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Prepared by:
Ryan Clark, Chris Floyd and Bruce Clarkson
Environmental Research Institute, Faculty of Science and Engineering, The University of Waikato

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Dave Smith
Department of Conservation

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Dominique Noiton

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By Ryan Clark, Chris Floyd, and Bruce Clarkson

Environmental Research Institute
Faculty of Science and Engineering
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Environmental Research Institute
Te Pūtahi Rangahau Taiao
THE UNIVERSITY OF WAIKATO

Executive Summary

This report outlines the results of a desktop inventory and significance assessment of the karst landscapes of the Waikato Region. It is the second report (replacing and extending the first) from a project which identifies and prioritises significant karst ecosystems. It is primarily designed to assist Waikato Regional Council and District Councils to make preliminary decisions when assessing applications for consents and funding, and establishing priorities for management and legal protection.

Karst ecosystems are often small, concealed or subterranean, and hence conventional Significant Natural Areas (SNA) techniques, using aerial photography, were not appropriate for this project. Potential karst presence was mapped based on an assessment of limestone geology data. Approximately 9% of the Waikato Region contains limestone within the geological strata, although surface expression may be up to an order of magnitude lower. While significant areas of indigenous vegetation still remain over some of the region's karst landscapes, the predominant vegetation cover in these environments is now exotic grassland.

The assessed limestone area was divided into over 25,000 karst SNA sites using spatial data indicating terrestrial vegetation and surface catchment boundaries. With such a high number of karst SNA sites, a geo-spatial (automated) method was developed to assess both geomorphological and ecological significance. The highest ranked geomorphological and ecological sites were all in Waitomo District. The majority of high ranking sites in most districts receive no formal protection.

While the automated geo-spatial process allowed the assessment of a large number of sites, it had limitations, particularly due to the coarse scale of some of the available spatial data. Relying solely on this assessment method risked failing to capture known locations of karst-specific Historically Threatened Ecosystems and threatened species, and hence separate outputs were generated to identify these sites.

Insufficient information was available to conduct any meaningful exercise to prioritise karst SNA sites for protection or management. A field-based assessment is recommended for sites that scored highly in the geomorphological and ecological significance assessments; together with those sites where threatened species have been recorded. The significance assessment process may have included a bias towards sites in Waitomo District and it is therefore recommended to include high ranking sites from other districts in any field-based assessment.

The location, values and threats associated with Waikato karst still require additional study and recommendations for further research are also provided in this report.

Disclaimer: This report presents an assessment of Significant Natural Areas, specifically addressing karst ecosystems. The Waikato Regional Council notes that while every effort has been made to ensure accuracy there are limitations with respect to the methodology used to identify the karst ecosystems. In particular this report is based on a desktop assessment of available data with input from local experts. There has been no ground truthing of the information. The information should therefore be used with caution and only as a guide to the location and likely karst ecosystem present. Further a ranking of the top 50 karst ecosystem types is currently in progress and it will be published as a separated dataset/layer (DM number, 9628536 draft version).

The Waikato Regional Council strongly advise that the data be used only in conjunction with field surveys, especially if the data will be used to help with decisions on resource consents, the development of district plan and regional plan schedules, or funding priorities. The absence of an existing karst ecosystem area from this report does not imply that such an area is not, or cannot be considered, a significant natural area, a significant area of indigenous vegetation or significant habitat for indigenous species. Such areas should be assessed when and if required.

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1 Introduction

1.1 Significant Natural Areas program

1.1.1 Project background

Regional and district councils are required by the Resource Management Act to recognise and provide protection for areas of significant indigenous vegetation and significant habitats of indigenous fauna. Waikato Regional Council (the council) is currently undertaking a process of identifying and prioritising significant natural areas in the Waikato Region (the Waikato), using criteria developed within the framework of the Regional Policy Statement (RPS). This Significant Natural Areas (SNA) program has included Terrestrial and Wetland SNA projects by territorial authority area, while other key ecosystem based projects have been conducted at regional level.

The University of Waikato was engaged to identify karst areas of potential ecological significance within the Waikato, and to prioritise karst areas for biodiversity management. A preliminary assessment was undertaken in 2008/09 [Floyd & Clarkson 2009] which identified the likely extent of karst within the Waikato. The present report incorporates and updates the 2009 output, and includes an assessment of identified karst SNA sites in terms of both their geomorphological and ecological significance. This second output also provides a record of sites containing karst-associated threatened species, together with an assessment of each site for the presence of four karst-associated ecosystem types that are recognised as historically rare[1] in New Zealand.

Both stages of this project have utilised existing spatial data and literature sources. While the locations of many karst features have been newly collated for this study, no field survey has been conducted.

1.1.2 Abolishment of Franklin District

This study was undertaken before the abolishment of the territorial authority of Franklin District in 2010. Prior to 2010, the regional responsibilities of the district were divided between Auckland and Waikato Regional Councils. In 2010, with the formation of Auckland as a unitary authority, Franklin District was formally abolished, with approximately 40% in the north of the district becoming incorporated into Auckland. The larger 60% of the former district was incorporated into Waikato

[1] The term ‘naturally uncommon’ is now preferred over ‘historically rare’ (see 1.3.1).

and Hauraki Districts within the Waikato Region. All references in this report to regional and territorial authority areas and boundaries are based upon the situation prior to the 2010 changes.

While new areas were incorporated into the Waikato Region as part of the 2010 changes, a subsequent review does not indicate that any karst ecosystems are present in these areas.

1.2 Karst formation and extent

Karst landscapes are typically identified through their characteristic features such as disrupted surface drainage, caves, underground drainage systems and dolines (surface depressions) [Williams 1982]. A geomorphological definition of karst, however, refers to the method of formation (karstification) of these features through the dissolving of bedrock by natural waters [Jennings 1985]. While karst in other parts of the world can occur in other substrates, such as evaporates [White 1988], karst in New Zealand is most commonly associated with calcareous sedimentary rocks such as limestone [Smith 1998].

Chemical weathering occurs where a weak carbonic acid (H_2CO_3), is formed through the absorption of atmospheric carbon dioxide (CO_2) by rainwater (H_2O). The acid reacts with the calcium carbonate ($CaC0_3$) of the limestone to create the water soluble compounds Ca^{2+} and HCO_3^- [Smith 1998]. This process of the dissolving of limestone by carbonic acid is called dissolution. CO_2 levels are often significantly higher in soils, or beneath vegetation, as a result of plant root respiration and bacterial decay of organic matter [Jennings 1985]. A more effective carbonic acid is often formed in these environments with the power to create the spectacular subterranean features commonly associated with karst [Smith 1998].

Similar features to those created by karst can be formed in other substrates by alternative processes, for example lava tunnels and sea caves [Jennings 1985]. These features are commonly referred to as pseudo-karst and are not included in the scope of this study.

The Waikato has one of the largest areas of karst landscapes in New Zealand, with approximately 1000 km^2 in the Department of Conservation (DOC) Maniapoto Area alone [Smith 1998]. All exposed limestone in the Waikato is likely to show some karst expression [D Smith pers comms] and is concentrated mainly in the west of the region along a band running from Port Waikato in the north through to Mokau in the south. A small isolated area of limestone is also exposed in the north of the Coromandel Peninsula [Edbrooke 2001].

The most well recognised and highest concentration of karst known in the Waikato is focused in an area around the Waitomo Caves, northwest of the town of Te Kuiti. Many significant geological sites are present in this area, including three caves of international geological importance [Worthy 1990].

1.3 Ecological importance of karst

The geomorphological diversity of karst environments, together with alkaline, lime-rich, and often shallow soils, provides unique opportunities for unusual flora and fauna, and high levels of biodiversity [Smith 1998].

Plant species are usually adapted to prefer either acid or alkaline soils. Waikato karst soils are formed from limestone or other calcareous substrates and are therefore lime-rich and alkaline. Lime-loving species, otherwise known as calcicoles or calciphyles, are therefore a common feature of karst landscapes. As a result of this chemical influence of karst soils, the vegetation composition of limestone areas is often characteristic, with the distinctive vegetation composition of the main limestone areas of the Waikato well described in the Karst Landscapes chapter of Botany of the Waikato [Clarkson 2002]. The character of limestone vegetation in the Waikato is also influenced by latitude, with many species reaching their northern or southern extremes in the region [Clarkson 2002].

In addition to the chemical influence of lime-rich soils, the physical habitat created by characteristic karst features also influences the inhabiting biota.

Dissolution features such as caves, arches and tomos, often limit light availability, creating a cooler, darker and more humid environment with associated plant and animal communities particularly suited to these conditions. These communities are most commonly characterised by a diverse array of ferns, mosses and liverworts [Clarkson 2002]. The recently discovered and rare fern *Asplenium cimmeriorum* is particularly strongly associated with cave entrances [Brownsey & de Lange 1997].

In contrast, limestone cliffs and rock outcrops provide drier, lighter, more exposed habitats with a very different biotic composition [Smith 1998]. In the Waikato, these are often characterised by dense shrub thickets and tangles of kiekie with a variety of shrubs and herbs on exposed cliff faces [Clarkson 2002].

Limestone is often exposed at the earth's surface in disconnected locations and this geographical separation of individual karst areas may promote regional endemism among the inhabiting flora and fauna. The karst ecosystems of the Waikato host species that are found nowhere else, including the cliff-dwelling shrub *Hebe scopulorum* [Clarkson 1993], and a number of subterranean invertebrates [Smith 1998; I. Millar pers comms].

1.3.1 Historically Rare Ecosystems

A 2007 study, conducted for the Ministry for the Environment (MfE), identified 72 New Zealand ecosystems that were considered to be historically rare [Williams et al 2007]. These ecosystems typically arise due to unusual environmental conditions, are mostly small, often support unique biodiversity, and commonly have an ecological importance, disproportionate to their size [LCR 2014]. These systems would have naturally occurred over only a small area prior to human activity, and given their rarity, are often poorly recognised, poorly understood and poorly managed [LCR 2014].

The term 'historically rare' was the preferred term for these ecosystems during the data analysis and initial production of this report, and has been retained through this report for consistency. The term 'naturally uncommon' is now preferred, however, as it equates with the New Zealand Threat Classification System developed for threatened species [LCR 2014]. The terms 'originally rare' and 'naturally rare' have also previously been used to describe these ecosystems.

The Historically Rare Ecosystems are grouped into six categories, with the Subterranean & Semi-Subterranean category of particular relevance to karst. This category includes the Historically Rare Ecosystems: 'Cave Entrances'; 'Sinkholes'; and 'Caves & Cracks in Karst'. A further Historically Rare Ecosystem: 'Calcareous Cliffs, Scarps and Tors', which has been grouped in the 'Inland & Alpine' category, is also of relevance to karst.

Each Historically Rare Ecosystem is described in a factsheet on the Landcare Research website [LCR 2014], with additional information provided on the values and threats associated with each ecosystem. The description of each of the four ecosystems deemed by this study to have particular relevance to karst, are repeated here for ease of reference.

> **Cave entrances**: "This ecosystem comprises the opening of a cave, extending just to the furthest limit of light penetration. Sites typically are shaded and may be either wet or dry. They may include cave walls and associated rockfalls and the cavern floor. Implicit in this definition is that the entrance leads to an area that is sufficiently large not to receive daylight. They occur primarily in calcareous karst landscapes but also in other rock types, including volcanic rocks. This definition excludes smaller spaces like cliff cavities and rock shelters."

> **Sinkholes:** "Sinkholes are bowl-shaped depressions in the ground. They are mostly formed in calcareous karst landscapes by solution weathering or downward movement of sediments. This occurs in various ways and although there is a complex classification of dolines describing these differences, here they are considered all together as sinkholes. A skeletal soil layer is usually present, but bare rock may or may not be exposed. As they represent areas of local concentration of drainage into the underground, their soils may be quite damp compared with on a flat surface nearby. This may not apply where the covering sediments are still present, and where collapse is occurring, mostly invisibly, beneath a contemporary surface."

> **Caves & Cracks in Karst**: "Karst caves are formed primarily by solution of bedrock along lines of weakness which water can penetrate. Enlargement may then be aided through other physical processes such as collapse. A cave, in recreational terms, is a macrocavern that a human body can get through, but there are extensive zones of smaller solution voids (mesocaverns), down to the order of a few tens of millimetres in diameter, both within caves themselves and within the karst generally. Some research suggests that these voids, which are not directly accessible to humans, actually constitute the major habitat used by obligate cave fauna."

> **Calcareous Cliffs, Scarps and Tors:** "Cliffs are high steep faces and scarps are cliffs along the edge of a plateau, while tors are mounds of glacial eroded bedrock with steep sides. Together, they provide many varied habitats - from

bare rock that can be colonised only by mosses and lichens to deeper soils supporting woody vegetation, from highly exposed situations to heavily shaded and sheltered habitats, and from very dry to permanently wet surfaces. Hebes, some heath-like shrubs, flaxes and native grasses are important on cliffs. Plants seldom grow on the massive cliff faces but are rooted within the instices of ledges, crevices, and cracks. Long tap-like roots are a noteable trait of limestone cliff plants such as cheesemanias and pachycladons. Many native shrubs, grasses, and herbs that have been lost from neighbouring habitats find refuge on cliffs, scarps and tors. Some limestone outcrops are important sites of both ancient depositional fossils and New Zealand biota that has become extinct since humans arrived."

Criteria for the International Union for Conservation of Nature (IUCN) draft Ecosystem Red List have been applied to New Zealand's Historically Rare Ecosystems with 45 of the 57 classified as threatened [Holdaway et al 2012]. The threat classifications for the four Historically Rare Ecosystems deemed of relevance to karst are:

Cave Entrances:	Critically endangered
Sinkholes:	Endangered
Caves & Cracks in Karst:	Not threatened
Calcareous Cliffs, Scarps and Tors:	Vulnerable

1.3.2 Rare and notable species of karst ecosystems

A range of rare and threatened species have been recorded from the karst landscapes of the Waikato, however, the majority have no particular reliance on karst ecosystems, with similar distributions in non-karst landscapes. The council's Terrestrial and Wetland SNA program is designed to capture records of all threatened species, and hence there was no benefit to duplicating that data in this report. It is recognised, however, that a small number of rare plant and animal species have a particular association with karst habitats, and this aspect of the report is limited to these species.

Four threatened or at risk species were identified as having an association with limestone or karst in the Waikato: the cave spleenwort fern, *Asplenium cimmeriorum*; the endemic cliff-dwelling shrub, *Hebe scopulorum*; the limestone shrub, *Teucridium parvifolium* and the long-tailed bat, *Chalinolobus tuberculatus*.

Two other species: the king fern, *Ptisana salicina*; and New Zealand falcon, *Falco novaeseelandiae* also have important populations in karst landscapes of the Waikato, but no evidence was found that suggested a particular association with either the chemical properties of limestone soils or particular geomorphological karst features.

King fern have been heavily impacted by grazing livestock and wild pigs and its presence in cave entrances, tomos and limestone gorges is thought to be largely due to the inaccessibility to these pest animals [NZPCN 2014] rather than any particular natural association. New Zealand falcon will nest on open exposed areas of limestone but also selects similar habitats on other substrates, in other parts of New Zealand and is not deemed to hold any strong karst association.

A number of troglobitic invertebrates, including endemic carabid beetles and some of the first subterranean pseudo-scorpions in New Zealand, have been collected from the subterranean karst environments of the Waikato Region [I. Millar pers comms]. However, invertebrates of New Zealand subterranean environments are still poorly described, particularly in the Waikato karst, and while several species may eventually be classified as threatened or at risk, there is currently insufficient information to assess the distribution or threat status of these species [I. Millar pers comms; Scarsbrook et al 2008].

The cave spleenwort (***Asplenium cimmeriorum***) is a New Zealand endemic fern, restricted on the North Island to limestone areas of the Waitomo District and most commonly associated with cave entrances. The dark blue-green fern resembles a smaller version (fronds 20-100mm long) of the more common hen and chicken fern (*A.bulbiferum*) but lacks the characteristic bulbils of the larger species. Cave spleenwort often forms small colonies at the threshold of light in cave entrances, and in the Waikato is usually found under the shade of taller ferns or paritaniwha (*Elatostema rugosum*) [Brandon et al 2004; Brownsey & de Lange 1997]. *Asplenium cimmeriorum* is listed as 'At Risk - Naturally Uncommon' in the most recent threatened plant classification [de Lange *et al* 2012].

Awaroa koromiko (***Hebe scopulorum***) is a small shrub with bluish-green leaves that is found exclusively on limestone rocks and has a very localised distribution around the headwaters of the Awaroa River [Bayly *et al* 2002; NZPCN 2014]. This limestone hebe, also previously known as *Hebe rigidula* form 1; *Hebe* 'Lady'; or *Hebe*

‘Awaroa’ [Clarkson 1993] was discovered in 1961 [Bayly *et al* 2002] and is possibly the Waikato region’s only endemic plant [Clarkson 2002]. *Hebe scopulorum* is listed as At Risk - Naturally Uncommon’ in the most recent threatened plant classification [de Lange *et al* 2012].

The small-leaved shrub (***Teucridium parvifolium***) occurs on stream sides and river terraces in lowland dry podocarp-broadleaf forest, in sporadic locations across New Zealand. The shrub is commonly associated with limestone substrate, and has significant populations in karst areas around Waitomo. *Teucridium parvifolium* is listed as ‘At Risk - Declining’ in the most recent threatened plant classification [de Lange *et al* 2012].

The New Zealand endemic long-tailed bat (***Chalinolobus tuberculatus***), is listed in the current threat classification lists as ‘Threatened - Nationally Vulnerable’ [O’Donnell et al, 2012]. While the North Island populations are thought to be healthier than those on the south island, the long-tailed bat is still threatened by the effects of roost loss and competition and predation from introduced mammals. The long-tailed bat will roost in old mature trees, however, they are also known to congregate as significant populations in some cave sites in the Waitomo area [D Smith pers comms].

1.4 Threats

While natural threats to karst do exist [Williams 1993] the major concerns for karst in the Waikato are human induced [Urich 2002]. Impacts on karst ecosystems occur both above and below ground, and through the influence of hydrology, can be affected by activities away from, as well as within, karst terrain [Williams 1993].

The most significant impacts on karst ecosystems are often associated with vegetation clearance and subsequent agricultural practices [Williams 1993], both of which have been widely experienced throughout the Waikato. Localised vegetation clearance around karst features can lead to changes in environmental conditions, with subsequent pressure on associated biota and an increased risk of weed invasion. For example, vegetation clearance around cave entrances can increase light, desiccation and temperature extremes to previously cool, shaded, humid environments [LCR 2014].

More widespread loss of indigenous surface vegetation can impact on karst ecosystems through the influence of hydrology at a catchment scale. Land cleared for agriculture or urbanisation does not have the same ability as forested habitat to attenuate heavy rain events and hence karst, and particularly subterranean, environments are at risk of increased frequency and magnitude of flood events [DOC 1999].

Other changes to hydrological processes in the catchment through water abstraction, damming, and degradation of water quality from point-source and diffuse pollution are also widespread issues [Urich 2002; Williams 1993]. Agriculture in the catchment can lead to an increase in nutrients, sediment loads and temperature increases to subterranean aquatic ecosystems [Scarsbrook et al 2008], while urbanisation could see the influence of other chemical pollutants. Plantation forestry in the catchment could see significant sediment flows to subterranean habitats, at harvest time [DOC 1999].

The impact of terrestrial activity on sub-surface catchments may be difficult to identify, however, as subterranean hydrology does not match surface catchment boundaries and may often pass beneath both valleys and ridges on the ground [DOC 1999].

More localised impacts on karst include dumping of waste, with cave entrances, tomos and dolines making convenient places to dispose of unwanted rubbish. In addition to infilling, this waste can then continue to act as a long-term pollution source for any connected subterranean system [LCR 2014].

Quarrying and construction activity can result not only in a change of the ecosystem present in a karst environment, but its complete removal. Sites for quarrying and development should therefore be carefully chosen to avoid significant karst geomorphological features and ecosystems.

Cave tourism is economically important in the region, particularly in the Waitomo area, but can result in vandalism, disturbance of fauna and impacts associated with lighting and elevated CO_2 levels if not appropriately managed [Waitomo Caves 1982]. Rock climbing has the potential to adversely impact limestone cliff environments through localised trampling where climbers gather at the top and bottom of climbs, and disturbance of cliff habitats in-between [LCR 2014].

Some threats that apply to wider terrestrial ecosystems in the Waikato, including the impacts of pest animals and plants, are likely to apply similarly to terrestrial karst ecosystems. However, goats are known to utilise the shelter of limestone overhangs and similar features, which is likely to lead to a localised increase in grazing impact around these features [LCR 2014].

2 Project scope and outputs

The original project scope was outlined in the contractual agreement between the council and the University of Waikato, with expected outputs in line with the council's Terrestrial and Wetland SNA program. Due to the complexity of this project, and the particular difficulty of clearly identifying karst presence, revisions to the project scope and outputs were agreed. This helped to ensure that the core aim of producing relevant data that is of practical use to end-users was achieved.

Output 1 [Floyd & Clarkson 2009] focussed on the production of GIS data that identified the location of known and potential karst areas in the Waikato. To meet this output, geological data from several sources were collated to produce a Limestone Geology Likelihood (LGL) spatial data set that classified parts of the Waikato into areas with three different likelihoods of limestone presence. The total spatial area of the LGL layer was then divided into individual karst SNA sites based on several sources of indigenous terrestrial vegetation data and watershed boundaries.

This second part of the project has focussed on establishing the relative significance of the individual karst SNA sites and producing results that will be of direct use to regional and local government in their policy and regulatory activities.

Interpreting existing and newly collated spatial data has enabled the assessment of potential karst SNA sites utilising the presence of karst features, together with land cover type. Secondly, each potential karst SNA site has also been assessed for the presence of karst specific Historically Rare Ecosystems, with the intention of feeding directly into the assessment of criterion 5 of the council's operative Regional Policy Statement (RPS) ecological significance criteria (Appendix 3 of the operative RPS).

3 Methodology

3.1 Karst ecosystems - working definition

While dictionary definitions of karst refer to the formation of features through dissolution processes, it is extremely difficult to practically identify these on the ground. This is made particularly difficult by the problem of separating the influence of the geophysical elements of features formed by dissolution from the chemical influence of the limestone substrate and resulting calcareous soils. It was therefore necessary to develop a working definition of karst ecosystems to determine which areas would be identified as part of this project.

The most obvious ecosystems to capture are those associated with the characteristic karst features that have also been assessed as being ‘historically rare’ (see 1.3.1). Three of these rare ecosystems are characteristic of Waikato karst environments, namely: ‘sinkholes’; ‘cave entrances’; and ‘caves/cracks in karst’. These karst ecosystems provide particular environmental conditions that are often cooler, darker and more humid than the wider surrounding terrestrial ecosystem, and the biotic communities that develop tend to be more suited to these conditions. These are the characteristic ecosystems that typify karst environments and it was therefore important to ensure that these were captured by this project.

In the Waikato, karst is restricted to limestone or similar calcareous sedimentary rocks [Smith 1998] and the resulting alkaline soils strongly influence the plant communities that develop. It is therefore often difficult to separate the effects of the geo-physical structure of karst on biotic communities from those of the calcareous substrate. Consequently, it is extremely difficult to separate limestone ecosystems into those formed on features created by karst dissolution and those formed by alternative non-dissolution processes. In particular, limestone cliff faces formed by non-dissolution processes could provide similar habitats to vertical cave entrances formed by dissolution. In addition it could be argued that all exposed limestone surfaces will be subject to some dissolution processes, even if they were not the initial feature-forming process [D Smith pers comms], and therefore meet the more technical karst definition. It was therefore recognised that it was important to ensure that any features that meet the historically rare ‘calcareous cliffs, scarps and tors’ definition [LCR 2014] should also be captured by this project.

Restricting the focus of this project to known karst features, matching the four historically rare ecosystems, was however, likely to fail to capture large areas of limestone substrate, where karst expression may be influencing resultant ecosystems. Where limestone substrate dominates, irrespective of whether known karst features are present, lime-rich soils will influence the biotic communities present. Further, dissolution processes are still likely to act on surface limestone in these environments, and while they may not always create the more characteristic karst features, other smaller-scale features such as karren and epikarst are likely to be abundant [D Smith pers comms]. It is also possible that some of the more characteristic karst features are also present in these areas, but not yet identified, particularly where they are small and still covered by indigenous vegetation.

Therefore, for the purposes of this project an inclusive approach has been adopted to attempt to capture all areas where ecosystems are likely to have developed on limestone substrate. This approach alleviates the difficulty of separating the physical effects of karst features from the chemical influence of the calcareous substrate, but is further justified by the likely presence of small dissolution features and yet unidentified characteristic features across the wider limestone substrate.

Despite taking this inclusive approach to this project, it is recognised that the historically rare ecosystems associated with karst are of particular importance, particularly as three of the four ecosystems are classified as threatened [Holdaway 2012]. In addition these ecosystems are known to include rare flora and fauna that are atypical of the wider calcareous terrestrial environment. For this reason the identification of these historically rare ecosystems has still been retained as a key aspect of this study (see 3.4.1 & 3.6).

3.2 Assessing geological extent

Assessing the likely extent of karst ecosystems in the Waikato has presented particular difficulties. Often, much of the ecosystem is below ground, while the surface component may be limited to small depressions or cave entrances. Standard aerial photography is therefore of minimal value for identifying karst ecosystems, and delineation of them in a GIS is very limited. Methods commonly used for the remote identification and prioritisation of other terrestrial ecosystems in the region were therefore not sufficient to meet the requirements of this project.

Some existing data sets [e.g. RIVI 1995; TOPO 2009; WtDC (no date)] provide an indication of well-known and likely areas of karst, or limestone outcropping, but these are not comprehensive. Additionally, these data are often individual point locations and do not represent the full extent of the karst feature or system.

Accepting that the karst of the Waikato is only expected to form on limestone, and furthermore that all limestone may feature some form of karst expression, it was therefore decided that the geographical extent of this study would encompass the extent of limestone substrate within the region. Prior to this study, no single spatial data set clearly identified the extent of limestone within the Waikato region. Three existing data sets were therefore analysed to identify areas where limestone was likely to form a substrate component:

- Land Environments of New Zealand (LENZ 2003) incorporates a parent material class indicating not just the rock type but specifically the type in the soil-forming layer.
    - *LIMESTONE AND MARBLE (LENZpm = Li/Mb)* - **Included**

      Local knowledge of the authors indicated that the area delineated by this class was not comprehensive, with some obvious limestone areas missing.
    - *TERTIARY CALCAREOUS SEDIMENTARY* (LENZpm = TCS) – **Excluded**

      This group appeared too extensive and included areas where limestone and karst are known to be unlikely. This LENZ group is an amalgamation of six parent material classes [Leathwick *et al* 2003], however the component groups are not included in supplementary data and are not thought to have been recorded [M. McLeod pers comms]. In the absence of component rock type data, it was decided to exclude this group in preference of other data sources.
- Land Resource Inventory (LRI 2004) includes stratigraphic data for rock types identifying predominant surface (TOPROCK) and underlying (BASEROCK) rock types
    - *TOPROCK = LIMESTONE* (LRI TOPROCK = Li) – **Included**

The 'TOPROCK' class is derived from the 'ROCK' class but indicates the principal surface rock type. Where TOPROCK is limestone it gives a strong indication that limestone is present in the soil forming layer.

- *ROCK: TOP LAYER OF SECONDARY STRAT UNIT = LIMESTONE*

  (LRI ROCK: Top of 2° unit = Li) – **Included**

  The 'ROCK' class often includes a secondary stratigraphic unit which can be shown as one rock type over another. For example Ar+Li/Gw indicates that argillite would be the main surface material (TOPROCK), but that limestone over greywacke would be the secondary stratigraphic unit with limestone locally present at the surface.

- *BASEROCK = LIMESTONE* (LRI BASEROCK = Li) – **Included**

  The 'BASEROCK' class is derived from the 'ROCK' class and indicates the principal underlying rock type. This could be a good indicator of subterranean karst.

- *ROCK = LIMESTONE ANYWHERE ELSE IN CODE*

  (LRI ROCK: Li included anywhere) – **Included**

  Anywhere where the 'ROCK' class features Li other than meeting the requirements above.

- GNS QMAP (2005) Geological Units include data on the dominant (mainrock) and secondary (subrock) rock types in addition to the identification of particular stratigraphic units.

  - MAINROCK = LIMESTONE (QMAP: MAINROCK = Li) – **Included**

    The QMAP series is focused on surface geology, however, this geology can be overlain by unconsolidated sediments such as loess, ash or unconsolidated sandstones and these can sometimes be quite deep. It would be reasonable, however, to assume that if limestone was the MAINROCK that it would be likely to make some surface appearance at some point within the unit – i.e. cuttings, gorges, outcrops even if it were not the main soil forming material over most of the unit [D. Heron pers comms]. These groups will include the major karst areas around Waitomo, mostly featured in the Upper (and to a lesser extent Lower) Te Kuiti groups [S. Edbrooke pers comms].

- ADDITIONAL UNITS INCLUDE LIMESTONE (QMAP: ADDL UNITS inc Li) – **Included**

  The presence of limestone or calcareous sediments as a secondary rock type included a large number of different formations and individual rock types, often containing bands of calcareous material within wider sedimentary formations. Individual formations and rock types were assessed based on descriptions in geological texts [Edbrooke 2001, Edbrooke 2005] and in discussions with the author, Steve Edbrooke.

These results were then grouped into three Limestone Geology Likelihood (LGL) classes, reflecting the likelihood of limestone presence in the strata and the subsequent likelihood of surface expression (Table 1).

Table 1: Summary of geological data grouped into three likelihood classes reflecting the likely presence of limestone and the likelihood of surface expression.

Limestone Geology Likelihood (LGL) ranking:	**4**	**3**	**2**
Limestone likelihood :	**Likely**	**Likely**	**Less likely**
Predominantly surface / underlying :	**Surface**	**Surface / Underlying**	**Surface / Underlying**
LENZ pm class			
LENZpm = Li /Mb	Y		
LRI			
LRI TOPROCK = Li	Y		
LRI ROCK: Top of 2° unit = Li	Y		
LRI BASEROCK = Li		Y	
LRI ROCK: Li included anywhere			Y
GNS - QMAP			
QMAP: MAINROCK = Li		Y	
QMAP: ADDL UNITS inc Li (likely*)		Y	
QMAP: ADDL UNITS inc Li (possible*)			Y

*****Further details of the grouping of additional QMAP stratigraphic units are presented in Appendix 1.

The three resulting geological layers total approximately 218,000 hectares, equating to 8.9% of the Waikato region[2]. Areas covered by each individual layer are shown in Table 2 and geographically represented in Figure 1.

Table 2: Area (hectares) covered by each of the three Limestone Geology Likelihood (LGL) layers.

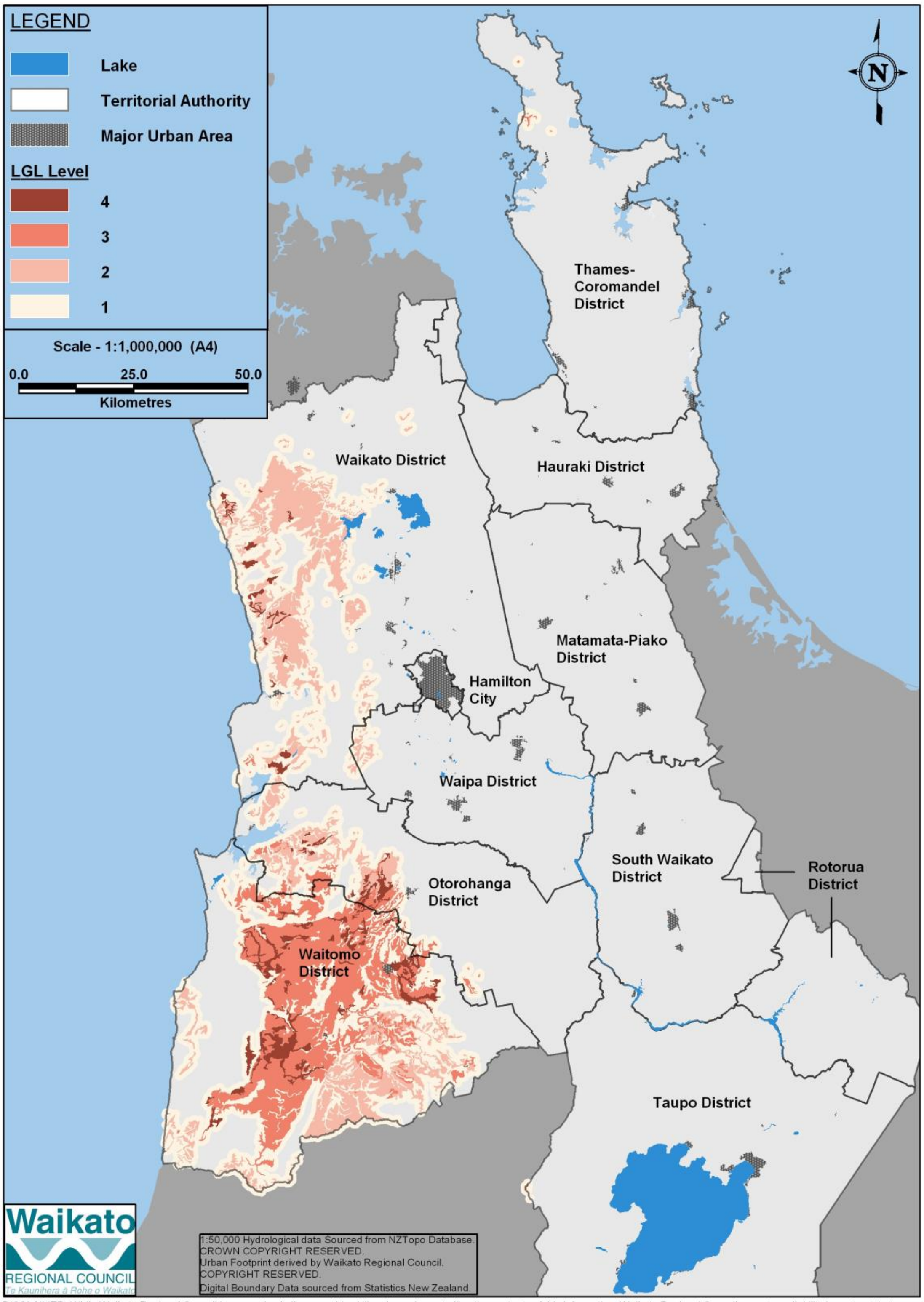
	Area (Ha)	Percentage of limestone (217,924 Ha)	Percentage of region * (2,449,300 Ha)
LGL 4	22,686	10.4%	0.9%
LGL 3	99,088	45.5%	4.0%
LGL 2	96,149	44.1%	3.9%
Total	217,924	100.0%	8.9%

*prior to 2010 regional boundary changes

[2] Prior to 2010 regional boundary changes (see 1.1.2).

The LGL layers provide a strong indication of where karst features are likely to occur within the Waikato Region. It is recognised, however, that there is the potential for individual karst features to exist outside of these likelihood layers, given the small size of some individual karst features and the coarse resolution of the geological data sets. This assumption was supported by the presence of karst indicator features from other data sets in the marginal area, outside the LGL layers. To account for this, it was decided to create a one kilometre buffer zone around the three LGL layers for further study and site delineation. This buffer zone was identified as LGL level 1.

Figure 1: Geographical coverage of potential karst sites by Limestone Geological Likelihood (LGL)



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3.3 Site identification & delineation

Having identified the potential geographical extent of karst presence throughout the Waikato by assessing the extent of limestone geology, other factors were then considered to divide this large area into individual sites for further assessment and ranking.

3.3.1 Terrestrial vegetation data

The ecological significance of terrestrial ecosystems is often determined largely from the vegetation communities present. Additionally, the type of terrestrial vegetation present is known to influence the integrity of karst processes beneath the surface [Williams 1993]. Existing data representing indigenous terrestrial vegetation cover therefore provided a sensible primary method of delineating individual sites. The following indigenous terrestrial vegetation cover data sets were utilised:

- Terrestrial SNA sites with specific karst or limestone reference (available for the Waitomo [SNA Waitomo 2008] & Otorohanga [SNA Otorohanga 2003] Districts only).
- DOC public conservation land units [DOC 2008] with specific karst or limestone references in the Maniapoto Karst Plan [Smith 1998] (covers DOC Maniapoto area only).
- Terrestrial SNA with no specific karst reference (Waitomo District only [SNA Waitomo 2008]).
- DOC public conservation land units, not previously included [DOC 2008].
- QEII Trust covenants data [QEII 2009]
- Nga Whenua Rahui Kawenata (covenant) data [NWR 2008]
- District Council Reserves data [CRS Parcel 2009]
- District Council Conservation Covenants data (available for Franklin and Waikato Districts only) [FDC 2009; WkDC 2009].
- Key Ecological Sites data [KES 1999]
- Biodiversity Vegetation data (available for the Waitomo District only) [Bioveg 2002]

- Regional Indigenous Vegetation Inventory [RIVI 1995]

Spatial data from these sources was introduced sequentially to create a 'Karst SNA' data set, which included key attribute data from each primary source. Datasets or subsets most likely to provide reliable karst relevant data were introduced first, followed by those with the most reliable indication of indigenous vegetation data. A spatial difference function was used when introducing each data set to ensure that only data for areas not already captured from previous sources were added to the Karst SNA data set. Sites comprising of multiple polygons (i.e. included more than one area or component) had the potential to possess different likelihoods of karst presence, and were therefore split to allow for the separate analysis of each individual component.

A trial exercise was initially undertaken in the Waitomo District, for which the most comprehensive existing data was available, before expanding the method to the rest of the Waikato.

3.3.2 Division by hydrology

After incorporating the indigenous terrestrial vegetation data, extensive areas of the LGL layer, covered primarily by non-indigenous vegetation, were not yet included in the Karst SNA data set. To enable inclusion of these large areas in the data set, they needed to be objectively divided into individual, comparable sites that would allow for more practical and consistent assessment.

Water movement plays a critical role in the creation of karst features and can also be important in managing these environments, particularly in relation to water quality [Smith 1993; Urich 2002]. It was therefore considered appropriate to use hydrological data, watershed, or sub-catchment data in particular, as a method of delineating these remaining extensive limestone areas for inclusion into the Karst SNA data set. The watersheds data produced as part of the National Institute of Water and Atmospheric Research (NIWA) River Environment Classification database [REC 2004] was used for this process.

Additionally, some of the karst SNA sites originating from indigenous terrestrial vegetation data were considered very large in terms of the scale in which karst may be expressed. It was therefore decided to also divide these areas by the REC watershed data to allow for more detailed analysis. Dividing all indigenous terrestrial vegetation sites by watershed was considered. However, this created an inordinate and unnecessary number of very small sites and was therefore abandoned. The mean watershed size within the study area is approximately 45 hectares (ha), and it was decided that adequate division of the larger indigenous terrestrial vegetation sites could be achieved if restricted to those that were more than twice this size.

Despite limiting division by watershed to sites over 90ha, the spatial difference functions used for incorporating indigenous terrestrial vegetation data created a large number of small sites in the Karst SNA data set. Sites less than 0.5ha in size were below the minimum mapping unit for this study, and were therefore merged with the adjacent site with the largest shared boundary. An exception was made for any site less than 0.5ha that contained a known karst feature, in which case it was retained as a separate site.

3.4 Significance assessment and ranking of karst SNA sites.

The inclusive nature of the site delineation exercise produced a large number (>25,000) of individual potential karst SNA sites, far too many to consider for any manual significance assessment or management prioritisation exercise. Methods were therefore developed to allow for an 'automated scoring' of the significance of each site using new and existing data sets. Each site was scored against a range of criteria and then ranked in terms of the following:

1. its known or likely karst geomorphological significance, and
2. its known or likely karst ecological significance (incorporating geomorphology and landcover).

3.4.1 Stage 1: Karst geomorphological significance

A selection of datasets, (see sections 3.4.1.1 – 3.4.1.10), were spatially assessed against the Karst SNA data to allow for an automated assessment of the likelihood of the presence of karst features, and hence, the potential karst geomorphological significance of each site. Ten criteria, that may indicate karst presence, were developed (see sections 3.4.1.1 – 3.4.1.10) based on the available data. Each karst SNA site was spatially assessed against each of the ten criteria, with the results of each assessment categorised and scored.

The scores resulting from each of the 10 criteria were weighted according to their relative likelihood of indicating karst presence and/or significance. One of the weighting factors applied is worth particular mention: 'Karst Habitat Diversity' was weighted low to prevent duplicating the emphasis of the individual karst features from which the data was derived

The weighted scores for each of the ten categories were then summed to provide an overall 'geomorphological significance score' for each site. The range of possible geomorphological significance scores was 0 to 600.

While the calculation of this score was primarily a step in producing the 'ecological significance' score (see section 3.4.2), the geomorphological significance score also has potential value as a data set in its own right. In particular, the geomorphological score could be used to indicate the potential significance of subterranean ecosystems, where vegetation is not a factor, given the absence of light. Additionally, given the small size and inaccessibility of some karst ecosystems, there is the possibility that sites with a high geomorphological score could host localised, rare plant communities, even if coarse resolution land cover data does not indicate intact indigenous vegetation. Furthermore, this data could be of use in determining the restoration potential of karst SNA sites by identifying sites with the highest geomorphological value, irrespective of current vegetation cover.

The assessment against each of the 10 criteria is described in the following sections, with the scoring and weighting coefficients summarised in Table 4.

3.4.1.1 Limestone Area Likelihood (LAL) application

For each karst SNA site, the area, in hectares (ha), of each Limestone Geology Likelihood (LGL) level (see section 3.2) was calculated. The area results for each LGL level were weighted according to the expected likelihood of karst presence (Table 3), with the sum of these weighted areas calculated to produce an LAL result for each karst SNA site.

Table 3: Weightings applied to the area (ha) of different LGL levels overlying each karst SNA site, reflecting the decreasing likelihood of karst expression in lower LGL levels.

LGL Level	Weighting Factor
LGL 4	1
LGL 3	0.4
LGL 2	0.2

*Example: 100ha karst SNA site is comprised of 25ha of LGL4, 25ha of LGL3, 25% of LGL2 and 25ha outside of these layers: LAL result = (25x1) + (25x0.4) + (25x0.2)+(25*0) = 25+10+5+0 = 40.*

The LAL calculation uses the actual area (ha) rather than the proportion of each site, as it is reasonable to expect the likelihood of locating karst to change in respect of site size, as well as differing LGL composition. For example, it is more likely to expect to find a previously unrecorded cave entrance, in a 50ha area than a 5ha area of the same LGL level.

The karst SNA sites were then categorised into five 20 percentile groups by LAL result and applied a corresponding score as shown in Table 4.

3.4.1.2 Cave entrances

Records of cave entrance locations were collated from a number of data sets [Allan Herbarium 2009; Auckland Museum 2009; G Kessels pers comms; Smith 1998; Smith 2009; SNA Waitomo 2008; Te Papa 2009; TOPO 2009; UoW Herbarium 2009], and assessed to determine the presence and abundance of cave entrances in each site.

It was deemed likely that the same entrances could have been recorded in more than one data set, but the name and location details may have been recorded differently, giving rise for potential duplication. Cave entrance locations from herbarium records were further compounded because of potential duplication where many individual specimens may have been collected from the same cave entrance. For these reasons we opted to derive the abundance of entrances in each karst SNA site only from our primary cave entrance data set [Smith 2009].

Cave entrance records from other data sets were only used for karst SNA sites not including a record from the primary data set [Smith 2009]. To alleviate the risk of potential duplication within these additional datasets, a maximum of one cave entrance was attributed to each of these additional sites, irrespective of the number of individual records.

Karst SNA sites were then categorised and scored based on the number of cave entrances recorded, as shown in Table 4.

3.4.1.3 Soakholes / sinkholes

While more commonly referred to as sinkholes, vertical shafts, or tomos, are referred to as soakholes in our source data for this feature [TOPO 2009]. The use of 'soakhole' to describe these vertical features is in contrast to the Historically Rare Ecosystems definition of soakhole which is closer to the description of dolines in the TOPO [2009] data. Karst SNA sites were categorised and scored based on the number of soakholes present in each site, as shown in Table 4.

3.4.1.4 Rock outcrops

The score for this category was derived from the number of individual features, recorded in each karst SNA site. The main source for this category was TOPO [2009] data, however, additional data was also available from other literature (e.g. herbarium records), but with no way of assessing potential duplication. For this reason we opted to derive the abundance in each karst SNA site from our main data set [TOPO 2009].

Rock outcrop records from other data sets were only used for karst SNA sites not including a record from the primary data set [TOPO 2009]. To alleviate the risk of potential duplication within these additional datasets, a maximum of one rock outcrop was attributed to each of these additional sites, irrespective of the number of individual records.

Any cliff records, from additional data sources, were also included in this section where the length requirement for the assessment of cliffs (see section 3.4.1.5) was not known.

Sites were then categorised and scored based on the number of outcrops recorded, as shown in Table 4.

3.4.1.5 Cliffs

Cliff data was available from TOPO [2009] data as a linear feature, and therefore allowed a different measure of abundance than other features. The total lengths (in kilometres) of all cliffs (on LGL levels 1-4) within each karst SNA site were calculated. The karst SNA sites were then categorised into five 20 percentile groups by total cliff length and applied a corresponding score as shown in Table 4.

3.4.1.6 Dolines

No spatial data specifically for dolines is known to exist for the Waikato; however, depression contours on limestone geology are likely to be a strong indicator of doline presence. Therefore, depression contours from TOPO [2009] data were used as a surrogate for dolines where they occurred on LGL levels 1-4. The total depression contour area (ha) was calculated for each karst SNA site. The sites were then categorised into five 20 percentile groups by total depression contour area and applied a corresponding score as shown in Table 4.

3.4.1.7 Subterranean cave data

Each karst SNA site was assessed to determine the area of the site that overlapped any of the Waitomo District Council (WtDC) Caves subterranean polygons [WtDC (no date)]. Sites with an area of WtDC cave data were categorised into five 20 percentile groups based on total subterranean cave and applied a corresponding score as shown in Table 4.

It should be noted that data for subterranean cave area was only available for the Waitomo District area.

3.4.1.8 Herbarium (and museum) collections - Limestone reference

Herbarium and museum collection data [Allan Herbarium 2009; Auckland Museum 2009; Te Papa 2009; UoW Herbarium 2009] were searched for any inclusion of the words ‘karst’; ‘limestone’ or ‘cave’, or the collection of known calciphilic species.

Recognising the potential for numerous specimens to have been collected from the same site, or the influence of disproportionate sampling effort over actual abundance, it was decided to restrict this criterion to a single presence/absence score.

3.4.1.9 Sites of geological importance

The number of significant geological features in each karst SNA site was recorded, based on geocoded co-ordinates from Kenny & Hayward [1996]. Karst SNA sites that contained features were categorised and scored based on the number of features present, as shown in Table 4.

3.4.1.10 Karst habitat diversity

The number of different types of characteristic karst features (3.4.1.2 – 3.4.1.7) present in each site was calculated as a measure of karst diversity. Cliffs and rock outcrops were treated as a single feature type, given their habitat similarity. Sites with one or more karst feature were divided into five categories, with corresponding scores, based on the number of karst feature types present.

Table 4: Karst geomorphological significance, assessment and weighting scores.

Criteria	1 Limestone Geology Likelihood (LGL)		2 Caves		3 Soakholes		4 Rock Outcrops		5 Cliffs		6 Dolines		7 Subterranean		8 Herbarium 'Limestone' Reference		9 Site of Geological Importance		10 Karst Habitat Diversity	
	Weighting	5		10		8		5		4		5		7		4		10		2
Priority score	High (80-100 percentile)	10	High (>2 caves)	10	High (3 soakholes)	10	High (>2 outcrops)	10	High (80-100 percentile)	10	High (80 100 percentile)	10	High (80-100 percentile)	10	Present	6	High - 3 sites present	10	High (5 types present)	10
	Med-High (60-80 percentile)	8	Medium (2 caves)	8	Medium (2 soakholes)	8	Med (2 outcrops)	8	Med-High (60-80 percentile)	8.5	Med-High (60-80 percentile)	8.5	Med-High (60-80 percentile)	8.5			Medium - 2 sites present	8	Med-High (4 types present)	8
	Med (40-60 percentile)	6	Low (1 cave)	6	Low (1 soakhole)	6	Low (1 outcrop)	6	Med (40-60 percentile)	7	Med (40-60 percentile)	7	Med (40-60 percentile)	7			Low - 1 site present	6	Medium (3 types present)	6
	Low-Med (20-40 percentile)	4							Low-Med (20-40 percentile)	5.5	Low-Med (20-40 percentile)	5.5	Low-Med (20-40 percentile)	5.5					Low-Med (2 types present)	4
	Low (0-20 percentile)	2							Low (0-20 percentile)	4	Low (0-20 percentile)	4	Low (0-20 percentile)	4					Low (1 type present)	2

3.4.2 Stage 2: Karst ecological (incorporating geomorphological) significance

The ecosystem values of karst habitats are clearly a function of both biotic and abiotic components, and it is necessary to consider both aspects in assessing current ecological values or significance.

This section describes the use of existing land cover data to indicate vegetation communities, and its use in combination with geomorphological scores from section 3.4.1 to assess and rank karst SNA sites in terms of their ecological importance.

3.4.2.1 Land cover assessment

MfE land cover data (LCDB2) [MfE 2007] was used to indicate the type of land cover for each karst SNA site. The MfE land cover data is a three tier hierarchical classification with: eight broad first order classes based on the physical characteristics of the land; 18 second order classes based on other characteristics (LCDB1); and further division into 61 more detailed (LCDB2) classes. The council's 'Bioveg' dataset [Bioveg 2002] was alternatively considered, but although Bioveg was a more recent data set, its mapping was limited to classes relevant to regional biodiversity, and hence did not provide full coverage of the area overlapped by all karst SNA sites.

To calculate a land cover score for each karst SNA site, the proportion of each LCDB2 class in each karst SNA site was multiplied by a factor reflecting the habitat value the land cover type was likely to provide. These individual scores for each LCDB2 class were then added to give an overall land cover/habitat value for the site.

In determining the factors to apply to each land cover class, we grouped the classes and applied the same factor to each class in the group. These groups were derived from the LCDB first order class, but further divided into separate indigenous and exotic vegetation. The resulting grouping is shown in Table 5a, with the factors applied to each grouping shown in Table 5b.

Possible scores ranged from zero (highly modified land cover) to ten (entire site covered by indigenous forest).

Table 5a: Grouped LCDB2 vegetation classes based on the indigenous/exotic division of Landcover Database (LCDB1) classes.

LCDB 1st Order Class (original)	Grouped Vegetation Class (new)	Code	Individual LCDB2 class
Artificial surfaces	Artificial surfaces	AS	Built up area Surface mine Transport infrastructure Urban parkland
Bare surfaces	Open ground (naturally)	OG	Alpine gravel and rock Coastal sand & gravel Landslide River and lakeshore gravel and rock
Cropland	Cropland	CR	Orchard & perennial crops Short-rotation crops Vineyard
Forest	Exotic forest	EF	Afforestation - imaged Afforestation - not imaged Deciduous hardwoods Forest harvested Major shelterbelts Other exotic forest Pine forest - closed canopy Pine forest - open canopy
	Indigenous forest	IF	Indig forest Mangrove
Grassland / Sedge / Saltmarsh	Exotic grassland	EG	High producing exotic grassland Low producing grassland
	Indigenous grass / sedge / saltmarsh	IG	Flaxland Herbaceous freshwater vegn Herbaceous saline vegn
Scrub & shrubland	Exotic shrubland / scrub	ES	Gorse & broom Matagouri Mixed exotic shrubland
	Indigenous shrubland / scrub	IS	Broadleaved Indig hardwoods Fernland Manuka &kanuka
Water bodies	Water bodies	WB	Estuarine open water Lake & pond River

Table 5b: Landcover weighting factors applied to each grouped vegetation class.

Grouped Vegetation Class	Code	LC Factor
Indigenous forest	IF	10
Indigenous grass / sedge / saltmarsh	IG	8
Indigenous shrubland / scrub	IS	7
Open ground (naturally)	OG	6
Water bodies	WB	6
Exotic forest	EF	2
Exotic shrubland / scrub	ES	2
Exotic grassland	EG	1
Artificial surfaces	AS	0
Crops	CR	0

3.4.2.2 Calculation of ecological significance score

The ecological significance score for each karst SNA site is a product of the geomorphological (3.4.1) and land cover (3.4.2.1) scores. The highest score that could theoretically be obtained is 6000 (*600 geomorphological * 10 land cover*).

3.5 Threatened species

Of the species currently recognised as under threat by DOC, three plant and one animal species were considered as having a particular association with Waikato limestone or karst habitats (see 1.3.2 & Table 6).

Table 6: Threatened species recognised as having a particular association with limestone or karst landscapes in the Waikato Region.

Common name	Species name	Current threat status	Classification Ref.
Cave spleenwort	*Asplenium cimmeriorum*	Naturally uncommon	deLange et al 2009
Awaroa koromiko	*Hebe scopulorum*	Naturally uncommon	deLange et al 2009
Teucridium	*Teucridium parvifolium*	Declining	deLange et al 2009
Long-tailed bat	*Chalinolobus tuberculatus* "N.Island"	Nationally vulnerable	Hitchmough et al 2007

*Although the threat status of these species has not changed between the data analysis of this project and the finalisation of this report, more recent threat classifications have been published [de Lange et al 2012; O'Donnell et al 2012].

Threatened species records were collated largely from point source data provided by herbaria and museums [Allan Herbarium 2009; Auckland Museum 2009; Te Papa 2009; UoW Herbarium 2009]. Threatened species records associated with source polygons [e.g. DOC 2008; SNA Waitomo 2008] were used where the source polygon had not been divided by REC watershed data. Where the source polygon had been divided to create karst SNA sites, and it was not possible to determine from which site the species had been recorded, the record was not used.

During the karst SNA assessment process a number of ways of incorporating threatened species data into the significance assessment process were explored. However, it was decided that clearly identifying the sites where these threatened, karst-associated species have been recorded was important for their identification and management, and hence these sites are presented separately. Exact locations of the species recorded are not presented in the results in order to minimise the risk to these populations from additional disturbance.

3.6 Historically Rare Ecosystem assessment

Karst specific ecosystems are just one component of the overall ecological value or significance of an area, and hence also need to be considered in relation to these wider values. This karst specific, region wide, desk-top study does not have the capacity to assess the wider ecological significance of each potential karst SNA. For this reason, one of the key aims of this study is to provide data that can be incorporated into the Terrestrial & Wetland ecosystems component of the council's SNA programme, which provides a more comprehensive assessment of the overall ecological significance of each site.

The current methodology for Terrestrial & Wetland SNA assessments includes an assessment of ecological significance using the 11 criteria of the RPS, which includes a criterion for the presence of historically rare ecosystems (criterion 5). Four historically rare ecosystems (from Williams et al. 2007) associated with Waikato karst landscapes are identified and discussed in section 3.1 of this report, namely: sinkholes; cave entrances; calcareous cliffs, scarps and tors; and caves/cracks in karst. This study has interpreted available data to assess the likelihood of the presence of each of these four historically rare ecosystems in each karst site, with the intention that the results can be utilised as part of future terrestrial and wetland SNA assessments.

The presence or absence of three of the historically rare ecosystems (sinkholes; cave entrances; calcareous cliffs, scarps and tors), was able to be derived from outputs described in sections 3.4.1.2 – 3.4.1.6 of this report.

Fully subterranean ecosystems, i.e. 'caves/cracks in karst', are much more difficult to assess than ecosystems exhibiting some surface expression. While some spatial data is available for larger cave systems in the Waitomo District [WtDC (no date)], such data was not available for other districts. Additionally, some research suggests that it is smaller cracks and meso-caverns, not directly accessible to humans, which actually constitute the major habitat used by obligate cave fauna [LCR 2014]. For this reason we have also used the likelihood of limestone presence as a surrogate for 'caves/cracks in karst', through the development of a Limestone Proportional Likelihood (LPL) score.

3.6.1 Limestone Proportional Likelihood (LPL) score

The LPL is derived by determining the proportion of each site overlapping any of the Limestone Geology Likelihood (LGL) areas, and weighting the proportions according to the expected likelihood of limestone presence. The proportion of each karst SNA site overlapping LGL 4 was applied a factor of 1.0, while LGL3, LGL2 and LGL1 proportions were applied factors of 0.4, 0.2 and 0 respectively, reflecting the decreasing likelihood of karst expression. Proportions were used, as opposed to the actual area used in section 3.4.1.1, as this assessment was concerned with the probability of karst expression at any single point, rather than the likelihood of it occurring anywhere within the site, and hence actual site area was not relevant. Figure 2 shows an example calculation for a karst SNA site with 20% of LGL 4; 30% of LGL3; 50% of LGL2.

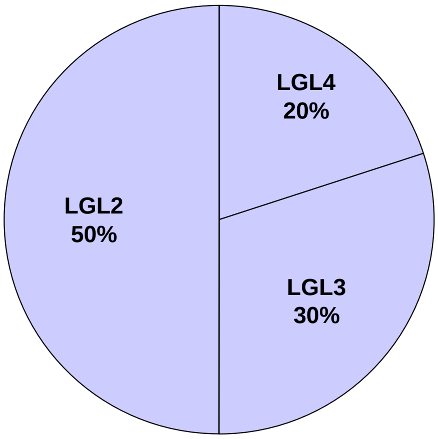

Figure 2: An example calculation for LPL score.

	Proportion of site area	Weighting factor	Weighted score
LGL4	0.2	1	0.20
LGL3	0.3	0.4	0.12
LGL2	0.5	0.2	0.10
LGL1	0	0	0.00
		Site LPL score:	**0.42**

LPL scores were then categorised as 'High', 'Medium', 'Low' or 'Absent' as detailed in Table 7.

Table 7: LPL categorisation summary, showing the category limits and distribution of karst SNA sites across the categories.

	High (H)	**Medium (M)**	**Low (L)**	**Absent (A)**	**Total**
LPL category	H >0.4	0.4≥ M >0.2	0.2≥ L >0	A =0	
Number of sites	4069	5184	7818	8072	**25143**
Percent of total sites	16.2%	20.6%	31.1%	32.1%	**100%**

3.6.2 Historically Rare Ecosystem outputs

While the LPL categories were derived as a surrogate for the likely presence of 'caves/cracks in karst', it was also recognised that they would add assurance to the assessment of the presence of the other three historically rare karst ecosystems.

Records of karst features indicating the presence of historically rare ecosystems were therefore spatially assessed in conjunction with the LPL categories, as shown in Table 8, to provide the overall outputs for historically rare ecosystem presence. The outputs for this component of the study have been chosen to match those used in the assessment of the 11 ecological significance criteria of the RPS (YES; LIKELY; INDETERMINATE; NO), to allow for the direct use of this data in the Terrestrial & Wetland SNA assessments. Where more than one feature of the same type was present within a karst site, the highest output level was recorded (YES), irrespective of the LPL level.

Table 8: Data sources and methodology used to provide the 'historically rare ecosystems' (HRE) outputs. Each output (YES; LIKELY; INDETERMINATE; NO) is based on the presence/absence of each particular feature type (listed in the Data Source column of the table) in conjunction with each of the four LPL categories.

Historically Rare Ecosystem type:	Data Source	Report Description	Historically Rare Ecosystem Presence			
			LPL: "High"	LPL: "Med"	LPL: "Low"	LPL: "Absent"
Cave entrances	Cave entrance dataset (based on Smith 2009)	3.4.1.2	YES	YES	YES	LIKELY
Sinkholes	Soakholes: LINZ soakhole dataset (TOPO 2009)	3.4.1.3	YES	YES	LIKELY	INDETERMINATE
	Dolines: LINZ doline dataset (TOPO 2009)	3.4.1.6	YES	YES	LIKELY	INDETERMINATE
Calcareous cliffs, scarps and tors	Outcrops: Combined dataset based on LINZ outcrop dataset (TOPO 2009)	3.4.1.4	YES	LIKELY	INDETERMINATE	NO
	Cliffs: LINZ cliff dataset (TOPO 2009)	3.4.1.5	YES	LIKELY	INDETERMINATE	NO
Caves / cracks in karst	WtDC Subterranean caves - Waitomo	3.4.1.7	YES	YES	YES	LIKELY
	LPL only - Surrogate for subterranean limestone	3.6.1	LIKELY	LIKELY	INDETERMINATE	NO

4 Results

4.1 Limestone geology extent

A total of 25,143 karst SNA sites overlap the Limestone Geology Likelihood (LGL) layers, with a mean size of 18 hectares (Table 9). The sites are most heavily concentrated in the Waitomo District, accounting for 69% of the total sites and 55% of the total karst SNA area. There are significant but more localised distributions in the Waikato (13% sites / 20% area), Otorohanga (9% sites / 12% area) and Franklin[3] (7% sites / 11% area) Districts. A low number of localised sites are present on the western margins of Waipa and Taupo Districts and in the north of the Coromandel Peninsula.

Table 9: Summary of Karst SNA site distribution and protection status, showing the number of individual sites and their cumulative area in hectares (prior to 2010 territorial authority and regional boundary changes).

Territorial Authority	Protected		Unprotected		Total	
	No. Sites	Total Area	No. Sites	Total Area	No. Sites	Total Area
Franklin	89	495	1731	50084	1820	50579
Otorohanga	349	6599	1910	47377	2259	53976
Taupo	19	799	0	0	19	799
Thames-Coromandel	52	1351	142	2353	194	3704
Waikato	300	7269	3058	81950	3358	89219
Waipa	24	336	218	5138	242	5474
Waitomo	1861	39426	15390	210218	17251	249644
Total	**2694**	**56275**	**22449**	**397120**	**25143**	**453395**

*prior to 2010 regional boundary changes

Of the total sites identified, only 2694 are on protected land, representing approximately 11% of all sites and 12% of the total area assessed.

4.2 Ranking of karst SNA sites

All sites were scored and ranked in terms of their geological and ecological significance, according to the processes described in section 3.4. Summary statistics for the ten karst feature categories assessed, as well as geomorphological and ecological significance scores, are shown in Table 10.

Table 10: Summary statistics from the karst SNA site automated scoring exercise. "Mean (values)" excludes zero scores, while "Mean (all data)" includes zero scores).

[3] prior to 2010 territorial authority and regional boundary changes (see 1.1.2).

Category (and relevant report section)	Max	Min (values)	Mean (values)	Mean (all data)
Limestone Geology Likelihood (3.4.1.1)	50	10	30.0	20.4
Cave Entrances (3.4.1.2)	100	60	67.7	0.8
Soakholes (3.4.1.3)	80	48	49.3	0.3
Rock Outcrops (3.4.1.4)	50	30	32.2	0.2
Cliffs (3.4.1.5)	40	16	29.5	0.4
Dolines (3.4.1.6)	50	20	35.0	2.0
Subterranean (3.4.1.7)	70	28	49.0	1.6
Herbarium 'Limestone' Reference (3.4.1.8)	24	24	24.0	0.0
Site of Geological Importance (3.4.1.9)	100	60	79.3	0.1
Karst Diversity (3.4.1.10)	20	4	5.2	0.5
Geomorphology Significance Score (G)	**410**	**4**	**38.6**	**26.3**
Landcover score (L)	10	0.004	3.6	3.6
Ecological Significance Score (=G*L)	**3260**	**0.19**	**129.6**	**88.4**

4.2.1 Geomorphological significance ranking

The top twenty ranked karst SNA sites based on geomorphological significance, irrespective of land cover, are shown in Table 11.The top fifty sites, including additional data fields, are listed in Appendix 2.

Table 11: The top 20 ranked geomorphologically significant karst SNA sites in the Waikato Region. (Protection status: NWR = Nga Whenua Rahui kawenata)

Geomorph. Significance Rank	Geomorph. Significance Score	Site ID	Hectares	Ecological District	Territorial Authority	Protection Status	Site Name	Ecological Significance Rank
1	410	23091	114	Waitomo	Waitomo	Unprotected		694
2	348	19721	57	Waitomo	Waitomo	Unprotected		770
3	342	20136	161	Waitomo	Waitomo	Unprotected		1437
4	330	20356	122	Waitomo	Waitomo	Unprotected		1713
5	328	10368	40	Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)	6
6	326	10680	23	Waitomo	Waitomo	Unprotected		1
7	322	10847	77	Waitomo	Waitomo	Unprotected		7
8	320	1014	17	Waitomo	Waitomo	Unprotected		1746
9	316	19939	169	Waitomo	Waitomo	Unprotected		1681
10	314	13595	61	Waitomo	Waitomo	Unprotected		166
11	310	21912	96	Waitomo	Waitomo	Unprotected		1784
12	296	19854	32	Waitomo	Waitomo	Unprotected		2099
13	294	11366	58	Waitomo	Waitomo	Unprotected		1835
14	294	19356	64	Waitomo	Waitomo	Unprotected		2131
15	292	4392	39	Waitomo	Waitomo	Unprotected		2161
16	287	10915	38	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve	375
17	286	4615	82	Waitomo	Waitomo	Unprotected		2
18	286	13585	13	Waitomo	Waitomo	Unprotected		470
19	286	23838	29	Herangi	Waitomo	Unprotected		2237
20	285	10901	32	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve	429

The highest geomorphological score achieved was 410 for an unprotected site in the Waitomo District that included: cave entrance; doline; soakhole; and subterranean features. Ten of the top 50 ranked geomorphological sites also feature in the top 50 ranked ecological sites (see 4.2.2). Only three of the top twenty sites ranked by geomorphology alone are under any known formal protection.

The top fifty geomorphologically ranked sites all occur in the Waitomo District. The highest ranked site from outside of Waitomo District was an unprotected site in Waipa District, which ranked 64th. Table 12 lists the top ten geomorphologically significant sites in each territorial authority. The majority of the top ten sites for each district occur on private land and have no formal protection; with the exception of Taupo District where all sites are within Pureora Forest Park.

Table 12: A list of the top 10 geomorphologically significant karst SNA sites for each territorial authority (Protection status: NWR = Nga Whenua Rahui kawenata).

Geomorph. Significance Rank	Geomorph. Significance Score	Site ID	Hectares	Territorial Authority	Protection Status	Site Name	Ecological Significance Rank
FRANKLIN DISTRICT							
118	208	14568	119	Franklin	Unprotected		2515
131	198	14398	96	Franklin	Unprotected		2409
233	168	14369	171	Franklin	Unprotected		4014
395	138	14607	10	Franklin	Unprotected		1804
426	134	14069	43	Franklin	Unprotected		4035
427	134	14600	43	Franklin	Unprotected		4255
489	124	14578	42	Franklin	Unprotected		2826
490	124	14583	43	Franklin	Unprotected		4990
537	114	5148	18	Franklin	Unprotected		777
538	114	5599	78	Franklin	Unprotected		1675
OTOROHANGA DISTRICT							
94	224	18550	32	Waitomo / Otorohanga	Unprotected		2595
135	194	10069	121	Otorohanga	DOC	Stewardship Land - Hauturu Forest (west block)	15
143	190	10269	88	Otorohanga	NWR	Hauturu West Trust	18
200	177	24880	47	Otorohanga	Unprotected		827
203	174	5766	11	Otorohanga	Unprotected		336
204	173	17607	46	Otorohanga	Unprotected		67
206	172	24864	45	Otorohanga	Unprotected		3048
234	168	18438	26	Otorohanga	Unprotected		766
224	168	9752	229	Otorohanga	DOC	Te Kauri Park Scenic Reserve	4017
259	162	5849	42	Otorohanga / Waitomo	Unprotected		258
TAUPO DISTRICT							
5963	40	13507	42	Taupo	DOC	Pureora Forest Park	7272
5965	40	13515	64	Taupo	DOC	Pureora Forest Park	8313
5962	40	13506	45	Taupo	DOC	Pureora Forest Park	11293
8918	30	8855	4	Taupo	DOC	Pureora Forest Park	1859
15674	10	8853	80	Taupo	DOC	Pureora Forest Park	5805
15675	10	8854	4	Taupo	DOC	Pureora Forest Park	6051
19917	0	8856	22	Taupo	DOC	Pureora Forest Park	19917
21591	0	13434	107	Taupo	DOC	Pureora Forest Park	21591
21592	0	13441	33	Taupo	DOC	Pureora Forest Park	21592
21593	0	13444	74	Taupo	DOC	Pureora Forest Park	21593
THAMES-COROMANDEL DISTRICT							
2469	50	9012	21	Thames-Coromandel	Unprotected		543
2921	50	13698	45	Thames-Coromandel	Unprotected		5123
5356	40	9032	28	Thames-Coromandel	Unprotected		1096
5355	40	9030	25	Thames-Coromandel	Unprotected		1172
5354	40	9028	30	Thames-Coromandel	Unprotected		1184
5358	40	9037	70	Thames-Coromandel	DOC	Coromandel Forest Park	1430
5357	40	9035	24	Thames-Coromandel	Unprotected		1606
5353	40	9025	35	Thames-Coromandel	Unprotected		1824
5352	40	9003	29	Thames-Coromandel	Unprotected		2262
5351	40	8988	45	Thames-Coromandel	DOC	Coromandel Forest Park	3649
WAIKATO DISTRICT							
100	222	17128	68	Waikato	Unprotected		1706
136	194	16712	32	Waikato / Waipa	Unprotected		2997
138	193	15497	32	Waikato	Unprotected		835
278	158	15869	98	Waikato	Unprotected		4216
305	154	16650	79	Waikato	Unprotected		4029
396	138	15829	40	Waikato	Unprotected		5174
438	132	15608	89	Waikato	Unprotected		4914
447	130	15835	86	Waikato	Unprotected		4458
448	130	15916	25	Waikato	Unprotected		4475
455	128	17009	51	Waikato	Unprotected		2225
WAIPA DISTRICT							
64	238	16964	45	Waipa	Unprotected		2750
136	194	16712	32	Waikato / Waipa	Unprotected		2997
614	106	16840	66	Waipa	Unprotected		5453
971	94	16176	23	Waikato / Waipa	Unprotected		6164
1259	84	16941	86	Waipa	Unprotected		6672
1260	84	16946	53	Waipa	Unprotected		7162
1476	78	17002	67	Waipa	Unprotected		450
1568	74	16782	123	Waipa / Waikato	Unprotected		7513
1709	72	16945	48	Waipa / Waikato	Unprotected		7659
1737	70	17134	96	Waipa	Unprotected		7792
WAITOMO DISTRICT							
1	410	23091	114	Waitomo	Unprotected		694
2	348	19721	57	Waitomo	Unprotected		770
3	342	20136	161	Waitomo	Unprotected		1437
4	330	20356	122	Waitomo	Unprotected		1713
5	328	10368	40	Waitomo	NWR	Taumatatotara A5 North (NWR)	6
6	326	10680	23	Waitomo	Unprotected		1
7	322	10847	77	Waitomo	Unprotected		7
8	320	1014	17	Waitomo	Unprotected		1746
9	316	19939	169	Waitomo	Unprotected		1681
10	314	13595	61	Waitomo	Unprotected		166

4.2.2 Ecological significance ranking

The top twenty ranked karst SNA sites based on ecological significance, incorporating geomorphology and land cover, are shown in Table 13. The top fifty sites, including additional data fields, are listed in Appendix 3.

Table 13: The top 20 ranked ecologically significant karst SNA sites in the Waikato Region (Protection status: NWR = Nga Whenua Rahui kawenata; QEII = Queen Elizabeth II National Trust covenant).

Ecological Significance Rank	Ecological Significance Score	Site ID	Hectares	Ecological District	Territorial Authority	Protection Status	Site Name	Geomorph. Significance Rank
1	3260	10680	23	Waitomo	Waitomo	Unprotected		6
2	2672	4615	82	Waitomo	Waitomo	Unprotected		17
3	2620	12453	41	Herangi	Waitomo	Unprotected		37
4	2500	10916	5	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve	43
5	2380	10764	25	Waitomo	Waitomo	Unprotected		45
6	2330	10368	40	Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)	5
7	2305	10847	77	Waitomo	Waitomo	Unprotected		7
8	2300	10635	21	Waitomo	Waitomo	Unprotected		78
9	2280	11298	138	Waitomo	Waitomo	DOC	Waipuna Scenic Reserve	83
10	2217	10990	103	Waitomo	Waitomo	Unprotected		23
11	2120	10850	49	Waitomo	Waitomo	DOC	stewardship land - Tawarau Forest	112
12	2075	12470	16	Herangi / Waitomo	Waitomo	Unprotected		116
13	2034	10718	50	Waitomo / Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)	103
14	2000	10831	39	Waitomo	Waitomo	QEII	5/03/049	127
15	1940	10069	121	Kawhia	Otorohanga	DOC	Stewardship Land - Hauturu Forest (west block)	135
16	1927	11369	18	Waitomo	Waitomo	Unprotected		86
17	1925	10781	85	Waitomo	Waitomo	Unprotected		125
18	1900	10269	88	Kawhia	Otorohanga	NWR	Hauturu West Trust	143
19	1888	1567	25	Waitomo	Waitomo	DOC	Koropupu Scenic Reserve	66
20	1877	10640	123	Kawhia	Waitomo	DOC	Stewardship Land - Taumatatotara Forest (south block)	144

The top ecologically ranked site, with a score of 3260, was an unprotected site in Waitomo District, close to a DOC administered area, Matakana Stewardship Land. The proportion of protected ecologically significant sites is higher than geomorphological sites, with 20 of the top 50 under some form of legal protection.

All of the top 200 ecologically ranked sites are within either the Waitomo or Otorohanga Districts, with a QEII covenant site in (until recently) Franklin District the next highest at number 226. Table 14 lists the top ten ecologically significant sites in each territorial authority.

Table 14: A list of the top 10 ecologically significant karst SNA sites for each territorial authority (Protection status: NWR = Nga Whenua Rahui kawenata; QEII = Queen Elizabeth II National Trust covenant).

Ecological Significance Rank	Ecological Significance Score	Site ID	Hectares	Territorial Authority	Protection Status	Site Name	Geomorph. Significance Rank
FRANKLIN DISTRICT							
226	805	1699	3	Franklin	QEII	5/03/064	914
345	658	5256	13	Franklin	Unprotected		925
396	600	10619	16	Franklin	Unprotected		2031
414	578	5066	6	Franklin	Unprotected		1786
566	500	10620	30	Franklin	Unprotected		2594
618	500	9256	52	Franklin	Unprotected		2470
620	500	10621	92	Franklin	Unprotected		2595
733	489	1704	44	Franklin	QEII	5/03/067	2290
763	482	10623	37	Franklin	Unprotected		2596
777	477	5148	18	Franklin	Unprotected		537
OTOROHANGA DISTRICT							
15	1940	10069	121	Otorohanga	DOC	Stewardship Land - Hauturu Forest (west block)	135
18	1900	10269	88	Otorohanga	NWR	Hauturu West Trust	143
36	1540	9774	45	Otorohanga	DOC	Te Kauri Park Scenic Reserve	303
40	1480	10108	114	Otorohanga	DOC	Awaroa Scenic Reserve	331
58	1309	1648	9	Otorohanga	DOC	Te Raumauku Caves Scenic Reserve	317
67	1215	17607	46	Otorohanga	Unprotected		204
72	1177	9980	46	Otorohanga	NWR	Hauturu West Trust	500
130	960	10443	34	Waitomo / Otorohanga	DOC	Waitomo Forest Stewardship Land	818
165	871	9995	29	Otorohanga	DOC	Stewardship Land - Hauturu Forest (east block)	942
167	867	5492	41	Otorohanga	Unprotected		926
TAUPO DISTRICT							
1859	300	8855	4	Taupo	DOC	Pureora Forest Park	8918
5805	100	8853	80	Taupo	DOC	Pureora Forest Park	15674
6051	97	8854	4	Taupo	DOC	Pureora Forest Park	15675
7272	78	13507	42	Taupo	DOC	Pureora Forest Park	5963
8313	63	13515	64	Taupo	DOC	Pureora Forest Park	5965
11293	42	13506	45	Taupo	DOC	Pureora Forest Park	5962
19917	0	8856	22	Taupo	DOC	Pureora Forest Park	19917
21591	0	13434	107	Taupo	DOC	Pureora Forest Park	21591
21592	0	13441	33	Taupo	DOC	Pureora Forest Park	21592
21593	0	13444	74	Taupo	DOC	Pureora Forest Park	21593
THAMES-COROMANDEL DISTRICT							
543	500	9012	21	Thames-Coromandel	Unprotected		2469
1096	400	9032	28	Thames-Coromandel	Unprotected		5356
1172	400	9030	25	Thames-Coromandel	Unprotected		5355
1184	400	9028	30	Thames-Coromandel	Unprotected		5354
1430	372	9037	70	Thames-Coromandel	DOC	Coromandel Forest Park	5358
1606	348	9035	24	Thames-Coromandel	Unprotected		5357
1824	308	9025	35	Thames-Coromandel	Unprotected		5353
2024	300	9005	19	Thames-Coromandel	Unprotected		8933
2153	293	9014	19	Thames-Coromandel	Unprotected		8934
2262	284	9003	29	Thames-Coromandel	Unprotected		5352
WAIKATO DISTRICT							
234	790	9612	82	Waikato	DOC	Pirongia Forest Park	543
264	740	10625	68	Waikato	Unprotected		1537
388	616	24823	52	Waikato	Unprotected		1149
395	602	9638	16	Waikato	Unprotected		1788
458	540	16459	19	Waikato	Unprotected		1793
520	500	13459	105	Waikato	Unprotected		2908
558	500	5799	10	Waikato	Unprotected		2419
590	500	9633	29	Waikato	Unprotected		2482
616	500	5723	43	Waikato / Otorohanga	Unprotected		2416
625	500	17199	20	Waikato	Unprotected		3376
WAIPA DISTRICT							
450	546	17002	67	Waipa	Unprotected		1476
1004	400	9552	36	Waipa	Unprotected		5373
2579	258	16996	55	Waipa	Unprotected		9891
2619	253	5239	12	Waipa	Unprotected		8472
2750	239	16964	45	Waipa	Unprotected		64
2997	213	16712	32	Waikato / Waipa	Unprotected		136
3193	200	9529	7	Waipa	Unprotected		12541
3211	200	9528	46	Waipa	Unprotected		12540
3566	189	9581	14	Waikato / Waipa	Unprotected		8966
3588	188	1619	6	Waipa	DOC	Karamu Scenic Reserve	7962
WAITOMO DISTRICT							
1	3260	10680	23	Waitomo	Unprotected		6
2	2672	4615	82	Waitomo	Unprotected		17
3	2620	12453	41	Waitomo	Unprotected		37
4	2500	10916	5	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve	43
5	2380	10764	25	Waitomo	Unprotected		45
6	2330	10368	40	Waitomo	NWR	Taumatatotara A5 North (NWR)	5
7	2305	10847	77	Waitomo	Unprotected		7
8	2300	10635	21	Waitomo	Unprotected		78
9	2280	11298	138	Waitomo	DOC	Waipuna Scenic Reserve	83
10	2217	10990	103	Waitomo	Unprotected		23

4.3 Threatened species

There are 39 karst SNA sites that include records of karst-associated threatened species. These sites are all in either the Waitomo or Otorohanga Districts. More than half of the sites are not offered any formal protection, with the remainder protected under DOC administration or Nga Whenua Rahui covenants. Three sites have records of two threatened species, while the remainder have a single species recorded. The territorial authority and protection status of the sites are summarised in Table 15, with a full list provided as Appendix 4.

Table 15: Summary of karst SNA sites containing karst-associated threatened species records by territorial authority, protection status and the number of species recorded from each site. (Protection status: NWR = Nga Whenua Rahui kawenata)

	Otorohanga District		Waitomo District	
	1 Species	2 Species	1 Species	2 Species
Unprotected	10	-	12	1
DoC	2	-	7	2
NWR	3	-	2	-
Total	15	-	21	3

Only five of the sites including threatened species records appear in the top 50 ecologically ranked sites. Only four are listed in the top 50 geomorphologically ranked sites.

4.4 Historically Rare Ecosystems

Of the total 25,143 potential karst SNA sites assessed, 1,951 were identified as containing at least one of the four historically rare ecosystems associated with karst. Of this number, 493 contained more than one 'historically rare ecosystem' type.

Table 16a shows the number of historically rare ecosystems potentially present in Karst SNA sites, together with the level of expectancy. Table 16b shows the frequency with which multiple historically rare ecosystem types occur in Karst SNA sites.

Table 16a: The number of karst SNA sites potentially including historically rare ecosystems (HRE), classified by the type of HRE and the expected likelihood of presence.

HRE presence:	YES	LIKELY	INDETERMINATE
Cave entrances	297	3	0
Sinkholes	1308	149	37
Calcareous cliffs, scarps & tors	134	101	246
Caves/cracks in karst	803	8506	7778

Table 16b: The frequency with which multiple historically rare ecosystems occur in Karst SNA sites known to contain one or more HRE (HRE = YES).

Number of confirmed HRE's	Frequency
4	4
3	90
2	399
1	1458
Total	1951

Four sites were identified as containing all four historically rare ecosystems. These were all in the Waitomo District, and comprised Koropupu Scenic Reserve and three unprotected sites. Table 17 lists the number of sites where historically rare ecosystems are present, classified by territorial authority and protection status.

Table 17: The distribution and protection status of Karst SNA sites with historically rare ecosystem presence (HRE = YES) (prior to 2010 territorial authority and regional boundary changes).

Territorial Authority	Protected	Unprotected	Total
Franklin	2	24	**26**
Otorohanga	12	53	**65**
Waikato	2	17	**19**
Waipa		1	**1**
Waitomo	170	1670	**1840**
Total	**186**	**1765**	**1951**

5 Discussion

5.1 Limitations of methodology

This karst SNA assessment presented a unique set of challenges that have resulted in a different output format to that envisaged at the start of the project. While the initial scope of the project was to simply identify and map karst features and then rank them in order of ecological significance, each step of the process has proven challenging and had to be revised, sometimes several times.

Establishing what was meant by karst, in the context of this study, proved to be an early challenge given the difficulty of separating the influence of the geophysical elements of karst features from the chemical influence of the limestone substrate and resulting calcareous soils, and a working definition had to be developed (3.1).

The very nature of karst is cryptic; its expression is often subterranean, hidden beneath surface vegetation, or comprised of small characteristic features; making karst impossible to identify using conventional, aerial photography based, SNA techniques. Some karst areas are well known, particularly on DOC estate around Waitomo, but otherwise records of karst presence are generally poor or unavailable.

Having decided to use limestone geological data as a surrogate for karst, it became evident that no single geological layer existed that reliably indicated limestone presence, and certainly none that differentiated the limestone types likely to exhibit karstification. The LGL layer produced is at a broad scale that can only be an indication of where karst expression might be expected to be found, especially given the small scale of such expression.

The division of the LGL layer into individual karst SNA sites follows existing spatial data boundaries for either, vegetation type, protection status or surface catchments and as a result may not represent the boundaries of karst features, ecosystems or subterranean hydrology.

The geomorphological significance assessment of each karst SNA site has two main limitations. Firstly, the broad scale of the LGL layer may limit the accuracy of the LAL calculation (3.4.1.1), which indicates the total area of karst forming limestone likely to be present.

Secondly, the remaining categories in the geomorphological assessment (3.4.1) rely heavily on known records of characteristic karst features. This assessment is therefore, likely to be biased in favour of areas with known karst expression, such as some of the Waitomo karst, rather those where karst is still poorly studied. This is particularly the case for the Subterranean category (3.4.1.6) where data was only available for the Waitomo district, especially with this category being given a high weighting in the overall calculation.

In the process of delineating karst SNA sites some large sites were divided by watershed (3.3.2), to increase accuracy of the subsequent significance assessments. Where records of karst features or threatened species from the pre-division sites [Smith 1998; SNA Waitomo 2008; SNA Otorohanga 2003] did not include sufficient detail to identify the records with a post-division karst SNA site, the records were not used in the significance assessments. While, the use of additional point data from other sources is likely to have acted as a replacement for most of the discarded data, it is possible that some records of karst feature or threatened species data have been excluded from the significance assessments as a result of this process.

With the geomorphological significance results contributing to the ecological significance assessment, the limitations discussed in the previous paragraphs will also apply to the ecological assessment (3.4.2). In addition, the land-cover component in this assessment is also subject to limitations. The use of MfE land-cover data is a very coarse method of applying ecosystem habitat values to karst SNA sites. While this approach was necessary, given the large number of karst SNA sites; the coarse scale of the land-cover data in relation to the small size of karst features/ecosystems will limit the accuracy of this assessment.

While the aim of the ecological significance assessment was to broadly identify the karst SNA sites with higher ecosystem values, these sites do not correlate with the records of karst-associated threatened species. This is likely to be because these threatened species often require specific geomorphological habitats that may be small in size and not necessarily related to the condition of the wider general environment around them, which would be represented by the land-cover element of the ecological significance assessment. Karst SNA sites with threatened species records were therefore identified as a separate output of this study.

The initial scope of this project included the intention to conduct an ecosystem ranking exercise. However, because karst ecosystems overlap with other ecosystem types and do not operate in isolation from other areas of the natural environment, this proved extremely difficult. In practical terms, the attempts to conduct an ecosystem ranking exercise came very close to repeating the ranking part of the Terrestrial and Wetland SNA program, and this exercise was therefore not continued.

Given that an ecosystem ranking exercise was not pursued, an alternative method was selected to provide results of known karst presence that could contribute to a wider ecosystem ranking assessment. This was achieved by identifying the presence of geomorphological features indicative of karst Historically Rare Ecosystems. This output is intended to be used to satisfy the requirements of criterion 5 of the 11 criteria RPS assessment in the more comprehensive Terrestrial and Wetland SNA rankings. There are limitations to this process, however, as not all karst features meeting this criterion are likely to have been identified or recorded.

5.2 Recommended further work

Section 5.1 of this report includes limitations of this study, many of which relate to the accuracy of available spatial data. Further improvements to the quality of this data could help improve the accuracy of the significance assessments of this project and could include:

- Geo-referencing of mapped cave systems (eg from NZ Cave Atlas);
- Liaison with DoC (Maniapoto) to establish the location of karst features referred to in the Maniapoto Karst Plan [Smith 1998] so that they can be attributed to individual karst SNA sites, where the original DOC spatial data has been divided by watershed.

Given that many karst features are likely to be too small to be identified using conventional techniques, and that spatial data is likely to be at too coarse a scale to provide an accurate assessment of their significance, some form of further assessment is likely to be required to provide a better indication of karst presence and allow a more accurate significance assessment. While for well-studied sites, relevant data might be available from existing literature, most sites are likely to require visiting to establish karst presence and significance. Ground-based assessments are of particular importance in less studied karst areas such as those of the Waikato (and previously Franklin) District.

While the limitations of the karst geomorphological and ecological significance assessments have been highlighted above, the results of these assessments are still considered to provide a strong indication of karst presence and importance and could be a valuable tool in selecting ground-based assessment sites.

Higher-scoring ecological significance assessment sites are likely to indicate karst ecosystems associated with wider areas of indigenous vegetation. These larger areas of indigenous vegetation are important to preserve karst formation processes and to prevent adverse effects on wider karst environments, and ground based assessment is therefore recommended for high scoring sites.

It is also important to ensure that geomorphologically significant sites are also further assessed. The small scale of some karst ecosystems means that they may not score highly out of the ecosystem significance assessment, because the coarse scale of the land-cover data may fail to indicate where a small site is still locally dominated by indigenous vegetation. In this situation the geomorphological significance score will provide a better indication of karst presence and significance.

Karst SNA sites containing threatened species records are also recommended for further investigation. It is recommended that these sites are assessed for the significance of their threatened species populations in consultation with DOC with additional ground-based assessment conducted and appropriate management and/or protection encouraged.

Further work could also be implemented to address known and potential threats to karst ecosystems. This work could address:

- Improved research into the ecology (and particularly invertebrate fauna) of subterranean karst environments.
- Improved knowledge of the effects of water quality on subterranean ecosystems;
- Catchment management to improve water quality for key sites;
- Possible planning policy changes to promote protection, management and restoration of key karst ecosystems;
- Development of karst specific restoration guidelines.

6 Acknowledgments

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In particular, we are grateful for the support and assistance of other council staff, especially Yanbin Deng and Derek Phyn.

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Susan Wiser of Landcare Research, Lincoln for providing information gathered on karst ecosystems for the MfE Historically Rare Ecosystems Project.

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Appendix 1: Detailed selection and grouping of GNS QMAP stratigraphic groups and units into Limestone Geology Likelihood (LGL) levels.

***Group* / Strat unit**	**Limestone (Ls) presence ***	**Geographical location of Unit ***
Limestone Geology Likelihood (LGL) 3.		
Lower Te Kuiti Subgroup	Combination of (oldest first) Waikato coal, Mangakotukuku, Glen Massey, Whaingaroa, Aotea formations.	TK groups thickest in north (500m Nr Rotowaro) and much thinner in South, although limestone is thickest in south. These cumulative units are used when strat units are too thin to be used in isolation - mostly in south.
Upper Te Kuiti Subgroup	Combination of (oldest first) Orahiri limestone (south) / Te Akatea (north), Waitomo sandstone, Otorohanga limestone formations.	TK groups thickest in north (500m Nr Rotowaro) and much thinner in South, although limestone is thickest in south. These cumulative units are used when strat units are too thin to be used in isolation - mostly in south.
Orahiri Limestone	Variety of Ls types from moderately sandy through to pure flaggy limestones. Steep cliffs and bluffs throughout and solution weathering conspicuous.	Thickest at N extent, S of Kawhia Harbour (60m) thinning S to Awakino Gorge and E to beyond TK.
Otorohanga Limestone	Youngest (overlaying) TK formation. Pure white / light grey flaggy Ls with nr vertical cliffs and well developed karst.	Southern half of region and thickest around Waitomo (70m) but more typically 30m.
Torehina Formation	Limestone locally upto 35m	Local distribution in N. Coromandel peninsula. Forms isolated part of TK group.
Papakura Limestone	Ls lenses typically 1 -3 m thick but up to 8m commonly present at top of Kawau subgroup (Waitemata group)	Kawau subgroup outcrop between Cape Rodney and Raglan Harbour and N.Coromandel peninsula.
Taumatamaire Formation	Flaggy to massive bioclastic Ls beds upto 25m thick interbedded with mudstone in Awakino gorge area and east of Te Kuiti.	Formation consists mostly of up to 800m of mudstone, mostly to SE of region. Forms part of Mahoenui group.
Limestone Geology Likelihood (LGL) 2		
Aotea Formation	Ls at the base of formation in the west locally upto 50m thick but typically <12m	Present across much of western Waikato but lithologically variable- max thickness of 200m at Kawhia and thinning southwards to 60m at TK.
Te Akatea Formation	Sandy siltstone / Ls at base of formation grading southwards to a fine-grained flaggy Ls with muddy lenses. Ls thickest N of Raglan harbour (23m)	NW of Waikato and grades into Orahiri east of Karioi. Formation thickest = 100m
Whaingaroa Formation	Basal sandy bioclastic Ls locally S of Kawhia. Local sandy Ls south of Raglan often forming bluffs.	Formation upto 150m thick in north but less than 50m south of TK. Best developed in west as far south as Awakino Gorge area and thin or absent in east.
Glen Massey Formation	Thin flaggy sandy Ls or greensand at base of silt and sandstone layers.	N of Kawhia
Manganui Formation	Ls likely restricted to rare shelly lenses. Calcareous concretions within mudstone.	Exposed in far SW of region
Otunui Formation	Formation base is locally sandy bioclastic Ls or calcareous sandstone upto 40m thick	Present throughout King Country Basin S of TK but thickest (300m) east of Ohura fault.

*** Data Sources**

Edbrooke 2005 - Geology of the Waikato area

Edbrooke 2001 - Geology of the Auckland area

D Heron pers comms

S Edbrooke pers comms

Appendix 2: Top 50 ranked geomorphologically significant Karst SNA sites, including interim results used to calculate geomorphological and ecological ranking scores.

Geomorph. Significance Rank	Site ID	Hectares	Ecological District	Territorial Authority	Protection Status	Site Name	LGL2 Area (Ha)	LGL3 Area (Ha)	LGL4 Area (Ha)	LAL Score	LAL Wcat	CAVES Wcat	SOAKHOLE Wcat	OUTCROP Wcat	CLIFF Wcat	DOLINE_ Wcat	SUBTERR Wcat	HERB/MUS Wcat	SIG GEO SITES Wcat	DIVERSITY Wcat	Geomorph. Sig Score	Landcover Score	Ecological Sig Score	Ecological Sig Rank
1	23091	114	Waitomo	Waitomo	Unprotected			83.7	30.5	63.9	50	100	64	0	0	50	70	0	60	16	410	1.2	495	694
2	19721	57	Waitomo	Waitomo	Unprotected			45.9		18.3	50	80	48	30	0	50	70	0	0	20	348	1.4	480	770
3	20136	161	Waitomo	Waitomo	Unprotected			161.4		64.5	50	60	0	0	0	50	70	0	100	12	342	1.1	371	1437
4	20356	122	Waitomo	Waitomo	Unprotected			121.8		48.7	50	80	64	0	0	50	70	0	0	16	330	1.0	330	1713
5	10368	40	Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)		39.2		15.7	50	60	48	30	0	50	70	0	0	20	328	7.1	2330	6
6	10680	23	Waitomo	Waitomo	Unprotected			22.7	0.3	9.4	50	100	48	0	0	43	70	0	0	16	326	10.0	3260	1
7	10847	77	Waitomo	Waitomo	Unprotected			76.0		30.4	50	60	0	0	0	50	70	0	80	12	322	7.2	2305	7
8	1014	17	Waitomo	Waitomo	Unprotected			17.2		6.9	40	80	64	0	0	50	70	0	0	16	320	1.0	323	1746
9	19939	169	Waitomo	Waitomo	Unprotected			169.2		67.7	50	100	0	30	0	50	70	0	0	16	316	1.1	335	1681
10	13595	61	Waitomo	Waitomo	Unprotected			61.3		24.5	50	60	0	0	0	43	70	0	80	12	314	2.8	868	166
11	21912	96	Waitomo	Waitomo	Unprotected			84.9	10.6	44.5	50	60	64	0	0	50	70	0	0	16	310	1.0	316	1784
12	19854	32	Waitomo	Waitomo	Unprotected			32.4		12.9	50	100	0	0	40	20	70	0	0	16	296	1.0	296	2099
13	11366	58	Waitomo	Waitomo	Unprotected			45.9		18.3	50	60	48	0	0	50	70	0	0	16	294	1.0	294	1835
14	19356	64	Waitomo	Waitomo	Unprotected			64.3		25.7	50	60	48	0	0	50	70	0	0	16	294	1.0	306	2131
15	4392	39	Waitomo	Waitomo	Unprotected			11.4	28.0	32.5	50	80	48	0	0	28	70	0	0	16	292	1.0	292	2161
16	10915	38	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve		13.0	25.4	30.6	50	100	0	30	0	35	0	0	60	12	287	2.2	621	375
17	4615	82	Waitomo	Waitomo	Unprotected			82.2		32.9	50	60	48	0	0	43	70	0	0	16	286	9.3	2672	2
18	13585	13	Waitomo	Waitomo	Unprotected			12.5		5.0	40	80	48	0	0	43	60	0	0	16	286	1.0	287	470
19	23838	29	Herangi	Waitomo	Unprotected			25.7	2.5	12.8	50	60	0	40	0	50	70	0	0	16	286	1.8	522	2237
20	10901	32	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve		20.1	11.5	19.5	50	80	0	0	0	35	28	0	80	12	285	2.0	570	429
21	19820	91	Waitomo	Waitomo	Unprotected			91.2		36.5	50	80	0	0	40	28	70	0	0	16	284	1.1	298	2069
22	19290	30	Waitomo	Waitomo	Unprotected			29.9		12.0	50	60	0	0	0	43	39	0	80	12	283	1.9	547	447
23	10990	103	Waitomo	Waitomo	Unprotected			40.8	39.3	55.6	50	100	0	0	0	50	70	0	0	12	282	7.9	2217	10
24	13564	64	Waitomo	Waitomo	Unprotected			62.8	1.0	26.1	50	100	0	0	0	50	70	0	0	12	282	1.5	412	496
25	18672	25	Waitomo	Waitomo	Unprotected			25.1	0.1	10.2	50	0	48	0	0	43	49	0	80	12	282	1.8	507	963
26	19592	59	Waitomo	Waitomo	Unprotected			52.3	6.8	27.8	50	100	0	0	0	50	70	0	0	12	282	1.2	351	1566
27	23004	52	Waitomo	Waitomo	Unprotected			0.5	52.0	52.2	50	100	0	0	0	50	70	0	0	12	282	1.0	282	2293
28	13597	75	Waitomo	Waitomo	Unprotected			73.8	1.0	30.5	50	60	48	0	0	43	60	0	0	16	276	1.1	290	2193
29	22190	169	Waitomo	Waitomo	Unprotected			64.0	104.7	130.3	50	100	0	0	0	43	70	0	0	12	274	1.0	274	2405
30	13605	37	Waitomo	Waitomo	Unprotected			26.3		10.5	50	60	48	0	0	28	70	0	0	16	272	1.0	272	2428
31	10761	49	Waitomo	Waitomo	NWR	Taumatatotara A5 North (NWR)		45.3	3.4	21.5	50	60	48	0	0	35	60	0	0	16	268	4.6	1240	63
32	21703	41	Waitomo	Waitomo	Unprotected			15.5	25.8	32.0	50	60	0	0	0	50	0	0	100	8	268	1.6	431	912
33	13665	35	Waitomo	Waitomo	Unprotected			34.9		13.9	50	100	0	0	0	35	70	0	0	12	267	1.1	283	2278
34	19781	139	Waitomo	Waitomo	Unprotected			138.5		55.4	50	60	0	0	28	50	60	0	0	16	264	0.7	172	3925
35	1901	61	Waitomo	Waitomo	DOC	Stewardship Land - Scopelands Limited Lease		58.9	1.6	25.2	50	80	0	0	0	50	70	0	0	12	262	1.1	280	3
36	4761	35	Waitomo	Waitomo	DOC	Hollow Hill Scenic Reserve		16.3	17.7	24.2	50	60	0	30	0	50	0	0	60	12	262	6.2	1625	32
37	12453	41	Herangi	Waitomo	Unprotected			38.9		15.5	50	80	0	0	0	50	70	0	0	12	262	10.0	2620	2093
38	21543	117	Waitomo	Waitomo	Unprotected			80.3	36.9	69.0	50	80	0	0	0	50	70	0	0	12	262	1.1	296	2317
39	19669	28	Waitomo	Waitomo	Unprotected			28.3		11.3	50	100	0	0	0	28	70	0	0	12	260	1.0	260	2557
40	19893	90	Waitomo	Waitomo	Unprotected			89.9		36.0	50	0	0	0	0	50	70	0	80	8	258	1.0	258	2577
41	4841	9	Waitomo	Waitomo	DOC	Waitomo Caves Scenic Reserve		0.2	5.7	5.7	40	60	0	0	0	20	0	24	100	8	252	4.1	1040	95
42	19015	80	Waitomo	Waitomo	Unprotected			43.7	25.1	42.6	50	100	0	0	0	20	70	0	0	12	252	1.0	261	2545
43	10916	5	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve		3.0	2.1	3.3	40	60	0	30	0	28	0	0	80	12	250	10.0	2500	4
44	19792	64	Waitomo	Waitomo	Unprotected			52.9		21.2	50	0	0	0	0	20	70	0	100	8	248	1.0	248	2672
45	10764	25	Waitomo	Waitomo	Unprotected			24.6		9.9	50	80	0	0	0	35	70	0	0	12	247	9.6	2380	5
46	19344	36	Waitomo	Waitomo	Unprotected			34.1	0.7	14.3	50	80	0	0	0	35	70	0	0	12	247	1.1	266	794
47	19608	56	Waipa	Waitomo	Unprotected			3.6	51.9	53.4	50	80	0	0	0	35	70	0	0	12	247	1.9	474	2497
48	1569	21	Waitomo	Waitomo	DOC	stewardship land - Reserve Cave		17.9	2.6	9.8	50	80	0	0	0	43	60	0	0	12	244	1.9	467	818
49	7494	45	Waitomo	Waitomo	Unprotected			45.4		18.2	50	60	0	0	0	50	70	0	0	12	242	7.0	1695	28
50	13559	109	Waitomo	Waitomo	Unprotected			108.4	0.8	44.2	50	60	0	0	0	50	70	0	0	12	242	1.3	321	91

Appendix 3: Top 50 ranked ecologically significant Karst SNA sites, including interim results used to calculate geomorphological and ecological ranking scores.

Ecological Significance Rank	Site ID	Hectares	Ecological District	Territorial Authority	Protection Status	Site Name	LGL2 Area (Ha)	LGL3 Area (Ha)	LGL4 Area (Ha)	LAL Score	LAL Wcat	CAVES Wcat	SOAKHOLE Wcat	OUTCROP Wcat	CLIFF Wcat	DOLINE_ Wcat	SUBTERR Wcat	HERB/MUS Wcat	SIG GEO SITES Wcat	DIVERSITY Wcat	Geomorph. Sig Score	Landcover Score	Ecological Sig Score	Geomorph. Sig Rank
1	10680	23	Waitomo	Waitomo	Unprotected	stewardship land - Matakana		22.7	0.3	9.4	50	100	48	0	0	43	70	0	0	16	326	10.0	3260	6
2	4615	82	Waitomo	Waitomo	Unprotected			82.2		32.9	50	60	48	0	0	43	70	0	0	16	286	9.3	2672	17
3	12453	41	Herangi	Waitomo	Unprotected	Whareorino Forest Stewardship Land Extension		38.9		15.5	50	80	0	0	0	50	70	0	0	12	262	10.0	2620	37
4	10916	5	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve		3.0	2.1	3.3	40	60	0	30	0	28	0	0	80	12	250	10.0	2500	43
5	10764	25	Waitomo	Waitomo	Unprotected	stewardship land - Matakana		24.6		9.9	50	80	0	0	0	35	70	0	0	12	247	9.6	2380	45
6	10368	40	Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)		39.2		15.7	50	60	48	30	0	50	70	0	0	20	328	7.1	2330	5
7	10847	77	Waitomo	Waitomo	Unprotected	Waipuna Scenic Reserve Extension		76.0		30.4	50	60	0	0	0	50	70	0	80	12	322	7.2	2305	7
8	10635	21	Waitomo	Waitomo	Unprotected	stewardship land - Matakana		18.5	2.6	10.0	50	0	48	0	0	50	70	0	0	12	230	10.0	2300	78
9	11298	138	Waitomo	Waitomo	DOC	Waipuna Scenic Reserve		138.3		55.3	50	60	64	0	0	43	0	0	0	12	228	10.0	2280	83
10	10990	103	Waitomo	Waitomo	Unprotected	TUMUTUMU RD		40.8	39.3	55.6	50	100	0	0	0	50	70	0	0	12	282	7.9	2217	23
11	10850	49	Waitomo	Waitomo	DOC	stewardship land - Tawarau Forest		34.2	14.3	28.0	50	60	48	0	0	43	0	0	0	12	212	10.0	2120	112
12	12470	16	Herangi / Waitomo	Waitomo	Unprotected			15.7		6.3	40	100	0	0	0	0	60	0	0	8	208	10.0	2075	116
13	10718	50	Waitomo / Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)		18.7	1.8	9.3	50	0	48	0	0	50	60	0	0	12	220	9.2	2034	103
14	10831	39	Waitomo	Waitomo	QEII	5/03/049		39.0		15.6	50	100	0	0	0	43	0	0	0	8	200	10.0	2000	127
15	10069	121	Kawhia	Otorohanga	DOC	Stewardship Land - Hauturu Forest (west block)	108.2	12.7		26.7	50	60	0	30	0	43	0	0	0	12	194	10.0	1940	135
16	11369	18	Waitomo	Waitomo	Unprotected			17.9		7.1	50	60	0	0	0	35	70	0	0	12	227	8.5	1927	86
17	10781	85	Waitomo	Waitomo	Unprotected	Marokopa River Extension		85.3		34.1	50	0	0	30	0	43	70	0	0	12	204	9.4	1925	125
18	10269	88	Kawhia	Otorohanga	NWR	Hauturu West Trust		64.5		25.8	50	0	48	30	0	50	0	0	0	12	190	10.0	1900	143
19	1567	25	Waitomo	Waitomo	DOC	Koropupu Scenic Reserve		4.3	21.0	22.7	50	60	0	30	0	50	28	0	0	16	234	8.1	1888	66
20	10640	123	Kawhia	Waitomo	DOC	Stewardship Land - Taumatatotara Forest (south block)		80.6	31.6	63.9	50	0	48	30	0	50	0	0	0	12	190	9.9	1877	144
21	13663	71	Waitomo / Herangi	Waitomo	Unprotected			61.9		24.8	50	60	0	0	0	0	70	0	0	8	188	10.0	1876	153
22	11290	40	Waitomo	Waitomo	DOC	stewardship land - Tawarau Forest		39.6	0.9	16.7	50	0	48	0	28	43	0	0	0	12	180	10.0	1799	172
23	7724	7	Waitomo	Waitomo	Unprotected			7.1		2.9	40	0	0	0	28	43	60	0	0	12	182	9.9	1795	169
24	11267	19	Waitomo	Waitomo	Unprotected	Waipuna Scenic Reserve Extension		13.1		5.3	40	60	0	0	0	0	70	0	0	8	178	10.0	1780	175
25	10730	60	Waitomo	Waitomo	Unprotected	stewardship land - Matakana		58.9	0.3	23.9	50	0	0	0	0	50	70	0	0	8	178	10.0	1780	174
26	4478	10	Waitomo	Waitomo	Unprotected			9.7		3.9	40	80	0	0	0	0	60	0	0	8	188	9.2	1726	146
27	11083	25	Waitomo	Waitomo	Unprotected			7.6	6.9	10.0	50	0	0	0	0	50	39	24	0	8	170	10.0	1700	209
28	7494	45	Waitomo	Waitomo	Unprotected			45.4		18.2	50	60	0	0	0	50	70	0	0	12	242	7.0	1695	49
29	11081	33	Waitomo	Waitomo	Unprotected			24.4	3.3	13.1	50	0	0	0	0	50	60	0	0	8	168	10.0	1678	225
30	4231	10	Waitomo	Waitomo	Unprotected	Koropupu Scenic Reserve Extension		6.3	4.2	6.7	40	60	0	0	0	0	70	0	0	8	178	9.2	1633	173
31	11956	22	Waitomo	Waitomo	Unprotected	marginal strip - Mangaorongo Stream Extension		1.4	20.7	21.2	50	0	0	0	40	0	70	0	0	8	168	9.7	1628	227
32	4761	35	Waitomo	Waitomo	DOC	Hollow Hill Scenic Reserve		16.3	17.7	24.2	50	60	0	30	0	50	0	0	60	12	262	6.2	1625	36
33	7690	85	Herangi	Waitomo	Unprotected			30.9	45.0	57.3	50	80	0	0	0	50	0	0	0	8	188	8.4	1576	147
34	10910	50	Waitomo	Waitomo	NWR	Taumatatotara A5 North (NWR)		49.6		19.8	50	0	48	0	0	50	0	0	0	8	156	10.0	1560	289
35	10851	45	Waitomo	Waitomo	DOC	Waitanguru Scenic Reserve		45.2		18.1	50	100	0	0	0	0	0	0	0	4	154	10.0	1540	304
36	9774	45	Kawhia	Otorohanga	DOC	Te Kauri Park Scenic Reserve	42.7		2.5	11.0	50	100	0	0	0	0	0	0	0	4	154	10.0	1540	303
37	10349	105	Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)		103.3		41.3	50	0	48	0	0	50	0	0	0	8	156	9.7	1512	286
38	11287	33	Waitomo	Waitomo	Unprotected			33.1		13.3	50	0	48	0	0	50	0	0	0	8	156	9.6	1494	290
39	10661	18	Waitomo	Waitomo	Unprotected	stewardship land - Matakana		17.7		7.1	40	0	0	0	0	50	60	0	0	8	158	9.4	1483	276
40	10108	114	Kawhia	Otorohanga	DOC	Awaroa Scenic Reserve		39.0		15.6	50	60	0	30	0	0	0	0	0	8	148	10.0	1480	331
41	10286	38	Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)		38.3		15.3	50	0	48	0	0	43	0	0	0	8	148	10.0	1480	332
42	11398	43	Waitomo	Waitomo	Unprotected			43.1		17.3	50	0	48	0	0	50	70	0	0	12	230	6.4	1469	79
43	11982	9	Waitomo	Waitomo	Unprotected	marginal strip - Mangaorongo Stream Extension		4.4	4.2	5.9	40	0	0	0	40	0	60	0	0	8	148	9.9	1458	337
44	11310	63	Waitomo	Waitomo	DOC	stewardship land - Tawarau Forest		60.0	3.2	27.2	50	0	48	0	0	43	0	0	0	8	148	9.8	1448	336
45	10912	15	Waitomo	Waitomo	QEII	5/03/049		15.4		6.2	40	100	0	0	0	0	0	0	0	4	144	10.0	1434	366
46	11292	55	Waitomo	Waitomo	DOC	stewardship land - Tawarau Forest		53.6	1.0	22.4	50	0	64	0	0	20	0	0	0	8	142	10.0	1420	372
47	11270	38	Waitomo	Waitomo	DOC	stewardship land - Tawarau Forest		38.2		15.3	50	0	48	0	0	35	0	0	0	8	141	10.0	1409	381
48	11209	23	Waitomo	Waitomo	DOC	stewardship land - Tawarau Forest		21.7	1.5	10.1	50	0	48	0	0	35	0	0	0	8	141	9.9	1394	380
49	1017	3	Waitomo	Waitomo	Unprotected			2.9		1.2	30	60	0	0	0	43	49	0	0	12	194	7.2	1387	134
50	1907	52	Waitomo/Kawhia/Herangi	Waitomo	DOC	Ngahuinga Bluff Scenic Reserve		35.2	11.5	25.6	50	60	0	30	0	0	0	0	0	8	148	9.3	1382	329

Appendix 4: Karst SNA sites containing threatened species records of species showing a particular association with karst or limestone.

(*Asplenium cimmeriorum; Hebe scopulorum; Teucridium parvifolium; Chalinolobus tuberculatus "N.Island"*)

Site ID	Number of Threatened Species	Hectares	Ecological District	Territorial Authority	Protection Status	Site Name	Geomorph. Significance Rank	Ecological Significance Rank
1567	2	25	Waitomo	Waitomo	DOC	Koropupu Scenic Reserve	66	19
4796	2	34	Waitomo	Waitomo	DOC	Grand Canyon Nature Reserve	221	2710
21065	2	31	Waitomo	Waitomo	Unprotected		7108	10784
10847	1	77	Waitomo	Waitomo	Unprotected		7	7
10718	1	50	Waitomo / Kawhia	Waitomo	NWR	Taumatatotara A5 North (NWR)	103	13
10269	1	88	Kawhia	Otorohanga	NWR	Hauturu West Trust	143	18
10108	1	114	Kawhia	Otorohanga	DOC	Awaroa Scenic Reserve	331	40
9980	1	46	Kawhia	Otorohanga	NWR	Hauturu West Trust	500	72
5682	1	4	Waitomo	Waitomo	Unprotected		470	73
13616	1	46	Waitomo	Waitomo	Unprotected		54	91
10674	1	121	Kawhia / Waitomo	Waitomo	NWR	Taumatatotara A5 North (NWR)	391	107
8844	1	43	Kawhia	Otorohanga / Waitomo	Unprotected		1219	187
10245	1	41	Kawhia	Otorohanga / Waitomo	Unprotected		1223	188
10391	1	22	Kawhia	Waitomo	Unprotected		1226	196
5766	1	11	Kawhia	Otorohanga	Unprotected		203	336
10292	1	27	Kawhia	Otorohanga / Waitomo	Unprotected		1831	370
10915	1	38	Waitomo	Waitomo	DOC	Ruakuri Caves & Bush Scenic Reserve	16	375
1905	1	34	Waitomo	Waitomo	DOC	Marokopa Natural Tunnel Scenic Reserve	261	402
10234	1	22	Kawhia	Waitomo	DOC	Scenic Reserve - WG Johnston acquisition	1535	426
9916	1	34	Kawhia	Otorohanga	NWR	Hauturu West Trust	1432	449
10095	1	48	Kawhia	Otorohanga	DOC	Awaroa Scenic Reserve	2520	849
10169	1	107	Kawhia	Waitomo	DOC	Stewardship Land - Hauturu Forest (east block)	1220	881
4225	1	1	Waitomo	Waitomo	Unprotected		522	974
11112	1	11	Waitomo	Waitomo	Unprotected		2673	1238
19939	1	169	Waitomo	Waitomo	Unprotected		9	1681
5129	1	8	Kawhia	Otorohanga	Unprotected		7754	2783
18829	1	60	Waitomo	Waitomo	Unprotected		205	3862
19781	1	139	Waitomo	Waitomo	Unprotected		34	3925
18085	1	51	Kawhia	Otorohanga / Waitomo	Unprotected		1857	4151
2830	1	5	Waitomo	Waitomo	Unprotected		318	4389
1910	1	3	Waitomo	Waitomo	DOC	Mangapohue Natural Bridge Scenic Reserve	915	4927
10062	1	59	Kawhia	Otorohanga / Waitomo	DOC	Conservation Area - Hauturu East	2517	6087
13542	1	0	Waitomo	Waitomo	Unprotected		1551	7406
18165	1	34	Kawhia	Otorohanga	Unprotected		7785	9621
10754	1	17	Waitomo / Kawhia	Waitomo	DOC	Stewardship Land - Taumatatotara Forest (south block)	15889	10502
18936	1	3	Waitomo	Waitomo	Unprotected		10114	12651
18050	1	8	Kawhia	Otorohanga	Unprotected		10013	13093
1828	1	6	Waitomo	Waitomo	DOC	Mapara Scenic Reserve	17832	17832
18036	1	4	Kawhia	Otorohanga	Unprotected		23306	23306