Waikato Regional Council Technical Report 2011/29

Geothermal Vegetation of the Waikato Region - An Update Based on 2007 Aerial Photographs

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera à Rohe o Waikato

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July 2011

Document #: 2063137

Approved for release by:
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GEOTHERMAL VEGETATION OF THE WAIKATO REGION - AN UPDATE BASED ON 2007 AERIAL PHOTOGRAPHS

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Geothermal Vegetation of the Waikato Region - An Update Based on 2007 Aerial Photographs

Contract Report No. 2348

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SUMMARY

This study was undertaken for Waikato Regional Council and provides an updated inventory of the current distribution and extent of geothermal vegetation, and assessment of the relative significance of each site based on 2007 aerial photographs and field survey of selected sites during 2010 and 2011. Approximately 70% of the extent of New Zealand's geothermal vegetation occurs within the Waikato Region. Associated with geothermal sites are characteristic plant species and vegetation types. These include plants capable of surviving high soil temperatures, disjunct populations found a considerable distance from other plants 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. Many geothermal sites are dynamic and unstable and changes in surface geothermal activity are reflected in changes in the extent and composition of geothermal vegetation. The geothermal vegetation of the Waikato Region includes populations of several plant species which in New Zealand have a national threat ranking.

For this survey, *c.*734 ha of geothermal vegetation (including nonvegetated raw-soilfield) over 64 sites in fifteen geothermal fields was described, mapped, and ranked from field surveys and existing information. An additional *c.*106 ha was mapped as geothermal water where it was an integral part of a geothermal site. The grouping of individual areas of geothermal habitats as sites can be somewhat arbitrary, however groupings are generally based on areas of geothermal surface manifestations that are located nearby each other, and are easy to discuss together as a single unit. There are likely to be some small areas of unmapped geothermal vegetation on hill slopes above Tokaanu that have not been mapped in this report. Geothermal vegetation and habitats were mapped into three broad categories, nonvegetated raw-soilfield (*c.*92 ha in the Waikato Region), emergent wetland (*c.*81 ha in the Waikato Region) and terrestrial vegetation (*c.*561 ha in the Waikato Region). Terrestrial vegetation is all vegetation that was not mapped as geothermal wetland, and nonvegetated raw-soilfield and includes (but is not limited to) forest, scrub, shrubland, fernland and mossfield. For 19 sites, a geophysical assessment was carried out.

The vegetation of each site has been described and classified using predefined vegetation structural classes 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 outlined. Each site was assessed for significance and then assigned a relative significance level of International, National, Regional, or Local. Significance and relative significance were assessed using the criteria in the Waikato Regional Policy Statement (applying the guidelines delineated in 2002 updated in accordance with the revised threat classification lists). Vegetation type boundaries have been digitised and the extent calculated of each geothermal vegetation type. Topographical location maps of each site are provided and vegetation maps of each site are presented in this report.

Each of the 64 sites meets one or more of the criteria for ecological significance in the Waikato Regional Policy Statement and each site was ranked as being of International, National, Regional oror Local Significance. Four sites were ranked as being of International Significance and part of one of other site (with other parts of this site being ranked as Regional and Local Significance), encompassing *c.*205 ha or 24% percent of the geothermal vegetation in the Waikato Region. Eight sites were of National Significance, with two sites

being partly of National Significance and partly of Local Significance encompassing *c.*382 ha or 46% of geothermal habitat in the Waikato Region. Twenty-three sites were identified as being of Regional significance, with an additional two sites being partly of Regional and Local significance. In total, *c.*242 ha or 29% of geothermal habitat in the Waikato Region was identified as being Regionally Significant. The remainder of sites (25) were identified as being of Local Significance (*c.*11 ha or *c.*1% of geothermal habitat).

Wildland Consultants (2004) used Ecological Districts as the framework of the study. While ecological districts are used to show the distribution of geothermal sites in the landscape, greater emphasis is placed on recognised Geothermal Fields in this report. Geothermal Fields are 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 in geothermal surface manifestations. The character of 17 Geothermal Fields are described in this report, with geothermal vegetation mapped and described for sites. The following areas of geothermal vegetation were mapped in each geothermal field by size: Waiotapu (*c.*221 ha), Wairakei-Tauhara (*c.*151 ha), Rotokawa (*c.*104 ha), Tokaanu-Waihi-Hipaua (*c.*60 ha), Te Kopia (*c.*60 ha), Orakeikorako (*c.*58 ha), Tongariro (*c.*25 ha), Waikite (*c.*25 ha), Ohaaki (*c.*19 ha), Reporoa (*c.*7 ha), Mokai (*c.*3 ha), Ngatamariki (*c.*2 ha), Atiamuri (*c.*0.1 ha); two fields have less than 0.1 ha of geothermal vegetation (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.*86%), while Taupo and Tongariro Ecological Districts contain *c.*9% and *c.*5% of the vegetation of the region respectively. Geothermal vegetation in the Waikato Region is distributed relatively evenly between two local authorities; Rotorua District (51%) and Taupo District (*c.*49%).

Historical site changes were assessed using a combination of historical photos and existing literature. The extent of geothermal vegetation was found to have decreased in 23 sites between the 1940s or 1960s and the present day. In six sites, the extent of geothermal vegetation has increased compared to what was historically present. There has been no discernible change to the extent in vegetation cover at eight sites. No information was able to be found for the remainder of the sites.

In the Atiamuri Ecological District there has been a significant decline, estimated to be approximately 30%, in the extent of geothermal vegetation since European settlement. However there has been an estimated gain of approximately 4% in the Taupo 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, 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, especially 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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This report should be cited as:

Wildland Consultants 2011: Geothermal vegetation of the Waikato Region - An update based on 2007 aerial photographs. *Wildland Consultants Ltd Contract Report No. 2348.* Prepared for Waikato Regional Council. 515 pp.

1. INTRODUCTION

This study was undertaken for Waikato Regional Council and provides an inventory of the current distribution and extent of geothermal vegetation in the Region, and assessment of the relative significance of each site. 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 2004 and 2007, as well as updated information based on site inspections of selected sites, improved knowledge about sites from other studies, and inspection of better quality aerial photographs (2007 WRAPS[1]) than were present during the 2004 study (which was based on 2002 aerial photographs).

The Waikato Region is located in the upper part of central North Island. It extends from Coromandel-Colville in the north to Mt 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, Taupo Ecological District and Tongariro Ecological District, contain all areas of geothermal vegetation larger than 1 hectare. While small isolated surface geothermal expressions occur elsewhere in the Waikato, in general they are very small (usually small surface springs) and are not known to contain any geothermal vegetation of ecological significance. Many of these have been converted into hot pools, while others are hot springs amongst sand on the ocean edge that do not support any vegetation.

Wildland Consultants (2004) used ecological districts as the framework for the study. While ecological districts are used to show the distribution of geothermal sites in the landscape, greater emphasis is placed on recognised geothermal fields in the updated project. Geothermal fields are 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 in geothermal surface manifestations. Assessments based on ecological districts become an issue where the same geothermal field extends across two ecological districts, as occurs at Tokaanu-Waihi-Hipaua geothermal field (Tongariro and Taupo Ecological Districts) and Wairakei-Tauhara Geothermal Field (Atiamuri and Taupo Ecological Districts).

Almost 80% of New Zealand's geothermal systems occur within the Waikato Region (Environment Waikato 1998). Associated issues and values range from exploitative resource use, such as thermal energy extraction and the utilisation of mineralised fluids, to historical, amenity, cultural, spiritual, conservation and scientific values (Environment Waikato 1998; Merrett & Clarkson 1999) and the environmental management objectives of Waikato Regional Council are derived from these. The objectives are to maintain the variety of characteristics and to achieve protection and efficient take of the regional geothermal resource (Environment Waikato 1998). Pest plants and pest animals are degrading ecological values at many sites and if these are not controlled then the ecological values of these sites are likely to decline. Tourism operations at geothermal sites are also of significant economic importance to the

[1] WRAPS = Waikato Region Aerial Photograph Syndicate.

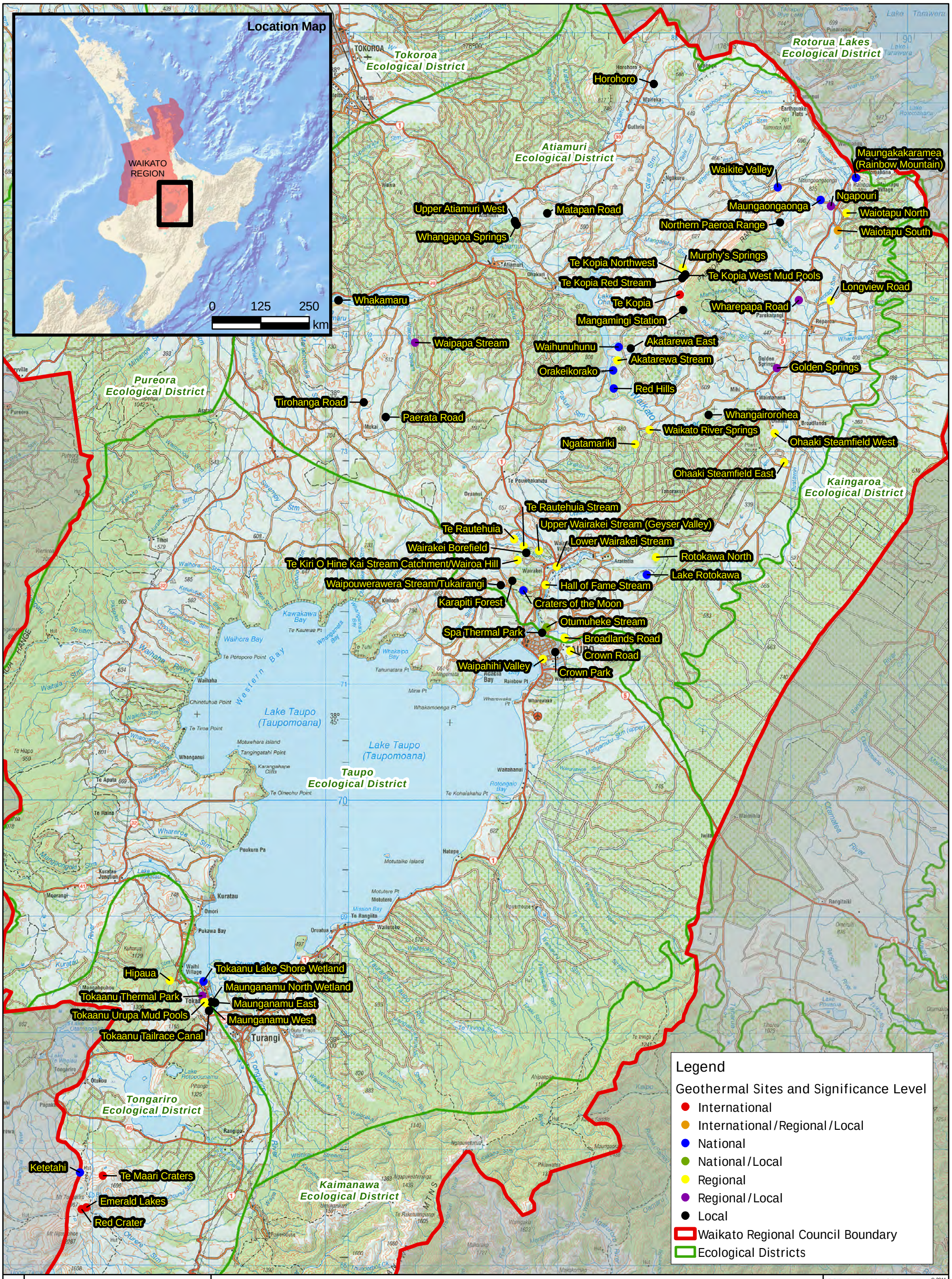
region. Other economic uses, such as power generation, may have negative impacts on ecological and geophysical characteristics of geothermal sites, and aspects of tourism operations at sites also require monitoring to ensure sites are not degraded.

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

This report updates the 2004 report (Wildland Consultants 2004), and incorporates extra information about geothermal sites collected in 2006 and 2007 (Wildland Consultants 2006, 2007a&b). Selected sites were revisited in 2010 and 2011 for this report. Vegetation maps and descriptions have been updated using new vegetation descriptions and codes, including the addition of broad vegetation classes. New codes for sites have been used to replace the codes based on the New Zealand Topographical map series NZMS260, which is no longer in use. New site codes relate to the geothermal field each site in located in. Threatened species rankings have been updated using de Lange *et al.* (2009) for plants and Miskelly *et al.* (2008) for birds. Additional information has been included from the 2004 report, 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 were determined through examination of aerial photographs held by Waikato Regional Council from between 1941-1961 and compared with recent (2007) aerial photographs to determine the extent of change of geothermal sites over this timeframe. A summary of changes that could be clearly identified are presented for each site.

The ecological significance of each site was reassessed as either being of international, national, regional, or local significance as determined by the updated criteria defined in the Waikato Regional Policy Statement (2002). This has been revised to reflect more recent changes to the New Zealand Threat Classification Lists (refer to Appendices 10 and 11). Ecosystem Ranking assessments were completed for all sites with a relative significance of Regional, National, or International Significance (see Wildland Consultants 2011a).

The objectives of this 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 all sites (see Appendix One) between 2003 and 2011. The exceptions are Hipaua and Ketetahi Springs, Maunganamu North, and parts of Tokaanu Lakeshore Wetland for which permission to undertake field survey was withheld. Of the 64 sites reported on in detail in this report, 31 sites were re-surveyed in 2010/2011, including 13 sites which previously had not been surveyed in detail. Each site has been remapped using 2007 aerial photography and all boundaries have been checked at high resolution. Any parts of sites that were unsafe to access due to the geothermal hazards were assessed based on 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.



Data Acknowledgment

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

0 7.5 15 km

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This report includes an index of the geothermal sites, and the appendices include information on sites for which field work was undertaken, unranked sites, vegetation codes, a glossary of technical terms including threatened and uncommon plant categories, and notes on the vascular flora of geothermal areas.

A list of sites of geothermal surface expressions not known to comprise any significant geothermal vegetation, found elsewhere in the Waikato Region are presented in Appendix 3. These sites are all generally small and many have been altered for recreational use, such as swimming, or have been altered for farming or commercial uses. Several are also on the sea margin in sand and contain no vegetation.

Project Assignment

Waikato Regional Council commissioned Wildland Consultants to update the 2004 Wildand Consultants (Report No. 896) on geothermal vegetation of the Waikato Region to the 2007 aerial photographs (WRAPs). This report incorporates information from a series of other reports undertaken for Waikato Regional Council between 2004 and 2007 (Wildland Consultants 2006, 2007a and 2007b). Information collected is compatible with the Waikato Regional Council biodiversity prioritisation project.

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). Rankings of the relative scientific or conservation significance of some sites containing geothermal vegetation and flora have been assigned in Given 1978 & 1980a, Clarkson 1987a, 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. Beadel and Bill (2000) and Wildland Consultants (2004) provide important resources on which future reports have been based.

This report is an updated and expanded report of Wildland Consultants (2004), including additional sites updated and described in Wildland Consultants 2006, 2007a and 2007b. Selected sites have been resurveyed and 13 sites not previously included in this study have been included. Some site names have been changed on occasion to better reflect Waikato Regional Council preferred place names (where a site name has been changed, the site report has been annotated appropriately). Site numbers have also been changed, as outlined above, and are now based on geothermal field. 2004 site numbers are included in footnotes to allow cross referencing. The relative ecological significance of all sites has been re-evaluated.

3. METHODOLOGY

3.1 Existing information

Existing information on the distribution and botany 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 unpublished, Department of Conservation 1997, and personal knowledge. Department of Conservation staff provided some additional information on geothermal sites for this 2011 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 previous botanical rank (from Given 1996), and Wildland Consultants 2004, 2006, and 2007a&b.

3.2 Ecological districts

Three ecological districts in the Waikato Region contain sites with geothermal vegetation. These are Atiamuri Ecological District, Taupo Ecological District (both of which occur within the Central Volcanic Plateau Ecological Region) and Tongariro Ecological District (within the Tongariro Ecological Region).[1] A tiny portion of Maungakakaramea occurs in the Rotorua Lakes Ecological District (<1 ha) and also in the Bay of Plenty Region.

3.3 Field survey

Field survey of 37 sites was carried out between June 2010 and June 2011 using a survey team of two people for safety reasons. Sites were visited where there was the greatest expectation of change (e.g. new road construction in the vicinity of the site), if there were major changes indicated on 2007 aerial photographs, or if the site had not been inspected before. It should be noted that change may have occurred at some sites such as Lake Rotokawa and Rotokawa North, but field survey was beyond the resources allocated to this study. Some sites were not field surveyed as access from landowners could not be arranged, e.g. some Tokaanu field survey sites.

Geothermal vegetation types were described for each site, and the extent of each type was mapped onto colour printouts of digital aerial photographs (2007) (scale *c.*1:5,000). Field assessments addressed the following components: the extent and

[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.

type of vegetation present; indigenous flora (including the presence of any threatened plants); fauna present (which included a literature review for each site); current condition; invasive exotic plants; human impacts; grazing; adjoining land use and management requirements.

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

3.4 Geophysical properties

Geophysical assessments have been undertaken for all or parts of 19 sites (listed in Table 1). Specific methods for these assessments varied slightly between the geophysical consultants, but generally the following methods were used. Locations for each feature were recorded using a GPS. Direct temperature measurements were made with a thermocouple on a 4 4 m long wire, or a 100 100 mm long rigid probe, connected to a Fluke multimeter. If the surface to be measured was not accessible, a Fluke IR thermometer was used, however this is subject to limitations, particularly if steam is present. 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 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: Sites and dates for which geophysical assessments were carried out. The assessments are included in the site reports contained in Appendix 1.

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 (about 1/3 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
TKV04	Te Kopia West Mud Pools	29 June 2010
TKV05	Te Kopia Red Stream	29 June 2010
TKV03	Te Kopia Northwest	29 June 2010
TKV02	Murphy's Springs	29 June 2010
TKV06	Mangamingi Station	28 June 2010
OKV03	Orakeikorako	1 August 2010 (about 1/2 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 (about 1/2 of site)
TOV09	Tokaanu Urupa Mud Pools	7 February 2007

3.5 Vegetation and habitat types

The previous editions of this report (e.g. Wildland Consultants 2004, 2007a&b) based vegetation assessments on Merrett and Clarkson (1999), with some additional types added. This study bases its classification of geothermal vegetation and habitat types on methods used in a similar study undertaken in the Bay of Plenty Region, specifically Wildland Consultants (2005a&b). This was based on methodology outlined in Wildland Consultants (2003) and Atkinson (1985). This report follows broad types outlined in Wildland Consultants 2007b, as well as additional broad types and structural types found during field survey for this report. These are listed below in Table 2, by structural class and broad type.

Table 2: List of geothermal vegetation types and habitats. (Note this table includes vegetation types identified in Wildland Consultants (2004) and a study of geothermal vegetation in the Bay of Plenty Region (Wildland Consultants 2005), not all of which occur in the Waikato Region.

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
01	01	**Pohutukawa-dominant forest** 01 Pohutukawa × northern rata-kamahi forest 02 Pohutukawa × northern rata/mingimingi-prostrate kanuka forest 03 Pohutukawa forest 04 Pohutukawa-kanuka forest 05 Pohutukawa × northern rata/prostrate kanuka-mingimingi forest
01	02	**Wattle forest** 01 Black wattle forest
01	03	**Treefern-dominant forest**
01	04	**Kanuka-dominant forest** 01 Kanuka/mingimingi forest 02 (Eucalyptus)/kanuka-Tasmanian blackwood/mingimingi forest 03 Kanuka forest 04 Kanuka-kohuhu/koromiko-blackberry forest 05 Kanuka-radiata pine/manuka-mingimingi forest 06 (Rewarewa)/kanuka forest. 07 Eucalyptus/kanuka forest 08 Kanuka-pohutukawa forest 09 Kanuka-grey willow-crack willow-arrow bamboo/broom-blackberry forest 10 Kanuka-rewarewa forest 11 Kanuka forest⇔kanuka shrubland
01	05	**Exotic pines forest** 01 Radiata pine/kanuka/mingimingi forest 02 Macrocarpa/prostrate kanuka forest 03 Maritime pine -false acacia forest 04 Radiata pine/mingimingi forest 05 Radiata pine forest 06 Maritime pine-radiata pine/manuka-mingimingi forest
01	06	**Willow-dominant forest** 01 Grey willow/*Schoenoplectus tabernaemontani*-raupo-swamp kiokio forest 02 Grey willow/wheki forest 03 Grey willow forest
01	07	**Kamahi-dominant forest** 01 Kamahi-pohutukawa/manuka forest 02 Kamahi-kanuka-manuka forest
01	08	**Kahikatea-dominant forest** 01 Kahikatea forest
01	09	**Plantation-mixed indigenous forest** 01 Tasmanian blackwood-manuka-kanuka-whauwhaupaku-kamahi-ti kouka/blackberry-rank exotic grasses forest

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
02	01	**Wattle treeland** 01 Silver wattle treeland
	02	**Radiata pine-dominant treeland**
	03	**Pohutukawa-dominant treeland** 01 Pohutukawa/exotic grasses treeland
	04	**Tree fern-dominant treeland**
	05	**Mixed exotic treeland** 01 Eucalyptus/mingimingi-manuka/mown lawn-nonvegetated raw-soilfield treeland 02 (Alder)-(bamboo)/manuka-*Histiopteris incisa* treeland
	06	**Silver birch-dominant treeland** 01 Silver birch/narrow-leaved carpet grass treeland
	07	**Eucalyptus treeland** 01 Eucalyptus/nonvegetated raw-soilfield treeland
	08	**Grey willow/mixed sedge treeland** 01 Grey willow/*Baumea juncea*-harakeke-*Coprosma propinqua* treeland ⇔ manuka-harakeke shrubland
03	01	**Japanese honeysuckle-dominant vineland** 01 Japanese honeysuckle-*Paesia scaberula* vineland
	02	**Grape vine -dominant vineland** 01 Grape vineland
	03	**Mixed exotic vineland** 01 Pohue-Japanese honeysuckle-blackberry vineland
04	01	**Prostrate kanuka-dominant scrub** 01 Prostrate kanuka scrub 02 Prostrate kanuka-mingimingi scrub 03 Prostrate kanuka-mingimingi-manuka scrub 04 (Pohutukawa)/prostrate kanuka scrub 05 Prostrate kanuka-manuka-mingimingi scrub 06 (Dead pohutukawa x northern rata)/prostrate kanuka-mingimingi scrub 07 Tasmanian blackwood/prostrate kanuka scrub 08 Exotic pine/prostrate kanuka scrub 09 Manuka/prostrate kanuka scrub 10 Prostrate kanuka-manuka-Chinese privet scrub 11 Maritime pine/prostrate kanuka-blackberry scrub
	02	**Mingimingi-dominant scrub** 01 Mingimingi-manuka scrub 02 Mingimingi-manuka-kanuka scrub 03 Mingimingi-prostrate kanuka-manuka scrub ⇔ *Histiopteris incisa* fernland ⇔ *Hypolepis distans* fernland ⇔ gorse scrub. 04 Mingimingi-kanuka scrub 05 Mingimingi-kanuka-prostrate kanuka scrub 06 Mingimingi-bracken-manuka scrub 07 Dead pohutukawa × northern rata/manuka-mingimingi scrub 08 (Dead pohutukawa × northern rata)-(wheki)/mingimingi-*Histiopteris incisa*-*Gahnia setifolia*-gorse scrub 09 Black wattle/mingimingi-manuka scrub 10 Mingimingi-*Histiopteris incisa* shrubland 11 Mingimingi scrub ⇔ manuka scrub 12 Mingimingi scrub 13 Exotic pine/mingimingi scrub 14 (Radiata pine)/mingimingi-prostrate kanuka scrub 15 Mingimingi-kanuka-manuka-karamu/bracken scrub 16 Mingimingi-manuka-prostrate kanuka scrub 12 Tasmanian blackwood/mingimingi scrub 13 Mingimingi-manuka-blackberry-indigenous broadleaved species scrub 14 Mingimingi-blackberry-manuka-prostrate kanuka scrub
	03	**Manuka-dominant scrub** 01 Manuka scrub 02 Manuka-mingimingi scrub 03 Eucalyptus/manuka-mingimingi scrub 04 Manuka-kanuka/mingimingi scrub

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
		05 (Grey willow)-(ti kouka)/manuka scrub 06 Black wattle/manuka scrub 07 Grey willow/manuka scrub 08 Manuka mingimingi-broom scrub 09 Manuka-Spanish heath scrub 10 Manuka-kanuka-Spanish heath scrub 11 Manuka-prostrate kanuka scrub 12 Manuka-mingimingi scrub ⇔ prostrate kanuka shrubland 13 Exotic pine/manuka-mingimingi scrub 14 Manuka-mingimingi scrub ⇔exotic pine/karamu-wheki-mamaku scrub 15 (Scattered radiata pines)/manuka-mingimingi scrub 16 Manuka-mingimingi scrub ⇔radiata pine-maritime pine/karamu-wheki-mamaku scrub 17 Manuka-prostrate kanuka-Chinese privet scrub 18 Manuka-mingimingi-blackberry-bracken scrub
	04	**Kanuka-dominant scrub** 01 Kanuka scrub 02 Kanuka/mingimingi scrub 03 Kanuka-mahoe scrub 04 Kanuka/prostrate kanuka scrub 05 Eucalyptus/manuka mingimingi scrub 06 Kanuka-kohuhu/koromiko-blackberry scrub 07 (Silver birch)/kanuka-mingimingi scrub 08 Kanuka/narrow-leaved carpet grass scrub 09 Kanuka-pohutukawa-black wattle scrub
	05	**Indigenous mixed shrubs-dominant communities** 01 Mingimingi-manuka-blackberry-indigenous broadleaved species scrub 02 Whauwhaupaku scrub 03 Whauwhaupaku-kanuka/mingimingi scrub
	06	**Gorse-dominant scrub** 01 Gorse scrub
	07	**Exotic and indigenous plantings scrub**
	08	**Blackberry-dominant scrub** 01 Blackberry scrub 02 Blackberry-Himalayan honeysuckle-pohue scrub 03 Silver birch-Chinese privet/blackberry scrub 04 (Silver birch)/blackberry-manuka-prostrate kanuka scrub 05 (Silver birch)/blackberry-prostrate kanuka scrub
	09	**Exotic-dominant scrub** 01 Barberry/blackberry scrub 02 Radiata pine-maritime pine/broom-manuka-mingimingi scrub
	10	**Buddleia-dominant scrub** 01 Buddleia scrub
	11	**Chinese privet-dominant scrub** 01 Chinese privet scrub
	12	**Monoao-dominant scrub** 01 Monoao scrub
05	01	**Prostrate kanuka-dominant shrubland** 01 Prostrate kanuka shrubland 02 Prostrate kanuka-mingimingi shrubland 03 (Kanuka)/prostrate kanuka-mingimingi-*Carex secta* shrubland 04 (Kanuka)/prostrate kanuka-rank grasses shrubland 05 Prostrate kanuka-manuka-bracken shrubland 06 Prostrate kanuka-mingimingi-monoao-toru shrubland 07 Prostrate kanuka/narrow-leaved carpet grass shrubland 08 Prostrate kanuka-manuka shrubland 09 Prostrate kanuka-*Hypolepis ambigua* shrubland 10 Prostrate kanuka/sweet vernal shrubland 11 Prostrate kanuka/nonvegetated raw-soilfield 12 Wilding pine/prostrate kanuka-mingimingi shrubland 13 Prostrate kanuka-broom-blackberry shrubland 14 Wilding pine/prostrate kanuka shrubland

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
		15 Prostrate kanuka-mingimingi-manuka shrubland 16 Prostrate kanuka/ exotic grass shrubland 17 Wilding pine/prostrate kanuka-mingimingi shrubland 18 Wilding pine/prostrate kanuka-mingimingi-manuka shrubland 19 Prostrate kanuka-kamahi-wheki-whauwhaupaku/blackberry shrubland
	02	**Mingimingi-dominant shrubland** 01 Mingimingi-*Histiopteris incisa*-bracken shrubland 02 Mingimingi-manuka shrubland 03 Mingimingi-prostrate kanuka shrubland 04 Mingimingi-*Hypolepis distans*-turutu shrubland ⇔ *Hypolepis distans*-turutu-bracken fernland ⇔ prostrate kanuka scrub 05 Exotic pine/mingimingi-prostrate kanuka shrubland 06 Mingimingi shrubland
	03	**Manuka-dominant shrubland** 01 Manuka shrubland 02 Manuka-(kamahi) shrubland 03 (Emergent mixed exotic trees)/manuka-kanuka-mixed exotic species shrubland 04 Manuka-mingimingi shrubland 05 Manuka-kanuka-mingimingi shrubland 06 Manuka-prostrate kanuka shrubland 07 Manuka/bracken shrubland 08 Manuka/narrow-leaved carpet grass shrubland 09 (Silver birch)/manuka/*Cyperus ustulatus-Hypolepis distans* shrubland 10 Manuka-prostrate kanuka/*Lycopodiella cernua* shrubland 11 Manuka/gorse-creeping bent/nonvegetated raw-soilfield shrubland 12 Manuka-kanuka/*Histiopteris incisa* shrubland 13 (Manuka)-(monoao)-(*Gaultheria paniculata*)-(prostrate kanuka)/*Racomitrium sanuginosum* shrubland 14 Manuka/*Baumea rubiginosa* shrubland 15 Manuka-wheki/*Histiopteris incisa-Hypolepis ambigua* shrubland 16 Manuka-mingimingi-monoao shrubland 17 Manuka/Spanish heath-exotic grasses shrubland 18 Manuka-mingimingi-*Histiopteris incisa*-bracken shrubland 19 Manuka-mingimingi-broom shrubland 20 Manuka shrubland↔raupo-*Carex secta-Cyperus ustulatus* reedland 21 Manuka-harakeke shrubland 22 Manuka-pampas shrubland 23 Black wattle/manuka-blackberry-bracken shrubland 24 Manuka/bracken-broom shrubland ↔broom-bracken-blackberry shrubland↔prostrate kanuka scrub 25 (Maritime pine)/manuka-broom-blackberry-Himalayan honeysuckle shrubland 26 Manuka-harakeke-*Cyperus ustulatus* shrubland 27 Manuka/*Histiopteris incisa-Carex secta* shrubland 28 Maritime pine/manuka-pampas shrubland 29 Manuka-prostrate kanuka-mingimingi shrubland
	04	**Kanuka-dominant shrubland** 01 Kanuka-mingimingi shrubland 02 (Kanuka)/prostrate kanuka-rank grasses shrubland 03 Kanuka/Mercer grass shrubland 04 Kanuka-mingimingi-bracken shrubland 05 Kanuka/Mercer grass-narrow-leaved carpet grass shrubland 06 Kanuka shrubland 07 Kanuka-manuka/oioi shrubland 08 Wilding pine/prostrate kanuka shrubland 09 Wilding pine/kanuka-mingimingi-manuka shrubland
	05	**Pohutukawa-dominant shrubland** 01 Pohutukawa shrubland
	06	**Gorse-dominant shrubland** 01 Gorse shrubland

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
	07	**Planted indigenous shrubland** 01 Panted indigenous shrubland and manuka-mingimingi shrubland 02 (Harakeke)-(kohuhu) shrubland/nonvegetated ground
	08	**Mixed indigenous shrubland** 01 Kanuka/prostrate kanuka-blackberry-mingimingi-*Carex virgata* shrubland 02 Rewarewa-kamahi-(toru)/prostrate kanuka-monoao shrubland 03 Mixed indigenous shrubs/mixed fern species shrubland 04 (Maritime pine)/kiokio-blackberry-bracken-buddleia shrubland
	09	**Exotic planted shrubland** 01 Cultivar manuka-mingimingi-flowering cherry-red hot poker-harakeke (and other garden plants) shrubland.
	10	**Mixed indigenous-exotic shrubland** 01 (Mingimingi)-(arrow bamboo)-(manuka)-(broom)-(silver birch)/narrow-leaved carpet grass-Mercer grass/raw-soilfield shrubland 02 (Wheki-kohuhu-tī kouka)/wheki-kiokio-blackberry shrubland
	11	**Mixed-exotic shrubland** 01 Gorse-blackberry/Yorkshire fog-*Hypolepis ambigua-Histiopteris incisa* shrubland
	12	**Monoao dominant shrubland** 01 Monoao-manuka-prostrate kanuka-mingimingi shrubland
	13	**Blackberry-dominant shrubland** 01 (Grey willow)/blackberry-*Carex geminata* shrubland 02 Exotic pine/blackberry-prostrate kanuka shrubland 03 (Indigenous species)/blackberry-bracken-kiokio shrubland 04 Blackberry (dead) shrubland 05 Blackberry-broom/Yorkshire fog shrubland 06 Blackberry- *Cyclosorus interruptus* shrubland 07 Blackberry shrubland 08 Blackberry-mingimingi-*Nephrolepis flexuosa* shrubland
	14	**Ti kouka-dominant shrubland** 01 Ti kouka-kanuka shrubland
	15	**Monoao dominant shrubland** 01 Monoao-manuka-prostrate kanuka-mingimingi shrubland
06	01	**Pampas tussockland**
	02	**Mixed pampas tussockland**
07	01	***Dicranopteris*-dominant fernland** 01 *Dicranopteris linearis* fernland 02 *Dicranopteris linearis*-narrow-leaved carpet grass fernland
	02	***Hypolepis dicksonioides*-dominant fernland**
	03	**Bracken-dominant fernland** 01 Bracken fernland 02 Wheki/bracken fernland 03 Bracken-Japanese honeysuckle-Himalayan honeysuckle fernland 04 (Dead manuka)bracken-mingimingi-gorse fernland 05 Bracken-mingimingi-blackberry fernland
	04	***Histiopteris incisa*-dominant fernland** 01 *Histiopteris incisa* fernland 02 *Histiopteris incisa*-narrow-leaved carpet grass-gorse fernland 03 *Histiopteris incisa*-mingimingi fernland
	05	**Mixed fernland** 01 *Histiopteris incisa*-bracken-mingimingi fernland 02 Dead manuka/bracken-turutu-*Histiopteris incisa*-mingimingi fernland 03 *Histiopteris incisa*-bracken-mingimingi-Mercer grass-Yorkshire fog fernland 04 *Histiopteris incisa*-mingimingi-bracken fernland 05 *Hypolepis ambigua-Histiopteris incisa* fernland 06 *Dicranopteris linearis- Christella* aff. *dentata* ("thermal")-*Nephrolepis flexuosa* fernland 07 *Histiopteris incisa*-gorse-*Hypolepis ambigua-Carex virgata* fernland 08 Bracken-kiokio-blackberry-wheki-*Paesia scaberula* fernland 09 *Histiopteris incisa-Cyperus ustulatus* fernland 10 *Paesia scaberula*-exotic grasses fernland

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
		11 *Histiopteris incisa*-bracken-wheki fernland 12 *Hypolepis distans-Gleichenia microphylla-Hypolepis ambigua* fernland 13 Bracken- *Cyclosorus interruptus*-blackberry-pampas/nonvegetated raw-soilfield fernland 14 *Dicranopteris linearis-Histiopteris incisa* fernland 15 Mixed fernland 16 Manuka-(makomako)/*Hypolepis ambigua* fernland 17 Bracken-Baumea rubiginosa-mixed fern sedgeland
	06	***Christella* aff. *dentata* ("thermal")-dominant fernland** 01 *Christella* aff. *dentata* ("thermal")-fernland 02 *Christella* aff. *dentata* ("thermal")-blackberry-rank exotic grasses fernland 03 *Christella* aff. *dentata* ("thermal")-*Nephrolepis flexuosa*-blackberry fernland
	07	**Lycopodiella-dominant fernland** 01 *Lycopodiella cernua* fernland
	08	***Nephrolepis flexuosa*-dominant fernland** 01 *Nephrolepis flexuosa* fernland 02 *Nephrolepis flexuosa-Dicranopteris linearis* fernland *03* *Nephrolepis flexuosa*-bracken-*Christella* aff. *dentata* ("thermal")-blackberry fernland
	09	***Hypolepis ambigua*-dominant fernland** 01 *Hypolepis ambigua-Histiopteris incisa* fernland
	10	***Nephrolepis cordifolia*-dominant fernland** 01 *Nephrolepis cordifolia* fernland
	11	***Paesia scaberula-dominant fernland*** 01 *Paesia scaberula* fernland
	12	**Deparia-dominant fernland** 01 Deparia fernland
	13	**Cheilanthes-dominant fernland** 01 *Cheilanthes sieberi*-Mercer grass fernland 02 *Cheilanthes sieberi*-buffalo grass fernland
	14	***Cyclosorus*-dominant fernland** 01 *Cyclosorus interruptus* fernland
08	01	**Yorkshire fog-dominant grassland** 01 Yorkshire fog grassland 02 Prostrate kanuka/Yorkshire fog grassland 03 Manuka/Yorkshire fog grassland
	02	**Narrow-leaved carpet grass-dominant grassland** 01 Narrow-leaved carpet grassland 02 Mosaic of narrow-leaved carpet grassland, manuka-mingimingi shrubland, and nonvegetated raw-soilfield 03 Narrow-leaved carpet grass-exotic garden plants grassland 04 (Manuka)-(prostrate kanuka)/narrow-leaved carpet grassland 05 Narrow-leaved carpet grass-wild serradella grassland
	03	**Creeping bent grassland**
	04	**Mercer grass-dominant grassland** 01 Mercer grass-*Paesia scaberula* grassland 02 Mercer grass-narrow-leaved carpet grassland 03 Mercer grass grassland 04 Mercer grass-*Cyclosorus interruptus-Hypolepis ambigua* grassland
	05	**Kikuyu grassland**
	06	**Mixed exotic-dominant grassland** 01 Mercer grass-creeping bent-*Microlaena stipoides* grassland. 02 Sweet vernal-browntop grassland 03 Mown and rank exotic grassland 04 (Prostrate kanuka)/rank exotic grasses grassland 05 (*Baumea antrhrophylla*)/mixed exotic grasses-raw-soilfield grassland
	07	**Indian doab-dominant grassland** 01 Indian doab grassland
	08	**Reed sweet grass-dominant grassland** 01 Reed sweet grassland 02 Reed sweet grass-raupo-*Schoenoplectus tabernaemontani* grassland

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
		03 Raupo/reed sweetgrass- *Schoenoplectus tabernaemontani*-swamp millet grassland
09	01	***Carex geminata*-dominant sedgeland** 01 *Carex geminata* sedgeland
	02	***Cyperus ustulatus*-dominant sedgeland** 01 *Cyperus ustulatus* sedgeland 02 *Cyperus ustulatus-Cortaderia fulvida-Juncus edgarae-Histiopteris incisa* sedgeland 03 *Cyperus ustulatus-Cortaderia fulvida*-blackberry sedgeland 04 Dead kanuka/*Cyperus ustulatus*-pampas sedgeland 05 Wheki-ponga/*Cyperus ustulatus-Cyclosorus interruptus* sedgeland 06 *Cyperus ustulatus*-raupo sedgeland
	03	***Carex virgata*-dominant sedgeland** 01 *Carex virgata-Nephrolepis flexuosa* sedgeland 02 Gorse-*Carex virgata-Cyperus ustulatus* sedgeland
	04	***Baumea rubiginosa*-dominant sedgeland** 01 *Baumea rubiginosa* sedgeland 02 Wheki/*Baumea rubiginosa*-kiokio sedgeland
	05	**Mixed sedgeland** 01 *Carex virgata-Carex secta-Cyperus ustulatus-Baumea articulata* sedgeland 02 Grey willow/*Carex secta*-raupo-*Schoenoplectus tabernaemontani* sedgeland
	06	***Carex secta*-dominant sedgeland** 01 *Carex secta*-raupo sedgeland 02 (Kanuka)/*Carex secta* sedgeland
	07	***Isolepis distigmatosa*-dominant sedgeland** 01 *Isolepis distigmatosa* sedgeland
	08	**Oioi-dominant sedgeland** 01 Oioi sedgeland
10	01	***Juncus prismatocarpus*-dominant rushland** 01 *Juncus prismatocarpus-Carex geminata* rushland
11	01	**Raupo-dominant reedland** 01 Raupo reedland 02 (Ti kouka)-(grey willow)/raupo-harakeke-manuka/*Juncus effusus-Isolepis distigmatosa* reedland 03 Raupo-*Cyperus ustulatus* reedland 04 (Grey willow)-raupo-*Carex secta-Schoenoplectus tabernaemontani* reedland ⇔ raupo-pohuehue-Schoenoplectus tabernaemontani reedland 05 (Grey willow)-raupo-*Schoenoplectus tabernaemontani-Carex secta*-reedland 06 Raupo-*Schoenoplectus tabernaemontani-Carex secta* reedland 07 (Alder)/raupo reedland 08 Raupo-*Schoenoplectus tabernaemontani*-Japanese honeysuckle reedland 09 Raupo/*Carex virgata* reedland 10 (Grey willow)-(silver birch)-(ti kouka)/raupo-blackberry reedland 11 Raupo-blackberry reedland 12 Raupo-*Schoenoplectus tabernaemontani-Carex secta-Baumea rubiginosa* reedland 13 (Crack willow)/raupo reedland 14 (Ti kouka)-(manuka)/raupo-*Cyperus ustulatus-Schoenoplectus tabernaemontani* reedland 15 Grey willow/raupo reedland 16 Raupo-harakeke reedland ⇔ *Carex secta-Baumea rubiginosa-Baumea juncea* sedgeland
	02	***Baumea articulata*-dominant reedland** 01 *Baumea articulata* reedland
	03	***Baumea arthrophylla*-dominant sedgeland** 01 *Baumea arthrophylla* sedgeland
	04	**Mixed *Baumea* sedgeland**

Vegetation Structural Class	Broad Vegetation Type	Detailed Vegetation Types and Habitats
	06	***Baumea rubiginosa*-dominant sedgeland** 01 (Manuka)-(wheki)/*Baumea rubiginosa* sedgeland
12		**Cushionfield**
13	01	**Herbfield** 01 *Polygonum maculosa* herbfield 02 Arrow grass herbfield
14	01	***Racomitrium*-dominant Mossfield** 01 *Racomitrium sanuginosum* mossfield
	02	***Campylopus*-dominant mossfield** 01 *Campylopus capillaceous* mossfield 02 *Campylopus* sp. mossfield
15		**Lichenfield**
16		**Rockland**
17	01	**(Sparse vegetation)/boulderfield** 01 (Prostrate kanuka)/boulderfield
18		**Stonefield/gravelfield**
19		**Sandfield** 01 Geothermally heated sandfield
20		**Loamfield/Peatlfield**
21		**Flaxland**
22	01	**Geothermal water** 01 Geothermal water 02 Mud pools 03 Geothermal sands and hot springs 04 Geothermal springs, mud pools, geothermal stream and sinter.
23	01	**Wheki-dominant treefernland** 01 Wheki/gorse-*Histiopteris incisa* treefernland 02 (Dead pohutukawa × northern rata)/wheki-*Gahnia setifolia* treefernland 03 (Dead pohutukawa × northern rata)/wheki-kamahi treefernland 04 Wheki treefernland
24		**Mudfield**
25		**Cliffland**
26		**Turf**
27		**Algalfield**
28	01	**Nonvegetated raw-soilfield** 01 Nonvegetated raw-soilfield 02 Nonvegetated raw-soilfield (mining operations) 03 Geothermal sand 04 Nonvegetated raw-soil field (geothermal and landslide debris) 05 Bare ground 06 Prostrate kanuka/nonvegetated raw-soilfield shrubland
	02	**(Prostrate kanuka)/raw-soilfield** 01 (Prostrate kanuka)/nonvegetated raw-soilfield
	03	**(Sparse indigenous vegetation)/raw-soilfield** 01 (Kanuka)-(pohutukawa)-(mingimingi)-(silver birch)/ nonvegetated raw-soilfield 02 (Pohutukawa)-(manuka)-(Mercer grass)/ nonvegetated raw-soilfield 03 (Manuka)-(*Cyperus ustulatus*)/ nonvegetated raw-soilfield 04 (Prostrate kanuka)-(manuka)/ nonvegetated raw-soilfield 05 (Manuka)/ nonvegetated raw-soilfield 06 (*Juncus edgarae*)-(*Carex virgata*)-(*Morelotia affinis*)-(mixed exotic grasses)/ nonvegetated raw-soilfield 07 (*Cyperus ustulatus*)-(kanuka)-(*Cortaderia fulvida*)/nonvegetated raw-soilfield
	04	**Exotic grasses/ nonvegetated raw-soilfield** 01 Dead kikuyu-dead narrow-leaved carpet grass/ nonvegetated raw-soilfield.
29	01	**Residential development-scattered geothermal vegetation** 01 Residential development-scattered geothermal vegetation
30	01	**Bamboo-dominant bambooland** 01 Arrow bambooland

3.6 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. A cover class index based on Allen (1992) (see Table 3) was used to indicate the relative abundance of weeds at each site.

Table 3: 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

3.7 Site mapping

Vegetation type boundaries for each site were digitised in ArcView (V.9.3) (on the 2007 WRAPs) at a scale of 1:5,000 with the following data fields; Site Name, ECOSIG2003, BOTRANK 96, new site number, NZTM Eastings and Northings, Vegetation Code, Broad Vegetation Class, Vegetation description, Ecological District, Ecological Significance Ranking, Geothermal Field, Hydroclass, Territorial Local Authority, Structural Class Code, Broad Class Code, and Area (ha).

3.8 Historical site changes

Historical site changes were undertaken by examining aerial photographs held by Waikato Regional Council from the 1940s-1960s to determine the extent of change of geothermal sites. Due to the nature of the historic aerial photos (differing scales/ black and white), 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 in terms of broad percent ranges of hectare lost or gained.

3.9 Assessment of botanical significance by Given (1996)

Given (1996) applied four ranking systems that had been defined in earlier reports - Given's 1995 geothermal survey - full set of criteria; Given's 1995 geothermal survey - biodiversity criteria only; the criteria outlined in Whaley *et al*. 1995; and the 'Waimakariri system' (Meurk *et al*. 1993). Each site was ranked using each ranking system and a final assessment was then made by combining the four separate

assessments. The sites were grouped into four categories (A-D), where 'A' is the highest rank and 'D' is the lowest. These are listed in the notes section for each site.

3.10 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 Environment Waikato Regional Policy Statement (2002). This has recently been updated to reflect more recent changes to the New Zealand Threat Classification Lists (refer to Appendices 10 and 11). Using these criteria, each site was assigned to one of four levels of relative significance: Internationally Significant, Nationally Significant, Regionally Significant, or Locally Significant. The rankings were completed in the pre-formatted Excel spreadsheet provided by the Council.

3.11 Data analysis data

Data was generated from analyses of mapped vegetation for each site. The extent of each geothermal vegetation type (as per Table 2) in each site was calculated. The extent of geothermal vegetation in each ecological district, geothermal field, and in each administrative district was also calculated (see Tables 5, 9, 10, and 11). These totals exclude geothermal water. A total is given for geothermal water, and terrestrial and emergent geothermal wetland habitats, at each site.

Vegetation mosaics have been included in the site descriptions and accompanying maps for more accurate descriptions, however for GIS data compilation, the mosaics were assigned to the vegetation type dominant in a mosaic, thereby providing a scale appropriate for analysis at a regional level.

3.12 Presentation of results

Geothermal Fields

Site information is presented in order of geothermal field, generally following a North to South alignment, and then a West to East alignment.

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

1. A list of geothermal sites within the Waikato Region.
2. A separate data sheet for each geothermal site (see Table 4 below).
3. Maps
   - Topographic maps showing the location of each geothermal site (scale 1:20,000).
   - Vegetation maps of sites overlain on aerial photographs (vegetation map scales vary from 1:2,000 to 1:15,000 depending on the size of the site).
4. All geothermal sites are listed in Table 5, within relevant geothermal fields and ecological districts. The area (ha) of geothermal vegetation at each site and the significance ranking assigned to the site are provided in Table 6 (see Section 5).

Table 4: Format and categories for presentation of information on geothermal sites.

SITE NAME

Site Number:
Grid Reference:
GPS Reference:
Local Authority:
Ecological District:
Geothermal Field:
Bioclimatic Zone:
Tenure:
Altitude:
Extent of Geothermal Habitat:
Extent of Geothermal Vegetation:
Date of Field Survey:

Code	Type	Landform	Extent

Geophysical Assessment:[1]
Indigenous Flora:
Fauna:
Current Condition (Year of Most Recent Assessment):
Threats/Modification/ Vulnerability:
Invasive pest plants (*Year of most recent Assessment*):
Human impacts (*Year of most recent Assessment*):
Grazing (*Year of most recent Assessment*):
Adjoining land use (*Year of most recent Assessment*):
Site Change:
Recent Change:
Historical:
Management Requirements:
Significance Level:
Significance Justification:
Notes:
References:

[1] Selected sites only.

Explanatory Notes for the Site Summary Sheet

Explanatory notes for the site summary sheet are provided below:

Site Number: Number assigned to a site during the current survey. These have all been updated since the Wildland Consultants (2004) report, and previous site numbers are provided in a footnote for cross reference.

Grid Reference: Central grid reference of the site from the relevant NZTopo50 topographic map. The 2004 to 2007 reports were based on NZMS260, which are no longer being used.

GPS Reference: The grid reference is also provided as a GPS reference in NZTM (New Zealand Transverse Mercator).

Local Authority: Local authority with jurisdiction over the area.

Ecological District: Ecological district within which the site lies. Ecological districts each have distinctive characteristics of climate, geology, landform, soils and biological features (Myers *et al.* 1987). Three ecological districts in the Waikato Region contain sites with geothermal vegetation.

Geothermal Field: Name of the geothermal field within which the site lies. Geothermal surface features are supplied with mineralised hot water or steam from underlying geothermal resevoirs, and one field may supply many discrete geothermal sites. Geothermal field names and the assignment of each site to a geothermal field were undertaken by the Waikato Regional Council.

Bioclimatic Zone: Bioclimatic zones follow Leathwick *et al.* (1995), and are defined in Appendix 5.

Tenure: Tenure is shown as either protected or unprotected private land, or both if applicable. If the area is protected, the type of protection (e.g. reserve, covenant) is shown.

Altitude: Altitude of the site given in metres, determined from topographical maps. For larger sites a range is given.

Extent of Geothermal Habitat: Total area of geothermal habitat. This includes geothermal water and geothermal vegetation in hectares (see geothermal vegetation below).

Extent of Geothermal Vegetation: Total area of geothermal vegetation (see Table 2). This excludes geothermal water, but includes nonvegetated raw-soilfield in hectares.

Date of Field Survey: Date of the most recent field survey.

Vegetation Code: A numeric code based on structural class, broad vegetation type, and detailed vegetation type following Wildland Consultants (2005) Contract Reports 1056 and 1072, and additional types included in Table 2.

Vegetation Type: A vegetation classification using predefined structural classes and a protocol for assigning type names based on the dominant plant species, as described in Atkinson (1985), Wildland Consultants Contract Report No. 757, and additional types observed during the current field survey (see Table 2).

Landform: Describes the physical landform on which a vegetation type occurs.

Geophysical Assessment: Describes the unique geothermal physical aspects of the site (note that this assessment has only been carried out on selected sites and at some larger sites, only parts of the geophysical aspects were assessed).

Indigenous Flora: Any species characteristic of geothermal sites, and nationally threatened or uncommon species (as per de Lange *et al*. 2009) are listed. Relevant information may also be provided about plant distribution (for more detail refer to Appendix 4).

Fauna: A list of fauna known to occur at the site. Previous reports focussed on indigenous species only, but all fauna information has been included in this report where possible. A literature review was undertaken for each site, although for most sites, no further information was found.

Current Condition: Comments on the overall current condition of the site as determined from field reconnaissance and existing information. May include comment on features related to the character and history of the site which have influenced vegetation composition.

Threats/Modification/Vulnerability: Any current or potential threats to the indigenous vegetation and integrity of the geothermal ecosystem, particularly the occurrence and abundance of invasive exotic plants, potential and current human threats, and threats from domestic stock or pest animals, and adjoining landuse.

Site Change Recent Change: Any changes to the site since the last field visit (and general comments about change in the last ten years) were noted, and any changes evident in the 2007 aerial photographs compared with recent earlier surveys. Changes that are not a real change, but simply a result of better quality aerial photographs were noted.

Site Change Historical: Historical changes determined from 1940s to 1960s aerial photographs and relevant literature. Aerial photograph codes recorded as follows, for example a site with the code SN 172 Run 1176 Photos 5-6, 1946: SN = survey run number, Run = flight path number, Photos = number of photo(s) into the flight path, 1946 = year of photograph.

Management Requirements: Recommendations for action necessary to prevent, minimise or remedy any known threats or modification to the site.

Significance Level: The significance level assigned to the site from the ecological evaluation criteria based on Waikato Regional Council Technical Report TR2002/15 (Environment Waikato and Wildland Consultants 2002). Areas of Significant Indigenous Vegetation and Habitats of Indigenous Fauna in the Waikato Region: Guidelines to apply Regional Criteria and Determine Level of Significance (refer to Appendix 11).

Significance/Justification: A brief explanation of why a site was assigned to a particularsignificance level.

Notes: Any further comments including and previous rankings of geothermal vegetation (e.g. Given 1995).

References: References which are of direct relevance to the site.

An index by site and page number has been prepared to make information in this report more readily accessible (presented at the end of the report).

Location Map

Figure 1 (scale *c.*1:300,000) shows the location of each geothermal site with its significance level(s).

Table 5: Breakdown of broad geothermal hydroclass and vegetation groups within each site ordered by geothermal field and ranked by area of geothermal vegetation, Waikato Region.

Site Name	Site Number	Ecological District	Hydroclass/Vegetation Grouping					Total Site Area (Geothermal Vegetation and Geothermal Water) (ha)	Size Rank for Extent of Geothermal Vegetation within the Waikato Region (by Geothermal Field)
			Geothermal Water (ha)	Geothermal Vegetation			Total Geothermal Vegetation (ha)		
				Nonvegetated Raw-Soilfield (ha)	Terrestrial Vegetation (ha)	Emergent Wetland (ha)			
Horohoro Geothermal Field									
Horohoro	HHV01	Atiamuri	<0.1		<0.1		<0.1	<0.1	<0.1 ha
		Total	**<0.1**		**<0.1**		**<0.1**	**<0.1**	
Waikite Geothermal Field									
Waikite Valley	WAV01	Atiamuri	1.2	0.3	18.6	5.6	24.6	25.8	7
Northern Paeroa Range	WAV02	Atiamuri		0.3			0.3	0.3	
		Total	**1.2**	**0.6**	**18.6**	**5.6**	**24.9**	**26.1**	
Waiotapu Geothermal Field									
Maungaongaonga	WTV01	Atiamuri		0.7	8.4		9.1	9.1	1
Ngapouri	WTV02	Atiamuri	0.5	<0.1	3.1		3.1	3.6	
Waiotapu North	WTV03	Atiamuri	2.9	4.6	41.3		45.8	48.8	
Maungakakaramea (Rainbow Mountain)	WTV04	Atiamuri/ Rotorua Lakes	3.4	4.3	46.2		50.6	54.0	
Waiotapu South	WTV05	Atiamuri	20.6	8.4	77.8	26.3	112.4	133.0	
		Total	**27.4**	**18.0**	**176.7**	**26.3**	**221.0**	**248.4**	
Mokai Geothermal Field									
Whakamaru	MKV01	Atiamuri		<0.1			<0.1	<0.1	10
Waipapa Stream	MKV02	Atiamuri			1.1		1.1	1.1	
Tirohanga Road	MKV03	Atiamuri	0.3	<0.1	0.1		0.2	0.5	
Paerata Road	MKV04	Atiamuri	0.2	0.4	1.3		1.7	1.8	
		Total	**0.5**	**0.4**	**2.5**		**2.9**	**3.4**	
Atiamuri Geothermal Field									
Upper Atiamuri West	ATV01	Atiamuri			<0.1		<0.1	<0.1	12
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**	**0.2**	
Te Kopia Geothermal Field									
Te Kopia	TKV01	Atiamuri	1.1	5.5	48.9	4.4	58.8	59.9	5
Murphy's Springs	TKV02	Atiamuri			0.2		0.2	0.2	
Te Kopia Northwest	TKV03	Atiamuri		<0.1			<0.1	<0.1	
Te Kopia West Mud Pools	TKV04	Atiamuri			<0.1		<0.1	<0.1	
Te Kopia Red Stream	TKV05	Atiamuri			0.2		0.2	0.2	

Site Name	Site Number	Ecological District	Hydroclass/Vegetation Grouping					Total Site Area (Geothermal Vegetation and Geothermal Water) (ha)	Size Rank for Extent of Geothermal Vegetation within the Waikato Region (by Geothermal Field)
			Geothermal Water (ha)	Geothermal Vegetation			Total Geothermal Vegetation (ha)		
				Nonvegetated Raw-Soilfield (ha)	Terrestrial Vegetation (ha)	Emergent Wetland (ha)			
Mangamingi Station	TKV06	Atiamuri		0.1	0.4		0.5	0.5	
		Total	**1.1**	**5.6**	**49.8**	**4.4**	**59.8**	**60.9**	
Orakeikorako Geothermal Field									
Waihunuhunu	OKV01	Atiamuri	2.3		0.3	2.7	3.0	5.3	6
Akatarewa Stream	OKV02	Atiamuri			1.4		1.4	1.4	
Orakeikorako	OKV03	Atiamuri	<0.1	2.1	40.3		42.4	42.4	
Red Hills	OKV04	Atiamuri	0.1	0.3	11.1		11.4	11.5	
Akatarewa East	OKV05	Atiamuri		<0.1	<0.1		<0.1	<0.1	
		Total	**2.5**	**2.3**	**53.2**	**2.7**	**58.2**	**60.7**	
Ngatamariki Geothermal Field									
Waikato River Springs	NMV01	Atiamuri	0.2	<0.1		0.4	0.4	0.6	11
Ngatamariki	NMV02	Atiamuri	0.2	0.4	1.0	<0.1	1.5	1.7	
		Total	**0.4**	**0.4**	**1.0**	**0.4**	**1.9**	**2.3**	
Whangairorohea Geothermal Field									
Whangairorohea	WGV01	Atiamuri	<0.1		<0.1		<0.1	<0.1	<0.1 ha
		Total	**<0.1**		**<0.1**		**<0.1**	**<0.1**	
Reporoa Geothermal Field									
Longview Road	RPV01	Atiamuri	0.2	1.5	1.9		3.4	3.6	9
Wharepapa Road	RPV02	Atiamuri	0.2	1.2	2.2		3.3	3.5	
Golden Springs	RPV03	Atiamuri	<0.1		0.1	0.3	0.5	0.5	
		Total	**0.4**	**2.6**	**4.4**	**0.3**	**7.2**	**7.6**	
Ohaaki Geothermal Field									
Ohaaki Steamfield West	OHV01	Atiamuri	0.1	2.2	9.5		11.7	11.8	8
Ohaaki Steamfield East	OHV02	Atiamuri		3.1	3.7		6.8	6.8	
		Total	**0.1**	**5.3**	**13.2**		**18.5**	**18.6**	
Wairakei-Tauhara Geothermal Field									
Otumuheke Stream	THV01	Atiamuri			2.3		2.3	2.3	2
Spa Thermal Park	THV03	Atiamuri		<0.1	0.1		0.1	0.1	
Broadlands Road	THV04	Atiamuri	<0.1	4.6	25.2		29.8	29.8	
Crown Park	THV05	Taupo		0.1	0.6		0.7	0.7	
Crown Road	THV06	Taupo/Atiamuri		3.7	13.8		17.5	17.5	
Waipahihi Valley	THV07	Taupo			0.3		0.3	0.3	
Te Rautehuia	WKV01	Atiamuri		0.5	7.2		7.7	7.7	
Te Rautehuia Stream	WKV02	Atiamuri		0.5	1.6		2.1	2.1	
Upper Wairakei Stream	WKV03	Atiamuri		0.2	4.5		4.7	4.7	

Site Name	Site Number	Ecological District	Hydroclass/Vegetation Grouping					Total Site Area (Geothermal Vegetation and Geothermal Water) (ha)	Size Rank for Extent of Geothermal Vegetation within the Waikato Region (by Geothermal Field)
			Geothermal Water (ha)	Geothermal Vegetation			Total Geothermal Vegetation (ha)		
				Nonvegetated Raw-Soilfield (ha)	Terrestrial Vegetation (ha)	Emergent Wetland (ha)			
(Geyser Valley)									
Wairakei Borefield	WKV04	Atiamuri			<0.1		<0.1	<0.1	
Te Kiri O Hine Kai Stream Catchment/Wairoa Hill	WKV05	Atiamuri	0.2	3.3	36.8		40.1	40.3	
Lower Wairakei Stream	WKV06	Atiamuri	<0.1		<0.1		<0.1	<0.1	
Karapiti Forest	WKV07	Atiamuri			0.6		0.6	0.6	
Hall of Fame Stream	WKV08	Atiamuri			0.1		0.1	0.1	
Waipouwerawera Stream/Tukairangi	WKV09	Atiamuri			0.1		0.1	0.1	
Craters of the Moon	WKV10	Atiamuri		1.5	43.1		44.6	44.6	
		Total	**0.3**	**14.4**	**136.3**		**150.7**	**151.0**	
Rotokawa Geothermal Field									
Rotokawa North	RKV01	Atiamuri	<0.1	3.3	31.1		34.3	34.4	3
Lake Rotokawa	RKV02	Atiamuri	67.9	13.1	56.2		69.4	137.3	
		Total	**68.0**	**16.4**	**87.3**		**103.7**	**171.7**	
Tokaanu-Waihi-Hipaua Geothermal Field									
Hipaua	TOV02	Tongariro		0.4	11.0		11.3	11.3	
Tokaanu Lake Shore Wetland	TOV05	Taupo/ Tongariro	3.3			39.1	39.1	42.4	
Maunganamu West	TOV07	Taupo/ Tongariro				0.6	0.6	0.6	
Tokaanu Thermal Park	TOV08	Tongariro	0.2	0.1	6.7	0.8	7.6	7.8	4
Tokaanu Urupa Mud Pools	TOV09	Taupo			<0.1		<0.1	<0.1	
Maunganamu East	TOV10	Taupo				<0.1	<0.1	<0.1	
Maunganamu North Wetland	TOV11	Taupo				0.9	0.9	0.9	
Tokaanu Tailrace Canal	TOV14	Tongariro				<0.1	<0.1	<0.1	
		Total	**3.5**	**0.5**	**17.7**	**41.4**	**59.5**	**63.0**	
Tongariro Geothermal Field									
Te Maari Craters	TGV01	Tongariro		4.9			4.9	4.9	
Ketetahi	TGV02	Tongariro		8.2			8.2	8.2	8
Emerald Lakes	TGV03	Tongariro	0.8	11.3			11.3	12.1	
Red Crater	TGV04	Tongariro		0.7			0.7	0.7	
		Total	**0.8**	**25.1**			**25.1**	**25.9**	
Grand Total			**106.2**	**91.8**	**560.7**	**81.1**	**733.6**	**839.88**	

4. DEFINITION OF 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 found elsewhere 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.

Refer to Appendix 6 for explanations of these terms. This was accompanied by a hierarchical classification of geothermally influenced terrestrial and emergent wetland vegetation, of which detailed vegetation types and habitats are included in site reports.

4.1 Basis of summarising extent of geothermal habitat, geothermal vegetation, and open water

The broad summaries of geothermal vegetation and habitats in this report include all mapped 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 mapped if it was an integral part of a geothermal site. Open water is included in "extent of geothermal habitat" in site reports, but not in "extent of geothermal vegetation".

4.2 Geothermal wetland vegetation

Adapted from Wildland Consultant 2005 (Report No. 1072).

The definition of geothermal wetland for this study follows Clarkson *et al*. (2002) and Johnson (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*. 1992)

"A hydrosystem where volcanic activity produces hot surface waters, or heated soils (30^{o}C or more) or where geothermal chemistry affects wetland habitats." (Johnson 2004)

Wetlands habitats have been mapped as best as possible within limitations of time, difficulty of safe access and issues of very small scales. Many wetland vegetation types cover a very small area and are too small to be mapped.

Examples where limitations of a single site visit approach and scale of mapping exists to determine geothermal wetland boundaries include:

- heated wet air (steam) from fumaroles and hot pools can extend for either small distances, or quite considerable distances from the surface geothermal activity, and are generally difficult to map.

- heated water flowing over waterfalls produces graduations of habitats affected by water flow, splash, spray (Johnson 2004) and through seepages and associated increased air and soil temperatures providing habitat for plant species typical of geothermal activity.

- the presence of surface geothermal activity can fluctuate at a particular location and across a landscape.

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. raupo (*Typha orientalis*) wetland). In this situation the vegetation is mapped as one broad class. Generally the water present will have geothermal derived chemical inputs.

Wetlands are quite varied both within and between geothermal sites, for example at Waiotapu South, there are extensive areas of wetland manuka (*Leptospermum scoparium*) scrub, with additional areas of raupo reedland, and *Baumea juncea* sedgeland, while at Te Kopia Wetland areas are dominated by *Baumea rubiginosa*. In the Tokaanu Lakeshore Wetland, there are extensive areas of raupo reedland, with small areas of oioi (*Apodasmia similis*) rushland present at Tokaanu Thermal Park. Geothermal wetlands provide habitat for threatened fern species such as *Thelypteris confluens* at Waikite and *Cyclosorus interruptus* at Waiotapu South.

4.3 Nonvegetated raw-soilfield (Source: Merrett & Clarkson 1999)

Areas that are bare of vegetation that are (i) too hot to support plant life, (ii) are cooled but hydrothermally altered, sinter pavements, or (iii) are subjected to regular mud ejection or gas emission that prevent colonisation and established 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^{o}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.

4.3.1 Basis of mapping of nonvegetated raw-soilfield for this study

This study is based on both field survey and interpretation of vegetation cover based on aerial photographs. At many sites, particularly large ones, not all units of vegetation and habitats could be viewed in the field, nor was it safe to do so. Occasional scattered vascular and non-vascular plants are included in mapping, particularly in areas that appear as bare ground on aerial photographs, and in areas that could not be viewed by field survey. On this basis, nonvegetated raw-soilfield is included in tallies of terrestrial geothermal vegetation in the summary of vegetation types by geothermal field.

Large areas with open water and abundant mud pools were mapped as open geothermal water, while small mud pools amongst nonvegetated raw-soilfield have been mapped as nonvegetated raw-soilfield. Open water areas containing abundant mud pools were given a separate vegetation code (22.01.02).

5. GEOTHERMAL SITES IN THE WAIKATO REGION

A total of 64 sites have been described in Appendix 1 and are listed in Table 5. The only known major exception is the hill slopes above Tokaanu, which are likely to contain some sites with significant examples of geothermal vegetation. Landowner pemission was not received to enable survey of these sites, so these sites were not surveyed or mapped. While these sites are considered to be relatively small, field survey of them should be a high priority if access can be arranged. Details of the vegetation, condition, and significance of each site are presented in Appendix 1, together with vegetation type maps on an aerial photograph backdrop, and topographic maps showing site boundaries. 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). Therefore, each site was assigned a relative significance level; International, National, Regional, or Local following the assessment method in Appendix 11. Four sites were identified as being of International significance (Te Kopia, Te Maari Craters, Emerald Lakes and Red Crater) and part of another site (Waiotapu South), encompassing *c.*205 ha or 24% of geothermal habitat in the Waikato Region (see Table 6). Eight sites were of National significance, with two sites being partly of National significance and partly of Local significance, encompassing *c.*382 ha or 46% of geothermal habitat in the Waikato Region. Twenty-three sites were identified as being of Regional significance, with an additional two sites being partly of Regional and partly of Local significance. Parts of Waiotapu South were identified as being of International, Regional and Local significance. In total, *c.*242 ha or 29% of geothermal habitat in the Waikato Region was identified as being Regionally significant. The remainder of the sites (25) were

identified as being of Local significance. The total area of geothermal habitat of Local significance in the Waikato Region was *c.*11 ha or *c.*1%.

Table 6: Ecological significance ranking of geothermal sites ordered by geothermal field, Waikato Region.

Site Name (Site Number)	Ecological District	Area (ha) of Site According to Ecological Significance Ranking			
		International	National	Regional	Local
Horohoro Geothermal Field					
Horohoro (HHV01)	Atiamuri				<0.1
	Total				**<0.1**
Waikite Geothermal Field					
Waikite Valley (WAV01)	Atiamuri		25.8		
Northern Paeroa Range (WAV02)	Atiamuri				0.3
	Total		**25.8**		**0.3**
Waiotapu Geothermal Field					
Maungaongaonga (WTV01)	Atiamuri		9.1		
Ngapouri (WTV02)	Atiamuri			0.8	2.8
Waiotapu North (WTV03)	Atiamuri			48.8	
Maungakakaramea (Rainbow Mountain) (WTV04)	Atiamuri/Rotorua Lakes		54.0		
Waiotapu South (WTV05)	Atiamuri	127.2		5.3	0.5
	Total	**127.2**	**63.1**	**54.9**	**3.3**
Mokai Geothermal Field					
Whakamaru (MKV01)	Atiamuri				<0.1
Waipapa Stream (MKV02)	Atiamuri		0.8		0.3
Tirohanga Road (MKV03)	Atiamuri				0.5
Paerata Road (MKV04)	Atiamuri				1.8
	Total		**0.8**		**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**
Te Kopia Geothermal Field					
Te Kopia (TKV01)	Atiamuri	59.9			
Murphy's Springs (TKV02)	Atiamuri			0.2	
Te Kopia Northwest (TKV03)	Atiamuri				<0.1
Te Kopia West Mud Pools (TKV04)	Atiamuri				<0.1
Te Kopia Red Stream (TKV05)	Atiamuri				0.2
Mangamingi Station (TKV06)	Atiamuri				0.5
	Total	**59.9**		**0.2**	**0.8**
Orakeikorako Geothermal Field					
Waihunuhunu (OKV01)	Atiamuri		5.3		
Akatarewa Stream (OKV02)	Atiamuri			1.4	
Orakeikorako (OKV03)	Atiamuri		42.4		
Red Hills (OKV04)	Atiamuri		11.5		
Akatarewa East (OKV05)	Atiamuri				<0.1
	Total		**59.2**	**1.4**	**<0.1**

Site Name (Site Number)	Ecological District	Area (ha) of Site According to Ecological Significance Ranking			
		International	National	Regional	Local
Ngatamariki Geothermal Field					
Waikato River Springs (NMV01)	Atiamuri			0.6	
Ngatamariki (NMV02)	Atiamuri			1.7	
	Total			**2.3**	
Whangairorohea Geothermal Field					
Whangairorohea (WGV01)	Atiamuri				<0.1
	Total				**<0.1**
Reporoa Geothermal Field					
Longview Road (RPV01)	Atiamuri			3.6	
Wharepapa Road (RPV02)	Atiamuri			3.2	0.3
Golden Springs (RPV03)	Atiamuri			0.5	<0.1
	Total			**7.3**	**0.3**
Ohaaki Geothermal Field					
Ohaaki Steamfield West (OHV01)	Atiamuri			11.8	
Ohaaki Steamfield East (OHV02)	Atiamuri			6.8	
	Total			**18.6**	
Wairakei-Tauhara Geothermal Field					
Otumuheke Stream (THV01)	Atiamuri		1.8		0.4
Spa Thermal Park (THV03)	Atiamuri				0.1
Broadlands Road (THV04)	Atiamuri			29.8	
Crown Park (THV05)	Taupo				0.7
Crown Road (THV06)	Taupo/ Atiamuri			17.5	
Waipahihi Valley (THV07)	Taupo			0.3	
Te Rautehuia (WKV01)	Atiamuri			7.7	
Te Rautehuia Stream (WKV02)	Atiamuri			2.1	
Upper Wairakei Stream (Geyser Valley) (WKV03)	Atiamuri			4.7	
Wairakei Borefield (WKV04)	Atiamuri				
Te Kiri O Hine Kai Stream Catchment/ Wairoa Hill (WKV05)	Atiamuri			40.3	
Lower Wairakei Stream (WKV06)	Atiamuri			<0.1	
Karapiti Forest (WKV07)	Atiamuri				0.6
Hall of Fame Stream (WKV08)	Atiamuri			0.1	
Waipouwerawera Stream/Tukairangi (WKV09)	Atiamuri				0.1
Craters of the Moon (WKV10)	Atiamuri		44.6		
	Total		**46.4**	**102.7**	**2.0**
Rotokawa Geothermal Field					
Rotokawa North (RKV01)	Atiamuri			34.4	
Lake Rotokawa (RKV02)	Atiamuri		137.3		
	Total		**137.3**	**34.4**	
Tokaanu-Waihi-Hipaua Geothermal Field					
Hipaua (TOV02)	Tongariro			11.3	
Tokaanu Lake Shore Wetland (TOV05)	Taupo/ Tongariro		42.4		

Site Name (Site Number)	Ecological District	Area (ha) of Site According to Ecological Significance Ranking			
		International	National	Regional	Local
Maunganamu West (TOV07)	Taupo/ Tongariro			0.6	
Tokaanu Thermal Park (TOV08)	Tongariro/ Taupo			7.8	<0.1
Tokaanu Urupa Mud Pools (TOV09)	Tongariro			<0.1	
Maunganamu East (TOV10)	Taupo				<0.1
Maunganamu North Wetland (TOV11)	Taupo				0.9
Tokaanu Tailrace Canal (TOV14)	Tongariro/ Taupo				<0.1
	Total		**42.4**	**19.7**	**0.9**
Tongariro Geothermal Field					
Te Maari Craters (TGV01)	Tongariro	4.9			
Ketetahi (TGV02)	Tongariro		8.2		
Emerald Lakes (TGV03)	Tongariro	12.1			
Red Crater (TGV04)	Tongariro	0.7			
	Total	**17.7**	**8.2**		
Grand Total		**205**	**382**	242	11

Changes in the number of sites identified at each significance level from the Wildland Consultants (2004) report are the result of several factors. The increase in the number of Internationally Significant sites is largely due to the addition to the study of three sites within Tongariro National Park which are ranked as Internationally Significant due to their location within a World Heritage Site and their unmodified nature. Only three sites were previously identified as Locally significant, compared to the 25 full and five parts of sites indentified as Local in this report. These are mostly sites that were not described or assessed in Wildland Consultants (2004) (for two sites additional areas were added to those sites which were subsequently ranked at a different level than the parts of the site which were identified in 2007 (i.e. Paerata Road and Otumuheke Stream). The classification of 10 previously ranked sites has been revised since 2004, due to one or more of the following factors: the updated ranking criteria, the revision of the threatened status of all New Zealand plant species by de Lange *et al.* (2009)[1], and additional information which has been collected for each site (Table 7). These latter sites are generally small sites with moderate-sized populations (on a nationwide basis) of an „At Risk' species. These changes in rankings are described in Table 7.

[1] This review changed the threat status of many of the species that occur in geothermal sites that were ranked as threatened and at risk in de Lange *et al*. (2004).

Table 7: Geothermal sites for which the level of significance has been revised between 2007 and 2011.

Site No.	Site Name	Assessments of Relative Significance		Reason for Change of Significance Ranking
		Previous Assessment (2004-2007)	2011 Assessment	
MKV03	Tirohanga Road	Regional	Local	An „At Risk' species, prostrate kanuka (*Kunzea ericoides* var. *microflora*), is present, but the population is small. A number of sites have larger areas of vegetation dominated by this species.
MKV04	Paerata Road	Regional (part) Local (part)	Local	An „At Risk' species, prostrate kanuka, is present, but the site is not an important habitat for the conservation of this species.
OKV02	Akatarewa Stream	National	Regional	Reclassification* of the threat status of *Christella* aff. *dentata* ("thermal").
NMV02	Ngatamariki	National (part) Regional (part)	Regional	Reclassification* of the threat status of *Cyclosorus interruptus.*
RKV02	Lake Rotokawa	Regional	National	Based on ongoing improvements to the condition of the site, size, the wide diversity of geothermal habitats present, and the presence of a large and important population of *Calochilus robertsonii*, an „At Risk' species.
NMV01	Waikato River Springs	National	Regional	Reclassification* of the threat status of *Christella* aff. *dentata* ("thermal").
THV05	Crown Park	Regional	Local	An „At Risk' species, prostrate kanuka, is present, but the population is small. A number of sites have larger areas of vegetation dominated by this species.
WKV04	Wairakei Borefield	Regional	Local	An „At Risk' species, prostrate kanuka, is present, but the population is small. A number of sites have larger areas of vegetation dominated by this species.
WKV06	Lower Wairakei Stream	National	Regional	Reclassification* of the threat status of *Christella* aff. *dentata* ("thermal").
WKV07	Karapiti Forest	Regional	Local	An „At Risk' species, prostrate kanuka, is present, but the population is small. A number of sites have larger areas of vegetation dominated by this species.

* In 2009, the threat classification of the New Zealand's vascular flora was revised and updated (de Lange *et al*. 2009). The ranking for many species was revised including several species present in geothermal areas: *Cyclosorus interruptus, Christella* aff. *dentata* ("thermal") and prostrate kanuka were revised from „Chronically Threatened' (de Lange *et al.* 2004) to „At Risk' (de Lange *et al.* 2009). These revised rankings resulted in the significance level for some sites being revised downward. See Appendix 4 for details of 2009 threat rankings for plant species typical of geothermal areas.

6. GEOTHERMAL VEGETATION OF THE WAIKATO REGION - AN OVERVIEW

A total of *c.*734 ha of geothermal vegetation (including raw-soilfield) was mapped in the Waikato Region in this study, with an additional 106 ha of open water mapped. This is an increase of *c.*21% to the area mapped in Wildland Consultants (2004), where *c.*579 ha was mapped. The increase reflects an increase to the scope of the project rather than a real increase in the extent of geothermal vegetation and habitats. This is discussed in full in Section 8 below. Most of this change can be accounted for by the addition of existing sites to this project in Wildland Consultants 2006, 2007a, 2007b, and the current study. Additional parts of sites were also found, most notably at Waiotapu South where additional areas of geothermal wetland were found.

6.1 Assessment by geothermal field

Horohoro Geothermal Field

The geothermal features of this field (an overflowing pool and a seepage) is mapped in this report 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 2004 were *Lycopodiella cernua*, mingimingi (*Leucopogon fasciculatus*), and *Gleichenia microphylla*. *Nephrolepis flexuosa* has been recorded from this site in the past (Given 1995), but is presumed extinct at this site (Bycroft and Beadel 2007). This field has <1 ha of geothermal vegetation, surrounding hot springs. The Horohoro Geothermal Field is classified as a „Development Geothermal System' by Waikato Regional Council[1].

Waikite Geothermal Field

The geothermal features of this site 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 this report.

A total of *c.*24.9 ha of geothermal vegetation has been mapped in the Waikite Geothermal Field, most of it in the Waikite Valley site. This comprises about 3.4% of the geothermal vegetation in the Waikato Region, and is made up of *c.*5 ha of geothermal wetland, *c.*0.6 ha of nonvegetated raw-soilfield and *c.*18.6 ha of terrestrial geothermal vegetation. In addition to the above, *c.*0.2 ha of geothermal water has also been mapped in this field. A total of *c.*6.0 ha of this field was mapped as indigenous scrub and shrubland, and of this 4.9 ha was mapped as being dominated by prostrate kanuka (*c.*1.3 % of the area of vegetation dominated by this species in the Waikato Region).

Most of the vegetation mapped (24.5 ha) is contained within the Waikite Valley site and includes several disjunct areas of geothermal activity near several small bodies of open water to the north of the site, and hot springs, heated soils, sinter pavements, geothermal wetlands, and plants present on the margins of heated geothermal streams.

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

Surface water draw-off to supply a public swimming pool is the only extractive use of the geothermal resource. Extensive areas to the north of the Waikite Swimming Baths are farmed, and areas that were previously wetlands have been drained for farming purposes. Vegetation along most stream margins, and geothermal wetlands has been subjected to grazing by both cattle and stock in the past. Most of the wetlands 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. 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 site contains important habitat for a number of „At Risk' plant species including the second largest population of *Christella* aff. *dentata* ("thermal") in New Zealand. Five other „At Risk' species (as per de Lange *et al.* 2009) are known from this site; prostrate kanuka, *Cyclosorus interruptus*, *Thelypteris confluens*, *Nephrolepis flexuosa*, *Dicranopteris linearis*, and *Hypolepis dicksonioides*.

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 vegetation of this field is mapped over five sites, although the boundaries of these sites are somewhat arbitrary, with geothermal vegetation being almost continuous between these five sites. A total of *c.*221.0 ha of geothermal vegetation was mapped, which comprises almost a third (*c.*30.1%) of the geothermal vegetation of the Waikato Region. As the sites are currently mapped, Waiotapu South is the largest of the sites in this field comprising *c.*112.4 ha of geothermal vegetation, followed by Maungakakaramea (Rainbow Mountain) (*c.*50.6 ha), Waiotapu North (*c.*45.8 ha), Maungaongaonga (*c.*9.06 ha), and Ngapouri (*c.*3.1 ha). Most or all of Maungakakaramea (Rainbow Mountain), Maungaongaonga, and Waiotapu South are protected and administered by the Department of Conservation. A small part of Ngapouri Station is also protected as a Covenant. Other sites and parts of these sites are in private ownership and are surrounded by farmland and plantation forests.

The area mapped in the Waiotapu Geothermal Field comprises 176.7 ha of terrestrial vegetation, *c.*18.0 ha of nonvegetated raw-soilfield, and *c.*26.3 ha of geothermal wetland. All of the area mapped as geothermal wetland was in the southern part of the geothermal field in part of the area mapped as Waiotapu South. This is the best geothermal wetland vegetation in the Waikato Region with the wetland extending beyond the area mapped into non-geothermal wetland. The geothermal portion of this wetland comprises *c.*32.4% of the geothermal wetland vegetation of 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. The areas mapped as nonvegetated raw-soilfield (*c.*18% of this type in the Waikato Region) include some of the largest area of sinter terraces remaining in

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

New Zealand, as well as extensive areas of geothermally heated bare ground. The site contains *c.*176.3 ha (*c.*31.4%) of the terrestrial geothermal vegetation in the Waikato Region. The field includes *c.*198.6 ha of indigenous geothermal scrub and shrubland (which includes some extensive areas of geothermal wetland mapped as manuka scrub). Of this, 146.94 ha is dominated by prostrate kanuka scrub and shrubland (38.7% 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.

Taxa present in this geothermal field classed as „At Risk' in de Lange *et al*. (2009) are prostrate kanuka, *Cyclosorus interruptus*, *Schizaea dichotoma* (sparse), *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 present at any geothermal site in New Zealand. Other species of interest are *Lycopodiella cernua, S. fistulosa* and *S. bifida*, *Psilotum nudum*, *Caladenia atradenia*, *Thelymitra carnea, T. decora*, and *T. ixioides.*

This geothermal field, particularly the parts protected in Scenic Reserves at Maungaongaonga, Maungakakaramea (Rainbow Mountains), and the Waiotapu South site contains the greatest area of habitat of any geothermal field in New Zealand. Management of pest plants, particularly wilding pines is a priority in protected areas, and some control of these species has been undertaken by land managers and the Department of Conservation recently. Extensive damage by pigs through trampling and making tracks thoughout the geothermal wetland vegetation was observed in the Orutu Wetland of Waiotapu South during the current study. 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 are subject to grazing and extensive areas 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 areas should be regularly monitored for management issues and formal protection and a restoration plan for these areas would enhance and/or protect the highly significant ecological values of this field.

Mangakino Geothermal Field

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

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

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 area (*c.*2.9 ha) of associated geothermal vegetation. This is *c.*0.4% of the geothermal vegetation in the Waikato Region. An additional area of *c.*0.4 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") (ranked as At Risk-Declining in de Lange *et al*. 2009) in New Zealand. Prostrate kanuka (another „At Risk' species) was recorded from Paerata Road and Tirohanga Road. Other plants characteristic of geothermal sites include *Psilotum nudum* which is uncommon in the Waikato Region, (formally an „at risk' species classed as „RRange Restricted' in de Lange *et al*. 2004, but now no longer considered threatened), *Doodia australis*, *Lycopodiella cernua*, and *Campylopus capillaceus*.

A geothermal power plant began producing electricity at the Mokai Geothermal Field by drawing off geothermal fluid in November 1999 and now generates 96 MW (http://www.mightyriverpower.co.nz/Generation/AboutUs/Geothermal/Mokai.aspx accessed 4 July 2011). All geothermal fluid is being re-injected 4 km from the site (Stretch 2000 in Merrett & Fitzgerald 2004). Monitoring is recommended to assess the impacts of energy extraction on geothermal features in this field. 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 are excluded from the site.
- Wildling pines are an issue at Waipapa Stream. Future plantation pine planting at the site should allow a buffer between the plantation and geothermal features, and any wilding trees should be regularly removed from the site.

Atiamuri Geothermal Field

Several hot springs and pools occur at the Whangapoa Springs and the Matapan Road Geothermal sites, and several other surface expressions of geothermal activity are present at Upper Atiamuri West. There is evidence from past records that the area once had hotter temperatures (Cave *et al.* 1993), and two pools are known to have been submerged by Lake Atiamuri. There are similarities between 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 taken place at this site since the 2004 study. The other two sites are within farmland, or in fenced gullies adjacent to farmland, with no significant ecological values found. This field

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

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 at Te Kopia Geothermal Field (*c.*59.21 ha) comprises *c.*8.2% of the geothermal vegetation of Waikato Region, which is the fifth largest area of geothermal vegetation within a geothermal field in the Waikato Region. This vegetation has been mapped over six geothermal sites, with most of the vegetation being present at Te Kopia (TKV01); *c.*58.8 ha. Most of this site is within the Te Kopia Scenic Reserve and is surrounded by a large area of indigenous vegetation; mainly forest within the Te Kopia Scenic Reserve. The geothermal vegetation of Te Kopia (TKV01) is in good condition, and this site was identified as being 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 49.8 ha of terrestrial geothermal vegetation, *c.*5.6 ha of nonvegetated raw-soilfield, and *c.*4.4 ha of emergent wetland. An additional one hectare was mapped as geothermal water. The field has *c.*5% of the geothermal wetland and 8.8% of the geothermal terrestrial vegetation in the Waikato Region. Approximately 44 ha was mapped as indigenous scrub or shrubland, and *c.*20.5 ha of this was mapped as prostrate kanuka scrub and shrubland, which is about 5% of the total area of prostrate kanuka in the Waikato Region.

This site contains very high quality examples of geothermal vegetation. One of the largest populations in New Zealand of the fern *Dicranopteris linearis* (classed as „At Risk' in de Lange *et al*. 2009) occurs here. *D. linearis* is known from *c.*24 sites in New Zealand. Murphy's Springs contains a good sized population of *Christella* aff. *dentata* ("thermal") (also classed as „At Risk') with about 100 plants present. Other „At Risk' species known from this field include *Schizaea dichotoma*, *Calochilus paludosus, C. robertsonii, Korthalsella salicornioides,* and *Nephrolepis flexuosa*.

Key management issues in Te Kopia Geothermal Field include fencing of 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 plants should continue to be monitored and controlled in Te Kopia Scenic Reserve, particularly wilding pines. Formal protection (e.g. Covenant) should be considered for geothermal areas outside of the 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 at Orakeikorako Geothermal Field (*c.*58.2 ha) comprises *c.*7.9% of the geothermal vegetation of Waikato Region, and is the sixth largest area

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

of geothermal vegetation in the Waikato Region. An additional 2.5 ha was mapped as geothermal water. The vegetation has been mapped over five sites with the largest areas of geothermal vegetation present at two sites; Orakeikorako (*c.*42.4 ha) and Red Hills (*c.*11.4 ha). This includes *c.*2.3 ha of nonvegetated raw-soilfield, *c.*2.7 ha of wetland, and the remainder as terrestrial geothermal vegetation. In this field, a total of *c.*52.6 ha of vegetation has been mapped as indigenous scrub and shrubland, with *c.*10.4 ha being mapped as scrub and shrubland dominated by prostrate kanuka - this is about 2.7% of the prostate kanuka dominated vegetation in the Waikato Region.

Present day geothermal features and vegetation 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) note that any development for exploitation of the Te Kopia and Ngatamariki fields would need to be investigated to establish the nature and extent of possible connections with Orakeikorako. Te Kopia is classed as a „Protected Geothermal Systems' by Waikato Regional Council[1]. Ngatamariki is a „Development Geothermal System' and Mighty River Power has consent to develop it, however early warning monitoring wells are being drilled between Ngatamariki and Orakeikorako which will be monitored for pressure changes with protocols to ensure there is no effect on Orakeikorako (K. Luketina pers. comm.)..

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 a large population of the „At Risk' fern, *Dicranopteris linearis* (classed as „At Risk' in de Lange *et al*. 2009). As well as *D. linearis*, there are a relatively high number of other at risk species including good populations of several at risk ferns; *Christella* aff. *dentata* („thermal), *Schizaea dichotoma*, *Nephrolepis flexuosa, Thelypteris confluens, and Cyclosorus interruptus*; and the orchids *Calochilus robertsonii* and *Prasophyllum pumilum* (Given 1989). Other notable geothermal 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 in the eastern side of Lake Whakamaru where it is currently rare. Recent control work of wilding pines at Orakeikorako has improved the long-term viability of this site. Pampas (*Cortaderia selloana*) should be controlled around any geothermal features, and royal fern in wetlands. 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.*1.9 ha of geothermal vegetation in the Ngatamariki Geothermal Field containing small areas of nonvegetated raw-soilfield and geothermal wetland. The

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

vegetation has been mapped over two sites. A high proportion of Ngatamariki (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 30 plants of *Cyclosorus interruptus* (a Chronically Threatened species classed as „At Risk-Declining' in de Lange *et al*. 2009) are present at this site. Other species characteristic of geothermal sites include prostrate kanuka, *Campylopus,* arrow grass, and *Lycopodiella cernua*. *Psilotum nudum* has also been recorded here (Ecroyd 1979b). A small population of *Christella* aff. *dentata* ("thermal") was recorded from Waikato River Springs in 2006 (Wildland Consultants 2006).

The Ngatamariki Geothermal Field is classified as a „Development Geothermal System' by Waikato Regional Council[1]. An 82 MW electricity generating development is planned in the Ngatamariki Geothermal Field possibly to be constructed by the end of 2013[2].

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.

Whangairorohea Geothermal Field

This geothermal field has a 10 × 15 m wide geothermal spring surrounded by sedges, reeds and exotic terrestrial vegetation, the site being about 0.1 ha in size. The few pest plants surrounding the pool should be removed (e.g. poplars (*Populus* sp.), Spanish heath (*Erica lusitanica*), blackberry, and buddleia (*Buddleja davidii*)).

Reporoa Geothermal Field

Reporoa Geothermal Field contains *c.*7.4 ha of geothermal vegetation spread over three sites. Several unmapped areas of surface activity are also present in this field (e.g. Butchers' Pool), but are not thought to contain any geothermal vegetation. The mapped vegetation is made up of *c.*4.4 ha of terrestrial vegetation, *c.*0.3 ha of emergent wetland, and *c.*2.6 ha of nonvegetated raw-soilfield.

The atmospheric influence of the Golden Springs enables the occurrence of the fern *Christella* aff. *dentata* ("thermal") (classed as „At Risk' in de Lange *et al*. 2009), which occurs only 14 geothermal sites in New Zealand. There is also a small population of prostrate kanuka (classed as „At Risk' in de Lange *et al*. 2009) and some *Campylopus capillaceus,* as well as areas of manuka/mingimingi shrubland, and arrow grass herbfield.

Parts of the site at Golden Springs and Wharepapa Road are unfenced and grazed by stock, and values of the sites would improve if the sites were fenced. Geothermal features have been impacted by drainage at all sites. It is recommended that no

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

[2] http://www.nzgeothermal.org.nz/elec_geo.html: Accessed 24 July 2011.

further drainage of geothermal wetlands and features is undertaken at any of these sites. 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 18.5 ha of geothermal vegetation which is *c.*2.5% of the geothermal vegetation in the Waikato Region. The vegetation here comprises *c.*5.3 ha of nonvegetated raw-soilfield, and *c.*13.16 of terrestrial geothermal vegetation. About 10.0 ha is dominated by prostrate kanuka scrub and shrubland, *c.*2.6% of the prostrate kanuka dominant vegetation of the Waikato Region. The vegetation has been mapped over two sites on each side of the Waikato River.

The Ohaaki Geothermal Field is classified as a „Development Geothermal System' by Waikato Regional Council[1]. From 1989, Ohaaki Geothermal Power Station supplied electricity to the national grid, and this exploitation has affected the geothermal features of both sites examined in the current survey. All geothermally influenced pools in this area are now dry and ground temperatures have decreased in places; however, in others they have increased resulting in an overall increase in the extent of geothermal vegetation (Merrett & Burns 1998a). However Merrett *et al.* (2003) found no apparent evidence of any negative impact 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, and the spread of wilding pines from surrounding plantation into geothermal sites. Overall the values of these sites could be enhanced through restoration including pest plant control and appropriate planting to enhance and maintain the ecological values present.

Small areas of relatively undisturbed geothermal vegetation dominated by prostrate kanuka are present. Scattered areas of monoao (*Dracophyllum subulatum*) is 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.*24 sites in New Zealand). Arrow grass (Burns 1997a) and *Psiloum nudum* (Merrett *et al*. 2003) have been recorded in this geothermal field.

Wairakei-Tauhara Geothermal Field

The Wairakei-Tauhara Geothermal contains *c.*150.7 ha of geothermal vegetation, which is *c.*20.5% of the geothermal vegetation in the Waikato Region. The vegetation has been mapped over 16 sites with the largest sites being Craters of the Moon (44.5 ha), Te Kiri O Hine Kai Stream Catchment/Wairoa Hill (40.09 ha), Broadlands Road (29.76 ha) and Crown Road (17.48 ha). A total of *c.*136.3 ha was mapped as terrestrial geothermal vegetation and *c.*14.42 ha of nonvegetated raw-soilfield. An area of *c.*122.2 ha was mapped as scrub and shrubland dominated by prostrate kanuka,

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

which represents 29.0% of the prostate kanuka dominant vegetation of the Waikato Region.

Geothermal features associated with the Wairakei-Tauhara Geothermal Field occur in both the Atiamuri and Taupo 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, and in shallow aquifers and 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 is continuing to change. Geothermal vegetation had decreased and/or declined in quality at most sites (e.g. Upper Wairakei Stream (Geyser Valley)), however this has been partly compensated by an increase of geothermal vegetation at the Broadlands Road site (Burns *et al.* 1995). This reflects a similar increase at Craters of the Moon, which has occurred due to draw-off from the power station (Burns 1996).

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

- The crecent loss of vegetation to both road and industrial development, particularly sites near Taupo Township at Crown Road and Broadlands Road. The sites near Taupo are also particularly vulnerable to fire, with a fire at Crown Road in 2002.

- Grazing occurs at several sites in Wairakei Geothermal Field (e.g. parts of Te Rautehuia, and Te Rautehuia Stream). It is recommended that these areas are fenced to exclude stock.

- Pine plantation is present to the margins of many sites in this field. These provide a source of wilding pines, so all sites should be monitored for their spread. Pines should be felled away from geothermal areas when harvesting, and a buffer of at least 10 m should be established around geothermal sites. Other pest plants 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 kanuka (classed as „At Risk' in de Lange *et al*. 2009). Good populations of two ferns, *Cyclosorus interruptus* (a chronically threatened species classed as „At Risk-Declining' in de Lange *et al*. 2009) and *Christella* aff. *dentata* ("thermal") (classed as „At Risk' in de Lange *et al*. 2009) 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 between Te Kiri O Hine Kai Stream Catchment/Wairoa Hill, Te Rautehuia Stream, and Craters of the Moon. Other taxa present in the Wairakei-

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

Tauhara Geothermal field include *Hypolepis dicksonioides, Campylopus capillaceus*, *Psilotum nudum, Lycopodiella cernua,* and rock fern (*Cheilanthes sieberi*). *Asplenium flabellifolium* and *Fimbristylis velata* have also been recorded from the site in the past (Given 1989a), but not in recent surveys.

Rotokawa Geothermal Field

The Rotokawa Geothermal Field contains *c.*103.7 ha of geothermal vegetation and habitats, which is *c.*23.4% of the geothermal vegetation in the Waikato Region. An additional 67.9 ha has been mapped as geothermal water; specifically Lake Rotokawa. Of the *c.*103.7 ha, *c.*16.4 ha of this field 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 (69.4 ha) and Rotokawa North (34.3 ha). The vegetation between parts of the two sites is continuous with the boundaries between them being somewhat arbitrary. Most of the Lake Rotokawa site is administered by the Department of Conservation as Lake Rotokawa Conservation Area. An area of *c.*64.9 ha was mapped as scrub and shrubland dominated by prostrate kanuka, which represents 17.1% of the prostate kanuka dominant vegetation of 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 plantations which dominate the northern end of this field (Cave *et al.* 1993). Considerable control of pest plants 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 kanuka scrub and shrubland is a key feature of the geothermal field. Large areas of manuka scrub and shrubland are also present. Small populations of *Nephrolepis flexuosa* and *Dicanopteris linearis* were recorded near one spring in 2004. A relatively large population of *Calochilus robertsonii* was recorded from the Lake Rotokawa site in November 2006 (Bycroft 2007). Within Lake Rotokawa, two species of flagellate algae (*Euglena anabaena* and *Chlamydomonas* sp.), a leech (*Helobdella* sp.), and larvae of *Chironomus zealandicus*, a chironomid 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, and, associated with this, larvae of the thermal mosquito, *Culex rotoruae* and the thermal fly, *Ephydrella thermarum* (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 35 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

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems: Accessed 24 July 2011.

world[1]. The impacts of this energy extraction on the vegetation and features in this geothermal field should be monitored to assist with future management of this field.

Horomatangi Geothermal Field

This geothermal field occurs on the bed of Lake Taupo. It comprises sinter-depositing springs on the bed of the lake, sinter tubes and associated specialised ecosystems[2]. The Horomatangi Geothermal Field is classified as a „Protected Geothermal System' by the Waikato Regional Council[1]. As this Geothermal Field is under Lake Taupo, no terrestrial or emergent wetland geothermal vegetation will be present in this geothermal field, 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.*59.5 ha of geothermal vegetation, which is *c.*8.1% of the geothermal vegetation in the Waikato Region. An additional *c.*3.5 ha has been mapped as geothermal water. This field contains an estimated 41.4 ha of geothermal wetland habitat; about 50% of the 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 it is of considerable ecological significance. Most of the area mapped as geothermal wetland was present at Tokaanu Lakeshore Wetland (*c.*39.1 ha). A small area was mapped as nonvegetated raw-soilfield (0.4 ha). About 10.8 ha was mapped as prostrate kanuka dominant scrub and shrubland, which is about 2.8% of this vegetation type in the Waikato Region.

Geothermal activity at Tokaanu has changed 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 Taupo (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* (an „At Risk' species in de Lange *et al*. 2009), occurs at this site. *Schizaea dichotoma* (an „At Risk' species in de Lange *et al*. 2009) is also present and there are historical records of the fern *Christella* aff. *dentata* ("thermal") and *Nephrolepis flexuosa* (both classed as „At Risk' in de Lange *et al*. 2009) from the site (Given 1995, de Lange *et al.* 2005). Oioi occurs at site Tokaanu Thermal Park, outside its normal coastal distribution. Tokaanu Lakeshore Wetland contains an extensive area of wetland, with steam seen rising through raupo at regular intervals throughout much of the mapped site. Most of the prostrate kanuka dominant vegetation occurs at Hipaua, however while it is presumed to be of high quality, there has been no botanical survey here since 1996

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1 http://www.nzgeothermal.org.nz/nz_geo_fields.html#Rotokawa: Accessed 24 July 2011. http://www.nzgeothermal .org.nz/elec_geo.html

2 http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/accessed 24 July 2011.

(Given 1996). Hipaua was ranked highly by Given due to a high diversity of edaphic factors, and for the overall integrity and maintenance of processes.

Tongariro Geothermal Field

Mt Tongariro has four areas of geothermal vegetation covering *c.*25.1 ha, or 3.4% of the geothermal vegetation in the Waikato Region. One site was not surveyed in this study (Ketetahi) and its analysis was based on aerial photographs and descriptions of Given (1995). The other three sites (Red Crater, Emerald Lakes, and Te Maari Craters) were included in this project for the first time. An estimated *c.*25.1 ha of geothermal vegetation occurs in this geothermal field, the only subalpine geothermal vegetation mapped in this study. 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. 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 Taupo Districts with *c.*51.1% in the Rotorua District and 48.9% in the Taupo District (see Table 8).

Table 8: Area of geothermal vegetation (includes terrestrial vegetation, nonvegetated raw-soilfield and wetland, but not geothermal water) in the Waikato Region in the Rotorua and Taupo Districts.

Administrative District	Area (ha)[1]	Area (%)
Rotorua	374.9	51.1
Taupo	358.6	48.9
Total	**733.5**	**100**

6.3 Assessment by Ecological District

The majority (85.9%) of geothermal vegetation in the Waikato Region occurs in the Atiamuri Ecological District (see Table 9). Taupo Ecological District and Tongariro Ecological District contain *c.*8.9% and 5.4% of the vegetation in the region respectively.

[1] All areas (ha) given refer to the area of geothermal vegetation, not the area of the site.

Table 9: Area of geothermal vegetation (includes terrestrial vegetation, nonvegetated raw-soilfield and wetland, but not geothermal water) and geothermal water in the Waikato Region of the Atiamuri, Rotorua Lakes, Taupō, and Tongariro Ecological Districts.

Ecological District	Hydroclass/Vegetation Grouping					Total (ha)
	Geothermal Water (ha)	Geothermal Vegetation			Total Geothermal Vegetation (ha)	
		Nonvegetated Raw-Soilfield (ha)	Terrestrial Vegetation (ha)	Emergent Wetland (ha)		
Atiamuri	101.4	62.5	528.1	39.7	630.6	731.8
Rotorua Lakes	0.5	0.5	0.1	0.0	0.6	1.0
Taupo	3.5	3.3	21.1	41.3	65.7	69.2
Tongariro	0.9	25.5	11.2	0.1	36.7	37.6
Grand Total	**106.2**	**91.8**	**560.5**	**81.1**	**733.66**	**839.7**

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 Taupo Ecological District (Wildland Consultants 2004). There has probably been little change in the extent of geothermal vegetation in the Tongariro Ecological District.

7. CHANGES IN EXTENT OF GEOTHERMAL SITES BETWEEN 1940s/1950s AND 2007

Historical photos of 52 sites held by the Waikato Regional Council library were studied. 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 or 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 able to be assessed (Table 10). 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 for e.g. roading, pasture, and spread of weeds.

Table 10: Summary 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.
Te Kopia Northwest	TKV03	No historical photos.
Te Kopia West Mud Pools	TKV04	No historical photos.
Te Kopia Red Stream	TKV05	No historical photos.
Mangamingi Station	TKV06	No historical photos.
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.

[1] Ordered by geothermal field.

Site Name	Site Number	Type of Change
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 Urupa 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.

8. CHANGES IN EXTENT OF GEOTHERMAL SITES (2002 AND 2007 AERIAL PHOTOS)

The mapped extent of geothermal vegetation at 37 sites changed by less than 1 ha as a result of better quality aerial photographs and field survey. Sites where real changes to the extent and quality of vegetation were anticipated since the last field visit were re-visited in the field where possible. Also, additions to sites were made based on new information about areas of geothermal vegetation at particular sites. Sites in this category are Waiotapu South, Waiotapu North, Maungakakaramea (Rainbow Mountain), and Waipapa Stream. The changes in extent of mapped geothermal vegetation at Orakeikorako and Te Kopia were largely as a result of better quality aerial photographs.

There was a real increase in extent of geothermal vegetation at one site (Waikite Valley) while there was a real decline in the extent of geothermal vegetation at another (Crown Road). Restoration works undertaken in one of the geothermal wetlands at Waikite Valley included increasing water table levels in this wetland and its surrounds (drains previously dug through this wetland had resulted in a lowered water table in this wetland). Recent restoration has resulted in a significant increase in the area of geothermal habitat at this site, which is now *c.*7 ha larger than the 2004 study. At Crown Road *c.*1.5 ha of geothermal vegetation was destroyed during land development for industrial use, and roading developments. Reasons for changes to the extent of geothermal vegetation are provided in Table 1, with more detailed notes for each site in Appendix 1.

Table 11: Changes in extent of each site between 2002 and 2007 aerial photos (as mapped in Wildland Consultants 2004, 2006, 2007a & b and current report). Reasons for change are noted in comments column. Other observed changes that have occurred at these sites since 2000 are also noted.

Site Name	Site Number	Ecological District	Area of Geothermal Vegetation Mapped (ha)		Overall Real Change	Comments
			2004-2007	2011		
Horohoro Geothermal Field						
Horohoro	HHV01	Atiamuri	<0.1 (Wildland Consultants 2004)	<0.1	No change	Not resurveyed in 2011, assessment based on 2004 study and viewing 2007 aerial photographs. No change likely.
		Total	**<0.1**	**<0.1**		
Waikite Geothermal Field						
Waikite Valley	WAV01	Atiamuri	17.6 (Wildland Consultants 2007b)	24.6	Increase	Restoration works have taken place in one of the geothermal wetlands at this site. This included increasing water table levels in this wetland and its surrounds. Drains dug through this wetland had lowered the water table in this wetland in the past. This has significantly increased the area of geothermal habitat at this site.
Northern Paeroa Range	WAV02	Atiamuri	Not surveyed	0.3	Unlikely	Not previously included in study. Significant change unlikely.
		Total		**24.9**		
Waiotapu Geothermal Field						
Maungaongaonga	WTV01	Atiamuri	9.1 (Wildland Consultants 2004)	9.1	No change	No field work was undertaken for this site in 2010-11. Site appeared similar in 2007 aerial photographs to the area mapped in Wildland Consultants 2004.
Ngapouri	WTV02	Atiamuri	3.1 (Wildland Consultants 2004)	3.1	No change	No field work was undertaken for this site in 2010-11. Site appeared similar in 2007 aerial photographs to the area mapped in Wildland Consultants 2004.
Waiotapu North	WTV03	Atiamuri	40.7 (Wildland Consultants 2004)	45.8	No change	Change related to additional areas of geothermal habitat discovered in 2010 survey, not a real change in the extent of geothermal vegetation and habitat at this site between the 2004 and 2010-11 studies.
Maungakakaramea (Rainbow Mountain)	WTV04	Atiamuri/ Rotorua Lakes	41.7 (Wildland Consultants 2004)	50.6	No change	Change related to boundaries being better defined on better quality 2007 aerial photographs, and new geothermal habitat found during field survey. The authors do not consider that the extent of geothermal vegetation has increased at this site between the 2004 and 2011 surveys.

Site Name	Site Number	Ecological District	Area of Geothermal Vegetation Mapped (ha)		Overall Real Change	Comments
			2004-2007	2011		
Waiotapu South	WTV05	Atiamuri	69.5 (Wildland Consultants 2004)	112.4	No change	Extensive areas of geothermal wetland vegetation were identified in the 2010-11 survey and added to this site. Additional areas of geothermal vegetation were discovered near stream margins. However, the authors of this report do not consider that the overall extent of vegetation at this site has increased between the 2004 and 2010-11 studies.
		Total	**164.1**	**221.0**		
Mokai Geothermal Field						
Whakamaru	MKV01	Atiamuri	Not surveyed	<0.1	Unlikely	Not previously included in study. Significant change unlikely.
Waipapa Stream	MKV02	Atiamuri	0.7 (Wildland Consultants 2004a)	1.1	No change	An additional area of geothermal vegetation was identified in the 2011 field survey. The authors of this report do not consider that the overall extent of vegetation at this site has increased between the 2004 and 2010-11 studies.
Tirohanga Road	MKV03	Atiamuri	0.4 (Wildland Consultants 2007a)	0.2	Decrease	There has been some vegetation clearance and adjustment of boundaries based on better quality aerial photographs.
Paerata Road	MKV04	Atiamuri	1.3 (Wildland Consultants 2004)	1.7	No change.	Change related to boundaries being better defined on 2007 aerial photographs, not a real change in vegetation extent.
		Total	**3.4**	**2.9**		
Atiamuri Geothermal Field						
Upper Atiamuri West	ATV01	Atiamuri	<0.1 (Wildland Consultants 2007a)	<0.1	No change	No field assessment in 2010-11. No change likely.
Whangapoa Springs	ATV02	Atiamuri	0.1 (Wildland Consultants 2004)	0.1	No change	While the vegetation surrounding the site has improved in quality, it has not changed in overall extent.
Matapan Road	ATV03	Atiamuri	Not surveyed	<0.1	Unlikely	Not previously included in study. Significant change unlikely.
		Total	**0.1**	**0.1**		
Te Kopia Geothermal Field						
Te Kopia	TKV01	Atiamuri	56.4 (Wildland Consultants 2004)	58.8	No change	Site not field surveyed for 2010-11 study. Slight change in hectares is based on remapping of vegetation boundaries, which are more clearly identified on 2007 aerial photographs, than those used in Wildland Consultants 2004.

Site Name	Site Number	Ecological District	Area of Geothermal Vegetation Mapped (ha)		Overall Real Change	Comments
			2004-2007	2011		
Murphy's Springs	TKV02	Atiamuri	Not surveyed	0.2	Unlikely	Not previously included in study. Significant change unlikely.
Te Kopia Northwest	TKV03	Atiamuri	Not surveyed	<0.1	Unlikely	Not previously included in study. Significant change unlikely.
Te Kopia West Mud Pools	TKV04	Atiamuri	Not surveyed	<0.1	Unlikely	Not previously included in study. Significant change unlikely.
Te Kopia Red Stream	TKV05	Atiamuri	Not surveyed	0.2	Unlikely	Not previously included in study. Significant change unlikely.
Mangamingi Station	TKV06	Atiamuri	Not surveyed	0.5	Unlikely	Not previously included in study. Significant change unlikely.
		Total	**56.4**	**59.8**		
Orakeikorako Geothermal Field						
Waihunuhunu	OKV01	Atiamuri	3.0 (Wildland Consultants 2007b)	3.0	No change	Not resurveyed in 2011. Assessment based on Wildland Consultants 2007b and revising the site boundaries using 2007 aerial photographs. No change likely.
Akatarewa Stream	OKV02	Atiamuri	1.4 (Wildland Consultants 2007b)	1.4	No change	Not resurveyed in 2011. Assessment based on Wildland Consultants 2007b and revising the site boundaries using 2007 aerial photographs. No change likely.
Orakeikorako	OKV03	Atiamuri	39.2 (Wildland Consultants 2007b)	42.4	No change	Additional vegetation identified based on better detail on 2007 aerial photographs, and some additional geothermal vegetation found in 2010-11 field survey. The authors do not consider that there has been any change in the extent of geothermal vegetation and habitat at this site between 2004 and 2011.
Red Hills	OKV04	Atiamuri	11.5 (Wildland Consultants 2007b)	11.4	No change	No field survey undertaken in 2010-11. Slight refinement of boundaries based on 2007 aerial photographs.
Akatarewa East	OKV05	Atiamuri	Not surveyed	<0.1	Unlikely	Not previously included in study. Significant change unlikely.
		Total	**57.4**	**58.2**		
Ngatamariki Geothermal Field						
Waikato River Springs	NMV01	Atiamuri	<0.1 (Wildland Consultants 2006)	0.4	No change	Additional geothermal vegetation and habitat found in 2011 field survey. The authors do not consider this to be an increase in the extent of geothermal vegetation and habitat at this site. Additional areas may be found in the future when lower river levels permit full access to the site.
Ngatamariki	NMV02	Atiamuri	1.4 (Wildland Consultants 2007b)	1.5	No change	Minor change in boundaries based on remapping of site boundaries based on 2007 aerial photographs and field survey in 2011. Overall the authors consider that there has been no change in the extent of geothermal vegetation and habitat at this site.
		Total	**1.4**	**1.9**		

Site Name	Site Number	Ecological District	Area of Geothermal Vegetation Mapped (ha)		Overall Real Change	Comments
			2004-2007	2011		
Whangairorohea Geothermal Field						
Whangairorohea	WGV01	Atiamuri	Not surveyed	<0.1	Unlikely	Not previously included in study. Significant change unlikely.
		Total	**<0.1**	**<0.1**		
Reporoa Geothermal Field						
Longview Road	RPV01	Atiamuri	3.4 (Wildland Consultants 2004)	3.4	No change	Site assessment based on 2007 aerial photographs, site not field surveyed between 2010-2011.
Wharepapa Road	RPV02	Atiamuri	3.4 (Wildland Consultants 2004)	3.3	No change	Not resurveyed in 2011, assessment based on 2004 study and viewing 2007 aerial photographs. No change likely. Slight boundary changes are based on remapping site boundaries, but are not considered as real change in extent of geothermal vegetation.
Golden Springs	RPV03	Atiamuri	0.5 (Wildland Consultants 2007b)	0.5	No change	Not resurveyed in 2011, assessment based on Wildland Consultants 2007b and viewing 2007 aerial photographs. No change likely.
		Total	**7.3**	**7.4**		
Ohaaki Geothermal Field						
Ohaaki Steamfield West	OHV01	Atiamuri	10.5 (Wildland Consultants 2004)	11.7	No change	Slight change to site size is related to more accurate mapping of site boundaries on better quality 2007 aerial photographs, compared to aerials available for Wildland Consultants 2004 study.
Ohaaki Steamfield East	OHV02	Atiamuri	6.0 (Wildland Consultants 2004)	6.8	No change	Slight change to site size is related to more accurate mapping of site boundaries on better quality 2007 aerial photographs, compared to aerials available for Wildland Consultants 2004 study.
		Total	**16.5**	**18.5**		
Wairakei-Tauhara Geothermal Field						
Otumuheke Stream	THV01	Atiamuri	2.0 (Wildland Consultants 2004)	2.3	No change	Slight change to site based on remapping site boundaries, and a small additional area of geothermal vegetation and habitat found in the 2010 field survey. The authors do not consider this to be real change in the extent of geothermal vegetation and habitat at this site.
Spa Thermal Park	THV03	Atiamuri	0.1 (Wildland Consultants 2006)	0.1	No change	Slight change to site based on remapping site boundaries, not a real change in the extent of geothermal vegetation and habitat at this site.

Site Name	Site Number	Ecological District	Area of Geothermal Vegetation Mapped (ha)		Overall Real Change	Comments
			2004-2007	2011		
Broadlands Road	THV04	Atiamuri	30.3 (Wildland Consultants 2006)	29.8	No change	Slight change to site based on remapping site boundaries, not a real change in the extent of geothermal vegetation and habitat at this site.
Crown Park	THV05	Taupo	0.7 (Wildland Consultants 2006)	0.7	No change	Not resurveyed in 2011, assessment based on Wildland Consultants 2006 and viewing 2007 aerial photographs.
Crown Road	THV06	Taupo	19.0 (Wildland Consultants 2004)	17.5	Decrease	Vegetation has decreased following land development for industrial use, and roading developments.
Waipahihi Valley	THV07	Taupo	0.2 (Wildland Consultants 2004)	0.3	No change	Minor changes vegetation boundaries following restoration works, and easier access to parts of site. Overall no change in extent of geothermal vegetation and habitats at this site over these timeframes.
Te Rautehuia	WKV01	Atiamuri	7 (Wildland Consultants 2006)	7.7	No change	Slight change to site based on remapping site boundaries, not a real change in the extent of geothermal vegetation and habitat at this site.
Te Rautehuia Stream	WKV02	Atiamuri	2.2 (Wildland Consultants 2006)	2.1	No change	Slight change to site based on remapping site boundaries, not a real change in the extent of geothermal vegetation and habitat at this site.
Upper Wairakei Stream (Geyser Valley)	WKV03	Atiamuri	4.6 (Wildland Consultants 2004)	4.7	No change	Slight change to site based on remapping site boundaries, not a real change in the extent of geothermal vegetation and habitat at this site.
Wairakei Borefield	WKV04	Atiamuri	<0.1 (Wildland Consultants 2007a)	<0.1	No change	Not resurveyed in 2011, assessment based on Wildland Consultants 2007a study and viewing 2007 aerial photographs. Very small site.
Te Kiri O Hine Kai Stream Catchment/ Wairoa Hill	WKV05	Atiamuri	40.0 (Wildland Consultants 2007b)	40.1	No change	Slight change to site based on remapping site boundaries, not a real change in extent of geothermal vegetation at this site.

Site Name	Site Number	Ecological District	Area of Geothermal Vegetation Mapped (ha)		Overall Real Change	Comments
			2004-2007	2011		
Lower Wairakei Stream	WKV06	Atiamuri	<0.1 (Wildland Consultants 2007a)	<0.1	No change	Not resurveyed in 2011, assessment based on Wildland Consultants 2007b and viewing 2007 aerial photographs. No change likely.
Karapiti Forest	WKV07	Atiamuri	0.4 (Wildland Consultants 2004)	0.6	No change	Not resurveyed in 2011, assessment based on 2011 field survey and viewing 2007 aerial photographs. Minor change is based on remapping site rather than real site change.
Hall of Fame Stream	WKV08	Atiamuri	0.1 (Wildland Consultants 2004)	0.1	Unlikely	Not resurveyed in 2011, assessment based on Wildland Consultants 2007b and viewing 2007 aerial photographs. No change likely.
Waipouwerawera Stream/Tukairangi	WKV09	Atiamuri	0.7 (Wildland Consultants 2004)	0.1	No change	Minor changes to site boundaries are based on both field survey and better quality aerial photographs. No real change to the extent of the site between field surveys.
Craters of the Moon	WKV10	Atiamuri	45.7 (Wildland Consultants 2004)	44.6	No change	Changes based on viewing 2007 aerial photographs, are the result of boundaries being better defined on better quality aerial photographs, rather than any real change in the extent of geothermal vegetation at these sites.
		Total	**153.0**	**150.7**		
Rotokawa Geothermal Field						
Rotokawa North	RKV01	Atiamuri	33.8 (Wildland Consultants 2004)	34.3	No change	Small units were added to the site from the authors' knowledge of the site, and based on better quality aerial 2007 aerial photographs. No real change identified in extent of geothermal vegetation of this site based on a desktop exercise.
Lake Rotokawa	RKV02	Atiamuri	68.7 (Wildland Consultants 2004)	69.4	No change	Site change based on realigning boundaries on better quality aerial photographs, rather than real site change in the extent of geothermal vegetation. Change assessed on basis of analysis of aerial photograph, not onfield assessment.
		Total	**102.5**	**103.7**		
Tokaanu-Waihi-Hipaua Geothermal Field						
Hipaua	TOV02	Tongariro	8.7 (Wildland Consultants 2004)	11.3	No change	Site not field assessed in 2004-7, or 2010-11. Site boundary changes are based on better quality site photographs, rather than real site change.
Tokaanu Lake Shore Wetland	TOV05	Tongariro/ Taupo	Not surveyed	39.1	No change	Not previously included in study, no real change considered likely.

Site Name	Site Number	Ecological District	Area of Geothermal Vegetation Mapped (ha)		Overall Real Change	Comments
			2004-2007	2011		
Maunganamu West	TOV07	Tongariro/ Taupo	0.6 (Wildland Consultants 2007a)	0.6	No change	Not reassessed in 2010-11. No evidence of real change.
Tokaanu Thermal Park	TOV08	Tongariro	7.8 (Wildland Consultants 2007a)	7.6	No change	Change related to better delineation on better quality aerial photographs. No field survey undertaken for 2010-11 study.
Tokaanu Urupa Mud Pools	TOV09	Taupo	<0.1 (Wildland Consultants 2007a)	<0.1	No change	Not resurveyed in 2011, assessment based on 2007a study and viewing 2007 aerial photographs. No change likely. Very small site.
Maunganamu East	TOV10	Taupo	<0.1 (Wildland Consultants 2007a)	<0.1	No change	Not resurveyed in 2011, assessment based on 2007a study and viewing 2007 aerial photographs. No change likely. Very small site.
Maunganamu North Wetland	TOV11	Taupo	Not surveyed	0.9	No change	Not previously included in study, but no change is considered likely.
Tokaanu Tailrace Canal	TOV14	Tongariro	<0.1 (Wildland Consultants 2007a)	<0.1	No change	Not resurveyed in 2011, assessment based on 2007a study and viewing 2007 aerial photographs. No change likely. Very small site.
		Total	**17.1**	**59.5**		
Tongariro Geothermal Field						
Te Maari Craters	TGV01	Tongariro	Not surveyed	4.9	Unlikely	Not previously included in study. Significant change unlikely.
Ketetahi	TGV02	Tongariro	Not surveyed	8.2	Unlikely	Not previously included in study. Significant change unlikely.
Emerald Lakes	TGV03	Tongariro	Not surveyed	11.3	Unlikely	Not previously included in study. Significant change unlikely.
Red Crater	TGV04	Tongariro	Not surveyed	0.7	Unlikely	Not previously included in study. Significant change unlikely.
		Total	**N/A**	**25.1**		
Grand Total			**510**	**734**		

9. NATURAL DYNAMICS

Many geothermal sites are very active and dynamic, and their habitats are therefore somewhat unstable. 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, or 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.

10. 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 can 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 (e.g. Karapiti), or decreases in temperature which result in the disappearance of species. Extraction of energy can have the potential to alter underground geothermal systems, and can both change the quality of these systems and the distribution and composition of species in vegetation of surface geothermal manifestations. 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 are now either completely absent or much reduced in abundance and distribution here. The cooler ground has also allowed the invasion of adventive weeds. However, in nearby Karapiti, a ten-fold increase in heat output has occurred following development of the Wairakei field (Huser 1989); botanical values for some species have been enhanced with considerable development of geothermal vegetation and large populations of plants characteristic of geothermal sites (Given 1989b).

    - Large scale energy development has been undertaken in the following fields; 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 uses 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 undertaken in these geothermal resources to date. A

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/: Accessed 25 July 2011.

total of *c.*277.7 ha of geothermal vegetation was mapped in Development Fields, 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 takes that will not damage surface features[1]. A total of *c.*59.6 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 takes and those undertaken for scientific research into the system are allowed[1]. A total of 7.3 ha of geothermal vegetation was mapped in this Geothermal Field, which represents *c.*1% of the geothermal vegetation in the Waikato Region.

- Six Geothermal Fields are protected from development and classified as protected geothermal systems by Waikato Regional Council. These are Horomatangi, Orakeikorako, Te Kopia, Tongariro, Waikite and Waiotapu 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 by unsuitable land uses. A total of *c.*389.0 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, especially to popular tourist sites such as Waiotapu, Wairakei, and Maungakakaramea (Rainbow Mountain), Craters of the Moon, and Upper Wairakei Stream (Geyser Valley, and Orakeikorako). Some sites such as Craters of the Moon have produced a plan to reduce the impacts of tourists to these sites, by discouraging visitors from walking off formed tracks. Geothermal sites are particularly vulnerable to trampling damage, particularly populations of threatened ferns, and prostrate kanuka 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.

  Vegetation and features at Crown Road have been destroyed for motorcross track construction.

[1] http://www.waikatoregion.govt.nz/environmental-information/Geothermal-resources/Classifying-geothermal-systems/: Accessed 25 July 2011.

Mountain bikers should be discouraged from riding in vegetation and features at Craters of the Moon and other Wairakei sites. This should also be the case if a mountain bike track is constructed at Maungakakaramea (Rainbow Mountain).

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

- *Pest Plants*. Adventive plants, particularly blackberry and wilding pines, are the most obvious threat to most sites. 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 (*Teline monspessulana*), tree lucerne (*Chamaecytisus palmensis*), Himalayan honeysuckle (*Leycesteria formosa*), broom (*Cytisus scoparius*), Spanish heath, *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. 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. The protection of any rare and threatened species present is important, e.g. *Christella* aff. *dentata* ("thermal") at Waikite Valley. Each site larger than 10 hectares (apart from those in Tongariro National Park) ideally should have a management plant for pest plants to monitor and control pest plants at these sites.

- *Domestic Livestock Damage*. Where livestock have access to geothermal vegetation they are a major threat to its viability, and stock-proof fencing is a high priority, e.g. the north-east area of Waikite Valley. 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 were noted to have caused considerable damage to some units by trampling in prostrate kanuka shrubland at Te Rautehuia Stream in 2006.

- *Plantation Forestry and Shelterbelts.* A number of geothermal sites in the Waikato Region are adjacent to plantation forest and wilding pines are invading the geothermal vegetation, particularly around the margins. For example seven species of wilding pines are known from Maungakakaramea (Rainbow Mountain), and earlier reports noted it covering 6-20% of the geothermal vegetation. However considerable pine control work has been undertaken at this site by the Department of Conservation. Pine control has also taken place at neighbouring Waiotapu, Te Kopia, Orakeikorako and several Wairakei sites. Where geothermal areas adjoin plantations, management and harvesting operations need to be undertaken with care to avoid damaging the geothermal vegetation or associated buffer vegetation. Such damage can allow 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.

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

- *Introduced Pest Animals*. Animal pests such as possums, deer and pigs 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 kanuka and monoao and great care needs to be taken with fire in the vicinity of geothermal sites. Fire has been a problem at several sites in the Waikato Region including Crown Road. Smoking should be discouraged from 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). Only locally-sourced plants should be used, say from within the same ecological region or district.

- *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/Roading Development*: Sites near urban areas have been destroyed by replacing vegetation for industrial, residential and roading developments. This has been particularly noted at sites near Taupo where the new State Highway 1 bypass around Taupo has passed through the Crown Road site, and areas to the south of the site have recently been converted to industrial land use.

11. FUTURE MANAGEMENT

11.1 Regulatory controls

All areas of geothermal vegetation ranked as being significant are worthy of formal protection and management to protect them from the threats listed 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.

11.2 Buffers and connections

Protective buffers enhance the viability of natural areas and are an important management issue. They buffer sensitive ecosystems from external modifying influences such as wind and weed invasion. Geothermal habitats were previously surrounded by larger areas of non-geothermal indigenous vegetation, which also previously 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.

The presence of surface geothermal activity can fluctuate at a particular location and across the landscape. A good sized buffer is desirable around many geothermal sites to allow for this variability.

11.3 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.

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. Some reserves (or parts of them) may also warrant an upgraded classification to reflect their relative significance for nature conservation.

11.4 Ecological restoration

Ecological restoration of degraded geothermal sites would enhance the conservation values and viability of many areas - particularly the smaller areas.

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance of the following people during the project.

- Landowners for allowing access to study areas and providing useful information.
- Katherine Luketina (Waikato Regional Council) for organising the project, and providing aerial photography and logistical support.
- Paul Cashmore and Pete Corson (Department of Conservation, Rotorua Field Centre) for providing background information on existing and new geothermal sites. Paul Cashmore, Brendon Christensen, and Jolene Kelly (Department of Conservation, Rotorua Field

Centre), and Angela Padget and Harry Keys (Department of Conservation, Tongariro-Taupo Conservancy) provided assistance for permits to undertake this study.

- JoAnne Evelyn (Waikato Regional Council) for assistance with finding historical aerial photographs.

- Manfred Hochstein (University of Auckland), Juliet Newson, and Julian McDowell (Independent Consultants) for geophysical assessment of selected sites.

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SITE DESCRIPTIONS

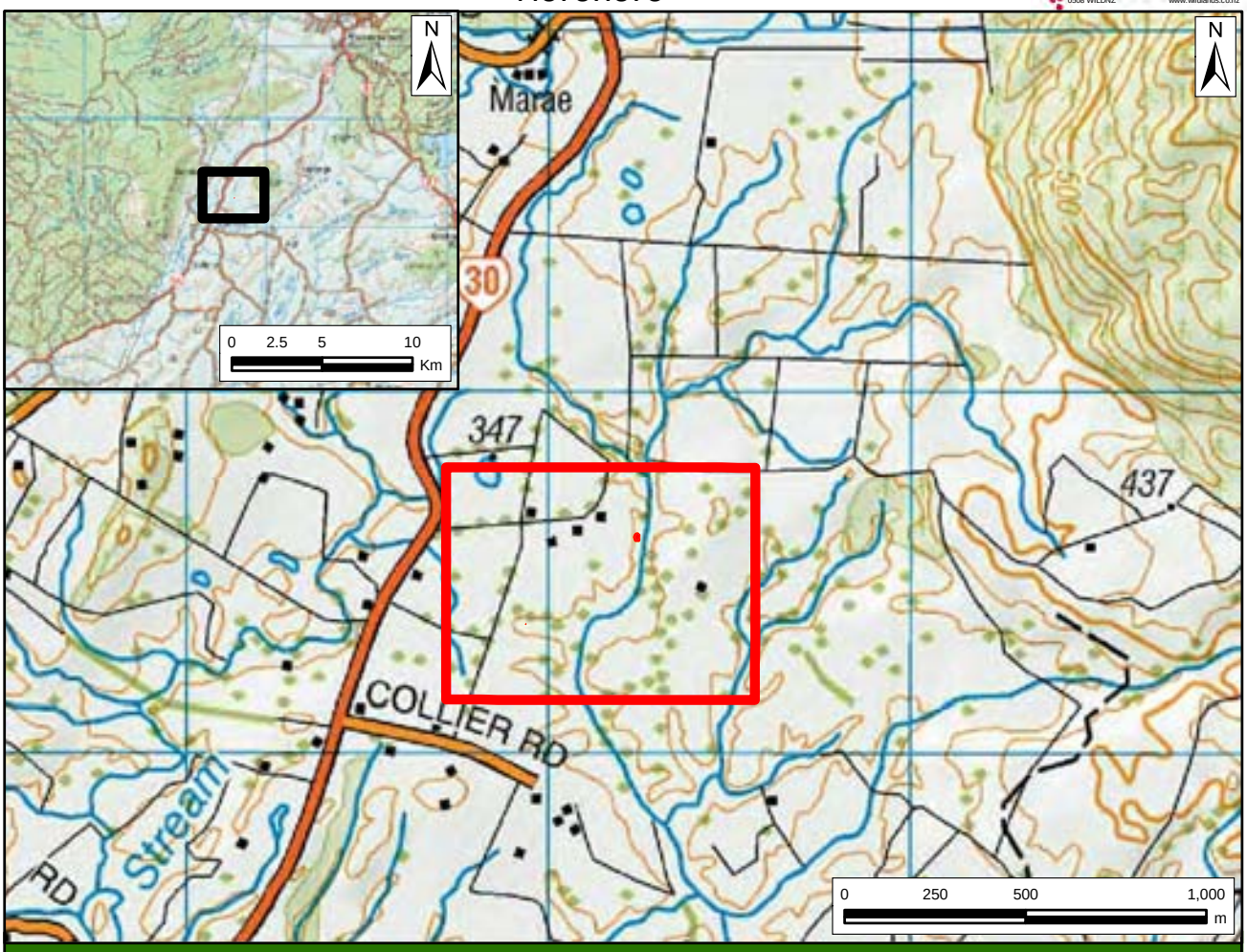
1.1 HOROHORO GEOTHERMAL FIELD

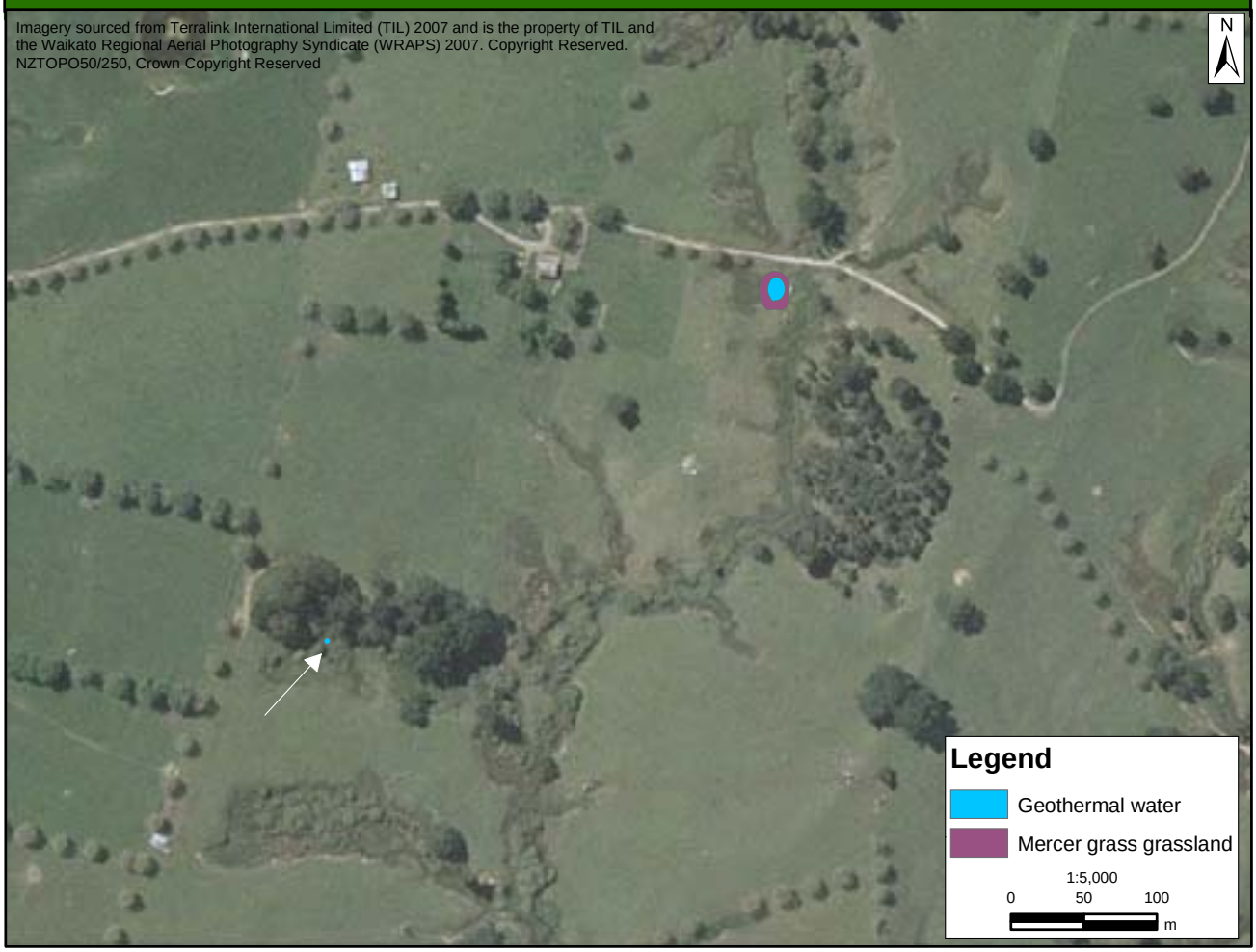
List of Geothermal Sites

HHV01 Horohoro

HHV01

Horohoro





HOROHORO

Site Number: HHV01[1]
Grid Reference: NZTopo50 BF37 782 616
GPS Reference: NZTM E1878243 N5761598
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Horohoro
Bioclimatic Zone: Submontane
Tenure: Unprotected private land (Waipupumahana C - Maori freehold land)
Altitude: 340 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 12 May 2003

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
08.04 08.04.03	**Mercer grassland** **Mercer grass grassland** Pasture dominated by Mercer grass (*Paspalum distichum*), catsear (*Hypochoeris radicata*), and browntop (*Agrostis capillaris*) surrounds an area of geothermal water. At the eastern end of the pool a small 2 × 1 m patch dominated by wetland sedges most notably *Eleocharis acuta*. There are a few small patches of bare ground. On the banks surrounding the pool there is occasional *Lycopodiella cernua*, *Histiopteris incisa*, *Blechnum penna-marina*, *Gleichenia microphylla*, and mingimingi.	Hillslopes	<0.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Two hot springs are present. One spring is under a shelter belt and has no geothermal vegetation around it.	Open water	<0.1 ha

Indigenous Flora: *Lycopodiella cernua*, a plant that is characteristic of geothermal areas, is present. *Nephrolepis flexuosa* (classed as „At Risk-Declining' in de Lange *et al.* 2009) was recorded by Given in 1995 but was not present in 2003.

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

Current Condition (2003 Assessment): Pool 1: The vegetation is highly modified with only occasional indigenous species present.

Pool 2: No indigenous geothermal vegetation present.

[1] Previously identified as U16/9 in Wildland Consultants (2004).

Threats/Modification/ Vulnerability:

Invasive pest plants (*2003 Assessment*)*:*	The geothermal pools are surrounded by exotic pasture species.
Human impacts (*2003 Assessment*)*:*	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.
Grazing (*2003 Assessment*)*:*	The site is not fenced to exclude livestock and livestock have modified the vegetation surrounding the hot pools.
Adjoining land use (*2003 Assessment*)*:*	Farmland.

Site Change:

Recent change:	Not assessed. Changes unlikely to be significant.
Historical:	This site is too small to identify any evidence of change since 1948 (Historical photo SN 255 Run 715 Photo 69, 1948).
Management Requirements:	Site lacks characteristic geothermal species apart from *Lycopodiella cernua* and mingimingi. Indigenous values could be restored by fencing the pools to exclude grazing animals, and undertaking restoration planting.
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; Unpublished Atiamuri PNAP data 1995; Waikato Regional Council unpublished; Wildland Consultants 2004.

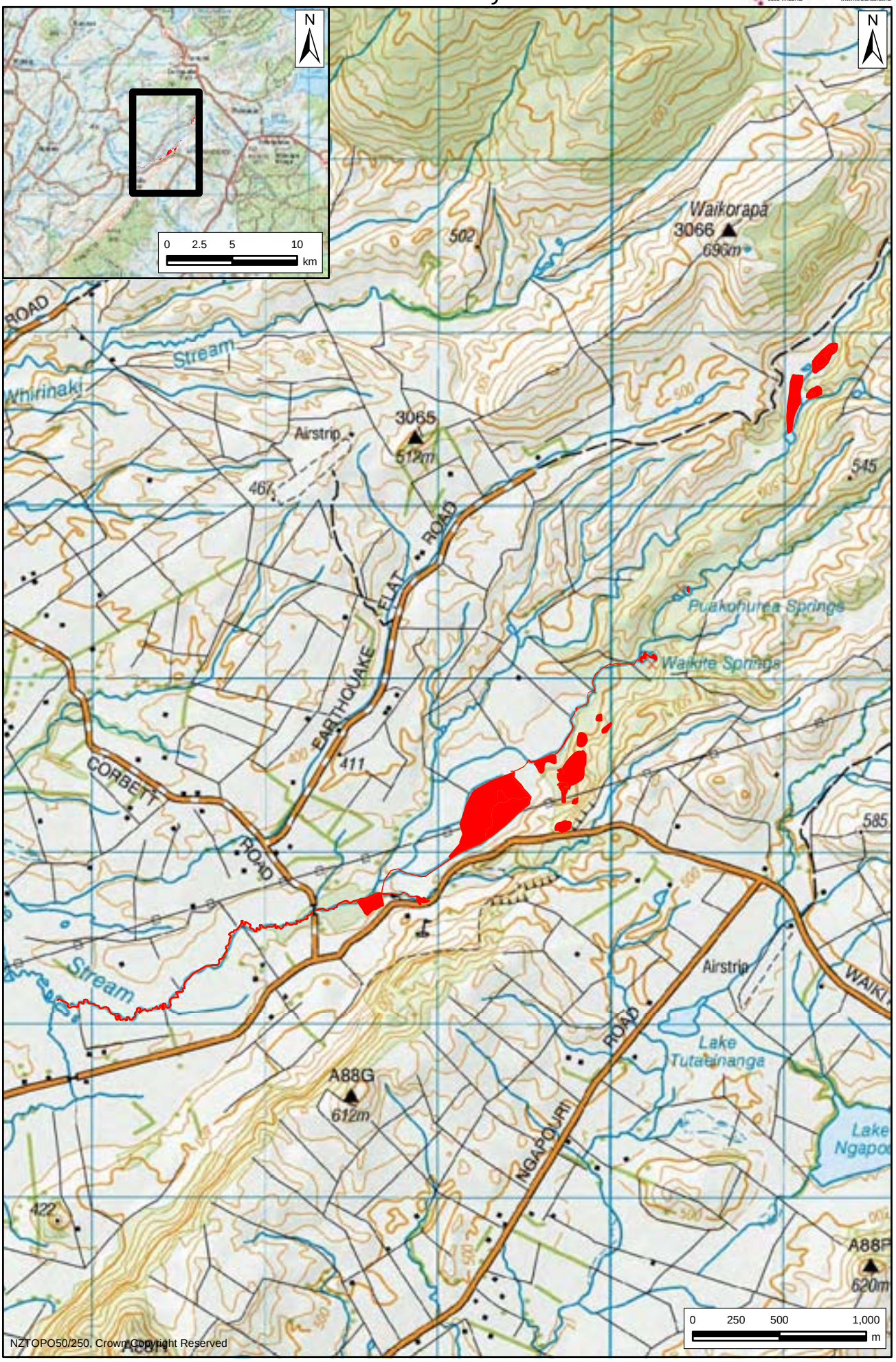
1.2 WAIKITE GEOTHERMAL FIELD

List of Geothermal Sites

WAV01	Waikite Valley
WAV02	Northern Paeroa Range

WAV01

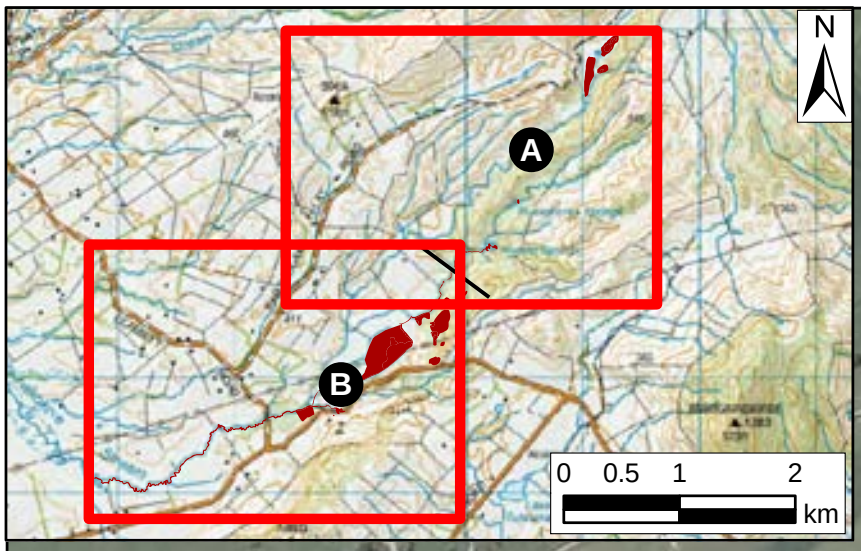
Waikite Valley



WAV01

Waikite Valley

Wildlands
0508 WILDNZ
www.wildlands.co.nz



Map Join Line

Map Join Line

Legend

- *Nephrolepis flexuosa-Dicranopteris linearis* fernland
- Barberry/blackberry scrub
- Blackberry scrub
- Geothermal water
- Grey willow forest
- Manuka-harakeke-*Cyperus ustulatus* shrubland
- Mercer grass grassland
- Nonvegetated raw-soilfield
- Prostrate kanuka shrubland
- Prostrate kanuka/Yorkshire fog grassland
- Raupo reedland
- Raupo-*Schoenoplectus tabernaemontani-Carex secta-Baumea rubiginosa* reedland
- ***A*** **See text**

1:12,500

0 250 500 m

WAIKITE VALLEY

Site Number: WAV01[1]
Grid Reference: NZTopo50 BF37 890 529
GPS Reference: NZTM E1889034 N5752934
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waikite
Bioclimatic Zone: Submontane
Tenure: Protected (Waikite Stewardship Area; Otamakokore Stream Marginal Strip; Waikite Wildlife Management Reserve) and unprotected private land.
Altitude: *c.*380-440 m
Extent of Geothermal Habitat: *c.*25.8 ha
Extent of Geothermal Vegetation: *c.*24.5 ha
Date of Field Survey: 3 February 2011 (parts of this site were surveyed 17-29 May 2007)

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
01.06 01.06.03[2]	**Willow-dominant forest** **Grey willow forest** Grey willow (*Salix cinerea*) forms a canopy over raupo, *Carex secta*, *Baumea rubiginosa*, *Schoenoplectus tabernaemontani*, blackberry, water purslane (*Ludwigia palustris*), swamp kiokio (*Blechnum minus*), swamp millet (*Isachne globosa*), bracken (*Pteridium esculentum*), and harakeke (flax; *Phormium tenax*). Several areas with elevated water temperatures (up to 24°C) were found. In one of these areas, *Cyclosorus interruptus* was common with one small population of *Thelypteris confluens*. (Information collected in 2007).	Wetland	*c.*2.0 ha
04.08 04.08.01	**Blackberry-dominant scrub** **Blackberry scrub** Dense blackberry scrub is dominant beside many streams and drains with this site. Scattered plants of *Christella* aff. *dentata* ("thermal") and occasional *Cyclosorus interruptus* are present. Other species commonly present include swamp kiokio, kiokio (*Blechnum novae-zelandiae*), bracken, *Carex secta*, *Cyperus ustulatus*, *Histiopteris incisa*, pohue (*Calystegia sepium* subsp. *roseata*), *Hypolepis ambigua, Schoenoplectus tabernaemontani* and Mercer grass, and there is occasional manuka, patches of *Nephrolepis flexuosa*, *Baumea arthrophylla, Carex virgata,* and *Baumea juncea* on open margins. (Information collected in 2011).	Stream margins	*c.*1.8 ha

[1] Previously identified as U16/6 in Wildland Consultants (2004).
[2] Not surveyed in 2011.

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.09 04.09.01[2]	**Exotic-dominant scrub** **Barberry/blackberry scrub** For *c.*2.2 km west of the Corbett Road Bridge, the margins of Otamakokore Stream are dominated by a dense cover of blackberry, barberry (*Berberis glaucocarpa*), and bracken. The barberry is up to *c.*4 m tall. Pohue, introduced grasses (including Mercer grass and Yorkshire fog (*Holcus lanatus*)), and *Cyperus ustulatus* are common throughout. About 200 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, Histiopteris incisa,* kiokio, *Deparia petersenii*, *Baumea rubiginosa, Carex geminata,* raupo, lotus (*Lotus pedunculatus*), ivy, feijoa (*Feijoa sellowiana*), Lawson's cypress (*Chamaecyparis lawsoniana*), pampas, and fleabane (*Conyza sumatrensis*), with local emergent grey willow, kohuhu (*Pittosporum tenuifolium*), karamu (*Coprosma robusta*), and ti kouka (*Cordyline australis*). Ten plants of *Hypolepis dicksonioides* are present. The site margins are mostly fenced on the true-right side of the stream, but on the true left stock have access to large parts of the stream. Rank exotic pasture grassland is common along stream margins in places. (Information collected in 2007). The vegetation along several hundred metres of stream margin was illegally cleared west of the Corbett Road Bridge in 2007. The nearby terrace above the stream has been replanted with indigenous species. Most *Christella* aff. *dentata* ("thermal") that was previously present alongside the stream margins in this area have been destroyed. (Information collected in 2007).	Stream margins	*c.*2.5 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka forms a low shrubland around loamfields, fumaroles and boiling mud, with scattered mingimingi and Spanish heath. Mats of moss (*Campylopus capillaceus* and *Sphagnum cristatum*) with local patches of *Nephrolepis flexuosa* and wild portulaca (*Portulaca oleracea*) form a sparse groundcover. *Dicranopteris linearis* and *Psilotum nudum* were recorded in this area in 1976 (Ecroyd & Coham 1976). In areas where this vegetation type merges with stream margins *Baumea arthrophylla* and *Baumea juncea* are present. (Information collected in 2011).	Gentle slopes at foot of scarp	*c.*4.9 ha
05.03 05.03.26[1]	**Manuka-dominant shrubland** **Manuka-harakeke-*Cyperus ustulatus* shrubland** Manuka, harakeke, and *Cyperus ustulatus*, with small	Wetland	*c.*1.1 ha

[1] Not surveyed in 2011.

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	patches of raupo, are dominant over *Baumea rubiginosa,* swamp kiokio, *Carex secta, C. virgata*, and watercress, with occasional grey willow. 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. Occasional plants of *Cyperus involucratus* are present near the northern margin of this area. (Information collected in 2007).		
07.08 07.08.02	***Nephrolepis flexuosa*-dominant fernland** ***Nephrolepis flexuosa-Dicranopteris linearis* fernland** A mosaic of several fern species, including *Nephrolepis flexuosa* and *Dicranopteris linearis* surrounding the Te-Manaroa Hot Spring and the stream that flows downstream. Several areas of *Nephrolepis flexuosa* and *Dicranopteris linearis* occur near the Te-Manaroa Spring. *Christella* aff. *dentata* ("thermal") plants are scattered downstream of the spring. *Lycopodiella cernua*, bracken, *Histiopteris incisa,* kiokio, *Deparia petersenii*, *Diplazium australe* and *Hypolepis ambigua* are also present in this area, with occasional kohuhu, karamu, whauwhaupaku (*Pseudopanax arboreus*), and kamahi (*Weinmannia racemosa*) on cooler sites. Blackberry becomes more abundant along stream margins downstream of the Waikite Pools. An exotic species, *Cyperus involucratus*, has spread from ornamental plantings into indigenous geothermal vegetation on stream margins, and surrounding wetlands outside of the area mapped as 07.08.02. (Information collected in 2007).	Stream gully	*c.*0.3 ha
08.01 08.01.02	**Yorkshire fog-dominant grassland** **Prostrate kanuka/Yorkshire fog grassland** A newly fenced area next to the raupo reedland is dominated by Yorkshire fog with emergent prostrate kanuka scattered throughout. (Information collected in 2007).	Flat	*c.*7.7 ha
08.04 08.04.03	**Mercer grass-dominant grassland** **Mercer grass grassland** Mercer grass dominates this area. Other species present include Indian doab (*Cynodon dactylis*), browntop, and Yorkshire fog. Scattered prostrate kanuka occur close to the margins of the hottest geothermal areas. Local patches of blackberry are also present, with small areas of nonvegetated raw-soilfield. (Information collected in 2011).	Flat areas and gentle slopes at the foot of scarp	*c.*0.4 ha
11.01 11.01.01	**Raupo-dominant reedland** **Raupo reedland** Raupo dominates this area with harakeke, *Carex secta*, *Cyperus ustulatus, Schoenoplectus tabernaemontani, Baumea rubiginosa*, *Deparia petersenii*, blackberry and bracken common around the margins. *Hypolepis*	Flat/wetland	*c.*2.6 ha

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	distans, Juncus articulatus, Carex virgata and kiokio are also present, and emergent kanuka (*Kunzea ericoides*) is scattered throughout. *Nephrolepis flexuosa* and *Christella* aff. *dentata* ("thermal") occur locally where hot water flows into the reedland. Until recently, cattle accessed this wetland and trampling resulted in local damage to the vegetation. (Information collected in 2011).		
11.01.12[1]	**Raupo-*Schoenoplectus tabernaemontani-Carex secta-Baumea rubiginosa* reedland** A large wetland surrounding several small ponds. Elevated temperatures were recorded in parts of wetland (up to *c.*25°C). The vegetation cover is quite varied, with raupo, *Schoenoplectus tabernaemontani*, and *Carex secta* all locally dominant, in association with *Histiopteris incisa*, kiokio, and scattered *Baumea rubiginosa*, and grey willow. Manuka, blackberry, and bracken are common in dry parts. A large population of *Thelypteris confluens* occurs in the north-west corner (an estimated 800 fronds over *c.*10 m^2).	Wetland	*c.*1.0 ha
14.02 14.02.01[2]	***Campylopus* mossfield** ***Campylopus* mossfield (not mapped)** Small areas of *Campylopus capillaceus* are present amongst prostrate kanuka shrubland.	Gentle slopes at foot of scarp	
22.01 22.01.01	**Geothermal water** **Geothermal water** Hot springs, geothermally influenced ponds and streams. Arrow grass is present in small thermal streams.	Flat, gully	*c.*1.2 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Thermally altered clay, sinter, hot springs, and fumaroles. Occasional *Cheilanthes sieberi* and wild portulaca are present in Area A, amongst the nonvegetated raw-soilfield.	Hillslopes, gentle slope	*c.*0.3 ha

Indigenous Flora:

A large population of *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al*. 2009) is present. Some plants are threatened by grazing stock. Bycroft & Beadel (2007) estimated that there were *c.*400 plants at this site in 2007.

Scattered populations of *Nephrolepis flexuosa* are present alongside stream margins, Waikite scarp, and beside geothermal wetlands at the site. *N. flexuosa* is also classed as „At Risk-Declining' by de Lange *et al.* (2009). Bycroft & Beadel (2007) estimated that there were *c.*100 clumps of *N. flexuosa* at the Waikite site.

Also present are small populations of *Dicranopteris linearis* and *Hypolepis*

[1] Not surveyed in 2011.

[2] Areas of this vegetation type occur within the mapped area as 05.01.01, however they were too small to be mapped separately.

dicksonioides (both classed as ‚At Risk-Naturally Uncommon' in de Lange *et al*. 2009). Bycroft & Beadel (2007) recorded ten plants of *H. dicksonioides* from this site in 2007. All plants were downstream of the Corbett Road Bridge. The same survey 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.*24 sites in New Zealand.

Several populations of *Cyclosorus interruptus* and *Thelypteris confluens* (both classed as ‚At Risk-Declining' in de Lange *et al.* 2009) are present; generally these 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. Some of the *Cyclosorus interruptus* plants are threatened by stock. Bycroft & 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. The same study found about 800 fronds of *T. confluens* in Waikite Wildlife Management Reserve.

Prostrate kanuka (classed as ‚At Risk-Naturally Uncommon' in de Lange *et al*. 2009) and *Campylopus capillaceous*, which are both endemic and restricted to geothermal areas, occur at this site.

Psilotum nudum has been recorded from this site (Ecroyd & Coham 1976), and *Lycopodiella cernua*, *Cheilanthes sieberi*, *Baumea juncea*, *Baumea arthrophylla,* arrow grass, sea rush, and *Doodia australis* also occur here. These species are characteristic species of geothermal areas. Bycroft & Beadel (2007) found that *L. cernua* was common around Te-Manaroa Hot Spring, and in prostrate kanuka shrubland habitats.

Fauna:

Spotless crake (classed as ‚At Risk-Relict' in Miskelly *et al.* 2008), North Island fernbird and pied stilt (both classed as ‚At Risk-Declining' in Miskelly *et al.* 2008) are present at this site. Other common indigenous and introduced bird species typical of the habitat include spur-winged plover, grey warbler, silvereye, greenfinch, yellowhammer, paradise shelduck, fantail, pukeko, welcome swallow, grey duck, mallard, blackbird and Australian magpie.

Current Condition (2011 Assessment):

This site is highly significant in terms of its flora. The geothermal vegetation ranges from very high ecological quality to moderately poor quality. Whilst in places the geothermal vegetation is in excellent condition, in other places quality is poor due to a high density of adventive species. The geothermal vegetation is discontinuous and is often surrounded by vegetation dominated by adventives. Although many key geothermal areas are fenced, the margins are heavily infested with blackberry. Some populations of thermal ferns are open to stock access.

A geothermal stream has been rediverted into an area of raupo reedland. This wetland area and an adjacent paddock have also been fenced to exclude stock. Change in vegetation composition is expected to occur over time in this area. The location of the 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 completing for

habitat with „At Risk' ferns.

Threats/Modification/ Vulnerability:

Invasive pest plants (2007 and *2011 Assessments*): Invasive exotic plants are common and include blackberry (51-75% cover), broom (1-5% cover), barberry (1-5% cover), Spanish heath (1-5% cover), water purslane (<1% cover), *Cyperus involucratus* (1-5% cover), pampas (<1%), and ivy (1-5%). It appears that the population of *Cyperus involucratus* at this site has increased in size between 2007 and 2011, particularly around the thermal swimming pool complex, and reaches 90% cover on some stream banks within the site.

Human impacts (*2007 and 2011 Assessments*): 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).

A board walk has been built to Te-Manaroa Spring.

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

Grazing (*2007 and 2011 Assessments*): The central wetland north and north-east of the pool complex has recently had stock excluded from that part of the site.

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.

Parts of the north-east area are under threat from farming operations. The hot streams with at risk ferns and areas alongside Otamakokore Creek are particularly vulnerable to trampling, pugging, and grazing damage by cattle.

Adjoining land use (*2007 and 2011 Assessments*): Farmland and public thermal baths.

Site Change:

Recent change: Recent geothermal stream diversion, management to raise water tables (to negate impacts of drains), restoration planting, and fencing to exclude stock from raupo wetlands and larger surrounding area will change the vegetation composition of the central part of this site (these works have been funded by Waikato Regional Council). Since 2004, the areas of known geothermal habitats identified have increased, however this does not generally represent a real change in the area of geothermal vegetation at this site. However, the geothermal wetland at the southern end of the farm is now larger due to water table management.

Historical: It appears that a pool complex and farm development have reduced the extent of geothermal vegetation and habitats since 1961 (Historical photo: SN 1394 Run 3170 Photos 18-20, 1961). 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 grazed, with an extensive drain network similar to those observed in the field surveys undertaken in earlier 2000. The wetland above Corbett Road bridge and the vegetation around Te Manaroa Hot Spring appear similar 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 top part of Otumakokore Stream was viewed on the 1961 aerial photographs.

Management Requirements:

Blackberry and broom are now well established and are difficult to control without damaging the indigenous vegetation. Rotorua District Council has outlined policies for the protection of the biological features of Waikite Thermal Valley Reserve, although weeds remain a problem. Areas where water tables are being restored should be monitored for impacts on threatened fern populations. Ungrazed habitats where stock have been removed from stream margins should be monitored for pest plant invasion and management actions to control pest plants identified and implemented. Unfenced geothermal vegetation and habitats should be fenced to exclude grazing animals.

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 dominated by *Cyperus involucratus*. Both of these species require urgent control before they spread further within this site and into other nearby geothermal sites.

Significance Level:

National (Table 1 - Criteria 1, 3, 5, 7, 9; Table 2 - Factor 6, 8).

Significance Justification:

This site is of national significance because it is a good quality, representative, example of a habitat type that is nationally uncommon. It contains a good population of an „At Risk' species (*Christella* aff. *dentata* ("thermal") that is known at only 14 sites in the North Island. Six other „At Risk' plant species are present: *Cyclosorus interruptus,* prostrate kanuka, *Nephrolepis flexuosa*, *Thelypteris confluens*, *Dicranopteris linearis,* and *Hypolepis dicksonioides*. Spotless crake (classed as „At Risk-Relict' in Miskelly *et al.* 2008), North Island fernbird and pied stilt (both classed as „At Risk-Declining' in Miskelly *et al.* 2008) are also present

Notes:

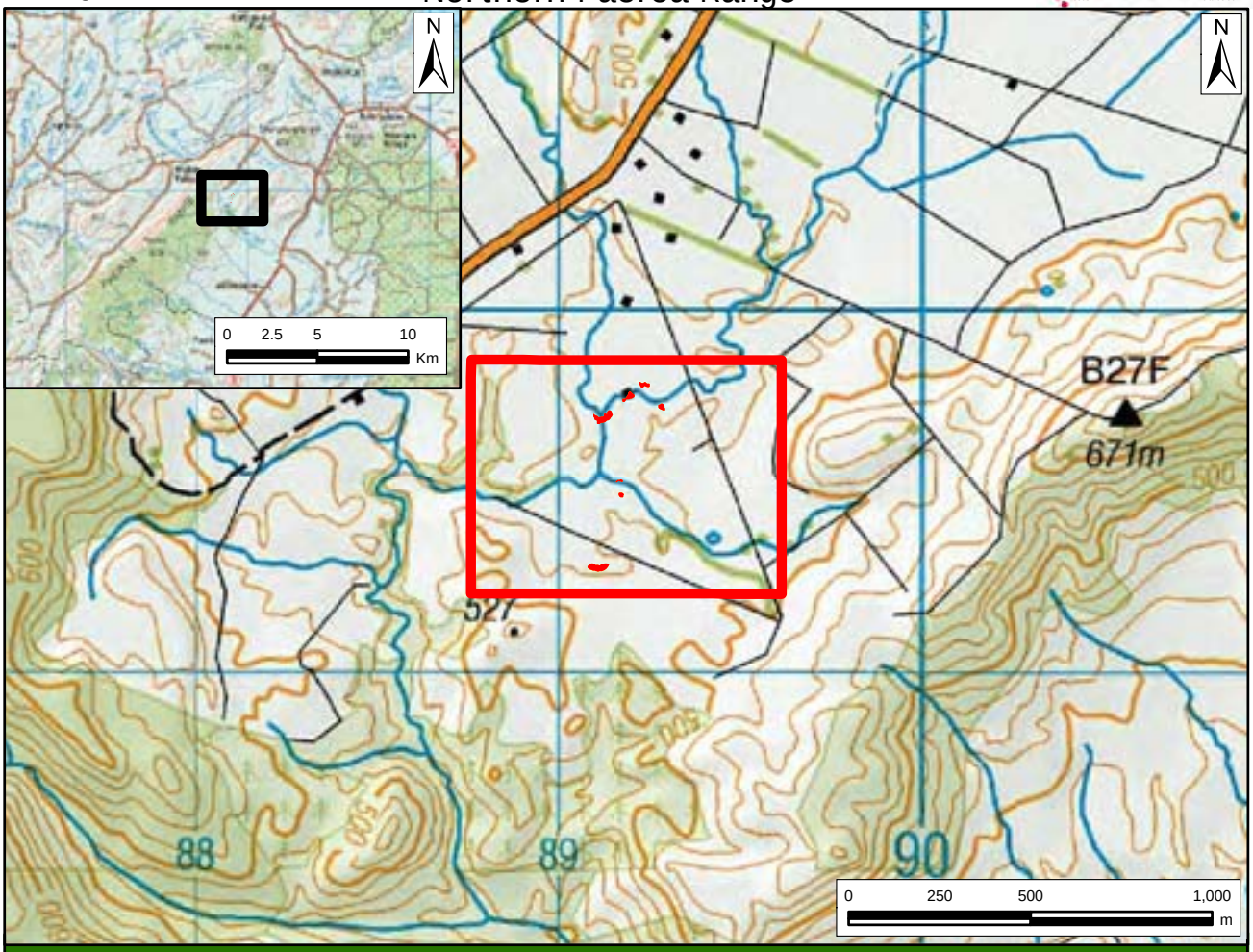
This site comprises three areas ranked in Given (1996): "Waikite Valley", "Paeroa Scarp" and "Otamakokore Stream". Given ranked these areas as A, B, and B respectively.

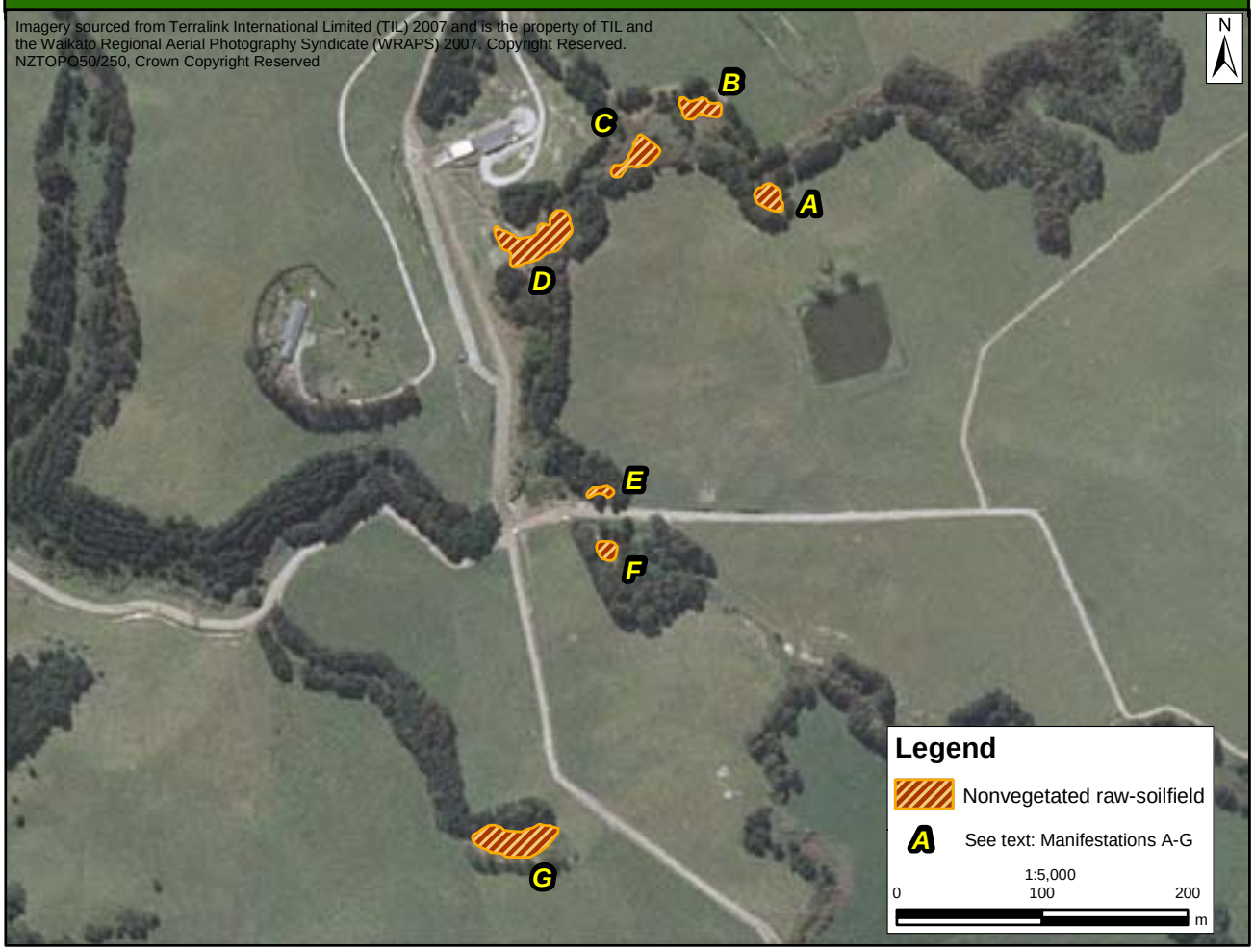
References:

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

WAV02

Northern Paeroa Range





NORTHERN PAEROA RANGE

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

Code	Type	Landform	Extent
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Seven units of nonvegetated raw-soilfield which are described in units as indicated on accompanying map from north to south. Area A: Nonvegetated raw-soilfield, surrounded by plantation pines with an understorey of manuka shrubland. Small patches of Yorkshire fog are present. While this area has been active in the recent past, there was no steaming evident. This unit was viewed with binoculars from across the creek. Area B: Nonvegetated raw-soilfield with abundant pine needles, and several plants of prostrate kanuka. A concrete pipe is present in the hottest area of geothermal activity. Occasional browntop present. Surrounded by maritime pine (*Pinus pinaster*) forest with a manuka subcanopy to *c.*3 m with occasional mingimingi, as well as a stand of grey willow and patches of blackberry scrub. Area C: Nonvegetated raw-soilfield. The site is surrounded by pine plantation, manuka-mingimingi scrub with occasional blackberry, broom and bracken. Several small patches of Yorkshire fog grassland. Most of this site is on the western side of the stream but a small portion is present on the eastern bank. Area D: The site is predominantly exposed geothermal clays, currently there is no elevated temperature noticeable at this site, but it has been actively geothermal in the past. The site is surrounded by planted exotic pines. Occasional manuka to 3 m on margins. *Histiopteris incisa* and mingimingi are also present on the margins beneath planted pines. A small wetland <5 × 5 m is present, with *Juncus edgariae* and rank exotic grasses, including Yorkshire fog, and browntop. Area E: Nonvegetated raw-soilfield. Surrounded by pine plantation with manuka and mingimingi with occasional *Histiopteris incisa,* and bracken in the understorey. Occasional	Gully (Area D is gully and wetland)	*c.*0.3 ha

[1] Previously identified as U17/36 in Wildland Consultants (2004).

Code	Type	Landform	Extent
	Yorkshire fog, sweet vernal (*Anthoxanthum odoratum*), manuka seedlings and four plants of prostrate kanuka on nonvegetated raw-soilfield. Area F: Nonvegetated raw-soilfield. Surrounded by pines and eucalyptus (*Eucalyptus* sp.) plantation. One monoao plant and five prostrate kanuka plants present. Area G: Nonvegetated raw-soilfield. This area is surrounded by plantation radiata pine (*Pinus radiata*), and planted eucalyptus to *c.*12 m tall, with an understorey of manuka scrub and shrubland, with common broom and bracken. Occasional manuka and prostrate kanuka are present on margins. Occasional sweet vernal and browntop were present on cooler parts of raw-soilfield. *Juncus prismatocarpus* was present by a warm spring.		

Geophysical Assessment:[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 north 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

This is 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

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

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 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 the location 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 a 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 which lead into the main stream which originates in the northeast.

The southeastern area of the site 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 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 and 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^{o}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^{o}C at 0.25 m depth. At 2m distance the temperatures are between 18-27^{o}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^{o}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^{o}C and an estimated outflow of 0.5 l/s. As the stream reaches the western exposed rocks it has cooled to 15^{o}C, and after it has passed this area of weak thermal activity the temperature is 16^{o}C. The pH of the stream is between 3.2 and 3.7.

Flora:

Prostrate kanuka, classed as ‚At Risk-Naturally Uncommon' in de Lange *et al.* (2009) was present as occasional scattered plants scattered through small units of geothermal vegetation. Other species typical of geothermal habitats recorded were manuka, bracken, mingimingi, and *Histiopteris incisa*.

Fauna:

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

Current Condition

In a moderate condition. Most features have had some impact from stock.

(2011 Assessment):	Sites are surrounded by exotic plantation. One geothermal feature has been altered with a concrete pipe.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2011 Assessment*):	Most areas of geothermally-altered soils are largely devoid of vegetation. Blackberry and grey willow are common on margins in places. However management of pest plants at this site is a low priority compared with other geothermal sites in the Waikato Region.
Human impacts (*2011 Assessment*):	A concrete pipe is present in Unit B.
Grazing (*2011 Assessment*):	While all sites are fenced, stock sign was present in most sites.
Adjoining land use (*2011 Assessment*):	Plantation; farming; riparian margin vegetation.
Site Change:	
Recent change:	This site was not visited during the 2004-7 geothermal survey of geothermal vegetation in the Waikato Region. However the site is unlikely to have undergone any significant change over this time period.
Historical:	Site not assessed, no historical photos found. Site margins are currently plantation and have been grazed in the past. As most sites are in gullies and relatively small it is unlikely that changes will be visible on black and white aerial photographs.
Management Requirements:	Fences should be maintained to ensure stock cannot access site.
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 (i.e. geothermal habitat) and it includes a small population of an „At Risk' species, prostrate kanuka.
References:	Background information on this site from Paul Cashmore (Department of Conservation, Rotorua).

Northern Paeroa Range Geothermal Area B. Plates 1 to 5: refer to Geophysical text for Northern Paeroa Range Geothermal Area.

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Figure A1-1: Northern Paeroa Range Geothermal Area B. Field Sketch Map indicating main features and photo locations at manifestation B on Northern Paeroa Range Geothermal Area site map.

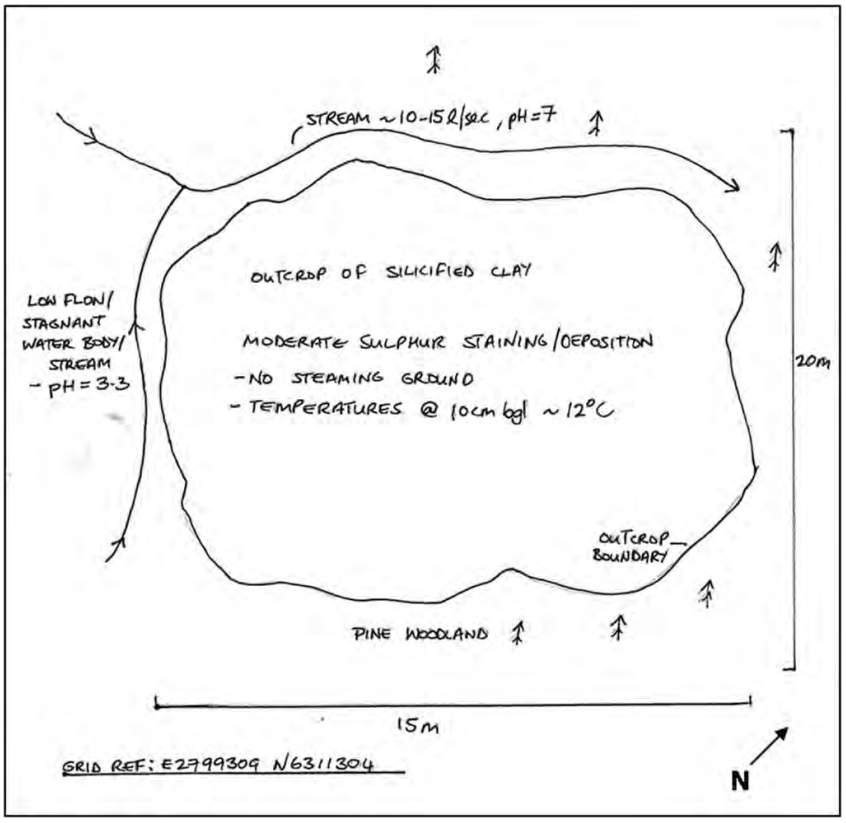
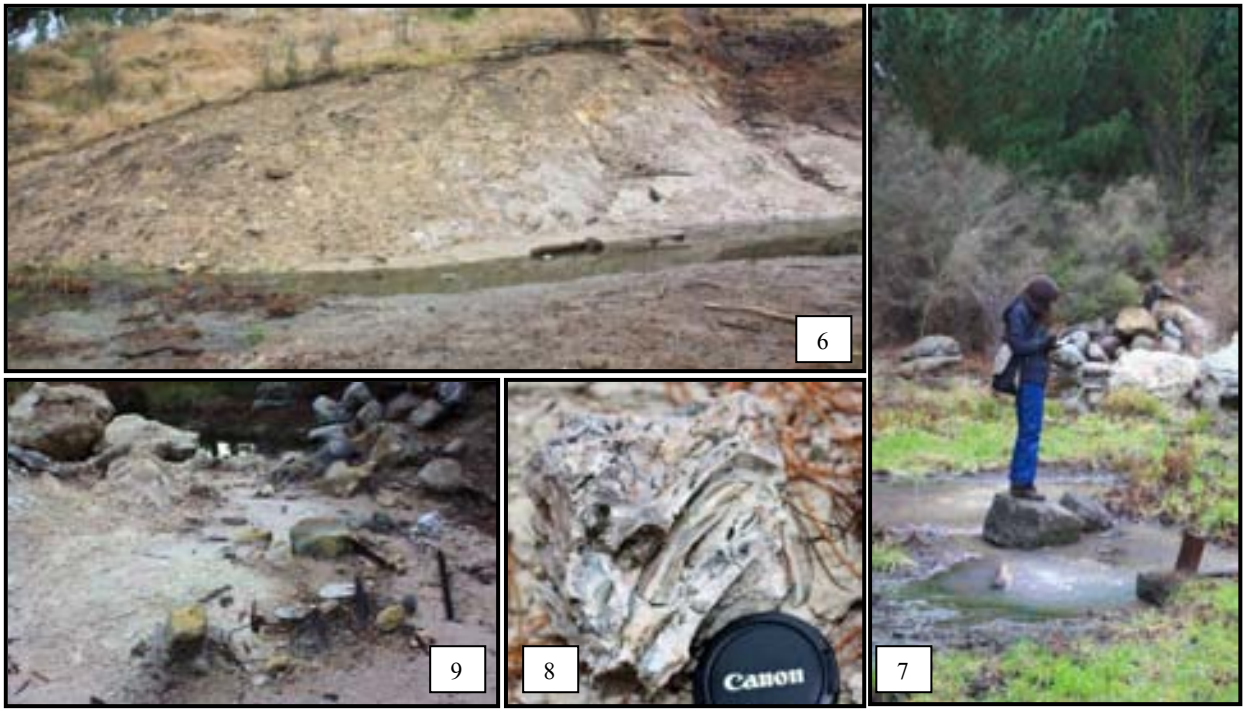


Figure A1-2: Northern Paeroa Range Geothermal Area C. Field Sketch Map indicating main features at manifestation C on Northern Paeroa Range Geothermal Area site map. The grid reference labelled here is NZMG.

Figure A1-3: Northern Paeroa Range Geothermal Area D. Field Sketch Map indicating main features and photo locations at manifestation D on Northern Paeroa Range Geothermal Area site map. The grid reference labelled here is NZMG.



Plates 8-9: Northern Paeroa Range Geothermal Area D. Area Photographs (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.

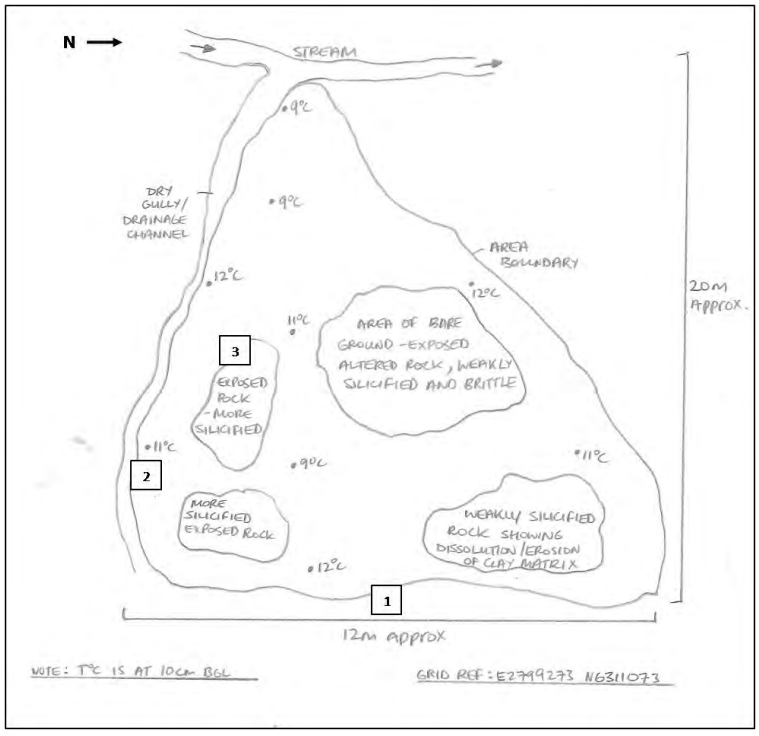
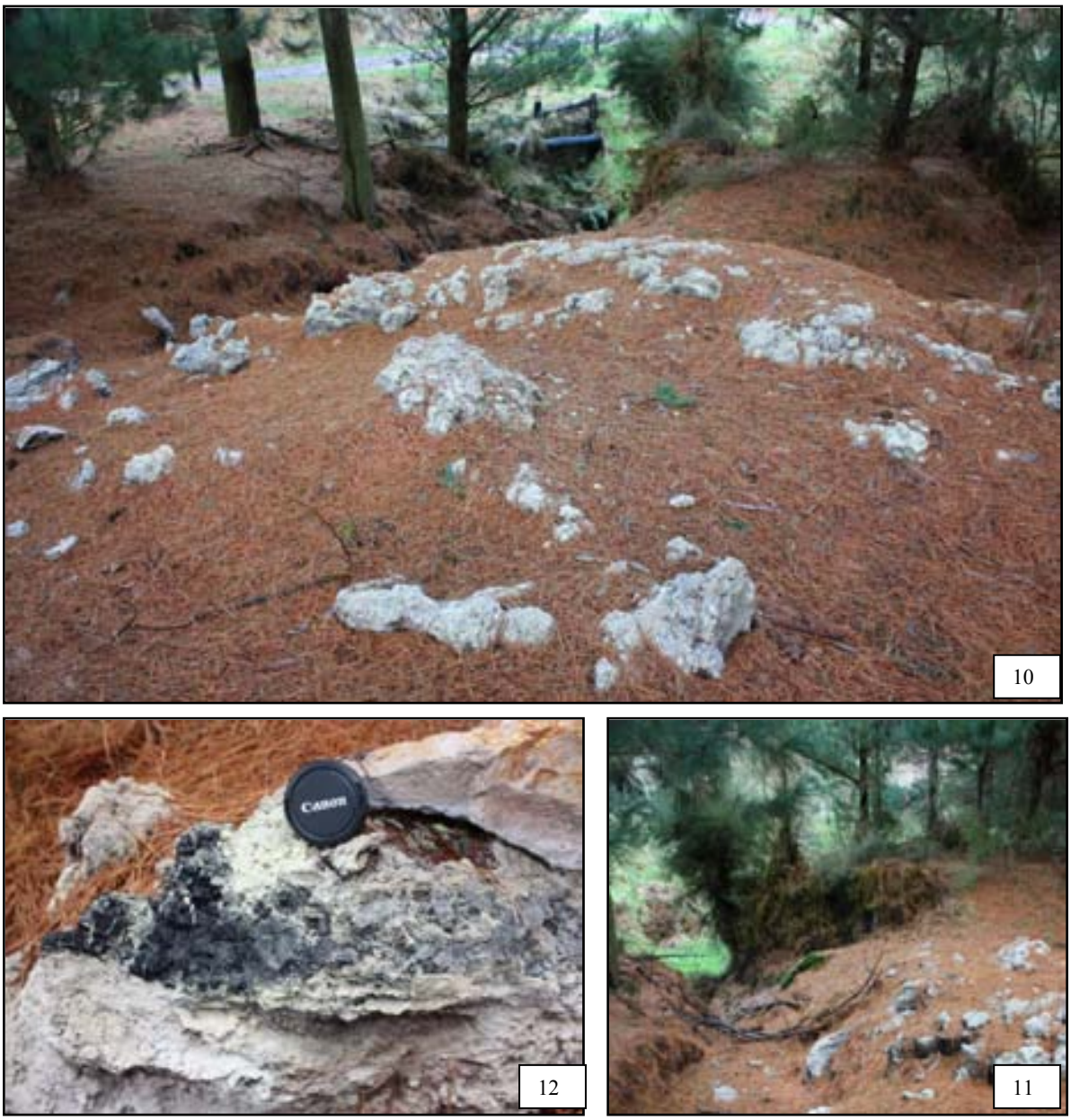


Figure A1-4:
Northern Paeroa Range Geothermal Area E. Field Sketch Map indicating main features and photo locations at manifestation E on Northern Paeroa Range Geothermal Area site map. The grid reference labelled here is NZMG.



Plates 10-12: Northern Paeroa Range Geothermal Area E. Photographs (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 A1-5: Northern Paeroa Range Geothermal Area F. Field Sketch Map indicating main features and photo locations at manifestation F on Northern Paeroa Range Geothermal Area site map. The grid reference labelled here is NZMG.

Plate 13: Northern Paeroa Range Geothermal Area F.

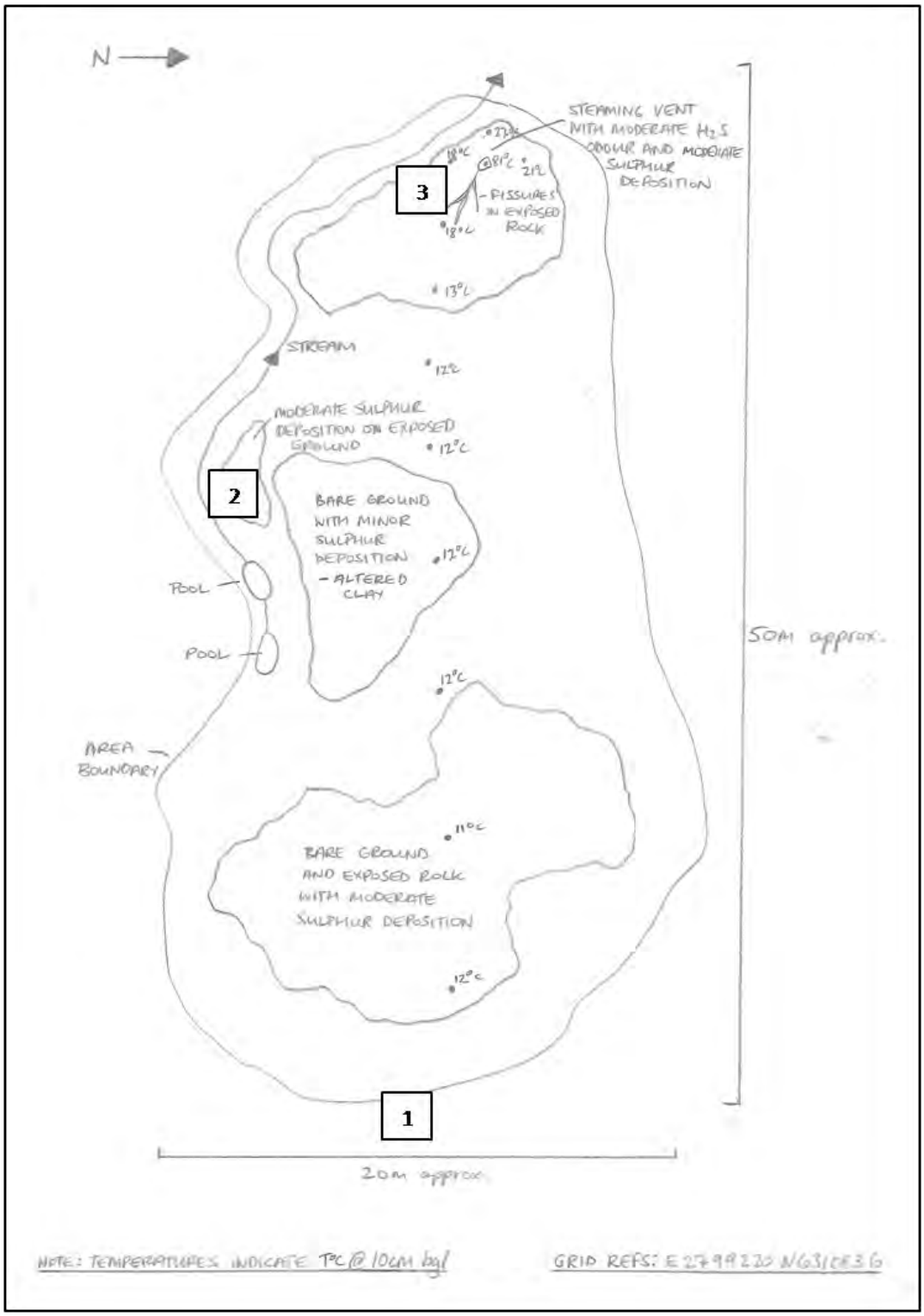


Figure A1-6: Northern Paeroa Range Geothermal Area G. Field Sketch Map indicating main features and photo locations at manifestation G on Northern Paeroa Range Geothermal Area site map. The grid reference labelled here is NZMG.

Plates 14-16: Northern Paeroa Range Geothermal Area G. Area Photographs (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.

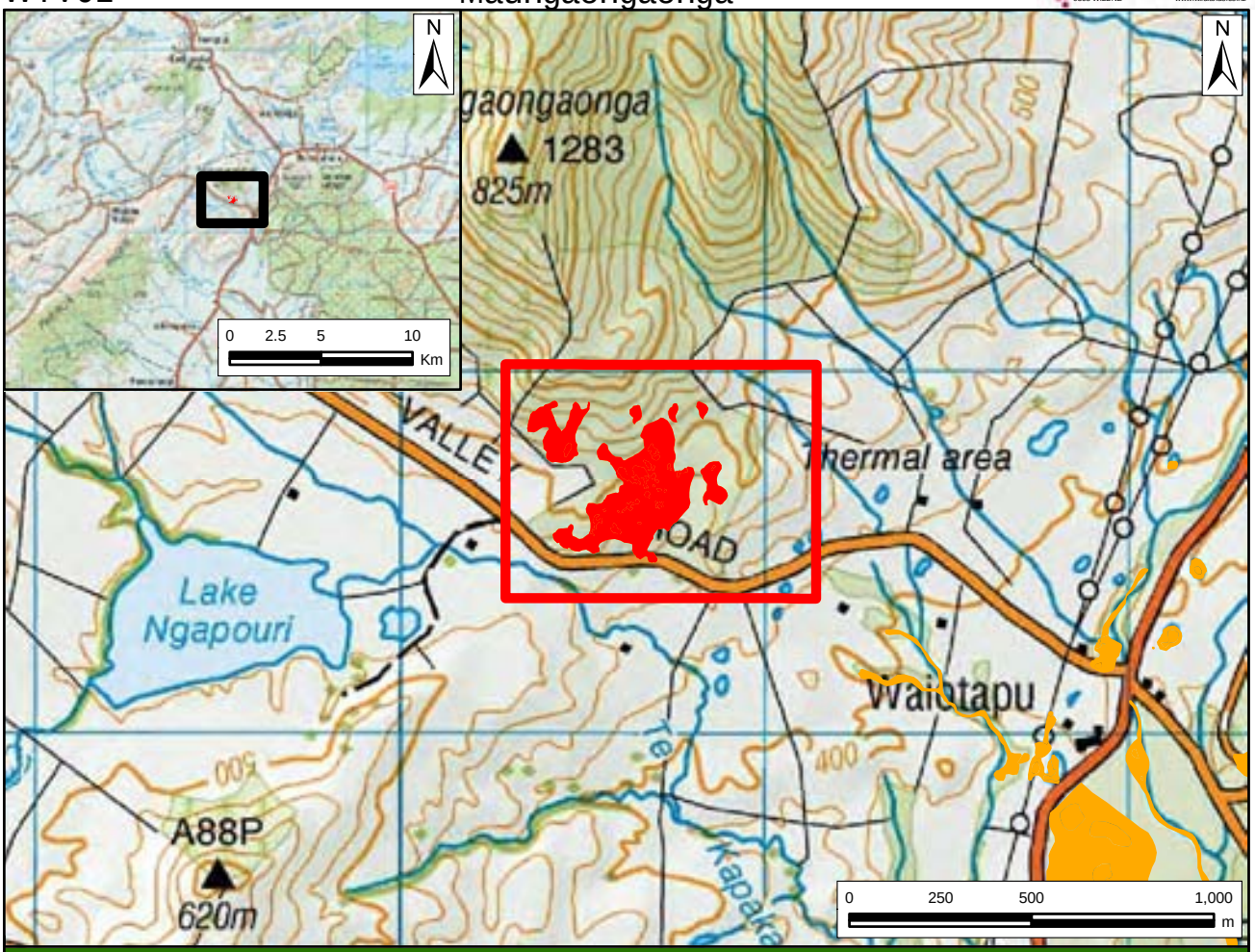
1.3 WAIOTAPU GEOTHERMAL FIELD

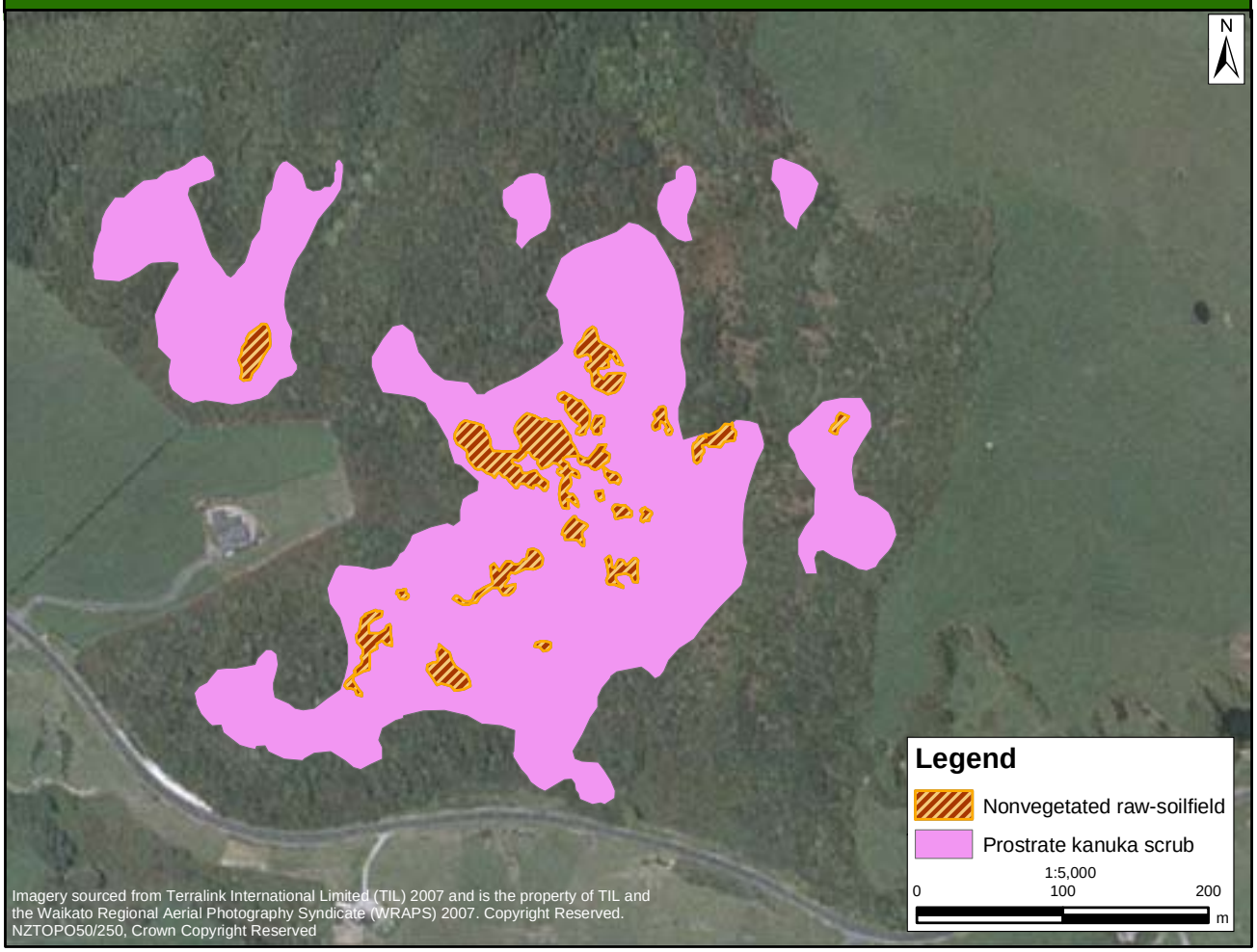
List of Geothermal Sites

WTV01	Maungaongaonga
WTV02	Ngapouri
WTV03	Waiotapu North
WTV04	Maungakakaramea (Rainbow Mountain)
WTV05	Waiotapu South

WTV01

Maungaongaonga





MAUNGAONGAONGA

Site Number: WTV01[1]
Grid Reference: NZTopo50 BF37 926 516
GPS reference NZTM E1892615 N5751642
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Protected (Maungaongaonga Scenic Reserve)
Altitude: *c.*540 m
Extent of Geothermal Habitat: *c* 9.1 ha
Extent of Geothermal Vegetation: *c* 9.1 ha
Date of Field Survey: 27 May 2004

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** A dense canopy of prostrate kanuka up to 1.5 m high dominates this area, in association with locally scattered manuka, mingimingi, and local patches of monoao (up to 50% cover in places). The groundcover is dominated by moss (*Dicranoloma billardierei* and *Sphagnum cristatum*) with local scattered turutu (*Dianella nigra*) and hound's tongue fern (*Microsorum pustulatum*). Manuka and monoao form a dense scrub up to 2 m high, in association with prickly mingimingi (*Leptecophylla juniperina* subsp. *juniperina*) and locally scattered whauwhaupaku. Kamahi and toru (*Toronia toru*) occur on several rocky outcrops. The groundcover associated with these outcrops comprises scattered turutu with local *Gleichenia microphylla* and a few examples of hound's tongue fern. Small patches of *Nephrolepis flexuosa* and *Dicranopteris linearis* are present beneath the prostrate kanuka canopy.	Hillslope and rocky outcrops	*c*.8.4 ha
05.01 05.01.01[2]	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland (not mapped)** Prostrate kanuka 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 *Cladonia capitellata* (a lichen) (Beadel 1995a) are also present. *Lycopodiella cernua* is locally present in areas of relatively high geothermal activity. *Histiopteris incisa* is common near steam vents. This vegetation type occurs sporadically amongst the prostrate kanuka scrub.	Hillslope	

[1] Previously identified as U16/11 in Wildland Consultants (2004).
[2] Areas of this vegetation type occur within the area mapped as 04.01.01, however were too small to be mapped separately.

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Geothermal clays, mud pools, geothermally altered soils, and fumaroles.	Hillslope	*c*.0.7 ha

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Declining' in de Lange *et al.* 2009), a species endemic to geothermal areas, is present. A population of *Korthalsella salicornioides*, a semi-parasitic mistletoe (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), is also present.

A few patches of *Nephrolepis flexuosa*, (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), a species which in New Zealand is confined to geothermal areas in the North Island, and at least 50 plants of *Dicranopteris linearis* (classed as „At Risk-Declining' in de Lange *et al.* 2009, and known from only *c.*24 sites in New Zealand), are present at this site (numbers based on 2004 field assessment).

Other species of interest present are *Lycopodiella cernua* (which is a characteristic feature of geothermal areas) and *Schizaea bifida* (Beadel 1995a). *S. bifida* was not recorded in the 2004 survey.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including tui, silvereye, and fantail.

Current Condition (2004 Assessment): The geothermal vegetation is largely unmodified. It is relatively untracked and adventive species are uncommon.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2004 Assessment*)*:* Weeds are uncommon in this site. The main weed species present are blackberry (1-5%), radiata pine (<1%), Douglas fir (*Pseudotsuga menziesii*) (<1%), Spanish heath (<1%), gorse (*Ulex europaeus*) (<1%) and narrow-leaved carpet grass (*Axonopus fissifolius*) (<1%). The distribution of environmental weeds in Maungaongaonga Scenic Reserve was mapped and described in Wildland Consultants (1998).

Human impacts (*2004 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) however this track now appears to be little used.

Grazing (*2004 Assessment*)*:* Livestock are not a threat to this area.

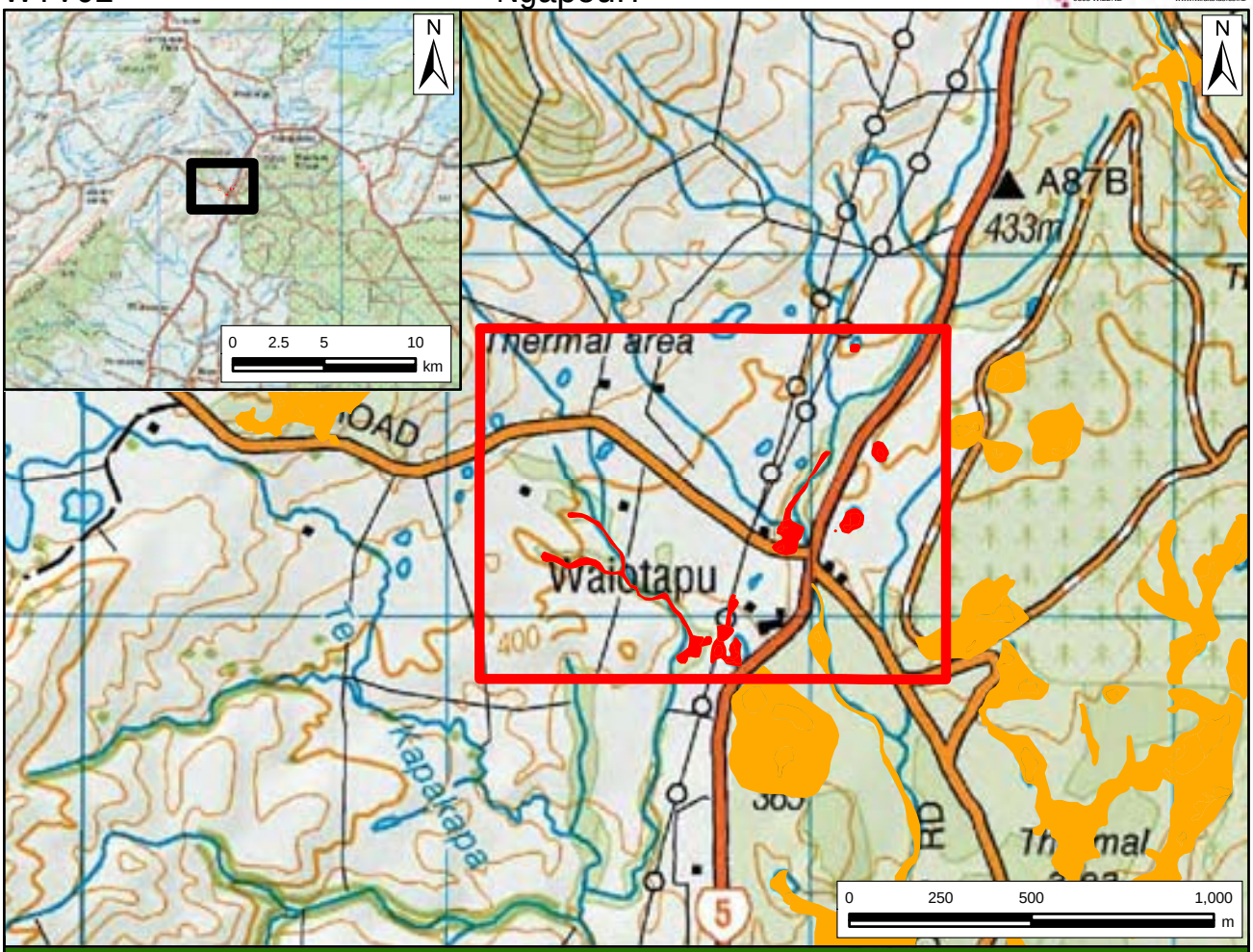
Adjoining land use (*2004 Assessment*)*:* Farmland; indigenous forest and scrub.

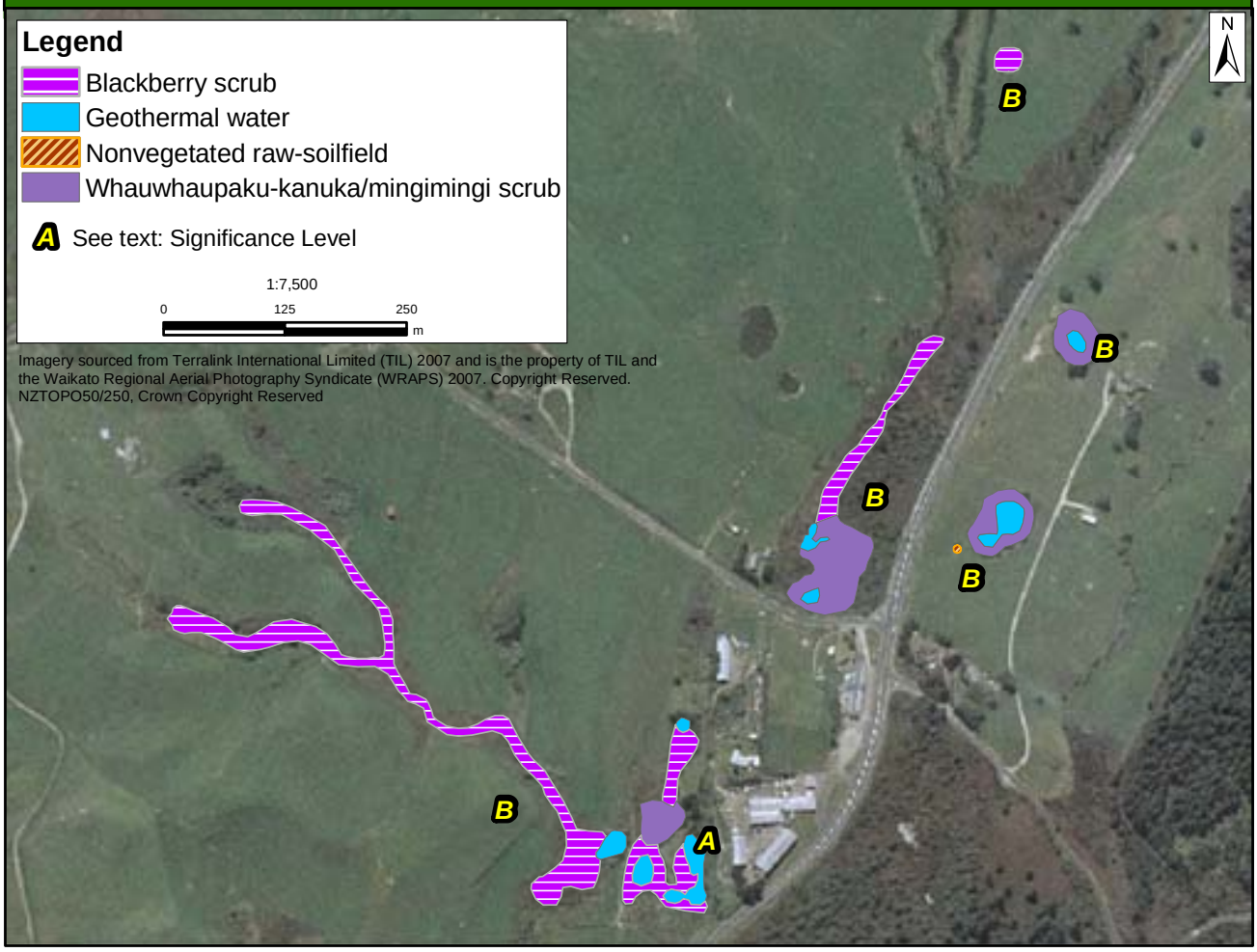
Site Change:

Recent change: No new field assessment undertaken since 2004. Any change to area mapped is based on better quality aerial photographs rather than any real site change. The authors do not consider any change to geothermal vegetation at this site to be significant.

Historical:	It is difficult to determine the difference between geothermal and non-geothermal scrub on the historic black and white photos (Historical photo: SN 172 Run 1158 Photos 2-4, 1941). However, surrounding the geothermal vegetation, the vegetation has developed from scrub in 1941 to secondary forest. There is considerably more bare ground visible historically, and the cooler geothermal soils have probably 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 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 6, 8).
Significance Justification:	This site is of national significance because it comprises a very high quality example of geothermal vegetation, a nationally uncommon vegetation type. The site is part of an ecological sequence that extends from geothermal vegetation (including prostrate kanuka shrubland and *Lycopodiella cernua* herbfield) to tall forest (including tall podocarp-hardwood forest and early successional types; Nicholls 1974a; Clarkson 1981b; Beadel 1995a) (from *c.*460 m to *c.*580 m). The vegetation is of good quality and is relatively unmodified. Four ‚At Risk' plant species (prostrate kanuka, *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. It 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 & Bill 2000; Clarkson 1981b; Nicholls 1974; Wildland Consultants 1998 & 2004.

WTV02 Ngapouri





NGAPOURI

Site Number: WTV02[1]
Grid Reference: NZTopo50 BF37 934 511
GPS Reference: NZTM E1893493 N5751107
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Protected (Ngapouri Covenant) and unprotected private land
Altitude: *c.*400 m
Extent of Geothermal Habitat: *c*.3.6 ha
Extent of Geothermal Vegetation: *c*.3.1 ha
Date of Field Survey: 12 August 2004

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.05 04.05.03	**Indigenous scrub-dominant communities** **Whauwhaupaku-kanuka/mingimingi scrub** Whauwhaupaku comprises the canopy (*c.*6 m high) with locally scattered wheki (*Dicksonia squarrosa*), kohuhu and kamahi, the latter confined to the area north of Waikite Valley Road. The groundcover is dominated by bracken with local patches of *Paesia scaberula*. The example of this vegetation type south of Waikite Valley Road is surrounded by blackberry.	Small gullies, flat, and undulating marginal strip	*c*.1.0 ha
04.08 04.08.01	**Blackberry-dominant scrub** **Blackberry scrub** This area comprises a dense cover of blackberry with whauwhaupaku, kanuka and manuka (up to 4 m high) scattered throughout, and local patches of kanuka and broom along the margin of SH 5. The groundcover comprises local patches of bracken and *Paesia scaberula* along hot pool margins. To the south of Waikite Valley Road the understorey includes locally common *Carex secta, Hypolepis ambigua* and *Juncus effusus*. Throughout the area extending parallel to Waikite Valley Road steaming vents are scattered on streamside banks.	Small gullies, flat and undulating marginal strip	*c*.2.0 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Heated pools.	Flat	*c*.0.5 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Heated soils, sinter and mud pools.	Crater	<0.1 ha

Indigenous Flora: *Lycopodiella cernua*, a characteristic feature of geothermal areas, is present.

[1] Previously identified as U16/7 in Wildland Consultants (2004).

Fauna: Common indigenous and introduced bird species typical of the habitat are present including grey warbler, tui, fantail, pukeko and spur-winged plover.

Current Condition (2004 Assessment): The vegetation is highly modified. Adventive plants are common and many parts south of Waikite Valley Road are grazed.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2004 Assessment*)*:* Large parts of this site are dominated by invasive exotic plants including blackberry (51-75% cover), broom (1-5% cover), crack willow (*Salix fragilis*) (1-5% cover), Tasmanian blackwood (*Acacia melanoxylon*), wilding pines, and apple (*Malus ×domestica*) (all with <1% cover).

Human impacts (*2004 Assessment*)*:* Herbicide drift, and run-off from State Highway 5 to the immediate east and farmland to the west, 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 (*2004 Assessment*)*:* The areas to the north of Waikite Valley Rd are well fenced from stock, but sheep have access to the southern areas.

Adjoining land use (*2004 Assessment*)*:* Farmland; Arataki Honey factory.

Site Change:

Recent change: Not assessed. Little change has been noted in this area, which is well known to the authors.

Historical: On aerial photographs taken in 1941 (Historical photos: SN172 Run 1158, Photo 4, 5 - 1941), it appears geothermal vegetation and habitat may have been more extensive, particularly behind (west of) the Waiotapu Hotel, prior to more intensive farm development. Several pools evident on the 1941 aerial photographs are no longer present. This may be a result of wetland drainage in the vicinity. It also appears that there are bare areas in what is now farmland on the north side of Waikite Valley Road, particularly upslope toward Maungaongaonga. These also may have been geothermal habitat which has been destroyed in land development. Most areas of geothermal vegetation is unlikely to be visible in aerial photographs as it is either in gullies or covered in vegetation unlikely to be discernible from other adjacent vegetation on aerial photographs.

Management Requirements: The southern areas require fence maintenance, removal of existing rubbish from fumaroles, and the prevention of further rubbish dumping.

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

Significance Justification:

A: The parts of the site identified as A on the map are of regional significance because they are protected as a conservation covenant under the Reserves Act 1977.

B: The parts of the site identified as B on the map are locally significant

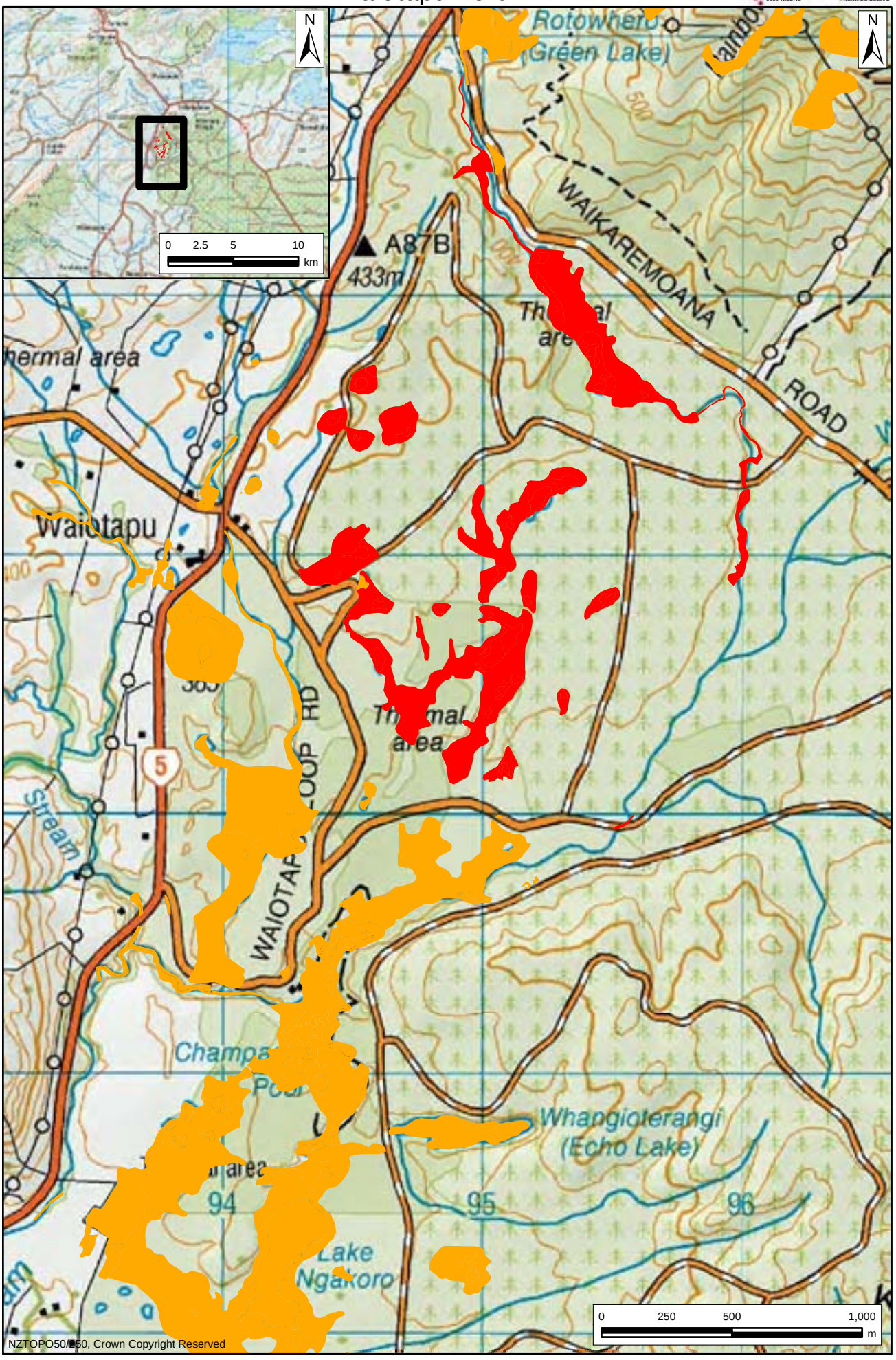
because they are small examples of geothermal habitat (some of which is degraded), which is a nationally uncommon habitat.

Notes: Parts of the geothermal vegetation and habitats that are not protected are subject to grazing and extensive areas 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 areas should be regularly monitored for management issues and formal protection and a restoration plan for these areas would enhance and/or protect the highly significant ecological values of this field.

References: Beadel 1995b; Beadel & Bill 2000; Wildland Consultants 2004.

WTV03

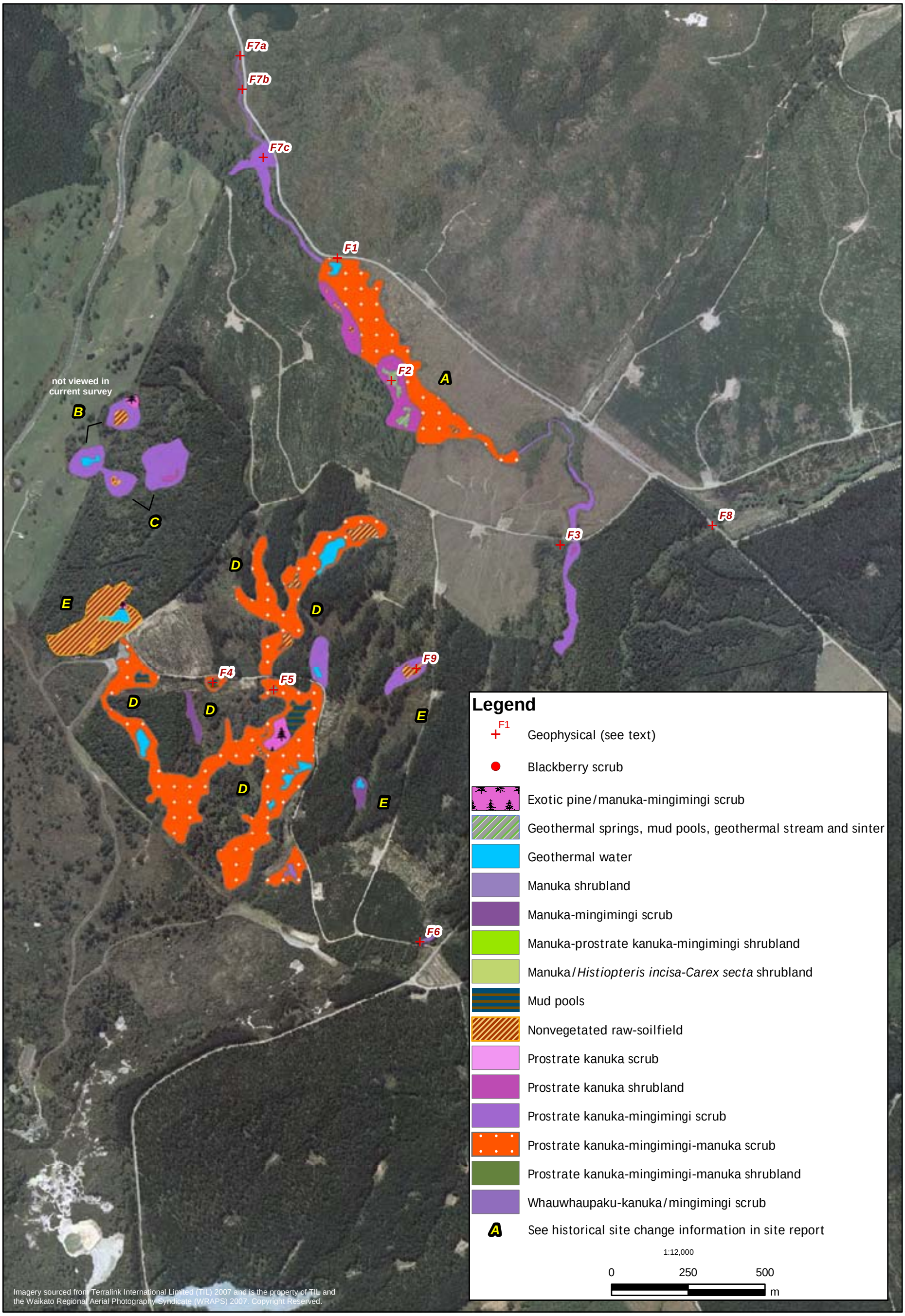
Waiotapu North



WTV03

Waiotapu North

Wildlands
0508 WILDNZ
www.wildlands.co.nz



WAIOTAPU NORTH[1]

Site Number: WTV03[2]
Grid Reference: NZTopo50 BF37 949 502
GPS reference NZTM E1894927 N5750233
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Unprotected private land and protected (Waiotapu Scenic Reserve)
Altitude: *c.*380-420 m
Extent of Geothermal Habitat: *c.*51.9 ha
Extent of Geothermal Vegetation: *c.*48.9 ha
Date of Field Survey: 26-29 July 2011

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.02	**Prostrate kanuka-dominant scrub** **Prostrate kanuka-mingimingi scrub** Prostrate kanuka and mingimingi (*c.*1-3 m high) form a dense cover, with manuka and kanuka common throughout, and occasional kamahi and wilding pines. In wet areas and along stream margins, manuka becomes more common. The groundcover comprises scattered bracken and *Histiopteris incisa*. Wilding pines, Japanese cedar (*Cryptomeria japonica*), broom, and blackberry become common at the margins of this area. At many sites pine control has been undertaken since 2004.	Sides of crater, flat and lake margins	*c.*8.8 ha
04.01 04.01.03	**Prostrate kanuka-dominant scrub** **Prostrate kanuka-mingimingi-manuka scrub** Prostrate kanuka 0.3-3 m tall with common areas of mingimingi. Manuka dominates in wet areas. Similar to Type 04.01.02 in composition. These are generally large areas and only representative parts of the site were surveyed.		*c.*31.0 ha
04.03 04.03.02	**Manuka-dominant scrub** **Manuka-mingimingi scrub** Manuka and mingimingi (2-4 m high) dominate the canopy with emergent wilding pines scattered throughout. The groundcover is sparse, with scattered *Gleichenia microphylla*, turutu and *Hypolepis distans*. Several plants of *Dicranopteris linearis* are present in this vegetation type.	River terraces, flat, and gently undulating	*c.*0.7 ha
04.03 04.03.13	**Manuka-dominant scrub** **Exotic pine/manuka-mingimingi scrub** Similar to Vegetation Type 04.03.02 described	River terraces, flat, and gently undulating	*c.*0.8 ha

[1] This site was called Waiotapu 2 in Beadel & Bill (2000).
[2] Previously identified as U16/1 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	above, but with a greater occurrence of wilding pines (radiata pine and black pine (*Pinus nigra*)) which are both scattered throughout and locally form small groves. Black wattle, prickly mingimingi, wheki, wheki-ponga (*Dicksonia fibrosa*) and broom are also scattered throughout. Several heated pools, seepages, boiling mud and heated ground patches occur in this type.		
04.08 04.08.01	**Blackberry-dominant scrub (not mapped)** **Blackberry scrub** About 30 m north of the bridge to the northeast of the site (see F8 on map) near E1896462 N5751308. Steam was seen rising from blackberry. It was too difficult to find the exact location to enable it to be described in more detail.		
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Dense prostrate kanuka (*c.*0.3-4 m high) dominates, with mingimingi scattered throughout; also locally scattered prickly mingimingi, monoao and wilding pines (e.g. lodgepole pine (*Pinus contorta*)) with occasional patches of *Lycopodiella cernua*.	Hillslope, gently rolling	*c.*2.7 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Geothermally-influenced lakes and pools, mud pools.	Flat and craters	*c.* 1.8 ha
22.01 22.01.02	**Geothermal water** **Mud pools** Mud pools surrounded by raw-soilfield, occasional hot springs.	Flat, craters	*c.*0.8 ha
22.01 22.01.04	**Geothermal water** **Geothermal springs, mud pools, geothermal stream and sinter**		*c.*0.4 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** This includes heated ground, sinter pavements, hot water springs and seepages, boiling mud and steaming ground.	River terraces, flat, and gently undulating	*c.*4.9 ha

Geophysical Assessment[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 north-western edge of the lake. The temperature was measured (using the IR thermometer)

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson,2010.

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 1-2L/sec. 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.

Plate 18: Large clear blue hot (boiling) pool. Note: Discharge was to the

south, towards stream in the background. Sinter terrace also visible on lhs of photo, Feature 2, Waiotapu North.

Plate 19: Small shallow pools discharging to the west. Note: minor sulphur deposition and sinter terrace, Feature 2, Waiotapu North.

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 north-eastern 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). The majority 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 less than 1L/sec. 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: View from southeast of sinter terrace and shallow pool area. Note stream flow from right to left in background and main discharge channel on lhs of photo, Feature 3, Waiotapu North.

Plate 21: Hot pool with geyserite structure rim, Feature 3, Waiotapu North.

Plate 22: Small hot pool (90^{o}C) with sheen, Feature 3, Waiotapu North.

Plate 23: Discharge from sinter terrace and pools into stream, Feature 3, Waiotapu North.

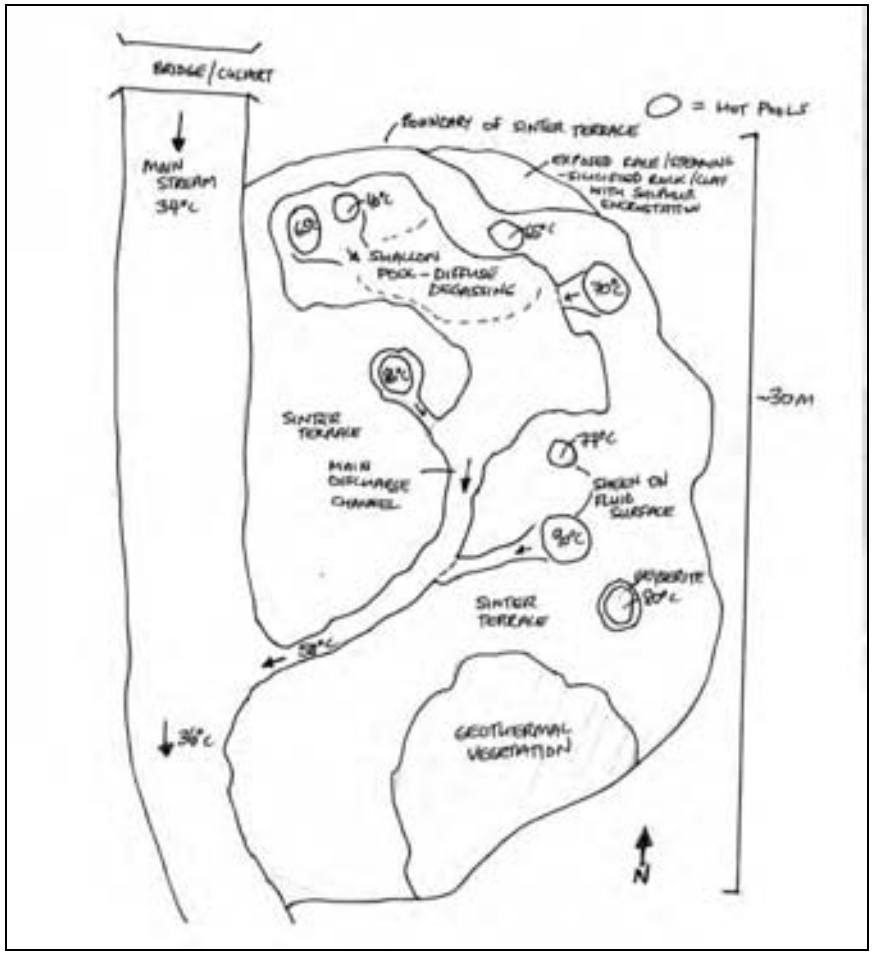


Figure A1-7: Field sketch of Hot pools and sinter terrace, Feature 3, Waiotapu North.

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 these was noted to erupt 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 its pale green colour suggests a sulphuric input. Access was not sufficient to take a temperature measurement.

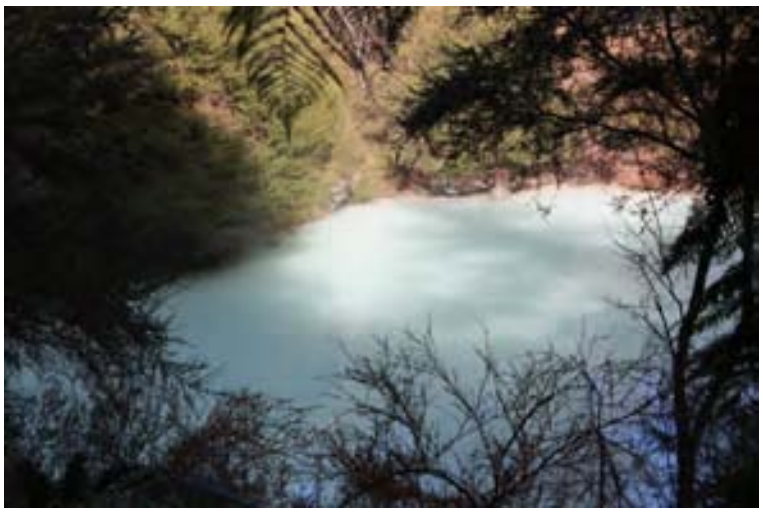


Plate 25: Pale green lake with minor steam discharge, Feature 5, Waiotapu North.

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 <0.1L/sec 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 this was deposition of silica 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 200L/sec.

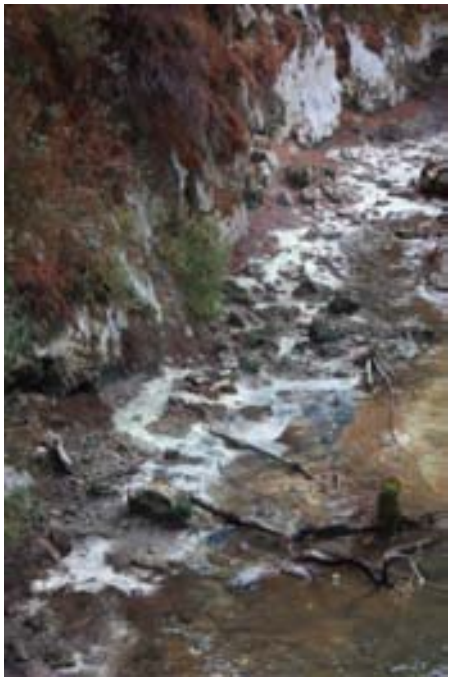


Plate 26: Steaming ground and hot springs on western bank of stream, Feature 6, Waiotapu North.

Grid Reference: E1895977 N5753920
Feature 7: Freshwater Stream with geothermal inputs

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 200L/sec. 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*.1L/sec). The temperatures ranged from 33°C to 79°C and had pH values of approximately 6.

(b) Grid Reference: E1894928 N5752731. Small clear pool on the eastern bank with a temperature of 95°C discharging approximately 0.5L/sec through a 2m 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. Small spring outflow at an outcrop of silicified clay discharging 95°C fluid into stream. Flow is approximately 0.2L/sec.

Plate 27: Area of hot pools discharging into stream (a), Feature 7, Waiotapu North.

Plate 28: Small clear, near boiling pool, 0.2L/sec 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 would appear to be 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.

Indigenous Flora: Prostrate kanuka and *Dicranopteris lineraris* (both classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) are present. A small population of *Lycopodiella cernua*, a species which is characteristic of geothermal areas, is present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present, including tui, grey warbler, fantail, tomtit, silvereye, Australasian harrier, bellbird, and welcome swallow. Pied stilt (classed as „At Risk-Declining' in Miskelly *et al.* 2008) were observed nesting on the site in Beadel & 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 forests, exotic scrub and farmland. Whilst there is a relatively low diversity of some of the threatened species that can occur at geothermal sites, the site is of high ecological interest as a result of a wide diversity of geothermal habitats present. The site links the geothermal habitat of Waiotapu South with the Maungakakaramea (Rainbow Mountain) and Ngapouri sites.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2004 Assessment*)*:* The margins of the geothermal vegetation is dominated by invasive exotic plants; wilding pines are still common, with a cover of 5-25%, despite the considerable control of wilding pines that has been undertaken since 2004. Also present is broom (6-24% cover), blackberry (1-5% cover), Spanish heath (1-5% cover), grey willow (1-5% cover), apple, climbing rose (*Rosa* sp.), and *Cotoneaster glaucophyllus* (all with <1% cover). Blackberry and grey willow are often common on geothermal stream margins.

Human impacts (*2004 Assessment*)*:* This site has well maintained roads, and Kerosene Creek is a popular bathing area for tourists and locals, however the main areas with geothermal vegetation are seldom visited as most can not be seen from the main roads.

Grazing (*2004 Assessment*)*:* Livestock have no access to this site and are only a potential threat to the Landcorp Protective Covenant; however the fencing in this area is currently stock proof.

Adjoining land use (*2004 Assessment*)*:* Plantation forests, farmland, Waiotapu Scenic Reserve.

Site Change:

Recent change: Several new units of vegetation were identified which were not found in the 2004 survey. These were mostly found based on areas being more visible in recently cleared pine plantation, as well as being more visible on better quality 2007 aerial photographs. Some minor loss of geothermal vegetation has occurred in places following harvesting of pine trees; however in most instances it appears that the land manager has taken reasonable care to avoid damage to geothermal sites. Replanting of plantation trees has generally taken place outside of geothermal areas.

Historical: 1941 aerial photographs (Historical photos: SN 172 Run 1158 Photos 6-7, 1941) were compared with 2007 aerial photographs. At this site the

boundaries between geothermal vegetation and non-geothermal vegetation, particularly scrub and shrubland, is difficult to determine on aerial photographs. On aerial photographs it is only possible to determine changes to the larger geothermal sites. In the area identified as A on the aerial photograph, the southern part of the site is now in plantation. The site in 2007 is only about two-thirds of the size of the site in 1941. Some of the bare ground has been invaded by shrubs and pine trees. These are probably in areas of lower geothermally-active soils.

It is difficult to determine change in the area marked C. Wilding pines have established in parts of the site, but otherwise these areas are similar in 1941 to the geothermal vegetation visible in the 2007 photos.

The two areas identified as D on the accompanying map were in a poor condition in 1941. It appears that stock had access to the western parts of these sites and vegetation had been cleared through part of the sites, possibly for power lines. However, the area of scrub around geothermal features extends further around the site. There is also the possibility of more raw geothermal soilfield to the west of these units. This area is about 5-20% larger than current size.

Pines and shrubs have invaded further into raw-soilfield habitats in areas marked as D. There has been a 10-25% reduction in raw-soilfields, mud pools, geothermal water habitat in this area, and a 25-50% reduction of shrubland habitats because of plantation forestry, and wilding pines. Few wilding pines were present in the southern part of this vegetation type 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%. Some vegetation would have already been cleared prior to 1941.

Management Requirements:

Wilding pines in core geothermal areas, particularly those in the prostrate kanuka scrub, need to be removed. An infestation of African feather grass (*Cenchrus macrourus*) occurs near the mud pools to the southwest of this site, adjacent to geothermal areas mapped as part of this study. 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 & Bishop 1997; Wildland Consultants 2004).

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', is an important habitat of prostrate kanuka, which is an „At Risk' species. In addition, the site comprises a relatively large example of a nationally uncommon habitat type. *Dicranopteris lineraris* („At Risk-Naturally Uncommon') is also present. 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:

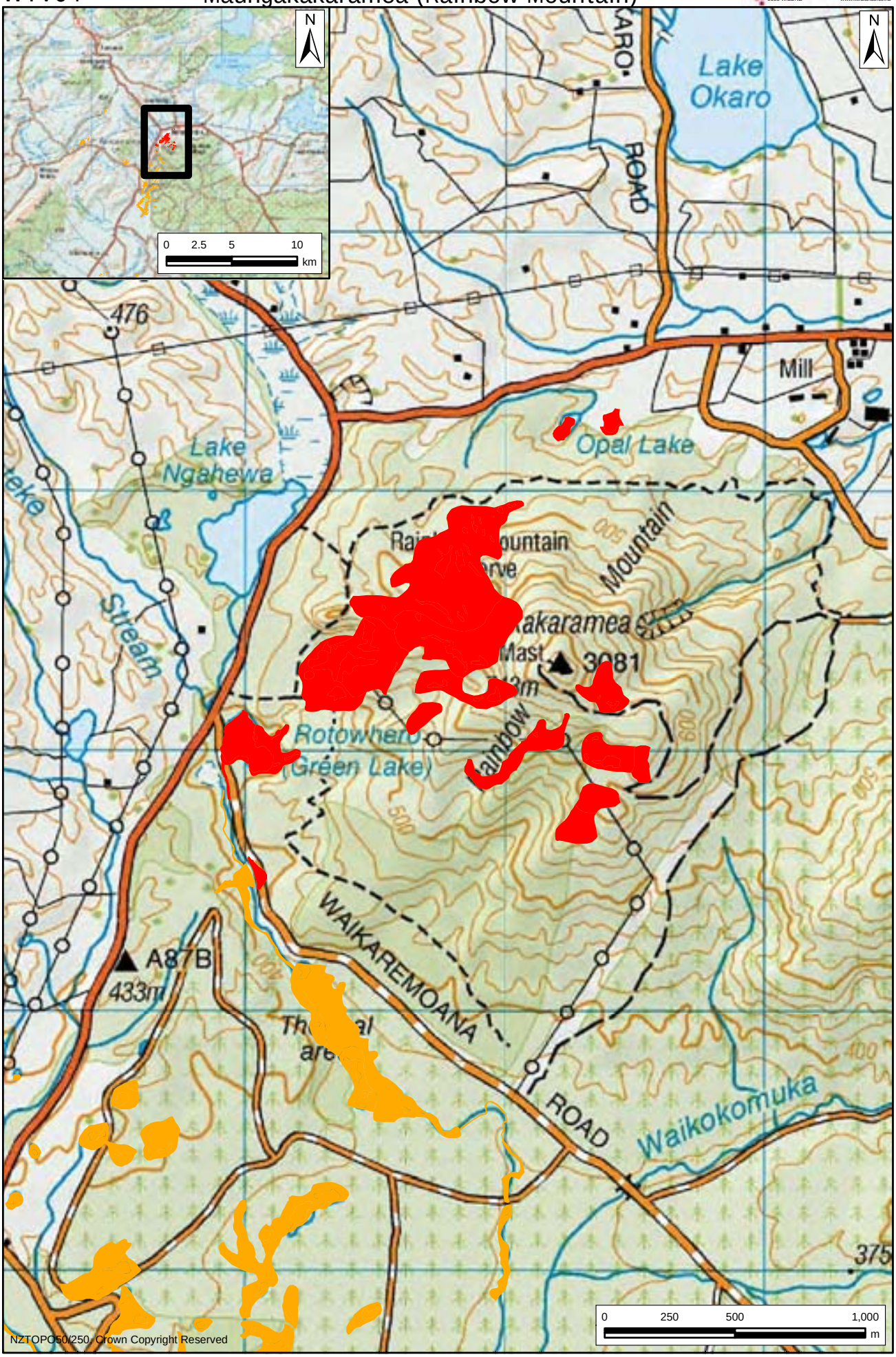
Ecological surveys and assessments were made of the parts of this site managed by Kaingaroa Timberlands in April 2004 (see Wildland Consultants 2004b). It was determined that these areas were a "high conservation value forest" as defined by the Forest Stewardship Council criteria for assessment of high conservation value forests.

Parts of the geothermal vegetation and habitats that are not protected are subject to grazing and extensive areas 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 areas should be regularly monitored for management issues and formal protection and a restoration plan for these areas would enhance and/or protect the highly significant ecological values of this field.

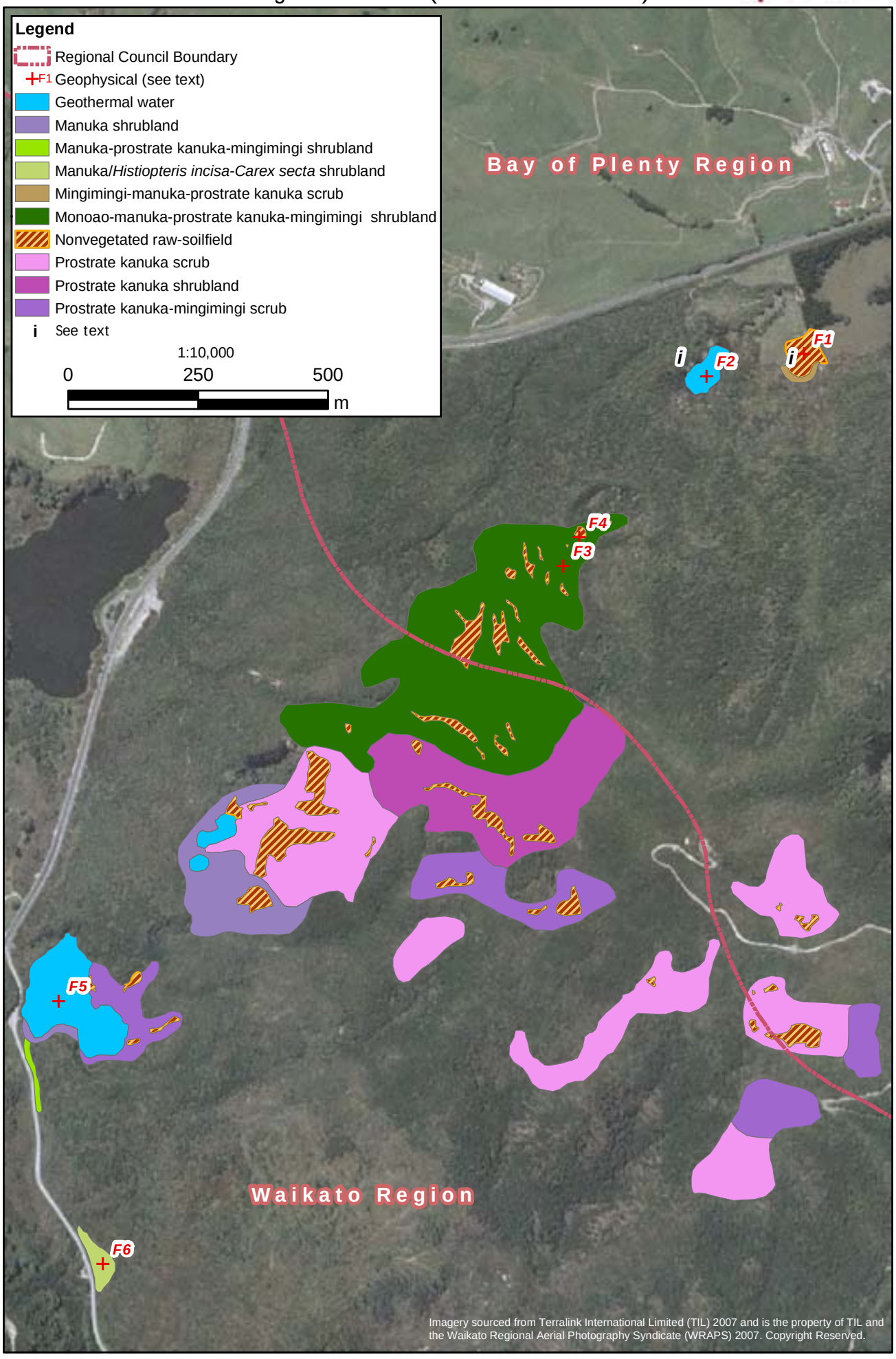
References:

Beadel & Bishop 1997; Beadel & Bill 2000; Given 1995; Wildland Consultants 2004.

WTV04 Maungakakaramea (Rainbow Mountain)



WTV04 Maungakakaramea (Rainbow Mountain)



MAUNGAKAKARAMEA (RAINBOW MOUNTAIN)

Site Number: WTV04[1]
Grid Reference: NZTopo50 BF37 956 534
GPS Reference: NZTM E1895633 N5753443
Local Authority: Rotorua
Ecological District: Atiamuri; Rotorua Lakes
Geothermal Field: Waiotapu
Bioclimatic Zone: Lowland - submontane
Tenure: Protected (Rainbow Mountain Scenic Reserve) and unprotected private land
Altitude: *c*.400-740 m
Extent of Geothermal Habitat: *c*.53.97 ha
Extent of Geothermal Vegetation: *c*.50.57 ha
Date of Field Survey: 26 July 2010

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka dominates the canopy (0.3-3 m high) with kamahi and kanuka scattered throughout; there is locally scattered mingimingi, prickly mingimingi, tawiniwini (*Gaultheria antipoda*), toru, rewarewa (*Knightia excelsa*) and toatoa (*Phyllocladus toatoa*). The groundcover comprises bracken, *Gleichenia microphylla*, and turutu.	Hillslope and road escarpment	*c*.14.5 ha
04.01.02	**Prostrate kanuka-mingimingi scrub** This area is a mosaic of prostrate kanuka scrub (described above) and mingimingi scrub (dominated by mingimingi). Kamahi, rewarewa, manuka, and karamu occur over mingimingi, turutu, *Gleichenia microphylla*, tawiniwini, and bracken in cooler areas. Fumaroles are abundant throughout this vegetation type. Wilding pines, particularly radiata pine, are establishing in places. Monoao occurs amongst patches of prostrate kanuka scrub.	Hillslope and shallow basin	*c*.6.2 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** The areas of geothermal activity are dominated by a low cover of prostrate kanuka shrubland (0.3-0.75 m high), with patches of mossfield interspersed with areas of nonvegetated heated ground and steaming ground. Monoao, mingimingi and *Cladia retipora* are locally scattered in this area. Other vascular species present include turutu, toru, *Lycopodiella cernua*, and kanuka in association with mingimingi, manuka, and prickly mingimingi. Kamahi, with prostrate kanuka, occurs at the margins of the thermal areas. Local populations of *Dicranopteris linearis* and *Nephrolepis flexuosa* are present. Wilding pines are establishing in this	Hillslope, spur tops and cliffs	*c*.21.7 ha

[1] Previously identified as U16/2 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	vegetation type.		
05.03 05.03.01	**Manuka-dominant shrubland** **Manuka shrubland** Manuka is dominant over an understorey of mingimingi, bracken, turutu, and kiokio, with prostrate kanuka in more geothermally active areas. In wet areas *Sphagnum cristatum* often forms the ground cover. Occasional plants of wheki and kamahi are present. *Histiopteris incisa* and *Carex geminata* occur locally near areas of hot water.	Hillslope	*c.*3.2 ha
05.03.27	**Manuka/*Histiopteris incisa-Carex secta* shrubland** The canopy, 2-4 m high, is mainly manuka with prostrate kanuka and mingimingi scattered throughout. Other species present include wheki-ponga, wheki, karamu, broom, and grey willow. The groundcover is dominated by *Histiopteris incisa* and *Carex secta*, with local patches of raupo in the wetter geothermal areas. Whauwhaupaku, kohuhu and kamahi occur around the margins of this type, and locally throughout. Several crack willow are present.	Wetland at toeslope	*c.*0.4 ha
22.01 22.01.01	**Geothermal water** **Geothermal water (geothermal lake)** Geothermally influenced lakes.	Basins	*c.*3.4 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Geothermally-altered soil, mud, sinter, explosion craters and fumaroles.	Flat, hill, hillslope	*c.*4.3 ha

Geophysical Assessment:[1]

Feature 1: Thermal Ground, Steaming Ground (see Plates 31-33)

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^{o}C) while the rest of the area had temperatures ranging from 22^{o}C on the eastern perimeter to 56^{o}C on the western perimeter.

A large cold (3^{o}C, air temp: 4^{o}C) 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.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson,2010.

Plate 31: View of thermal ground looking south from bund. Note outcrop left of centre, Feature 1, Maungakakaramea (Rainbow Mountain).

Plate 32: Steaming outcrop, southern end of area, 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 lake, 4°C (air temp: 5°C), 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 were not above 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. In the middle of the lake on the western side there 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.

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 consisting of 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 consisting of pink and whit 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. Within the clay matrix are angular pumice fragments which are highly silicified.

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 across the majority of its 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 litres/sec) from the lake had a temperature of between 28-32°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 area measures approximately 20 × 20 m. The area consists of 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 60L/sec.

Plate 41: Geothermal wetland with numerous hot clear pools, Feature 6, Maungakakaramea (Rainbow Mountain).

Indigenous Flora: The following species characteristic of geothermal vegetation occur here: prostrate kanuka, *Schizaea dichotoma* and *Dicranopteris linearis* (all classed „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), a small population of *Nephrolepis flexuosa* (classed as „At Risk-Declining' in de Lange *et al.* 2009), and *Schizaea* sp. (cf. *S. fistulosa*). *D. linearis* is known from only *c.*24 sites in New Zealand. Four orchid species - *Calochilus paludosus*, *C. robertsonii*, *Petalochilus alatus* (recorded on 10 October 2006; Bycroft 2006), and *Stegostyla atradenia* (all classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) - have been recorded at the site (Rotorua Botanical Society 2006) but were not recorded in 2004 or during the current study. Several populations of *C. robertsonii* were recorded at this site in November 2005 (Chris Bycroft pers. comm.).

Other species of interest found in the reserve in previous surveys but not necessarily in geothermal areas are *Ileostylus micranthus* (P. Cashmore pers. comm.), *Thelymitra carnea, T. nervosa, T. ixioides, T. pulchella, T pauciflora*, and *Psilotum nudum* (see species list, Rotorua Botanical Society 2006).

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

(Note: All species mentioned above have been seen by one of the authors, between 2000 and 2011, unless referenced)

Fauna: Common indigenous bird species typical of the habitat are present, including North Island robin, spur-winged plover, grey warbler, blackbird, Australian magpie, welcome swallow, fantail, and bellbird. Dabchick were recorded at Feature 2 (F2 on 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. 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 new small area of geothermal activity recently found by the authors to the north of the site. This small area is in a poor condition.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*)*:* Wilding pines are the key invasive exotic plant species in areas of geothermal vegetation. Whilst geothermal hot spots appear to be resistant to weed invasion, wilding pines are a threat to the prostrate kanuka scrub which occurs on cooler soils and this is particularly apparent on the eastern side. Pest gymnosperm species known from the reserve include bishop pine (*Pinus muricata*), lodgepole pine, European larch (*Larix deciduas*), black pine, maritime pine, radiata pine, and strobus pine (*Pinus strobus*). 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 small. Crack willow and grey willow are present alongside stream margins. In total, wilding pines cover <1% of the area in which geothermal vegetation occurs. Spanish heath was found at this site in 2006, by John Hobbs, but was removed by him. Any new infestations should be removed. Gorse (<1%) and Spanish heath (<1%) are present in geothermal areas alongside Kerosene Creek Road and site

margins. *Hakea salicifolia* (1-5% cover) has become considerably 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): 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 map)

Adjoining land use (2011 Assessment): Surrounded by indigenous vegetation in Rainbow Mountain Scenic Reserve. Farmland; roads; plantation forests.

Site Change:

Recent change: The most notable change since the previous survey is the continued control of pines by Department of Conservation. The site is in a markedly improved condition as a result. Other changes to the site are as a result of new parts of the site identified on better quality aerial photographs (2007 photos), and additional units of geothermal vegetation have been found.

Historical: A series of 1941 photographs were compared with 2007 photographs (Historical photos: SN 172 Run 1157 Photos 7-12, 1941; SN 172 Run 1158 Photos 7-8, 1941). In most places it is difficult to determine the differences between geothermal and non-geothermal scrub and shrublands. The following points were noted:

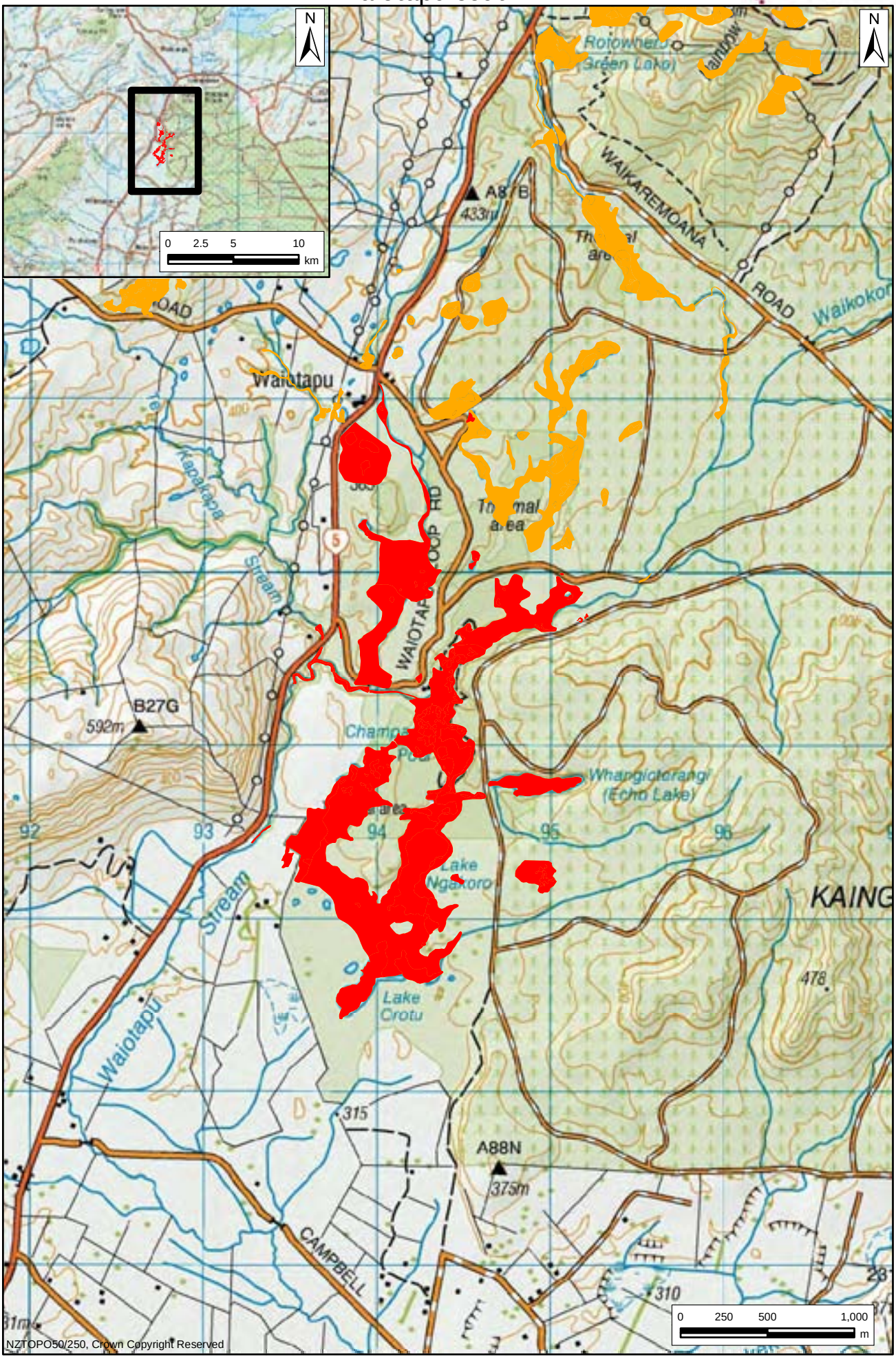
- A small lake, which may have been geothermal, is no longer present to the south-west of Lake Rotowhero (approximately E1894870 N5752800). There was also significantly more bare ground in this southern portion of the site, on the 1941 photographs (c.f. 2007), probably as a result of weed invasion, and establishment of plantation forests on historically geothermal soils.
- There was considerably more bare ground visible on the eastern and northern slopes of Maungakakaramea. This is partly as a result of cooling geothermal soils, and establishment of shrubs and exotic pines.
- More bare ground was evident on margins of Lake Rotowhero, but not markedly so.
- There seems to have been a considerable reduction of geothermal vegetation (including a geothermal lake) to the north of the site, near SH38, as land has been converted to industrial and farm uses. A geothermal lake and surrounding vegetated and nonvegetated raw-soilfield have been converted to pasture. The lake at F3 on the map may have also been more active in 1941, with bare ground on northern and southern margins of the lake.

If it is taken into account that many areas that were historically bare geothermal sites have been invaded by indigenous shrubs, and wilding pines, are still geothermally active, then 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. Fencing of geothermal features to the north of the site near SH38 should be considered. Stock have access to geothermal features in this part of the site.
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 - a nationally uncommon habitat type. It is a good quality representative example of an ecological sequence grading from geothermal vegetation to tall forest - manuka-kanuka shrubland, whauwhaupaku-kohuhu forest, kamahi forest, and totara (*Podocarpus totara* var. *totara*)-rimu (*Dacrydium cupressinum*)/kamahi forest (Nicholls 1974; Clarkson 1981b; Beadel 1995a), over an elevation gradient of 380-743 m. It 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, B.D. 1981a). Eight species classed as ‚At Risk' have been recorded at the site: prostrate kanuka, *Schizaea dichotoma*, *Nephrolepis flexuosa*, *Dicranopteris linearis*, *Calochilus paludosus*, *C. robertsonii*, *Petalochilus alatus,* and *Stegostyla atradenia*.
References:	Beadel & Bill 2000; Burns 1997b; Bycroft 2006; Clarkson 1981a & 1982b; Merrett & Burns 1998a; Rotorua Botanical Society 2006; Watt 1986; Wildland Consultants 1998 & 2004.

WTV05

Waiotapu South



WTV05

Waiotapu South

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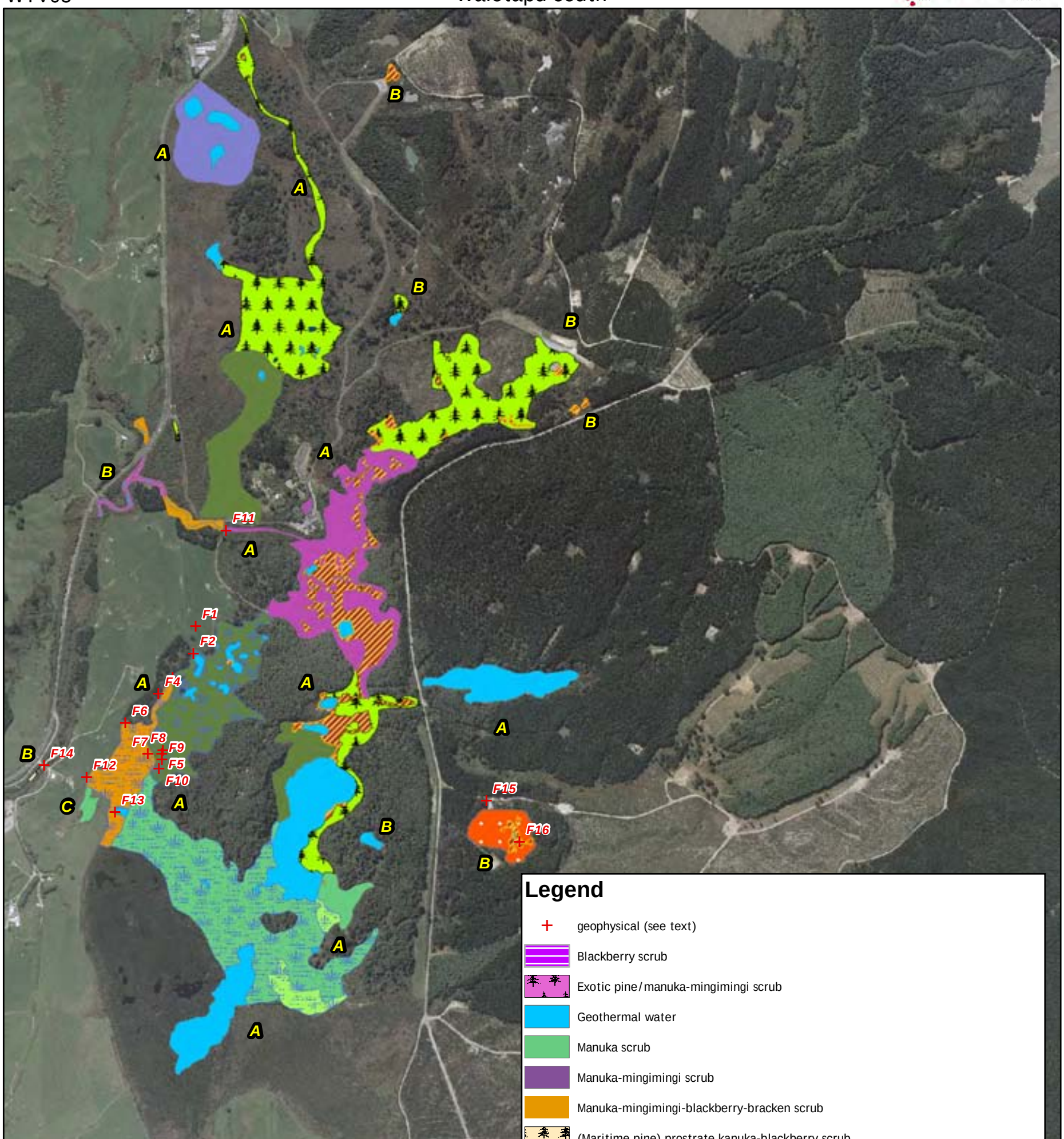


WAIOTAPU SOUTH[1]

Site Number WTV05[2]
Grid Reference: NZTopo50 BF37 945 487
GPS reference: NZTM E1894491 N5748676
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Protected (Waiotapu Stewardship Area, Waiotapu Scenic Reserve)
Altitude: *c.*320-380 m
Extent of Geothermal Habitat: *c.*129.9 ha
Extent of Geothermal Vegetation: *c.*05109.5 ha
Date of Field Survey: 9 December 2010, 10 July 2011

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.01 04.01.11	**Prostrate kanuka-dominant scrub** **(Maritime pine)/prostrate kanuka-blackberry scrub** Several hot springs on margin of Waiotapu Stream. Scattered maritime pine overhangs the stream. Prostrate kanuka is common on stream margins and springs. Blackberry and mingimingi dominate less geothermally active areas. Other common species include turutu, *Histiopteris incisa*, broom, harakeke, and Yorkshire fog. This vegetation type extends at least 50 m downstream and 20 m upstream of the bridge.	Stream margins	*c.*0.2 ha
04.02 04.02.19	**Mingimingi-dominant scrub** **Mingimingi-manuka-blackberry-indigenous broadleaved species scrub** This vegetation occurs along stream margins. Blackberry becomes dominant on cooler soils, but with abundant steam. *Histiopteris incisa*, turutu, and bracken are common. This vegetation type was mostly viewed from a distance.	Stream margins	*c.*0.8 ha
04.03 04.03.01	**Manuka-dominant scrub** **Manuka scrub** Extensive areas of wetland to south. Pig sign was abundant throughout. Manuka 2-4 m tall dominates with *Baumea rubiginosa*, kiokio, *Carex secta*, *Hypolepis distans*, and exotic grasses such as Yorkshire fog in drier areas. Free-standing water was present in most areas during survey. Prostrate kanuka and mingimingi were common around sinter and hot springs. Patches of *Schoenoplectus tabernaemontani*, *Carex secta*, and *Carex virgata* are present. Arrow grass occurs in several locations on sinter, and raupo reedland occurs locally.	Wetland	*c.*23.9

[1] This site was called Waiotapu 1 in Beadel & Bill (2000).
[2] Previously identified as U17/1 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.03.18	**Manuka-mingimingi-blackberry-bracken scrub** A highly diverse vegetation type with large extensive areas of manuka, scrub, mingimingi scrub, blackberry scrub, and bracken fernland. Broom is common in places, and wheki and wheki-ponga occur in wet areas. Scattered wilding maritime pines are present. Mud pools and hot springs are common, with sinter present near many of the hot springs.	Flat, rolling hills, gently undulating	*c.*5.9
05.01 05.01.01	**Prostrate kanuka shrubland** **Prostrate kanuka shrubland** Prostrate kanuka forms a low discontinuous canopy (*c.*0.1-1.0 m high) in association with scattered mingimingi, and local *Lycopodiella cernua* in areas of relatively high geothermal activity.	Gently undulating, flat	*c.*11.9 ha
05.01.15	**Prostrate kanuka-mingimingi-manuka shrubland** A dense canopy of prostrate kanuka, mingimingi and manuka, with locally dominant kanuka and local monoao. Maritime pine is locally common on cooler soils along the margins of these areas.	Flat area , gently rolling hills	*c.*21.7 ha
05.01.18	**Wilding pine/protstrate kanuka-mingimingi-manuka shrubland** Wilding radiata and maritime pine occur over kanuka, mingimingi, manuka, broom, prickly mingimingi, *Coprosma lucida*, blackberry, and whauwhaupaku. Occasional black wattle is present. The groundcover includes bracken, *Carex secta*, turutu, *Hypolepis ambigua*, kiokio, swamp kiokio and *Paesia scaberula*. This type forms a narrow strip along the margins of heated streams, with local small areas of steaming ground. In or near these areas wilding pines (mostly radiata pine and maritime pine) occur over prostrate kanuka (1-6 m high), mingimingi, prickly mingimingi and manuka. Local kamahi and whauwhaupaku are present. The groundcover is sparse and includes turutu, *Lycopodiella cernua* and *Gleichenia microphylla*. Boiling mud pools are scattered throughout this area. Blackberry is very dense in non-geothermal areas.	Flat areas, stream margins and wetland Flat area and gently rolling hills	*c.*27.7 ha
05.01.19	**Prostrate kanuka-kamahi-wheki-whauwhaupaku/blackberry shrubland** Prostrate kanuka, kamahi, wheki and whauwhaupaku comprise the canopy over blackberry with *Hypolepis ambigua* and *Paesia scaberula* locally common around steam vents.	Stream margin	*c.*6.8 ha
07.14 07.14.01[1]	**Cyclosorus-dominant fernland** ***Cyclosorus interruptus* fernland** (not mapped) *Cyclosorus interruptus* occurs amongst raupo reedland and on margins of sinter terraces, in association with heated areas.	Wetland	

[1] Areas of this vegetation type occur within the area mapped as 10c, however were too small to be mapped separately.

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
11.01 11.01.16	**Raupo reedland** **Raupo-harakeke reedland⇔*Carex secta-Baumea rubiginosa-Baumea juncea* sedgeland** This area comprises a mosaic of harakeke-raupo reedland and *Carex secta-Baumea rubiginosa-Baumea juncea* sedgeland with patches of manuka shrubland throughout. Blackberry is common in dry areas. Harakeke with raupo forms a reedland in association with *Austroderia toetoe*, koromiko (*Hebe stricta* var. *stricta*), *Coprosma propinqua,* karamu, and kiokio. *Carex secta, Carex virgata, Schoenoplectus tabernaemontani*, *Baumea rubiginosa*, and *Baumea juncea* dominate the sedgeland, in association with rushes and *Eleocharis acuta*. Geothermal activity is evident in areas throughout this vegetation type with occasional *Cyclosorus interruptus* present.	Wetland	*c*.2.4 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Geothermally influenced pools and lakes.	Open water	*c*.20.4 ha
22.01.02	**Mud pools**	Mud pools, craters	*c*.0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Includes craters, steaming ground, boiling mud, hot pools, and sinter terraces.	Flat, gently rolling	*c*.8.0 ha

Geophysical Assessment[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.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson,2010.

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 at 15^{o}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.

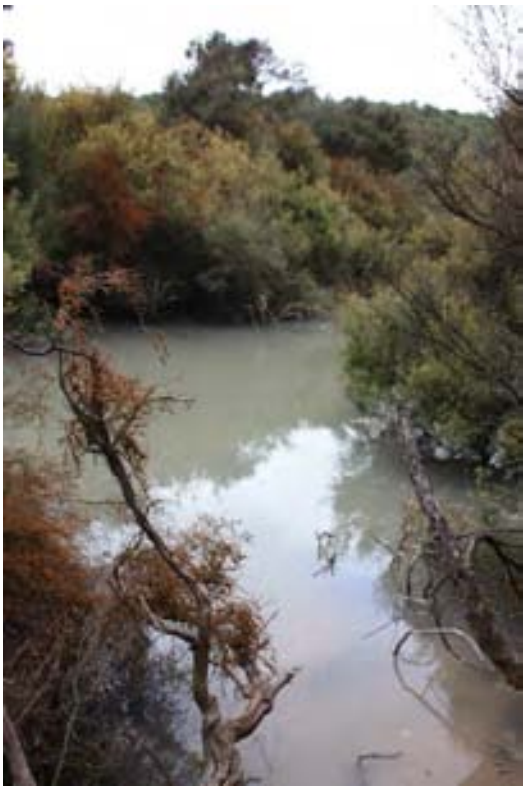


Plate 43: View from northern end of lake. Degassing was noted in middle ground of photo, Feature 2, Waiotapu South.

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/sec. The pH was found to be 7.6 in the pools in this area. 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.

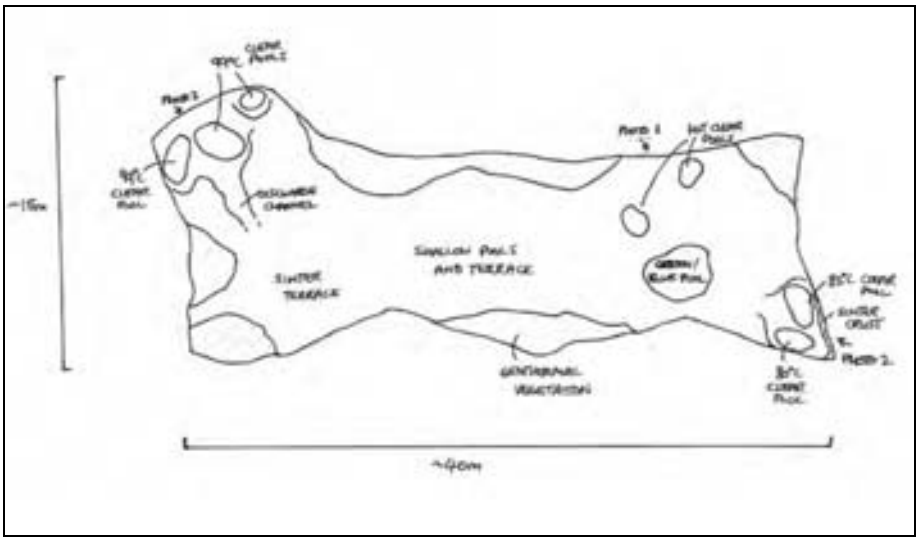


Figure A1-8: Field sketch of area of hot pools and sinter terrace, Feature 3, Waiotapu South.

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 6, Waiotapu South.

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 was infrequent bubbling 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 noted to be 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 <0.1L/sec.

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^oC. 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 which flows through the northern section of the Waiotapu tourist park had a temperature of 26^oC near the visitors centre. At the grid reference listed above the temperature was 28^oC. This location is further downstream 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^oC locally (common public hot spring bathing temperature). The flow of the stream was estimated to be in the order 150-200L/sec.

Feature 12: Mud pool
Grid Reference: E1893477 N5748452

A mud pool with a surface temperature of 60^oC 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 at this location with a temperature of 18^oC and pH of 4.9 at its western margin. An area at the southern end of the lake had moderate steam discharge (Plate 51) and as such an upwelling of hotter

fluid is suggested. There is an outflow from the lake at its southern margin which had a temperature of 21°C, pH of 4.8 and a flow of approximately 5-6L/sec. 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 south-eastern part of the site were around 32°C, while the majority 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 oftwo main pits of 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.

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), which is endemic and restricted to geothermal areas, occurs here.

A large population of *Cyclosorus interruptus* (classed as „At Risk-Declining' in de Lange *et al.* 2009), is present in the wetland to the south of the reserve. Hobbs (2002) recorded 329 plants in Orutu Wetland to the south part of this site in 2002. The population is likely to be considerably larger than this, as much of this part of the site is inaccessible. One frond of *Dicranopteris linearis* (classed as „At Risk-Naturally Uncommon' and known from only *c.*24 sites in New Zealand) has been recorded near „Twin Rivers' geothermal stream (Paul Cashmore pers. comm. 2007).

Fauna: Two threatened bird species (spotless crake and North Island fernbird) classed as „At Risk-Relict' and „At Risk-Declining' respectively (in Miskelly *et al.* 2008) are present in the wetland at the southern end of the site. New Zealand dabchick (Threatened-Nationally Vulnerable in Miskelly *et al.* 2008) are present on Lake Orutu. Other species present include shining cuckoo, grey warbler, bellbird, tui, fantail, Australasian shoveler, grey duck, mallard, pied tit, North Island robin, greenfinch, house sparrow, and Australasian magpie.

Current Condition (2004 Assessment): In the tourist area, areas around the key geothermal features are well maintained for public viewing; however the vegetation is modified by the presence of maritime pine. Few other invasive exotic plants are present and overall this site is in good condition, particularly at the southern end. Some management of wilding pines has taken place in recent years, improving the quality of the site. Exotic pines continue to be a major threat, particularly in the area between Waiotapu Loop Road and State Highway 5. 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 pest plants, 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 since the 2004 survey. 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 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*)*:* Livestock have no access to most of this site, although sheep have had access to the wetland to the south-western portion of the site due to broken

fences. These have recently been replaced. Feral pigs have done a lot of damage in the southern and western wetlands, with tracks crossed every few metres when walking through wetland. Possum sign was also abundant. Deer are also likely to graze the site. The small area amongst Ngapouri Station is grazed by stock.

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

Site Change:

Recent change: Most of the changes in site mapping since 2004 is related to new parts of the site only becoming known to the authors recently, 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, particularly its indigenous character. Overall, the extent of geothermal habitat at Waiotapu South is considered to be similar to the 2004 study.

Historical: An assessment was made comparing 1941 (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) to 2007 aerial photographs. The most significant change in historical photographs from 1941 is the lack of wilding pines and trees in 1941. In the south of the site, the wetland extended most of the way to State Highway 5 and the wetland may have been one-third larger than it is today. However, most of this wetland would not have been geothermal. There was also a greater buffer between geothermal features and plantation forests 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 may have been lost since 1941, and wilding pines may have caused degradation to 25% of the site. Some of these pines have been controlled in recent years.

Management Requirements: Weed 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.

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: 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 habitat, a nationally uncommon habitat type.

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.

Because of the size of this site, very broad classes of vegetation are described. While small areas of most parts of the site have been visited in 2004 and 2011, some parts are too dangerous to access. Areas where most doubt exists to exact boundary of geothermal habitat are the wetland to the south near Lake Orutu, and in the area between Waiotapu Loop Road and State Highway 5. There is no clear cut boundary between geothermal wetland and non-geothermal wetland in the south and southwest of this site.

Parts of the geothermal vegetation and habitats that are not protected are subject to grazing and extensive areas 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 areas should be regularly monitored for management issues and formal protection and a restoration plan for these areas would enhance and/or protect the highly significant ecological values of this field.

References:

Beadel & Bill 2000; Clarkson 1982; Given 1995 & 1996; Hobbs 2002; Miller & Miller 1983; Rasch 1989; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 1998 & 2004.

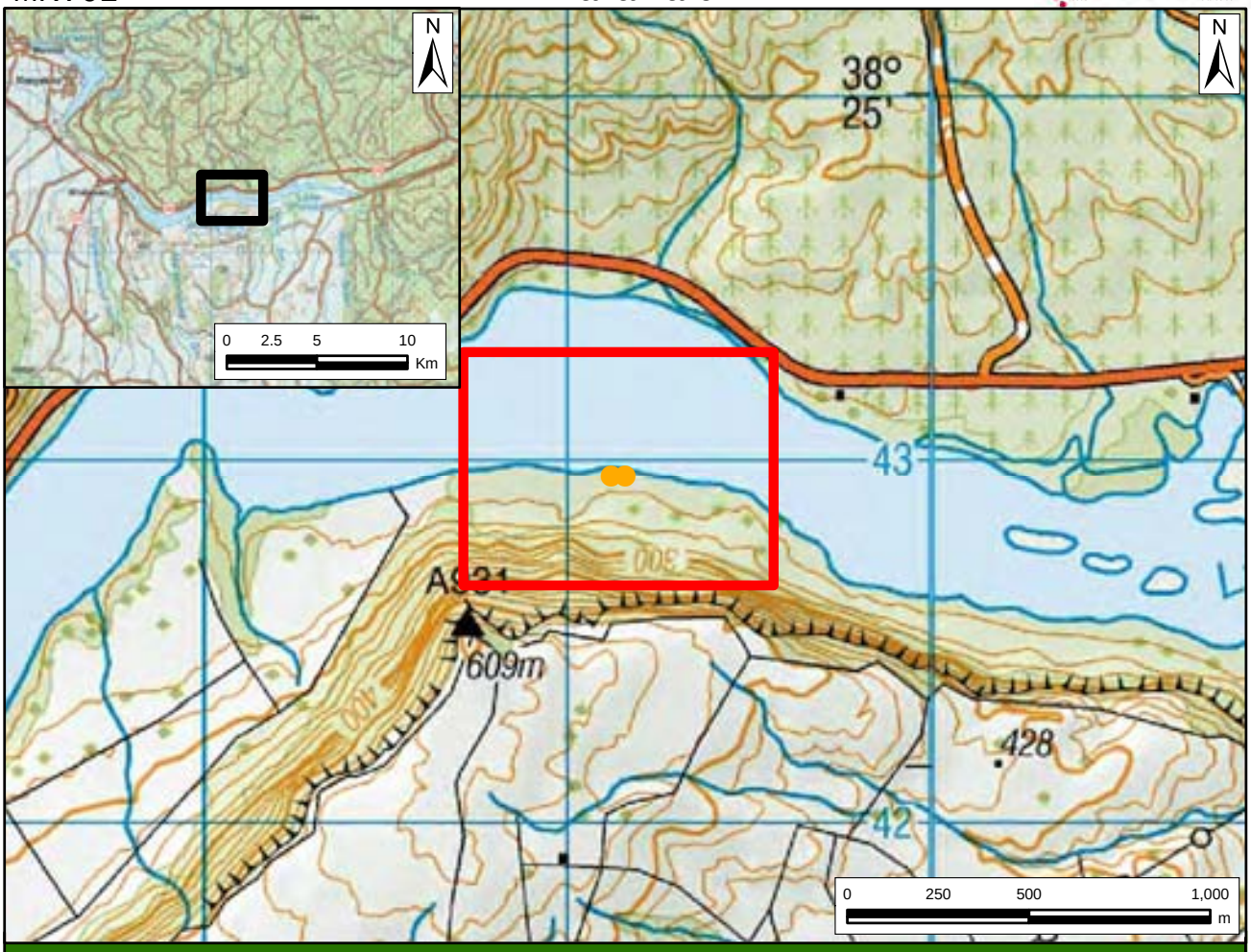
1.4 MOKAI GEOTHERMAL FIELD

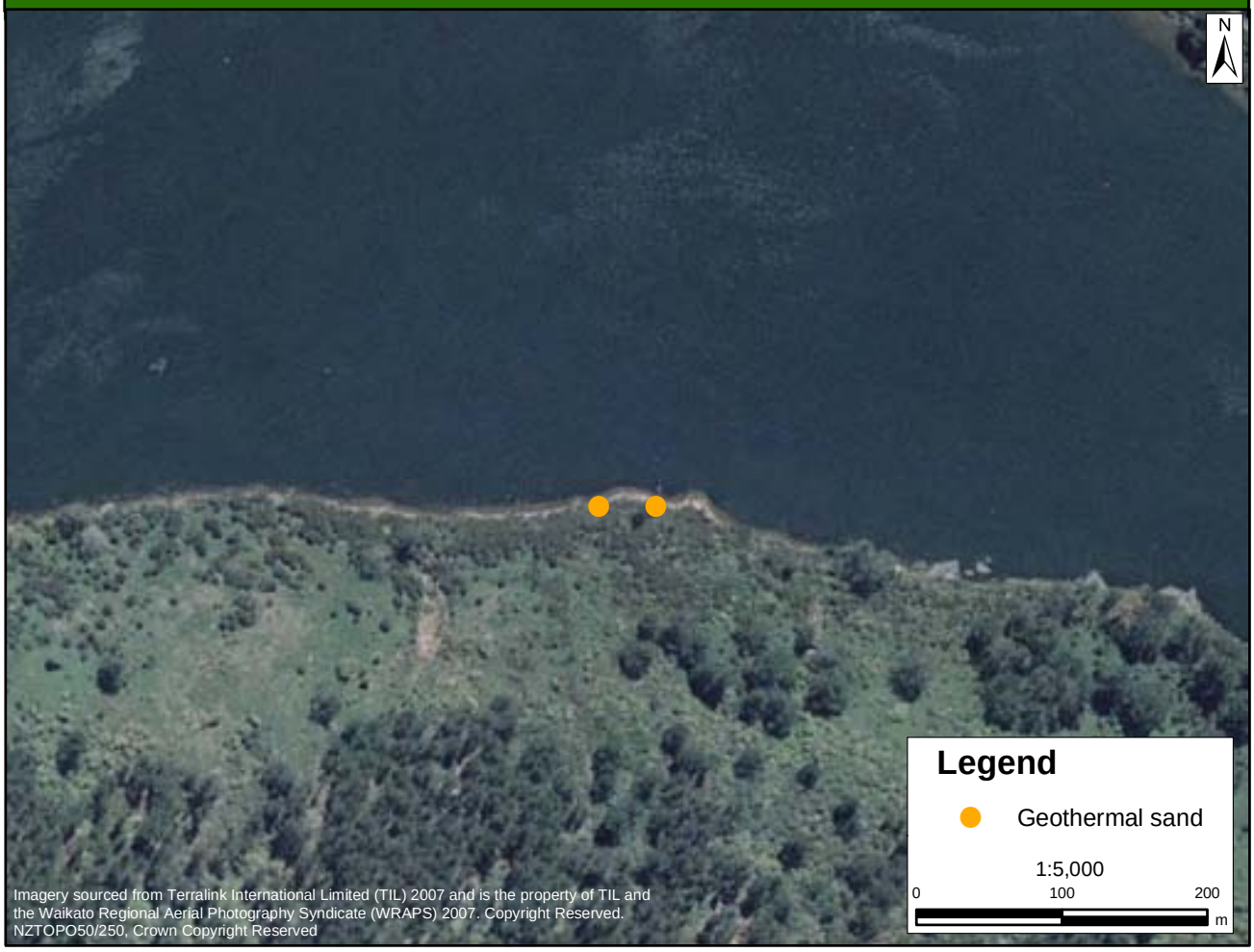
List of Geothermal Sites

MKV01	Whakamaru
MKV02	Waipapa Stream
MKV03	Tirohanga Road
MKV04	Paerata Road

MKV01

Whakamaru





WHAKAMARU

Site Number: MKV01[1]
Grid Reference: NZTopo50 BF35 511 429
GPS Reference: NZTM E1851114 N 5742958
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Whakamaru
Bioclimatic Zone: Lowland
Tenure: Unprotected private land
Altitude: *c.*220 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 17 February 2008

Code	Type	Landform	Extent
28.01 28.01.03	**Nonvegetated raw-soilfield** **Geothermal sands** Several hot pools in lakeshore sands around the margins of Lake Whakamaru. Two pools were noted during the field visit with temperatures of 45.7°C and 46.2°C, but more geothermal pools are likely to be present. The pools are surrounded by occasional *Morelotia affinis,* and manuka seedlings. Canopy comprises kanuka scrub.	Beach	<0.1 ha

Indigenous Flora: Species typical of geothermal habitats are present near the geothermal springs including kanuka, manuka, *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. Values are not greatly significant in terms of its vegetation component for a geothermal site.

Threats/Modification/ Vulnerability:

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

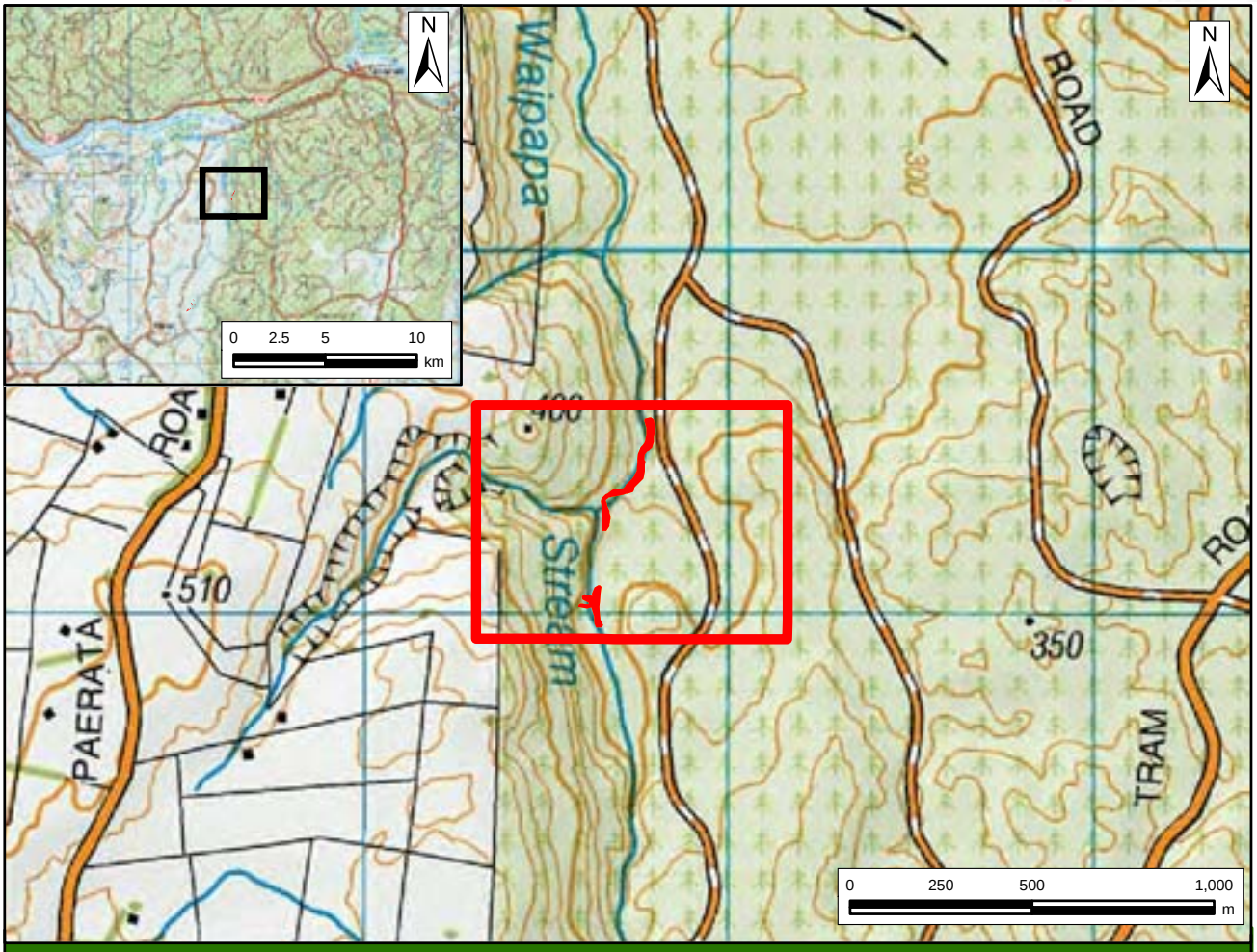
Human impacts (*2008 Assessment*)*:* Holes are often dug in the sand to create small hot water pools for bathing by people who access the site by boat.

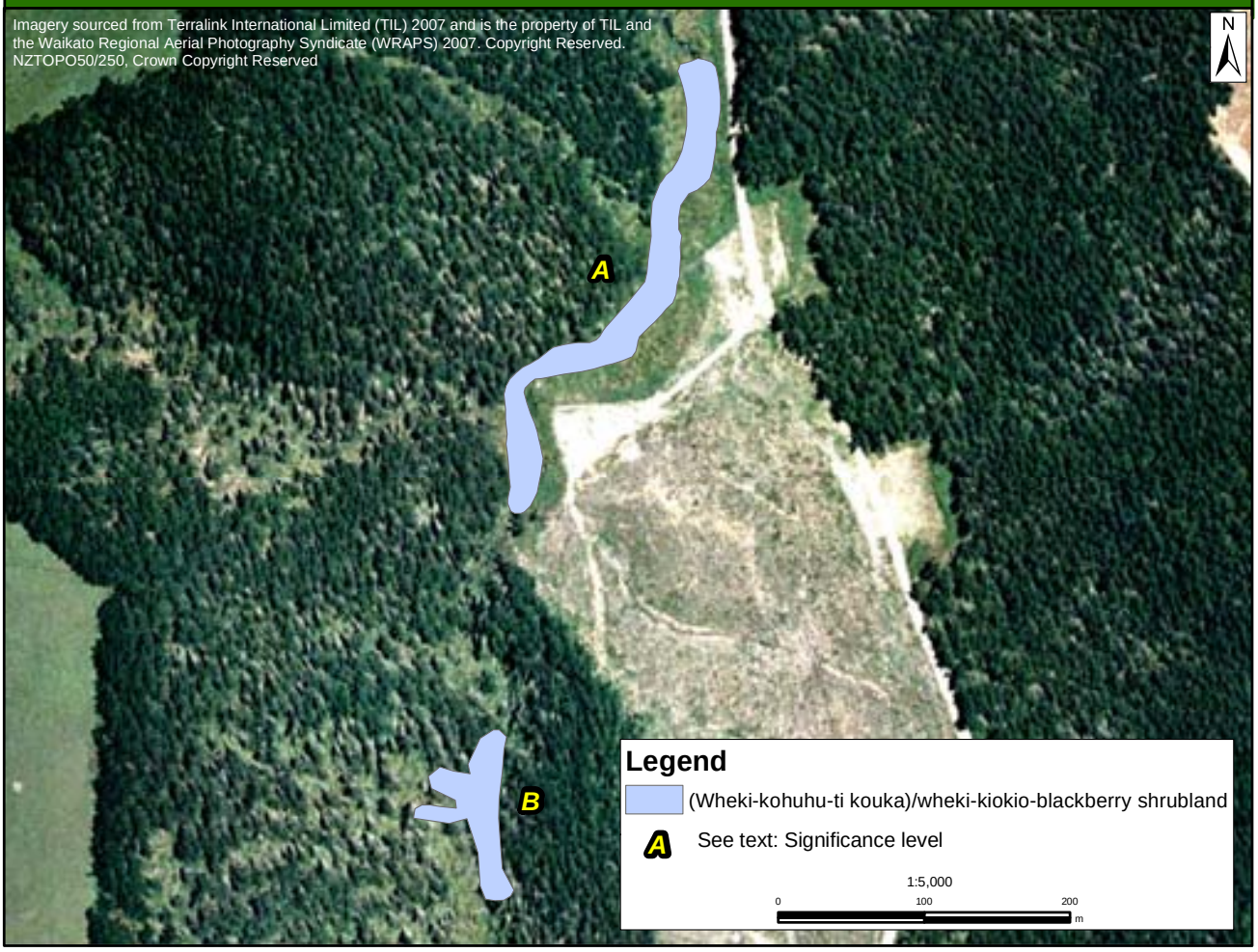
[1] Previously identified as T17/7 in Wildland Consultants (2004).

Grazing (*2008 Assessment*):	This site is not grazed by stock.
Adjoining land use (*2007 Assessment*):	Lake Whakamaru; iindigenous forest and scrub
Site Change:	
Recent change:	Unknown; this site was only surveyed in 2008.
Historical:	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 (Historical photos: SN 258 Run 1071 Photos 72-73, 1949).
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.
Notes:	The above information is based on a site visit with the Rotorua Botanical Society on 17 February 2008.
References:	Department of Conservation 1998; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004.

MKV02

Waipapa Stream





WAIPAPA STREAM

Site Number: MKV02[1]
Grid Reference: NZTopo50 BF36 577 393
GPS Reference: NZTM E1857719 N5739348
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Mokai
Bioclimatic Zone: Lowland
Tenure: Unprotected private land
Altitude: 286 m
Extent of Geothermal Habitat: *c.*1.1 ha
Extent of Geothermal Vegetation: *c.*1.1 ha
Date of Field Survey: 30 March 2011

Code	Type	Landform	Extent
05.10 05.10.02	**Mixed indigenous-exotic shrubland (Wheki-kohuhu-ti kouka)/wheki-kiokio-blackberry shrubland** Tall wheki (*c.*2-3m tall), kohuhu and ti kouka are emergent over kiokio, wheki, whauwhaupaku, blackberry and bracken along the stream margins. Tutu (*Coriaria arborea* var. *arborea*), koromiko, mahoe (*Melicytus ramiflorus* subsp. *ramiflorus*), *Austroderia fulvida*, buddleia, and fleabane are scattered throughout. There is also local *Cyperus ustulatus, Paesia scaberula*, and *Christella* aff. *dentata* ("thermal"). Occasional pampas and grey willow are present. At least two geothermally heated tributary streams, *c.*75 m long, flow into the main stream through cutover plantation. Vegetation includes the above species, but the canopy cover is younger and lower, and there are dead and fallen radiata pine and localised 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 the stream, and springs, hot steam vents and small geothermally heated tributary streams that feed into the main stream. Apart from one plant at the southern site, the *Christella* aff. *dentata* ("thermal") occurs at the northern site.	Alluvial terrace	*c.*1.1 ha
05.13 05.13.03	**Blackberry dominant shrubland (Wheki-mingimingi)/blackberry-bracken-kiokio shrubland (not mapped)** 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*, wheki, *Paesia scaberula,* and *Christella* aff. *dentata* ("thermal"). Karamu, kanuka, harakeke, koromiko, mingimingi, and *Cyperus ustulatus* are scattered throughout, with local patches of *Lycopodiella cernua*.	Stream gully	

[1] Previously identified as T17/1 in Wildland Consultants (2004).

Code	Type	Landform	Extent
07.06 07.06.01	***Christella* aff. *dentata* ("thermal")-dominant fernland** ***Christella* aff. *dentata* ("thermal") fernland (not mapped)** Small populations of *Christella* aff. *dentata* ("thermal") occur along stream banks adjacent to hot steam vents and seepages. These populations occur on both sides of the Waipapa Stream over a distance of *c.*1 km.	Stream gully	

Indigenous Flora: A large population of *c.*400 plants of *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al.* 2009) was recorded in 2004, and *c.*200-300 plants were recorded in other surveys (Beadel & Clarkson 1986, Beadel & Bill 2000, Merrett & 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* (recorded in this survey) and *Psilotum nudum* (not recorded in the current survey (Beadel & Clarkson 1986)), which are 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, magpie, blackbird, Australasian harrier hawk 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. Although there are areas of indigenous vegetation along the stream margins, which provide a buffer between the plantation and the threatened fern populations, it appears that recent harvesting has disturbed the indigenous vegetation with tree fall across the stream. There is a log jam at one place in the stream.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Invasive pest plants include blackberry with a cover in localised patches of 6-25% (overall cover is 1-5%). Radiata pine, buddleia, Himalayan honeysuckle, Japanese honeysuckle (*Lonicera japonica*) and mint (*Mentha* sp.) have a cover of less than 1%. Australian fireweed (*Senecio bipinnatisectus*) and fleabane are present in the harvested areas, and are encroaching into open areas of this site (however cover of these species is less than 1% in the site at present). Waikato Regional Council has recently undertaken control of pines, broom, and buddleia at this site.

Human impacts (*2011 Assessment*): In the 1970s the pine plantation at the southern half of the site was harvested. Following this, the populations of *Christella* aff. *dentata* ("thermal") were disturbed for several years (Beadel & Clarkson 1986). Recent harvesting to the west of the stream may have impacted on the presence of *Christella* aff. *dentata* ("thermal") as only one plant was located here during this survey. Elsewhere the population appears to be stable.

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

Wilding pines in the northern site have been controlled. However, the site should be inspected regularly for threats and management requirements, and further control of pest plants should be undertaken in the future.

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

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

Site Change:

Recent change: Recent harvesting operations adjacent to the southern part of the site has impacted negatively on the stream and adjacent vegetation with tree falls altering natural water flows and damaging the stream banks. It appears that populations of *Christella* aff. *dentata* ("thermal") may have been negatively affected. However, the narrow indigenous buffer will allow habitat for this species to remain, and a recovery as recorded in 1986 (Beadel & Clarkson 1986) is likely to occur. Management of wilding pines at the site has been undertaken by the landowner since 2004. Changes were evident with some of the geothermal pools on the eastern side of the stream at the northern part of the site being 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 has not been previously assessed.

Historical: Site not assessed, no historical photos found.

Management Requirements: Harvesting operations and subsequent management of the surrounding plantations require care to ensure that this site does not continue to be disturbed. Monitoring of any impacts relating to power draw-off from the Mokai geothermal field should continue. Ongoing protection of *Christella* aff. *dentata* ("thermal") from the potential impacts of wilding and planted radiata pine trees (outlined in Wildland Consultants 2004a) will assist in the stabilisation of these populations.

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 comprises the third largest population of *Christella* aff. *dentata* ("thermal") (an „At Risk-Declining' species) in New Zealand. This species is known from only 14 other sites in New Zealand.

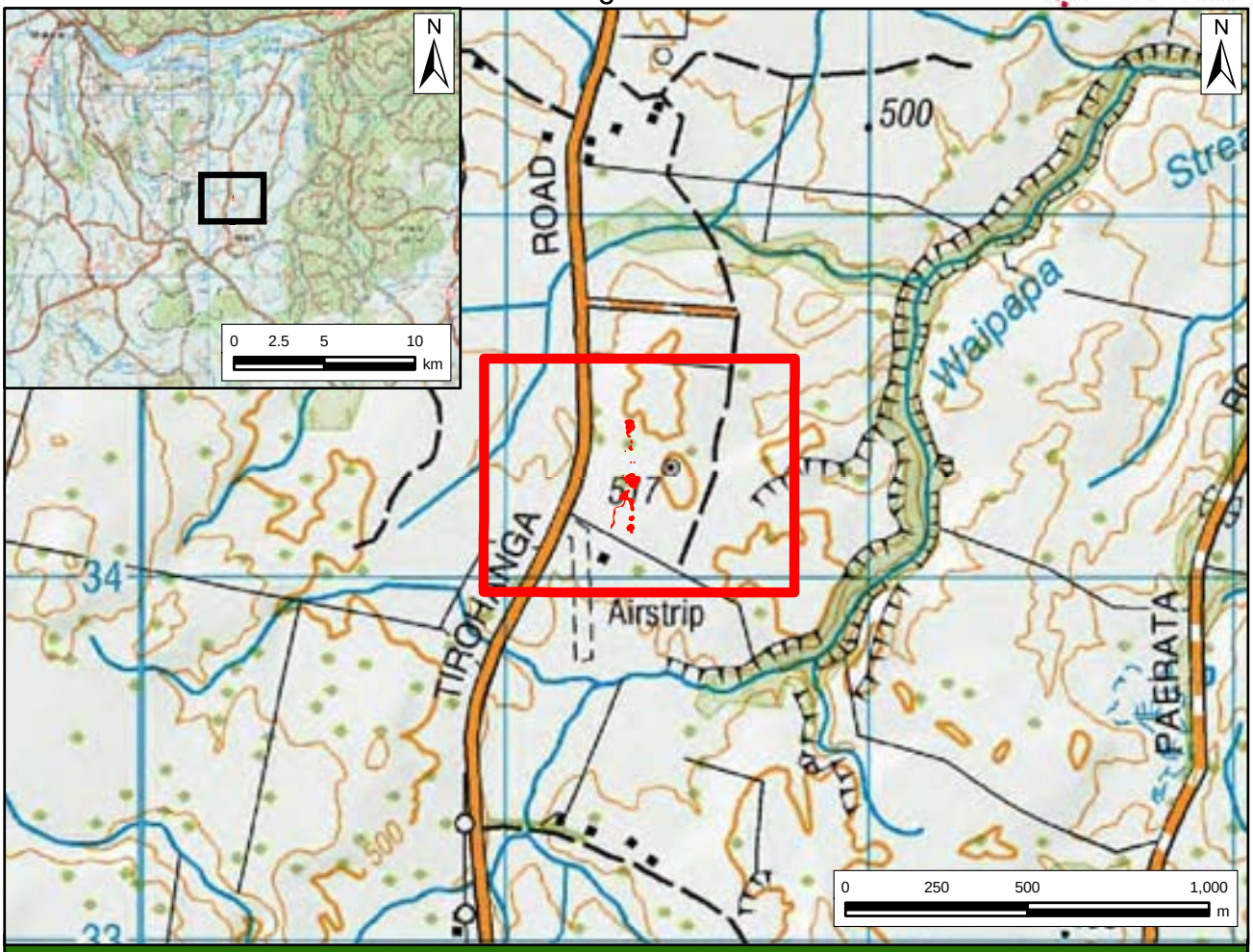
B: The part of the site identified as B is of local significance as it comprises a small example of geothermal habitat - a nationally uncommon vegetation type.

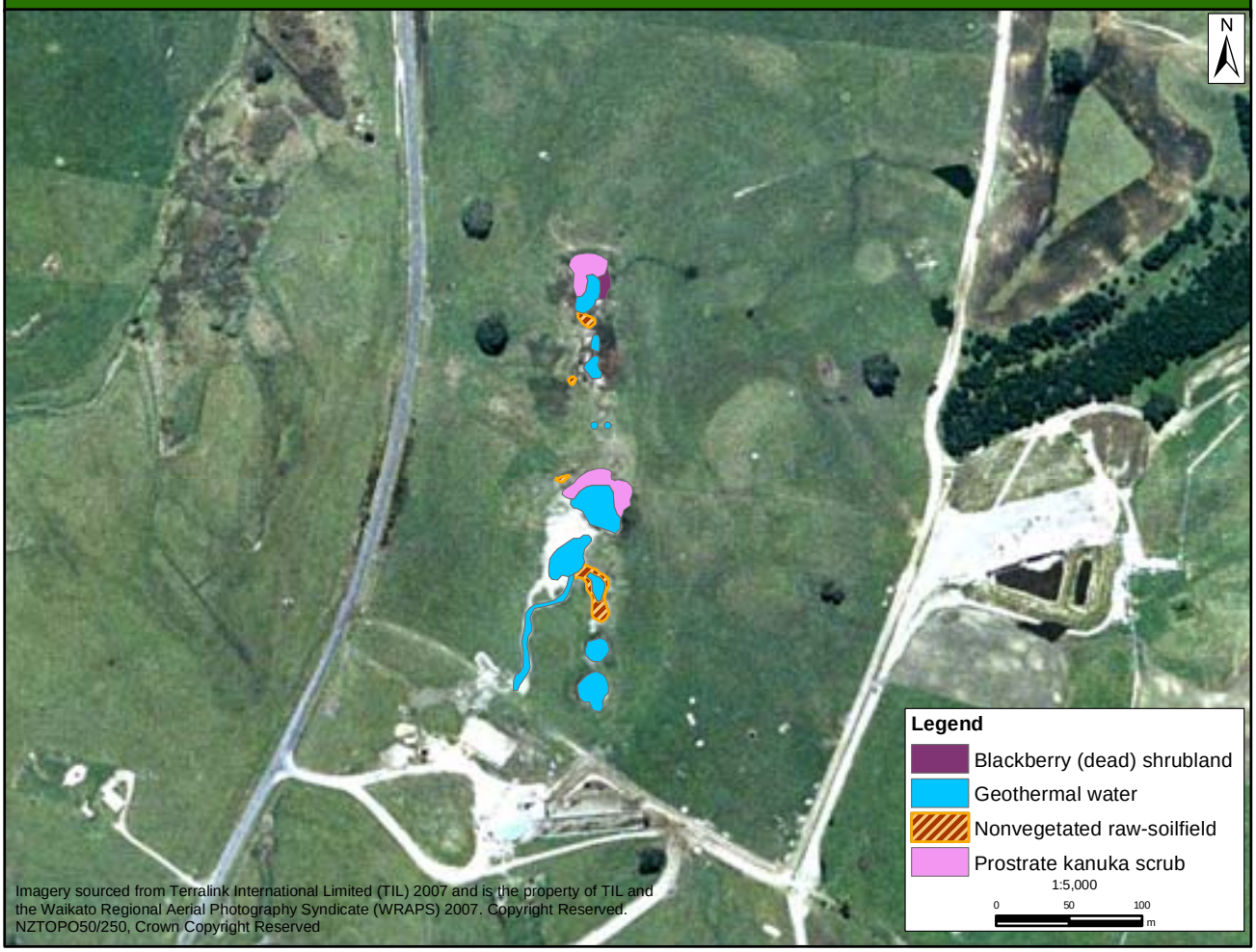
Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and this site was classed as Category B - the second highest category.

References: Beadel & Bill 2000; Beadel & Clarkson 1986; Given 1989a & 1996; Merrett 2001a & 2001b; Merrett *et al*. 1999; Merrett & Fitzgerald 2004; Merrett & Smale 1999; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004a.

MKV03

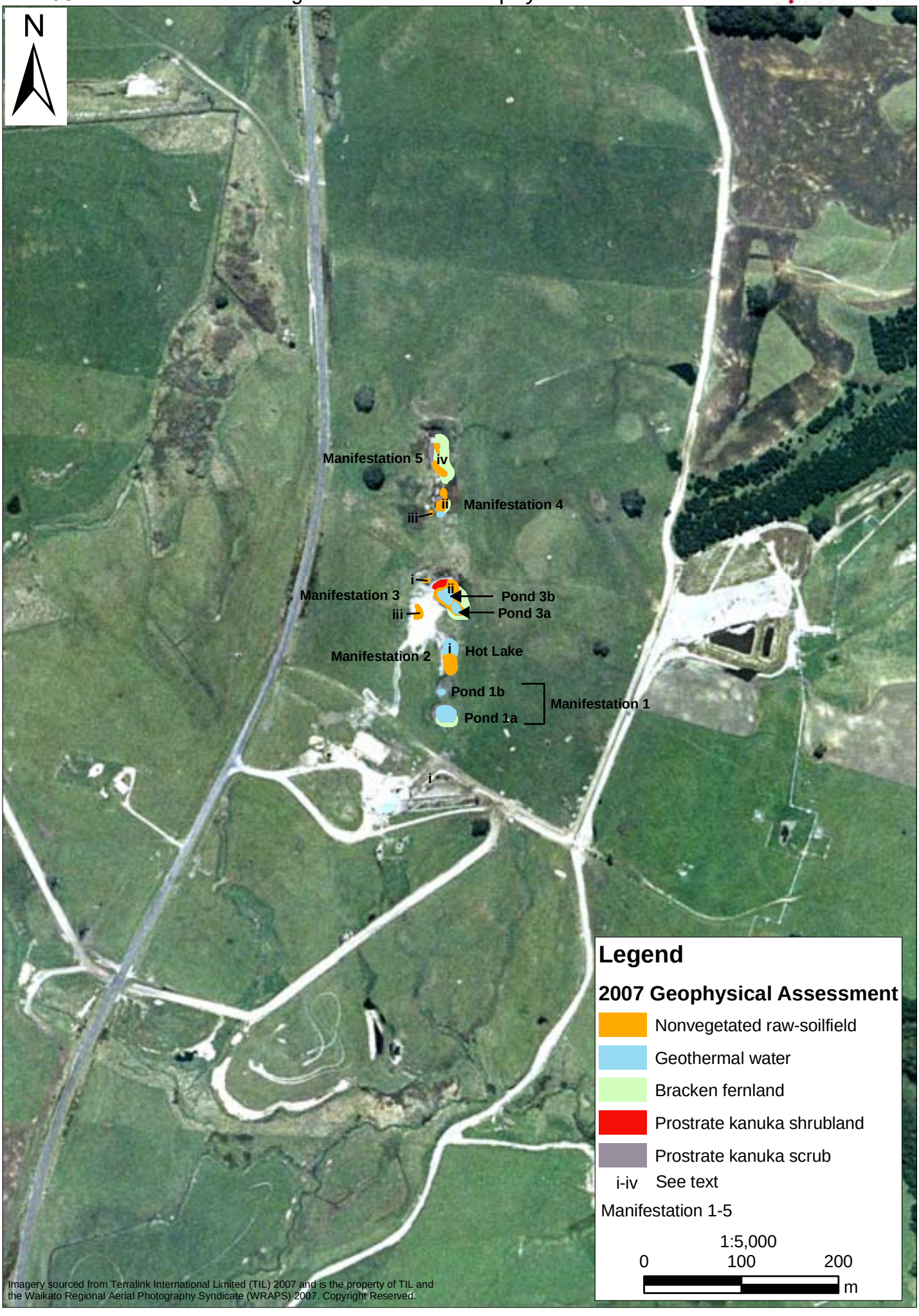
Tirohanga Road





MKV03

Tirohanga Road - 2007 Geophysical Assessment



TIROHANGA ROAD

Site Number: MKV03[1]
Grid Reference: NZTopo50 BF36 533 342
GPS Reference: NZTM E1853319 N5734204
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Mokai
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: 498 m
Extent of Geothermal Habitat: *c.* 0.4 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 2 March 2011

Code	Type	Landform	Extent
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Occasional manuka, mingimingi, and kamahi (less than 5 m tall) occur over prostrate kanuka scrub (to *c.*1 m) tall surrounded by rank exotic grasses (e.g. Yorkshire fog, brown top and Indian doab) with occasional patches of *Paesia scaberula*. Blackberry patches (both alive and dead from herbicide spray) occur on the margins. Small areas of nonvegetated raw-soilfield are present in this vegetation type.	Crater rim	*c.*0.1 ha
05.13 05.13.04	**Blackberry-dominant shrubland** **Blackberry (dead) shrubland** An area of sprayed, dead blackberry occurs around the northern most geothermal pool.	Crater rim	<0.1 ha
20.01 22.01.01	**Geothermal water** **Geothermal water** A series of geothermal pools, oriented in a north-south series, with browntop grassland with patches of blackberry (alive, sprayed, and dead), bracken and Californian thistle (*Cirsium arvense*) around the margins. There are occasional patches of *Histiopteris incisa* and Yorkshire fog, and some small isolated patches of nonvegetated raw-soilfield.	Base of craters	*c.*0.3 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Heated soil, vents and mud pools occur along the length of this site. Indian doab, paspalum (*Paspalum dilatatum*), browntop, Yorkshire fog, sheep's sorrel (*Rumex acetosella*), fleabane, and bracken occur on the margins of these areas.	Crater; gently sloping; geothermal hole	<0.1 ha

Geophysical Assessment[2]:

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

[1] Previously identified as T17/4 in Wildland Consultants (2004).
[2] Undertaken by Hochstein in 2007

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 hundreds of 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 re-injected 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 the previous time by M. Hochstein 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. It exhibits at present 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). Its present level is significantly higher than that observed a year ago when the pond area was much smaller (<30 m^2) exposing 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 now 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° and 24°C. The pond might not be re-charged 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 and 56°C. There appears to be a small up-flow zone near its 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 its bottom. 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 trickle outflow of lake water (<1 kg/s) which infiltrates the ground. Further downstream to the south, another shallow, small outflow emerges. There was no lake at this site a year ago 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 re-injected water now ascending in the fracture zone.

Manifestation 3A - Large Mud Pool 3A:

About 50 m north of the new hot lake lies the old, large mud pool (3A), used in the past 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?) near its centre (elsewhere the surface lake temperature was 28°C). The present day colour of the lake water is quite different from that observed 10 months ago when it was a dark-brown (humic-acid coloured?) stagnant water. In comparison to a survey in March 2006, the present-day lake surface area of 3A has not increased significantly (although a minor increase was noticed along its western shore).

On top of the western rim of Pool 3A, a small strip of thermally altered ground is exposed. Its ground temperature at 0.2 m depth was found to be 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 large), 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 Lake 3A. Some water of the smaller pond appears to seep through a small, *c.*1 m wide dam which separates the two and which could be breached at any time. The surface temperature of the larger 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 south-west of Pool 3A was a *c*.2.5 m deep, almost circular pit (*c*.3 m diameter), which exhibits almost vertical walls (E1853320 N5734250). The temperature on the dry bottom was c.20°C (i.e. non active feature). Pits with a similar wall structure occur in the Waiotapu geothermal field where they are caused most likely 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° 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 Road Manifestations:

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 nor does it exhibit any visible thermal activity. However, at the northern end of the deep, elongated structure lies an old Maori „steam pit (umu)' where the ground temperature at the bottom was *c*.38°C (0.4 m below surface). Some residual prostrate kanuka shrubs were found along the northernmost western rim. However, ground temperatures at 0.2 m depth beneath 1.0-1.5 m high prostrate kanuka 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 south-east of the Tirohanga Road manifestations), from where they are transmitted by surface pipes to three re-injection 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 re-injection 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 re-injection (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 2004/5. 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 re-injection wells, since deeper re-injection has been considered. One of the new, deep re-injection 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.

Indigenous Flora:

Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) is present on the crater rims.

Fauna:

Common indigenous and introduced bird species are present, including Australasian magpie, yellowhammer, and goldfinch.

Current Condition (2011 Assessment):

Geothermal habitat is surrounded by rank exotic grasses and blackberry, 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 current survey. This site is vulnerable to draw-off from the geothermal field and the vegetation and geothermal features underwent large changes with the establishment of Mokai Power Station. Parts of the geothermal site have been used as a rubbish dump in the past, and some of this material was still present in 2007 (Wildland Consultants 2007a). A cooking pit (umu) is present at the north of the site.

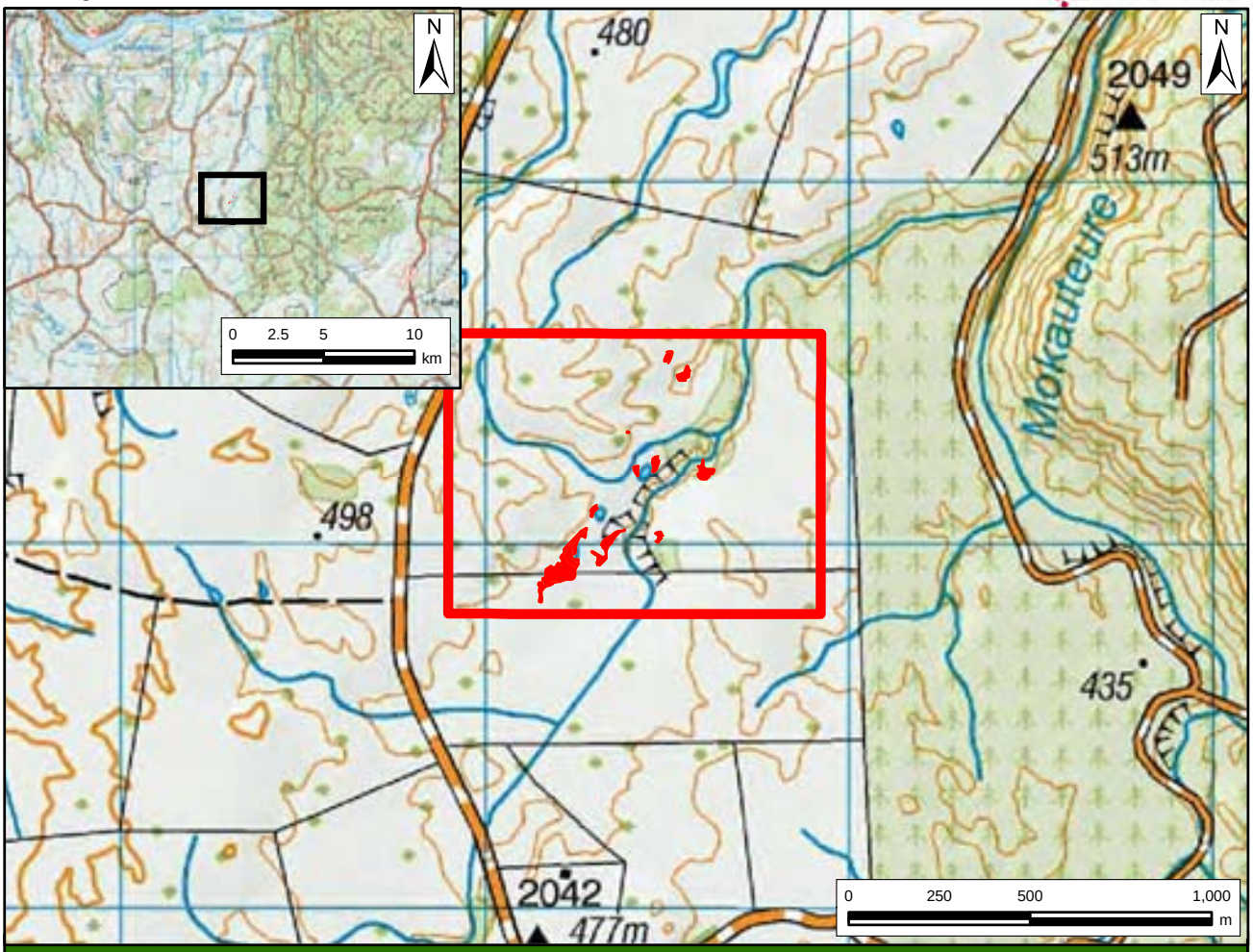
Grazing (*2011 Assessment*):

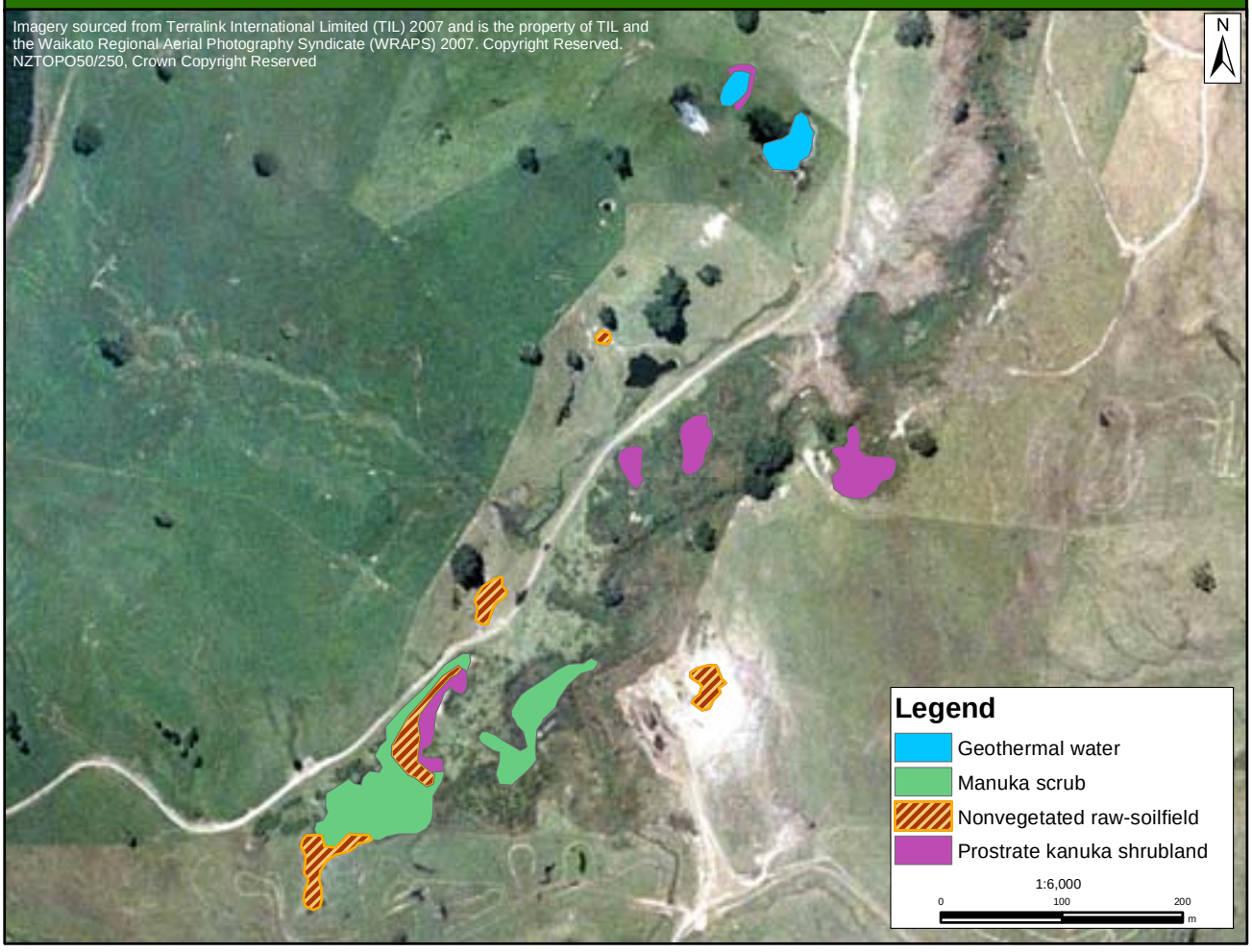
Whilst stock gained access to the site in 2007 (see Wildland Consultants 2007a), this situation appears to have been rectified, and stock currently do not have access to this site.

Adjoining land use (*2011 Assessment*):	This site is surrounded by pastoral land.
Site Change:	
Recent change:	It appears that the fence excluding stock has been relocated further away from the geothermal expressions (parts of the old fence remain). Recent spraying has killed large areas of blackberry; as well as prostrate kanuka scrub and manuka (and possibly *Histiopteris incisa*). Between the geothermal expressions and the fence, brown top-Yorkshire fog-paspalum grassland dominates. Waste material that had been dumped into geothermal features, noted in 2007, appears to have been removed from site.
Historical:	Site not assessed, no historical photos found.
Management Requirements:	Changes to geothermal vegetation that appear to be associated with draw-off from the geothermal field should be monitored. 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.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).
Significance Justification:	Tirohanga Road is of local significance because it is a small example of a nationally uncommon habitat type and it contains a small population of prostrate kanuka, an „At Risk' species.
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.
References:	Beadel & Bill 2000; Beadel & Clarkson 1986; Department of Conservation 1998; Given 1996; Hochstein 2006 & 2007; Merrett & Fitzgerald 2004; Wildland Consultants 2004 & 2007a.

MKV04

Paerata Road





PAERATA ROAD

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

Code	Type	Landform	Extent
04.03 04.03.01	**Manuka-dominant scrub** **Manuka scrub** A discontinuous canopy of manuka of varying height (*c.*0.5-1.5 m high), with mingimingi, blackberry and broom scattered throughout. The understorey comprises *Histiopteris incisa,* bracken and blackberry with local turutu and kiokio, and small patches of sedges, rushes, ferns (including kiokio) and prostrate kanuka. Occasional grey willow are also present.	Flat to undulating farmland; small gullies	*c.*0.8 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka dominates the depression faces around geothermal mud pools (not mapped separately). Blackberry, broom, mingimingi, manuka, bracken, and *Histiopteris incisa* are scattered throughout.	Geothermal depressions	*c.*0.4 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** An area of geothermal water with nonvegetated raw-soilfield, and patches of prostrate kanuka, mingimingi and exotic grasses (including Yorkshire fog and browntop) on its margins.	Flat to undulating farmland	*c.*0.2 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Bare ground and hot water pools (not mapped). Introduced grasses (mainly Yorkshire fog, browntop, and Indian doab), *Gonocarpus micranthus* subsp. *micranthus* and *Campylopus capillaceus* occur around the margins of these areas with scattered manuka, koromiko, mingimingi, prostrate kanuka, broom, bracken, *Histiopteris incisa*, *Paesia scaberula,* and blackberry on cooler sites.	Flat to undulating farmland	*c.*0.4 ha

Indigenous Flora: A small population of prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al*. 2009), an endemic plant species restricted to geothermal areas, is present. *Lycopodiella cernua* and *Psilotum nudum*,

[1] Previously identified as T17/3 in Wildland Consultants (2004).

both species characteristic of geothermal areas, occur at this site (the latter species was last seen in 1986, see Beadel & Clarkson 1986).

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; margins have been planted as part of a pine plantation, and common pest plants are 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, either intentionally or accidentally, also been applied to the edge of the manuka scrub. Rubbish has also been dumped down the bank and into the stream/geothermal vegetation margin. Radiata pines have recently been planted on the margins of some of the features and future shading by the pines may 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 (possibly an escapee from a nearby paddock).

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 kanuka is not tolerant of complete canopy closure.

Human impacts (*2011 Assessment*): Radiata pine have recently been planted (during the last year) within 5 m of some geothermal features. In preparation for planting, large areas of blackberry were sprayed and, in some cases, adjacent manuka (and possibly other indigenous plant species) have died as a result of herbicide application. This site has been used as a rubbish dump, with refuse present adjacent, and encroaching into, geothermal areas. Large wilding radiata pines have been felled into areas of prostrate kanuka.

Grazing (*2011 Assessment*): Geothermal features between the stock race and the eastern stream edge are fenced to exclude stock (one sheep was present at the time of survey). 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: Blackberry has been sprayed and radiata pine planted. Some geothermal vegetation has been cleared and some has been sprayed with herbicide.

Historical: Site not assessed, no historical photos found. As most features are small, changes are unlikely to be evident on historical photos.

Management Requirements: A set back is recommended of at least 10 m from the edge of all geothermal areas for the radiata pine plantation.

Unfenced areas require fencing to prevent further damage from stock. Restoration activities 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 comprises geothermal habitat, a nationally uncommon habitat type, and it is includes a small population of an „At Risk' species, prostrate kanuka.

Notes: This site was identified as a recommended area for protection (RAP) under the Protected Natural Areas Programme (Unpublished Atiamuri PNAP data 1995).

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.

In a previous assessment (Wildland Consultants 2004) this site was divided into parts for the assessment of relative significance as it was appropriate at the time. Parts were assessed as being locally significant and other parts were assessed as being of regional significance because they provide habitat for an „At Risk' species, prostrate kanuka. In the current study, the entire site is assessed as being of local significance because human disturbance at the site since 2004 has resulted in a significant reduction in the extent of prostrate kanuka. However, if stock is excluded, and pest plants are managed, prostrate kanuka has the potential to re-establish at this site.

This site still contains the largest area of prostrate kanuka shrubland in the Mokai geothermal field.

References: Beadel & Bill 2000; Beadel & Clarkson 1986; Given 1989 & 1996; Merrett 2001; Merrett & Fitzgerald 2004; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004.

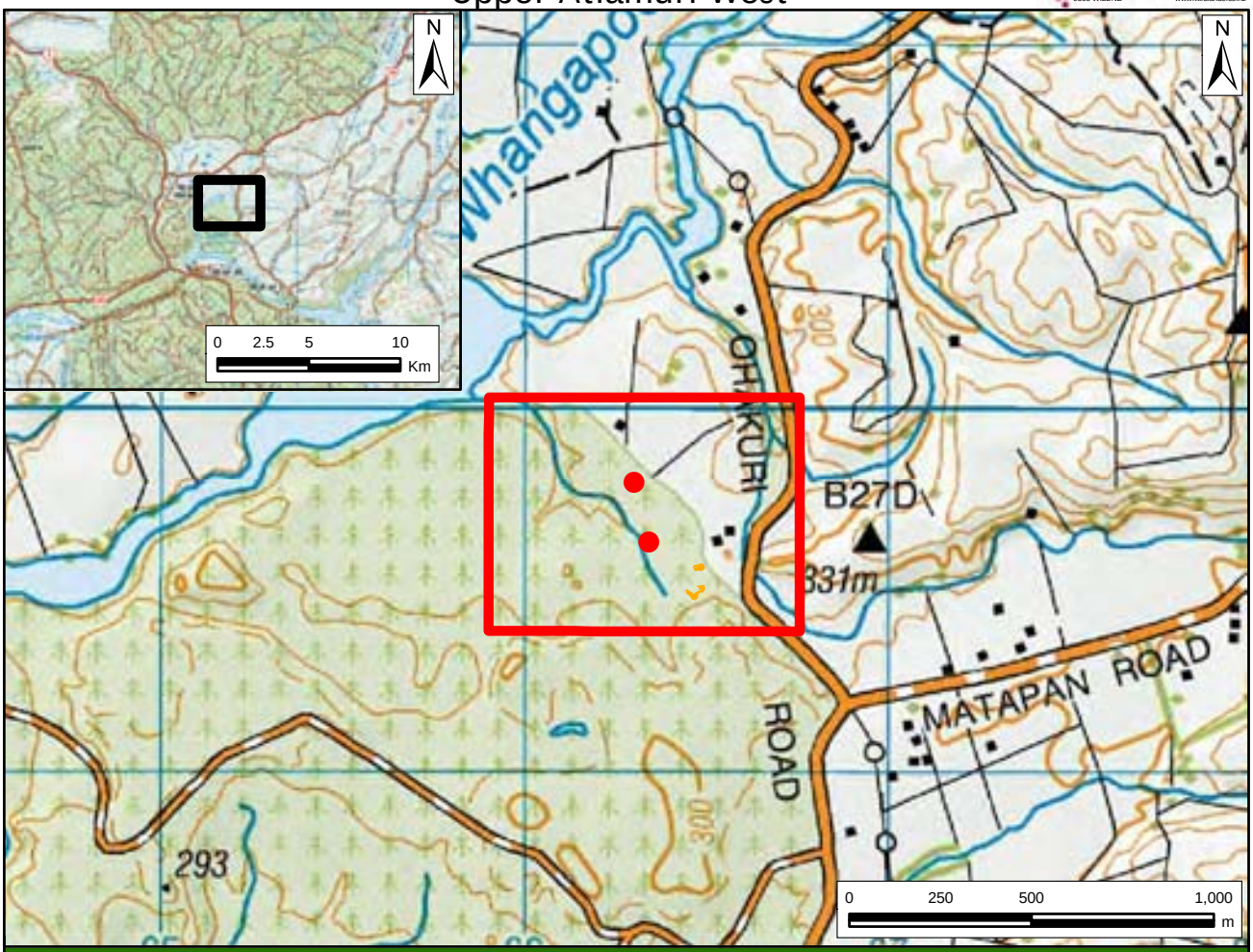
1.5 ATIAMURI GEOTHERMAL FIELD

List of Geothermal Sites

ATV01	Upper Atiamuri West
ATV02	Whangapoa Springs
ATV03	Matapan Road

ATV01

Upper Atiamuri West



UPPER ATIAMURI WEST

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

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.08 04.08.01	**Blackberry-dominant scrub** **Blackberry scrub** Dense blackberry with common Himalayan honeysuckle and broom over a tomo with a geothermal spring at the base (2 m wide and 2.5 m deep). The sides of the hole have scattered *Hypolepis distans*. A sinter deposit which extends *c.*1 m into the tomo is present.	Geothermal pit (*c.*2 m diameter).	<0.1 ha
13.01 13.01.01	**Herbfield** ***Polygonum maculosa* herbfield** 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 (0.3 m diameter). Geothermal pit (*c.*2 m diameter).	<0.1 ha

Geophysical Assessment[2]:

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 still in the range of 20° 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 north-west 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

[1] Previously identified as U16/10 in Wildland Consultants (2004 and 2007a).
[2] Undertaken by Hochstein in 2007.

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 which 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 a 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^{o}C. The ground around the vent is heated to *c*.40^{o}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.

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 cover.

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

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

Adjoining land use (*2007 Assessment*)*:* Farmland

Site Change:

Recent change: This site has not been revisited by the authors since 2007, but is unlikely to have undergone significant change over this timeframe.

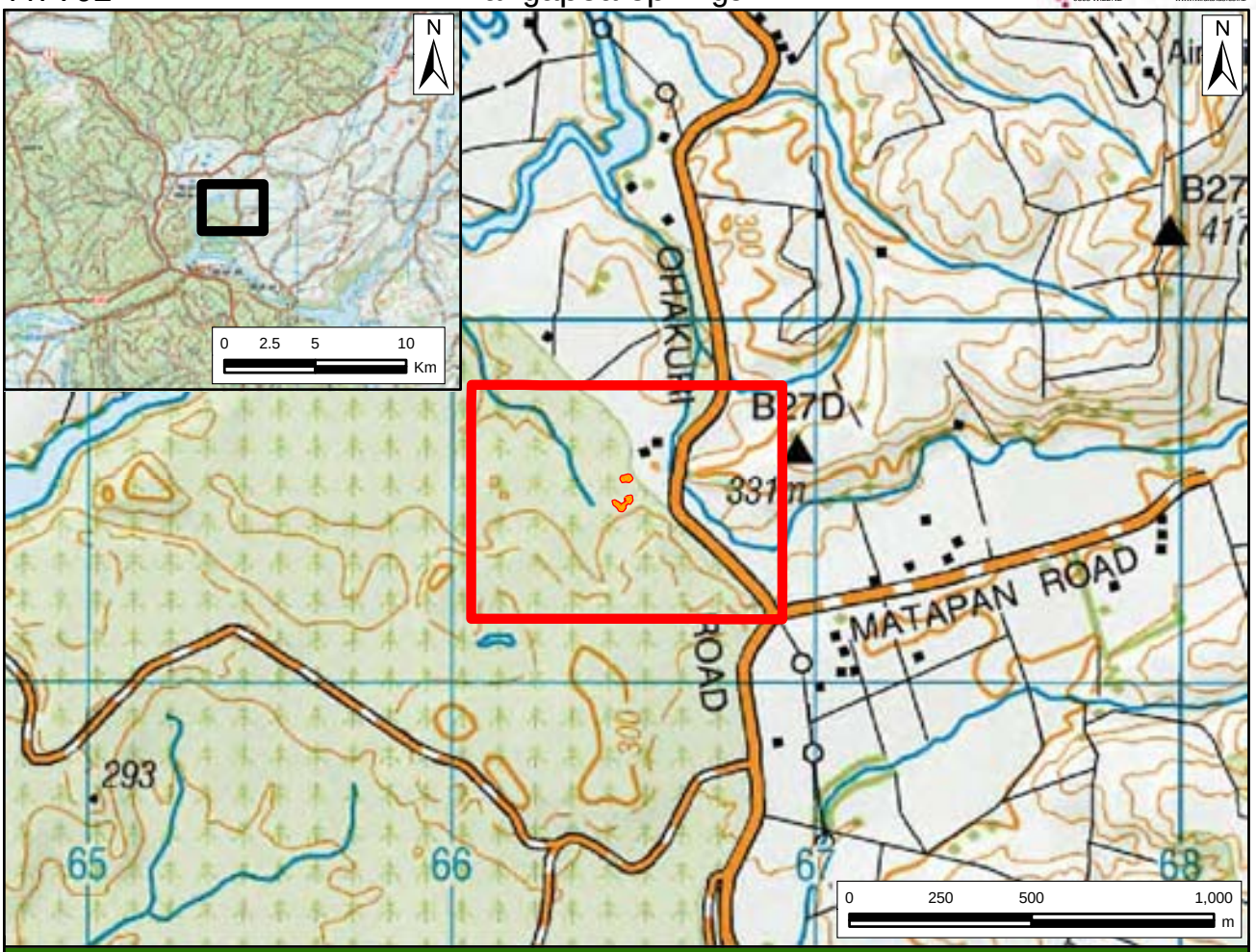
Historical: Site not assessed, as it is too small to be assessed based on historical photographs.

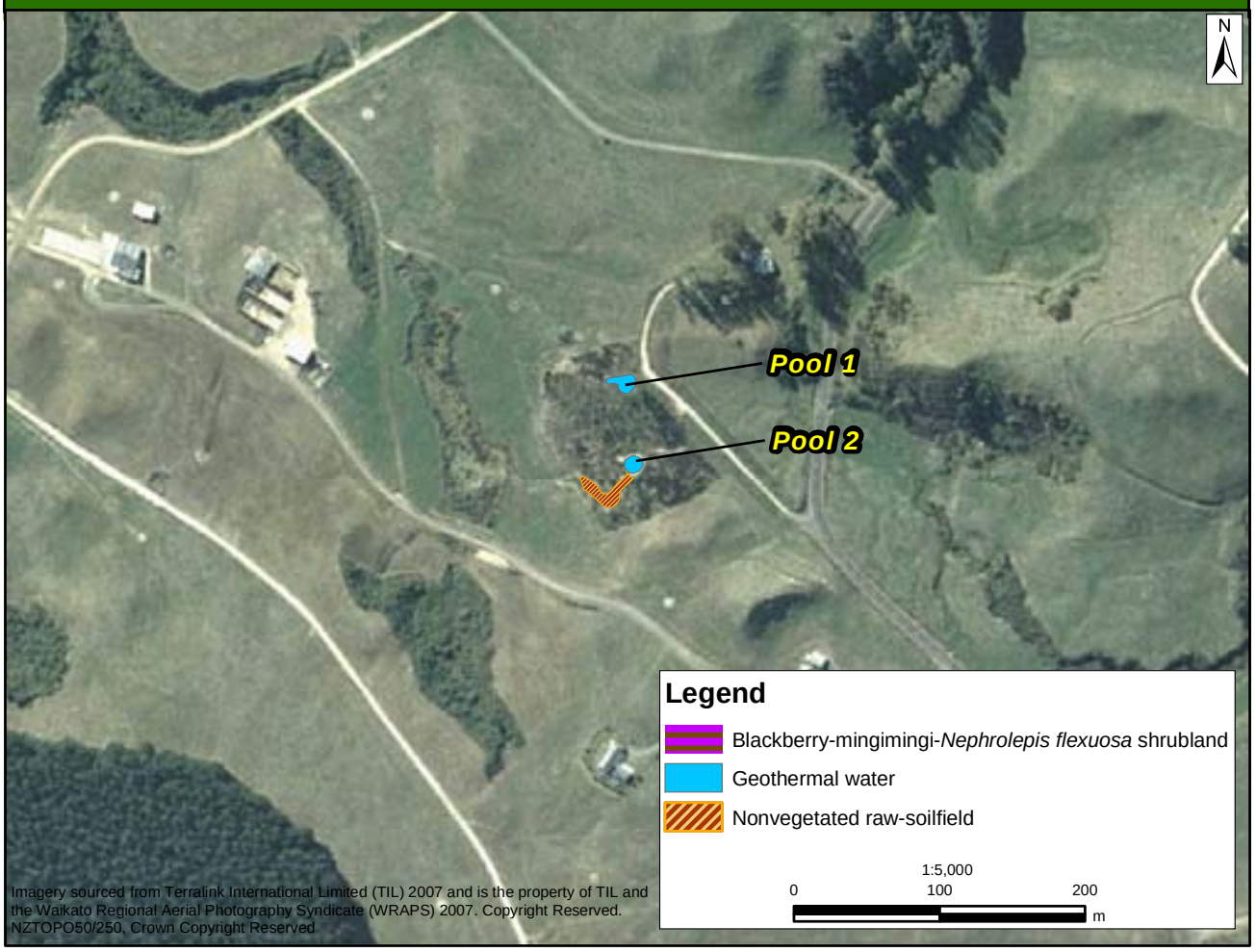
Management Requirements: Restoration of the adjacent gully margins, which support geothermal and non-geothermal habitat and features, could be considered. There is the potential to link any restoration works with the nearby Whangapoa Springs site.

Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19)
Significance Justification:	Upper Atiamuri West is of local significance because it comprises geothermal habitat, a nationally uncommon habitat type. However the geothermal features are very small and highly modified, with few indigenous species present.
References:	Hochstein 2007; Wildland Consultants 2004 & 2007a.

ATV02

Whangapoa Springs





WHANGAPOA SPRINGS[1]

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

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
05.13 05.13.07	**Blackberry-dominant shrubland** **Blackberry-mingimingi-*Nephrolepis flexuosa* shrubland** Both pools are mainly surrounded by blackberry, bracken, and broom with occasional Spanish heath, buddleia, *Paesia scaberula*, and *Cortaderia fulvida*. *Nephrolepis flexuosa* is common amongst the shrubs. This vegetation/habitat type also surrounds the spring outlet.	Hillslope terrace	*c.*0.1 ha
07.08 07.08.01[2]	***Nephrolepis flexuosa*-dominant fernland (not mapped)** ***Nephrolepis flexuosa* fernland** Several small patches of *Nephrolepis flexuosa* occur around Pool 1 on steep banks above the hot spring. (Population size: (1) 3×0.2 m; (2) 7×2 m; and (3) 2×1 m (based on 2003 survey). The *N. flexuosa* was viewed through the fence in 2011 and the population size appeared relatively unchanged; however some of the population was obscured from view.	Steep bank	<5 x 5 m
22.01 22.01.01	**Geothermal water** **Geothermal water**	Hot spring	<0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Pool 2 is surrounded by silica deposits with occasional *Cortaderia fulvida*, turutu, kiokio, and several prostrate kanuka plants. A small sinter terrace occurs downslope of Pool 2.	Hillslope terrace	<0.1 ha

Geophysical Properties[3]: 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

[1] Previously named Upper Atiamuri (site U16/8) in Wildland Consultants (2004)
[2] Areas of this vegetation type occur within the northern area mapped as 05.13.07, however were too small to be mapped separately.
[3] Undertaken by Hochstein in 2007.

outflow and overflow at the SW rim, thermal water was discharged at a rate of *c.*1 kg/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 kg/s (discharging at 53°C).

Indigenous Flora: *Nephrolepis flexuosa* and prostrate kanuka (classed as „At Risk-Declining' and „At Risk-Naturally Uncommon' respectively in de Lange *et al.* 2009), occur around the margins of these two hot springs. In 1979 only two clumps of *Nephrolepis flexuosa* were present (Ecroyd 1979) which were smaller than the clumps present at the recent site inspection (1979 population size: 0.3×0.3 m and 1.5×0.5 m; c.f. description in above table). 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.

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 significantly controlled and planting of indigenous tree species has taken place. The cover of an „At Risk-Declining' species (*Nephrolepis flexuosa*) appears to have increased since 1979 (Ecroyd 1979a).

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. We were not permitted past this fence on 2 February 2011. 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. This was no longer present in 2011.

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

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

Site Change:

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

Historical: Site not assessed, no historical photos found.

Management Requirements: The area of blackberry shrubland has potential for restoration.

Significance Level: Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 6).

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 kanuka and *Nephrolepis flexuosa*).

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 & Hayward 1993).

Notes: The surrounding site has been planted in indigenous tree species.

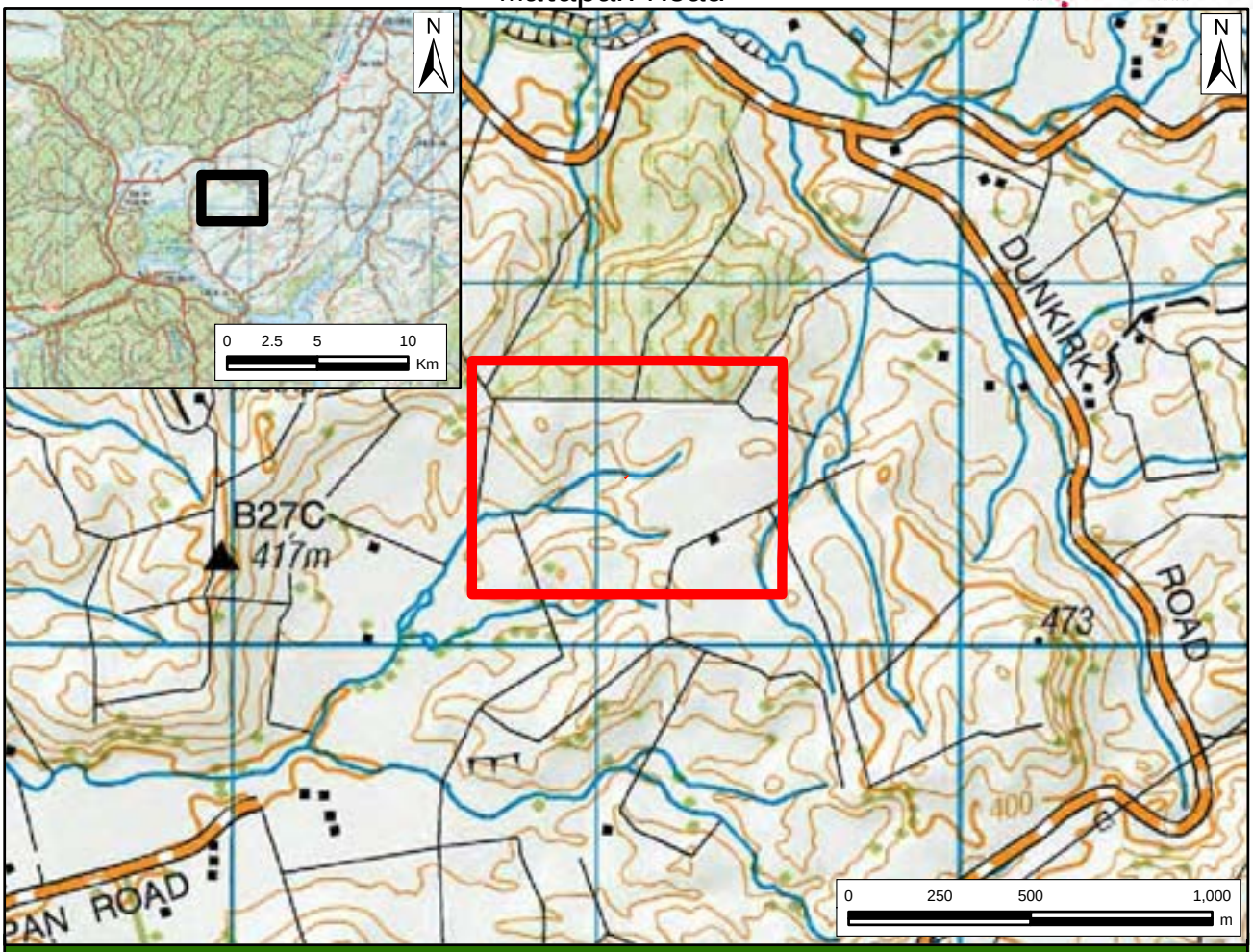
Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and in this study, this site was classed as Category C - the third highest category.

In earlier assessments (e.g. Wildland Consultants 2004 & 2008) this site was called "Upper Atiamuri".

References: Ecroyd 1979a; Given 1996; Hochstein 2007a; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004 & 2008.

ATV03

Matapan Road



MATAPAN ROAD

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

Code	Type	Landform	Extent
07.12 07.12.01	***Deparia*-dominant fernland** ***Deparia* fernland** *Deparia petersenii* occurs around a geothermal spring. Green, orange and red algae are present on the substrate behind the waterfall below the spring. *Paesia scaberula*, wheki, *Asplenium oblongifolium*, and tall willow herb (*Epilobium ciliatum*), occur on the cooler margins.	Hillslope	<0.1 ha
08.01 08.01.01	**Yorkshire fog-dominant grassland** **Yorkshire fog grassland** Pasture surrounding the *Deparia* fernland includes Yorkshire fog, tall fescue (*Schedonorus arundinaceus*), and creeping bent (*Agrostis stolonifera*).	Hillslope	<0.1 ha

Geophysical Assessment[1]: 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.

Indigenous Flora: No „Threatened' or „At Risk' species of flora were recorded.

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

Current Condition (2011 Assessment): This small (*c.*10 m x 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 was 69.1°C. The thermal stream enters another small (cold) stream *c.*20 m below the spring.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson,2010.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*):	None evident, surrounded by pasture grasses.
Human impacts (*2011 Assessment*):	Surrounded by farm land.
Grazing (*2011 Assessment*):	This spring is unfenced and within grazed pasture.
Adjoining land use (*2011 Assessment*):	Farming, pine plantation nearby.

Site Change:

Recent change:	Site has not been assessed previously, but is unlikely to have undergone significant recent change.
Historical:	Site not assessed, no historical photos found.
Management Requirements:	This site should be fenced to exclude domestic animals and 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 a geothermal vegetation and habitat, a type that is nationally uncommon.
References:	Newson 2010.

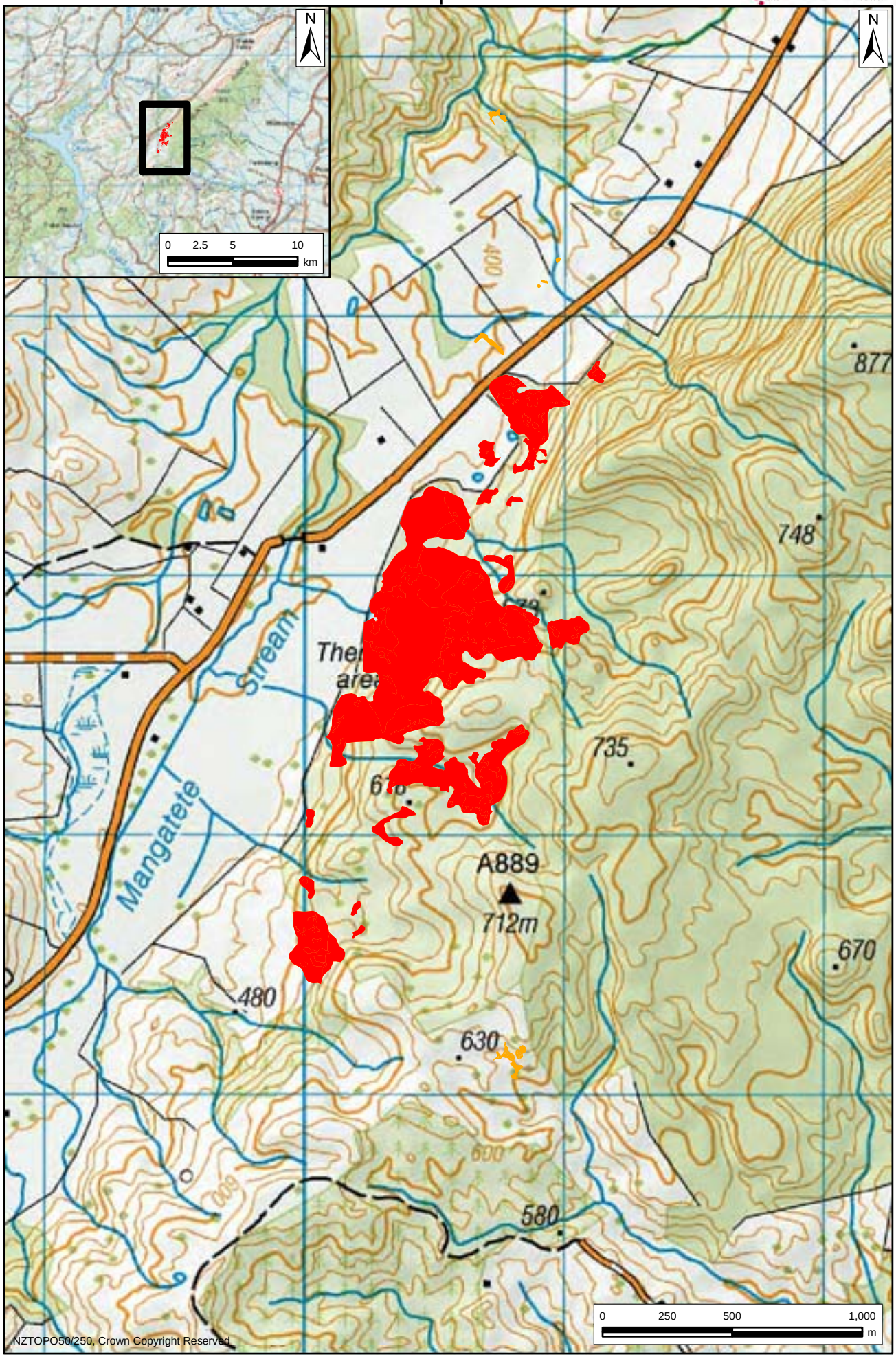
1.6 TE KOPIA GEOTHERMAL FIELD

List of Geothermal Sites

TKV01	Te Kopia
TKV02	Murphy's Springs
TKV03	Te Kopia Northwest
TKV04	Te Kopia West Mud Pools
TKV05	Te Kopia Red Stream
TKV06	Mangamingi Station

TKV01

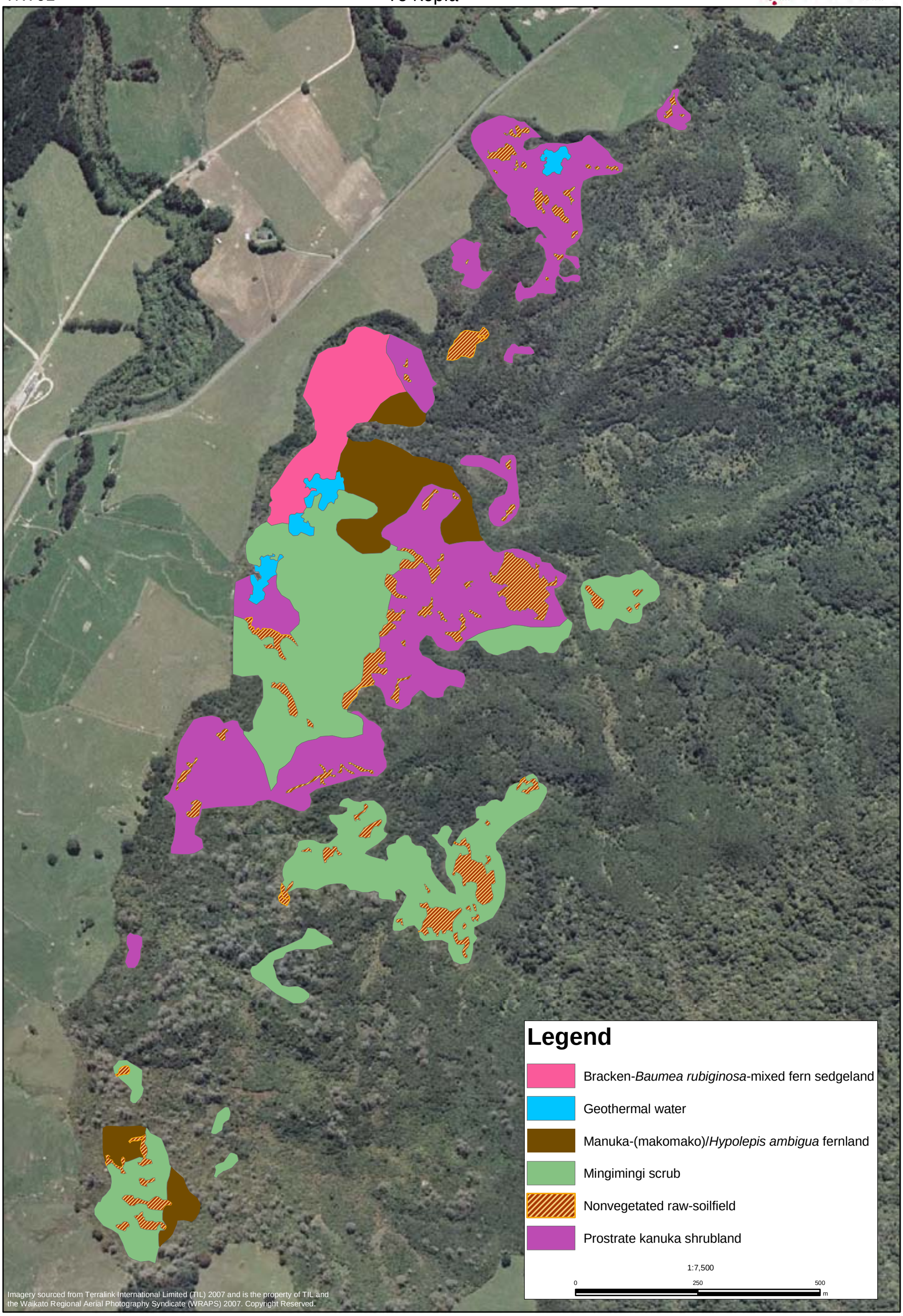
Te Kopia



TKV01

Te Kopia

Wildlands
0508 WILDNZ
www.wildlands.co.nz



TE KOPIA

Site Number: TKV01[1]
Grid Reference: NZTopo50 BF37 805 434
GPS reference: NZTM E1880502 N5743445
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Te Kopia
Bioclimatic Zone: Submontane
Tenure: Protected (Te Kopia Scenic Reserve) and unprotected private land
Altitude: *c*.440-620 m
Extent of Geothermal Habitat: *c*.59.9 ha
Extent of Geothermal Vegetation: *c*.58.8 ha
Date of Field Survey: 31 May & 1 June 2004

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.02 04.02.12	**Mingimingi-dominant scrub** **Mingimingi scrub** Confined to relatively cooler soils, the 2-4 m high canopy is dominated by mingimingi, manuka and occasional kamahi, with 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 turutu, and a moss and liverwort mat on which *Schizaea dichotoma* and *Schizaea* sp. (cf. *fistulosa*) occur (Burns & Leathwick 1995). Prostrate kanuka is abundant on soils with raised temperatures in this vegetation type.	Foot of scarp; hillslopes	*c*.23.1 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** This occurs around the most active geothermal features, and comprises a sparse low canopy of prostrate kanuka (0.3-1 m high) with occasional mingimingi and monoao. The groundcover is dominated by *Campylopus* and *Dicranoloma* (mosses), with lichens, liverworts, and *Lycopodiella cernua* also present. Unvegetated areas occur locally throughout this vegetation type. Manuka-kamahi/prickly mingimingi scrub is locally common around the margins (Burns & Leathwick 1995). 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.	Foot of scarp; hillslopes	*c*.20.5 ha

[1] Previously identified as U17/13 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
07.05 07.05.16	**Mixed fernland** **Manuka-(makomako)/*Hypolepis ambigua* fernland** Occurs on an alluvial fan with raised soil temperatures. Manuka and makomako (*Aristotelia serrata*) comprise the canopy over a dense fernland of *Hypolepis ambigua* and *Histiopteris incisa*, with local dense patches of *Carex geminata*. Locally common species include *Muehlenbeckia australis*, wheki and *Baumea teretifolia.* (Burns & Leathwick 1995).	Alluvial fan	*c*.5.3 ha
07.05.17	**Bracken-*Baumea rubiginosa*-mixed fern sedgeland** A wetland in the base of an old explosion crater, where harakeke, *Cortaderia fulvida*, and manuka are emergent over a dense cover of bracken and *Baumea rubiginosa* and *Hypolepis ambigua*. Locally common species include *Gleichenia microphylla, Baumea tenax, Hypolepis distans, Histiopteris incisa*, swamp kiokio and kiokio.	Old explosion crater	*c*.4.4 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Hot springs and hot pools.	Foot of scarp; hillslopes	*c*.1.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Thermally altered clay, mud and sinter (Burns & Leathwick 1995) and mud pools.	Foot of the Paeroa fault scarp; hillslopes	*c*.5.5 ha

Indigenous Flora:

Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) dominates a large percentage of the geothermal vegetation present.

Large colonies of *Dicranopteris linearis* (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009, and known from only *c*.24 sites in New Zealand) are present. *Schizaea dichotoma* (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), a fern which occurs in the kauri forests of Northland and South Auckland, and locally at geothermal sites, is known from this site. A small population of *Nephrolepis flexuosa* („At Risk-Declining') is present and two „At Risk-Naturally Uncommon' orchids (de Lange *et al.* 2009), *Calochilus paludosus* and *C. robertsonii* are also well represented here. *Schizaea* sp. (cf. *fistulosa*) has been recorded here in the past (Clarkson 1984; Burns & Leathwick 1995).

A survey of *Korthalsella salicornioides* (dwarf mistletoe; classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) estimated the population at this site to be 100-200 plants (Anon 2000).

Fauna:

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

Current Condition (2004 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 up until recently. However, 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 a natural vegetation zonation (extending over *c.*579 m in altitude) which includes geothermal vegetation, ranging from tall kamahi-dominated forest through to prostrate kanuka shrubland and geothermal wetland (see also Clarkson 1984).

Threats/Modification/ Vulnerability:

Invasive pest plants (*2004 Assessment*)*:* Pine control is ongoing in the reserve over recent years. The invasion of pines (was previously about 6-25% cover, but has significantly reduced since 2004, now more likely to be 1-5% cover) is a continuing problem in this area, and there is potential for weed invasion along the walking tracks. Blackberry (1-5% cover) and gorse (<1% cover) are also present.

Human impacts (*2004 Assessment*)*:* There are few walking tracks and human impact is low.

Grazing (*2004 Assessment*)*:* The reserve is fenced, although the fence line was damaged in places in 2004.

Adjoining land use (*2004 Assessment*)*:* The adjoining area comprises indigenous vegetation in Te Kopia Scenic Reserve.

Site Change:

Recent change: The only significant change noted was the large number of dead pine trees in 2007 photographs, following control work at this site undertaken by the Department of Conservation. The changes to vegetation and site boundaries were based on better quality aerial photographs available in the current study, rather than real change.

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

Burns (1996b) has 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 remained approximately unchanged. Areas with vegetation dominated by prostrate kanuka 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, and can be seen as dead trees on 2007 aerial photographs.

Management Requirements: Wilding pines spread should continue to be controlled and the geothermal area kept as weed free as possible. Fences should be regularly checked and maintained.

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 (including prostrate kanuka shrubland and nonvegetated raw-soilfield) through to tall forest (including kamahi-rewarewa forest, rimu/black maire forest, rimu-northern rata/tawa-hinau-rewarewa-mangeao-kamahi forest, rimu/kamahi forest, and Hall's totara/kanuka-broadleaf-tawheoeheo forest; Clarkson 1984) and 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* (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009, and known from only *c.*24 sites in New Zealand) in New Zealand occurs here. This site also contains one of the largest populations of prostrate kanuka (classed as „At Risk-Naturally Uncommon'), as well as good populations of four other species classed as „At Risk' (*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 (Unpublished Atiamuri PNAP data 1995).

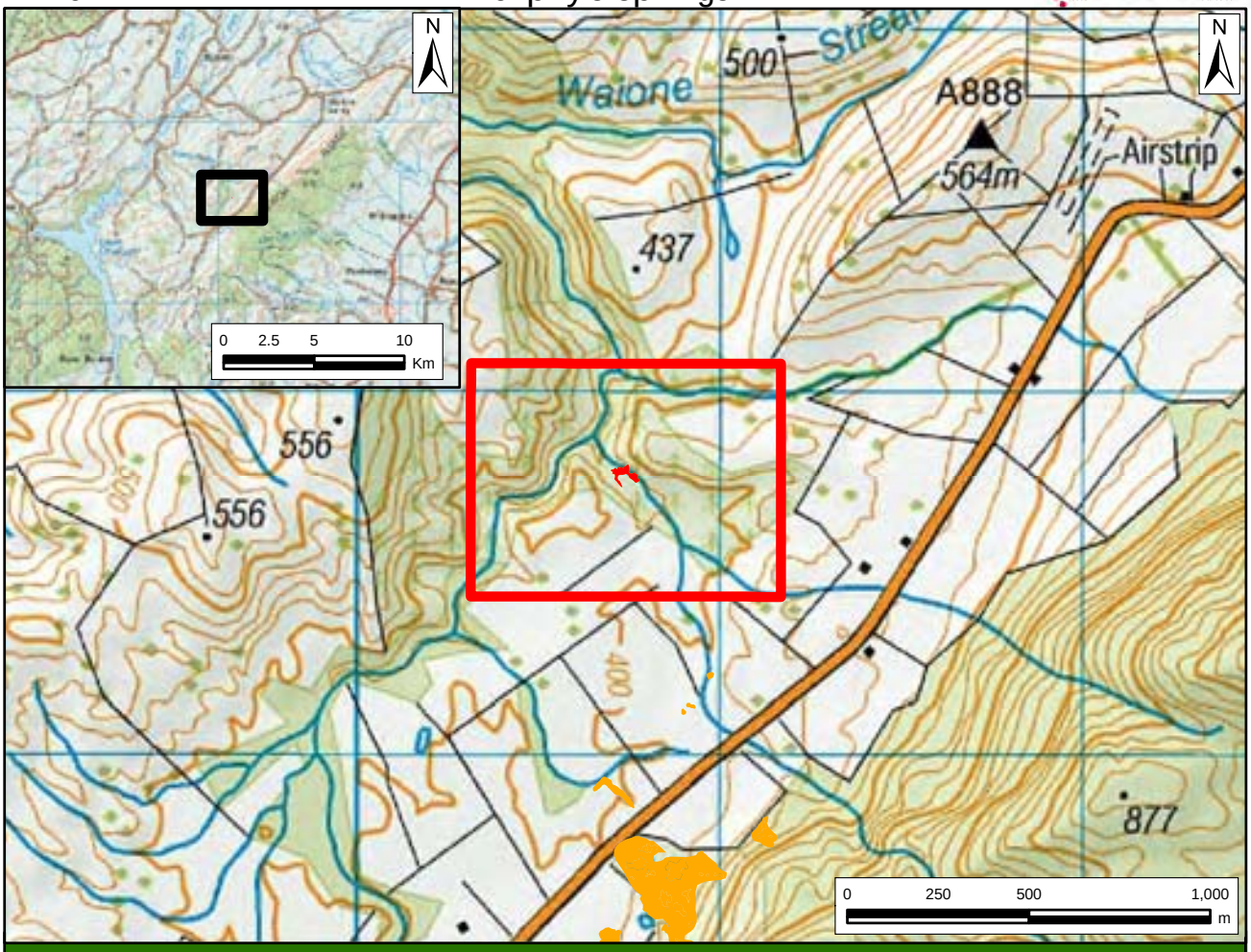
Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in this survey this site was classed as Category A - the highest category.

References:

Anon 2000; Beadel & Bill 2000; Burns 1996b & 1997b; Burns & Leathwick 1995; Clarkson 1984; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004.

TKV02

Murphy's Springs



MURPHY'S SPRINGS

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

Code	Type	Landform	Extent
05.08 05.08.03	**Mixed indigenous shrubland** **Mixed indigenous shrubs/mixed fern species shrubland** Occasional plantation pines occur over mixed broadleaved and shrubland species, including kohuhu, karamu, manuka, wheki, *Coprosma propinqua* over an understorey of ferns (particularly bracken, kiokio, and *Deparia petersenii* subsp. *congrua*) and turutu. *Carex geminata* and *C. secta* are common on stream margins; at the time of the site inspection pines had recently been felled into the site. Black nightshade, exotic grasses (particularly Yorkshire fog), and lotus are common in recently disturbed areas. *Christella* aff. *dentata* ("thermal") is common in steam alongside geothermal springs and stream margins.	Gully	*c.*0.2 ha

Geophysical Assessment:[2]

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 10L/sec 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 these were estimated to be in the order of 5L/sec, while the accessible spring had a flow rate of approximately 20L/sec. The temperatures 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, would tend 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.

[1] Previously identified as U17/38 in Wildland Consultants (2004).
[2] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

Downstream of the thermal spring inputs the main stream has a flow of between 80-100L/sec, 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.

Indigenous Flora: *Christella* aff. *dentata* ("thermal"), classed as an „At Risk-Declining' species (in de Lange *et al.* 2009), is common alongside geothermally heated stream margins. An estimated 100 plants are present. Other species typical of geothermal habitats include manuka, bracken, and turutu.

Fauna: Common indigenous and exotic species typical of the habitats are present. Fantail were recorded during 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. However the site has the potential to recover well if it is fenced and pest plants are controlled as required.

Threats/Modification/ Vulnerability:

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

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

Grazing (*2011 Assessment*): The site is not fenced, and cattle have had access to site following recent tree felling and conversion of neighbouring land to pasture.

Adjoining land use (*2011 Assessment*):	Plantation; recently cleared plantation; and pasture.
Site Change:	
Recent change:	Unknown. Some felling of pine trees into geothermal areas is evident.
Historical:	Site not assessed, no historical photos found. However 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.
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"), which is known from only 14 other sites in New Zealand.
Notes:	The pine plantation around the site has recently been harvested, or is in the process of being harvested, and the adjacent land is in the process of being converted into pasture. Mapping is based on GPS waypoints obtained during field survey and not on assessment of aerial photographs as the vegetation of the site has changed markedly since 2007 aerial photographs.

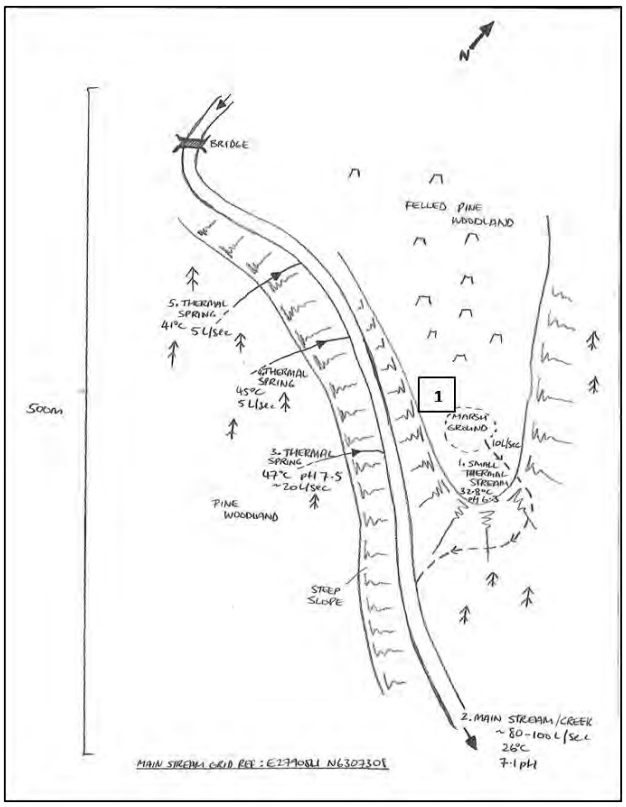
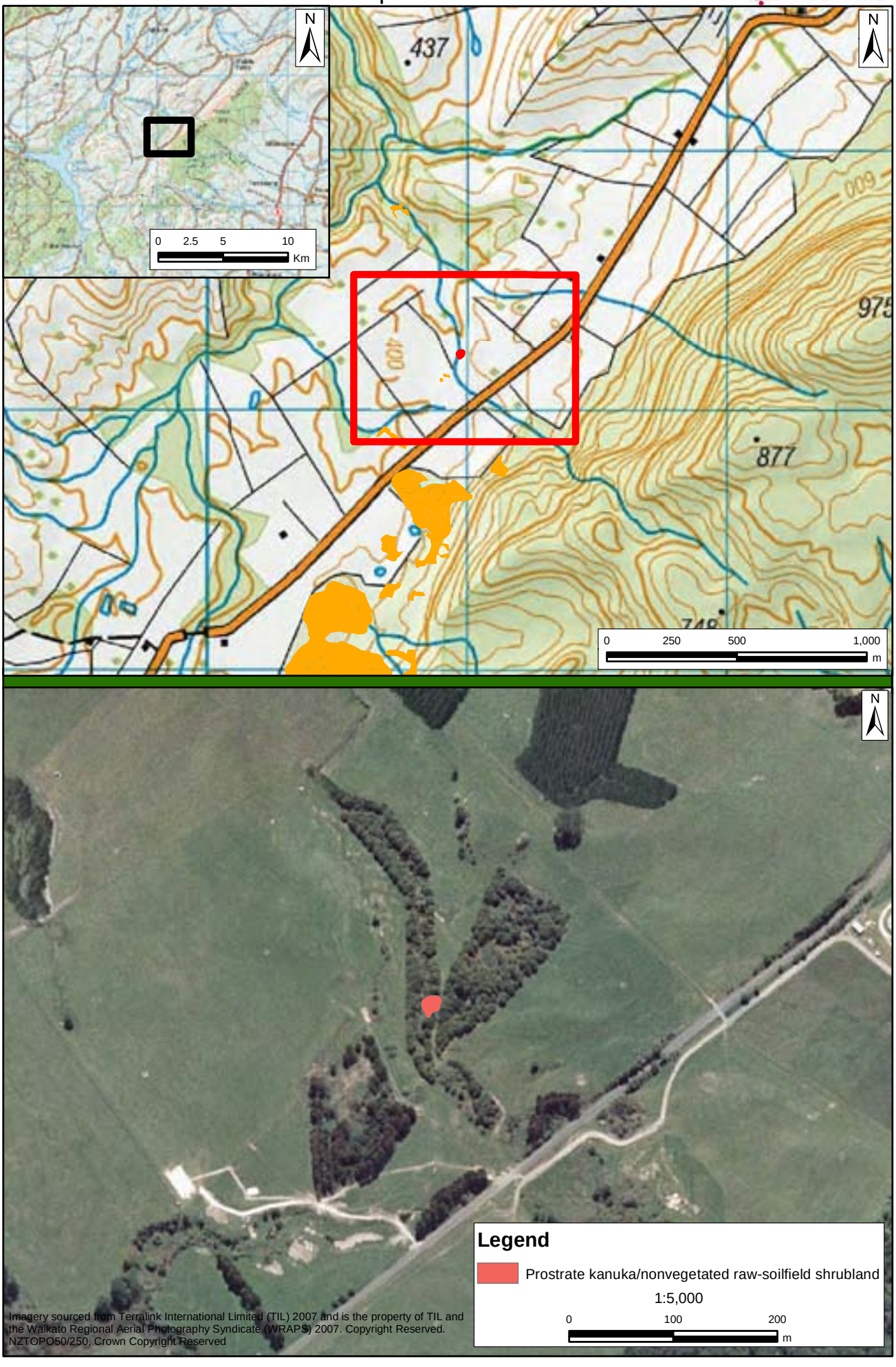


Figure A1-9: Murphy's Springs Geothermal Area:
Sketch Map showing main features and photograph location.
The grid reference labelled here is E1880411 N5745753 (NZTM).

TKV03

Te Kopia Northwest



TE KOPIA NORTHWEST

Site Number: TKV03[1]
Grid Reference: NZTopo50 BF37 810 452
GPS Reference: NZTM E1880972 N5745221
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Te Kopia
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*400 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 29 June 2010

Code	Type	Landform	Extent
05.01 05.01.11	**Prostrate kanuka shrubland** **Prostrate kanuka/nonvegetated raw-soilfield shrubland** A small geothermal manifestation in a gully to the north of Te Kopia Mud Pools. Much of the site is unstable bare ground with an extensive network of springs present. This contains areas of *Campylopus* mossfield, and scattered plants of Mercer grass and creeping bent. In one place, a few scattered macrocarpa (*Cupressus macrocarpa*) occur over prostrate kanuka scrub with occasional blackberry. Three plants of *Nephrolepis flexuosa* occur at N1880977 E5745224. Occasional *Lycopodiella cernua* are also present. Turutu and *Rubus schmidelioides* var. *schmidelioides* are common on geothermal margins. A stream passes through the southern part of the site. This is surrounded by kamahi, whauwhaupaku, karamu, makomako, wheki, kohuhu, and macrocarpa forest.	Gully	<0.1 ha

Geophysical Assessment[2]:

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.*30l/sec) 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.

[1] Previously identified as U17/39 in Wildland Consultants (2004).
[2] Geophysical assessment undertaken by Juliet Newson and Julian McDowell,2010.

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 kanuka 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 12.6-13.2°C with pH between 5.7 and 5.9.

Indigenous Flora: Three plants of *Nephrolepis flexuosa* classed as „At Risk-Declining' in de Lange *et al.* (2009) are present. A small area of vegetation dominated by prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) was also present.

Fauna: None noted. Common indigenous and exotic species typical of shrubland habitat likely to be present.

Current Condition (2007 Assessment): The geothermal feature is in good condition, with an „At Risk' fern species present. The site is surrounded by exotic plants.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*): Whilst surrounded by exotic species, there are no urgent management requirements for pest plants.

Human impacts (*2007 Assessment*): Macrocarpa has been planted close to the site.

Grazing (*2007 Assessment*): Site has been fenced to exclude stock.

Adjoining land use (*2007 Assessment*): Macrocarpa plantation and farm land.

Site Change:

Recent change: Site has not been inspected by Wildland Consultants previously.

Historical: Site not assessed, no historical photos found. As vegetation is in a gully, and site is small, changes are unlikely to be visible on historical black and white photographs.

Management Requirements: None noted.

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

Significance Justification: Te Kopia Northwest is a locally significant site because it is an example of a nationally uncommon habitat type (geothermal) and supports small populations of two ‚At Risk' species (prostrate kanuka and *Nephrolepis flexuosa*).

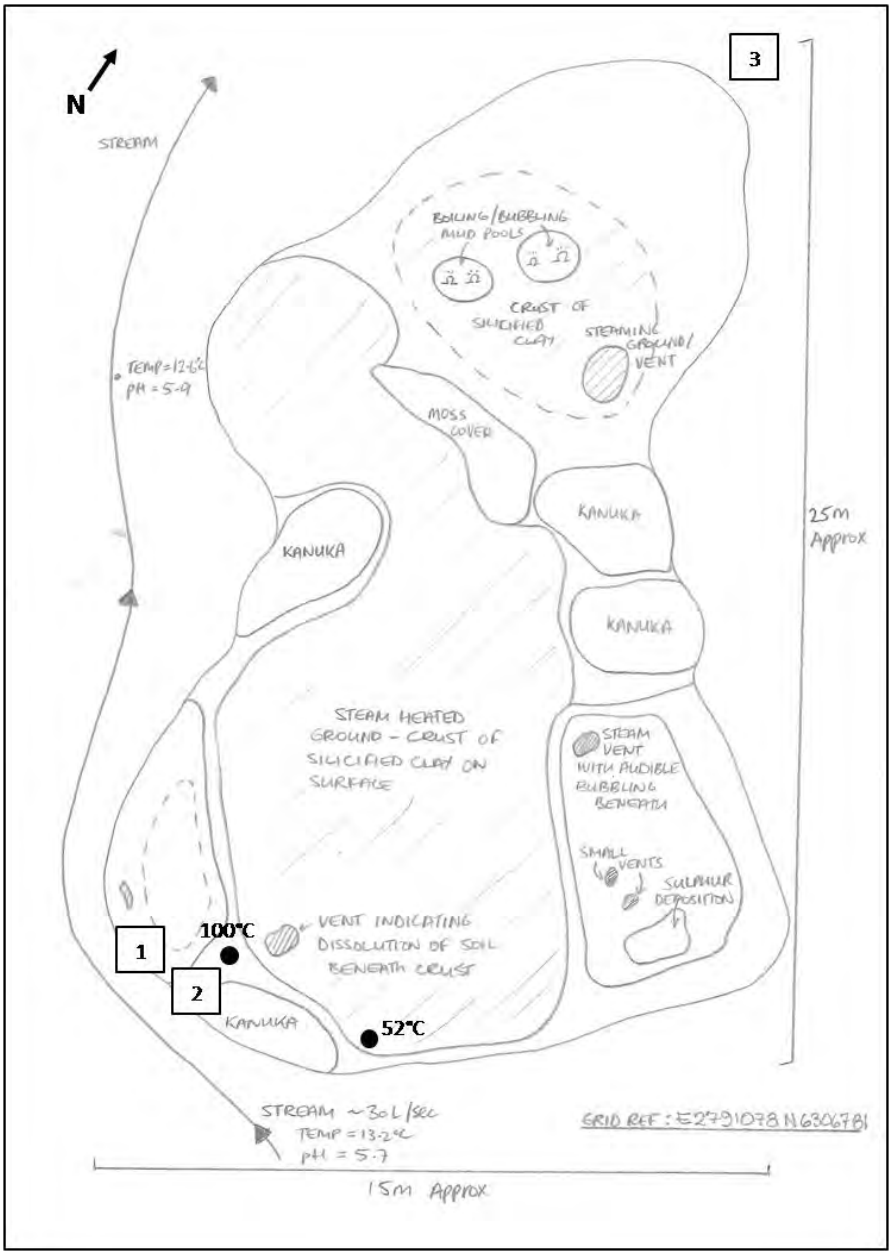


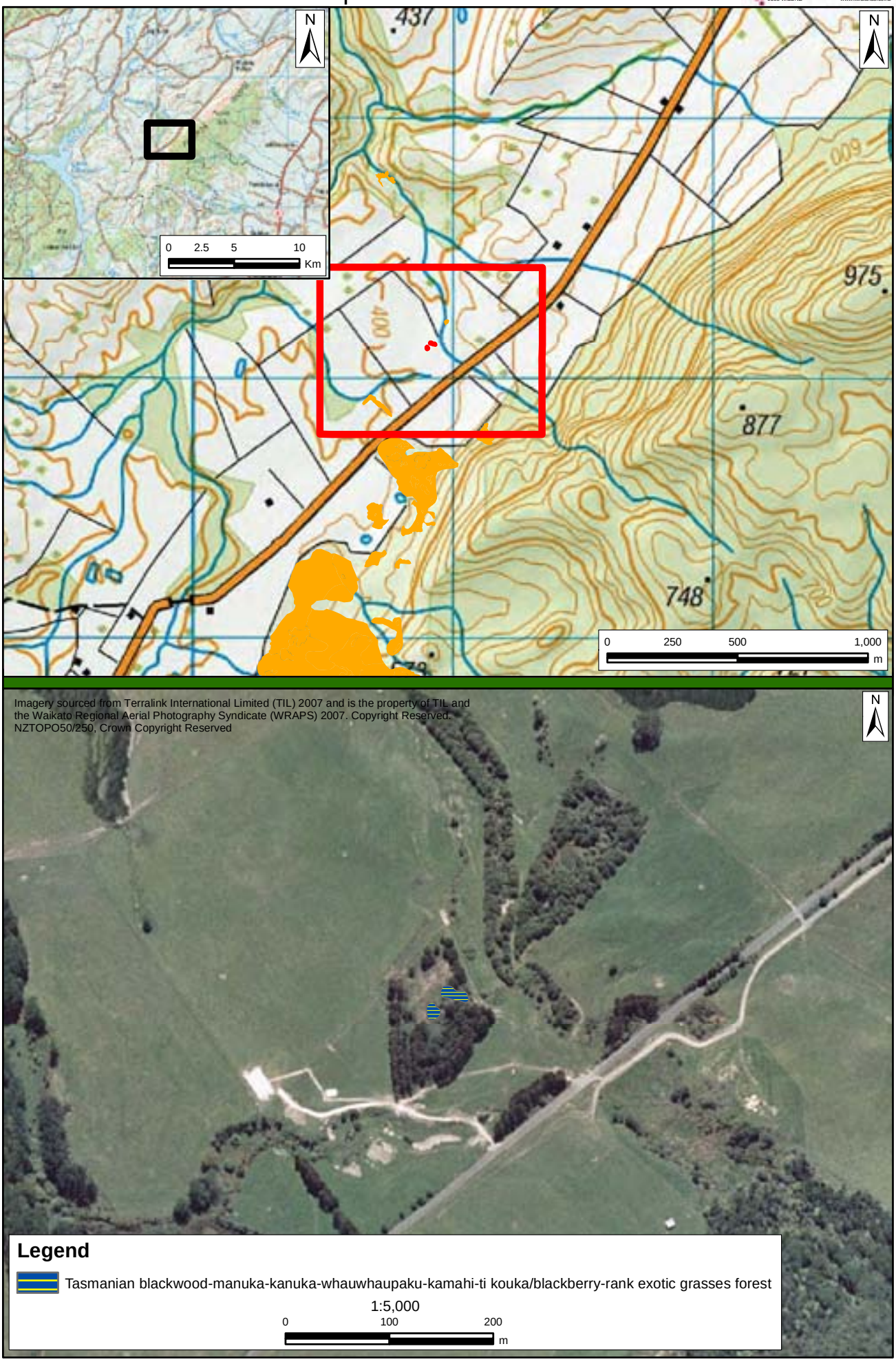
Figure A1-10: Te Kopia - Northwest. Field Sketch Map indicating main features and photo locations. The grid reference labelled here is NZMG.

Plates 57-59:

57. View of area from southwest corner. Note: prostrate kanuka 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 kanuka/*Campylopus* cover.

TKV04

Te Kopia West Mud Pools



TE KOPIA WEST MUD POOLS

Site Number: TKV04
Grid Reference: NZTopo50 BF37 809 451
GPS Reference: NZTM E1880919 N5745136
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Te Kopia
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*400 m
Extent of Geothermal Habitat: *c.*0.1 ha
Extent of Geothermal Vegetation: *c.*0.1 ha
Date of Field Survey: 29 June 2010

Code	Type	Landform	Extent
01.09 01.09.01	**Plantation-mixed broadleaved forest** **Tasmanian blackwood-manuka-kanuka-whauwhaupaku-kamahi-ti kouka/blackberry-rank exotic grasses forest** Three mud pools surrounded by a mostly failed Tasmanian blackwood plantation, with brush wattle and indigenous tree species, including kanuka, whauwhaupaku, kamahi, and ti kouka. Turutu, *Hypolepis ambigua* and bracken are common in the understorey. A notable feature of the kamahi beside the eastern pool is the burnt foliage in the line of steam from the pool. Many of the trees surrounding all mud pools have a thin layer of mud from mud pool activity. 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	*c.*0.1 ha

Geophysical Assessment:[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 Rd. 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 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

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell,2010.

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.

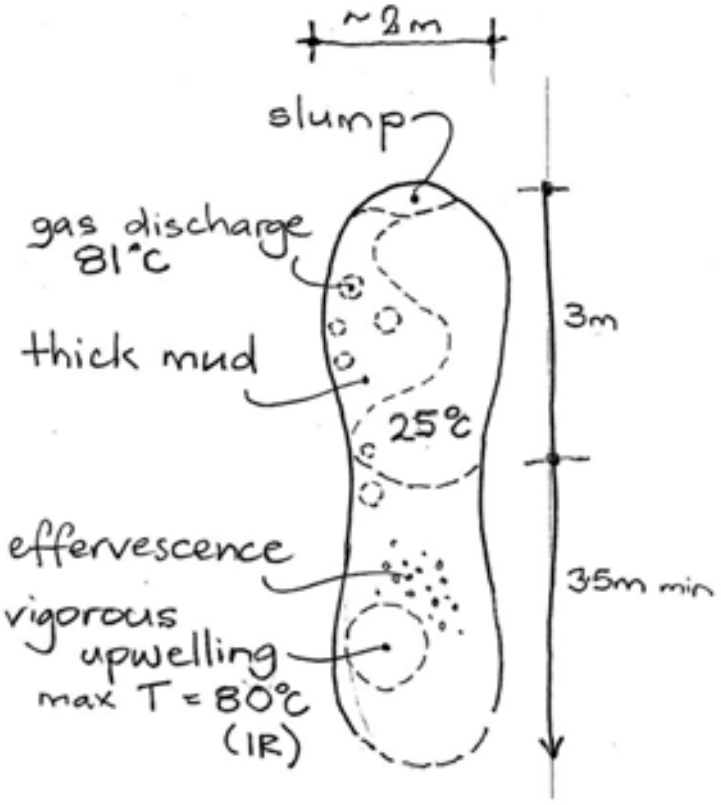


Figure A1-11: Sketch map of the eastern-most mud pool, Te Kopia West Mud Pools.

Plate 60: Apron of mud over the northern lip of the Northern 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 also 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 east 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.

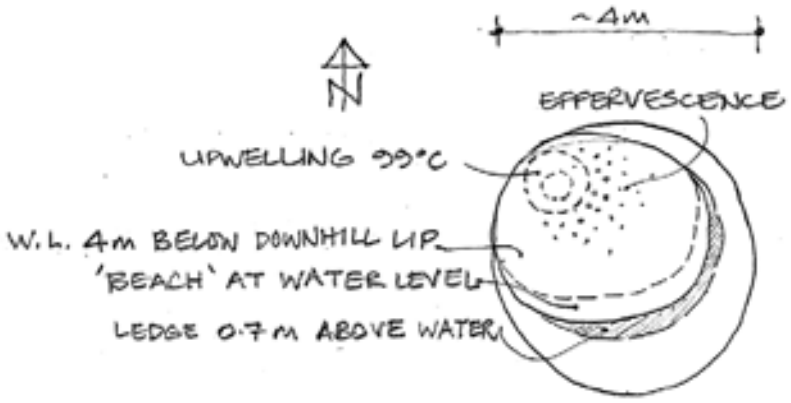


Figure A1-12: Sketch map of middle pool, Te Kopia West Mud Pools.

Plate 62: Middle pool, Te Kopia West Mud Pools.

Southern Pool
Grid Ref: 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.

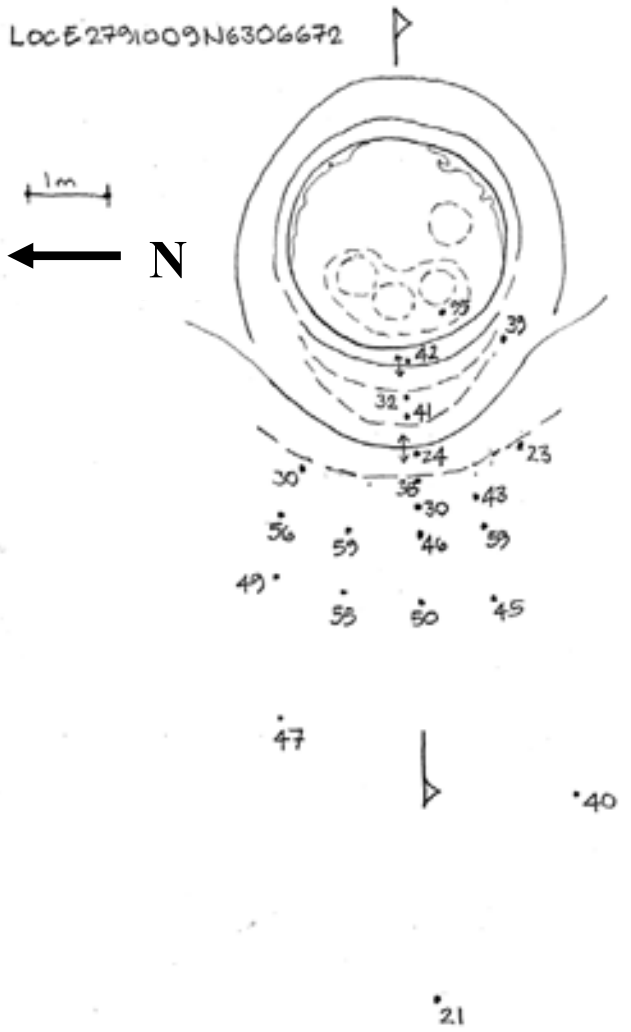


Figure A1-13: Sketch map of southern pool, indicating temperature in degrees Celsius. Reference is in New Zealand Map Grid.

The ground immediately in front of the pool has elevated temperatures (23 to 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.

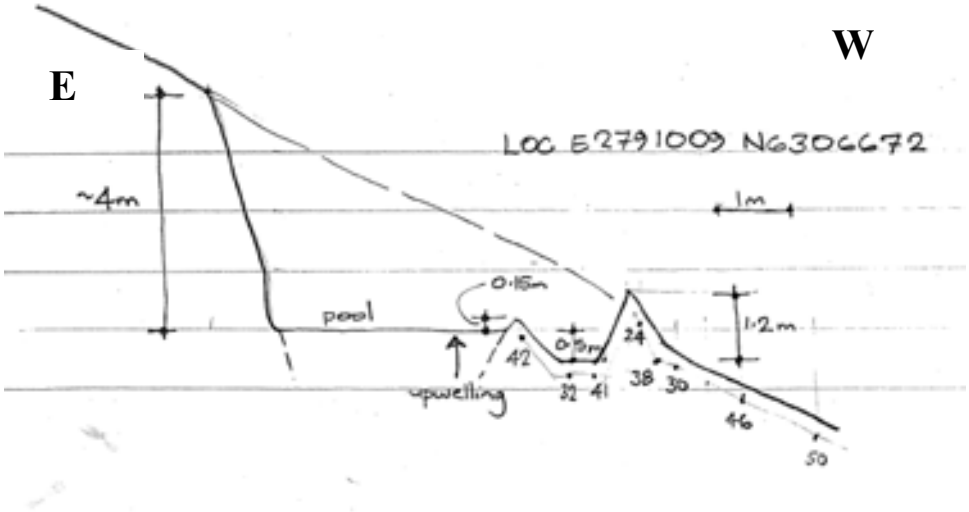


Figure A1-14: Sketch cross section E-W through the feature showing the inner dam confining the pool, and the soil temperatures at 0.1 m depth. Southern Pool, Te Kopia West Mud Pools. Grid reference is in New Zealand Map Grid.

Plate 63: The southern pool showing inner dam in foreground.

Indigenous Flora: No „Threatened' or „At Risk' species as listed in de Lange *et al.* (2009) are known from this site.

Fauna: Possum sign. Common indigenous and exotic species typical of the habitats present are likely to be present. Australasian magpie was recorded during the site inspection.

Current Condition (2011 Assessment): The site is surrounded by indigenous and exotic species, but geothermal features are in a good condition.

Threats/Modification/ Vulnerability:

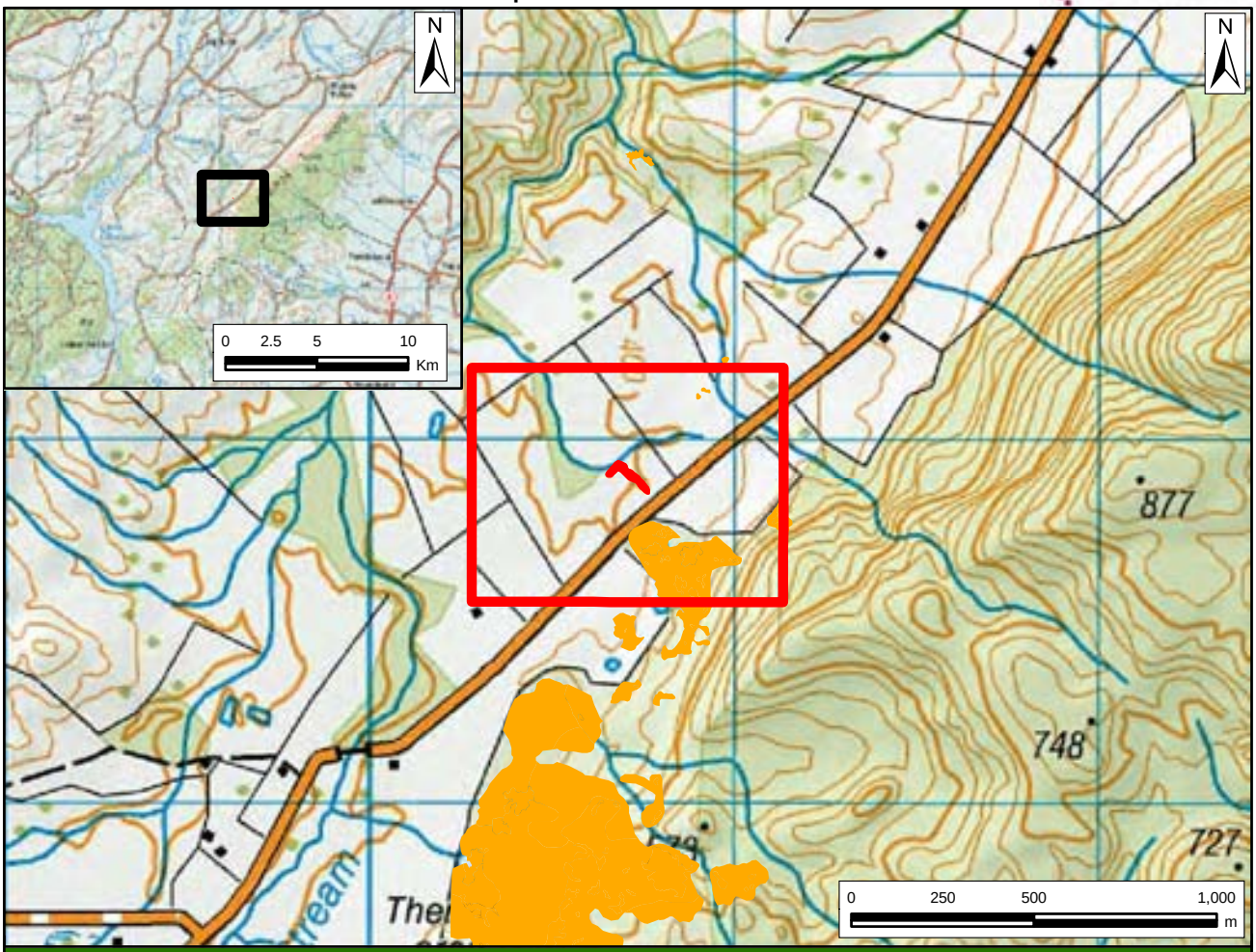
Invasive pest plants (*2011 Assessment*):	Tasmanian blackwood and brush wattle, while pest plant species, are not having a significant impact on geothermal features of the site. However, control of these species is recommended.
Human impacts (*2011 Assessment*):	The site is fenced to exclude stock. A track has been made through blackberry to the southern mud pool. Tasmanian blackwood has been planted near the mud pools.
Grazing (*2011 Assessment*):	The mud pools are fenced to exclude stock.
Adjoining land use (*2011 Assessment*):	Tasmanian blackwood plantation; farmland.

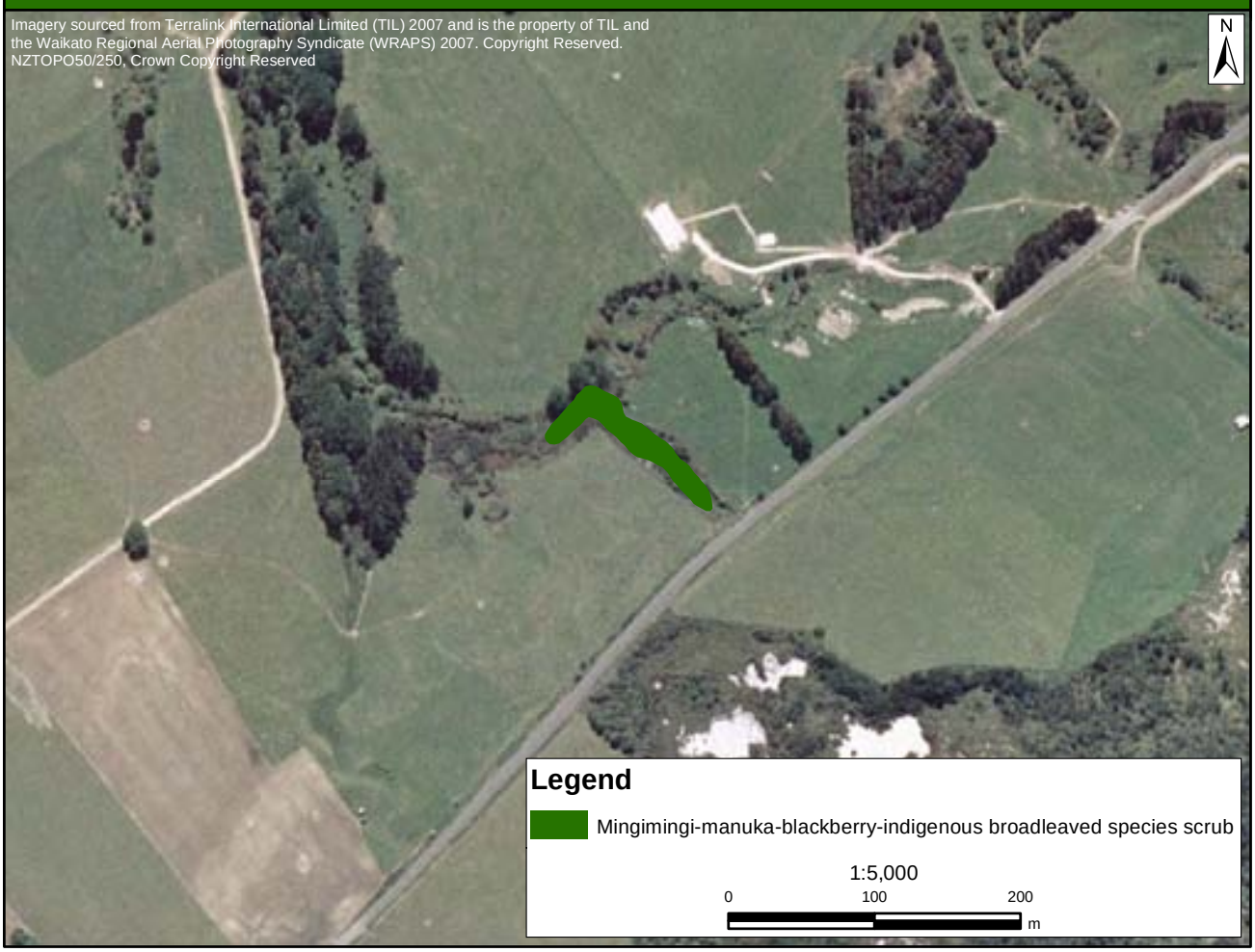
Site Change:

Recent change:	The farmer advised that the southern mud pool has become more vigorous in recent years.
Historical:	Site not assessed, no historical photos found. Unlikely to be visible on black and white aerial photographs.
Management Requirements:	None noted.
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19).
Significance Justification:	Te Kopia Mud Pools is a locally significant site because it comprises a small example of a nationally uncommon vegetation and habitat type (i.e. geothermal habitat).
References:	Hochstein 2007.

TKV05

Te Kopia Red Stream





TE KOPIA RED STREAM

Site Number: TKV05
Grid Reference: NZTopo50 BF37 807 449
GPS Reference: NZTM E1880706 N5744908
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Te Kopia
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*400 m
Extent of Geothermal Habitat: *c.*0.2 ha
Extent of Geothermal Vegetation: *c.*0.2 ha
Date of Field Survey: 29 June 2010

Code	Type	Landform	Extent
04.05 04.05.01	**Indigenous mixed shrubs-dominant communities** **Mingimingi-manuka-blackberry-indigenous broadleaved species scrub.** Vegetation surrounding a small geothermal stream. Ferns (e.g. *Deparia petersenii* subsp. *congrua*, *Histiopteris incisa*, *Gleichenia microphylla*, and bracken), *Carex secta*, mingimingi, manuka, and wheki are common on upper stream margins with raised 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 kamahi, whauwhaupaku, kohuhu, karamu, horoeka (*Pseudopanax crassifolius*), and occasional common alder (*Alnus glutinosa*) and *Cotoneaster glaucophyllus*. Scattered lianes of *Rubus schmidelioides* var. *schmidelioides* are present. Turutu is common in the understorey. Blackberry becomes increasingly dense away from geothermal stream margins until it is the dominant cover. This gully was steeply sided with unsafe access over much of the site, so only small parts of the stream were viewed.	Gully	0.2 ha

Geophysical Assessment:[1]

This is a small stream west of the 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

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

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 to 59°C at 0.01 m) 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.

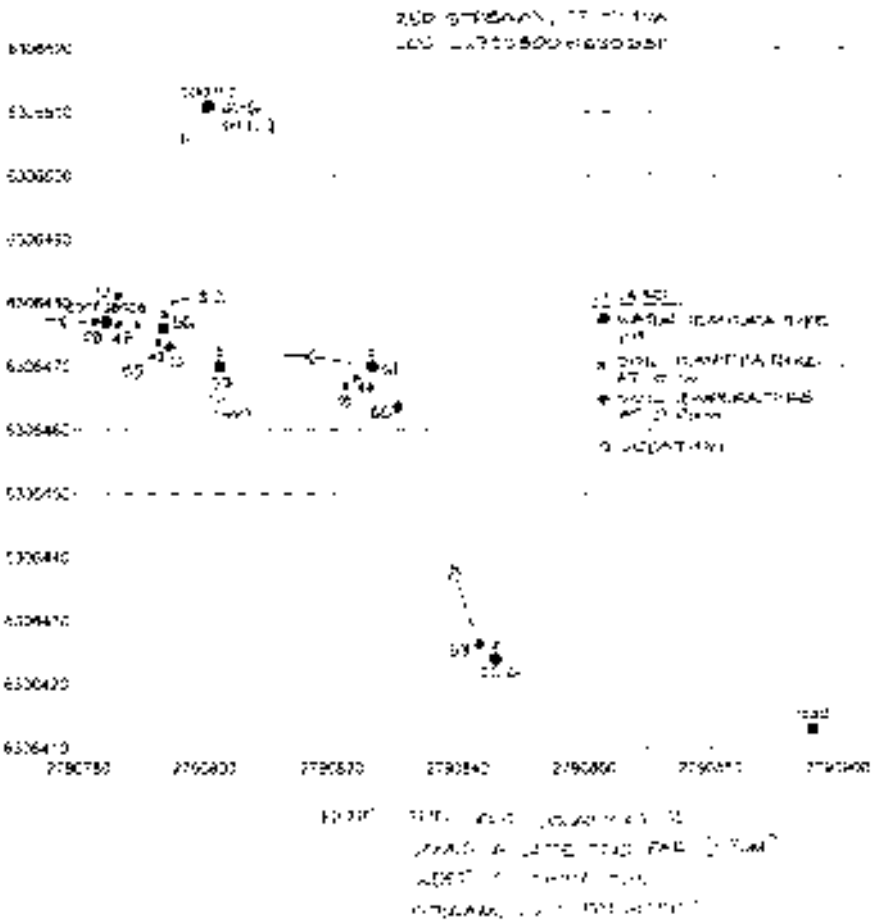


Figure A1-15: Red Stream, Te Kopia. The grid reference labelled here is NZMG.

Indigenous Flora: No „Threatened' or „At Risk' species (as listed in de Lange *et al.* 2009) were recorded from this site. However, other species typical of geothermal habitats present included manuka, mingimingi, *Deparia petersenii* subsp. *congrua*, *Histiopteris incisa*, *Gleichenia microphylla*, turutu, and bracken.

Fauna: None noted. Common indigenous and exotic birds typical of the habitats are likely to use this area.

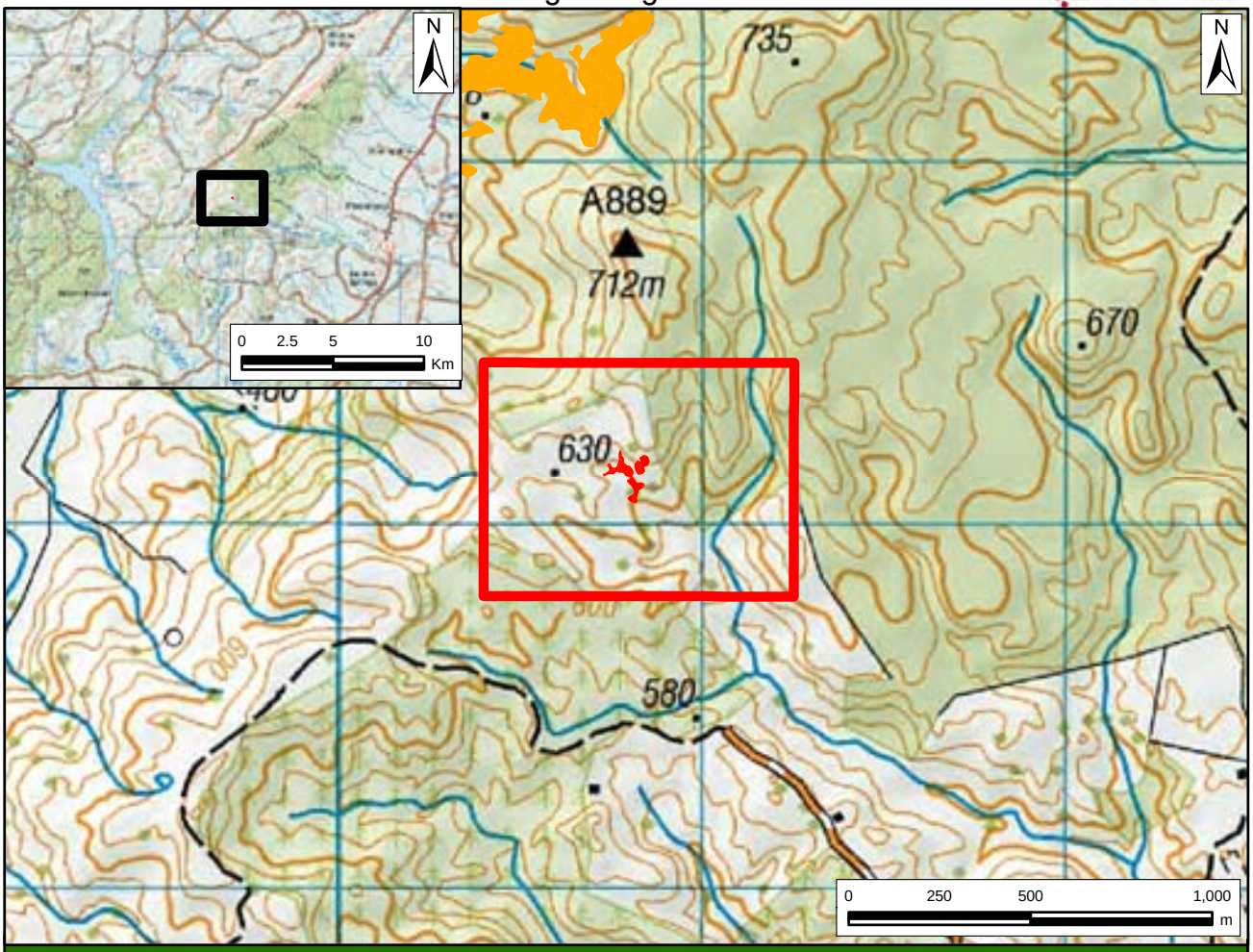
Current Condition (2011 Assessment): The site is in a moderate ecological condition. The gully vegetation is fenced to exclude stock and the stream is surrounded by mixed indigenous

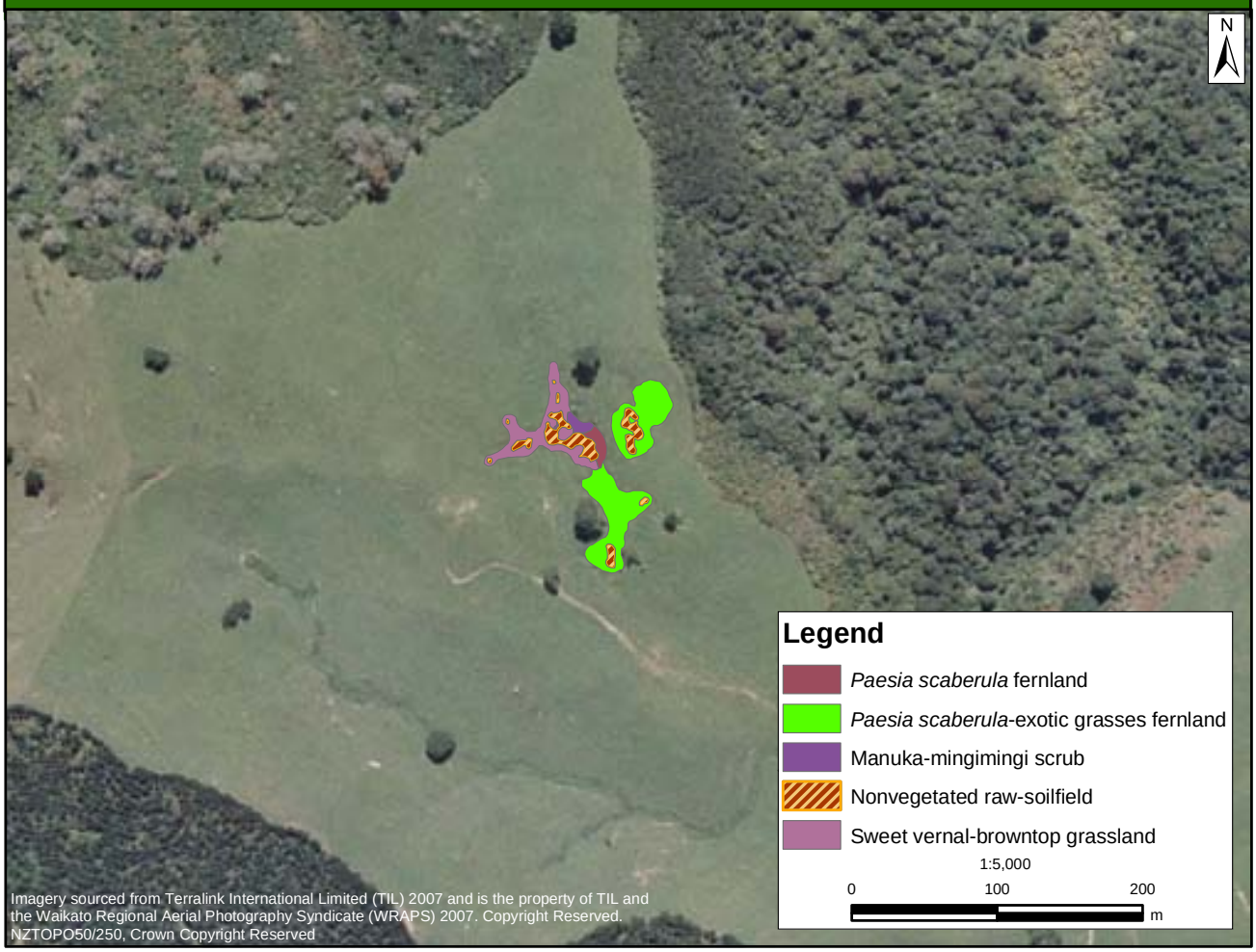
	and exotic scrub vegetation. Exotic pest plants are common.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2011 Assessment*):	Blackberry is very common alongside cooler stream margins and margins of the site (5-25% cover). Other pest plants present include common alder (<1% cover), and *Cotoneaster glaucophyllus* (<1% cover).
Human impacts (*2011 Assessment*):	Difficult access. None noted, and site has been fenced to exclude stock.
Grazing (*2011 Assessment*):	The site has been fenced to exclude stock.
Adjoining land use (*2011 Assessment*):	Scrub and farmland.
Site Change:	
Recent change:	Unknown: This site has not been assessed previously.
Historical:	Site not previously assessed, no historical photos found. As features are all in a gully, it is unlikely to be visible on aerial photographs. Blackberry and other pest plants will have in part changed the character of the site from historical times. The extent of the site is unlikely to have undergone significant change following human settlement.
Management Requirements:	Fences should be maintained to exclude stock. The ongoing spread of pest plants should be monitored at regular intervals (e.g. five-yearly). *Cotoneaster glaucophyllus* and alder should be removed from the site.
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19)
Significance Justification:	Te Kopia Red Stream is a locally significant site because it comprises a small example of a nationally uncommon vegetation and habitat type (i.e. geothermal habitat).
Notes:	Background information on these sites was provided by Paul Cashmore and Pete Corson (Department of Conservation, Rotorua). This site was referred to as „Road Spring' in Hochstein (2007).
References:	Hochstein 2005 & 2007

Plate 64: Te Kopia Red Stream showing water colour and vegetated banks.

TKV06

Mangamingi Station





MANGAMINGI STATION

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

Code	Type	Landform	Extent
04.03 04.03.02	**Manuka dominant scrub** **Manuka-mingimingi scrub** Small area of manuka and mingimingi dominant scrub above an area of geothermal activity. This area is influenced by geothermal activity below. Other species present include kohuhu, wheki, horoeka, and tawiniwini. One rimu 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
07.05 07.05.10	**Mixed fernland** ***Paesia scaberula*-exotic grasses fernland** This vegetation type is a mosaic of *Paesia scaberula* fernland (07.11.01) and sweet vernal-browntop grassland (08.06.02). Several patches of kiokio and *Doodia australis* are also present.	Hillslope	*c.*0.3 ha
07.11 07.11.01	***Paesia scaberula* dominant fernland** ***Paesia scaberula* fernland** *Paesia scaberula* dominant fernland, with common patches of *Lycopodiella cernua* and *Hypolepis ambigua*, and scattered mingimingi, turutu, and prostrate kanuka. There are local patches of pasture dominated by sweet vernal, browntop, white clover (*Trifolium repens*), and sheep's sorrel. Three juvenile plants of *Dicranopteris linearis* were recorded at one location in this vegetation type (see flora section below).	Hillslope	<0.1 ha
08.06 08.06.02	**Mixed exotic grassland** **Sweet vernal-browntop grassland** Well grazed pasture. Common species present include sweet vernal, browntop, white clover, and sheep's sorrel with occasional Scotch thistle (*Cirsium vulgare*) and cocksfoot (*Dactylis glomerata*). Patches of *Paesia scaberula* were common. Occasional plants of *Gonocarpus micranthus* were present.	Hillslope, gully	*c.*0.1 ha

[1] Previously identified as U17/37 in Wildland Consultants (2004).

Code	Type	Landform	Extent
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Bare geothermal influenced clays and silicified rocks (see geophysical description below) and several pools of geothermally influenced water. Mostly bare ground, but scattered areas of mossfield and exotic grasses. Scattered plants of the following species are present; prostrate kanuka, *Lycopodiella cernua, Paesia scaberula, Histiopteris incisa,* mingimingi, prickly mingimingi*, Blechnum fluviatile,* and Spanish heath. Common non-vascular plant species present include *Campylopus capillaceus, Wijkia extenuata*, *and Monoclea fosteri*, however a detailed non-vascular plant survey was not undertaken.	Hillslope, gully	<0.1 ha

Geophysical Assessment:[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 a 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: This is an approximately triangular area of thermal ground. Approximately

[1] Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

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 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 0.1 m 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.

Flora: Two species listed as „At Risk-Naturally Uncommon' in de Lange *et al.* (2009) are present: *Dicranopteris linearis* and prostrate kanuka. Prostrate kanuka is scattered through the site, and three juvenile plants of *D. linearis* were recorded at NZTM E1880808 N6303706. *D. linearis* is known from only *c.*24 sites in New Zealand. Other species typical of geothermal habitats recorded were *Lycopodiella cernua*, turutu, *Campylopus capillaceous*, *Paesia scaberula*, manuka, mingimingi, prickly mingimingi, tawiniwini, *Blechnum penna-marina* subsp. *alpina*, *Doodia australis, Hypolepis ambigua, Gonocarpus micranthus*, and *Histiopteris incisa*.

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 this site has the capacity to provide suitable habitat for prostrate kanuka and *Dicranopteris linearis* to extend further into this site if major pest plants such as blackberry and Spanish heath are controlled.

Threats/Modification/ Vulnerability:

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

Human impacts (*2011 Assessment*)*:*	The site is farmed.
Grazing (*2011 Assessment*):	The site is part of a farm paddock which is currently grazed by sheep.
Adjoining land use (*2011 Assessment*):	Farmland.

Site Change:

Recent change:	Unknown. The site has not previously been assessed but it is unlikely to have undergone significant recent change.
Historical:	Probably 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. Site too small to locate on 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. It also supports small populations of two ‚At Risk' species, prostrate kanuka and *Dicranopteris linearis*. However, if fenced to exclude stock, the indigenous vegetation of the site may improve markedly, and the ecological values of the site would increase. The character of geothermal activity at the site is suitable for prostrate kanuka and *Dicranopteris linearis* to establish in areas that are currently unvegetated because of stock impacts.
Notes:	The site is about 700 m to the east of other patches of geothermal vegetation mapped at Te Kopia (U17/13). 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.

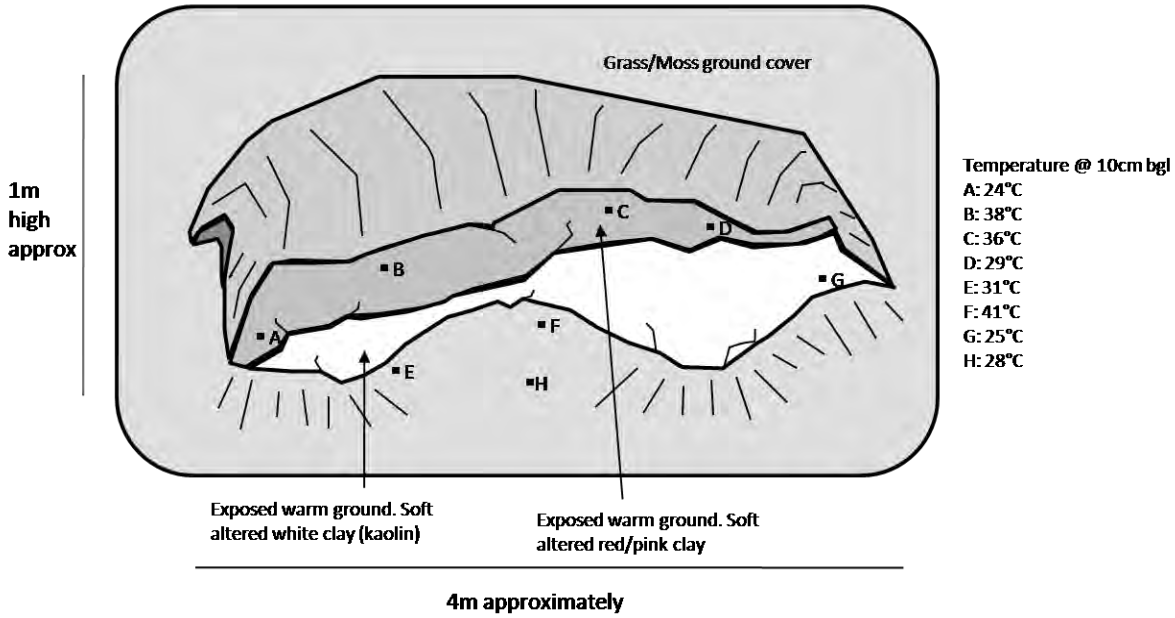


Figure A1-16: Geothermal activity at Locality 1.

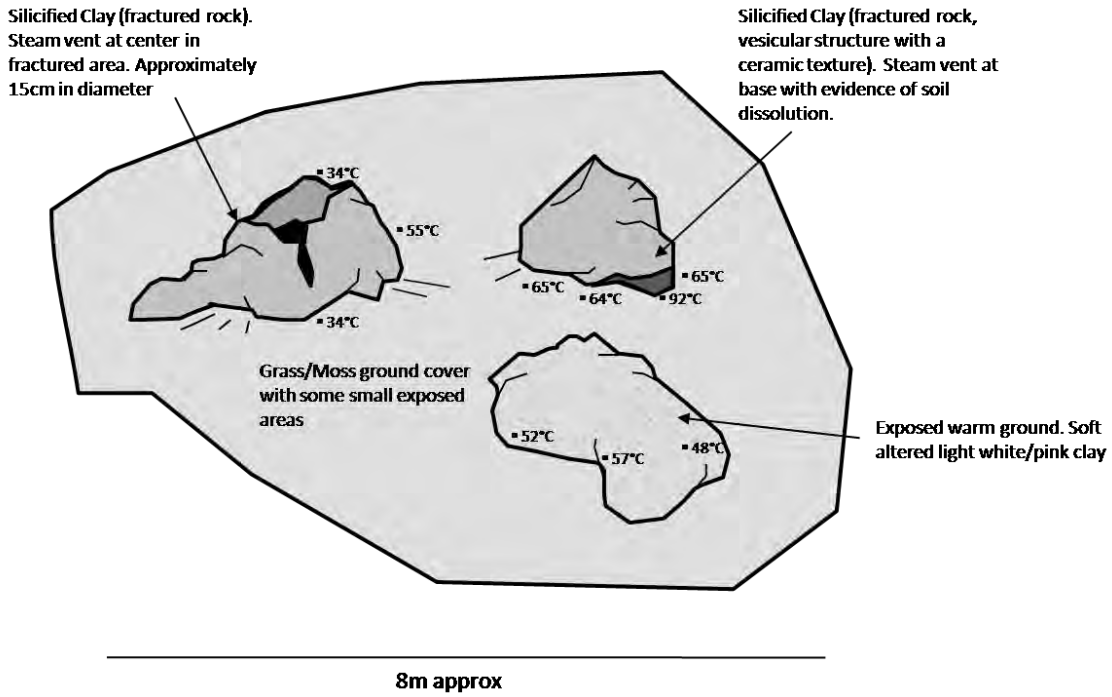


Figure A1-18: Geothermal activity at Locality 6.

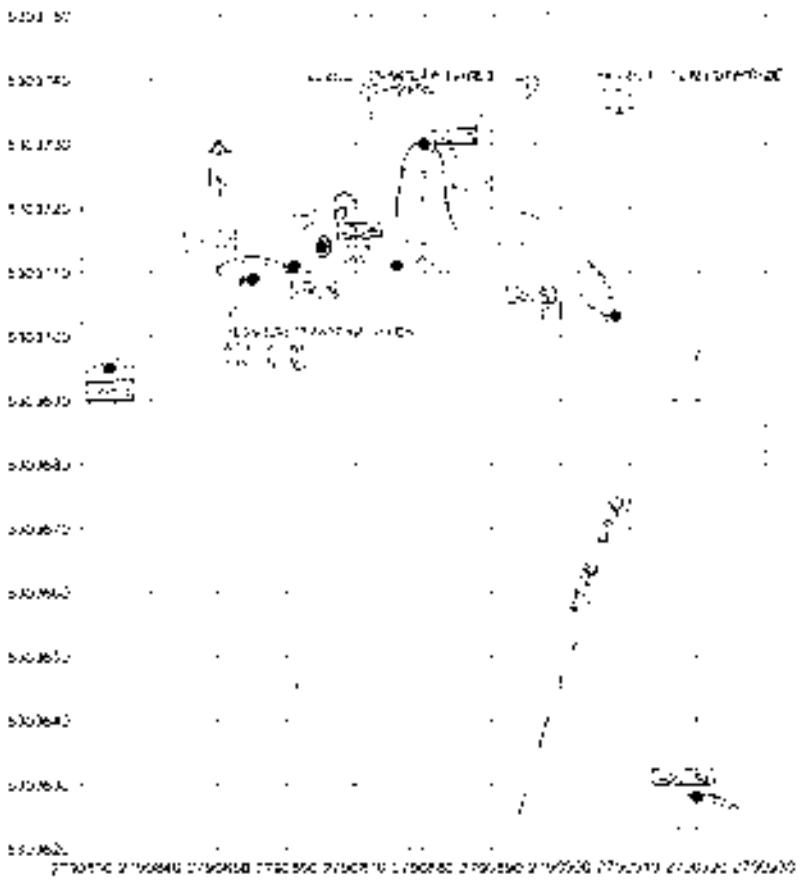


Figure A1-19:
Sketch map of geothermal features at Mangamingi Station. Grid references are in NZMG in the sketch and NZTM in the table opposite.

1	1880729	5742138
2	1880750	5742152
4	1880760	5742157
3	1880756	5742154
5a	1880803	5742146
5b	1880771	5742154
5c	1880775	5742173
6	1880815	5742071

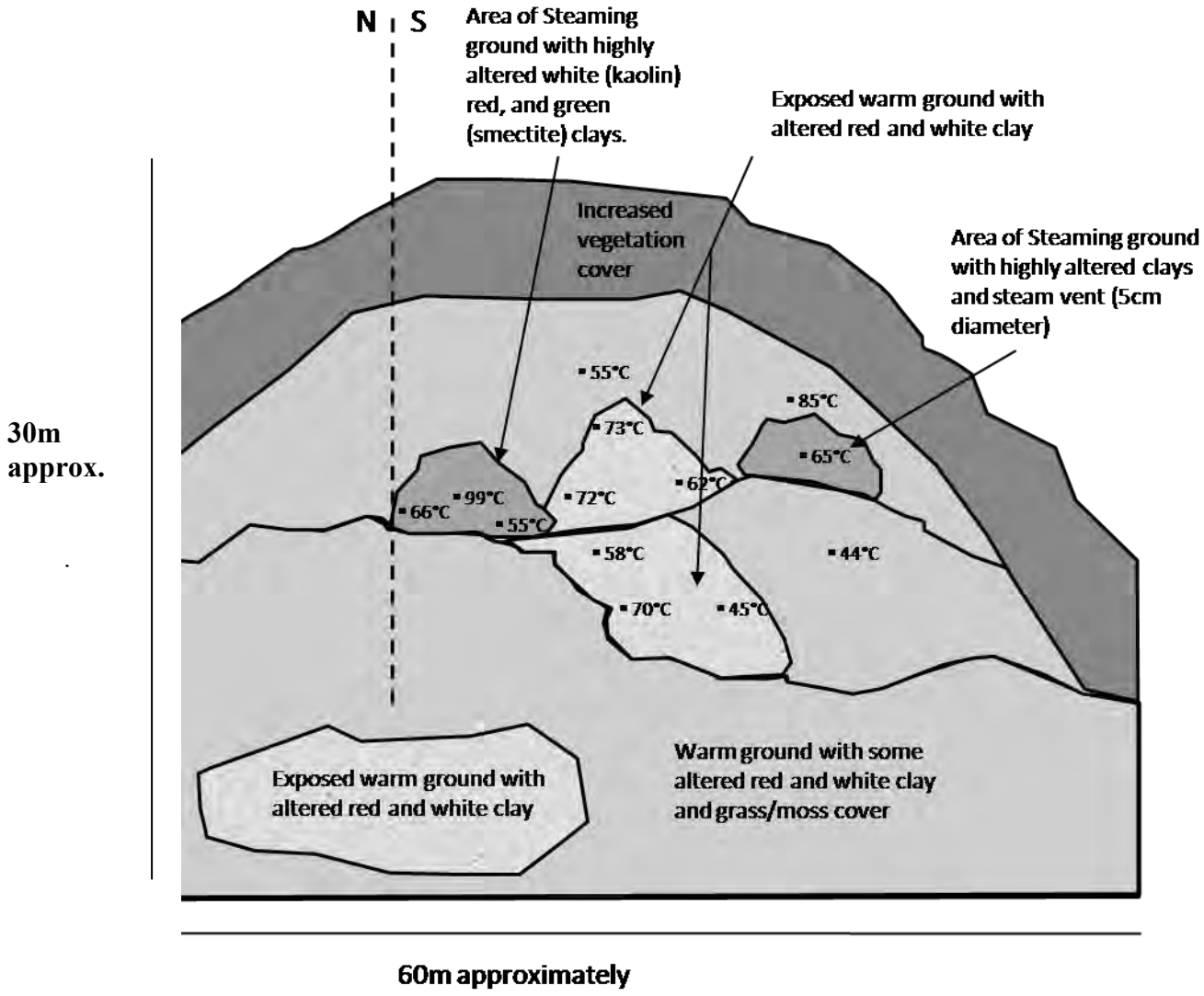


Figure A1-17: Sketch map of geothermal activity at Locality 5S (see other sketch map) at Mangamingi Station.

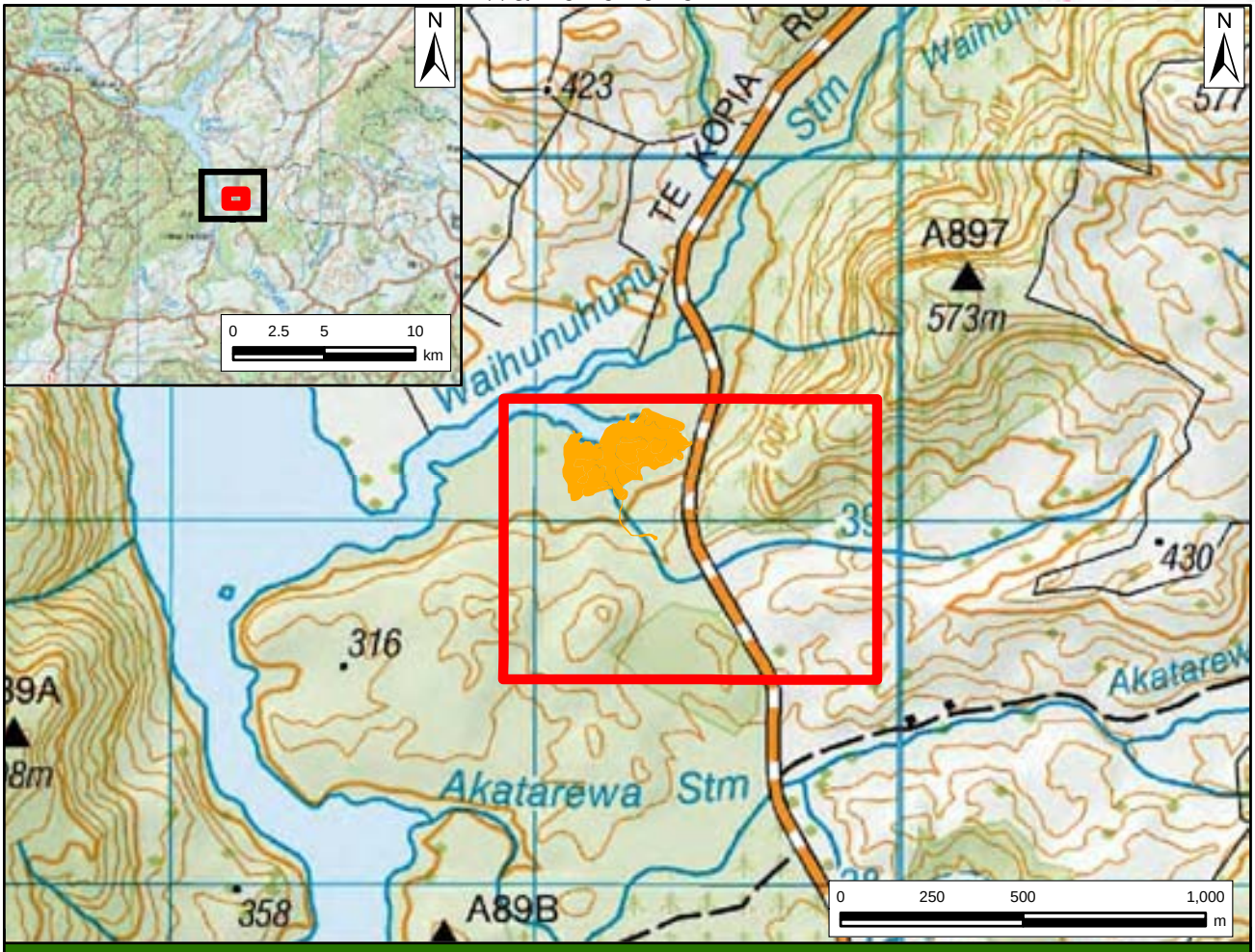
1.7 ORAKEIKORAKO GEOTHERMAL FIELD

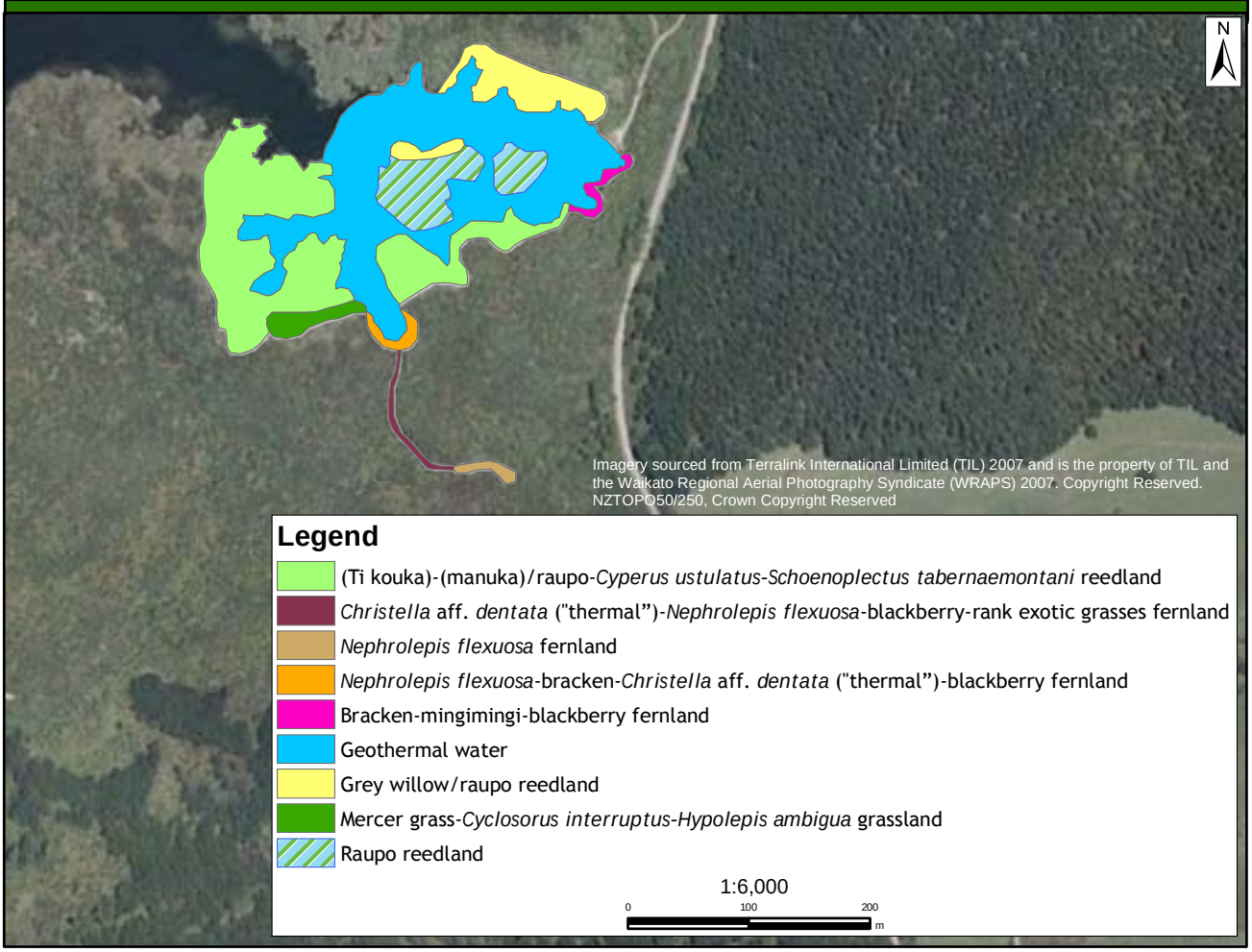
List of Geothermal Sites

OKV01	Waihunuhunu
OKV02	Akaterewa Stream
OKV03	Orakeikorako
OKV04	Red Hills
OKV05	Akatarewa East

OKV01

Waihunuhunu





WAIHUNUHUNU

Site Number: OKV01[1]
Grid Reference: NZTopo50 BF36 752 390
GPS Reference: NZTM E1875248 N5738978
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Lowland - Submontane
Tenure: Unprotected private land
Altitude: 300 m
Extent of Geothermal Habitat: *c.*5.3 ha
Extent of Geothermal Vegetation: *c.*3.1 ha
Date of Field Survey: 8 March 2007

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
07.03 07.03.05	**Bracken-dominant fernland** **Bracken-mingimingi-blackberry fernland** Scattered emergent karamu, kohuhu, mamaku (*Cyathea medullaris*), and wheki are present over bracken, mingimingi, and blackberry. On lake margins patches of *Baumea articulata*, *Schoenoplectus tabernaemontani*, *Baumea rubiginosa*, 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
07.06 07.06.03	***Christella* aff. *dentata* ("thermal")-dominant fernland** ***Christella* aff. *dentata* ("thermal")-*Nephrolepis flexuosa*-blackberry fernland** Narrow band of vegetation on each side of an unnamed hot water stream which flows into the Waihunuhunu Arm of Lake Ohakuri. The stream is fed by hot springs upstream of this vegetation type, but hot water seepages were also present within the stream bed. The banks of the stream are dominated by *Christella* aff. *dentata* ("thermal") and *Nephrolepis flexuosa*. *Cyperus ustulatus* is also common along stream margins. Blackberry and bracken shrubland occurs upslope of these species. Planted radiata pine plantation surrounds this vegetation type. Along small parts of the stream, indigenous species form a canopy above this geothermal vegetation type, often comprising karamu, kohuhu, and wheki. The stream was viewed at several points along its length, although access into the stream is very difficult due to the steep sides and very hot stream temperatures.	Stream margins	*c.*0.1 ha
07.08 07.08.01	***Nephrolepis flexuosa*-dominant fernland** ***Nephrolepis flexuosa* fernland** The upstream part of the unnamed hot water stream, where the margins of hot springs and a hot water stream are dominated by *Nephrolepis flexuosa* fernland. Several patches of *Dicranopteris linearis* are also present. There is	River margins	<0.1 ha

[1] Previously identified as U17/31 in Wildland Consultants (2004 and 2007b).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	scattered *Carex virgata*, blackberry, mingimingi, *Hypolepis ambigua*, wheki, fleabane, buddleia, *Christella* aff. *dentata* ("thermal"), Spanish heath, Scotch thistle, bracken, ti kouka, Yorkshire fog, and *Cyperus ustulatus*.		
07.08.03	***Nephrolepis flexuosa*-bracken-*Christella* aff. *dentata* ("thermal")-blackberry fernland** This type is located on the banks above Lake Ohakuri where hot geothermal water from a geothermal stream discharges into the lake. Patches of *Nephrolepis flexuosa* and bracken are common. Plants of *Christella* aff. *dentata* ("thermal"), blackberry, and mingimingi are also common with scattered *Dicranopteris linearis,* Spanish heath, wheki, karamu, kohuhu, and swamp kiokio.	Lake margins	*c.*0.1 ha
08.04 08.04.04	**Mercer grass-dominant grassland** **Mercer grass-*Cyclosorus interruptus*-*Hypolepis ambigua* grassland** A Mercer grass dominated grassland with common *Cyclosorus interruptus* and *Hypolepis ambigua*. Narrow-leaved plantain (*Plantago lanceolatum*), blackberry, lotus, Spanish heath, Scotch thistle, fleabane, kohuhu, *Histiopteris incisa*, *Cyperus ustulatus*, manuka, and bracken are scattered through this area. Several hot springs are present.	Ephemeral wetland	*c.*0.1 ha
11.01 11.01.01	**Raupo-dominant reedland** **Raupo reedland** Raupo reedland with common patches of *Carex virgata* and *Carex secta* and occasional grey willow, cleavers (*Galium aparine*), *Centella uniflora*, *Carex maorica,* lotus*, Carex virgata, Eleocharis acuta,* wheki, swamp kiokio, *Juncus edgariae,* and *Baumea articulata*.	Wetland	*c.*0.5 ha
11.01 11.01.14	**Raupo-dominant reedland** **(Ti kouka)-(manuka)/raupo-*Cyperus ustulatus*-*Schoenoplectus tabernaemontani* reedland** Scattered ti kouka and manuka are present over raupo reedland, with other areas dominated by *Cyperus ustulatus* sedgeland, *Schoenoplectus tabernaemontani* reedland, and several patches of *Eleocharis acuta*. Some small areas of bare soil around hot springs are present. Other common species include *Carex virgata*, wheki, swamp kiokio, and *Baumea articulata*.	Wetland	*c.*1.7 ha
11.01 11.01.15	**Raupo-dominant reedland** **Grey willow/raupo reedland** Grey willow is common over raupo.	Wetland	*c.*0.4 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Geothermally heated waters of Waihunuhunu Arm of Lake Ohakuri. Includes several hot springs, as well as inputs from several hot streams.	Open water	*c.*2.3 ha

Indigenous Flora: *Christella* aff. *dentata* ("thermal") and *Nephrolepis flexuosa* (both classed as ‚At Risk-Declining' in de Lange *et al.* 2009) are scattered alongside stream margins throughout this site, and alongside lake margins.

One large population of *Cyclosorus interruptus* (classed as „At Risk-Declining' in de Lange *et al.* 2009) is present. This population comprises 52 large patches over a 60 m^2 area.

Two small populations of *Dicranopteris linearis* (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009, and known from only *c.*24 sites in New Zealand) 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.

Other species present that are typical of geothermal habitat include *Cyperus ustulatus*, turutu, *Histiopteris incisa*, raupo, mingimingi, and manuka.

Thelypteris confluens has been recorded from this site in the past (E. Miller pers. comm. in Hobbs 2002) but was not recorded during this survey or by Hobbs. *T. confluens* is classed as an „At Risk-Declining' fern in de Lange *et al.* (2009).

Fauna:

North Island fernbird, spotless crake, grey warbler, bellbird, spur-winged plover, tui, pukeko, and little shag were present. Other common indigenous and introduced bird species typical of the habitat are likely to be present.

Spotless crake and North Island fernbird are classed as „At Risk-Declining' and „At Risk-Relict' respectively in Miskelly *et al.* 2008.

Current Condition (2007 Assessment):

This site is mainly in good ecological condition providing good habitat for four threatened fern species. However, pest plants (e.g. grey willow and crack willow) are common in the wetland. Blackberry scrub and exotic plantation trees are common around the geothermal streams.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*)*:*

Blackberry (5-25% cover), grey willow (1-5% cover), crack willow (1-5% cover), and buddleia (<1% cover).

Human impacts (*2007 Assessment*)*:*

Litter is common near hot springs near road entrance. Exotic plantations are near the hot geothermal stream at this site.

Grazing (*2007 Assessment*)*:*

The site is not farmed. Some feral pig sign was evident.

Adjoining land use (*2007 Assessment*)*:*

Plantation forest, farmland, recreation area.

Site Change:

Recent change:

Not assessed prior to 2007, unlikely to be significant change since that field survey.

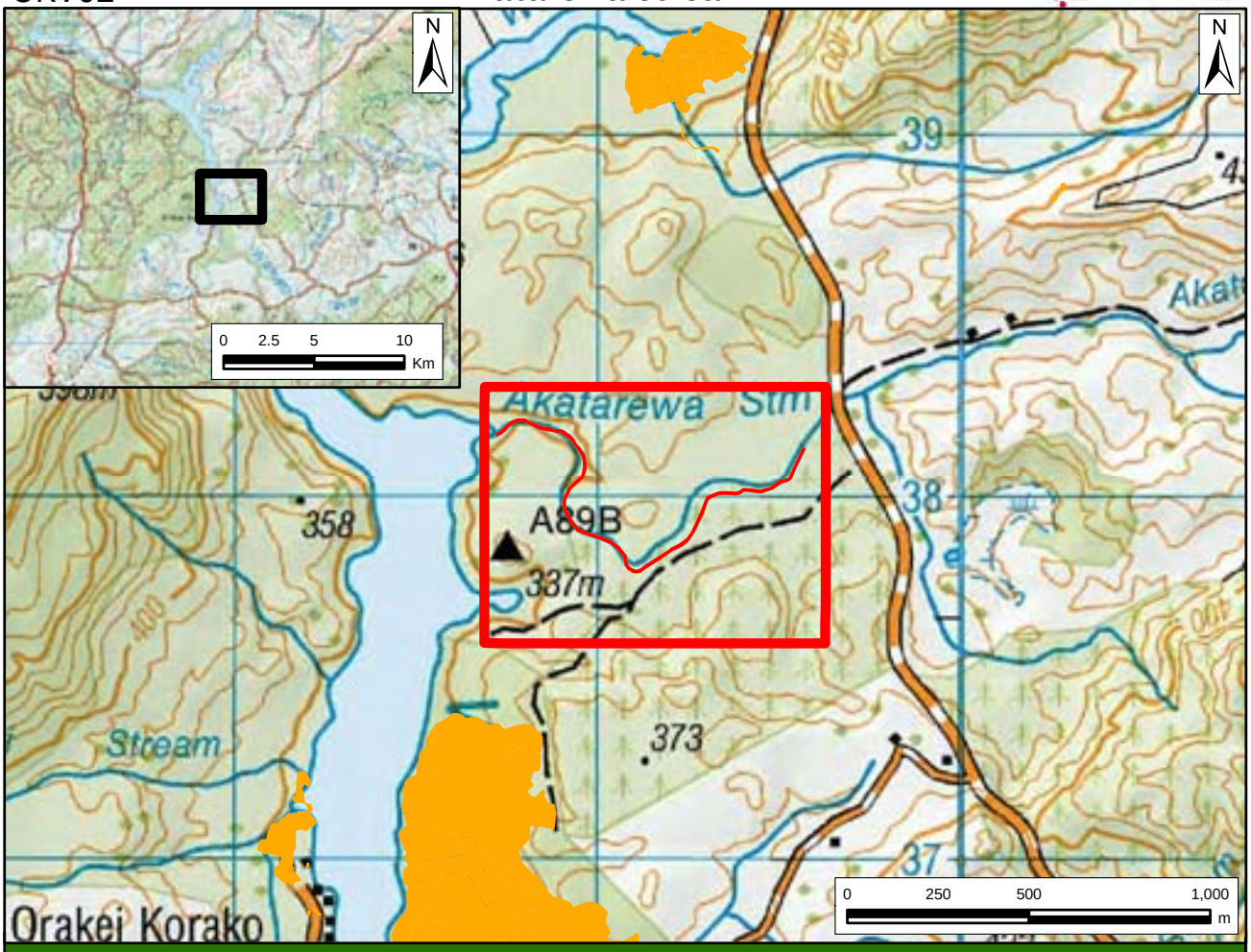
Historical:

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 a head of a bay that was previously a long valley (*c.*1 km in length) (Historical photo: SN358 run 1074 1944-49). Heated water in this arm of the lake indicates that there is considerable geothermal activity beneath the lake here. The higher lake level has however 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. Based on the above assumptions we could presume that a loss of *c.*75% of terrestrial geothermal habitats has occurred with the raising of Lake Ohakuri. About 25% of this has since become geothermal wetland, indicating a total vegetation loss of *c.*50% since 1961.
Management Requirements:	This site has great potential for ecological restoration through management of pest plants (e.g. willow trees in wetland).
Significance Level:	National (Table 1 - Criteria 3, 5, 6, 7, 9; Table 2 - Factor 8).
Significance Justification:	This site is of national significance because it is a very good quality example of a habitat that is nationally uncommon. 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.
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:	Beadel & Bill 2000; Given 1989, 1995 & 1996; Hobbs 2002; Merrett & Burns 1999; Smith-Dodsworth 1993; Wildland Consultants 2004 & 2007b.

OKV02

Akatarewa Stream



AKATAREWA STREAM

Site Number: OKV02[1]
Grid Reference: NZTopo50 BF36 751 378
GPS Reference: NZTM E1875142 N5737819
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Lowland Submontane
Tenure: Unprotected private land
Altitude: *c.*300 m
Extent of Geothermal Habitat: *c.*1.4 ha
Extent of Geothermal Vegetation: *c.*1.4 ha
Date of Field Survey: 28 May 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
05.08 05.08.04	**Mixed indigenous shrubland** **(Maritime pine)/kiokio-blackberry-bracken-buddleia shrubland** Kiokio, blackberry, bracken, and *Cyperus ustulatus* are common along stream margins, with scattered maritime pine, ti kouka, whauwhaupaku, kohuhu, buddleia, harakeke, karamu, and wheki. Creeping bent, Yorkshire fog, *Deparia petersenii*, *Histiopteris incisa, Paesia scaberula, Hypolepis ambigua*, creeping buttercup, paku (*Pneumatopteris pennigera*), *Carex secta*, and lotus are also common. Several patches of *Gleichenia microphylla* are present. There are scattered *Christella* aff. *dentata* ("thermal") plants (47 mature plants recorded). These are more common along the lower reaches of the Akatarewa Stream, however plants are less common below the waterfall at the bathing pool closest to the lake. Seepages of hot water and occasional sinter are present along the entire length of stream. A eucalyptus plantation borders the margins of this vegetation type.	Stream margins	*c.*1.4 ha

Indigenous Flora:

Christella aff. *dentata* ("thermal") (classed as an „At Risk-Declining' species in de Lange *et al.* 2009) is scattered alongside stream margins throughout this site. Forty-seven mature plants were recorded.

Cyclosorus interruptus was recorded at this site in 2002 (Hobbs 2002). In 2007 the stream was inspected 50 m upstream and downstream of the location of the 2002 sighting, but no plants of *C. interruptus* were found. *C. interruptus* is an „At Risk-Declining' species (in de Lange *et al.* 2009). *C. interruptus* appears to be a seasonal species in the Bay of Plenty/Waikato and is not always visible at a site during all seasons, so this species could still be present at this site.

Dicranopteris linearis (classed as an „At Risk-Naturally Uncommon' species in de Lange *et al.* 2009, and known from only *c.*24 sites in New

[1] Previously identified as U17/30 in Wildland Consultants (2004). This site was also updated in 2007 (Wildland Consultants 2007b).

Zealand) was also been recorded from this site in 2002 (Hobbs 2002), but was not recorded in the 2007 survey.

Other species typical of geothermal sites present include *Histiopteris incisa*, bracken, and *Cyperus ustulatus*.

Fauna: North Island robin, grey warbler, North Island fantail, bellbird, pied tit, and tui. Other common indigenous and introduced bird species typical of the habitat are likely to be present.

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 (*2007 Assessment*)*:* Blackberry (5-25%), pampas (<1%), grey willow (<1%), buddleia (1-5%), Himalayan honeysuckle (<1%).

Human impacts (*2007 Assessment*)*:* Several bridges and culverts. Bathing pools. Plantation forest harvesting operations nearby.

Grazing (*2007 Assessment*)*:* Livestock have no access to the area

Adjoining land use (*2007 Assessment*)*:* Camping ground, and plantation forestry.

Site Change:

Recent change: This site has not been revisited by the authors since 2007, but is unlikely to have undergone significant change over this timeframe.

Historical: We compared 2007 aerial photographs with those from 1949 (Historical photos: SN 358 Run 1074 Photos 92-94, 1949). 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 the 1949 photo. This area is now in plantation forest. Overall, there has been at least a 25% loss of geothermal vegetation and habitats at this site since 1949.

Management Requirements: The stream margins are potential ecological restoration sites. Management would include the control of pest plant species (e.g. patches of dense blackberry scrub) and planting of suitable, locally-sourced indigenous species. A buffer 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, 6; Table 2 - Factor 12).

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 14 known sites of *Christella* aff. *dentata* ("thermal") in the

North Island.

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.

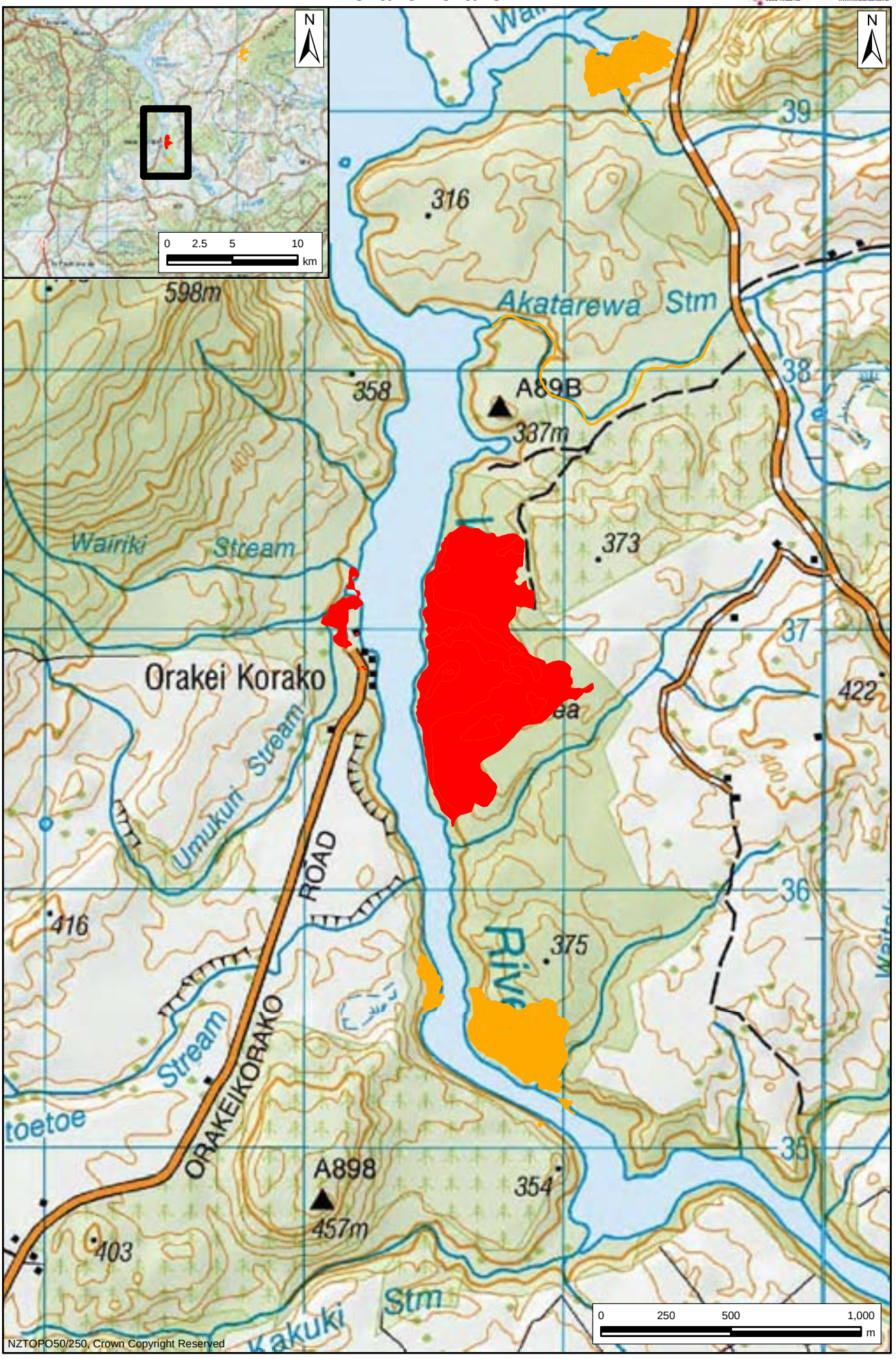
Some of the *Christella* aff. *dentata* ("thermal") plants may have been damaged during recent harvesting operations - hence the lower number of plants recorded here than by Merrett & Burns (1999) who recorded 96 plants at the site before harvesting was undertaken in 1999.

This site was formerly identified as being of national significance (Wildland Consultants 2007b) 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 & Bill 2000; Given 1989a, 1995, & 1996; Hobbs 2002; Merrett & Burns 1999; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004, 2007b, & 2007c.

OKV03

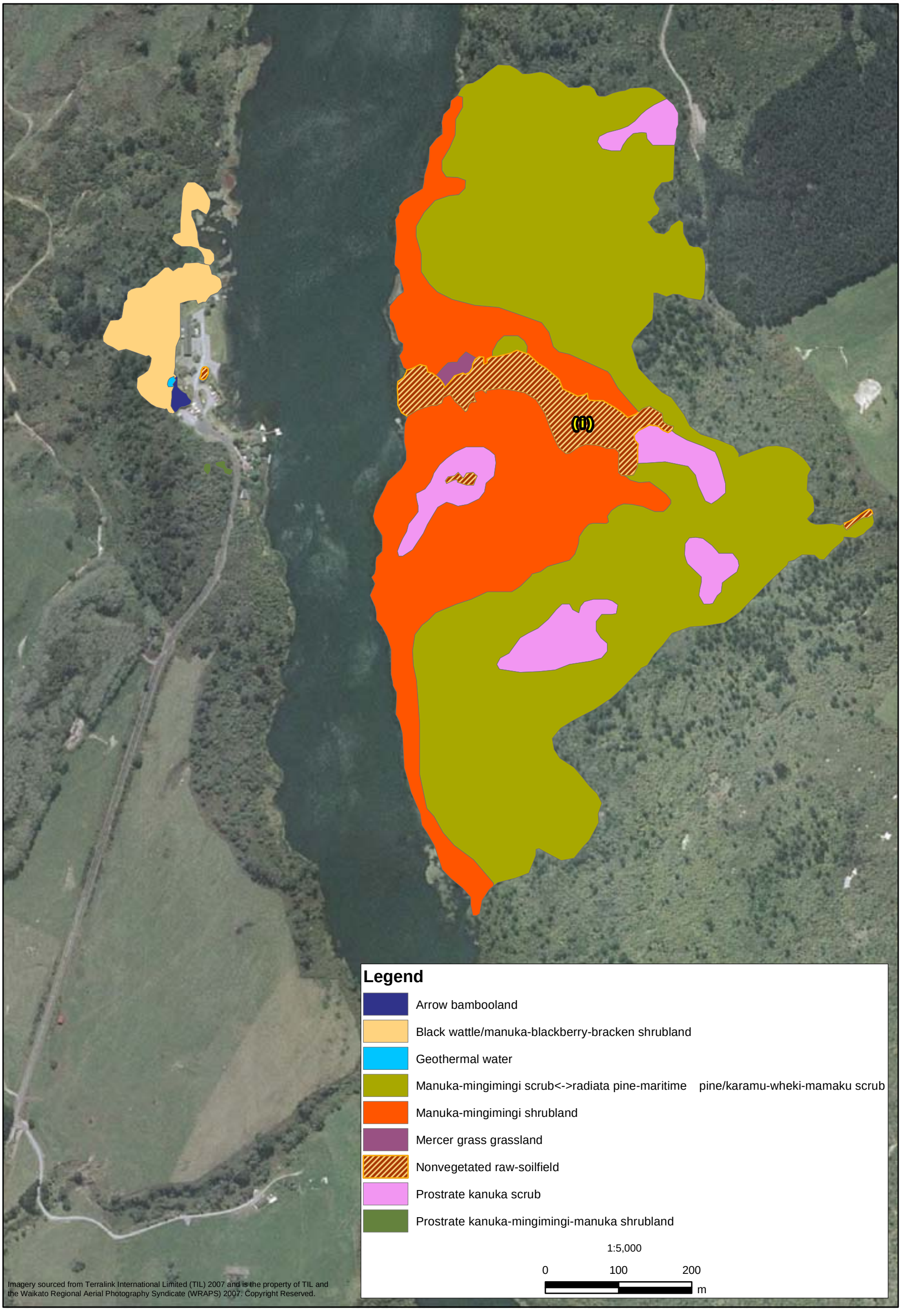
Orakeikorako



OKV03

Orakeikorako

Wildlands
0508 WILDNZ
www.wildlands.co.nz



ORAKEIKORAKO

Site Number: OKV03[1]
Grid Reference: NZTopo50 BF36 747 369
GPS Reference: NZTM E1874726 N5736937
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Submontane
Tenure: Protected (Lake Ohakuri Stewardship Area administered by DOC) and unprotected private land
Altitude: *c.*300-340m
Extent of Geothermal Habitat: *c.*42.4 ha
Extent of Geothermal Vegetation: *c.*42.4 ha
Date of Field Survey: 1 August 2010 (east side of Lake Ohakuri)
2 February 2011 (west side of Lake Ohakuri)

Code	Type	Landform	Extent
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka (1-3 m high) forms a dense canopy with mingimingi and manuka scattered throughout. Prickly mingimingi and karamu are also present. The groundcover comprises local *Lycopodiella cernua, Dicranopteris linearis*, Indian doab and bracken, with turutu 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
04.03 04.03.16	**Manuka dominant scrub** **Manuka-mingimingi scrub ⇔ (radiata pine)-(maritime pine)/karamu-wheki-mamaku scrub** This area comprises a mosaic of manuka-mingimingi scrub and karamu-wheki-mamaku scrub, where manuka-mingimingi scrub is the predominant vegetation type. Occasional rimu are present. Broadleaved species and tree ferns are common including rewarewa, kohuhu, ponga (*Cyathea dealbata*), and *Cyathea smithii*. *Morelotia affinis,* kiokio, and turutu are common in the understorey. Fumaroles occur throughout, and prostrate kanuka is associated with areas of heated soil. Mingimingi, prostrate kanuka, *Histiopteris incisa*, kiokio and wheki are common around mud pools. Pampas has expanded its range in this vegetation type following pine control. Patches of wilding pine still remain at some localities, but the cover is greatly reduced from the 2004 and 2007 surveys.	Hillslopes and alluvial terraces	*c.*24.7 ha
05.01 05.01.01[2]	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** (not mapped) Low prostrate kanuka (<0.5 m) forms a sparse canopy in local areas around the margin of the sinter terrace and other		

[1] Previously identified as U17/11 in Wildland Consultants (2004 and 2007).
[2] Areas of this vegetation type occur within the area mapped as 04.01.01, however were too small to be mapped separately.

Code	Type	Landform	Extent
	areas of nonvegetated raw-soilfield. Mingimingi becomes more common on margins, and manuka becomes more common in poorly drained areas. *Baumea juncea*, sea rush, and oioi occur occasionally in cooler wet areas.		
05.01.15	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka-mingimingi-manuka shrubland** Small areas of heated soils (up to 30°C) with prostrate kanuka, mingimingi and manuka occur nearby the road. Other species in this area include bracken, maritime pine, fleabane, Japanese honeysuckle, silver birch, and Spanish heath.	Hillslope	<0.1 ha
05.03 05.03.04	**Manuka dominant shrubland** **Manuka-mingimingi shrubland** Manuka and mingimingi in association with scattered kanuka and prostrate kanuka and occasional karamu and kohuhu. *Gleichenia microphylla,* bracken, *Paesia scaberula*, *Histiopteris incisa*, kiokio, and turutu. These 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.*10.7 ha
05.03.23	**Manuka dominant shrubland** **Black wattle/manuka-blackberry-bracken shrubland** Emergent black wattle and maritime pine occur in association with manuka, blackberry, bracken and Japanese honeysuckle with small patches of raupo, mingimingi, and prostrate kanuka (up to *c.*3 m tall). Blackberry occurs in large swaths and in places is the dominant canopy cover. Other common species include mingimingi, bracken, *Lycopodiella cernua*, *Paesia scaberula*, swamp millet, *Baumea rubiginosa,* Mercer grass, karamu, wheki, turutu, *Gleichenia microphylla*, greater bindweed, *Cyperus ustulatus*, buddleia, 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.*1.7 ha
07.01 07.01.01[1]	***Dicranopteris*-dominant fernland** ***Dicranopteris* fernland** (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 kanuka scrub and shrubland.	Hillslope	
08.04 08.04.03	**Mercer grass-dominant grassland** **Mercer grass grassland** A small area of grassland dominated by Mercer grass with local *Gleichenia microphylla, Histiopteris incisa* and *Paesia scaberula*. *Cyperus ustulatus* and *Baumea juncea* occur around a small thermal seepage.	Alluvial terrace	*c.*0.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Hot seepage and hot springs with blackberry. *Cyclosorus*	Alluvial terrace	<0.1 ha

Code	Type	Landform	Extent
	interruptus and *Christella* aff. *dentata* ("thermal") are present in small numbers (*c.* <5 plant of each) along the warm margins.		
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** The large sinter deposit terrace on the eastern side of the river is the most prominent geothermal feature of the site (mapped as (i) on 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 this site, but these were too small to map within the context of this project. Occasional sea rush and manuka, and patches of exotic grasses, are present.	Hillslopes and alluvial terrace	*c.*2.1 ha
30.01 30.01.01	**Bamboo-dominant bambooland** **Arrow bambooland** Near the visitor car park an area of arrow bamboo (*Pseudosasa japonica*) with occasional maritime pine, black wattle, *Cotoneaster glaucophyllus*, and Japanese honeysuckle occurs.	Hillslope	*c.*0.1 ha

Geophysical Assessment:[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.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

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 50-60^{o}C. At one point the thickness of the sinter was observed through a break in the crust to be about 10 cm thick.

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

Above the scarp and sinter deposition channels a relic sinter depositing pool/geyser was identified. 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). Luckily, during the monitoring round, the geyser did play at 11.55 a.m. for approximately 30 seconds - 1 minute. There is a main central fissure (again 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^{o}C) while directly to the east the temperatures ranged from 60^{o}C to 80^{o}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.

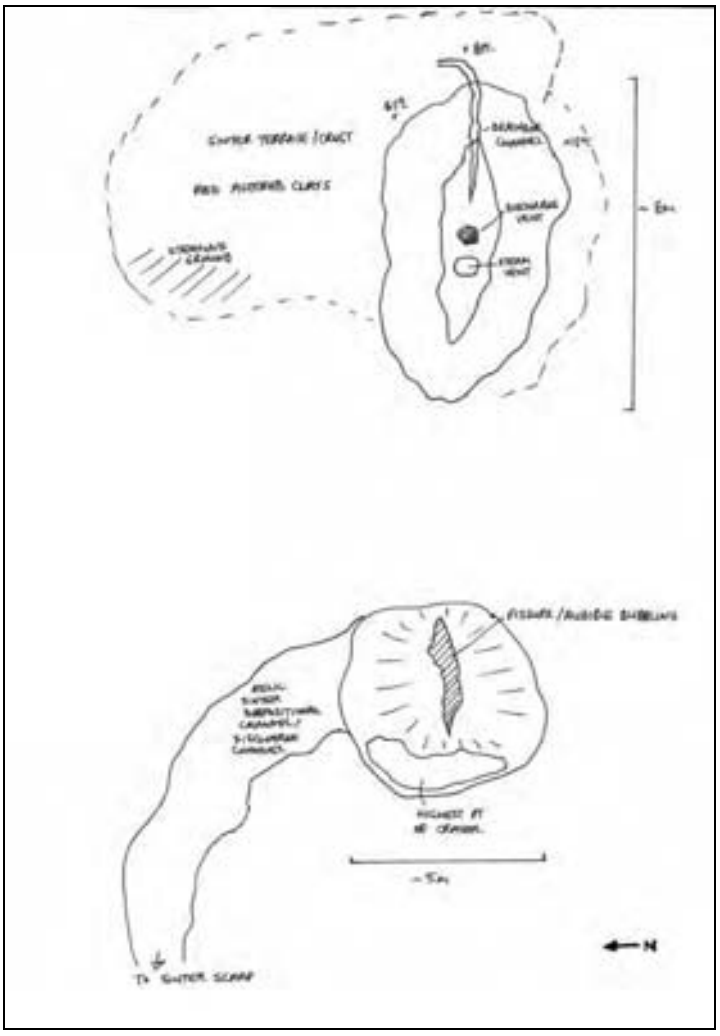


Figure A1-20: Field Sketch of Relic Pool/Geyser of Feature 4 (bottom) and Active Geyser of Feature 5 (top) at Orakeikorako.

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^oC. 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 a less viscous mud and minor steam discharge. A mud volcano approximately 30 cm high lies adjacent to it. Thick vegetation prevented access for temperature measurement.

Plate 72: Mud Volcano

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 its discharge channels.

Plate 73: Pool at Artistes Palette July 2010 on left, July 2009 on right.

Indigenous Flora:

Prostrate kanuka and *Dicranopteris linearis*, which are both classed as „At Risk-Naturally Uncommon' (in de Lange *et al.* 2009) and characteristic of geothermal areas, are present. *D. linearis* is known from only *c.*24 sites in New Zealand.

At least 50 plants of *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining', in de Lange *et al.* 2009) 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' in de Lange *et al.* 2009), some of which are immature and are not expected to survive.

Schizaea dichotoma (classed as „At Risk-Naturally Uncommon'; in New Zealand, restricted to kauri forests of Northland and South Auckland, and locally at geothermal sites), *Calochilus robertsonii* (classed as „At Risk-Naturally Uncommon'), *Psilotum nudum* (restricted to geothermal and northern coastal areas), *Lycopodiella cernua*, arrow grass, *Schizaea bifida*, sea rush, manuka, turutu, and *Campylopus capillaceous*, which are characteristic of geothermal areas, are also present.

Species recorded from previous surveys at the site, but not during the 2004 survey or the current survey are: *Nephrolepis flexuosa* (in New Zealand, this species is confined to geothermal areas in the North Island) (classed as „At Risk-Declining' in de Lange *et al*. 2009), and *Corunastylis pumila* (both classed as „At Risk-Naturally Uncommon').

Other species of interest which 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, tui, New Zealand scaup, North Island robin, spur-winged plover, mallard, yellowhammer, and magpie. One New Zealand

bush falcon (classed as 'Threatened-Nationally Vulnerable' in Miskelly *et al*. 2008) was recorded flying over the eastern side of the site on 2 February 2011. Grey duck classed as 'Threatened-Nationally Critical', and black shag 'At Risk-Naturally Uncommon', in Miskelly *et al.* (2008) 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 (classed as 'Threatened-Nationally Vulnerable' in Miskelly *et al.* 2008) 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).

Current Condition (2011 Assessment):

Overall, the site is in an excellent ecological condition. Recent removal (2008/2009) of wilding pines has improved the quality of the geothermal vegetation on the western side of this site markedly since 2004, with most tree stumps not visible to the naked eye from the car park on the eastern side. However, pampas has become established in places following pine control. Some small areas of wilding pines on the site are still to be controlled.

Vegetation on the western side of the river has localised patches of adventive weed species, and control of maritime pine, black wattle, blackberry, Japanese honeysuckle and bamboo should be undertaken.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*):

Recent removal of wilding pines (maritime pine and radiata pine) has improved the ecological condition of this site. Several patches of wilding maritime pines remain, e.g. at E1874602 N3736832. Wilding pines are still present although at a lower, 1-5%, cover. Spanish heath (1-5 % cover), blackberry (1-5 % cover), bamboo (<1% cover), black wattle (1-5% cover), broom (<1% cover), Montpellier broom (<1% cover), and Japanese honeysuckle (1-5 % cover) are also present. Pampas has increased in cover and is now present at 1-5% cover. Arrow bamboo and blackberry was only recorded as common on the western side of the river. The eastern side of the river is unusual in that blackberry is extremely rare. Wildland Consultants (2008) only reported one plant from the eastern side of the river.

In April 2011, subsequent to the field component of this project, Waikato Regional Council funded the aerial control of pampas at this site.

Human impacts (*2011 Assessment*):

Two royal fern plants were recorded at Orakeikorako on 11 March 2009 (Wildland Consultants 2009), which 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.

Grazing (*2011 Assessment*):

The site is not farmed and stock do not have access to the site. Pig and possum sign were noted. Deer are also likely to utilise this site.

Adjoining land use (*2011 Assessment*):

Pine plantation; Waikato River (Lake Ohakuri); accommodation facilities; tourist use; and nearby farmland.

Site Change:

Recent change: The boundaries of the site have been updated following pine control, and better quality aerial photographs provided in 2007. The most significant real change to the site is the management of pine trees on the eastern side of the river/lake. Otherwise, change is considered to be minimal compared with 2004 and 2007 surveys.

Historical: 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 in Given 1989a).

The reduction of the extent of geothermal vegetation and habitats is marked from the historical photos (Historical photos: SN 358 Run 1074 Photos 92-94, 1949), particularly on the western side of Lake Ohakuri, when compared with 2007 aerial photographs. Extensive areas of raw-soilfield were evident, presumably a large portion of it being 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. A considerable loss of habitat with the construction of Lake Ohakuri is evident. Due to the steep nature of the landforms present an accurate measure of loss of geothermal is impossible; however, the previous estimates of 75% loss by Lloyd (1972) (particularly with the losses on the western side of the river) seem reasonable. In the areas that were not flooded by 1961, a greater extent of bare ground is visible in the historical photos (i.e. there is an increase in vegetation cover between 1961 and 2007). Increased vegetation could be due to a number of factors including reduced heat from geothermal systems. Development since the 1949 photos also includes 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 bamboo control here would allow geothermal species such as prostrate kanuka, mingimingi, *Cyclosorus interruptus*, and *Christella* aff. *dentata* ("thermal") populations to expand their range. On the eastern side of the river the impacts of pampas expanding its density following pine control should be monitored and managed as necessary. Follow-up control of pines should be undertaken on a regular basis. The site should be regularly checked for new pest plant invasions, and when rare weeds such as royal fern are found, they should be removed.

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

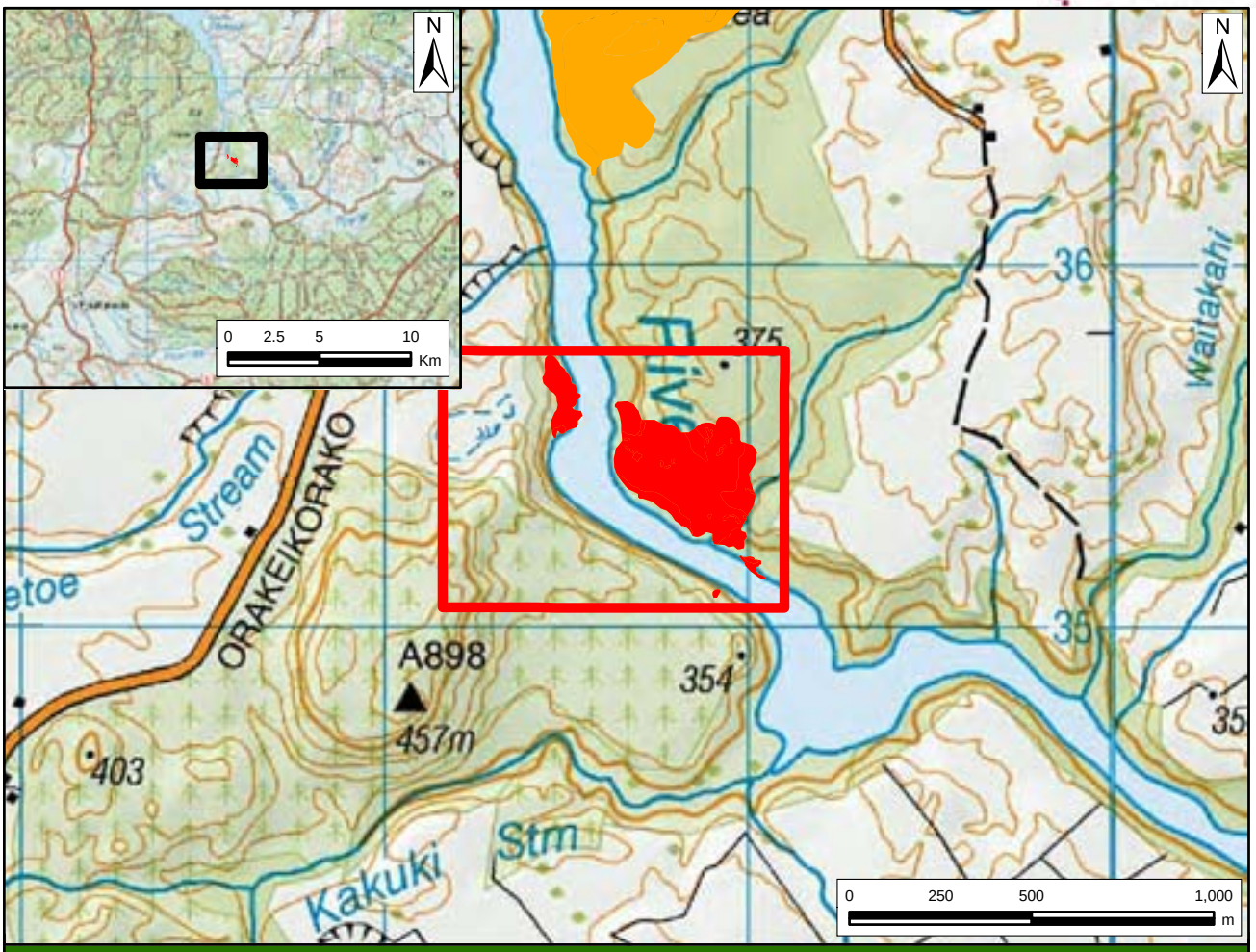
Significance Justification: This site is of national significance because it is a good quality example of geothermal vegetation, a nationally uncommon habitat type, and one of the best examples in the Waikato Region. It includes populations of eight „At Risk' species including: prostrate kanuka, *Christella* 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. Grey duck (classed as „Threatened-Nationally Critical' in Miskelly *et al.* 2008) and black shag („At Risk-Naturally Uncommon') have been recorded at the site.

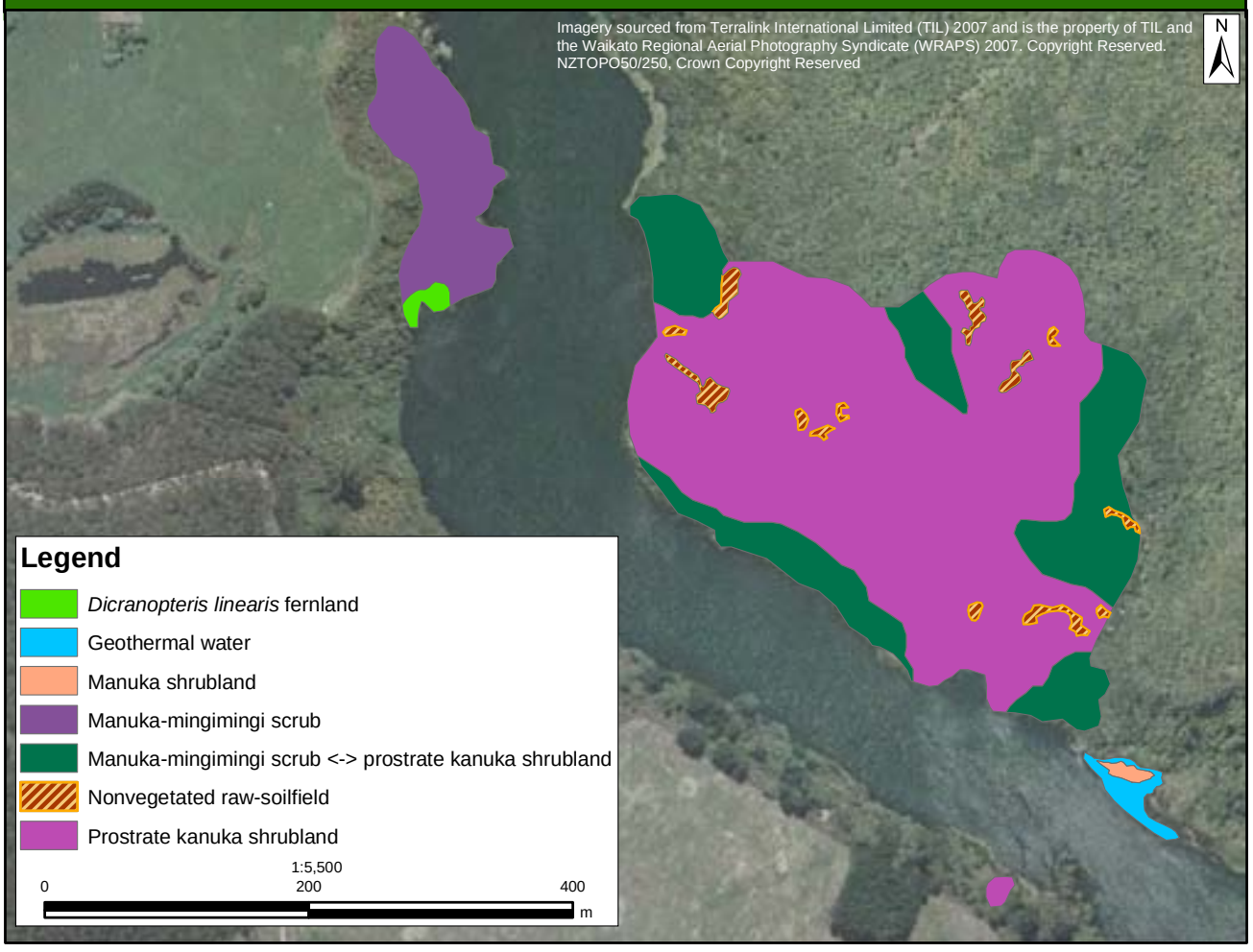
Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in this study this site was classed as Category A - the highest category.

References: Beadel 1995b; Beadel & Bill 2000; Ecroyd 1986; Given 1989a & 1995; Smith-Dodsworth 1993; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004, 2007b, & 2009a&b.

OKV04

Red Hills





RED HILLS

Site Number: OKV04[1]
Grid Reference: NZTopo50 BF36 748 354
GPS Reference: NZTM E1874822 N5735404
Local Authority: Rotorua/Taupo
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Submontane
Tenure: Protected (Lake Ohakuri Conservation Area administered by DOC)
Altitude: *c.*300-340 m
Extent of Geothermal Habitat: *c.*11.6 ha
Extent of Geothermal Vegetation: *c.*11.5 ha
Date of Field Survey: 16 June 2004 (part of site field surveyed on 8 March 2007)

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.03 04.03.02	**Manuka-dominant scrub** **Manuka-mingimingi scrub** Manuka and mingimingi are dominant, with scattered kanuka and prostrate kanuka, as well as occasional karamu and kohuhu. Emergent wilding pines (maritime pine and radiata pine) are scattered throughout. The groundcover comprises *Gleichenia microphylla*, bracken, *Paesia scaberula*, *Histiopteris incisa*, kiokio, and turutu with large local patches of *Dicranopteris linearis*. *Dicranoloma* sp. (a moss) is also abundant. Fumaroles are scattered throughout and there are a number of seepages which flow directly into Lake Ohakuri. Occasional Spanish heath and Chinese privet plants are present on the margins.	Hillslopes and alluvial terraces	*c.* 1.3 ha
04.03.12	**Manuka-mingimingi scrub ⇔ prostrate kanuka shrubland** A mosaic of predominantly manuka-mingimingi scrub (refer to 04.03.02) with local prostrate kanuka shrubland (refer to 05.01.01) 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 maritime pines are present with occasional *Christella* aff. *dentata* ("thermal") on lake margins.	Alluvial terrace, hillslopes	*c.*2.5 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** This type comprises a low discontinuous canopy of prostrate kanuka (*c.*0.5 m high) with mingimingi and monoao scattered throughout. The groundcover comprises local patches of moss, most notably *Dicranoloma* sp., *Campylopus capillaceus* and *Lycopodiella cernua*. Local patches of mature wilding pines (mainly maritime pine) are present.	Hillslopes	*c.*7.3 ha

[1] Previously identified as U17/10 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
05.03 05.03.01[1]	**Manuka-dominant shrubland** **Manuka shrubland** Scattered manuka over rank exotic grassland species (e.g. tall fescue, creeping bent, and ragwort - *Jacobaea vulgaris*), as well as occasional Spanish heath and prostrate kanuka. Several areas of geothermal sandfield. Water temperatures were recorded up to 69 ºC on lake margins.	Lake margins	<0.1 ha
07.01 07.01.01	***Dicranopteris*-dominant fernland** ***Dicranopteris* fernland** A small south-facing section on the western bank of the lake with a steaming fumarole. *Dicranopteris linearis* forms the cover.	Alluvial terrace	*c.*0.1 ha
07.01.01[2]	**Dicranopteris fernland** (not mapped) Many small areas are almost completely dominated by *Dicranopteris linearis.*	Hillslopes	
22.01 22.01.01	**Geothermal water** **Geothermal water**	Open water	*c.*0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** 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.	Flat, hillslopes	*c.* 0.3 ha

Indigenous Flora: Extensive areas of prostrate kanuka and *Dicranopteris linearis* (both classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), are present at this site. *D. linearis* is known from only *c.*24 sites in New Zealand. Fifty mature plants of *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al.* 2009) were recorded in March 2007; most of these were present near a hot stream in the south of the site (GPS reference: E1874474 N5735523). *Campylopus capillaceus*, 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, Australasian harrier, spur-winged plover and Australian magpie.

Current Condition (2007 Assessment): Generally the site is in excellent condition with large areas of geothermal vegetation with no pest plants. Whilst wilding pines are locally prominent, few other pest plant species are present.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*)*:* Wilding pines (maritime pine and radiata pine) are the main invasive exotic plant species, forming a *c.*6-25% cover. There has been extensive control of wilding pines at the site. Chinese privet (currently <1% cover) is present

[1] Field survey 2007.

[2] Areas of this vegetation type occur within the area mapped as 04.03, however were too small to be mapped separately.

at the camp/picnic area adjacent to the southern side of the site, and is beginning to invade the manuka-mingimingi scrub. It could spread rapidly if it is not controlled.

Human impacts (*2007 Assessment*)*:* Direct human impact is low, as the site is relatively inaccessible and appears dangerous. A bath has been constructed near the south end of the site. Some control of wilding pines has been undertaken at the site. The vegetation of the site is very susceptible to damage by trampling.

Grazing (*2007 Assessment*)*:* Livestock do not have access to this area.

Adjoining land use (*2007 Assessment*)*:* Pine plantations and the Waikato River.

Site Change:

Recent change: No known changes to the extent and quality of geothermal activity 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: The site has become considerable 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 (Historical photos: SN 358 Run 1074 Photos 92-94, 1949) shows extensively 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: Wilding pines and Chinese privet should be controlled.

Significance Level: National (Table 12 - Criteria 1, 3, 5, 7, 9; Table 2 - Factors 8).

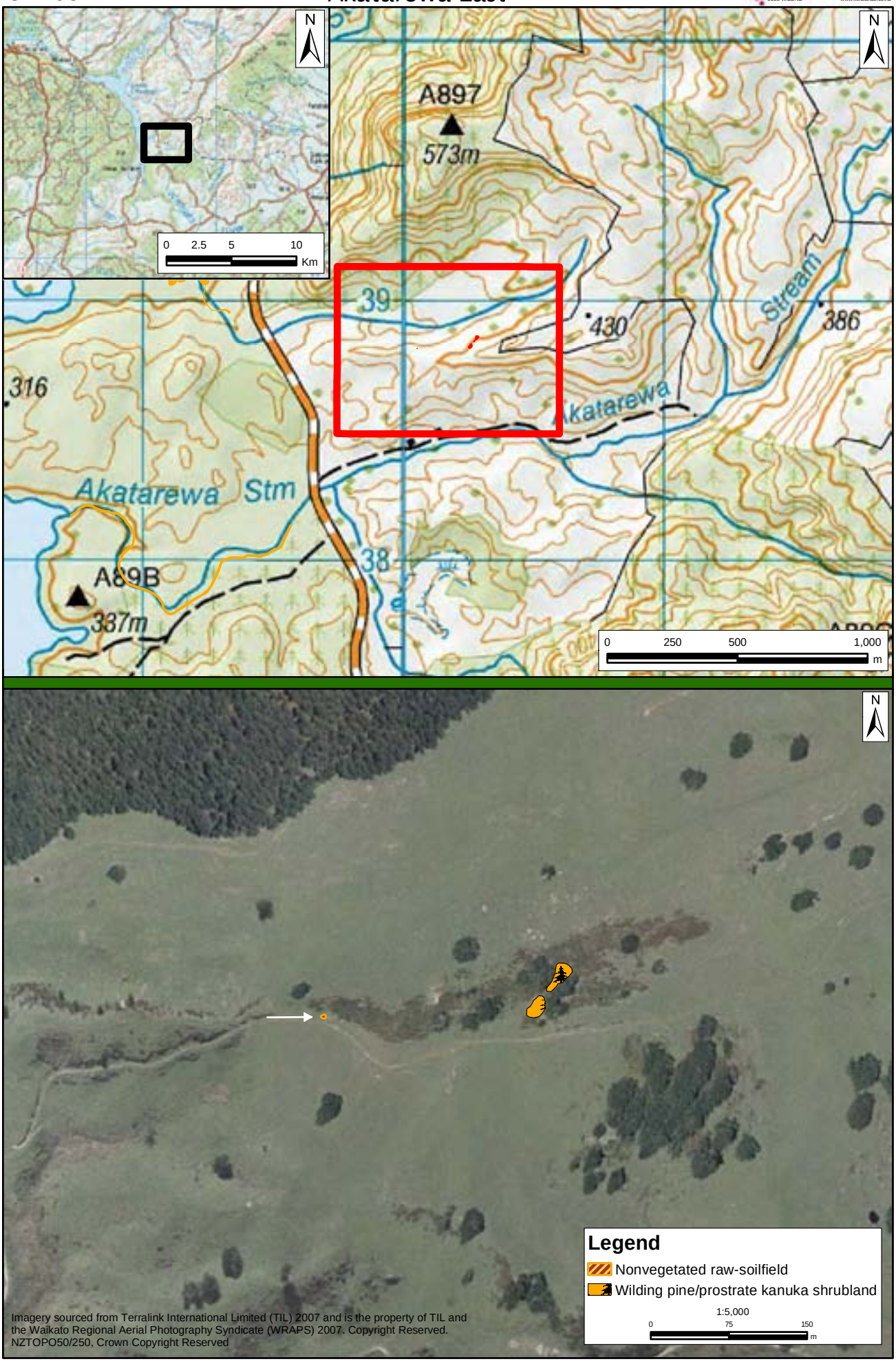
Significance Justification: This site is nationally significant because it is a very good quality example of a habitat type that is nationally uncommon (i.e. geothermal). Together with Orakeikorako (site OKV03, *c.*1 km to the north) it comprises one of the best examples of geothermal vegetation in the Waikato Region. Red Hills has an extensive area of prostrate kanuka shrubland, and stable, relatively large, populations of *Christella* aff. *dentata* ("thermal"), and *Dicranopteris linearis* (all ‚At Risk' species).

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 A - the highest category.

References: Beadel 1995b; Beadel & Bill 2000; Given 1996; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004 & 2007b.

OKV05

Akatarewa East



AKATAREWA EAST

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

Code	Type	Landform	Extent
05.01 05.01.14	**Prostrate kanuka-dominant shrubland** **Exotic pine/prostrate kanuka shrubland** One tall (*c.*20 m) radiata pine is emergent over prostrate kanuka, with scattered Spanish heath, buddleia, paspalum and sweet vernal. Other species include blackberry, bracken, manuka, *Cheilanthes sieberi* and occasional patches of *Dicranopteris linearis*.	Steep hillslope	<0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** 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. *Paesia scaberula* and Spanish heath seedlings are also present.	Hillslope	<0.1 ha

Indigenous Flora: Prostrate kanuka and *Dicranopteris linearis*, which are both classified as „At Risk-Naturally Uncommon' (de Lange *et al.* 2009) and are characteristic of geothermal vegetation, are present. *Dicranopteris linearis* is present in small patches but is known from only *c.*24 sites in New Zealand.

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. Domestic stock has access to this site but 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% of cover) is present on the geothermal margins and Spanish heath (1-5% cover) is scattered throughout. Buddleia (1-5% cover) and blackberry (<1% cover) are also present.

Human impacts (*2011 Assessment*):	Site adjacent to farmland.
Grazing (*20011 Assessment*):	This site is unfenced and grazed. Some parts of the site are steep and stock are unlikely to be a threat in these areas.
Adjoining land use (*2011 Assessment*):	Farming and pine plantation.

Site Change:

Recent change:	Not assessed. There is no known ecological information for this site prior to the current study.
Historical:	Site not assessed, no historical aerial photos found. However, since the site is small and is in a gully it is unlikely that change would be able to be identified between historic and recent aerial photographs for this site.
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 comprises a small example of geothermal vegetation, which is a nationally uncommon habitat type. It also provides habitat for two „At Risk' plant species: prostrate kanuka and *Dicranopteris linearis*.
Notes:	There may be more features and small geothermal areas on the vertical face but access is an issue. This site was identified for this study based on a summary of known geothermal features in Hochstein (2007 Figure 4.1, Page 92). 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 2007; Lloyd 1974.

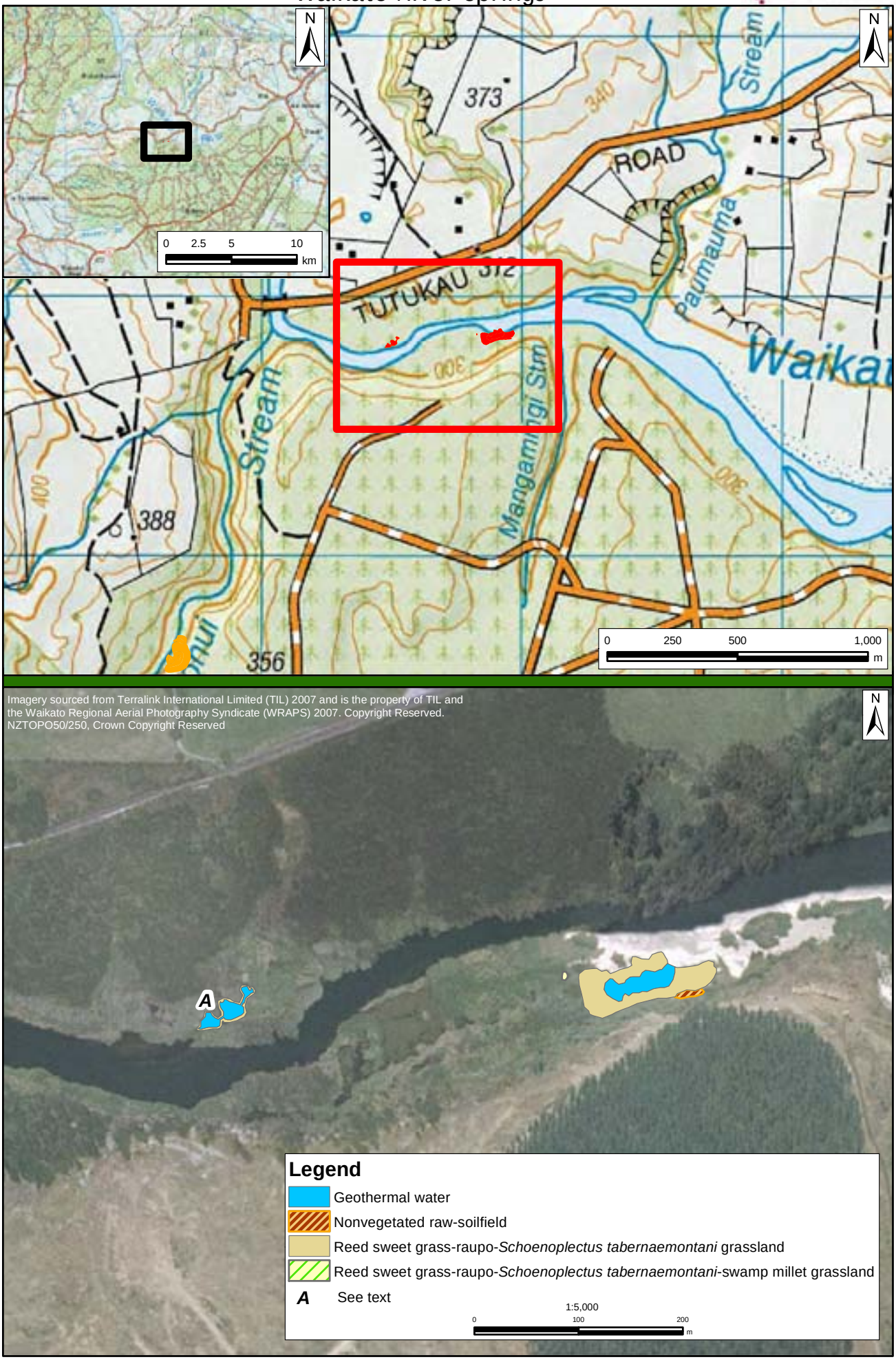
1.8 NGATAMARIKI GEOTHERMAL FIELD

List of Geothermal Sites

NMV01	Waikato River Springs
NMV02	Ngatamariki

NMV01

Waikato River Springs



WAIKATO RIVER SPRINGS

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

Code	Type	Landform	Extent
08.08 08.08.02	**Reed sweet grass-dominant grassland** **Reed sweet grass-raupo-*Schoenoplectus tabernaemontani* grassland** Reed sweet grass, raupo and *Schoenoplectus tabernaemontani* dominate the margins of a geothermally influenced pool (temperatures up to 45°C in the northern pools at the time of survey). Grey willow, blackberry, harakeke, Chinese privet, bracken and radiata pine are emergent on the drier margins. Other species present include *Cyperus ustulatus*, mercer grass and localised patches of blackberry.	Stream margins, pond margins	*c.*0.4 ha
08.08.03	**Raupo/reed sweetgrass-*Schoenoplectus tabernaemontani* swamp millet grassland** Occasional raupo is emergent over reed sweetgrass (*Glyceria maxima*), *Schoenoplectus tabernaemontani*, and swamp millet. Other species present include *Carex maorica,* lotus, *Cyperus ustulatus*, mint, and pohue.	Wetland	<0.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Hot spring, hot stream, pools. In cooler water, water lily (*Nymphaea alba*) is common.	Stream, pools	*c.*0.2 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Geothermally-heated soil.	Terraces	<0.1 ha

Indigenous Flora: Plants of *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al.* 2009) have previously been recorded at this site (Wildland Consultants 2006). No specimens were located during the current survey but the entire site couldn't be inspected due to high river conditions and the population probably still exists.

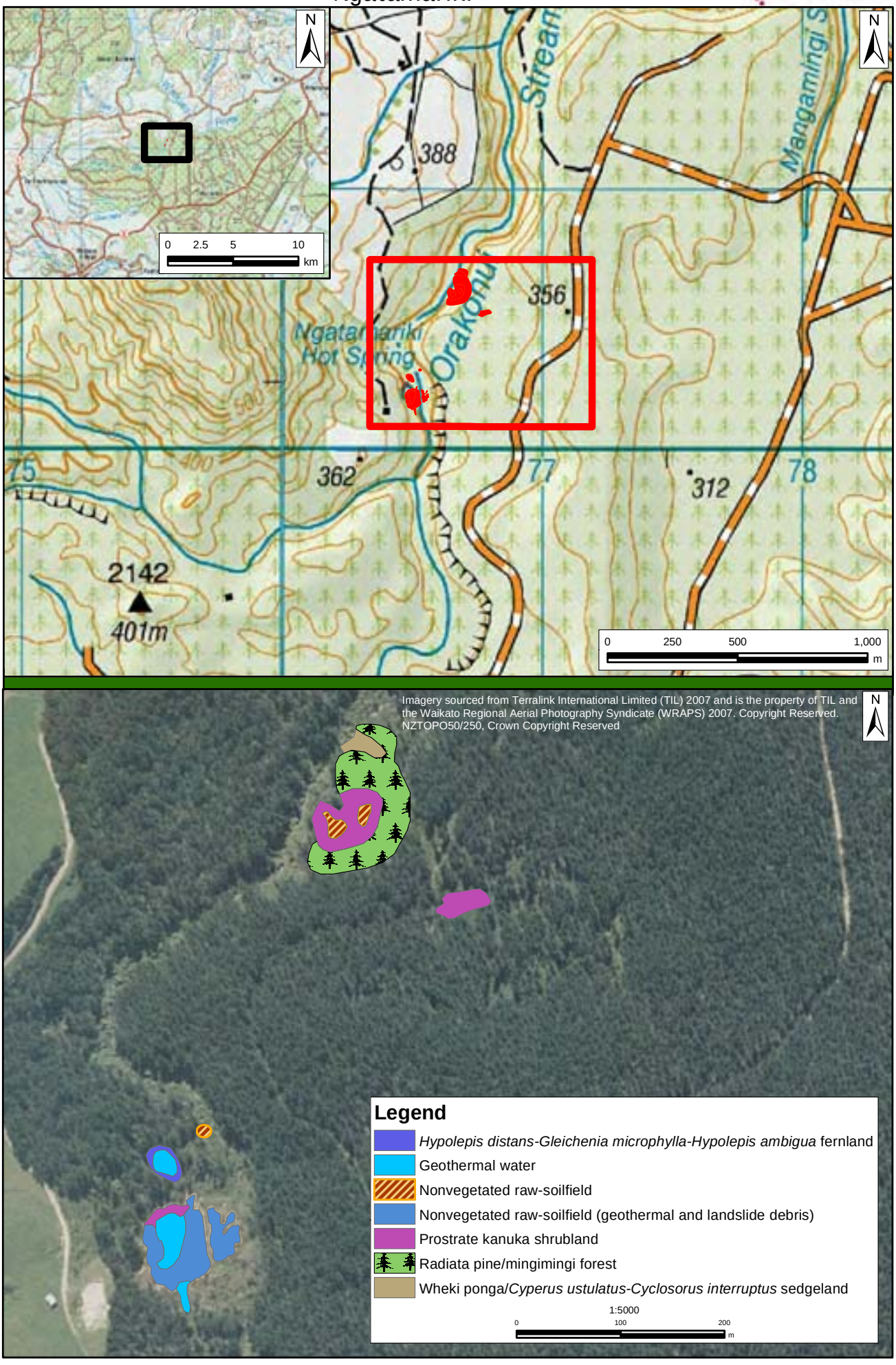
Fauna: North Island fernbird (classed as „At Risk-Declining' in Miskelly *et al.* 2008) has been recorded at this site (Wildland Consultants 2006). Common indigenous and exotic species including Californian quail, greenfinch, blackbird, tui, yellowhammer, goldfinch and fantail are also present.

[1] Previously identified as U17/29 in Wildland Consultants (2004).

Current Condition (2011 Assessment):	Weed species such as reed sweet grass dominate the wetland areas of this site.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2011 Assessment*):	Chinese privet (1-5% cover), radiata pine <1% cover), reed sweet grass (75-100% cover), grey willow (1-5% cover), buddleia (1-5% cover), and blackberry (1-5% cover) are all present at this site.
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*):	Grazing is not an issue at this site.
Adjoining land use (*2011 Assessment*):	Waikato River marginal strip; plantation forestry.
Site Change:	
Recent change:	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:	This site is too small to see any evidence of change since 1941 (Historical photos: SN 172 Run 1168 Photos 15-16, 1941) and the site is subject to water level fluctuations in the Waikato River.
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 sweet grass 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 3, 5, 9; Table 2 - Factor 12)
Significance Justification:	This site is of regional significance because it contains a small population of *Christella* aff. *dentata* ("thermal"), which is an „At Risk' species that is known from only 14 sites in New Zealand.
Notes:	Part of this site was recorded as Lake Ohakuri/Tainui Road in Beadel & Bill 2000 and Wildland Consultants 2004. The water temperature in one spring was 65ºC with a flow rate of 1 litre a second. The water temperature in one stream was 54ºC. The spring was depositing small amounts of sinter. Water flow was *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 & Bill 2000; Wildland Consultants 2004 & 2006.

NMV02

Ngatamariki



NGATAMARIKI

Site Number: NMV02 [1]
Grid Reference: NZTopo50 BF37 767 306
GPS Reference: NZTM E1876675 N5730627
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Ngatamariki
Bioclimatic Zone: Submontane
Tenure: Protected (Ngatamariki Hot Springs Scenic Reserve) and unprotected private land.
Altitude: 310 m
Extent of Geothermal Habitat: *c.*1.7 ha
Extent of Geothermal Vegetation: *c.*1.5 ha
Date of Field Survey: 2 February 2011 (northern part of site is based on survey undertaken on 25 May 2007)

Code	Type	Landform	Extent
01.05 01.05.04[2]	**Exotic pine forest** **Radiata pine/mingimingi forest** Radiata pine forms the canopy over mingimingi, *Histiopteris incisa*, bracken, kiokio and blackberry. Several patches of *Dicranopteris linearis* were recorded in May 2007, a species not previously recorded at this site.	Hillsopes	*c.*0.6 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka forms a shrubland around the hot pools and seepages with mingimingi, prickly mingimingi and manuka scattered throughout, as well as local patches of *Baumea teretifolia* and *Cyperus ustulatus*. The ground cover is sparse, with small patches of mosses (including *Campylopus capillaceus*) and *Lycopodiella cernua*. Radiata pine are common on margins.	Alluvial terraces	*c.*0.4 ha
07.05 07.05.12	**Mixed fernland** ***Hypolepis distans-Gleichenia microphylla-Hypolepis ambigua* fernland** The margins of the hot spring are covered with a mixed fernland of *Hypolepis distans, Gleichenia microphylla, Hypolepis ambigua,* bracken, with occasional kiokio and manuka.	Hot spring margins	<0.1 ha
09.02 09.02.05	***Cyperus ustulatus*-dominant sedgeland** **Wheki-ponga/*Cyperus ustulatus-Cyclosorus interruptus* sedgeland** *Cyperus ustulatus* dominates vegetation surrounding a small hot water stream that flows from a hot water seepage down to the Orakonui Stream. Sixteen clumps of *Cyclosorus interruptus*, comprising *c.*122 fronds, were present amongst the *Cyperus ustulatus* in May 2007. Also present is wheki-ponga, occasional patches of bracken and *Histiopteris incisa*, and several prostrate kanuka shrubs. This vegetation is surrounded by tall radiata pine plantation forest.	Alluvial terraces	*c.*0.1 ha

[1] Previously identified as U17/15 in Wildland Consultants (2004).
[2] Not surveyed in 2011.

Code	Type	Landform	Extent
22.01 22.01.01	**Geothermal water** **Geothermal water** Small geothermal pools occur at this site. On the margins there is scattered kiokio, *Cyperus ustulatus*, *Hypolepis distans*, bracken, mingimingi, raupo, *Histiopteris incisa*, wheki, blackberry, prostrate kanuka, pampas, buddleia, grey willow, Yorkshire fog, karamu, koromiko, and radiata pine. *Lemna minor* and water purslane are present in cooler water.		*c.*0.2 ha
28.01 28.01.01[1]	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Sinter with hot pools, mud pools, springs and seepages. A good population of arrow grass present in 2004 in the northern two units of nonvegetated raw-soilfield (this area was not resurveyed during the current study). Scattered plants of prostrate kanuka, manuka, Spanish heath, bracken, *Histiopteris incisa*, and *Lycopodiella cernua* are present.	Alluvial terraces	*c.*0.1 ha
28.01 28.01.04	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield (geothermal and landslide debris)** Recent geothermal activity in this area has left nonvegetated geothermal and landslide debris on both sides of the stream.	Alluvial terraces	*c.*0.4 ha

Indigenous Flora: Sixteen clumps of *Cyclosorus interruptus* (classed as „At Risk-Declining' in de Lange *et al.* 2009) were recorded in the northern part of this site in May 2007. In May 2007, *Dicranopteris linearis* (classed as „At Risk-Naturally Uncommon' in de Lange *et al*. 2009) was discovered in the northern part of this site, under radiata pine trees. The latter species had not previously been recorded from this site and is known from only *c.*24 sites in New Zealand.

Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) and *Campylopus capillaceus*, which are both endemic species restricted to geothermal areas, occur 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) has also been recorded below a waterfall (Ecroyd 1979b). *Psilotum nudum* was not seen during the 2004, 2007, or 2011 surveys, or by Given (1995), but this is may reflect the inaccessibility of the site rather than a population decline.

Fauna: North Island fernbird („At Risk-Declining' in Miskelly *et al.* 2008) has been recorded here in the past. Whitehead, fantail, grey warbler, kingfisher, tui, greenfinch, yellowhammer, magpie, and North Island robin are also present.

[1] Not surveyed in 2011.

Current Condition (2011 Assessment): The site comprises two areas of geothermal features and vegetation that contain plant species of note. 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. Prostrate kanuka, manuka and *Cyperus ustulatus* are scattered within this area.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Radiata pine plantation is in close proximity to this site, and some trees have fallen into geothermal vegetation and features. Other adventive plant species present include buddleia (*c.*1-5% cover), pampas (<1% cover), blackberry (1-5% cover), and Himalayan honeysuckle (<1% cover). Some control work on radiata pine has been undertaken by the Department of Conservation.

Human impacts (*2011 Assessment*): This is a reasonably isolated site and human impacts are only likely to occur during future harvesting of the neighbouring pine plantation, which could severely damage the geothermal vegetation. A geothermal power scheme is planned for the Ngatamariki Geothermal Field.

Grazing (*2011 Assessment*): Livestock are not a threat to the site.

Adjoining land use (*2011 Assessment*): There are pine plantations adjacent to this site.

Site Change:

Recent change: Geothermal activity has changed the landforms and species composition of the southern end of this site. A hydrothermal eruption has formed a new geothermal lake and mud pools, and deposited hydrothermal eruption debris.

Historical: 1941 aerial photographs (Historical photo: SN 172 Run 1168 Photo 14, 1941) were compared with 2007 aerial photographs. There is a larger buffer between geothermal features and forestry operations, particularly around the southern part of the site. There is more geothermal vegetation (scrub and shrubland) around the geothermal features in 1941. The area of bare ground is also more extensive in 1941. The northern units cannot be readily identified on aerial photographs, but there is a greater buffer of between geothermal features and plantation forests. Geothermal vegetation and habitats is likely to have declined by 10-25%, but may be mostly related to weed invasion, and change of land use to plantation forestry.

Management Requirements: Radiata pine within geothermal areas and on the margins of the site should be removed. Damage during harvesting operations is a potential threat. Ongoing monitoring should occur due to recent geothermal activity within the site, and energy extraction.

Significance Level: Regional (Table 1 - Criteria 1, 3, 5, 6, 9; Table 2 - Factors 9, 12)

Significance Justification: Ngatamariki is of regional significance because it is protected as a Scenic Reserve and is an important habitat for three „At Risk' species: *Cyclosorus interruptus, Dicranopteris linearis, and* prostrate kanuka.

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 B - the second highest category.

Part of Ngatamariki was formerly identified as being of national significance because it provides habitat for *Cyclosorus interruptus* which, at that time, was classified as a „Chronically Threatened' species (de Lange *et al.* 2004). However, in the most recent revision of the threat classification list, this species is now classified „At Risk' (de Lange *et al.* 2009).

Ngatamariki is the best quality area of geothermal vegetation in the Ngatamariki Geothermal Field.

References:

Beadel & Bill 2000; Department of Conservation 1997; Ecroyd 1979b; Given 1989, 1995 & 1996; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004 & 2007b.

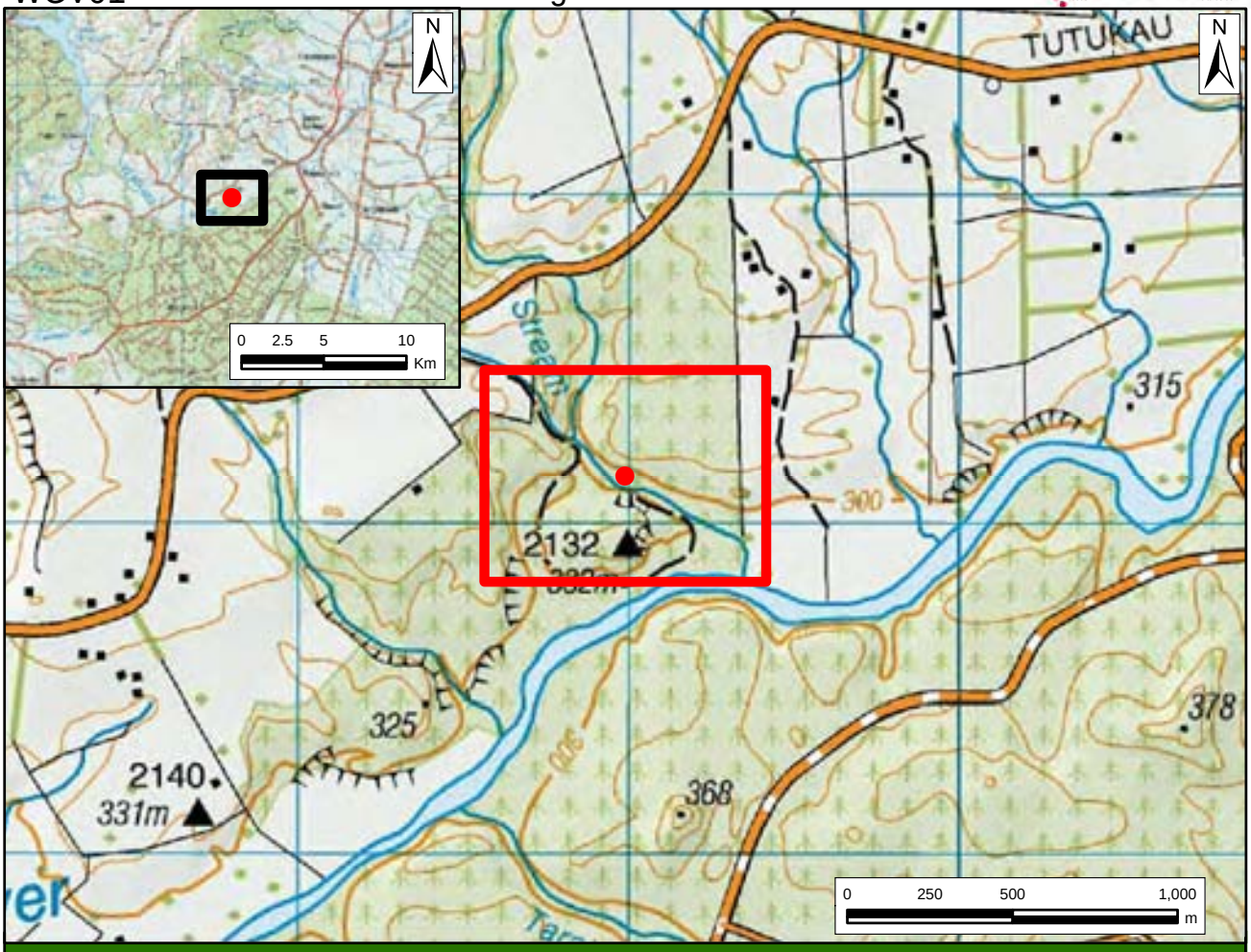
1.9 WHANGAIROROHEA GEOTHERMAL FIELD

List of Geothermal Sites

WGV01 Whangairorohea

WGV01

Whangairorohea



WHANGAIROROHEA

Site Number: WGV01[1]
Grid Reference: NZTopo50 BF37 830 331
GPS Reference: NZTM E1882987 N5733149
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Whangairorohea
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: 310 m
Extent of Geothermal Habitat: *c.*0.1 ha
Extent of Geothermal Vegetation: *c.*0 ha
Date of Field Survey: 3 February 2011

Code	Type	Landform	Extent
22.01 22.01.01	**Geothermal Water** **Geothermal Water** A pool *c.*10 × 15 m filled with clear water that was *c.*36°C at the time of survey. Vegetation on the margins comprises a mosaic of species, which includes *Carex secta*, raupo, *Eleocharis acuta* and a band of *Schoenoplectus tabernaemontani* (*c.*15 × 1m). Spanish heath (up to *c.*2.5 m tall), blackberry, koromiko, bracken and rank exotic grasses occur on the drier terrace. Exotic grasses and herb species around the perimeter of the pool include cocksfoot, Yorkshire fog, narrow-leaved plantain, and lotus. One or two plants of poplar and buddleia are also present. *Blechnum penna-marina* subsp. *alpina* and *Pimelea prostrata* subsp. *prostrata* occur at the northern side of the pool. There was no evidence of heated geothermal soils surrounding the pool.	Steep hillslope	*c.*0.1 ha

Indigenous Flora: *Blechnum penna-marina* subsp. *alpina* and *Pimelea prostrata* subsp. *prostrata* are present amongst the exotic grassland on the northern side of the pool. These species are not common in Atiamuri Ecological District.

Fauna: Magpie and tui were recorded at this site however other birds of plantation forests are likely to also be present.

Current Condition (2011 Assessment): This site comprises a geothermal pool situated within a radiata pine plantation. There is a buffer zone of 20 m around the spring which is not planted in pine. The buffer zone comprises exotic grassland and a small, blackberry-filled gully dissected by access tracks. The pool is used for bathing, with a constructed jetty built towards the centre for easy access.

[1] Previously identified as U17/33 in Wildland Consultants (2004).

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*):	Local patches of Spanish heath (1-5% cover), poplar (<1%), and scattered buddleia (<1% cover) and blackberry (1-5% cover) are also present.
Human impacts (*2011 Assessment*):	Impacts of adjacent forestry operations can be excluded from this site because there is a 20 m buffer between the geothermal pool and the plantation forest. There is a permanent wooden structure that provides access into the pool for bathers. Litter was noted within the pool and around its margins.
Grazing (*2011 Assessment*):	Stock do not have access to this site.
Adjoining land use (*2011 Assessment*):	Radiata pine plantation.

Site Change:

Recent change:	Wildland Consultants has not assessed this site previously, but, from inspection of aerial photographs, recent change appears unlikely.
Historical:	The geothermal lake was located on the 1941 aerial photograph (Historical photo: SN 172 Run 1167 Photo 2, 1941) and appears to be of a similar size to the current 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 is a small example of a nationally uncommon habitat type.
Notes:	The stream to the south of the site is eroding and undercutting the steep bank to the south of the pool. This could eventually result in the pool disappearing. A sign identifies this site as „Taahunaa tapu a waiariki o Toa'.
References:	Wildland Consultants 2004

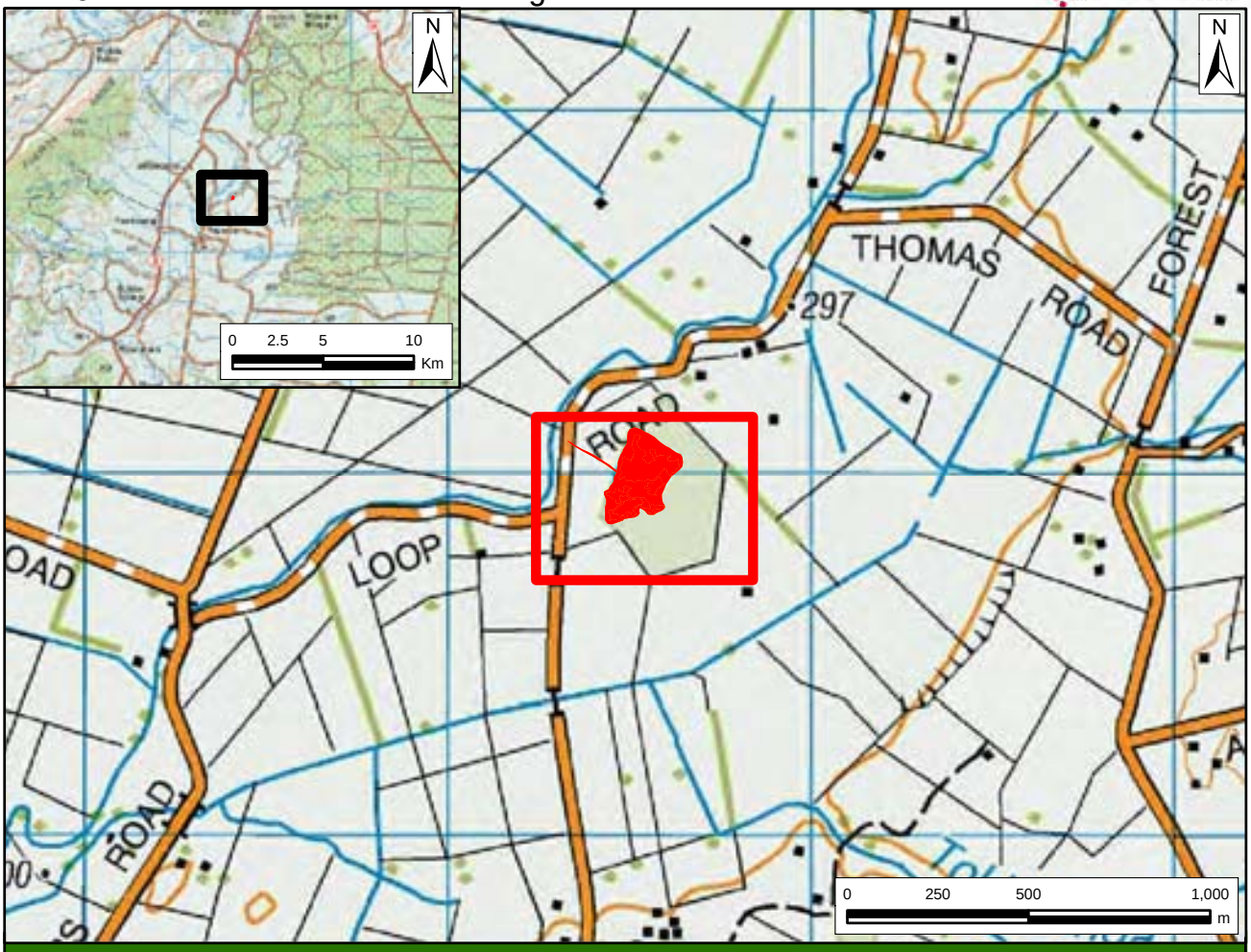
1.10 REPOROA GEOTHERMAL FIELD

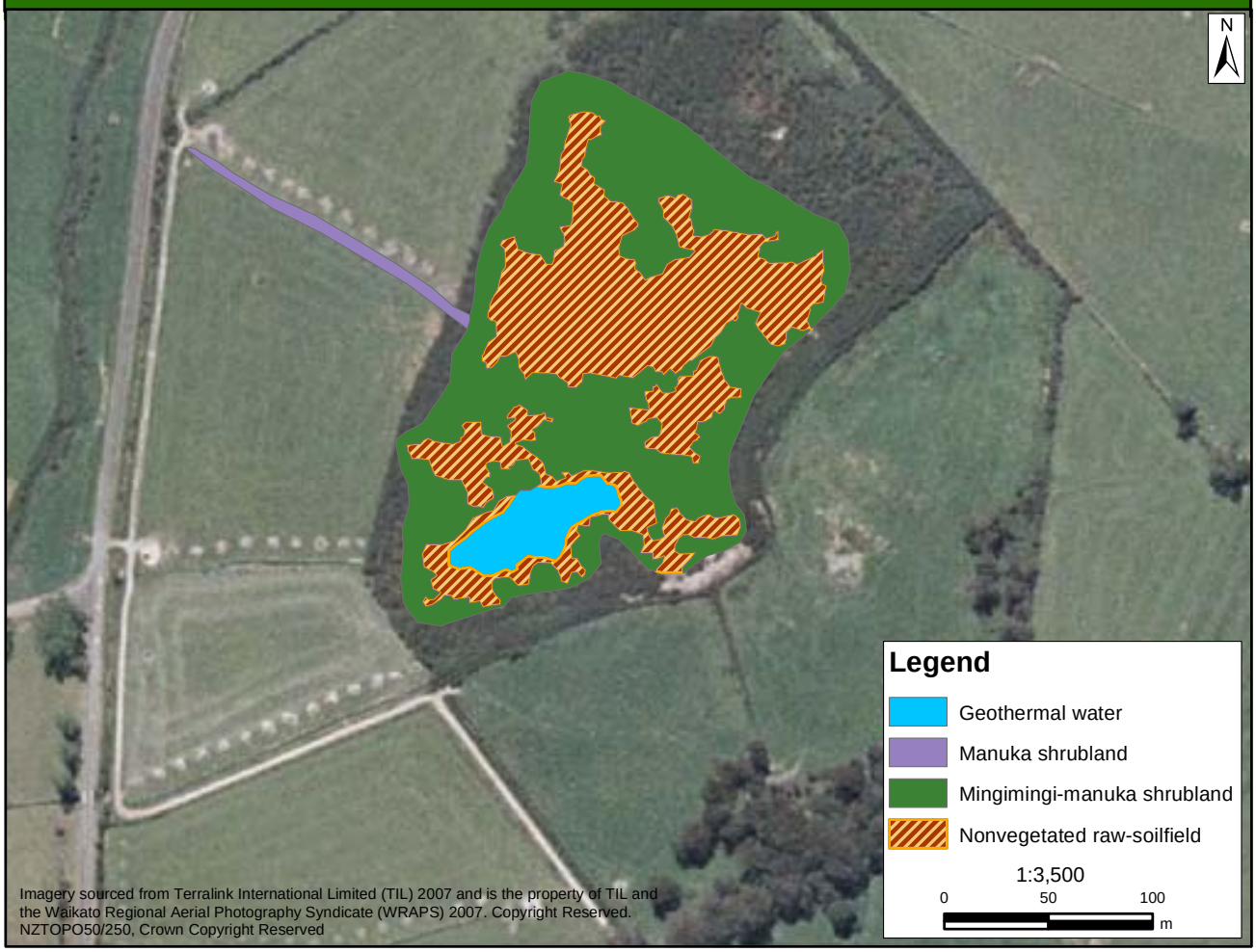
List of Geothermal Sites

RPV01	Longview Road
RPV02	Wharepapa Road
RPV03	Golden Springs

RPV01

Longview Road





LONGVIEW ROAD

Site Number: RPV01[1]
Grid Reference: NZTopo50 BF37 935 430
GPS reference NZTM E1893489 N5742976
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Reporoa
Bioclimatic Zone: Submontane
Tenure: Protected (Molloy Conservation Covenant)
Altitude: *c*.300 m
Extent of Geothermal Habitat: *c*.3.6 ha
Extent of Geothermal Vegetation: *c*.3.4 ha
Date of Field Survey: 27 May 2004

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
05.02 05.02.02	**Mingimingi-dominant shrubland** **Mingimingi-manuka shrubland** Mingimingi dominates the canopy (which ranges from 0.3-4 m high), with scattered manuka. Local patches of blackberry and bracken with scattered *Muehlenbeckia australis* are present, particularly in the northeast corner.	Flat	*c*.1.8 ha
05.03 05.03.01	**Manuka-dominant shrubland** **Manuka shrubland** A narrow band of manuka (often only *c*.1 m wide) occurs alongside heated creeks. Other vascular plant species present include mingimingi, blackberry, *Histiopteris incisa*, *Juncus effusus*, *Juncus edgariae*, and rank grasses (predominantly Yorkshire fog).	Flat	<0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Sinter pavement, boiling water and hot springs.	Flat	*c*.1.5 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Hot springs, geothermal lakelets.	Flat	*c*.0.2 ha

Indigenous Flora: Prostrate kanuka, classed as „At Risk-Naturally Uncommon' (in de Lange *et al*. 2009) was at the site in 2000 (Beadel & Bill 2000), however it was not found in the 2004 survey.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including fantail, harrier and pukeko.

[1] Previously identified as U17/18 in Wildland Consultants (2004).

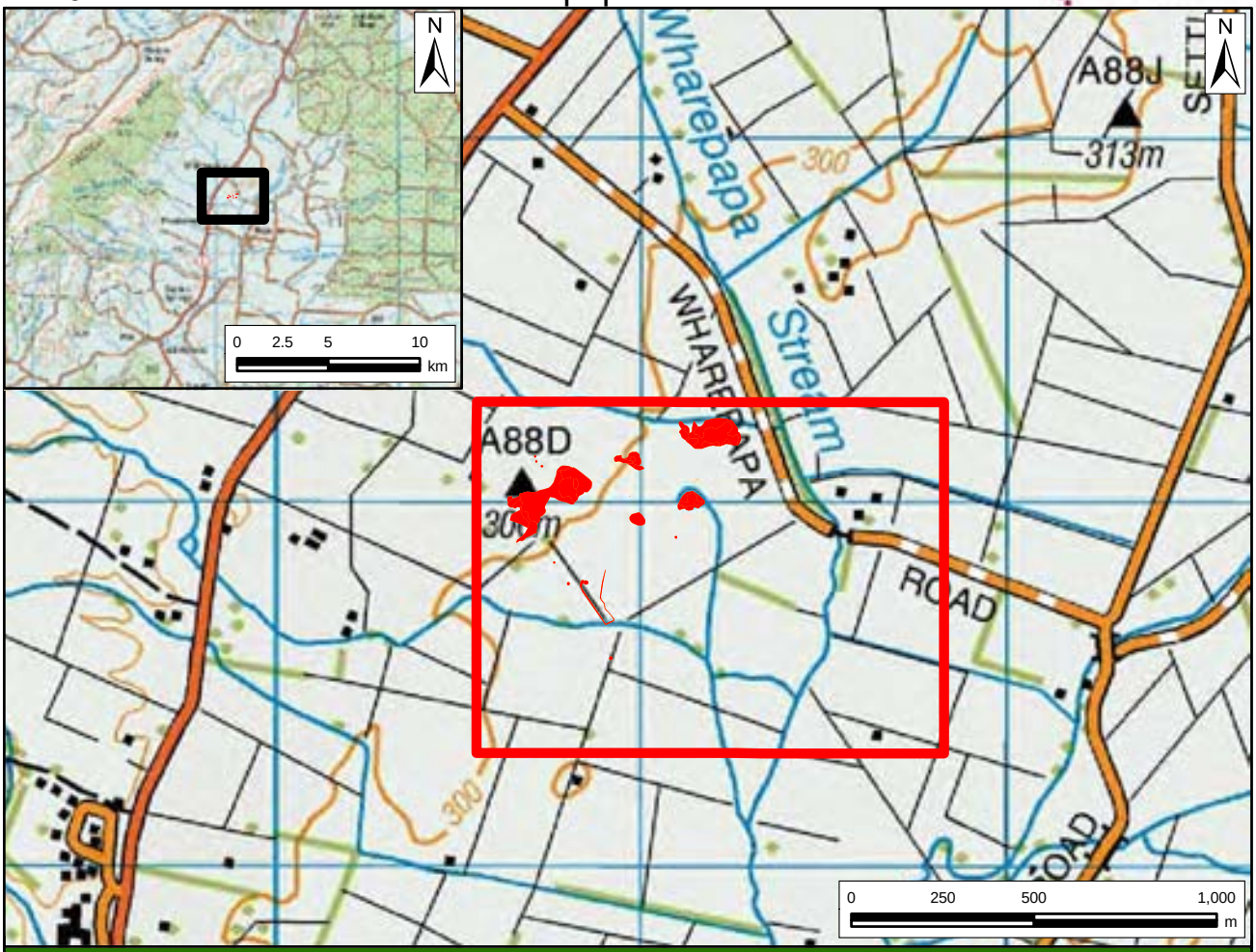
Current Condition (2004 Assessment):	Overall this site is in good condition. It is well buffered with indigenous vegetation and there are few weeds[1]. However, the site is small in size and has a long history of disturbance from fire, cattle grazing, and drainage channel development (see Unpublished Atiamuri PNAP data 1995). The site is now fenced, so grazing is no longer a threat.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2004 Assessment*)*:*	Blackberry (6-25% cover) poses the greatest threat to margins of the site and, if left uncontrolled, is likely to spread into the manuka-mingimingi shrubland areas.
Human impacts (*2004 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. Damage to the vegetation also occurs from recreational use (e.g. trampling of geothermal vegetation and features during duck shooting season).
Grazing (*2004 Assessment*)*:*	Apart from the narrow strip of manuka shrubland alongside drains, the site is fenced to exclude stock. Along the edges of the drains with geothermal water there is some manuka die-back corresponding with bank erosion, which tends to occur where cattle can access the drain.
Adjoining land use (*2004 Assessment*)*:*	Farmland.
Site Change:	
Recent change:	Based on aerial photographs, the site appears similar to the 2004 study.
Historical:	It appears that the surrounding land use (farming) has intensified since 1941 (Historical photos: SN 172 Run 1162 Photos 5-6, 1941). 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. The area of manuka scrub is over twice the size of the current area, based on 2007 aerial photographs. Almost all change to this site is as a result of land drainage and development into pasture.
Management Requirements:	Blackberry, if left uncontrolled is likely to spread into surrounding manuka and mingimingi dominated shrubland and further spread of blackberry should be prevented. Drainage (by adjacent farm drains) may be a key issue for managing blackberry at this site, as lowered water levels provide sites for blackberry to establish. No further drainage channels should be created and the margins of the heated creeks/channels need to remain fenced to exclude grazing animals. Trampling of vegetation and geothermal features should be kept to a minimum. Fences should be checked regularly and maintained.
Significance Level:	Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 10).

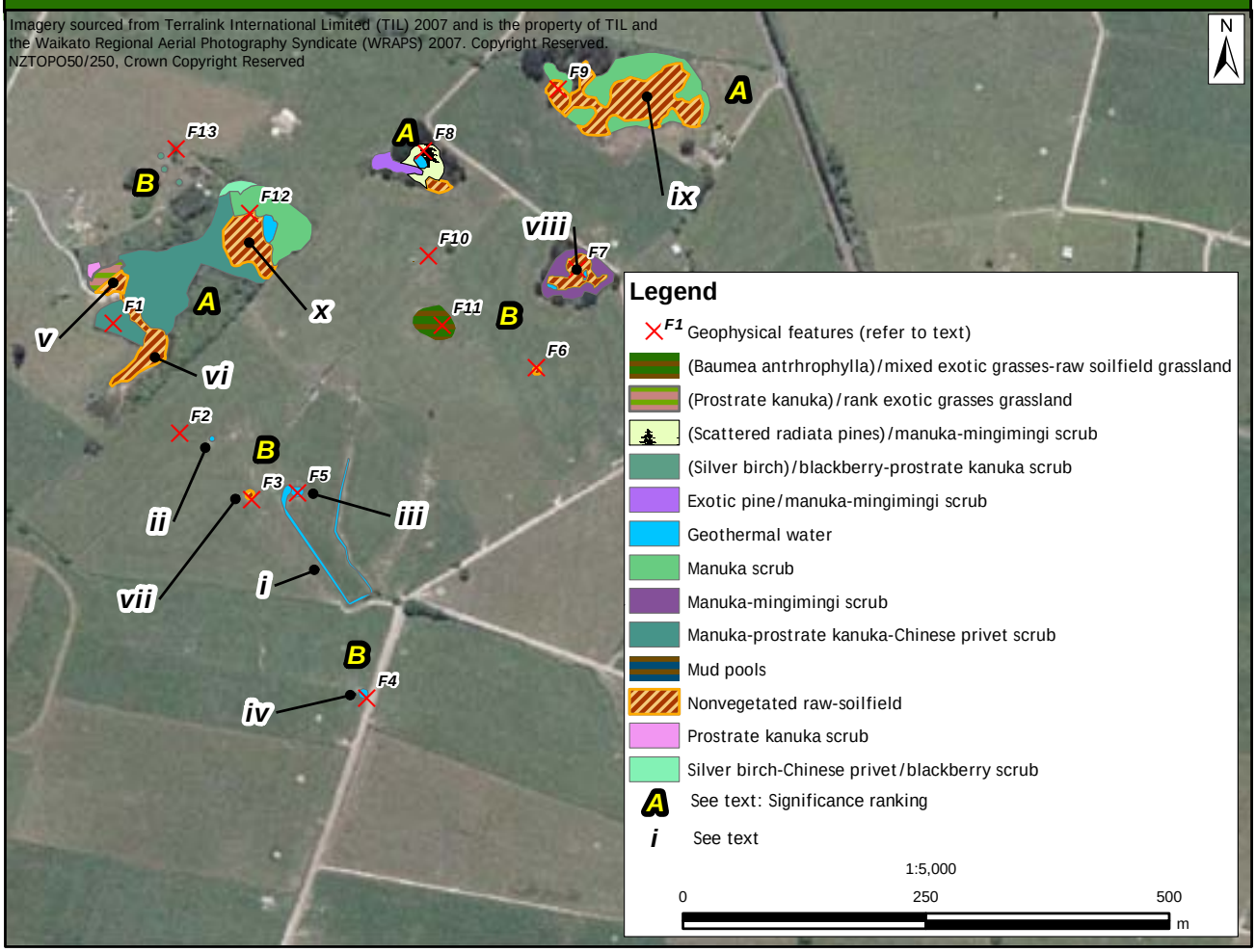
[1] Apart from in the narrow band of manuka shrubland outside the protected area.

Significance Justification:	This site is of regional significance because it is protected by a conservation covenant. It is the best example of geothermal vegetation associated with the Reporoa Geothermal Field.
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 category.
References:	Beadel & Bill 2000; Given 1995 & 1996; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004.

RPV02

Wharepapa Road





WHAREPAPA ROAD

Site Number: RPV02[1]
Grid Reference: NZTopo50 BF37 907 430
GPS reference: NZTM E1890738 N5743011
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Reporoa
Bioclimatic Zone: Lowland - Submontane
Tenure: Unprotected private land
Altitude: *c.*300 m
Extent of Geothermal Habitat: *c.*3.5 ha
Extent of Geothermal Vegetation: *c.*3.3 ha
Date of Field Survey: 30 July 2010

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** A small area of prostrate kanuka scrub to 3 m tall. Occasional blackberry, Mercer grass, Chinese privet seedlings, and sheep's sorrel in understorey.	Gentle slope	<0.1 ha
04.03 04.03.01	**Manuka-dominant scrub** **Manuka scrub** Manuka-dominant scrub (1-4 m tall) surrounds geothermal features. Scattered blackberry is present. Occasional prostrate kanuka shrub.	Flat	*c.*0.8 ha
04.03 04.03.02	**Manuka-dominant scrub** **Manuka-mingimingi scrub** Manuka to 4 m tall is present, with patches of mingimingi-bracken scrub. Radiata pine surrounds the site. Several trees have been felled into the site.	Flat	*c.*0.1 ha
04.03.13	**Manuka dominant scrub** **(Exotic pine)/manuka-mingimingi scrub** Radiata pine is emergent over mixed manuka-mingimingi scrub with a canopy height of 2-5 m.		<0.1 ha
04.03 04.03.15	**Manuka-dominant scrub** **(Scattered radiata pine)-manuka-mingimingi scrub** Scattered radiata pines over manuka (to 4 m) and mingimingi scrub, with occasional prostrate kanuka present. Several oaks (*Quercus* sp.) and silver birch on margins.	Crater walls/flat	*c.*0.1 ha
04.03 04.03.17	**Manuka-dominant scrub** **Manuka-prostrate kanuka-Chinese privet scrub** Manuka, prostrate kanuka, 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 *Cotoneaster simonsii*.	Flat	*c.*0.9 ha
04.08 04.08.03	**Blackberry-dominant scrub** **Silver birch-Chinese privet/blackberry scrub**	Flat/ gently rolling	<0.1 ha

[1] Previously identified as U17/32 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	Chinese privet and silver birch are emergent over blackberry scrub. Scattered broom present. Browntop and Yorkshire fog present in understorey.		
04.08 04.08.05	**Blackberry-dominant scrub** **(Silver birch)/blackberry-prostrate kanuka scrub** Occasional silver birch emergent over blackberry scrub, with scattered patches of prostrate kanuka. Fumaroles and small mud pools present.	flat	<0.1 ha
08.06 08.06.04	**Mixed exotic-dominated grassland** **(Prostrate kanuka)/rank exotic grasses grassland** Occasional prostrate kanuka over mixed exotic grassland species, including Indian doab, wild seradella (*Ornithopus perpusillus*), hawksbeard, browntop, Mercer grass, catsear, and lotus). Soil temperature was 15°C at 5 cm depth on winter morning.	flat	<0.1 ha
08.06 08.06.05	**Mixed exotic-dominated grassland** **(*Baumea arthrophylla*)/mixed exotic grasses-raw-soilfield grassland** Emergent *Baumea arthrophylla* is present over rank exotic grassland species, including browntop, catsear, white clover, *Gonocarpus micranthus*, sheep's sorrel, and sweet vernal. Approximately 25 × 50 m of geothermal activity, including fumaroles, mud pools, and heated bare soils. Scattered pumice rocks were common.	Gently sloping/ Flat	*c.*0.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** (i) Geothermal water in drain, surrounded by exotic grasses, including reed sweet grass, Yorkshire fog, and *Rumex crispus*. Mosquitofish were recorded in drains. (ii) Hot pool. (iii) Geothermal pool surrounded by mossfield. *Gonocarpus micranthus* on margins. Spring is surrounded by pasture grasses. (iv) Geothermal spring in ditch surrounded by rank grassland species, particularly reed sweetgrass and Yorkshire fog. The temperature was *c.*47°C with green and orange algae present near spring outflow and drainage channel.	Open water	*c.*0.2 ha
22.01 22.01.02	**Geothermal water** **Mud pool** A mud pool surrounded by sheep's sorrel and grazed pasture grasses. Wood has been thrown into the mud pool.	Open water	<0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** (v) Sinter terrace, hot pools, occasional prostrate kanuka, occasional manuka. Scattered patches of Indian doab and hawsbeard. (vi) Patches of arrow grass on sediments from geothermal springs. Overflow from geothermal springs, 7°C during field survey.	Flat	*c.*1.2 ha

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	(vii) Steaming ground. Five fumaroles. Occasional sheep's sorrel, Yorkshire fog, and annual poa (*Poa annua*). Small patch of sinter present. (viii) Occasional mingimingi on margins. Scattered oaks and silver birch overhanging. (ix) Nonvegetated raw-soilfield, including a mud pool. Downstream of mud pool, scattered arrow grass, Yorkshire fog, and *Baumea arthrophylla* on overflow margins. (x) Bare ground, geothermal water. Occasional prostrate kanuka to 3 m tall, manuka seedlings, arrow grass, *Lachnagrostis* sp.		

Geophysical Assessment:[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 0.9L/sec (based on a channel width of 0.15 m, depth of 0.03 m and a velocity of 0.2 m/sec). 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 0.1L/sec.

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.

[1] Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

Plate 74: Hot Clear Pool, sinter apron and terrace. Note two main chambers and discharge channels at Feature 1, Wharepapa Road.

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.

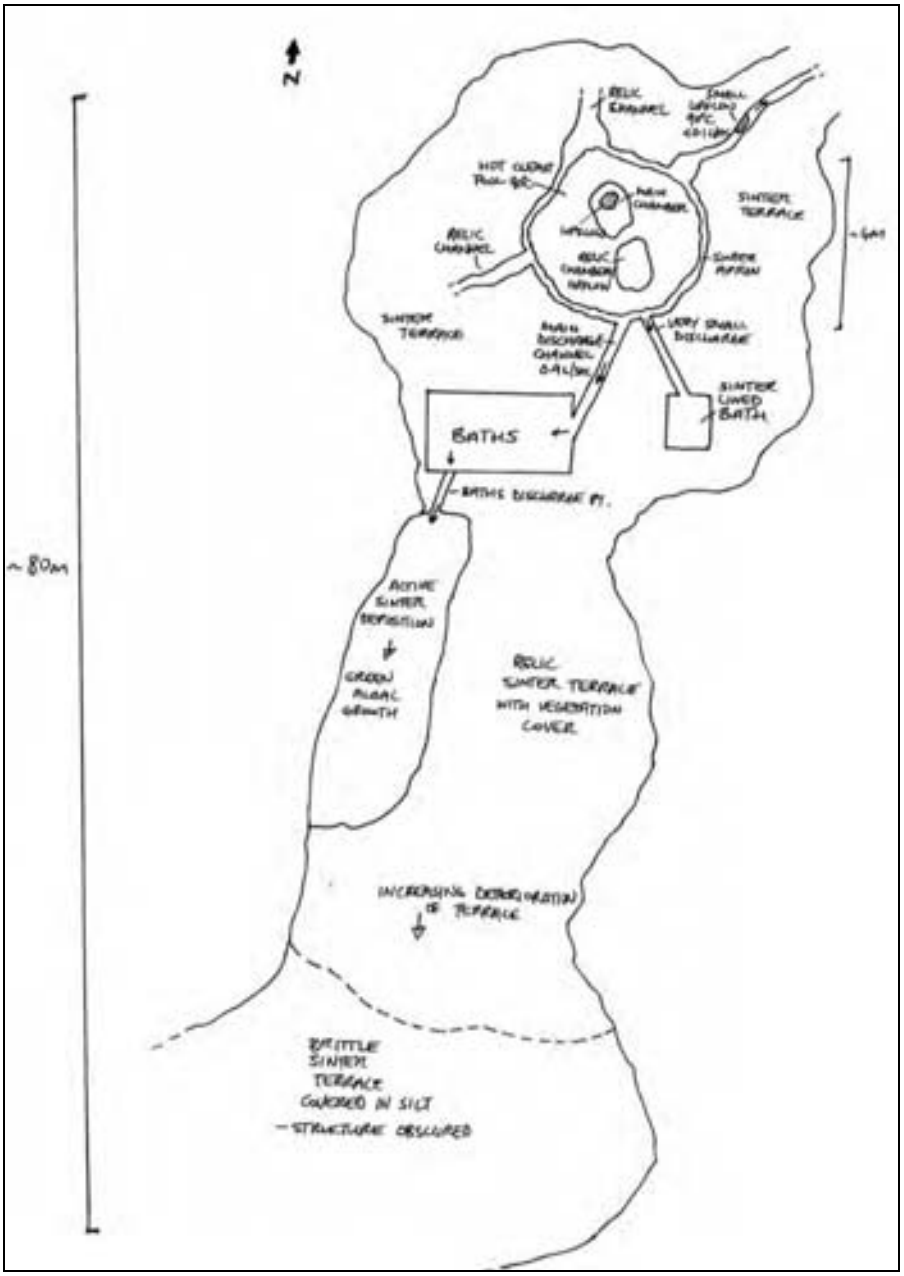


Figure A1-21: Field sketch map of hot pool, drainage and sinter terraces at Feature 1, Wharepapa Road.

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^{o}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 does exist to the southeast of the pool. The soil temperatures surrounding the pool ranged from 12^{o}C to 47^{o}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

There is 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^{o}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 4 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 1.5L/sec. 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^oC 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^oC and there is no further silica deposition (Plate 86). The discharge channel from the pool has a section measuring 1 m which made the flow estimation very straightforward, approximately 4.5L/sec. 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^{o}C), Feature 5, Wharepapa Road.

Plate 87: Minor stream with hot spring inputs, Feature 5, Wharepapa Road.

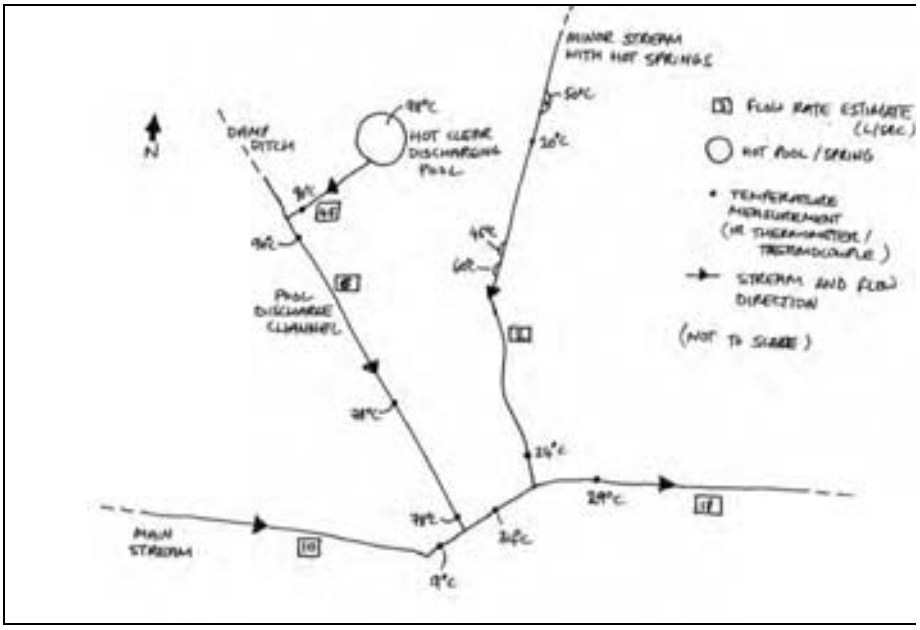


Figure A1-22: Schematic of hot pool drainage, temperature and local stream inputs, Feature 5, Wharepapa Road.

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^{o}C at surface, Feature 7, Wharepapa Road.

Plate 91: Mud pit with multiple fumaroles discharging steam, Feature 7, Wharepapa Road.

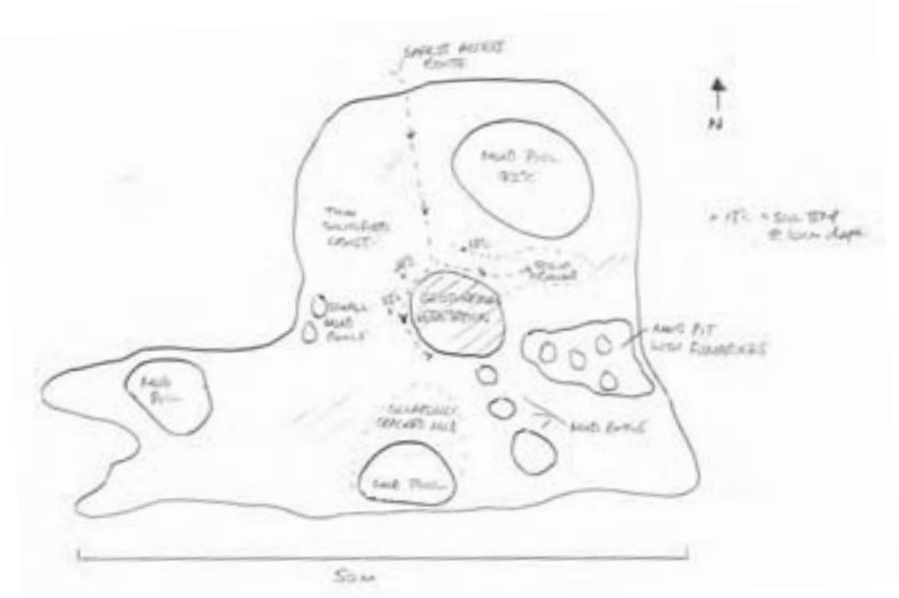


Figure A1-23: Field Sketch map of location, Feature 7, Wharepapa Road.

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^oC and two warm pools with dark green cloudy water with temperatures of approximately 30^oC. 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^oC), Feature 8, Wharepapa Road.

Feature 9: Exposed ground, Hot Clear Pool, Mud pools (labelled F9 on feature map)
Grid Reference: E1891114 N5743198

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.

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 its discharge channel. The discharge flowed to the east and was estimated to be approximately 1L/sec. 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 4-5L/sec. 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/sec.

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.

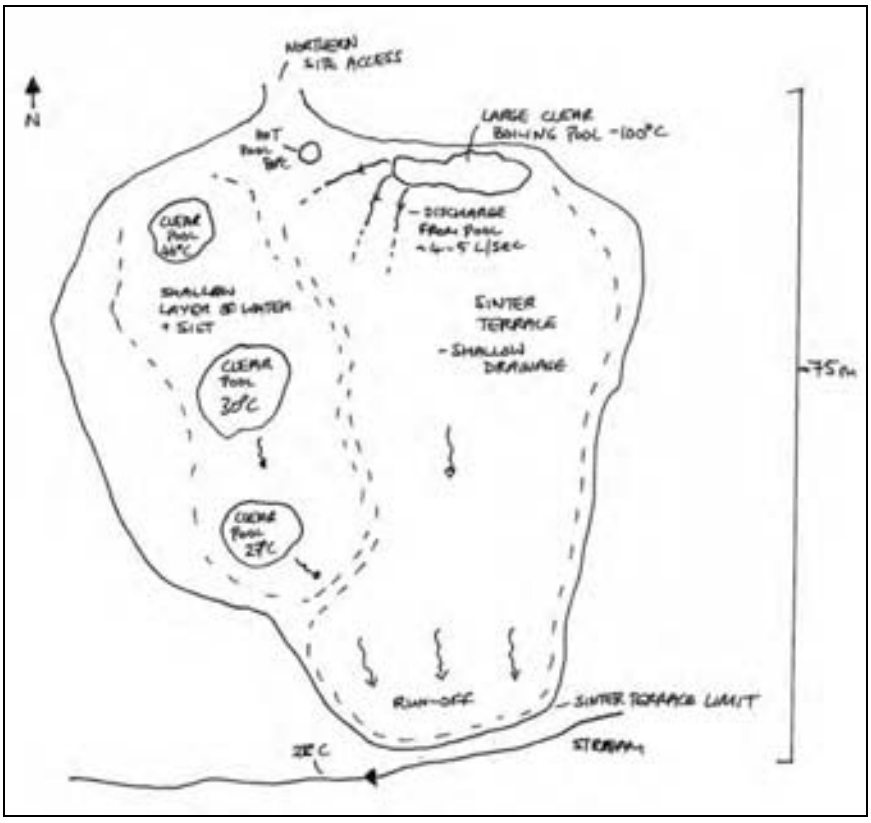


Figure A1-24: Field Sketch of Boiling Pool/Sinter Terrace, Feature 12, Wharepapa Road.

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^oC. There was also refuse and tree branches in the pools.

Plate 98: Mud pool with refuse, Feature 13, Wharepapa Road.

Indigenous Flora: Small populations of both prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al*. 2009) and *Campylopus* sp. occur here. Both are endemic species restricted to geothermal areas. An interesting population of *Baumea arthrophylla* is present. Other species characteristic of geothermal habitat include mingimingi, manuka, and *Histiopteris incisa*.

Fauna: CCommon indigenous and introduced bird species typical of the habitats are likely to be present, including Australasian harrier, spur-winged plover, grey warbler, Australasian magpie, pukeko, fantail, house sparrow, blackbird, goldfinch, welcome swallow, and skylark. Pied stilt classed as „At Risk-Declining' in Miskelly *et al.* (2008) use the habitats present. Mosquitofish were recorded in drains.

Current Condition (20101 Assessment): These small and isolated areas surrounded by farmland are in poor condition; highly modified by dairy farming and the dumping of rubbish. A number of sites are fenced to exclude stock and have geological features of high significance. Pest plants are common, but the site is good potential habitat for indigenous geothermal plants.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2010 Assessment*)*:* Several exotic species occur in each of these areas and are likely to continue to increase in extent under current management. Key weed species present are rank pasture grasses (26-50% cover), *Cotoneaster simonsii* (1-5% cover), blackberry (6-25% cover), oaks (1-5% cover), silver birch (1-5% cover), *Pinus* spp. (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, is dumped on the sinter terraces. Several drainage channels from the hot pools extend across the farmland, and these lower the water table and alter ground temperatures (Unpublished Atiamuri PNAP data 1995). Several geothermal baths are present at the site. Until recently, this pool 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 poor in places, allowing livestock access.

Adjoining land use (2010 Assessment): Farmland, shrubland.

Site Change:

Recent change: More features were found in the 2010 survey than earlier surveys; however these would have been present in earlier surveys.

Historical: Historical photos of the site from 1941 were studied to assess long-term change at this site (Historical photos: SN 172 Run 1162 Photos 2-3, 1941). The development of farmland around these geothermal sites was less intense in 1941, with shrubland linking most of the features together. The geothermal activity to the north-east of the site appears to have become more active. The area of mud pools and bare ground appears to be shrubland in 1941, and the area of bare ground is about five times the size it was in 1941. The large unit to the south-west of the site has considerably more bare ground. Because of conversion to pasture, and taking into account shrubland masking geothermal surface features in the 1941 photographs, the 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 a nationally uncommon habitat type. They contain small populations of an „At Risk' species (prostrate kanuka).

B: These areas are of local significance because they contain small, disjoint, degraded examples of a nationally uncommon habitat type (geothermal).

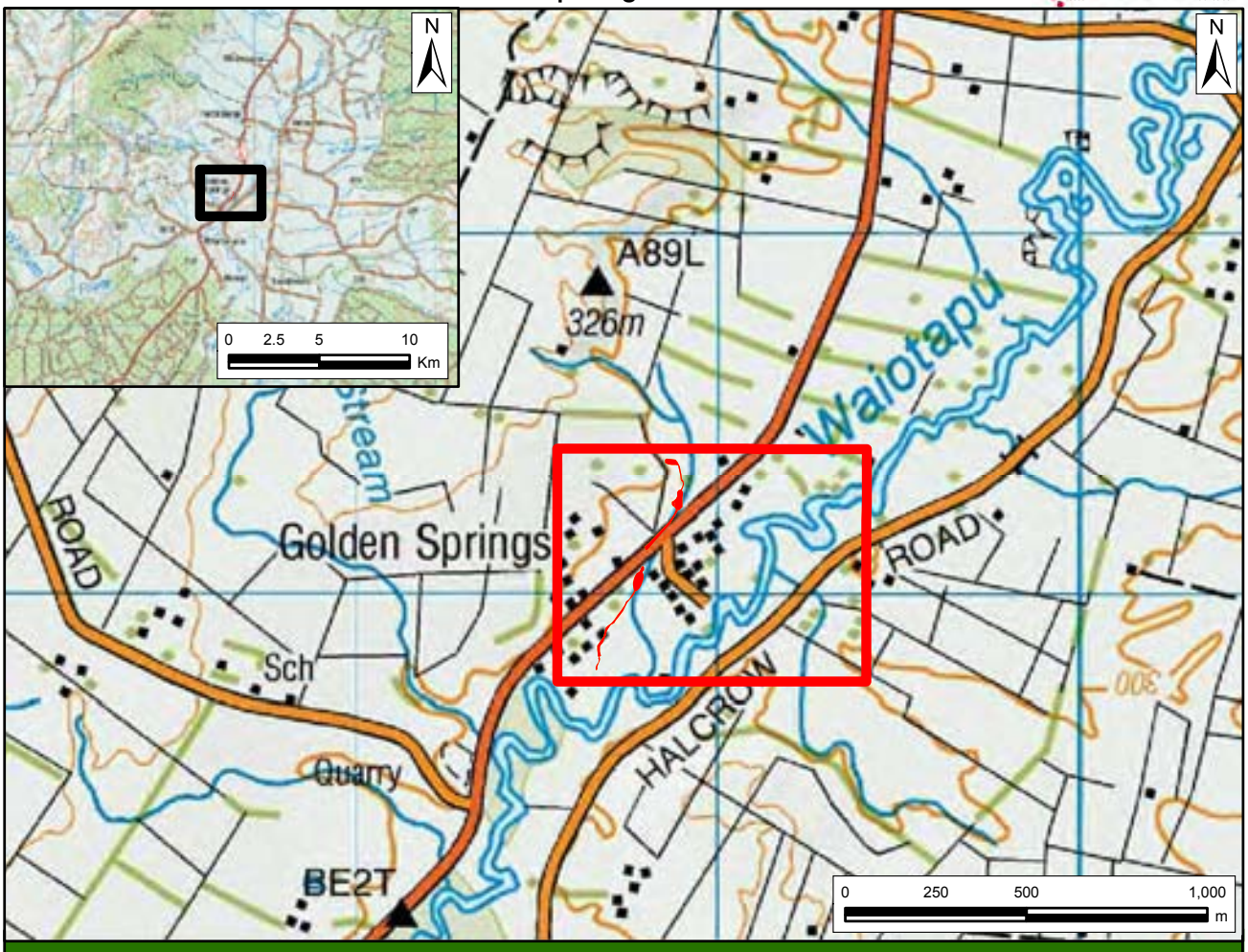
Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in this study this site was classed as Category B - the second highest category.

Features 2 and 12 are also listed in Waikato Regional Council (unpublished) as "South (SE) Spring" and "Opaheke Spring" respectively.

References: Beadel & Bill 2000; Given 1995 & 1996; Unpublished Atiamuri PNAP data 1995; Waikato Regional Council (unpublished); Wildland Consultants 2004.

RPV03

Golden Springs



GOLDEN SPRINGS

Site Number: RPV03[1]
Grid Reference: NZTopo50 BF37 889 372
GPS Reference: NZTM E1888850 N5737187
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Reporoa
Bioclimatic Zone: Lowland
Tenure: Unprotected private land
Altitude: 300 m
Extent of Geothermal Habitat: *c*.0.5 ha
Extent of Geothermal Vegetation: *c*.0.4 ha
Date of Field Survey: 14 May 2007

Code	Type	Landform	Extent
04.08 04.08.01	**Blackberry-dominant scrub** **Blackberry scrub** Stream margins are dominated by blackberry scrub with scattered *Christella* aff. *dentata* ("thermal"). Kanuka is common in the canopy.	Stream margins	<0.1 ha
07.06 07.06.02	***Christella* aff. *dentata* ("thermal")-dominant fernland** ***Christella* aff. *dentata* ("thermal")-blackberry-rank exotic grasses fernland** A narrow band along stream margins, where steam from the geothermal stream that flows past Golden Springs camping ground creates suitable habitat for *Christella* aff. *dentata* ("thermal"). Scattered, planted, ornamental garden plant species are common in places. Other common species present include sweet vernal, annual poa, white clover, black nightshade, fleabane, scotch thistle, agapanthus (*Agapanthus praecox*), Spanish heath, ivy, Japanese honeysuckle, Chinese privet, *Cyperus ustulatus*, arrow bamboo, *Carex secta*, *Carex virgata*, blackberry, *Deparia petersenii*, *Histiopteris incisa,* shaking brake (*Pteris tremula*), kiokio, swamp kiokio, and bracken. Blackberry scrub becomes dominant in this type at the south end of the site. Several prostrate kanuka plants are present. The stream has been extensively altered in places with a diversion for water wheels, and channels have also been dug. A concrete structure is present at the northern end of the block.	Stream margins	*c*.0.1 ha
11.01 11.01.09	**Raupo-dominant reedland** **Raupo/*Carex virgata* reedland** A small geothermal wetland dominated by raupo with common patches of *Carex virgata*, *Carex secta*, and *Hypolepis ambigua*. Blackberry is common on the margins and there are occasional grey willows.	Wetland	*c*.0.1 ha
11.01 11.01.10	**Raupo-dominant reedland** **(Grey willow)-(silver birch)-(ti kouka)/raupo-blackberry reedland** A raupo and blackberry-dominated geothermal drain alongside	Roadside drain	*c*.0.1 ha

[1] Previously identified as U17/27 in Wildlands (2004 and 2007b).

Code	Type	Landform	Extent
	State Highway 5. Emergent grey willow, silver birch, ti kouka, and wheki are common. Plants of *Christella* aff. *dentata* ("thermal") are present at the south end of the drain. Other common species include Chinese privet, kiokio, and *Carex virgata*.		
11.01 11.01.11	**Raupo-dominant reedland** **Raupo-blackberry reedland** A small geothermal wetland dominated by raupo with blackberry common in dry parts. Other species present include *Carex virgata*.	Wetland	*c*.0.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Geothermal hot springs and open water habitats surrounded by exotic pasture species. Common species on the margins include sweet vernal, *Eleocharis acuta*, *Paesia scaberula*, Mercer grass, *Schoenoplectus tabernaemontani*, creeping buttercup, fleabane, water purslane and blackberry.	Open water	0.1 ha

Indigenous Flora: *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al*. 2009) is scattered along stream margins throughout this site.

A few scattered prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al*. 2009) are present. Prostrate kanuka is endemic to geothermal habitat in New Zealand.

Fauna: North Island fantail, bellbird, spur-winged plover, blackbird and pukeko were recorded. Other common indigenous and introduced bird species typical of the habitat are likely to be present.

Current Condition (2007 Assessment): This site is generally in a poor ecological condition. The part of the site on the western side of the road is mostly unfenced and accessible to 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. The downstream (southern) end of the site is overrun with blackberry. Exotic plantings are common along the length of the stream.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*): Blackberry (5-25% cover), Chinese privet (1-5% cover), grey willow (1-5% cover), Japanese honeysuckle (1-5% cover), and ivy (1-5% cover).

Human impacts (*2007 Assessment*): Part of the site is farmed. The rest is negatively impacted by stream management including concreted stream sections, water wheels, exotic plantings, and mowing close to stream margins.

Grazing (*2007 Assessment*): Stock have access to most geothermal features on the western side of State Highway 5.

Adjoining land use (*2007 Assessment*): Farmland, camping ground, state highway, residential.

Site Change:

Recent change: Not assessed. Any significant change is unlikely.

Historical: 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 maintained at the site and stock should be excluded from geothermal areas. Management options should be discussed with land managers to maintain populations of the threatened *Christella* aff. *dentata* ("thermal"). Fencing of the site is likely to result in an increased area of suitable habitat for this species, which is susceptible to grazing. 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"). Bycroft & Beadel (2007c) estimated that there were 45 mature plants present at this site in 2007. This species is only known from 14 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 habitat - a nationally uncommon habitat.

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 B - the second highest category. Area A of this site was ranked as being of National importance in Wildland Consultants (2007b), due to the presence of *Christella* aff. *dentata* ("thermal") which was then classified as „Chronically Threatened'. However the threat status of this species was downgraded in de Lange *et al*. (2009) and the site ranking has consequently been changed to Regional significance in this study.

References: Beadel & Bill 2000; Bycroft & Beadel 2007c; Given 1989, 1995 & 1996; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004, 2007b & 2007c.

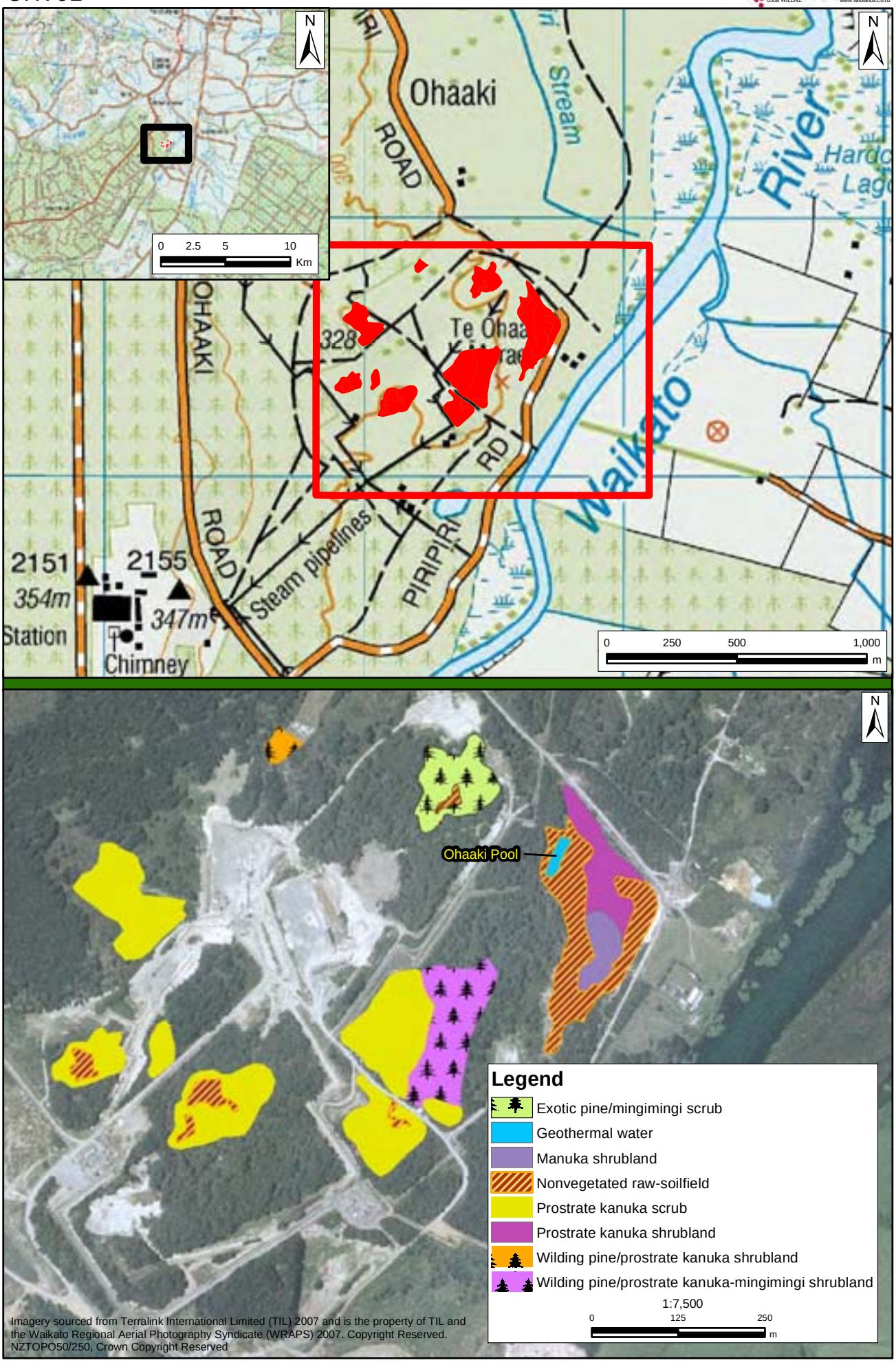
1.11 OHAAKI GEOTHERMAL FIELD

List of Geothermal Sites

OHV01	Ohaaki Steamfield West
OHV02	Ohaaki Steamfield East

OHV01

Ohaaki Steamfield West



OHAAKI STEAMFIELD WEST

Site Number: OHV01[1]
Grid Reference: NZTopo50 BF37 887 316
GPS Reference: NZTM E1888672 N5731579
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Ohaaki
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*300-320 m
Extent of Geothermal Habitat: *c.*11.9 ha
Extent of Geothermal Vegetation: *c.*11.8 ha
Date of Field Survey: 28 January 2011

Code	Type	Landform	Extent
01.05 01.05.06	**Exotic pines forest** **Maritime pine-radiata pine/prostrate kanuka-mingimingi forest** Scattered, emergent maritime pine and radiata pine occur over prostrate kanuka. *Lycopodiella cernua* and small patches of Indian doab and Mercer grass are also present.	Hillslope	*c.*0.2 ha
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka up to *c.*1.5 m tall forms a dense cover with scattered mingimingi and manuka, and frequent emergent radiata pine and maritime pine up to *c.*10 m tall. Bracken, turutu, *Gleichenia microphylla*, *Paesia scaberula*, kiokio, and *Histiopteris incisa* are also present. Small patches of nonvegetated raw-soilfield occur amongst this vegetation type with scattered *Lycopodiella cernua*, Spanish heath, fleabane, gorse, buddleia and broom present.	Low hills; hillslopes and alluvial terrace	*c.*5.4 ha
04.02 04.02.13	**Mingimingi-dominant scrub** **Exotic pine/mingimingi scrub** Mingimingi dominates the canopy with scattered patches of kanuka, and scattered emergent radiata pine and maritime pine. Bracken, *Dicranopteris linearis*, buddleia, whauwhaupaku, kohuhu and wheki are also present.	Hillslope	*c.*1.0 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** This area comprises prostrate kanuka shrubs, up to a height of *c.*0.75 m, and areas of bare soil. Occasional pampas are present.	Alluvial flat	*c.*0.9 ha
05.01.12	**Prostrate kanuka-dominant shrubland** **Wilding pine/prostrate kanuka-mingimingi shrubland** Maritime pine is emergent over prostrate kanuka and patches of mingimingi.	Alluvial flat	*c.*1.6 ha

[1] Previously identified as U17/25 in Wildland Consultants (2004).

Code	Type	Landform	Extent
05.03 05.03.01	**Manuka-dominant shrubland** **Manuka shrubland** Manuka dominated shrubland with scattered prostrate kanuka, Spanish heath, blackberry, buddleia, and occasional maritime pine saplings.	Low hills, alluvial flat	*c.*0.5 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Geothermal pool (Ohaaki Pool).	Alluvial terrace	*c.*0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Sinter clay, small sinter terraces (unmapped) and steaming fumaroles, fissures and bare ground with areas of prostrate kanuka, *Lycopodiella cernua, Campylopus capillaceus* and exotic grasses (including narrow-leaved carpet grass and tall fescue). Around Ohaaki Pool there are local patches of kanuka in association with manuka and scattered Spanish heath, pampas, and blackberry with small, isolated areas of *Baumea juncea*.[1]	Alluvial terrace	*c.*2.2 ha

Indigenous Flora: Prostrate kanuka, *Dicranopteris linearis* (5-10 plants) (both „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), *Campylopus capillaceus* and *Lycopodiella cernua* are all species characteristic of geothermal sites that occur here. *D. linearis* is known from only *c.*24 sites in New Zealand.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including fantail, kingfisher, tui, grey warbler, North Island robin and pheasant. Rabbit were also recorded at the site.

Current Condition (2011 Assessment): This site has been fragmented by industrial activities and road works, with additional clearance recorded since the 2007 survey (a small area of prostrate kanuka 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 a major problem with pest plants (particularly exotic pines). However, most of the site still has significant ecological values.

Wilding pines have been controlled in some areas but they remain prominent in 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% and some areas now classed as forest rather than scrub or shrubland. Also 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

[1] At the time of the field survey the southern parts of this site (E1888564 N5731359) were flooded by water from the Waikato River.

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.

Human impacts (*2011 Assessment*): Geothermal extraction and related earthwork operations present ongoing threats to the geothermal features and vegetation of this site. Temperatures 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 where it is adjacent to pine plantations.

Grazing (*2011 Assessment*): Grazing is not an issue at this site.

Adjoining land use (*2011 Assessment*): Geothermal power plant operations; plantation forestry; Waikato River.

Site Change:

Recent change: Some wilding pine control has been undertaken at the site since 2004, however there are many areas in which pine encroachment is continuing to expand in extent.

An area of prostrate kanuka has been cleared for access tracks and laying of pipe.

A population of prostrate kanuka has established on bare ground near the marae, in an area that was previously mapped as nonvegetated raw-soilfield.

Historical: In 1941 there was bare ground and low shrubland in the vicinity of this site, which may reflect more geothermal vegetation and habitat in the area (Historical photos: SN 172 Run 1167 Photos 7-9, 1941). Merrett & 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 kanuka. The density of weed species has steadily increased at this site since 1984.

The Ohaaki Power Station was commissioned in 1989. Prior to the development of field, the large boiling pool to the northeast of the site (Ohaaki Ngawha) 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 Ngawha drop. This 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;
- hot springs producing chloride water and depositing sinter.

Most of these features have since 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 urupa to the northwest of the site, and the ground has opened up in places (http://www.waikatoregion.govt.nz/Environmental-information/Geothermal-resources/Geothermal-systems-map/Ohaaki/ : Accessed 30 June 2011).

Land development has 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 & Burns 1998a).

Management Requirements:

Wilding pine and other pest plant species control should be ongoing.

Monitoring of steamfield management and the vegetation response to changing temperatures should be ongoing, including monitoring the *Dicranopteris linearis* population.

Future infrastructure developments on the site should aim to avoid the 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 of a nationally uncommon vegetation type (geothermal), contains a large population of an „At Risk' species (prostrate kanuka), and a small population of *Dicranopteris linearis,* another „At Risk' species.

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 & 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."

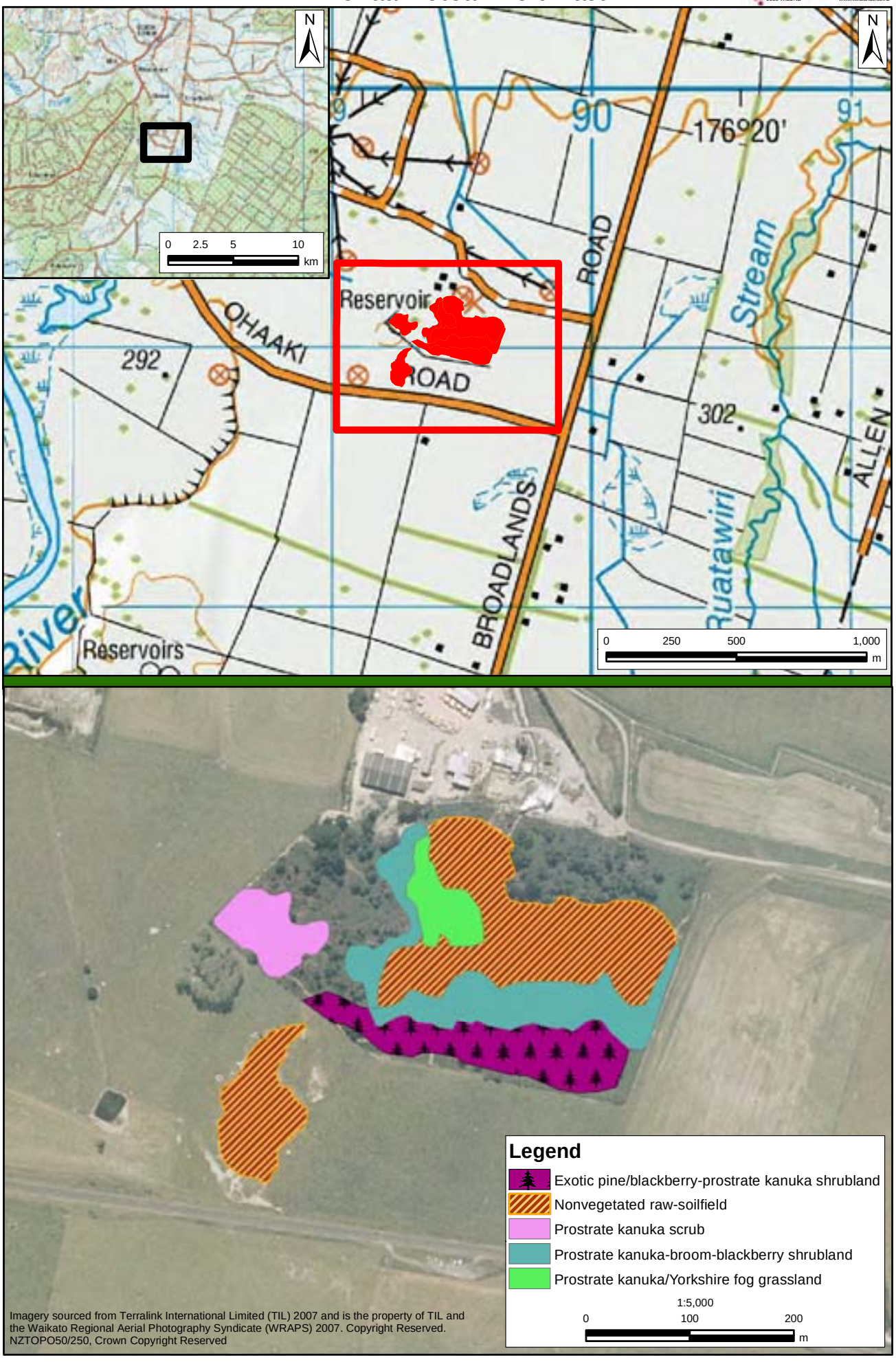
This site was called Ohaaki Steamfield 1 in Beadel & Bill 2000.

References:

Beadel & Bill 2000; Bromley *et al.* 1997; Given 1996; Merrett & Burns 1998a; Merrett *et al*. 2003; Vaile 1939; Wildland Consultants 2004.

OHV02

Ohaaki Steamfield East



OHAAKI STEAMFIELD EAST

Site Number: OHV02[1]

Grid Reference: NZTopo50 BG37 895 291
GPS Reference: NZTM E1889483 N5729076
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Ohaaki
Bioclimatic Zone: Submontane
Tenure: Part unprotected private land, part protected (QEII)
Altitude: 305 m
Extent of Geothermal Habitat: *c.*6.8 ha
Extent of Geothermal Vegetation: *c.*6.8 ha
Date of Field Survey: 28 January 2011

Code	Type	Landform	Extent
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka scrub dominates this area with occasional patches of manuka scrub. Mingimingi, monoao, Spanish heath, broom and bracken are present on the margins with scattered emergent radiata pine and maritime pine, and small areas of raw-soilfield and moss patches are also present.	Geothermal basin	*c.*0.5 ha
05.01 05.01.13	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka-broom-blackberry shrubland** Occasional maritime pine and radiata pine are emergent over prostrate kanuka, broom and blackberry. Yorkshire fog, lotus, fleabane and gorse are also present.	Geothermal basin	*c.*1.5 ha
05.13 05.13.02	**Blackberry-dominant shrubland** **Exotic pine/blackberry-prostrate kanuka shrubland** Scattered maritime pine and radiata pine occur over blackberry, broom, Spanish heath, gorse, and manuka, with patches of prostrate kanuka in thermal areas.	Geothermal basin	*c.*1.2 ha
08.01 08.01.02	**Yorkshire fog-dominant grassland** **Prostrate kanuka/Yorkshire fog grassland** Scattered patches of prostrate kanuka occur throughout Yorkshire fog grassland. Fleabane, grey willow and bracken occur on the margins.	Geothermal basin	*c.*0.4 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** 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 kanuka, fleabane, lotus and Yorkshire fog.	Low hills	*c.*3.1 ha

Indigenous Flora: Prostrate kanuka, ‚At Risk-Naturally Uncommon' (de Lange *et al.* 2009) 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).

[1] Previously identified as U17/14 in Wildland Consultants (2004).

Fauna:

Common indigenous and introduced bird species typical of the habitat are present including spur-winged plover, chaffinch, Californian quail, house sparrow and fantail.

Cat sign was noted during this survey.

Current Condition (2011 Assessment):

Given (1989a) 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.

The landowner has recently mulched a track through the blackberry and has started to fell 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.

The site is currently in relatively poor condition, with abundant pest plants and recent human disturbance, however values are likely to be improved if management of site threats is undertaken.

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 (with cones) is present in this site.

Human impacts (*2011 Assessment*):

Ohaaki Power Station draws water from the underlying geothermal resources and this may potentially affect features dependent on geothermal heat. However, to date there is no evidence of cooling or heating of the site (Burns 1997a; Merrett & 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 kanuka seedlings were noted along the newly formed track and may continue to grow on the disturbed sites.

Grazing (*2011 Assessment*):

Most of this site is fenced to exclude domestic livestock but one area of nonvegetated raw-soilfield is in a grazed paddock.

Adjoining land use (*2011 Assessment*):

This site is mainly surrounded by farmland with the Ohaaki Thermal Kiln operation on the northern margin.

Site Change:

Recent change: With no geothermal wastewater entering the centre of this site, and no geothermal water present, vegetation changes have occurred since the site was last mapped in 2004. Prostrate kanuka has become established on part of what was previously nonvegetated raw-soilfield.

Blackberry appears to have increased in its dominance, particularly in the southern half of the site (the fenced portion).

Historical: In 1941 (Historical photos: SN 172 Run 1169 Photos 27-29, 1941) the site appeared to be in a considerable 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 as a percentage loss of geothermal vegetation at the site is difficult to determine. The vegetation present is likely to be of a significantly higher quality due to the lack of pest plants and industrial waste. A crude estimate is that it is likely that there was *c.*10-25% more geothermal vegetation and habitats at this site in 1941 than in 2007. The extent of nonvegetated raw-soilfield is also greater.

Management Requirements: Adventive weeds that need to be controlled at this site include wilding pines, blackberry, Spanish heath and gorse. The existing, recently-formed tracks could be used to provide access for weed control and planting, but they should be allowed to be naturally reduced in width as the prostrate kanuka 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.

Options for injecting geothermal water will probably also need to be assessed by engineers and geologists.

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

Significance Justification: Ohaaki Steamfield East is of regional significance because it is partially protected by aa QEII National Trust covenant and is a relatively large example of a nationally uncommon habitat type. It contains a good population of an ‚At Risk' species (prostrate kanuka).

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 B - the second highest category.

This site was called Ohaaki Steamfield 2 in Beadel & Bill 2000.

References: Beadel 1986; Beadel & Bill 2000; Burns 1997a; Given 1989a & 1996; Merrett & Burns 1998a; Merrett *et al*. 2003; Wildland Consultants 2004.

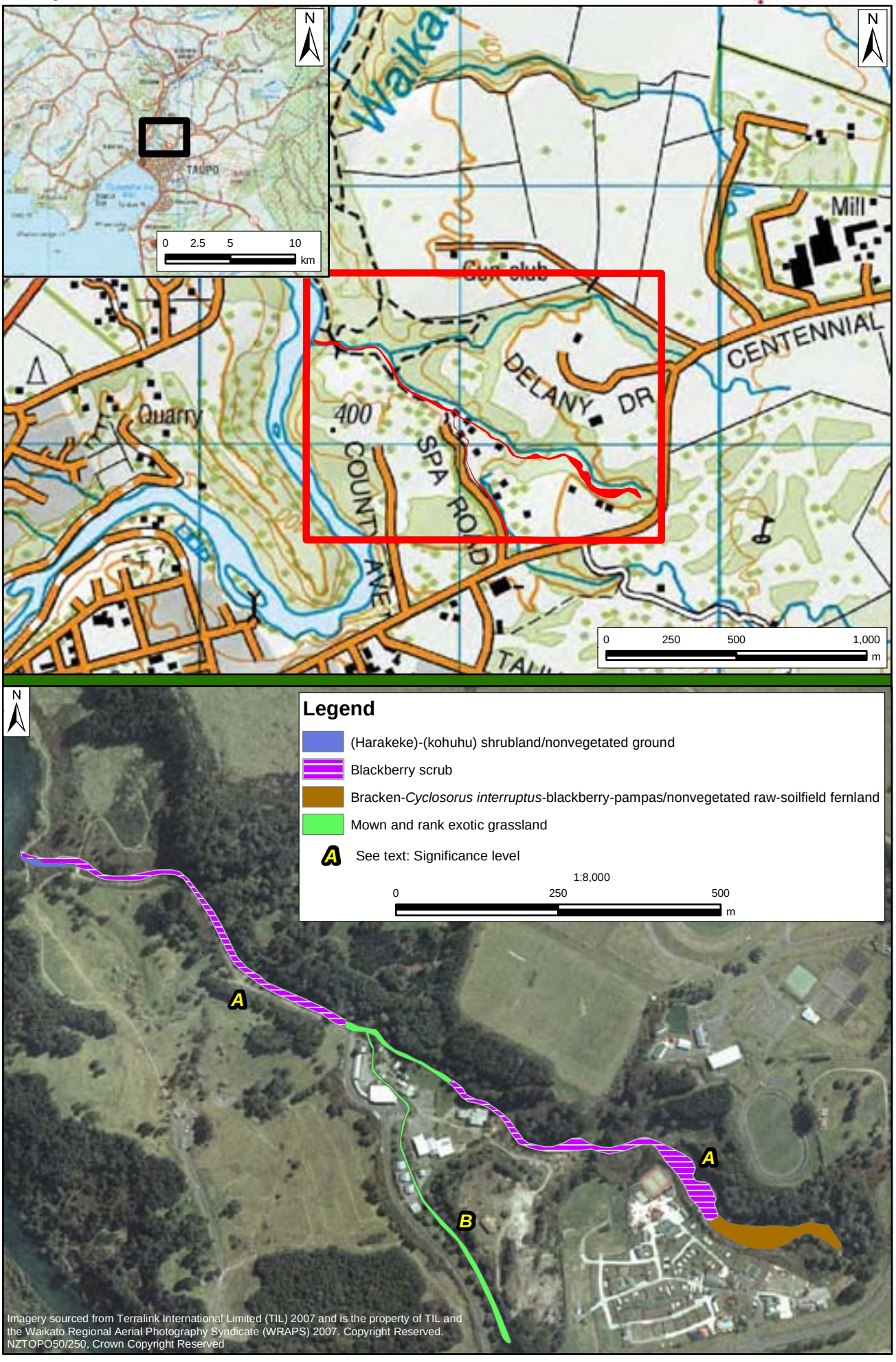
1.12 WAIRAKEI-TAUHARA GEOTHERMAL FIELD

List of Geothermal Sites

THV01	Otumuheke
THV03	Spa Thermal Park
THV04	Broadlands Road
THV05	Crown Park
THV06	Crown Road
THV07	Waipahihi Valley
WKV01	Te Rautehuia
WKV02	Te Rautehuia Stream
WKV03	Upper Wairakei Stream (Geyser Valley)
WKV04	Wairakei Borefield
WKV05	Te Kiri O Hine Kai Stream Catchment/Wairoa Hill
WKV06	Lower Wairakei Stream
WKV07	Karapiti Forest
WKV08	Hall of Fame Stream
WKV09	Waipouwerawera Stream/Tukairangi
WKV10	Craters of the Moon

THV01

Otumuheke



OTUMUHEKE

Site Number: THV01[1]
Grid Reference: NZTopo50 BG36 691 151
GPS Reference: NZTM E1869068 N5715075
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Protected (Patuiwi Marginal Strip) and unprotected private land
Altitude: *c.*380-400 m
Extent of Geothermal Habitat: *c.*2.3 ha
Extent of Geothermal Vegetation: *c.*2.3 ha
Date of Field Survey: 10 December 2010

Code	Type	Landform	Extent
05.07 05.07.02	**Planted indigenous shrubland** **(Harakeke)-(kohuhu) shrubland/nonvegetated ground** Nonvegetated ground with scattered indigenous plantings on the true left bank of the stream mouth. The bare ground is a result of herbicide application and subsequent planting of a small suite of indigenous species including harakeke, kohuhu, and manuka. The planted species are not thriving and several have died. In most places this vegetation type extends to the top of the stream bank, but the cleared vegetation extends to the stream margin in one location.	Stream margin	*c.*0.1 ha
07.05 07.05.13	**Mixed fernland** **Bracken-*Cyclosorus*-blackberry-pampas/nonvegetated raw-soilfield fernland** A mixed fernland dominated by bracken, *Cyclosorus interruptus*, *Hypolepis ambigua,* and *Histiopteris incisa. Cyclosorus interruptus* is increasingly common towards the eastern part of this vegetation type, near the most geothermally active part of the site. Occasional pampas and blackberry are present. There are patches of raupo, tall fescue*, Juncus edgariae*, *Carex secta* and *Cyperus ustulatus* in the cooler wetland areas, and prostrate kanuka on hummocks within the wetland. The eastern-most part of this vegetation type is the most geothermally active, with areas of sinter beside the stream and local patches of *Lycopodiella cernua*. The geothermally active parts of the wetland are difficult to access due to scalding water and an unstable streambed. Species present on dry, cooler sites include Indian doab, Yorkshire fog, sweet vernal, karamu, inkweed (*Phytolacca octandra*), umbrella sedge (*Cyperus eragrostis*), wilding pine seedlings, and extensive areas of giant bindweed.	Floor of an incised stream gully	*c.*0.5 ha
04.08 04.08.01	**Blackberry-dominant scrub** **Blackberry scrub** Blackberry, bracken, and *Muehlenbeckia australis* dominate the banks of the Otumuheke Stream, with exotic grasses such as	Stream margin	*c.*1.3 ha

[1] Previously identified as U18/3 (Otumuheke Stream) in Wildland Consultants (2004).

Code	Type	Landform	Extent
	tall fescue and Yorkshire fog, buddleia, and bracken. There are occasional patches of crack willow, wilding pine (mostly maritime pine), lupin (*Lupinus arboreus*), tradescantia (*Tradescantia fluminensis*), silver birch, gorse, and broom, which are encroaching from the margins. In places, the blackberry vineland is overhung by tall maritime pines and there are local patches of kanuka and false acacia (*Robinia pseudoacacia*). The false acacia trees, most of which are present a short distance upstream of the Spa Hotel, have been poisoned, but seedlings are establishing beneath them. *Histiopteris incisa* and occasional wheki-ponga occur above the vehicle bridge. On the steep stream banks downstream of the Spa Hotel there are small, scattered patches of *Nephrolepis flexuosa* and *Christella* aff. *dentata* ("thermal"). They become more common near the mouth of the stream but populations of both species, particularly *Nephrolepis flexuosa*, have been damaged by vegetation clearance at this location. Other ferns on the steep banks include *Deparia petersenii*, kiokio, and occasional *Cyclosorus interruptus*.		
08.06 08.06.03	**Mixed exotic-dominant grassland** **Mown and rank grassland** Within the grounds of the Spa Hotel, the banks of the Otumuheke Stream are dominated by mown and rank grasses with adventive plants and planted ornamentals. Grasses include Yorkshire fog, Indian doab, paspalum, and browntop. Occasional planted specimen trees include kahikatea (*Dacrycarpus dacrydioides*), totara, kohuhu, plum (*Prunus ×domestica*), and feijoa. Naturalised species include foxglove (*Digitalis purpurea*), lotus, flowering cherry, silver birch, ivy, blackberry, and umbrella sedge. Species present on the banks of the side stream that flow into Otumuheke Stream include umbrella sedge, lotus, silver birch seedlings, blackberry, and turutu. Upstream of the tavern, the stream has been redirected into a channel between low stone walls with overhanging harakeke, Tasmanian blackwood, and oak. There is a single clump of *Christella* aff. *dentata* ("thermal") and a clump of *Hypolepis dicksonioides* on the banks above the stream.	Stream margin	*c*.0.4 ha

Indigenous Flora:

Approximately 44 clumps of *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al.* 2009) and four clumps of *Nephrolepis flexuosa* (classed as „At Risk-Declining' in de Lange *et al.* 2009) occur near where the Otumuheke Stream flows into the Waikato River. A further three clumps of *Christella* aff. *dentata* ("thermal") occur at GPS Ref 1868683 5715377. There are also single plants of *Christella* aff. *dentata* ("thermal") alongside the stream in the lower half of the gully.

Cyclosorus interruptus (classed as „At Risk-Declining' in de Lange *et al.* 2009) is abundant in the upper part of the valley in Vegetation Type 07.05.13 with at least 200 plants present.

Hypolepis dicksonioides (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) is present along the side stream, and may also be

present elsewhere. The plants recorded in 2004 are no longer present in the same location.

Lycopodiella cernua (a species characteristic of geothermal areas) is abundant at the eastern end of the site in Vegetation Type 07.05.13.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including fantail, shining cuckoo, kingfisher, chaffinch, song thrush, tui, and grey warbler.

Current Condition (2010 Assessment): The geothermal wetland in the upper reaches of the site is in relatively good condition and is one of few such areas of sinter wetland remaining around Taupo. The remainder of the stream gully is highly modified and is dominated by invasive exotic plants. 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 (*2010 assessment*)*:* Blackberry (50-75% cover) dominates the stream margins, and wilding pines (1-5% cover) and pampas (5-25% cover) are scattered throughout (each with 1-5% cover). Himalayan honeysuckle is also present (<1% cover).

Human impacts (*2010 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 are present and ornamental trees are present.

Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) (www.nzgeothermal.org.nz site accessed 28/6/11) and this may further alter the geothermal vegetation.

Grazing (*2010 assessment*)*:* Livestock are not a current threat to this area.

Adjoining land use (*2010 assessment*)*:* Scrub comprising adventive and indigenous species.

Site Change:

Recent change: Since 2009, vegetation clearance works near the stream mouth has destroyed a large portion of the *Nephrolepis flexuosa* population and a few plants of *Christella* aff. *dentata* ("thermal"). The *Nephrolepis flexuosa* population has become particulary vulnerable because of increased erosion, and exposure to frosts.

An additional geothermal stream near the Spa Hotel was found. In previous surveys, this area was under thick blackberry and thus was not recorded.

Flooding has caused dieback of blackberry on stream margins and has

probably washed out some ferns recorded in earlier surveys. This may provide new habitat for establishment of „At Risk' fern species. Pines have also been removed from gully walls, and pampas has been controlled by the Waikato Regional Council, particularly in the upper stream gully (Waikato Regional Council 2011).

Historical: This site is too small to see any evidence of change since 1946 (Historical photos: SN 172 Run 1176 Photos 4, 1946). A geothermal wetland once occurred at the site of the Spa Hotel (Given 1989a).

Management Requirements: The geothermal wetland (Vegetation Type 07.05.13), and the stream and its margins should be managed as a single unit to ensure that the ecological sequence is preserved. Weed control efforts should focus on preventing the establishment of blackberry, pampas, and wilding pines within the geothermal swamp (07.05.13).

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.

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.

Changes in vegetation associated with draw-off from the geothermal field need monitoring.

Significance Level: A: National (Table 1 - Criteria 3, 5, 6; 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 a nationally uncommon habitat type. The thermal swamp at the head of the Otumuheke Stream remains in excellent condition despite disturbances downstream. With its close proximity to Centennial Drive, it is one of few such areas close to Taupo.

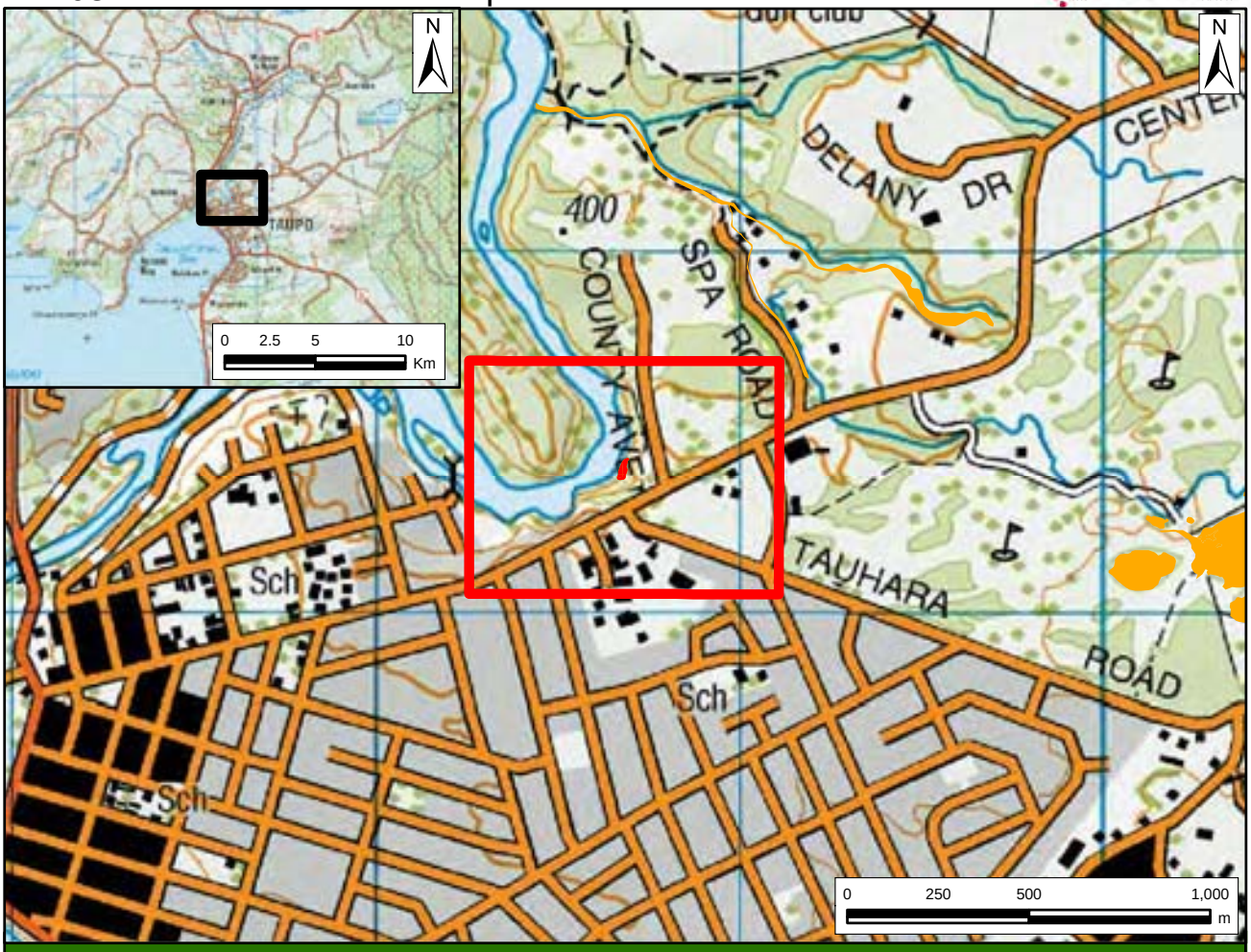
This site contains sizeable populations of two „At Risk' species: *Christella* aff. *dentata* ("thermal") and *Cyclosorus interruptus*. It is one of only 14 populations of *Christella* aff. *dentata* ("thermal") in existence and comprises at least 44 clumps. There are at least 200 plants of *Cyclosorus interruptus* at the eastern end of the site, and a small population of *Hypolepis dicksonioides* („At Risk-Naturally Uncommon') and *Nephrolepis flexuosa* („At Risk-Declining') are also present.

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, a nationally rare habitat type. It contains a small population of *Christella* aff. *dentata* ("thermal") and geothermal habitat.

Notes:	This site comprises two areas ranked in Given (1996): "Upper Spa Stream" and "Lower Spa Stream", ranked as B and C sites respectively.
References:	Beadel & Bill 2000; Given 1989a & 1996; Waikato Regional Council 2011; Wildland Consultants 2004.

THV03

Spa Thermal Park



SPA THERMAL PARK[1]

Site Number: THV03[2]
Grid Reference: NZTopo50 BG36 687 144
GPS Reference: NZTM E1868685 N5714383
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Tauhara
Bioclimatic Zone: Submontane
Tenure: Protected (Taupo District Council Reserve)
Altitude: *c.*400 m
Extent of Geothermal Habitat: *c.*0.1 ha
Extent of Geothermal Vegetation: *c.*0.1 ha
Date of Field Survey: 7 April 2004 (partly revised on 20 December 2011)

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.01 04.01.02	**Prostrate kanuka-dominant scrub** **Prostrate kanuka-mingimingi scrub** Prostrate kanuka forms *c.*80% of the canopy in association with mingimingi and occasional broom. There is at least one wild radiata pine that is *c.*5m tall. This type occurs below the cliff.	Steep slopes	<0.1 ha
04.02 04.02.12	**Mingimingi-dominant scrub** **Mingimingi scrub** Mingimingi dominates the scrub above the cliff, with occasional prostrate kanuka and silver birch seedlings.	Steep slopes	<0.1 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka with mingimingi form a shrubland around small patches of nonvegetated raw-soilfield on the steep slopes above the true right side of the Waikato River. Other species present include occasional gorse, broom, browntop, koromiko, and karamu.	Steep slopes	<0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Bare geothermal soils occur on a cliff near the Waikato River, with bracken present at the base of the cliff.	Steep slopes	<0.1 ha

Indigenous Flora: Prostrate kanuka, which is characteristic of geothermal habitats and is classed as „At Risk-Naturally Uncommon' (in de Lange *et al.* 2009), 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 kanuka indicate activity in recent times. Non-geothermal vegetation appears to be encroaching downslope at present, and this is likely to continue if geothermal activity at the site does

[1] This site is called Broadlands Road/Wairakei Park in Beadel & Bill (2000).
[2] Previously identified as U18/11 in Wildlands (2004 and 2006).

not increase.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 assessment*)*:* Broom (5-25% cover), gorse (1-5% cover), and wilding pine trees (1-5% cover) are present and are probably expanding in extent within the areas of geothermal vegetation.

Human impacts (*2011 assessment*)*:* Rubbish (e.g. beer bottles, tape decks, old clothing) is present on the site. Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) (www.nzgeothermal.org.nz site accessed 28/6/11) and this may further alter the composition of the geothermal vegetation.

Grazing (*2011 assessment*)*:* No threat from grazing.

Adjoining land use (*2011 assessment*)*:* Riparian margin scrub and shrubland, and cliff faces. Most of the surrounding vegetation is blackberry, Himalayan honeysuckle, broom, and wilding pines. The site is about 20 m above the Waikato River. About 20 m above the site is a recreational park.

Site Change:

Recent change: The site appears similar to 2004. Although the 2011 site area is slightly larger than that mapped in 2004, this increase is mostly related to better quality aerial photographs.

Historical: This site is too small to see any evidence of change since 1946 (Historical photos: SN 172 Run 1176 Photos 3-4, 1946). According to Bromley *et al.* (2010), Spa Park was historically geothermally active, but has now cooled off resulting in areas of previously heated ground being covered in prostrate kanuka. According to Burns *et al.* (1995), in 1938 there was an area of prostrate kanuka comprising *c.*10 ha within Spa Park. Soil temperatures under the prostrate kanuka are lower than those usually found, suggesting that the remaining prostrate kanuka is a relict population from when soil temperatures were higher (Burns *et al.* 1995).

Management Requirements: Changes in vegetation associated with draw-off from the geothermal field should be monitored. This site is a low priority for management.

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

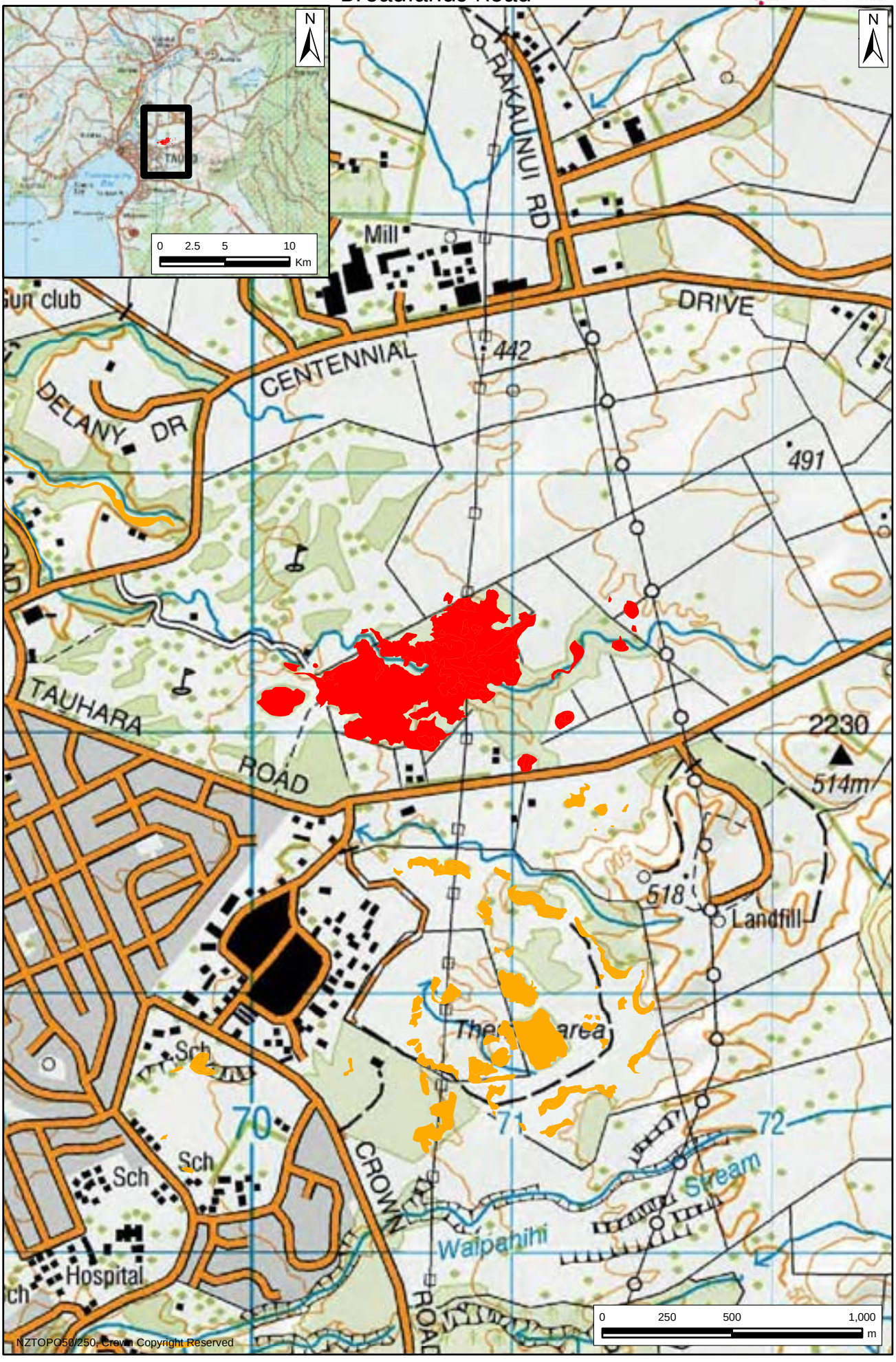
Significance Justification: This site is of local significance because it is a habitat that is nationally uncommon (geothermal), and it contains a small population of a species classed as „At Risk' (i.e. prostrate kanuka).

Notes: It is anticipated that soil temperatures will continue to cool, resulting in a reduction of geothermal vegetation over time. Proposed future development of the geothermal field is not expected to significantly affect this trend. (Bromley *et al.* 2010.)

References: Beadel & Bill 2000; Bromley *et al.* 2010; Burns *et al.* 1995; Given 1996; Wildland Consultants 2004 & 2006.

THV04

Broadlands Road



THV04

Broadlands Road

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Legend

- Blackberry-broom/Yorkshire fog shrubland
- Geothermal water
- Kanuka shrubland
- Manuka/bracken-broom shrubland<->broom-bracken-blackberry shrubland<->prostrate kanuka scrub
- Nonvegetated raw-soilfield
- Prostrate kanuka scrub
- Prostrate kanuka shrubland
- State Highway constructed since 2007 (Approximate boundary)

1:6,500

0 500 1,000 m

BROADLANDS ROAD

Site Number: THV04[1]
Grid Reference: NZTopo50 BG36 706 140
GPS Reference: NZTM E1870625 N5713977
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Protected (Broadlands Road Geothermal Scenic Reserve) and unprotected private land
Altitude: 455 m
Extent of Geothermal Habitat: *c.*29.8 ha
Extent of Geothermal Vegetation: *c.*29.7 ha
Date of Field Survey: 3 March 2011

Code	Type	Landform	Extent
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** A dense canopy of prostrate kanuka (up to *c.*1 m high) with occasional monoao. The ground cover comprises a mixture of lichens, mosses (including *Campylopus* spp.) and liverworts, with occasional *Lycopodiella cernua*. There are occasional emergent maritime and radiata pine (more common on the western side of this site).	Undulating plateau	*c.*18.9 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka 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
05.03 05.03.24	**Manuka-dominant shrubland** **Manuka/bracken-broom shrubland ⇔ broom-bracken-blackberry shrubland ⇔ prostrate kanuka scrub** A large area dominated by exotic shrubs (broom and blackberry) with occasional emergent manuka and maritime pine. Small areas of prostrate kanuka shrubland are present within this area. Bracken and kiokio are abundant throughout and Mercer grass and Indian doab are dominant in open areas which occur locally.	Undulating plateau	*c.*5.9 ha
05.13 05.13.05	**Blackberry-dominant shrubland** **Blackberry-broom/Yorkshire fog shrubland** This type is dominated by blackberry, broom, Himalayan honeysuckle and Yorkshire fog along a narrow strip in a valley floor. There are scattered prostrate kanuka. Small wetland areas are present dominated by *Carex virgata* and *Baumea rubiginosa,* and are surrounded by Yorkshire fog.	Gully	*c.*0.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Geothermal pond.	Explosion crater	*c.*0.1 ha

[1] Previously identified as U18/7 in Wildland Consultants (2004, 2006)

Code	Type	Landform	Extent
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Steaming ground, mud pools, explosion craters and fumaroles. Small patches of prostrate kanuka occur on the margins. No sinter was recorded from this site.	Plateau	*c.*4.5 ha

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) and *Campylopus* spp., which are restricted to geothermal areas occur here. *Lycopodiella cernua*, and *Psilotum nudum*, which are both characteristic of geothermal areas, are also present. (Note the latter of these was observed at the site in 2007).

Fauna: New Zealand pipit classed as „At Risk-Declining' (Miskelly *et al.* 2008) have been recorded at this site. Common indigenous and introduced bird species typical of the habitat, including spur-winged plover, fantail, Australasian blackbird and magpie have been recorded at this site.

Current Condition (2011 Assessment): Anew State Highway 1 bypass around Taupo has been constructed over part of the site, however no geothermal vegetation has been lost from this site due to this construction.

This site contains a relatively large area of prostrate kanuka shrubland and scrub. Whilst adventive species are common in the reserve, the areas of prostrate kanuka 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 plants 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%), strawberry tree (*Arbutus unedo*; one recorded in 2007).

Human impacts (*2011 Assessment*): The new State Highway 1 bypass around Taupo has been constructed over part of the site, although not through areas of geothermal activity. The site is still vulnerable to further degradation from farming activities and Golf Course expansion. The new highway 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. A fire was recorded near the site on 7 June 2007.

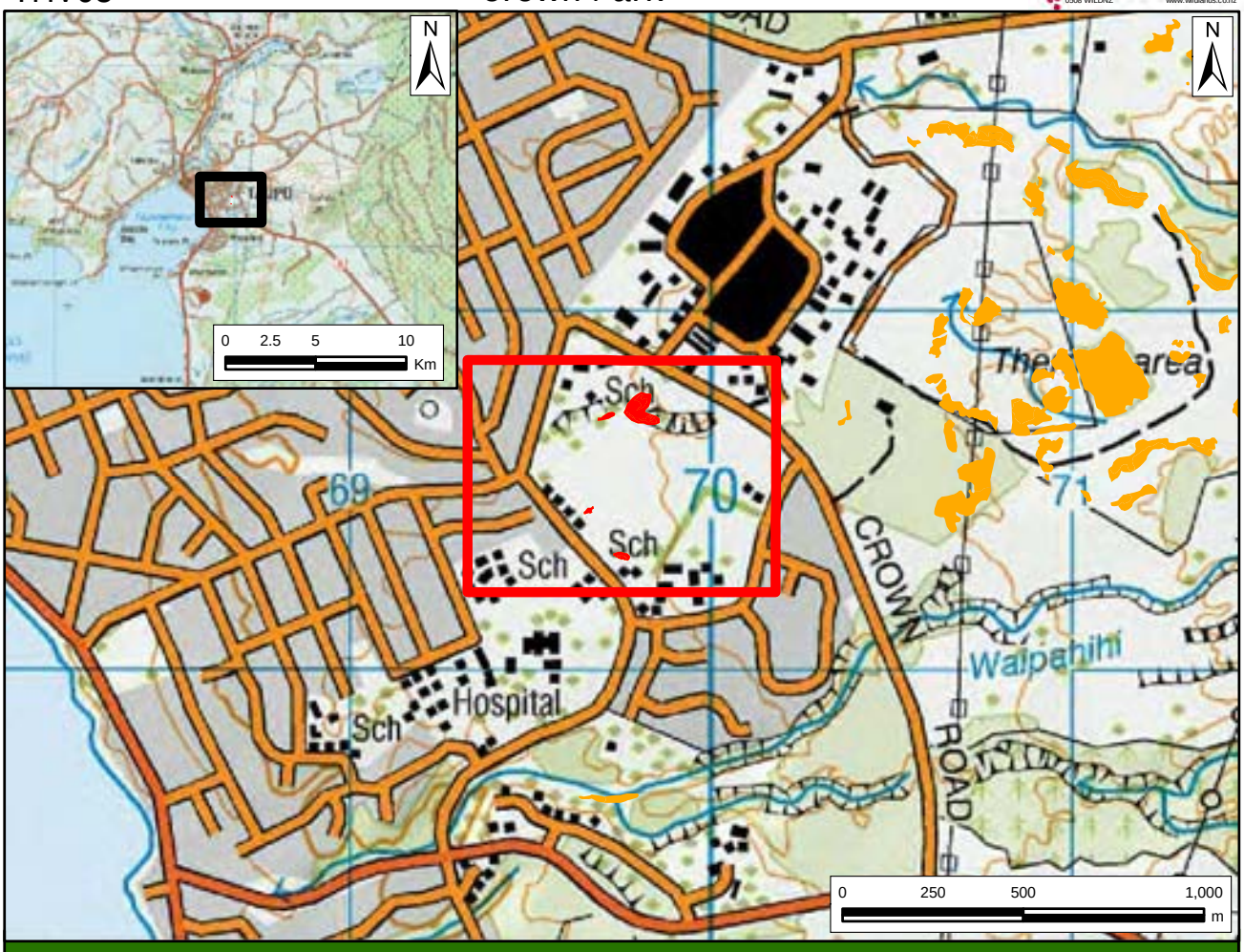
This site is also vulnerable to the impacts of draw-off from the geothermal field and the vegetation and geothermal features underwent large changes with the establishment of Wairakei Power Station (Burns 1996a). Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) (www.nzgeothermal.org.nz site accessed 28/6/11) and this may further alter the geothermal vegetation.

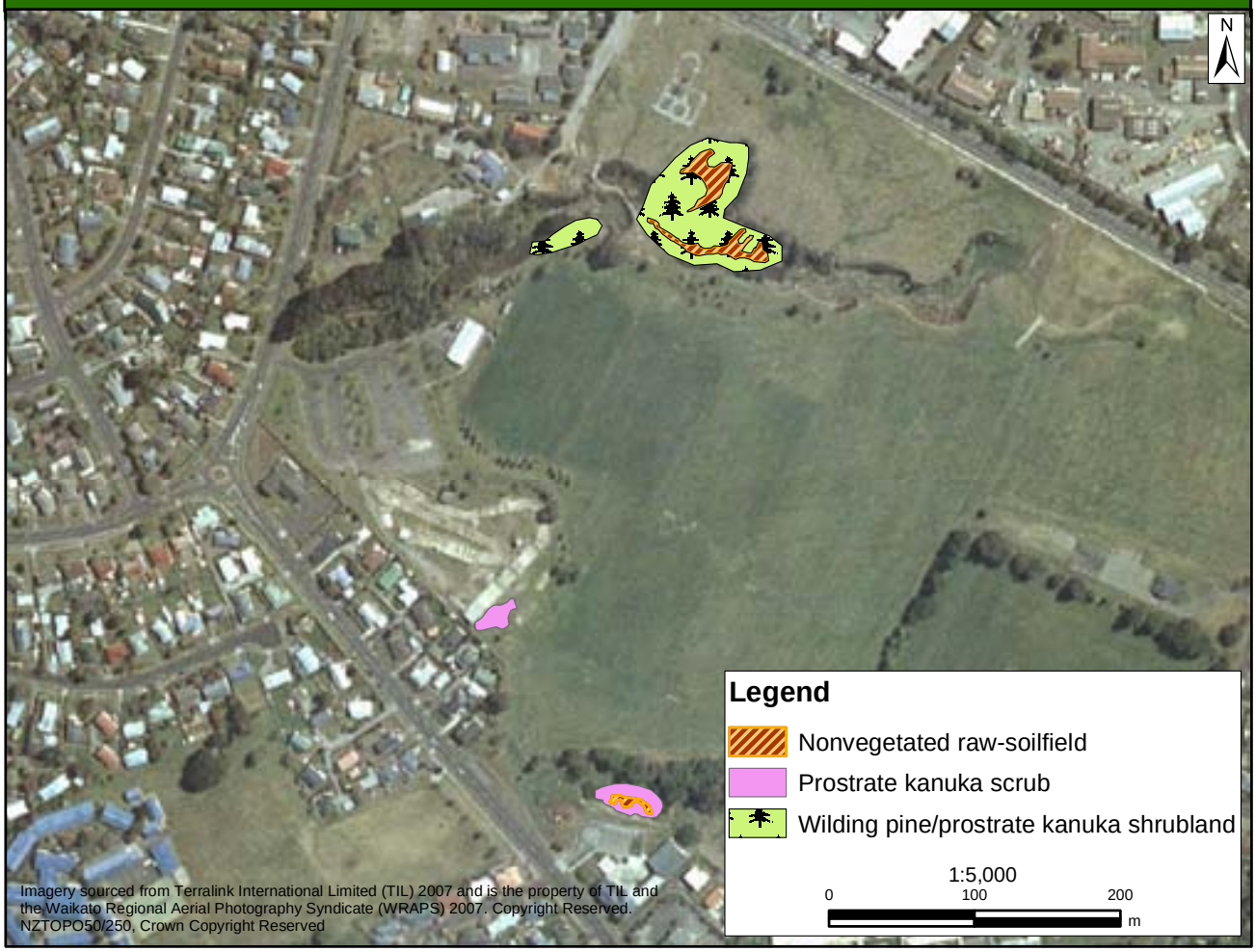
Grazing (*2011 Assessment*): Small areas to the east of the reserve are accessible to stock. Pest animals, including rabbits, hares, and possums, are also likely to impact geothermal sites by grazing and browse.

Adjoining land use (*2011 Assessment*):	Golf course; farming; state highway.
Site Change:	
Recent change:	The new State Highway 1 bypass around Taupo now passes through this 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:	In 1946 there was bare ground in the vicinity of the site. This may indicate that the cover of geothermal vegetation and habitat was more extensive at that time than it is today (Historical photos: SN 172 Run 1176 Photos 5-6, 1946). Burns *et al* (1995) also noted that the 1938 and 1963 photographs showed respectively 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 should continue to be removed from areas where prostrate kanuka is dominant. Changes in vegetation associated with draw-off from the geothermal field need monitoring.
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 kanuka (an „At Risk' species), and comprises a relatively large example of geothermal habitat, a nationally uncommon habitat type.
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 B - the second highest category. 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 2004.
References:	Beadel & Bill 2000; Bromley *et al.* 2010; Burns 1995 & 1996a; Given 1989a & 1996; Grove *et al*. 1999; Wildland Consultants 2004, 2006 & 2007e.

THV05

Crown Park





CROWN PARK

Site Number: THV05[1]
Grid Reference: NZTopo50 BG36 698 127
GPS Reference: NZTM E1869808 N5712732
Local Authority: Taupo
Ecological District: Taupo
Geothermal Field: Tauhara
Bioclimatic Zone: Submontane
Tenure: Protected (Taupo District Council Reserve)
Altitude: *c.*440 m
Extent of Geothermal Habitat: 0.7 ha
Extent of Geothermal Vegetation: 0.7 ha
Date of Field Survey: 7 April 2004 (partly revised on 7 June 2006)

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Two small units of prostrate kanuka. The small unit to the east surrounds a small patch of nonvegetated raw-soilfield and contains occasional broom, blackberry, manuka, and *Banksia* sp. Several patches of narrow-leaved carpet grass were present. The small patch of prostrate kanuka to the west contains occasional pampas.	Plateau, gully	0.1 ha
05.01 05.01.14	**Prostrate kanuka-dominant shrubland** **Exotic pine/prostrate kanuka shrubland** Maritime pine on margins occurs over a prostrate kanuka shrubland. Other species present include the occasional broom, blackberry, pampas, Himalayan honeysuckle, and eucalyptus. Blackberry occurs with prostrate kanuka in the eastern unit of this geothermal area. Several plants of *Lycopodiella cernua* are present.	Shallow gully	0.5 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Heated soils, fumaroles with small patches of prostrate kanuka.	Shallow gullies	0.1 ha

Indigenous Flora: The site supports a small area (i.e. less than 1 ha) of prostrate kanuka (classed as an „At Risk-Naturally Uncommon' species in de Lange *et al.* 2009). *Lycopodiella cernua*, a species characteristic of geothermal areas, is also present.

Fauna: No „Threatened' or „At Risk' species as listed in Miskelly *et al.* (2008) are known from this site. Common indigenous and introduced bird species typical of the habitat are present.

[1] Previously identified as U18/12 in Wildland Consultants (2006).

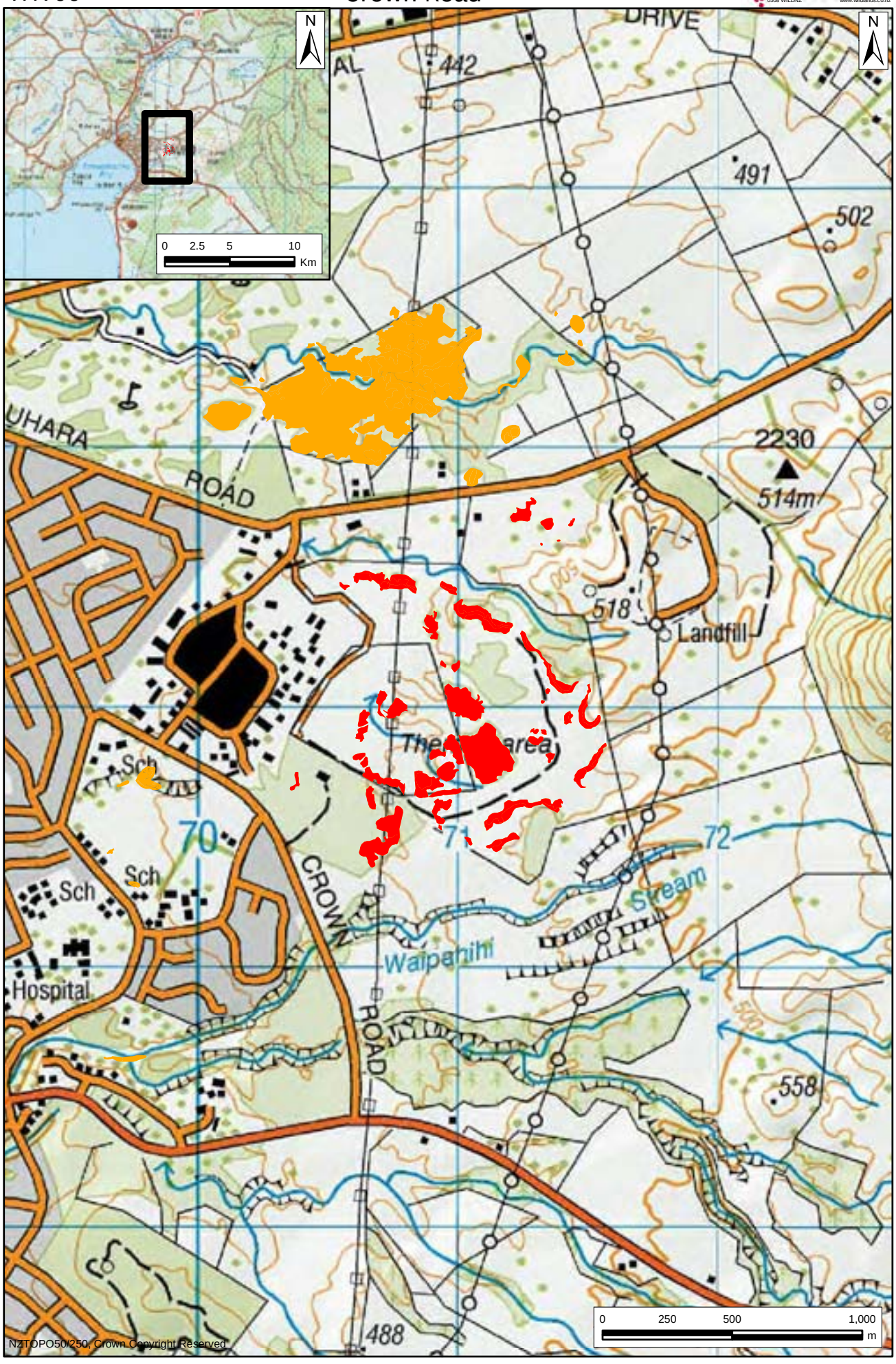
Current Condition (2006 Assessment):	The site is in poor condition with a large number of pest plants present amongst the prostrate kanuka. Rubbish and walking tracks dissect areas of prostrate kanuka.
Threats/Modification/ Vulnerability:	
Invasive pest plants (*2006 Assessment*)*:*	The site is threatened by pest plant species infestation, particularly blackberry which currently covers 5-25% of the site, and wilding maritime pines which cover 5-25% of site. Control of wilding pines has been undertaken by Waikato Regional Council in recent years (Katherine Luketina pers. comm. 2011) and the cover of pines is likely to have reduced to <5%. Following the pine control work, ongoing pest plant control (particularly pine seedlings and broom) has been carried out by Waikato Regional Council. Other pest plant species present include flowering cherry, eucalyptus, pampas, broom, and Himalayan honeysuckle, each with 1-5% cover.
Human impacts (*2006 Assessment*)*:*	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. Additional draw-off from the Tauhara geothermal field has been consented (250 MW power plant) (www.nzgeothermal.org.nz site accessed 28/6/11) and this may result in further changes to the geothermal vegetation cover.
Grazing (*2006 Assessment*)*:*	Livestock are not a threat to this area.
Adjoining land use (*2006 Assessment*)*:*	Recreation reserve.
Site Changes:	
Recent change:	This site was not revisited as part of this study, however pest plant control and the removal of rubbish has been undertaken by Waikato Regional Council (Katherine Luketina, pers. comm. 2011) and therefore the extent of pest plants at the site is likely to be smaller than in 2006.
Historical:	This site is too small to see any evidence of change since 1946 (Historical photos: SN 172 Run 1176 Photos 4-5, 1946). Burns *et al.* (1995) found that 1963 aerial photos showed a 10-20% loss of the gully area due to infilling.
Management Requirements:	Any reinvasion of wilding pines and other pest plants in this site should be contained. Monitoring of vegetation changes as a result of geothermal draw-off should be carried out.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2 - Factor 19).
Significance Justification:	This site is of local significance because it is an example of a nationally uncommon habitat type and contains a small population of an „At Risk' species - prostrate kanuka.
Notes:	This site was previously identified as being of regional significance because it provides habitat for prostrate kanuka, an „At Risk' species (Wildland

Consultants 2006). However, the revised criteria for relative significance state that a site must be a habitat of "considerable importance" for an „At Risk' species to achieve regional significance status. This site is in poor condition and includes only a small population of prostrate kanuka.

References: Burns *et al.* 1995; Wildland Consultants 2004 & 2006.

THV06

Crown Road



THV06

Crown Road

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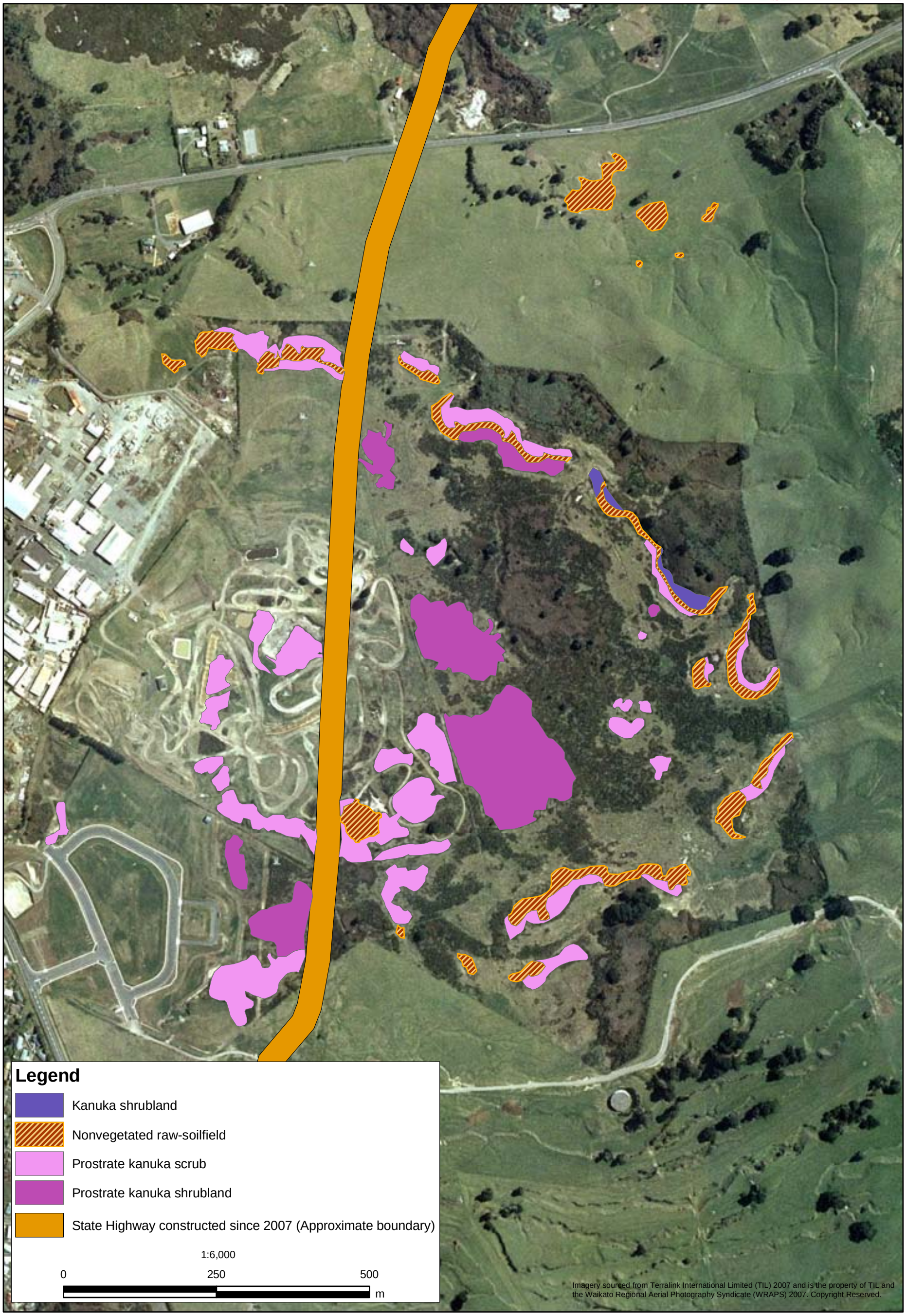


CROWN ROAD

Site Number: THV06[1]
Grid Reference: NZTopo50 BG36 711 128
GPS Reference: NZTM E1871110 N5712827
Local Authority: Taupo
Ecological District: Taupo; Atiamuri
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: 460 m
Extent of Geothermal Habitat: *c.*17.5 ha
Extent of Geothermal Vegetation: *c.*17.5 ha
Date of Field Survey: 3 March 2011

Code	Type	Landform	Extent
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka is abundant in association with occasional mingimingi. Occasional broom and emergent wilding pines (maritime pine and radiata pine) are scattered throughout with local patches of blackberry. Mosses and patches of *Lycopodiella cernua* are present locally, particularly around steam vents.	Shallow gullies and flat plateau	*c.*7.4 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka is common with scattered broom, blackberry and exotic grasses. An area of prostrate kanuka that had previously been burned (in 2002) has now re-established as prostrate kanuka shrubland. Broom, buddleia and blackberry occur in localised areas.	Flat plateau	*c.*6.0. ha
05.04 05.04.06	**Kanuka-dominant shrubland** **Kanuka shrubland** Kanuka shrubs dominate the margins of several geothermal areas in association with mingimingi. Broom, blackberry and occasional emergent maritime pine and are also present.	Hillslope	*c.*0.3 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Fumaroles and geothermally heated bare ground is dominant with small patches of prostrate kanuka and exotic grasses.	Shallow gullies	*c.*3.7 ha

Indigenous Flora: The site supports sizeable areas of prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) scrub and shrubland. The area of prostrate kanuka 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), an „At Risk-Naturally Uncommon' species and *Psilotum nudum* were recorded in the southeast corner of the

[1] Previously identified as U18/2 in Wildland Consultants (2004).

site. *D. linearis* is known from only *c.*24 sites in New Zealand.

Fauna: New Zealand pipit (classed as 'At Risk-Declining' in Miskelly *et al.* 2008), tui, bellbird, Australasian harrier hawk, grey warbler, black-backed gull, fantail, paradise shelduck and spur-winged plover were recorded at the site.

Current Condition (2011 Assessment): The new State Highway 1 bypass around Taupo has been constructed through the middle of this site, which has destroyed some geothermal vegetation. Additional vegetation has been 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 kanuka scrub and shrubland, with the development and use of a motorcross track having caused considerable fragmentation of part of 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 south-western area (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 kanuka scrub and shrubland.

Human impacts (*2011 Assessment*): The site has been bisected by the new State Highway 1 bypass around Taupo and is vulnerable to further degradation by farming, motorcycles, and further development for industrial and residential uses. It is also threatened by urban sprawl and human-induced changes to the geothermal field. A fire in the south-western part of the site in March 2002 greatly reduced the cover of prostrate kanuka 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) (www.nzgeothermal.org.nz site accessed 28/6/11) and this may further alter the geothermal vegetation.

Grazing (*2011 Assessment*): The eastern part of the site is farmed and has not been fenced to exclude stock.

Adjoining land use (*2011 Assessment*): Farmland; motorbike track; state highway; industrial area.

Site Change:

Recent change: Approximately 1.5 ha of geothermal vegetation has been lost since 2004. The loss was due, in part, as a result of roading development and construction of an industrial subdivision. Prostrate kanuka shrubland is still recovering after a fire in 2002. Parts of the western side of the new highway are now fenced to exclude stock. The Waikato Regional Council

has recently carried out control of pest plants in areas of prostrate kanuka scrub and shrubland adjoining the new highway.

Historical: Burns *et al*. (1995), following a study of aerial photographs taken in 1963, indicates 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). Historical photos (1946: SN 172 Run 1176 Photos 5-6) show more bare ground than is currently present.

Management Requirements: Formal protection could be considered for parts of this site, which contains good examples of prostrate kanuka shrubland and associated areas of hydrothermally altered soils and heated soilfield. 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.

Significance Level: Regional (Table 1 - Criteria 3, 5, 9; Table 2 - Factors 12, 14).

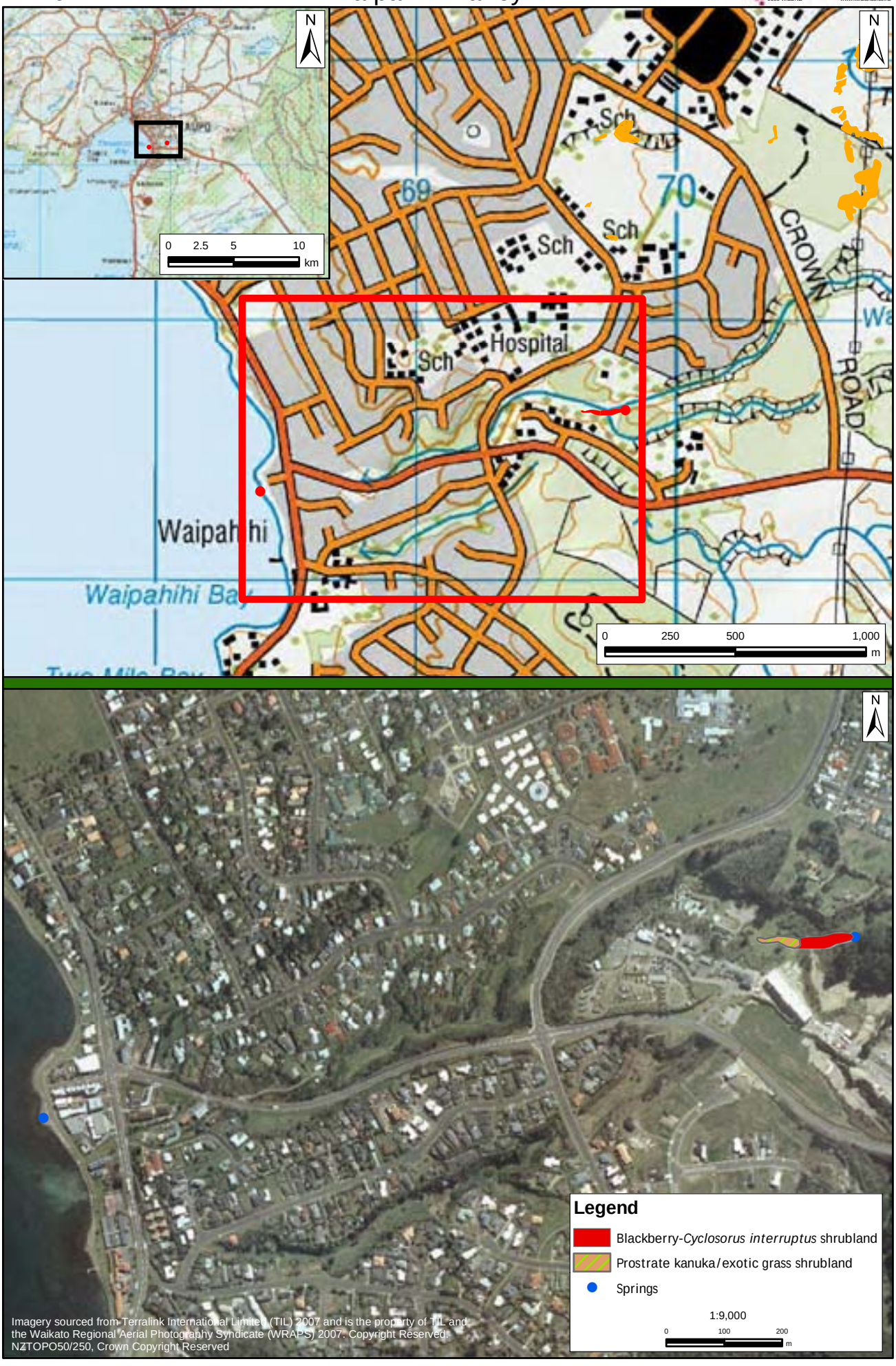
Significance Justification: This site is of regional significance because it comprises a relatively large example of geothermal habitat, which is a nationally uncommon habitat type. It includes prostrate kanuka shrubland and a small population of *Dicranopteris linearis*, both of which are 'At Risk' species. Areas of hydrothermally altered soils and heated soilfield are also present.

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 B - the second highest category for protection.

References: Beadel & Bill 2000; Bromley *et al.* 2010; Burns *et al.* 1995; Given 1989a & 1996; Grove *et al.* 1999.

THV07

Waipahihi Valley



WAIPAHIHI VALLEY[1]

Site Number: THV07[2]
Grid Reference: NZTopo50 BG36 697 116
GPS Reference: NZTM E1869718 N5711647
Local Authority: Taupo
Ecological District: Taupo
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Protected (Waipahihi Stream Conservation Area) and unprotected private land.
Altitude: 420 m
Extent of Geothermal Habitat: *c.*0.3 ha
Extent of Geothermal Vegetation: *c.*0.3 ha
Date of Field Survey: 16 December 2009

Code	Type	Landform	Extent
05.01 05.01.16	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka/exotic grass shrubland** A grassed area has been mown to the stream edge. Scattered prostrate kanuka (1.5-2 m tall) occur on the margins. Small seedlings (up to 3 cm tall) are abundant in areas that are not heavily mown. Grassland species include Yorkshire fog, sweet vernal, prairie grass (*Bromus willdenowii*), browntop, and tall fescue. Occasional harakeke and *Carex secta* are also present. A small modified pool is within this vegetation type.	Valley floor	*c.*0.1 ha
05.13 05.13.06	**Blackberry-dominant shrubland** **Blackberry-*Cyclosorus interruptus* shrubland** Blackberry dominates the stream edges below a geothermal spring. *Cyclosorus interruptus* (*c.*20 clumps) is scattered along stream margins and, in places, is emergent over small plants of blackberry, and exotic herbs and grasses (including sweet vernal, Yorkshire fog, pohue, and Californian thistle). Arrow grass is present on sinter and prostrate kanuka (1.5-2 m tall) occurs along the stream margins. Planted olive (*Olea* sp.) trees and ornamental cherry (*Prunus* sp.) trees are present near the spring.	Valley floor	*c.*0.2 ha

Indigenous Flora: A small population (*c.*20 clumps) of *Cyclosorus interruptus* classed as ‚At Risk-Declining' (de Lange *et al.* 2009) is present, near the spring on the stream margins. Prostrate kanuka and *Hypolepis dicksonioides*, both classed as ‚At Risk-Naturally Uncommon' (de Lange *et al.* 2009) are also present. Arrow grass, which is present near the stream, is more commonly found in coastal situations.

[1] Previously named Waipahihi Stream (De Bretts Thermal Pool) in Beadel & Bill 2000.
[2] Previously identified as U18/5 in Wildland Consultants (2004).

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

Current Condition (2010 Assessment): The spring is fenced, grassed and planted with exotic trees including olive and ornamental cherry. Recent control work to reduce the dominance of blackberry below the spring has provided increased potential habitat for *Cyclosorus interruptus*. Prostrate kanuka occurs in local patches and reaches a height of *c.*2 m. Heated water enters the stream close to the lake edge.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2010 Assessment*): Extensive control work has been undertaken to reduce blackberry (1-5% of cover) along the stream margins near the spring. Other pest plant species include radiata pine (1-5% total cover), ivy (1-5% total cover), ornamental cherry (<1% total cover), olive (<1% total cover), pampas <1% total cover). The Waikato Regional Council has undertaken some small-scale pampas control at this site.

Human impacts (*2011 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 kanuka and *Cyclosorus interruptus* populations. The adjoining landowner has 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) (www.nzgeothermal.org.nz accessed 28/6/11) and this may further alter the geothermal vegetation.

Grazing (*2011 Assessment*): Grazing occurs in fenced area above spring, but stock are excluded from the spring area.

Adjoining land use (*2011 Assessment*): Grazing occurs to the north of this site. Parking, recreational areas and the spa pool complex are present further along the gully floor. A mosaic of indigenous and exotic forest, and restoration plantings occur on the gully sides. Residential dwellings, subdivision and accommodation amenities occur on the valley terraces.

Site Change:

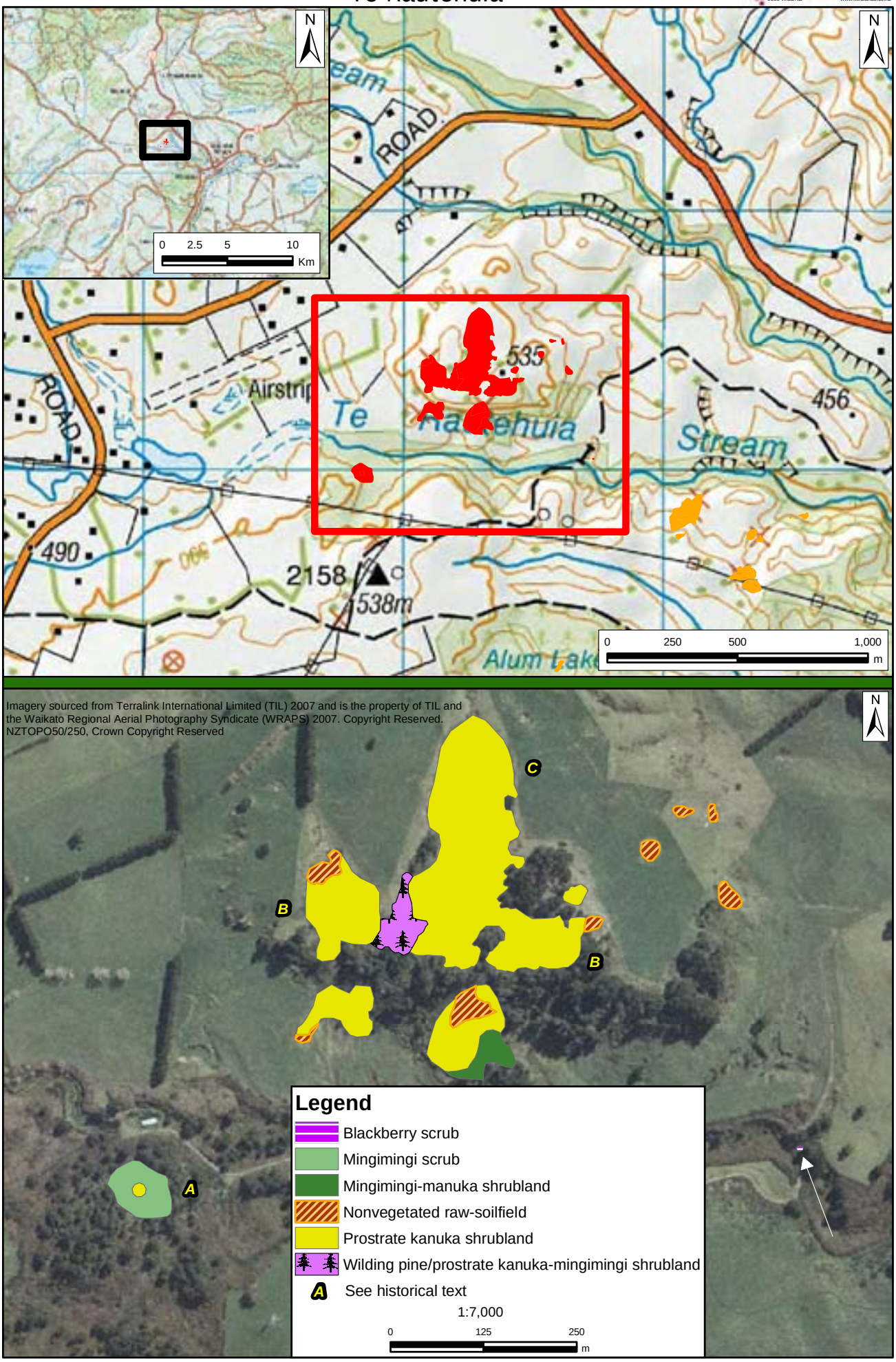
Recent change: Weed control has reduced the blackberry infestation below the spring area.

Historical: An assessment of change in extent and character of geothermal vegetation was made between 1946 historic photographs (Historical photo: SN 172 Run 1177 Photo 5, 1946) and 2007 aerial photographs. 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, although the vegetation in the gully floor is unclear in places. The site was probably significantly larger in the 1940s, and may be at least five to ten times its current size (2007/2011). The stream below the site is likely to have been more geothermal in character.

	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 Taupo (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 raupo 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).
Management Requirements:	A conservative approach to blackberry control is recommended to minimise the risk of sudden exposure to *Cyclosorus interruptus* 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 site should be monitored to identify any potential changes in vegetation associated with draw-off from the geothermal field.
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 and it provides habitat for three 'At Risk' species: prostrate kanuka, *Hypolepis dicksonioides,* and *Cyclosorus interruptus*.
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 for protection.
References:	Beadel & Bill 2000; Cody 1993; Given 1996; Wildland Consultants 2004.

WKV01

Te Rautehuia



TE RAUTEHUIA

Site Number: WKV01[1]
Grid Reference: NZTopo50 BG36 663 225
GPS Reference: NZTM E1866262 N5722450
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: 427 m
Extent of Geothermal Habitat: *c.*7.7 ha
Extent of Geothermal Vegetation: *c.*7.7 ha
Date of Field Survey: 27 January 2011

Code	Type	Landform	Extent
04.02 04.02.12	**Mingimingi-dominant scrub** **Mingimingi scrub** Mingimingi dominates with kanuka, manuka and wheki common throughout and scattered emergent wilding pines.	Hillslope	*c.*0.5 ha
04.08 04.08.01	**Blackberry-dominant scrub** **Blackberry scrub** A small heated spring (73°C at time of survey) is surrounded by blackberry and pohue with lesser amounts of broom and lotus. Water purslane is present in the cooler margins of the pool.	Shallow gully	<0.1 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka 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.*6.1 ha
05.01.17	**Wilding pine/prostrate kanuka-mingimingi shrubland** Radiata pine and maritime pine occur over prostrate kanuka and mingimingi.	Hillslope	*c.*0.4 ha
05.02 05.02.02	**Mingimingi-dominant shrubland** **Mingimingi-manuka shrubland** Occasional maritime pine occur over scrub dominated by mingimingi and manuka. Prostrate kanuka occurs on heated soils near the margins of this type where it adjoins prostrate kanuka shrubland.	Hillslope	*c.*0.3 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Heated clays, fumaroles and mud pools. Occasional prostrate kanuka and *Lycopodiella cernua*. Heated fumaroles present in open pasture with Indian doab on margins.	Shallow gullies, crater, hillslope	*c.*0.5 ha

[1] Previously identified as U17/22 in Wildland Consultants (2004 and 2006).

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) 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' in de Lange *et al.* 2009) were recorded at this site in 2006. *D. linearis* is known from only *c.*24 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, magpie, tui, yellowhammer, chaffinch, green finch, Californian quail, and blackbird. New Zealand pipit (classed as „At Risk-Declining' in Miskelly *et al.* 2008) is also present.

Deer graze parts of the prostrate kanuka shrubland and fumaroles within pasture.

Current Condition (2011 Assessment): This site comprises several small geothermal areas surrounded by pine plantations and farmland. Domestic livestock, particularly deer, have access to some geothermal areas, although parts have been fenced off and stock excluded. The overall condition is very good with few weeds; however areas that are grazed are more degraded.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): There is a pine plantation contiguous with the geothermal area and wilding pines are a key threat to this site. Broom and blackberry in low densities are present (each of <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 fenced areas.

Adjoining land use (*2011 Assessment*): Pine plantation and farmland.

Site Change:

Recent change: Radiata pine and maritime pine continue to invade naturally occurring geothermal vegetation, particularly prostrate kanuka scrub and shrubland. Prostrate kanuka does not tolerate shading well. Feral deer access the fenced prostrate kanuka shrubland with tracks and signs of trampling throughout. Blackberry (<1%) is scattered through parts of the prostrate kanuka shrubland.

Historical: Burns *et al.* (1996) assessed vegetation change at this site using aerial photographs from 1945 to 1993. In an area inclusive of Te Rautehuia Stream (WKV02), they found that geothermal vegetation decreased by at least 23% between 1945 and 1993.

An assessment was made of 1961 aerial photographs (Historical photos: SN

1394 Run 3187 Photos 22-23, 1961) with 2007 aerial photographs (WRAPs). This estimate of a decline of one-quarter by Burns 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 appears considerably larger in 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 well be twice the current (2007) size. Fewer pines were present in this unit. There is an area of raw-soilfield to the south which is no longer present which may have been caused by surface geothermal activity, but may also be caused by farming activities. The units labelled as B are in shadow, so are hard to determine boundaries, but are probably similar in size to current day. The area labelled as C appears very similar to 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: Livestock should be removed from all geothermal areas and fumaroles in open pasture should be fenced. Wilding pines (<1% of total cover) should be controlled within prostrate kanuka shrubland. Blackberry (<1% of total cover) should be controlled before it out-competes indigenous vegetation present, and detracts from the ecological values.

Significance Level: Regional (Table 1 - Criteria 3, 5, 9; Table 2 - Factor 14).

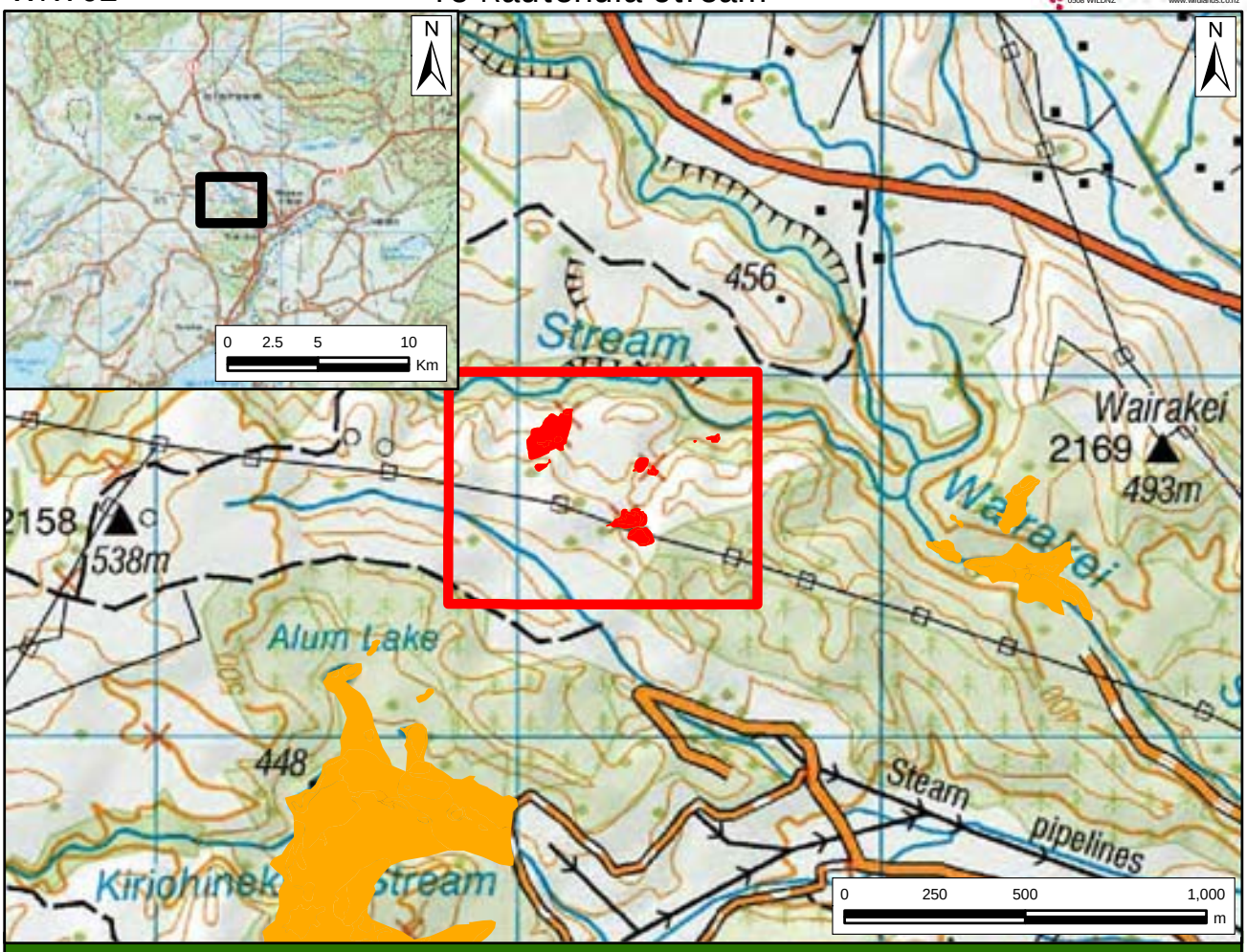
Significance Justification: This site is of regional significance because it is a relatively large example of a nationally uncommon habitat type. It also contains populations of three 'At Risk' species (*Dicranopteris linearis*, *Nephrolepis flexuosa*, and prostrate kanuka).

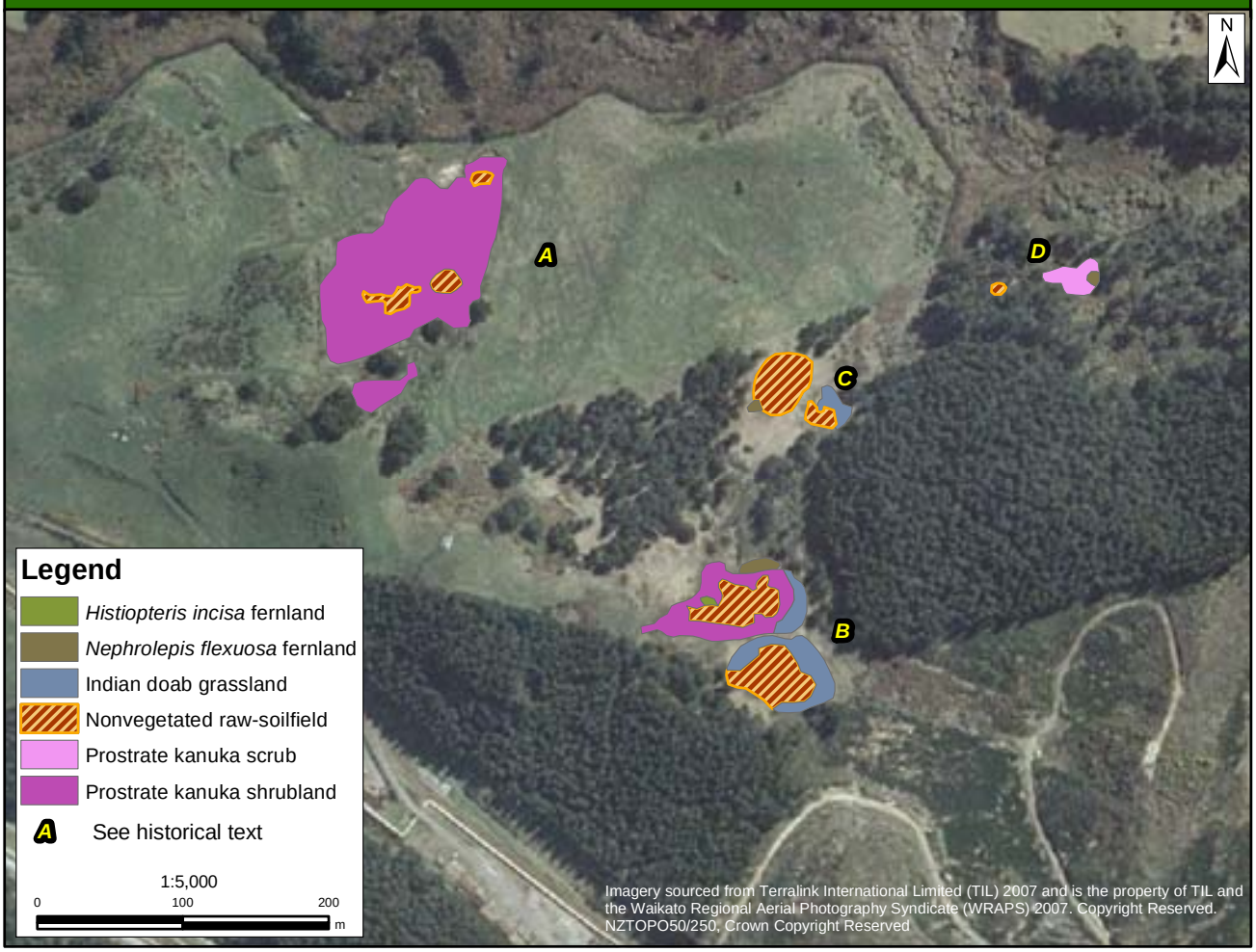
Notes: This site is to the west of Te Rautehuia Stream site and is considered part of the same site in some studies (e.g. Burns *et al.* 1996).

References: Beadel & Bill 2000; Burns *et al*. 1996; Merrett & Burns 1998b & 1998c; Wildland Consultants 2004 & 2006.

WKV02

Te Rautehuia Stream





TE RAUTEHUIA STREAM

Site Number: WKV02[1]
Grid Reference: NZTopo50 BG36 671 218
GPS Reference: NZTM E1867084 N5721842
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Unprotected private land, Wairakei Tourist Park, Riparian marginal strip.
Altitude: 430 m
Extent of Geothermal Habitat: *c.*2.1 ha
Extent of Geothermal Vegetation: *c.*2.1 ha
Date of Field Survey: 27 January 2011

Code	Type	Landform	Extent
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka 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
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka with scattered mingimingi forms a low cover (up to *c.*1 m tall) with abundant *Lycopodiella cernua* and *Campylopus capillaceus*, and occasional emergent maritime pine and radiata pine. Some geothermally-influenced bare ground is present. There is scattered bracken, *Histiopteris incisa*, Spanish heath, monoao, manuka, broom, blackberry, karamu, prickly mingimingi, manuka and turutu 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
07.04 07.04.01	***Histiopteris incisa*-dominant fernland** ***Histiopteris incisa* fernland** *Histiopteris incisa* fernland occurs on a hillslope above a steaming fumarole.	Hillslope	<0.1 ha
07.08 07.08.01	***Nephrolepis flexuosa*-dominant fernland** ***Nephrolepis flexuosa* fernland** These areas comprise small patches of *Nephrolepis flexuosa* fernland surrounded by exotic grasses (e.g. Indian doab and paspalum). Bracken, prostrate kanuka and *Lycopodiella cernua* occur throughout. Blackberry is encroaching from the margins.	Hillslope	<0.1 ha
08.07 08.07.01	**Indian doab-dominant grassland** **Indian doab grassland** Indian doab occurs around the margins of areas of heated soils.	Shallow gullies, hillslopes	*c.*0.2 ha

[1] Previously identified as U17/20 in Wildland Consultants (2004).

Code	Type	Landform	Extent
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Fumaroles, a geothermal crater (with boiling mud) and heated sinter clays. Prostrate kanuka, mingimingi, *Histiopteris incisa*, *Hypolepis ambigua*, maritime pine, radiata pine, pampas, blackberry, Spanish heath and *Lycopodiella cernua* occur on the margins.	Shallow gullies, crater, hillslope	*c.*0.5 ha

Indigenous Flora: *Nephrolepis flexuosa* and prostrate kanuka (classed as „At Risk-Declining' and „At Risk-Naturally Uncommon' respectively in de Lange *et al.* 2009) occur 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 magpie, tui, yellowhammer, chaffinch, green finch, Californian quail, and blackbird.

Current Condition (2011 Assessment): This site comprises several areas of geothermal expressions. It is surrounded by pine plantations 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 to be 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 vegetation disturbance to the area is significant.

Adjoining land use (*2011 Assessment*): Farmland and pine plantation.

Site Change:

Recent change: Mixed fernland on the walls of the geothermal crater (NZTM E1867136 N5721902) which was recorded in 2006 (Wildland Consultants 2006), appears to be no longer present and this area now comprises predominantly nonvegetated raw-soilfield with prostrate kanuka, manuka, mingimingi, blackberry, broom, *Lycopodiella cernua*, and bracken scattered around the margins. Otherwise site is similar to previous survey.

Historical: Burns *et al.* (1996) assessed vegetation change between 1945 to 1993 at this site using aerial photographs. He found that, in an area inclusive of Te Rautehuia (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 (Historic Photos: SN 1394 Run 3187 Photo 23, 1961). The area labelled as A has been converted to pasture and appears to about half the size of earlier surveys. This part of the site extended further to the south in 1961. Other units were more difficult to assess site change. The area labelled B currently has fewer pines than in the 1961, but overall there is no strong evidence of change in site area since 1961. Area C was likely to be in a better condition, surrounded by pine plantation and may not have been heavily browsed. Area D is difficult to determine 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: Wilding pines should be removed from geothermal areas. Where stock have access, geothermal features and vegetation should be fenced. Blackberry requires control.

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

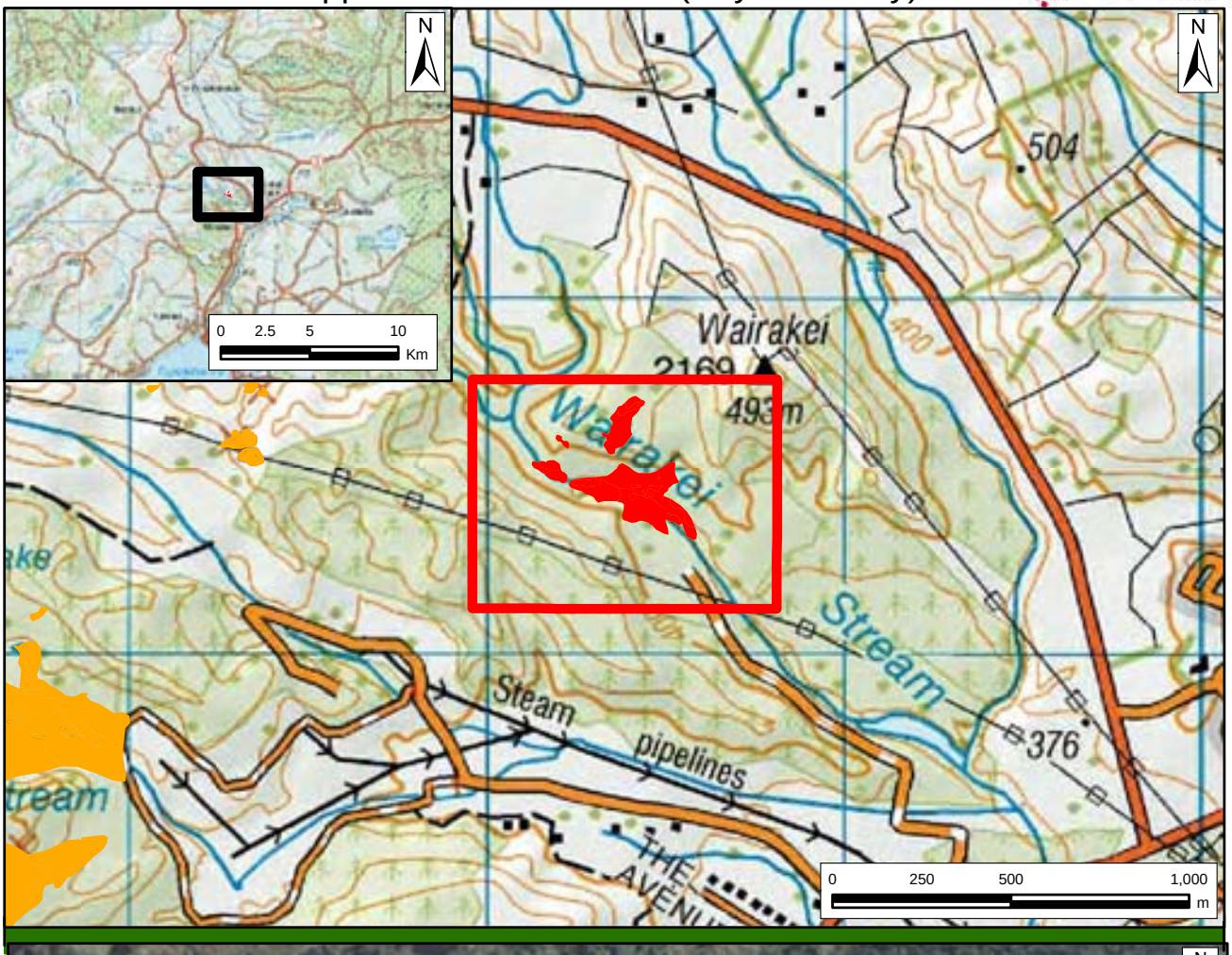
Significance Justification: This site is of regional significance because it is an important habitat for an ‚At Risk' species, *Nephrolepis flexuosa*, and contains moderate-sized areas of prostrate kanuka scrub and shrubland (also an ‚At Risk' species).

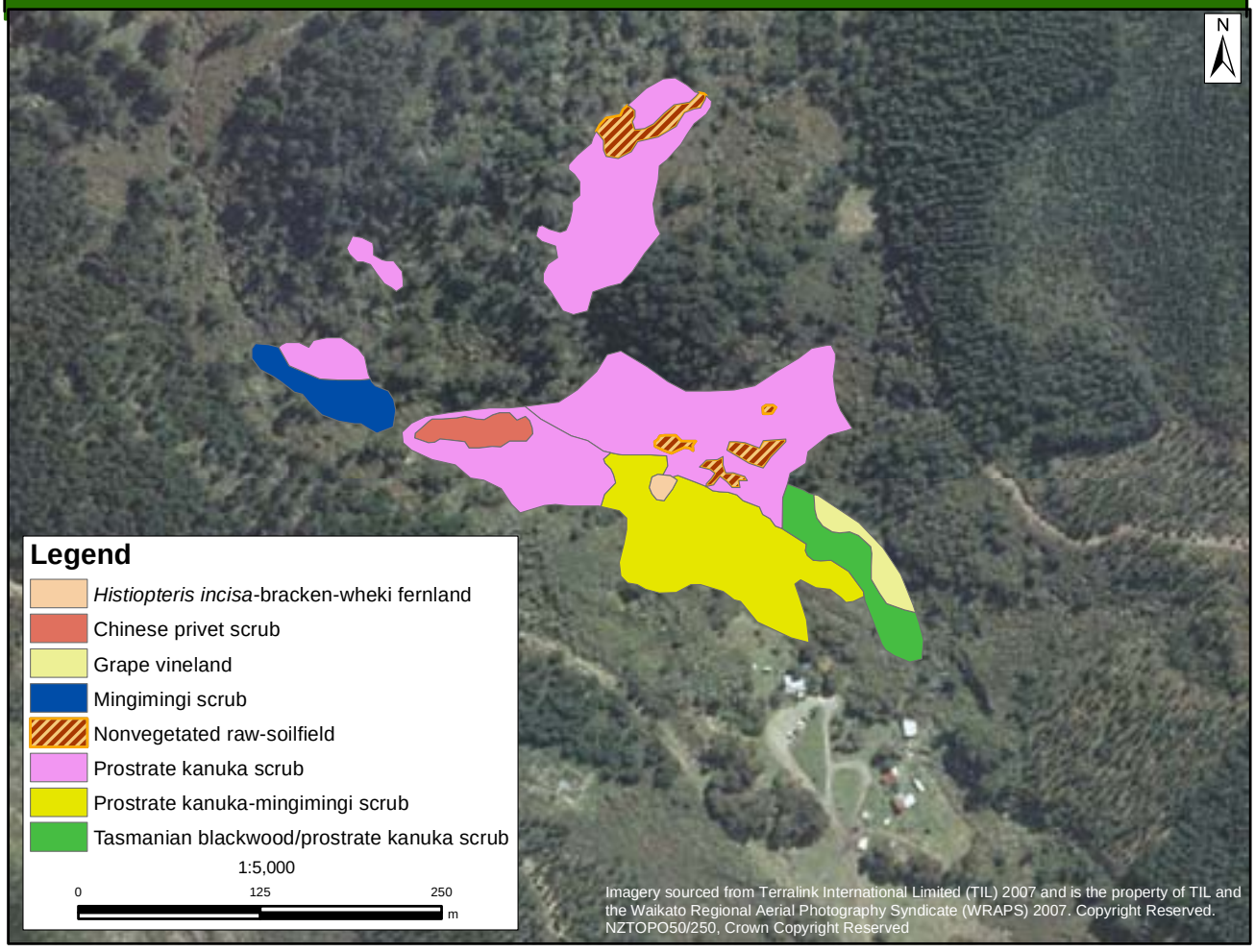
Notes:

References: Burns *et al.* 1996; Department of Conservation 1997; Merrett & Burns 1998a; Wildland Consultants 2004 & 2006.

WKV03

Upper Wairakei Stream (Geyser Valley)





UPPER WAIRAKEI STREAM (GEYSER VALLEY)

Site Number: WKV03[1]
Grid Reference: NZTopo50 BG36 684 214
GPS Reference: NZTM E1868407 N5721446
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Protected (Wairakei Thermal Park)
Altitude: 386 m
Extent of Geothermal Habitat: *c.*4.7 ha
Extent of Geothermal Vegetation: *c.*4.7 ha
Date of Field Survey: 28 January 2011

Code	Type	Landform	Extent
03.02 03.02.01	**Grape vine-dominant vineland** **Grape vineland** A large area on the northern side of the thermal stream is dominated by a grape vine. It has spread over the prostrate kanuka and is smothering it.	Hillslope	*c.*0.1 ha
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka forms a dense monotypic cover, generally up to *c.*1.0 m high. The groundcover comprises mosses and lichens with scattered *Lycopodiella cernua*, local *Dicranopteris linearis*, and turutu around the margins. Fumaroles and dried mud pools occur throughout.	Terrace, hillslope	*c.*2.7 ha
04.01 04.01.02	**Prostrate kanuka-dominant scrub** **Prostrate kanuka-mingimingi scrub** Prostrate kanuka (up to *c.*3.0 m high) occurs with scattered mingimingi, mapou (*Myrsine australis*), wilding pine, false acacia, Chinese privet, and Tasmanian blackwood. There is occasional pampas, Spanish heath, blackberry, and turutu present on the track margins. *Dicranopteris linearis* and *Nephrolepis flexuosa* occur locally. Steaming vents occur throughout this type.	Terrace, hillslope	*c.*1.1 ha
04.01 04.01.07	**Prostrate kanuka-dominant scrub** **Tasmanian blackwood/prostrate kanuka scrub** Tasmanian blackwood is emergent over prostrate kanuka, mingimingi and mapou with a variety of exotic species including wilding pines, Chinese privet, false acacia, ovens wattle (*Acacia pravissima*), Himalayan honeysuckle and Spanish heath also present in the canopy. Manuka and mapou are common in the shrub tier with broom and karamu scattered throughout. There are patches of prostrate kanuka and *Dicranopteris linearis*. Mingimingi scrub dominates on lower hillslopes (refer to 04.02.12). Several steaming vents occur adjacent to a warm stream, and whauwhaupaku, kamahi, mahoe and several fern species (e.g. kiokio, *Pneumatopteris pennigera*, *Gleichenia microphylla*, and sapling wheki) are	Hillslope; gully	*c.*0.3 ha

[1] Previously identified as U17/3 in Wildland Consultants (2004).

Code	Type	Landform	Extent
	common. Tradescantia occurs along stream banks.		
04.02 04.02.12	**Mingimingi-dominant scrub** **Mingimingi scrub** Mingimingi scrub is present on the southern side of the stream with mapou and bracken common throughout, scattered wheki-ponga, kiokio and pohue, and several exotic species including Chinese privet, Himalayan honeysuckle and maritime pines. Occasional prostrate kanuka plants are present.	Hillslope	*c.*0.2 ha
04.11 04.11.01	**Chinese privet-dominant scrub** **Chinese privet scrub** Chinese privet dominates a small area (*c.*40 × 15 m) north of the thermal stream. Prostrate kanuka scrub (Type 04.01.01) surrounds this type.	Hillsope	*c.*0.1 ha
07.05 07.05.11	**Mixed fernland** ***Histiopteris incisa*-bracken -wheki fernland** *Histiopteris incisa*, bracken and wheki form the dominant cover on the steep face of a large steaming vent (named the 'Witches Cauldron'). Blackberry, inkweed, turutu, mingimingi, *Gleichenia microphylla*, prostrate kanuka, *Dicranopteris linearis,* pampas, and mapou are also present.	Steaming vent	<0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Steaming sinter clay soilfield occurs on a scarp with patches of *Lycopodiella cernua*, prostrate kanuka, turutu, and *Campylopus* sp. Blackberry, beggars' ticks (*Bidens frondosa*), mingimingi, prostrate kanuka, pohue, wheki, kiokio, turutu, *Histiopteris incisa*, and koromiko are present on the margins of a thermal stream at the base of the scarp. A small area of sinter terrace (not mapped) occurs here.	Scarp	*c.*0.2 ha

Indigenous Flora: Prostrate kanuka, *Dicranopteris linearis* (both classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009), *Nephrolepis flexuosa* (classed as „At Risk-Declining' in de Lange *et al.* 2009), *Lycopodiella cernua* and *Campylopus capillaceus*, are all plants characteristic of geothermal areas which occur at this site. *D. linearis* is known from only *c.*24 sites in New Zealand.

Given (1976) recorded *Christella* aff. *dentata* ("thermal") from this site in the early 1970s, but it has not been recorded from this site in recent surveys (Bycroft *et al*. 2007, Merrett & Burns 1998).

Fauna: Common indigenous and introduced bird species typical of this type of habitat are present including whitehead, bellbird, tui, North Island robin, grey warbler, fantail, yellowhammer, shining cuckoo, house sparrow, and song thrush.

Current Condition (2011 Assessment): Geothermal vegetation at this site is under serious threat of weed invasion from adventive weed species, particularly grape. It appears that some geothermal features have become less active. The slopes surrounding the site have become dense with pest plant infestations, particularly blackberry, which may have covered previously bare ground. Some areas of geothermal vegetation and habitats remain relatively intact.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Parts of this site are highly modified by invasive pest plants, particularly on cooler ground at the lower end of the valley. A grape vine covers a large area along the side of the gully (cover of 6-25%). Tasmanian blackwood and Chinese privet comprise 6-25% cover each, with the latter scattered throughout the prostrate kanuka scrub. Wilding pines (6-25% cover), false acacia (1-5% cover), broom (1-5% cover), pampas (<1% cover), tradescantia (<1% cover), heather (*Calluna vulgaris*) (<1% cover), *Cotoneaster glaucophyllus* (<1%), blackberry (<1%), and Spanish heath (1-5% cover) are also present.

Human impacts (*2011 Assessment*): The geothermal valley is run as a tourism venture with a circuit walking track which appears to be well adhered to. 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 (Given 1989a). Lowered soil temperatures have enabled the establishment of many adventive plant species, although in some areas the soil temperatures are increasing (Merrett & Burns 1998c).

Chickens and other domesticated fowl from the tea rooms have free access to the site, but are unlikely to have negative impacts on the site.

Grazing (*2011 Assessment*): Livestock do not have access to the site.

Adjoining land use (*2011 Assessment*): Plantation forest; scrub dominated by woody exotic species; indigenous scrub.

Site Change:

Recent change: It appears that some minor weed control has occurred on the track margins but the grape infestation covers a larger extent than previously mapped in 2004. False acacia is emergent in the prostrate kanuka-mingimingi scrub on the south side of the thermal stream.

Historical: Burns *et al.* (1996) has 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: Large areas within this site require weed control of species such as grape vine, wilding pines, Tasmanian blackwood, Chinese privet, false acacia,

blackberry, and tradescantia. 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.

Significance Level: Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factors 10, 12).

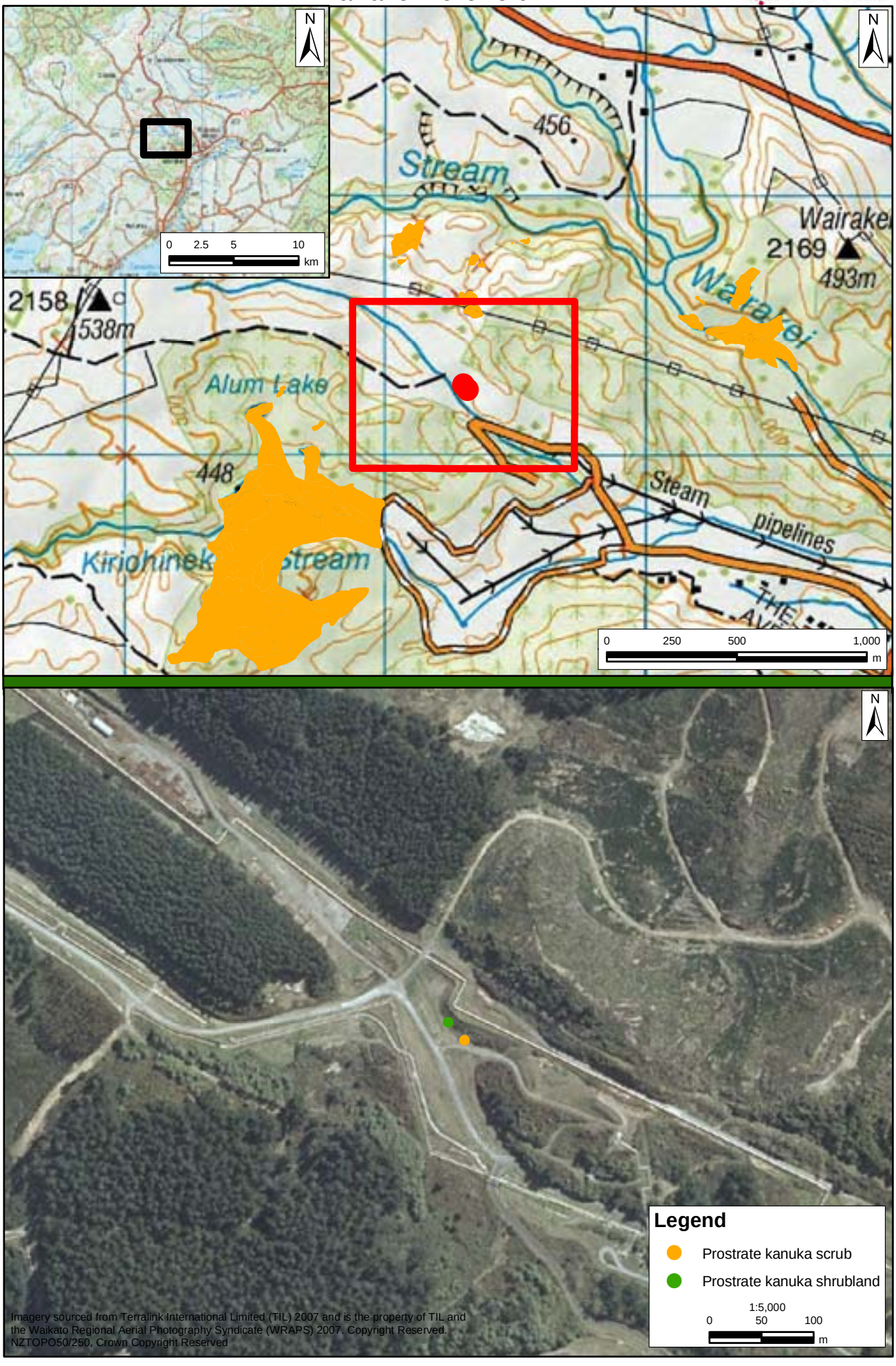
Significance Justification: This site is of regional significance because it is protected under the Reserves Act (1977) and contains stable populations of three „At Risk' species: prostrate kanuka, *Dicranopteris linearis* and *Nephrolepis flexuosa.*

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 B - the second highest category.

References: Beadel & Bill 2000; Burns *et al*. 1996; Bycroft *et al*. 2007; Given 1976, 1989a & 1996; Merrett & Burns 1998c; Wildland Consultants 2004.

WKV04

Wairakei Borefield



WAIRAKEI BOREFIELD

Site Number: WKV04[1]
Grid Reference: NZTopo50 BG36 672 212; BG36 673 212
GPS Reference: NZTM E1867298 N5721272; E1867314 N5721248
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*440 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 25 January 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka up to *c.*0.75 m high with local *Lycopodiella cernua*. Occasional narrow-leaved carpet grass and broom present. Soil temperature at 10 cm depth was 50°C. Geothermal vegetation covers an area of 5 × 5 m.	Hillslope	<0.1 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka to *c.*0.75 m tall with occasional patches of bare ground. Lotus, gorse, broom and narrow-leaved carpet grass are common on margins. Geothermal vegetation covers an area of 10 × 10 m. Soil temperature at 10 cm depth was 49.8 °C.	Hillslope	<0.1 ha

Indigenous Flora: Prostrate kanuka (classed as an „At Risk-Naturally Uncommon' species in de Lange *et al.* 2009) 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 (2007 Assessment): Two small patches of prostrate kanuka surrounded by an industrial site.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*)*:* Broom (1-5% cover) and gorse (1-5% cover).

[1] Previously identified as U17/35 in Wildland Consultants (2004).

Human impacts (*2007 Assessment*)*:*	Industrial site. 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 operational use of the site.
Grazing (*2007 Assessment*)*:*	The site is not grazed by stock.
Adjoining land use (*2007 Assessment*)*:*	Industrial
Site Change:	
Recent change:	This site has only been field surveyed once for Waikato Regional Council as part of this study, and because of its small size, recent changes to vegetation are not clearly visible on aerial photographs. There is probably no change in extent of vegetation present.
Historical:	This site is too small to be assessed on the historical aerial photographs available.
Management Requirements:	None noted.
Significance Level:	Local (Table 1 - Criterion 5; Table 2 - Factor 19).
Significance Justification:	This site is of local significance because it is an example of a nationally uncommon habitat type (geothermal) and contains a small population of prostrate kanuka (an ‚At Risk-Declining' species).
References:	Wildland Consultants 2004 & 2007a.

WKV05 Te Kiri O Hine Kai Stream Catchment/Wairoa Hill

WKV05 Te Kiri O Hine Kai Stream Catchment /Wairoa Hill

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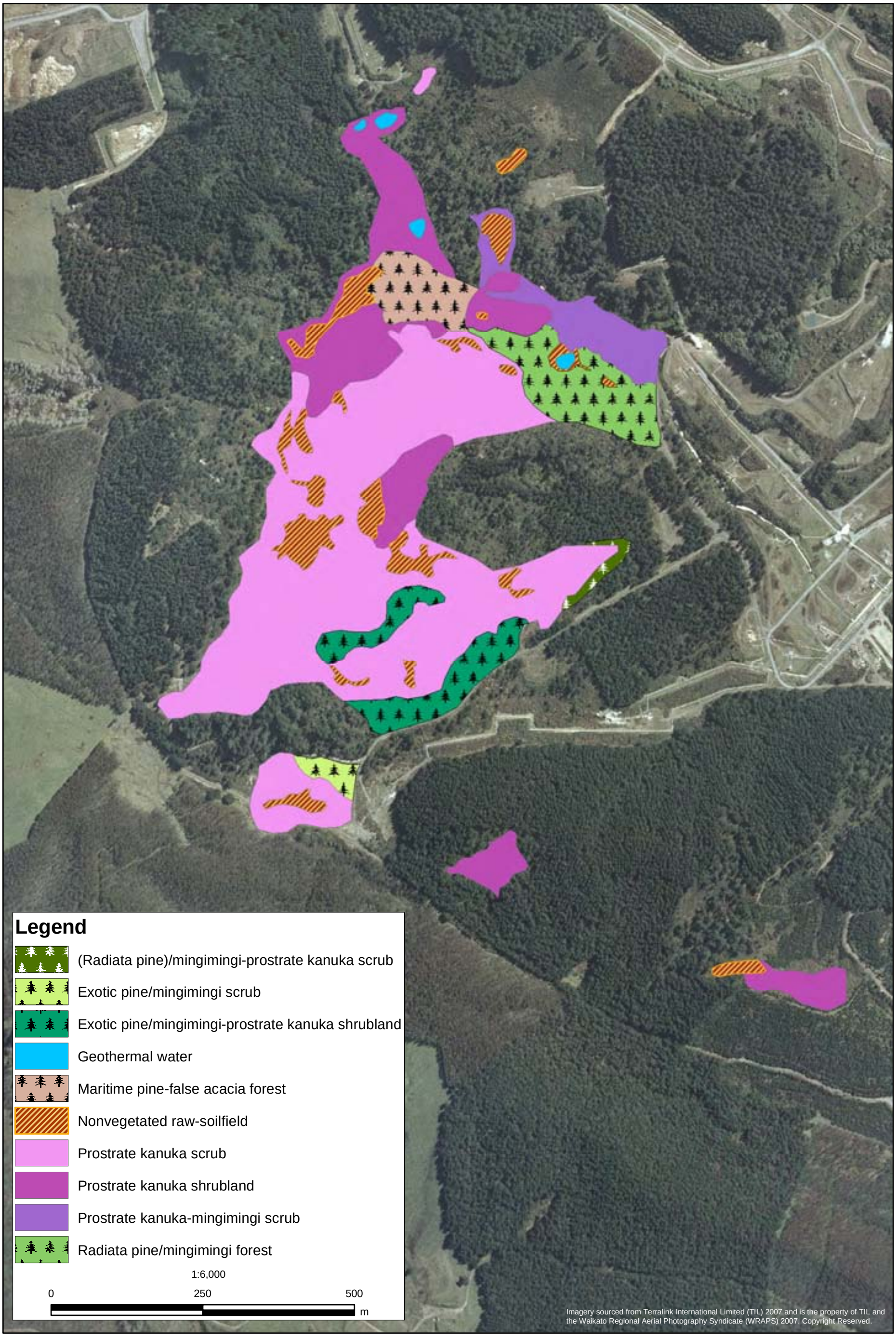


TE KIRI O HINE KAI STREAM CATCHMENT/WAIROA HILL

Site Number: WKV05[1]
Grid Reference: NZTopo50 BG36 666 206
GPS Reference: NZTM E1866576 N5720644
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Unprotected private land (Unallocated Crown Land administered by Contact Energy)
Altitude: *c.*460-520 m
Extent of Geothermal Habitat: *c.*40.3 ha
Extent of Geothermal Vegetation: *c.*40.1 ha
Date of Field Survey: 27 January 2011

Code	Type	Landform	Extent
01.05 01.05.03	**Exotic pines forest** **Maritime pine-false acacia forest** Maritime pine and false acacia are common over an understorey comprising bracken and mingimingi.	Hillslopes	*c.*1.6 ha
01.05.04	**Radiata pine/mingimingi forest** Radiata pine is emergent over mingimingi. Other species include blackberry, buddleia, Spanish heath, bracken, whauwhaupaku, and Himalayan honeysuckle.	Hillslopes	*c.*2.7 ha
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka forms a dense cover up to *c.*0.5 m high, with *Sphagnum* sp., *Campylopus capillaceus,* and *Dicranoloma* sp. 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* and *Lycopodiella cernua* are present. Exotic species are present throughout include Spanish heath, buddleia, pampas and blackberry.	Undulating plateau	*c.*20.0 ha
04.01.02	**Prostrate kanuka-mingimingi scrub** Prostrate kanuka 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 present.	Hillslopes, gully	*c.*2.1 ha
04.02 04.02.13	**Mingimingi-dominant scrub** **Exotic pine/mingimingi scrub** Scattered radiata pine and maritime pine occur over mingimingi, with wheki-ponga and prickly mingimingi common throughout. The groundcover is dominated by turutu	Hillslopes	*c.*0.4 ha

[1] Previously identified as U17/5 in Wildland Consultants (2004).

Code	Type	Landform	Extent
	and bracken. Small patches of prostrate kanuka, *Dicranopteris linearis*, and *Nephrolepis flexuosa* are present.		
04.02.14	**(Radiata pine)/mingimingi-prostrate kanuka scrub** Emergent radiata pine over mingimingi and prostrate kanuka, with occasional manuka.	Hillslopes	*c.*0.3 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka forms a low cover (up to 0.5 m high) with abundant *Lycopodiella cernua* and *Campylopus capillaceus*. Local patches of mature, wilding, maritime pine and radiata pine (up to 10 m tall) are present, with an understorey of mingimingi, prickly mingimingi, karamu, turutu, and *Gleichenia microphylla*. At the southern end of the site prostrate kanuka occurs in association with *Dicranopteris linearis*, local patches of *Nephrolepis flexuosa*, and adventive species such as Himalayan honeysuckle, fleabane, foxglove, Yorkshire fog, wild portulaca, and occasional aloe (*Aloe* sp.).	Undulating plateau; valley floor, hillslopes	*c.*7.5 ha
05.02 05.02.05	**Mingimingi-dominant shrubland** **Exotic pine/mingimingi-prostrate kanuka shrubland** Radiata pine and scattered maritime pine are emergent and, in some areas, dominant over mingimingi, prostrate kanuka, tawiniwini, and bracken. Occasional plants of *Dicranopteris linearis* are present.	Hillslopes	*c.*2.3 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Hot water and mud lakes, including Alum Lake. The two northernmost lakes are within a steep sided depression. Pampas, *Carex secta*, raupo, and *Histiopteris incisa* occur on the margins, with *Lemna minor* and *Azolla rubra* present in the cooler water.	Lakes	*c.*0.2 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Geothermal clays, mud pools, and fumaroles with patches of prostrate kanuka shrubland scattered throughout. Pampas, kiokio, *Histiopteris incisa*, radiata pine seedlings and bracken also occur in these areas.	Hillslopes, undulating plateau, crater	*c.*3.2 ha

Indigenous Flora: Prostrate kanuka, *Dicranopteris linearis* (both classed as „At Risk-Naturally Uncommon'), and *Nephrolepis flexuosa* (classed as „At Risk-Declining' in de Lange *et al.* 2009) 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") was recorded near geothermal lakes at this site in 2001 (Nick Singers pers. comm. 2007).

D. linearis is known from only *c.*24 sites in New Zealand.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including, tui, Australasian harrier, shining cuckoo, kingfisher, tui, chaffinch, grey warbler, fantail, blackbird and bellbird. New Zealand pipit (classed as „At Risk-Declining' in Miskelly *et al.* 2008) has been recorded at this site. Skink and gecko have been reported from this site (Unpublished

Atiamuri PNAP data 1995).

Current Condition (2011 Assessment): A large and mostly contiguous area of geothermal features and vegetation surrounded by pine plantations and geothermal extraction operations. Geothermal drawdown is ongoing.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2011 Assessment*): Wilding radiata pine and maritime pine threaten geothermal vegetation at this site. Other adventive species present include blackberry, pampas and Spanish heath.

Human impacts (*2011 Assessment*): Access tracks, logging, and geothermal extraction all occur along the boundaries of this site.

Grazing (*2011 Assessment*): The surrounding land is not farmed.

Adjoining land use (*2011 Assessment*): Pine plantation and geothermal gas extraction.

Site Change:

Recent change: Radiata pine growth has seen mingimingi scrub (recorded in 2007) at the southern end of the site change to (exotic pine)/mingimingi-kanuka scrub. In the middle of this site an area recorded as prostrate kanuka-mingimingi scrub in 2007 is now classed as radiata pine/mingimingi forest.

Historical: Burns *et al.* (1996) assessed vegetation change at this site using aerial photographs from 1945 to 1993 and found that geothermal vegetation decreased by 20% between 1945 and 1993. In addition, an assessment of aerial photos from 1961 (Historical photos: SN 1394 Run 3187 Photos 22, 23, 1961; SN 1394 Run 3188 Photos 23, 24, 1961) compared with more recent aerial photographs indicate a marked increase in wilding pines in the site.

Management Requirements: Wilding pines that are invading and, in some places, dominating to the point of almost complete canopy closure over geothermal vegetation should be controlled. Most threatened geothermal species do not respond to shading well. Areas where blackberry is scattered either on the margins or within the geothermal vegetation should be controlled before it becomes dominant.

Significance Level: Regional (Table 1 - Criteria 1, 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 (a nationally uncommon habitat type), and contains a relatively large population of three „At Risk' species (prostrate kanuka, *Dicranopteris linearis*, and *Nephrolepis flexuosa*). The site is somewhat degraded in quality, with adventive plant species common. A small population of *Christella* aff. *dentata* ("thermal") (an „At Risk' species) has been recorded from the site in the past, but it has not been recorded since 2001.

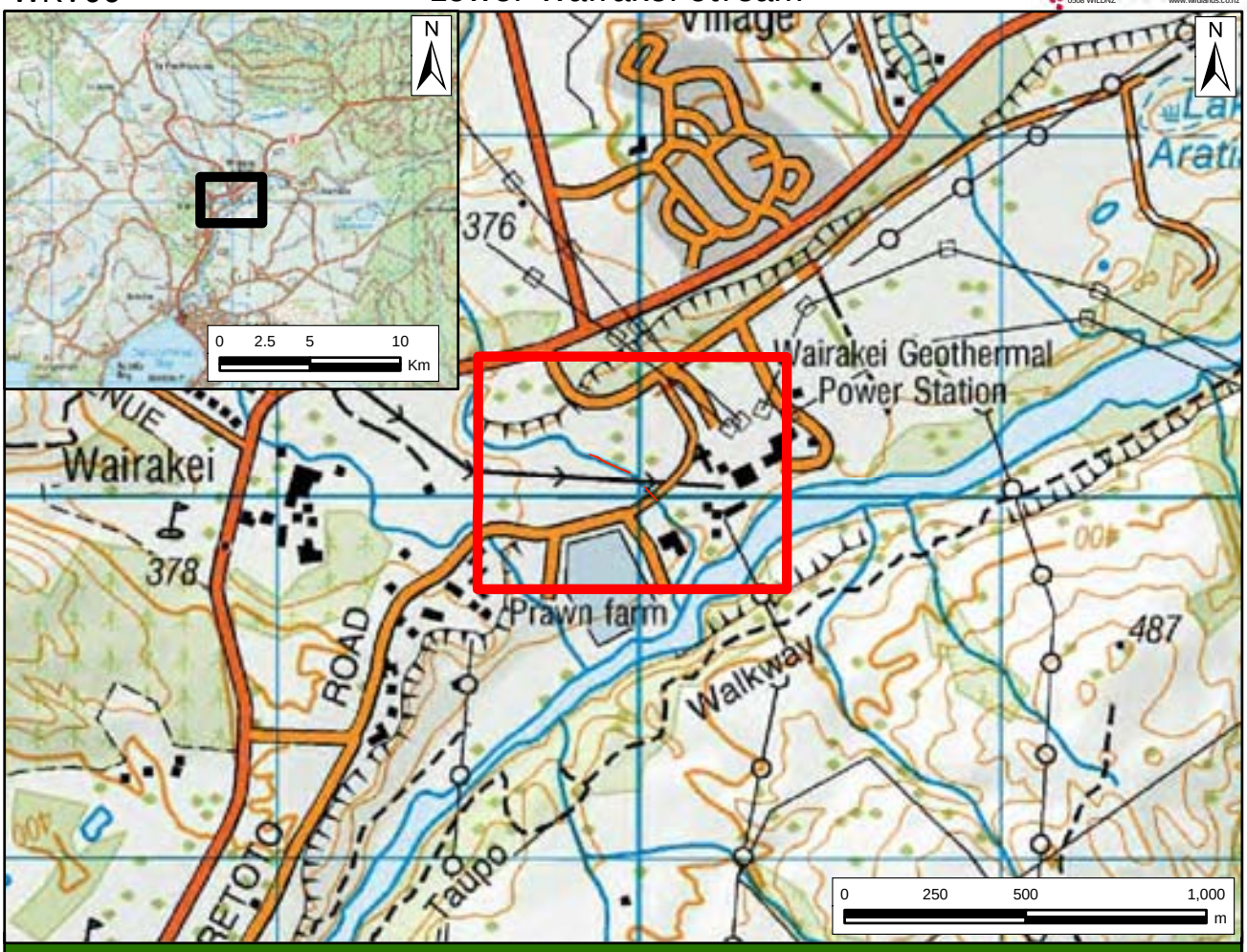
Notes: This site comprises two areas ranked in Given (1996) as Category A (the

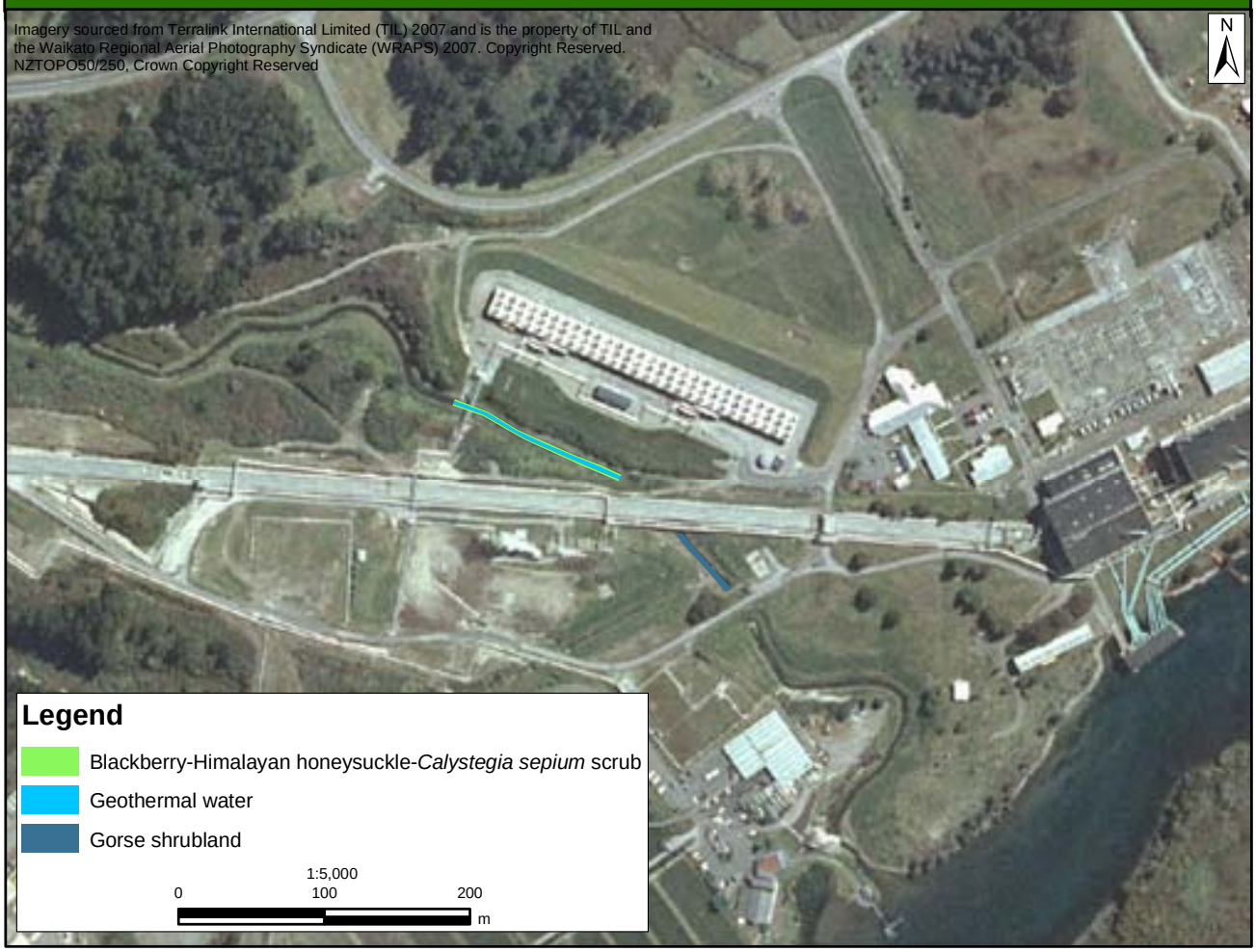
highest category) - “Wairakei: Waiora Hill” and “Wairakei: Upper Wairakei Stream”.

References: Anon 1990; Beadel & Bill 2000; Burns *et al.* 1996; Given 1989; Merrett & Burns 1986b & 1986c; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004 & 2007b.

WKV06

Lower Wairakei Stream





LOWER WAIRAKEI STREAM

Site Number: WKV06[1]
Grid Reference: NZTopo50 BG36 699 201
GPS Reference: NZTM E1869918 N5720089
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: 350 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 25 January 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.08 04.08.02	**Blackberry-dominant scrub** **Blackberry-Himalayan honeysuckle-pohue scrub** Stream margins are surrounded by blackberry with common Himalayan honeysuckle, pohue, and Japanese honeysuckle. Scattered plants of buddleia, *Deparia petersenii,* kiokio, pampas, and karamu are present. Patches of rank exotic grassland species (e.g. lotus, yarrow (*Achillea millefolium*), Yorkshire fog, sweet vernal, and cleavers are also present. Scattered populations of *Christella* aff. *dentata* ("thermal") (47 clumps) are present between the outlet of geothermal water into the Wairakei Stream (E1869871 N5720120) and where the stream enters a culvert (E1869999 N5720067).	Stream margins	<0.1 ha
05.06 05.06.01	**Gorse-dominant shrubland** **Gorse shrubland** An area of gorse shrubland on stream margins. Two clumps of *Christella* aff. *dentata* ("thermal") were present on margins in this type. Exotic grassland species (e.g. lotus, fleabane, pohue, Yorkshire fog, and sweet vernal) and montbretia (*Crocosmia* ×*crocosmiiflora*) are common, with occasional lupin, and *Deparia petersenii*.	Stream margins	<0.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Geothermal stream with a temperature of 32°C at one location. Temperatures are likely to be significantly warmer at other locations (not mapped); however most of the stream was inaccessible. Geothermal water is fed into the Wairakei Stream through an outlet at E1869871 N5720120.	Stream	<0.1 ha

Indigenous Flora: Forty-nine clumps of *Christella* aff. *dentata* ("thermal") (AK297076) were found in 2007, compared to seven clumps recorded at this site in 1998 (Merrett & Clarkson 1998a). *Christella* aff. *dentata* ("thermal") is

[1] Previously identified as U17/2 in Wildland Consultants (2004, 2007a).

classified ‚At Risk-Naturally Uncommon' (de Lange *et al.* 2009).

Hypolepis dicksonioides (also ‚At Risk-Naturally Uncommon') has been recorded from this site in the past (Merrett & Clarkson 1998), but was not recorded in 2007.

Fauna: Common indigenous and introduced bird species typical of the habitat are likely to be present. Mallard, silvereye, chaffinch and Indian myna were recorded.

Current Condition (2007 Assessment): This site is in a poor condition and pest plants are common. However, the site provides habitat for a threatened plant species and comprises geothermal habitat.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*)*:* Blackberry (50% cover), Himalayan honeysuckle (5-25% cover), Japanese honeysuckle (1-5% cover), gorse (1-5% cover), buddleia (<5% cover), pampas (<5% cover), and lotus are present.

Human impacts (*2007 Assessment*)*:* The geothermal vegetation occurs alongside a stream which has been modified as part of the ongoing management of the Wairakei Power Station.

Grazing (*2007 Assessment*)*:* Not a threat to this site.

Adjoining land use (*2007 Assessment*)*:* Industrial site.

Site Change:

Recent change: This site was not re-surveyed. Any changes to vegetation boundaries are a result of better quality aerial photographs and are not likely to be significant.

Historical: This site is too small to see any evidence of change since 1941 (Historical photo: SN 172 Run 1173 Photo 3, 1941). However, changes are likely to have been significant with the construction of the Wairakei Power Station in close proximity to this site. Stream channels have been significantly altered as a consequence, which will have altered the extent of geothermal vegetation. Draw-down of geothermal water for power generation will have also probably 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 the ongoing maintenance of the stream margins as part of an operational industrial site.

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

Significance Justification: This site is of regional significance because it contains an important population of an ‚At Risk' species - *Christella* aff. *dentata* ("thermal"). This species is currently only known from 14 sites in New Zealand (Bycroft

& Beadel 2007).

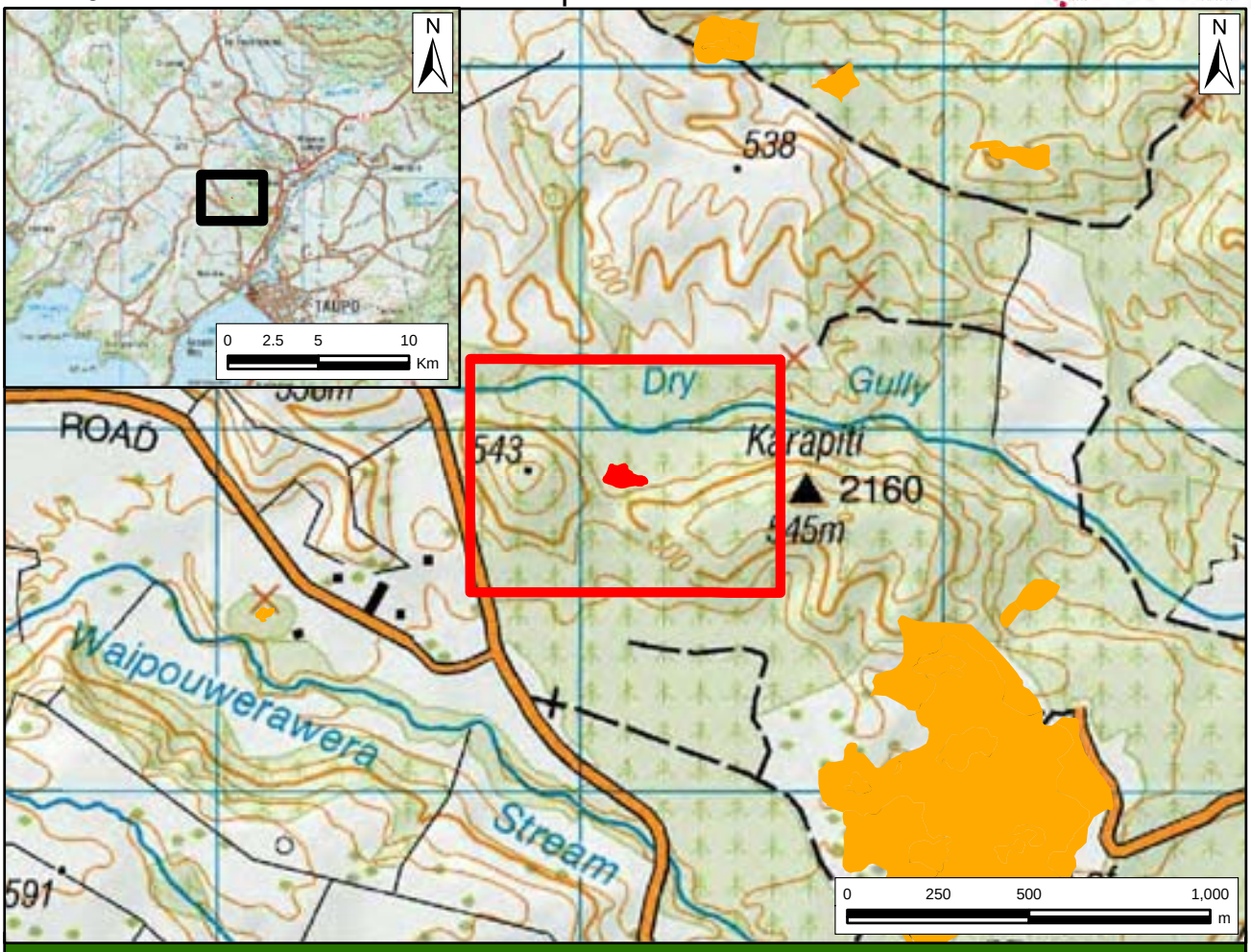
Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in this study this site was classed as Category B - the second highest category.

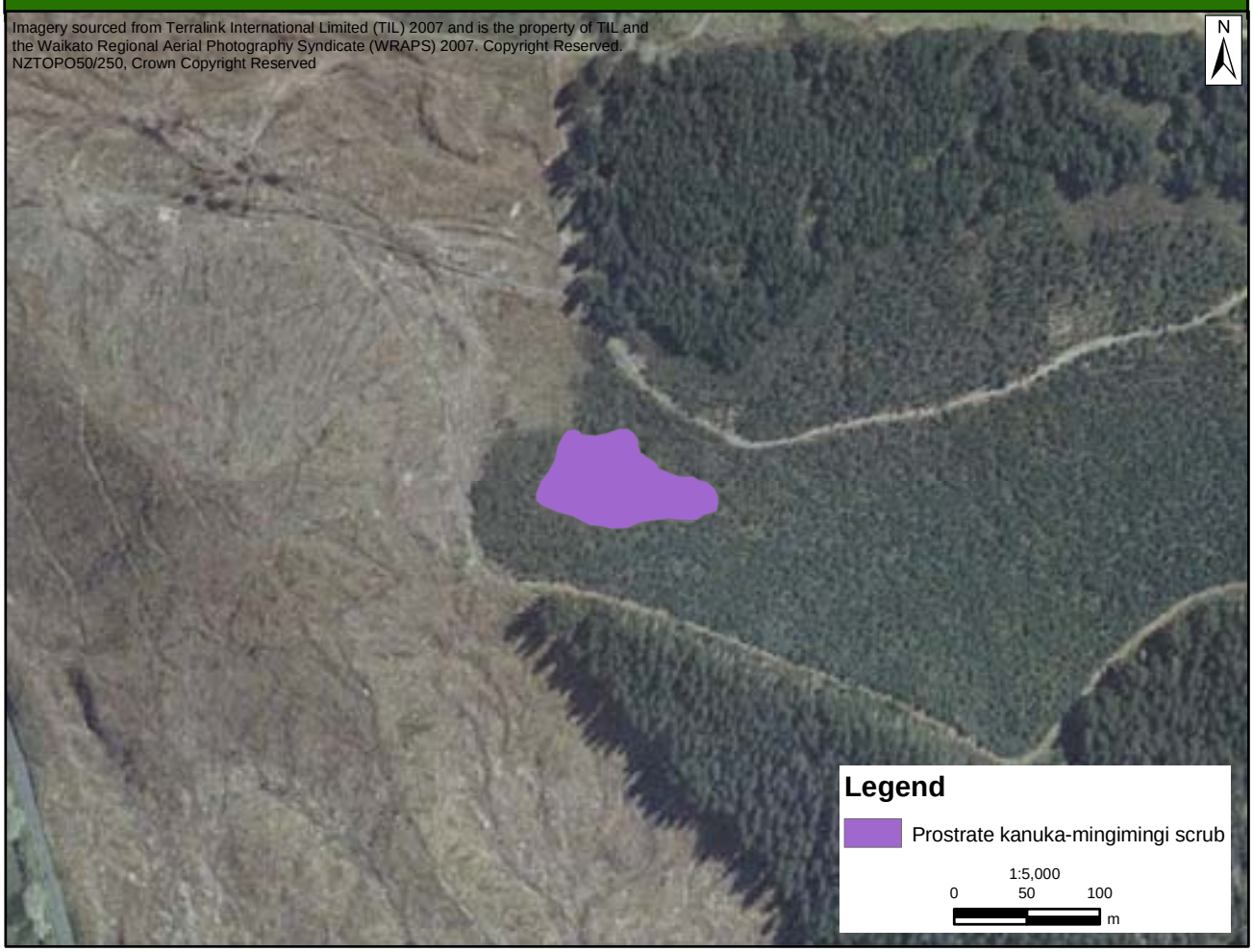
In 2007 this site was assessed as nationally significant because, at that time *Christella* aff. *dentata* ("thermal") was classified as „Chronically Threatened-Gradual Decline' (de Lange *et al.* 2004). This species is now classified as „At Risk-Naturally Uncommon' (de Lange *et al*. 2009), which in turn affects the significance assessment.

References: Bycroft & Beadel 2007; Given 1989a & 1996; Merrett & Burns 1998b; Wildland Consultants 2004 & 2007a.

WKV07

Karapiti Forest





KARAPITI FOREST

Site Number: WKV07[1]
Grid Reference: NZTopo50 BG36 661 189
GPS Reference: NZTM E1866117 N5718870
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*480 m
Extent of Geothermal Habitat: *c.*0.6 ha
Extent of Geothermal Vegetation: *c.*0.6 ha
Date of Field Survey: 20 April 2004

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04 01 04 01 02	**Prostrate kanuka-dominant scrub** **Prostrate kanuka-mingimingi scrub** Prostrate kanuka up to *c.*0.3 m high forms a dense cover with locally common monoao, occasional wilding radiata pine and maritime pine, and scattered mingimingi. The groundcover comprises patches of *Campylopus capillaceus*. Numerous fumaroles occur throughout this area. On the margins, mingimingi up to *c.*3 m high is dominant, with occasional manuka and scattered wilding radiata pines. Blackberry, Himalayan honeysuckle, bracken, turutu and large patches of *Dicranopteris linearis* are common in the understorey, and *Lycopodiella cernua,* mosses, and *Histiopteris incisa* are common around fumaroles which are scattered throughout this area.	Toe slope	*c.*0.6 ha

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) and *Lycopodiella cernua*, both of which are characteristic of geothermal areas, are present.

Also present is *Dicranopteris linearis* (also classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) which is known from only *c.*24 sites in New Zealand.

Fauna: Common indigenous and introduced bird species typical of the habitat are present, including bellbird, fantail, and silvereye.

Current Condition (2004 Assessment): This is a small site in relatively good condition with relatively few weeds. Recent harvesting operations have resulted in disposal of slash in some of the hotter parts of geothermal activity which has damaged these sites. A larger buffer would help protect geothermal features in the future.

[1] Previously identified as U17/19 in Wildland Consultants (2004).

Threats/Modification/ Vulnerability:

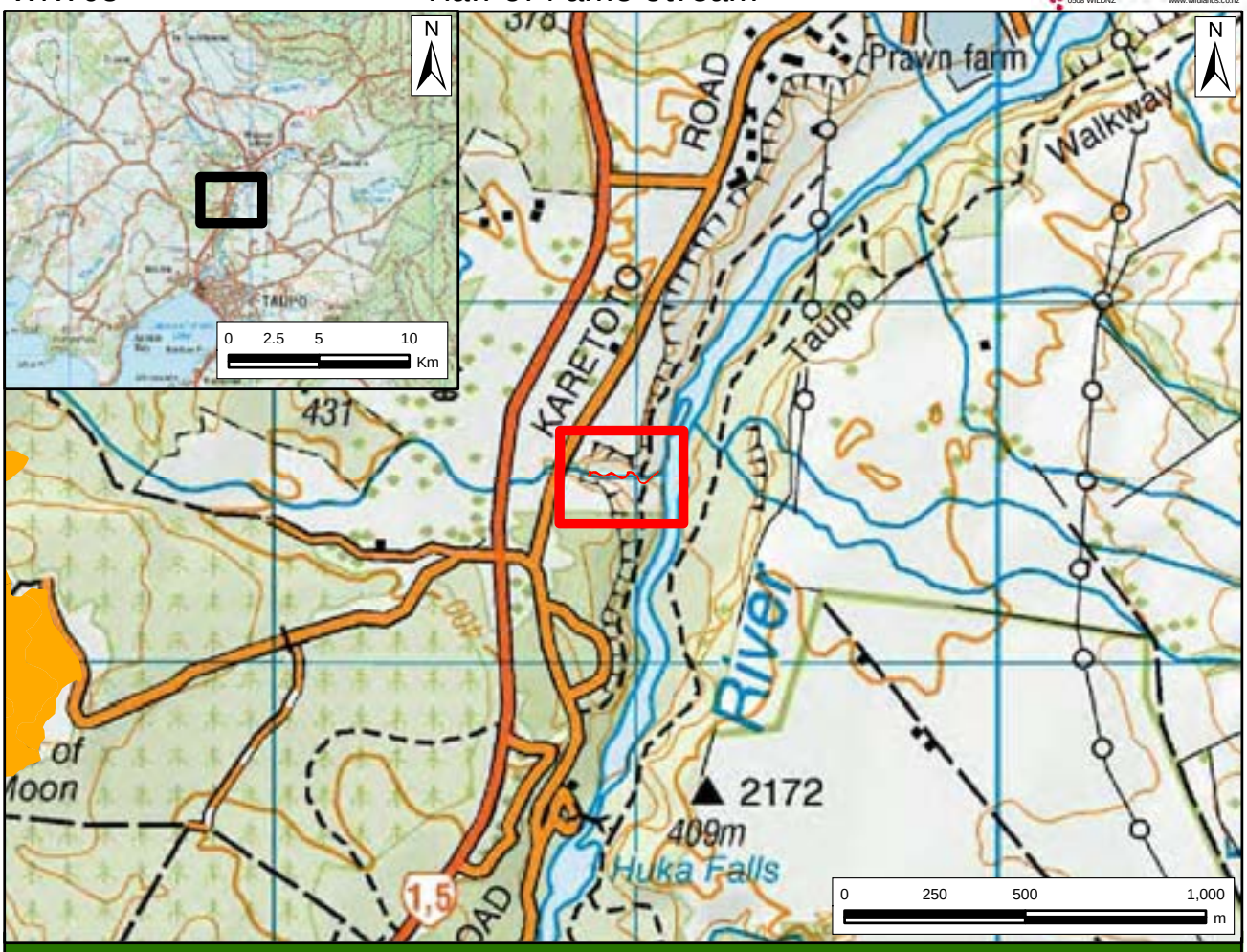
Invasive pest plants (*2004 Assessment*)*:*	The site is surrounded by plantation pine forest, however the number of wilding pines (1-5% cover) establishing is limited by high soil temperatures. Provided soil temperatures do not cool (see below), wilding pine invasion should remain static. Himalayan honeysuckle and blackberry are also present (1-5% cover), and occasional pampas (<1% cover), but these species are mainly confined to the margins of the geothermal area.
Human impacts (*2004 Assessment*)*:*	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 & Burns 1998b&c), however the impacts of draw-off on this area are not currently known. Recent harvesting has left piles of slash along some of the geothermal vegetation margins.
Grazing (*2004 Assessment*)*:*	Livestock are not a threat to this area.
Adjoining land use (*2004 Assessment*)*:*	Harvesting and ongoing management operations of the surrounding pine plantation could result in ongoing damage to the geothermal vegetation.

Site Change:

Recent change:	The site appears similar on 2007 aerial photographs to the 2004 assessment. Plantation trees near the site are markedly taller than they were at the time of the 2004 survey.
Historically:	An assessment was made between 1961 aerial photographs (Historical photos: SN 1394 Run 3188 Photos 22-23, 1961) 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. 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 is of local significance because it is a small example of a nationally uncommon habitat type and provides habitat for two „At Risk' species, prostrate kanuka and *Dicranopteris linearis*. This site is a small, highly active geothermal area, relatively undisturbed and currently has very low densities of invasive exotic plants.
References:	Beadel & Bill 2000; Burns *et al.* 1996; Department of Conservation 1998; Merrett & Burns 1998b, 1998c; Wildland Consultants 2004.

WKV08

Hall of Fame Stream



HALL OF FAME STREAM

Site Number: WKV08[1]
Grid Reference: NZTopo50 BG36 689 186
GPS Reference: NZTM E1868965 N5718516
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei
Bioclimatic Zone: Submontane
Tenure: Protected (Huka Falls Scenic Reserve)
Altitude: *c.*360 m
Extent of Geothermal Habitat: *c.*0.1 ha
Extent of Geothermal Vegetation: *c.*0.1 ha
Date of Field Survey: 14 May 2003

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
07.05 07.05.15	**Mixed fernland** **Mixed fernland** Hot seepage surrounded by bare ground, with several plants of *Christella* aff. *dentata* ("thermal"), kiokio, *Adiantum cunninghamii*, *Blechnum vulcanicum*, *Pneumatopteris pennigera*, makomako, kotukutuku, rangiora, *Urtica incisa*, and wall lettuce.	Steep hillslope	<0.1 ha
05.13 05.13.07	**Blackberry-dominant shrubland** **Blackberry shrubland** Shrubland dominated by blackberry, Himalayan honeysuckle, and radiata pine surrounds a stream gully in which there are several hot springs. There is occasional Chinese privet, kotukutuku, *Carex geminata*, mahoe, kiokio, *Pneumatopteris pennigera*, and bracken.	Gully flowing water	<0.1 ha

Indigenous Flora: A small population of *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al.* 2009) occurs at the head of the gully.

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

Current Condition (2003 Assessment): The main stream gully is dominated by blackberry, Himalayan honeysuckle and radiata pine.

Threats/Modification/ Vulnerability:

Invasive pest plants (2003 Assessment): The main stream gully is dominated by blackberry and Himalayan honeysuckle (>75% cover).

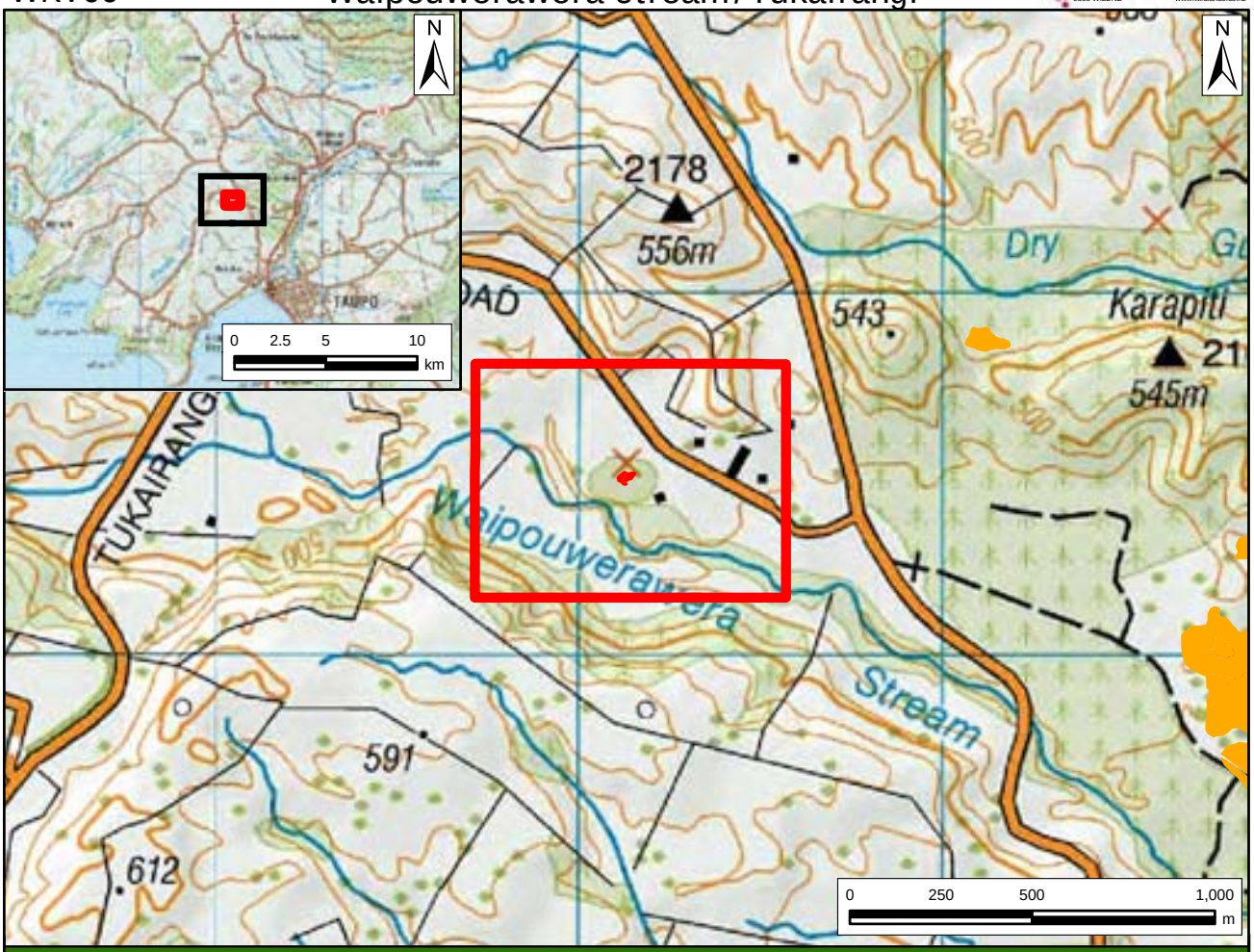
Human impacts (2003 Assessment): This site is in the Wairakei geothermal field and is vulnerable to changes in ground temperature associated with power station draw-off (refer to Burns

[1] Previously identified as U17/6 in Wildland Consultants (2004).

	et al. 1996; Merrett & Burns 1998b&c), however the impacts to this area of draw-off are not currently known.
Grazing (*2003 Assessment*)*:*	Livestock are not a threat to this area.
Adjoining land use (*2003 Assessment*)*:*	Scenic Reserve administered by Department of Conservation. A walking track passes through the site.
Site Change:	
Recent change:	Not assessed. Any significant change unlikely.
Historical:	This site is too small to see any evidence of change since 1941 (Historical photos: SN 172 Run 1174 Photos 2, 3, 1941).
Management Requirements:	None required at present.
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 contains a small population of an „At Risk' plant species (*Christella* aff. *dentata* "thermal").
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.
References:	Given 1989a & 1996; Merrett & Burns 1998a; Wildland Consultants 2004.

WKV09

Waipouwerawera Stream/Tukairangi



WAIPOUWERAWERA STREAM/TUKAIRANGI

Site Number: WKV09[1]
Grid Reference: NZTopo50 BG36 651 185
GPS Reference: NZTM E1865128 N5718488
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei-Tauhara
Bioclimatic Zone: Submontane
Tenure: Protected (Waipouwerawera Stream Conservation Area)
Altitude: 468 m
Extent of Geothermal Habitat: *c*.0.1 ha
Extent of Geothermal Vegetation: *c*.0.1 ha
Date of Field Survey: 3 March 2011

Code	Type	Landform	Extent
05.03 05.03.25	**Manuka-dominant shrubland** **(Maritime pine)/manuka-broom-blackberry-Himalayan honeysuckle shrubland** 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 manuka, prostrate kanuka, broom, blackberry, and Himalayan honeysuckle. Tawiniwini, turutu, and small patches of *Paesia scaberula* and *Gleichenia microphylla* are also present. Small areas of nonvegetated raw-soilfield occur on the crater floor, and also amongst larger patches of manuka and mingimingi. On the cooler crater rim whauwhaupaku is emergent over manuka, broom, and a thick margin of blackberry.	Crater walls	*c*.0.1 ha
05.15 05.15.01	**Monoao-dominant shrubland** **Monoao shrubland** A patch of monoao shrubland occurs on crater walls in the north-east corner of the explosion craters. There are occasional emergent maritime pines and radiata pines. Prostrate kanuka, kanuka, 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
28.01 28.01.01	**Nonvegetated raw-soilfield (not mapped)** **Nonvegetated raw-soilfield** Patches of geothermally-influenced bare soil are present. No elevated temperatures were found, although access around the site is very difficult.	Crater floor and walls	

[1] Previously identified as U18/10 and U17/9 in Wildland Consultants (2004).

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) is present. *Dicranopteris linearis* (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) and *Lycopodiella cernua* have been recorded at the site in the past (Given 1989), but were not seen in 2003 or during the current survey, and are unlikely to still be present.

Fauna: Common bird species typical of the habitat (including magpie and blackbird) are present.

Current Condition (2011 Assessment): The extent of geothermal vegetation and habitat appears to be declining at this site. There was no evidence of the fumaroles or hot ground previously recorded in 1989 (Given 1989), but not seen in 2003 or 2011 surveys. It appears that, since 1989, vegetation cover comprising a mixture of species typical of geothermal and non-geothermal habitats) on the crater floor has 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, 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 fully fenced and stock does not have access.

Adjoining land use (*2011 Assessment*): This site is surrounded by farmland.

Site Change:

Recent change: 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.

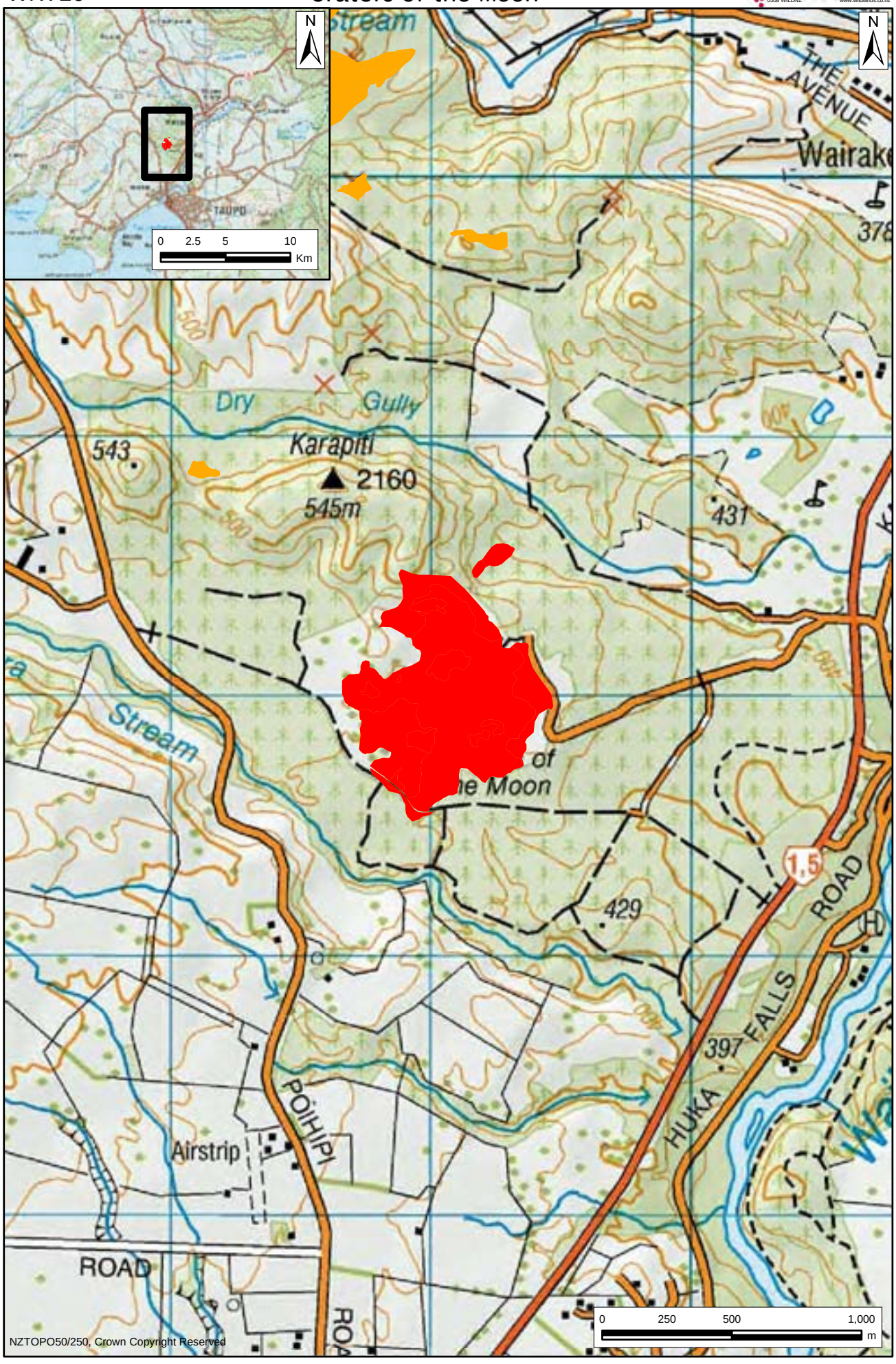
Historical: In the 1961 photos (Historical photos: SN 1394 Run 3188 Photos 22-23, 1961) a greater extent of bare ground is visible to that which is visible in the 2007 photos (i.e. there is an increase in extent of vegetation in the 2007 aerials). Increased extent of vegetation (including non-geothermal 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.

Significance Level:	Local (Table 1 - Criteria 1, 3, 5; Table 2 - Factor 19)
Significance Justification:	This site is of local significance because it contains a small example of a „nationally uncommon' habitat (geothermal), and a small population of an „At Risk' species (prostrate kanuka).
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 & Burns 1998a; Wildland Consultants 2004.

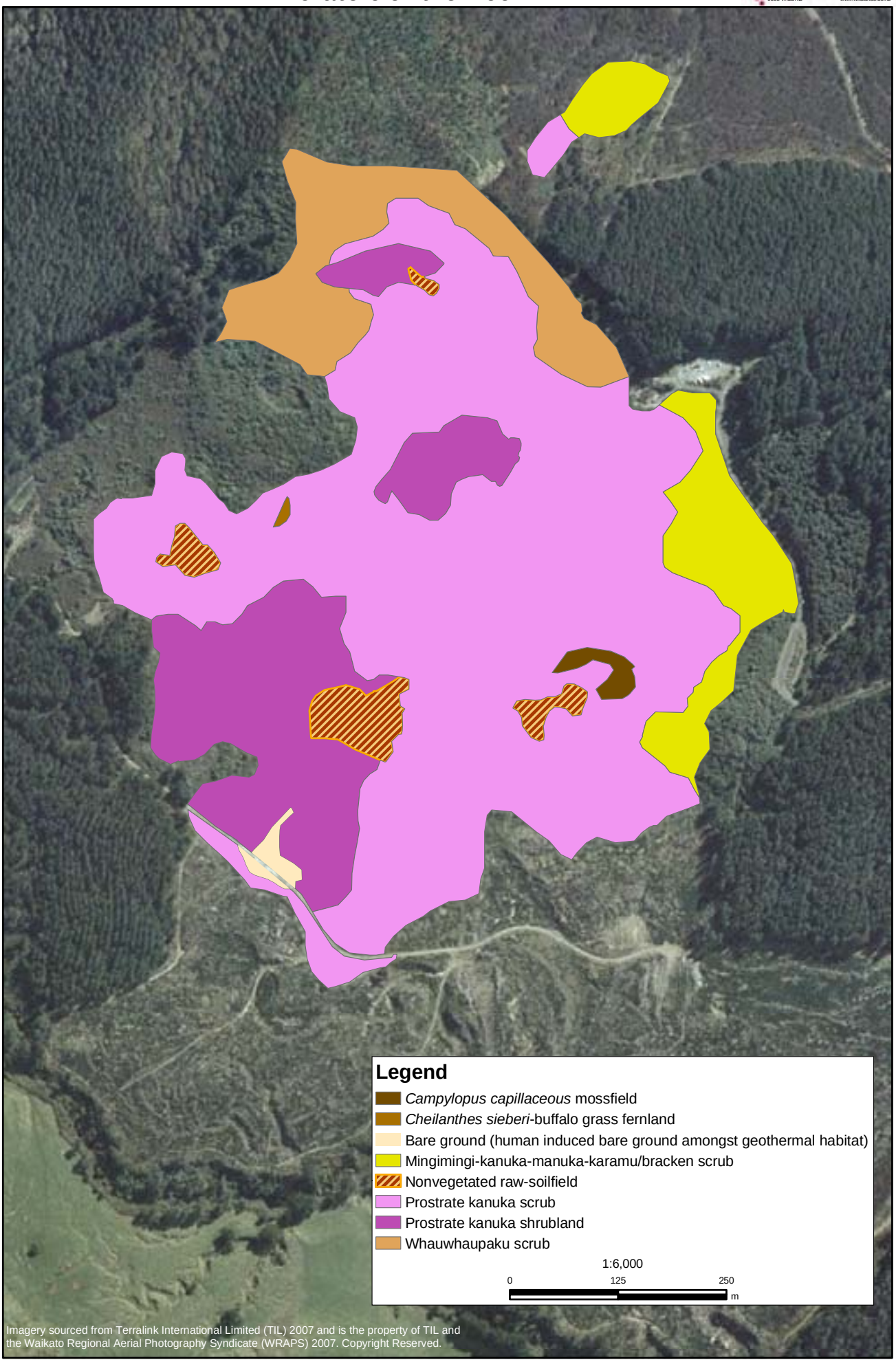
WKV10

Craters of the Moon



WKV10

Craters of the Moon



CRATERS OF THE MOON[1]

Site Number: WKV10[2]
Grid Reference: NZTopo50 BG36 671 180
GPS reference: NZTM E1867064 N5718041
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Wairakei
Bioclimatic Zone: Submontane
Tenure: Protected (Ministry of Tourism Reserve)
Altitude: *c.*440-460 m
Extent of Geothermal Habitat: *c.*44.6 ha
Extent of Geothermal Vegetation: *c.*44.6 ha
Date of Field Survey: 12 August 2004 (a partial site inspection was undertaken on 29 August 2007)

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka up to *c.*1 m high dominates these areas, with scattered monoao and patches of *Lycopodiella cernua* and *Dicranopteris linearis*. Patches of *Campylopus capillaceus* are common and there are occasional wilding pines throughout.	Flat	*c.*27.4 ha
04.02 04.02.15	**Mingimingi-dominant scrub** **Mingimingi-kanuka-manuka-karamu/bracken scrub** A mixture of mingimingi, kanuka, manuka and karamu 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.*3.6 ha
04.05 04.05.02	**Indigenous broadleaved species-dominant communities** **Whauwhaupaku scrub** Occasional wilding radiata pine up to *c.*10 m tall are emergent over abundant whauwhaupaku. Scattered 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, in association with mahoe and young kamahi, dominates a recently cleared hillslope.	Hillslope	*c.*4.3 ha

[1] This site was called Karapiti (Craters of the Moon) in Beadel & Bill (2000).
[2] Previously identified as U18/4 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka to a height of *c.*0.3-0.5 m is dominant, with patches of *Lycopodiella cernua, Campylopus capillaceus,* lichen, and loamfield throughout.	Flat	*c.*7.5 ha
07.01 07.01.01	***Dicranopteris*-dominant fernland (not mapped)** ***Dicranopteris linearis* fernland** *Dicranopteris linearis*, in association with *Lycopodiella cernua*, forms the dominant cover, with prostrate kanuka, turutu and emergent manuka scattered throughout. Monoao and *Histiopteris incisa* occur occasionally. This vegetation type occurs amongst prostrate kanuka scrub and shrubland but is too small to map separately.	Flat and hillslope	*c.*1.2 ha
07.05 07.05.14	**Mixed fernland (not mapped)** ***Dicranopteris linearis-Histiopteris incisa* fernland** *Dicranopteris linearis* and *Histiopteris incisa* dominate the margins of an active fumarole, with local patches of *Paesia scaberula*, bracken, monoao, *Campylopus capillaceus* and *Sphagnum cristatum*. Occurs amongst prostrate kanuka scrub and shrubland but is too small to map separately.	Fumarole	*c.*<0.1 ha
07.07 07.07.01	***Lycopodiella*-dominant fernland (not mapped)** ***Lycopodiella* fernland** A discontinuous cover of *Lycopodiella cernua* over dense mats of *Campylopus capillaceus* occurs in association with heated loamfield. Occurs amongst prostrate kanuka scrub and shrubland but is too small to map separately.	Flat	*c.*2.8 ha
07.13 07.13.01	**Cheilanthes-dominant fernland** ***Cheilanthes sieberi*-buffalo grass fernland** This small area is dominated by *Cheilanthes sieberi* and mixed exotic grasses, mainly buffalo grass and Indian doab. It is near a walking track and appears to have developed following disturbance.	Flat	<0.1 ha
14.02 14.02.01	**Campylopus-dominant mossfield** ***Campylopus capillaceus* mossfield** *Campylopus capillaceus* forms the dominant cover with patches of buffalo grass, Indian doab, and locally scattered prostrate kanuka. Fumaroles, steaming pits, and areas of nonvegetated raw-soilfield are common throughout.	Flat	*c.*0.3 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Sinter pavement. Small patches of *Campylopus capillaceus* mossfield with occasional *Lycopodiella cernua* are present.	Flat	*c.*1.3 ha
28.01 28.01.05	**Nonvegetated raw-soilfield** **Bare ground (human-induced bare ground amongst geothermal habitat)** These areas comprise human-induced bare ground within areas of geothermal habitat.	Flat	*c.*0.2 ha

Indigenous Flora:

Prostrate kanuka (classed as an 'At Risk-Declining' species in de Lange *et al.* 2009) and *Campylopus capillaceus*, which are both endemic and restricted to geothermal areas, are common throughout this site.

Other 'At Risk' species present include *Dicranopteris linearis* and *Hypolepis dicksonioides* (both classed as 'At Risk-Naturally Uncommon'), and *Nephrolepis flexuosa* (classed as 'At Risk-Declining' in de Lange *et al.* 2009). *D. linearis* is known from only *c.*24 sites in New Zealand. *Lycopodiella cernua* and *Psilotum nudum* (both of which are characteristic of geothermal areas) are also present.

Other species of interest include *Cheilanthes sieberi* (currently known to be present at this site). 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 then.

Fauna:

Common indigenous and introduced bird species typical of the habitat are present including, tui, New Zealand pipit and grey warbler.

Current Condition (2004 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 1980a). 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 (*2007 Assessment*)*:*

Several wilding pines (particularly radiata pine and maritime pine), and eucalyptus are scattered through the site, despite some control of wilding pines having been recently undertaken. Other invasive plant species present are blackberry, privet, tree lucerne, Himalayan honeysuckle, broom, buddleia, pampas, Spanish heath, buffalo grass, and paspalum (each with 1-5% 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. Buffalo grass is present on the edge of many craters. Its bright green colour is not typical of indigenous geothermal vegetation, and it therefore negatively impacts on the indigenous character of the site.

Human impacts (*2004 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 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 old paths, 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 tracks.

The network of informal tracks created by visitors trying to get closer to geothermal features is compacted, which 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.

Grazing (*2004 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 (*2004 Assessment*)*:* Plantation forests.

Site Changes:

Recent change: Some management of pest plants 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: 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 & 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 is a nationally uncommon vegetation type. 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 1980a). Four species classed as 'At Risk' are present: prostrate kanuka, *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 this study this site was classed as Category A - the highest category.

References: Beadel & Bill 2000; Burns *et al.* 1996; Clarkson 1989; Given 1980a, 1989a & 1996; Merrett & Burns 1998b&c; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004 & 2007d.

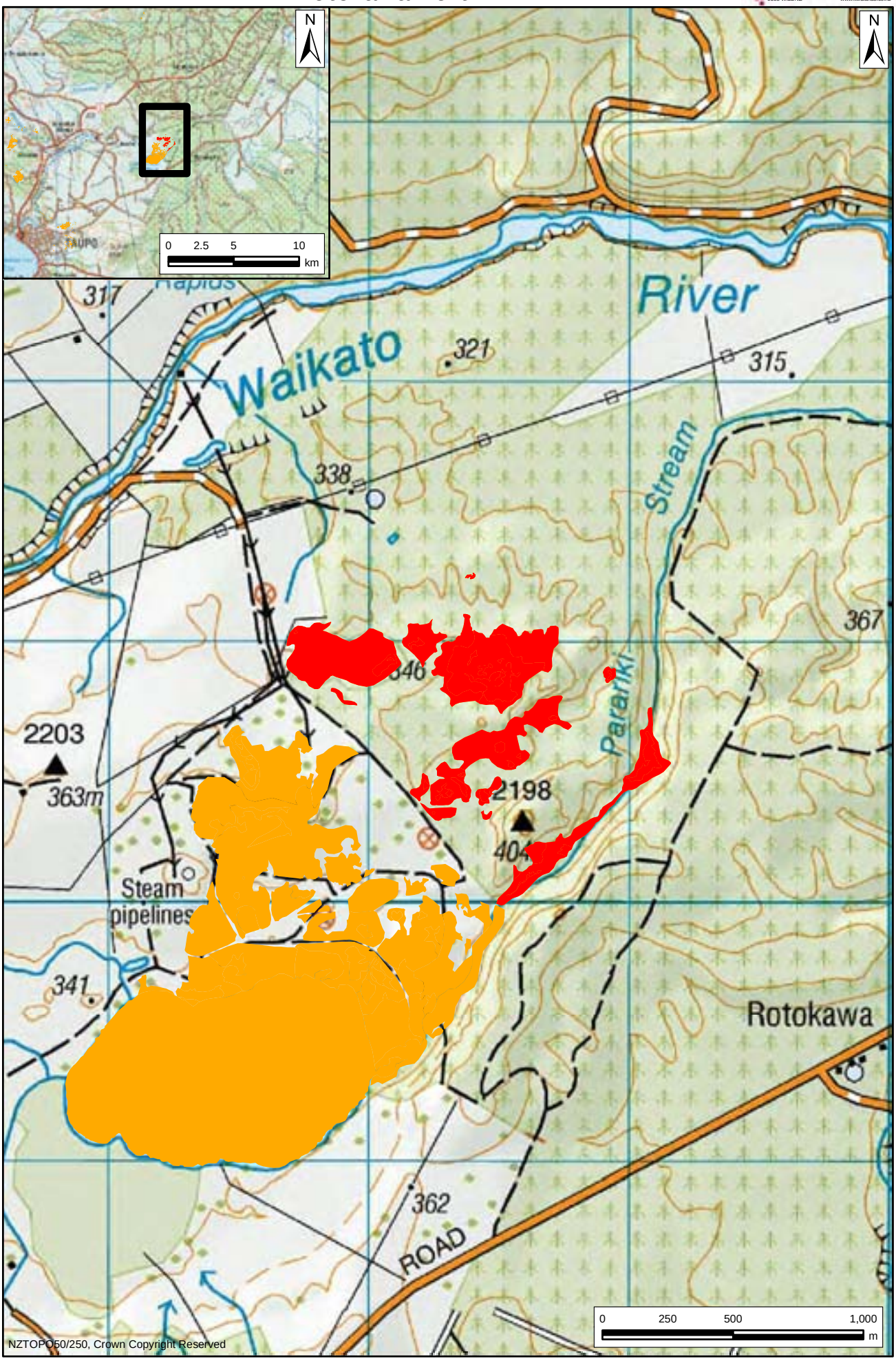
1.13 ROTOKAWA GEOTHERMAL FIELD

List of Geothermal Sites

RKV01	Rotokawa North
RKV02	Lake Rotokawa

RKV01

Rotokawa North



RKV01

Rotokawa North

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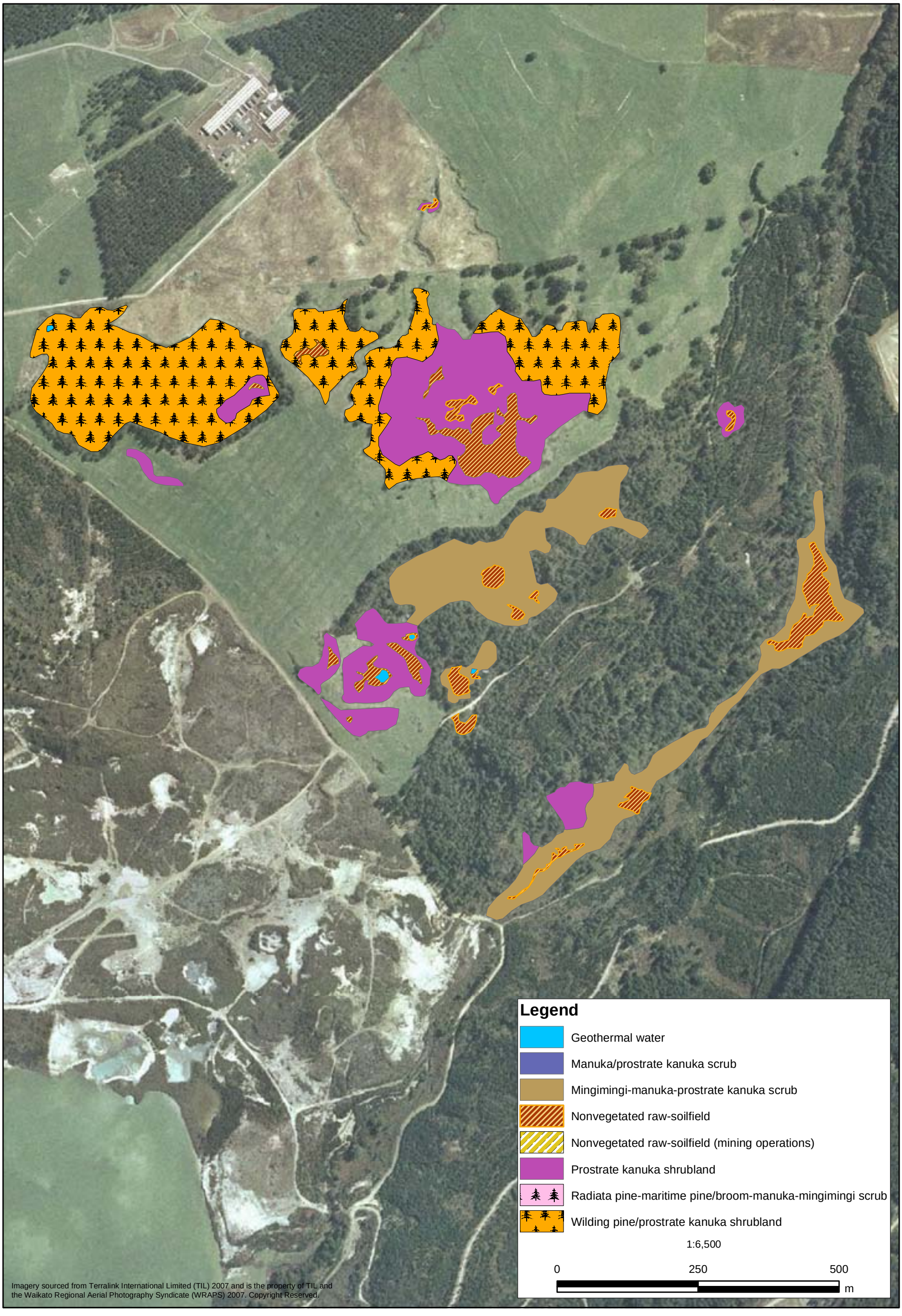


ROTOKAWA NORTH

Site Number: RKV01[1]
Grid Reference: NZTopo50 BG37 784 209
GPS Reference: NZTM E1878482 N5720902
Local Authority: Taupō
Ecological District: Atiamuri
Geothermal Field: Rotokawa
Bioclimatic Zone: Submontane
Tenure: Protected (Lake Rotokawa Conservation Area) and unprotected private land
Altitude: *c.*320-400 m
Extent of Geothermal Habitat: *c.*34.4 ha
Extent of Geothermal Vegetation: *c.*34.3 ha
Date of Field Survey: 4 May 2004

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.02 04.02.16	**Mingimingi-dominant scrub** **Mingimingi-manuka-prostrate kanuka scrub** Mingimingi, manuka, and prostrate kanuka form a cover to *c.*2 m high, with occasional maritime pine and radiata pine emergent and small patches of monoao and nonvegetated raw-soilfield.	Flat and gentle hillslopes	*c.*9.2 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka is dominant with scattered mingimingi throughout. Kanuka, manuka, monoao, prickly mingimingi, and bracken are locally common on cooler soils; broom and buddleia are common, and wilding pines (mostly maritime 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 area. Several plants of *Dicranopteris linearis* and *Nephrolepis flexuosa* were present in 2004.	Flat and gentle hillslopes	*c.*8.7 ha
05.01.14	**Exotic pine/prostrate kanuka shrubland** Maritime pine and some radiata pine appear to be establishing in large areas of prostrate kanuka shrubland. *Lycopodiella cernua*, mingimingi, Mercer grass, prickly mingimingi, bracken, *Gleichenia microphylla*, *Paesia scaberula*, and *Hypolepis distans* are scattered throughout. Mingimingi and blackberry become more common towards margins. Sheep's sorrel and wild seradella occur in disturbed sites.	Flat and gentle hillslopes	*c.*13.2 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Hot water.	Flat and gentle hillslopes	*c.*0.1 ha

[1] Previously identified as U17/34 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Sinter deposits, fumaroles, mud pools. Patches of prostrate kanuka, and broom.	Flat	*c.*3.3 ha

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) and *Lycopodiella cernua* are present. Prostrate kanuka is endemic to geothermal sites, and *Lycopodiella cernua,* is a characteristic feature of geothermal areas.

Dicranopteris linearis (*c.*10 plants) and *Nephrolepis flexuosa* (*c.*2 plants), classed as „At Risk-Naturally Uncommon' and „At Risk-Declining' respectively in de Lange *et al.* (2009), were present on the sides of a hot spring at GPS reference: E1877709 N5721043 in 2004.

D. linearis is known from only *c.*24 sites in New Zealand.

Fauna: New Zealand pipit, harrier, spur-winged plover, fantail, grey warbler and tui were recorded in a 2004 survey.

Current Condition (2004 Assessment): This area and its surrounds have been modified by forestry operations and pastoral farming, resulting in a reduction in extent of the original geothermal vegetation. Invasive exotic plant species comprise a large component of the vegetation in the north of the site, in particular wilding pines (mainly radiata pine and maritime pine, with some lodgepole pine), which in some areas dominate the canopy over a lower tier of indigenous geothermal vegetation. However, geothermal vegetation remains relatively intact in several areas.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2004 Assessment*)*:* Wilding pines (6-25% cover) are visually dominant, and are a serious threat to plant communities on the cooler ground. In some areas pines are dominant over a lower indigenous tier comprising prostrate kanuka and mingimingi. Other invasive pest plants present include broom, Himalayan honeysuckle, buddleia, pasture grasses (including creeping bent, browntop, sweet vernal, Yorkshire fog and ryegrass) and blackberry, each of which has approximately 1-5% cover.

Human impacts (*2004 Assessment*)*:* Forestry and pastoral farming occurs between areas of indigenous geothermal vegetation. A geothermal power station has been installed (Merrett & Burns 1997). The impacts of draw-off are unknown.

Grazing (*2004 Assessment*)*:* Livestock have access to some of the smaller units of geothermal vegetation.

Adjoining land use (*2004 Assessment*)*:* Plantation forests and farmland.

Site Change:

Recent change: Changes to the mapping (between 2004 and 2011) are based on better site information rather than real change in the total extent of geothermal

vegetation. Changes are a consequence of the 2007 aerial photographs being of better quality than those used in 2004.

Historical: An assessment was undertaken of the site based on 1941 aerial photographs (Historical photo: SN 172 Run 1173 Photos 10-13, 1941). 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 vegetation are minimal in 1941. While more bare ground was present in 1941, it is difficult to determine if this is related to surface geothermal activity or other land uses such as farming.

Management Requirements: The spread of wilding pines and other exotic trees needs to be contained, with emphasis on those areas which are still predominantly indigenous. Wilding pines which occur in stands should be removed carefully, taking care not to disturb the remaining indigenous communities. 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).

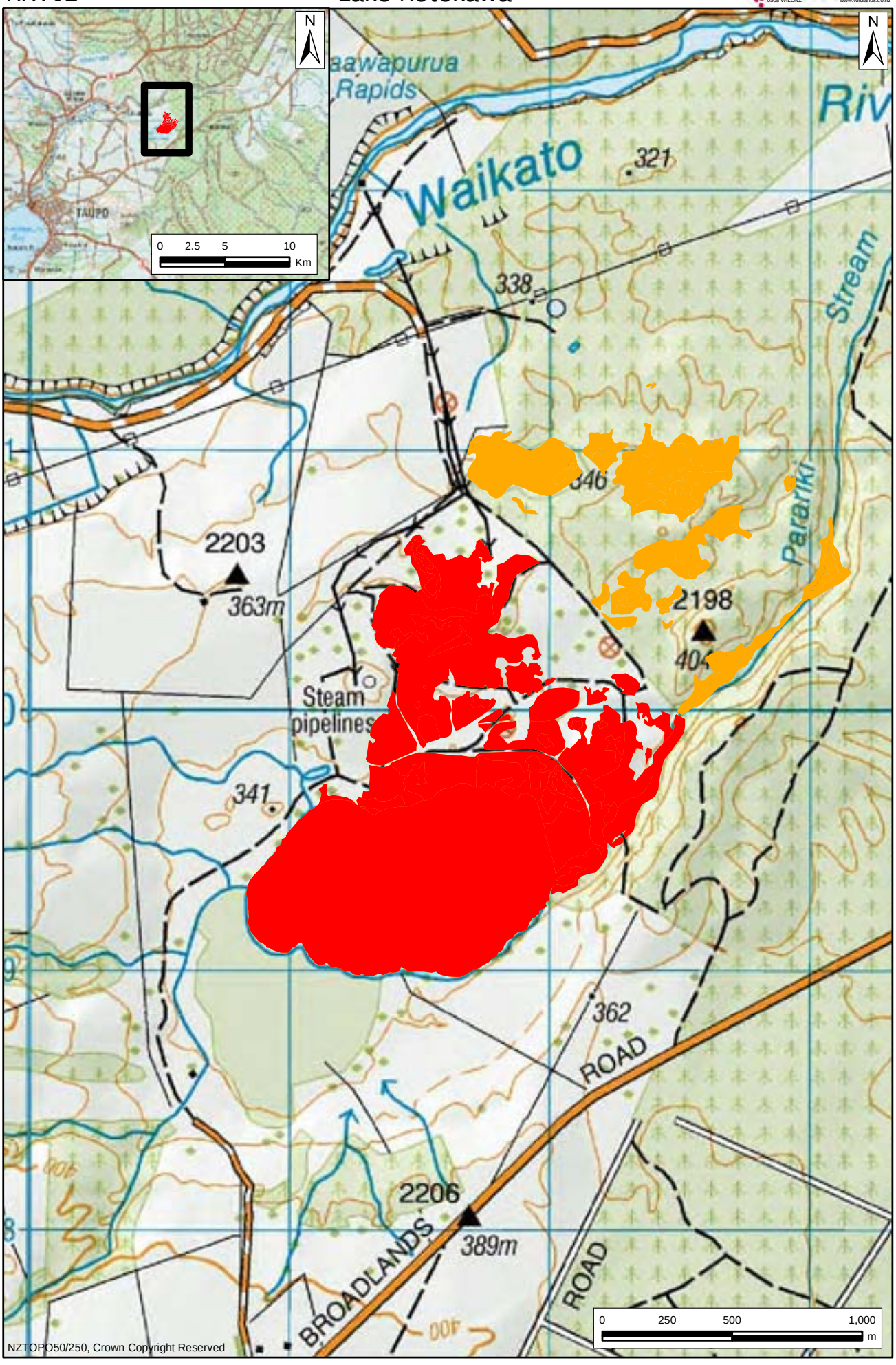
Significance Justification: This site is of regional significance because it comprises a large area of geothermal vegetation, a nationally uncommon vegetation and habitat type. While parts are degraded in quality, an „At Risk' species (prostrate kanuka) covers extensive areas and small populations of *Dicranopteris linearis* and *Nephrolepis flexuosa* (also classed as „At Risk') are present.

Notes: This area was not surveyed in Beadel & Bill (2000).

References: Merrett & Burns 1997; Merrett *et al*. 2003; Wildland Consultants 2004.

RKV02

Lake Rotokawa



RKV02

Lake Rotokawa

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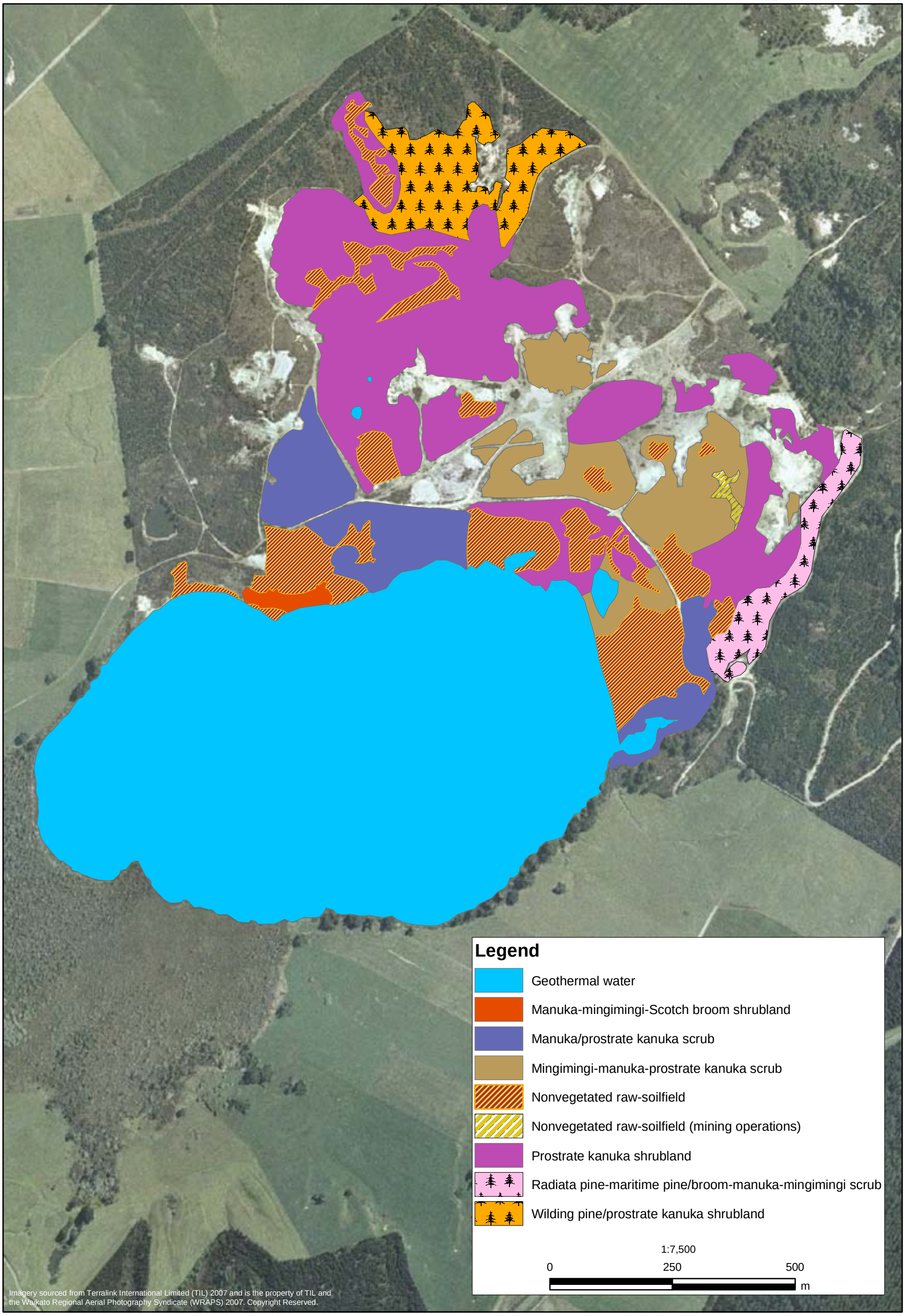


LAKE ROTOKAWA

Site Number: RKV02[1]
Grid Reference: NZTopo50 BG37 778 198
GPS Reference: NZTM E1877887 N5719763
Local Authority: Taupo
Ecological District: Atiamuri
Geothermal Field: Rotokawa
Bioclimatic Zone: Submontane
Tenure: Protected (Lake Rotokawa Conservation Area) and unprotected private land
Altitude: *c.*340-360 m
Extent of Geothermal Habitat: *c.*137.3 ha
Extent of Geothermal Vegetation: *c.*69.3 ha
Date of Field Survey: 14 April 2004

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.02 04.02.16	**Mingimingi-dominant scrub** **Mingimingi-manuka-prostrate kanuka scrub** Mingimingi, manuka, and prostrate kanuka (prostrate kanuka is at a much lower density in this type than when it occurs within prostrate kanuka shrubland) form a cover up to *c.*2 m high. Occasional maritime pine and radiata pine are present with small patches of monoao and nonvegetated raw-soilfield.	Flat and gentle hillslopes	*c.*9.6 ha
04.03 04.03.11	**Manuka-dominant scrub** **Manuka/prostrate kanuka scrub** Manuka to 2 m tall dominates this vegetation type, with patches of prostrate kanuka in warmer areas, and scattered patches of nonvegetated raw-soilfield.	Flat	*c.*9.1 ha
04.09 04.09.02	**Exotic-dominant scrub** **Radiata pine-maritime pine/ broom-manuka-mingimingi scrub** Radiata pine (some planted) and maritime pine are emergent over broom, manuka, mingimingi, and occasional prostrate kanuka. Broom dominates some areas.	Flat and gentle slopes	*c.*3.0 ha
05.01 05.01.01	**Prostrate kanuka-dominant shrubland** **Prostrate kanuka shrubland** Prostrate kanuka is dominant with mingimingi scattered throughout. Kanuka, manuka, monoao, prickly mingimingi, and bracken are locally common on cooler soils; broom and buddleia are common along the northern lake margin, and wilding pines (mostly maritime pine) are scattered throughout. Groundcover is patchy, comprising mainly lichens (*Cladia* and *Cladonia*). Fumaroles, thermal springs and gas vents are scattered throughout this area.	Flat and gentle hillslopes	*c.*27.9 ha

[1] Previously identified as U17/7 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
05.01.14	**Wilding pine/prostrate kanuka shrubland** Maritime pine and some radiata pine appear to be establishing in large areas of prostrate kanuka shrubland. Some control is evident in some parts with recently felled trees. *Lycopodiella cernua*, bracken, *Gleichenia microphylla*, and *Paesia scaberula* are scattered throughout.	Flat and gentle hillslopes	*c.*6.0 ha
05.03 05.03.19	**Manuka-dominant shrubland** **Manuka-mingimingi-broom shrubland** Mingimingi (up to 2 m high) dominates this area in association with broom. Manuka and wilding pines (mostly maritime pine and radiata pine) are emergent throughout. Also present are prickly mingimingi and patotara (*Leucopogon fraseri*). The groundcover is sparse with occasional tawiniwini and turutu, as well as mosses, liverworts and lichens. Bracken and exotic grasses (particularly Yorkshire fog) dominate large areas within this vegetation type.	Gentle hillslopes	*c.*0.6 ha
22.01 22.01.01	**Geothermal water** **Geothermal water** Lake Rotokawa, geothermal lakes, hot streams, and mud lakes.	Flat and gentle hillslopes	*c.*67.9 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Sinter deposits, fumeroles, mud pools. Patches of prostrate kanuka, and broom.	Flat	*c.*12.9 ha
28.01.02	**Nonvegetated raw-soilfield (mining operations)** Areas of open pumice loamfield which has been mined for sulphur are present throughout.	Flat	*c.*0.3 ha

Indigenous Flora: Prostrate kanuka (classed as „At Risk' in de Lange *et al*. 2009) and *Lycopodiella cernua* are present. At least 70 plants of *Calochilus robertsonii* (classed as „At Risk-Naturally Uncommon' in de Lange *et al*. 2009) were recorded from the site in a Rotorua Botanical Society trip to the site in November 2007 (Bycroft 2008). Prostrate kanuka is endemic to geothermal sites, and *Lycopodiella cernua,* is a characteristic feature of geothermal areas.

A field survey of the site by Rotorua Botanical Society on 3 November 2007 recorded a total of 27 indigenous and 24 naturalised vascular plant species (Bycroft 2008). Other indigenous species typical of geothermal habitat include monoao, tawiniwini, manuka, prickly mingimingi, mingimingi, potatara, *Lycopodiella cernua*, *Gleichenia microphylla*, *Histiopteris incisa*, turutu, and bracken.

Fauna: Banded dotterel and North Island fernbird (classed „Threatened-Nationally Vulnerable' and „At Risk-Declining' respectively in Miskelly *et al.* 2008) are present (Merrett & Burns 1997). Banded dotterel breed at this site. Banded dotterel and N.I. fernbird were not recorded in the 2004 survey. Pied stilts (also classed as „At Risk-Declining' in Miskelly *et al.* 2008), nesting black backed gulls and other water birds are also present on and

around the 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.

A 2007 survey of the site recorded one banded dotterel, and a number of common indigenous and exotic bird species, including Indian myna, paradise shelduck, spur winged plover, grey warbler, black-backed gull, Australian magpie, pheasant, California quail, greenfinch, skylark, and starling (Bycroft 2007).

Current Condition (2004 Assessment):

This area has been extensively modified during more than 50 years of sulphur mining, resulting in a reduction in the original extent of geothermal vegetation. However, indigenous geothermal vegetation has begun to re-establish in unvegetated areas in recent years. Invasive exotic plant species make up a large component of the vegetation, in particular wilding pines (particularly radiata pine and maritime pine, with some black pine and lodgepole 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 north-east of the lake.

Threats/Modification/ Vulnerability:

Invasive pest plants (*2004 Assessment*):

Wilding pines (6-25% cover) are visually dominant, and are a serious threat to indigenous plant communities on cooler ground. Some control of wilding pines is evident at the site with recently felled trees present. In some areas pines are dominant over a lower indigenous tier comprising prostrate kanuka and mingimingi. Other invasive exotic plant species present include broom, Himalayan honeysuckle, buddleia, pasture grasses (including creeping bent, browntop, sweet vernal, Yorkshire fog and ryegrass) and blackberry, each of which has approximately 1-5% cover.

A 2007 visit to the site by the Rotorua Botanical Society recorded the following pest trees: radiata pine, maritime pine, silver birch, and tree lucerne. The Society noted the recent wilding pines control work undertaken by the Department of Conservation. Other exotic pest plants recorded were gorse, broom, blackberry, buddleia, pampas, grey willow, Montpellier broom, and Spanish heath, and exotic grassland species, including browntop, Yorkshire fog, sweet vernal, lotus, and catsear (Bycroft 2008).

Human impacts (*2004 Assessment*):

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. Some control of wilding pines has taken place.

Grazing (*2004 Assessment*):

The site is fenced and neither livestock nor livestock damage was observed in the current survey.

Adjoining land use (*2004 Assessment*):

Plantation forests and farmland.

Site Change:

Recent change:

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 quality of this site in recent years.

Historical:

The most dramatic change at this site from historical photographs (Historical photos: SN 172 Run 1173 Photos 10-13, 1941) taken in 1941 is that it appears that the site was farmed, and there were few wilding pines amongst geothermal vegetation and habitat. More bare ground may have been present in 1941, but this may also be indicative of human land use, rather than a decline in geothermal surface features over time.

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:

The spread of wilding pines, silver birch, and grey willow needs to be contained, with emphasis on those areas which are still predominantly indigenous. Wilding pines which occur in stands should be removed carefully, taking care not to disturb the remaining indigenous communities. Pampas should also be controlled. The site should be monitored to identify changes that may relate to 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, good quality, area of geothermal vegetation which is a nationally uncommon vegetation and habitat type, including a wide diversity of geothermal habitats and at risk plant and animal species. While the site has a long history of modification, the quality of the site is noticeably improving since management has moved to the Department of Conservation.

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 category.

There would be significant value in reassessing the boundaries of geothermal vegetation at this site in the near future. The vegetation of the site is recovering well following cessation of mining and management of pines by the Department of Conservation. The effects on terrestrial geothermal vegetation of geothermal energy extraction from this field should be monitored.

Merrett & 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 & Bill 2000; Bycroft 2008; Clarkson *et al.* 1989; Department of Conservation 1998; Merrett & Burns 1997; Merrett & Clarkson 1999; Merrett *et al*. 2003; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004.

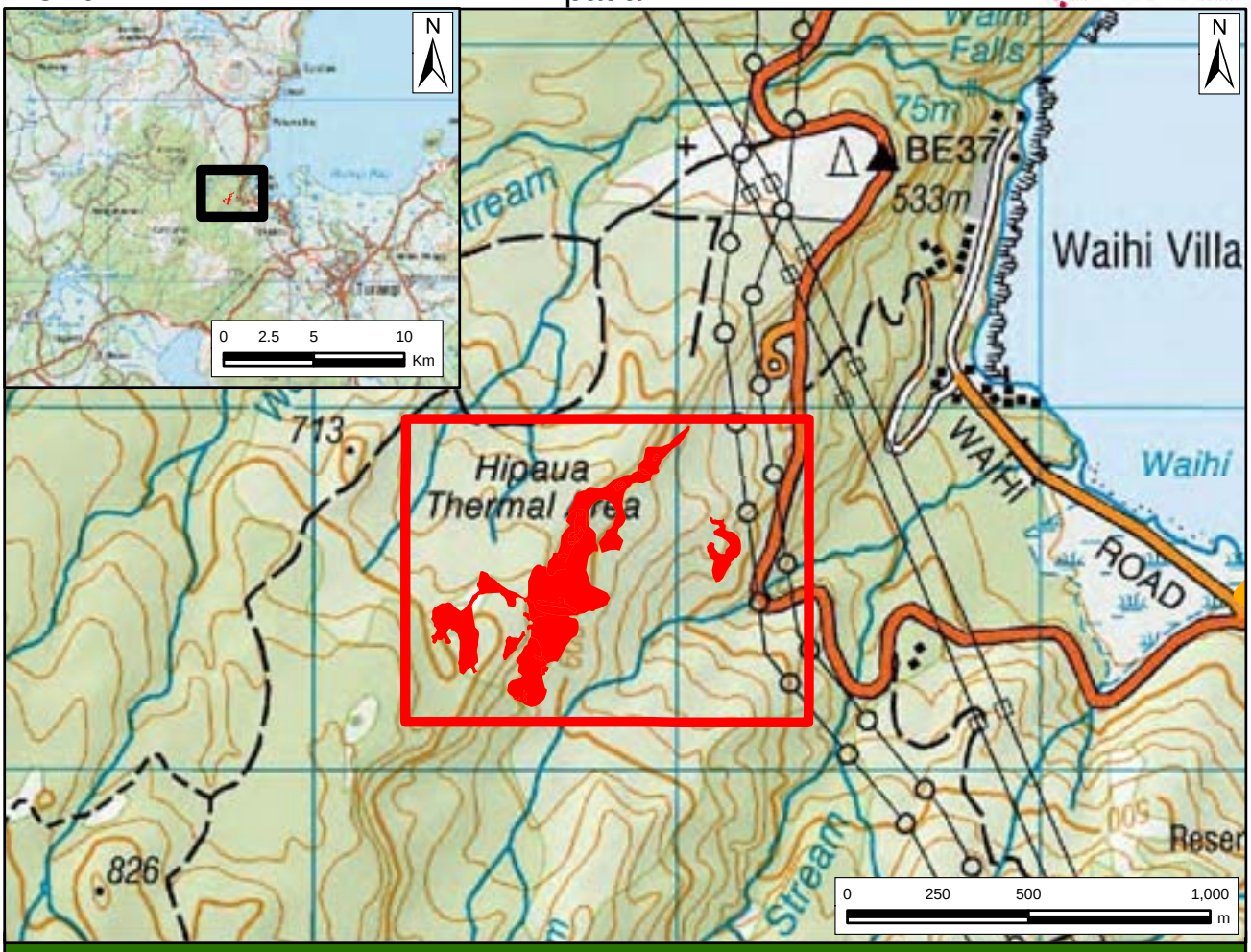
1.14 TOKAANU-WAIHI-HIPAUA GEOTHERMAL FIELD

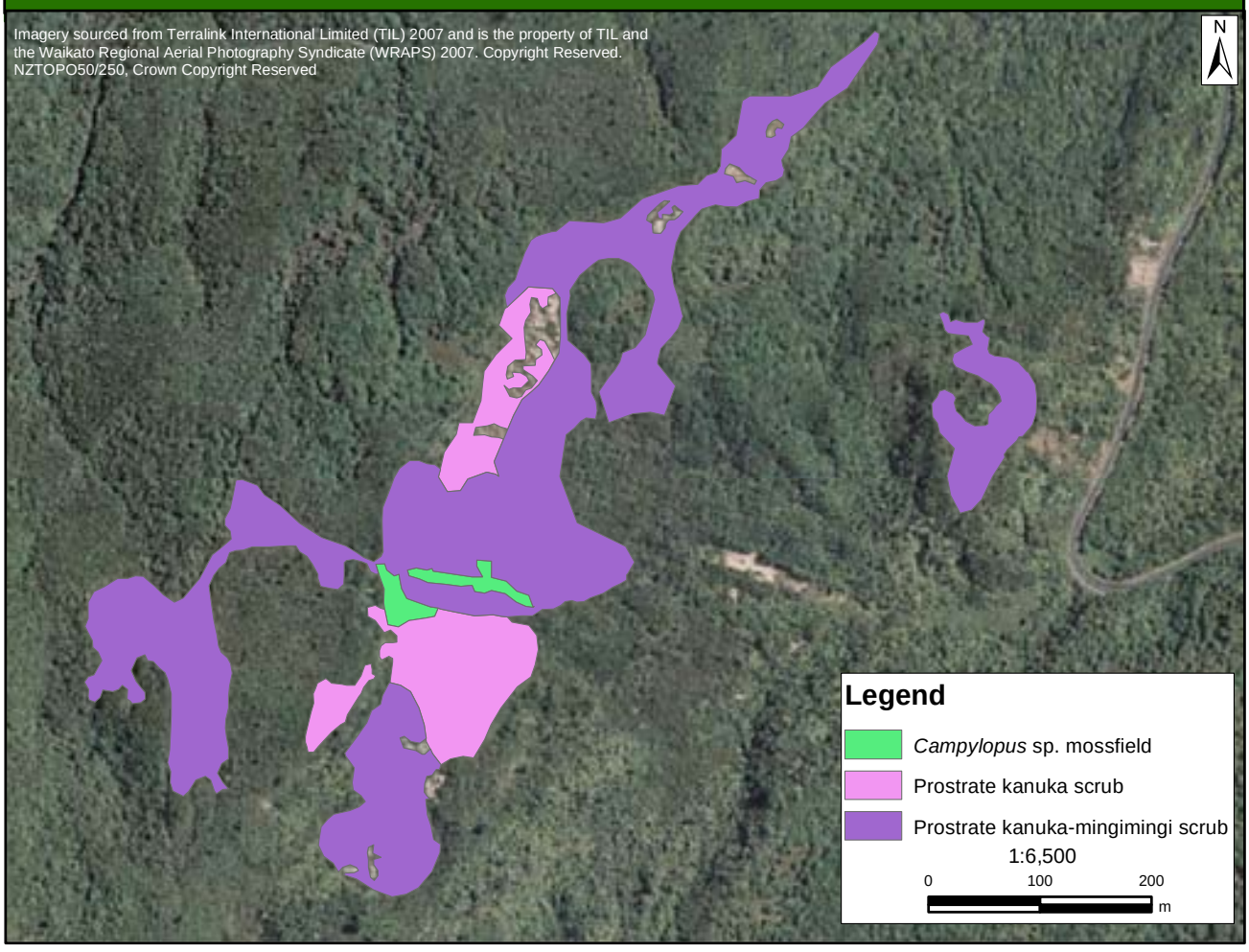
List of Geothermal Sites

TOV02	Hipaua
TOV03/TOV04/	
TOV05/TOV06	Tokaanu Lakeshore Wetland
TOV07	Maunganamu West
TOV08	Tokaanu Thermal Park
TOV09	Tokaanu Urupa Mud Pools
TOV10	Maunganamu East
TOV11	Maunganamu North Wetland
TOV14	Tokaanu Tailrace Canal

TOV02

Hipaua





HIPAUA

Site Number: TOV02[1]
Grid Reference: NZTopo50 BH35 368 845
GPS reference NZTM E1836790 N5684476
Local Authority: Taupo
Ecological District: Tongariro
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: 550-700 m
Extent of Geothermal Habitat: *c.*11.4 ha
Extent of Geothermal Vegetation: *c.*11.4 ha
Date of Field Survey: No survey. Observed from main road on 19 October 1999.

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** A dense cover of prostrate kanuka and local patches of *Campylopus* moss amongst scattered steaming fissures.	Hillslope	*c.*2.0 ha
04.01.02	**Prostrate kanuka-mingimingi scrub** Prostrate kanuka and mingimingi form a dense cover with occasional fumaroles. Karamu and whauwhaupaku occur locally, particularly at the margins of this type where the prostrate kanuka-mingimingi scrub merges with whauwhaupaku-karamu-kamahi/tutu scrub (outside of site). (Source: Given 1995)	Hillslope, shallow gullies	*c.*8.7 ha
14.02 14.02.02	***Campylopus*-dominant mossfield** ***Campylopus* sp. mossfield** *Campylopus* sp. occurs in patches amongst steaming fissures.	Hillslope	*c.*0.3 ha
28.01 28.01.01	**Nonvegetated raw-soilfield (not mapped)** **Nonvegetated raw-soilfield** Heated bare soil (estimated from aerial photographs). Appears to be geothermal clays in site photographs, but should be assessed in the field.		*c.*0.4 ha

Indigenous Flora: Prostrate kanuka (classed as ‚At Risk-Naturally Uncommon' in de Lange *et al.* 2009) 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

[1] Previously identified as T19/1 in Wildland Consultants (2004).

corresponding to soil temperatures (Given 1995).

Threats/Modification/ Vulnerability:

Invasive pest plants: Unknown. There appears to be some pampas visible on photographs (taken from a helicopter), provided by Waikato Regional Council (July 2002).

Human impacts: Human impacts are currently very low, and the site is virtually unaltered by human interference (Given 1995).

Grazing: Livestock have no access to this area.

Adjoining land use: Surrounded by indigenous vegetation on unprotected private land.

Site Change:

Recent change: Any change in site boundaries is primarily based on improved 2007 aerial photographs.

Historical: Photographs from 1941 (Historical photo: SN 178 Run 207 Photos 27, 1941) were assessed. The site has probably changed little since 1941, although boundaries between the different vegetation types present, particularly the boundary between geothermal scrub and non-geothermal scrub, are difficult to determine.

Management Requirements: 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 1, 3, 5, 7, 9, 10; Table 2 - Factors 12, 14).

Significance/ Justification: This site is of regional significance because it is an important habitat for an „At Risk' species (prostrate kanuka) and is a relatively large area of a nationally uncommon habitat type, and is thus 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 assess 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 Taupo to the summit of Kakaramea, Tihia and Pihanga and including Lake Rotopounamu and Lake Rotoaira.

Notes: Access to this site was not granted, and the descriptions and assessments have been compiled from existing literature, digital aerial photographs (2007) and a visual inspection from SH 41 using binoculars during the 1999-2000 survey.

The 2007 aerial photographs used for this report are of considerably higher quality than those used in the 2004 report on geothermal vegetation in the Region (Wildland Consultants 2004), and as a result, additional areas were

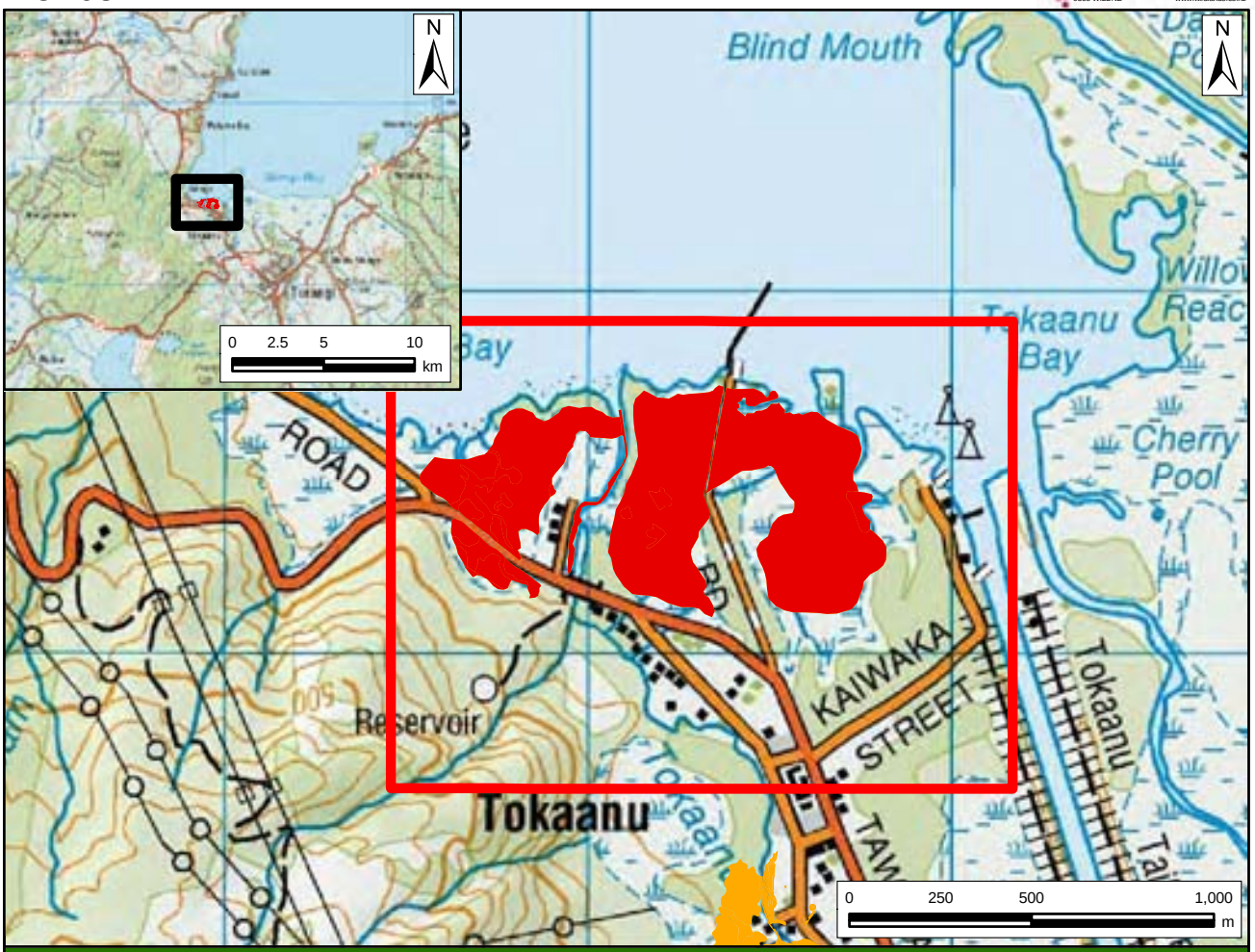
added to the site. However, if site access is granted in the future, the boundaries should be reassessed, and the site should be inspected in detail for all features.

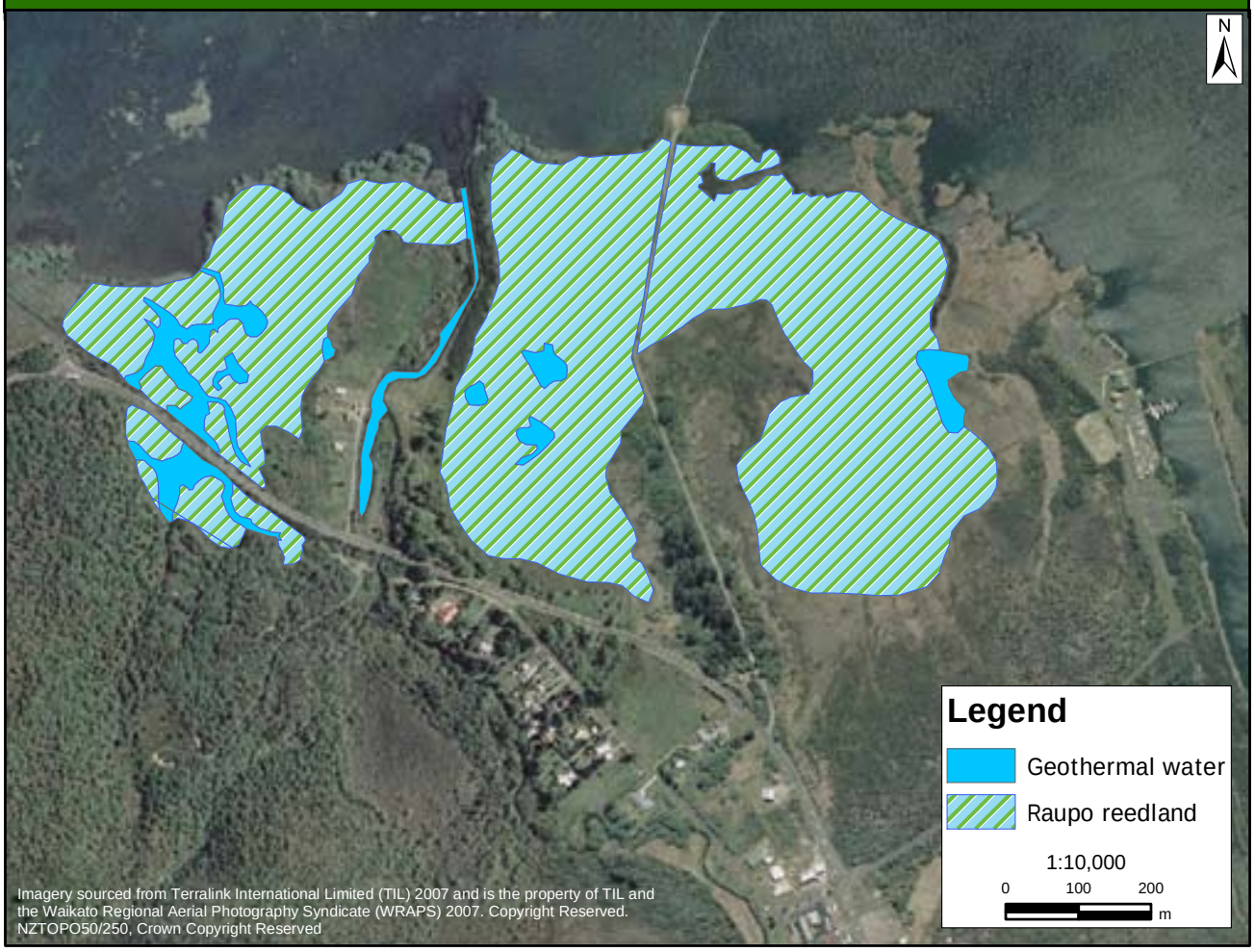
Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category A - the highest category.

References: Department of Conservation 1998; Given 1995 & 1996; Wildland Consultants 2004.

TOV03

Tokaanu Lake Shore Wetland





TOKAANU LAKE SHORE WETLAND

Site Number: TOV03/TOV04/TOV05/TOV06[1]
Grid Reference: NZTopo50 BG35 394 024
GPS reference: NZTM E1839400 N5702400
Local Authority: Taupo
Ecological District: Taupo; Tongariro
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Unprotected private land and Protected (Tokaanu Recreation Reserve)
Altitude: *c.*340 - 360 m
Extent of Geothermal Vegetation: *c.*42.4 ha
Date of Field Survey: 13 February 2007

Code	Type	Landform	Extent
11.01 11.01.01	**Raupo-dominant reedland** **Raupo reedland** An extensive area of raupo reedland. A small population of arrow grass was viewed from the road on 13 February 2007. Crack willow and grey willow were recorded in this wetland, particularly on the margins of Lake Taupo and recently reclaimed wetland. Steam could be seen rising from the wetland at some locations, but access to most sites is very difficult.	Lake margin wetland	*c.*39.1 ha
22.01 22.01.01	**Geothermal water** **Geothermal water (occurs within 11.01.01, not mapped)** Geothermally-influenced water. Steam was viewed rising from this water on 13 February 2011.		

Indigenous Flora: No „Threatened' or „At Risk' species were noted during the 2007 survey; however a full field survey has not been carried out due to the difficulty of accessing most of this site.

Fauna: One „Threatened' and two „At Risk' (Miskelly *et al.* 2008) bird species were recorded in this wetland; New Zealand dabchick („Threatened-Nationally Vulnerable'), spotless crake („At Risk-Relict'), and North Island fernbird („At Risk-Declining'). Australasian bittern („Threatened-Nationally Critical' in Miskelly *et al*. 2008) 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] Previously identified as T19/9, T19/10, T19/11, T19/12 in Wildland Consultants (2007).

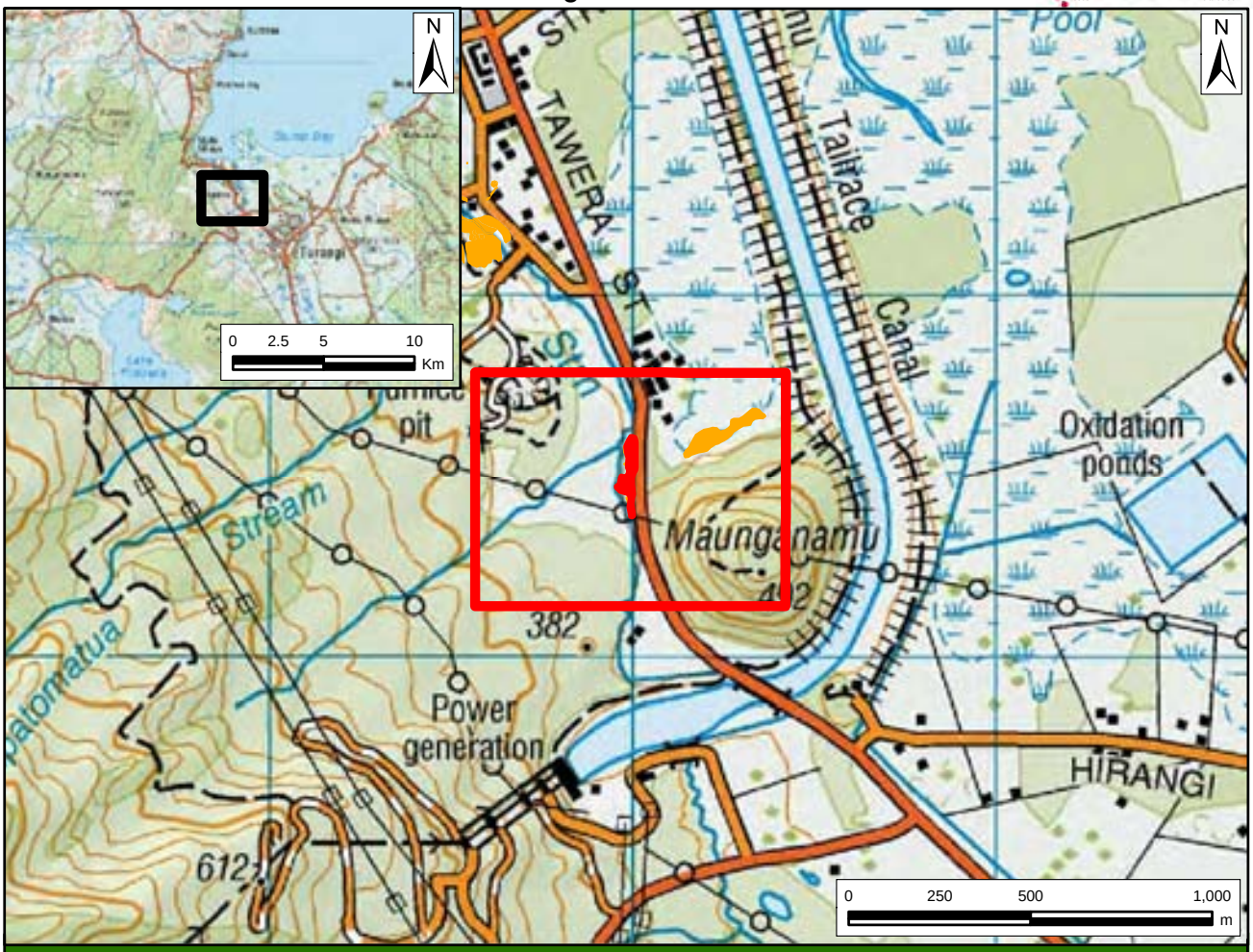
Human impacts (*2007 Assessment*):	Drains have been constructed through parts of the wetland. Parts of the wetland have been converted to pasture and residential housing, and roads have been constructed to access the lake.
Grazing (*2007 Assessment*):	No grazing is known to occur within the remaining wetland.
Adjoining land use (*2007 Assessment*):	Farming; roads; Lake Taupo; wetland; residential.

Site Change:

Recent change:	Not assessed. No significant change is known to have taken place in this wetland in the last ten years.
Historical:	An inspection was undertaken of 1941 aerial photographs of this site (Historical photos: SN 178 Run 207 Photos 29-31, 1941). While little evidence of change is seen when 1941 and 2007 aerial photographs are compared, a canal (Tokaanu Tailrace Canal) that has been constructed through the eastern part of the wetland 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 lake margins in 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, 11; Table 2 -, Factors 7, 8).
Significance Justification:	The site is of national significance because it provides habitat for a „Threatened' species (Australasian bittern), and because it is a good quality example of a nationally uncommon habitat type (i.e. geothermal). It is one of the best examples of a wetland-geothermal sequence in Taupo Ecological District and is part of a large freshwater wetland in which is in excellent ecological condition.
Notes:	The temperature of the substrate was measured in many locations in the eastern part of the site, but no evidence of geothermal vegetation was found with temperatures ranging from 17-19^{o}C. However, extensive areas of geothermal vegetation were found further inland. Part of the area of raupo reedland was viewed from the road and entered by kayak on 13 February 2007. This is an extensive area of wetland vegetation and it is likely geothermal habitat is 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. This site was not assessed in Wildland Consultants (2004 & 2007).
References:	Bromley & Mongillo 1991; Hochstein 2007; Wildland Consultants 2007.

TOV07

Maunganamu West



MAUNGANAMU WEST

Site Number: TOV07[1]
Grid Reference: NZTopo50 BH35 400 825
GPS Reference: NZTM E1839981 N5682478
Local Authority: Taupo
Ecological District: Taupo; Tongariro
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Protected (Tokaanu Public Garden Reserve) and unprotected private land
Altitude: 360 m
Extent of Geothermal Habitat: *c.*0.6 ha
Extent of Geothermal Vegetation: *c.*0.6 ha
Date of Field Survey: 13 February 2007

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
11.01 11.01.01	**Raupo-dominant reedland** **Raupo reedland** Occasional crack willow occurs over raupo reedland in association with *Baumea rubiginosa*, *Schoenoplectus tabernaemontani*, *Eleocharis acuta*, pohue, lotus, and creeping bent. Blackberry and Japanese honeysuckle are common on margins. Soil temperatures at 10 cm depth were around 22.5^{o} and 25.4^{o}C (measured with the thermocouple probe). At 1 m depth temperatures were recorded up to 49.1 ^{o}C.	Wetland	*c.*0.6 ha

Geophysical Assessment: Several airborne IR anomalies were recorded to occur along the eastern banks of the Tokaanu Stream along a *c.*200 m long stretch to the north of 6 244 000 m N. Thermal springs and minor mud pools were mapped by Healy (1942) within this stretch.

Indigenous Flora: No „Threatened' or „At Risk' species as listed in de Lange *et al.* (2009) are known from this site.

Fauna: Common indigenous and introduced species typical of the habitats were present. The wetland vegetation is likely to provide habitat for fernbird and spotless crake (classed as „At Risk-Declining' and „At Risk-Relict' respectively in Miskelly *et al.* 2008), in conjunction with the adjacent large area of wetland habitat.

Current Condition (2007 Assessment): Weeds are present on the margins, and occasional crack willow is present in the wetland.

[1] Previously identified as T19/6 in Wildland Consultants (2004 and 2007a).

Threats/Modification/ Vulnerability:

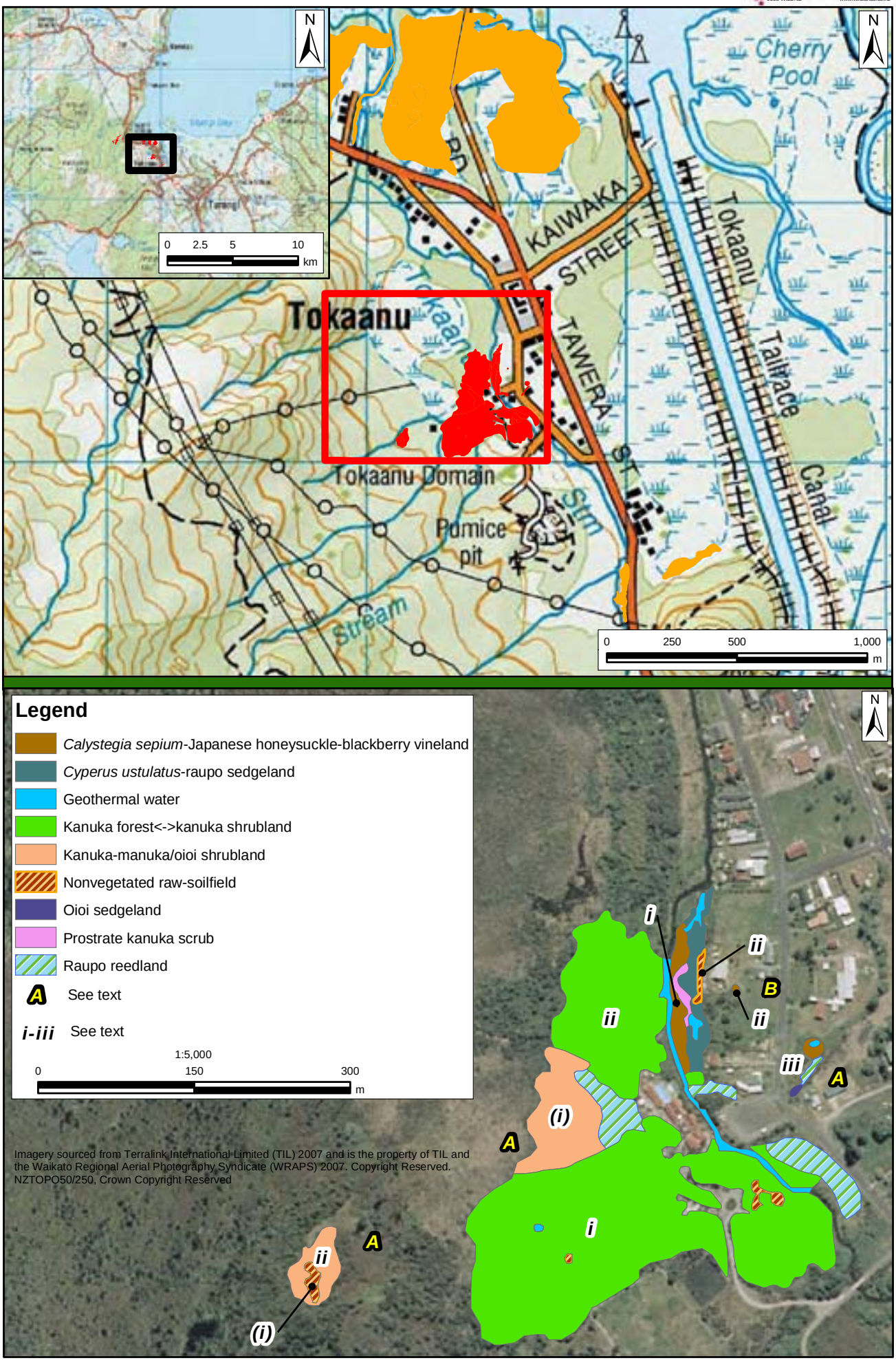
Invasive pest plants (*2007 Assessment*)*:*	Blackberry (1-5% cover); Japanese honeysuckle (1-5% cover); and crack willow (1-5% cover).
Human impacts (*2007 Assessment*)*:*	There is a road within 10 m of the site. A culvert is also present.
Grazing (*2007 Assessment*)*:*	This site is not grazed by stock.
Adjoining land use (*2007 Assessment*)*:*	Tokaanu Stream and State Highway.

Site Change:

Recent change:	Not assessed. Any change not likely to be significant.
Historical:	This site is too small to see any evidence of change since 1941 (Historical photos: SN 178 Run 207 Photos 29-31, 1941).
Management Requirements:	Control of pest plants (particularly crack willow) will maintain the ecological values of the site.
Significance Level:	Regional (Table 1 - Criteria 5, 6, 10; Table 2 - Factor 9).
Significance Justification:	This site is of regional significance because it is protected and managed by the Department of Conservation and it forms a small part of an extensive ecological sequence that extends from the shores of Lake Taupo to the summit of Kakaramea, Tihia and Pihanga and includes Lake Rotopounamu and Lake Rotoaira. This ecological sequence includes extensive areas of geothermal habitat.
References:	Bromley & Mongillo 1991; Wildland Consultants 2004 & 2007a.

TOV08

Tokaanu Thermal Park



TOKAANU THERMAL PARK

Site Number: TOV08[1]
Grid Reference: NZTopo50 BH35 364 833
GPS reference: NZTM E1839472 N5683151
Local Authority: Taupo
Ecological District: Taupo
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Protected (Tokaanu Thermal Park Recreation Reserve administered by DOC)
Altitude: *c.*360 m
Extent of Geothermal Habitat: *c.*7.8 ha
Extent of Geothermal Vegetation: *c.*7.6 ha
Date of Field Survey: 23 August 2004 (partly updated in February 2007)

VEGETATION		LANDFORM	EXTENT
CODE	**TYPE**		
01.04 01.04.11	**Kanuka forest** **Kanuka forest ⇔ kanuka shrubland** (i) Kanuka forest forms the vegetation cover over *c.*80% of this vegetation unit. Kanuka up to *c.*7 m high with a diameter at breast height of *c.*10-15 cm comprises the canopy, with an understorey of kanuka, mingimingi and oioi, with scattered turutu, hound's tongue fern, *Cyperus ustulatus* and manuka. Mud pools and hot water pools are common beneath the kanuka canopy. Kanuka shrubland forms the vegetation cover over the remaining *c.*20% of this area and generally occurs around the site margins. Kanuka shrubs are common with local *Cyperus ustulatus* and narrow-leaved carpet grass. Moss (including *Wijkia extenuata* and *Ptychomnion aciculare*) often form a dense groundcover. Manuka 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 (*Rhododendron* sp. (unidentified)), are present. Other common species present include kohuhu, whauwhaupaku, turutu, karamu, wheki, swamp kiokio and *Paesia scaberula*. (ii) Kanuka 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 with a fluke and soil probe in this vegetation type. Ivy, blackberry, *Microsorum pustulatum*, turutu, Japanese honeysuckle and mingimingi are common in places. Atakororeke	Flat	*c.*5.7 ha

[1] Previously identified as T19/3 in Wildland Consultants (2004 and 2007a).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	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 (fluke thermocouple) at 10 cm depth in substrate. *Cyperus ustulatus* and kiokio are common along stream margins beneath a kanuka canopy. Blackberry becomes thick around stream margins *c*.100 m upstream of where the stream flows into the Tokaanu River. Prostrate kanuka was common, particularly towards the northern portion of this site near stream margins.		
03.03 03.03.01	**Mixed exotic vineland** **Pohue-Japanese honeysuckle-blackberry vineland** (i) A dense vineland comprising pohue and Japanese honeysuckle growing over blackberry. Patches of tall fescue are common. Mud pools and hot springs are scattered throughout this vegetation type. (ii) A small mud pool hole has a small bubbling spring (temperature recorded of 88°C). (iii) Vineland surrounding a hot spring.	River margins; mud pool; hot spring	*c*.0.2 ha
04.01 04.01.01	**Prostrate kanuka-dominant scrub** **Prostrate kanuka scrub** Prostrate kanuka shrubland with a canopy height of 1-2 m. Pohue, Japanese honeysuckle and blackberry are common on margins.	Flat	<0.1 ha
05.04 05.04.07	**Kanuka-dominant shrubland** **Kanuka-manuka/oioi shrubland** (i) Emergent kanuka is common in association with scattered manuka over a dense cover of oioi. Small patches of nonvegetated raw-soilfield are also present in places. (ii) A canopy dominant with manuka (height of 3 m), with occasional kanuka and mingimingi, over an understorey of oioi and sinter. The site is surrounded by dense blackberry scrub.	Hillslope	*c*.0.8 ha
09.02 09.02.06	***Cyperus ustulatus*-dominant sedgeland** ***Cyperus ustulatus*-raupo sedgeland** Dense *Cyperus ustulatus* and raupo to 2.5 m. Japanese honeysuckle and blackberry common on margins. Patches of sinter and nonvegetated raw-soilfield are common.	Wetland	*c*.0.2 ha
09.08 09.08.01	**Oioi-dominant sedgeland** **Oioi sedgeland** Oioi is dominant, with local *Eleocharis acuta*, *Schoenus maschalinus* and adventive grasses, including creeping bent and Yorkshire fog.	Wetland	<0.1 ha
11.01 11.01.01	**Raupo-dominant reedland** **Raupo reedland** Raupo forms a dense reedland, with scattered *Carex virgata* and *Schoenoplectus tabernaemontani*, and a few saplings of grey willow and crack willow. *Cyperus*	Flat	*c*.0.5 ha

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	ustulatus is locally dominant and blackberry is common along the road margin. Grey willow is present.		
14.02 14.02.02	***Campylopus*-dominant mossfield** (not mapped) ***Campylopus* sp. mossfield**	Pools; sinter terraces	
22.01 22.01.01	**Geothermal water** **Geothermal water** 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
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** 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. • A sinter terrace with oioi common on margins. • Nonvegetated raw-soilfield (thermally altered soils) with common raupo and prostrate kanuka and *Cyperus ustulatus* on margins. Hot springs and mud pools are common. Temperatures of up to 96.7°C (fluke thermocouple) were recorded.	Flat; gently sloping; hillslope	*c.*0.1 ha

Geophysical Assessment[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 geysering 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 (98.5°C) of the discharged hot water is still close to local boiling point.

However, 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

[1] Hochstein 2007

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 kg/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.

Indigenous Flora:

A moderate sized population of *Korthalsella salicornioides* occurs at this site (Beadel & Bill 2000). *Korthalsella salicornioides* is a semi-parasitic mistletoe classed as „At Risk-Naturally Uncommon' in de Lange *et al.* (2009). *Schizaea dichotoma* (also classed as an „At Risk-Naturally Uncommon' species in de Lange *et al.* 2009) known from kauri forests of Northland and South Auckland, and locally at geothermal sites, is also present (Beadel & Bill 2000). This is the southern limit of distribution for this species. (Note no plants of *Korthalsella salicornioides* or *Schizaea dichotoma* were recorded in the 2004 or 2007 survey.

A good sized population of prostrate kanuka (classed as „At Risk-Naturally Uncommon' in de Lange *et al.* 2009) is present.

Given (1995) recorded *Christella* aff. *dentata* ("thermal") (classed as „At Risk-Declining' in de Lange *et al.* 2009) from this site, but it is now considered extinct at this site. *Nephrolepis flexuosa* (classed as „At Risk-Declining' in de Lange *et al*. 2009) was recorded from this site in 1987 (de Lange *et al*. 2009), but has not been recorded in subsequent surveys and is also presumed extinct at this site.

Fauna:

North Island fernbird (classed as „At Risk-Declining' in Miskelly *et al.* 2008) are present at this site. Other birds present include tui, 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 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 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.

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*)*:*	Livestock are not a threat to this area.
Adjoining land use (*2007 Assessment*)*:*	Indigenous vegetation; blackberry scrub; residential; farm land; recreation facilities (swimming baths, tracks).

Site Change:

Recent change:	Any changes to the extent of geothermal vegetation are likely to be minor. Additional areas were added to this site in 2007, based on additional information on geothermal vegetation. However, this does not represent real change. The site has not been re-assessed in the field.
Historical:	An inspection was made of black and white aerial photographs (Historical photo: SN 178 Run 207 Photos 29-31, 1941). 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 notes above). 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 is evident on the geothermal site. 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 map). The site contains populations of three species ranked as „At Risk' (*Korthalsella salicornioides,* prostrate kanuka, and *Schizaea dichotoma*). The site is protected under the Reserves Act (1977) and comprises a relatively large example of geothermal vegetation, including a wide diversity of habitat types. This site is also part of an extensive natural area extending from the shores of Lake Taupo to the summit of Kakaramea, Tihia and Pihanga and including Lake Rotopounamu and Lake Rotoaira. A small part of the site (marked as B on map) is of local significance because it contains geothermal habitat, a nationally uncommon habitat type, however it is very small and highly modified with no indigenous plant species recorded.
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 B - the second highest category.

It is difficult to safely undertake a detailed inspection of the site because of the geothermal activity which makes it difficult to determine the exact boundary of geothermal activity in the wetland. However, the geothermal area mapped in this report is similar to the area shown in IR anomalies in Bromley & Mongillo 1991, and Hochstein 2007, Figure 3.2, Page 73).

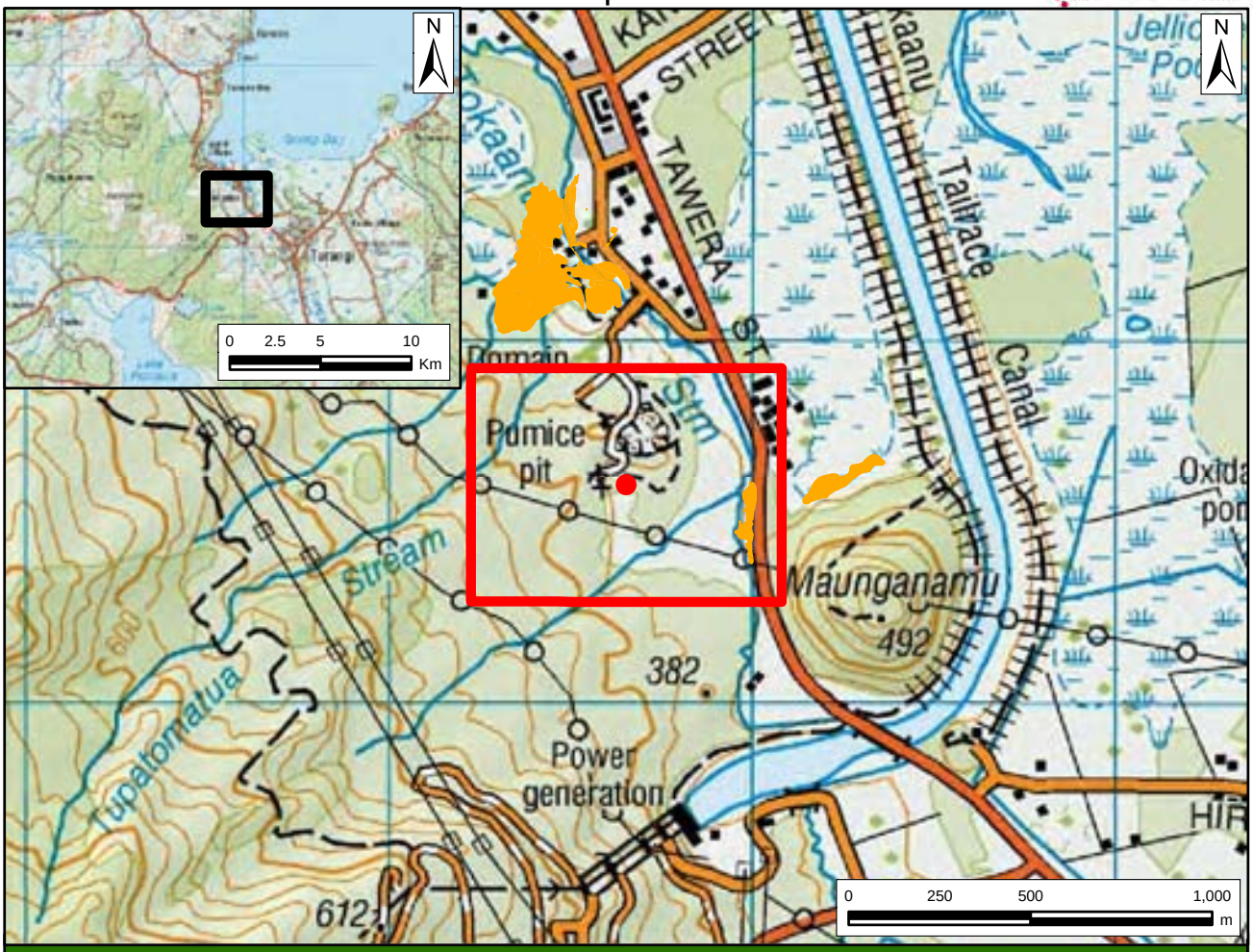
Two pools within this site are listed in Waikato Regional Council (unpublished) as Taumatapuhipuhi spring (an unfenced pool of *c.*75ºC, which periodically erupts hot water) and Takarea No. 5 (a fenced pool of *c.*75ºC).

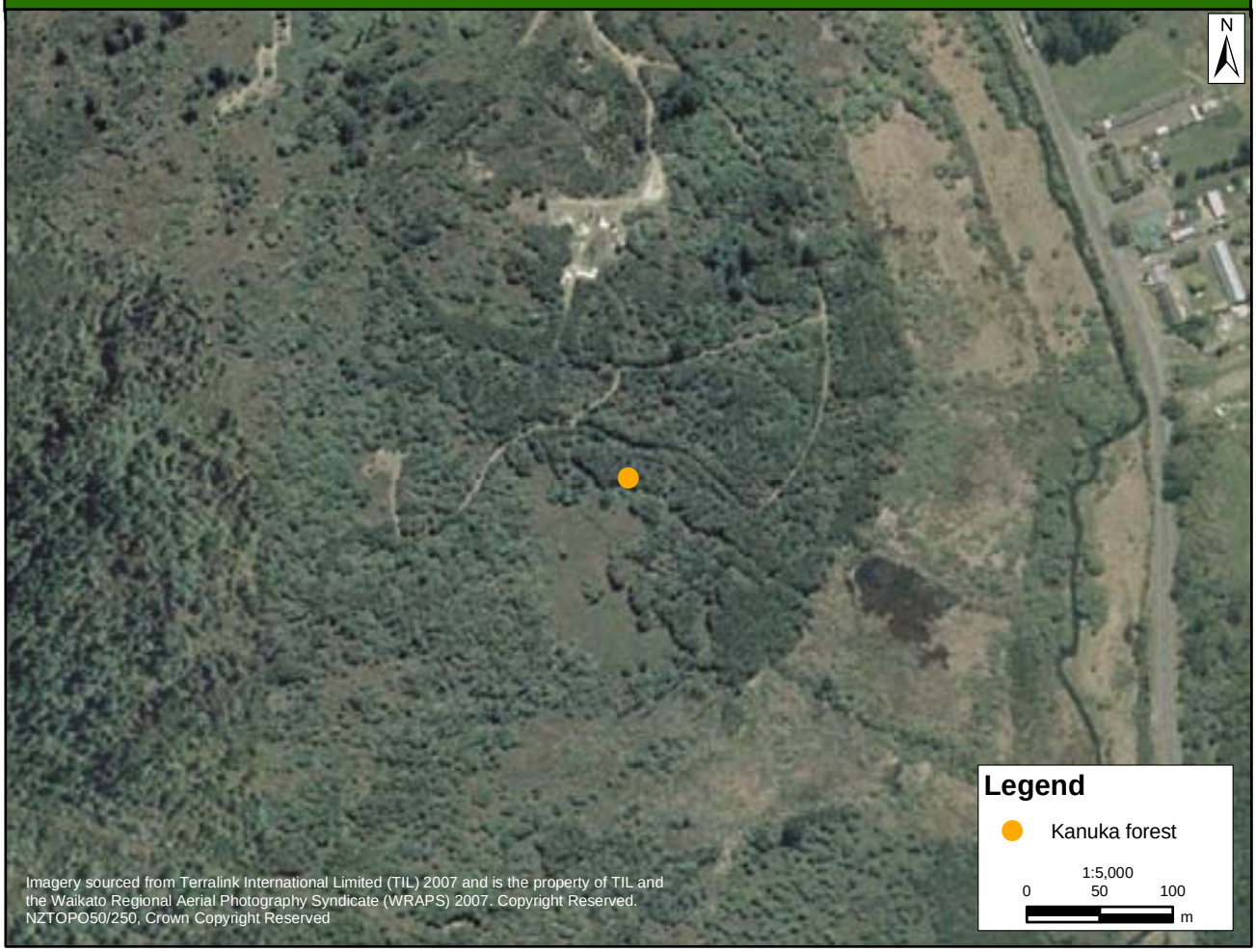
References:

Anon. no date; Beadel & Bill 2000; Department of Conservation 1997; Given 1995 & 1996; Healy 1942; Hochstein 2007; Waikato Regional Council (unpublished); Wildland Consultants 2004 & 2007a.

TOV09

Tokaanu Urupa Mud Pools





TOKAANU URUPA MUD POOLS

Site Number: TOV09[1]
Grid Reference: NZTopo50 BH35 397 826
GPS Reference: NZTM E1839651 N5682603
Local Authority: Taupo
Ecological District: Tongariro
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Protected (Tokaanu Hot-Springs Reserve)
Altitude: *c.*380 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 7 February 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
01.04 01.04.03	**Kanuka-dominant forest** **Kanuka forest** Kanuka forest to *c.*7 m tall overhangs two mud pools. There is occasional whauwhaupaku and mapou present in the canopy. There is scattered turutu, mingimingi, and blackberry around the mud pools (one 5 × 5 m and the other 4 × 4 m).	Mud pool	<0.1 ha

Geophysical Assessment[2]: 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 kanuka 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° 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).

Indigenous Flora: Kanuka, turutu, and mingimingi are species typical of geothermal habitat.

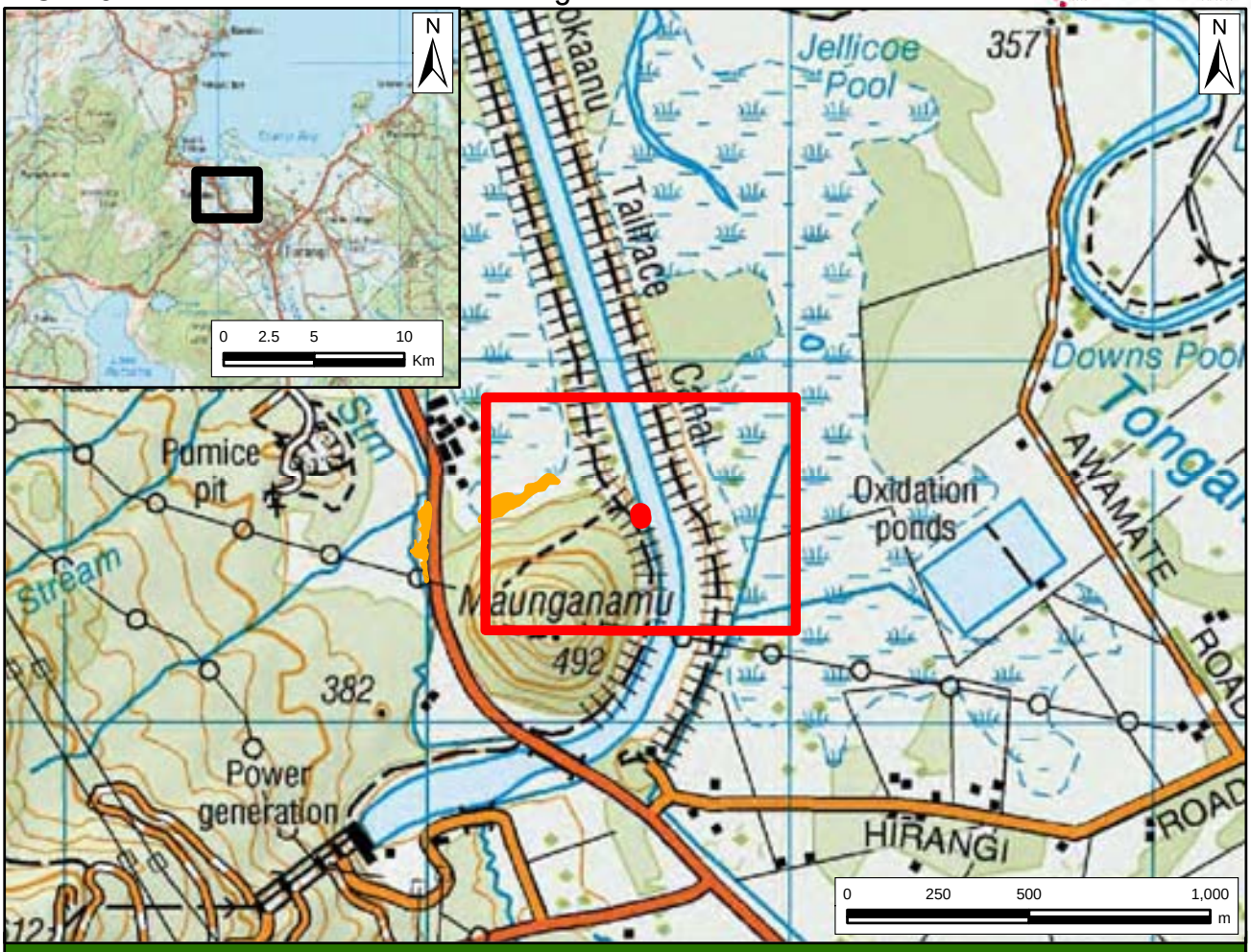
Fauna: Common cicadas were audible during the field survey. Common indigenous and introduced bird species typical of the habitats are likely to be present.

[1] Previously identified as T19/5 in Wildland Consultants (2004 and 2007a).
[2] Hochstein 2007.

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*)*:*	Horses have been taken to the site, but there were no signs of horse grazing in the area.
Adjoining land use (*2007 Assessment*)*:*	Indigenous forest and vehicle track.
Site Change:	
Recent change:	Not assessed. Any changes are not likely to be significant.
Historical:	This site is too small to see any evidence of change since 1941 (Historical photo: SN 178 Run 207 Photo 30, 1941). 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 5, 10; Table 2 - Factor 16).
Significance Justification:	The mud pools are within an extensive natural area that is of regional significance as it forms part of an extensive ecological sequence extending from the shores of Lake Taupo to the summit of Kakaramea, Tihia, and Pihanga, and including Lake Rotopounamu and Lake Rotoaira. The ecological sequence includes extensive areas of geothermal habitat.
References:	Healy 1942; Hochstein 2007; Wildland Consultants 2004 & 2007a.

TOV10

Maunganamu East



MAUNGANAMU EAST

Site Number: TOV10[1]
Grid Reference: NZTopo50 BH35 405 826
GPS Reference: NZTM E1840588 N5682576
Local Authority: Taupo
Ecological District: Taupo
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*360 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 7 February 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
11.01 11.01.01	**Raupo reedland** Raupo reedland with abundant creeping bent and occasional pohue. Geothermal seepages are also present in the open canal water.	Canal margins	<0.1 ha

Geophysical Assessment[2]:

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.*14^0 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 raupo 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° 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)

[1] Previously identified as T19/7 in Wildland Consultants (2004 and 2007a)
[2] Undertaken by Hochstein in 2007

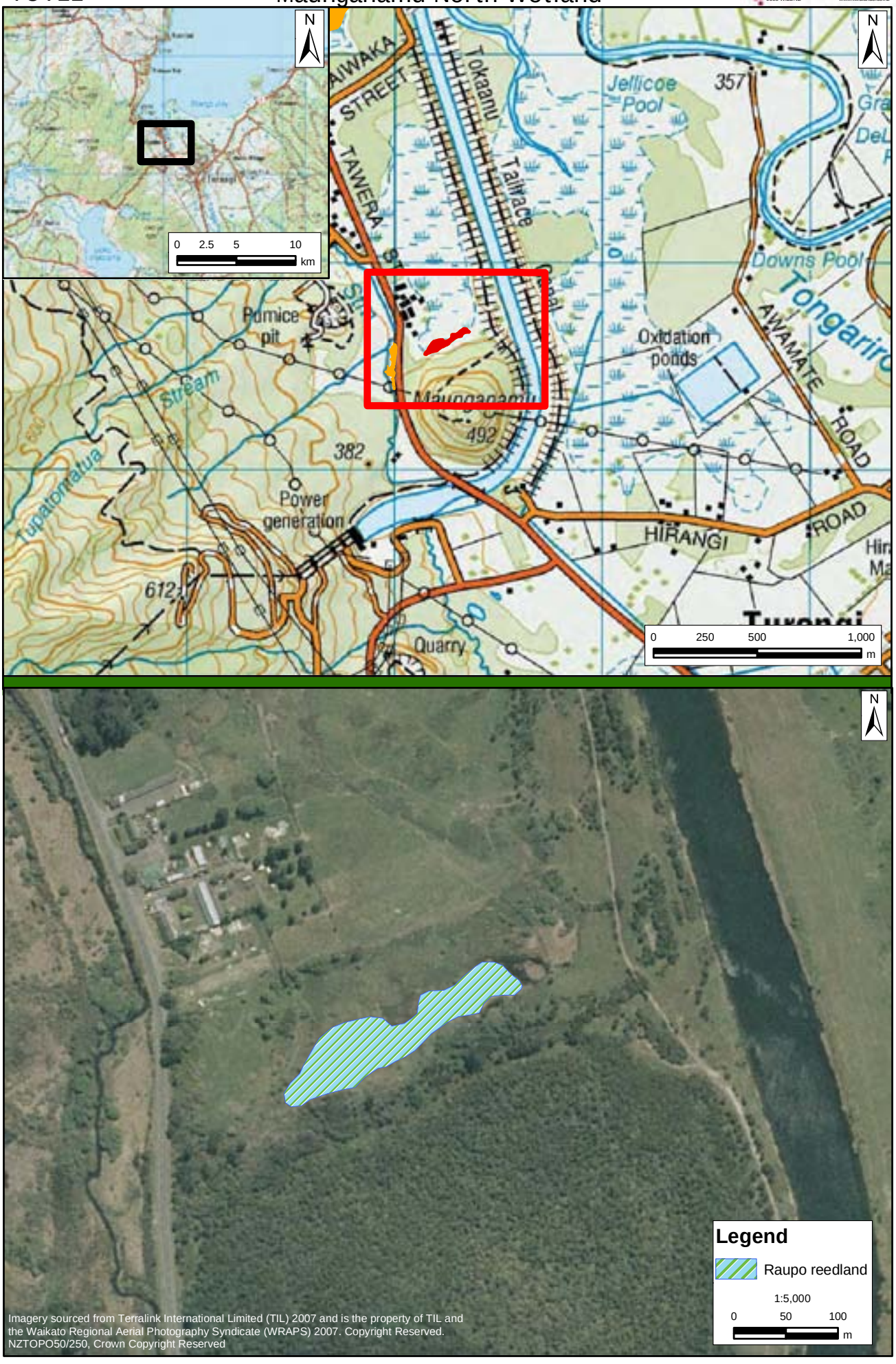
	temperatures of 20° and 23°C in this area were observed using the IR gun. At the second site a maximum temperature of 62.1°C was observed at *c*.0.3 m depth; the lake bottom also exhibited a growth of brown-grey algae. Smaller seeps of thermal water occurred on land, *c*.0.2 m above the stream margins, with temperatures of up to 44°C were 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.
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 (*2007 Assessment*)*:*	Tokaanu Stream and State Highway.
Site Change:	
Recent change:	Not assessed. Any changes not likely to be significant.
Historical:	In 1941 there was bare ground in the vicinity of the site (which may be indicative of the presence of a greater extent of geothermal vegetation and habitat in the area at that time) and it appears that construction of the Tokaanu Tailrace Canal (constructed in conjunction with the Tokaanu Power Station, commissioned in 1973) resulted in a reduction of the extent of this site (Historical photos: SN 178 Run 207 Photos 29-31, 1941; SN 1099 Run A Photo 2, 1958).
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, a habitat that is nationally uncommon.

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.

References: Bromley & Mongillo 1991; Hochstein 2007; Wildland Consultants 2004 & 2007a.

TOV11

Maunganamu North Wetland



MAUNGANAMU NORTH WETLAND

Site Number: TOV11[1]
Grid Reference: NZTopo50 BH35 403 826
GPS Reference: NZTM E1840178 N5682636
Local Authority: Taupo
Ecological District: Taupo
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Unprotected private land and protected (Tokaanu Thermal Park Recreation Reserve).
Altitude: *c*.440 m
Extent of Geothermal Habitat: *c*.0.9 ha
Extent of Geothermal Vegetation: *c*.0.9 ha
Date of Field Survey: February 2007

Code	Type	Landform	Extent
11.01 11.01.01	**Raupo-dominant reedland** **Raupo reedland** The site was viewed from the distance and appeared to be a raupo reedland with common emergent crack willow. This site is included as geothermal based on geothermal presence found near site at Oasis Motel, and evidence of Hochstein (2007) and Bromley & Mongillo (1991).	Wetland	*c*.0.9 ha

Geophysical Properties[2]: 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 raupo reedland wetland (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.

Indigenous Flora: No „Threatened' or „At Risk' flora species 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 (classed as „At Risk-Relict' in Miskelly *et al*. 2008).

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 was probably minimal. The wetland is in a moderate condition with common emergent crack willow.

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1 Previously identified as T19/8 in Wildland Consultants (2007).
2 Hochstein 2007

Threats/Modification/ Vulnerability:

Invasive pest plants (*2007 Assessment*):	Crack willow (5-25% cover) is present in the wetland. This 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 (*2007 Assessment*):	Farming and Department of Conservation Reserve. Fences were over-run by blackberry in 2007.

Site Change:

Recent change:	Unknown. Probably no significant change.
Historical:	In the 1958 photograph 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 (Historical photo: SN 1099 Run A Photo 2, 1958).
Management Requirements:	Willow control should be undertaken, and the site should be fenced to exclude stock.
Significance Level:	Local (Table 1 - Criteria 5, 6; Table 2 - Factor 19)
Significance Justification:	This site is locally significant because it is an example of a nationally uncommon habitat type (geothermal wetland). A very small portion of the site is legally protected.

Notes:

Small groups of hot springs were reported by Healy (1942) to occur in a stretch of swampy ground over the north region of Mt Maunganamu. One hot spring (77^{o}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 & Klyen (1968); its temperature was 66^{o}C. It is likely that thermal springs in the swampy area were detected by their IR signature in 1991; other recorded IR signals (Bromley & 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 has been given by Hochstein (2005).

A neighbouring landowner has reported geothermal steam coming from this site. It is currently a raupo 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.

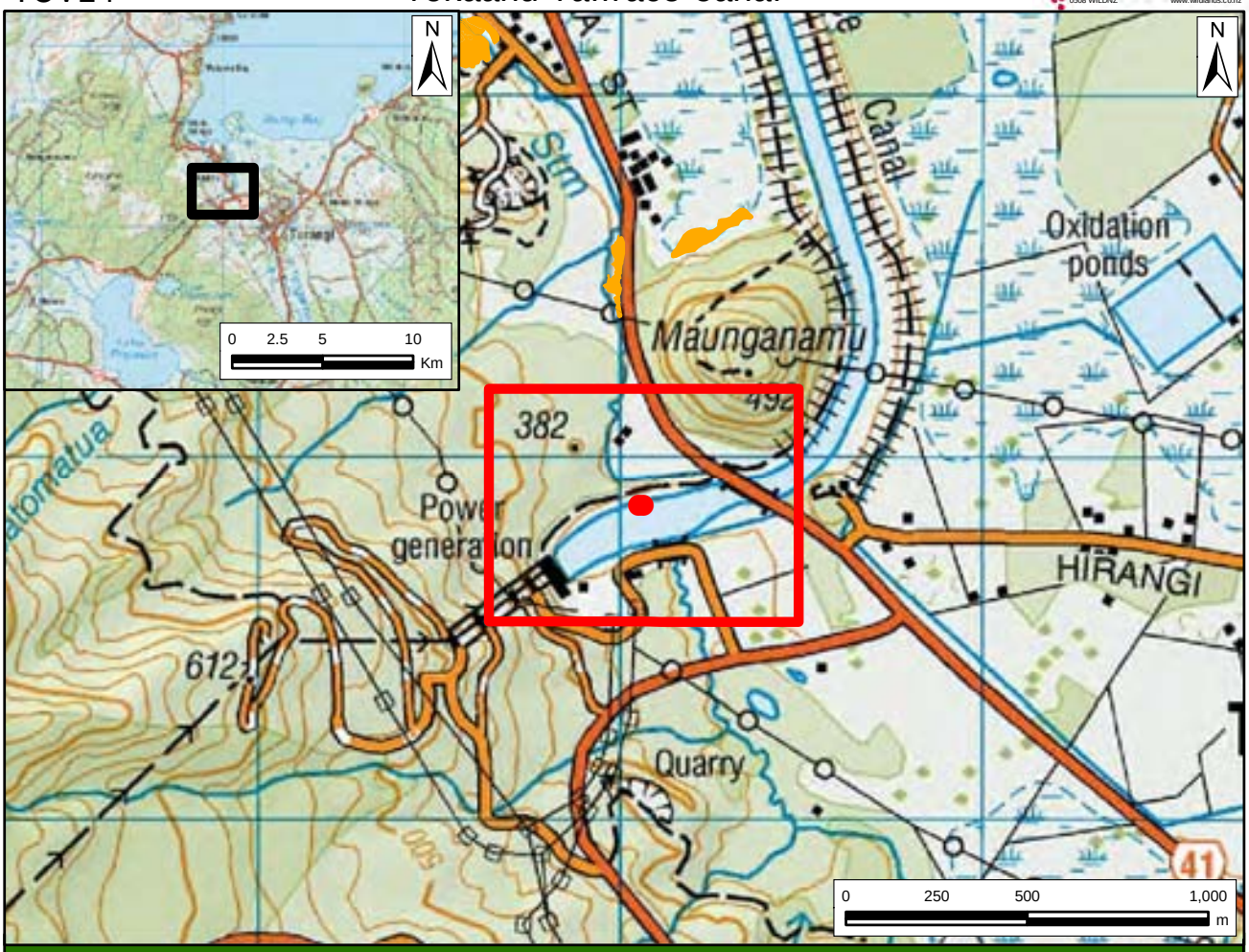
This site has not been assessed in any previous assessment of ecological values of geothermal sites.

References:

Bromley & Mongillo 1991; Healy 1942; Hochstein 2005 & 2007; Mahon & Klyen 1968; Wildland Consultants 2007.

TOV14

Tokaanu Tailrace Canal



TOKAANU TAILRACE CANAL

Site Number: TOV14[1]
Grid Reference: NZTopo50 BH35 400 819
GPS Reference: NZTM E1840064 N5681876
Local Authority: Taupo
Ecological District: Taupo
Geothermal Field: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: *c.*360 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 7 February 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
11.01 11.01.13	**Raupo-dominant reedland** **(Crack willow)/raupo reedland** Occasional crack willow occurs over a raupo reedland with patches of *Baumea rubiginosa,* swamp kiokio*, Juncus edgariae*, and creeping bent. Other species present include Yorkshire fog, harakeke, *Carex virgata* and tall fescue.	Wetland	<0.1 ha

Geophysical Assessment:[2]

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 MWe Tokaanu hydro-power station in the tailrace canal had a range of *c.*14° to 17°C.

Manifestations above the bridge alongside the tailrace canal were visited for which locations were inferred from an old infra-red (IR) 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

[1] Previously identified as T19/4 in Wildland Consultants (2004 and 2007a).
[2] Undertaken by Hochstein in 2007.

	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 *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° 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).
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):	Site is in a moderate condition and indigenous habitat has formed alongside 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 (*2007 Assessment*)*:*	Canal; roads.
Site Change:	
Recent change:	Not assessed as site is too small.
Historical:	In 1958 there was bare ground in the vicinity of the site (only a small portion of this is likely to be geothermal). However the Tokaanu Tailrace Canal (constructed in conjunction with the Tokaanu Power Station, commissioned in 1973) is likely to have flooded part of this site (Historical photo: SN 1099 Run A Photos 3, 1958), but it is not possible to determine the extent of loss.
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.

Notes: More geothermal sites may be found alongside the canal if the site was surveyed by boat, particularly when water levels are low.

References: Bromley & Mongillo 1991; Hochstein & Prebble 2006; Hochstein 2007; Wildland Consultants 2004 & 2007a.

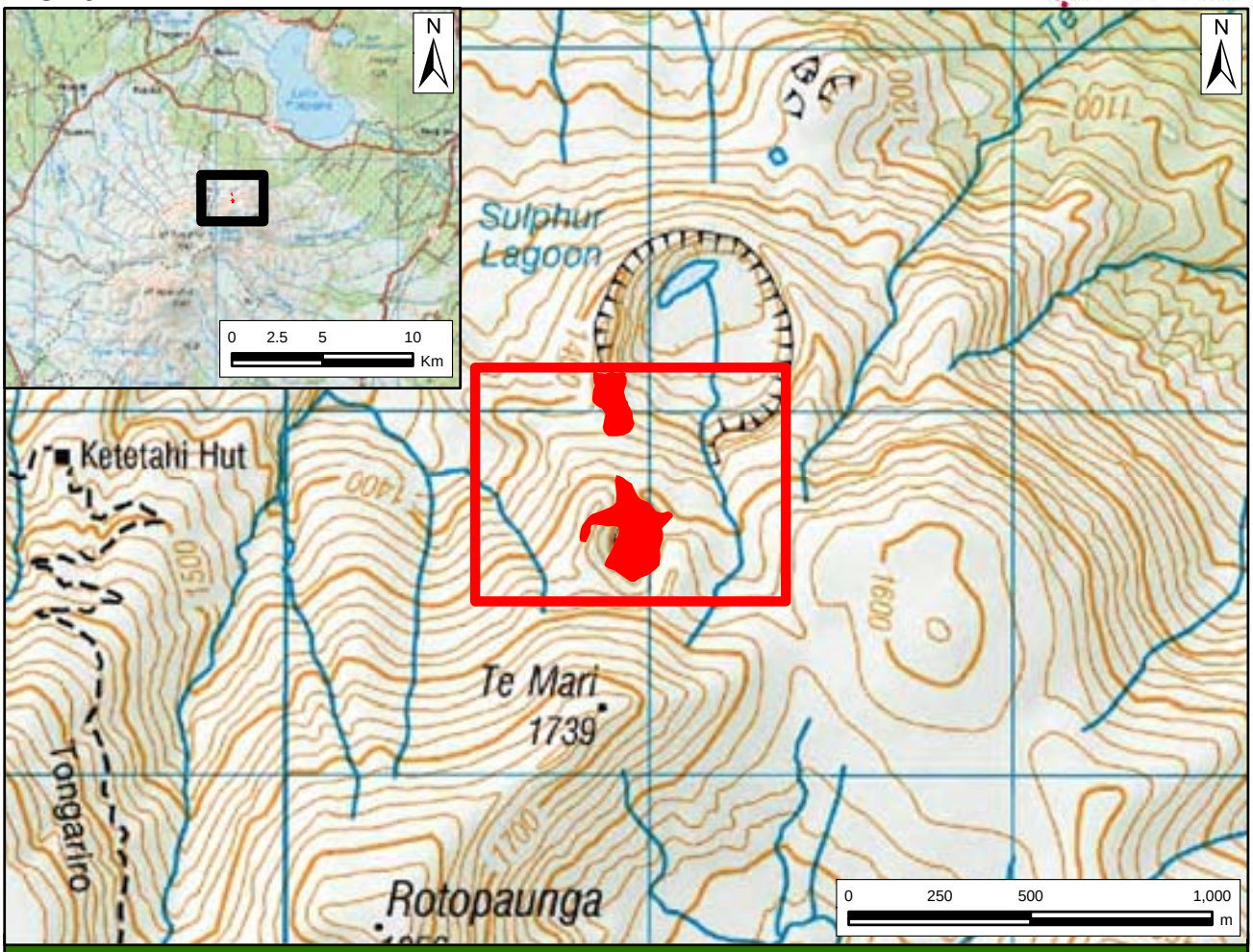
1.15 TONGARIRO GEOTHERMAL FIELD

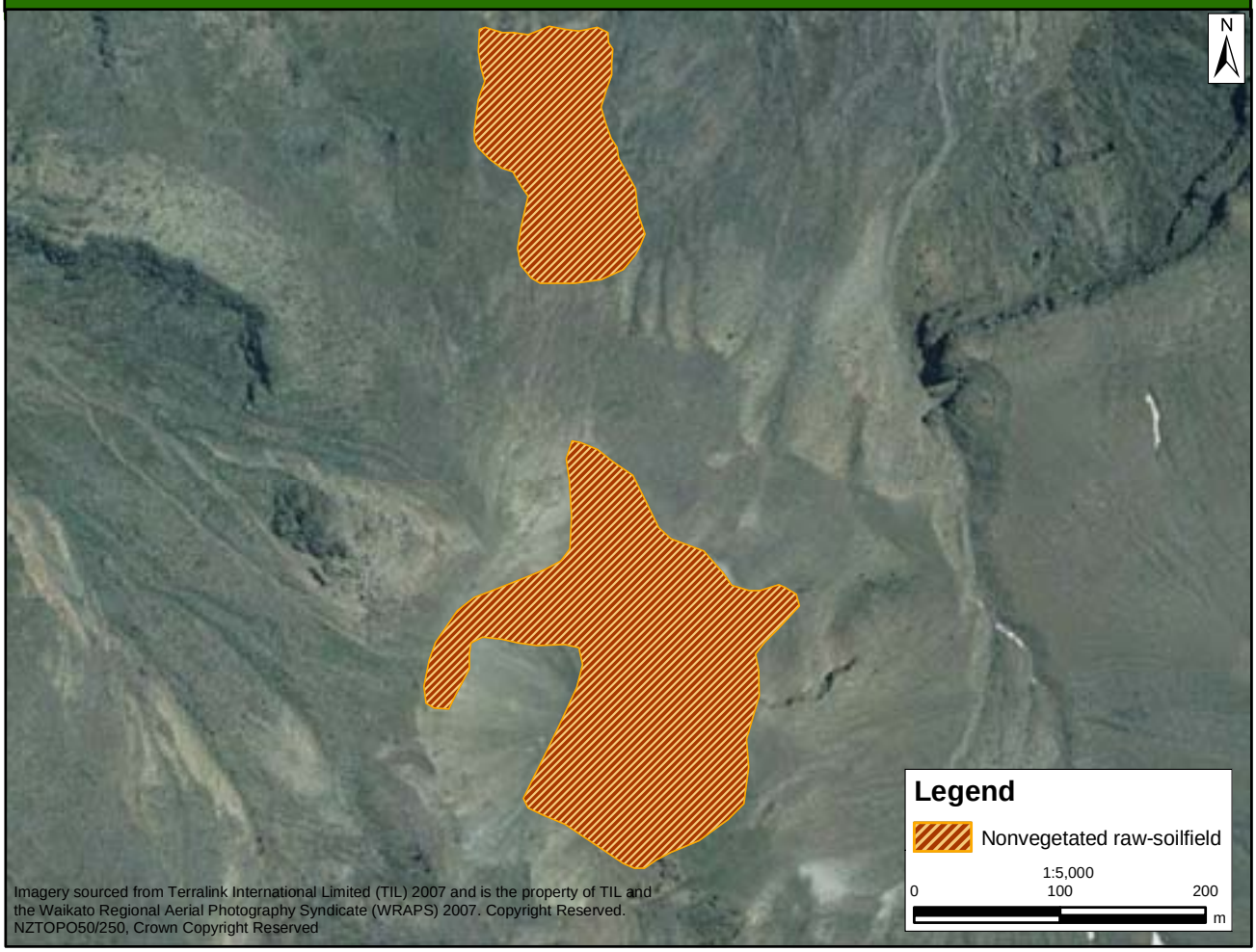
List of Geothermal Sites

TGV01	Te Maari Craters
TGV02	Ketetahi
TGV03	Emerald Lakes
TGV04	Red Crater

TGV01

Te Maari Craters





TE MAARI CRATERS

Site Number: TGV01[1]
Grid Reference: NZTopo50 BH35 310 683
GPS Reference: NZTM E1831000 N5668300
Local Authority: Taupo
Ecological District: Tongariro
Geothermal Field: Tongariro
Bioclimatic Zone: Subalpine
Tenure: Protected (Tongariro National Park)
Altitude: *c.*1,525 m
Extent of Geothermal Habitat: *c.*4.9 ha
Extent of Geothermal Vegetation: *c.*4.9 ha
Date of Field Survey: 14 June 2011

Code	Type	Landform	Extent
07.07 07.07.01	***Lycopodiella*-dominant fernland (not mapped)** ***Lycopodiella cernua* fernland** Several small vents on the edge of Te Maari Crater (facing north, NZTM E1830927 N5667972) are surrounded by *Lycopodiella cernua*, low stature manuka, *Gleichenia dicarpa*, *Dracophyllum recurvum*, *Epacris alpina* and *Gaultheria colensoi.*	Crater face	<0.1 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** There are scattered plants of *Rytidosperma setifolium*, *Celmisia spectabilis* subsp. *spectabilis*, *Gaultheria colensoi*, and *Racomitrium* on the scree slopes.	Crater rim, crater face	*c.*4.9 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 were recorded during the survey. New Zealand falcon 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

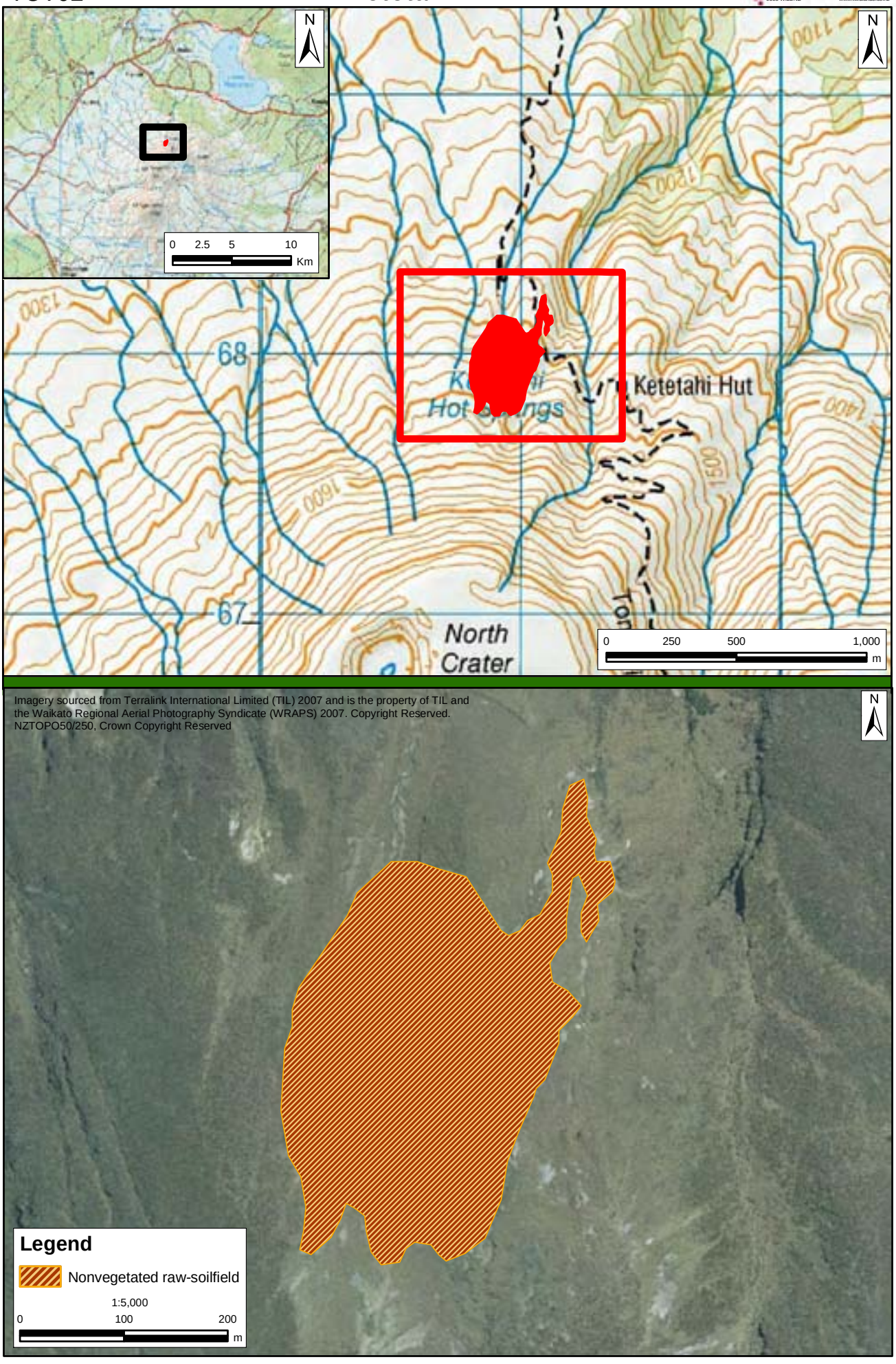
Human impacts (*2011 Assessment*): This site is *c.*1.5 km to the east of an internationally recognised walking track (Tongariro Alpine Crossing). It is in a remote experience zone, and is only occasionally visited by tramping parties.

[1] Previously identified as T19/20 in Wildland Consultants (2007).

Grazing (*2011 Assessment*):	Site in National Park, not farmed. Hares present near site and may visit occasionally.
Adjoining land use (*2011 Assessment*):	Tongariro National Park (Remote Experience Zone). Occasionally visited by trampers.
Site Change:	
Recent change:	Unknown. Not previously assessed.
Historical:	Site change is not easily identified from historical photos (Historical photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957).
Management Requirements:	
Significance Level:	International (Table 1 - Criteria 1, 5, 10; Table 2 - Factor 2)
Significance Justification:	Te Maari Crater is an internationally significant site because it is located within Tongariro National Park, which is 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.
References:	Wildland Consultants 2007

TGV02

Ketetahi



KETETAHI

Site Number: TGV02[1]

Grid Reference: NZTopo50 BH35 289 680
GPS Reference: NZTM E1828935 N5667965
Local Authority: Taupo
Ecological District: Tongariro
Geothermal Field: Tongariro
Bioclimatic Zone: Subalpine
Tenure: Unprotected private land
Altitude: *c.*1460 m
Extent of Geothermal Habitat: *c.*8.2 ha
Extent of Geothermal Vegetation: *c.*8.2 ha
Date of 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.

Code	Type	Landform	Extent
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** 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: No significant pest plants known.

Human impacts: 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: Not grazed. Surrounded by Tongariro National Park. Hares and deer are likely to be present on margins on occasion.

Adjoining land use (*2011 Assessment*): Tongariro National Park.

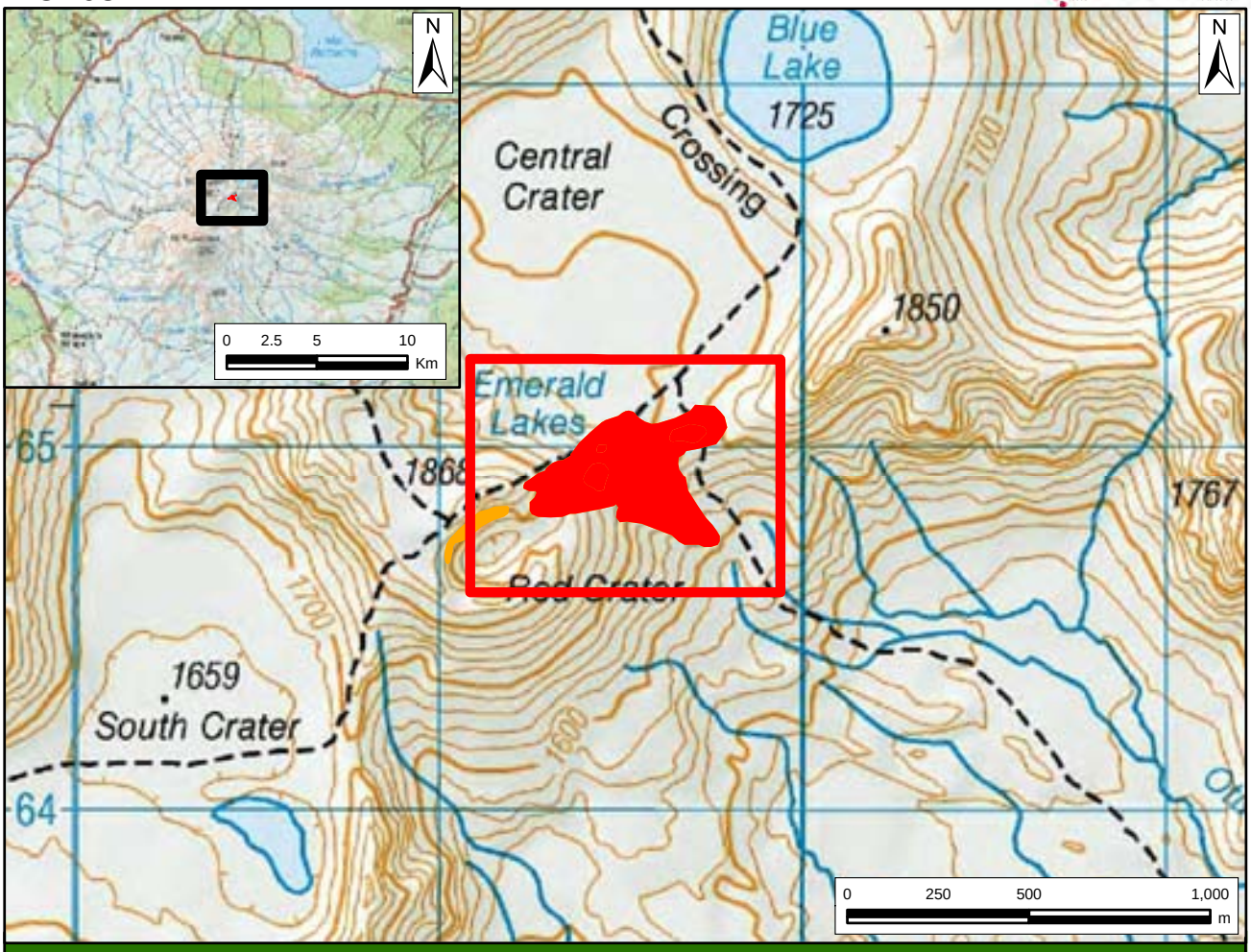
[1] Previously identified as T19/15 in Wildland Consultants (2007).

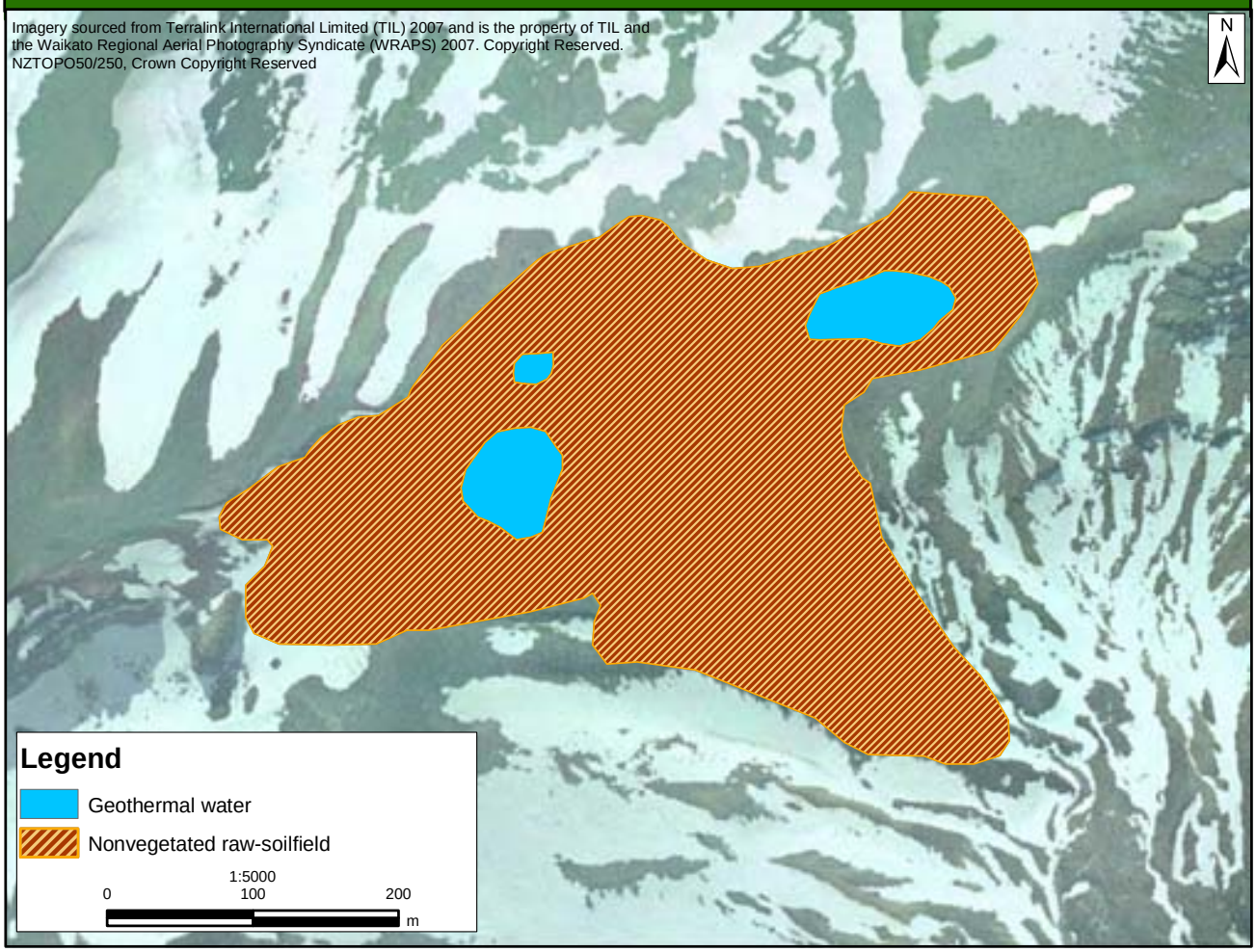
Site Change:

Recent change:	Unknown. Probably no significant change as the site is rarely visited. Natural changes to surface geothermal manifestations are likely.
Historical:	Apart from fluctuations in surface geothermal activity, little change to this site is likely. Site change is not easily identified from historical photos (Historical; photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957).
Management Requirements:	Unknown.
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.
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.

TGV03

Emerald Lakes





EMERALD LAKES

Site Number: TGV03[1]
Grid Reference: NZTopo50 BH35 297 651
GPS Reference: NZTM E1829672 N5665082
Local Authority: Taupo
Ecological District: Tongariro
Geothermal Field: Tongariro
Bioclimatic Zone: Subalpine
Tenure: Protected (Tongaririo National Park)
Altitude: *c.*1700 m
Extent of Geothermal Habitat: *c.*12.1 ha
Extent of Geothermal Vegetation: *c.*11.3 ha
Date of Field Survey: 14 June 2011

Code	Type	Landform	Extent
22.01 22.01.01	**Geothermal water** **Geothermal water** Three geothermally influenced lakelets are included in this site. *Juncus bolbosus* is present in the shallow margins. While the 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.*0.8 ha
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Occasional patches of *Rytidosperma setifolium* occur amongst otherwise unvegetated screefield.	Crater walls	*c.*11.3 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.

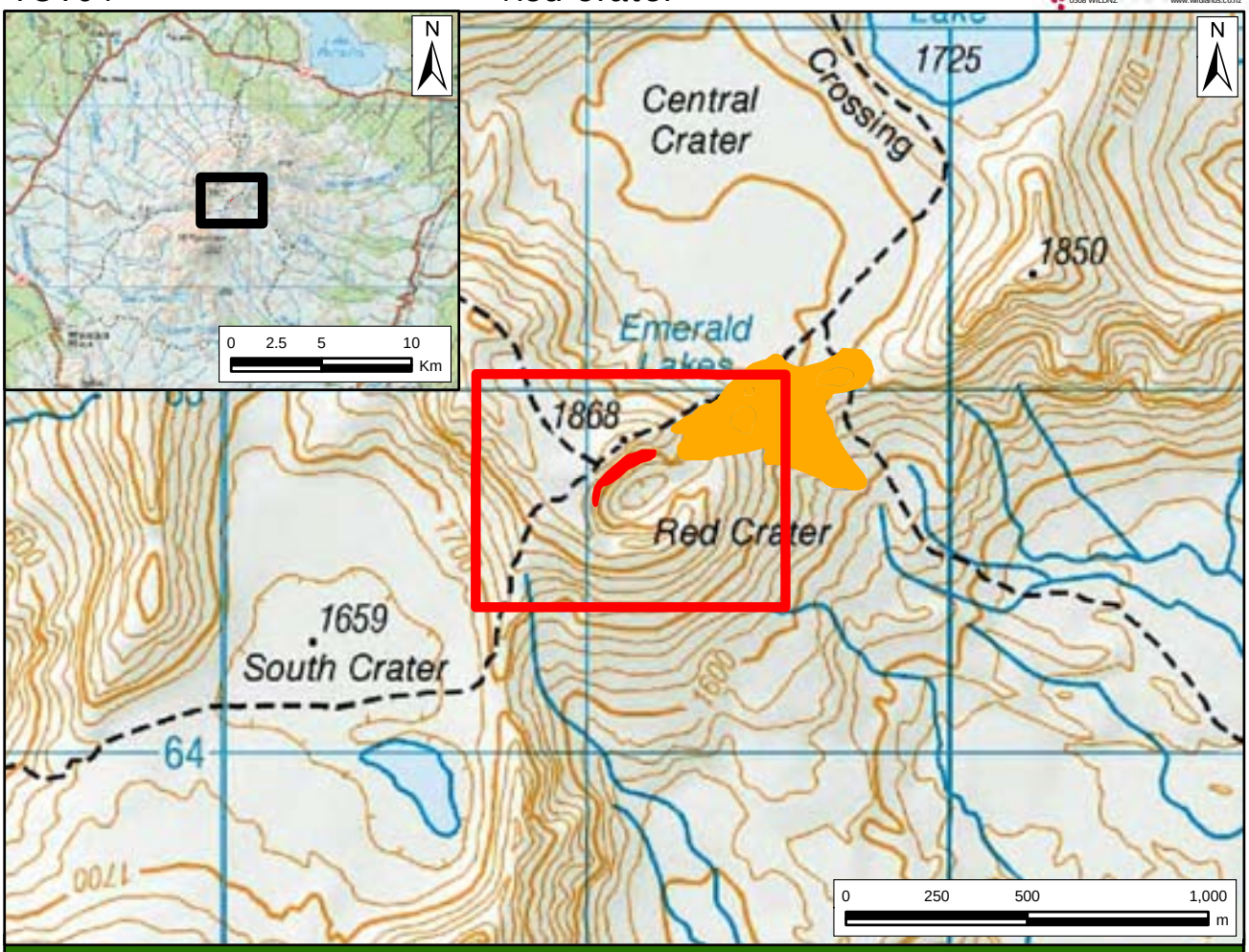
Human impacts (*2011 Assessment*): An internationally renowned walking track (Tongaririo Alpine Crossing) passes within close proximity to the Emerald Lakes, and track users have access to the site. Occasional trampling of features and vegetation are the main human impacts.

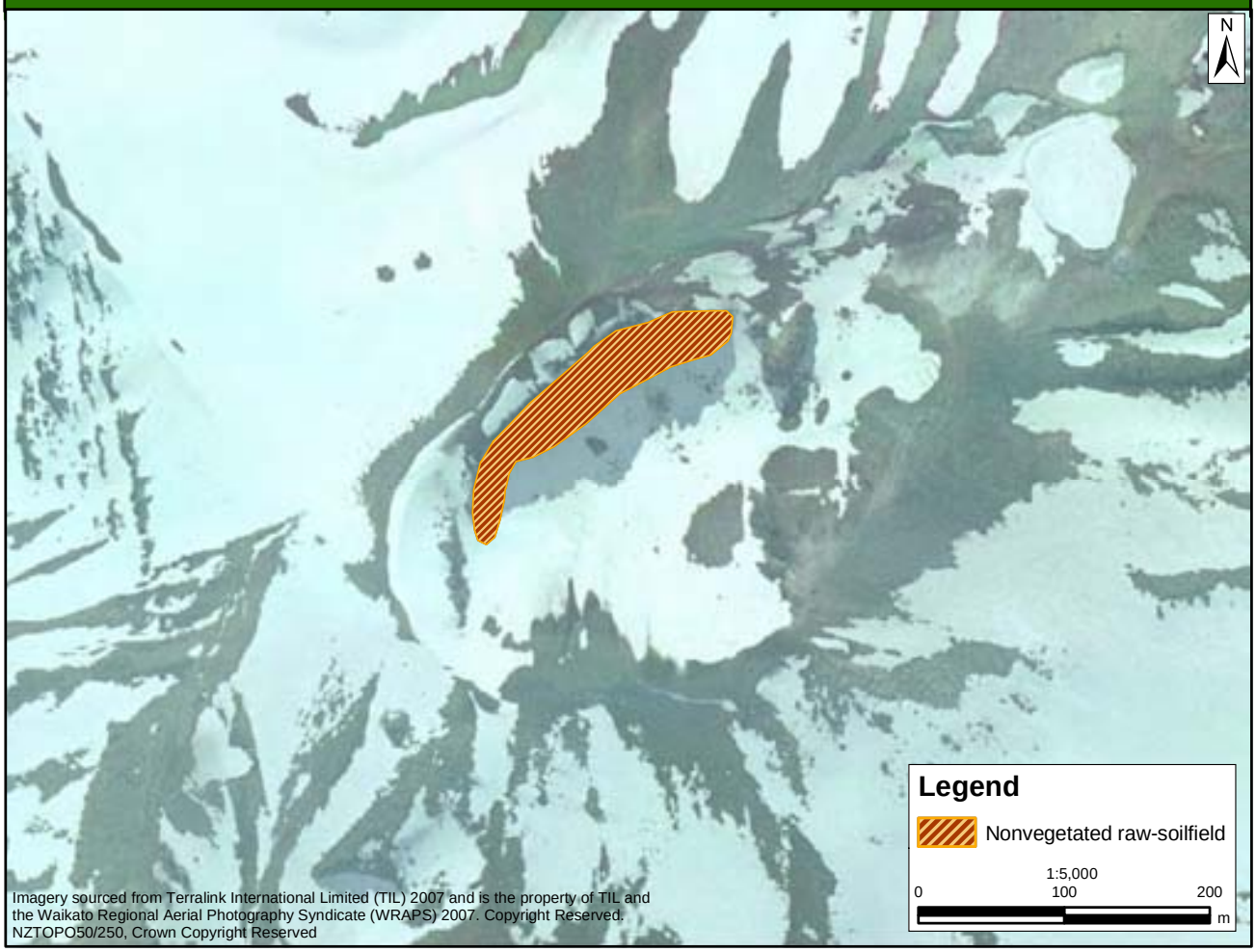
[1] Previously identified as T19/18 in Wildland Consultants (2007).

Grazing (*2011 Assessment*):	Grazing of domestic stock is not an issue at the Emerald Lakes (National Park and the site is not farmed). Introduced mammal impacts on this site are likely to be minor.
Adjoining land use (*2011 Assessment*):	Tongariro National Park.
Site Change:	
Recent change:	No known significant ecological change is known to have occurred at this site in the last ten years.
Historical:	Site change is not easily identified from historical photos (Historical photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957). The site is under snow in these historical photographs. The authors know of no major change at this site in the last 50 years.
Management Requirements:	None noted.
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 Tongariro National Park, which is a 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 2007a; Williams 2001.

TGV04

Red Crater





RED CRATER

Site Number: TGV04[1]

Grid Reference: NZTopo50 BH35 292 648
GPS Reference: NZTM E1829200 N5664800
Local Authority: Taupo
Ecological District: Tongariro
Geothermal Field: Tongariro
Bioclimatic Zone: Subalpine - Alpine
Tenure: Protected (Tongaririo National Park)
Altitude: *c.* 1860 m
Extent of Geothermal Habitat: *c.*0.7 ha
Extent of Geothermal Vegetation: *c.*0.7 ha
Date of Field Survey: 14 June 2011

Code	Type	Landform	Extent
28.01 28.01.01	**Nonvegetated raw-soilfield** **Nonvegetated raw-soilfield** Bare heated scoria and soils. Fumarole present. Site viewed from the distance.	Crater and crater walls	*c.*0.7 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): The active Red Crater is located on the slopes of Mount Tongariro.

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*): Grazing is not an issue in the Crater, Tongariro National Park.

Adjoining land use (*2011 Assessment*): Tongariro National Park.

[1] Previously identified as T19/18 in Wildland Consultants (2007).

Site Change:

Recent change:	Unknown. Probably little change (see historical change below). The site appears to have changed little in the last 20 years (Chris Bycroft pers. comm. 2011).
Historical:	Site change is not easily identified from historical photos (Historical photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957). Geothermal activity is likely to change through natural variation over time, but human impacts are likely to be negligible.
Management Requirements:	None noted.
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 Tongariro National Park, which is a World Heritage Site.

SITES FOR WHICH FIELD INSPECTIONS WERE MADE AS PART OF THIS STUDY

Site No.	Site Name	Ecological District	Year of Most Recent Field Survey[1]
Horohoro Geothermal Field			
HHV01	Horohoro	Atiamuri	2003
Waikite Geothermal Field			
WAV01	Waikite Valley	Atiamuri	2011 (part)
WAV02	Northern Paeroa Range	Atiamuri	2010
Waiotapu Geothermal Field			
WTV05	Waiotapu South	Atiamuri	2004
WTV04	Maungakakaramea (Rainbow Mountain)	Atiamuri	2004
WTV03	Waiotapu North	Atiamuri	2004
WTV02	Ngapouri	Atiamuri	2004
WTV01	Maungaongaonga	Atiamuri	2004
Mokai Geothermal Field			
MKV04	Paerata Rd	Atiamuri	2011
MKV03	Tirohanga Rd	Atiamuri	2011
MKV02	Waipapa Stream	Atiamuri	2011
MKV01	Whakamaru	Atiamuri	2008
Atiamuri Geothermal Field			
ATV02	Whangapoa Springs	Atiamuri	2011
ATV03	Matapan Rd	Atiamuri	2011
ATV01	Upper Atiamuri West	Atiamuri	2007
Te Kopia Geothermal Field			
TKV06	Mangamingi Station	Atiamuri	2010
TKV02	Murphy's Springs	Atiamuri	2010
TKV03	Te Kopia Northwest	Atiamuri	2010
TKV05	Te Kopia Red Stream	Atiamuri	2010
TKV04	Te Kopia West Mud Pools	Atiamuri	2010
TKV01	Te Kopia	Atiamuri	2004
Orakeikorako Geothermal Field			
OKV05	Akatarewa East	Atiamuri	2011
OKV03	Orakeikorako	Atiamuri	2011
OKV02	Akatarewa Stream	Atiamuri	2007
OKV04	Red Hills	Atiamuri	2007
OKV01	Waihunuhunu	Atiamuri	2007
Ngatamariki Geothermal Field			
NMV02	Ngatamariki	Atiamuri	2011
NMV01	Waikato River Springs	Atiamuri	2011
Whangairorohea Geothermal Field			
WGV01	Whangairorohea	Atiamuri	2011
Reporoa Geothermal Field			
RPV02	Wharepapa Rd	Atiamuri	2010
RPV03	Golden Springs	Atiamuri	2007
RPV01	Longview Rd	Atiamuri	2004
Okaaki Geothermal Field			
OHV02	Ohaaki Steamfield East	Atiamuri	2011

[1] Date of most recent survey given. Some sites have been surveyed multiple times between 2000 and 2011.

Site No.	Site Name	Ecological District	Year of Most Recent Field Survey[1]
OHV01	Ohaaki Steamfield West	Atiamuri	2011
Wairakei-Tauhara Geothermal Field			
THV04	Broadlands Rd	Atiamuri	2011
THV06	Crown Rd	Taupo	2011
WKV01	Te Rautehuia	Atiamuri	2011
WKV02	Te Rautehuia Stream	Atiamuri	2011
WKV03	Upper Wairakei Stream (Geyser Valley)	Atiamuri	2011
WKV05	Te Kiri O Hine Kai Stream Catchment/Wairoa Hill	Atiamuri	2011
WKV09	Waipouwerawera Stream/Tukairangi	Atiamuri	2011
THV01	Otumuheke	Atiamuri	2010
THV07	Waipahihi Valley	Taupo	2009
WKV04	Wairakei Borefield	Atiamuri	2007
WKV06	Lower Wairakei Stream	Atiamuri	2007
THV03	Spa Thermal Park	Atiamuri	2006
THV05	Crown Park	Taupo	2006
WKV07	Karapiti Forest	Atiamuri	2004
WKV10	Craters of the Moon	Atiamuri	2004
WKV08	Hall of Fame Stream	Atiamuri	2003
Rotokawa Geothermal Field			
RKV02	Lake Rotokawa	Atiamuri	2004
RKV01	Rotokawa North	Atiamuri	2004
Tokaanu-Waihi-Hipaua Geothermal Field			
TOV10	Maunganamu East	Taupo	2007
TOV07	Maunganamu West	Taupo	2007
TOV14	Tokaanu Tailrace Canal	Taupo	2007
TOV08	Tokaanu Thermal Park	Taupo	2007
TOV09	Tokaanu Urupa Mud Pools	Taupo	2007
TOV03 to TOV06	Tokaanu Lakeshore Wetland	Taupo	2007
TOV02	Hipaua	Tongariro	1999
Tongariro Geothermal Field			
TGV03	Emerald Lakes	Tongariro	2011
TGV02	Ketetahi	Tongariro	2011
TGV04	Red Crater	Tongariro	2011
TGV01	Te Maari Craters	Tongariro	2011

SITES FOR WHICH FIELD INSPECTIONS WERE NOT UNDERTAKEN AS PART OF THIS STUDY

No field inspection was carried out for the 20 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	Kathleen Spring
Location	Taupō
Grid Reference (NZTM)	E1869700 N5714500
Geothermal Field	Tauhara/Taupo
Ecological District	Taupo
Vegetation	Geothermal vegetation comprises less than 1 ha. *Lycopodiella cernua* present.
Notes	This spring ceased flowing in 1997 and there was no further evidence of flow in 2009 according to Bromley *et al.* (2010).
References	Beadel & Bill 2000; Given 1989a.

Site Name	Waihi Geothermal site
Location	Waihi Village, Lake Taupo
Grid Reference (NZTM)	E1837824 N5685065 (estimate only)
Geothermal Field	Tokaanu
Ecological District	Taupo
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 is 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).

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 which are restricted to geothermal sites, and those which have dispersed into geothermal sites because the habitat mimics aspects of the usual habitat of the species (Given 1995). Prostrate kanuka is the best known example of a plant restricted to geothermal areas, and the moss *Campylopus capillaceus,* is another example which may be virtually an obligate geothermal species (Given 1995). Plants which occur in geothermal sites because the habitat mimics that of 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*:** New Zealand, Australia, and New Caledonia. More commonly found in coastal sites, it is currently known from three sites in the Waikato Region: Waikite Valley, Craters of the Moon, and Akatarewa East.
Threatened species ranking[1]: Not threatened.

Plate 99: *Cheilanthes sieberi* at Craters of the Moon, August 2007.

***Christella* aff. *dentata* ("thermal"):** North Island, Kermadec Islands, and probably also in tropics and subtropics of the old world. 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 14 sites in the Taupo Volcanic Zone, with ten of these sites in the Waikato Region. Several populations have less than ten plants present and are very vulnerable to extinction (e.g. Hall of Fame Stream and Waikato River Springs). Three sites have

[1] From de Lange *et al.* 2009.

a declining population of *Christella* aff. *dentata* ("thermal") (Akatarewa Stream, Golden Springs and Otumuheke Stream), while the populations at Waikite appear to be immediately threatened by the marked increase of blackberry scrub around stream margins and stock access to drains and waterways. One site, Lower Wairakei Stream, has had a population increase since the survey of Merrett and Burns (1999), although this population is vulnerable to the clearance of stream margins and to any increase in density of blackberry at the site. There are six populations with *c*.50 or more plants present - Waipapa Stream, Red Hills, Waihunuhunu, Murphys Farm, 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 it is presumed to be extinct from these sites.
Threatened species ranking[1]: At Risk-Declining.

Plate 100: *Christella* aff. *dentata* ("thermal") alongside Otamakokore Stream, Waikite, May 2007.

***Cyclosorus interruptus*:** Pantropical. This species is found in the North Island in New Zealand; and also in Australia, south-east Asia, and the Pacific. In the North Island it is confined to geothermal areas in the Taupo 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 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.

Plate 101: *Cyclosorus interruptus* at Waihunuhunu, 2007.

In the Waikato Region it is known from eight sites in the following five geothermal fields; Waikite, Waiotapu, Orakeikorako, Ngatamariki, Wairakei-Tauhara. 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.

[1] From de Lange *et al.* 2009.

***Dicranopteris linearis*:** Pantropical. In New Zealand it is confined to geothermal habitats of the Taupo Volcanic Zone, North Island, where it occurs in prostrate kanuka scrub and shrubland, and also other scrub, shrubland and fernland habitats around heated water (hot springs and geothermally-heated streams), and geothermally heated soils. Several populations are present in forest nearby geothermal sites (e.g. Te Kopia and Ngatamariki). These 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). It is known from *c.*24 sites in the Waikato Region; however 12 of these populations are very small. It is present in the following geothermal fields; Waikite, Waiotapu, Te Kopia, Orakeikorako, Ngatamariki, Ohaaki, Wairakei-Tauhara and Rotokawa. The most important populations in terms of size for 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.

Plate 102: *Dicranopteris linearis* at Maungaongaonga.

Threatened species ranking[1]: At Risk-Naturally Uncommon.

***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 Taupo Volcanic Zone, where it favours light soils or disturbed ground on forest margins, or streams and ditches (Brownsey and Smith-Dodsworth 2000). Known from three geothermal sites in the Waikato Region. *Hypolepis dicksonioides* is probably naturally rare at geothermal sites in the Waikato Region. It is a naturally short-lived, somewhat ephemeral, opportunistic species, which requires disturbance to create fresh habitats to colonise. It also is known from three geothermal sites in the Bay of Plenty Region (Wildland Consultants 2005). However, all populations at geothermal sites are of botanical

Plate 103: *Hypolepis dicksonioides* alongside Otamakokore Stream, downstream of Corbett Road bridge, May 2007.

interest as they often occur at sites outside its normal altitudinal range. The three Waikato populations in geothermal sites (Otumuheke Stream, Waipahihi Valley, and Waikite) are vulnerable to competition with pest plants (particularly blackberry).
Threatened species ranking: 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.

Plate 104: *Lycopodiella cernua* at Te Maari Craters, June 2011.

***Nephrolepis flexuosa* (native ladder fern: distinct from *N. cordifolia*):** 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. Abundant in coastal forest and scrub on Raoul Island, otherwise in New Zealand confined to the North Island where it is only known from active geothermal fields from Kawerau, Rotorua Lakes District to Lake Taupo. 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 usually in scrub, shrubland, and fernland. 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 Waihunuhunu Geothermal Area (where it is common along the entire length of the unnamed geothermal stream), Upper Wairakei Stream, and Te Kiri O Hine Kai Catchment/Wairoa Hill. There is also a large population of this species at Waimangu-Rotomahana in

Plate 105: *Nephrolepis flexuosa* at Waihunuhunu, 2007.

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.

***Psilotum nudum*:** Pantropical. Coastal northern New Zealand, and geothermal sites in the central North Island - Bay of Plenty. It is known from nine geothermal sites in New Zealand, three of these in the Waikato Region.
Threatened species ranking[1]: Not threatened.

***Schizaea bifida* (forked comb fern):** 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 two sites 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). This species if 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.[2] It has been recorded from two geothermal sites in the Waikato Region. These are Waikite Wildlife Management Reserve, where two small populations are present (Bycroft and Beadel 2007), and Waihunuhunu. Although it has not been seen at this latter site in recent surveys, it is probably still present.

Plate 106: *Thelypteris confluens* at Waikite Wildlife Management Reserve.

Threatened species ranking:At Risk-Declining.

DICOTYLEDONOUS TREES AND SHRUBS

***Korthalsella salicornioides*:** New Zealand endemic. A semi-parasitic, dwarf mistletoe which grows on a variety of hosts. It is known from at Maungaongaonga, Te Kopia, and Tokaanu Thermal Park in the Waikato Region.
Threatened species ranking[1]: An „At Risk' species classed as „Naturally Uncommon'.

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1 From de Lange *et al.* 2009.
2 http://nzpcn.org.nz: Accessed 19 September 2011.

***Kunzea ericoides* var. *microflora* (prostrate kanuka):** New Zealand endemic. Prostrate kanuka 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. Known from one geothermal site in the Waikato Region (also occurs at Lake Whangape in the Waikato Region).
Threatened species ranking[1]: At Risk-Naturally Uncommon.

MONOCOTYLEDONOUS HERBS

***Triglochin striata* (arrow grass):** In New Zealand, generally a coastal species which occasionally occurs inland. Known from at least six geothermal sites in the Waikato Region from the following geothermal fields; Waikite, Waiotapu, Ngatamariki, Reporoa, Ohaaki, and Waiarakei-Tauhara.
Threatened species ranking[1]: Not threatened.

Plate 108: Arrow grass (*Triglochin striata*) at Waikite Valley, February 2011.

ORCHIDS

***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.
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 three geothermal sites in the Waikato Region in the Waiotapu, Te Kopia, and Rotokawa Geothermal Fields.
Threatened species ranking[1]: At Risk-Naturally Uncommon.

***Prasophyllum pumilum* (leek orchid):** Australia and New Zealand. Recorded from coastal and inland sites in the northern half of the North Island, including one geothermal site in the Waikato Region.
Threatened species ranking[1]: Not threatened.

[1] From de Lange *et al.* 2009.

BIOCLIMATIC ZONES (SOURCE: LEATHWICK *ET AL*. 1995)

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 which are typified by frequent windblown salt and a marked reduction in the severity of frost. The zones are described below:

Coastal Less than 1 km from the coast, and with altitude less than 300 m.

Lowland Extending from the coastal zone up to an altitude of 300 m = the warm-temperate zone of Meurk (1984).

Submontane Extending from 300 m to 800 m altitude = the warmer part of the Cool Temperate zone of Meurk (1984).

Montane Extending from 800 m to 1300 m altitude = the cooler part of the Cool Temperate zone of Meurk (1984).

Subalpine Extending from 1,300 m to 1,800 m = the Subantarctic zone of Meurk (1984).

Alpine Extending upwards from 1,800 m = the Low Antarctic zone of Meurk (1984).

HABITATS FOR GEOTHERMAL VEGETATION (SOURCE: MERRETT & CLARKSON 1999)

Heated Ground	Geothermally heated soils generally have temperatures above 20°C at 10 cm depth and increasing with depth.
Geothermal Wetlands	Permanently or intermittently wet areas, shallow water, or land water margins that support a natural ecosystem of plants adapted to wet conditions, and in which some or all of the water is geothermally sourced.
Cooled Hydrothermally-Altered Soils	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.
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).

VEGETATION CLASSES (DEFINITIONS FOR THOSE CLASSES USED IN THIS REPORT) (SOURCE: ATKINSON, 1985)

Bambooland — Vegetation in which the cover of bamboo in the canopy is 20-100% and in which the bamboo cover exceeds that of any other growth form or bare ground.

Boulderfield — Land in which the area of unconsolidated bare boulders (>200 mm diameter) exceeds the area covered by any one class of plant growth form. Boulderfields are named from the leading species when plant cover ≥ 1%.

Cushionfield — Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions. The growth form occurs in all species of *Donatia, Gaimardia, Hectorella, Oreobulus,* and *Phyllachne* as well as in some species of *Aciphylla, Celmisia, Centrolepis, Chionohebe, Colobanthus, Dracophyllum, Drapetes, Haastia, Leucogenes, Luzula, Myosotis, Poa, Raoulia* and *Scleranthus.*

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 30^0 C or more; and 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

[1] Definition from Waikato Regional Council Regional Plan.

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 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.

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 of vegetation that are too hot to support plant life, are cooled but hydrothermally altered, 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^{o}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 that regularly eject hot mud around their margins 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 *Baumea articulata*.

Rockland Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover ≥1% e.g. [koromiko] rockland.

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 ≥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. (Note: the term scrubland is not used in this classification.)

Stonefield/gravelfield

Land in which the area of unconsolidated bare stones (20-200 mm diameter) exceeds the area covered by any one class of plant growth form. The appropriate name is given depending on whether stones or gravel form the greater part of the ground surface. Stonefields are named from the leading species when plant cover ≥1%.

Vegetation Type

A term which 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. 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

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*
Australian fireweed	*Senecio bipinnatisectus*
barberry	*Berberis glaucocarpa*
beggars' ticks	*Bidens frondosa*
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*
broom	*Cytisus scoparius*
browntop	*Agrostis capillaris*
buddleia	*Buddleja davidii*
buffalo grass	*Stenotaphrum secundatum*
Californian thistle	*Cirsium arvense*
catsear	*Hypochoeris radicata*
Chinese privet	*Ligustrum sinense*
cleavers	*Galium aparine*
climbing rose	*Rosa* sp.
cocksfoot	*Dactylis glomerata*
common alder	*Alnus glutinosa*
crack willow	*Salix fragilis*
creeping bent	*Agrostis stolonifera*
creeping buttercup	*Ranunculus repens*
Douglas fir	*Pseudotsuga menziesii*
dwarf mistletoe	*Korthalsella salicornioides*
eucalyptus	*Eucalyptus* sp.
European larch	*Larix decidua*
false acacia	robinia; black locust; *Robinia pseudoacacia*
feijoa	*Feijoa sellowiana*
fleabane	*Conyza sumatrensis*
foxglove	*Digitalis purpurea*
gorse	*Ulex europaeus*
grape	*Vitis vinifera*
greater bindweed	*Calystegia silvatica*
grey willow	*Salix cinerea*
harakeke	flax, *Phormium tenax*
heather	*Calluna vulgaris*

Himalayan honeysuckle	*Leycesteria formosa*
horoeka	lancewood, *Pseudopanax crassifolius*
hound's tongue fern	kowaowao; *Microsorum pustulatum*
Indian doab	*Cynodon dactylon*
inkweed	*Phytolacca octandra*
ivy	*Hedera helix*
Japanese cedar	*Cryptomeria japonica*
Japanese honeysuckle	*Lonicera japonica*
kahikatea	*Dacrycarpus dacrydioides*
kamahi	*Weinmannia racemosa*
kanuka	*Kunzea ericoides*
karamu	*Coprosma robusta*
kiokio	*Blechnum novae-zelandiae*
kohuhu	*Pittosporum tenuifolium*
koromiko	*Hebe stricta* var. *stricta*
Lawson's cypress	*Chamaecyparis lawsoniana*
lodgepole pine	contorta pine; *Pinus contorta*
lotus	*Lotus pedunculatus*
lupin	*Lupinus arboreus*
macrocarpa	*Cupressus macrocarpa*
mahoe	*Melicytus ramiflorus* subsp. *ramiflorus*
makomako	wineberry, *Aristotelia serrata*
mamaku	*Cyathea medullaris*
manuka	*Leptospermum scoparium* agg.
mapou	*Myrsine australis*
maritime pine	*Pinus pinaster*
Mercer grass	*Paspalum distichum*
mingimingi	*Leucopogon fasciculatus*
mint	*Mentha* sp.
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*
ornamental cherry	*Prunus* sp.
olive	*Olea* sp.
ovens wattle	*Acacia pravissima*
pampas	*Cortaderia selloana*
paspalum	*Paspalum dilatatum*
patotara	*Leucopogon fraseri*
plum	*Prunus ×domestica*
pohue	*Calystegia sepium* subsp. *roseata*
ponga	silver fern; *Cyathea dealbata*
poplar	*Populus* sp.
prairie grass	*Bromus willdenowii*
prickly mingimingi	*Leptecophylla juniperina* subsp. *juniperina*
prostrate kanuka	*Kunzea ericoides* var. *microflora*
radiata pine	*Pinus radiata*

ragwort	*Jacobaea vulgaris*
raupo	*Typha orientalis*
reed sweetgrass	*Glyceria maxima*
rewarewa	*Knightia excelsa*
rhododendron	*Rhododendron* sp.
rimu	*Dacrydium cupressinum*
Scotch thistle	*Cirsium vulgare*
sea rush	*Juncus kraussii* var. *australiensis*
sheep's sorrel	*Rumex acetosella*
shaking brake	turawera, *Pteris tremula*
silver birch	*Betula pendula*
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*
tawiniwini	*Gaultheria antipoda*
ti kouka	cabbage tree; *Cordyline australis*
toatoa	*Phyllocladus toatoa*
toru	*Toronia toru*
totara	*Podocarpus totara* var. *totara*
tradescantia	*Tradescantia fluminensis*
tree lucerne	*Chamaecytisus palmensis*
tree privet	*Ligustrum lucidum*
turutu	*Dianella nigra*
tutu	*Coriaria arborea* var. *arborea*
umbrella sedge	*Cyperus eragrostis*
water purslane	*Ludwigia palustris*
water lily	*Nymphaea alba*
whauwhaupaku	fivefinger; *Pseudopanax arboreus*
wheki-ponga	*Dicksonia fibrosa*
wheki	*Dicksonia squarrosa*
white clover	*Trifolium repens*
wild portulaca	*Portulaca oleracea*
wild seradella	*Ornithopus perpusillus*
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, EW, 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, EW = Environment Waikato , 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, EW	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 EW. 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, EW, 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, EW	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. kanuka). 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, EW, P Copies of Whaley *et al*. (1995) can be obtained from EW.	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/Taupo 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, EW	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, EW, 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, EW, 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, EW, 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, EW, 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.	

A. RPS Criteria met (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
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
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

A. RPS Criteria met (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
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.	

A. RPS Criteria (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
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
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 _____

A. RPS Criteria (see Table 1 above)	B. FACTORS TO BE ASSESSED	C. NOTES	D. RESPONSE (Yes / No / Not Sure)
			Y / N / NS
	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 CLASSIFICATIONS SYSTEM
(from Townsend *et al.* 2008) followed in de Lange *et al.* (2009).

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)'[3] 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.

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