

Applied Research Plan for conservation management, rehabilitation and expansion of cushionfield

July 2025

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Manaaki Whenua Contract Report: LC4626

Prepared for: Matakanui Gold Limited



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Summary

Project, client

- In March 2025 Matakanui Gold Ltd (the client, hereafter 'Matakanui Gold') requested Manaaki Whenua – Landcare Research (MWLR)¹ deliver a framework of the activities for applied research and monitoring that would identify management actions to enhance the area and condition (ecological integrity) of 'herbfields' on the Bendigo and Ardgour project area, including establishing new herbfields on mined areas. The request followed initial baseline ecological assessment and interim reporting.
- This report presents an Applied Research Plan (ARP) intended to guide and deliver the conservation management, rehabilitation and expansion of a high-value subset of herbfields, which are cushionfield ecosystems.

Objectives

- The objective of this report is to deliver a framework of the activities and timing for applied research and monitoring that identifies management actions to enhance the area and condition (ecological integrity) of cushionfields in the managed landscape, including establishing new cushionfields and patches of kōwhai (*Sophora microphylla*) shrubland on mined areas.

Background

- The Bendigo-Ophir Gold Project (the project) could remove up to 92 ha of herbfields,² with significant ecological impacts. Cushionfields are a high-value subset of herbfields which have or support high regional and/or national ecological values.
- Cushionfields are characteristically dominated by indigenous *Raoulia* species and there is often a presence of indigenous spring annual herbs. Cushionfield ecosystems are being rapidly lost to development across the region and could now be classified as regionally threatened ecosystems. They contain many plants and invertebrates of high ecological value, while some spring annual herbs that occur within them are nationally threatened.
- Experience in the management, rehabilitation and expansion of cushionfields is very limited. *Raoulia* and many other cushionfield species are propagated in nurseries but none have previously been planted at scale. Most past research has focused on accelerating a transition away from cushionfield to taller-stature native vegetation. However, some recent small-scale trials have begun to investigate the use of amendments (e.g. sugar, to reduce fertility), and earthworks to favour cushionfield, while monitoring and observations indicate ongoing browse and/or grazing by rabbits and/or sheep may be required.

¹ From 01 July 2025 Manaaki Whenua – Landcare Research will be an internal group of the New Zealand Institute for Bioeconomy Science, or 'Bioeconomy Science Institute (BSI).

² Herbfields were mapped as 17% of the 540 ha Direct Disturbance Footprint (DDF), which is the area within which all vegetation could be removed.

Recommendations: Applied Research Plan

The project landscape is a mosaic of cushionfields, tussock grassland, grey scrub and introduced pasture, requiring a range of management tools to achieve success. It is proposed to apply management at three scales:

- Whole site or 'broad scale' mapping and monitoring of cushionfield (including the threatened spring annuals). The area to be mapped is confined to areas on Ardgour and Bendigo Stations where MGL has access agreements in place. This area is hereafter referred to as the 'managed landscape'.
- 'Paddock scale' manipulation of browsing and stock grazing, weed management and soil treatments to promote natural regeneration of vegetation associated with cushionfields while suppressing competing vegetation.
- Small 'patch scale' interventions and management, involving (1) trials to propagate *Raoulia* species and establish them into areas where it is absent (e.g. pasture and mined areas); and (2) fencing of remnant kōwhai trees, shrubs, and potentially spring annual herbs with interplanting to assist regeneration of high-value native plant species found within cushionfields.

The Applied Research Plan for cushionfield ('cushionfield ARP') has six components with implementation commencing in years 1 and 2 and expected to run for at least 7 years, depending on results.

- Component 1. Map the present extent of cushionfield across the managed landscape to determine its present distribution and confirm success criteria for the condition of key cushionfield attributes using ground-based surveys and testing drone-captured aerial photography (Year 1).
- Component 2. Identify current baseline pressures on cushionfield and best current management for the cushionfield vegetation type (Year 2)
- Component 3. Identify areas where cushionfield could be most likely and effectively enhanced (including a range of typical co-occurring herbaceous and woody species), and develop a range of practical extensive and intensive interventions (Year 2)
- Component 4. Implement restoration trials (Years 2 to 6)
- Component 5. Develop methods for *Raoulia* propagation and establishment and respond to those trials (Years 2 to 7)
- Component 6. Trial methods to protect and replant genetically diverse kōwhai treeland and shrubland areas within cushionfield mosaic (Years 2 to 7).

Components 4, 5 and 6 would require ongoing monitoring for at least 7 years.

1 Introduction

1.1 Context

Matakanui Gold Ltd, (hereafter called 'the client', or 'MGL', with contract through Santana Minerals) requested Manaaki Whenua Landcare Research (MWLR) deliver a framework of the activities for applied research and monitoring that would identify management actions to enhance the area and condition (ecological integrity) of herbfields on Bendigo and Ardour Stations, including establishing new herbfields on mined areas.

This document outlines a programme of research – an Applied Research Plan (ARP) for cushionfields – that is intended to reduce uncertainty with respect to the success of mitigating the loss of one particular high value type of herbfield which is the *cushionfield community*.

The intention of the cushionfield ARP is to provide (through further survey, analysis, and experimental trials) a clearer understanding of the magnitude of effects and the viability of effects management options that could be employed to offset adverse effects.

1.2 The need for this research

The Matakanui Gold Bendigo-Ophir Gold Project (the project) proposes to remove about 92 hectares of cushionfield in the Direct Disturbance Footprint (DDF) (Figure 1). In addition to removal, there may be edge effects (Simcock et al 2022) which affect cushionfields beyond the contingency zone that is included within DDF.

In response, MGL proposes to implement ARP recommendations to manage areas of cushionfield. The intention includes further work to better understand the extent of cushionfields in the area and the viability of mitigations to protect and enhance cushionfields using that knowledge to:

- a increase the areal extent and improve the ecological condition of cushionfields within the managed landscape; and
- b rehabilitate cushionfield in relatively small areas on engineered landforms within the DDF, with the intent to scale up to larger areas if outcomes are favourable.

Whether these mitigation goals can be achieved is currently unknown. This has driven the proposals in the ARP to obtain and action that mitigation once success can be determined. There is little existing research, knowledge or experience of management actions which have attempted to understand cushionfield communities and/or achieve these goals. Applied research is therefore needed to reduce the uncertainty and define and refine the management interventions that Matakanui Gold will need to sustain and expand cushionfield. The necessary programme of research is set out in this report.

A proposed workplan for Threatened and At Risk spring annual herbs is appended to this ARP (Appendix 3). Spring annual herbs are closely associated with cushionfield. It is therefore important that the cushionfield ARP and the workplan for spring annual herbs work closely together.

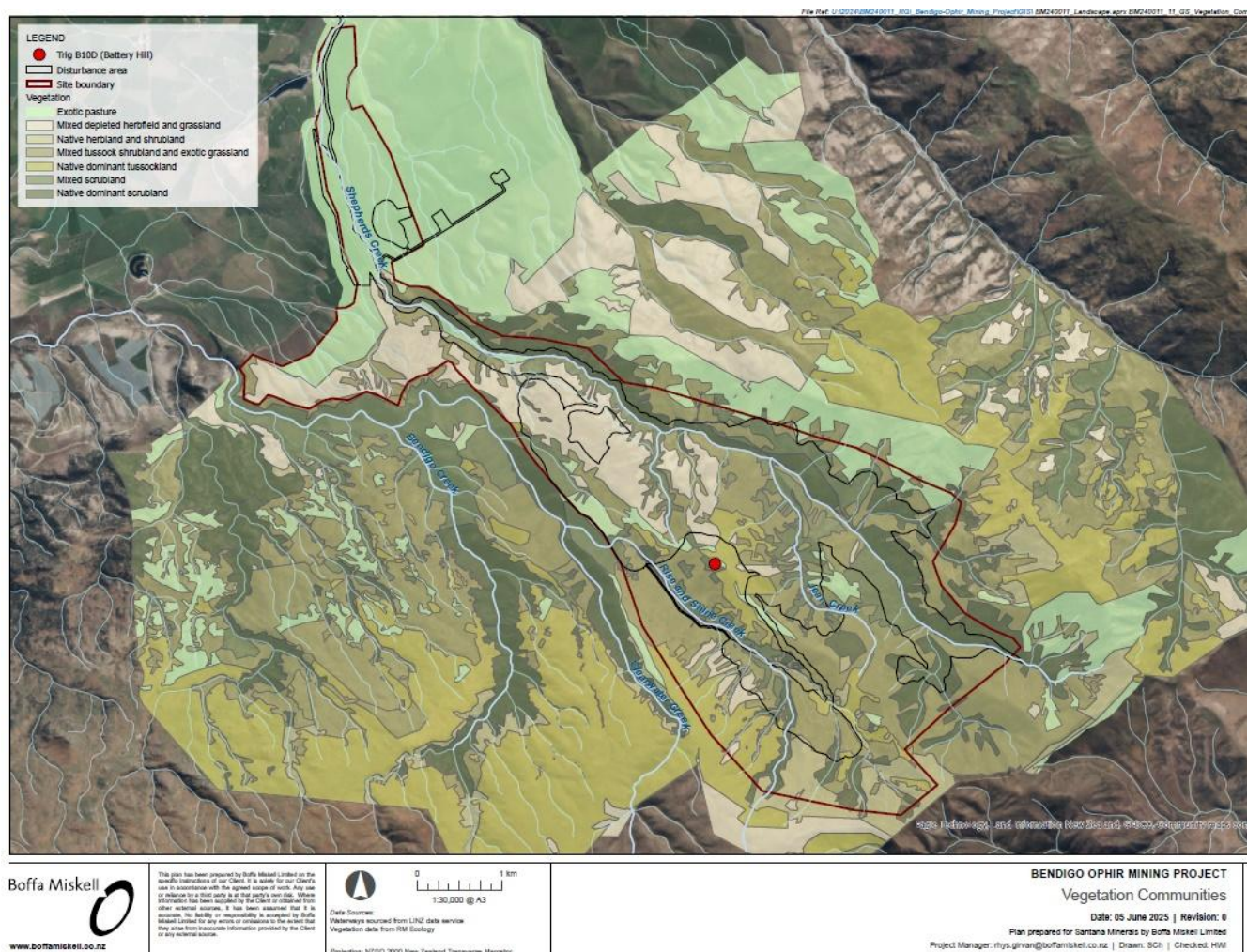


Figure 1. Vegetation communities mapped in the Ecological Study Area (ESA) (about 5,000 ha) using colours to highlight cushionfields (cream, mapped over 10% of the surveyed area as depleted herbfield and grassland) and exotic pasture (bright green). The black line outlines the Direct Disturbance Footprint (DDF) within which all vegetation is potentially removed. About 10% of the ESA and 17% of the DDF is likely to be cushionfields). (Source: Data sourced from RMA Ecology and map created by Boffa Miskell, April 2025.)

1.3 Location of the research

MGL has the ability to manage approximately 29 km² across Ardgour and Bendigo Stations. The ARP described in this report will be focused on these areas, hereafter referred to as the 'managed landscape' (Figure 2, see also Appendix 1 [Map A1.3]). However, results may be applicable beyond this area.

The ARP will apply to low to mid-altitude areas across both stations. The areas of most interest are those mapped as 'mixed depleted herbfield and grassland' by RMA Ecology (Figure 1, Figure 3, Appendix One using surveys between 2023 and 2025). It is likely that most cushionfields will occur within these areas. The ARP outlines the requirement to refine the definition of cushionfield and to use that definition to locate and map the boundaries of cushionfields at a fine scale. It also identifies the requirement to establish trials in interstitial areas in which taller vegetation such as treeland and shrubland remains or can be rehabilitated within cushionfield mosaics. It is noted, however, that there are small areas of cushionfields and cushionfield mosaics on Ardgour Station

that will not be able to be surveyed in Spring 2025 (to provide enough paddocks for lambing which occurs during the peak period of spring annual growth).

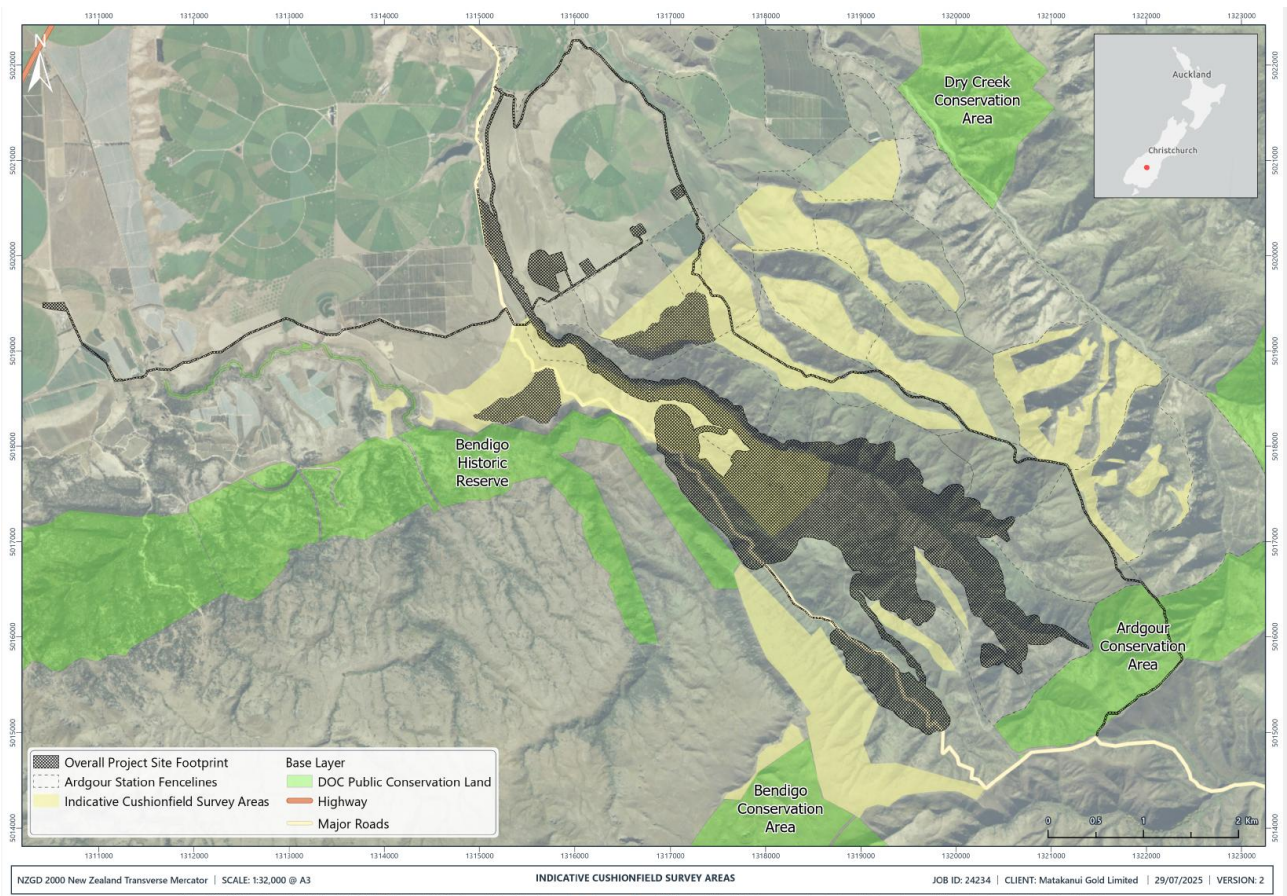


Figure 2. Indicative cushionfield survey areas forming the 'Managed landscape'. (Source: MGL July 2025)

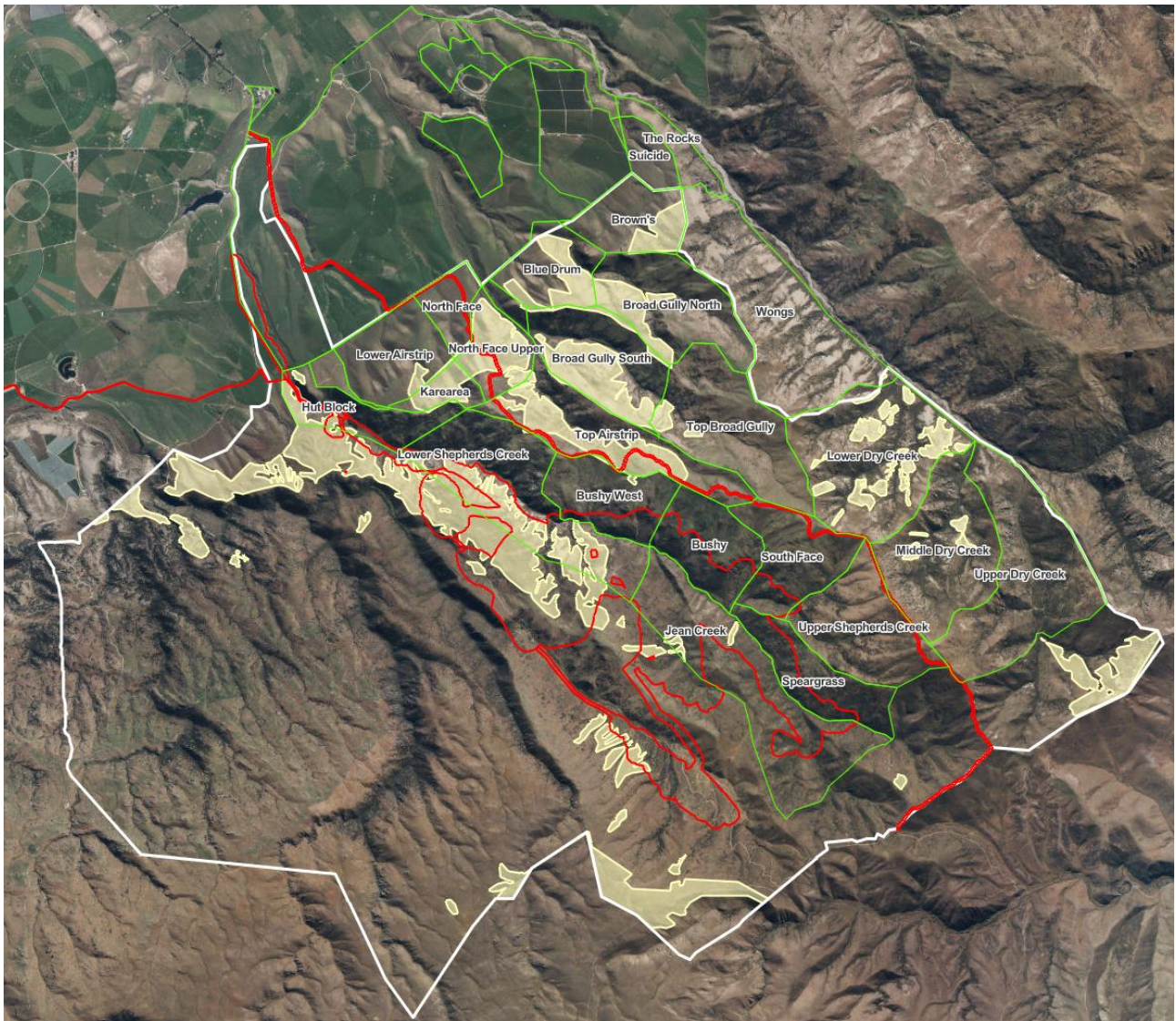


Figure 3. Depleted herbfield and grassland (cream polygons) that is likely to contain cushionfield vegetation as mapped by RMA Ecology in 2025 within the surveyed area (white line). The figure shows the present management blocks / paddocks (green outlines and names) on Ardour Station and the DDF (red outline). (Source: RMA Ecology April 2025.)

2 Objectives

The objective of this report is to deliver a framework of the activities, timing and resulting methods and actions for applied research, monitoring and mitigation that identifies management actions to enhance the area and condition (ecological integrity) of cushionfields in the managed landscape, including establishing new cushionfields and patches of kōwhai (*Sophora microphylla*) on mined areas.

3 Background

This background section explains how the current locations of cushionfields probably reflect land management history and ecological context. The cushionfield ecosystem and its ecological values

at the site are then described and the Threatened and At Risk plant species managed within the cushionfields area identified. The section concludes by identifying the key areas proposed for cushionfield management, separated into: (a) mine site management units (predominantly on Bendigo station and immediately adjacent to the mine infrastructure); (b) Ardgour Station management units.

3.1 Cushionfield

The locations of cushionfields reflect land management history and ecological context. Cushionfields are variable,³ but all are characterised by compact mats and cushions of low-growing (50–200 mm tall) plants with only the growing tips visible (Kleier & Trenary 2017). Photographs of areas of cushionfields are provided in Figure 5 and Figure 6.

Cushionfields have very low biomass⁴ (Meurk 1978) and are naturally found from alpine areas down to sea level (e.g. Kaitorete Spit and braided riverbeds). Their low form resists damage from wind and abrasion and helps minimise moisture losses and grazing/browse. In Central Otago and the project site *Raoulia australis* is the most common 'cushion' species, locally known as 'scabweed'. Cushionfields grade into and form mosaics with taller 'grey scrub', tussockland and exotic grassland (Figures 1, 5 and 6). In adjacent parts of Bendigo Station and public conservation land, cushionfield forms a mosaic with both 'grey scrub' and more commonly, kānuka (which is largely absent from the DDF and Ardgour Station). Cushionfield generally occupies sunny, exposed spurs, while taller grassland and shrubland occupies sheltered and shadier sites with lower moisture stress. The level of moisture stress and depth of gullies controls whether cushionfield is dominant or forms 'fingers' across dissected slopes (Figure 1, Figure 3). In lower-elevation areas outside the project area cushionfield also occupies the most 'water-deficient' sites (Hubbard & Wilson 1987) but it is also dominant in saline and sodic soils. These soils have not been identified in the project area.

Cushionfields in the project area are an induced vegetation, with their distribution reflecting historical and current types of management which removed original taller vegetation to form an estimated 1 million hectares of cushionfield in 1911 (Mather 1983); fire and grazing have benefitted cushionfields whereas oversowing and topdressing, weeds, and some vegetation controls have inhibited cushionfields. Cushionfield species possess traits that have enabled them to avoid grazing (e.g. temporal avoidance in the native annual flora, structural defence in the low-growing, tightly packed *Raoulia* mat species and sclerophyllous dwarf grasses such as the desert poa (*Poa maniototo*) (Walker 2000).

Fire was infrequent before human settlement, and then became more frequent after early Māori settlement, when it was used periodically to clear scrub for hunting and travel (Rogers et al. 2007). A wave of very frequent burning accompanied early European settlement. Pastoralists burned tussock approximately annually to stimulate growth for grazing. The frequent pastoral fires from about 1850, combined with grazing, led to widespread depletion of tall snow tussock which at some stage was almost completely eliminated from the highest areas on Bendigo and has not

³ This variability will be quantified using data collected in a cushionfield-specific survey as the broadscale vegetation mapping of 23 cushionfield plots in 2023 to 2025 does not provide the level of detail required for the ARP.

⁴ Biomass is 2–4 kg/m².

returned. This local eradication of snow tussock provided space for an initial expansion of shorter tussocks from lower elevations; and then, on drier landforms, fire depleted tussock grassland first to bare ground and then to a sparse cover of annual plants and plants with cushion and mat growth forms which did not have high enough biomass to support fires (Mather 1983, McGlone 2001). Bare ground on northwest facing slopes is exposed to frequent dry north-westerly winds, which stripped topsoils laid bare by fire and grazing disturbance. This reduced soil carbon on exposed slopes, thereby reducing soil moisture storage and chemical fertility and favouring cushion fields. The opposite effects occurred in gullies and on southeast slopes where the eroded topsoil was deposited (Hewitt 1996).

Plague levels of rabbits are regarded as 'creators' of cushionfield. The frequent burning and grazing (by rabbit and sheep) of tussock on sunny dry faces created ideal conditions for rabbits, which in turn have maintained the short plant cover ever since by slowing or stopping establishment of taller plants through grazing and disturbance (Wardle 1985, Walker 2000, Rogers et al 2005). Both sheep and rabbits browse on grasses, herbs and woody shrubs in cushionfield, helping to maintain bare areas and adding faecal matter, which is concentrated around 'camps'. Norbury (1996) tabulated species of the short tussock grasslands that are affected by rabbits, noting rabbits were implicated in the demise of three plant species that are presumed extinct. However, Norbury also noted some small annual herbs benefit from the open disturbed ground and suppression of exotic grasses and herbs delivered by rabbit grazing: *Ceratocephalus pungens*, mousetail (*Myosurus minimus*), and New Zealand forget-me-not (*Myosotis colensoi*). Cattle do not usually target cushionfield but may pass through and cause soil disturbance and add faecal matter.

Habitat loss and modification through weed invasion and agricultural development (particularly irrigation and fertilisation of dryland habitats has resulted in *Raoulia australis* (common scabweed) being provided the current conservation status of At Risk-Declining, along with other species of cushionfields (New Zealand Plant Conservation Network [NZPCN] n.d.).⁵ Cushionfields have been deliberately converted to taller (productive) vegetation across the Central Otago terraces, lowlands and hills using a combination of oversowing with non-native pasture seed (grasses and legumes) and topdressing with phosphate and/or sulphur fertilisers. Lime may have been applied in some areas although raising soil pH but is not generally necessary to reach pH>5.5 in this geology. Many accessible areas have been ploughed and irrigated (e.g. for vineyard, orchard or crop establishment, Wardle 2024). In relatively small, discrete areas of the project area, but very large areas in areas towards Cromwell, cushionfields have been smothered by non-native plants that are competitors, usually alongside disturbance. However, research indicates that *Raoulia* cushions do not facilitate establishment of woody shrubs (Kleier & Trenary 2017). In areas such as Cromwell indigenous cushionfield species are threatened by competition from species such as stonecrop (*Sedum acre*), viper's bugloss (*Echium vulgare*), thyme (*Thymus vulgaris*) and invasive nitrogen-fixing species, as well as by wilding conifers. Fortunately, stonecrop, thyme and pine are largely absent from the project area.

⁵ See: [Raoulia australis • New Zealand Plant Conservation Network](#)

3.2 Cushionfield in the Bendigo-Ophir project area

Cushionfield is the highest-value ecosystem in the Site because it contains patches of native spring annual herbs and supports a suite of other 'Threatened' and 'At Risk' plant species (Table 1). In 2025 RMA Ecology mapped cushionfield as 'mixed depleted herbfield and grassland' (Figure 1; see also Appendix 1 [Maps A1.1 and A1.2], and Appendix 2). Their vegetation survey included 23 plots within cushionfield sites. This data recorded the threatened species, *Raoulia australis*, *Raoulia beauverdii* and *Poa maniototo* as abundant and *Hypericum involutum* (grassland hypericum) as common. Other abundant and common native species recorded in the survey were *Cheilanthes sieberi* (rock fern), the herbs *Dichondra repens*, *Geranium brevicaule*, and *Oxalis exilis* and the dense, low shrub *Pimelea aridula* (up to about 60 cm tall but 10–15 cm in exposed rock outcrops). *Raoulia australis* was the most frequently occurring native species.

The RMA Ecology 2023–2025 vegetation survey (Appendix One) identified abundant and common species (Appendix Two) and species occasionally found in 'mixed depleted herbfield and grassland'. The latter included *Acaena buchannii*, *Carmachaelia petrei*, *Geranium* aff. *microhyllum* and *G. potentilloides*, *Luzula banksiana* var. *rhadina*, *Olearia lineata* and *O. odorata*, *Poa lindsayi*, *Stylphelia nana* and *Vittadinia australis*. These species were found in most vegetation associations across the surveyed area so are not included in Table 1 despite having a regional or national threat status.

Table 1. Species with an Otago regional or national threat status that were most commonly identified in cushionfield by the RMA Ecology 2025 site vegetation survey.

Species	National threat status	Regional threat status
<i>Ceratocephala pungens</i>	Threatened - Nationally Critical	Threatened – Regionally Critical
<i>Myosotis brevis</i>	Threatened - Nationally Vulnerable	Threatened – Regionally Endangered
<i>Myosurus minimus</i> subsp. <i>novae-zelandiae</i>	At Risk - Declining	Threatened – Regionally Endangered
<i>Cheilanthes sieberi</i>	NT	At Risk Regionally Naturally uncommon
<i>Colobanthus brevisepalus</i>	At Risk - Declining	Threatened – Regionally Vulnerable
<i>Daucus glochidiatus</i>	Threatened – Nationally Vulnerable	Threatened – Regionally Critical
<i>Hypericum involutum</i>	At Risk – Declining	Regionally data deficient
<i>Pimelea aridula</i>	At Risk - Declining	At Risk – Regionally Declining
<i>Poa maniototo</i>	At Risk – Declining (abundant here)	At Risk – Regionally Declining
<i>Raoulia australis</i>	At Risk – Declining (abundant here)	At Risk – Regionally Declining
<i>Raoulia beauverdii</i>	At Risk – Declining (abundant here)	Threatened – Regionally Vulnerable
<i>Xanthoparmelia semiviridis</i>	At Risk - Declining	No status available (lichen)

Note: Bolded species are spring annual herbs.

Note: Threat classification extracted from NZ Plant Conservation Network

Note: There are other Regionally or Nationally At Risk or Threatened species found within cushionfields in the project area, including *Colobanthus strictus*, *Agrostis muscosa*, *Epilobium hectorii*, *Myosotis antarctica* subsp. *antarctica*, *Pellaea caliduripum*, *Poa lindsayi*, *Rytidosperma maculatum* and *Rytidosperma pumilum*.

The most frequently occurring native species (*Raoulia australis*) was recorded at a lower frequency than the non-native *Anthoxanthum odoratum* (sweet vernal), *Trifolium arvense* (hare's foot trefoil) and *Rosa rubiginosa* (sweet brier). Common smothering non-native herbs recorded included *Cirsium arvense* (Californian thistle), *Echium vulgare* (viper's bugloss) and *Verbascum* species (mulleins). *Thymus vulgaris* was recorded in cushionfield within the direct disturbance footprint and cushionfield in the wider mapped area. *Sedum acre* was found in cushionfield only in the surrounding area, and *Pinus radiata* was only found within cushionfield in the direct disturbance footprint.

The vegetation survey by RMA Ecology identified that the cushionfields on average have 3% exotic shrub (mainly brier, *Rosa rugosa*), 3% native shrub, 2% tussock and 18% exotic grass. Native and non-native herbs together covered 31% of plots on average. There were high proportions of bare ground (21%) and of rocks (15%) (see Figure 4, Figure 5 and Figure 9).



Figure 4. A variety of low- to mid-elevation cushionfields and cushionfield components on Bendigo Station (photos taken in April 2024). Left: Native woody shrubs in cushionfield have very low recruitment due to moisture stress and grazing. Centre: *Raoulia australis* (scabweed) and heavily grazed short tussocks (*Festuca novae-zelandiae*). Right: Depleted cushionfield on mid-elevation slopes: pale grey areas are scabweed cushions, and larger mounds are *Melicytus alpinus* (porcupine shrub).



Figure 5. Vegetation on Bendigo and Ardgour Stations (photos taken in Spring 2024) mapped as 'depleted herbfield'. Left: Kōwhai within depleted herbfield (pale grey *Raoulia* cushions are present but sparse). Younger (7–13 cm diameter at breast height [DBH]) trees are adjacent to a single old tree (Ardgour Station). Centre: Patch of spring annuals in the proposed Come In Time (CIT) pit. Sloped terrain with a high proportion of bare ground is typical habitat for the spring annual *Myosotis brevis* (marked with blue tags), and individuals/clusters were generally found adjacent to or within cushionfields (out of the photograph). Right: *Pimelea aridula* seedling growing in a *Raoulia* cushion.

RMA Ecology scored the relative value of mixed depleted herbfield and exotic grassland areas based on likelihood of presence of 'At Risk' or 'Threatened' plant species across Bendigo and Ardgour Stations (Figure 6), creating four classes:

- Blue = lowest value: probably no 'At Risk' or 'Threatened' plant species.
- Green = Moderate value: areas dominated by exotic plants but with at least 1 'At Risk' plant species.
- Yellow = High value: areas with two or more 'At Risk' plant species.
- Red = Very high value: presence or high likelihood of presence of 'Threatened' plant species (*Ceratocephala pungens*, *Daucus glochidiatus*, *Myosotis brevis*)

Areas of Figure 6 shown in green, yellow and red are likely to be cushionfield. Figure 6 was created using 1 ha cells using the 'mixed depleted herbfield and exotic grassland' areas. Field work to create a map that delineates the spatial distribution of cushionfield in the landscape outside the Ecological Study Area (ESA, defined by RMA Ecology for the Bendigo-Ophir Project) is proposed as the first step in the ARP to establish the values and condition of cushionfields and refine cushionfield boundaries.

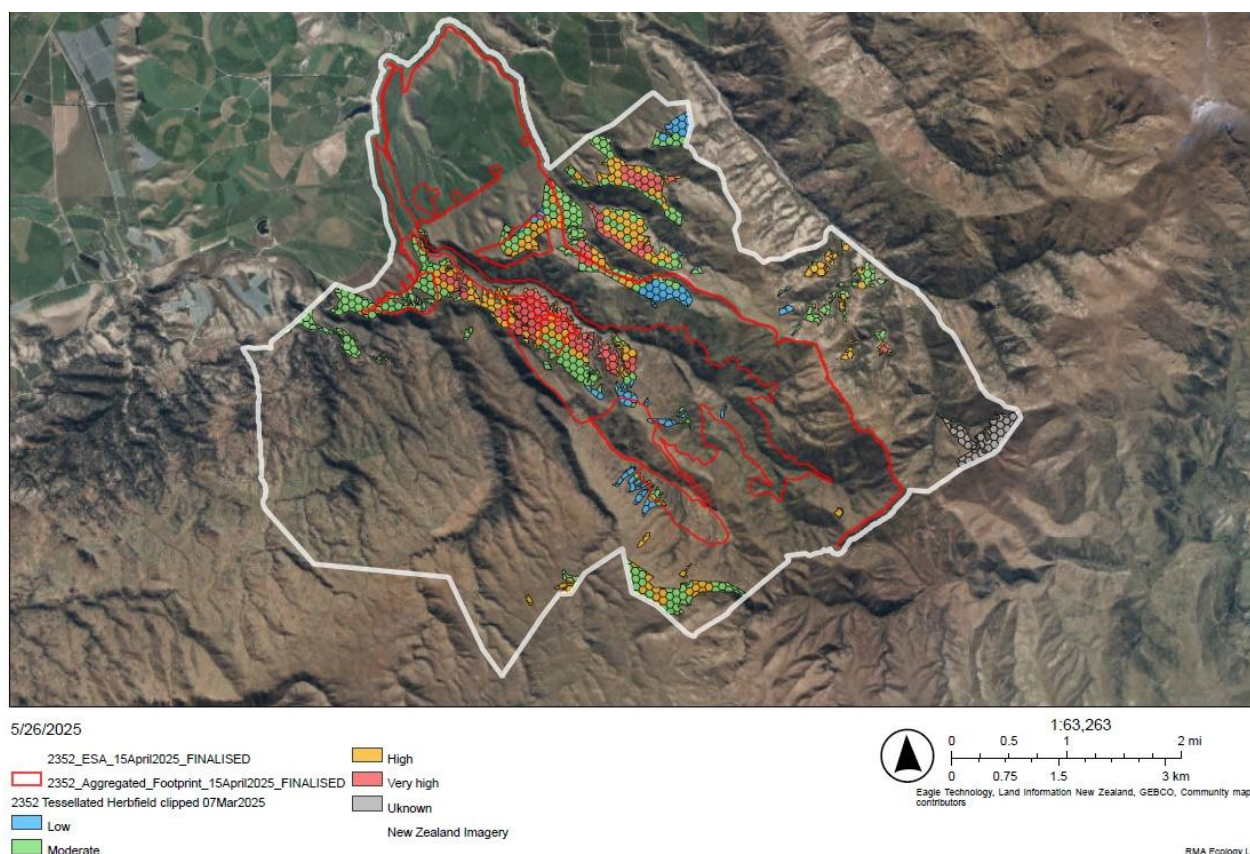


Figure 6. Map of cushionfields based on surveys undertaken by RMA Ecology in 2023-2025. Small areas are present outside the boundaries but were not part of the systematic survey. Blue = lowest value: probably no 'At Risk' or 'Threatened' plant species. Green = Moderate value: areas dominated by exotic plants but with at least 1 'At Risk' plant species. Yellow = High value: areas with two or more 'At Risk' plant species. Red = Very high value: presence or high likelihood of presence of 'Threatened' plant species. The proposed mine footprint is outlined in red. White lines show the surveyed area.
Source: RMA Ecology.

3.3 Cushionfield management units within the managed landscape

Cushionfields not removed as part of mining activities will be managed to protect and enhance their ecological values in areas adjacent to the DDF (predominantly on Bendigo Station), and on parts of Ardgour Station. This is a change to management that has occurred under a "no mining" scenario in that over-sowing and top dressing will be halted and control of brier prioritised.

'Mine management units' are shown in Figure 7 and include four 'Mine Regeneration Zones' (MRZ). MRZ-B1 contains the majority of cushionfields and MRZ-B2 contains small areas of cushionfields as does the Ardgour Predator Exclusion Area (also see Appendix 1).

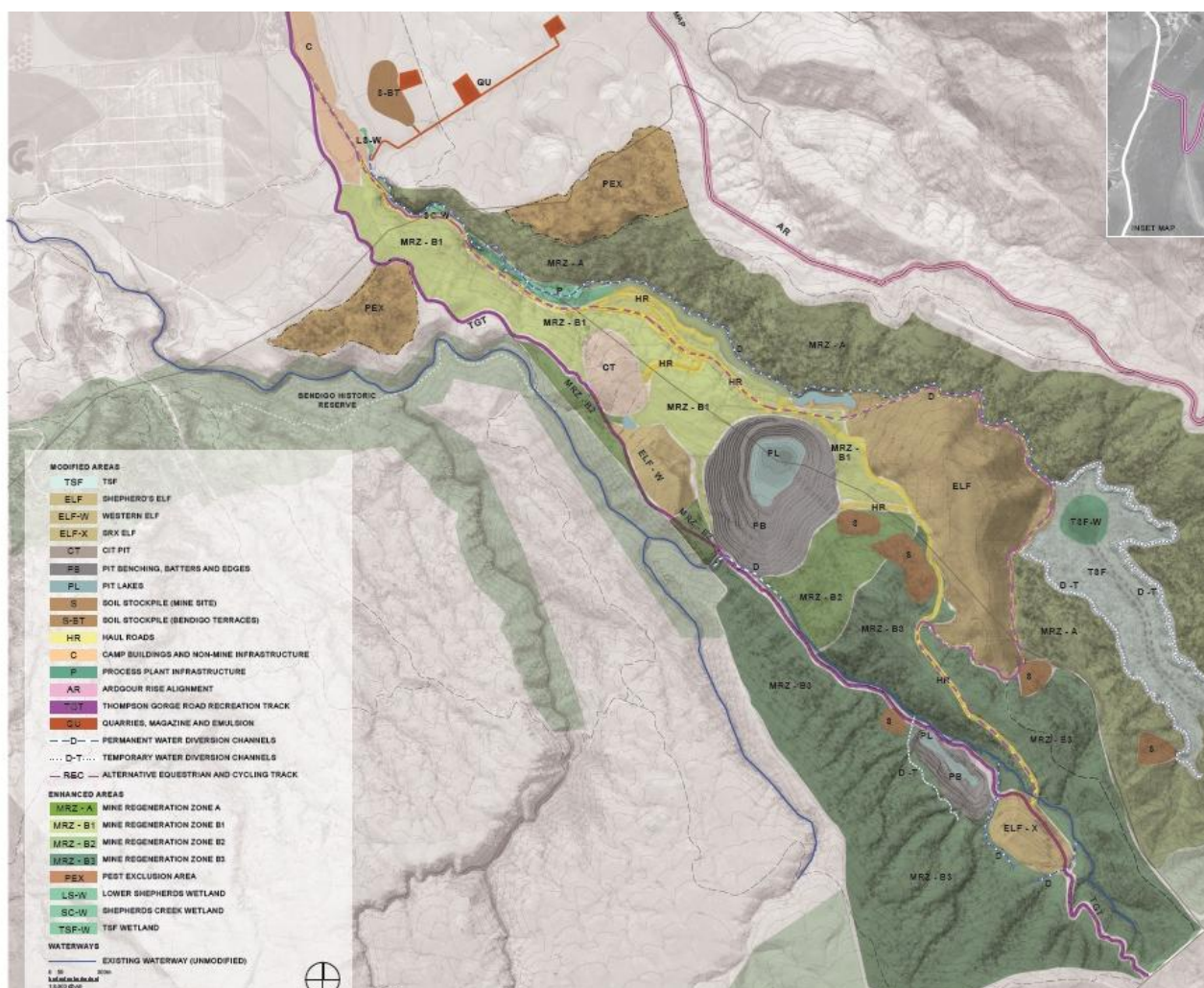


Figure 7. Rehabilitation Concept: Bendigo-Ophir Mine Landscape Management Units with cushionfield priority. The pale green unit (Mine Regeneration Zone MRZ – B1) is the primary focus for management that enhances existing cushionfield and the brown Western Engineered Land Form (ELF – W) and light grey CT (backfilled Come in Time pit) are the primary focus areas for de novo cushionfield rehabilitation. Source: Boffa Miskell May 2025.

The ARP will test methods to create cushionfields de novo within the DDF. The mine rehabilitation areas prioritised include the Western Engineered Land Form (ELF - W in Figure 7; Table 2), where field trials for establishing cushionfields are proposed starting by the end of Year 2, and the Come In Time Pit (CT) and its haul road if these are developed with the exception of approximately 3 ha of the CIT which is scheduled to be stripped as part of the main mine development and is not conditional on success of this ARP.

Table 2. Bendigo-Ophir Mine Landscape Management Units with cushionfield priority. The location of these units is shown in Figure 6 in this report.

Management unit	Name and description
MRZ – B1	Mine Regeneration Zone – Bendigo 1. A 480 ha area. MRZ-B1 aims to protect and enhance cushionfields, native spring annual herbs, and associated invertebrates as dominant components of the vegetation mosaic. A second objective is to provide an increased flow and diversity of native propagules across and into the Western ELF. MRZ-B1 is centred on the Come In Time (CIT) pit, covering north-east to north-west facing slopes. It is assumed that spring annual herb surveys (See Appendix 3: Draft proposed spring annual herb work programme, which is additional to the cushionfield ARP) will refine boundary locations with MRZ - B2, trough locations and access track locations. The priority is to maximise areas where spring annuals can be maintained by grazing if necessary. These spring annual surveys will also inform edge management for edges of haul roads and pits, focusing on sediment/runoff control, dust control, and weed management (targeting brier and species that threaten cushionfields as well as weed species that can be eradicated). Final fencing sites will consider specific management interventions and practicality of stock/rabbit control. Ongoing management will control or remove non-native woody weeds and herbaceous weeds that threaten cushionfield and spring annual herb habitat. The Applied Research Plan (APR) will develop and refine this management, with successful management interventions applied across this zone. Since cushionfield vegetation has low biomass, MRZ-B1 will serve as a fire buffer zone extending to the Rise And Shine pit high walls. This fire buffer zone may require targeted removal or reduction in plant biomass. Small rabbit-fenced enclosures will be located to promote natural seedling establishment of high-value native woody plants at the margins of cushionfields, targeting <i>Pimelea</i>, <i>Melicytus</i>, and <i>Carmichaelia</i>. Large rabbit-fenced enclosures will be established on lower slopes and in some incised gullies that separate the cushionfield spurs in areas with higher moisture and currently in non-native pasture and/or brier. In these areas (up to 1,000 m²) kowhai trees and highly palatable species will be established, taking advantage of the long-term protection provided by the surrounding fire buffer.
ELF – W	Western Engineered Landform. An 18 ha landform that is constructed within the first 2 years of mine life using the first overburden/waste rock removed from the RAS pit. Although currently shown with angular slopes, the final landforms will have slopes and aspects that better mimic the adjacent landscape, with a specific focus on creating landforms and root zones on aspects that favour establishment of cushionfields and spring annual herbs. Surface and revegetation treatments will be modified to reduce the use of palatable species so it can be grazed with sheep if necessary.
CT	Come In Time Pit. A13.8 ha pit that may be excavated towards the end of mine operations, with the particular date determined by the results and success of the Spring Annuals Applied Research programme. Edge effects management is critical including dust management. If mined, the CIT pit will be backfilled and shaped to form land contours that integrate with the surrounding terrain and blend with adjacent land features. Contours and root zones will include at least 4.5 ha of contours and soils with greatest potential to support spring annual herbs and cushionfields. Surface and revegetation treatments will be modified to reduce the use of palatable native species (which would be removed by sheep). Habitat features of rock stacks and rubble pits are likely to be concentrated away on the margins and downwind of areas where cushionfields and spring annual herbs will be established to reduce propagule pressures from native woody species into cushionfield. Patches of highly palatable species including <i>Carmichaelia</i> and kowhai will be protected using enclosures.
PEX	Predator Exclusion Fence areas. These areas will be managed primarily for lizards while also maintaining cushionfield areas that are within them

The Ardgour Station Restoration Plan (D. Norton, pers. comm. June 2025, in draft) complements the ARP and the Mine Landscape and Rehabilitation plan (Boffa Miskell June 2025, in draft). The Ardgour Station Restoration Plan has a primary objective of enhancing woody ecosystems and a secondary objective of sustaining cushionfields with their associated Threatened and At Risk flora. The cushionfields are managed as Ardgour LMU 5 (Figure 8) and cover about 258 ha of moderate to steep, north-west to north-east facing slopes within areas of 'mixed depleted herbfield and grassland' (Figure 9). Outcomes of the Applied Research Plan will be applied to these areas. The mine site and Ardgour Station are separated by proposed fire buffers shown in Figure 10.



Figure 8. Ardgour Station Restoration Area Land Management Units. The cushionfield restoration unit is LMU 5 (in teal green) on north to north-west facing, low- to mid-elevation slopes. Source: Habitat NZ.



Figure 9. Cushionfields on steeper slopes. Left: On Ardgour Station with remnant woody vegetation within rock outcrop. Right: Above Shepherds Valley on Bendigo Station with flowering *Pimelea aridula* (photos taken in spring 2024).

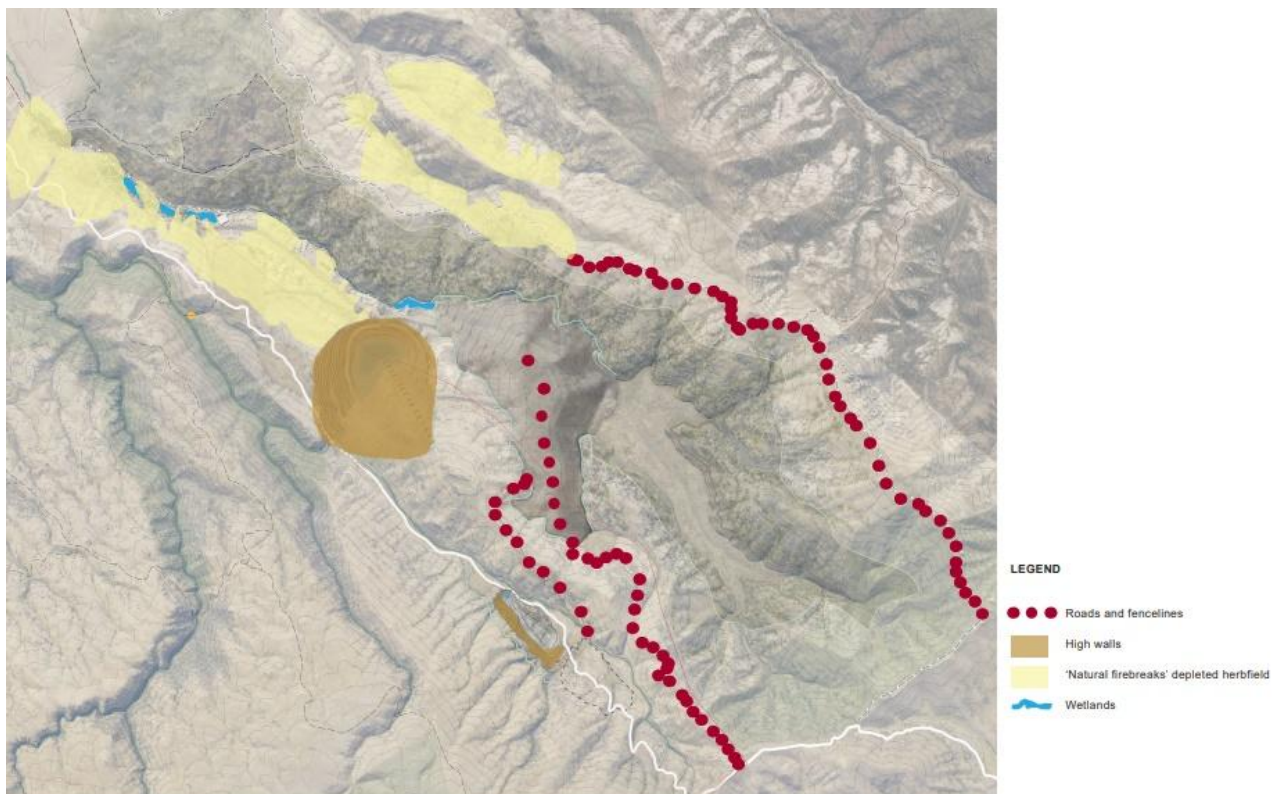


Figure 10. Draft fire buffers that are partly delivered by cushionfields, 8 March 2025. Yellow shows current large blocks of cushionfield, red are proposed ridgeline fire-buffers along roads and fencelines that will be established and maintained with low biomass plants such as cushionfields or grazed pasture. Source: Boffa Miskell

3.4 Cushionfield cultivation

This section covers background information relevant to addressing component 5 of the ARP (Develop methods for *Raoulia* propagation and establishment).

Raoulia australis is cultivated and available for purchase from some nurseries in New Zealand, including nurseries in Central Otago. There are established cultivation techniques for plants, both from seed or from divisions. For example, Moen and Meurk (1982) propagated *R. australis* for a pot experiment by taking *Raoulia* cushions from the Mackenzie Basin, cutting out equal-sized pieces from the expanding border of the cushions and planting them into 1-litre pots filled with a mix of two parts shredded bark and one part c. 2 mm crushed gravel, then irrigating as needed. Most propagation advice emphasises the need to maintain a sandy, free-draining mix to reduce impacts of root rot, and some also recommend taking cuttings or divisions in spring when plants are actively growing. The pot experiment manipulated nutrients and light, reporting that in competition with *Hieracium*, (which can overtop cushions), *R. australis* is probably most competitive when nutrients were at low levels (Moen and Meurk 1982).

4 Research aims

This ARP aims to develop and trial management prescriptions that, together, will deliver a high certainty that MGL can:

- a increase the areal extent and improve the ecological condition of cushionfields and the cushionfield mosaic within the managed landscape
- b rehabilitate cushionfield in relatively small areas on engineered landforms within the DDF, with the intent (and commitment) to scale up to larger areas if outcomes are favourable.⁶

5 Requirements of the Applied Research Plan (ARP)

Carrying out this ARP requires botanists and ecologists suitably experienced in depleted herbfields and associated plant species to undertake both the research component and aspects of the field work on site. Field work can be facilitated by engaging suitably experienced local botanists and ecologists to undertake the frequent on the ground observations required at key times of the season. Field programmes could be supported and made more efficient by assistance from staff at MGL. For example, MGL staff may have expertise in flying drones which has potential to lower the cost and increase the efficiency of some mapping and monitoring.

⁶ For example, consent conditions might be:

- Deliver a net 10% increase in the total area covered by low- to mid- elevation cushionfield ecosystem (from the baseline extent mapped in spring 2025) across areas managed by Matakau Gold over 10 years (to c. 2036), increasing to an overall 15% net increase over 20 years (to c. 2046).
- No net decrease in the condition of remaining cushionfields across the project area within 5, 10, 15 and 20 years is demonstrated by monitoring of permanent plots.

To carry out this ARP, there will also need to be coordination with farmers to manage areas of both Bendigo and Ardgour Stations to maximise ecological outcomes with no fertilisation, over sowing, application of herbicide to grey scrub, or cattle-grazing in the interim, and coordinating of lambing to allow field surveys of spring annuals when these plants are most readily observed and abundant.

6 Applied Research Plan for cushionfield ('Cushionfield ARP')

6.1 Scales and components

Cushionfields occur within a mosaic of vegetation which requires the application of a range of management tools at three scales to achieve success, as follows.

- Managed landscape 'broad scale' mapping and monitoring of cushionfield; the managed landscape area has been defined by MGL and is confined to areas they can manage on Bendigo and Ardgour Stations
- 'Paddock scale' manipulation of browse/stock grazing, of weed management and soil treatments to promote natural regeneration of vegetation associated with cushionfields while suppressing competing vegetation
- Small 'patch scale'. This involves trials to propagate *Raoulia* and establish it into areas where it is absent (e.g. mined areas), and fencing of remnant kōwhai trees, shrubs, and potentially spring annual herbs with interplanting to assist regeneration of high-value native plant species found within cushionfields.

The ARP has six components (listed below) which operate across the three scales.

Component 1: Define (map) the present extent and record the composition of the present cushionfields across the managed landscape using ground-based surveys and drone captured aerial photography (managed landscape scale).

Component 2: Identify and document the management practices and pressures that lead to cushionfield expansion and cushionfield contraction (managed landscape scale).

Component 3: Develop a range of practical extensive and intensive interventions that have potential to enhance or extend cushionfield and other elements of the cushionfield mosaic. Design trials applying these interventions supported by a suitable associated network of permanent monitoring plots (managed landscape and paddock scales).

Component 4: Establish the permanent plots and commence the restoration trials (paddock and patch scale).

Component 5: Develop methods to establish new populations of the *Raoulia* cushion species which dominate cushionfields in appropriate microhabitats, and identify methods that are unsuccessful (patch scale).

Component 6: Trial methods to protect and replant genetically diverse kōwhai treeland and shrubland areas within the cushionfield mosaic (patch scale).

This ARP is anticipated to run for at least 7 years, with most of the effort and cost in the first 4 years as the later years will mainly involve monitoring the trials. However, it is expected that monitoring of the permanent plots will be continued for a considerably longer period.

6.2 Complementarity between the cushionfield ARP and the spring annuals work programme

There is some overlap and complementarity between this cushionfield ARP and existing the spring annuals work programme (Appendix 3 of this report). The threatened spring annual species occur largely or even entirely within cushionfield.

Both the cushionfield ARP and the spring annuals work programme require more detailed, targeted surveys than has been undertaken to date. The base 2023 to 2025 RMA Ecology vegetation survey (Appendix One) will be used to inform and increase the efficiency of the detailed surveys. For example, in both this ARP and the spring annuals work programme, the information from the base survey suggests a focus on edges and gradients between cushionfields and either pasture areas or areas with taller woody vegetation will be useful.

It is also important for the Component 1 mapping to identify where spring annuals are present within areas of the managed landscape with largely non-native vegetation that may otherwise be a target for establishment of cushionfields. This reduces the risk that spring annual populations would be harmed during the process of establishing cushionfields.

6.3 Components of the cushionfield ARP

The six components of the ARP are described below. Each component will include 'by exception' annual reporting and three-yearly comprehensive reporting. The timing provided is before the commencement of mining, which may be in 2026.

Given the importance of outcomes, subsequent actions, and the potential regional and national value of ARP, field and desk-based review by one or two suitably qualified independent reviewers is proposed for each comprehensive report. It is considered that independent reviewers could assist the outcomes of this ARP by generating additional ideas for management interventions.

6.3.1 ARP Component 1. Map the present extent and record the composition of the present cushionfields across the managed landscape.

This component (ARP 1) will provide a map and detailed information about the distribution and condition of known key plant communities and plant species within the ESA, with a focus on cushionfield.

This mapping will underpin the other components of the ARP. It will also help to prevent inadvertent harm to cushionfield within the managed landscape through ensuring that harmful activities and actions (such as installing stock watering infrastructure, fences, and tracks) are located away from ecologically valuable features and locations. The mapping will also be used to inform changes (if any) of stock fence locations to provide for ongoing grazing of sheep and/or rabbits (cattle will not be used) and to complement fire buffer zones.

The work in ARP 1 will undertake the following tasks.

- Determine appropriate indicators of the presence of cushionfield (e.g. *Raoulia* species cover, rock and soil cover, presence of indicator species, maximum cover in higher tiers and species in those tiers).
- Sample vegetation plots in a modified fish-net grid that covers areas where cushionfields are and potentially could be present (but not sampling sites where cushionfields are always absent).
- Collect (and arrange analyses of) soil samples from across the sampling grid to determine what soil factors (if any) are driving the presence and quality of cushionfield (an estimated 140 samples required to cover the gradient).
- Use the data collected from the vegetation sampling plots to:
 - map the boundaries of cushionfields across the managed landscape
 - define a cushionfield condition gradient to score patches of cushionfield vegetation. The condition score may include indicators such as cover of cushions, indigenous species diversity, presence of selected indigenous indicator species, bare soil and rock cover, weed presence and cover, and soil disturbance
 - map the distribution of key weed species (e.g. stonecrop, viper's bugloss, sweet brier, mullein, thyme) to assist with the biosecurity plan and planning effective management interventions.
- Apply the condition gradient to identify and map areas where cushionfield is healthy or expanding and unhealthy or contracting.

When: Spring 2025 but to be confirmed by MGL.

Requirements

- Development of appropriate survey methods (influenced by analysis done for 2024 data and capabilities of drone imagery), then survey and analysis of results. Survey time will depend on the number of sampling points (TBD by fieldwork scoping).
- Scoping field work to confirm effectiveness of approach.
- Main fieldwork campaign.
- Liaison with drone operator (likely to be a MGL contractor) to confirm flight paths, timing to detect species of interest, data capture and management of files.
- Data entry, compilation and analysis of survey results to create classification of plots.
- Creating polygons that identify boundaries of current cushionfield.
- Developing a cushion quality gradient from the data and classification and add condition classes and/or scores to the map.
- Initial consultation with MGL's farm consultants and technical experts on the ground.
- Collection and analysis of soil samples. It is anticipated c.140 samples are needed to cover the gradient and that analysis will be confined to nitrogen, phosphorus, sulphur, and organic matter. Sodium and salinity will only be measured if any suspected saline areas are encountered. Soil pH is not considered a driver on these soils and farmers do not apply lime to these hills.

Dependencies

- Establishment and coordination of technical experts in cushionfield and pasture management by MGL.
- Access during lambing period to areas of Bendigo and Ardour Stations with cushionfields. Verbally confirmed by M Askey (M Askey, MGL pers. comm., May 2025) with map of paddocks and timing of access).

6.3.2 ARP Component 2. Identify and document the management practices and pressures that lead to cushionfield expansion and contraction

Use the map of cushionfield quality/condition from Component 1 to identify thresholds or early indicators of transformation to another vegetation type (e.g. weeds that facilitate competing plants to establish such as brier, mullein, and viper's bugloss).

Understand both current disturbances and past disturbances (over the last 20–30 years) using data from Component 1 and aerial photographs, interviews with land managers/farmers, and records of disturbance for drilling/prospecting held by MGL, and data on rabbit browse pressure or densities.⁷

Conduct interviews with farmers and farm managers (as appropriate) to help to confirm the recent and past management regimes across the site, particularly the timing of grazing, and the rabbit control and oversowing and topdressing (OSTD) history if these are unavailable.

MGL records of drilling will be reviewed as this will show when areas through cushionfields were stripped and when pasture (erosion control) was established along drill tracks and drill sites.

These steps will help identify the most favourable management regime to maintain cushionfield in the interim as a 'base treatment' and ensure that this regime continues, because this is a least risk approach.

At the end of this stage a report with recommendations and the baseline dataset will be delivered. These results will be used to inform ARP 3.

When: Summer 2026 (i.e. immediately after completion of Component 1).

Requirements

- Data collection, i.e.
 - liaison with rabbit monitoring contractor to confirm areas, timing and data required,
 - Matakanui Gold records of areas disturbed and sown
 - farmer and farm manager interviews- –review of maps/data/records.
- Data entry and analysis of results.
- Creating maps of factors that influence cushionfield distribution.

⁷ Measurement of rabbit densities is likely to be proposed as part of the pest management plan and for compliance with Otago Regional Council Pest Management requirements. However, to achieve desired ecological outcomes it may be necessary to maintain relatively consistent rabbit densities (which has also been linked to minimising predation of lizards by mice, as higher pasture grasses density tends to support higher mouse densities)

- Analysis and write up of reports.

Dependencies

- Successful completion of ARP Component 1.
- Collaboration with farmers/land managers.
- Data from MGL on areas disturbed during prospecting and their treatments.
- Drone and rabbit monitoring contractors available and able to provide required data.

6.3.3 ARP Component 3. Develop a range of practical extensive and intensive interventions that have potential to enhance or extend cushionfield and other elements of the cushionfield mosaic. Design trials applying these interventions supported by a suitable associated network of permanent monitoring plots.

The output from this component is an experimental design, which will include locations and types of treatments, and the permanent plots and methods needed to monitor them.

ARP 3 will first identify the extensive (large-scale) and intensive (small-scale) interventions that are likely to promote natural establishment of new plants. *Raoulia* species produce large amounts of light seed that are blown across the landscape, potentially providing for natural establishment of seedlings that will later form cushions.

ARP 3 will then use data from ARP 1 and 2 to identify where extensive management interventions are probably 'easy' (low risk, low-cost, long-term) and where they are 'possible' but more difficult (higher risk, more intensive manipulation needed). Pressures are likely to be both direct and indirect and include plant competition, soil properties (fertility/water holding capacity/rooting depth) and grazing. (This is why ARP 1 includes the survey of areas where there is currently no cushionfield, to cover all possible environments.)

Having identified the treatments and layout of the experimental programme, ARP 1 data will then also be used to identify how many plots are needed to detect statistically robust changes across the manipulated and 'control' areas.

Extensive interventions are likely to include the following and would be applied to whole paddocks on Ardgour Station within LMU 5 (Figure 7) and to MRZ-B1 on Bendigo Station (Figure 6). These include:

- sheep grazing management using the timing, intensity and duration to control competition of non-native herbaceous species with cushionfield species
- rabbit management (without sheep grazing);
- targeted control of non-native plant species (removal of brier and other weed plants identified in the survey as having potential to invade and suppress cushionfields and considered to have feasible methods for control).

Intensive interventions are likely to be applied to parts of paddocks where the density of *Raoulia* cushions can be increased or patches expanded without compromising habitat for spring annual herbs. Treatments are likely to increase the natural establishment of a range of native species, hence a mixture of methods is likely to be adopted to target higher-value native species. ARP 3

will identify a subset of areas in which to apply these intensive interventions. The majority of these sites are likely to be in MRZ-B1.

The interventions could include:

- harvesting and removal of non-native grass with/without scalping of soil with the aim of lowering fertility and increasing drought stress
- timing soil disturbance /plant removal and creation of seed beds with peak *Raoulia* seed release (providing the seeds a 'head start' in the most favourable window of opportunity)
- adding salt (to reduce competitiveness of less tolerant species) or sugar (to reduce fertility and increase drought stress (with the timing and concentration of both amendments important)
- broad-scale or spot application of herbicide to competing weeds, and managing tap rooted weedy species (such as hemlock and thistles) that suppress cushionfield vegetation, noting that some of these areas support spring annual populations
- seeding *Raoulia* or planting nursery-raised and fully-hardened *Raoulia* seedlings (see Section 6.3.4) for all proposed interventions).

When: Autumn–winter 2026, after the completion of ARP 2.

Requirements

- Power analysis to determine the appropriate number of permanent monitoring plots for extensive areas.
- Co-ordination with Pest Plant and Pest Animal Management Plans (providing efficiencies in control and monitoring), Invertebrate Management Plan and Lizard Management Plan (all these Plans are from Matakanui Gold).
- Liaison with Matakanui Gold and farm manager/s for grazing treatments, to determine the practicality of the experimental design.

Dependencies

- This work will be based on the results of ARP Components 1 and 2.

6.3.4 ARP Component 4. Implement restoration trials and establish the permanent plots

This component implements the agreed experimental design from ARP Component 3. It includes establishing the permanent plots, which are measured in spring 2026 before any treatments are applied. The treatments are initiated the following early spring (2027 year 3) and the permanent plots are remeasured then, and again annually thereafter in spring for (at least) a further 4 years, this being a period that is likely needed to show sustained outcomes given potential variability in annual growing conditions and slow growth rates of *Raoulia* likely at this site.

When: Starts spring 2026, after the completion of ARP 3, continuing over the following 4 springs.

Requirements

- Permanent plot establishment for the experimental design in spring.

- Rabbit fencing and other standard control methods within specified zones and around specified plant species.
- Targeted weed management and intensive interventions with controls.
- Monitoring of plot across the experimental treatments annually in spring.

Dependencies

- This work will be based on the results of ARP Components 1, 2, and 3.
- MGL installation of any infrastructure (e.g. rabbit fences) and any intensive interventions (e.g. soil scraping) and treatments (e.g. weed spraying or physical removal, stock management).
- Permanent plot monitoring requires access each spring (i.e. there can be no lambs or lambing in the experimental areas).

The development and implementation of a comprehensive biosecurity plan that identifies pest plants and manage their eradication where practicable or control their spread (e.g. sedum, echium, hemlock, thyme, mullein, *Festuca filiformis*). The biosecurity effort is required to protect the investment in cushionfield management, and slow invasion of 'clean' areas by 'keeping clean areas clean'. For example, ensuring species such as stonecrop and thyme remain absent at these sites is a precondition for enabling cushionfield retention and expansion.

6.3.5 ARP Component 5. Develop methods for *Raoulia* propagation and establishment of new populations of *Raoulia* cushion species and identify methods that are unsuccessful

Raoulia species are the dominant indigenous plants in cushionfields. This component will provide information on *Raoulia* species rooting, to inform the soils and root zones that are created on mined landforms. It will also shift established *Raoulia* alongside scheduled soil and vegetation stripping, and planting nursery-raised *Raoulia* into mined areas and areas with intact soils (to expand or 'fill' existing areas of cushionfield). This is proposed as a small initial investment because anecdotal reports of individual clump relocation (associated with earthworks for cycleways and housing subdivisions has been attempted at three local sites) indicate no success to limited success (Wardle 2024). However, *Raoulia australis* and *R. beauverdii* are propagated and grown by specialist nurseries in New Zealand and are reputed to be readily propagated from fresh seed and rooted pieces under nursery conditions (see Section 3.4).

Work will be performed in areas where cushionfield is to be removed for mining activities and excavate *Raoulia* cushions from across a range of slopes and aspects. The work will characterise the root distribution of the excavated *Raoulia* in relation to soil profiles to understand local rooting depths, changes at soil textural boundaries, and spread of roots from individual plants.

Destination sites for these cushions will be selected to ensure soils are similar and without high weed burdens. Initially, a transfer of >50 m² of *Raoulia* mats in spring and early summer over 3 successive years, by excavating entire rooting depth of whole plants. Rooting depth is anticipated to be 300 to 600 mm or more, and the transfer is anticipated to be most successful in spring when soils are moist and less crumbly. Then it is necessary to monitor these transplants and the disturbed soils adjacent to them (where new seedlings may emerge from translocated soils or from wind-blown seed) for at least 3 years after establishment. These destination areas may include previously mined areas.

A local nursery may be able to grow two *Raoulia* species in two pot depths (to achieve different rooting depths, which in mature plants are shown as concentrated in the upper 40 cm but extending in moderate density through alluvial soils to 1.7 m depth (Wardle 1991)) from seeds and propagules collected from the site. Plants will be hardened off onsite for at least 6 months (enabling them to acclimate to the harsh local conditions prior to planting out) and planted out at least 80 plants/year in each of 3 successive years into favourable root zones (i.e. planned as soils with > 1.2 m potential rooting depth of soil over weathered brown rock) and locations in the Western ELF (due for completion of profiles in Year 2) and degraded areas of MRZ-B1, using results from ARP1 (survey)). It will be necessary to monitor survival and growth of *Raoulia* and adjacent plants (assessing their potential impact on *Raoulia*) for at least 3 years after establishment.

When: Starts in 2026 for at least 6 years (from Year 2).

Requirements

- Initial work to arrange suitable nursery contract and/or lease/rent space in local nursery.
- Coordination with earth-moving / vegetation stripping contractor and MGL staff to schedule and identify suitable stripping and relocation sites for translocation trial.
- Supervision of the translocation of plants.
- Measurements of rooting characteristics of translocated plants.
- Ongoing monitoring of translocated and transplanted plant health.

Dependencies

- Nursery able to grow the number of plants to the standard required.
- A plant hardening off area is available on site to store and acclimate the nursery plants prior to planting out.
- Mine rehabilitation areas available on site from which to strip cushionfield and *Raoulia* mats, and to re-establish and protect them in areas that will not be subsequently disturbed to ensure their protection from establishment onwards.

6.3.6 ARP Component 6. Trial methods to protect and replant genetically diverse kōwhai treeland and shrubland areas within the cushionfield mosaic

Results of ARP 3 will be used to identify areas that are not favourable for cushionfield but within the cushionfield ecosystem mosaic. Within these areas, sites will be identified that are likely to be suitable for the re-establishment of kōwhai treeland and shrubland and fence them securely against stock and rabbits, to create exclosures. These areas will usually have relic short tussocks and be in periodically moist microsites with deeper soils, such as in gullies, on the downwind and southerly aspect of rounded spurs, around rock tors and outcrops, or on seeps.

The trial aims to determine how practical and achievable it is to provide for the re-establishment of more browse-sensitive tree and shrub species, especially kōwhai (*Sophora microphylla*) and drought-tolerant shrubs, such as *Melicactus*, *Pimelea*, and *Corokia*, all of which are vulnerable to seedling browse.

Progress from trial plantings onto full-scale plantings depending on the results.

Manage weed invasion and competition.

When: Starting with planting into exclosures in spring 2026 for at least 7 years.

Requirements

- Identify and delineate suitable sites using prior on-the-ground and drone surveys from ARP Components 1 to 3.
- Fencing and local rabbit exclosure fencing by MGL staff.
- Propagation – Contract or lease/rent space in established nursery. Ideally a local nursery propagator and field botanist.
- Planting – once a year (depending on number of plants and number of sites, probably spread over 2 visits as planting is weather dependent);
- Monitoring of survival and natural recruitment once a year for at least 3 years following establishment by field botanist and MGL staff.
- Ongoing management of fences, competing plants (weeding), once a year (depending on number of plants, number of sites, weeds being controlled and growth conditions) and with reference to the MGL's Pest Plant Management Plan.

Dependencies

- Nursery able to grow the number of plants to the standard required.
- Hardening-off area is available on site.
- Fencing is effective at excluding rabbits.

7 Program Review and Closeout

A whole-of-program review will be undertaken in year 6 (i.e. at the completion of the year five program). This review is intended to inform the development of potential future programs of work, including ongoing development and enhancement of cushionfields and further research (and/or monitoring) if necessary. This timing is likely to provide adequate time to assess trends, consider ongoing and alternative measures and develop an agreed program that can commence at the completion of the program proposed in this plan (i.e. end of year 7).

A final report on the program will be completed at completion to close out the program of work.

8 Conclusions

This ARP is intended to inform the conservation management, rehabilitation and expansion of cushionfield ecosystems. Cushionfields are characteristically dominated by indigenous *Raoulia* species and there is often a presence of indigenous spring annual herbs. and invertebrates of high ecological value

- Experience in the management, rehabilitation and expansion of cushionfields is extremely limited. *Raoulia* and many other cushionfield species are propagated in nurseries but none

have previously been planted at scale. However, some recent small-scale trials have begun to investigate the use of amendments, and earthworks to favour cushionfields, while monitoring indicates ongoing browse and/or grazing management may be required.

The project landscape is a mosaic of cushionfields, tussock grassland, grey scrub and introduced pasture, requiring a range of management tools to achieve success at three scales.

- Whole site or 'broad scale' mapping and monitoring of cushionfield (including the threatened spring annuals) in areas managed by Matakani Gold on Ardour and Bendigo Stations. This area is referred to as the 'managed landscape'.
- 'Paddock scale' manipulation of browsing and stock grazing, weed management and soil treatments to promote natural regeneration of vegetation associated with cushionfields while suppressing competing vegetation.
- Small 'patch scale' interventions and management, involving (1) trials to propagate *Raoulia* species and establish them into areas where it is absent (e.g. pasture and mined areas); and (2) fencing of remnant kōwhai trees, shrubs, and potentially spring annual herbs with interplanting to assist regeneration of high-value native plant species found within cushionfields.

The Applied Research Plan for cushionfield ('cushionfield ARP') has six components implemented across at least 7 years.

Component 1. Map the present extent of cushionfield across the managed landscape to determine its present distribution and confirm success criteria for the condition of key cushionfield attributes using ground-based surveys and testing drone-captured aerial photography (Year 1).

Component 2. Identify current pressures on cushionfield and best current management for the cushionfield vegetation type (Year 2)

Component 3. Identify areas where cushionfield could be most likely enhanced (including a range of typical co-occurring herbaceous and woody species), and develop a range of practical extensive and intensive interventions and (Year 2)

Component 4. Implement restoration trials and establish permanent plots (from Year 2)

Component 5. Develop methods for *Raoulia* propagation and establishment (from Year 2)

Component 6. Protect and replant genetically diverse kōwhai treeland and shrubland areas within cushionfield mosaic (from Year 2).

9 Acknowledgements

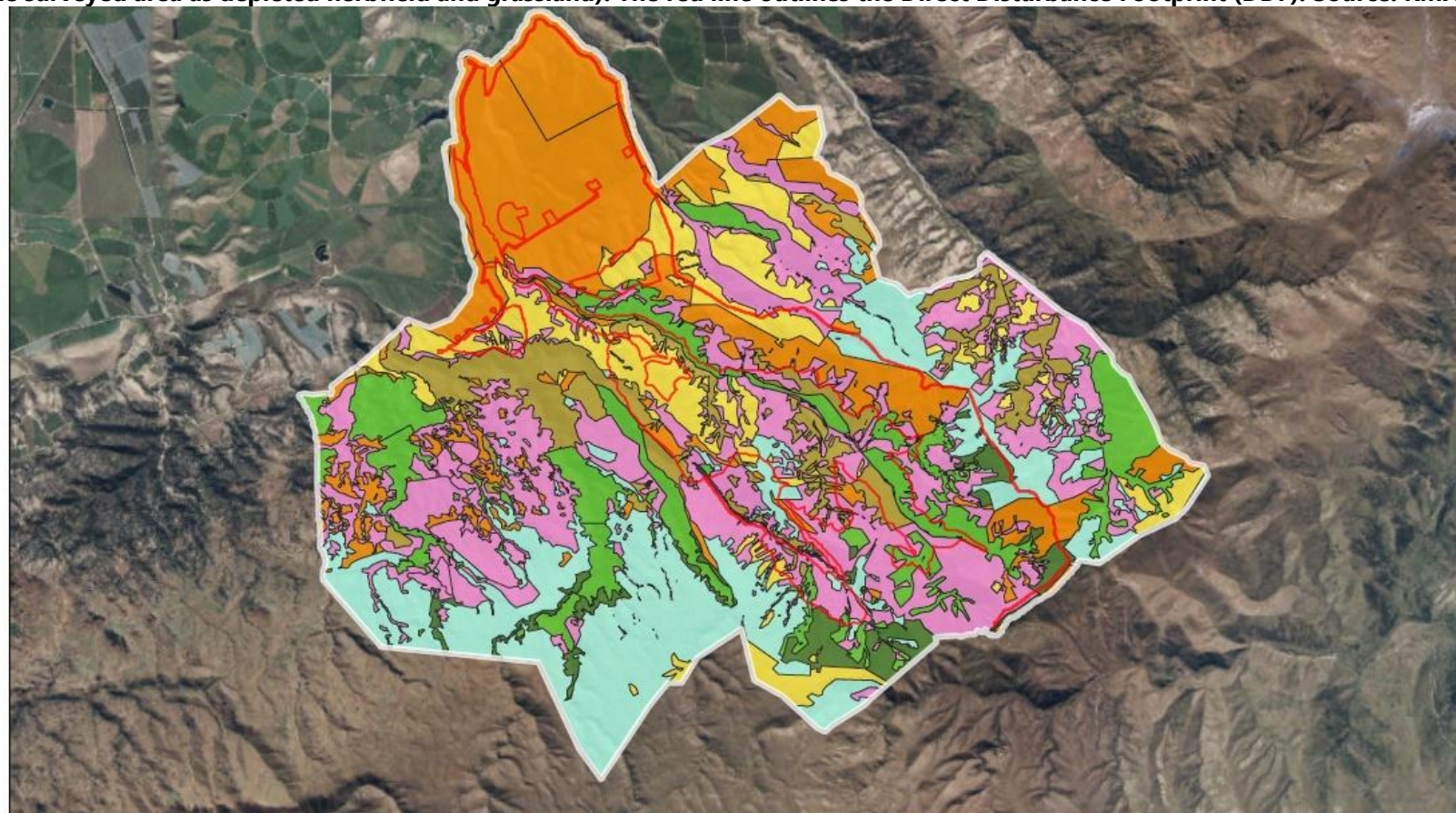
The draft ARP was reviewed by Matt Baber (and ecology project lead), Zac Milner, Duncan Nicol and Graham Ussher (RMA Ecology) and Keith Barber (Habitat NZ). RMA Ecology and Habitat NZ provided the maps used in the report and gave permission for their use, Zac Milner (RMA Ecology) provided summary data from vegetation surveys and detailed review comments, David Norton provided observations and management information for Ardour Station. The ARP was reviewed by Mary Askey (Environmental Manager) and Damien Spring (CEO) of MGL.

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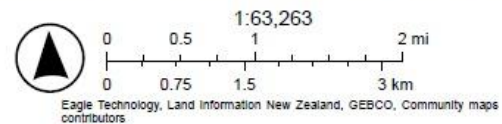
Appendix 1 – Maps

Map A1.1. Vegetation communities in the Ecological Study Area (ESA) (about 5,000 ha) outlined in white. Cushionfields are yellow, mapped over 10% of the surveyed area as depleted herbfield and grassland). The red line outlines the Direct Disturbance Footprint (DDF). Source: RMA Ecology, May 2025.



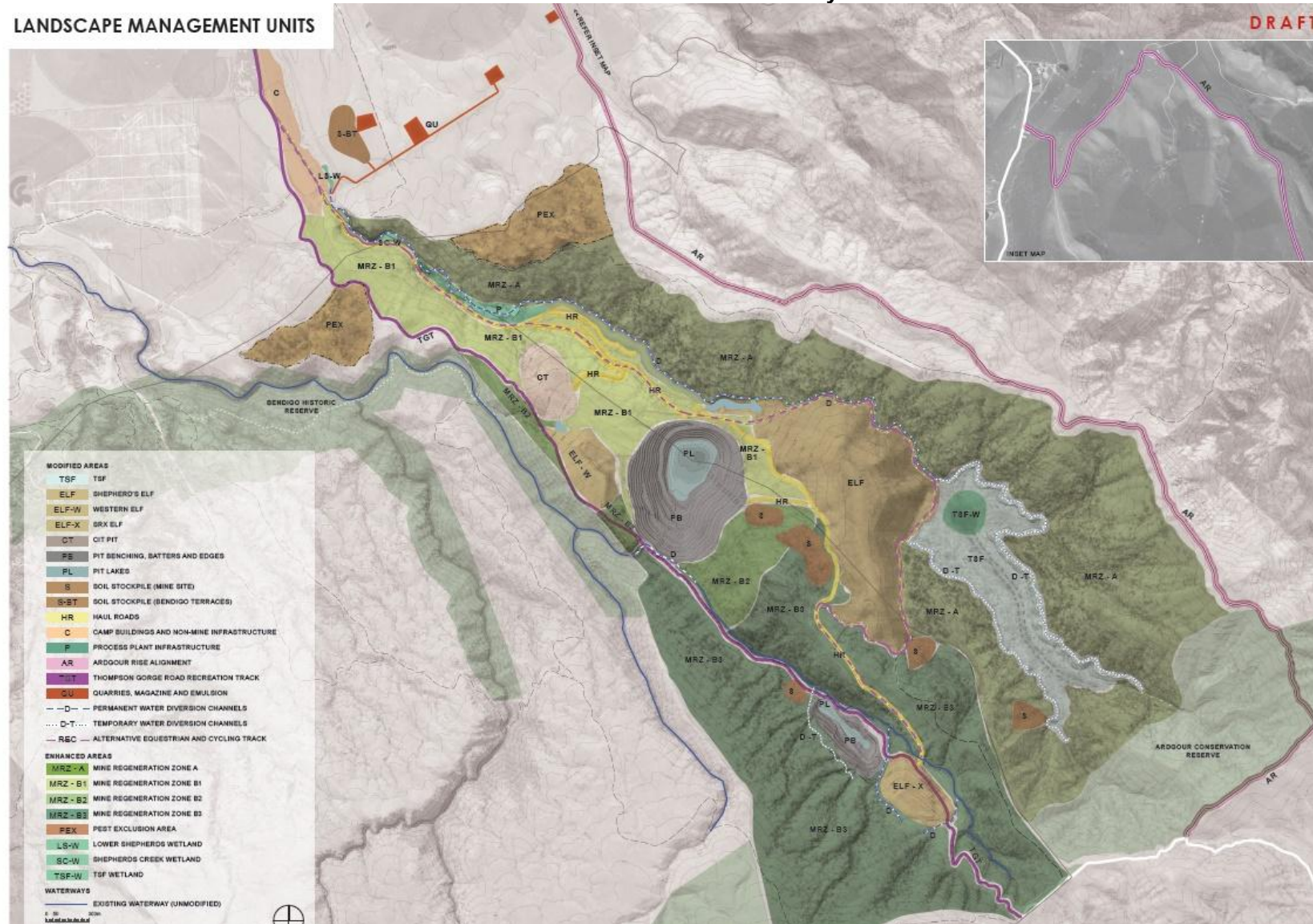
5/26/2025

- | | |
|---|---|
| 2352_ESA_15April2025_FINALISED | Native dominant tussockland |
| 2352_Aggregated_Footprint_15April2025_FINALISED | Mixed tussock shrubland and exotic grassland |
| 2352_Vegetation_excluding_wetlands_within_ESA_16April2025_FINALISED | Mixed depleted herbfield (cushionfield) and grassland |
| Native herbland (taramea) and shrubland | Exotic pasture |
| Native dominant scrubland | New Zealand Imagery |
| Mixed scrubland | |

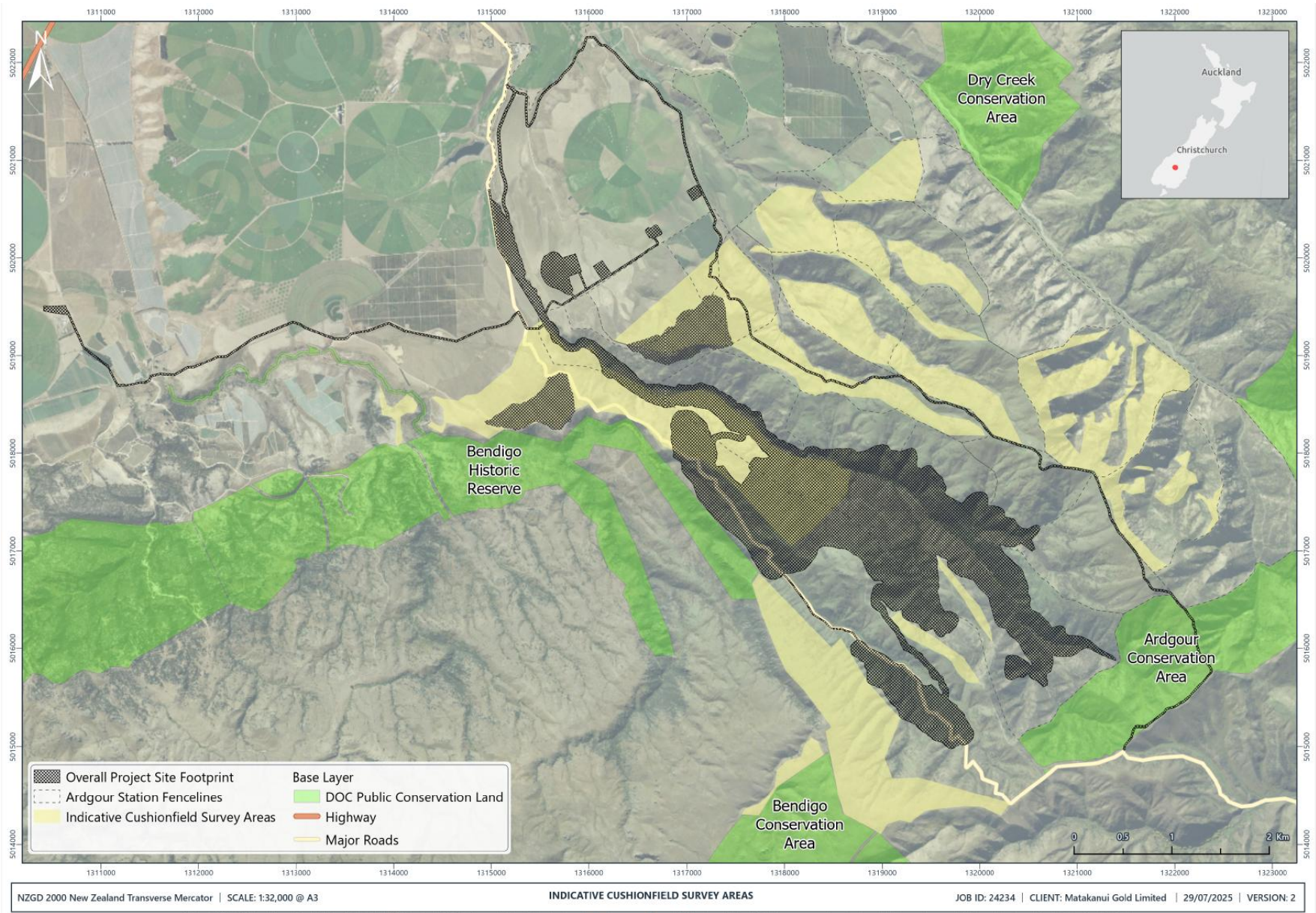


RMA Ecology Ltd

Map A1.2. Rehabilitation Concept: Bendigo-Ophir Mine Landscape Management Units with cushionfield priority. The Mine Regeneration Zone MRZ-B1 (pale green) is a focus for cushionfield enhancement, the Western Engineered Landform (ELF-W) and CT (backfilled Come in Time pit) are the primary focus areas for cushionfield rehabilitation in mined areas. Source: Boffa Miskell May 2025.



Map A1.3. Indicative cushionfield survey areas forming the 'Managed landscape'. Source: MGL July 2025.



Appendix 2 – Species within ‘mixed depleted herbfield and grassland’ that were abundant or common in RMA Ecology vegetation survey plots 2023-2025.

Mixed depleted herbfield (cushionfield) and grassland species	
Scientific name	Common name
<i>Acaena agnipila</i> var. <i>aequispina</i>	sheep's bur
<i>Aira caryophyllea</i> subsp. <i>caryophyllea</i>	silvery hair grass
<i>Alchemilla arvensis</i>	field parsley/parsley piert
<i>Anthoxanthum odoratum</i>	sweet vernal
<i>Bromus diandrus</i>	ripgut brome
<i>Bromus hordeaceus</i>	soft brome
<i>Bromus tectorum</i>	cheatgrass
<i>Cheilanthes sieberi sieberi</i>	rock fern
<i>Cirsium arvense</i>	Californian thistle
<i>Dichondra repens</i>	dichondra
<i>Echium vulgare</i>	viper's bugloss
<i>Erodium cicutarium</i>	storksbill
<i>Geranium brevicaule</i>	Alpine crane's bill
<i>Hypericum involutum</i>	
<i>Hypericum perforatum</i>	Saint John's wort
<i>Marrubium vulgare</i>	horehound
<i>Myosotis stricta</i>	blue forget-me-not
<i>Oxalis exilis</i>	creeping oxalis, yellow oxalis
<i>Pilosella officinarum</i>	mouse-ear hawkweed
<i>Pimelea aridula aridula</i>	
<i>Poa maniototo</i>	desert poa
<i>Raoulia australis</i>	golden scabweed
<i>Raoulia beauverdii</i>	
<i>Reseda luteola</i>	wild mignonette
<i>Rosa rubiginosa</i>	sweet brier
<i>Rumex acetosella</i>	sheep's sorrel
<i>Stellaria gracilentia</i>	slender chickweed
<i>Trifolium arvense</i>	hares-foot trefoil
<i>Verbascum thapsus</i>	woolly mullein
<i>Verbascum virgatum</i>	moth mullein
<i>Veronica verna</i>	spring speedwell

Note In this table, no common name is provided for species where none is known or not yet agreed green identifies native species. Source: RMA Ecology, provided May 2025.

Appendix 3 – Proposed spring annual herb work programme

March 2025

R Simcock, G Brownstein, S Walker

1. Introduction

Populations of 'Threatened' and 'At Risk' spring annual herbs were identified within the project footprint in spring 2024. Four spring annual species were recorded, including *Ceratocephala pungens* and the mousetail *Myosurus minimus* subsp. *novae-zelandiae* (both in the buttercup family), and *Myosotis brevis* and *Myosotis a. subsp antarctica* (two forget-me-nots in the borage family) (Fig. A3.1). Later, the botanical survey also identified the presence of *Daucus glochidiatus* in the Ecological Survey Area (New Zealand carrot; usually a biennial up to 300–800 mm high but has an annual habit in harsh conditions such as found in Central Otago). It is possible that this species is also within the project footprint, although it has not yet been found there.



Figure A3.1. Three of the spring annual herb species growing together within the project site. (Figure: Zac Milner RMA Ecology, Spring 2024.)

A heat map was developed which shows the predicted presence of the threatened spring annual species (*Ceratocephala pungens* and *Myosotis* spp.) across the proposed mine footprint (Fig. A3.2).

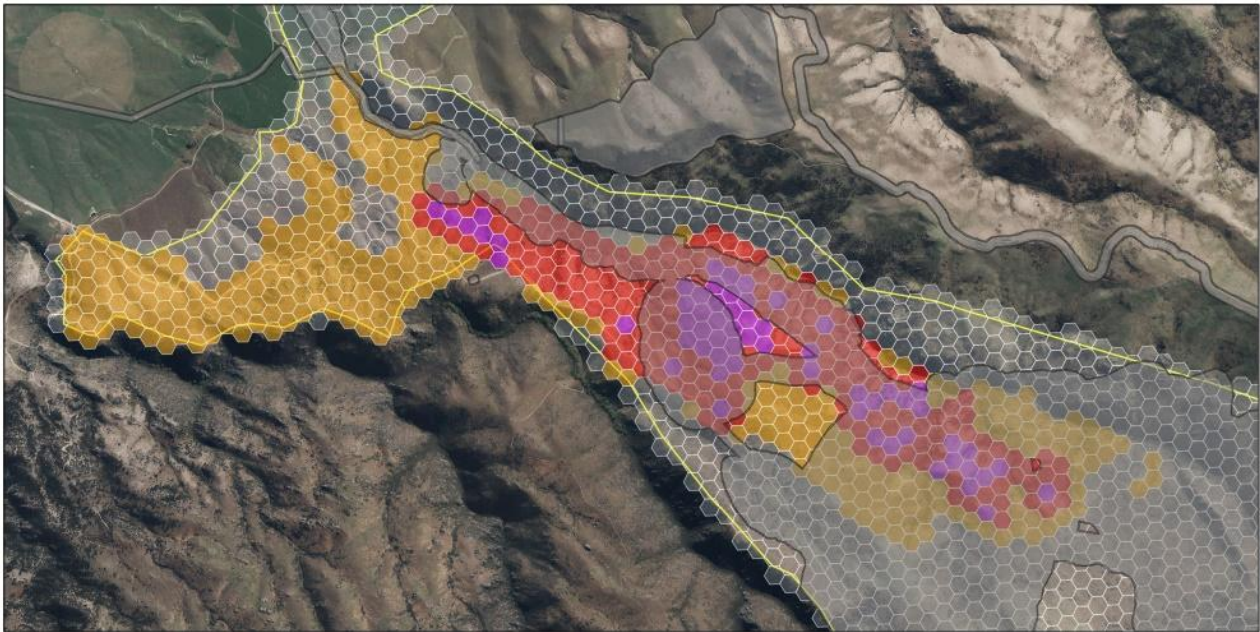


Figure A3.2. Heat map for likelihood of threatened spring annual species (*Ceratocephala pungens* and *Myosotis* spp.) across part of the proposed mine footprint (yellow lines): PURPLE = confirmed; RED = likely; ORANGE = possible; GREY = unlikely. Yellow lines are the project footprint. The tessellation grid unit size is 0.5 ha. (Source: Milner 2024.)

The heat map was finalised on 23 Dec 2024 and the variables used to identify potential habitat, included aspect, vegetation community, shading, soils, competition, proximity to nearby known presences, searched areas, and effort expended. It is posited an association between these predictors and the local distribution of the target species, and now the association needs to be tested statistically. It is important to note that because lambing constrained access, data were gathered towards the end of the season when some individuals had already senesced and blown away. Therefore, the heat map is likely to underestimate the true extent and likelihood of occurrence.

Spring annuals are unusual and distinct in New Zealand flora, as very few plant species show this life history.⁸ Spring annuals are adapted to the seasonally dry environments of eastern New Zealand; they germinate in the late winter and early spring while the soils are still moist. As soils dry, the plants flower, set seed, and die off, leaving (dormant) seed to survive the summer. Timing of these stages is likely to vary across years (e.g. perhaps depending on the severity of winter cold, the timing of cold snaps, the duration of winter-spring moisture levels), and across the landscape (e.g. with elevation).

The conservation needs of these species are unclear. They have patchy distributions in the landscape, and little is known about their habitat and 'microhabitat' requirements or basic phenology (what pollinates the flowers, when seeds are ripe, how many seeds per plant, seed dispersal range/method, and how long can seeds be stored for). However, all four species appear to require bare or sparsely vegetated ground with low competition, and perhaps some form of disturbance to maintain a population (Figure A3.1, Figure A3.3, Rogers et al 2007). Rogers et al.

⁸ Rogers et al. 2002 list four species, however the *Myosotis* genus has been revised since then.

(2002) contrast the 'genuine non-forest habitats' of ephemeral wetland of *Myosurus*, the "desert" pavement habitat of *Ceratocephala*, and the turf and gravel habitat surrounding water bodies of *Myosotis*, all of which have a strong summer moisture deficit with the 'facultative farming-induced' scabweed or mat vegetation on dry hillslopes. Bendigo populations likely fall into the latter category as sodic or saline soils have not been identified.

None of the four spring annual herbs can compete with pasture (weedy) grasses and herbs, as the native annuals are tiny (leaves generally <30 mm tall although some mousetail inflorescences may be taller) and so easily smothered. Therefore, the persistence of spring annuals is threatened by changes in animal management (sheep and rabbits) and legitimate over-sowing and topdressing activities which are accepted methods of improving pastoral productivity.⁹ Nevertheless, spring annuals have occasionally been reported growing among taller, winter-dormant herbaceous plants. Wardle (2024) reported *Myosurus minimus* growing near and amongst hemlock in 2023 and 2024 on the Dunstan Range. Similarly, individuals were found growing within a patch of *Cirsium arvense* (Californian thistle) in the DDF.

Research is required to understand how to manage these fragmented populations and how to maintain their presence in the MGL project area. Populations have disappeared where management has reduced grazing and disturbance (Rogers et al 2007), so simply placing legal protections around the areas where they presently occur may not be sufficient to ensure their persistence or survival. Rogers et al. (2002) contrast the 'genuine non-forest habitats' of ephemeral wetland of *Myosurus*, the "desert" pavement habitat of *Ceratocephala*, and the turf and gravel habitat surrounding water bodies of *Myosotis*, all of which have a strong summer moisture deficit with the 'facultative farming-induced' scabweed or mat vegetation on dry hillslopes. Bendigo populations likely fall into the latter category as sodic or saline soils haven't been identified (to date

This document outlines the research work recommended to conserve populations and establish new populations. The purpose is to reduce uncertainty with respect to the success of mitigation options, and the research is not mitigation itself. Similar work on threatened species has been done for *Sticherus tener* and *S. ureolatus* ferns at Escarpment Mine, and for a variety of herbaceous native species by nurseries and Botanic Gardens.¹⁰

2. The spring annual herb species

The species of interest, and their key characteristics are as shown below.¹¹

- *Ceratocephala pungens* (Figure A3.3 and A3.5). Threat status Threatened – Nationally Critical, occupies saline sites and (non-saline) hillslope herbfields; anecdotally hard to grow, spiny achenes are dispersed by attachment and possibly granivory; germinates in late August; likes bare ground; poor competitor with weedy species and easily shaded by taller plants although present in small light wells with *Myosurus minimus* amongst regenerating kānuka in the vicinity of Bendigo Reserve.

⁹ Also impacts of direct drilling over the last decades, although the presence of drilling may anecdotally have led to lower farm inputs (would be useful to have information on this)

¹⁰ E.g. Christchurch Botanic Gardens *Leptinella nana* (Martin 2020), Auckland Botanic Garden *Euphorbia glauca* (Hobbs and Bodley 2017)

¹¹ Drawn largely from NZPCN [New Zealand's Flora • New Zealand Plant Conservation Network](#)

- *Myosurus minimus* subsp. *novae-zelandiae*. (Figure A3.5). Threat status At Risk – Declining, occurs in saline sites, hillslope herbfields, and waterbody margins; supposedly easy to grow from fresh seed; likes to be partially submerged in water; salt tolerant; germinates mid-winter; can survive sparse weeds; may benefit from grazing to maintain open/short habitat)
- *Myosotis brevis* (Figure A3.4 and A3.5). Threat status – Threatened Nationally Vulnerable, occurs in open and more or less shingly places which are free draining but seasonally moist; cannot tolerate over-shading; a strict annual; self-sows readily but can be difficult to maintain; possibly germinates as early as May-June; was part of the *M. pygmaea* group; can co-occur with *M. Myosotis a. subsp antarctica* (Figure A3.4).
- *Myosotis Myosotis a. subsp antarctica* (threat status Threatened – Nationally Vulnerable, occupies saline sites, hillslope herbfields, waterbody margins, short turf and beach gravels; supposedly easy to grow; but genetics uncertain (was part of the *M. pygmaea* group); germinates as early as May-June, can persist with sparse weeds, and may benefit from grazing).¹²

Populations of all the spring annual herb species are likely to be in decline in the central Otago drylands. This increases the importance of outcomes for these species, both negative and positive, linked to the MGL project. Ewans (2024), Wardle (2024) and Harding (2024) presented evidence on declines in the dryland communities in evidence related to the TK Holdings subdivision (associated with the Central Otago District Council (ODC) consent hearing in November 2024). Wardle (2024) provided a submission providing evidence of decline of 'kānuka-cushion field' vegetation in the vicinity of the Dunstan Ecological District/Mountains due to land-use change from pasture (grazed by sheep and rabbits) to vineyards and subdivision.¹³ Harding (2024) in his evidence referred to a 2022 unpublished contract report for ORC that estimated 12,000 ha of kānuka/mānuka (and 40,000 ha of indigenous vegetation in total) in the Otago Region between 1996 and 2018 using Land Cover Data Base analysis.

Existing information suggests that populations of spring annuals are in decline across Central Otago. The number of subpopulations identified in 2024 in surveys on Ardgour and Bendigo Stations by RMA Ecology for Matakanui, and a recent series of incomplete surveys centred on Rocky Point and extending to Bendigo Historic Reserve, indicate that the populations which occur in the vicinity of Bendigo in the Dunstan Ecological District represent the most important known national stronghold for spring annuals.

¹² Understanding which *Myosotis* species are present requires help of expert taxonomists – two samples were lodged with the Allan Herbarium (CHR) in December 2024 (Zac Milner pers. Comm RMA Ecology December 2024). See Meudt et al. 2025.

¹³ Using CODC mapping tool, Wardle (2024) calculated that approx. 140 ha of land was cleared for horticulture and associated infrastructure within five (5) km of the site. This clearance would have comprised a mosaic of cushionfield, regenerating kānuka and/or grey shrubland, and dryland herbfield.

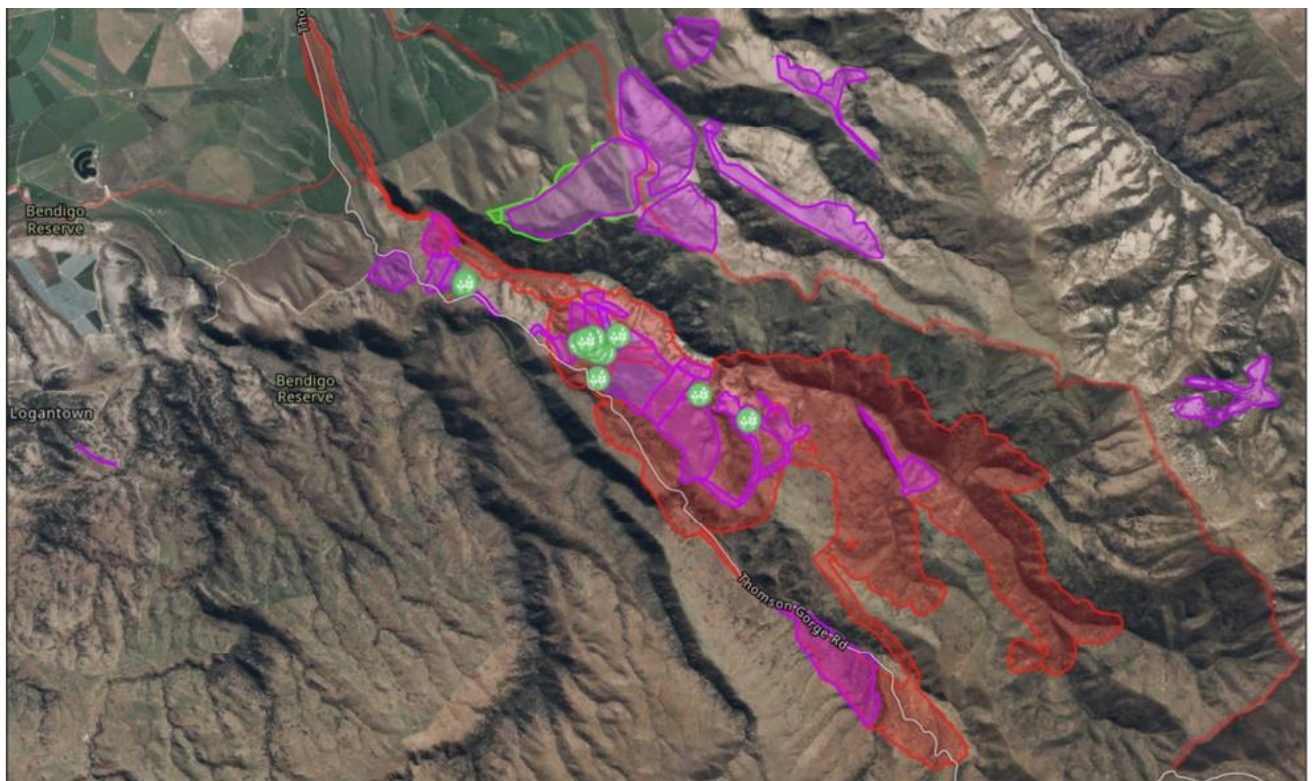


Figure A3.3. Locations of *Ceratocephala pungens* based on late spring 2024 surveys (green circles) Purple areas are the areas surveyed. Red outline is the DDF at that time. (Source: Milner 2024, Fig. 1.)

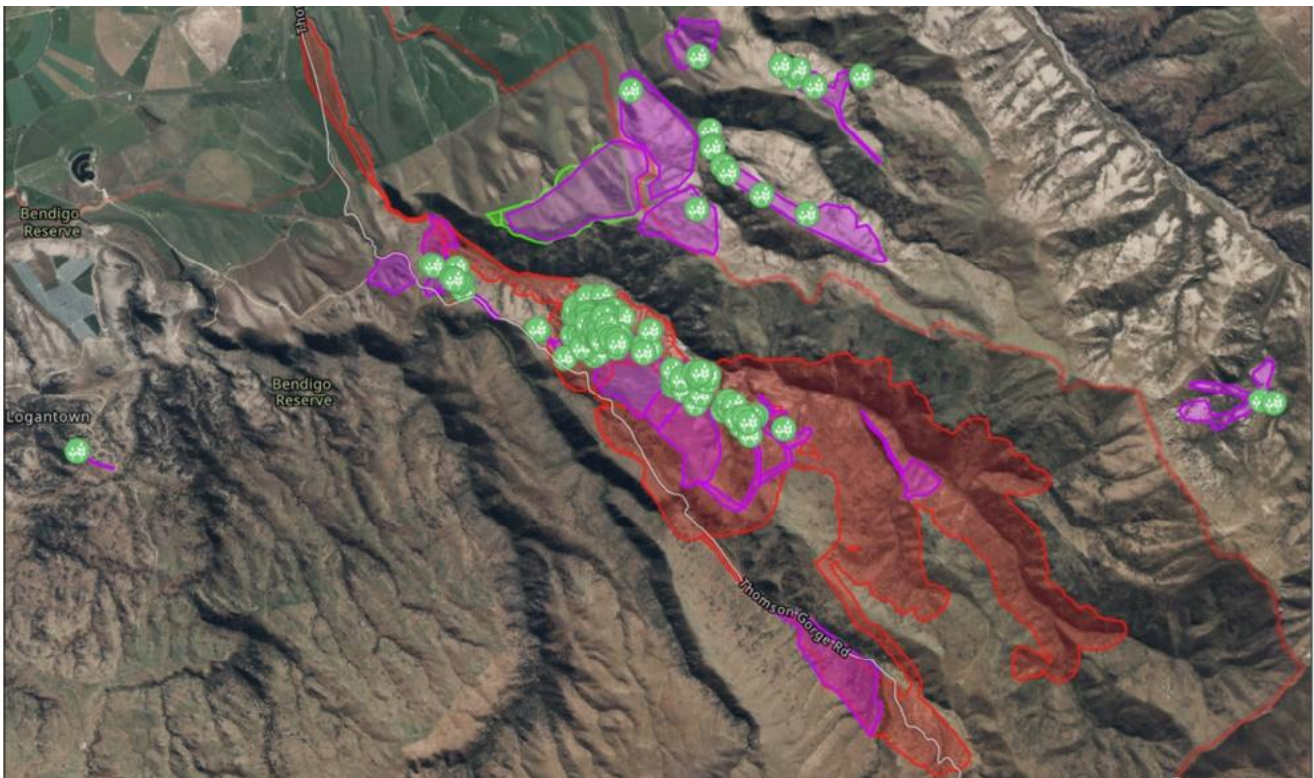


Figure A3.4. Map showing locations of native *Myosotis* species based on late spring 2024 surveys. (green circles) Purple areas are the areas surveyed. Red outline is the DDF at that time (Source: Milner 2024, Fig 2.)



Figure A3.5. Top left: *Myosotis brevis*, native forget-me-not (brown leafed form) with arrow pointing to fully open white flowers. Top right: Blue tags mark locations of this annual herb near a drill site; green plants are non-native plants, including a non-native *Acaena* (bidibid) and *Anagallis arvensis* (scarlet pimpernel), photographed November 2024 within footprint of CIT pit). Bottom left: The mousetail *Myosurus minimus* (green plant) with erect flowers within brown moss (about 1.5 times natural size). Bottom right: *Ceratocephala pungens* (about 2 times natural size). Both plants in the upper row are in the borage family (Boraginaceae), and both plants in the lower row are in the buttercup family (Ranunculaceae).

3. Proposed success criteria

The aim of the work programme is to determine the most effective methods of maintaining existing populations and establishing new (sub-)populations of spring annual species. It is intended to decrease uncertainty related to the magnitude of effect of the mine, and the options for mitigating that effect. The work programme will undertake the research needed for MGL to produce an increase in the number of discrete, self-sustaining sub-populations of all four spring annual plant species in areas managed by MG (i.e. within Bendigo and Ardour Stations).

It is unknown how many sub-populations of spring annuals are present, and sub-populations are likely to vary from year to year. This means it is useful to break down success into four parts. The highest-priority species is *Ceratocephala pungens*, because it has the highest threat ranking (Nationally Critical) and because it is considered to be the 'least tolerant of competition from other plants, native or exotic' (Rogers 2024), and it may need animals or deliberate introduction to spread to new sites. However, maintaining and expanding populations of *C. pungens* alongside other spring annual species is desirable.

The following success criteria could be suitable:

- maintain or deliver net 50% increase in the number of 2024/2025 discrete sub-populations of *Ceratocephala pungens* in areas managed by Matakanui Gold ¹⁴ over 10 years,¹⁵ by establishing new sub-populations
- develop methods for successful ex-situ propagation and establishment of *Ceratocephala pungens* should on-site propagation be unsuccessful
- over 10 years, maintain or deliver a net increase in area over which other native spring annual herbs are present, including *Myosurus minimus* subsp. *novae zealandiae* and the two *Myosotis* species.¹⁶

The target numbers of sub-populations and what area 'counts' will be based on the spring 2024 survey and results of a spring 2025 survey which is carried out earlier in spring when these small plants are most visible (i.e. during the September/October lambing season which barred access in 2024). The 2025 survey, done at the optimum time, is likely to identify more individuals and sub-populations. The spring 2025 survey will also provide information on sub-population densities, which will help define how many individuals 'count' as a sub population.¹⁷

(Note: The definition of a 'discrete sub-population' by site and number of individuals will be based on analysis of the spring 2024 survey but allow for a revised definition using the spring 2025

¹⁴ Specifying a net increase allows for removal of populations in some areas. Including 'area' ensures a focus on expanding some existing populations (which may be an efficient approach).

¹⁵ Would aim for 5 years to provide maximum flexibility for timing of CIT excavation but 10 years would provide better data as numbers are likely to vary from year to year depending on climate.

¹⁶ The taxonomy, distinguishing features and habitats of the (at least) two *Myosotis* species have not been fully resolved, so there is uncertainty about the species present.

¹⁷ Likely to be between 10 and 50 individuals as limited data to date indicates this is a moderate density, with 'high' densities probably being hundreds of plants within several hundreds of square metres.

survey. Natural year-to-year variation means the number of sub-populations and individuals to deliver 'closure consent condition' should be an average across a defined number of years)

4. Proposed research to deliver conservation of spring annual herbs

Because (to our knowledge) the annual herbs have never been introduced to new areas, or propagated, and have probably not been deliberately 'managed' in the past, the proposed success criteria need to be supported by surveys and research. Site surveys in MGL areas of interest in spring 2024 surveys were focused on defining the extent of populations, not their density and were done after lambing, at the end of the growing season when plants are becoming difficult to see (they die and blow away). Therefore, the extent of the areas occupied by the different species is likely to have been underestimated. Furthermore, the taxonomy, for distinguishing features and describing habitats of the (at least) two native species of *Myosotis* species, has not been fully resolved.

The proposed research is framed as four key questions. Each is outlined below but they inter-link and should be developed as part of a detailed plan.

5. Consultation

Consultation with mana whenua is strongly recommended, so that their views can be incorporated from the outset. The detailed plan must involve identifying partners (e.g. local nurseries) and contractors/suppliers (e.g. video camera operators, universities) and be informed by a thorough review of grey and published literature (references in this document are just a start). The detailed plan would benefit from refinement with Department of Conservation (DOC) technical experts, mana whenua and key partners and contractors. The target species all occur on nearby public conservation and private lands. Collaboration to simultaneously and collaboratively survey populations within the project footprint and other local sites (which collectively are probably their national stronghold) is likely to provide valuable information and assist conservation of these species. Permissions are likely required to collect or propagate these species at sites other than the project footprint.

When: Spring 2025.

Requires

- Time to approach and discuss with mana whenua, the Department of Conservation, potential propagators (local nurseries and Christchurch/Dunedin Botanic Gardens) and suppliers, do the literature review, and develop the draft plan.

Key Question 1 – What is the environmental niche extent of these spring annuals?

A targeted systematic survey is needed¹⁸, building on the Spring 2024 spring annual herb survey data (Figures A3.3 and Figure A3.4) to divide area into three classes: a) where sub-populations were found in spring 2024; b) where sub-populations might be (specifically including drill pads and tracks of known rehabilitation dates); c) where sub-populations are unlikely to be. The systematic survey across potential habitat at Bendigo and Ardgour Stations, including areas in *Raoulia* (scabweed) adjacent to Bendigo Reserve above vineyards and adjacent to kānuka reserve) as well as on Ardgour Station.

Search effort will be allocated based on this categorisation, being sure to include unlikely areas. Keith (2008) explains the importance of recording the known zeros – i.e. where the target plants are not found. This method is used for sparse and uncommon species that are unevenly distributed. A grid will then be established, and effort (time) spent in defined areas (e.g. plots along a defined transect length), within each class, reducing according to the predicted likelihood of detection. At each grid point soils and plant data will be collected in a 50 cm² plot and the surrounding 3 m radius searched for spring annuals (count total number of plants, and number of flowering plants). Leaf samples will be collected from individual plants of each species of interest from defined grid points to quantify the genetic diversity within and between populations of these four species, particularly the *Myosotis* species.¹⁹ If the species boundaries are unclear, leaf samples alone will be insufficient for DNA analyses and samples will need to be referenced to a complete collection with flowers or seeds to make taxonomic sense.²⁰ Rooting depth and spread will be quantified at a subset of sites, covering a range of soils textures and depths.

This systematic baseline ecological survey will collect information on soils (salinity/sodicity, depth, nutrients, drainage status, water-holding and organic content), landforms, aspect/elevation/slope, co-occurring plant species, surface features (bare ground, scarification, rabbit/sheep dung) and land use (intensity of grazing, e.g. rabbit pellets). A subset of permanent sites will be established to facilitate remeasurements.

For populations near future site works, the full extent of the population should be mapped so impacts can be responded to through appropriate avoidance, mitigation and compensation mechanisms with avoidance being prioritised within the contingency zone. This information informs design of slopes and surfaces on rehabilitated landforms such as the ELF and backfilled RAS (if mined).

¹⁸ Such surveys also help quantify the extinction risk at the site, and nationally if data from other sites is provided (hence the value of co-ordinating surveys with Department of Conservation). Because the national populations are rapidly declining, even recent records (e.g. 2021–2024 i-Naturalist records) do not ensure those populations are present in 2024/25.

¹⁹ Noting the number might depend on the number of individuals and how many is determined to leave behind, especially in outlier populations and for *Ceratocephala pungens*.

²⁰ Samples may be taken for DNA assessment where taxonomists consider this is required to help understand if populations are separated (but see Te Papa paper on difficulty of using DNA to separate *Myosotis* species where speciation is recent). Regardless, some eDNA analyses will be useful to inform animal pest eDNA work.

Example: Bangel et al. (2023) report investigations for a threatened woody plant in New South Wales with some similar characteristics of fragmentation on disturbed land and intolerance of competition, and nothing is known about its dispersal or establishment

When: August – November 2025.

Requires

- Time to develop the survey (influenced by analysis done for spring 2024 data), then do the survey. Survey time depends on size of area and number of points. Maybe 3 weeks with 4 people.
- Soil samples.
- Population genetics.
- Access to defined areas in spring (late August through to the end of October) – i.e. through the lambing period of Bendigo and Ardgour stations.

Key Question 2 – What management will ensure existing populations persist (and expand locally)?

Walker et al. (2019) describes indigenous dryland vegetation as being generally open and short in stature, and its species are adapted to naturally stressful and low-productivity (infertile and summer-dry) conditions. Such stress-adapted species compete well for water below ground but have limited ability to grow fast and tall when moisture and fertility increase. As productivity increases, competition among plants increases, and the zone of competition switches from primarily below-ground to above-ground, favouring plants with superior ability to compete for light, which in this context are pasture grasses. Rogers (2024) and Wardle (2024 – with photos along fence lines) concur with research on spring annuals in the 1990s and 2000s that highlighted the role that sheep and rabbits have in persistence of the spring annual herbs (Rogers et al 2007), through: a) control of competing pasture grasses (e.g. in locations where they maintain a 'close-cropped turf'); b) preventing succession to shrubs (e.g. cushionfield areas); and/or c) ground disturbance and nutrient enhancement through addition of dung. Rogers (2024) reported that at Conroy's Reserve 'the *Ceratocephala* clearing was partly created by rabbit scarification and where their faeces accumulated'; at Flat Top Hill Conservation Area spring annual habitat was typified by 'sheep and rabbit mediated bare soil areas' in early 2000s but showed progressive decline at four sites to extinction following invasion of dense thyme and rank grasses; and at Cairnmuir Mountains, 'scattered bare soil patches, maintained by hoof impacts of [sheep and goats]', were habitat for very small populations of spring annual herbs. In 2020 the Bannockburn Sluicings Historic Reserve contained 18 *Ceratocephala* sites with many populations of 50–100 individuals. Rogers (2024) suggested that two types of micro-habitat provided the best chance for persistence of medium-term populations: a) 'bare, silty, mildly saline eroding pavement on knoll crests and b) damp, moss-covered east-facing slopes below the escarpments. Another large population was recorded at Bendigo east of old Welsh-town where hundreds of *Ceratocephala* were recorded in clearings or light-gaps within kānuka scrub that were 'heavily mediated by sheep and rabbits'.

Key Question 2 work will use results of the targeted systematic survey (Key Question 1) to define sub-populations with similar characteristics. Different management will then be applied in areas a) that support the species; and b) in adjacent and contiguous areas of potential habitat. Management treatments will create a gradient of competition from plants using sheep/rabbits

browse and/or weeding. Plant community and species sub-population responses to removal of grazing (by sheep) but retaining rabbits at densities that meet ORC pest animal requirements will be tested. A second trial will create 'more favourable' surfaces adjacent to sub populations. This may include use of scarification, scalping, salt additions or herbicide²¹ to reduce competition.

The response to disturbance by tracking and drill sites may be instructive – it may lead to spread of plants, but this may be a short term spike only depending on competition and fertility. For example, some individuals of *Ceratocephala pungens* were found within a patch of thistles on a disturbed area. It is unclear whether these individuals grew from an in-situ seedbank despite disturbance, or whether windblown seed had been trapped by the thistles, and the combination of conditions allowed germination.

If seed can be procured, then nursery-based experiments could be used to test spring annual responses to a range of environmental conditions, such as varying levels of light, herbicide, and nutrients.

When: 2026 to 2030.

Requires

- Establishment of field trial areas, and annual monitoring of field trials (targeting flowering to early seeding period to combine with information on pollinators).
- Phase trial establishment to distribute hours across years.
- Time: 10 days per year for 2 people (annually for 5 years).
- Potential for glasshouse trials by nursery/botanist or postgraduate student.
- Access to paddocks in spring, during lambing (late August through to the end of October/November).

Key Question 3 – How to maximise seed number and viability of Ceratocephala pungens? What pollinates these species, and will increasing pollination increase seed production?

Successful pollination is a crucial step for most plants – if pollination fails or is inadequate, fruit (seeds) will not be produced or will be less fit. Many native species are unable to self-fertilise (i.e. are self-incompatible), so they require pollen from nearby plants to be blown or carried onto their stigmas. Even when species can self-fertilise, seeds from out-crossed plants may be larger and/or produce more successful seedlings. The research for Key Question 3 will identify when pollination occurs, what pollinates the plants, if plants are self-compatible, if movement of pollen between plants is necessary or advantageous for seed production, and when seed is ripe (e.g. as done by Bischoff 2008, Figure A3.6).

Population monitoring should be carried out for populations of each species that represent the breadth of their observed niche. Monitoring should include size of population, the number/timing of plants flowering, pollination (observations and collections of flowers and insects – during day

²¹ This intervention is risky if herbicide has residual effects on spring annual seeds, so a pot trial is proposed. Established methods for this testing have been developed; check what rate and types of herbicide would be most likely used to control competing plants.

and at night under infra-red light) (Primak 1983) timing of seed set, and seed dispersal method. The observations may also identify plant browsers, and hence the benefit if specific pest control (some information may be also gathered through assessing gut/scat content of potential browsers). Naqvi et al. (2022) report camera traps are an effective tool for monitoring insect plant interactions. Camera traps have also been used by Plant and Food Research to identify what invertebrates pollinate avocados (Evans et al 2011).

When: August – Nov in 2025 to 2030.

Requires

- Using cameras and observations to monitor flowering, insect visitation, and seed dispersal. This is an increasingly popular method (reference) and used onsite by HabitatNZ for pest monitoring (although cameras with higher magnification may be needed). Another emerging method is using eDNA to examine flower visitation. The eDNA technique has been used to identify invertebrates visiting mānuka and ramarama (Pugh et al. 2025).
- Time: estimated 10 days per year for 2 people (annually for 5 years).
- Comparing seed production and viability in flowers that are bagged (to exclude pollinators) and plants that are unbagged. Repeated in at least 2 years.
- Access in spring (late August through to the end of October/November) to service the cameras and absence of stock (which can damage cameras, cattle and sheep). Repeated in at least 2 years.

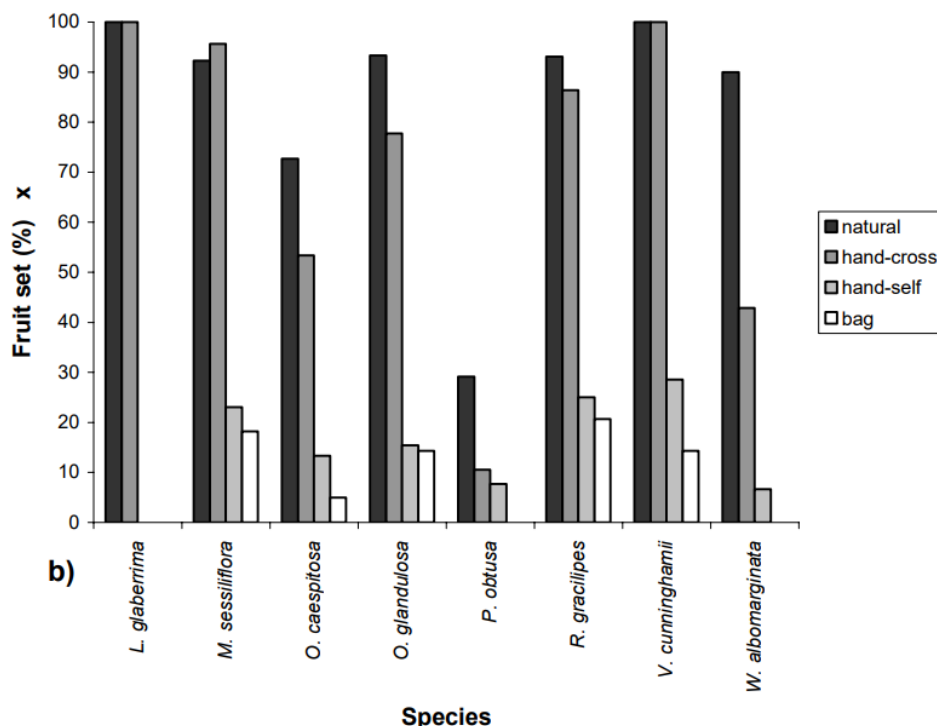


Figure A3.6. The core tests that establish self-compatibility based on number of fruit set and seeds per flower from natural pollination, hand self or inter-plant pollination, and bagging (the latter preventing insect pollination). From Bischoff (2008) for NZ alpine species in The Remarkables, Otago including *Ranunculus gracilipes* (a small, yellow-flowering alpine buttercup). Over 85% of the herbs (20 species) depended on pollinators (mainly by general visitors such as syphid flies and native bees), with only 3 species (13%) pollinator independent. Few of the alpine species studied were pollen limited.

Key Question 4 – How can new sub-populations be established?

New populations could be established through creating favourable areas via management intervention, or by seeding, or introducing plants to suitable areas with favourable management. All methods should be developed. It is likely new populations will be established using seed rather than translocation of plants. Ewans (2024) considered translocation of small herbaceous Threatened and At Risk plants risky with low survival rates. Wardle (2024) cited two examples of shifting *Raoulia* in drylands (one on the rail trail, and one subdivision) and considers both were not successful despite one of the sites having had irrigation. There has been success with translocation of alpine herb sods and individuals (University of Otago) and a range of alpine herbs in high-rainfall environments (lower moisture stress), as well as wetland species, but those are much less stressful environments.

A range of methods is proposed here: seeding, developing nursery-raised seedlings for planting, soil disturbance, and soil transplanting (see soil seedbank emergence experiment in Bangel et al. 2023). A key objective is to collect seed and grow ex-situ (e.g. in nurseries established in Central Otago or in Otago or Canterbury Botanic Gardens). This requires developing techniques for seed collection (within soil, as salvaged plants, or collected from 'wild' plants) and seed storage. Seed collection allows standard experiments to establish germination conditions (moisture, temperature, soil type, and nutrients). Success would be the development of techniques to establish or augment wild populations with seed from nursery grown material, and/or collection of wild material for sowing in the wild.

A range of experiments could be conducted, starting with the least invasive and most cost-effective methods. Suggestions for some of these are shown below.

- Develop seed salvage techniques ranging from least invasive, such as collecting seed from bagged or covered plants post-pollination and hand clipping seed from plants before they open,²² to more invasive/destructive techniques, such as removing plants to nursery (allowing seed collection in controlled conditions without wind) and harvesting soil from areas with plants.
- Investigate germination from salvaged soil grown in favourable sites or a nursery (e.g. Bangel et al. 2023). Soil with seed is likely to be concentrated in the upper 2–5 mm of surface soil. Experiments would also need to identify sites where such collection is least likely to adversely impact 'donor' populations, and for 'core' populations, using survey data.
- Collect seed and study it to enable seed management to optimise soil moisture, soil nutrients, and potentially soil salinity/salts (if the plant exhibits salt tolerance) and competition on seedling germination and survival.
- Conduct experiments and successful collection and storage of seed over 12 months (between years); this would provide a way to establish new populations or augment existing populations.

²² 2024 field observations by survey botanists with MWLR indicated that seed release happened within a few days and accelerated under dry conditions. Therefore, hand clipping in the field will not be straightforward and will require multiple visits.

- Conduct experiments and successful collection of seed; this would allow development of methods to enhance viability and evenness of germination (e.g. refrigeration, smoke treatment, heat treatment), if natural germination is low.
- Develop nursery-raised seedlings for planting into suitable new sites at the beginning of spring (probably difficult for an annual species – but worth attempting; such experiments will improve the understanding rooting morphology and growth rates under different conditions, and complementing studies in Key Question Three.
- E Create patches of c. 100–800 m² on engineered landforms with suitable aspects, slopes and subtending slopes for spring annuals (based on survey analysis) where nursery-raised plants or seed (in translocated soil) can be introduced.

A linked consent condition will be appropriate to require salvage of a minimum 0.5 m³ of Annual herb soils removed from 0–5 mm of the soil profile stored in appropriate conditions in a designated seed storage area

When: Starting in Nov 2025 for 5 years.

Requires

- Time /resources. estimated 1 day per week (c. 350 hr per year) for 5 years for fieldwork and nursery work.
- Growing facilities. Buy a small tunnel shade house and watering system or lease/rent space in established nursery.
- Ideally, a local nursery propagator and field botanist, with potential to include postgraduate student/s if seed can be collected.

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