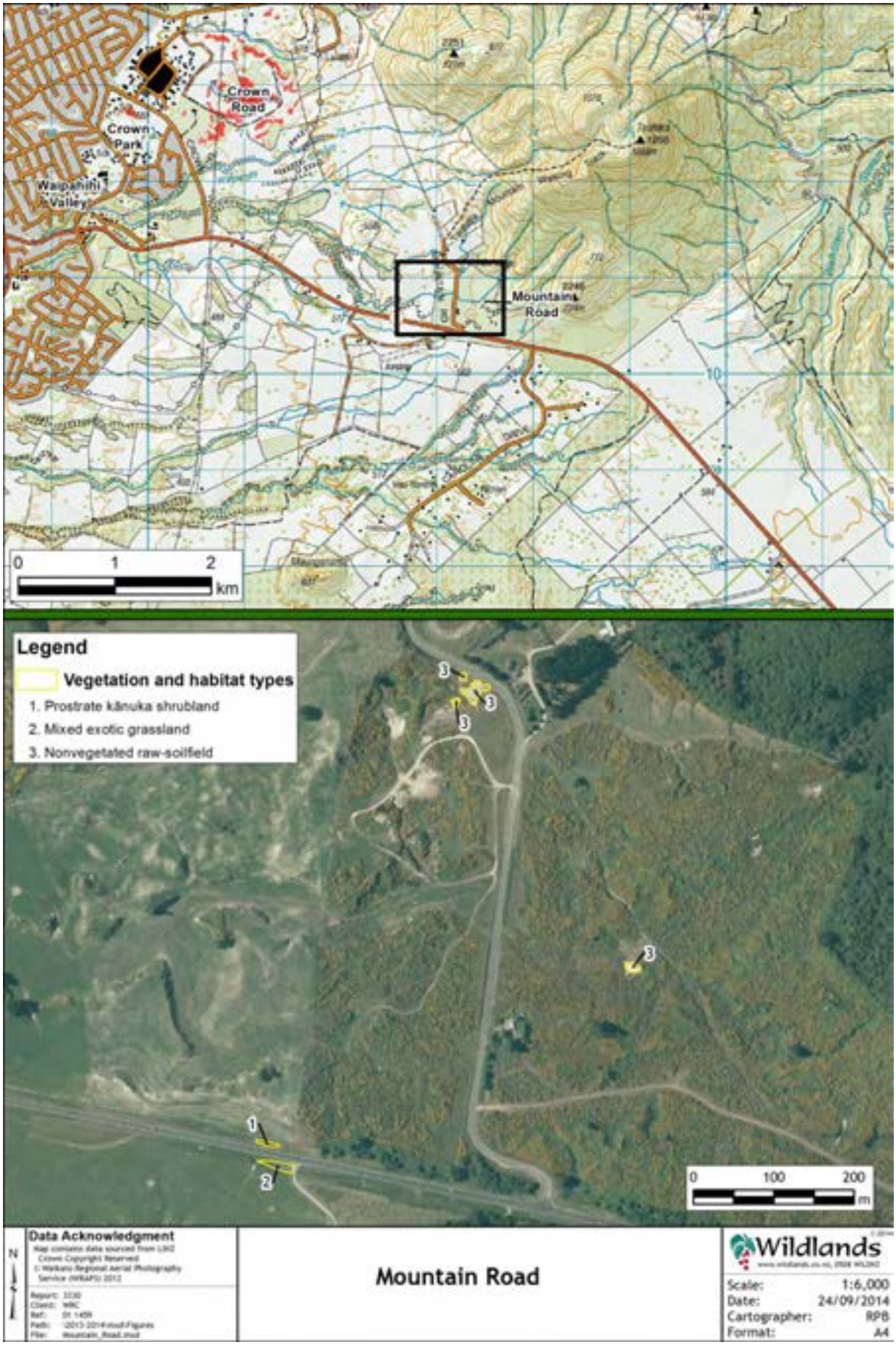
Significance Level: National (Table 1 - Criteria 1, 3, 5, 7, 9; Table 2 - Factor 8).

Significance Justification: Craters of the Moon is of national significance because it contains a good quality representative example of geothermal vegetation, which includes nationally uncommon ecosystem types (geothermally heated dry ground, fumaroles; Williams *et al.* 2007, Holdaway *et al.* 2012). It contains one of the best examples of thermotolerant vegetation zonation which has developed in response to soil temperatures, and is an area of high geothermal activity (Given 1980). Four species classed as 'At Risk' are present: prostrate kānuka, *Dicranopteris linearis*, *Hypolepis dicksonioides*,

and *Nephrolepis flexuosa*.

Notes: Given (1996) assessed the botanical values of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category A - the highest category.

References: Beadel and Bill 2000; Burns *et al.* 1996; Clarkson 1989; Given 1980, 1989a & 1996; Merrett and Burns 1998b&c; Spring-Rice 1996; Wildland Consultants 2004c, 2007c, & 2012.


Crown Road
Crown Park
Waipahihi Valley
Mountain Road
0 1 2 km
Legend
Vegetation and habitat types
1. Prostrate kānuka shrubland
2. Mixed exotic grassland
3. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Mountain Road
Wildlands
Scale: 1:6,000
Date: 24/09/2014
Cartographer: RPB
Format: A4

MOUNTAIN ROAD

Site Number: THV08
Grid Reference: NZTopo50
Ecological District: Taupō
GPS Reference: NZTM E1872910, N5710515, E1873365, N5710734, E1873145, N5711064
Geothermal Field: Wairaikei-Tauhara
Local Authority: Taupō
Bioclimatic Zone: Submontane
Altitude: 520 m
Tenure: Road reserve, unprotected private land
Extent of Geothermal Habitat: *c.*0.1 ha
Extent of Geothermal Vegetation: *c.*0.1 ha
Date of Most Recent Field Survey: 16 July 2014

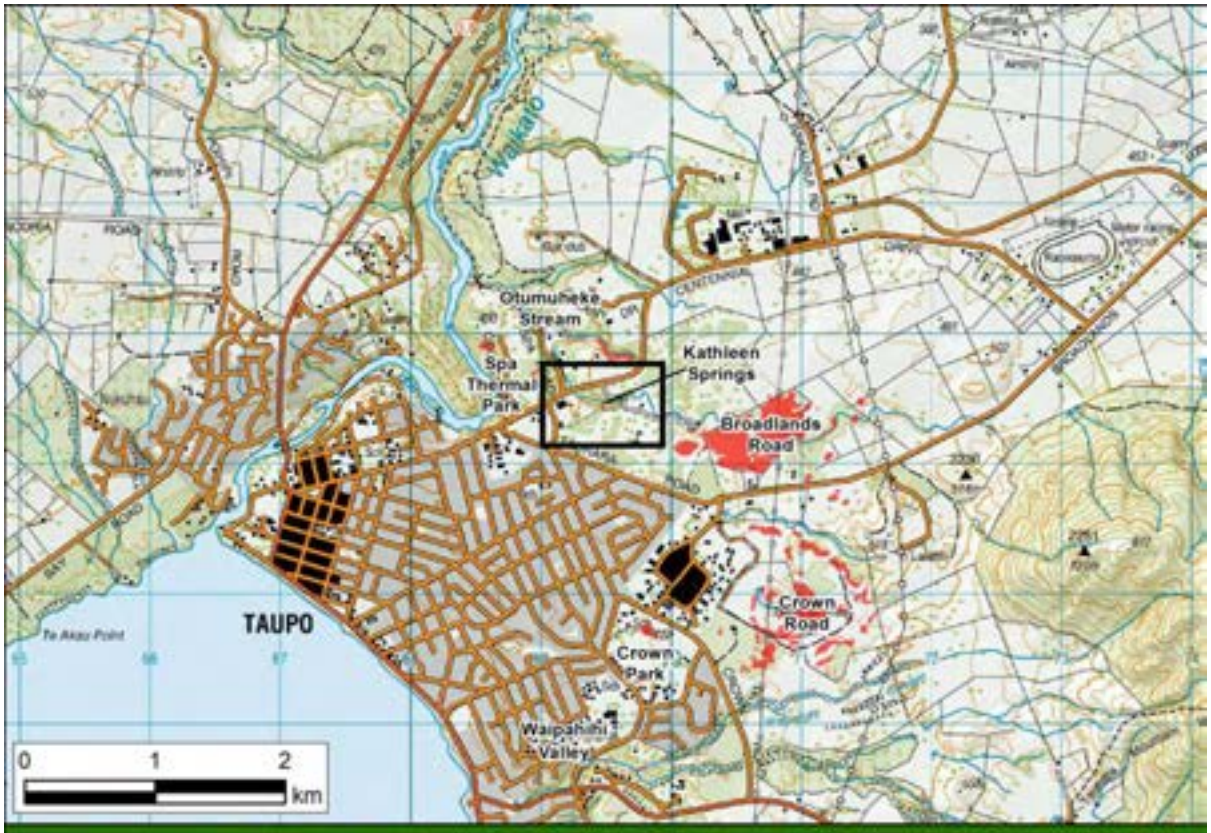
VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** A small area of geothermally heated soils in a roadside ditch with prostrate kanuka shrubland up to 0.25 m tall over exotic grassland dominated by narrow-leaved carpet grass, and patches of the moss *Wijkia extenuata*. The liverwort *Chiloscyphus semiteres* is also present.	Roadside ditch	<0.1 ha
Exotic grassland (08.01) **Mixed exotic grassland (08.01.15)** A small area of nonvegetated raw-soilfield with a cover of narrow-leaved carpet grass and Mercer grass grassland located in the base of a roadside ditch beside State Highway 5. Occasional *Lycopodiella cernua* is present on the banks of the ditch. A steam vent surrounded by rocks, moss, and grass is present within this type.	Roadside ditch	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Non-vegetated raw-soilfield surrounded by exotic grasses including narrow-leaved carpet grass, cocksfoot, and browntop. Steam is present rising from a hole (location marked as A on the site map), which appears to be used for cooking. Loose pumice is present on the surface. Soil temperatures up to 63.2 °C (2014 measurement) were recorded from within these areas and steam rising from the hole was *c.*80 °C.	Flat	*c.*0.1 ha

Indigenous Flora: A very small population of prostrate kānuka (At Risk-Naturally Uncommon[1]) is present within this site. *Lycopodiella cernua*, a plant characteristic of geothermal habitats is present in the parts of this site close to State Highway 5.

Fauna: Grey warbler and bellbird were recorded during the 2014 field survey. Other common indigenous and exotic bird species typical of the habitat types are likely to be present.

[1] All flora threat rankings are from de Lange *et al.* 2013.

Current Condition (2014 Assessment):	This small site has been degraded by human use, trampling by domestic stock, and invasion by exotic plant species.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2014 Assessment*):	Narrow-leaved carpet grass is common within this site. Broom and blackberry are locally present around the margins but are currently kept in check by domestic stock grazing.
Human impacts (*2014 Assessment*):	Part of the site is used for cooking food and appears to have been modified for this purpose. The areas within roadside ditches are likely to be regularly disturbed during routine roadside maintenance. The surrounding natural vegetation has been cleared for farming and transport infrastructure. Rubbish is present in the roadside ditches.
Grazing (*2014 Assessment*):	Domestic cattle and horses have access to parts of this site. Areas of nonvegetated raw-soilfield are grazed to the margins, and the soilfield is trampled.
Adjoining land use (*2014 Assessment*):	Farming, State Highway.
Site Change:	
Recent change (2014 Assessment):	This site has not previously been assessed. The vegetation within the roadside ditches appears to be similar to that described in Merret and Fitzgerald (2006).
Historical (*Assessed in 2011*):	No historical photos are available for this site.
Management Requirements:	Fence the areas of nonvegetated raw-soilfield within this site to exclude domestic stock.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).
Significance Justification:	This small site is locally significant because it contains a small area of a naturally uncommon habitat type (geothermally heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also includes a small population of an 'At Risk' indigenous plant species (prostrate kānuka), but does not represent habitat of considerable importance for the conservation of this species.
References:	Merret and Fitzgerald 2006



Data Acknowledgment

Kathleen Springs

Wildlands

Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

KATHLEEN SPRINGS

Site Number:	THV09	**Grid Reference:**	NZTopo50
Ecological District:	Taupō	**GPS Reference:**	NZTM E1869478 N5714492
Geothermal Field:	Wairaikei-Tauhara	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	400 m
Tenure:	Protected (Taupō District Council Reserve)		
Extent of Geothermal Habitat:	*c.*0.1 ha		
Extent of Geothermal Vegetation:	*c.*0.1 ha		
Date of Most Recent Field Survey:	17 July 2014		

VEGETATION TYPE	LANDFORM	EXTENT
Mixed indigenous and exotic shrubland (05.08) **(Wilding pine)/(Chinese privet)/prostrate kānuka-blackberry-water fern-*Hypolepis ambigua*-bracken shrubland (05.08.06)** Scattered radiata pine to 10 m tall and Chinese privet are present over a mixed shrub-fernland comprising prostrate kānuka, blackberry, water fern, *Hypolepis ambigua*, and bracken. Currently ferns are more common than the blackberry, but blackberry cover is increasing. Himalayan honeysuckle, mingimingi, karamū, mānuka, and kiokio are also locally common. The steep banks around the part of the site that was previously geothermally active have abundant maritime pine and radiata pine (up to *c.*30 m tall), and occasional silver birch. Several small patches of prostrate kānuka to 5 m tall are present. The site had flowing geothermal springs which ceased to flow between 1997 and 2000 (Bromley *et al.* 2010). The AC baths complex discharges water into the channel, downstream of the former springs.	Riparian margin	*c.*0.1 ha

Indigenous Flora: A very small population of prostrate kānuka (At Risk-Naturally Uncommon[1]) is present within this site. The site supported a population of *Cyclosorus interruptus* (At Risk-Declining) until at least 2006 (Merrett and Fitzgerald 2006, Burns *et al.* 1995), but no plants were found at the site in the current survey (2014). A small population of *Christella* aff. *dentata* ("thermal") (At Risk-Naturally Uncommon) has also previously been recorded from this site but has not been recorded at this site since 1995 (Burns *et al.* 1995).

Fauna: Common indigenous and exotic bird species typical of the habitat types are likely to be present.

Current Condition (2014 Assessment): This small site has been degraded by human use, and exotic plant species.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Blackberry is common within the site (20% cover), and has increased in cover since the last field inspection. Other invasive pest plant species present include radiata pine (5% cover), maritime pine (5% cover), Chinese

[1] All flora threat rankings are from de Lange *et al.* 2013.

privet (5% cover), Khasia berry 5% (cover), Himalayan honeysuckle (5% cover), silver birch (1% cover), ornamental cherry (1% cover), pampas (1% cover), and strawberry tree (1% cover).

Human impacts (*2014 Assessment*): Geothermal features within the site have become quiescent due to the continued drawdown from the field for geothermal power generation. Lowered soil temperatures have enabled the establishment of invasive pest plant species.

Grazing (*2014 Assessment*): Livestock do not have access to the site.

Adjoining land use (*2014 Assessment*): Road, recreation area, park.

Site Change:

Recent change (2014 Assessment): The site has been surveyed by Merret and Fitzgerald (2006), and Bromley *et al.* (2010). Since 2006, there has been a marked decrease in cover of geothermal vegetation. Geothermal vegetation within the site is slowly being replaced by exotic pest plant species.

Historical (*Assessed in 2011*): No historical photos are available for this site.

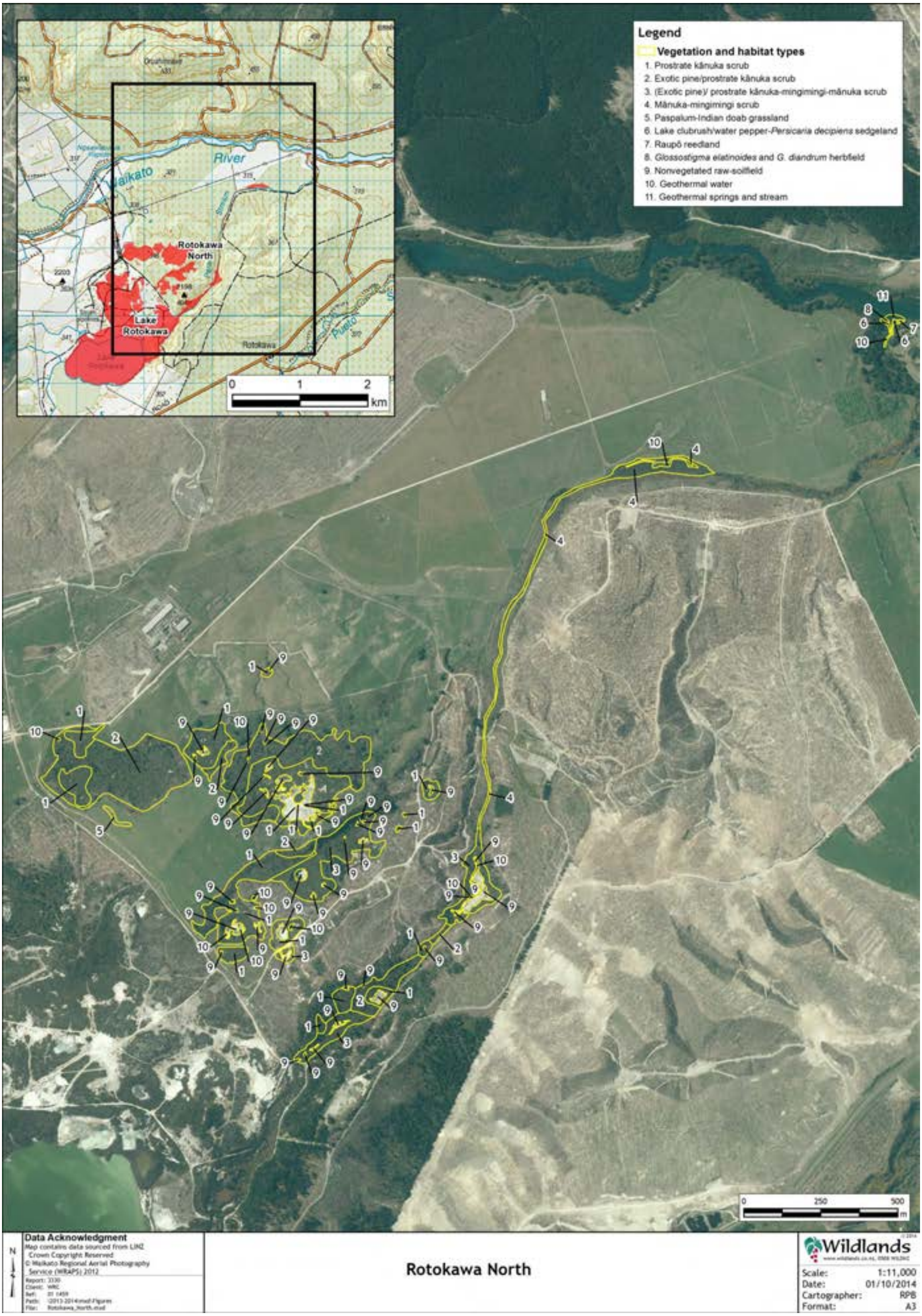
Management Requirements: Control of invasive pest plant species, particularly wilding pine and blackberry, could be undertaken within this site. However the site is a low priority for management. Monitoring of pest plant species and impacts associated with geothermal power station operation should continue.

Significance Level: Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).

Significance Justification: This small site is locally significant because it contains a small area of a naturally uncommon habitat type (geothermally habitat). The site also includes a small population of an 'At Risk' indigenous plant species (prostrate kānuka), but does not represent habitat of considerable importance for the conservation of this species.

References: Bromley *et al.* 2010, Merret and Fitzgerald 2006.

ROTOKAWA GEOTHERMAL FIELD


Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Exotic pine/prostrate kānuka scrub
3. (Exotic pine)/ prostrate kānuka-mingimingi-mānuka scrub
4. Mānuka-mingimingi scrub
5. Paspalum-Indian doab grassland
6. Lake clubrush/water pepper-Persicaria decipiens sedgeland
7. Raupō reedland
8. Glossostigma elatinoides and G. diandrum herbfield
9. Nonvegetated raw-soilfield
10. Geothermal water
11. Geothermal springs and stream
Waikato River
Rotokawa North
Lake Rotokawa
Rotokawa
0 1 2 km
0 250 500 m
Data Acknowledgment
Map contains data sourced from LINZ
Crown Copyright Reserved
© Waikato Regional Aerial Photography Service (WRAPS) 2012
Rotokawa North
Wildlands
Scale: 1:11,000
Date: 01/10/2014
Cartographer: RPB
Format: A3

ROTOKAWA NORTH

Site Number:	RKV01[1]	**Grid Reference:**	NZTopo50 BG37 784 209
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1878482 N5720902
Geothermal Field:	Rotokawa	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*320-400 m
Tenure:	Protected (Lake Rotokawa Conservation Area) and unprotected private land		

Extent of Geothermal Habitat: *c.*40.7 ha
Extent of Geothermal Vegetation: *c.*40.1 ha
Date of Most Recent Field Survey: 13 May 2014

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka forms a canopy up to *c.*2 m height with mingimingi and prickly mingimingi scattered throughout. Kānuka, mānuka, monoao, and bracken are locally common on cooler soils; broom and buddleia are common, and wilding pines (mostly radiata pine) are scattered throughout. The groundcover is patchy, comprising mainly lichens (*Cladia* and *Cladonia* species). Fumaroles, thermal springs, and gas vents are scattered throughout this type. **Exotic pine/prostrate kānuka scrub (04.01.03)** Maritime pine and some radiata pine are scattered to locally common within large areas of prostrate kānuka scrub. *Lycopodiella cernua*, mingimingi, Mercer grass, prickly mingimingi, bracken, *Gleichenia microphylla*, ring fern, and *Hypolepis distans* are scattered throughout. Mingimingi and blackberry become more common towards the margins. Sheep's sorrel and wild seradella occur in disturbed sites.	Flat and gentle hillslopes Flat and gentle hillslopes	*c.*11.8 ha *c.*15.3 ha
Prostrate kānuka-mingimingi scrub (04.02) **(Exotic pine)/ prostrate kānuka-mingimingi-mānuka scrub (04.02.04)** Mingimingi, mānuka, and prostrate kānuka form a canopy to *c.*2 m high, with occasional emergent maritime pine and radiata pine and small patches of monoao and nonvegetated raw-soilfield.	Flat and gentle hillslopes	*c.*6.3 ha
Mānuka-dominant scrub (04.04) **Mānuka-mingimingi scrub (04.04.02)** Mānuka forms a canopy up to *c.*5 m in height (range 1-5 m) over an understorey dominated by mingimingi and bracken on the margins of a geothermal stream (surface water temperature up to *c.*29 °C in 2014). *Lycopodiella cernua*, water fern, and *Hypolepis ambigua* are locally common. Patches of bracken fernland are present within this type, within local patches of gorse and occasional emergent radiata pine, eucalyptus, and Douglas fir. Small patches of prostrate kānuka, blackberry, and pampas form a	Riparian margins	*c.*2.4 ha

[1] Site number in 2004 was U17/34 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
canopy up to *c.*5 m height over bare soil on some moderate to steep slopes within this type. Local patches of umbrella sedge, *Cyperus ustulatus*, and *Eleocharis gracilis* occur close to the sream edge.		
Exotic grassland (08.01) **Paspalum-Indian doab grassland (08.01.14)** Exotic grassland dominated either by paspalum or Indian doab with occasional prostrate kānuka. Wild seradella and wild portulaca are common. These areas have declined in condition since 2004 (i.e. exotic species have become more common).	Flat	*c.*0.1 ha
Indigenous sedgeland (09.01) **Lake clubrush/water pepper-*Persicaria decipiens* sedgeland (09.01.06)** Lake clubrush sedgeland is common, in association with water pepper (*Persicaria hydropiper*) and *Persicaria decipiens*, and local umbrella sedge. Located on a small geothermally influenced river flat.	Wetland	*c.*0.1 ha
Reedland (11.01) **Raupō reedland (11.01.01)** Raupō dominated reedland with locally common lake clubrush and *Carex secta* scattered throughout a long, narrow geothermally influenced river flat. *Calystegia tuguriorum* is common. Scrub dominated by prostrate kānuka, blackberry, sharp-fruited rush (*Juncus acuminatus*), and *Carex geminata* with occasional grey willow fringes the landward side of the reedland.	River margin	<0.1 ha
Herbfield (13.01) ***Glossostigma elatinoides* and *G. diandrum* herbfield (13.01.03)** Submerged indigenous turfs dominated by *Glossostigma elatinoides* and *G. diandrum* occurs on the margins of the Waikato River is present around geothermal springs reaching 63.8 °C in 2014. Water purslane, *Callitriche petriei*, and *Myriophyllum pedunculatum* are present in cooler areas.	River margin	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Sinter deposits and fumaroles. Patches of prostrate kānuka and broom.	Flat	*c.*4.0 ha
Water (22.01) **Geothermal water (22.01.01)** Hot water and mudpools. **Geothermal springs and stream (22.01.03)** Springs located within water on the margins of the Waikato River (up to *c.*15 m from the river margins) and within Parariki Stream (to *c.*40 m upstream of the stream mouth).	Flat and gentle hillslopes River margin	*c.*0.5 ha *c.*0.1 ha

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[1]) and *Lycopodiella cernua* are present. Prostrate kānuka is endemic to geothermal sites, and *Lycopodiella cernua,* is a characteristic feature of geothermal areas.

Dicranopteris linearis (At Risk-Naturally Uncommon) (*c*.10 plants) and *Nephrolepis flexuosa* (At Risk-Declining) (*c*.2 plants), were present on the sides of a hot spring at GPS reference: E1877709 N5721043 in 2004. These plants were not observed in 2014 but dense steam made it difficult to see the crater margins.

D. linearis is known from only *c*.23 sites in New Zealand.

Fauna: New Zealand pipit (At Risk-Declining[2]), North Island fernbird (At Risk-Declining), New Zealand falcon (Threatened-Nationally Vulnerable), Australasian harrier, spur-winged plover, fantail, grey warbler, tūī, Australasian shovler, kōtare (sacred kingfisher), welcome swallow, Australian magpie, common myna, California quail, and common pheasant have been recorded from the site.

Current Condition (2014 Assessment): This area and its surrounds have been modified by forestry operations and pastoral farming, resulting in a reduction in extent of geothermal vegetation. Invasive exotic plant species form a large component of the vegetation in the north of the site, in particular wilding pines, which in some areas dominate the canopy over a lower tier of indigenous vegetation dominated by species characteristic of geothermal areas. However, geothermal vegetation remains relatively intact in several areas. Two areas of nonvegetated raw-soilfield have declined in condition since 2004 and now support exotic grassland.

Near the Waikato River, environmental pest plant species are common and the site is is likely to be disturbed on an intermittent basis during duck hunting season (a maimai is present within the site).

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*): Wilding pines (6-25% cover) are visually dominant, and are a serious threat to plant communities on cooler ground. In some areas pines are dominant over a lower indigenous tier comprising prostrate kānuka and mingimingi. Some wilding pine control has been undertaken along the margins of the geothermal stream. Other invasive pest plant species present include broom (5% cover), umbrella sedge (1% cover), Himalayan honeysuckle (1% cover), buddleia (1% cover), pasture grasses (including creeping bent, browntop, sweet vernal, Yorkshire fog, paspalum, Indian doab, and ryegrass) (1% cover), gorse (2% cover), pampas (1% cover), grey willow (<1% cover), cotoneaster (<1% cover), Montpellier broom (<1% cover), and blackberry (2% cover).

Human impacts (*2014 Assessment*): Forestry and pastoral farming occurs between areas of indigenous geothermal vegetation. A maimai is present on the lower hillslope above the lake clubrush reedland immediately beside Parariki Stream.

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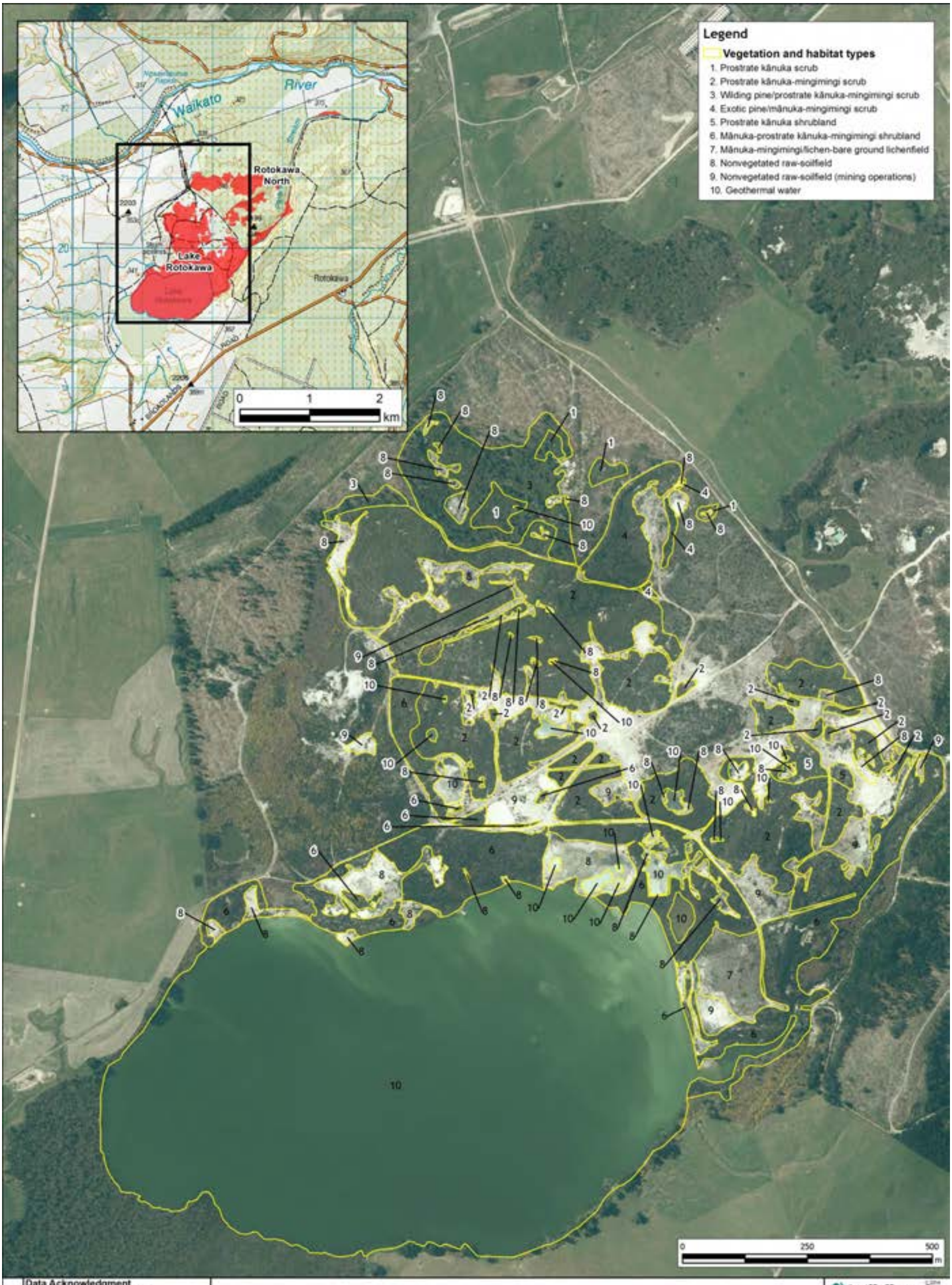
1 All flora threat rankings are from de Lange *et al.* 2013.
2 All avifauna threat rankings are from Robertson *et al.* 2013.

	A geothermal power station has been installed (Merrett and Burns 1997) in close proximity to the site. The impacts of draw-off are unknown.
Grazing (*2014 Assessment*):	Livestock have access to some of the smaller areas of geothermal vegetation.
Adjoining land use (*2014 Assessment*):	Plantation forest and farmland.
Site Change:	
Recent change (2014 Assessment):	Changes to the site map is based on better site information and aerial photograph quality rather than real change in the total extent of geothermal vegetation. The site has been extended down the Parariki Stream towards the Waikato River and now includes an area of geothermally influenced wetland on the margins of the Waikato River. This addition is not the result of new areas of geothermal activity but is rather a result of new information.
Historical (*Assessed in 2011*):	Comparison of 1941 aerial photographs[1] and 2007 aerial photographs was undertaken. In the 1941 photo there appears to have been more clearance for farming around geothermal features than in recent years. However by 2007, extensive areas had been planted in pine plantation. The impacts of wilding pines in geothermal habitats are minimal in 1941. While more bare ground was present in 1941, it is difficult to determine if these areas reflect surface geothermal activity or clearance caused by farming activities (e.g. stock).
Management Requirements:	A management plan for pest plant control, particularly wilding conifers, should be prepared and implemented for this siteThe spread of wilding pines and other exotic trees needs to be contained, with emphasis on those areas which are still predominantly indigenous. Pest plant control within this site should complement the work that has already been undertaken at the Lake Rotokawa site. Pampas and grey willow control should be undertaken within the part of this site near the Waikato River. The site should be monitored to identify changes that may relate to geothermal power draw-off.
Significance Level:	Regional (Table 1 - Criteria 3, 5, 7, 9; Table 2 - Factors 12, 14).
Significance Justification:	This site is of regional significance because it comprises a large area of geothermal vegetation, which includes nationally uncommon habitat types (fumaroles, geothermally heated dry ground, geothermal stream margins, lake shore wetland; Williams *et al*. 2007; Holdaway *et al.* 2012). While parts are degraded in quality, an 'At Risk' species (prostrate kānuka) covers extensive areas and small populations of two other 'At Risk' plant species: *Dicranopteris linearis* and *Nephrolepis flexuosa* are also present.
References:	Merrett and Burns 1997; Wildland Consultants 2004c & 2012.

[1] Historical photo: SN 172 Run 1173 Photos 10-13, 1941.


Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Prostrate kānuka-mingimingi scrub
3. Wilding pine/prostrate kānuka-mingimingi scrub
4. Exotic pine/mānuka-mingimingi scrub
5. Prostrate kānuka shrubland
6. Mānuka-prostrate kānuka-mingimingi shrubland
7. Mānuka-mingimingi/lichen-bare ground lichenfield
8. Nonvegetated raw-soilfield
9. Nonvegetated raw-soilfield (mining operations)
10. Geothermal water
Waikato River
Rotokawa North
Lake Rotokawa
Rotokawa
0 1 2 km
0 250 500 m
Data Acknowledgment
Map contains data sourced from LINZ
Crown Copyright Reserved
© Waikato Regional Aerial Photography Service (WRAPS) 2012
Lake Rotokawa
Wildlands
Scale: 1:7,000
Date: 24/09/2014
Cartographer: RPB
Format: A3

LAKE ROTOKAWA

Site Number:	RKV02[1]	**Grid Reference:**	NZTopo50 BG37 778 198
Ecological District:	Atiamuri	**GPS Reference:**	NZTM E1877887 N5719763
Geothermal Field:	Rotokawa	**Local Authority:**	Taupō
Bioclimatic Zone:	Submontane	**Altitude:**	*c.*340-360 m
Tenure:	Protected (Lake Rotokawa Conservation Area) and unprotected private land		

Extent of Geothermal Habitat: *c.*145.4 ha
Extent of Geothermal Vegetation: *c.*74.7 ha
Date of Most Recent Field Survey: 15 July 2014

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka forms a canopy up to *c.*1.5 m height with occasional emergent maritime pine. Mingimingi, bracken, and tūrutu are common. Extensive pine control has been undertaken within this vegetation type, with pine debris comprising *c.*20% of ground cover. Bare soil comprises a further *c.*20% of ground cover. Local patches of bracken are present and tūrutu is scattered throughout. Prickly mingimingi, mānuka, tāwiniwini, gorse, *Lycopodiella cernua*, and ring fern are also present.	Flat and gentle hillslopes	*c.*1.1 ha
Prostrate kānuka-mingimingi scrub (04.02) **Prostrate kānuka-mingimingi scrub (04.02.01)** Prostrate kānuka and mingimingi form a canopy up to *c.*2 m in height with monoao scattered throughout and occasional emergent whekī and kāmahi. Local patches of mānuka are present, and bracken and prickly mingimingi are common. **Wilding pine/prostrate kānuka-mingimingi scrub (04.02.03)** Maritime pine and occasional radiata pine up to *c.*15 m height are emergent over a prostrate kānuka and mingimingi dominated canopy (*c.*2 m height). Local patches of bracken are present, and tūrutu is scattered throughout. Prickly mingimingi, mānuka, tāwiniwini, gorse, *Lycopodiella cernua*, and ring fern are also present. Wilding pine control has been undertaken in parts of this type.	Gentle hillslopes, flat Gentle hillslopes	*c.*28.0 ha *c.*6.0 ha
Mānuka-dominant scrub (04.04) **Exotic pine/mānuka-mingimingi scrub (04.04.03)** Occasional emergent radiata pine and maritime pine over a mānuka and mingimingi dominated canopy (*c.*2.5 m height) on the margins of Parariki Stream. Prickly mingiminigi is locally common. Pines have been controlled within part of this type.	Riparian margin	*c.*2.4 ha
Prostrate kānuka shrubland (05.01) **Prostrate kānuka shrubland (05.01.01)** Prostrate kānuka forms a canopy up to *c.*1 m height over nonvegetated raw-soilfield. Minigminigi is locally common. Bracken, broom, and	Flat	*c.*0.8 ha

[1] Site number in 2004 was U17/7 (Wildland Consultants 2004c).

VEGETATION TYPE	LANDFORM	EXTENT
buddleia are locally common on cooler soils, with broom and buddleia particularly common along the northern lake margin. Fumaroles, thermal springs, and gas vents are scattered throughout this area.		
Mānuka-dominant shrubland (05.04) **Mānuka-prostrate kānuka-mingimingi shrubland (05.04.05)** Mānuka and prostrate kānuka (up to 1.5 m high) with scattered gorse, and occasional emergent radiata pine are present over bare ground. Patches of pātōtara (*Leucopogon fraseri*) and exotic grasses are present. Soil temperatures within this area were cool at the time of survey (*c.*12 °C in 2014) but the soils have been hydrothermally altered in the past	Gentle hillslopes, flat	17.9 ha
Lichenfield (15.01) **Mānuka-mingimingi/lichen-bare ground lichenfield (15.01.01)** Patches of mānuka and mingimingi (*c.*15% cover) with scattered monoao and prickly mingimingi are present over lichen and bare ground with scattered pumice on the surface. Soil temperatures within this area were cool at the time of survey (*c.*12 °C in 2014) but soils have been hydrothermally altered in this type in the past.	Flat	1.9 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Sinter deposits and fumeroles. Occasional patches of prostrate kānuka are present. **Nonvegetated raw-soilfield (human disturbance) (20.01.02)** Areas of open pumice loamfield which has been mined for sulphur are present throughout.	Flat Flat	*c.*7.0 ha *c.*9.6 ha
Geothermal water and mud pools (22.01) **Geothermal water (22.01.01)** Lake Rotokawa, geothermal lakes, hot streams, and mud lakes.	Flat and gentle hillslopes	*c.*70.8 ha

Indigenous Flora: Prostrate kānuka and *Calochilus robertsonii* (both At Risk-Naturally Uncommon[1]) and *Lycopodiella cernua* are present. Prostrate kānuka is endemic to geothermal sites, and *Lycopodiella cernua,* is a characteristic feature of geothermal areas. Other indigenous species typical of geothermal habitat include monoao, tāwiniwini, mānuka, prickly mingimingi, mingimingi, *Gleichenia microphylla*, water fern, tūrutu, and bracken.

A field survey of the site by Rotorua Botanical Society in November 2007 recorded a total of 27 indigenous and 24 naturalised vascular plant species, including 70 plants of *C. robertsonii*, (Bycroft 2008).

Fauna: Banded dotterel[2] (Threatened-Nationally Vulnerable[3]) and North Island fernbird (At Risk-Declining) are present, and banded dotterel breed at this site (Merrett and Burns 1997). Pied stilts (At Risk-Declining), nesting black backed gulls, and other water birds are also present on and around the

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] Banded dotterel and North Island fernbird were not recorded in the 2004 or 2014 surveys.
[3] All avifauna threat rankings are from Robertson *et al.* 2013.

lake. A leech, *Helobdella*, which is not found anywhere else in New Zealand, occurs in the lake (Department of Conservation 1990). Bellbird and spur-winged plover were also recorded at the site.

Other common indigenous and exotic bird species are also present, including bellbird and grey warbler. Possum, rabbit, and pig sign (scat) were observed during the 2014 survey.

Current Condition (2014 Assessment):

Most of this site has been extensively modified during more than 50 years of sulphur mining, resulting in a reduction in the extent of geothermal vegetation and habitats. However, indigenous geothermal vegetation has begun to re-establish in unvegetated areas in recent years. Invasive exotic plant species are locally common, in particular wilding pines (particularly radiata pine and maritime pine), which in some areas dominate the canopy over a lower tier of indigenous vegetation. Geothermal vegetation remains intact in several areas, particularly to the northeast of the lake.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2014 Assessment*):

Extensive wilding pines control has been undertaken in recent years, and are no longer visually dominant within the site (*c.*5% total cover). However, local patches of wilding pines continue to be a serious threat to indigenous plant communities on cooler ground. Other invasive exotic plant species present include silver birch (<1% cover), broom (1% cover), Himalayan honeysuckle (<1% cover), buddleia (<1% cover), gorse (1% cover), blackberry (<1% cover), Montpellier broom (<1% cover), pampas (<1% cover), and pasture grasses (including creeping bent, browntop, sweet vernal, Yorkshire fog, and ryegrass) (1-5% cover).

Other pest plant species that have been recorded from the site include tree lucerne, grey willow, and Spanish heath (Bycroft 2008).

Human impacts (*2014 Assessment*):

Historical human impacts on this area have been significant and mainly associated with the extraction of sulphur, however this has now ceased. A geothermal power station has been recently installed, but the impacts of draw-off are at present unknown. Control of wilding pines has been undertaken over large parts of this site.

Grazing (*2014 Assessment*):

The site is fenced. Some old cattle sign (faeces) was observed on the track margins in the west of the site during the current survey.

Adjoining land use (*2014 Assessment*):

Plantation forest and farmland.

Site Change:

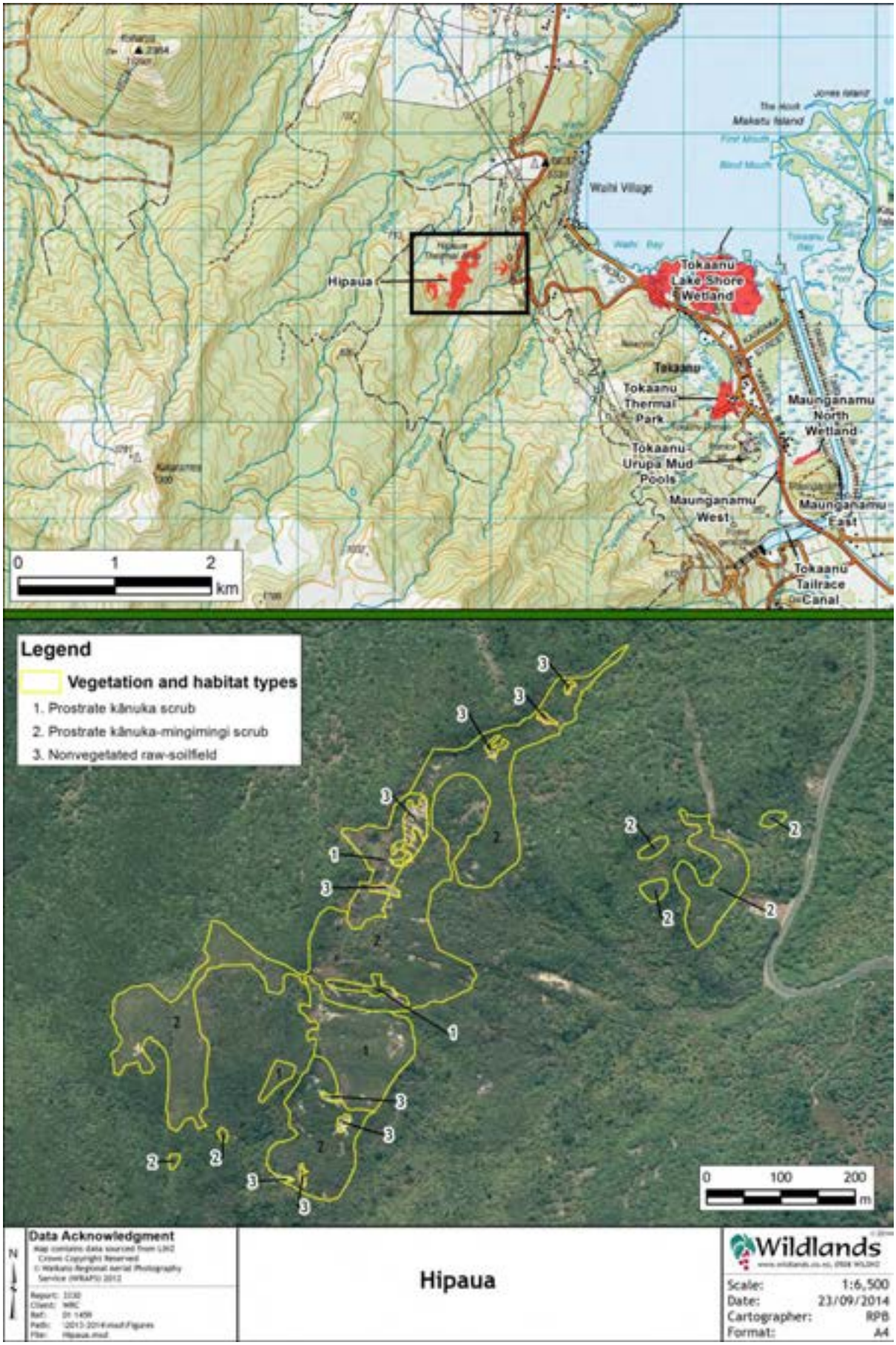
Recent change (2014 Assessment):

The vegetation is continuing to improve in quality over time as it re-establishes after a history of mining and road construction throughout this site. Pest plant control, mainly pines, has improved the ecological quality of this site in recent years. Any changes in the extent of this site are as a result of better quality aerial photographs available in 2014 compared with previous years.

Historical (*Assessed in 2011*):	Comparison of 2007 and 1941[1] aerial photographs show dramatic change in this site. In 1941, it appears that the site was farmed, and there were few wilding pines amongst geothermal vegetation and habitat. More bare ground appears to have been present in 1941, but this may be non-geothermal bare ground rather than geothermal bare ground. Extensive sulphur mining was undertaken at this site between the 1960s to 1980s, stripping large areas of hot ground, destroying contours and geothermal vegetation in the vicinity (http://www.waikatoregion.govt.nz/Environmental-information/Geothermal-resources/Geothermal-systems-map/Rotokawa; Accessed 2 July 2011).
Management Requirements:	Control of wilding pines should be continued, particularly the area of pines near E1878263, N5719788. The spread of silver birch and grey willow should also be contained. Pampas should also be controlled. Monitoring should continue to assess the impacts of geothermal power draw-off.
Significance Level:	National (Table 1 - Criteria 1, 3, 4, 5, 7, 9; Table 2 - Factor 8).
Significance Justification:	This site is of national significance because it is comprises a large, relatively good quality area of geothermal vegetation, which includes nationally uncommon habitat types (fumaroles, geothermally heated dry ground, geothermal stream margins; Williams *et al*. 2007; Holdaway *et al.* 2012). The site also includes a wide diversity of geothermal habitats, and provides habitat for several At Risk plant and animal species. While the site has a long history of modification, the quality of the site is noticeably improving since the Department of Conservation has started managing it.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category C - the third highest category. Merrett and Burns (1997) note that the geothermal area on the northern shore of Lake Rotokawa is of biological significance for both the geothermal vegetation growing there, and as a breeding site for banded dotterel and black-billed gulls.
References:	Beadel and Bill 2000; Bycroft 2008; Clarkson *et al.* 1989; Department of Conservation 1998; Merrett and Burns 1997; Merrett and Clarkson 1999; Spring-Rice 1996; Wildland Consultants 2004c & 2012.

[1] Historical photos: SN 172 Run 1173 Photos 10-13, 1941.

TOKAANU-WAIHI-HIPAUA GEOTHERMAL FIELD


Hipaua
Wairakei Village
Tokaanu
Lake Shore
Wetland
Tokaanu
Tokaanu
Thermal
Park
Tokaanu
Urupa Mud
Pools
Maunganamu
West
Maunganamu
North
Wetland
Maunganamu
East
Tokaanu
Tailrace
Canal
0 1 2
km
Legend
Vegetation and habitat types
1. Prostrate kānuka scrub
2. Prostrate kānuka-mingimingi scrub
3. Nonvegetated raw-soilfield
0 100 200
m
Data Acknowledgment
Hipaua
Wildlands
Scale: 1:6,500
Date: 23/09/2014
Cartographer: RPB
Format: A4

HIPAUA

Site Number:	TOV02[1]	**Grid Reference:**	NZTopo50 BH35 368 845
Ecological District:	Tongariro	**GPS Reference:**	NZTM E1836790 N5684476
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Local Authority:**	Taupō
		Altitude:	550-700 m
Bioclimatic Zone:	Submontane		
Tenure:	Unprotected private land		

Extent of Geothermal Habitat: *c.*12.1 ha
Extent of Geothermal Vegetation: *c.*12.1 ha
Date of Most Recent Field Survey: No survey. Observed from main road on 19 October 1999.

VEGETATION TYPE	LANDFORM	EXTENT
Prostrate kānuka-dominant scrub (04.01)		
Prostrate kānuka scrub (04.01.01) A dense cover of prostrate kānuka with local patches of *Campylopus* moss amongst scattered steaming fissures.	Hillslope	*c.*2.5 ha
Prostrate kānuka-mingimingi scrub (04.01.05) Prostrate kānuka and mingimingi form a dense cover with occasional fumaroles. Karamū and whauwhaupaku occur locally, particularly at the margins of this type where the prostrate kānuka-mingimingi scrub merges with whauwhaupaku-karamū-kāmahi/tutu scrub (outside of site). (Source: Given 1995)	Hillslope, shallow gullies	*c.*9.2 ha
Loamfield (20.01)	Hillslope	*c.*0.4 ha
Nonvegetated raw-soilfield (20.01.01) Heated bare soil (inferred from aerial photographs). Based on 2012 aerial photographs, so information on these areas is poor.		

Indigenous Flora: Prostrate kānuka (At Risk-Naturally Uncommon[2]) and *Campylopus* sp., which are both restricted to geothermal areas (Given, 1995), are present. Other 'At Risk' geothermal plant species may be present.

Fauna: Unknown. Common indigenous and introduced bird species typical of the habitat are likely to be present.

Current Condition (1999 Assessment): A relatively unmodified site well buffered by indigenous vegetation. It contains a good example of a mosaic of geothermal vegetation zones corresponding to soil temperatures (Given 1995).

Threats/Modification/ Vulnerability:

Invasive pest plants: *(1999 assessment)* Unknown. There appears to be some pampas visible on photographs (taken from a helicopter), provided by Waikato Regional Council (July 2002).

Human impacts: *(1999 assessment)* Human impacts are currently very low, and the site is virtually unaltered by human interference (Given 1995).

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[1] Site number in 2004 was T19/1 (Wildland Consultants 2004c).
[2] All flora threat rankings are from de Lange *et al.* 2013.

Grazing: *(1999 assessment)*	Livestock have no access to this area.
Adjoining land use: *(2014 assessment)*	Surrounded by indigenous vegetation on unprotected private land.

Site Change:

Recent change (2014 Assessment):	Any change in site boundaries is based on improved 2012 aerial photographs.
Historical (*Assessed in 2011*):	Photographs from 1941[1] were compared with 2007 aerial photographs. The site has probably changed little since 1941, although boundaries between vegetation types, particularly the boundary between geothermal scrub and non-geothermal scrub, are difficult to determine.
Management Requirements:	This site has not been surveyed recently, so obtaining information on the ecological values and management requirements is a high priority for this site. The current low levels of human impact should be maintained and the site should be monitored regularly to ensure that it remains in good condition. If pampas is present, as indicated by photographs, then it should be controlled.
Significance Level:	Regional (Table 1 - Criteria 3, 5, 7, 9, 10; Table 2 - Factors 12, 14).
Significance/ Justification:	This site is of regional significance because comprises important habitat for an 'At Risk' species (prostrate kānuka) and is a relatively large area of a nationally uncommon habitat type (geothermal habitat). The vegetation types present are representative of the ecological character of the Waikato Region. It is likely to have significant ecological values, however these are unknown as it has not been possible to undertake a field assessment of the site. The vegetation is highly intact, displaying good zonation and high indigenous component (Given 1995), and it is well buffered. The site is part of an extensive natural area extending from the shores of Lake Taupō to the summit of Kakaramea, Tihia, and Pihanga and including Lake Rotopounamu and Lake Rotoaira.
Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. Inspection of the 2012 aerial photographs indicates that some of the original vegetation has been destroyed since the 2007 aerial photographs were flown.
Notes:	Access to this site was not granted, and the descriptions and assessments have been compiled from existing literature, digital aerial photographs (2012), and a visual inspection from SH 41 using binoculars during the 1999-2000 survey. The 2012 aerial photographs used for this report are of considerably higher quality than those used in previous reports on geothermal vegetation in the Region (see Wildland Consultants 2004c & 2012). If site access is granted in the future, site information and boundaries should be reassessed, and all features should be inspected in detail.

[1] Historical photo: SN 178 Run 207 Photos 27, 1941.

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category A - the highest category.

References: Department of Conservation 1998; Given 1995 & 1996; Wildland Consultants 2004c & 2012.

Data Acknowledgment

Tokaanu Lake Shore Wetland

Wildlands

Scale: 1:8,000
Date: 30/09/2014
Cartographer: RPB
Format: A4

TOKAANU LAKE SHORE WETLAND

Site Number:	TOV03/ TOV04/ TOV05/ TOV06[1]	**Grid Reference:**	NZTopo50 BG35 394 024
		GPS Reference:	NZTM E1839489 N5684535
Ecological District:	Taupō; Tongariro	**Local Authority:**	Taupō
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Altitude:**	*c.*340 - 360 m
Bioclimatic Zone:	Submontane		
Tenure:	Unprotected private land and Protected (Tokaanu Recreation Reserve)		
Extent of Geothermal Habitat:	*c.*42.3 ha		
Extent of Geothermal Vegetation:	*c.*37.7 ha		
Date of Most Recent Field Survey:	13 February 2007		

TYPE	LANDFORM	EXTENT
Reedland (11.01) **Raupō reedland (11.01.01)** An extensive area of raupō reedland. A small population of arrow grass was viewed from the road on 13 February 2007. Crack willow and grey willow are present in this wetland, particularly on the margins of Lake Taupō and recently reclaimed wetland. Steam could be seen rising from the wetland at some locations, but access to most of these locations is hazardous.	Lake margin wetland	*c.*37.7 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermally-influenced water within the raupō reedland. Steam was viewed rising from this water on 13 February 2011.	Lake margin wetland	*c.*4.6 ha

Indigenous Flora: No 'Threatened' or 'At Risk' species (as per de Lange *et al.* 2013) were noted during the 2007 survey; however a full field survey has not been carried out due to the hazards of accessing most of this site.

Fauna: One 'Threatened' and two 'At Risk' (as per Robertson *et al.* 2013) bird species were recorded in this wetland during the 2007 survey: New Zealand dabchick (Threatened-Nationally Vulnerable), spotless crake (At Risk-Relict), and North Island fernbird (At Risk-Declining). Australasian bittern (Threatened-Nationally Critical) are also present in the area (W. Shaw, Wildland Consultants, pers. comm. 2009).

Current Condition (2007 Assessment): This wetland is in excellent ecological condition. Pest plants are relatively rare in most of this site, with willow species (crack willow and grey willow) noted, particularly on site margins. Some land has been reclaimed for road construction, pasture development, and canal construction.

Threats/Modification/ Vulnerability:

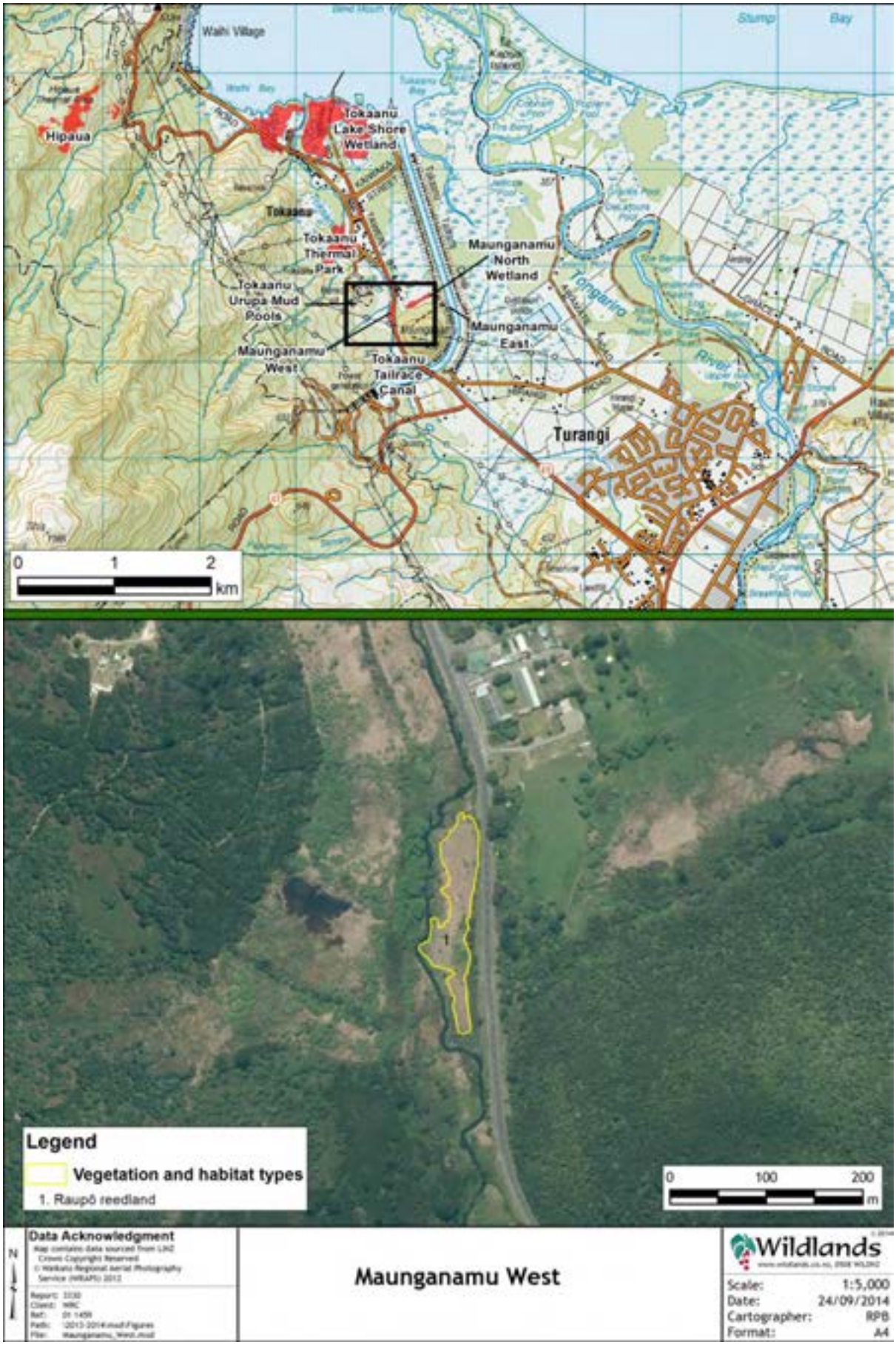
Invasive pest plants (*2007 Assessment*): Grey willow and crack willow were recorded in the wetland. These species should be controlled.

[1] Site number in 2004 was T19/9, T19/10, T19/11, T19/12 (Wildland Consultants 2007a).

Human impacts (*2007 Assessment*):	Drains are present in parts of the wetland although they do not appear to have been maintained recently. Parts of the wetland have been converted to pasture and residential housing, and roads have been constructed to access the lake.
Grazing (*2007 Assessment*):	No grazing is known to occur within this site.
Adjoining land use (*2014 Assessment*):	Farming, roads, Lake Taupō, wetland, residential.
Site Change:	
Recent change (2014 Assessment):	Not assessed. No significant change is known to have taken place in this wetland in the last ten years.
Historical (*Assessed in 2011*):	Comparison of 1941 aerial photographs of this site[1] with 2007 aerial photographs was undertaken. While little evidence of change was noted, Tokaanu Tailrace Canal has been constructed through the eastern part of the wetland, which is likely to have changed the character of parts of the wetland. Land has been reclaimed on each side of the canal. An area that was in pasture in 1941, to the east of the road that leads to the boat ramp and jetty (Wharf Road), has now reverted to wetland. Willows have become established alongside this road since 1941. No willows are obvious in 1941 aerials, but are common on the lake margins in the 2007 aerial photographs.
Management Requirements:	Control of willows and any other pest plants should be undertaken in this wetland.
Significance Level:	National (Table 1 - Criteria 3, 5, 6, 7, 9, 10; Table 2 -, Factors 7, 8).
Significance Justification:	The site is of national significance because it provides habitat for Threatened and At Risk indigenous bird species, and because it is a good quality example of a nationally uncommon habitat type (geothermal wetland. Wetlands are under-represented regionally and nationally (<10% of wetland extent remains nationally; Ministry for the Environment 1997). It is one of the best examples of a wetland-geothermal sequence in Taupō Ecological District and is part of a large freshwater wetland that is in excellent ecological condition.
Notes:	In 2007 the temperature of the substrate at the lake edge was measured in many locations, with temperatures ranging from 17-19^{o}C. However, extensive areas of geothermal habitat, including surface geothermal manifestations, are present further away from the lake. No vegetation characteristic of geothermal areas was found. Part of the area of raupō reedland was viewed from the road and entered by kayak on 13 February 2007. This is an extensive area of wetland vegetation and geothermal habitat is likely to be scattered throughout the site. The site was also viewed from State Highway 41 on 16 February 2007. Steam was seen rising from open water at several locations within this site. Based on these observations, it is therefore considered that extensive areas of geothermal water and geothermal wetland are present.

[1] Historical photos: SN 178 Run 207 Photos 29-31, 1941.

References: Bromley and Mongillo 1991; Hochstein 2007a&b; Wildland Consultants 2007a & 2012.


Waihi Village
Stump Bay
Hipaua
Tokaanu Lake Shore Wetland
Tokaanu
Tokaanu Thermal Park
Tokaanu Urupa Mud Pools
Maunganamu West
Tokaanu Tailrace Canal
Maunganamu North Wetland
Maunganamu East
Tongariro River
Turangi
0 1 2 km
Legend
Vegetation and habitat types
1. Raupō reedland
0 100 200 m
Data Acknowledgment
N
Maunganamu West
Wildlands
Scale: 1:5,000
Date: 24/09/2014
Cartographer: RPB
Format: A4

MAUNGANAMU WEST

Site Number:	TOV07[1]	**Grid Reference:**	NZTopo50 BH35 400 825
Ecological District:	Taupō; Tongariro	**GPS Reference:**	NZTM E1839981 N5682478
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Local Authority:**	Taupō
		Altitude:	360 m
Bioclimatic Zone:	Submontane		
Tenure:	Protected (Tokaanu Public Garden Reserve) and unprotected private land		
Extent of Geothermal Habitat:	*c.*0.6 ha		
Extent of Geothermal Vegetation:	*c.*0.6 ha		
Date of Most Recent Field Survey:	13 February 2007		

VEGETATION TYPE	LANDFORM	EXTENT
Reedland (11.01) **Raupō reedland (11.01.01)** Occasional crack willow occurs over raupō reedland in association with *Machaerina rubiginosa*, lake clubrush, *Eleocharis acuta*, pōhue, lotus, and creeping bent. Blackberry and Japanese honeysuckle are common on the margins. Soil temperatures at 10 cm depth were around 22.5 °C and 25.4 °C in 2007 (measured with the thermocouple probe). At 1 m depth temperatures were recorded up to 49.1 °C.	Wetland	*c.*0.6 ha

Indigenous Flora: No 'Threatened' or 'At Risk' species as listed in de Lange *et al.* (2013) are known from this site.

Fauna: Common indigenous and introduced species typical of the habitats are present. The wetland vegetation is likely to provide habitat for North Island fernbird (At Risk-Declining[2]) and spotless crake (At Risk-Relict), in conjunction with the adjacent large area of wetland habitat.

Current Condition (2007 Assessment): Weeds are present on the wetland margins, with occasional crack willow within the wetland.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*): Blackberry (1-5% cover), Japanese honeysuckle (1-5% cover), and crack willow (1-5% cover).

Human impacts (*2007 Assessment*): There is a road within 10 m of the site. A culvert is also present.

Grazing (*2007 Assessment*): This site is not grazed by stock.

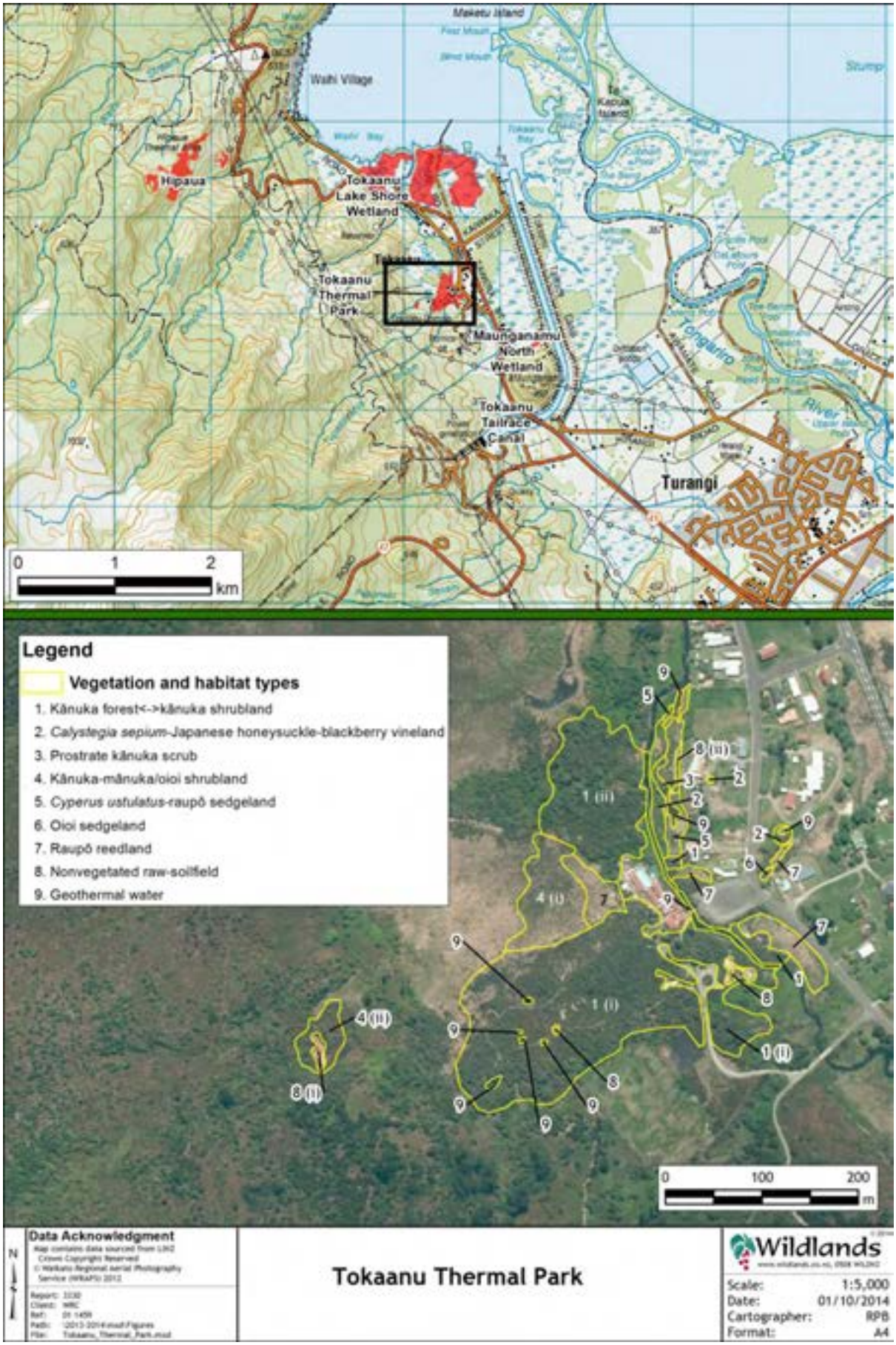
Adjoining land use (*2014 Assessment*): Tokaanu Stream and State Highway.

[1] Site number in 2004 was T19/6 (Wildland Consultants 2004c and 2007a).
[2] All avifauna threat rankings are from Robertson *et al.* 2013.

Site Change:

Recent change (2014 Assessment):	Not assessed. Any change not likely to be significant.
Historical (*Assessed in 2011*):	This site is too small to see any evidence of change since 1941[1].
Management Requirements:	Control of pest plant species (particularly crack willow) will maintain the ecological values of the site.
Significance Level:	Regional (Table 1 - Criteria 1, 5, 6, 10; Table 2 - Factor 16).
Significance Justification:	This site is of regional significance because it is protected and managed by the Department of Conservation and it forms part of an extensive ecological sequence that extends from the shores of Lake Taupō to the summit of Kakaramea, Tihia, and Pihanga, and which includes Lake Rotopounamu and Lake Rotoaira. This ecological sequence includes extensive areas of geothermal habitat.
Notes:	Several airborne infra-red anomalies were recorded along a *c*.200 m stretch of the eastern banks of Tokaanu Stream north of 6244 000 m N. Thermal springs and minor mud pools within this stretch were mapped by Healy (1942).
References:	Bromley and Mongillo 1991; Wildland Consultants 2004c, 2007a & 2012.

[1] Historical photos: SN 178 Run 207 Photos 29-31, 1941.


Maketu Island
Waihi Village
Hipaua
Tokaanu Lake Shore Wetland
Tokaanu Thermal Park
Maunganamu North Wetland
Tokaanu Tailrace Canal
Tongariro River
Turangi
0 1 2 km
Legend
Vegetation and habitat types
1. Kānuka forest<->kānuka shrubland
2. Calystegia sepium-Japanese honeysuckle-blackberry vineland
3. Prostrate kānuka scrub
4. Kānuka-mānuka/oioi shrubland
5. Cyperus ustulatus-raupō sedgeland
6. Oioi sedgeland
7. Raupō reedland
8. Nonvegetated raw-soilfield
9. Geothermal water
0 100 200 m
Data Acknowledgment
Tokaanu Thermal Park
Wildlands
Scale: 1:5,000
Date: 01/10/2014
Cartographer: RPB
Format: A4

TOKAANU THERMAL PARK

Site Number:	TOV08[1]	**Grid Reference:**	NZTopo50 BH35 364 833
Ecological District:	Taupō	**GPS Reference:**	NZTM E1839472 N5683151
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Local Authority:**	Taupō
		Altitude:	*c.*360 m
Bioclimatic Zone:	Submontane		
Tenure:	Protected (Tokaanu Thermal Park Recreation Reserve administered by DOC)		
Extent of Geothermal Habitat:	*c.*7.5 ha		
Extent of Geothermal Vegetation:	*c.*7.2 ha		
Date of Most Recent Field Survey:	23 August 2004 (partly updated in February 2007)		

VEGETATION TYPE	LANDFORM	EXTENT
Kānuka-dominant forest (01.01) **Kānuka forest ⇔ kānuka shrubland (01.01.02)** (i) Kānuka forest forms the vegetation cover over *c.*80% of this vegetation type. Kānuka forms a canopy up to *c.*7 m high, with an understorey of kānuka, mingimingi, and oioi, with scattered tūrutu, hound's tongue fern, *Cyperus ustulatus*, and mānuka. Mud pools and hot water pools are common beneath the kānuka canopy. Kānuka shrubland forms the vegetation cover over the remaining *c.*20% of this area and generally occurs around the site margins. Kānuka shrubs are common with local *Cyperus ustulatus* and narrow-leaved carpet grass. Mosses (including *Wijkia extenuata* and *Ptychomnion aciculare*) often form a dense groundcover. Mānuka and mingimingi are abundant in both vegetation types. Around cooking sites and disturbed areas, weeds, e.g. Japanese honeysuckle, yucca (*Yucca* sp.), blackberry, broom, and various ornamental trees such as rhododendron, are present. Other species common within the area include kōhūhū, whauwhaupaku, tūrutu, karamū, whekī, swamp kiokio, and ring fern. (ii) Kānuka forest to 4 m tall. Mud pools and hot springs are common throughout with several patches of nonvegetated raw-soilfield. Soil temperatures of up to 90.5 °C were recorded at 50 cm depth in this vegetation type. Ivy, blackberry, hound's tongue fern, tūrutu, Japanese honeysuckle, and mingimingi are common in places. Atakororeke Stream, a geothermal stream, passes through this vegetation type. The approximate location of this stream is shown on the site map. The surface temperature of water in the stream was 23.0 °C, but temperatures increased to 58.1°C at 10 cm depth in substrate. *Cyperus ustulatus* and kiokio are common along stream margins beneath a kānuka canopy. Blackberry becomes thick around stream margins *c.*100 m upstream of where the stream flows into the Tokaanu River. Prostrate kānuka is common near stream margins, particularly towards the northern portion of this site.	Flat	*c.*5.4 ha

[1] Site number in 2004 was T19/3 (Wildland Consultants 2004c and 2007a).

VEGETATION TYPE	LANDFORM	EXTENT
Exotic vineland (03.01) ***Calystegia sepium*-Japanese honeysuckle-blackberry vineland (03.01.01)** Dense vineland comprising pōhue and Japanese honeysuckle growing over blackberry. Patches of tall fescue are common. Mud pools and hot springs are scattered throughout this vegetation type.	River margins; mud pool; hot spring	*c.*0.2 ha
Prostrate kānuka-dominant scrub (04.01) **Prostrate kānuka scrub (04.01.01)** Prostrate kānuka with a canopy height of 1-2 m. Pōhue, Japanese honeysuckle, and blackberry are common on margins.	Flat	<0.1 ha
Kānuka-dominant shrubland (05.06) **Kānuka-mānuka/oioi shrubland (05.06.02)** (i) Emergent kānuka is common in association with scattered mānuka over a dense cover of oioi. Small patches of nonvegetated raw-soilfield are also present in places. (ii) Kānuka dominates the canopy in association with mānuka (height of 3 m) and occasional mingimingi, over an understorey of oioi and sinter. This area is surrounded by dense blackberry scrub.	Hillslope	*c.*0.8 ha
Indigenous sedgeland (09.01) ***Cyperus ustulatus*-raupō sedgeland (09.01.01)** Dense *Cyperus ustulatus* and raupō to 2.5 m. Japanese honeysuckle and blackberry are common on the margins. Patches of sinter and nonvegetated raw-soilfield are common. **Oioi sedgeland (09.01.02)** Oioi is dominant, with local *Eleocharis acuta*, *Schoenus maschalinus*, and adventive grasses, including creeping bent and Yorkshire fog.	Wetland Wetland	*c.*0.2 ha <0.1 ha
Reedland (11.01) **Raupō reedland (11.01.01)** Dense raupō with scattered *Carex virgata* and lake clubrush, and a few saplings of grey willow and crack willow. *Cyperus ustulatus* is locally dominant and blackberry is common along the road margin.	Flat	*c.*0.5 ha
Mossfield (14.01) ***Campylopus* sp. mossfield (14.01.02)**	Pools; sinter terraces	Not mapped
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Boiling water, sinter terraces, hot pools, and boiling mud. Scattered exotic grasses (e.g. narrow-leaved carpet grass, annual poa) and herbs (e.g. wild portulaca) were present. (i) A sinter terrace with oioi common on margins. (ii) Nonvegetated raw-soilfield (thermally altered soils) with common raupō and prostrate kānuka and *Cyperus ustulatus* on margins. Hot springs and mud pools are common. Temperatures of up to 96.7°C were recorded.	Flat; gently sloping; hillslope	*c.*0.1 ha

VEGETATION TYPE	LANDFORM	EXTENT
Water (22.01) **Geothermal water (22.01.01)** Hot stream and hot springs. Site was viewed from a distance and geothermal habitat was estimated from aerial photography.	Stream; hot springs; open water	*c.*0.2 ha

Indigenous Flora:

A moderate sized population of *Korthalsella salicornioides* (At Risk-Naturally Uncommon[1]), a semi-parasitic mistletoe classed, occurs at this site (Beadel and Bill 2000). *Schizaea dichotoma* (At Risk-Naturally Uncommon) is also present (Beadel and Bill 2000). This is the southern limit of distribution for *S. dichotoma*. (Note *Schizaea dichotoma* was not found during the 2004 or 2007 surveys).

A good sized population of prostrate kānuka (At Risk-Naturally Uncommon) is present.

Given (1995) recorded *Christella* aff. *dentata* ("thermal") (At Risk-Nautrally Uncommon) from this site, but it is now considered extinct at this site. *Nephrolepis flexuosa* (At Risk-Declining) was recorded from this site in 1987, but has not been recorded in subsequent surveys and is also presumed extinct at this site.

Fauna:

North Island fernbird (At Risk-Declining[2]) are present at this site. Other birds present include tūī, bellbird, and grey warbler.

Current Condition (2007 Assessment):

Historical photographs held at the tourism complex show that much of the present vegetation cover has developed over the last few decades. The dynamics of this site are not well understood and it is likely that the current vegetation will continue to evolve and change as the thermal activity changes. Continuing draw-off of heat or hot water from the site is likely to have ongoing impacts. However the vegetation is of relatively good quality, and is contiguous with an extensive wetland to the west. Pest plants are common in the surrounding vegetation and geothermal margins. The site is highly dissected by formed walking tracks.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*):

This site is vulnerable to pest plant invasion along track margins. The main weed species present at this site are Japanese honeysuckle (1-5% cover), ivy (<1-5 % cover), exotic grasses (1-5% cover), grey willow (1-5%), and bamboo (<1% cover). Several ornamental species have been planted around a geyser and bathing area. The spread of these species should be regularly monitored and control implemented as required.

[1] All flora threat rankings are from de Lange *et al.* 2013.
[2] All avifauna threat rankings are from Robertson *et al.* 2013.

Human impacts (*2007 Assessment*):	Human impacts relate to the draw-off of heat or hot water which is likely to have ongoing impacts and high use from walkers; however the tracks appear to be generally adhered to. Indigenous species have been planted in parts of this reserve.
Grazing (*2007 Assessment*):	Domestic livestock are not a threat to this area.
Adjoining land use (*2014 Assessment*):	Indigenous vegetation, blackberry scrub, residential, farmland, recreation facilities (swimming baths, tracks).
Site Change:	
Recent change (*2011 Assessment*):	Any changes to the extent of geothermal vegetation are likely to be minor. Additional information located in 2007 resulted in additional areas being added to the site, however this did not represent a real change in the extent of geothermal vegetation or habitats. The site has not been reassessed in the field.
Historical (*Assessed in 2011*):	Comparison of historic aerial photographs[1] with 2007 aerial photographs was undertaken. The Healy Bore to the south of the site, and its associated geothermal vegetation, was not evident on aerial photographs in 1941, as this was drilled in the 1950s (see geophysical assessment in Appendix 4). The boundary of geothermal surface manifestations at Tokaanu are difficult to determine on historical photos, as much of the site boundary is masked by wetlands. However, it is evident that some geothermal vegetation has been cleared for conversion to pasture and the establishment of a network of walking tracks. There also appears to be significantly more bare ground around the main tourist part of the geothermal site in 1941 than there is today, indicating that the character of this site has changed since the 1940s, and may be less active than in the recent past.
Management Requirements:	The site should be kept weed free.
Significance Level:	A: Regional (Table 1 - Criteria 1, 3, 5, 6, 7, 9, 10; Table 2 - Factors 12, 14). B: Local (Table 1 - Criterion 5; Table 2 - Factor 19)
Significance Justification:	Most of the site is ranked as being of Regional Significance (marked as A on the site map). The site contains populations of three species ranked as 'At Risk' (*Korthalsella salicornioides,* prostrate kānuka, and *Schizaea dichotoma*). The site is protected under the Reserves Act (1977) and comprises a relatively large example of geothermal vegetation which includes a wide diversity of habitat types. This site is also part of an extensive natural area extending from the shores of Lake Taupō to the summit of Kakaramea, Tihia, and Pihanga including Lake Rotopounamu and Lake Rotoaira. A small part of the site (marked as B on the site map) is of local significance because it is very small and highly modified with no indigenous plant species recorded. However, it does contain geothermal

[1] Historical photo: SN 178 Run 207 Photos 29-31, 1941.

habitat, a nationally uncommon habitat type.

Priority for Field Survey (2014 Assessment): This site is a high priority for field survey. Information on this site is dated (*c.*7 years old).

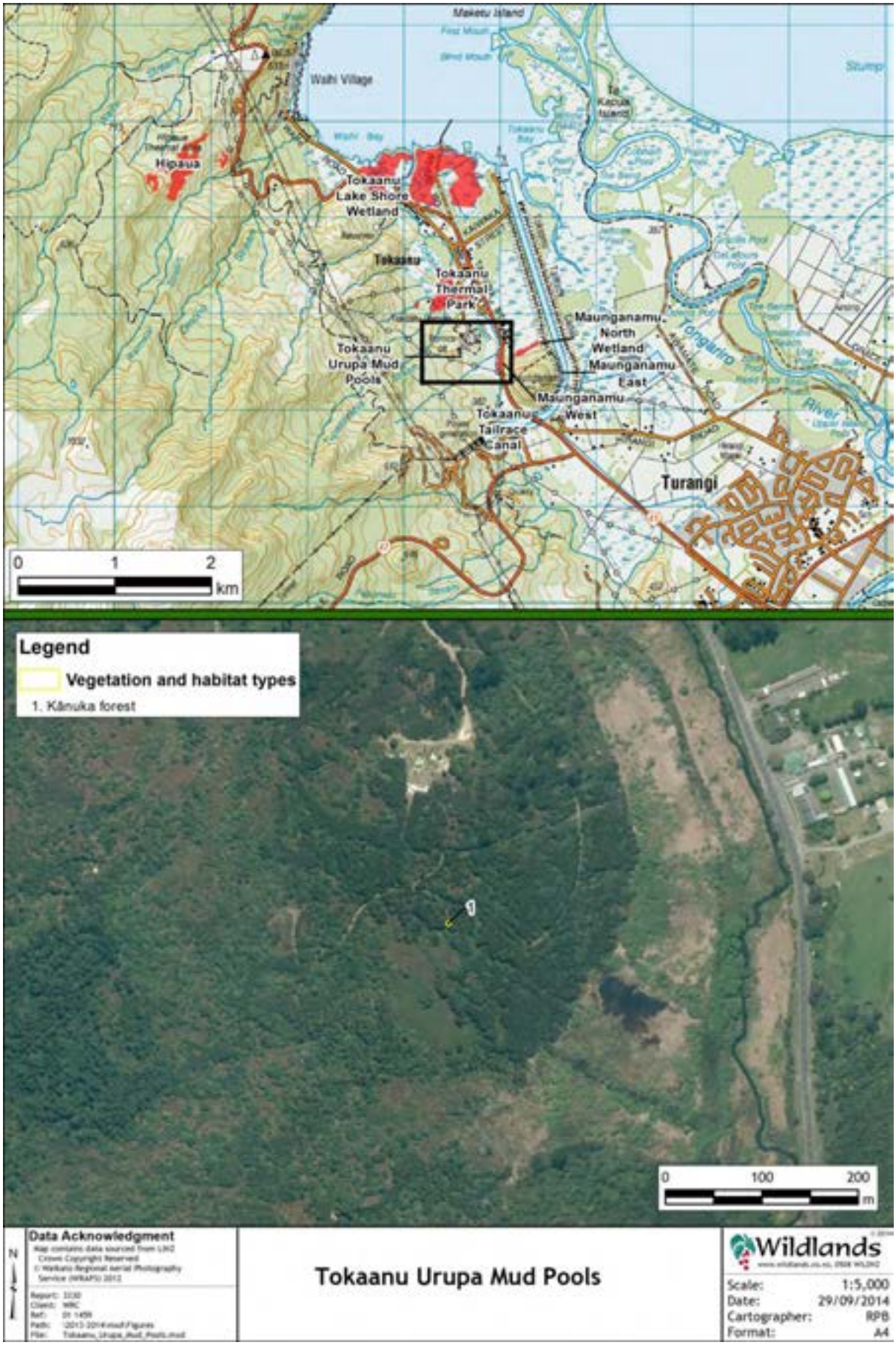
Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and and ranked this site as Category B - the second highest category.

It is difficult to safely undertake a detailed inspection to determine exact boundaries of the site because of the geothermal activity. However, the geothermal area mapped in this report is similar to the area shown in infrared anomalies in Bromley and Mongillo 1991, and Hochstein 2007b, Figure 3.2, Page 73).

Two pools within this site are listed in Waikato Regional Council (undated) as Taumatapuhipuhi spring (an unfenced pool of *c.*75ºC, which periodically erupts hot water) and Takarea No. 5 (a fenced pool of *c.*75ºC).

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.

References: Anon. no date; Beadel and Bill 2000; Department of Conservation 1997; Given 1995 & 1996; Healy 1942; Hochstein 2007b; Waikato Regional Council (undated); Wildland Consultants 2004c, 2007a & 2012.


Maketu Island
Waihi Village
Hipaua
Tokaanu Lake Shore Wetland
Tokaanu
Tokaanu Thermal Park
Tokaanu Urupa Mud Pools
Maunganamu North Wetland
Maunganamu East
Maunganamu West
Tokaanu Tailrace Canal
Turangi
Tongariro River
0 1 2 km
Legend
Vegetation and habitat types
1. Kānuka forest
0 100 200 m
Data Acknowledgment
Tokaanu Urupa Mud Pools
Wildlands
Scale: 1:5,000
Date: 29/09/2014
Cartographer: RPB
Format: A4

TOKAANU URUPĀ MUD POOLS

Site Number:	TOV09[1]	**Grid Reference:**	NZTopo50 BH35 397 826
Ecological District:	Tongariro	**GPS Reference:**	NZTM E1839651 N5682603
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Local Authority:**	Taupō
		Altitude:	*c.*380 m
Bioclimatic Zone:	Submontane		
Tenure:	Protected (Tokaanu Hot-Springs Reserve)		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	7 February 2007		

VEGETATION TYPE	LANDFORM	EXTENT
Kānuka-dominant forest (01.01) **Kānuka forest (01.01.01)** Kānuka forest to *c.*7 m tall overhangs two mud pools. There is occasional whauwhaupaku and māpou present in the canopy. Scattered tūrutu, mingimingi, and blackberry are present around the mud pools, which measure *c.*5 × 5 m and *c.*4 × 4 m.	Mud pool	<0.1 ha

Indigenous Flora: Kānuka, tūrutu, and mingimingi are species typical of geothermal habitat.

Fauna: Common cicadas were audible during the field survey. Common indigenous and introduced bird species typical of the habitats are likely to be present.

Current Condition (2007 Assessment): The site is in excellent condition with only scattered blackberry present.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*): Blackberry (1-5% cover).

Human impacts (*2007 Assessment*): A small unformed track leads to the site.

Grazing (*2007 Assessment*): At the time of field inspection there was evidence of horses having been present (faecal deposits).

Adjoining land use (*2014 Assessment*): Indigenous forest and scrub, vehicle track.

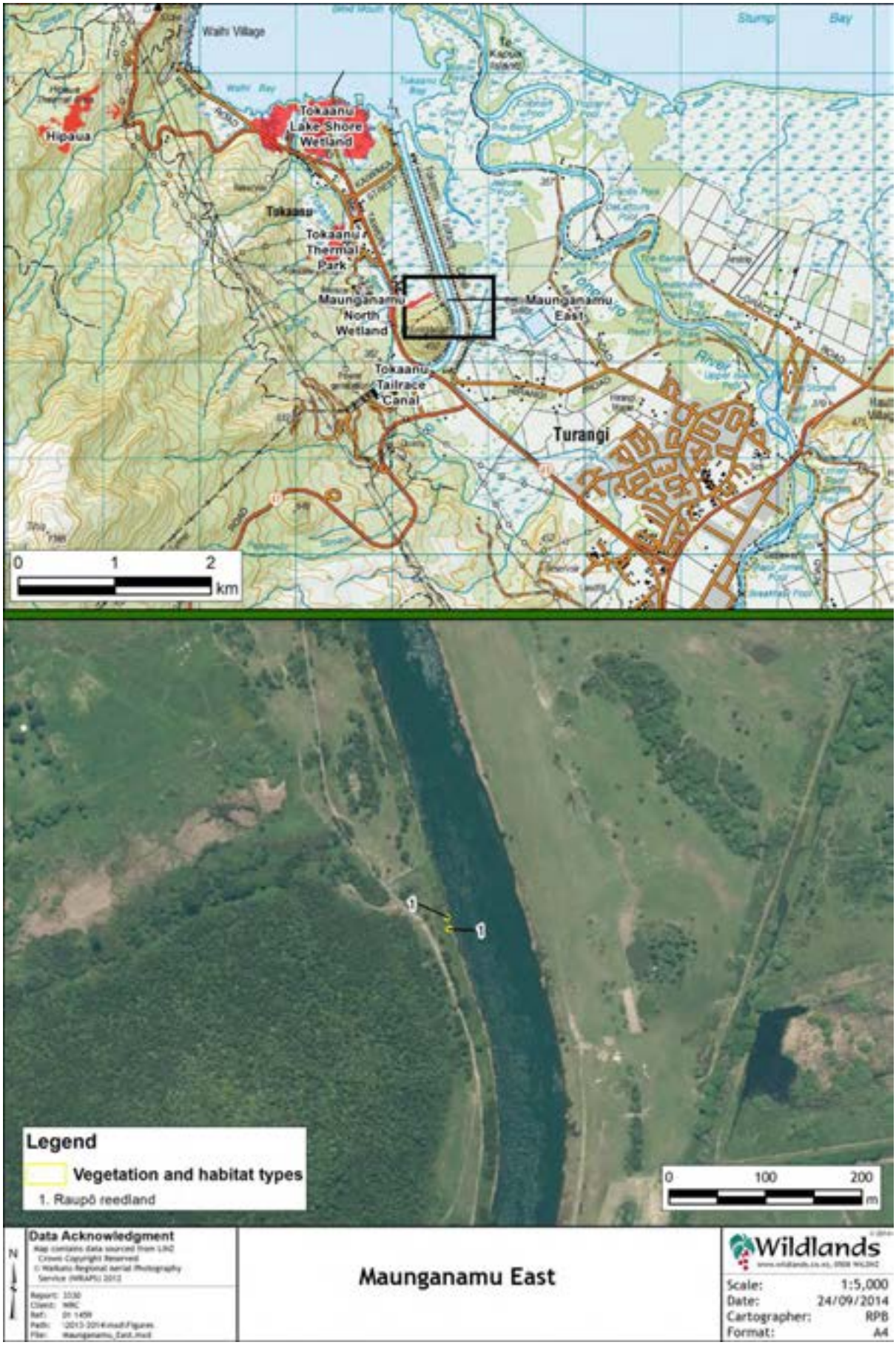
Site Change:

Recent change (2014 Assessment): Not assessed. Any changes are not likely to be significant.

[1] Site number in 2004 was T19/5 (Wildland Consultants 2004c and 2007a).

Historical (*Assessed in 2011*):	This site is too small to see any evidence of change since 1941[1]. The pools are shown on a map in a 1942 paper (see Figure 2 in Healy 1942) where they are listed as 'two larger mud pots'.
Management Requirements:	Maintain cover of indigenous vegetation around the mud pools.
Significance Level:	Regional (Table 1 - Criteria 1, 5, 10; Table 2 - Factor 16).
Significance Justification:	The mud pools are part of an extensive natural area of regional significance that extends from the shores of Lake Taupō to the summit of Kakaramea, Tihia, and Pihanga, and includes Lake Rotopounamu and Lake Rotoaira. This large natural area includes an excellent, representative example of an ecological sequence that includes extensive areas of geothermal habitat.
Notes:	A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.
References:	Healy 1942; Hochstein 2007a; Wildland Consultants 2004c, 2007a & 2012.

[1] Historical photo: SN 178 Run 207 Photo 30, 1941.


Waihi Village
Hipaua
Tokaanu Lake Shore Wetland
Tokaanu
Tokaanu Thermal Park
Maunganamu North Wetland
Maunganamu East
Tokaanu Tailrace Canal
Turangi
0 1 2 km
Legend
Vegetation and habitat types
1. Raupō reedland
0 100 200 m
Data Acknowledgment
Maunganamu East
Wildlands
Scale: 1:5,000
Date: 24/09/2014
Cartographer: RPB
Format: A4

MAUNGANAMU EAST

Site Number:	TOV10[1]	**Grid Reference:**	NZTopo50 BH35 405 826
Ecological District:	Taupō	**GPS Reference:**	NZTM E1840588 N5682576
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Local Authority:**	Taupō
		Altitude:	*c.*360 m
Bioclimatic Zone:	Submontane		
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	7 February 2007		

VEGETATION TYPE	LANDFORM	EXTENT
Reedland (11.01) **Raupō reedland (11.01.01)** Raupō reedland with abundant creeping bent and occasional pōhue. Geothermal seepages are present in the open canal water.	Canal margins	<0.1 ha

Indigenous Flora: Species typical of geothermal wetland are present.

Fauna: None recorded. Common indigenous and introduced bird species typical of the habitats are likely to be present.

Current Condition (2007 Assessment): Good condition.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*): Blackberry (1-5% cover).

Human impacts (*2007 Assessment*): The site is part of an artificial canal that is utilised for hydro-electricity.

Grazing (*2007 Assessment*): This site is not grazed by stock.

Adjoining land use (*2014 Assessment*): Tokaanu Stream, farmland, State Highway.

Site Change:

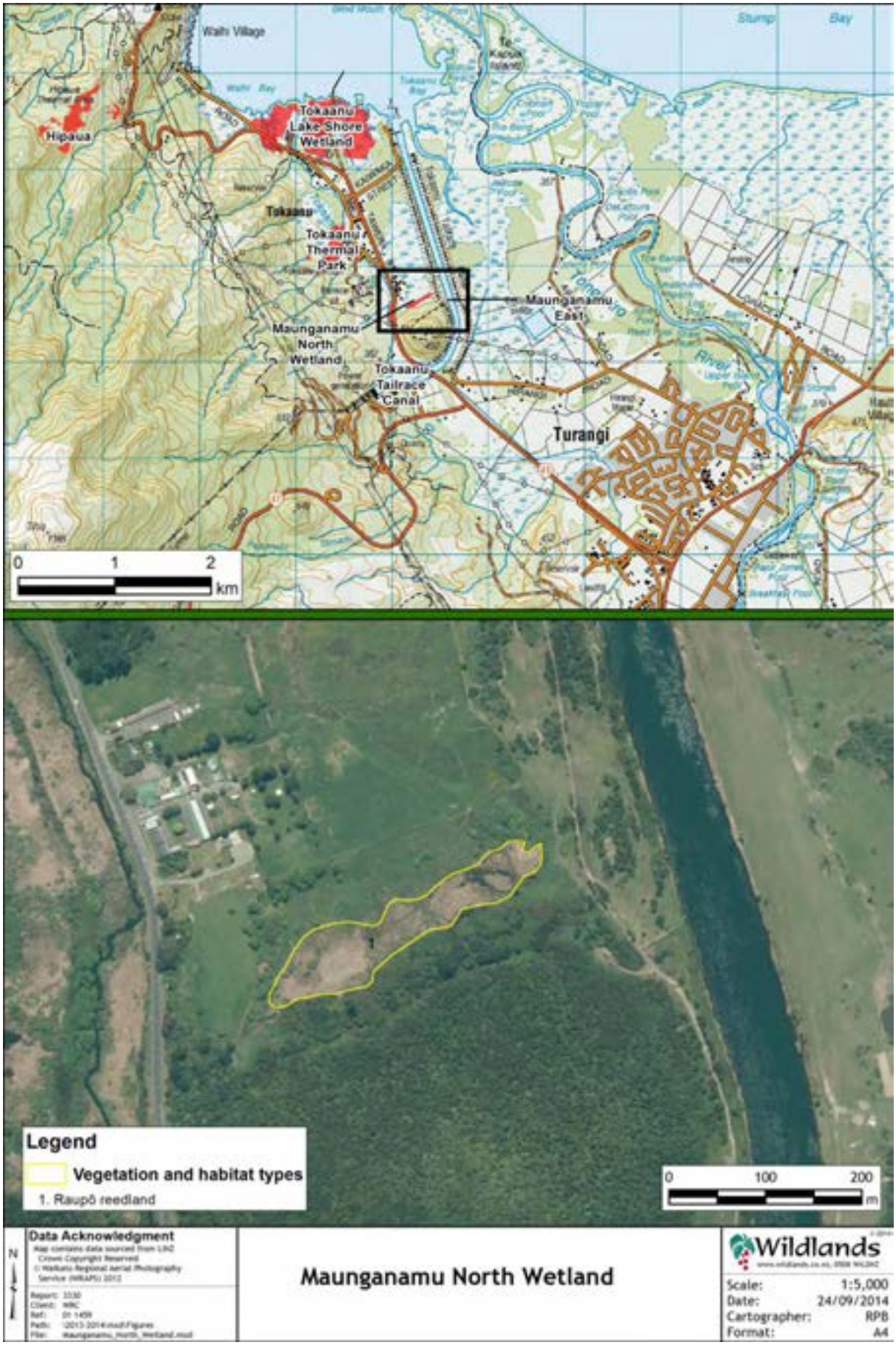
Recent change (2014 Assessment): Not assessed. Any changes are not likely to be significant.

Historical (*Assessed in 2011*): In 1941[2] there was bare ground in the vicinity of the site. This may be indicative of the presence of a greater extent of geothermal vegetation and habitat in the area at that time. Construction of the Tokaanu Tailrace Canal

[1] Site number in 2004 was T19/7 (Wildland Consultants 2004c and 2007a)

[2] Historical photos: SN 178 Run 207 Photos 29-31, 1941; SN 1099 Run A Photo 2, 1958.

	(constructed in conjunction with the Tokaanu Power Station, commissioned in 1973) appears to have resulted in a reduction in the extent of geothermal vegetation and habitats at this site.
Management Requirements:	None noted.
Significance Level:	Local (Table 1, Criterion 5; Table 2, Factor 19).
Significance Justification:	The site is of local significance as it is a small example of geothermal wetland. Wetlands are under-represented regionally and nationally (<10% of wetland extent remains nationally; Ministry for the Environment 1997).
Notes:	Further surveys are likely to result in the discovery of further examples of geothermal habitat in the vicinity of this site, particularly when water levels in the canal are low. A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.
References:	Bromley and Mongillo 1991; Hochstein 2007a; Wildland Consultants 2004c, 2007a &2012.


Waihi Village
Hipaua
Tokaanu Lake Shore Wetland
Tokaanu
Tokaanu Thermal Park
Maunganamu East
Maunganamu North Wetland
Tokaanu Tailrace Canal
Turangi
0 1 2 km
1
Legend
Vegetation and habitat types
1. Raupō reedland
0 100 200 m
Data Acknowledgment
Maunganamu North Wetland
Wildlands
Scale: 1:5,000
Date: 24/09/2014
Cartographer: RPB
Format: A4

MAUNGANAMU NORTH WETLAND

Site Number:	TOV11[1]	**Grid Reference:**	NZTopo50 BH35 403 826
Ecological District:	Taupō	**GPS Reference:**	NZTM E1840178 N5682636
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Local Authority:**	Taupō
		Altitude:	*c.*440 m
Bioclimatic Zone:	Submontane		
Tenure:	Unprotected private land and protected (Tokaanu Thermal Park Recreation Reserve).		
Extent of Geothermal Habitat:	*c.*1.4 ha		
Extent of Geothermal Vegetation:	*c.*1.4 ha		
Date of Most Recent Field Survey:	February 2007		

VEGETATION TYPE	LANDFORM	EXTENT
Reedland (11.01) **Raupō reedland (11.01.01)** The site was viewed from the distance and appeared to be a raupō reedland with emergent crack willow common. This site is included as geothermal based on elevated soil temperatures at the edge of the wetland in 2007, and evidence of Hochstein (2007a) and Bromley and Mongillo (1991).	Wetland	*c.*1.4 ha

Indigenous Flora: No 'Threatened' or 'At Risk' flora species (as per de Lange *et al.* 2013) were noted during the 2007 survey.

Fauna: No 'Threatened' or 'At Risk' fauna species were noted during the 2007 survey. However, the site is likely to provide habitat for wetland bird species, including spotless crake (At Risk-Relict[2]).

Current Condition (2007 Assessment): A full detailed site inspection has not been undertaken. Fences were poorly maintained near the site in 2007, however because the site was surrounded by blackberry, stock access is probably minimal. The wetland is in a moderate condition with common emergent crack willow.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*): Crack willow (5-25% cover) should be controlled.

Human impacts (*2007 Assessment*): The wetland is farmed near to its edges.

Grazing (*2007 Assessment*): The wetland has been farmed until recently, and stock may have access to margins.

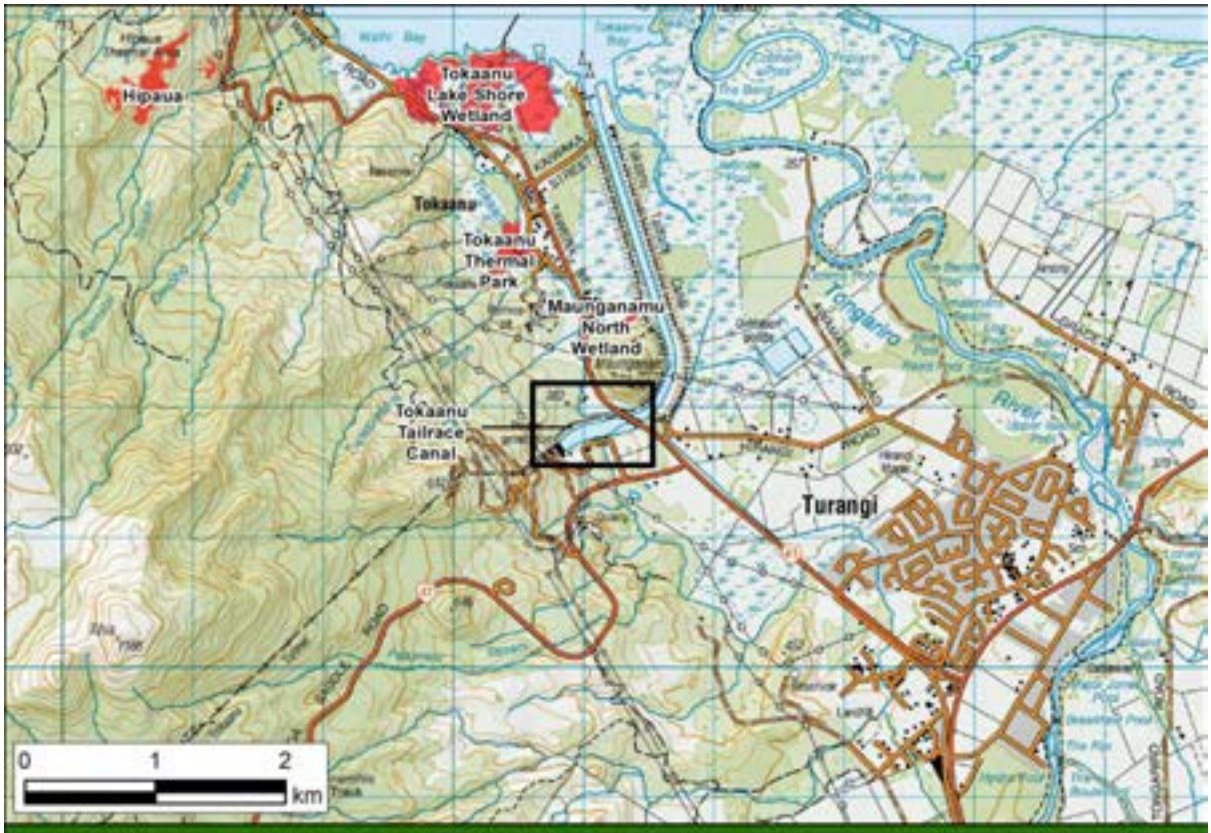
Adjoining land use (*2014 Assessment*): Farming and Department of Conservation Reserve. Fences were over-run by blackberry in 2007.

[1] Site number in 2004 was T19/8 (Wildland Consultants 2007a).
[2] All avifauna threat rankings are from Robertson *et al.* 2013.

Site Change:

Recent change (2014 Assessment):	Higher resolution of 2012 aerial photographs has resulted in a slight increase in extent of the site. This does not represent an increase in geothermal habitat at the site.
Historical (*Assessed in 2011*):	In the 1958 photograph[1] there appears to be bare ground in the vicinity of the site, of which only a small portion of this is likely to be geothermal.
Management Requirements:	Willow control should be undertaken, and the site should be fenced to exclude domestic stock.
Significance Level:	Local (Table 1 - Criteria 5, 6; Table 2 - Factor 19)
Significance Justification:	This site is locally significant as it is a small example of geothermal wetland. Wetlands are under-represented regionally and nationally (<10% of wetland extent remains nationally; Ministry for the Environment 1997).
Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. This site has never been surveyed in detail.
Notes:	Small groups of hot springs were reported by Healy (1942) in a stretch of swampy ground over the north region of Mt Maunganamu. One hot spring (77 °C) discharged *c*.100 m to the east of the main road and was sampled by Healy who apparently did not visit other manifestations in the same area. The same or an adjacent spring (Nr.52) was sampled and analyzed by Mahon and Klyen (1968); its temperature was 66 °C. It is likely that thermal springs in the swampy area were detected by their infrared (IR) signature in 1991; other recorded IR signals (Bromley and Mongillo 1991) are associated with thermal ground in paddocks to the east of the Oasis Motel. A short summary of the thermal manifestations in the North Maunganamu sector is given by Hochstein (2005). Further geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007. A neighbouring landowner has reported geothermal steam coming from this site. It is currently a raupō reedland wetland with common crack willow. As we did not have permission to access this site at the time of field survey in 2007, we have only examined this site from the road and neighbouring property.
References:	Bromley and Mongillo 1991; Healy 1942; Hochstein 2005 & 2007a; Mahon and Klyen 1968; Wildland Consultants 2007a & 2012.

[1] Historical photo: SN 1099 Run A Photo 2, 1958.



Data Acknowledgment

Map contains data sourced from LINZ
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Report: 3330
Client: WRC
Ref: 01 1459
Path: \2013-2014\mxd\Figures
File: Tokaanu_Tailrace_Canal.mxd

Tokaanu Tailrace Canal

Wildlands
www.wildlands.co.nz, 0508 WILDNZ

Scale:	1:5,000
Date:	01/10/2014
Cartographer:	RPB
Format:	A4

TOKAANU TAILRACE CANAL

Site Number:	TOV14[1]	**Grid Reference:**	NZTopo50 BH35 400 819
Ecological District:	Taupō	**GPS Reference:**	NZTM E1840064 N5681876
Geothermal Field:	Tokaanu-Waihi-Hipaua	**Local Authority:**	Taupō
		Altitude:	*c.*360 m
Bioclimatic Zone:	Submontane		
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	7 February 2007		

VEGETATION TYPE	LANDFORM	EXTENT
Reedland (11.01) **(Crack willow)/raupō reedland (11.01.03)** Occasional crack willow occurs over raupō reedland with patches of *Machaerina rubiginosa,* swamp kiokio*, Juncus edgariae*, and creeping bent. Other species present include Yorkshire fog, harakeke, *Carex virgata*, and tall fescue.	Wetland	<0.1 ha

Indigenous Flora: Species typical of geothermal wetland are present.

Fauna: None recorded. Common indigenous and introduced bird species typical of the habitats are likely to be present.

Current Condition (2007 Assessment): The site comprises small areas of indigenous habitats established alongside the artificial tailrace canal.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*): Crack willow (5-25% cover) is present near the site.

Human impacts (*2007 Assessment*): The site occurs beside an artificial canal.

Grazing (*2007 Assessment*): The site is not grazed by stock.

Adjoining land use (*2014 Assessment*): Canal, roads, mixed indigenous and exotic scrub.

Site Change:

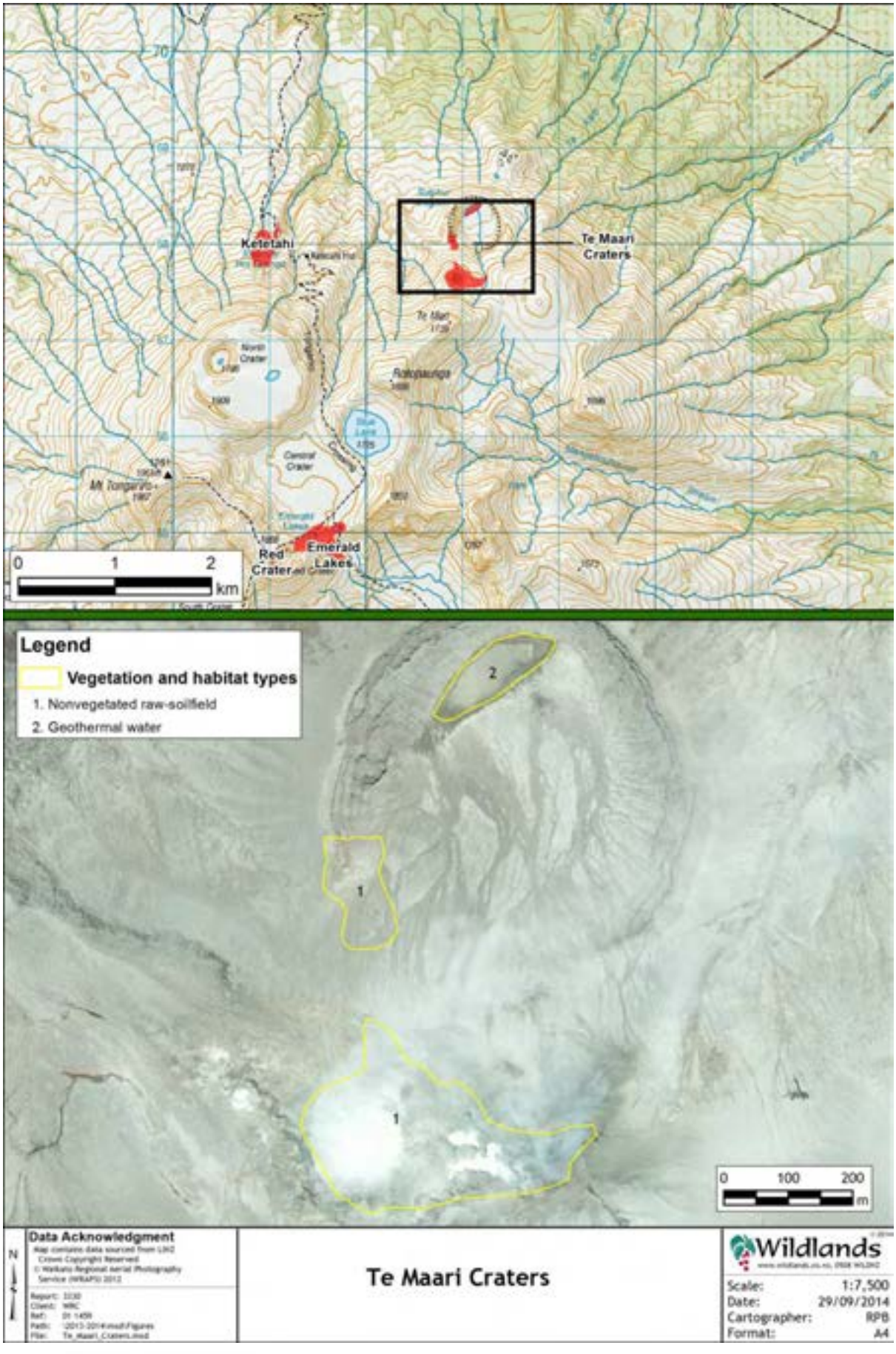
Recent change (2014 Assessment): Unknown. Probably no significant change. No change in extent was evident based on 2012 aerial photographs however the site is too small to allow accurate comparison.

[1] Site number in 2004 was T19/4 (Wildland Consultants 2004c and 2007a).

Historical (*Assessed in 2011*):	In 1958[1] there was bare ground in the vicinity of the site (only a small portion of this is likely to be geothermal). The Tokaanu Tailrace Canal (constructed in conjunction with the Tokaanu Power Station, commissioned in 1973) is likely to have flooded part of this site, but it is not possible to determine the extent of loss of geothermal vegetation or habitats associated with the flooding.
Management Requirements:	Control of crack willow would enhance the ecological values of the site.
Significance Level:	Local (Table 1, Criterion 5; Table 2, Factor 19).
Significance Justification:	The site is of local significance as it comprises a small example of a habitat that is nationally uncommon (lakeshore wetland; Williams *et al*. 2007; Holdaway *et al.* 2012).
Notes:	More geothermal sites may be found alongside the canal if the site was surveyed by boat, particularly when water levels are low. A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.
References:	Bromley and Mongillo 1991; Hochstein and Prebble 2006; Hochstein 2007a; Wildland Consultants 2004c, 2007a & 2012.

[1] Historical photo: SN 1099 Run A Photos 3, 1958.

TONGARIRO GEOTHERMAL FIELD


Ketetahi
Te Maari Craters
Red Crater
Emerald Lakes
0 1 2 km
Legend
Vegetation and habitat types
1. Nonvegetated raw-soilfield
2. Geothermal water
0 100 200 m
Data Acknowledgment
Te Maari Craters
Wildlands
Scale: 1:7,500
Date: 29/09/2014
Cartographer: RPB
Format: A4

TE MAARI CRATERS

Site Number:	TGV01[1]	**Grid Reference:**	NZTopo50 BH35 310 683
Ecological District:	Tongariro	**GPS Reference:**	NZTM E1831000 N5668300
Geothermal Field:	Tongariro	**Local Authority:**	Taupō
Bioclimatic Zone:	Subalpine	**Altitude:**	*c.*1,525 m
Tenure:	Protected (Tongariro National Park)		
Extent of Geothermal Habitat:	*c.*9.5 ha		
Extent of Geothermal Vegetation:	*c.*8.4 ha		
Date of Most Recent Field Survey:	14 June 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Indigenous fernland (07.01) (not mapped) ***Lycopodiella cernua* fernland (07.01.15)** Several small vents on the edge of Te Maari Crater are surrounded by *Lycopodiella cernua*, low stature mānuka, *Gleichenia dicarpa*, *Dracophyllum recurvum*, *Epacris alpina*, and *Gaultheria colensoi*.	Crater face	<0.1 ha
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** There are scattered plants of *Rytidosperma setifolium*, *Celmisia spectabilis* subsp. *spectabilis*, *Gaultheria colensoi*, and the moss *Racomitrium* on the scree slopes.	Crater rim, crater face	*c.*8.4 ha
Water (22.01) **Geothermal water (22.01.01)** Geothermal water in the base of a crater. Labelled 'Sulphur Lagoon' on topographic maps. No futher information is available as the water was covered in ice during the 2011 survey.	Crater	*c.*1.1 ha

Indigenous Flora: *Lycopodiella cernua* surrounds small north facing vents. In inland areas in the central North Island, this species only occurs in geothermal sites.

Fauna: New Zealand pipit (At Risk-Declining[2]) were recorded during the 2011 survey. New Zealand falcon (Threatened-Nationally Vulnerable) were recorded near the site by one of the authors in 2008.

Current Condition (2011 Assessment): The Te Maari Craters are in the remote experience zone of Tongariro National Park.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): None known

Human impacts (*2011 Assessment*): This site is *c.*1.5 km to the east of an internationally recognised walking track (Tongariro Alpine Crossing). It is in a remote experience zone, and is only occasionally visited by tramping parties.

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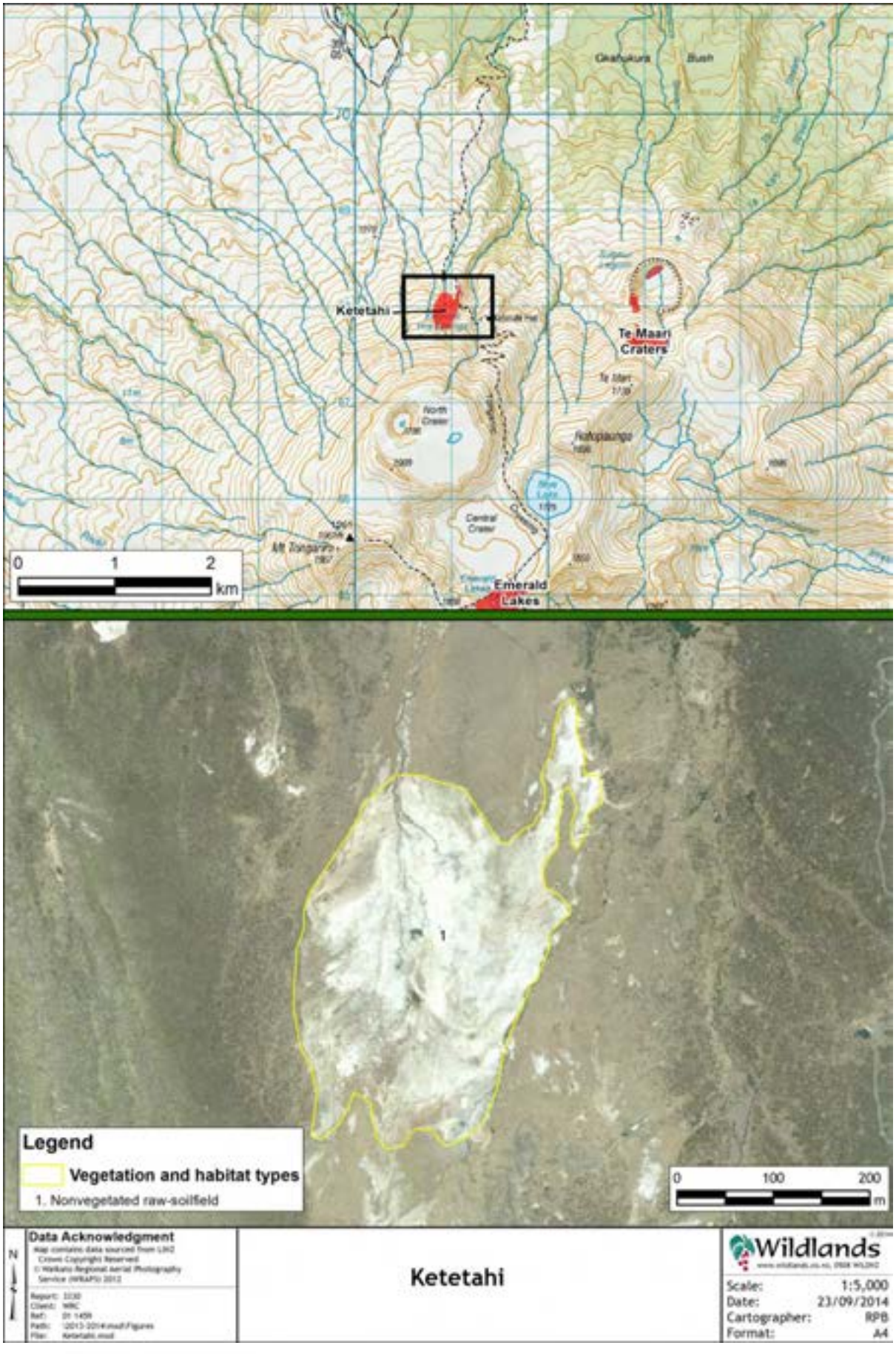
[1] Site number in 2004 was T19/20 (Wildland Consultants 2007a).
[2] All avifauna threat rankings are from Robertson *et al.* 2013.

Grazing (*2011 Assessment*):	Not grazed. Hares are present near the site and may visit occasionally.
Adjoining land use (*2014 Assessment*):	Tongariro National Park (Remote Experience Zone). Occasionally visited by trampers.
Site Change:	
Recent change (2014 Assessment):	The Te Maari craters erupted twice in 2012 (August and November). Changes in the vegetation composition of this site are likely to have occurred as a result of these eruptions but the extent of vegetation change at the site is unknown. The site boundaries have been redrawn based on the 2012 aerial photograhs and this has resulted in an increase in size of the site, comprising what appears to be bare ground and steaming ground.
Historical (*Assessed in 2011*):	Site change is not easily identified from historical photos[1].
Management Requirements:	None identified.
Significance Level:	International (Table 1 - Criteria 1, 5, 10; Table 2 - Factor 1)
Significance Justification:	Te Maari Craters is an internationally significant site because it is located within the part of Tongariro National Park that is listed as a World Heritage Site. The vegetation is of relatively low diversity but it is habitat of exceptional quality, with no recorded pest plant species and few human-induced impacts.
Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. Inspection of 2012 aerial photographs indicates that additional geothermal habitat is likely to be present as a result of the 2012 eruptions.
References:	Wildland Consultants 2007a & 2012.

[1] Historical photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957.


Okahukura Bush
Ketetahi
Te Maari Craters
North Crater
Central Crater
Mt Tongariro
Emerald Lakes
0 1 2 km
1
Legend
Vegetation and habitat types
1. Nonvegetated raw-soilfield
0 100 200 m
Data Acknowledgment
Ketetahi
Wildlands
Scale: 1:5,000
Date: 23/09/2014
Cartographer: RPB
Format: A4

KETETAHI

Site Number:	TGV02[1]	**Grid Reference:**	NZTopo50 BH35 289 680
Ecological District:	Tongariro	**GPS Reference:**	NZTM E1828935 N5667965
Geothermal Field:	Tongariro	**Local Authority:**	Taupō
Bioclimatic Zone:	Subalpine	**Altitude:**	*c.*1,460 m
Tenure:	Unprotected private land		
Extent of Geothermal Habitat:	*c.*8.2 ha		
Extent of Geothermal Vegetation:	*c.*8.2 ha		
Date of Most Recent Field Survey:	No field survey undertaken. Mapping is based on aerial photograph and descriptions in Given (1995 & 1996). There are likely to be additional thermal sites nearby.		

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Silica crusts and fumaroles.	Hillslope	*c.*8.2 ha

Indigenous Flora: Unknown. Not assessed in this survey.

Fauna: Unknown. No survey undertaken.

Current Condition (2007 Assessment): Exceptional quality, few human impacts.

Threats/Modification/ Vulnerability:

Invasive pest plants: *(2011 Assessment)* No significant pest plants known.

Human impacts (2011 Assessment): About twenty years ago a walking track passed through this site and it was a popular bathing spot. Public access is now restricted, the walking track has been relocated, and the site is now rarely visited by people. As a consequence, it is likely that there are few human impacts.

Grazing: *(2011 Assessment)* Not grazed. Surrounded by Tongariro National Park. Hares and deer are likely to be present on the margins on occasion.

Adjoining land use (*2014 Assessment*): Tongariro National Park.

Site Change:

Recent change (2011 Assessment): Unknown. Probably no significant change as the site is rarely visited. Natural changes to surface geothermal manifestations are likely.

Historical (*Assessed in 2011*): Apart from fluctuations in surface geothermal activity, little change to this site is likely. Site change is not easily identified from historical photos[2].

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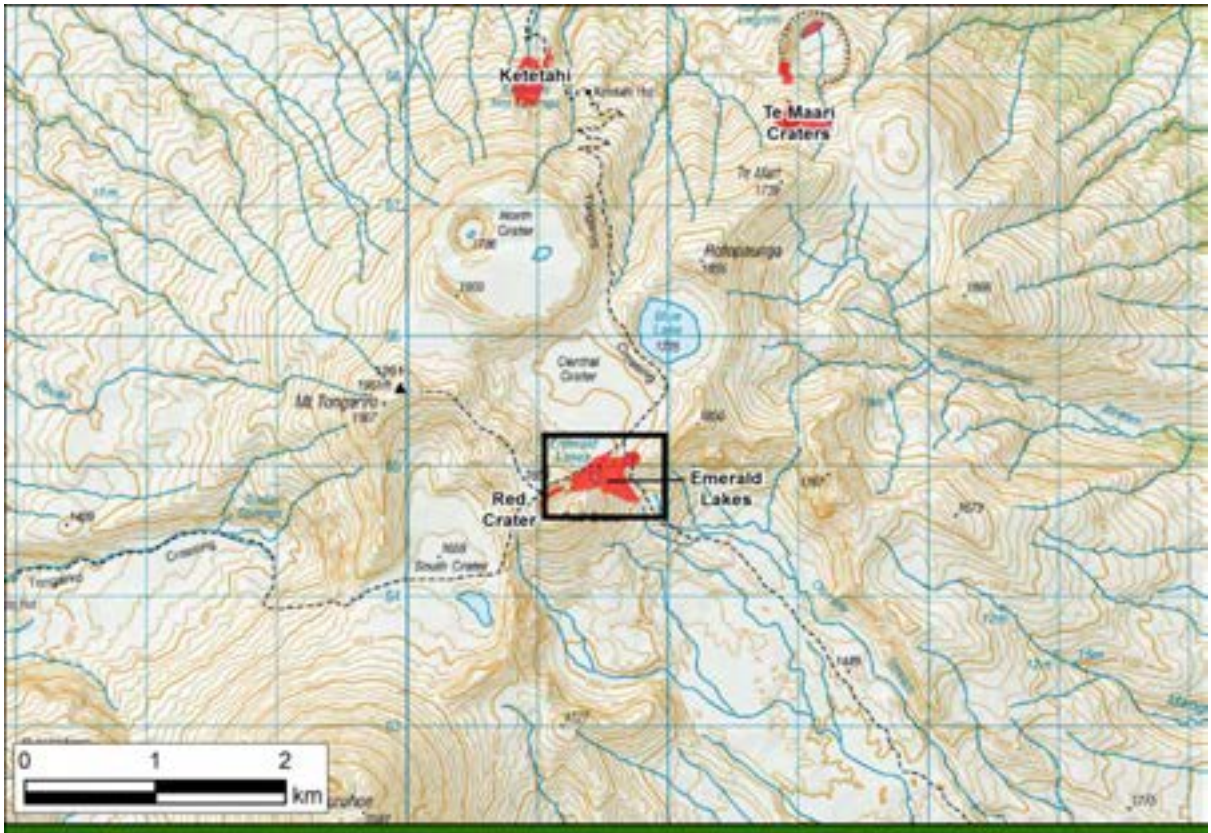
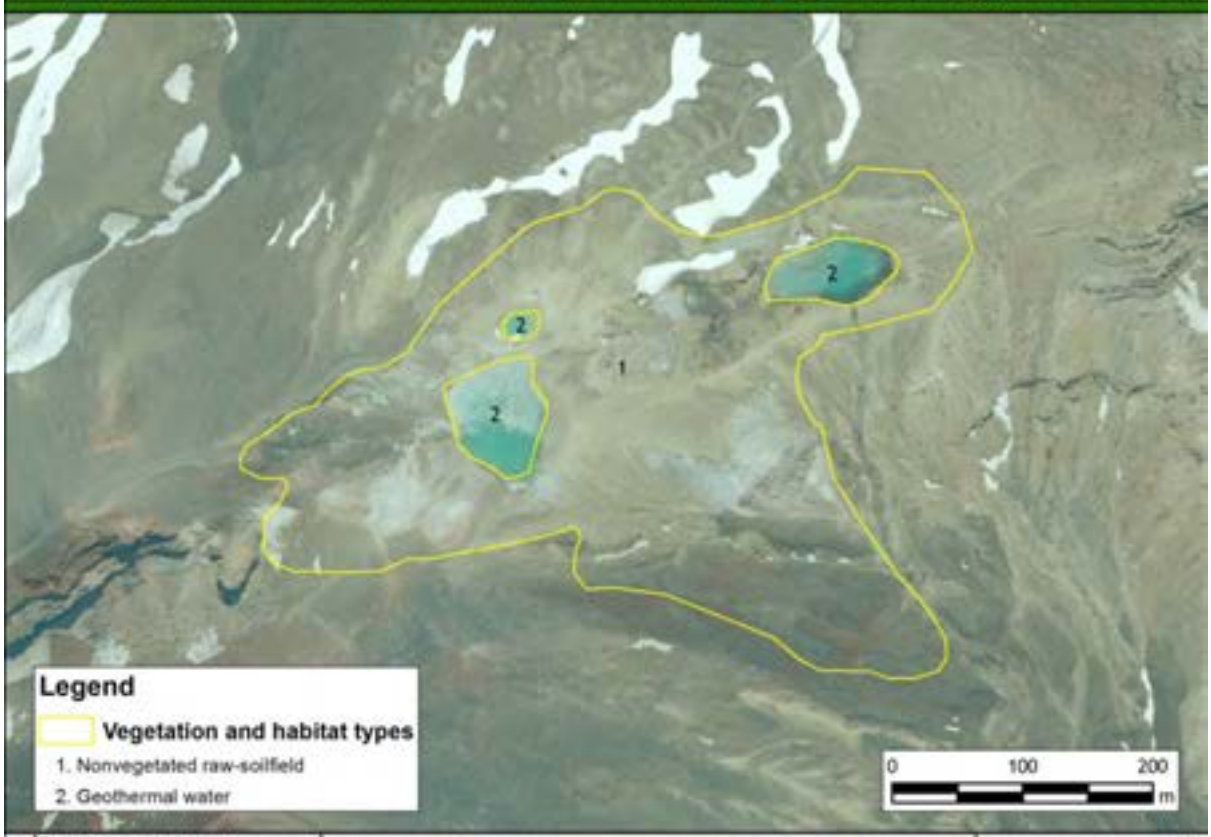
[1] Site number in 2004 was T19/15 (Wildland Consultants 2007a).

[2] Historical; photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957.

Management Requirements:	None identified.
Significance Level:	National (Table 1 - Criteria 5, 9, 10; Table 2 - Factor 8)
Significance Justification:	Ketetahi Hot Springs is known to be a very good quality example of a nationally uncommon habitat type (geothermally heated dry ground; Williams *et al*. 2007; Holdaway *et al.* 2012).
Priority for Field Survey (2014 Assessment):	This site is a high priority for field survey. This site has never been surveyed by the authors and information on this site is dated (>15 years old).
Notes:	This site was described by Given 1995 as being highly unusual in having no vegetation on the hot ground area, except for algal crusts on siliceous sites near fumaroles. Given (1995) states that it is an unusual site not replicated elsewhere in the region, and highly unusual even in a botanical sense on account of its lack of any flowering plants, mosses, or lichens. Given (1996) gave this site a botanical ranking of 'A' - the highest possible ranking.
References:	Given 1995 & 1996, Wildland Consulants 2007a & 2012.





Data Acknowledgment

Map contains data sourced from LINZ
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Report: 3330
Client: WRC
Ref: 01 1459
Path: \2013-2014\mxd\Figures
File: Emerald_Lakes.mxd

Emerald Lakes

Wildlands

Scale: 1:5,000
Date: 18/09/2014
Cartographer: RPB
Format: A4

EMERALD LAKES

Site Number:	TGV03	**Grid Reference:**	NZTopo50 BH35 297 651
Ecological District:	Tongariro	**GPS Reference:**	NZTM E1829672 N5665082
Geothermal Field:	Tongariro	**Local Authority:**	Taupō
Bioclimatic Zone:	Subalpine	**Altitude:**	*c.*1,700 m
Tenure:	Protected (Tongariro National Park)		
Extent of Geothermal Habitat:	*c.*12.1 ha		
Extent of Geothermal Vegetation:	*c.*11.2 ha		
Date of Most Recent Field Survey:	14 June 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Occasional patches of *Rytidosperma setifolium* occur amongst otherwise unvegetated screefield.	Crater walls	*c.*11.2 ha
Water (22.01) **Geothermal water (22.01.01)** Three geothermally influenced lakelets are included in this site. *Juncus bolbosus* is present in the shallow margins. While the lake water temperature is cold, there is a strong geothermal influence surrounding the lakes. The lakes are up to 4.5 m deep and have a pH of 3-5; their colour is caused by minerals, mainly fumarolic sulphur, entering the water forming polysulphide ions (Williams 2001).	Crater lakes	*c.*0.9 ha

Indigenous Flora: No 'Threatened' or 'At Risk' plant species are known to occur at this site.

Fauna: No 'Threatened' or 'At Risk' fauna species are known to use this site.

Current Condition (2011 Assessment): While not botanically diverse, the lakes and surrounding geothermal habitat is of exceptional ecological quality, of high scientific value, and high ecological interest.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): The exotic rush *Juncus bolbosus* is present in at least the lower Emerald Lake.

Human impacts (*2011 Assessment*): An internationally renowned walking track (Tongariro Alpine Crossing) passes within close proximity to the Emerald Lakes, and track users have access to the site. Occasional trampling of features and vegetation are the main human impacts.

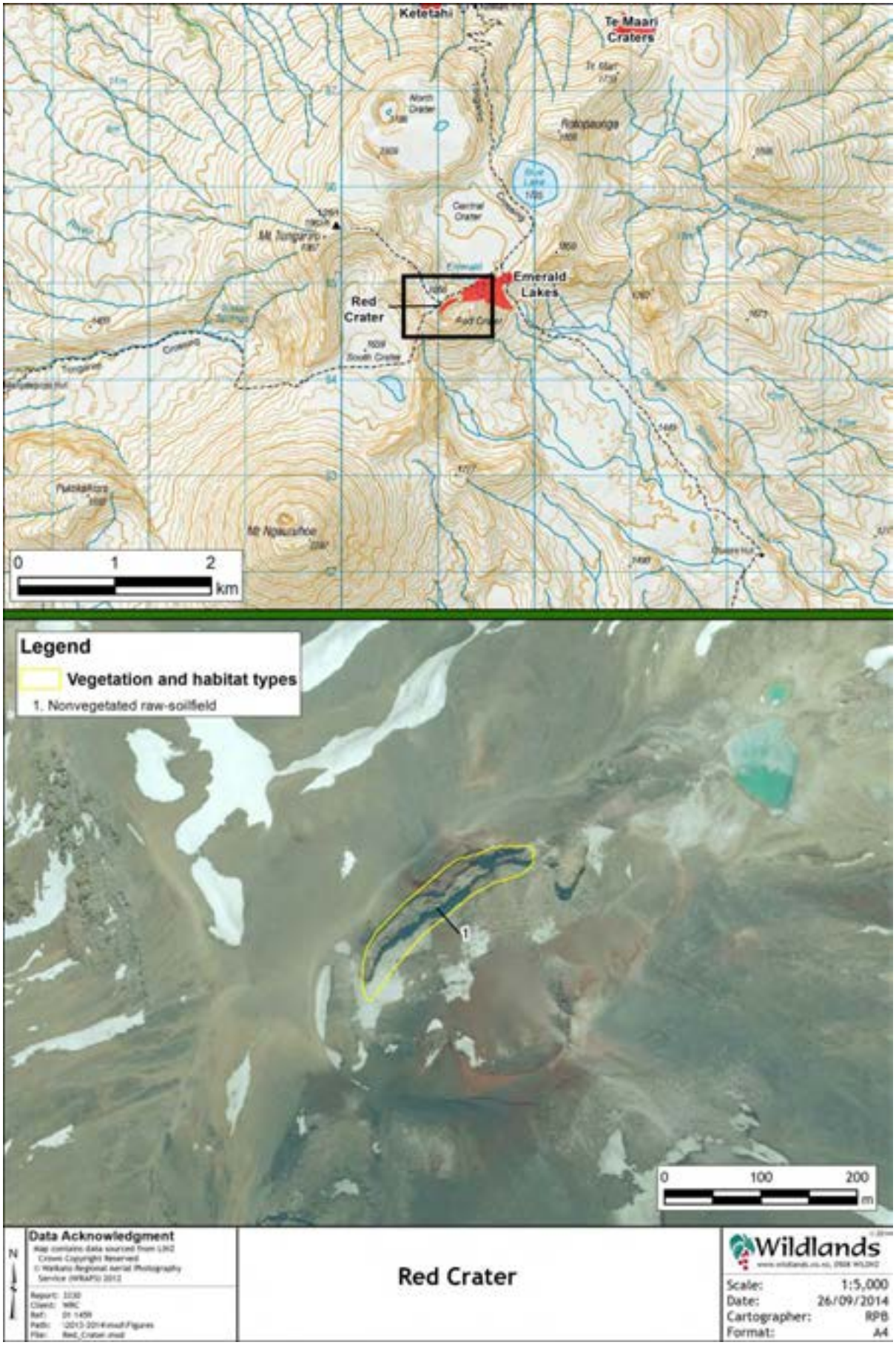
Grazing (*2011 Assessment*): Not grazed. Introduced mammal impacts on this site are likely to be minor.

Adjoining land use (*2014 Assessment*): Tongariro National Park, tramping track.

Site Change:

Recent change (2011 Assessment):	No significant ecological change is known to have occurred at this site in the last ten years.
Historical (*Assessed in 2011*):	Site change is not easily identified from historical photos[1]. The site is under snow in these historical photographs. No major change has been recorded in the literature at this site in the last 50 years.
Management Requirements:	Monitor impacts of human trampling around this site. This site is on the Tongariro Alpine Crossing track.
Significance Level:	International (Table 1 - Criteria 1, 5, 10; Table 2 - Factor 2)
Significance Justification:	Emerald Lakes is an internationally significant site because it is located within the part of Tongariro National Park that is listed as a UNESCO World Heritage Site.
Notes:	These lakes occur downslope of Red Crater. They comprise three explosion pits that have formed in the last 1,800 years (Williams 2001).
References:	Wildland Consultants 2012; Williams 2001.

[1] Historical photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957.


Ketetahi
Te Maari Craters
Red Crater
Emerald Lakes
Mt Ngauruhoe
0 1 2 km
Legend
Vegetation and habitat types
1. Nonvegetated raw-soilfield
1
0 100 200 m
Data Acknowledgment
Red Crater
Wildlands
Scale: 1:5,000
Date: 26/09/2014
Cartographer: RPB
Format: A4

RED CRATER

Site Number:	TGV04[1]	**Grid Reference:**	NZTopo50 BH35 292 648
Ecological District:	Tongariro	**GPS Reference:**	NZTM E1829200 N5664800
Geothermal Field:	Tongariro	**Local Authority:**	Taupō
Bioclimatic Zone:	Subalpine - Alpine	**Altitude:**	*c.*1,860 m
Tenure:	Protected (Tongaririo National Park)		
Extent of Geothermal Habitat:	*c.*0.8 ha		
Extent of Geothermal Vegetation:	*c.*0.8 ha		
Date of Most Recent Field Survey:	14 June 2011		

VEGETATION TYPE	LANDFORM	EXTENT
Loamfield (20.01) **Nonvegetated raw-soilfield (20.01.01)** Bare heated scoria and soils. Fumarole present. Site viewed through binoculars from a distance.	Crater and crater walls	*c.*0.8 ha

Indigenous Flora: No 'Threatened' or 'At Risk' plant species are present.

Fauna: No 'Threatened' or 'At Risk' fauna species are present.

Current Condition (2011 Assessment): Not known (viewed from distance).

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): None known.

Human impacts (*2011 Assessment*): Although near the Tongariro Alpine Crossing, the site is rarely visited and human impacts are negligible.

Grazing (*2011 Assessment*): Not grazed.

Adjoining land use (*2014 Assessment*): Tongariro National Park, tramping track.

Site Change:

Recent change (*2011 Assessment*): Unknown. Probably little change (see historical change below). The site appears to have changed little in the last 20 years.

Historical (*2011 Assessment*): Site change is not easily identified from historical photos[2]. Geothermal activity is likely to change through natural variation over time, but human impacts are likely to be negligible.

Management None noted.

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[1] Site number in 2004 was T19/18 (Wildland Consultants 2007a).

[2] Historical photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957.

Requirements:

Significance Level:	International (Table 1 - Criteria 1, 5, 10; Table 2 - Factor 2)
Significance Justification:	Red Crater is an internationally significant site because it is located within the part of Tongariro National Park that is listed as a UNESCO World Heritage Site.

APPENDIX 2

YEAR OF MOST RECENT FIELD INSPECTIONS FOR EACH SITE

Site No.	Site Name	Ecological District	Year of Most Recent Field Survey[1]
Horohoro Geothermal Field			
HHV01	Horohoro	Atiamuri	2014
Waikite Geothermal Field			
WAV01	Waikite Valley	Atiamuri	2014
WAV02	Northern Paeroa Range	Atiamuri	2010
Waiotapu Geothermal Field			
WTV01	Maungaongaonga	Atiamuri	2014
WTV02	Ngapouri	Atiamuri	2014
WTV03	Waiotapu North	Atiamuri	2011
WTV04	Maungakakaramea (Rainbow Mountain)	Atiamuri	2010
WTV05	Waiotapu South	Atiamuri	2010 (part), 2011 (part)
Mokai Geothermal Field			
MKV01	Whakamaru	Atiamuri	2008
MKV02	Waipapa Stream	Atiamuri	2011
MKV03	Tirohanga Rd	Atiamuri	2011
MKV04	Paerata Rd	Atiamuri	2011
Atiamuri Geothermal Field			
ATV01	Upper Atiamuri West	Atiamuri	2007
ATV02	Whangapoa Springs	Atiamuri	2011
ATV03	Matapan Rd	Atiamuri	2011
Te Kopia Geothermal Field			
TKV01	Te Kopia	Atiamuri	2014
TKV02	Murphy's Springs	Atiamuri	2010
TKV03	Western Te Kopia	Atiamuri	2010
TKV06	Mangamingi Station	Atiamuri	2010
Orakeikorako Geothermal Field			
OKV01	Waihunuhunu	Atiamuri	2014
OKV02	Akatarewa Stream	Atiamuri	2014
OKV03	Orakeikorako	Atiamuri	2010 (part), 2011 (part), 2014 (part)
OKV04	Red Hills	Atiamuri	2014
OKV05	Akatarewa East	Atiamuri	2011
Ngatamariki Geothermal Field			
NMV01	Waikato River Springs	Atiamuri	2011
NMV02	Orakonui	Atiamuri	2011
Whangairorohea Geothermal Field			
WGV01	Whangairorohea	Atiamuri	2014
Reporoa Geothermal Field			
RPV01	Longview Rd	Atiamuri	2014
RPV02	Wharepapa Rd	Atiamuri	2010
RPV03	Golden Springs	Atiamuri	2014
Okaaki Geothermal Field			
OHV01	Ohaaki Steamfield West	Atiamuri	2011
OHV02	Ohaaki Steamfield East	Atiamuri	2011

[1] Date of most recent survey given. Some sites have been surveyed multiple times between 2000 and 2014.

Site No.	Site Name	Ecological District	Year of Most Recent Field Survey[1]
Wairakei-Tauhara Geothermal Field			
THV01	Otumuheke	Atiamuri	2010
THV03	Spa Thermal Park	Atiamuri	2014
THV04	Broadlands Rd	Atiamuri	2011
THV05	Crown Park	Taupō	2014
THV06	Crown Road	Taupō	2011
THV07	Waipahihi Valley	Taupō	2014
THV08	Mountain Road	Taupō	2014
THV09	Kathleen Springs	Taupō	2014
WKV01	Te Rautehuia	Atiamuri	2011
WKV02	Te Rautehuia Stream	Atiamuri	2011
WKV03	Upper Wairakei Stream (Geyser Valley)	Atiamuri	2014
WKV04	Wairakei Borefield	Atiamuri	2014
WKV05	Te Kiri O Hine Kai Stream Catchment/Wairoa Hill	Atiamuri	2014
WKV06	Lower Wairakei Stream	Atiamuri	2014
WKV07	Karapiti Forest	Atiamuri	2014
WKV08	Hall of Fame Stream	Atiamuri	2014
WKV09	Waipouwerawera Stream/Tukairangi	Atiamuri	2011
WKV10	Craters of the Moon	Atiamuri	2014
Rotokawa Geothermal Field			
RKV01	Rotokawa North	Atiamuri	2014
RKV02	Lake Rotokawa	Atiamuri	2014
Tokaanu-Waihi-Hipaua Geothermal Field			
TOV02	Hipaua	Tongariro	1999
TOV03 to TOV06	Tokaanu Lakeshore Wetland	Taupō	2007
TOV07	Maunganamu West	Taupō	2007
TOV08	Tokaanu Thermal Park	Taupō	2007
TOV09	Tokaanu Urupā Mud Pools	Taupō	2007
TOV10	Maunganamu East	Taupō	2007
TOV14	Tokaanu Tailrace Canal	Taupō	2007
Tongariro Geothermal Field			
TGV01	Te Maari Craters	Tongariro	2011
TGV02	Ketetahi	Tongariro	1996
TGV03	Emerald Lakes	Tongariro	2011
TGV04	Red Crater	Tongariro	2011

SITES FOR WHICH FIELD INSPECTIONS WERE NOT UNDERTAKEN AS PART OF THIS STUDY

No field inspection was carried out for the 19 known geothermal sites listed below. This was due to either the site being extremely small, with little to no geothermal vegetation known to be present; or because landowner permission to access the site was withheld.

Site Name	**Parekiri Pool**
Location	Tirohanga Road
Grid Reference (NZTM)	E1853183 N5734523
Geothermal Field	Mokai
Ecological District	Atiamuri
Vegetation	No geothermal vegetation. Pool enclosed by dirt, concrete and wooden railings.
Notes	A small bathing pool securely fenced off. Wooden shed beside fence.
References	Waikato Regional Council (undated).

Site Name	**Atiamuri School Spring**
Location	Corner SH30 and Ohakuri Road
Grid Reference (NZTM)	E1867993 N5752733
Geothermal Field	Atiamuri
Ecological District	Atiamuri
Vegetation and Site Description	Highly modified spring surrounded by blackberry, that looks more like a culvert than a natural spring.
References	Waikato Regional Council (undated).

Site Name	**Mangatete Stream**
Location	Waikite Valley
Grid Reference (NZTM)	E1880300 N5746800
Geothermal Field	Te Kopia
Ecological District	Atiamuri
Vegetation	No geothermal vegetation present.
Notes	Site inspected on 7 May 2004. No geothermal vegetation or activity found within a kilometre upstream or downstream of the grid reference. The general area was also inspected from a vantage point hill on true left of Mangatete Stream. The landowner did not know of any geothermal vegetation in this area.
References	Spring-Rice (unpublished).

Site Name	**Lake Ohakuri/Tainui Road**
Location	Lake Ohakuri
Grid Reference (NZTM)	E1877700 N5731800
Geothermal Field	Ngatamariki
Ecological District	Atiamuri
Notes	A small hot spring and a number of warm seepages occur along the lake edge. Not located during 2000 survey.
References	Ecroyd 1979b.

Site Name	Butcher's Pool
Location	Broadlands Road, Reporoa
Grid Reference (NZTM)	E1891750 N5738690 (estimate only)
Geothermal Field	Reporoa
Ecological District	Atiamuri
Vegetation	No geothermal vegetation.
Notes	A small spring enclosed by man-made, wooden edges. Recreational use.

Site Name	Mihi
Location	Mangamingi
Grid Reference (NZTM)	Near: E1887950 N5734030
Geothermal Field	Ohaaki
Ecological District	Atiamuri
Vegetation	Tepid spring in pasture behind haybarn.
References	Waikato Regional Council (undated).

Site Name	Waihi Geothermal Site
Location	Waihi Village, Lake Taupō
Grid Reference (NZTM)	E1837824 N5685065 (estimate only)
Geothermal Field	Tokaanu
Ecological District	Taupō
Vegetation	Presence, extent and composition of geothermal vegetation is not known.
Notes	More than a dozen small springs discharging hot water along a *c*.0.7 km stretch of the Waihi foreshore following the main fracture zone of the Waihi Fault. Some areas of geothermal vegetation are mapped in this report in the Hipaua site (TOV02). It is likely that there are additional areas of geothermal vegetation that are not mapped in the Hipaua site, however permission to access this site was not granted in 2011.
References	Bromley and Mongillo 1991 cited in Hochstein 2005; Hochstein 2005.

Site Name	Southern Stream
Location	Turangi
Grid Reference (NZTM)	E1839428 N5682165 (estimate only)
Geothermal Field	Tokaanu
Ecological District	Tongariro
Vegetation	Presence, extent and composition of geothermal vegetation is not known.
Notes	Permission to access this site was not granted in 2011.
References	Bromley and Mongillo 1991 cited in Hochstein 2005.

Site Name	Toputomatua Stream
Location	Turangi
Grid Reference (NZTM)	E1838631 N5677862 (estimate only)
Geothermal Field	Tokaanu
Ecological District	Tongariro
Vegetation	Presence, extent and composition of geothermal vegetation is not known.
Notes	Permission to access this site was not granted in 2011.
References	Bromley and Mongillo 1991 cited in Hochstein 2005.

Site Name	Ngauruhoe Crater
Location	Tongariro National Park, Mount Ngauruhoe
Grid Reference (NZTM)	E1827400 N5662500
Geothermal Field	Tongaririo
Ecological District	Tongaririo
Vegetation	No geothermal vegetation present.

Site Name	Mokena Geyser
Location	Te Aroha
Grid Reference (NZTM)	Near E1839920 N5841305
Geothermal Field	Te Aroha
Ecological District	Hinuera
Vegetation	Surrounded by concrete. No vegetation present, geothermal or otherwise.
Notes	An artificial geyser located within the grounds of the Mokena private spa baths. Water temperature *c.*90ºC.
References	Waikato Regional Council (undated).

Site Name	Waitoa Spring
Location	Waitoa
Grid Reference (NZTM)	E1828164 N5845856
Geothermal Field	Waitoa
Ecological District	Hinuera
Vegetation	Spring in pasture. No geothermal vegetation present.
Notes	Located beside a farm drain. Water *c.*50ºC.
References	Waikato Regional Council (undated).

Site Name	Opal Baths
Location	Okauia
Grid Reference (NZTM)	E1850008 N5841305
Geothermal Field	Okauia
Ecological District	Hinuera
Vegetation	Bathing pools. No geothermal vegetation present.
Notes	Pools constructed for commercial, recreational use. Water *c.*40ºC.
References	Waikato Regional Council (undated).

Site Name	Okoroire Spring
Location	Okoroire
Grid Reference (NZTM)	E1846375 N5795776
Geothermal Field	Okoroire
Ecological District	Hinuera
Vegetation	Bathing pools. No geothermal vegetation present.
Notes	Natural spring around/beside which concrete pools have been constructed for commercial, recreational use (two pools).
References	Waikato Regional Council (undated).

Site Name	Miranda Hot Pools
Location	Waitakaruru
Grid Reference (NZTM)	E1806963 N5879559
Geothermal Field	Miranda
Ecological District	Hauraki
Vegetation	No geothermal vegetation present.
Notes	A spring contained by a metal shaft on a lawn behind the camping ground shop/office. Water *c.*50ºC.
References	Waikato Regional Council (undated).

Site Name	Kerepehi Spring
Location	Kerepehi
Grid Reference (NZTM)	E1823825 N5873435 (estimate only)
Geothermal Field	Kerepehi
Ecological District	Hauraki
Vegetation	Spring in pasture. No geothermal vegetation present.
Notes	Water is *c.*40ºC and escapes from pipe with variable pressure. Located on the far side of Paddock 76 from the race (on the boundary with the neighbouring farm).
References	Waikato Regional Council (undated).

Site Name	Waingaro Hot Pools
Location	Waingaro
Grid Reference (NZTM)	E1776332 N5826606
Geothermal Field	Waingaro
Ecological District	Raglan
Vegetation	Bathing pools. No geothermal vegetation present.
Notes	Pools constructed for commercial, recreational use. Fed by a bore opposite the entrance to the hot pools. Water *c.*50ºC.
References	Waikato Regional Council (undated).

Site Name	Naike (Te Maire) Spring
Location	Naike
Grid Reference (NZTM)	E1771803 N5848022
Geothermal Field	Naike
Ecological District	Raglan
Vegetation	Pool in pasture. Vegetation not assessed.
Notes	Pool bank is a little unstable. Water *c.*45ºC.
References	Waikato Regional Council (undated).

Site Name	Hot Water Beach
Location	Coromandel
Grid Reference (NZTM)	Near: E1851525 N5913975
Geothermal Field	Not known
Ecological District	Tairua
Vegetation	Hot water seepage on beach. No geothermal vegetation present.
References	Waikato Regional Council (undated).

GEOPHYSICAL ASSESSMENTS OF SURFACE GEOTHERMAL MANIFESTATIONS AT 20 SITES IN THE WAIKATO REGION (from Wildland Consultants 2012)

NORTHERN PAEROA RANGE[1]

Area A

Viewed from other side of creek. Similar to sites B, D and E, but no geophysical assessment undertaken.

Area B

This is a 25 × 15 m outcrop of poorly sorted, moderately rounded, and weakly cemented gravelly pumice with weakly defined bedding. This overlies pinkish poorly sorted coarse clayey pumice sand. The entire outcrop is >50% covered by pine needles.

Unfortunately we did not record orientation data, but estimated north is shown on the sketch. The northern end of the area is a roughly circular outcrop, with the margins showing moderate silicification; there is a strongly silicified outcrop on the western margin of this structure.

In the southern section of this area there is a 1 m diameter vertical concrete pipe around 1.2 m high. In the ground enclosed by this pipe are two small fumaroles with delicate sulphur structures (Plates 1 and 2). Within 2.5 m east and west of this pipe are two further fumaroles with sulphur encrusted walls, and south of these is a sulphur-encrusted east-west vent (Plates 3 and 4).

On the western margin of the area opposite the pipe is a 2 m diameter cracked and broken sinter mound (Plate 5).

Area C

Grid Reference: E1889201 N5749763

An area of bare ground and exposed altered rock. The area measures approximately 20 × 15 m. There is a dry gully on its southern flank with a small stream flowing past the northern boundary. A small low flowing/stagnant stream runs along the western boundary. Soil temperatures at 10 cm depth across the area were not elevated above ambient temperatures (12 °C). The exposed surface varies from altered pumiceous rock, which exhibit moderate alteration, to brittle silicified gravelly soils/clay. There is evidence of sulphur deposition however no steaming ground was observed. A moderate sulphur odour was present although a source was not found. It could be diffuse H_2S or simply related to the adjacent area (Paeroa North 2) with steaming ground. The area is surrounded by pine woodland and farmland. Photographs were not taken at this site due to fading light.

Area D

This site measures approximately 28 × 40 m in area and comprises areas of exposed ground, clay banks, marshland, two gas discharging cold pools and

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

two streams which meet at the centre of the southern end of the area. There is a slight H_2S odour at the area. The surrounding area is farmland and pine woodland.

On the western flank of this area is a clay slope or bank (Plate 6); soil temperatures were not above ambient conditions. The upper half of the slope is composed of poorly sorted gravelly clay. The gravels are coarse, angular to sub rounded, highly weathered and brittle. The clay matrix exhibits some flow banding in places. This would point towards the bank being formed as a result of a land slump or collapse. The lower half of the slope is composed of fine-grained gravelly clay. A stream flows from the northwest along the base of the slope and as such may erode and shape this bank over time.

There are two cold pools in the centre of the site which have vigorous gas discharge (Plate 7). The gas is likely to be a combination of H_2S and CO_2. The temperature of the pools was 9.5 °C and the pH was 3.5. Both pools are surrounded by a marsh/swamp area which includes various drainage channels that lead into the main stream, which originates in the northeast.

The southeastern part of this area is dominated by a silt/sand bank with abundant rock outcrops and areas of fractured or broken sinter. Many of the rocks include silicified wood and other organic matter (Plate 8). Also present are rock outcrops with weakly cemented gravelly horizontally layers and pumiceous rocks as well as occasional exposed welded ignimbrites with carbonized wood fragments. There is some minor sulphur deposition on the surface in this area (Plate 9). The main stream from the northeast flows past this area and joins the stream from the northwest at the southern end of the area. The main stream has a pH of 8. The soil temperatures at 10 cm depth across this area were not above ambient temperatures (11-12 °C).

Area E

This is an area of bare ground and exposed altered rock (Plate 10). The area measures approximately 12 × 20 m. There is a dry gully on its southern flank with a small stream flowing past the western boundary (Plate 11). Soil temperatures at 10 cm depth across the area were not elevated above ambient temperatures (range from 9 °C to 12 °C). The exposed surfaces vary from altered pumiceous rock, which exhibit moderate alteration, to brittle silicified gravelly soils/clays with dissolution features in the clay matrix. Organic material was also noted in the pumiceous rock (Plate 12). There is little or no evidence of sulphur deposition and no steaming ground was observed.

Area F

Grid Ref: E1889165 N5749531

This is an easterly facing bank of bare rock partially covered by pine needles (Plate 13). The bank is *c.*5 m high and 6 m wide.

The exposed rock is moderately acid altered pumiceous rock. The south and east margins of the outcrop are moderately to strongly silicified.

There is a stream running SW to NE along the base of the outcrop. The water temperature before and after it passes the outcrop is 12 °C and the pH is 6.4 -6.5. There is no indication of any current thermal activity.

Area G

Grid Reference: E1889113 N5749294

This site measures approximately 50 × 20 m and is an area of exposed ground on the edge of a pine woodland area. The long axis of the area runs in an east-west orientation. The area consists of three main areas of exposed lightly sulphur encrusted gravelly pumice (maximum thickness 0.5 m) over pinkish poorly sorted pumice sandstone. There is minor silicification of both clay soil and rock and some areas of intense sulphur deposition around small warm vents. A small stream/drainage channel originates from two small pools on the southern boundary of the area.

The eastern end of the site, nearest the road access point, is dominated by an area of cold bare ground (temperatures of between 11-12 °C at 10 cm depth) (foreground Plate 14).

In the centre of the site there are two small pools from which a small stream flows to the west along the southern boundary of the area (Plate 15). There is also an area of bare ground with minor sulphur deposition on top of altered/weathered clays.

In the western end of the site is a third area of exposed ground with sulphur-encrusted fissures with some small (<0.1 m diameter) vents (Plate 16). The ground temperatures increase towards the most active vent which was 85 °C at 0.25 m depth. At 2m distance the temperatures are between 18 and 27 °C.

The stream on the southern boundary originates in a small oval pool in the east, which is 0.3 × 0.4 m × 0.2 m deep (temperature 21 °C) with a very low outflow rate (estimated to be < 0.1 l/s) (Plate 15). This drains into a second pool of around 0.6 m diameter and 0.2 m depth, which has a temperature of 22 °C and an estimated outflow of 0.5 l/s. As the stream reaches the western exposed rocks it has cooled to 15 °C, and after it has passed this area of weak thermal activity the temperature is 16 °C. The pH of the stream is between 3.2 and 3.7.

Plate 1. Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.

Plate 2 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.

Plate 3 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.

Plate 4 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.

Plate 5 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.

Figure 2: Sketch map indicating main features and photo locations at manifestation B Northern Paeroa Range Geothermal Area.

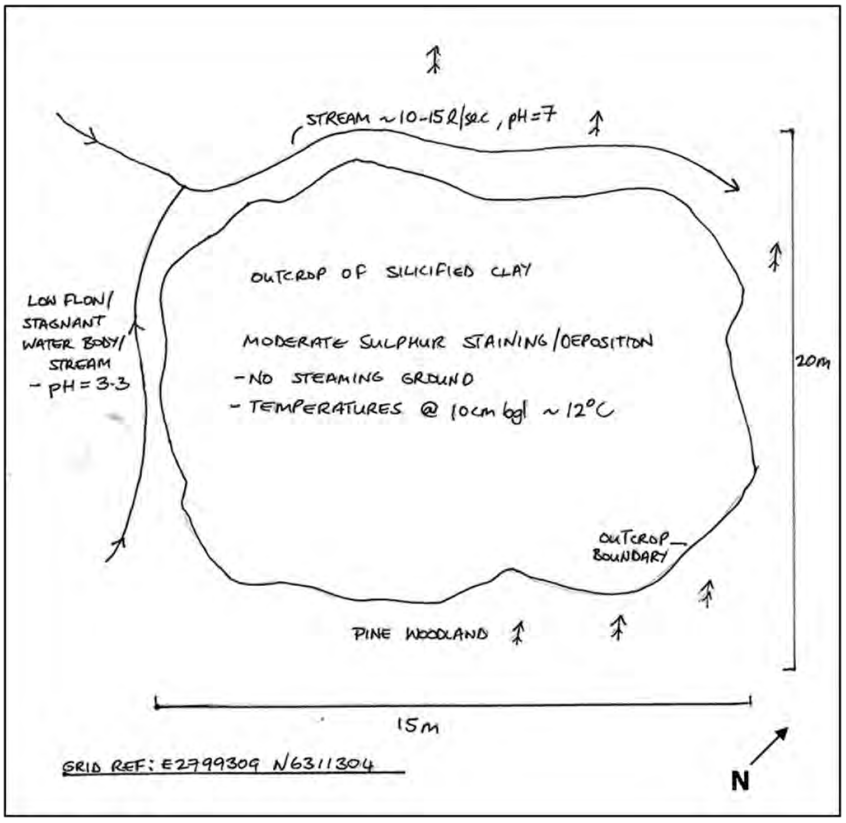
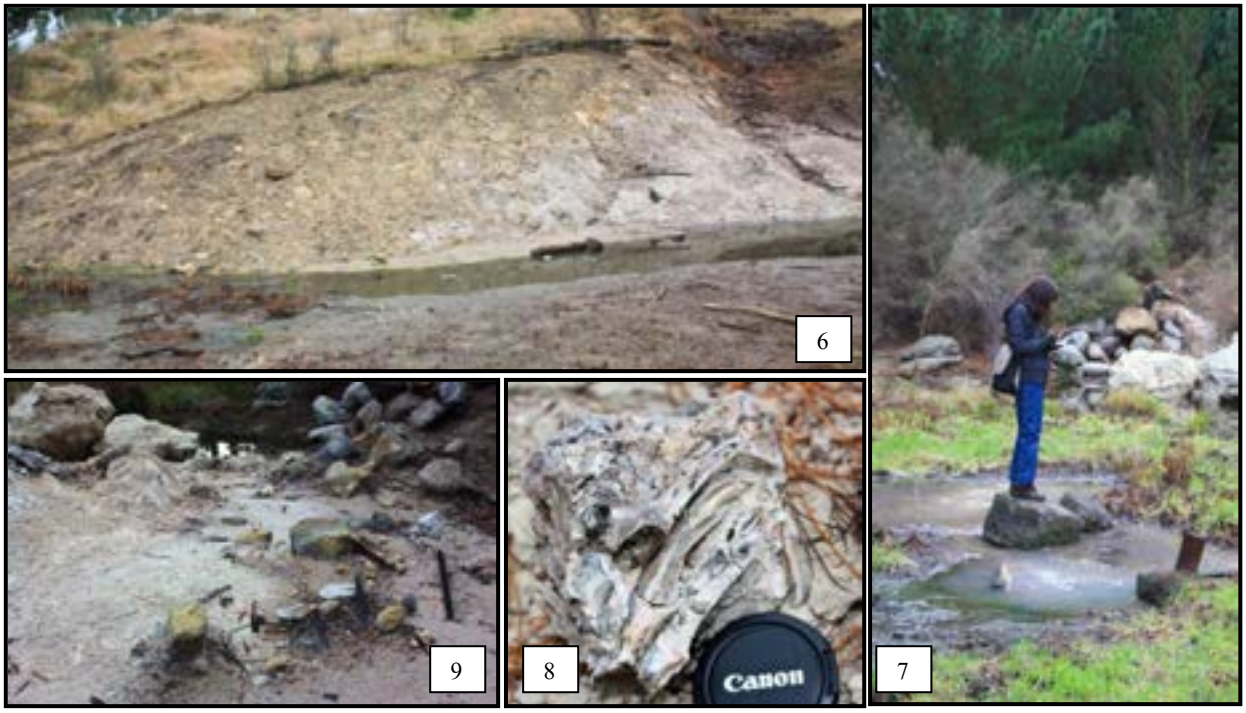


Figure 3: Field sketch map indicating main features at manifestation C, Northern Paeroa Range Geothermal Area. The grid reference labelled here is NZMG.

Figure 4: Field sketch map indicating main features and photo locations at manifestation D, Northern Paeroa Range Geothermal Area. The grid reference labelled here is NZMG.



Plates 8-9: Northern Paeroa Range Geothermal Area D. Clockwise from top left - 6. Clay Bank/Slope, southwestern orientation; 7. Cold Gas Discharging Pools northeastern orientation; 8. Silicified clay with silicified wood; 9. Exposed ground with rock outcrops, sulphur deposits and sinter, northern orientation.

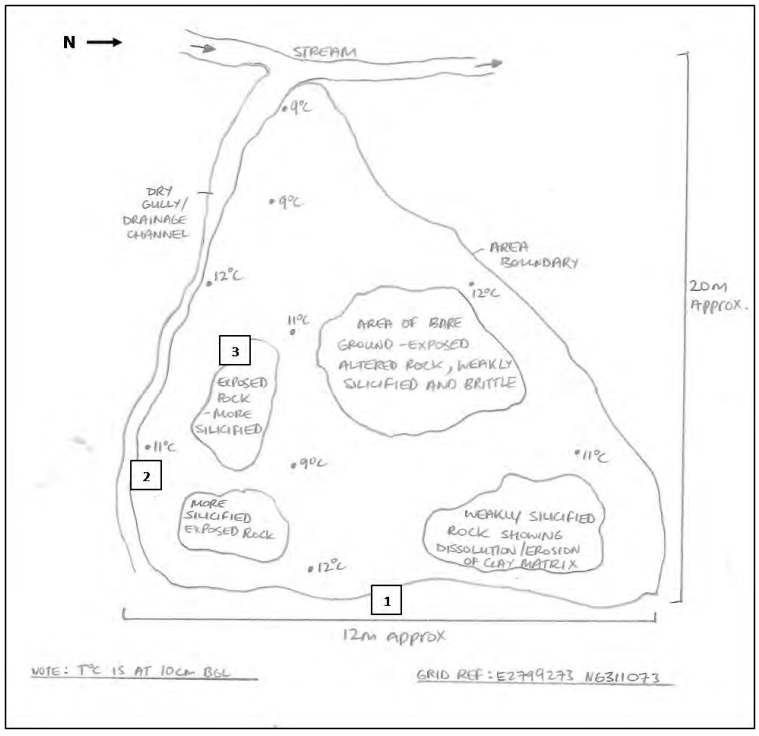
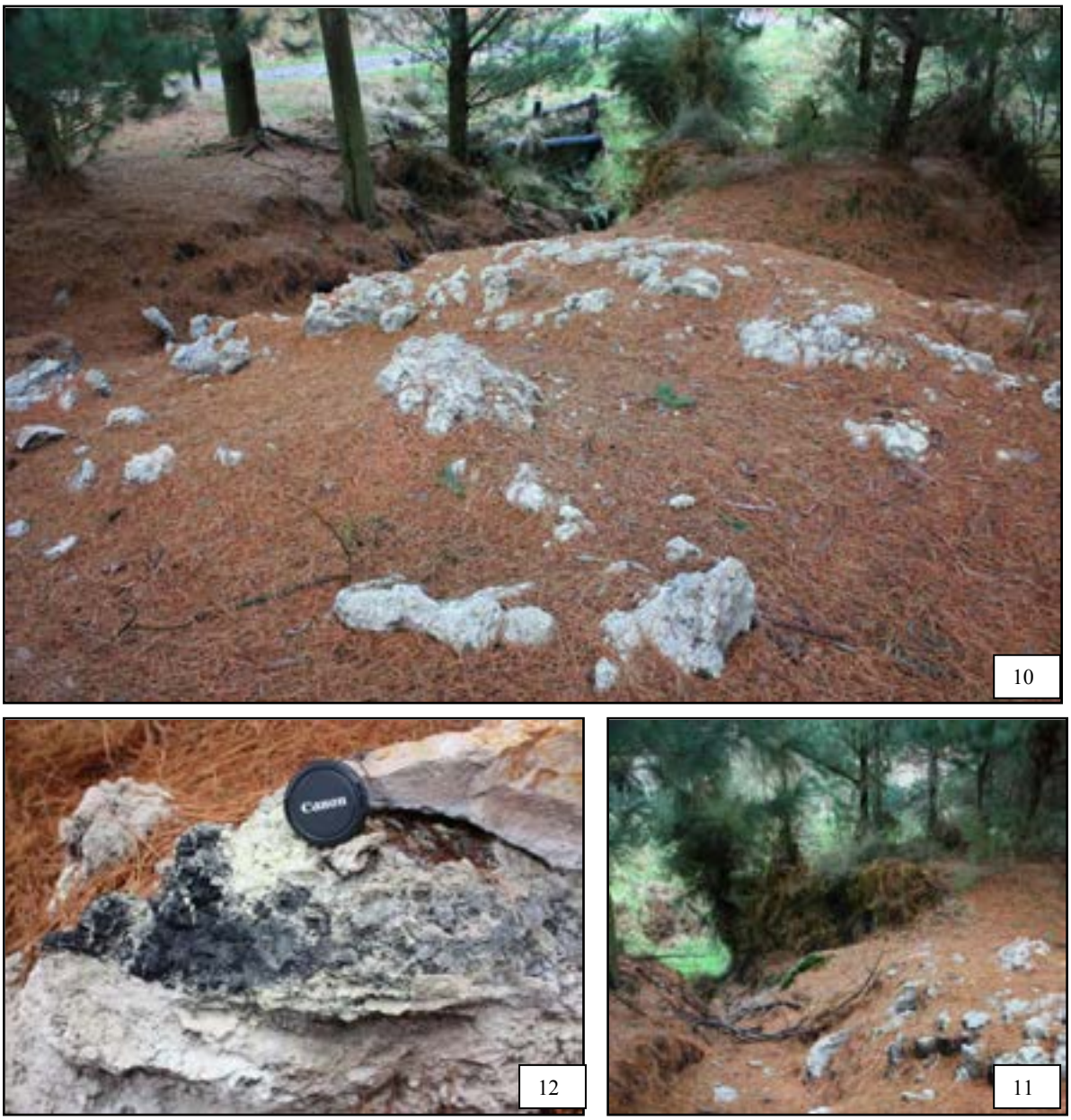


Figure 5:
Field Sketch Map
indicating main features and photo locations at manifestation E, Northern Paeroa Range Geothermal Area. The grid reference labelled here is NZMG.



Plates 10-12: Northern Paeroa Range Geothermal Area E. Clockwise from top left - 10. Bare Ground and exposed altered rock; 11. Dry Gully with exposed rock on sides; 12. Pumiceous altered rock, top left, and more brittle/ weathered silicified soil/clay with organic material beneath

Figure 6: Field Sketch Map indicating main features and photo locations at manifestation F, Northern Paeroa Range Geothermal Area.
The grid reference labelled here is NZMG.

Plate 13: Northern Paeroa Range Geothermal Area F.

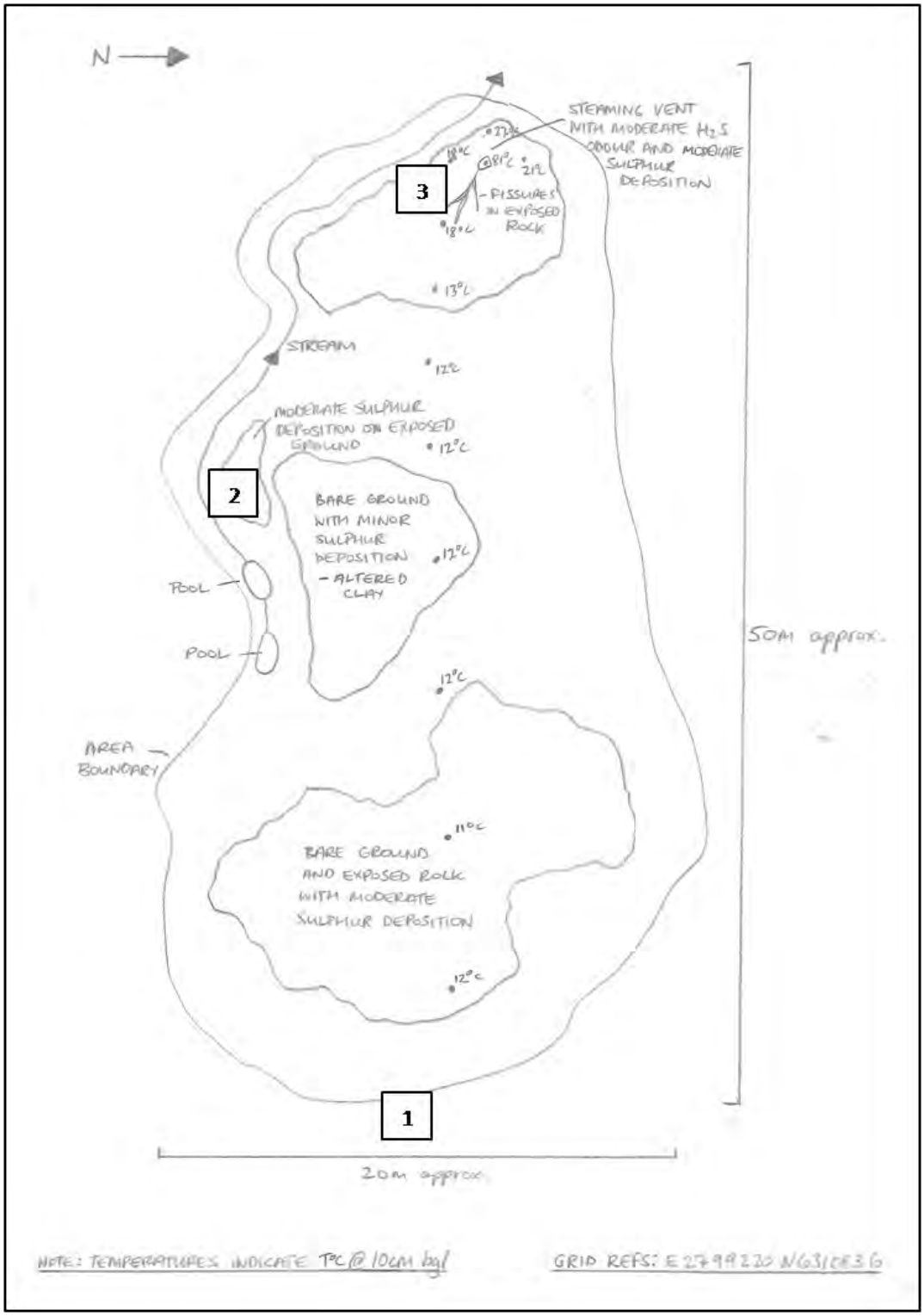


Figure 7: Field sketch map indicating main features and photo locations at manifestation G, Northern Paeroa Range Geothermal Area.
The grid reference labelled here is NZMG.

Plates 14-16: Northern Paeroa Range Geothermal Area G. Clockwise from top left - 14. Full area view from eastern end; 15. Pools and stream along southern boundary; 16. Steam vent showing sulphur deposition around edge and fissure through silicified rock.

WAIOTAPU NORTH[1]

Feature 1:
Geothermal lake

Grid Reference:
E1895238 N5752181

This lake is located on the southern side of the access road and measures approximately 50 × 70 m. There are steaming parts of the lake near the road. The vegetation cover did not allow an assessment of the source of the steam. As such it could be coming from the surface of the lake or separate discharges along the lake edge. The main stream enters at the northwestern edge of the lake. The temperature was measured (using an infrared (IR) thermometer) at 44°C. There was no access to take a pH reading.

Plate 17: Steam rising from northern part of lake, Feature 1, Waiotapu North.

Feature 2:
Hot pools and sinter terrace

Grid Reference:
E1895436 N5751840

Approximately 100 m to the south of the lake and access road there are a number of hot pools discharging silica laden fluid forming a sinter terrace on the banks of the stream. Among the pools is a large mound of sinter which incorporates a large deep pool (2.5 × 1 m) of near boiling water which discharges to the south (Plate 18). The water was clear with a blue tinge, indicating colloidal silica. The flow was estimated to be approximately 1-2 l/s. There are a number of other small, clear, slightly blue pools discharging small volumes into a channel which flowed into the stream to the west (Plate 19). Minor sulphur encrustation was noted along the channel from these pools. The temperatures of the pools ranged from 85°C to 97°C. Both the IR thermometer and thermocouple device were used. The pH in the large pool was 8.2.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson 2010.

Plate 18: Feature 2, Waiotapu North. A large clear blue hot (boiling) pool. Note: Discharge was to the south, towards stream in the background. Sinter terrace is also visible on left-hand side of the photo

Plate 19: Feature 2, Waiotapu North: small shallow pools discharging to the west. Note: minor sulphur deposition and sinter terrace.

Feature 3:
Hot pools and sinter terrace

Grid Reference:
E18960085 N5751239

This feature comprises an area of sinter terrace with numerous small hot pools discharging a small volume of fluid into the adjacent stream. A sketch has been prepared indicating the main features (Figure 7). There are up to eight distinguishable hot pools with fluid temperatures ranging from 40 °C to 90 °C. In the northern end of the area there is a large shallow pool with diffuse degassing. The temperature in this pool ranges from 40 °C to

65 °C. In the northeastern corner there is a bank of steaming ground composed of silicified rock with sulphur encrustation.

The discharge from the shallow pool flows to the south and passes other hot pools and small discharge channels. One hot pool in the centre of the area had 80 °C fluid. The rim of this pool was raised and composed of dark grey sinter and could be described as geyserite (Plate 21). There was no visible discharge from this pool. Two pools nearby had a sheen on the water surface (similar to a hydrocarbon sheen) (Plate 22). Most of the area comprised a sinter terrace. The full area of this site was approximately 30 × 20 m.

The main channel draining the area had a temperature of 58 °C and flow was <1 l/s. The stream temperature upstream of the sinter terrace was 34 °C while this had risen to 36 °C two metres downstream of the discharge channel.

Plate 20: Feature 3, Waiotapu North: view from southeast of sinter terrace and shallow pool area. Note stream flow from right to left in background and main discharge channel on the left-hand side of the photo.

Plate 21: Hot pool with geyserite structure rim, Feature 3, Waiotapu North.

Plate 22: Small hot pool (90 °C) with sheen, Feature 3, Waiotapu North.

Plate 23: Discharge from sinter terrace and pools into stream, Feature 3, Waiotapu North.

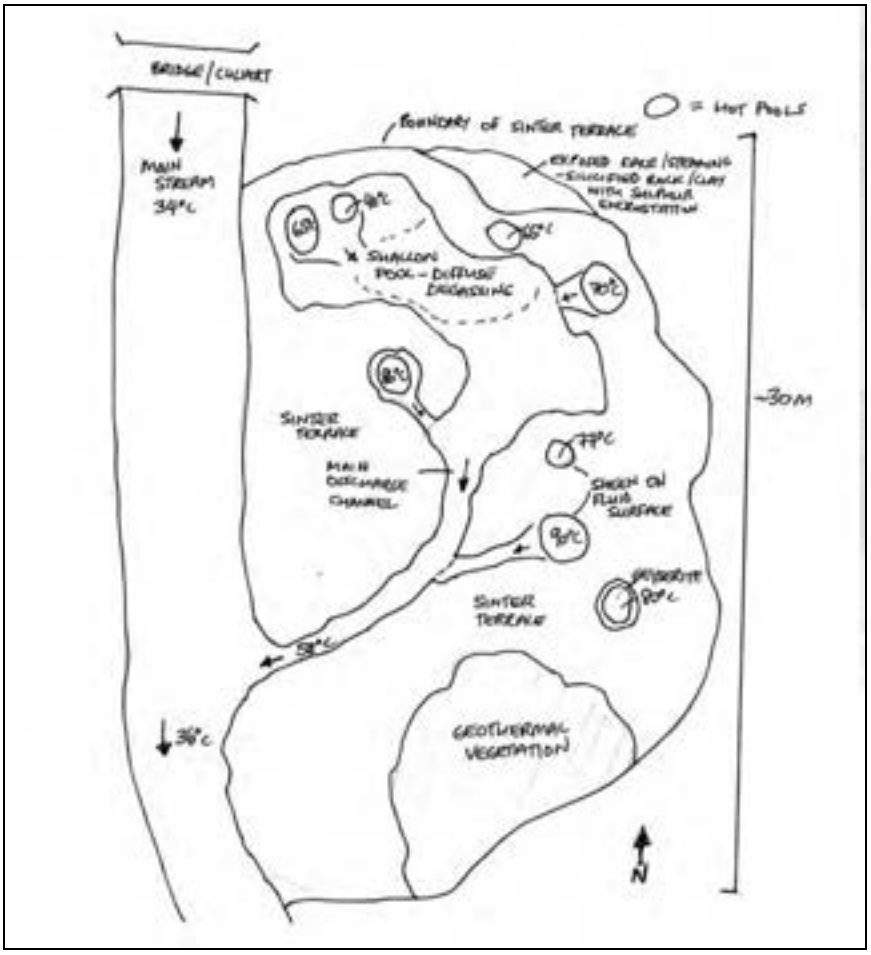


Figure A1-7: Field sketch of hot pools and sinter terrace, Feature 3, Waiotapu North.

Feature 4:
Shallow mud lake

Grid Reference:
E1894833 N5750814

This feature measures approximately 40 m^2 and comprises a shallow mud lake. There was no access to obtain temperature measurements. The southeast corner of the lake contained the most significant activity with significant steam and gas discharge associated with two erupting mud pools (Plate 24). The southern of the two mud pools erupted approximately every 30 seconds. Diffuse steam discharge and degassing was noted across the rest of the lake.

Plate 24: Southeast corner of shallow mud lake with two areas of erupting mud and significant steam discharge, Feature 4, Waiotapu North.

Feature 5:
Pale green, steaming lake

Grid Reference:
E1895025 N5750791

The lake measures approximately 30 m^2 and has a minor steam discharge at its surface. It is cloudy and pale green in colour, which suggests a sulphuric input. Access was not sufficient to take a temperature measurement.

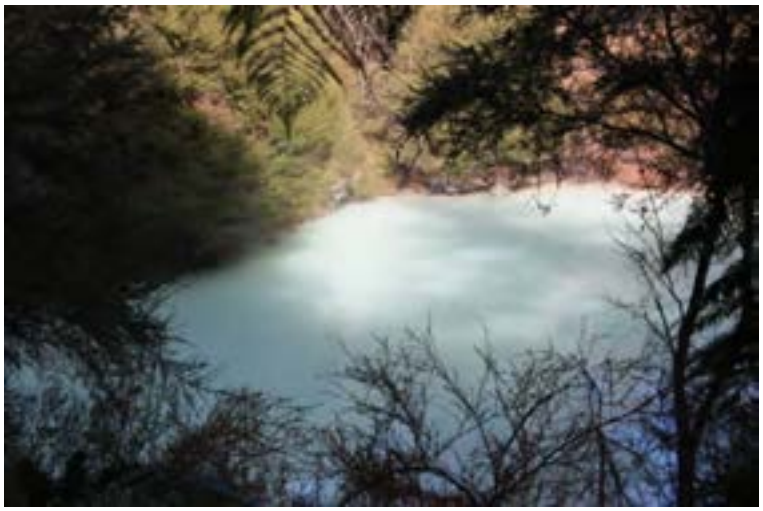


Plate 25: Pale green lake with minor steam discharge, Feature 5, Waiotapu North.

Feature 6:
Hot springs, steaming ground

Grid Reference:
E1895507 N5749948

Approximately 10 m to the north of the bridge at this location there are a number of hot springs discharging into a stream from its western bank. There was also a minor amount of steam discharge. The discharges are small <0.1 l/s and had a maximum temperature of 38 °C. The bank with the springs is cream with some minor sulphur deposition. From a distance it was not clear if the colour of the bank was as a result of silica deposition or bacterial/algal growth. The stream had a temperature of 20 °C and was slightly cloudy. The flow was estimated to be in order of 200 l/s.

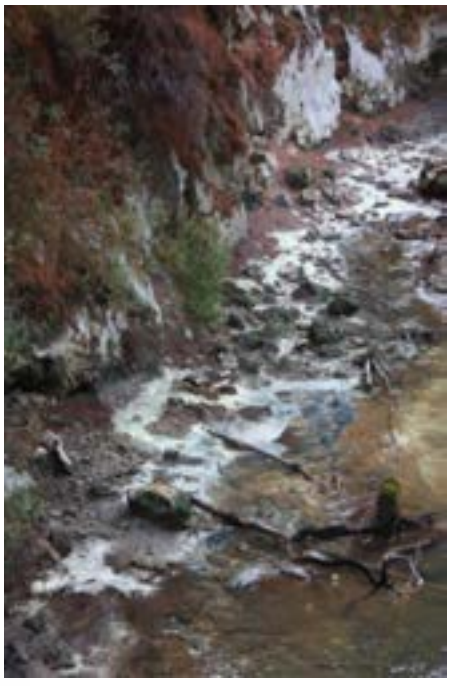


Plate 26: Steaming ground and hot springs on western bank of stream, Feature 6, Waiotapu North.

Feature 7:
Freshwater stream with geothermal inputs

Grid Reference:
E1895977 N5753920

A freshwater stream is culverted beneath the road and flows south near the western end of Lake Rotowhero. The stream had a temperature of 14-15 °C, a pH of 5.2 and had a flow or approximately 200 l/s. There are numerous geothermal springs which contribute fluid to and heat the stream along its course which flows south. The features are discussed below:

(a) Grid Reference: E1894920 N5752841. Area of hot pools with clear water and grey bases on the eastern bank discharging a small volume of fluid into the stream (*c*.1 l/s). The temperatures ranged from 33 °C to 79°C and had pH values of approximately 6.

(b) Grid Reference: E1894928 N5752731. A small clear pool on the eastern bank of the stream with a temperature of 95 °C discharging approximately 0.5 l/s through a 2 m long channel into the stream (Plate 28). Minor silica deposition in the channel. The temperature of the stream upstream of the pool discharge was 18 °C and 23 °C downstream. The pH of the pool was 6.6. On the western bank there were numerous areas of steaming ground which were not accessible.

(c) Grid Reference: E1894996 N5752509. A small spring outflow at an outcrop of silicified clay discharging 95 °C fluid into the stream. Flow is approximately 0.2 l/s.

Plate 27: Area of hot pools discharging into stream (a), Feature 7, Waiotapu North.

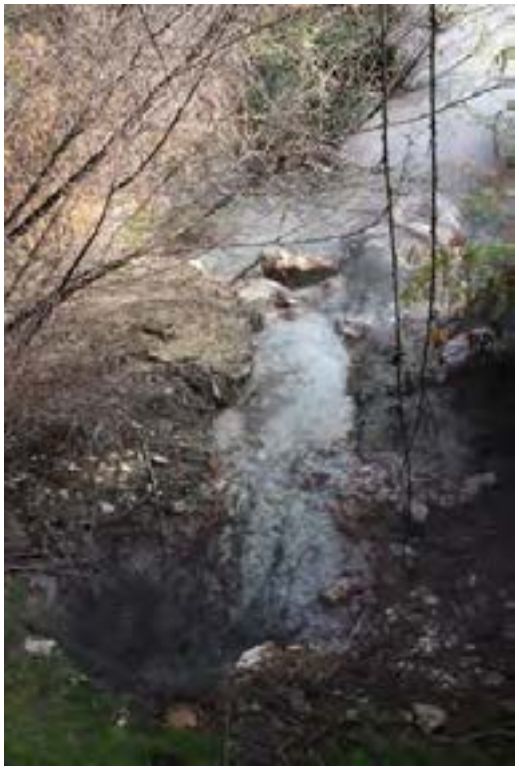


Plate 28: Small clear, near boiling pool, 0.2 l/s discharge into stream (b), Feature 7, Waiotapu North.

Feature 8:
Steaming ground

Grid Reference:
E1896462 N5751308

Approximately 30 m upstream from a bridge there is an area of steaming ground. There was no access to this area due to think blackberry vegetation. The steaming ground is close to a stream.

Feature 9:
Steaming ground, mud pools

Grid Reference:
E1895496 N5750840

This feature comprises an area of exposed ground with silicified pumiceous soil and four mud pools. The mud pools ranged from 1 × 4 m in diameter and had temperatures ranging from 50 °C to 78 °C. The mud pools were all dark grey and had significant steam and H_2S discharges. There were also isolated areas with sulphur encrustation on the surface. The deepest and hottest of the pools was bound on three sides by steep 2 m walls, while the other pools were shallower (Plates 28 and 29). All pools appear to be located in collapse craters formed by steam dissolution of the soil.

Plate 29: Large mud pool within collapse crater, Feature 9, Waiotapu North.

Plate 30: Steep sided collapse crater with mud pool at base, Feature 9, Waiotapu North.

MAUNGAKAKARAMEA (RAINBOW MOUNTAIN)[1]

Feature 1: Thermal ground, steaming ground

The feature comprises an area of bare ground with a silicified crust measuring approximately 65 × 40 m. Steam discharged in three areas, an area near the western boundary, an area in the centre (Plate 31), and an elevated outcrop of pumiceous altered rock at the southern end (Plate 32). The outcrop area had significant steam discharge from numerous small (<5 cm) fumaroles, along with abundant sulphur encrustation. Kaolinite was noted across much of the top surface of the area. The soil temperatures at 10 cm depth were highest nearest the outcrop (97 °C) while the rest of the area had temperatures ranging from 22 °C on the eastern perimeter to 56 °C on the western perimeter.

A large cold[2] lake is adjacent to the geothermal feature (Plate 33). While there was no evidence of geothermal heating, an area in the centre of the lake was noted to be bubbling or degassing - although no steam was visible. A man-made bund lies between the lake and the thermal ground. The lake pH was 8.7.

Plate 31: View of thermal ground looking south from bund. Note outcrop left of centre, Feature 1, Maungakakaramea (Rainbow Mountain).

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson,2010.
[2] Water temperature of 3 °C, air temperature 4 °C.

Plate 32: Steaming outcrop, southern end of Feature 1, Maungakakaramea (Rainbow Mountain).

Plate 33: Cold lake adjacent to area. Note: water vapour in background is due to sunlight heat, not caused by geothermal effects, Feature 1, Maungakakaramea (Rainbow Mountain).

Feature 2:
Cold acidic lake

This feature is a cold[1] lake with a pH of 3.3. At the northern end of the lake on the western side there is a small outcrop of silicified rock (Plate 34). Soil temperatures did not exceed ambient temperatures at 10 cm depth in this area. No steam was noted on or surrounding the lake, but there was a small area where the surface was disturbed by bubbling. On the western side of the lake in the approximate lake center is an area of exposed face; no steam was noted in this area. At the southern end of the lake there is a steep cliff face (Plate 35). The lake had a green colour and measures approximately 80 × 30 m.

[1] Water temperature of 4°C, air temperature 5°C.

Plate 34: Relic altered rock on northwestern edge of lake, Feature 2, Maungakakaramea (Rainbow Mountain).

Plate 35: View of lake from north, Feature 1, Maungakakaramea (Rainbow Mountain).

Feature 3:
Northern slope,
exposed thermal ground

Grid Reference:
E1895947 N5753865

This feature consists of isolated areas of bare ground comprising pink and white kaolinite clay (Plate 36). Ground temperatures at 10 cm depth are approximately 12°C. The areas range from 2 × 2 m to 4 × 1 m in size.

Plate 36: Area of exposed ground comprising pink and white kaolinite clay, Feature 3, Maungakakaramea (Rainbow Mountain).

Feature 4:
Exposed slope

Grid Reference:
E1895977 N5753920

This feature is a large face of altered white and red kaolinite clay (Plates 37-39). There was no evidence of steaming ground. Ground temperatures at 10 cm depth were 12°C. Highly silicified, angular pumice fragments are present within the clay matrix.

Plate 37: View of exposed slope, Feature 4, Maungakakaramea (Rainbow Mountain).

Plate 38: Close up of exposed slope, Feature 4, Maungakakaramea (Rainbow Mountain).

Plate 39: Kaolinite clay matrix with silicified pumice fragements, Feature 4, Maungakakaramea (Rainbow Mountain).

Feature 5:
Lake Rotowhero

Grid Reference:
E1894921 N5752951

This feature is a dark green lake with steam evident across most of the water surface. The temperature was 26 °C and the pH was 3.4 indicating an acidic input. The eastern end of the lake had an area of increased steam discharge near an area of exposed red/orange slope. The stream outflow (approximately 60-70 l/s) from the lake had a temperature of between 28 and 32 °C and a pH of 3.4. A small hot pool with clear fluid and grey base was located along the outflow channel closer to the lake at its southern end. It had a temperature of 83 °C and measured approximately 0.3 × 0.5 m.

Plate 40: Lake Rotowhero. Steam and exposed slope in background, Feature 5, Maungakakaramea (Rainbow Mountain).

Feature 6:
Geothermal wetland

Grid Reference:
E1895026 N5752555

The outflow from Lake Rotowhero flows through an area of geothermal wetland to the east of the main stream. The wetland measures approximately 20 × 20 m and contains hot clear pools, which are actively degassing H_2S. The temperatures of the pools range from 34 °C to 65 °C. There is various geothermal and wetland vegetation mixed in with the geothermal features (Plate 41). There are also areas of steaming ground associated with this area. The outflow from this area is culverted beneath the access road into the main stream. The temperature of the outflow is approximately 46 °C and the flow is in the region of 60 l/s.

Plate 41: Geothermal wetland with numerous hot clear pools, Feature 6, Maungakakaramea (Rainbow Mountain).

WAIOTAPU SOUTH[1]

Feature 1:
Steaming ground

This is an area of steaming ground surrounded by thick vegetation including blackberry (Plate 42). Access was not possible to identify the nature of the feature. From a distance of 20 m the steam discharge was considered moderate and there was no audible bubbling.

Plate 42: Steam rising from centre of densely vegetated area, Feature 1, Waiotapu South.

Feature 2:
Cool, slightly acidic lake

Grid Reference:
E1893847 N5748881

This feature is a lake which is slightly warmer than ambient temperature (water temperature of 15 °C) and had a pH of 4.1. This would indicate some geothermal input affecting both the temperature and pH, albeit rather small. Some minor degassing/bubbling was noted in one area of the lake.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

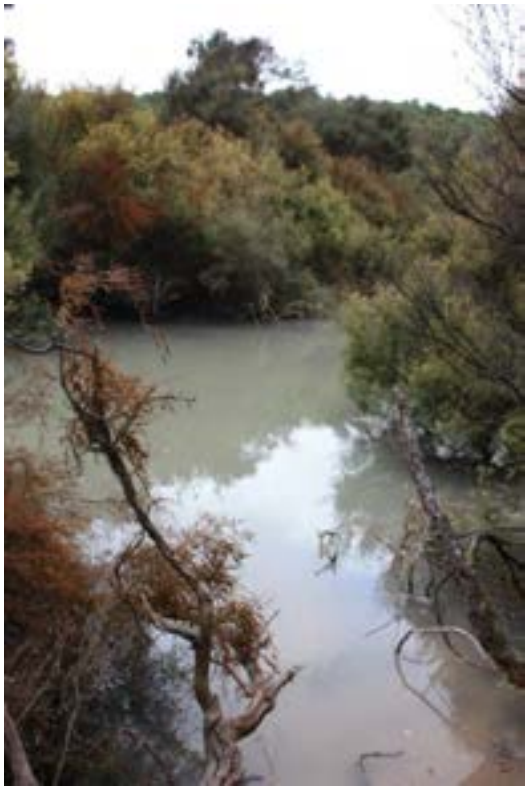


Plate 43: View from northern end of lake. Degassing was noted in middle ground of photo, Feature 2, Waiotapu South.

Feature 3: Geothermal pools/ sinter terrace/ shallow lake

Grid Reference: E1893775 N5748797

This feature measures 40 × 15 m and comprises an area of near boiling pools which are actively depositing silica. The central area of the feature is a shallow lake. The pools have clear water and a blue/green tinge, an attribute created by the presence of colloidal silica. A sketch map of the area has been prepared indicating the location of some of the mapped pools and the photographs (Figure A1-8). Not all the areas were accessible and caution was required around such unstable structures. The temperatures ranged from 80 °C to 99 °C; the hottest pools were found in the western limits of the area. These pools were discharging fluid; their discharge then depositing silica forming an area of sinter terrace (Plate 47). The diffuse discharge and limited access allowed only visual estimates of the flow. This was estimated to be in the order of 1-2 l/s. The pH of the pools in this area was 7.6. There was significant steam discharging from the area and a moderate H_2S odour. Measurements were taken using an in situ thermocouple device where access was safe and using an IR thermometer where access was not considered safe.

Plate 44: View of pool from northern edge, Feature 3, Waiotapu South.

Plate 45: Hot Pools with very small discharge at northeastern edge of area, Feature 3, Waiotapu South.

Plate 46: View from northeastern limit across shallow lake area and green pool, Feature 3, Waiotapu South.

Plate 47: View from western limit of feature showing two large boiling pools which discharge fluid forming a sinter terrace, Feature 3, Waiotapu South.

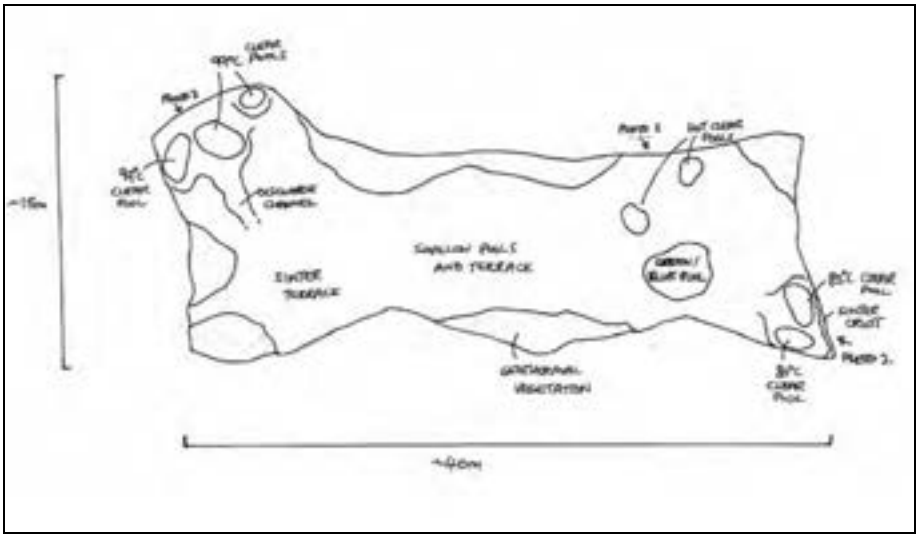


Figure A1-8: Field sketch of area of hot pools and sinter terrace, Feature 3, Waiotapu South.

Feature 4:
Concealed mud pools

Grid Reference:
E1893725 N5748742

Up to three concealed mud pools were noted at this location. Access was not safe; however steam discharge and audible bubbling distinctive of mud pools were noted.

Feature 5:
Shallow lake

Grid Reference:
E1893737 N5748532

This feature is a shallow lake with grey cloudy water. The temperature at the surface of the lake was 20 °C while the soil temperature at the lake edge was 15.7 °C. No steam was observed at the lake and there was no evidence of degassing. Some steaming ground was noted approximately 10 m south of the lake.

Feature 6:
Mud pool
Grid Reference:
E1893611 N5748639

A mud pool with significant steam discharge including an almost continuous 'hissing' vent was observed. The pool measured approximately 2 × 2 m. The base of the pool was 2 m below ground level. The surface temperature was between 60 °C and 64 °C.

Plate 48: Mud pool. Note steam vent on right hand side of photo,

Feature 7:
Cool mud pool

Grid Reference:
E1893689 N5748532

This feature comprised a cool mud pool that measured approximately 1 × 1.5 m and was approximately 1 m deep. The surface temperature was 39 °C. There was no steam discharge associated with this feature although there infrequent bubbling was noted. The surrounding vegetation was coated in a light grey mud indicating that the pool was eruptive in the past (Plate 48). On one side the vegetation was flattened.

Plate 48: Small mud pool in centre of photograph. Note mud coating on vegetation surrounding pit, Feature 7, Waiotapu South.

Feature 8:
Geothermal seepage

Grid Reference:
E1893742 N5748546

A clear very shallow seepage was noted at this location. The temperature was 43 °C. The flow was very low (<0.1 l/s).

Feature 9:
Mud pool

Grid Reference:
E1893738 N5748513

A grey mud pool was observed at this location which was approximately 3 m^2 in area (Plate 49). The feature had considerable gas and steam discharge. The temperature at the surface was between 70 °C and 80 °C. The soil temperature at 10 cm depth at the edge of the pool was 15.7 °C.

Plate 49: Mud pool, Feature 9, Waiotapu South.

Feature 10:
Geothermal pool

Grid Reference:
E1893728 N5748481

This feature is a large, deep, clear pool/lake 10 m^2 in area. The temperature at the surface was 55 °C. There was no safe access to take a pH measurement as the margins of the lake were heavily vegetated over a soft substrate. No evidence of silica deposition was noted. No outflow was noted.

Plate 50: Clear deep pool with soft margins, Feature 10, Waiotapu South.

Feature 11:
Freshwater stream with geothermal inputs

Grid Reference:
E1893961 N5749308

The stream that flows through the northern section of the Waiotapu tourist park had a temperature of 26 °C near the visitors centre. At the grid reference listed above the temperature was 28 °C. This location is further downstream and to the west of the main surface features. There are numerous areas of steaming ground in the vegetation on the banks of the stream and there are bathing areas where geothermal fluid inputs must raise the temperature closer to 35 °C locally (common public hot spring bathing temperature). The flow of the stream was estimated to be in the order 150-

200 l/s.

Feature 12:
Mud pool

Grid Reference:
E1893477 N5748452

A mud pool with a surface temperature of 60 °C was observed at this location. It contained a light grey liquid, measured 3 m^2 and was degassing. There was considerable vegetative cover.

Feature 13:
Warm Lake

Grid Reference:
E1893575 N5748330

A warm lake was observed with a temperature of 18 °C and pH of 4.9 at its western margin. An area at the southern end of the lake had moderate steam discharge (Plate 51) which may be the result of an upwelling of hotter fluid. An outflow is present at the southern margin, and had a temperature of 21 °C, a pH of 4.8, and a flow of approximately 5-6 l/s. The water was clear.

Plate 51: Warm lake with area of steam discharge at southern end, Feature 13, Waiotapu South.

Feature 14:
Hot spring

Grid Reference:
E1893329 N5748493

A hot spring discharging fluid of up to 40 °C was observed on the edge of the main stream running through the northern part of the Waiotapu tourist park (Plate 52). Green and orange algae were noted on the banks at the hot spring. The surface temperature of the stream at this point was 26 °C.

Plate 52: Hot spring with orange and green algal growth on bank of stream. View from road bridge, Feature 14, Waiotapu South.

Feature 15:
Exposed warm ground

Grid Reference:
E1894865 N5748370

This feature is an area of exposed silicified soil and pumice measuring approximately 20 × 30 m (Plate 53). There was widespread minor sulphur encrustation on the surface and occasional fragments of silicified organic material. A small area of steaming ground was identified at the southern end of the site. The steam discharge was not significant and was surrounded by geothermal vegetation. The soil temperatures at 10 cm depth here and in the southeastern part of the site were around 32 °C, while most of the exposed area had soil temperatures between 15 °C and 18 °C.

Plate 53: Exposed ground with silicified soil, pumice and organic material, Feature 15, Waiotapu South.

Feature 16:
Exposed ground, steaming ground, mud pools

Grid Reference:
E1894979 N5748228

This feature is a series of large areas of exposed steaming ground with fumaroles depositing sulphur, mud pools/pits and numerous small, hot, grey pools (Plate 55). The main area of mud pools measures approximately 30 × 60 m and consists of two main pits with mud pools and an extensive silicified crust. Sulphur encrustation was common across the area. There was moderate steam discharge and audible bubbling of the shallow water table beneath the silicified crust. One clear, grey pool measuring 0.2 × 0.2 m had a fluid temperature of 90 °C.

Plate 54: Main area of activity with two pits comprising mud pools seen in the foreground and background respectively (arrows), Feature 16, Waiotapu South.

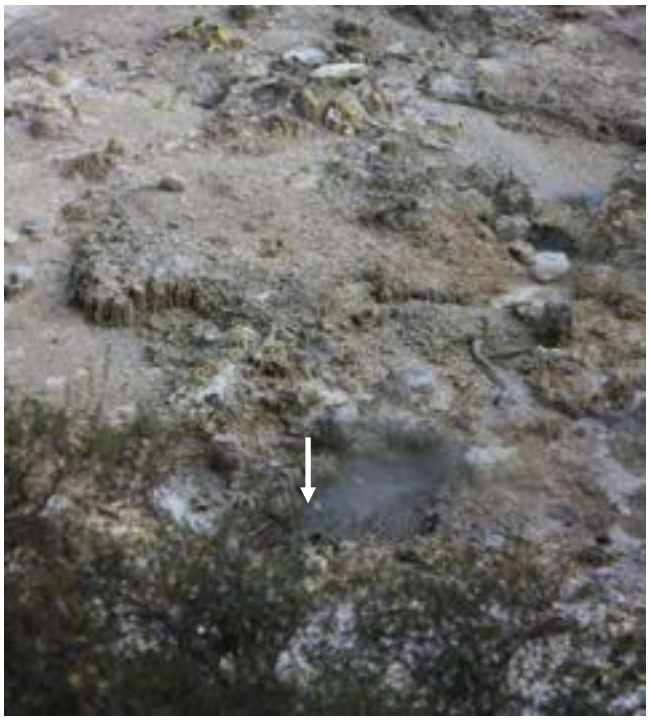


Plate 55: Small 90 °C clear grey pool, Feature 16, Waiotapu South.

TIROHANGA ROAD[1]

Overview of field work and background:

The thermal manifestations close to the Tirohanga Road in the Mokai Field were visited during the late morning on 5 February 2007 (refer to map Tirohanga Road - 2007 Geophysical Assessment). The sky was overcast and air and surface (ground) temperatures were between 18° and 20°C. These manifestations comprise a number of north-south aligned, often north-south elongated craters and small canyons which occur over a distance of *c*.300 m. In the past, steam was discharged along this fracture zone segment which derived from boiling of thermal water at a few hundred meters depth. Some of the acid condensates accumulated in a few muddy pools. When the Mokai Field was developed for electric power production in 2000, the separated thermal waste water from the power house was reinjected into a few drill holes *c*.500 m to the east of the then steaming mud pools. This led most likely to some quenching of underground vapour ascending in the fracture zone and thermal steam discharges ceased during 2005. All water-filled craters had cooled and exhibited ambient temperatures (*c*.20°C) when visited on 30 March 2006 (see Hochstein 2006).

During our visit on 5 February 2007 it was found that thermal water (not steam) is again entering most of the pools which had cooled down to quasi-ambient temperatures a year ago. The findings of the visit are listed in sequence, going from south to north along the *c*.300 m long segment of manifestations.

Manifestation 1A - Crater and Pond 1A:

This is the southern most, water-filled crater. At present, it exhibits a thin strip of black mud along its margin. The pond surface covers an area of *c*.300 m^2 (all areas cited in this report are order of magnitude estimates only using stepped out distances). The 2007 water level is significantly higher than that observed in 2006 when the pond area was much smaller (<30 m^2) and exposed a large area covered with black mud. The surface temperatures of the pond on 5 February 2007, when measured with the IR-gun, were between 28 and 29 °C. The water exhibits a dark, muddy colour. It is likely that the elevated surface temperatures are due to some input of thermal water.

Manifestation 1B - Crater and Pond 1B:

This small crater lies *c*.20 m north of Pond 1A. The pond in the crater covers an area of <50 m^2. It contains muddy, grey-brownish water with surface temperatures between 22 °C and 24 °C. The pond might not be recharged by thermal water.

Manifestation 2 - Hot Lake:

The hot lake lies *c*.50 m north of Pond 1B and covers an area of *c*.500 m^2 with surface temperatures (IR-gun) between 53 °C and 56 °C. There appears to be a small up-flow zone near the south margin where a maximum temperature of 67.1 °C was measured at *c*.0.2 m water depth with a thermocouple device. About 10 m to the south is a deep (2 m) collapse pit with *c*.53 °C stagnant water at the base. Elevated ground temperatures of *c*.27 °C occur at 0.2 m depth on land, half way between the lake and the collapse feature. At the northwest margin of the lake there is a shallow

[1] Undertaken by Hochstein in 2007

trickle outflow of lake water (<1 l/s) which infiltrates the ground. Further downstream to the south, another shallow, small outflow emerges. There was no lake at this site in 2006 although it was occupied by bare, partly steaming ground prior to 2000; it is likely that the hot lake is fed by thermal water which derives from reinjected water now ascending in the fracture zone.

Manifestation 3A - Large Mud Pool 3A:

About 50 m north of the new hot lake lies an old, large mud pool (3A), used historically as a rubbish tip but now almost cleared of rubbish. The pool area is covered by a muddy grey-brown coloured lake with an estimated surface area of *c*.500 m^2. The maximum surface temperature in the centre of the lake was *c*.30 °C, observed within a large discoloured water patch (up-flow?). The 2007 colour of the lake water is quite different from that observed in 2006 when it was a dark-brown stagnant water. The surface area of the lake has not changed considerably between 2006 and 2007 (although a minor increase was noticed along the western shore).

On top of the western rim of Pool 3A, a small strip of thermally altered ground is exposed. The ground temperature of the thermally altered ground at 0.2 m depth was 19 °C (i.e. non active ground).

Manifestation 3B - Adjacent Smaller Muddy Pool 3B:

Directly adjacent to the southeast margin of Pool 3A lies a smaller (*c*.150 m^2), water-filled, almost circular crater (Pool 3B), exhibiting a surface temperature of 35 °C (36.0 °C when measured with a thermocouple at 0.2 m depth). The elevated temperatures point to some significant input of thermal water. The level of the smaller pond (3B) was *c.*1 m above that of the larger pool/lake (3A). Some water of the smaller pond appears to seep through a small, *c.*1 m wide dam which separates the two ponds and which could be breached at any time. The surface temperature of the larger pool/lake (3A) was *c*.34 °C just adjacent to the dam. In March 2006, the surface level of Pool 3B was below that of the larger Pool 3A (Hochstein 2006).

A Deep Pit (*Acid Leaching?*)*:*

About 35 m to the southwest of Pool 3A was a *c*.2.5 m deep, almost circular pit (*c*.3 m diameter), which exhibits almost vertical walls (located at E1853320 N5734250). The temperature on the dry bottom was *c*.20 °C (i.e. a non active feature). Pits with a similar wall structure occur in the Waiotapu geothermal field where they are most likely caused by slow dissolution of pumice layers involving acid (steam) condensates. It is possible that some pits and canyons of the Tirohanga Road manifestations are also caused by 'acid leaching'.

Manifestation 4 - Deep Canyon:

An almost 15 m deep and *c*.40 m elongated (in north-south direction) 'canyon' lies *c*.100 m north of Manifestation 3. The bottom of the gully (Feature 4) is covered by a small lake. The surface temperature of the northern part of the lake was *c*.28 °C. There is a small, up-welling, muddy pool at the south end, associated with some wafting steam. The temperature at its southern margin was between 30 °C and 50 °C when measured from the rim with the IR gun. The walls of the canyon were too steep to climb to the bottom for closer inspection. However, some thermal water is obviously entering the bottom of this canyon.

Manifestation 5 - Canyon at the Northern End of the Tirohanga

Another *c*.50 m long, deep canyon (Feature 5) lies at the north end of the north-south aligned craters and canyons. This feature contains no pools and does not exhibit any visible thermal activity. However, at the northern end

Road Manifestations: of the deep, elongated structure lies an old Māori 'steam pit (umu)' where the ground temperature at the bottom was *c*.38 °C (0.4 m below surface). Some residual prostrate kānuka shrubs were found along the northernmost western rim. However, the ground temperature at 0.2 m depth beneath 1.0-1.5 m high prostrate kānuka was *c*.18 °C (i.e. non-thermal ground).

Interpretation of Findings: It is likely that the thermal water now emerging in five manifestations (Features 1A, 2, 3A, 3B, and 4) derives from thermal waste fluids discharged by the geothermal power station (located *c*.3.5 km to the southeast of the Tirohanga Road manifestations), from where they are transmitted by surface pipes to three reinjection wells (MK 4, 8, 9) which lie *c*.400 to 500 m east of the Tirohanga Road craters and pools. Since the commissioning of the plant in 2000 until 2005, *c*.800 t/hr of separated thermal waste water was injected into two of the three reinjection wells, down to depths of about 400 m. This rate was increased to *c*.1,400 t/hr from May/June 2005 onwards when the abstraction rates from hot bores supplying hot fluids to the power station were increased. During the first period of reinjection (i.e. from 2000 to *c*.2004) the injected wastes started to accumulate at depth and around the injection wells, which led to the quenching of naturally discharging steam beneath and within the Tirohanga Road thermal manifestations, which ceased to discharge steam by 2004/2005. All manifestations then cooled down and elevated ground temperatures could no longer be observed at the beginning of 2006. When the injection rate of the plant was increased in 2005 and after the quenching of ascending steam, thermal waste water must have started to ascend to the surface, as it was noticed during our visit on 5 February 2007.

The Mokai Geothermal Power Plant managers must have been aware about the underground pressure build-up around the reinjection wells, since deeper reinjection has been considered. One of the new, deep reinjection wells is presently being drilled near one of the old injection wells. Since rapid changes in the natural discharge rate of the injected waste fluids might occur, some detailed monitoring of the Tirohanga Road manifestations should be considered.

UPPER ATIAMURI WEST[1]

Overview of field work and background:

The site was inspected on 5 February 2007 in the early afternoon. Overcast conditions prevailed the whole day, it was calm, air and ground temperatures were in the range of 20 °C and 22 °C. Two smaller previously unknown manifestations had been recently reported by the farmer, Mr B. Bergs.

A circular pit exposing an active thermal spring:

A subsurface thermal spring discharges at the bottom of a *c*.2.5 m deep, almost circular pit (diameter *c*.2 m) on Bergs Farm at E1866338 N5749636. The site lies *c*.190 m northwest from the southern Atiamuri hot pool. Hot water with a temperature of 59.3 °C flows as a trickle across the bottom of the pit. The upper part of the almost vertical wall of the pit exposes a grey, *c*.0.5 m thick, old silica sinter layer. The pit lies on top of a *c*.2.5 m high sinter mound which points to a long deposition history of this manifestation. The trickle flow of thermal water at the bottom drains through a subsurface layer. The sinter mound is overgrown with dense scrub. The temperature of the hot spring is close to that measured at the surface of the nearby Upper Atiamuri hot pools (Site U16/6). No simple explanation can be put forward to describe the processes which might have led to the formation of a deep, vertical pit on top of an obviously old sinter mound.

A quenched fumarole:

About 350 m to the northwest from the southern Atiamuri hot pool, also on Bergs Farm at E1866297 N5749798, there is a small thermal feature which appears to be a quenched fumarole that occurs within a vertical vent of <0.3 m diameter. The vent is out of sight and occurs at the bottom of a *c*.2 m deep and *c*.5 m wide depression which is overgrown by dense exotic herbfield. Near the top of the vent, steam is condensed by liquid, black mud. The stable temperature *c*.0.1 m inside the mud layer was 97.5 °C. The ground around the vent is heated to *c*.40 °C at the surface, about 0.5 m away. Quenching of steam is associated with a hissing and bubbling noise. This feature was not described as a 'boiling mud pool' because of its small size.

[1] Undertaken by Hochstein in 2007.

WHANGAPOA SPRINGS[1]

The southern hot pool: This pool had a surface area of *c.*600 m^2, infilling a deep crater with clear bluish coloured thermal water. The surface temperature was rather constant at 60 °C (fluke thermocouple). Minor gas discharges showed up as bubbles in the centre of the pool. At the main outflow and overflow at the southwestern rim, thermal water was discharged at a rate of *c.*1 l/s at 58 °C (pH = 7).

The northern hot pool: About 60 m north of the southern pool lies the somewhat smaller northern hot pool, which covers an area of *c.*400 m^2. It occurs in a deep hollow, and is surrounded by 2-3 m high cliffs. The thermal water is also of a blue colour, but slightly less clear. The surface temperature was also constant (*c.*60 °C when measured with an IR gun). In the north corner, near a dug outflow channel, there was a significant gas discharge (continuous bubbles). Here, the pool temperature at *c.*0.2 m depth was 69 °C. At the north outlet, the outflow rate was estimated to be 1-2 l/s (discharging at 53 °C).

MATAPAN ROAD[2]

There are two springs, one discharging *c.*3 m above the pool with a temperature of 64 °C. A cooler spring with a smaller flow discharges from the right of the rock face around 1 m above the pool. No smell of H_2S was recorded. The rocks below the spring and in the pool are covered in black algae.

[1] Undertaken by Hochstein in 2007.

[2] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson,2010.

MURPHY'S SPRINGS[1]

Thermal Springs discharge into a stream along the edge of a pine plantation and a bank of recently felled pine. During the site visit, four thermal springs were identified, which discharge at various points along a *c.*200 m stretch of the gully. A small stream originates in an area of wetland on the east bank of cleared pines (Location 1 on sketch). The flow in this stream is approximately 10 l/s with a temperature of 32.8 °C and a pH of 6.3.

On the western side of the gully there are three thermal springs which discharge along the steep bank into the main stream. The access to these springs is difficult and only one of them, the furthest south, was directly measured using a pH meter and thermometer. The remaining two were obstructed by vegetation and fallen trees and were measured using the IR thermometer. The flow rates in the two obstructed springs were estimated to be in the order of 5 l/s, while the accessible spring had a flow rate of approximately 20 l/s. The temperatures in all springs ranged from 41 °C to 47 °C. The pH of the southern spring was 7.5 indicating a neutral spring. Pine forest, which has recently been felled around this site, tends to have slightly acidic soils; therefore the neutral pH of the thermal spring fluid would suggest that the source is deeper chloride water. All springs were discharging clear water.

Downstream of the thermal spring inputs the main stream has a flow of 80-100 l/s, a temperature of 26 °C, and a pH of 7.1.

Plate 56: Murphy's Springs geothermal area looking south across gully at largest spring on stream true right. Note the abundant *Christella* sp. aff. *dentata* ("thermal") alongside stream margins.

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

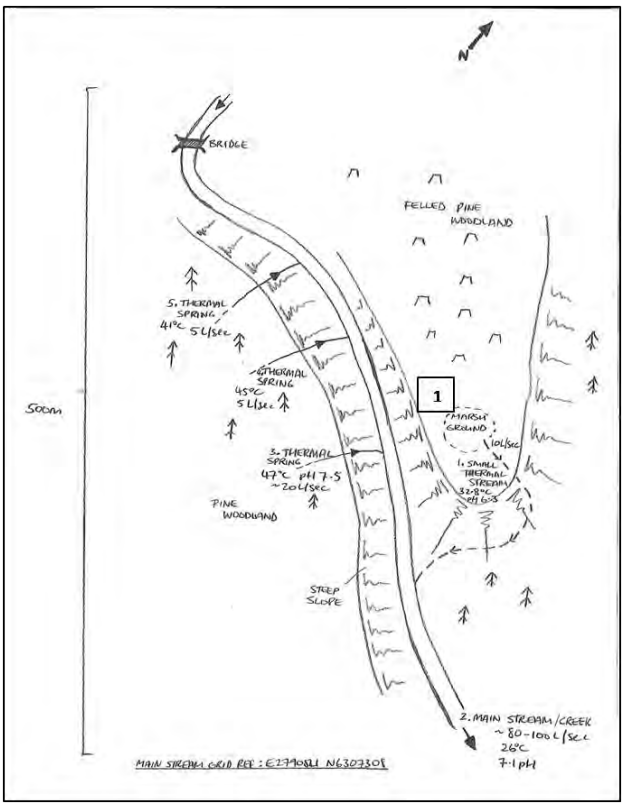


Figure A1-9: Murphy's Springs geothermal area:
Sketch map showing main features and photograph location.
The grid reference labelled here is E1880411 N5745753 (NZTM).

TE KOPIA NORTHWEST[1]

This is an area of bare, steam-heated ground which lies to the west of the mud pools described in the site Te Kopia West Mudpools (TKV04). It comprises 15 × 25 m of thermal ground consisting of areas of silicified crust, steam vents/fumaroles and bubbling mud pools (Plate 57). The area has a northwest-southeast orientation and falls by approximately 0.5 m from north to south. A small stream (*c.*30 l/s) flows along the western margin of the area.

The southeastern part of the area is dominated by a thin silicified crust which lies above steam heated soil. The crust was found to be very thin and unstable limiting movement and inspection of the area to the boundaries only (Plate 58). One soil temperature measurement at 0.1 m depth showed 52 °C (see map for location). Associated with this area are steam vents or fumaroles which are actively discharging gas with moderate H_2S content. Near one steam vent in this area, bubbling from beneath the crust could be heard. There is also active sulphur deposition occurring in this area. Between this area and the stream are some small steam vents where soil temperature was 100 °C (see map for location).

The central part of the area appears to be less active. This area, while still covered by the silicified crust/sinter, is encroached by prostrate kānuka and moss cover indicating cooler temperatures (Plate 59).

The northeastern part of the area comprises a silicified crust along with two mud pools (Plate 59). At the back of this area, where the slope rises, it comprises bare ground with altered rock and soil. The lower parts of the slope have active pools. There was no safe access to these pools so it is not known if the pools are boiling or only near to boiling; however rising steam was observed from all pools. This area has noticeably more steam discharge than the southeastern area.

The stream flowing along the western boundary does not appear to be affected by the thermal ground or display evidence of heating. Temperatures ranged from 12.6 °C to 13.2 °C with pH between 5.7 and 5.9.

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell,2010.

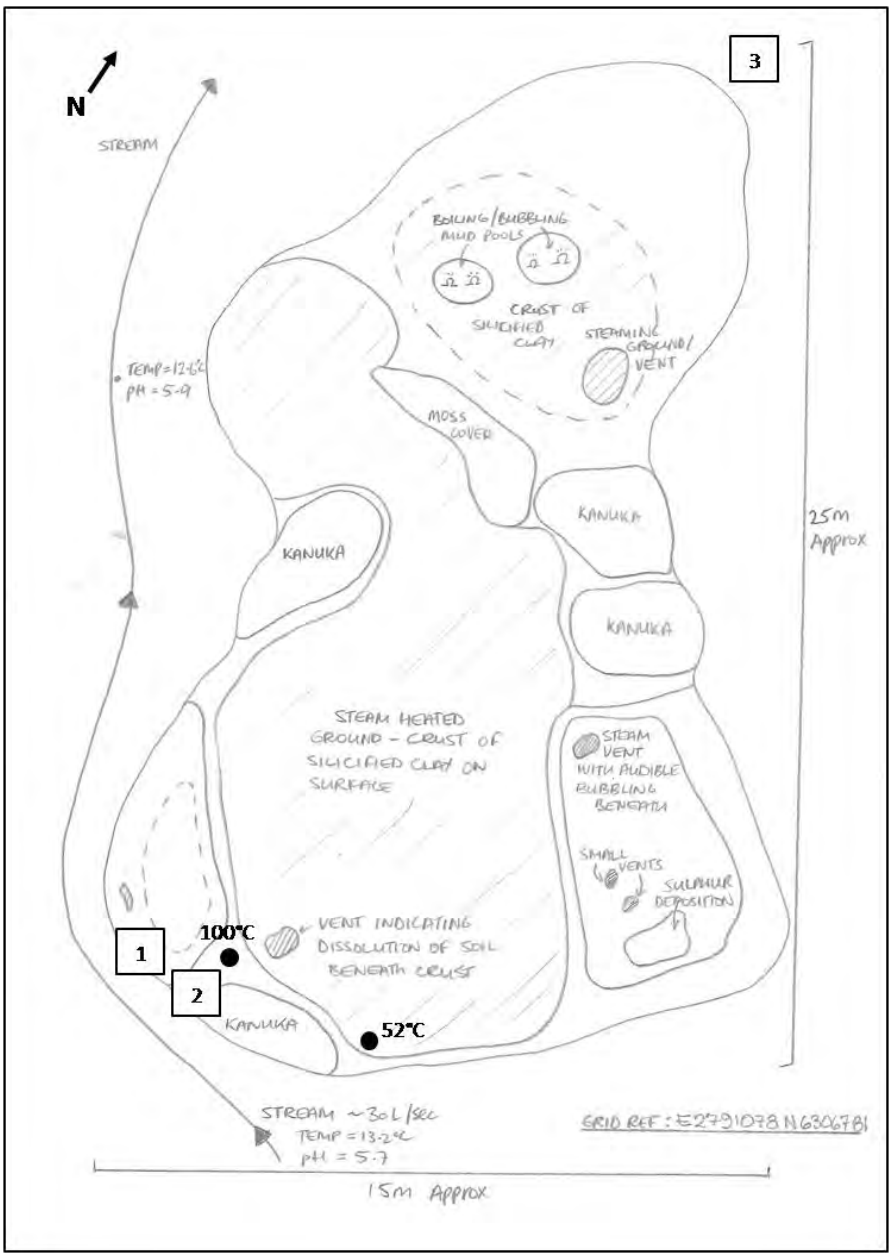


Figure A1-10: Te Kopia - Northwest. Field sketch map indicating main features and photo locations. The grid reference labelled here is NZMG.

Plates 57-59:

57. View of area from southwest corner. Note: prostrate kānuka and moss present in central area with steaming ground and mud pool in background.
58. View of silicified crust, steaming ground and sulphur deposition in southeastern corner.
59. View from elevated area in northeastern corner. Note mud pools in the foreground with adjacent central area of prostrate kānuka/*Campylopus* cover.

TE KOPIA WEST MUD POOLS[1]

This is a group of three mud pools on the slopes of a small north-south ridge on the west of the Te Kopia Road. All these features must be approached from the downhill side; there is nothing to break a slip into these from the top, and sides are often undercut. The temperature in all of the mud pools is >80 °C.

On the northern end of the ridge there are two deeply cut-in mud pools approximately 8 m apart.

Eastern Pool

The most eastern of these features is 1.5-2 m wide, and >6.5 m long. The southern end of this feature has undercut at least 3 m into the hill, although the full extent cannot be seen. The downhill lip of the pool has an apron of lumpy mud ejecta that extends at least 3 m downhill (Plate 60).

The pool has brown muddy water with two hot regions (81 °C and 80 °C), separated by a cool midsection (25 °C). There is significant effervescing gas associated with the major upwelling at the back of the overhang (Plate 61). There are smaller upwellings in thicker mud near the northern end of the pool. There is no visible liquid discharge.

The water level in the pool is *c.*2 m below the downhill lip. The near vertical walls of the pool are coated with vertically fluted mud which has recently sloughed off in patches.

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell,2010.

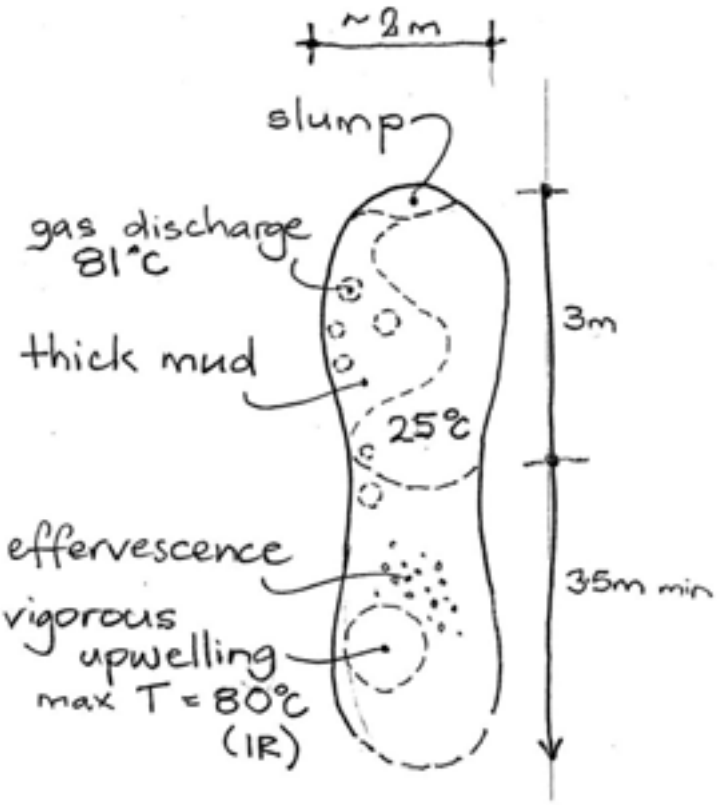


Figure A1-11: Sketch map of the eastern-most mud pool, Te Kopia West Mud Pools.

Plate 60: Apron of mud over the northern lip of the eastern mud pool, Te Kopia West Mud Pools.

Plate 61:
Looking south into the pool. The major upwelling is at the far end of the pool,
Te Kopia West Mud Pools.

Middle Pool

The middle feature is located on the northern slope. This is a 5 m diameter hole at the surface which narrows to a *c.*3 m diameter at the base, which is 4 m below the downhill lip.

There is an area of vigorous activity on the north side of the pool (99 °C), accompanied by significant effervescing gas. The pool is lightly undercut in this area. There is a 0.4 m wide beach on the southern and eastern sides of the hole and a ledge, possibly indicating a past water level, *c.*0.7 m above the present water level.

There is no visible liquid discharge.

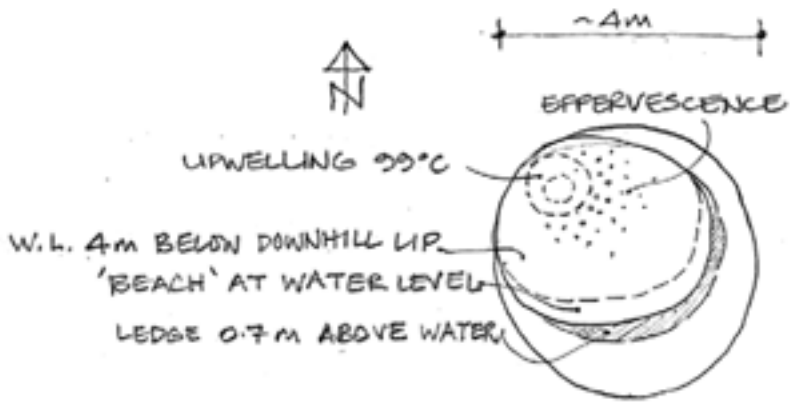


Figure A1-12: Sketch map of middle pool,

Plate 62: Middle pool, Te Kopia West Mud Pools.

Southern Pool

Grid Ref (NZTM):
E1880900 N5745117

The landowner has reported that this pool has become more active recently. The pool is set into the western side of the hill. The dimensions and form are shown in the accompanying sketch map and cross-section (Figures A1-13 and A1-14). A distinctive feature is the mud dam that is confining the present mud pool to the eastern portion of the feature. In front of the dam is a dry area with a floor that is 0.5 m below the pool water level, which may have been part of an earlier pool, and which is bounded to the west by the lip of the earlier pool.

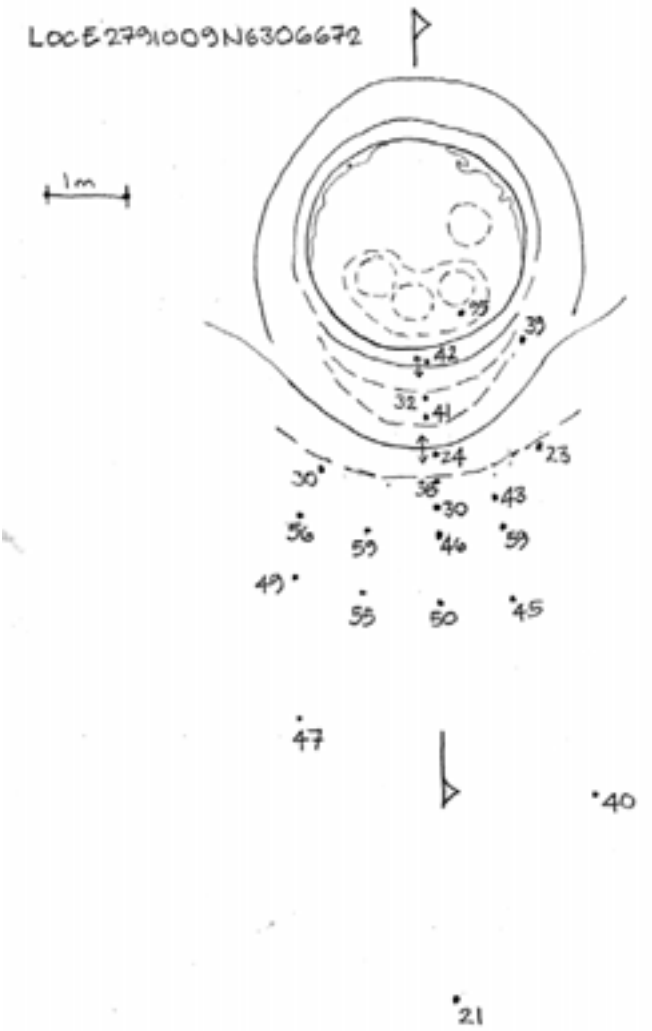


Figure A1-13: Sketch map of southern pool, indicating temperature in degrees celsius. Grid reference is in New Zealand Map Grid.

The ground immediately in front of the pool has elevated temperatures (23 C-41 °C), but between 1 and 5 meters away the ground temperature is in excess of 50 °C, and the vegetation is dying. The temperature measurements were paced out, but give an indication of the temperature distribution down-slope of the pool.

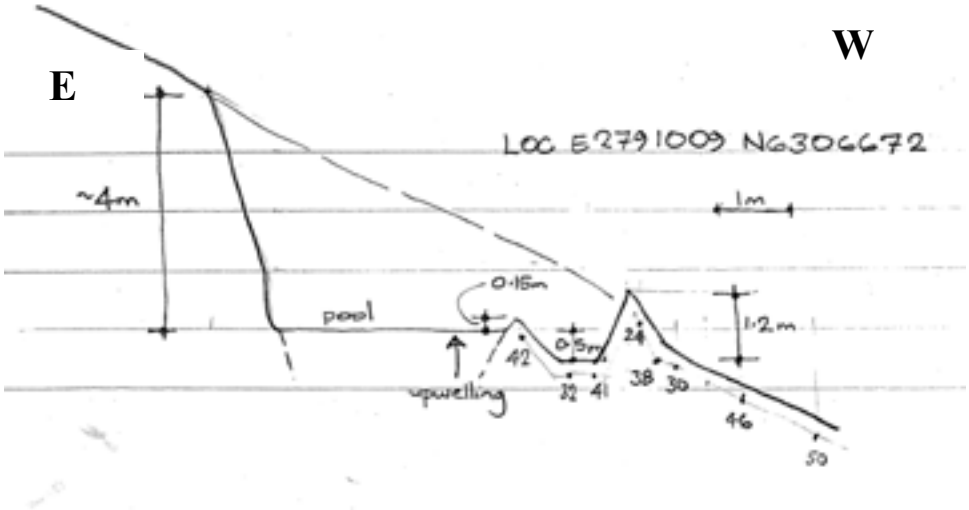


Figure A1-14: Sketch cross section E-W through the feature showing the inner dam confining the pool, and the soil temperatures at 0.1 m depth. Southern pool, Te Kopia West Mud Pools. Grid reference is in New Zealand Map Grid.

Plate 63: The southern pool showing inner dam in foreground.

TE KOPIA RED STREAM[1]

This is a small stream west of Te Kopia Road. The stream runs from the road for about 70 m to join a cold stream (12-13 °C, pH 6.3) flowing south through farmland. The flow rate of the cold stream is difficult to estimate as it flows through a large swampy area; the best estimate is 15 to 20 l/s. Below the confluence the temperature of the stream is 28 °C. The thermal stream bed has a rich, dark red coating, and the flow rate is also 15 to 20 l/s. Most of the stream is in a blackberry infested gully and access is difficult, however, there are sections where access is possible. Above the confluence the water temperature is 47 °C, and as we moved upstream the temperature increased to a maximum of 61 °C. Thereafter the next temperature measurement was 53 °C (Plate 64), and another 3 m along the stream 22 °C. This indicates that there is an approximately 50 m length of stream which has significant geothermal discharge. The soil on the edge of the stream (within 1 m of the water) was also warm (42-59 °C at 1 cm depth) but there is no thermal activity >1 m from the edge of the stream.

The accompanying map (see below) shows only measured temperatures at the recorded locations.

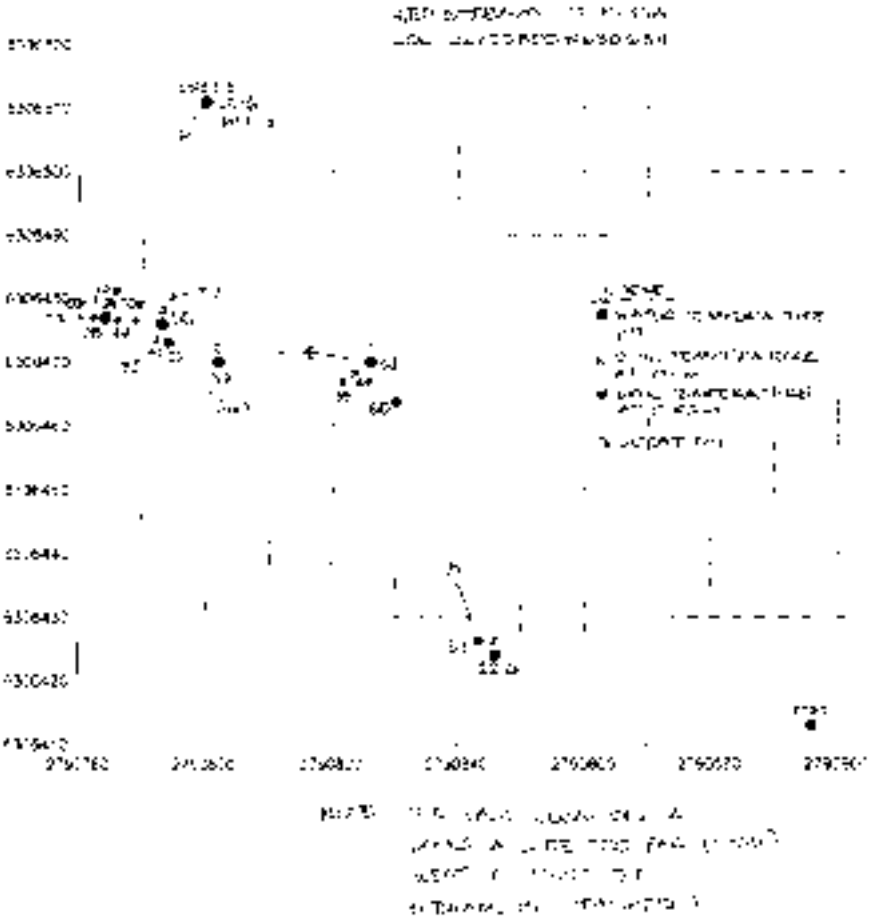


Figure A1-15: Red Stream, Te Kopia. The grid reference labelled here is NZMG.

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

MANGAMINGI STATION[1]

Overview of field work: This is an area of geothermal ground south of Te Kopia. The area was visited on 28 June 2010, in the afternoon. We arrived at the site at 1315 hrs. The weather was cold and overcast with a light wind. It rained intermittently all afternoon.

Areas are shown on diagrams at end of site sheet. The largest area of thermal ground (Area 5, which is *c.*200 m^2) is situated on a southwest facing slope, with small areas of warm ground (Areas 1 and 2, which are 4 m^2 and 16 m^2 respectively) outcropping on an adjacent southeast facing slope. There are two small pools, which are slightly above ambient temperature. Over the ridge to the southeast there is another smaller area of warm ground (Area 6, *c.*24 m^2), with steam issuing from a fracture in a rock outcrop.

Locality 1: This is a small exposed face consisting of thermally altered clay, which measures approximately 4 m^2. The face is 1 metre high and comprises a band of altered white clay at the base (kaolin) and red/ochre stained altered clay above it. The temperatures across the face and at the base range from 24 °C to 41 °C.

Localities 2 and 3: These areas are similar to Locality 1 approximately 15 m to the southeast. They comprise a small area of exposed altered pink and white clay measuring approximately 3 m^2. The temperatures across the exposed face range from 28 °C to 45 °C at 10 cm depth.

Locality 3 (*pool*) This 0.4 m diameter pool is 17 °C and has murky brown water.

Locality 4 (*pool*)*:* This oval pool is *c.*1 m long by 0.5 m wide and is 18 °C and also has murky brown water.

Locality 5: An approximately triangular area of thermal ground. Approximately 30% of the ground is exposed white (kaolin) clay or pink clay. Rocks that outcrop or lie on the ground in the area are silicified white clay.

The north of the area is a 5 m wide shallow gully stepping 18 m up the hillside in four small scarps of exposed thermally altered ground. Temperatures in this thermal ground are up to 91 °C at 10 cm depth.

In the southern half of the area there are five main areas of exposed ground (Figure A1-16). Three of these comprise altered pink and white clays and have temperatures ranging from 45 °C to 75 °C. There is minor diffuse steam discharge across all three areas. The two remaining areas have moderate steam discharge and temperatures ranging from 56 °C to 99 °C. Both of these areas are higher up, approximately halfway up the slope. The most northern of these, has smectite banding associated with the altered pink and white clays. This type of alteration is distinctive by a green staining of the clay. The southern point source of steam discharge comprises altered clays and silicified clay fragments. The small steam vent

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

measures approximately 5 cm in diameter. The temperature at this point was 85 °C at 10 cm depth.

Locality 6: This is a 24 m^2 area of thermal ground over the ridge from Locality 5. There is an outcrop of fractured silicified fine grained white rock. The junction of the fractures hosts a steam vent which is *c.*0.15 m wide. Ground temperatures at 10 cm depth around the base of the rock range from 34 to 55 °C. A second outcrop of silicified rock has a steam vent at the base of the rock where the ground is 92 °C. There is an area of soft white and pink clay with no grass cover which has temperatures ranging from 48 to 57 °C.

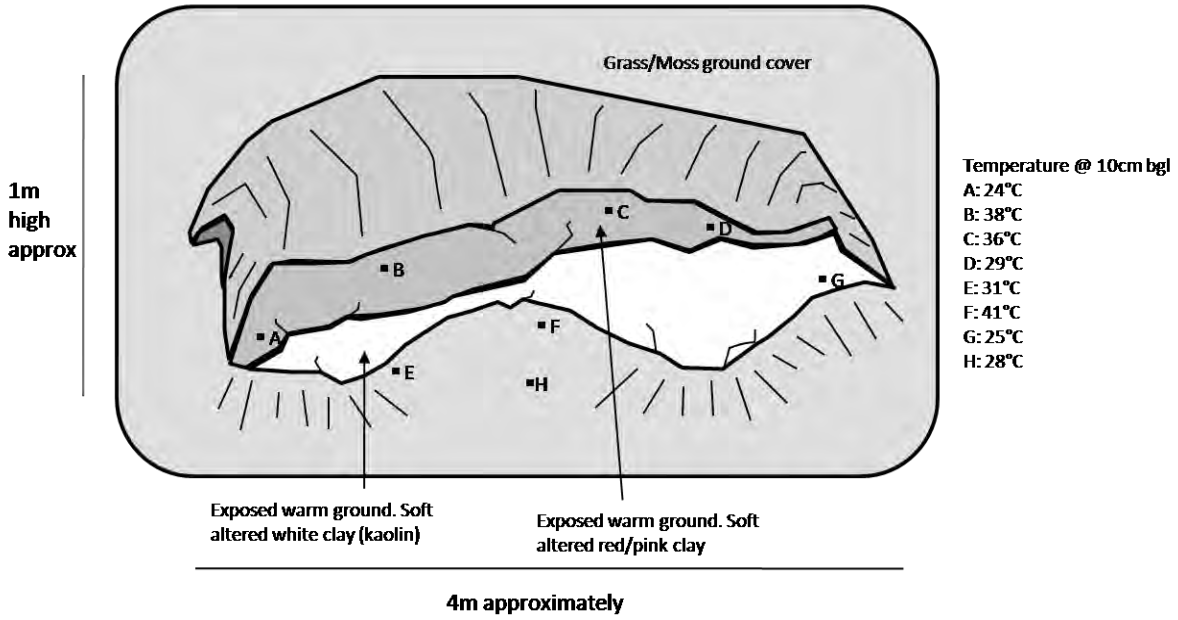


Figure X: Geothermal activity at Locality 1.

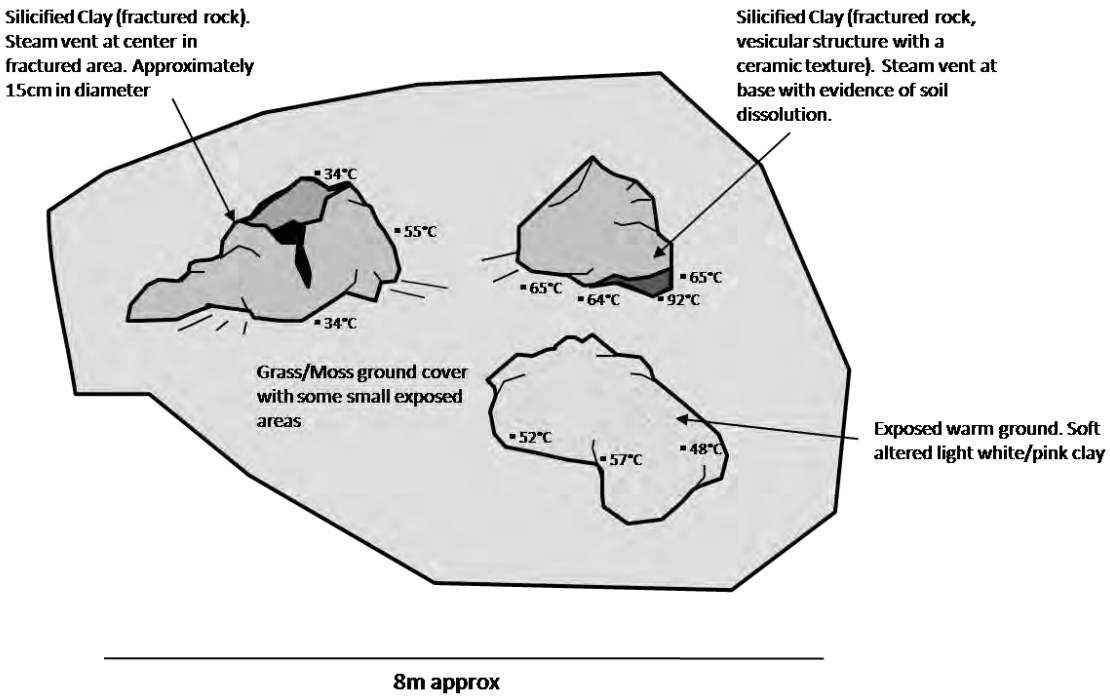


Figure X: Geothermal activity at Locality 6.

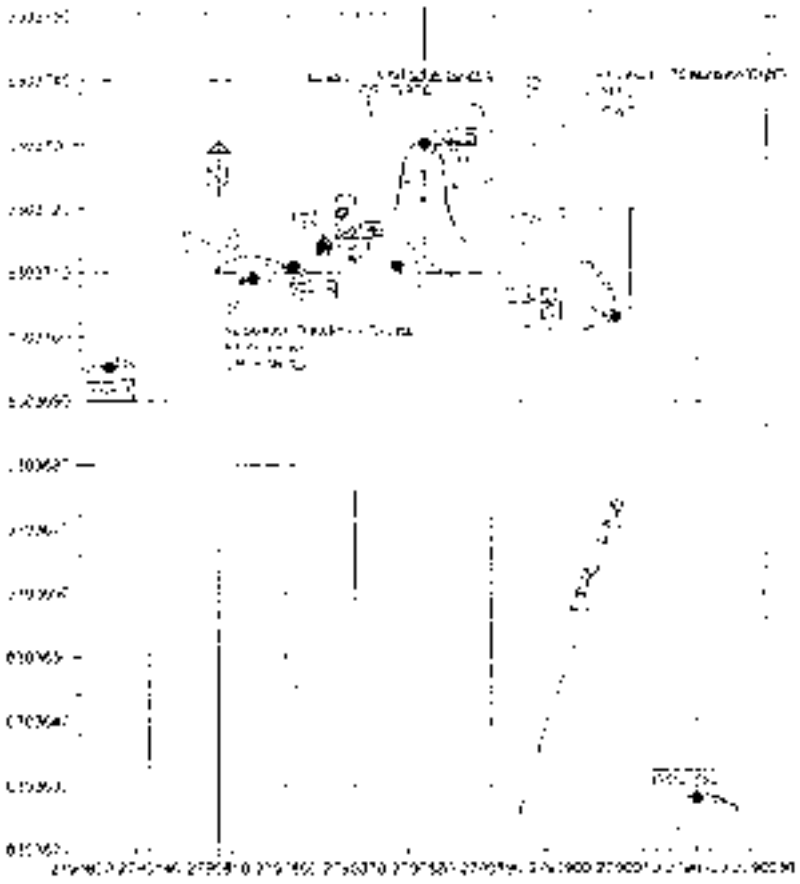


Figure X:
Sketch map of geothermal features at Mangamingi Station. Grid references are in NZMG in the sketch and NZTM in the table opposite.

1	1880729	5742138
2	1880750	5742152
4	1880760	5742157
3	1880756	5742154
5a	1880803	5742146
5b	1880771	5742154
5c	1880775	5742173
6	1880815	5742071

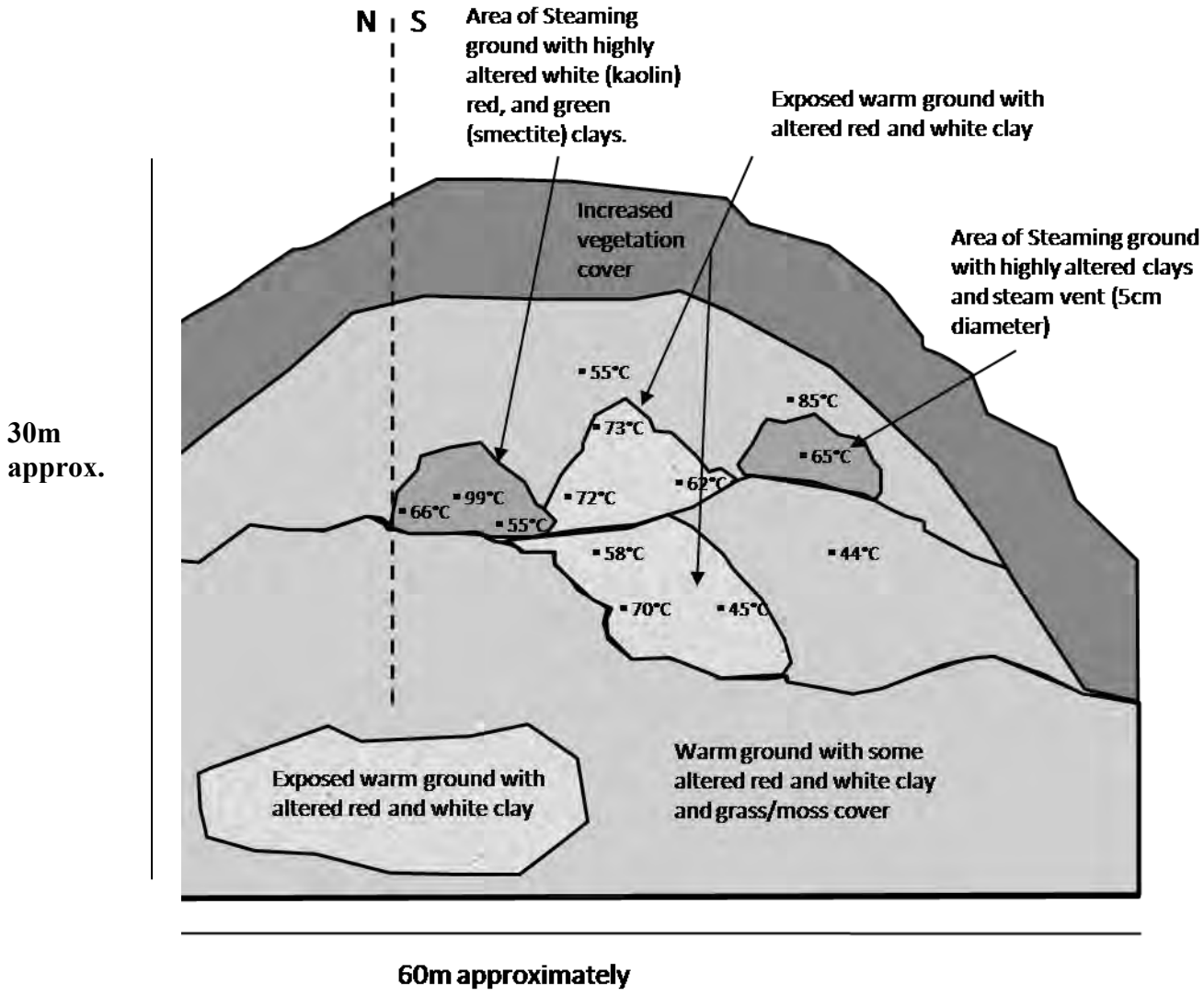


Figure X: Sketch map of geothermal activity at Locality 5S (see other sketch map) at Mangamingi Station.

ORAKEIKORAKO[1]

Feature 1:
Steaming ground, relic geyser mound

A small area of steaming ground was identified in the centre of a relic geyser. The sinter/geyserite mound measured 0.6 m^2 while the aperture measured 0.3 m^2. The temperatures in the centre ranged from 77 °C to 87 °C. The soil temperatures surrounding the feature ranged from 48 °C to 72 °C. The steam discharge was minor.

Plate 65: Relic geyser mound with steaming ground. Feature 1, Orakeikarako. Note the *Dicranopteris linearis* in photo.

Feature 2:
Sinter scarp

Grid Reference:
E1874513 N5736869

Directly behind the relic geyser mound is a large expanse of sinter scarp (30 × 8 m). The scarp was heavily vegetated in places and did not appear to be undergoing active deposition of sinter (wet surfaces appear to be soil run-off as opposed to silica laden fluids). At the base of the scarp were two areas with moderate steam discharge. The soil temperatures at 10 cm depth were between 50 °C and 60 °C. At one point the thickness of the sinter was observed through a break in the crust to be about 10 cm thick.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

Plate 66: Heavily vegetated sinter scarp. Feature 2, Orakeikorako.

Plate 67: Sinter structure on scarp. Note silicified organic material. Feature 2, Orakeikorako.

Feature 3:
Relic discharging pool/Geyser

Grid Reference:
E1874554 N5736837

A relic sinter depositing pool/geyser was identified above the scarp and sinter deposition channels. The sinter channel could be traced back to this feature. The feature consists of 6 × 5 m crater with audible bubbling at depth. The centre of the crater is dominated by an east-west trending fissure. The sinter apron has disintegrated considerably and the rock is stained pink-orange and grey. There was moderate steam discharge from this feature.

Plate 68: Relic discharging pool/geyser with east west fissure and sinter terrace in background, Feature 3, Orakeikorako.

Feature 4:
Active geyser

Grid Reference:
E1874564 N5736844

Approximately 10 m to the east of Feature 4 is an active geyser. The crater associated with the geyser is approximately 8×4 m and while the frequency of playing is not known, there are clear indications of geyser activity such as: rounded surfaces at the crater edge, a damp base (noticeable as there had not been any rainfall) with rounded pebbles, and a drainage channel which directed fluid back into the crater (Plates 69 and 70). During the monitoring round, the geyser played at 11.55 a.m. for approximately 30 seconds-1 minute. There is a main central fissure (with an east-west orientation and almost in line with Feature 4) in the crater with two identifiable vents - one seen to be discharging steam constantly, the other observed to be the fluid/steam discharge point when active. The jet of water/steam rose approximately 3 m above ground level.

Associated with the geyser is a large area of sinter and altered clay (Plate 71). There was also an area of steaming ground. The soil temperatures to the south of the geyser were not elevated (15 °C) while directly to the east the temperatures ranged from 60 °C to 80 °C. The sinter crust was very thin and delicate.

A sketch map of Features 4 and 5 has been prepared.

Plate 69: Geyser. Looking west, note main vent, fissure alignment, and rounded surfaces, Feature 5, Orakeikorako.

Plate 70: Geyser. View looking northeast. Note drainage channel back into crater, Feature 5, Orakeikorako.

Plate 71: Area of steaming ground with red altered clay and sinter to the north of the geyser. Feature 5, Orakeikorako.

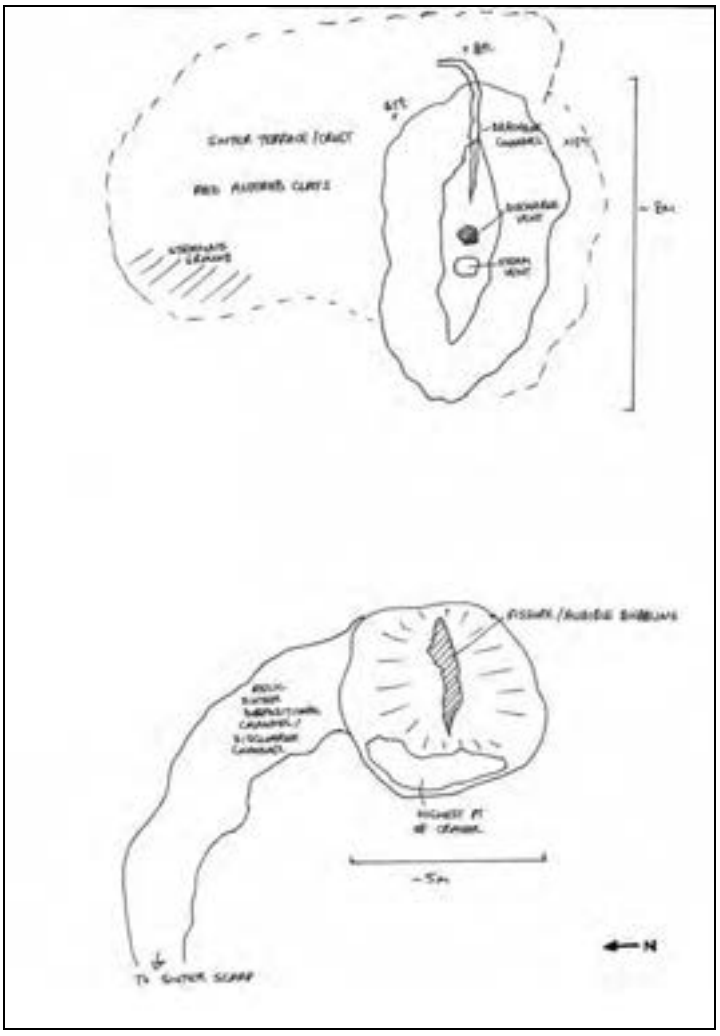


Figure A1-20: Field Sketch of Relic Pool/Geyser of Feature 4 (bottom) and Active Geyser of Feature 5 (top) at Orakeikorako.

Feature 6:
Steaming ground

Grid Reference:
E1874546 N5737104

An area of steaming ground was identified measuring 2 m^2 with soil temperatures ranging from 25-35 °C. This was located between Features 5 and 7.

Feature 7:
Mud pool

Grid Reference:
E1874593 N5737122

This feature was a small mud pool with viscous mud and vigorous bubbling. Thick vegetation prevented access.

Feature 8:
Mud pool and volcano

Grid Reference:
E1874607 N5737129

This feature is a mud pool with minor steam discharge and less viscous mud. A mud volcano approximately 30 cm high lies adjacent to it. Thick vegetation prevented access for temperature measurement.

Plate 72: Mud volcano, Feature 8.

Feature 9:
Artistes palette
(hot, clear pool)

The main pool in the Artistes Palette area was noted to have a very low water level (not visible) and was discharging steam. In July 2010 this pool was actively discharging chloride water with extensive algal growth along the discharge channels.

Plate 73: Pool at Artistes Palette - July 2010 on left, July 2009 on right.

WHAREPAPA ROAD[1]

Feature 1:
Hot clear pool, sinter terrace
(labelled as F1 on feature map).

This feature is a hot, clear pool with a slight blue colouration. The temperature of the water was 90 °C and the pH was 8.6. The pool measures approximately 4 m^2 and has two central fissures/chambers at least 1 m deep and approximately 0.5 m in diameter. The remaining area of the pool is shallow, 5-10 cm. Only one of the chambers appeared to be supplying fluid to the pool. There are at least three relic drainage channels from the pool and it is surrounded by a large, 25 m^2 sinter terrace. Two constructed channels now drain the outflow from the pool and as such the sinter terrace is no longer being deposited. The water level is 5-6 cm below the sinter apron. Both the sinter apron and discharge channels exhibit minor sulphur encrustation. The main man-made channel was measured to calculate the discharge. The flow from the pool was calculated to be approximately 0.9 l/s (based on a channel width of 0.15 m, depth of 0.03 m, and a velocity of 0.2 m/s). A second small up-welling of fluid was noted in one of the relic drainage channels (Plate 75). It had a temperature of 90 °C and flow of approximately 0.1 l/s.

The constructed channel directs the pool outflow to a series of baths after which the outflow meets the original sinter terrace formed by the pool which was deposited down a gentle slope to the southeast. The sinter terrace is extensive and measures 70 × 30 m, however the area of active deposition is small, near the bathing water discharge point (Plate 76). The vast majority of the terrace is deteriorating, and at its lowest point is covered by a layer of silt which makes the sinter structure barely visible (Plates 77 and 78). At this point the sinter is very brittle. A field sketch has been prepared of the pool and sinter terrace area.

Plate 74: Hot, clear pool, sinter apron, and terrace. Note two main chambers and discharge channels at Feature 1, Wharepapa Road.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

Plate 75: View of small upflow, sinter terrace, main pool and baths in background at Feature 1, Wharepapa Road.

Plate 76: Relic sinter terrace looking north towards baths. Active sinter deposition area out of sight in left hand corner at Feature 1, Wharepapa Road.

Plates 77 and 78: Deteriorating sinter terrace. Structure still visible but very brittle/soft underfoot at Feature 1, Wharepapa Road.

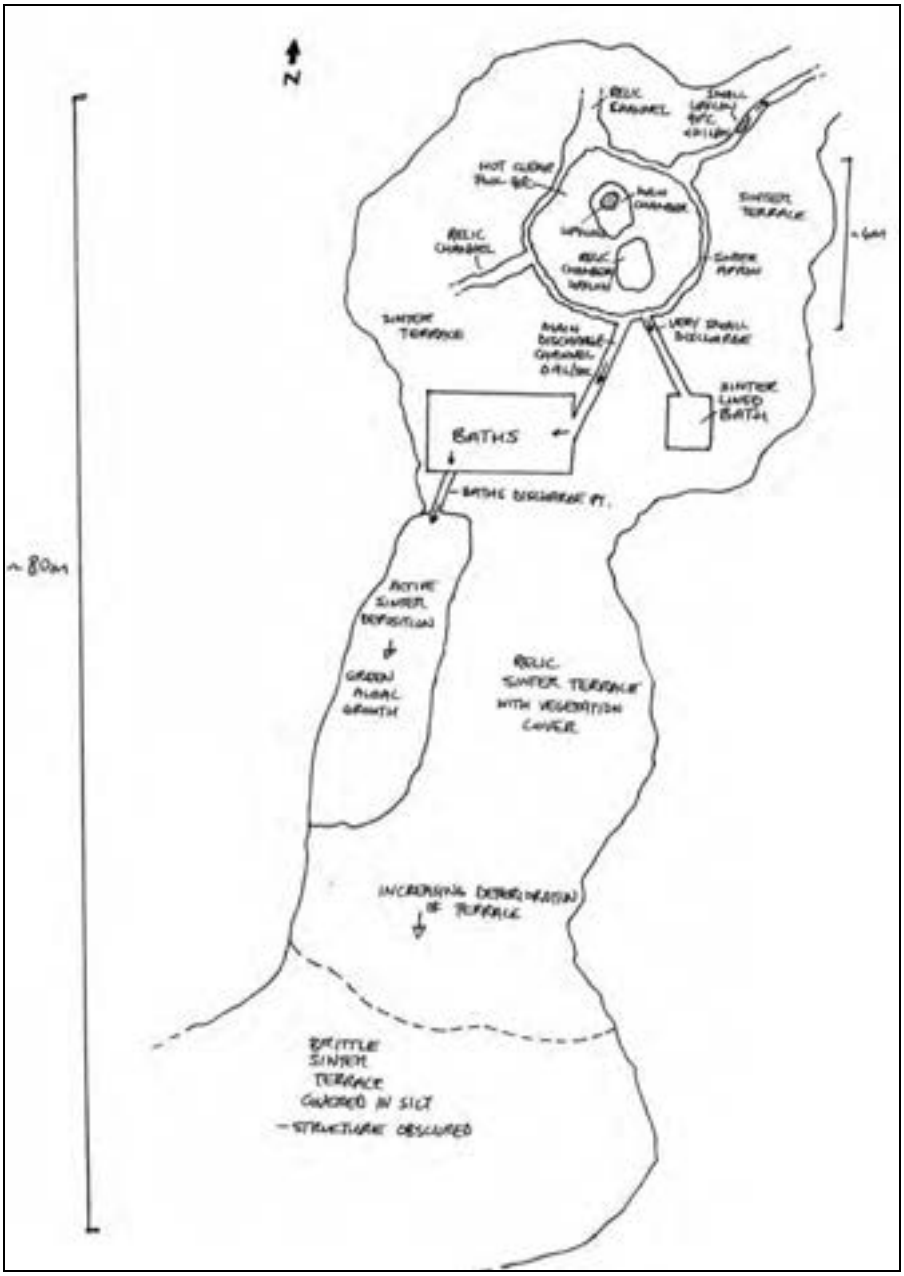


Figure A1-21: Field sketch map of hot pool, drainage and sinter terraces at Feature 1, Wharepapa Road.

Feature 2:
Hot clear pool
(labelled as F2 on site map)

Grid Reference:
E1890775 N5742844

This feature is a hot, clear pool with a dark grey base (Plate 79). There is evidence of a sinter apron around the pool, although it is weathered and is coated in dark grey soil. The pool is approximately 3 m long and has two main chambers, one of which was bubbling. The temperature of the water was 90 °C while the pH was a neutral 7.6. There was no discharge from the pool at the time of the visit but a damp discharge channel is present to the southeast of the pool. The soil temperatures surrounding the pool ranged from 12 °C to 47 °C, the highest point being within the channel. Adjacent to the pool are two outcrops of silicified pumice rock which appeared to have some sinter structure (Plate 80). They are both weathered and fractured.

Plate 79: Hot, clear pool with damp discharge channel at Feature 2, Wharepapa Road.

Plate 80: Silicified pumice outcrop to the east of pool at Feature 2, Wharepapa Road.

Feature 3:
Steaming ground, fumaroles
(labelled as F3 on feature map)

Grid Reference:
E1890799 N5742775

An area of steaming ground comprising five fumaroles, four of which are roughly in alignment along a NW/SE orientation (Plate 81). The vents are too deep to see the base, however there was audible bubbling and the thermocouple device was used to measure a temperature of 95 °C in one of them. The area is approximately 10 × 3 m. The largest of the fumaroles appeared to be a discharging feature in the past (either mud or water) as a discharge area with flow patterns was identified near the opening (Plate 82). In the area surrounding the fumaroles there is relic deteriorated sinter terrace and a sinter bank. It would appear that the features at this location discharged sinter depositing fluid in the past.

Plate 81: Line of four fumaroles in NW/SE orientation with silicified bank behind and deteriorating terrace in front, Feature 3, Wharepapa Road.

Plate 82: Large fumarole with relic sinter terrace and relic flow/drainage formations at opening (arrow), Feature 3, Wharepapa Road.

Feature 4:
Thermal spring
(labelled F4 on feature map)
Grid Reference:
E1890917 N5742571

A large pool within a ditch at the edge of a culvert had a steam discharge and temperature of 47 °C. There was no obvious upflow but the discharge from the pool was estimated to be approximately 1.5 l/s. There was abundant green and orange algal growth along the discharge channel.

Plate 83: Hot spring/pool. Note orange and green algae in discharge channel, Feature 4, Wharepapa Road.

Feature 5:
Hot, clear pool
(labelled F5 on feature map)

Grid Reference:
E1890856 N5742786

This feature is a large 5 m^2 clear pool. The water has a blue colouration (colloidal silica) and is at boiling point (99 °C using thermocouple). The pH of the water is 7.8. It is at least 2 m deep and is discharging via a discharge channel (Plate 84). The pool itself has a small/narrow sinter apron with grass meeting its margins while there is active silica deposition along the discharge channel and ditch (Plate 85). Both the discharge channel and silicified ditch appear to be manmade and direct the outflow into a stream to the south. At the point where the ditch meets the stream the temperature is 78 °C and there is no further silica deposition (Plate 86). The discharge channel from the pool has a section measuring 1 m length which made the flow estimation very straightforward, approximately 4.5 l/s. The point where the channel meets the ditch could provide a good location to install a weir for future flow recording.

To the east of the pool and sinter ditch there is another minor stream draining the land (Plate 87). There are numerous hot spring inputs into this stream ranging from 45 °C to 60 °C. The temperature of the minor stream is 24 °C before it also meets the main stream to the south. A schematic of the drainage system including the pool discharge, minor stream, and main stream is presented below showing flow rates and temperatures at various points.

Plate 84: Hot, clear blue pool with discharge channel in background, Feature 5, Wharepapa Road.

Plate 85: Pool discharge channel joining ditch - both have considerable silica deposition, Feature 5, Wharepapa Road.

Plate 86: Pool discharge meeting main stream. Note minimal sinter deposition at this point (78 °C), Feature 5, Wharepapa Road.

Plate 87: Minor stream with hot spring inputs, Feature 5, Wharepapa Road.

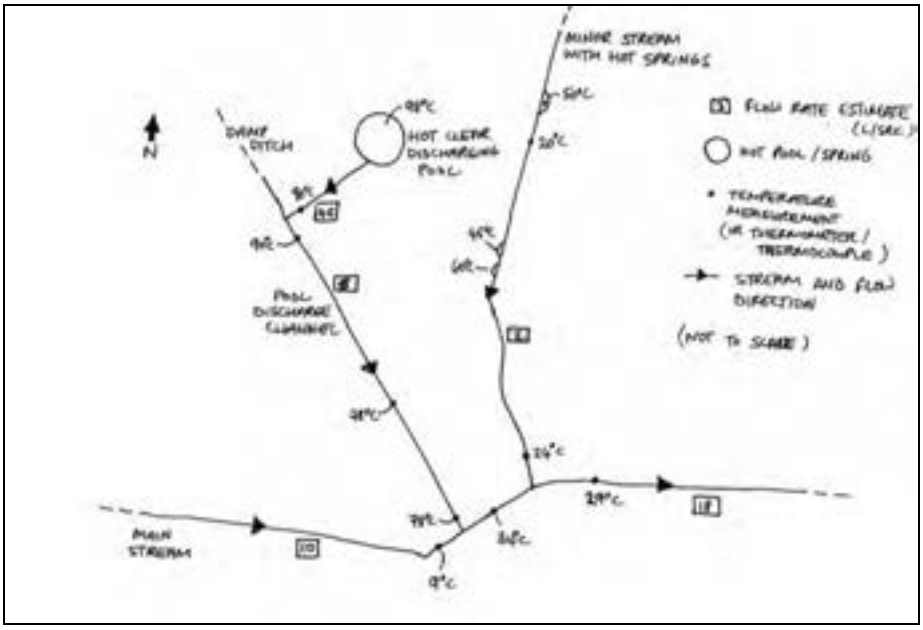


Figure A1-22: Schematic of hot pool drainage, temperature and local stream inputs, Feature 5, Wharepapa Road.

Feature 6:
Mud pool
(labelled F6 on feature map)

Grid Reference:
E1891092 N5742911

This feature is a small boiling mud pool which measures 1.5 m^2 and is approximately 1 m deep. The temperature of the fluid was 99 °C. At the edge of the pool there is evidence of relic sinter deposition (Plate 89), indicating historical silica laden fluid discharge in the past. Broken timber was at the base of the pool and at its edge.

Plate 88: Mud pool, Feature 6, Wharepapa Road.

Plate 89: Sinter structure at edge of mud pool, Feature 6, Wharepapa Road.

Feature 7: Exposed ground, fumaroles, mud pools (labelled as F7 on feature map)

Grid Reference: E1891134 N5743013

A large area of exposed ground with active fumaroles and mud pools lies 100 m to the northeast of the mud pool (Feature 34). The area measures approximately 25 × 50 m. Access to take *in situ* measurements was not deemed safe at this area; as such only the largest of the mud pools was measured using the IR thermometer and returned a temperature of 72 °C (Plate 90). A field sketch indicating the location and type of features is shown below. The location has four other large mud pool areas as well as many small pools and a pit consisting of multiple fumaroles (Plate 91). There is an isolated area of geothermal type vegetation in the centre of the area around which soil temperatures ranged from 13 °C to 53 °C at 10 cm depth. There were no outflows noted from any of the features.

Plate 90: Large mud pool, 72 °C at surface, Feature 7, Wharepapa Road.

Plate 91: Mud pit with multiple fumaroles discharging steam, Feature 7, Wharepapa Road.

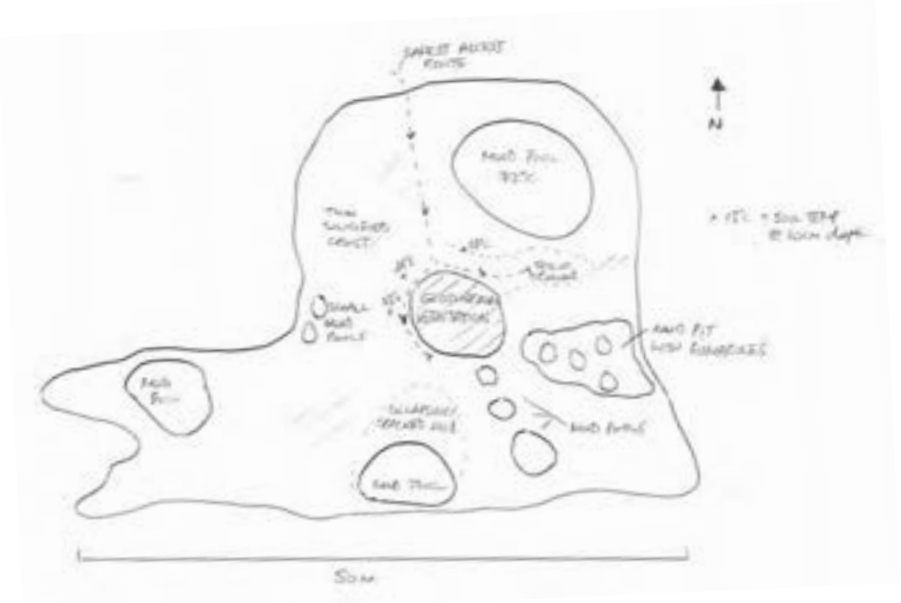


Figure A1-23: Field sketch map of location, Feature 7, Wharepapa Road.

Feature 8:
Exposed ground, mud pools
(labelled F8 on feature map)

Grid Reference:
E1890976 N5743135

This feature comprises a 30 m^2 area of exposed ground including three mud pools with temperatures ranging from 40-50 °C and two warm pools with dark green cloudy water with temperatures of approximately 30 °C. The warm pools were bubbling and discharging small amounts of gas. The area was covered in a layer of mud and pine needles, however beneath this a silicified crust was observed.

Plate 92: Two of the mud pools at this location. Note that pool to the right had more significant steam discharge (50 °C), Feature 8, Wharepapa Road.

Feature 9:
Exposed ground, hot clear pool, mud pools
(labelled F9 on feature map)

The western part of this area was mapped, while the eastern area was not accessible. The western area comprised an area of exposed ground with steaming ground, at least two mud pools, and one hot, clear green/blue pool.

Grid Reference:
E1891114 N5743198

The clear pool was approximately 1.5 × 3 m and appeared to be at least 2.5 m deep. The water had a green/blue colouration (colloidal silica), a temperature of 80-85 °C and a pH of 8.7. A sinter apron was well formed at its edge and along the discharge channel. The discharge flowed to the east and was estimated to be approximately 1 l/s. A wooden palette and bird feathers nearby indicated that this pool is used by local famers for cooking or game hunting related purposes.

Two metres to the west of the clear pool is a 2 m^2 mud pool with a temperature of 85 °C and two fumaroles with audible boiling/bubbling beneath the surface. It is thought that these are also mud pools.

A view through the vegetation into the eastern part of the area indicated an expanse of exposed ground and multiple mud pools and fumaroles.

Plate 93: Hot, clear green/blue pool. Note wooden palette access point to pool and sinter apron, Feature 9, Wharepapa Road.

Feature 10:
Fumaroles, mud pools (labelled F10 on feature map)

Grid Reference:
E1890981 N5743026

At this location there are two small fumaroles 0.3 m^2 with audible bubbling at depth and two mud pools with surface temperatures of 85 °C and 51 °C. Near the pools were two outcrops of silicified pumiceous rock.

Feature 11:
Fumaroles, mud pools (labelled F11 on feature map)

Grid Reference:
E1890995 N5742955

Forty metres to the south of Feature 10 is a larger area (25 × 50 m) of small mud pools, steaming ground and fumaroles. The temperatures in the mud pools ranged from 30 °C to 90 °C. Amongst the mud pools are large areas of silicified pumiceous rock outcrop. The largest mud pool has a temperature of 35 °C and measured 3 × 5 m.

Plate 94: Area of mud pools, fumaroles, and silicified outcrop, Feature 11, Wharepapa Road.

Feature 12:
Hot clear pools, sinter terrace
(labelled F12 on feature map)

Grid Reference:
E1890797 N5743070

This feature comprises an extensive sinter terrace measuring approximately 50 × 75 m with numerous small, clear, hot pools and one large boiling pool.

At the highest point of the terrace at the northern limit there is a large 10 × 2 m boiling clear blue pool (Plate 95). Two main upwelling/boiling areas were noted in the pool. The temperature reading on the IR thermometer was 110 °C while the thermocouple measured 100 °C; the pH of the pool was 7.3. The boiling areas were vigorous and the steam discharge from the pool was considerable. The discharge from the pool was diffuse from a number of channels and as such was estimated to be in the order of 4-5 l/s. The depth of the pool appeared to be at least 2-3 m. The sinter apron had sulphur deposition in places.

Numerous other shallow pools were observed at the location with temperatures ranging from 27 °C at the southern limit of the terrace to 80 °C approximately 5 m from the large boiling pool. The water level was very shallow across the terrace and there was considerable silt deposition across the southern half of the area. The discharge stream which forms beyond the lowest point of the terrace had a temperature of 22 °C and a flow of roughly 2 l/s.

A field sketch has been prepared indicating the main features at this location (A1-24).

Plate 95: Boiling, clear pool. View of most vigorously boiling area. Note sulphur deposition on edge, Feature 12, Wharepapa Road.

Plate 96: View of sinter terrace looking north to boiling pool (steaming area in background). Note shallow water level and silt deposition in foreground, Feature 12, Wharepapa Road.

Plate 97: Southern limit of terrace. Note dark sinter bank and small stream collecting the terrace run-off, Feature 12, Wharepapa Road.

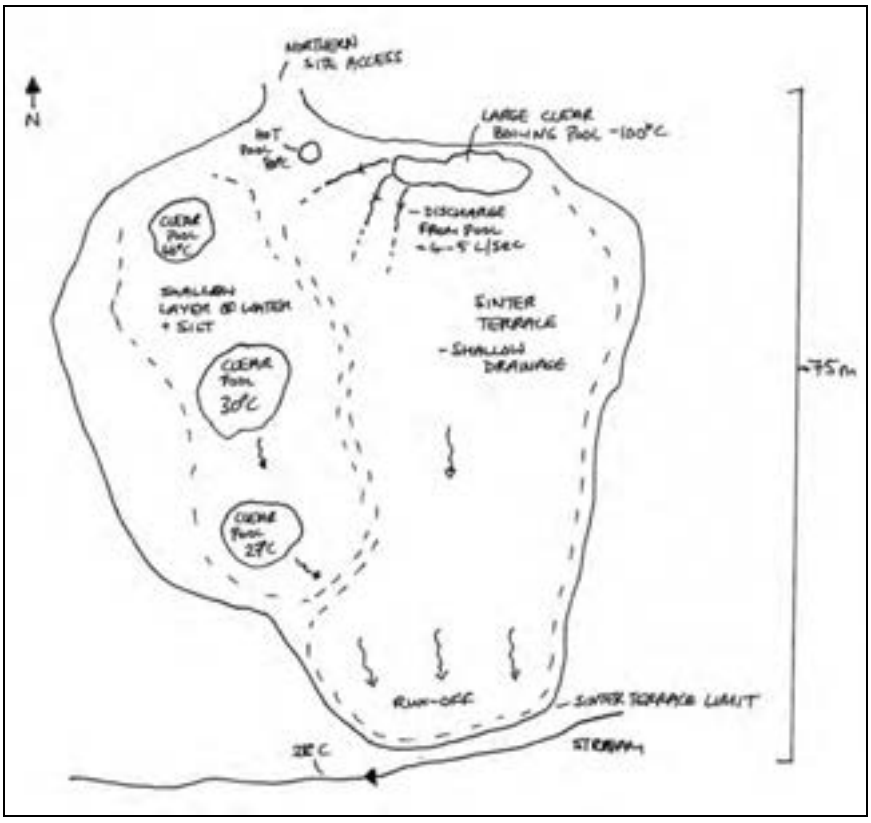


Figure A1-24: Field sketch of boiling pool/sinter Terrace, Feature 12, Wharepapa Road.

Feature 13:
Mud pools
(labelled F13 on feature map)

Grid Reference:
E1891134 N5743013

There are two mud pools at this location measuring 2 m^2 each. The temperatures ranged from 58-60 °C. There was also refuse and tree branches in the pools.

Plate 98: Mud pool with refuse, Feature 13, Wharepapa Road.

TOKAANU THERMAL PARK[1]

Overview of field work and background:

Several poorly-known thermal manifestations of the Tokaanu geothermal field were visited on Wednesday 7 February 2007. This was a hot, sunny day with the air temperature increasing from *c.*23 °C at 10.00 am to almost 30 °C at 2.00 p.m.

During the second half of the day selected manifestations in the Tokaanu Domain were inspected, along with the old discharging bore to the west of the Domain (BH2).

Visit of two selected manifestations in the Tokaanu Domain:

Manifestations in the Tokaanu Domain, which discharged water at boiling temperature in July 2005, were revisited. The first one was the old Taumatapuhipuhi geyser where geyser activity had ceased in 1966, shortly after commissioning of the first bath house well. The discharge changed then to some periodic ebullient discharge of boiling water as seen by the author on 14 July 2005. When revisited on 7 February 2007, the ebullient cycle had not changed - the temperature of the discharged hot water (98.5 °C) is still close to local boiling point.

A previously boiling spring, located halfway between Taumatapuhi and the bath Admin. Building, and which discharged at *c.*100 °C in July 2005 (see Hochstein 2005), had cooled down and discharged hot water at 72.6 °C when visited on 7 February 2007.

Visit of the old 'Healy Bore (*BH 2*)*:*

This *c.*97 m deep well lies at the western boundary of the Department of Conservation-administered Tokaanu Thermal Park. The well was drilled in 1942 and was sited by Mr. J. Healy. It freely discharges some deep thermal water (probably since 1951) which has created impressive, *c.*600 m^2 large silica sinter flats at E1839134 N5683066, covered in part by yellow algae. The site was visited to assess its thermal vegetation. Boiling water is discharged at the top of a sinter mound (*c.*3 m diameter). The discharge rate of the thermal water was found to be *c.*1-1.5 l/s. A similar rate had been reported by previous studies, summarized in Hochstein (2005), a summary which includes a short history of this manifestation. The recent growth of shrubs, blackberry, and bracken has made BH 2 an almost inaccessible but still a spectacular site.

[1] Undertaken by Hochstein in 2007.

TOKAANU URUPĀ MUD POOLS[1]

These pools are shown on a map in a 1942 paper (see Figure 2 in Healy 1942) where they are listed as 'two larger mud pots'. The mud pools were visited late afternoon on 7 February 2007 and were found to lie close to E1839752 N5682555, a position which is similar to that shown in the 1942 map by Healy. The pools are within kānuka forest, *c*.30 m to the east of a track and about 250 m to the southeast of the cemetery; the pools can be located by the sound of their bubbles. The western 'mud pot' has a diameter of *c*.4 m; the one adjacent to the east is *c*.5 m wide. The level of the larger pool is *c*.0.5 m below that of the smaller one. A maximum temperature of 87.4 °C was measured with a thermocouple device in a breached 'mud volcano crater' near the northeast rim of the smaller eastern pool; the temperature of upwelling liquid mud in other 'bubbles' in both pools varied between 74 °C and 84 °C (IR gun). Since little steam was visible, it can be inferred that almost all vapour is condensed by the liquid mud and that the driving agent of the 'bubbles' is gas, most likely CO_2 gas. There was no H_2S smell. The pH of the liquid mud was found to be close to neutral (assessed with a pH paper strip).

MAUNGANAMU EAST[1]

Overview of field work and background:

Several poorly known thermal manifestations of the Tokaanu geothermal field were visited on 07 February 2007. This was a hot, sunny day with the air temperature of *c*.23 °C at 10:00 am. The water temperature of the outflow of the 240MW Tokaanu hydro-power station in the tailrace canal had a range of *c*.14 °C and 17 °C.

Manifestations below the bridge alongside the tailrace canal (locations inferred from an old infra-red (IR) survey of the field (Bromley & Mongillo 1991)) were inspected. These IR anomalies were located on the west bank of the tailrace canal, *c*.0.6-0.7 km downstream from the SH 41 road bridge.

IR anomalies along the tailrace bank, downstream from the SH 41 bridge:

Three IR anomalies are shown in the Bromley & Mongillo (1991) study to occur along the western bank of the tailrace canal, *c*.600-700 m downstream from the SH 41 bridge. For most part, the banks are steep and lined by a strip of raupō reedland.

Close to the inferred northern-most site of one of the three IR anomalies, we found a stretch of shore water with surface temperatures of up to 24 °C (IR gun); the ambient water temperatures outside the stretch were *c*.18 °C. Probing with the thermocouple probe, temperatures between 52 °C and 60 °C were found at the first site at 0.3 m depth. The site (E1840593 N5682576), is distinguished by algae and subsurface plant growth which points to some zonation based on temperature gradients. The thermal water discharge occurred over a stretch along the shore at least *c*.10 m long; surface (water). Temperatures of 20 °C and 23 °C in this area were observed using the IR gun. At the second site a maximum temperature of 62.1 °C was observed at *c*.0.3 m depth; the lake bottom also exhibited a growth of brown-grey algae. Smaller seeps of thermal water occurred on land, *c*.0.2 m above the stream margins, with temperatures of up to 44 °C

[1] Undertaken by Hochstein 2007.

observed in one seep.

We did not search for the exact location of the other two IR anomalies located between 50-100 m upstream on the same bank because the manifestations are likely to be very small and possibly in the canal. These could be searched for and located using a boat with the approval of the canal managers.

MAUNGANAMU NORTH WETLAND[1]

We began the search for the manifestations with a visit of the Oasis Motel (owner M.R. Foxall) who showed us his 28 m deep thermal bore (present exit temperature was 68 °C in February 2007). Mr Foxall also pointed out the general area (to the east) behind his property where warm ground had been found in the past). As an example we were shown a 2 m deep soak hole (*c*.1 m diameter, concrete lining) at E1840218 N5682776 where a temperature of 30.5 °C was measured at the water-covered bottom, pointing to the presence of steam-heated, perched groundwater. We could not find the spring sampled by Healy and stopped our search at the western edge of the raupō reedland (near E1840178 N5682636), which is near the property boundary. Further searching would require permission for access from another landowner and possibly some preparatory shrub cutting.

TOKAANU TAILRACE CANAL[1]

Overview of field work and background:

Several poorly known thermal manifestations of the Tokaanu geothermal field were visited on 07 February 2007. This was a hot, sunny day with an air temperature of *c*.23 °C at 10:00 am. The water temperature of the outflow of the 240 MW Tokaanu hydro-power station in the tailrace canal had a range of *c*.14 °C to 17 °C.

Manifestations above the bridge alongside the tailrace canal were visited to determine locations inferred from an old infrared survey of the field (Bromley & Mongillo 1991).

Infra-red anomalies along the tailrace shores, close to the power station outlet:

An IR anomaly was observed during the 1991 airborne survey close to the southern shore of the tailrace canal, *c*.100-150 m downstream from the station outlet. Using an IR gun, a *c*.40 m long stretch of the shore line was searched without finding any temperature anomaly in the shallow water. We also searched for a thermal anomaly at the opposite site along the north bank where, according to Mr A. Hema (Tokaanu Power Station), some minor thermal activity had been noticed in the past *c*.100 m downstream from the outlet at low outflow level. However, no thermal anomaly was found near that site.

Another IR anomaly located by the 1991 survey points to a thermal site along the northern bank, *c*.275 m downstream from the power house outlet. The site is near a basic boat launching pad. This time a minor thermal anomaly was found as indicated by near-shore water temperatures of

[1] Undertaken by Hochstein in 2007

*c.*18 °C along a *c.*10 m long stretch; it was surrounded by water with ambient temperatures of *c.*15.5 °C. In the centre of the anomalous stretch (approximately at E1840049 N5681375), water temperatures between 28 °C and 29 °C were found at 0.3 m depth using a thermocouple device. The anomalous temperatures were reproducible when the site was re-occupied. The site lies close to the northeast corner of an old test pond dredged in 1969 to assess the danger of hydrothermal eruptions during excavation of the tailrace canal. The pond covered hot ground with boiling temperatures at shallow depths (Hochstein and Prebble 2006).

CHANGES IN EXTENT OF GEOTHERMAL SITES BETWEEN 1940S/1950S AND 2007 AERIAL PHOTOGRAPHS

In 2011, historical aerial photos of 52 sites held by the Waikato Regional Council library were compared with 2007 aerial photographs (2007 WRAPs). Photos for 12 sites were not able to be located. Of the 52 sites studied, photographs for 15 sites were not clear enough to determine any site change due to uncertainty of the surrounding landscape identification, cloud cover on the historical photograph, or were simply too small to identify any changes in extent. Where possible, existing literature was used to fill information gaps. Using a combination of historical photos and existing literature, the extent of geothermal vegetation has decreased in 23 out of the 37 sites that were able to be assessed (Table 13). In six sites, the extent of geothermal vegetation has increased compared to what was historically present, and eight sites have no discernable vegetation change.

Many of the historical photographs showed large, light coloured patches, often not present in 2007 aerials. These light coloured patches may be bare ground, but could also be short-statured vegetation (reflecting light), or open water. Bare ground can be indicative of heated soils resulting in less vegetation cover. It is possible that many sites have cooled over the last 60 years as a result of geothermal extraction, resulting in a corresponding increase in vegetation cover. Causes of a reduction in geothermal vegetation cover include an increase in ground temperature beyond the capacity to support vegetation, vegetation clearance, and spread of weeds.

Table 13: Summary of changes in extent and composition of geothermal vegetation and habitats between historical photos and 2007 aerial photographs[1].

Site Name	Site Number	Type of Change
Horohoro	HHV01	Too small to assess.
Waikite Valley	WAV01	Decrease.
Northern Paeroa Range	WAV02	No historical photos.
Maungaongaonga	WTV01	No significant change could be detected.
Ngapouri	WTV02	Decrease.
Waiotapu North	WTV03	Decrease.
Maungakakaramea (Rainbow Mountain)	WTV04	Decrease.
Waiotapu South	WTV05	Decrease.
Whakamaru	MKV01	Too small to assess.
Waipapa Stream	MKV02	No historical photos.
Tirohanga Road	MKV03	No historical photos.
Paerata Road	MKV04	No historical photos.
Upper Atiamuri West	ATV01	No historical photos.
Whangapoa Springs	ATV02	No historical photos.
Matapan Road	ATV03	No historical photos.
Te Kopia	TKV01	No significant change could be detected.
Murphy's Springs	TKV02	No historical photos.
Western Te Kopia		No historical photos.
Mangamingi Station	TKV06	No historical photos.

[1] Ordered by geothermal field.

Site Name	Site Number	Type of Change
Waihunuhunu	OKV01	Decrease.
Akatarewa Stream	OKV02	Decrease.
Orakeikorako	OKV03	Decrease.
Red Hills	OKV04	Decrease.
Akatarewa East	OKV05	Too small to assess.
Waikato River Springs	NMV01	Too small to assess.
Ngatamariki	NMV02	Increase.
Whangairorohea	WGV01	No significant change could be detected.
Longview Road	RPV01	Decrease.
Wharepapa Road	RPV02	Decrease.
Golden Springs	RPV03	Too small to assess.
Ohaaki Steamfield West	OHV01	Increase.
Ohaaki Steamfield East	OHV02	Increase.
Otumuheke	THV01	Too small to assess.
Spa Thermal Park	THV03	Decrease.
Broadlands Road	THV04	Increase.
Crown Park	THV05	Decrease.
Crown Road	THV06	Decrease.
Waipahihi Valley	THV07	Decrease.
Te Rautehuia	WKV01	Decrease.
Te Rautehuia Stream	WKV01	Decrease.
Upper Wairakei Stream (Geyser Valley)	WKV03	Decrease.
Wairakei Borefield	WKV04	Too small to assess.
Te Kiri O Hine Kai Stream Catchment/ Wairoa Hill	WKV05	Decrease.
Lower Wairakei Stream	WKV06	Too small to assess.
Karapiti Forest	WKV07	Decrease.
Hall of Fame Stream	WKV08	Too small to assess.
Waipouwerawera Stream/Tukairangi	WKV09	Increase.
Craters of the Moon	WKV10	Increase.
Rotokawa North	RKV01	No significant change could be detected.
Lake Rotokawa	RKV02	Decrease.
Hipaua	TOV02	No significant change could be detected.
Tokaanu Lakeshore Wetland	TOV03/ TOV04/ TOV05/TOV06	No significant change could be detected.
Maunganamu West	TOV07	Too small to assess.
Tokaanu Thermal Park	TOV08	Decrease.
Tokaanu Urupā Mud Pools	TOV09	Too small to assess.
Maunganamu East	TOV10	Decrease.
Maunganamu North Wetland	TOV11	Too small to assess.
Tokaanu Tailrace Canal	TOV14	No significant change could be detected.
Te Maari Craters	TGV01	Too small to assess.
Ketetahi	TGV02	No significant change could be detected.
Emerald Lakes	TGV03	Could not assess geothermal features.
Red Crater	TGV04	Too small to assess.

NOTES ON THE VASCULAR FLORA OF GEOTHERMAL AREAS

Distinctive vegetation types are a characteristic feature of geothermal areas. There are two categories of characteristic geothermal species: those that are restricted to geothermal sites, and those that have dispersed into geothermal sites because the habitat mimics aspects of the usual habitat of the species (Given 1995). Prostrate kānuka is the best known example of a plant restricted to geothermal areas, and the moss *Campylopus capillaceus,* is another example which may be an obligate geothermal species (Given 1995). Plants that occur in geothermal sites because the habitat mimics their usual habitat include plants of warmer climates which occur in regions generally recognised as being outside the climatic range of the species. In these cases, the geothermal heat creates a microclimate warmer than that of adjacent non-geothermal areas. In New Zealand, many tropical and temperate ferns and fern allies fall within this category (Given 1995).

FERNS AND FERN ALLIES

***Cheilanthes sieberi*:**
Found in New Zealand, Australia, and New Caledonia.

Usually found in coastal sites, it is currently known from four sites in the Waikato Region: Waikite Valley, Craters of the Moon, Te Kiri o Hine Kai stream catchment/Wairoa Hill, and Akatarewa East.

Threatened species ranking[1]: Not threatened

Plate 99: *Cheilanthes sieberi* at Craters of the Moon, August 2007.

***Christella* aff. *dentata* ("thermal"):**
Found in the North Island, Kermadec Islands, and probably also in tropics and subtropics of the old world.

[1] From de Lange *et al.* 2013.

Apparently distinct from *C. dentata*, which also occurs in New Zealand, by its shorter rhizome and smaller frond but its taxonomic status is not yet determined (Brownsey & Smith-Dodsworth 2000) in the North Island. In the central North Island it only occurs in geothermal areas. These geothermal populations are the southern limit for this taxon in the world. *Christella* aff. *dentata* ("thermal") is currently known from 15 sites in the Taupō Volcanic Zone, with 13 of these sites in the Waikato Region.

Plate 100: *Christella* aff. *dentata* ("thermal") alongside Otamakokore Stream, Waikite, May 2007.

Several populations have less than ten plants present and are therefore highly vulnerable to extinction (e.g. Hall of Fame Stream, Waikato River Springs, and Waipahihi Valley). Three sites have a declining population of *Christella* aff. *dentata* ("thermal") (Akatarewa Stream, Golden Springs, and Lower Wairakei Stream), while the populations at Waikite and Otumuheke appear to be immediately threatened by the density of blackberry scrub around stream. There are six populations with *c*.50 or more plants present - Waipapa Stream, Red Hills, Murphy's Springs, Orakeikorako, Otumuheke, and Waikite; the largest population in New Zealand occurs at Waimangu-Rotomahana in the Bay of Plenty Region (Bycroft and Beadel 2007). These sites are key sites for the conservation of this taxon in the North Island.

There are previous records from a further four sites in the Taupō Volcanic Zone in the Waikato Region (Tokaanu Thermal Park, Te Kiri O Hine Kai Stream Catchment/Wairoa Hill, Upper Wairakei Stream, and Kathleen Springs), but *Christella* aff. *dentata* ("thermal") is presumed to be extinct from these sites.

Threatened species ranking[1]: At Risk-Naturally Uncommon

***Cyclosorus interruptus*:**

Pantropical. This species is found in the North Island of New Zealand, and also in Australia, south-east Asia, and the Pacific. In the North Island it is confined to geothermal areas in the Taupō Volcanic Zone and coastal areas from Kawhia and Tauranga northwards (Brownsey and Smith-Dodsworth 2000). The populations that occur in geothermal areas are the southern limit for this species

Plate 101: *Cyclosorus interruptus* at Waihunuhunu, 2007.

[1] From de Lange *et al.* 2013

in the world. Where it occurs in geothermal-influenced sites it is present near geothermal hot springs, geothermally heated stream margins, geothermal wetlands, and steam vents.

In the Waikato Region it is known from seven sites in the following five geothermal fields: Waikite, Waiotapu, Orakeikorako, Ngatamariki, Wairakei-Tauhara. *C. interruptus* has been recorded historically from Akatarewa Stream (2002) and Kathleen Springs (2006) but has not been observed at these sites in recent surveys in spite of extensive searching. *C. interruptus* is a seasonal species in the central North Island and is not always visible during all seasons, so this species could still be present at these sites. The species is thought have become extinct at four geothermal sites in the last 40 years (Bycroft and Beadel 2007).

Threatened species ranking[1]: At Risk-Declining

***Dicranopteris linearis* var. *linearis*:**

Pantropical. In New Zealand it is confined to geothermal habitats of the Taupō Volcanic Zone, North Island, where it occurs in prostrate kānuka scrub and shrubland, and also other scrub, shrubland and fernland habitats around heated water (hot springs and geothermally-heated streams) and geothermally heated soils.

Plate 102: *Dicranopteris linearis* var. *linearis* at Maungaongaonga.

Several populations are present in forest within geothermal sites (e.g. Te Kopia and Orakonui). The populations in geothermal areas are the southern limit for this species in the world. Elsewhere it is widespread in the tropics and subtropics (Brownsey and Smith-Dodsworth 2000).

D. linearis is known from *c.*19 sites in the Waikato Region, and four sites in the Bay of Plenty Region (Fitzgerald and Smale 2010); however 12 of the 19 Waikato populations are very small. It is present in the following geothermal fields: Waikite, Waiotapu, Te Kopia, Orakeikorako, Ngatamariki, Ohaaki, Wairakei-Tauhara, and Rotokawa. The largest populations of this species at geothermal sites in the Waikato Region occur at Te Kopia, Orakeikorako, Red Hills, Te Kiri O Hine Kai Stream Catchment/Wairoa Hill, and Craters of the Moon. *D. linearis* has been recorded historically from three other sites within the Waikato Region (Akatarewa Stream, Crown Road, and Waipouwerawera Stream/Tukairangi) but has not been found at these sites in over 10 years and is therefore unlikely to still be present.

Threatened species ranking[1]:

At Risk-Naturally Uncommon

[1] From de Lange *et al.* 2013

***Hypolepis dicksonioides*:**

In New Zealand, it is known from Kermadec Islands, North Island, and South Island (Brownsey and Smith-Dodsworth), as well as the Chatham Islands (NZPCN website: accessed 4 May 2007). Outside New Zealand it is known from Norfolk Island, Samoa, Tahiti, and the Marquesas Islands (Brownsey and Smith-Dodsworth 2000). It is occasionally found in coastal areas of Northland and the Bay of Plenty, and very locally in coastal localities from Wairarapa to Cook Strait and north-west Nelson (Brownsey and Smith-Dodsworth 2000). In New Zealand it is also found in geothermal habitat of the Taupō Volcanic Zone, where it favours light soils or disturbed ground on forest margins, or streams and ditches (Brownsey and Smith-Dodsworth 2000).

Plate 103: *Hypolepis dicksonioides* alongside Otamakokore Stream, downstream of Corbett Road bridge, May 2007.

It is known from four geothermal sites in the Waikato Region (Waikite Valley, Waipahihi Stream, Lower Wairakei Stream, and Craters of the Moon) and is probably naturally rare at geothermal sites in the Waikato Region. *H. dicksonioides* has been recorded historically from Otumuheke Stream (2004) but has not been noted in recent surveys. However, it is a naturally short-lived, somewhat ephemeral, opportunistic species, which requires disturbance to create fresh habitats to colonise and may therefore be present at this site. *H. dicksonioides* is also known from two geothermal sites in the Bay of Plenty Region (Fitzgerald and Smale 2010). All populations at geothermal sites are of botanical interest as they often occur at sites outside its normal altitudinal range. The Waikato populations in geothermal sites (Craters of the Moon, Waipahihi Valley, and Waikite) are vulnerable to competition with pest plants (particularly blackberry).

Threatened species ranking[1]: At Risk-Naturally Uncommon

***Lycopodiella cernua*:**

Pantropical and warm temperate. In New Zealand this species usually occurs at coastal sites, or at geothermal sites where it is a characteristic feature. This species is common at geothermal sites throughout the Waikato Region. A new population was found in Te Maari Crater in June 2011.

Threatened species ranking[1]: Not threatened

[1] From de Lange *et al.* 2013

Plate 104: *Lycopodiella cernua* at Te Maari Craters, June 2011.

***Nephrolepis flexuosa* (ladder fern):**

This indigenous species is known with certainty from New Zealand, Raoul, Norfolk and Lord Howe Islands, and also Fiji and Rarotonga. This species may also be present in Samoa and Sri Lanka, and it is probably wide ranging throughout the Indian and Pacific Oceans. It may also be in Australia. It is abundant in coastal forest and scrub on Raoul Island, otherwise in New Zealand it is confined to the North Island where it is only known from active geothermal fields from Kawerau to Lake Taupō. It reaches a world southern limit at Tokaanu near Turangi (NZPCN website: accessed 4 May 2007). Its main habitats within geothermal sites are banks alongside stream margins, steam vents, and geothermally heated soils in scrub, shrubland, and fernland.

Plate 105: *Nephrolepis flexuosa* at Waihunuhunu, 2007.

It is known from *c.*15 sites in the Waikato Region. The most important populations for the conservation of *Nephrolepis flexuosa* in the Waikato Region are at Waihunuhunu (where it is common along the entire length of the unnamed geothermal stream), Upper Wairakei Stream, and Te Kiri O Hine Kai Stream Catchment/Wairoa Hill. There is also a large population of this species at Waimangu-Rotomahana in the Bay of Plenty Region. Several populations are small (several clumps only) and could be vulnerable to extinction. The population at Otumuheke Stream has declined since the 2004 survey, following restoration works at Otumuheke Stream mouth.

Threatened species ranking[1]: At Risk-Declining

[1] From de Lange *et al.* 2013

***Psilotum nudum*:**

Pantropical. Coastal northern New Zealand, and geothermal sites in the central North Island - Bay of Plenty. It is known from eleven geothermal sites in New Zealand, seven of these in the Waikato Region.

Threatened species ranking[1]: Not threatened

***Schizaea bifida* (forked comb fern):**

Present in New Zealand (North and South Islands), also Australia and New Caledonia. Local throughout New Zealand, present in geothermal areas in the central North Island, including at least one site in the Waikato Region.

Threatened species ranking[1]: Not threatened

***Schizaea dichotoma*:**

Pantropical. Kauri forests of Northland and South Auckland, and locally at geothermal sites in the central North Island - Bay of Plenty. Known from three sites in the Waikato Region.

Threatened species ranking[1]: At Risk-Naturally Uncommon

***Thelypteris confluens*:**

Common names are swamp fern, marsh fern, and swamp lady fern (Brownsey and Smith-Dodsworth 2000). This species is found in the North Island of New Zealand, and it is widely distributed from Africa to Australia. Its North Island distribution is from Te Paki in the north to the Waitakare in the west, and Bay of Plenty in the east. It is mostly found in coastal wetlands, but extends inland to wetlands near geothermal sites.

Plate 106: *Thelypteris confluens* at Waikite Wildlife Management Reserve.

It has been recorded from two geothermal sites in the Waikato Region: Waikite Wildlife Management Reserve, where two small populations are present (Bycroft and Beadel 2007), and Waihunuhunu. *T. confluens* has not been seen at Waihunuhunu since 2002 but is probably still present at this site.

Threatened species ranking[1]: At Risk-Naturally Uncommon

[1] From de Lange *et al.* 2013

DICOTYLEDONOUS TREES AND SHRUBS

***Korthalsella salicornioides*:**

New Zealand endemic. A semi-parasitic, dwarf mistletoe which grows on a variety of hosts.

Populations of this species have been recorded at three geothermal sites in the Waikato Region: Maungaongaonga, Te Kopia, and Tokaanu Thermal Park.

Threatened species ranking[1]: At Risk - Naturally Uncommon

***Kunzea ericoides* var. *microflora* (prostrate kānuka)[2]:**

New Zealand endemic. Prostrate kānuka is restricted to geothermal sites in the central North Island, and appears to be a distinct ecotype adapted to shallow warm soils.

Threatened species ranking[1]: At Risk-Naturally Uncommon.

Plate 107: Prostrate kanuka scrub at Craters of the Moon, August 2007.

SEDGES

***Fimbristylis velata*:**

Pantropical. In New Zealand it occurs occasionally at northern coastal and geothermal sites.

This species has been recorded historically from one geothermal site in the Waikato Region (Craters of the Moon) but has not been observed at this site for over 20 years. *F. velata* also occurs at Lake Whangape in the Waikato Region.

Threatened species ranking[1]: At Risk-Naturally Uncommon

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1 From de Lange *et al.* 2013.

2 Recent revision to the taxonomy of the *Kunzea ericoides* complex (see de Lange 2014) was not adopted in this iteration of the extent and composition of geothermal vegetation in the Waikato Region because field work was completed prior to the publication of the revision paper. Additional field work would be required at each site covered in this report in order to accurately determine the species composition of the "kānuka" and "prostrate kānuka" populations at each site according to the de Lange (2014) paper. This is discussed in more detail in Section 3.4.

MONOCOTYLEDONOUS HERBS

***Triglochin striata* (arrow grass):**

In New Zealand, generally a coastal species which occasionally occurs inland.

Known from at least seven geothermal sites in the Waikato Region from the following geothermal fields: Waikite, Waiotapu, Ngatamariki, Reporoa, Ohaaki, Wairakei-Tauhara, and Tokaanu-Waihi-Hipaua.

Threatened species ranking[1]: Not threatened

Plate 108: Arrow grass at Waikite Valley, February 2011.

ORCHIDS[2]

***Calochilus paludosus* (brown bearded orchid):**

Australia and New Zealand. Currently known from several sites in New Zealand, including areas of geothermally heated ground. Recorded from two geothermal sites in the Waikato Region (Maungakakaramea and Te Kopia).

Threatened species ranking[1]: At Risk-Naturally Uncommon

***Calochilus robertsonii* (red bearded orchid):**

Australia and New Zealand. Recorded from 15-20 coastal and geothermal sites in New Zealand, including two geothermal sites in the Waikato Region in the Orakeikorako and Rotokawa Geothermal Fields.

Threatened species ranking[1]: At Risk-Naturally Uncommon

***Corunastylis pumila*[3] (leek orchid):**

Endemic. New Zealand: North Island (from Te Paki south to about Kawhia, East Cape and the Bay of Plenty), Chatham Island. Recorded from coastal and inland sites in the northern half of the North Island, including one geothermal site in the Waikato Region (Orakeikorako).

Threatened species ranking[1]: At Risk-Naturally Uncommon

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1 From de Lange *et al.* 2013

2 Orchids are likely to be present at more sites than which they have been recorded, as field survey timing for this project is not conducive to detection of orchids.

3 Previously *Genoplesium pumilum*

***Petalochilus alatus*[1]**

Australia and New Zealand. Currently known from one geothermal site in the Waikato Region (Maungakakaramea).

Threatened species ranking[1]: At Risk-Naturally Uncommon

***Stegostyla atradenia*[2]**

Australia and New Zealand. Currently known from one geothermal site in the Waikato Region (Maungakakaramea).

Threatened species ranking[3]: At Risk-Naturally Uncommon

1 Previously *Caladenia alata*
2 Previously *Caladenia atradenia*
3 From de Lange *et al.* 2013

DEFINITIONS OF VEGETATION STRUCTURAL CLASSES USED IN THIS REPORT

(Source: Atkinson 1985)

Fernland — Vegetation in which the cover of ferns in the canopy is 20-100% and in which the fern cover exceeds that of any other growth form or bare ground. Tree ferns >10 cm dbh are excluded as trees (*cf.* forest).

Flaxland — Vegetation in which the cover of flax in the canopy is 20-100% and in which the flax cover exceeds that of any other growth form or bare ground.

Forest — Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants >10 cm dbh. Tree ferns >10 cm dbh are treated as trees.

Geothermal water[1]

Areas where 100% of the ground is covered by geothermally sourced water where geothermal water means water heated within the earth by natural phenomena to a temperature of 30 °C or more. Includes all steam, water, and water vapour, and every mixture of all or any of them that has been heated by natural phenomena.

Grassland — Vegetation in which the cover of grass in the canopy is 20-100% and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth form.

Herbfield — Vegetation in which the cover of herbs in the canopy is 20-100% and in which the herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses, or lichens.

Loamfield/peatfield

Land in which the area of loam and/or peat exceeds the area covered by any one class of plant growth form. The appropriate name is given depending on whether loam or peat form the greater part of the ground surface. Loamfields and peatfields are named from the leading plant species when plant cover ≥1%.

Lichenfield — Vegetation in which the cover of lichens in the canopy is 20-100% and in which the lichen cover exceeds that of any other growth form or bare ground.

[1] Definition from Waikato Regional Council Regional Plan.

Mossfield Vegetation in which the cover of mosses in the canopy is 20-100% and in which the moss cover exceeds that of any other growth form or bare ground.

Nonvegetated Raw-soilfield

Areas bare ground that are bare of vegetation and are too hot to support plant life, are cooled but hydrothermally altered, are sinter pavements, or are subjected to regular mud ejection or gas emission that prevent colonisation and establishment of plants. These areas are often small scale, and may not be visible on aerial photographs.

Very hot soils are often associated with steam vents and/or boiling mud craters, and soil temperatures at 10 cm depth are usually >90 °C. Hydrothermally altered soils often occur where geothermal expression has ceased, e.g., dried mud craters, that result in soils with unusual chemical composition. Vigorously boiling mud pools and craters regularly eject hot mud around their margins, which effectively prevents plant colonisation. In cases where toxic gas is emitted, vegetation is either absent, or if present, killed.

Reedland Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Examples include *Typha, Bolboschoenus, Schoenoplectus tabernaemontani, Eleocharis sphacelata,* and *Machaerina articulata*.

Sandfield Land in which the area of bare sand (0.02-2 mm diameter) exceeds the area covered by any one class of plant growth form. Dune vegetation often includes sandfields which are named from the leading species when plant cover is ≥1%.

Scrub Woody vegetation in which the cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (*cf.* forest). Shrubs are woody plants <10cm dbh.

Sedgeland Vegetation in which the cover of sedges in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. Included in the sedge growth form are many species of *Carex, Uncinia, Isolepis*, and *Bolboschoenus*. Tussock-sedges and reed-forming sedges (*cf.* reedland) are excluded.

Shrubland Vegetation in which the cover of shrubs in the canopy is 20-80% and in which the shrub cover exceeds that of any other growth form or bare ground. It is sometimes useful to separate tussock-shrublands as a sub-class for areas where tussocks are >20% but less than shrubs.

Vegetation Type

A term that includes the dominant canopy species and structural class of an area of vegetation, e.g. rimu/tawa-kamahi forest, *Isolepis nodosa*/*Muehlenbeckia complexa* sedge-vineland.

In addition, cover values and tiers are included, i.e.

(tawa)	less than 5% cover of the bracketed species
(rimu)/tawa	indicates less than 5% cover of rimu emergent over a canopy of tawa
tawa-hinau	indicates tawa and hinau occur in the same tier
↔	mosaic

Vineland — Vegetation in which the cover of unsupported (or artificially supported) woody vines in the canopy is 20-100% and in which the cover of these vines exceeds that of any other growth form or bare ground. Vegetation containing woody vines that are supported by trees or shrubs is classified as forest, scrub, or shrubland as appropriate. Examples of woody vines occur in the genera *Actinidia, Clematis, Lonicera, Metrosideros, Muehlenbeckia, Ripogonum, Vitis,* and others.

ABBREVIATIONS AND SYMBOLS

c.	approximately; about
DOC	Department of Conservation
ha	hectare
m	metre
/	separates various tiers of the vegetation in the type descriptions
-	links plants in the same tier
( )	less than 5% cover of the bracketed species
⇔	mosaic
IR	Infra red (used for finding hot spots in the ground that may indicate geothermal activity)

COMMON PLANT NAMES USED IN TEXT

acrid lettuce	*Lactuca virosa*
African feather grass	*Cenchrus macrourus*
agapanthus	*Agapanthus praecox*
aloe	*Aloe* sp.
apple	*Malus ×domestica*
annual poa	*Poa annua*
arrow bamboo	*Pseudosasa japonica*
arrow grass	*Triglochin striata*
barberry	*Berberis glaucocarpa*
bay grass	*Eragrostis brownii*
bishop pine	*Pinus muricata*
black nightshade	*Solanum nigrum*
black pine	*Pinus nigra*
black wattle	*Acacia mearnsii*
blackberry	*Rubus* sp. (*R. fruticosus* agg.)
bracken	rarahu; *Pteridium esculentum*
broad-leaved fleabane	*Conyza sumatrensis*
broom	*Cytisus scoparius*
browntop	*Agrostis capillaris*
brush wattle	*Paraserianthes lophantha*
buddleia	*Buddleja davidii*
buffalo grass	*Stenotaphrum secundatum*
Californian thistle	*Cirsium arvense*
catsear	*Hypochoeris radicata*
Chinese privet	*Ligustrum sinense*
climbing rose	*Rosa* sp.
cocksfoot	*Dactylis glomerata*
common alder	*Alnus glutinosa*
cotoneaster	*Cotoneaster glaucophyllus*
crack willow	*Salix fragilis*
creeping bent	*Agrostis stolonifera*
creeping buttercup	*Ranunculus repens*
Cretan brake	*Pteris cretica*
curled dock	*Rumex crispus*
Douglas fir	*Pseudotsuga menziesii*
elephants ear	*Alocasia brisbanensis*
eucalyptus	*Eucalyptus* sp.
European larch	*Larix decidua*
false acacia	robinia; black locust; *Robinia pseudoacacia*
feijoa	*Feijoa sellowiana*
fennel	*Foeniculum vulgare*
flowering cherry	*Prunus* sp.
foxglove	*Digitalis purpurea*
German ivy	*Delairea odorata*
gorse	*Ulex europaeus*

grape	*Vitis vinifera*
greater bindweed	*Calystegia silvatica*
grey willow	*Salix cinerea*
harakeke	flax, *Phormium tenax*
hawksbeard	*Crepis capillaris*
hawthorn	*Crataegus monogyna*
Himalaya fairygrass	*Miscanthus nepalensis*
Himalayan honeysuckle	*Leycesteria formosa*
holly	*Ilex aquifolium*
horoeka	lancewood, *Pseudopanax crassifolius*
hound's tongue fern	kowaowao; *Microsorum pustulatum*
houhere	lacebark; *Hoheria sexstylosa*
hydrangea	*Hydrangea macrophylla*
Indian doab	*Cynodon dactylon*
inkweed	*Phytolacca octandra*
ivy	*Hedera helix*
Japanese cedar	*Cryptomeria japonica*
Japanese honeysuckle	*Lonicera japonica*
jointed rush	*Juncus articulatus*
kahikatea	*Dacrycarpus dacrydioides*
kāmahi	*Weinmannia racemosa*
kānuka	*Kunzea ericoides*
karamū	*Coprosma robusta*
Khasia berry	*Cotoneaster simonsii*
kiokio	*Blechnum novae-zelandiae*
kōhūhū	*Pittosporum tenuifolium*
koromiko	*Hebe stricta* var. *stricta*
kōwhai	*Sophora microphylla*
lake clubrush	*Schoenoplectus tabernaemontani*
Lawson's cypress	*Chamaecyparis lawsoniana*
Lombardy poplar	*Populus nigra* 'Italica'
lotus	*Lotus pedunculatus*
lupin	*Lupinus arboreus*
macrocarpa	*Cupressus macrocarpa*
māhoe	*Melicytus ramiflorus* subsp. *ramiflorus*
makomako	wineberry, *Aristotelia serrata*
mamaku	*Cyathea medullaris*
mānuka	*Leptospermum scoparium* agg.
māpou	*Myrsine australis*
maritime pine	*Pinus pinaster*
marsh bedstraw	*Galium palustre*
Mercer grass	*Paspalum distichum*
Mexican daisy	*Erigeron karvinskianus*
mingimingi	*Leucopogon fasciculatus*
monoao	*Dracophyllum subulatum*
montbretia	*Crocosmia ×crocosmiiflora*
Montpellier broom	*Teline monspessulana*
narrow-leaved carpet grass	*Axonopus fissifolius*
narrow-leaved plantain	*Plantago lanceolatum*
oak	*Quercus* sp.

oioi	*Apodasmia similis*
olive	*Olea europaea*
pākau	gully fern; *Pneumatopteris pennigera*
pampas	*Cortaderia selloana*
paspalum	*Paspalum dilatatum*
pātōtara	*Leucopogon fraseri*
peppermint	*Mentha ×piperita*
perrywinkle	*Vinca major*
plum	*Prunus ×domestica*
pōhue	*Calystegia sepium* subsp. *roseata*
ponga	silver fern; *Cyathea dealbata*
poplar	*Populus* sp.
prickly mingimingi	*Leptecophylla juniperina* subsp. *juniperina*
prostrate kānuka	*Kunzea ericoides* var. *microflora*
purple pampas	*Cortaderia jubata*
radiata pine	*Pinus radiata*
ragwort	*Jacobaea vulgaris*
raupō	*Typha orientalis*
rautāwhiri	*Pittosporum colensoi*
reed sweetgrass	*Glyceria maxima*
rewarewa	*Knightia excelsa*
rhododendron	*Rhododendron* sp.
rimu	*Dacrydium cupressinum*
ring fern	*Paesia scaberula*
ripgut brome	*Bromus diandrus*
rye grass	*Lolium perenne*
Scotch thistle	*Cirsium vulgare*
sea rush	*Juncus kraussii* var. *australiensis*
selfheal	*Prunella vulgaris*
sharp-fruited rush	*Juncus acuminatus*
sheep's sorrel	*Rumex acetosella*
shaking brake	turawera, *Pteris tremula*
silver birch	*Betula pendula*
soft rush	*Juncus effusus* var. *effusus*
Spanish heath	*Erica lusitanica*
strawberry tree	*Arbutus unedo*
strobus pine	*Pinus strobus*
swamp kiokio	*Blechnum minus*
swamp millet	*Isachne globosa*
sweet vernal	*Anthoxanthum odoratum*
tall fescue	*Schedonorus arundinaceus*
tall willow herb	*Epilobium ciliatum*
Tasmanian blackwood	*Acacia melanoxylon*
tarata	lemonwood; *Pittosporum eugenioides*
tāwiniwini	*Gaultheria antipoda*
tī kōuka	cabbage tree; *Cordyline australis*
toatoa	*Haloragis erecta* subsp. *erecta*
toatoa	*Phyllocladus toatoa*
toetoe	*Austroderia fulvida*
toru	*Toronia toru*

totara	*Podocarpus totara* var. *totara*
track rush	*Juncus tenuis* var. *tenuis*
tradescantia	*Tradescantia fluminensis*
tree lucerne	*Chamaecytisus palmensis*
tūrutu	*Dianella nigra*
tutu	*Coriaria arborea* var. *arborea*
umbrella sedge	*Cyperus eragrostis*
Vasey grass	*Paspalum urvillei*
vetch	*Vicia sativa*
watercress	*Nasturtium officinale*
water fern	*Histiopteris incisa*
water lily	*Nymphaea alba*
water pepper	*Persicaria hydropiper*
water purslane	*Ludwigia palustris*
whauwhaupaku	fivefinger; *Pseudopanax arboreus*
whekī-ponga	*Dicksonia fibrosa*
whekī	*Dicksonia squarrosa*
white clover	*Trifolium repens*
wild kiwifruit	*Actinidia deliciosa*
wild portulaca	*Portulaca oleracea*
wild seradella	*Ornithopus perpusillus*
willow-leaved hakea	*Hakea salicifolia*
yarrow	*Achillea millefolium*
Yorkshire fog	*Holcus lanatus*
yucca	*Yucca* sp.

UPDATED* WAIKATO REGIONAL COUNCIL CRITERIA FOR THE EVALUATION OF INDIGENOUS VEGETATION AND HABITATS OF INDIGENOUS FAUNA

* Criterion 3 is updated to reflect the revised threat classification system of Townsend *et al.* (2008).

Complete Column E only if you need to determine level of significance.

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
SITE PROTECTED OR ASSESSED PREVIOUSLY				
1 It is indigenous vegetation or habitat that has been specially set aside by statute or covenant for protection and preservation, unless the site can be shown to meet none of Criteria 3-11.	This may include sites protected under the Conservation Act, Resource Management Act, or with QEII or NWR. The assumption inherent in this criterion is that legally protected areas have been assessed and deemed worthy of protection. Therefore such sites are assumed to be significant unless challenged, in which case the challenger would have to show that the site does not meet criteria 3-11.	DOC, WRC, NWR, QEII, TLA.	Y / N / NS	What type of legally protected area is it? E.g. Scenic Reserve, National Park, QEII Covenant. _____

[1] CE = Consultant Ecologist, CRI= Crown Research Institute e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA), DOC = Department of Conservation, WRC = Waikato Regional Council, NHF = Nature Heritage Fund, NWR = Nga Whenua Rahui, P = Published reports or maps, QEII = QEII National Trust, TLA = Territorial Local Authority (district or city council), UW = University of Waikato.

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
2 It is indigenous vegetation or habitat recommended for protection by the Nature Heritage Fund or Nga Whenua Rahui committees, or the Queen Elizabeth the Second National Trust Board of Directors, unless the site can be shown to meet none of Criteria 3-11.	Assumption is as above.	NHF, NWR, QEII	Y / N / NS	What type of legal protection has been recommended?
RARE / DISTINCTIVE FEATURES				
3 It is vegetation or habitat that is currently habitat for indigenous species or associations of indigenous species that are: • Classed as 'Threatened' or 'At Risk' in the New Zealand Threat Classification System, or; • Classed as 'Data Deficient' in the New Zealand Threat Classification System, or; • endemic to the Waikato Region, or • it is a habitat of importance for the	Species that are Threatened', 'At Risk' or 'Data Deficient' are indigenous species that have been evaluated and placed within categories under the New Zealand Threat Classification System. Endemic to the Waikato Region, means currently only occurs naturally within the Waikato Region.	CE, CRI, DOC, WRC	Y / N / NS	List the 'Threatened', 'At Risk' or 'Data Deficient' species and their classification _____ _____ _____ _____ _____ List any 'Threatened', 'At Risk' or 'Data Deficient' species that use the site which are international migrants. _____ _____ List any regionally endemic species _____ _____

A. Criteria		B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
	conservation of regionally threatened or regionally 'At Risk' species (or genetically distinct population) in the Waikato Region.				
4	It is indigenous vegetation or habitat type that is under-represented (10% or less of its known or likely original extent remaining) in an Ecological District, or Ecological Region, or nationally.	Maps of ecological districts and regions (McEwen 1987) are available from DOC and WRC. A "type" of indigenous vegetation or habitat could refer to a broad unit such as podocarp/tawa-dominant forest, or a more detailed classification and mapping unit such as harakeke flaxland. Definitions (and examples) of vegetation/habitat structural classes and vegetation types are provided in Atkinson (1985) and, for wetlands, Clarkson *et al*. (2002). Vegetation types for non-wetland vegetation in the Waikato Region are described in Leathwick *et al.* 1995. Comparison with known or likely original extent may require analysis (for example, using a Geographic Information System) of current extent and previous extent. Leathwick *et al.* 1995 mapped and described the extent of indigenous vegetation types in 1840 and 1995.	CE, CRI, DOC, WRC, P	Y / N / NS	List under-represented vegetation/habitat type(s) and state whether rare at the national, regional, or ecological district scale? _____ _____ _____ _____

A. Criteria		B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
		Vegetation types are not directly comparable and many vegetation types need to be grouped for comparison with the estimated 1840 extent. Future analysis using frameworks such as Land Environments may enable comparison with vegetation prior to human occupation. In the meantime comparison with the 1840 datum will provide useful information for most vegetation classes.			
5	It is indigenous vegetation or habitat that is, and prior to human settlement was, nationally uncommon, such as geothermal, Chenier plain, or karst ecosystems.	Geothermal habitats can include geysers, springs, sinter terraces, and hydro-thermally altered soils. They provide habitat for geothermally-influenced vegetation, and heat-tolerant bacteria. Chenier plain is a plain comprising shell ridges with infilled muds and other sediment between the ridges. An extensive area at Miranda provides habitat for international wader migrants. Karst ecosystems are limestone systems, providing habitat for specialist limestone plants (e.g. *Asplenium cimmeriorum, Gymnostomum calcereum*) and fauna (e.g. cave weta). Note that these three examples are not a comprehensive list of nationally uncommon vegetation or habitat types.	CE, CRI, DOC, WRC	Y / N / NS	Type of feature: _____ _____ Area: _____ Condition: _____ _____

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
6 It is wetland habitat for indigenous plant communities and/or indigenous fauna communities[1] that has not been created and subsequently maintained for or in connection with: (a) waste treatment; or (b) wastewater renovation; or (c) hydro electric power lakes[2]; or (d) water storage for irrigation; or (e) water supply storage; unless in those instances they meet the criteria in Whaley *et al*. (1995).	Wetlands have been severely depleted nation-wide, and are recognised as a rare habitat type. The RMA definition of a wetland is: "Wetland" includes permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions. Wetlands may have fluctuating water levels and the edge of a wetland may be difficult to define but will generally be where wetland plant species (e.g. raupo) are replaced with dryland species (e.g. kānuka). Note that manuka can occur in wetland and dryland habitats. All artificially-created wetlands listed in Criterion 6a-e should <u>also</u> be evaluated using the criteria in Whaley *et al*. (1995), as well as criteria 1-5 and 7-11 in Table 1.	CE, CRI, DOC, WRC, P Copies of Whaley *et al*. (1995) can be obtained from WRC.	Y / N / NS	Type of wetland habitats/indigenous communities present: _____ _____ _____ _____ _____ Origins of wetland (natural, artificial): _____ _____ Area (ha): _____

[1] Does not include exotic rush/pasture communities.

[2] Does not include Lake Taupo.

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
7. It is an area of indigenous vegetation or naturally occurring habitat that is large relative to other examples in the Waikato Region of similar habitat types, and which contains all or almost all indigenous species typical of that habitat type.	This criterion is not intended to select the largest single example of a habitat type in the Waikato Region. Refer to vegetation maps (e.g. Leathwick *et al*. 1995), to determine which other parts of the Region have similar habitat, and the size of those examples. Refer to natural area inventories (e.g. report by Wildland Consultants Ltd and EPRO Ltd 1999), DOC compilations of Sites of Special Wildlife Importance (SSWI), DOC Conservation Management Strategies for Waikato, Bay of Plenty, Wanganui, Auckland, and Tongariro/Taupō Conservancies, Protected Natural Area Programme reports (e.g. Coromandel PNAP) to help determine the species that are typical of each habitat type.	CE, CRI, DOC, WRC	Y / N / NS	Broad habitat types present: _____ _____ Area (ha) Notable flora or fauna: _____ _____ How does the size compare with other similar habitat types in the Region? *e.g. the site is part of one of the largest example of similar habitat types in the Region.* _____ _____

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
8 It is aquatic habitat that is a portion of a stream, river, lake, wetland, intertidal mudflat or estuary, and their margins, that is critical to the self sustainability of an indigenous species within a catchment of the Waikato Region and which contains healthy, representative populations of that species.	Excluding artificial water bodies, except those created for the maintenance and enhancement of biodiversity or as mitigation for a consented activity. Critical means essential for a specific component of the life cycle and includes breeding and spawning grounds, juvenile nursery areas, important feeding areas, and migratory pathways. It is likely that sound technical advice will need to be obtained from an appropriately qualified and experienced aquatic ecologist.	CE, CRI, DOC, WRC, UW	Y / N / NS	Catchment: _____ _____ Area (ha) or length of habitat: _____ Breeding species present: _____ _____ _____
REPRESENTATIVE EXAMPLES				
9 It is an area of indigenous vegetation or habitat that is a healthy, representative example of its type because: Its structure, composition, and ecological processes are largely intact, and if protected from the adverse effects of plant and animal pests and of adjacent landuse (e.g. stock, discharges, erosion), can maintain its ecological sustainability over time.	Fencing and pest control would be required for most mainland sites in the Region (irrespective of habitat type). Ecological sustainability means a site's ability to continue to exist as an area of indigenous vegetation or habitat for indigenous fauna when taking into account its size, shape, buffering from external effects, connection to other natural areas, and likely threats. It may change naturally into a different habitat but indigenous species are probably prominent or dominant and it will retain a natural character. Ecologists assessing this criterion should take into account the site's size,	CE, CRI, DOC, WRC, P This criterion will require the input of an experienced and qualified ecologist. Good information is probably required, and, in most instances, a field visit is probably	Y / N / NS	Rank the following factors High (H), Medium (M) or Low (L): structural intactness ____ ratio of indigenous: exotic species ____ connectivity to other natural areas ____ size of the area in the context of the relevant ecological district ____ degree of protection from likely threats (e.g., fenced, buffered) ____ species diversity ____

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
	shape, buffering from external effects, and connection to other natural areas. Other factors to be considered include indigenous regeneration (presence of fruit, seedlings, nests, juvenile animals etc), structural tiers (layers), hydrological processes in wetlands, invasive weeds, pest animals, domestic stock, threat management, and management history. Representative areas are sites that are the best examples of sites that form a network covering the full range of landforms, soil sequences, vegetation and fauna communities within an ecological district (c.f. Shaw 1994). The reality for many landscapes, particularly throughout much of the Waikato, is that a 'representative example' is probably the larger and most diverse remaining examples of indigenous vegetation and habitats.	necessary.		List no. of responses to the above questions: H _____ M _____ L _____ Indicate overall ecological quality of the site. _____ Would you consider this to be among the best examples of its type nationally (Y/N), in the Waikato Region (Y/N), or in a particular ecological region/ district (Y/N)? Provide justification. _____ _____ _____
10 Is it an area of indigenous vegetation or habitat that forms part of an ecological sequence that is either not common in the Waikato Region or an ecological district, or is an exceptional, representative example of its type.	Ecological sequence means a series of two or more connected ecosystems or vegetation types that retain natural transition zones along an environmental gradient. Ecological sequences that are not common in the Waikato Region include, but are not restricted to, indigenous dune vegetation through to	CE, CRI, DOC, WRC, P	Y / N / NS	Does the site include or is it part of one of the best or only examples of this type of ecological sequence nationally (Y/N), regionally (Y/N), or in the relevant ecological district (Y/N)? Location: _____

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
	coastal scrub or forest, lake margins or geothermal systems to indigenous forest, coastal to montane or alpine vegetation. Such sequences should be largely intact (e.g. perhaps bisected by roads but not by large tracts of non-indigenous land cover), such that they can be traversed by the majority of indigenous species that are reliant on such sequences for the completion of part or all of their life-cycles (e.g. by movement of key fauna or dispersal of propagules such as seed). It will probably be necessary to provide or obtain a map(s) of the sequence and the main vegetation types and habitats that it comprises. An exceptional, representative sequence is probably one of the best examples of its type, taking into account its intactness, composition, and ecological processes. GIS analysis using a vegetation map and an appropriate evaluation framework (e.g. ecological district boundaries) may demonstrate if a sequence is uncommon or one of the better examples.			Key elements of sequence: _____ _____ _____ _____ _____ Justification: _____ _____ _____ _____

A. Criteria	B. Definitions and Further Information	C. Likely Information[1] Sources	D. Response (Yes? No? Not Sure?)	E. If Yes, provide the information requested below to assist with determining level of significance
ROLE IN PROTECTION OF ECOLOGICALLY SIGNIFICANT AREA				
11 It is an area of indigenous vegetation or habitat for indigenous species (which habitat is either naturally occurring or has been established as a mitigation measure) that forms, either on its own or in combination with other similar areas, an ecological buffer, linkage or corridor, and which is necessary to protect any site identified as significant under Criteria 1-10 from external adverse effects.	This also includes riparian vegetation that protects a freshwater fishery.	CE, CRI, DOC, WRC, P	Y / N / NS	Key ecological function(s) of site (buffer, ecological linkage, other): _____ _____ Which site(s) does this area provide a buffer or linkage for? _____ _____ How significant is the site(s) listed above? i.e. which of criteria 1-10 does the buffered or linked site comply with? _____ _____ Justification: _____ _____ _____

UPDATED* WAIKATO REGIONAL COUNCIL CRITERIA FOR THE ASSESSMENT OF RELATIVE ECOLOGICAL SIGNIFICANCE OF INDIGENOUS VEGETATION AND HABITATS OF INDIGENOUS FAUNA

* Factors 7 and 12 are updated to reflect the revised threat classification system of Townsend *et al.* (2008).

In Column A, circle the criteria numbers for which you scored a 'Yes' in Table 1. Then consider the factors to be assessed, and complete Column D, using your answers in Table 1 Column E to justify your response.

A. RPS Criteria met (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
	INTERNATIONALLY SIGNIFICANT A site is Internationally Significant if you respond 'YES' to any of the questions in this section:	Internationally significant natural areas have usually been identified in previous assessments. These sites are so important that some of them are already protected by international conventions. For example, the Tongariro National Park is a World Heritage Area, and there are three wetlands in the Waikato listed as Wetlands of International Importance under the international RAMSAR Convention (Whangamarino Swamp, Kopouatai Peat Dome, and the Firth of Thames estuary). Other natural areas may be internationally significant if they contain high quality vegetation or habitat that is unique in the world - for example, geothermal systems at Waiotapu and Orakeikorako. Internationally significant sites are likely to attract the interest of overseas and NZ scientists, and be a primary attraction for international and national tourists, e.g. Miranda bird sanctuary, Tongariro National Park.	
1	1. Has it been recognised under international legislation or convention as an internationally significant area (e.g. as a World Heritage Site or a RAMSAR site)?		Y / N / NS

A. RPS Criteria met (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
2	2. Has it been recommended for protection as a World Heritage Site or Wetland of International Importance (RAMSAR site) by QEII or NWH, or NHF?		Y / N / NS
3	3. Is it currently habitat for an indigenous species which is threatened with extinction (in the categories Nationally Critical, or Nationally Endangered or Nationally Vulnerable) and endemic to the Waikato Region?		Y / N / NS
3	4. Is it a key habitat for the completion of the life cycle of species that migrate internationally and that would be threatened if these habitats weren't sustained?	An example of key habitat for international migrants is the Firth of Thames.	Y / N / NS
If meets several of 4 & 9 or 5 & 9 or 6 & 9 or 7 & 9 or 8 & 9 or 10 & 9	5. Is the site the best or only remaining large representative example in New Zealand of a suite of relatively intact indigenous ecosystems and ecological sequences e.g. a wetland/forest complex with altitudinal sequences?	This would need to be justified by several well-qualified and experienced ecologists.	Y / N / NS

A. RPS Criteria (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
	NATIONALLY SIGNIFICANT The site is **at least** Nationally Significant if you can answer 'YES' to any of the questions in this section.	**Nationally Significant** natural areas includes sites that contain healthy populations of threatened species (such as kokako and kaka habitat at Pureora), or are very good examples of nationally rare habitat or vegetation (such as the large wetlands in the northern Waikato). They also include sites that are the only location where certain species occur, such as the hooded orchid at Whangamarino, or the Mercury Islands tusked weta. Nationally significant sites tend to attract the interest of scientists, technical specialists, and/or tourists from other parts of New Zealand.	
1 or 2	6. Is it protected, or recommended for protection, under the Conservation Act 1987 (as an Ecological Area, or Forest Sanctuary), National Parks Act 1980, Marine Reserves Act 1971, or Reserves Act 1977 (as a Nature Reserve or Scientific Reserve).	In the Waikato Region these include: Tongariro National Park, Waihaha Ecological Area, Waipapa Ecological Area, Mangatutu Ecological Area, Rapurapu Ecological Area.	Y / N / NS

A. RPS Criteria (see Table 1 above)	**B. FACTORS TO BE ASSESSED**	**C. NOTES**	**D. RESPONSE (Yes / No / Not Sure)**
3	7. Is it habitat for an indigenous species (or genetically distinct population) threatened with extinction in the categories 'Nationally Critical', 'Nationally Endangered', or 'Nationally Vulnerable', OR It is one of the best quality examples, on a national basis, of habitats used on an ongoing basis by a species (or genetically distinct population) in the 'At Risk' category, OR It is a key habitat for the completion of the lifecycle of a species (or genetically distinct population) in one of the threat categories above, that migrate nationally and that would be threatened if these habitats were not sustained.	Sites where low numbers are present on only a few occasions (and are unlikely to be important for the long-term viability of the species) do not meet this factor. Sites that meet this factor will be used on an on-going basis, or be important for sustaining a population on a seasonal basis for key comiponents of its lifecycle (e.g. feeding site), or be an important migratory site, breeding site, or over-wintering site.	Y / N / NS Species: _____ _____ _____ Threat Status: _____ _____
4 & 9 or 5 & 9 or 6 & 9	8. Is it indigenous vegetation or habitat for indigenous species that is under-represented nationally (10% or less remains), or nationally uncommon (including wetland) that is a good quality example that is representative of its type?	Good quality examples would receive mostly highs or mediums for Criterion 9 in Table 1(taking into account size, presence of plant and animal pests, stock damage, and other damaging effects). For the definition of vegetation types refer to Criterion 4 in Table 1 above - Column B, Definitions and Further Information.	List no. of responses to criterion 9 in Table 1: H _____ M _____ L _____ Y / N / NS

A. RPS Criteria (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
	REGIONALLY SIGNIFICANT The site is **at least** Regionally Significant if you can respond 'YES' to any of the questions in this section:	**Regionally significant** natural areas include the best examples in the Waikato Region of habitats that may be common elsewhere in New Zealand - for example, our best dune systems or largest mangrove-filled estuaries, or large examples of more common vegetation types. They may also include examples of nationally rare features that are not in good condition.	
1	9. Is it protected under the Reserves Act 1977, as a Wildlife Management Reserve, Wildlife Refuge, Scenic Reserve, Nga Whenua Rahui Kawenata, or for any conservation purpose under the Conservation Act such as a Conservation Area or Conservation Park, with significant fauna and/or flora values.		Y / N / NS Status: _____ Recommended Status: _____ _____
1	10. Is it protected under the Queen Elizabeth the Second National Trust Act 1977 as an Open Space Covenant for any purpose other than those outlined for sites of international or national significance?		Y / N / NS
2	11. Is it a site that has been recommended for protection by NHF, NWR, or QEII?		Y / N / NS

A. RPS Criteria (see Table 1 above)	**B. FACTORS TO BE ASSESSED**	**C. NOTES**	**D. RESPONSE (Yes / No / Not Sure)**
3	12. Is it habitat of considerable importance for the conservation of an indigenous species (or genetically distinct population) in the 'At Risk' category or it is an important habitat for a species that is endemic to the Waikato Region, OR It is habitat of importance for the conservation of regionally threatened of regionally 'At Risk' species (or genetically distinct population) within the Waikato Region, although the species is secure elsewhere, OR Habitat considered, by several qualified and experienced ecologists to be of importance for the sustainability of a 'Data Deficient' species on a regional basis.	Species currently known to be endemic to the Waikato Region (defined as currently only occurs naturally within the Waikato Region) include: *Sporadanthus ferrugineaus*, Mercury Is. Tusked weta, Te Aroha stag beetle, Moehau stag beetle, *Hebe* 'Awaroa', *Corybas carsei.* Assessment of whether a species is classified as 'At Risk' or threatened in the Waikato Region would have to be justified by several well-qualified and experienced ecologists familiar with the species and ecology of the Waikato Region.	Y / N / NS Species: _____ _____ _____ Threat Status: _____ _____
4 & 9	13. Is it indigenous vegetation or habitat for indigenous species that is under-represented regionally (i.e. within relevant ecological regions and districts) and which is a good quality example that is representative of its type (taking into account size, plant and animal pests, stock damage, other damaging effects)?	Good quality examples would receive highs or mediums for Criterion 9 in Table 1. Assessment must be justified by a well qualified and experienced ecologist.	List no. of responses to question 9 in Table 1: H _____ M _____ L _____ Y / N / NS

A. RPS Criteria (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
4, 5, or 6	14. Is it a relatively large example of indigenous vegetation or habitat for indigenous species that is under-represented nationally, or nationally uncommon (including wetlands), but which is degraded in quality (taking into account presence of plant and animal pests, stock damage, other damaging effects)?	Assessment must be justified by a well qualified and experienced ecologist. Use the results from Criterion 9 in Table 1 to determine the relative quality of the site.	Y / N / NS
4	15. Is it the Region's only remaining representative example (irrespective of its size) of a particular indigenous vegetation type or indigenous species habitat that is degraded in quality?	Representative areas are the best examples of indigenous vegetation and habitats that comprise a network covering the full range of landforms, soil sequences, vegetation and fauna communities within an ecological district (c.f. Shaw 1994). The reality for many landscapes, particularly throughout much of the Waikato, is that a 'representative example' is probably the largest and most diverse remaining examples of indigenous vegetation and habitats. Degraded sites would receive mostly Low scores for the factors listed in Criterion 9.	List no. of responses to question 9 in Table 1: H _____ M _____ L _____ Y / N / NS
9 or 8 & 9 or 10 & 9	16. Is it one of the best representative examples in the Waikato Region of indigenous vegetation or habitat for indigenous fauna or an ecological sequence?	Assessment must be justified by a well qualified and experienced ecologist.	Y / N / NS
7 & 9	17. Is it a good quality example of indigenous vegetation or habitat for indigenous species representative of the ecological character typical of the Waikato Region?	This may include examples of indigenous vegetation that are large or moderately large relative to other similar habitats in the Region or within the relevant ecological district. They should be relatively intact and retain the main elements of their original composition structure. Examples would include relatively large tracts of indigenous forest and habitats on the Hakarimata Range and Kaimai Range.	Y / N / NS
11	18. Is it a buffer (or a key part of a buffer) to a site that is of international or national significance?	The site buffered must have first been shown to be of national or international significance using relevant sections above in Table 2.	Y / N / NS

A. RPS Criteria (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
All	**LOCALLY SIGNIFICANT** 19. The site is **at least** of Local Significance if you answered "Yes" to at least one criterion in Table 1 but did not answer "Yes" to any of the questions above in Table 2.	**Locally significant** natural areas are healthy examples of relatively common vegetation and habitat types. They are often small areas, but large enough to enable key ecological processes to occur, such as regeneration of seedlings or reproduction of indigenous fauna. These sites may not be particularly significant in their own right, but nevertheless play an important part in a network of natural areas. For example, a locally significant site might be important as a seasonal feeding or breeding area. It might also act as a stepping stone between other natural areas, allowing indigenous fauna to move in search of food or mates. Such sites are likely to provide representative examples of common or typical vegetation types or habitat for common indigenous species. They will not be among the best examples in the Region but will meet Criterion 9 as healthy, functioning, and ecologically viable sites.	Y / N
HOW SIGNIFICANT IS THE SITE?		Circle the highest level for which you allocated at least one "Yes" response in Table 2. This indicates the relative importance of the site.	International, National, Regional, Local

THREAT CLASSIFICATION SYSTEM
(from Townsend *et al.* 2008) followed in de Lange *et al.* (2013).

NATIONALLY CRITICAL

A. Very small population (natural or unnatural)

A taxon is 'Nationally Critical', regardless of population trend and regardless of whether the population size is natural or unnatural, when evidence[1] indicates that:

1. There are fewer than 250 mature individuals; or
2. There are ≤2 sub-populations and ≤200 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤1 ha (0.01 km^2).

B. Small population (natural or unnatural) with a high ongoing or predicted decline

A taxon is 'Nationally Critical' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status
1. The population comprises 250-1,000 mature individuals; or
2. There are ≤5 sub-populations and ≤300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤10 ha (0.1 km^2).

Trend
There is an ongoing or predicted decline of 50-70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

C. Population (irrespective of size or number of sub-populations) with a very high ongoing or predicted decline (>70%)

A taxon is 'Nationally Critical' when the population has an ongoing trend or predicted decline of >70% in the total population due to existing threats taken over the next 10 years or three generations, whichever is longer.

[1] Evidence in this context is defined as quantitative data and supporting information about the status of a candidate taxon.

NATIONALLY ENDANGERED

A. Small population (natural or unnatural) that has a low to high ongoing or predicted decline

A taxon is 'Nationally Endangered' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 250-1000 mature individuals; or
2. There are ≤5 sub-populations and ≤300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤10 ha (0.1 km^2).

Trend

There is an ongoing or predicted decline of 10-50% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

B. Small stable population (unnatural)

To trigger this pathway to 'Nationally Endangered', taxa must have current population sizes that result from unnatural causes. Such taxa are defined as 'Nationally Endangered' when evidence indicates that they fit at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 250-1,000 mature individuals; or
2. There are ≤5 sub-populations and ≤300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤10 ha (0.1 km^2).

Trend

The population is stable (±10%) and is predicted to remain stable over the next 10 years or three generations, whichever is longer.

C. Moderate population and high ongoing or predicted decline

A taxon is 'Nationally Endangered' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 1,000-5,000 mature individuals; or
2. There are ≤15 sub-populations and ≤500 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤100 ha (1 km^2).

Trend
There is an ongoing or predicted decline of 50-70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

NATIONALLY VULNERABLE

A. Small, increasing population (unnatural)

To trigger 'Nationally Vulnerable', taxa must have current population sizes that result from unnatural causes. Such taxa are defined as 'Nationally Vulnerable' when evidence indicates that they fit at least one Status criterion and the Trend criterion as follows:

Status
1. The total population size is 250-1,000 mature individuals; or
2. There are ≤5 sub-populations and ≤300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤10 ha (0.1 km^2).

Trend
The population is increasing (>10%) and is predicted to continue to increase over the next 10 years or three generations, whichever is longer.

B. Moderate, stable population (unnatural)

To trigger 'Nationally Vulnerable', taxa must have current population sizes that result from unnatural causes. Such taxa are defined as 'Nationally Vulnerable' when evidence indicates that they fit at least one Status criterion and the Trend criterion as follows:

Status
1. The total population size is 1,000-5,000 mature individuals; or
2. There are ≤15 sub-populations and ≤500 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 100 ha (1 km^2).

Trend
The population is stable (±10%) and is predicted to remain stable over the next 10 years or three generations, whichever is longer.

C. Moderate population, with population trend that is declining

A taxon is 'Nationally Vulnerable' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 1,000-5,000 mature individuals; or
2. There are ≤15 sub-populations and ≤500 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤100 ha (1 km^2).

Trend

There is an ongoing or predicted decline of 10-50% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

D. Moderate to large population and moderate to high ongoing or predicted decline

A taxon is 'Nationally Vulnerable' when evidence indicates that it fits at least one Status criterion and the Trend criteria as follows:

Status

1. The total population size is 5,000-20,000 mature individuals; or
2. There are ≤15 sub-populations and ≤1,000 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤1,000 ha (10 km^2).

Trend

There is an ongoing or predicted decline of 30-70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

E. Large population and high ongoing or predicted decline

A taxon is 'Nationally Vulnerable' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 20,000-100,000 mature individuals; or
2. The total area of occupancy is ≤10,000 ha (100 km^2).

Trend

There is an ongoing or predicted decline of 50-70% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

CRITERIA FOR 'AT RISK' TAXA

Taxa that qualify as 'At Risk' do not meet the criteria for any of the 'Threatened' categories. However, they are declining (though buffered by a large total population size and/or a slow decline rate), biologically scarce, recovering from a previously threatened status, or survive only in relictual populations.

Four 'At Risk' categories exist: 'Declining', 'Recovering', 'Relict' and 'Naturally Uncommon'. Definitions for each are provided below.

Declining

'Declining' taxa do not qualify as 'Threatened' because they are buffered by a large total population size and/or a slower decline rate. However, if the declining trends continue, these taxa may be listed as 'Threatened' in the future.

A. Moderate to large population and low ongoing or predicted decline

A taxon is 'Declining' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status
1. The total population size is 5,000-20,000 mature individuals; or
2. The total area of occupancy is ≤1000 ha (10 km^2).

Trend
There is an ongoing or predicted decline of 10-30% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

B. Large population and low to moderate ongoing or predicted decline

A taxon is 'Declining' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status
1. The total population size is 20,000-100,000 mature individuals; or
2. The total area of occupancy is ≤10,000 ha (100 km^2).

Trend
There is an ongoing or predicted decline of 10-50% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

C. Very large population and low to high ongoing or predicted decline

A taxon is 'Declining' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status
1. The total population size is >100,000 mature individuals; or
2. The total area of occupancy is >10,000 ha (100 km^2).

Trend
There is an ongoing or predicted decline of 10-70% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

Recovering

Taxa that have undergone a documented decline within the last 1,000 years and now have an ongoing or predicted increase of >10% in the total population or area of occupancy, taken over the next 10 years or three generations, whichever is longer. Note that such taxa that are increasing but have a population size of <1,000 mature individuals (or total area of occupancy of <10 ha) are listed in one of the 'Threatened' categories, depending on their population size.

A. Moderate population

A taxon is eligible for listing as 'Recovering (A)'[1] if its total population size is between 1000 and 5000 mature individuals or its area of occupancy is ≤ 100 ha (1 km^2).

B. Moderate to large population

A taxon is eligible for listing as 'Recovering (B)'[1] if its total population size is between 5,000 and 20,000 mature individuals or its area of occupancy is ≤1,000 ha (10 km^2).

Relict

Taxa that have undergone a documented decline within the last 1,000 years, and now occupy less than 10% of their former range and meet one of the following criteria:

A. Have 5,000-20,000 mature individuals and are stable (±10%)
B. Have more than 20,000 mature individuals and are stable or increasing at >10%

The range of a relictual taxon takes into account the area currently occupied as a ratio of its former extent. 'Relict' can also include taxa that exist as reintroduced and self- sustaining populations within or outside their former known range.

Naturally Uncommon

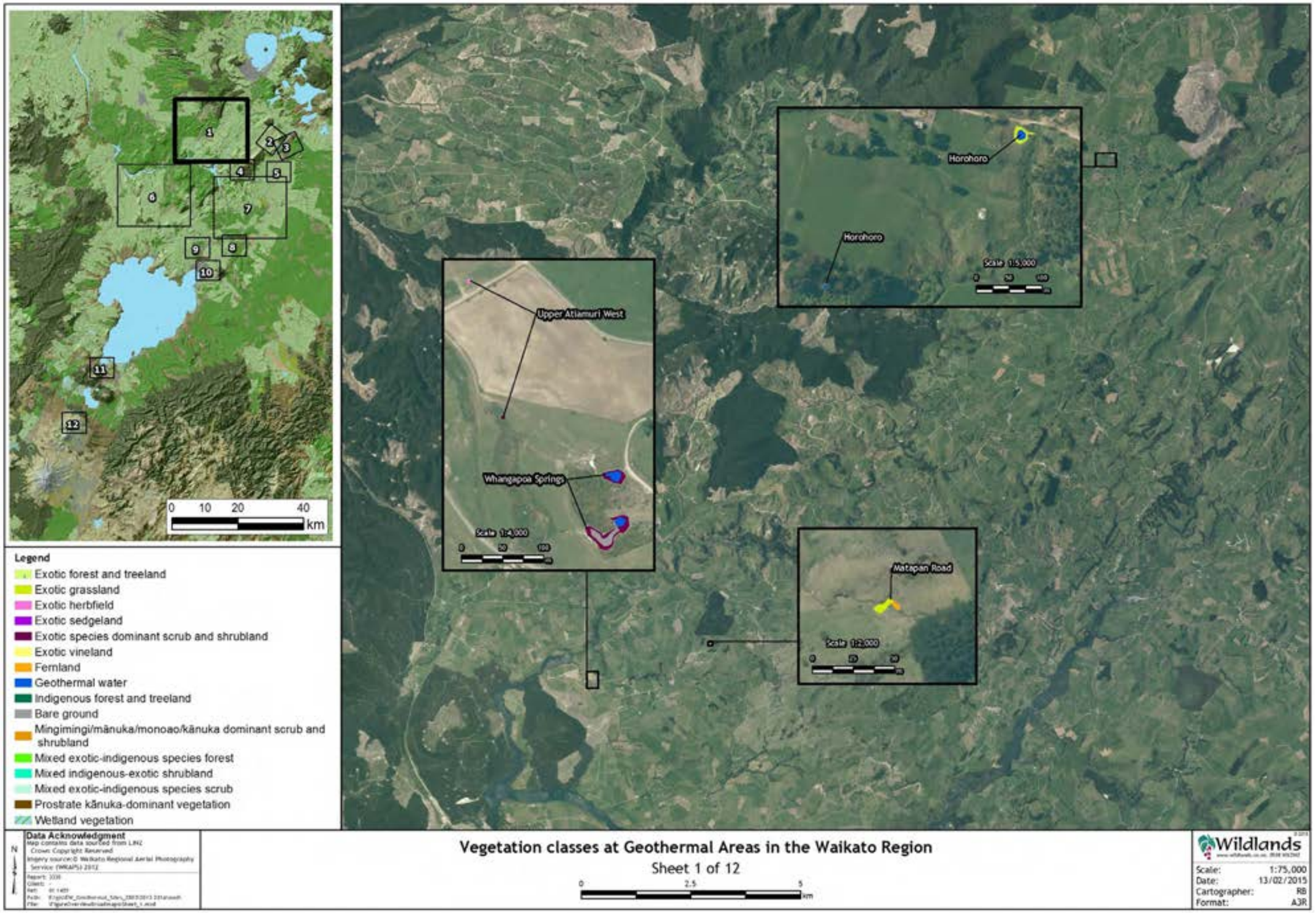
Taxa whose distribution is naturally confined to specific substrates (e.g. ultramafic rock), habitats (e.g. high alpine fellfield, hydrothermal vents), or geographic areas (e.g. subantarctic islands, sea-mounts), or taxa that occur within naturally small and widely scattered populations. This distribution is not the result of past or recent human disturbance. Populations may be stable or increasing. Note that a naturally uncommon taxon that has fewer than 250 mature individuals qualifies for 'Nationally Critical'. Taxa that have more than 20,000 mature individuals are not considered 'Naturally Uncommon', unless they occupy an area of less than 100,000 ha (1,000 km^2).

[1] Recovering (A) and Recovering (B) are two different categories, rather than two pathways to the same category, and hence it is necessary to add '(A)' or '(B)' when classifying taxa, unlike for other categories.

DEFINITION FOR EACH DATA FIELD IN THE GIS SHAPEFILE

Data Field	Definition
Site Name	Site name
Site Number	Site number. Also identifies the geothermal field.
NZTM Easting and Northing	New Zealand Transverse Mercator (NZTM) coordinates. Easting represents the eastward distance or location on a map, and Northing represents the northward distance or location on a map.
Geothermal Field	The geothermal field within which a site is located.
Ecological District	Ecological District.
Territorial Local Authority	Local authority (Rotorua District or Taupō District).
Site Area	Area (ha) of site.
Ecological Significance Ranking 2003	2003 Significance ranking of a site based on the Waikato Region Policy Statement Criteria (Local, Regional, National, or International).
Ecological Significance Ranking 2014	2014 Significance ranking of a site based on the Waikato Region Policy Statement Criteria (Local, Regional, National, or International).
Hydroclass	The hydrological classification of a particular site e.g. Terrestrial, palustrine, riverine, lacustrine.
Structural Class Code	A numerical code (two characters) based on the vegetation structural class (growth form) of the canopy species (e.g. forest) (e.g. 01).
Vegetation Class Code	A numerical code (four characters) which incorporates the structural class and the dominant species) (e.g. 01.02).
Vegetation Code	A numerical code (six characters) based on structural class, vegetation class (e.g. 01.02.03), and vegetation type/ habitat (see below).
Vegetation Class	Vegetation types and habitats were grouped into vegetation classes according to the most dominant species and the structural class.
Vegetation Type/Habitat	A vegetation/habitat type including the dominant species following the Atkinson (1985) method for vegetation classification (see Appendix 7).
Botanical Rank 1996	A four category ranking system (A-D) based on flora values of a site as reported in Given 1995 and Given 1996 and the criteria outlined in Whaley *et al.* 1995 and (Meurk *et al.* 1993). 'A' is the highest rank and 'D' is the lowest.

VEGETATION CLASS MAPS OF GEOTHERMAL AREAS IN THE WAIKATO REGION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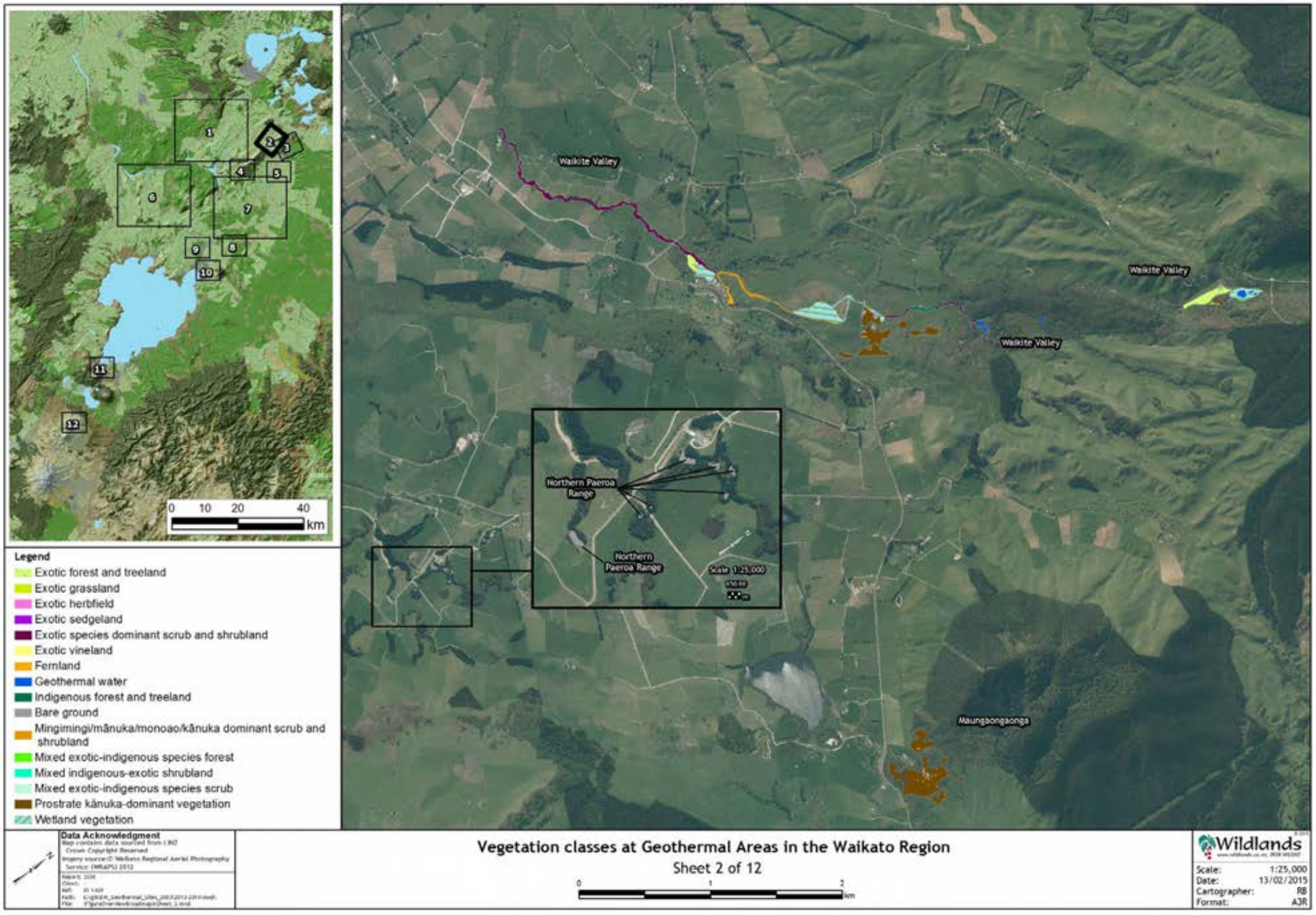
Matapan Road
Scale 1:2,000
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 1 of 12
0 2.5 5
km
Wildlands
Scale: 1:75,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


1
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12
0 10 20 40
km
Waikite Valley
Waikite Valley
Waikite Valley
Northern Paeroa Range
Northern Paeroa Range
Scale 1:25,000
Maungaongaonga
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 2 of 12
0 1 2
km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
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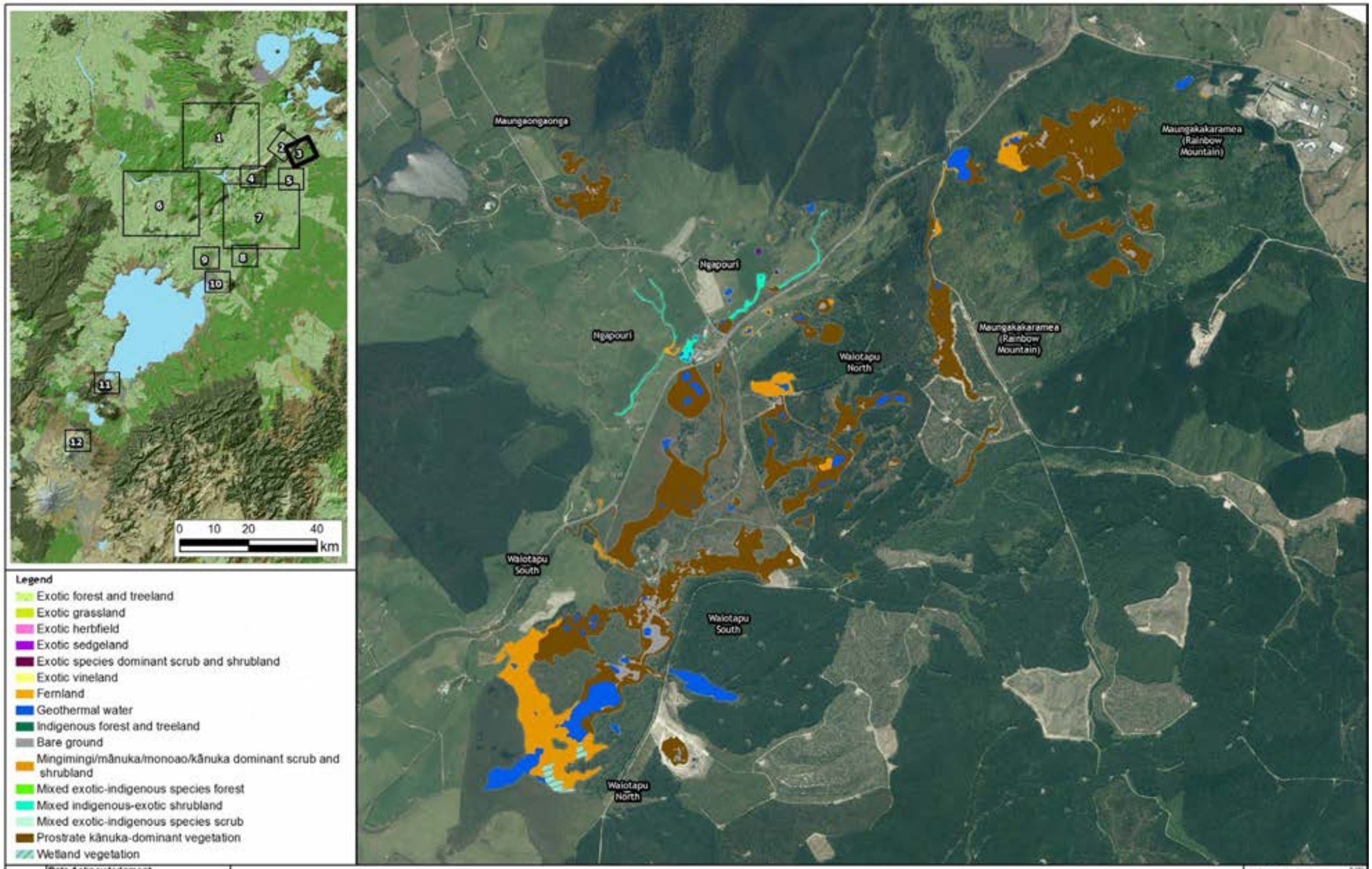
Maungaongaonga
Ngapouri
Ngapouri
Waiotapu North
Maungakakaramea (Rainbow Mountain)
Maungakakaramea (Rainbow Mountain)
Waiotapu South
Waiotapu South
Waiotapu North
1
2
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12
0 10 20 40
km
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
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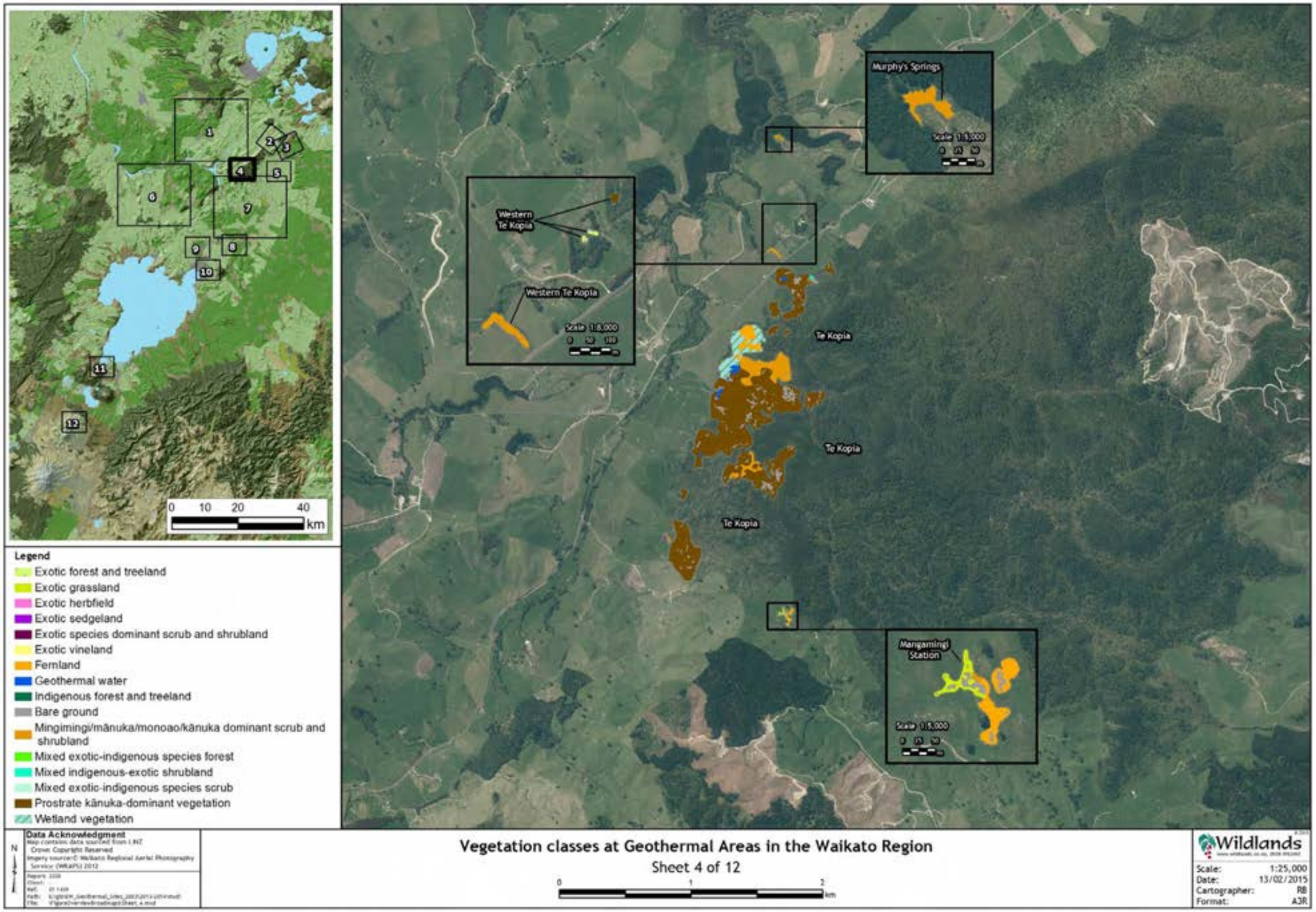
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 3 of 12
0 1 2
km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


1
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11
12
0 10 20 40
km
Murphy's Springs
Scale 1:8,000
Western Te Kopia
Western Te Kopia
Scale 1:8,000
Te Kopia
Te Kopia
Te Kopia
Mangamingi Station
Scale 1:8,000
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
N
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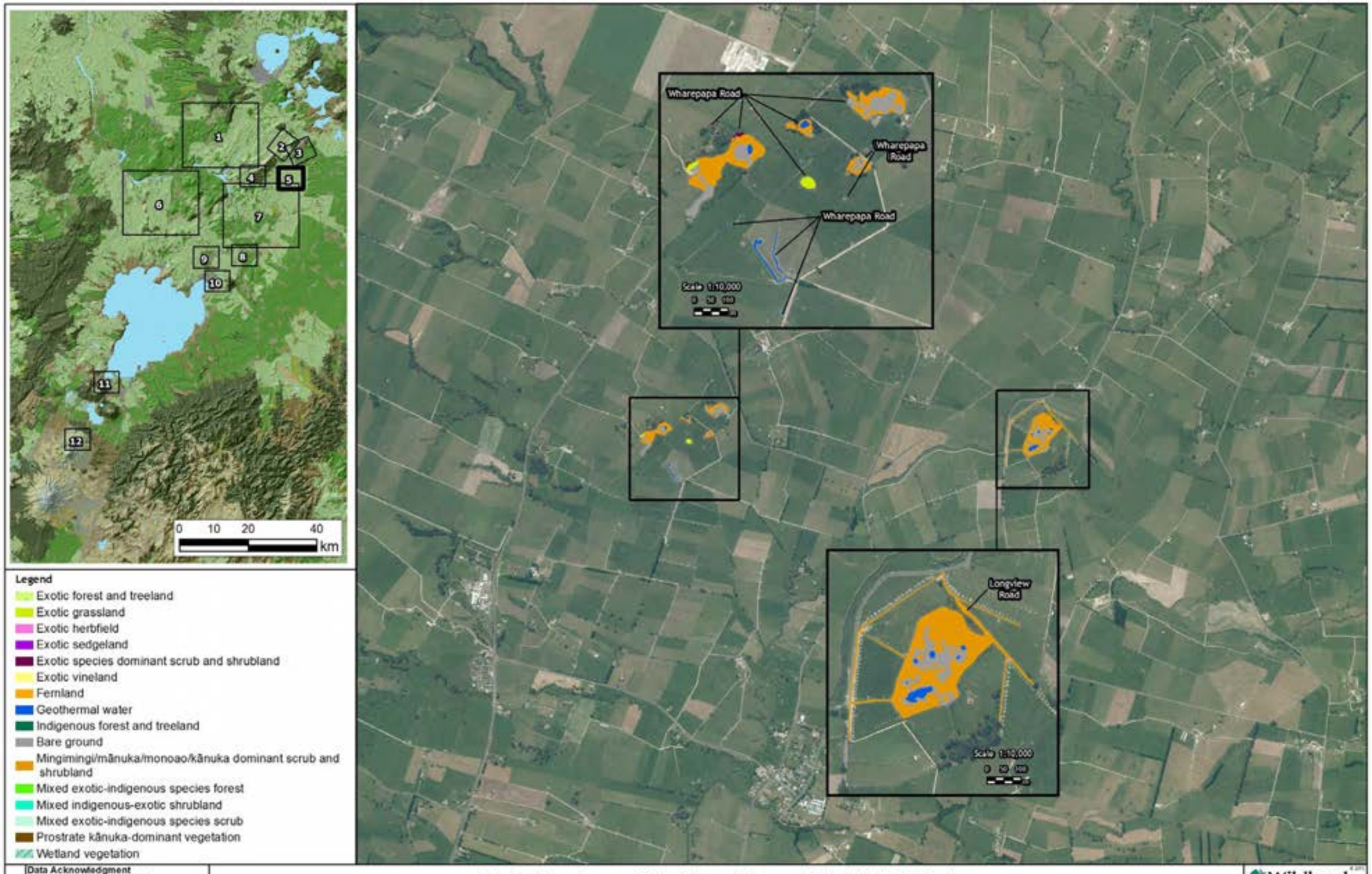
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 4 of 12
0 1 2
km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


1
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8
9
10
11
12
0 10 20 40
km
Wharepapa Road
Wharepapa Road
Wharepapa Road
Scale 1:10,000
Longview Road
Scale 1:10,000
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
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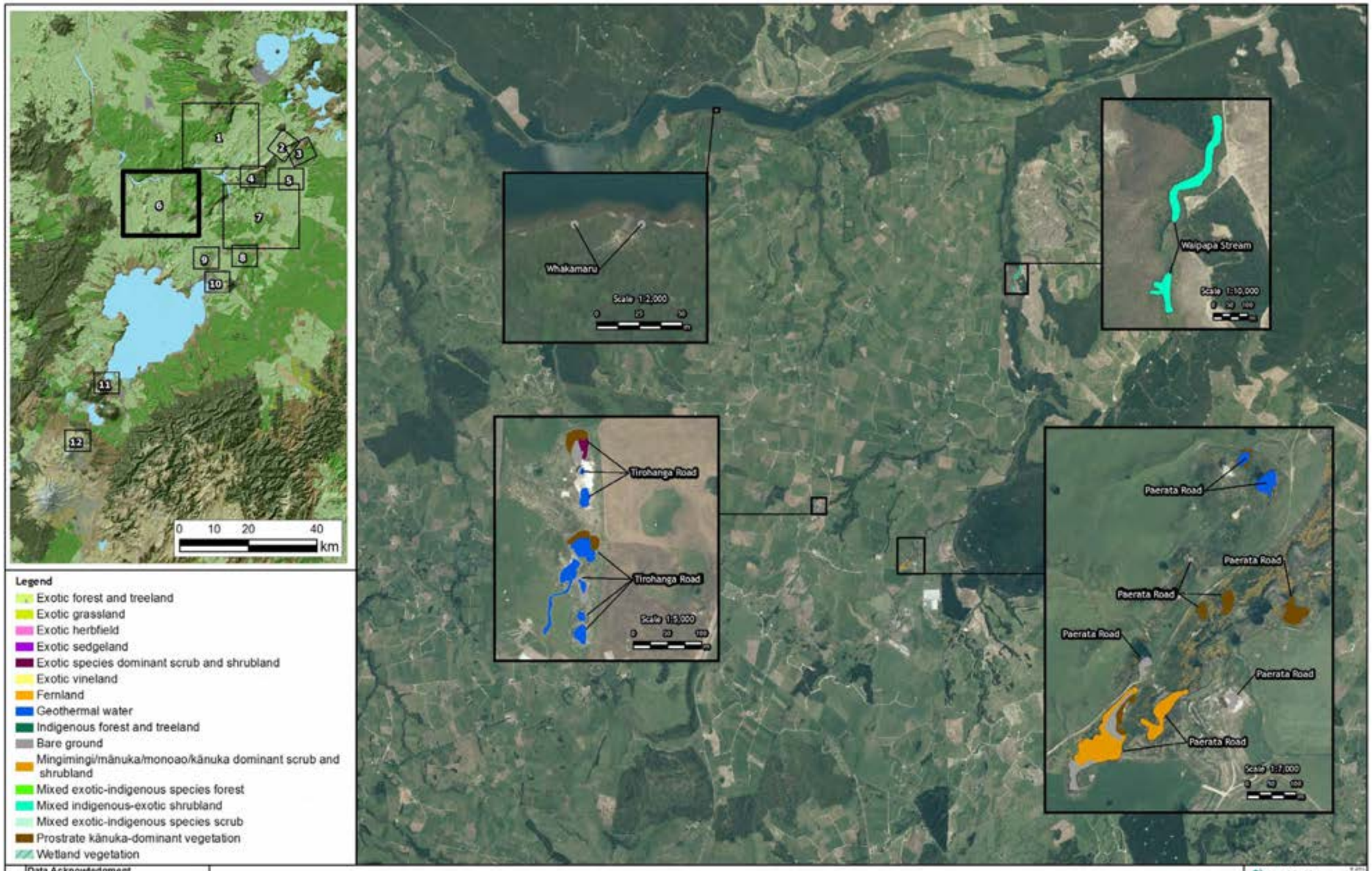
N
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 5 of 12
0 1 2
km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


1
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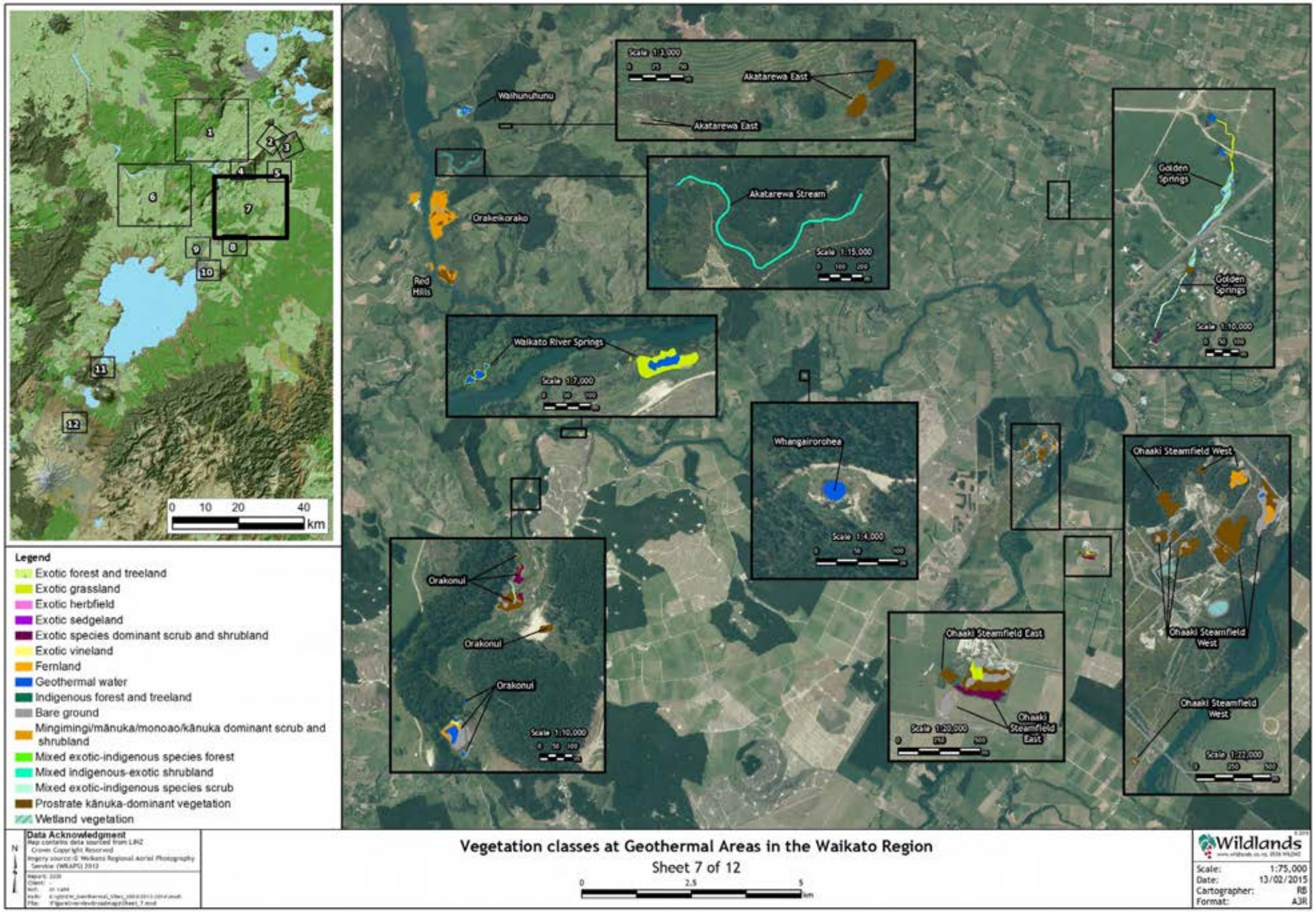
11
12
0 10 20 40
km
Whakamaru
Scale 1:2,000
Waipapa Stream
Scale 1:10,000
Tirohanga Road
Tirohanga Road
Scale 1:3,000
Paerata Road
Paerata Road
Paerata Road
Paerata Road
Paerata Road
Paerata Road
Scale 1:7,000
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
N
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 6 of 12
0 2.5 5
km
Wildlands
Scale: 1:75,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


Waihunuhunu
Akatarewa East
Akatarewa East
Scale 1:3,000
Orakeikorako
Akatarewa Stream
Scale 1:15,000
Red Hills
Golden Springs
Golden Springs
Scale 1:10,000
Waikato River Springs
Scale 1:7,000
Whangairorohea
Scale 1:4,000
Orakonui
Orakonui
Orakonui
Scale 1:10,000
Ohaaki Steamfield East
Scale 1:20,000
Ohaaki Steamfield East
Ohaaki Steamfield West
Ohaaki Steamfield West
Ohaaki Steamfield West
Scale 1:22,000
1
2
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4
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6
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8
9
10
11
12
0 10 20 40
km
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
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Vegetation classes at Geothermal Areas in the Waikato Region
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0 2.5 5
km
Wildlands
Scale: 1:75,000
Date: 13/02/2015
Cartographer: RB
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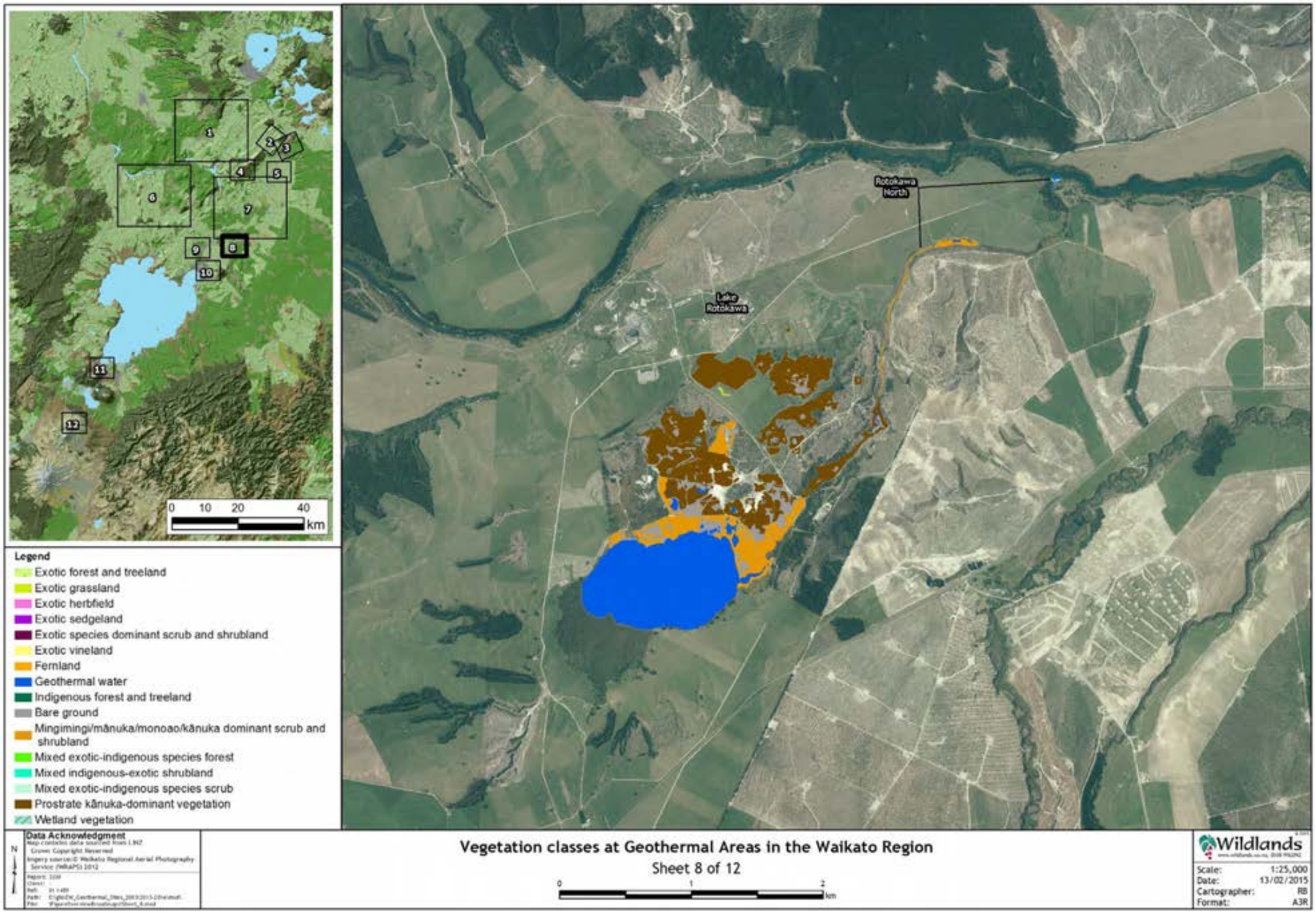
1
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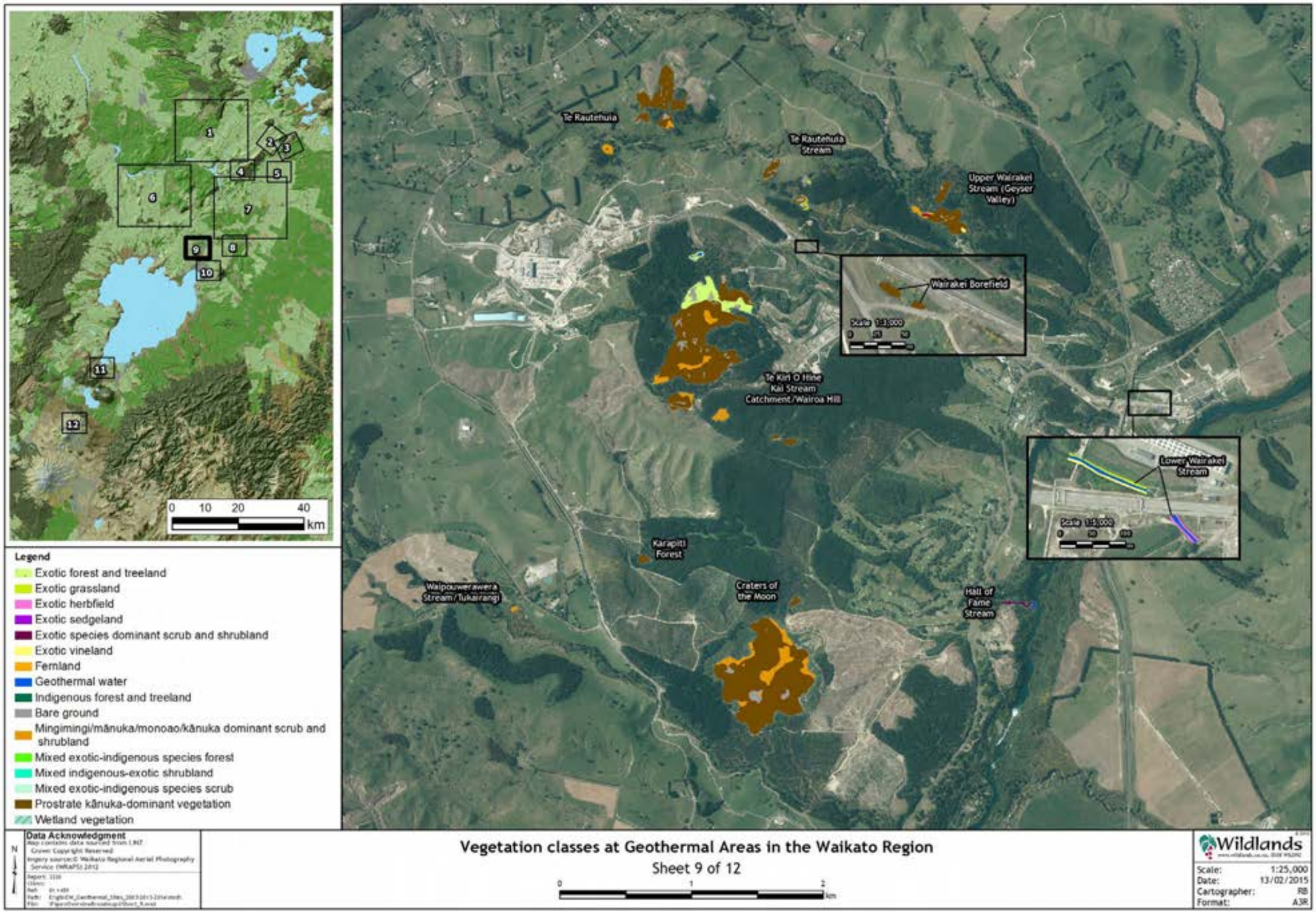
11
12
0 10 20 40
km
Rotokawa North
Lake Rotokawa
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
N
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 8 of 12
0 1 2
km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


Te Rautehuia
Te Rautehuia Stream
Upper Wairakei Stream (Geyser Valley)
Wairakei Borefield
Scale 1:3,000
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
Lower Wairakei Stream
Scale 1:5,000
Karapiti Forest
Craters of the Moon
Waipouwerawera Stream/Tukairangi
Hall of Fame Stream
0 10 20 40 km
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
Vegetation classes at Geothermal Areas in the Waikato Region
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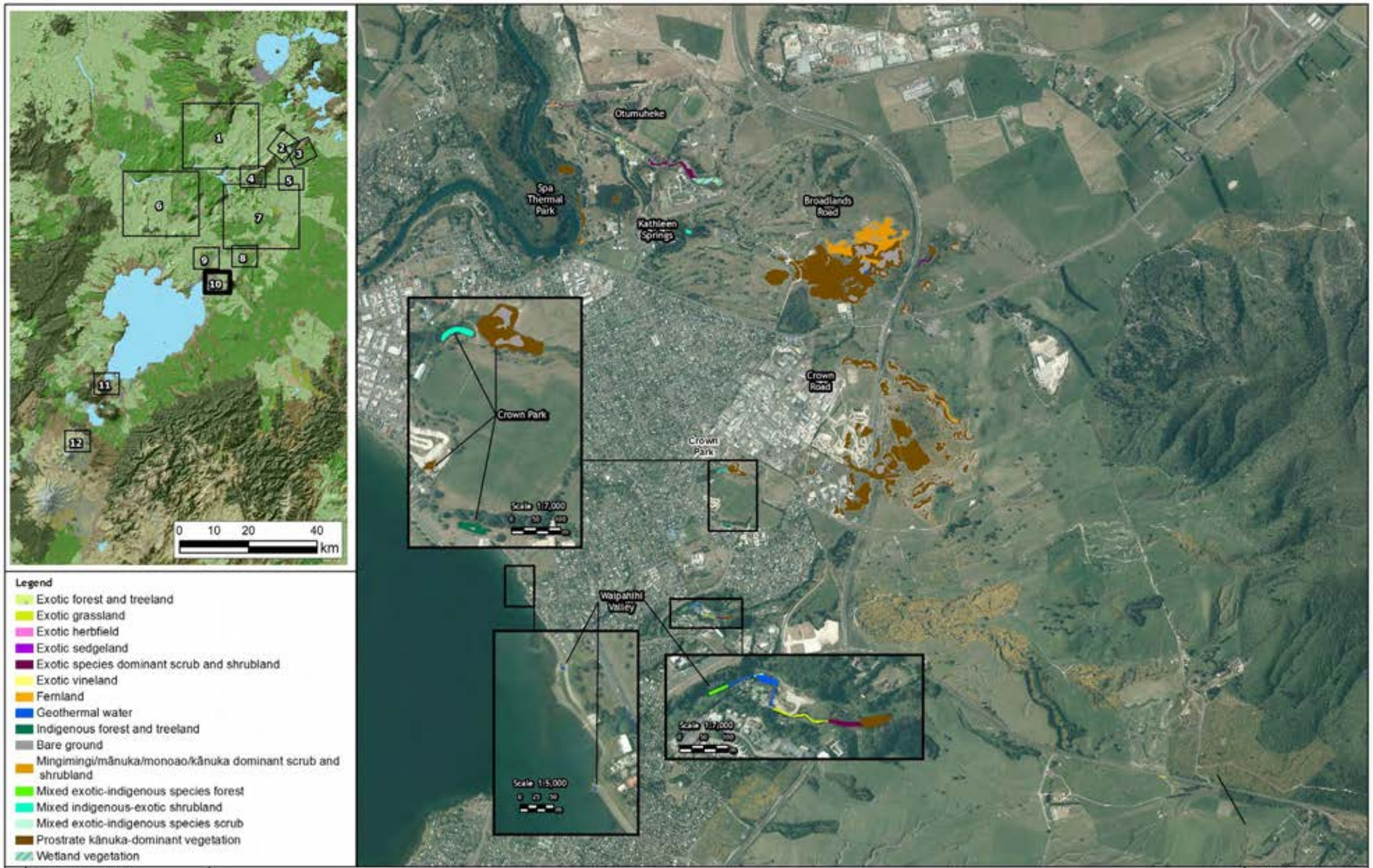
0 1 2 km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


Otumuheke
Spa Thermal Park
Kathleen Springs
Broadlands Road
Crown Road
Crown Park
Crown Park
Waipahihi Valley
Scale 1:2,000
Scale 1:2,000
Scale 1:5,000
0 10 20 40 km
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 10 of 12
0 1 2 km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
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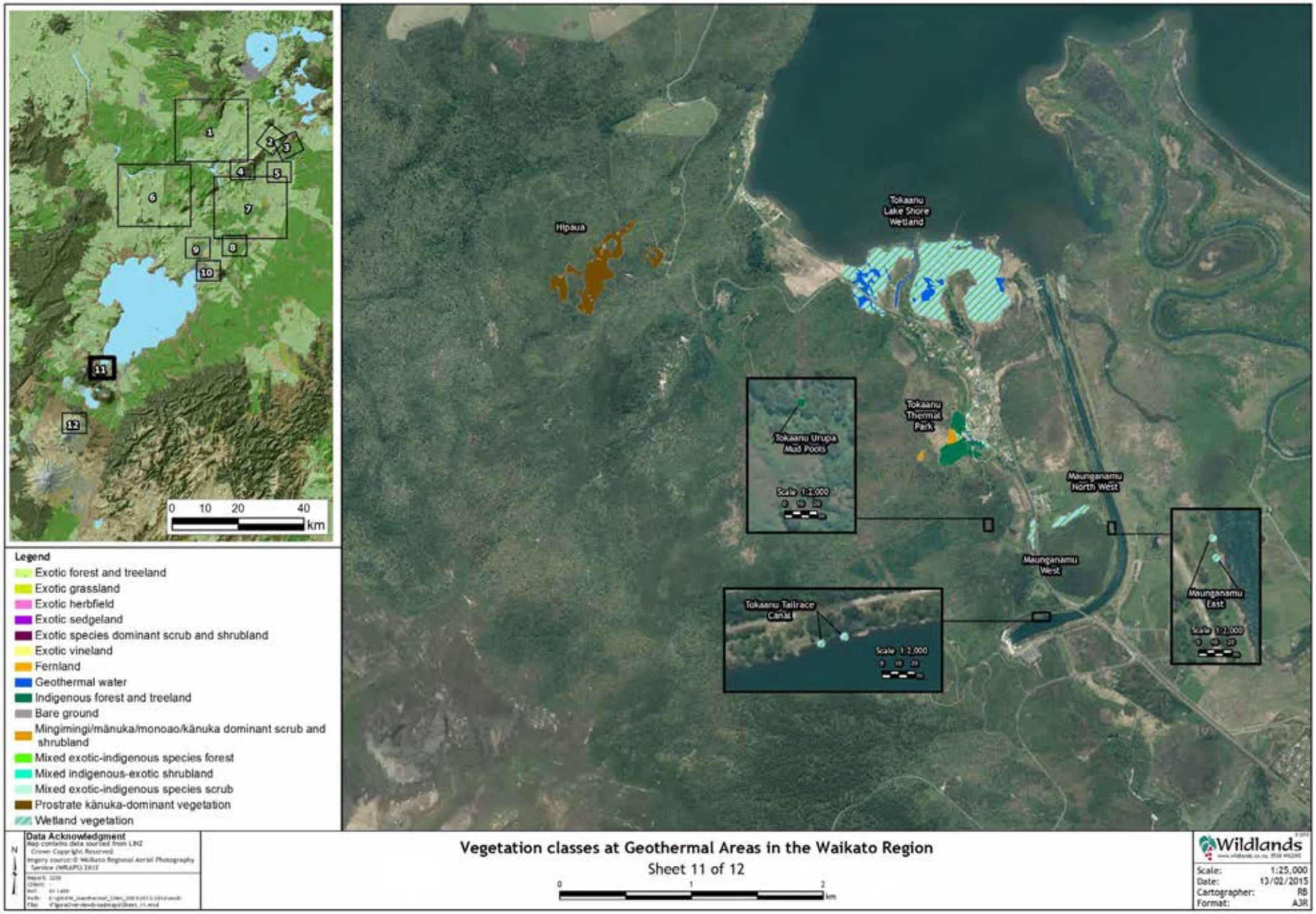
1
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10
11
12
0 10 20 40
km
Hipaua
Tokaanu Lake Shore Wetland
Tokaanu Thermal Park
Tokaanu Urupa Mud Pools
Scale 1:2,000
Maunganamu North West
Maunganamu West
Maunganamu East
Tokaanu Tailrace Canal
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
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Vegetation classes at Geothermal Areas in the Waikato Region
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0 1 2
km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
Format: A3R


1
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10
11
12
0 10 20 40
km
Ketetahi
Te Maari Craters
Red Crater
Emerald Lakes
Legend
Exotic forest and treeland
Exotic grassland
Exotic herbfield
Exotic sedgeland
Exotic species dominant scrub and shrubland
Exotic vineland
Fernland
Geothermal water
Indigenous forest and treeland
Bare ground
Mingimingi/mānuka/monoao/kānuka dominant scrub and shrubland
Mixed exotic-indigenous species forest
Mixed indigenous-exotic shrubland
Mixed exotic-indigenous species scrub
Prostrate kānuka-dominant vegetation
Wetland vegetation
Data Acknowledgment
N
Vegetation classes at Geothermal Areas in the Waikato Region
Sheet 12 of 12
0 1 2
km
Wildlands
Scale: 1:25,000
Date: 13/02/2015
Cartographer: RB
Format: A3R

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Waikato River Springs	7	195
Waikite Valley	2	73
Waiotapu North	3	98
Waiotapu South	3	109
Waipahihi Valley	10	268
Waipapa Stream	6	121
Waipouwerawera Stream/Tukairangi	9	309
Wairakei Borefield	9	288
Western Te Kopia	4	157
Whakamaru	6	117
Whangairorohea	7	207
Whangapoa Springs	1	139
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