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GEORGA: Managing biodiversity in geothermal sites

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GEORGA: Managing biodiversity in geothermal sites

Report prepared for Waikato Regional Council by

B. Willoughby and C. Beard

July 2014

Executive Summary

A logical development was identified for a geothermal site evaluation system to inform conservation/biodiversity management and economic development based on Waikato Regional Council resources available for geothermal site description and identifying relative significance on an international and national scale. To this end, a tool (GEORGA – Geothermal Resource General Assessment) for valuing a geothermal site across fourteen (14) parameters was developed. The intended final structural form of the tool is to employ four primary components.

1. Habitat quality
2. Environmental services
3. Threats
4. Economic opportunities

At this stage of development, GEORGA has components addressing habitat quality (1) and threats (3). Measurable parameters for environmental services (2) are also documented in this report, however, as information on some services are lacking, further groundwork and research is required to complete development. It is intended that the economic component (4) will be addressed in a different body of work.

Contents

Introduction

Geothermal sites, with their unique examples of flora and fauna, comprise but c 0.1 % by area of natural ecosystems in the Waikato Region and c 0.008 % nationally (pers. comm. S. Beadel 2014. Note from 2012 data and includes non-vegetated raw soil field and open water habitats). Many geothermal sites are small and isolated in the landscape context, meaning that habitat integrity, site sustainability and environmental service provision are often critically threatened. Given that habitat isolation, fragmentation and degradation are still occurring in today's landscape, a tailored management plan is required to conserve these rare ecosystems. In addition, a dearth of information on the unique flora and fauna, environmental services, landscape features, and in particular details of systems interrelationships, indicate that a precautionary approach must be adopted as geothermal sites and adjacent lands are developed.

A strategic plan for the management of geothermal sites in the first instance requires the development of decision tools to direct ecological decision making. Ecological decision making should be directed to the preservation of biodiversity (including flora and soil and its component macro- and micro-fauna), ecosystem functionality and resilience to ensure the provision of ecosystem services.

While many of the functional processes within geothermal ecosystems remain poorly understood, management decisions can be informed by assessments of site quality along with application of the precautionary principle while the details are researched. A management strategy should also address buffering from external influences that may be deleterious to the health of geothermal flora and soils, and recognise the role of connectivity in ensuring provision of services (such as pollination) that may not be contained fully within a site.

This project aims to integrate several assessment processes with an analysis of ecosystem services to help focus management decisions into areas that offer the best return on investment for conservation and economic objectives. Rapid-assessment site quality ranking methods developed for a soil macro-fauna survey of geothermal areas (Willoughby & Beard 2013), along with criteria identified for pest management in Bycroft *et al.* 2011 and information encapsulated in the geothermal site descriptions and evaluations in Wildland 2011 will be used to develop a ranking framework. We also consider threats to the integrity of geothermal ecosystems both above- and below-ground in the form of adjacent land-use and degree of isolation within a context of integrated landscape management.

Stage 1 of the work is designed to facilitate decision making for the allocation of resources to preserve geothermal site biodiversity and function, using evaluation methods that are loosely structured around the concept of total economic value and as such are risk-analysis based. By adopting a ranking scale within key criteria in a similar manner as the site quality assessment tool, it is envisaged that individual sites may be comparatively evaluated as to the probability of sustainably managing biodiversity and ecological services.

Stage 2 will involve field testing the decision tool to determine whether it is fit for purpose. There will be questions as to whether more or fewer parameters should be included and inevitably the process will also identify information gaps. One role of the testing will be how best to address these.

Geothermal Site Biodiversity Management Decision Tool

Background

The concept of developing a management decision tool arose from a positive response to the practical applications of a rapid-assessment site quality ranking system developed for geothermal areas (Willoughby and Beard 2013). Sites were selected on the basis of representative flora associated with geothermal features, following the classification of vegetation classes recognised in Wildland (2011).

A more comprehensive evaluation framework, modelled on Willoughby and Beard (2013), has now been developed. This makes use of, and builds on, information provided in the following the resource materials:

- Waikato regional geothermal resource (Luketina 2012)
- Geothermal Significant Natural Areas (SNAs). Sixty-four sites have been identified and characterised for the Waikato Regional Council (Wildland Consultants Ltd 2015a, in press).
- Priorities for pest plant control, pest animal control, and fencing at geothermal sites in the Waikato region in 2011. (Wildland Consultants Ltd, 2011)
- Geothermal Vegetation of the Waikato Region - an update based on 2007 Aerial Photographs (Wildland Consultants Ltd 2011)
- Soil macro-fauna in geothermal heated soils in the Waikato Region. (Willoughby 2012)
- Invertebrate macro-fauna in geothermal soil under native vegetation in the Waikato Region. (Willoughby and Beard 2013)
- Geothermal vegetation types of the Taupo volcanic zone (Smale and Fitzgerald 2013)

Wildland (2011) was a key resource for baseline information about most sites. This report identifies 64 sites in 15 geothermal fields identified from aerial maps dating from 2007. Note that an updated document has since become available but not in time to be used in this report. (Wildland Consultants Ltd, 2015b). At each site, the vegetation has been described and classified within vegetation structural classes based on the dominant plant species. Where site inspections were made, site condition, current threats, modifications and vulnerability were assessed, and in some instances management requirements identified. Each site was assigned a relative significance level of International, National, Regional, or Local based on criteria in the Waikato Regional Policy Statement (applying the guidelines delineated in 2002 updated in accordance with the revised threat classification lists).

Topographical location and vegetation maps of each site provide an important management resource.

The objective of the Geothermal Site Biodiversity Management Decision Tool is to facilitate the prioritisation of management objectives to give best value for resource investment on an individual site basis. The tool is also designed to rank the importance of linkages between both geothermal and non-geothermal plant and animal communities, and the role and dimensions of buffers to increase the resilience of what are currently mainly island geothermal ecosystems. The quality of individual sites is also ranked with respect to adjoining land-use, such as pasture, exotic forestry or native vegetation.

In its final form, the tool employs four primary components.

1. Site quality
2. Environmental services
3. Threats.
4. Economic opportunities

At this stage of development, three components have been addressed (1, 2, and 3). Within these components between one and three key measurable factors are used as indicators of quality.

For the purpose of reporting, each component is addressed independently in terms of development and function. An MS EXCEL version is available to demonstrate the functionality. (Appendix).

Geothermal site descriptions and area information is initially derived from Wildland (2011)

Habitat Quality

The geothermal habitat types, vegetation classes and spatial information described in Smale & Fitzgerald (2013) and Wildland Consultants Ltd (2011) were used as a framework for indicative measures of habitat quality of geothermal areas. The practicality of identifying key indicator indigenous plant species and/or associations for habitat health was also investigated.

In the absence of a direct measure of community health, proxy measures were devised based on the following indicators;

- *Dominance of indigenous species (plant)(Table 1)*
- *Presence of rare or threatened indigenous species (Table 1)*
- *Diversity of habitat types (vegetation classes)(Table 2)*

Dominance of indigenous species (plant)

Vegetation associations within a geothermal site are ranked according to the proportion of indigenous species present relative to exotic plant species. Rankings favour dominance by indigenous species, thus ignoring the potentially advantageous services provided by exotic species (for example the presence of flowering exotics providing food supply for nectar feeders, or exotic plants providing for erosion protection) are ignored in favour of dominance by indigenous species.

Presence of rare or threatened indigenous species taxa

This factor is introduced as an addendum to the indigenous dominance scale to accommodate an indicator of both the presence of indigenous vegetation and rare or threatened indigenous plant species. In light of the rarity of geothermal habitat, and the often isolated nature of geothermal sites, consideration might be given to incorporating the presence of rare species as a multiplier. This would significantly increase the weighting.

Table 1: Indigenous and rare indigenous species

A - Descriptor % area of indigenous plant species	Scale	**B** - Addendum Number of rare indigenous plant species	Scale
80 – 100	5	4+	5
60 – 80	4	3	4
40 – 60	3	2	3
20 – 40	2	1	2
0 - 20	1	0	1
		Total **A + B**	

Plate 1: Left*: Calochilus robertsonii* (red-bearded orchid). Right*: Korthalsella salicornioides* (dwarf/leafless mistletoe). Threat status of both plants: At Risk – Naturally Uncommon.

Diversity of habitat types

This ranking scale is based on the premise that the greater the diversity of habitats within a geothermal site, the greater the biodiversity values. There is a large body of evidence that diversity of vegetation may be used as a proxy for diversity of macro- and micro-fauna.

As such, a vegetation diversity scale may be inferred to reflect a range of habitats represented at an individual site. Used in conjunction with the dominance and rarity scales there is a recognition that diversity alone does not increase the value of a site (for example, a site may be diverse but as a result of its exotic component). The role of exotics contributing to environmental services and the implications for assessing diversity is beyond the scope of this exercise.

For the purposes of ranking, a measure of habitat diversity is calculated from the number of vegetation structural classes present at a site (classes are aligned with the thirty (30) vegetation structural classes identified by Wildland (2007) (Table 2). This aspect may be assessed as an office exercise prior to a site visit

The addendum (Table 2) draws on species area theory (for example; Conner & McCoy 1979, Losos & Schluter 2000, Koh & Ghazoul 2010) postulating that increased biodiversity is positively related to habitat area. The isolated nature of and specialised adaptations within the Waikato region geothermal habitats may be interpreted as island populations for management purposes.

Table 2: Vegetation classes as per Wildland (2011)

C - Descriptor Diversity (number of vegetation classes present)	Scale	**D** - Addendum Area (ha)	Scale
21 - 30	5	> 20	5
11 - 20	4	10 – 20	4
6 - 10	3	5 – 10	3
2 - 5	2	1 – 5	2
1	1	< 1	1
		Total **C + D**	

Plate 2: Prostrate kanuka and bare soilfield, Rotokawa

Site quality and landscape context

A vegetation and habitat quality evaluation system (Willoughby and Beard 2013) that offered a comparison between sites as to the nature and amount of human-induced disturbance (either direct or indirect) was used as the basis for identifying site disturbance (Table 3). As indicators may change rapidly over time it is recommended that site disturbance is scored during a site visit rather than relying on previous or desktop survey information.

Table 3: Disturbance

E – Descriptor **Site quality**	**Scale**
Site undisturbed (no animal tracks or signs of trampling or browse), no invasive exotic plant species present, landscape unmodified, site legally protected as park or reserve land.	4
Some animal disturbance evident (browse/tracking), invasive exotic plant species present but not dominant, site legally protected as park or reserve land.	3
Animal disturbance evident but not heavy, landscape modified, invasive exotic plant species present but not dominant, site not legally protected.	2
Signs of obvious disturbance (animal tracks, browse), invasive exotic plant species prominent, highly modified landscape, site not legally protected.	1
Sub Total E	

Table 4 addresses site quality within a landscape context. The method of ranking is based on that developed for the Australian State of Victoria Vegetation Quality Assessment (DPI 2004). The proportion of native vegetation cover within the three radii of each site can be estimated to the nearest ten percent using Waikato Regional Council GIS resources (WRAPS, BioVeg). The weighting reflects the relative proportions of the three landscape areas and is also included to ensure that the landscape rating does not become disproportionate.

Table 4: Landscape context

F - Addendum **Landscape context** **(% cover of native vegetation in surrounding landscape)**	**%** **(Estimate to nearest 10%)**	**weighting**	**sum (% x weighting)**
Percentage cover of native vegetation within 100m radius of site		0.1	
Percentage cover of native vegetation within 1 km radius of site		0.2	
Percentage cover of native vegetation within 5 km radius of site		0.3	
		Sub Total F	

Environmental Services

Three aspects of environmental services provided to and for geothermal areas are identified as relevant to biodiversity management in geothermal areas but remain poorly understood at this time. These services are potentially important to the health of a geothermal site and offer readily measurable parameters. The services include:

Pollination

Pollination is measurable by the presence of suitable pollinators at strategic times (Harris 1996). The quality of pollination as an environmental service has implications for sustainable indigenous plant communities in geothermal areas. While prostrate kanuka exhibits a generalist pollination syndrome (i.e. easily accessed dish-shaped flowers) the characteristics of some indigenous geothermal vegetation may preclude all but some specific pollinator species for effective pollination. Maintaining viable populations of these pollinators, whether birds, insects or both, will depend on continuity of a food supply (nectar). As an example, competition from honey bees at critical times may jeopardise specialist native pollinators. The field programme would be designed to identify the key pollinators (from observation at the flowering of key indigenous vegetation of New Zealand geothermal areas) and then determining whether there is suitable habitat and floral resource to support these pollinators within the prescribed geothermal area. Soil temperatures adjacent to a geothermal feature may preclude the survival of soil dwelling larval stages of potential pollinators. Consideration must be given to accommodating all habitats critical to a pollinator life cycle. Some sites may be best managed for native bee habitat to support pollination services, while others may offer opportunities for managed honey bee hives.

Plate 3: Geothermal/prostrate kanuka (*Kunzea tenuicaulis*)

2) Invertebrate fauna

Adult indigenous beetles (*Pyronota* sp. and *Eucolaspis brunnea* (Fabricius) have been noted in large numbers feeding and mating on prostrate kanuka, *Kunzea tenuicaulis* (Note; formally *Kunzea ericoides* var. *microflora)* in geothermal areas (Willoughby and Beard 2013). These scarab species are univoltine with a soil dwelling larval stage, inviting the question as to where the larvae live. It may be accepted that the insect species and plant have co-evolved, and there may be some mutual dependencies as yet unidentified. However, the future of the relationship relies on suitable soil conditions for larval survival. These conditions often do not exist within the immediate area of prostrate kanuka habitat because of elevated soil temperatures and may be limited outside hot areas due to the small size and un-buffered nature of most remnants. There is no record of the larvae of either species occurring in farmland. Managing adjacent soils and vegetation in terms of nutrient runoff and pests may be important in sustaining these species.

Plate 4: *Pyronota* sp. on geothermal kanuka

3) Ectomycorrhizal Fungi

The role of the ectomycorrhiza *Pisolithus* sp. in nutrient cycling has been questioned, particularly with respect to functionality in nutrient cycling (for example Orlovich & Cairney 2004). Where plant roots do not come in direct contact with the mineral soil, such as raised root mats of prostrate kanuka in geothermal sites, a question arises as to how nutrients are accessed. Moyersoen *et al.* (2003) identified the unique relationship between strains of Pisolithus and prostrate kanuka. *Pisolithus* sp. was observed to be widespread in survey of geothermal soils (Willoughby & Beard 2012). A clearer understanding of the fungi's role in nutrient uptake for kanuka in geothermal areas would be useful and could be assessed by associating presence/absence with site quality and possibly adjacent land-use. The association would be by implication but may prove useful from a biodiversity management point of view.

Threats

For the purpose of this exercise, threat has been categorised as intrinsic or extrinsic. The objective is to determine the extent of physical buffering a site might require to maintain biodiversity integrity. Threats are ranked on a Likert scale of 1 to 5, one being most threatening and five being least to allow the size of a cumulative score to reflect a higher quality site. Multipliers, defined by the periodicity of a threat, are incorporated as a method to incorporate risk.

Intrinsic threat

This is defined as a threat originating from within a geothermal site. An intrinsic threat may not be managed directly. The nature of the threat (the descriptor) and the periodicity (the addendum) define the magnitude of the threat.

A measurable intrinsic threat is the nature of the geothermal heating in a geothermal area to 'wander' or move spatially over time (Table 5). The capacity of a site to sustain this 'wandering' with minimal impact to the ecology and environmental services is identified as Intrinsic Threat 1 (IT1). The pattern of geothermal heating of the soil may change influencing that nature of the indigenous vegetation. Historical records of 'wandering' enable a determination to be made of the extent of a managed geothermal significant natural area (GeoSNA).

Table 5: Intrinsic threat 1 – Wandering (IT1)

G – Descriptor 'Wandering'	IT1 Scale	**H** – Addendum Periodicity	Scale
Less than 1% of site	5	Greater than 10 years	5
Up to 20% of site	4	Less than 10 years	4
Up to 50% 0f site	3	Less than 5 years	3
Up to 80% of site	2	Less than 2 years	2
100 % of site	1	Less than 12 months	1
		Total **G + H**	

A second measurable intrinsic threat (IT2) is the range of ejecta (steam or mud) to threaten the integrity of the site biodiversity. The size of the threat may be quantified by estimating the relative area threatened by ejecta and the frequency with which an ejectum event might occur (Table 6).

Table 6: Intrinsic threat 2 – Ejecta (IT2)

I – Descriptor Ejecta	IT2 Scale	**J** – Addendum Periodicity	Scale
Less than 1% of site	5	> 10 years	5
Up to 20% of site	4	5 - 10 years	4
Up to 50% 0f site	3	2- 5 years	3
Up to 80% of site	2	< 2 years	2
100 % of site	1	< 12 months	1
		Total **I + J**	

Extrinsic threat

An extrinsic threat is one existing outside the geothermal area. Extrinsic threats may be managed directly.

For this exercise two extrinsic threats are identified. These include the nature of adjacent land use and grazing/browsing.

The severity of threats from adjacent land use will be determined by the intensity of the land use and the proportion of the site boundary directly in contact with that land (Table 7). While the assumption is made that unmodified native vegetation does not pose a threat, ingress of weed species does pose a threat.

Land-use scenarios chosen range from plantation forestry to a range of farming activities from low intensity grazing through cropping to high intensity grazing. Included at the high end of the scale are industrial activities. Measurable impacts include nutrient runoff from chemical fertiliser and/or urine from grazing animals determined by farming intensity. Additional nitrogen and/or phosphorus may significantly alter the chemical profile of the soil within a GeoSNA, which in turn may impact on the soil micro flora and macro fauna. Depending on the mode of transport, vegetated buffer areas for interception may provide a solution.

Grazing animals may pose a direct threat to indigenous vegetation within a GeoSNA. It is important to note that the descriptors are interpreted from a threat perspective only. Land use may also include beehives, which can pose a threat to native pollinators and pollination systems.

Table 7: Extrinsic threat 1 – Adjacent land use (ET1)

K – Descriptor **Adjacent land use**	ET1 Scale	**L - Addendum** **Proportion of border**	ET1 Scale
Undisturbed indigenous or exotic vegetation	3	< 5%	6
Pastoral farming	2	< 20%	5
Industrial/urban development	1	< 40%	4
		< 60%	3
		< 80%	2
		100%	1
		Sub-total K + L	

Table 8: Extrinsic threat 2 – Grazing/browsing (ET2)

M – Descriptor Fencing	ET2 Scale	**N** - Addendum Proportion of border	ET2 Scale
Pest-proof fence	6	100%	6
Seven strand permanent fence	5	< 80%	5
Five strand/sheep netting (permanent)	4	< 60%	4
Two strand electric fence (permanent)	3	< 40%	3
Single wire electric fence (temporary)	2	< 20%	2
No fencing	1	< 5%	1
		Total **M + N**	

At this point of the development of the decision tool the total score reflects a relative biodiversity value as defined by measures of site quality. The higher the score is, the higher the biodiversity value is. The relative nature of the value requires field verification to identify an overall scale.

Environmental services and threats represent a measurable management component. The higher scores reflect reduced management inputs required to maintain site integrity.

It is intended that economic opportunities reflect the tension between conservation values and commercial opportunities.

The role of this decision support tool is to clarify a process leading to the effective management to maintain/restore biodiversity in geothermal features. It is not the intention of the authors that this tool replace the decision-making process.

Aside from the components yet to be included, being Environmental Threats and Economic Opportunities as discussed elsewhere in this report, a refinement to be considered may be to link the tool inputs in the form of matrices to be analysed by dominance analysis.

Discussion

Recognition of the intrinsic and extrinsic interconnectedness of geothermal sites combined with limited information indicates that the Geothermal Site Biodiversity Management Decision Tool GEORGA should be used in its entirety. That is, the components, should they be utilised independently to assess risk, may distort interpretation of threats and opportunities to better manage geothermal sites.

Many aspects of geothermal systems are yet to be understood; for example, the influence of pollination and the role of pollinators with respect to the sustainability of unique geothermal plants. Currently there is not enough information to identify confidently species requirements requirement for pollination services. What we can infer is that there may be competition for the pollen/nectar resource by both indigenous and exotic fauna including birds and insects.

While pollination/pollinators is but one example, it does serve the purpose of illustrating at this early stage in the development of the Geothermal Site Biodiversity Management Decision Tool that the components require field testing to verify that the aspects chosen to populate the tool are those most suitable in terms of practicality and robustness.

The process of developing GEORGA involved considering many different measurable indicators. In choosing what might be most suitable to populate the tool the authors have tried to keep to a profile of simplicity of operation, robustness and repeatability. An example a rejected indicator for vegetation health was measuring leaf chemical composition (chlorophyll, nitrogen, phosphorus, potassium) of key indigenous plant species (Maier *et al.* 2002, Poorter and de Jong 1999). However, the complexities of the geothermal soil environment in terms of temperature, nutrient and pH variation indicate that this approach is impractical as current knowledge deficiencies impede interpretation. A field evaluation of the tool in its current form is envisaged as a key part of the development process.

GEORGA is designed to complement the implementation of biodiversity management after ecological value assessment. Methodologies are currently being developed for ranking Significant Natural Areas (SNAs) of the Waikato Region. It is envisaged that the ranking produced will operate within the constraints and context of community, national (e.g. Threatened Environment Classification or TEC), international (e.g. Ramsar sites) and Department of Conservation priorities. Consideration would be given to cultural, social, amenity values; community and other agency involvement; the role of private ownership and consideration for any active management (e.g. pest control) in place. ‘GEORGA’ is designed to support the biodiversity management decision process in a landscape context. For example where the identification of a compromised or lack of an environmental service within a geothermal site may be provided from within a landscape context. ‘GEORGA’ will aid in identifying biodiversity trajectories within a range of management options from doing nothing to targeted management options. The decision tool will also have a role in planning offset opportunities and/or restoration potential.

Economic opportunities / threats

Consideration of economic opportunities and threats is beyond the scope of the current exercise. It is intended that this consideration will be addressed in a future project through joint research by resource economists and ecologists.

Recommendations

Recommendation 1.

It is recommended field testing of the GEORGA be undertaken as a second stage. Table 9 indicates the components of the decision tool that have been completed and are ready for testing. Evaluation would take the form of identifying geothermal sites that are disparate in terms of some key features. For example, an extensive site compared to a small site, sites with disparate adjacent land use. The initial evaluation would be done from the resources identified in Table 9 with a follow up field visit to each site for the purpose of identifying any potential weaknesses in the tool inputs.

Table 9: GEORGA components and information source

Component	Component description	Information Source
A	Site quality	Site field assessment
B	Landscape context	WRC GIS
C	% area of indigenous plant species	Wildland (2011)
D	Nos. rare indigenous plant species	Wildland (2011)
E	Diversity	Wildland (2011)
F	Site area	Wildland (2011) / WRC GIS
G	Threat – 'Wandering'	Site field assessment
H	'Wandering' periodicity	Site field assessment/local info
I	Threat – 'Ejecta'	Site field assessment
J	'Ejecta' periodicity	Site field assessment/local info
K	Threat – adjacent land use	WRC GIS
L	Adjacent land use % site border	WRC GIS
M	Threat - fencing	Bycroft et al.. (2011)
N	Fencing - % of site border	Bycroft et al.. (2011)
O	Environmental service 1	To be determined
P	Environmental service 2	To be determined
Q	Environmental service 3	To be determined
R	Economic opportunity 1	To be determined
S	Economic opportunity 2	To be determined
T	Economic opportunity 3	To be determined

Field testing would be designed as an indicative pilot study rather than a definitive study. That is, the depth of investigation confined to information that might populate the decision tool.

As such, stage two would involve selecting a range of sites (number to be confirmed) based on key factors identified in Stage 1. These key factors would come under the four categories.

1. Site quality

2. Environmental services (to be confirmed)

3. Threats.

4. Economic opportunities (to be completed)

Recommendation 2.

The second recommendation is to initiate a field programme to identify measurable environmental services. Three have been identified that are specific to geothermal features:

1. Pollination: the objective to clarify the role of both native pollinators (timing and abundance) and the honey bee (potential for disruption to native pollinator).
2. Invertebrate fauna: the objective to record the abundance and distribution of the native scarabs (*Pyronota* sp. and *Eucolaspis brunnea* (Fabricius)) at sites with differing adjacent land use to determine the relationship.
3. Ectomycorrhizal fungi: the initial objective would be to record abundance and distribution with respect to site characteristics. A fundamental question would be as to whether these fungi are confined to raised root mats of prostrate kanuka. The specifics of the role of the fungi would be the role of an academic study.

These studies are not envisaged to be ‘in depth’; rather designed to clarify a role in the decision tool to readily evaluate examples of measurable environmental services.

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Appendix

GEORGA

A geothermal site biodiversity management decision support tool

B. Willoughby and C. Beard

A – Descriptor **% area of indigenous plant species**	**Score**	**B- Addendum** **Number of rare or threatened taxa within site (flora and fauna)**	**Score**
80 – 100	5	4+	5
60 – 80	4	3	4
40 – 60	3	2	3
20 – 40	2	1	2
0 – 20	1	0	1
		Sub-total A + B	

C – Descriptor **Diversity (number of vegetation classes present)***	**Score**	**D - Addendum** **Site area (ha)**	**Score**
21 – 30	5	> 20	5
11 - 20	4	10 – 20	4
6 – 10	3	5 – 10	3
2 – 5	2	1 – 5	2
1	1	< 1	1
		Sub-total C + D	

E – Descriptor **Site quality**	**Scale**
Site undisturbed (no animal tracks or signs of trampling or browse), no invasive exotic plant species present, landscape unmodified, site legally protected as park or reserve land.	4
Some animal disturbance evident (browse/tracking), invasive exotic plant species present but not dominant, site legally protected as park or reserve land.	3
Animal disturbance evident but not heavy, landscape modified, invasive exotic plant species present but not dominant, site not legally protected.	2
Signs of obvious disturbance (animal tracks, browse), invasive exotic plant species prominent, highly modified landscape, site not legally protected.	1
Sub-total E	

F – Addendum **Landscape context (% native vegetation in surrounding landscape)**	**% (estimate to nearest 10%)**	**Weighting**	**sum (% x weighting)**
Percentage of native vegetation within 100m radius of site		0.1	0
Percentage of native vegetation within 1 km radius of site		0.2	0
Percentage of native vegetation within 5 km radius of site		0.3	0
		Sub-total F	0

G – Descriptor **'Wandering'**	**Score**	**H – Addendum** **Periodicity**	**Score**
Less than 1% of site	5	Greater than 10 years	5
Up to 20% of site	4	Less than 10 years	4
Up to 50% 0f site	3	Less than 5 years	3
Up to 80% of site	2	Less than 2 years	2
100 % of site	1	Less than 12 months	1
		Sub-total G + H	

I – Descriptor **Ejecta**	**Score**	**J – Addendum** **Periodicity**	**Score**
Less than 1% of site	5	> 10 years	5
Up to 20% of site	4	5 - 10 years	4
Up to 50% 0f site	3	2- 5 years	3
Up to 80% of site	2	< 2 years	2
100 % of site	1	< 12 months	1
		Sub-total I + J	

K – Descriptor **Adjacent land use**	**Score**	**L - Addendum** **Proportion of border**	**Score**
Undisturbed indigenous or exotic vegetation	3	< 5%	6
Pastoral farming	2	< 20%	5
Industrial/urban development	1	< 40%	4
		< 60%	3
		< 80%	2
		100%	1
		Sub-total K + L	

M – Descriptor **Fencing**	**Score**	**N - Addendum** **Proportion of border**	**Score**
Pest-proof fence	6	100%	6
Seven strand permanent fence	5	< 80%	5
Five strand/sheep netting (permanent)	4	< 60%	4
Two strand electric fence (permanent)	3	< 40%	3
Single wire electric fence (temporary)	2	< 20%	2
No fencing	1	< 5%	1
		Sub-total M + N	

Site score TOTAL	0.00

***Use Wildland (2015b)**