



Mount Buller Sustainable Water Security Project – Off-stream Storage

Hydrological and Ecological Monitoring and Adaptive Management Program Protocol

VERSION 5

Prepared for the Mount Buller and Mount Stirling Alpine Resort Management Board

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Glossary

Alpine Bogs	Both the EPBC Act threatened ecological community (Alpine Sphagnum Bogs and Associated Fens) and the FFG Act threatened community (Alpine Bog Community)
CMA	Catchment Management Authority
control sites	Seven unaffected Alpine Bogs within the Mount Buller and Mount Stirling Alpine Resorts, four of which are on the northern slopes of Mount Buller (Alpine Bogs 1, 2, 4.1/5/7 and 11.1) and three of which are on Mount Stirling (Bogs S1, S2 and S3)
DAWE	Australian Government Department of Agriculture, Water and the Environment, now DCCEEW
DCCEEW	Australian Government Department of Climate Change, Energy, the Environment and Water
DELWP	Victorian Government Department of Environment, Land, Water and Planning
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts, now DCCEEW
DGPS	Differential Global Positioning System
DoEE	Australian Government Department of the Environment and Energy, now DCCEEW
DSEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities, now DCCEEW
EPBC Act	Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i>
EVC	Ecological Vegetation Class
FFG Act	Victorian <i>Flora and Fauna Guarantee Act 1988</i>
HEMAMP	Hydrological and Ecological Monitoring and Adaptive Management Program
impact sites	Six indirectly affected Alpine Bogs downslope of the water storage (Alpine Bogs 4.2, 6, 8/9/10, 11.2, 12 and 13)
IQR	Inter-Quartile Range
PCF	Project Construction Footprint for the Mount Buller Sustainable Water Security Project
project	The Mount Buller Sustainable Water Security Project, including the water storage and ancillary infrastructure
the resort	Mount Buller Alpine Resort
RMB	Mount Buller and Mount Stirling Alpine Resort Management Board
SOP	Standard Operating Procedure
threatened	Species or ecological community listed as critically endangered, endangered or vulnerable under the EPBC Act and/or FFG Act
water storage	The 100 megalitre water storage approved for construction at Mount Buller

Summary

In 2018, an off-stream water storage and ancillary infrastructure (the project) was approved for construction at Mount Buller, between the summit and the village. The approvals require that a Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP) be implemented to limit potential indirect impacts on Alpine Bogs located downslope of the water storage. In accordance with the approved HEMAMP, baseline monitoring of the Alpine Bogs was undertaken in 2017/2018 and 2018/2019, before construction commenced in October 2019, and annual monitoring has continued since. This document outlines the HEMAMP protocol for continued post-construction monitoring and management of the Alpine Bogs.

Objectives

The HEMAMP is designed to maintain the extent and condition of Alpine Bogs that are downslope of the water storage. The overall objective is to achieve four performance criteria relating to the extent and condition of the Alpine Bogs. Additional objectives of the HEMAMP are to:

- Provide a detailed protocol for monitoring the hydrology and ecology of the Alpine Bogs.
- Specify adaptive management actions required to maintain the Alpine Bogs.
- Define triggers for implementing the adaptive management actions.

Performance criteria

The RMB's adaptive management will achieve outcomes that meet the following performance criteria, which aim to maintain the status quo within the Alpine Bogs at the impact sites, relative to the control sites:

- The '**extent**' criterion – no more than a 10% reduction in the total combined area of the affected Alpine Bogs, relative to control sites.
- The '**composition**' criterion – no more than a 10% reduction in the total 'bog-dependent' native flora species richness of the affected Alpine Bogs, relative to control sites.
- The '**encroachment**' criteria – no more than a 10% increase in the cover of 'non-bog-dependent' species within affected Alpine Bogs, relative to control sites, and weed cover will not exceed 5%.
- The '**structure**' criterion – no more than a 10% reduction in the average cover of Peat Moss (*Sphagnum* spp.) within the affected Alpine Bogs, relative to control sites.

Adaptive management triggers

Adaptive management actions will be triggered when monitoring results suggest that there has been:

- Greater than a 5% reduction in the extent (total combined area), composition (total 'bog-dependent' species richness) and structure (average Peat Moss cover) of impact sites, relative to control sites.
- Greater than a 5% increase in encroachment (cover of 'non-bog-dependent' species) at impact sites, relative to control sites, or a total weed cover that exceeds 2.5% at impact sites.
- Greater than a 10% reduction, over two consecutive years, in mean annual surface water flows to Boggy Creek and/or mean annual groundwater levels in the Boggy Creek catchment, relative to surface water flows and groundwater levels predicted by the HEMAMP's hydrological models.
- Any surface water or groundwater quality parameter that would be considered an outlier when compared with baseline water quality results.

1. Introduction

1.1 Monitoring and management context

In 2018, the Mount Buller and Mount Stirling Alpine Resort Management Board (the RMB) received approval, with conditions, to construct a 100 megalitre (ML) off-stream water storage and ancillary infrastructure (the project) on Mount Buller between the summit and the village (Figure 1 and Figure 2). The approvals were granted by the Victorian Government Department of Environment, Land, Water and Planning (DELWP) under the Victorian *Planning and Environment Act 1987* (Planning Permit PA1600138, dated 18 January 2018; Appendix 1) and by the Australian Government Department of the Environment and Energy (DoEE, later the Department of Agriculture, Water and the Environment or DAWE and now the Department of Climate Change, Energy, the Environment and Water or DCCEEW) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act Approval 2014/7303, dated 25 June 2018; Appendix 2).

The project has the potential to affect the hydrology of Alpine Bogs located downslope of the Project Construction Footprint (PCF). Alpine Bogs on the northern slopes of Mount Buller, downslope of the PCF, were identified and mapped by the Arthur Rylah Institute (ARI) in 2014 using aerial photo interpretation (Tolsma 2014). As part of the impact assessment for the project, GHD Pty Ltd (GHD) updated the Alpine Bog mapping in 2015 and identified affected and unaffected Alpine Bogs (GHD 2015). Biosis Pty Ltd (Biosis) further refined the Alpine Bog mapping in the baseline monitoring years (2017/2018 and 2018/2019). The final baseline Alpine Bog mapping, undertaken in February 2019 before construction of the project commenced in October 2019, identified more than 2.5 hectares of Alpine Bog downslope of the PCF (Biosis 2019c), including:

- 1.354 hectares of Alpine Bog known to have catchment areas that would be affected by the footprint for the water storage and its earth embankment. These are impact sites for the purposes of monitoring.
- 1.147 hectares of Alpine Bog that would be unaffected because the water storage and earth embankment would not interfere with their catchment areas. These are control sites for the purposes of monitoring.
- A further 0.347 hectares of previously unidentified Alpine Bogs. The potential impact of the water storage on these other sites is currently unknown.

Conditions of approval for the project require implementation of a Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP) to mitigate indirect impacts on Alpine Bogs downslope of the PCF. This HEMAMP protocol provides the details of a monitoring and adaptive management program to:

- Identify the nature and extent of any changes to site hydrology and hydrogeology as a result of implementing the project.
- Monitor the extent and condition of the Alpine Bogs in relation to any hydrological changes.
- Allow for early identification of potential impacts on Alpine Bogs.
- Enable implementation of measures to avoid and minimise impacts on Alpine Bogs.
- Document the effectiveness of any mitigation measures and inform future proactive and adaptive management activities.

1.2 Location of the water storage

The water storage is located within the Mount Buller Alpine Resort (the resort), on a gently to moderately sloping plateau, 700 metres east of the Mount Buller summit and 250 metres west of Mount Buller village (Figure 1). The majority of the PCF is north of the final section of the unsealed Mount Buller Summit Road and extends north down the hillside to the Summit Nature Walking Track (Figure 2). The PCF includes the construction footprint of the water storage, roads, stockpile areas and extensions of variable shape and length for a range of ancillary infrastructure leading to and from the water storage.

The PCF and HEMAMP monitoring sites are on Crown land that is permanently reserved for the purpose of the Mount Buller or Mount Stirling Alpine Resorts (Figure 2 and Figure 3). They are within the Goulburn River basin, Victorian Alps bioregion and management area of the Goulburn Broken Catchment Management Authority. The RMB is the public land manager.

1.3 Significance of the Mount Buller Alpine Bogs

Alpine Bogs are listed as a threatened ecological community under Commonwealth and State legislation. The Alpine Sphagnum Bogs and Associated Fens (ASBAF) ecological community is listed as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Alpine Bog Community is listed as threatened under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act). Throughout this document, the term 'Alpine Bogs' refers to both ASBAF and the Alpine Bog Community.

Alpine Bogs are groundwater dependent ecosystems with a scattered distribution in alpine, sub-alpine and montane environments across the Australian Alps, typically above the climatic treeline (DEWHA 2009; FFG Act Scientific Advisory Committee 2013). Alpine Bogs are restricted to wet sites and are generally characterised by the presence of Peat Moss (*Sphagnum* spp.). They are synonymous with seven of Victoria's Ecological Vegetation Classes (EVCs), including Sub-alpine Wet Heathland (EVC 210), Sub-alpine Wet Sedgeland (EVC 917) and Alpine Peaty Heathland (EVC 1011), which occur within the vicinity of the PCF (Biosis and GHD 2016). They are particularly susceptible to climate change given that they have a fragmented distribution and are already at their environmental tolerance limit (DEWHA 2009; Macdonald 2009).

Alpine Bogs have an inherent ecological value. Not only are they rare ecosystems but they also provide habitat for threatened species, such as Alpine Bog Skink *Pseudemoia cryodroma*, Alpine Stonefly *Thaumatoperla flaveola* and Stonefly *Riekoperla isosceles*, all of which are listed as threatened under the FFG Act. Conservation and restoration of Alpine Bogs is also crucial to maintaining inland water resources because these systems issue water to major north and south flowing rivers from the Great Dividing Range (DEWHA 2009).

The present extent of Alpine Bogs is estimated to be approximately 8,000 hectares on mainland Australia, 4,500 hectares in Victoria and 61.5 hectares within the Goulburn Broken catchment (TSSC 2008; Tolsma 2014). It is estimated that Mount Buller supports approximately 5% of the total area of Alpine Bogs within the Goulburn Broken catchment. More than 90% of the total area of Alpine Bogs at Mount Buller exist downslope of the PCF (Figure 2; Biosis and GHD 2016). Alpine Bogs therefore have a highly localised and restricted distribution at Mount Buller.

1.4 Previous investigations and monitoring

To support the concept design and associated planning documentation for the project, the PCF and surrounds were subject to a series of detailed investigations from 2013 to 2016. As part of these investigations, GHD conducted ecological mapping and established a network of groundwater monitoring bores to characterise site conditions.

In late 2014, the RMB commissioned GHD to establish a formal groundwater monitoring program at the site, including:

- Groundwater level and quality monitoring at various locations.
- Climate monitoring.
- Surface water (spring) flow monitoring and mapping (Boggy Creek Catchment).

The aim of this initial groundwater monitoring program was to characterise the seasonal behaviour of groundwater within the PCF and surrounds, including downslope Alpine Bogs.

In early 2015, GHD ground-truthed Alpine Bog mapping downslope of the PCF and defined catchment areas for the Alpine Bogs, which allowed for Alpine Bog impact sites and control sites to be identified.

From 2017 to 2019, further monitoring infrastructure (primarily for ecological monitoring) was established at Mount Buller and Mount Stirling (Figure 1) and baseline HEMAMP monitoring was conducted.

HEMAMP monitoring has continued annually since baseline monitoring occurred and improvements continue to be made to the monitoring methodology each year.

1.5 Protocol revisions

The HEMAMP protocol has been through multiple revisions to incorporate suggestions from independent reviews, recommendations from monitoring reports and new information collected over time. The history of HEMAMP protocol revisions is as follows:

- Version 1 (dated 22 August 2016) was prepared by Biosis and GHD as part of the planning permit application and draft EPBC Act preliminary documentation for the project.
- Version 2 (dated 28 April 2017) contained updates in response to comments on Version 1 received from DELWP (Nigel Waterhouse, Natural Environment Program Officer, Hume Region) and ARI (Dr Arn Tolsma, Program Leader, Disturbance Ecology).
- Version 3 (dated 21 September 2017) addressed comments on Version 2 from DoEE (Matt Plunket, Environmental Assessments Branch, Victoria and Tasmania) and accompanied the final EPBC Act preliminary documentation. Version 3 was the original approved version of the HEMAMP protocol, endorsed by Planning Permit PA1600138 (Appendix 1) and EPBC Act Approval 2014/7303 (Appendix 2).
- Version 4 (dated 15 October 2019) updated many of the monitoring specifics, which could not have been known before monitoring started (e.g. locations of transects and photo points that had not been established at the time of Version 3).
- Version 5 (this document) provides further updates to the monitoring methods and adaptive management measures. These updates address high priority recommendations and comments from the following:
 - Baseline and annual HEMAMP monitoring reports prepared from 2017 to 2021.
 - An independent peer review conducted by Monash University (Dr Joslin Moore, School of Biological Sciences, and Assoc. Prof. Mike Grace, Water Studies Centre and School of Chemistry), dated 10 September 2021.

- A joint letter from DELWP (Wendy Sherlock, Natural Environment Program Manager, Hume Region) and DAWE (Nicholas Scholar, Assistant Director, Environment Compliance Branch), dated 14 December 2021.
- A meeting attended by representatives of the RMB, DELWP, DAWE and Biosis on 21 February 2022, during which recommendations from the above documents were discussed in more detail.

This version of the HEMAMP protocol incorporates all refinements to date and is intended to supersede all previous versions. Further revisions of the HEMAMP protocol will require approval from DELWP and DCCEEW (refer to Section 7.2).

1.6 Objectives

The HEMAMP is designed to maintain the extent and condition of Alpine Bogs that are downslope of the water storage. Without implementation of the adaptive management actions outlined in this HEMAMP, around 1.354 hectares of Alpine Bog (as per the final baseline mapping of February 2019) could be indirectly affected because of changes to local hydrology brought about by the water storage. The overall objective of the HEMAMP is to achieve four performance criteria relating to the extent and condition of the Alpine Bogs (as specified in Section 2.2).

Additional objectives of the HEMAMP are to:

- Provide a detailed protocol for monitoring the hydrology and ecology of a selection of Alpine Bogs within the Mount Buller and Mount Stirling Alpine Resort, including impact sites and control sites.
- Specify additional performance criteria that will trigger adaptive management actions.
- Specify the duration and frequency of monitoring activities, reporting and review.

1.7 Scope

This HEMAMP focuses on the water storage site and the potential impacts associated with its construction and operation. Ecological monitoring is concentrated in and around Alpine Bog impact sites on the northern slopes of Mount Buller. All impact sites identified during the project's impact assessment have been included in the monitoring program, along with a similar number of nearby control sites. However, not all Alpine Bogs at Mount Buller have been included in the monitoring program. Similarly, the hydrological monitoring and associated management arrangements presented in this HEMAMP do not consider the hydrological or hydrogeological impacts of ancillary structures, such as delivery pipelines, power supply, pumping stations or roads. Much of this infrastructure is located away from the Alpine Bogs.

1.8 Relationship with other protocols

The RMB has adopted four other plans, with the general aim of avoiding, minimising, rehabilitating, or offsetting long-term impacts of the project. These plans include:

- The Site Environmental Management Plan (SEMP; ERM 2019), which specified procedures for minimising environmental impacts during construction.
- The Ecological Rehabilitation Plan (ERP; Biosis 2020), which provides procedures for re-establishing native vegetation within the PCF.

- The ERP Addendum (Biosis 2022), which specifies the requirements for remediating and monitoring impact areas outside of the PCF, including unauthorised impacts that occurred on Alpine Bogs, Pole Line 6, the environmental watering system alignment, and Burnt Hut stockpile site during construction.
- An Offset Management Plan (OMP; Biosis 2019a), which outlines management obligations for offsetting impacts to native vegetation and threatened species habitat, as required under State and Commonwealth legislation and policy.

1.9 Responsibilities and capabilities

The RMB is responsible for implementation of this HEMAMP and has the experience and resource capabilities to do so. The RMB has a history of conducting successful environmental monitoring and adaptive management programs, including:

- Management and ongoing monitoring of a population of endangered Mountain Pygmy-possum *Burramys parvus*.
- Long-standing management of water infrastructure (including wastewater treatment facilities) and monitoring of water quality as the local public 'water supplier' under Victoria's *Safe Drinking Water Act 2003*.

The monitoring component follows a simple yet scientifically robust and repeatable design that has been refined in consultation with DCCEEW, DCCEEW's predecessors, DELWP and DELWP's Arthur Rylah Institute for Environmental Research. The management component consists of two essential parts:

- Control of environmental weeds, which the RMB already conducts within the resorts.
- Environmental watering of Alpine Bogs, which will be achieved through a simple watering system and in priority to all other water demands within the resort.

The RMB has fully costed the program and is committed to its implementation.

2. Overview of the HEMAMP

2.1 Components of the HEMAMP

The HEMAMP aims to achieve certain performance criteria, which are provided in Section 2.2. Performance is assessed through regular monitoring, the methods for which are outlined in Section 3 (climate), Section 4 (hydrology – surface water), Section 5 (hydrology – groundwater), Section 6 (ecology) and in Standard Operating Procedures (SOPs) provided in Appendices 3 to 5. The reporting requirements and review processes for the HEMAMP are specified in Section 7.

The focus of the monitoring is to enable early identification of potential changes to the hydrology, extent, structure, and composition of the local Alpine Bogs throughout the lifetime of the water storage facility. This will enable proactive and adaptive management actions to be developed, implemented, and assessed on an ongoing basis, as outlined in Section 8.

2.2 Performance criteria

The HEMAMP's performance criteria are expressed in terms of ecological parameters within the Alpine Bog monitoring sites. It is ultimately the ecological condition of the Alpine Bogs, as a threatened ecological community, that is protected under the EPBC and FFG Acts, as opposed to their climatological or hydrological condition. However, Alpine Bogs are sensitive to climatological and hydrological changes, which may lead to a decline in ecological condition. For this reason, ecological and hydrological triggers have been set for adaptive management, as specified in Section 8.

The RMB's adaptive management will achieve outcomes that meet the following performance criteria, which aim to maintain the status quo within the Alpine Bogs at the impact sites, relative to the control sites:

- The '**extent**' criterion – there will be no more than a 10% reduction in the total combined area of the impact sites, determined by on-ground or remote (aerial) monitoring, taking into account natural variation based on extent observations across control sites.
- The '**composition**' criterion – there will be no more than a 10% reduction in the total 'bog-dependent' native flora species richness of the impact sites, taking into account natural variation based on species richness observations across control sites.
- The '**encroachment**' criteria:
 - Atypical species – there will be no more than a 10% increase in the cover of 'non-bog-dependent' species within the impact sites, taking into account natural variation based on observations across control sites.
 - Weeds – the total cover of weeds (introduced flora species) within the impact sites will not exceed 5%.
- The '**structure**' criterion – there will be no more than a 10% reduction in the cover of Peat Moss *Sphagnum* spp. within the impact sites, taking into account natural variation based on Peat Moss cover across control sites.

Performance criteria are expressed in terms of all impact sites collectively, relative to all control sites collectively. Performance criteria for individual impact sites would be unrealistic, especially as smaller bogs at

Mount Buller are marginal and were already showing signs of drying before construction of the water storage (Tolsma 2014; A Tolsma, pers. comm., July 2016; Biosis 2019c).

The magnitude of the changes expressed in the performance criteria are within known natural fluctuations of Alpine Bogs. The extent and condition of Alpine Bogs are known to vary greatly due to stochastic events of varying duration and intensity, such as drought, fire, pest animal activity or simply the way in which vegetation recovers in spring after being covered in snow (e.g. Clarke and Martin 1999; Wahren *et al.* 1999; Hope 2002; McDougall 2003; Good *et al.* 2010). Ecological monitoring as part of this HEMAMP has shown that these natural fluctuations can be rapid. For example, the area of the control sites at Mount Stirling decreased by almost 8% in just one year during baseline monitoring (Biosis 2019c). Comparison of the baseline and historical mapping (e.g. Scott 1974) of Alpine Bogs on the northern slopes of Mount Buller also suggests that the distribution of Alpine Bogs has changed considerably over the past 40 years.

While the performance criteria are within known natural fluctuations, the HEMAMP monitoring design focusses on detecting changes that are not attributable to natural fluctuations i.e. changes at impact sites relative to control sites. The 10% performance criteria take into consideration limitations of statistical power needed to detect these changes. There is a high level of confidence that the monitoring program will be able to detect much less than a 10% change outside of natural fluctuations, allowing pre-emptive management to commence. The 10% targets are therefore achievable, particularly given our knowledge of natural fluctuations in Alpine Bogs and the potential for variability brought about by stochastic events.

2.3 Monitoring design

2.3.1 Climatological and hydrological monitoring design

Alpine Bogs are sensitive to climatological and hydrological changes, including changes to rainfall, groundwater, and surface water. The water storage and earth embankment has been constructed within the catchment areas of six Alpine Bogs at Mount Buller (impact sites), potentially affecting their hydrology. For this reason, the HEMAMP includes climatological and hydrological monitoring as a means of supporting ecological monitoring and pre-empting potential ecological change.

Climatological monitoring (Section 3) makes use of:

- Daily meteorological data from the Mount Buller weather station, maintained by the Bureau of Meteorology (BoM) at Tirol Flat, approximately 260 metres east of the nearest Alpine Bog monitoring site at Mount Buller (Figure 2).
- Daily snow depth information from Buller Ski Lifts, sourced from gauges at Tirol Flat, Boggy Creek and Family Run, respectively located approximately 200 metres east, 180 metres south and 515 metres south-west of the nearest Alpine Bog monitoring sites at Mount Buller (Figure 2).
- Daily meteorological data from the RMB's BoM-compliant weather station at Weather Station Ramble, approximately 125-425 metres from the Alpine Bog monitoring sites at Mount Stirling (Figure 3).

Surface water monitoring (Section 4) characterises the total runoff yield from the Boggy Creek catchment, in which the water storage has been constructed at Mount Buller. There are four surface water monitoring locations at Mount Buller (Figure 2), as follows:

- The water storage discharge point, located in an enclosed concrete pit at the northern edge of the water storage earth embankment. There are meters within the pit that record drainage from the groundwater de-watering system below the water storage, discharge from the water storage to the environmental watering system and discharge from the water storage to the aqueduct. Readings from these meters are taken weekly, outside of the declared snow season.

- Boggy Creek Weir 1, Pickup 1, located approximately 700 metres north and downslope of the water storage and approximately 80 metres east and across slope from Pickup 2. Stage height is recorded at this location as an estimate of daily runoff from the eastern side of the Boggy Creek catchment (including runoff from impact and control sites).
- Boggy Creek Weir 1, Pickup 2, located approximately 700 metres north and downslope of the water storage and approximately 80 metres west and across slope from Pickup 1. Stage height is recorded at this location as an estimate of daily runoff from the western side of the Boggy Creek catchment (including runoff from impact and control sites).
- Boggy Creek Weir 2, located approximately 1.5 kilometres north and downslope of the water storage and approximately 800 metres north and downslope of Weir 1. At this location, stage height is recorded and flow of pumped raw water to the Burnt Hunt Reservoir is metered as an estimate of total runoff for the Boggy Creek catchment.

Groundwater monitoring (Section 5) relies on a groundwater bore monitoring network established at Mount Buller in 2014. Automated daily monitoring of water levels, coupled with periodic manual measurements and water quality sampling, takes place at the following five bores in proximity to the Alpine Bogs and PCF at Mount Buller (Figure 2):

- Borehole 6 (BH06), located near the summit carpark at the western end of the PCF, approximately 110 metres west and across slope from the water storage earth embankment and approximately 78 metres south and upslope of Bog 4.1/5/7 (a control site).
- Borehole 9 (BH09), located at the northern edge of the PCF, approximately 9 metres south and upslope of the environmental watering system, approximately 15 metres north and downslope of the foot of the water storage earth embankment and approximately 14 metres south and upslope of Bog 4.2 (an impact site).
- Borehole 16 (BH16), located approximately 128 metres north-west and downslope of the water storage earth embankment and 2-4 metres within the south-western boundary of Bog 4.1/5/7 (a control site).
- Borehole 17 (BH17), located approximately 24 metres north and downslope of the environmental watering system, approximately 45 metres north and downslope of the water storage earth embankment and 1-2 metres within the south-western boundary of Bog 11.2 (an impact site).
- Borehole 18 (BH18), located near the Baldy Turret water tank and top of Poleline 6 at the eastern extent of the PCF, approximately 180 metres north-east and downslope of the water storage earth embankment and on eastern boundary of Bog 1 (a control site).

All hydrological monitoring sites are within the Boggy Creek catchment at Mount Buller, which is where the water storage has been constructed. No hydrological monitoring sites are present at Mount Stirling due to its remoteness and because the establishment of monitoring sites for the HEMAMP would have resulted in damage to intact native vegetation and waterways.

Due to the complex hydrology within the Boggy Creek catchment, none of the hydrological monitoring sites at Mount Buller are guaranteed to be true control sites. Each surface water and groundwater monitoring location may have been affected in some way by construction of the water storage. For this reason, climatological and hydrological monitoring follows a quasi-experimental design, with climatological parameters as proxy control groups for hydrological parameters.

Climatological and hydrological parameters are linked by the water cycle. Of the precipitation (rain and snow) that falls on Mount Buller, some evaporates directly or is transpired by vegetation (evapotranspiration), some infiltrates the ground and recharges the water table (groundwater) and some runs off the land surface and

into waterways (surface water). This strong link between precipitation (rain and snow), evapotranspiration, groundwater and surface water has allowed for development of hydrological models (or water balance models) that define the relationship between each of these climatological and hydrological variables in the Boggy Creek catchment.

The hydrological models allow for precipitation and evapotranspiration to be used as hydrological proxies. For example, reliable precipitation and evapotranspiration records for the Boggy Creek catchment are up to 25 years longer than groundwater or surface water records. This provides the opportunity for the precipitation and evapotranspiration records to be used to extend or 'reconstruct' the baseline (pre-construction) groundwater and surface water records.

More importantly, the hydrological models allow for precipitation and evapotranspiration to act as proxy control groups for the hydrological variables. Precipitation and evapotranspiration are landscape-scale parameters that are unlikely to have been affected by construction of the water storage. Using post-construction records for precipitation and evapotranspiration, the baseline hydrological models can be used to predict the groundwater levels and surface water flows that would be expected from the Boggy Creek catchment under 'normal' (baseline) conditions. If post-construction groundwater and surface water records diverge significantly from the expected levels and flows, there will be strong reason to infer that the water storage is having (or has had) an impact on groundwater and surface water.

2.3.2 Ecological monitoring design

Ecological monitoring (Section 6) focuses on the extent, structure, and composition of the Alpine Bogs through transect monitoring, photo points and mapping undertaken at impact and control sites. These methods have been carefully designed to minimise the potential impacts that the monitoring procedures may have on Alpine Bogs (e.g. impacts from trampling).

Monitoring follows a Before-After-Control-Impact (BACI) design, incorporating:

- Seven control sites within the Mount Buller and Mount Stirling Alpine Resorts (Figure 2, Figure 3 and Figure 4), including four unaffected Alpine Bogs on the northern slopes of Mount Buller (Bogs 1, 2, 4.1/5/7 and 11.1, with a total combined areas of 1.115 hectares of Alpine Bog as at February 2019) and three Alpine Bogs on Mount Stirling (Bogs S1, S2 and S3, with a total combined area of 0.903 hectares as at February 2019).
- Six impact sites (Figure 2 and Figure 4), which are the six affected Alpine Bogs downslope of the water storage (Bogs 4.2, 6, 8/9/10, 11.2, 12 and 13, with a total combined area of 1.354 hectares as at February 2019).
- Two years of baseline (before impact) monitoring, denoted as Baseline Year 1 (BY1; June 2017 to May 2018) and Baseline Year 2 (BY2; June 2018 to May 2019).
- Multiple years of post-impact monitoring for the lifetime of the water storage facility, denoted as Impact Year 1 (IY1; June 2019 to May 2020), Impact Year 2 (IY2; June 2020 to May 2021) and so on.

The BACI survey design is a widely accepted environmental monitoring technique around the world, particularly for wetland ecosystems (Green 1979; Stewart-Oaten *et al.* 1986; USEPA 2002; DoE 2011). Although the intention of the HEMAMP is to avoid and minimise impacts, the terms 'impact site' and 'control site' are used throughout this HEMAMP protocol, in line with the BACI design. Ongoing post-impact monitoring is required (with scope for review) because potential impacts may occur over multiple years rather than a single, one-off impact that is typical of many BACI designs.

An important qualification is that the BACI design does not focus on monitoring the change in impact sites over time (Stewart-Oaten *et al.* 1986). The focus is on monitoring the change in the *difference* between impact

sites and control sites over time. The HEMAMP's performance criteria (defined in Section 2.2) therefore relate to changes at impact sites relative to changes at control sites. Monitoring is not intended to detect changes that affect all bogs equally (e.g. changes brought about climate change). Monitoring is designed to detect changes in the difference between impact and control sites over time (e.g. increased susceptibility to the effects of climate change due to localised disturbances). Care has been taken to ensure that there are ecological control sites that are sufficiently far from the water storage site so as not to be affected by it (i.e. at Mount Stirling), yet close enough to the impact sites so as to be influenced by the same regional natural phenomena (Stewart-Oaten *et al.* 1986).

The BACI method can have certain spatial and temporal limitations, leading to confounding variables giving rise to false correlations (Quinn and Keough 2002). The current monitoring design has minimised these limitations and the potential for confounding. The effect of spatial confounding has been reduced by having multiple impact and control sites (all Alpine Bogs that were identified as impact sites during the project's impact assessment and an even greater number of control sites are being monitored). The effect of temporal confounding has been minimised by having multiple impact and control sites in any one given year. In this respect, this monitoring program conforms to the 'Beyond BACI' survey design, which is considered better able to detect impacts than traditional BACI monitoring (Underwood 1992).

As is common with all BACI environmental monitoring studies, there is a risk that the assumption of spatial and temporal independence of observations (an assumption of many statistical tests) may be violated by spatial and temporal pseudo-replication (Hurlbert 1984; Underwood 1992). The HEMAMP requires repeated observations over time from the same Alpine Bogs, some of which are in close proximity to each other.

The proximity of some sites (particularly impact sites) to each other cannot be avoided and may result in spatial autocorrelation. Spatial autocorrelation is one reason that the Alpine Bogs are not analysed individually. Performance criteria are expressed collectively in terms of all impact sites relative to all control sites, meaning that impact sites will not be individually managed but managed as a whole.

Independence of observations through time is difficult to achieve with this type of environmental monitoring. Observations (dissimilarities) from one year are likely to be dependent on what was observed in previous years, with a risk that an impact will be falsely detected (Type I statistical error) and management (such as environmental watering) will commence when it is not actually needed. It is for this reason that robust analytical methods, such as Repeated Measures ANOVA, which account for temporal dependence, are used.

2.5 Monitoring schedule

Monitoring years run from June to May (winter to autumn). The ecological condition of Alpine Bogs in summer and autumn is expected to respond strongly to the hydrological and climatological conditions of the preceding winter and spring.

2.5.1 Climatological and hydrological monitoring schedule

Climate, surface water and groundwater monitoring involves a combination of automated and manual procedures conducted for the life of the storage (subject to review), as specified in Table 1.

Table 1 Schedule and summary of climatological and hydrological monitoring

Project phase	Year	Parameter/Data	Description	Frequency
Pre-construction	BY1 and BY2	Meteorological (rainfall, temp. and, for Mt Buller, evapotranspiration)	Automated data from Mt Buller BoM Station 083024 and Mt Stirling Weather Station	Daily, for the entire year
	BY1 and BY2	Meteorological (snow depth)	Buller Ski Lifts snow gauge monitoring from three sites	Daily, during snow season
	BY1 and BY2	Surface water flow (stage height)	Boggy Creek Weir 1 Boggy Creek Weir 2	Daily (6 hourly)
	BY1 and BY2	Surface water extraction (pumped metering)	Boggy Creek Weir 2	Daily (as pumped to Burnt Hut, part of Mt Buller Water Supply System)
	BY1 and BY2	Surface water quality and inspection	Sampling, inspection, manual measurements and laboratory analysis of surface water	Twice yearly (once in November and once in February)
	BY1 and BY2	Groundwater level	Automated water level logging	Daily (4 hourly)
	BY1 and BY2	Groundwater quality and inspection	Sampling, inspection, manual measurements and laboratory analysis of groundwater	Twice yearly (once in October and once in February)
	BY1 and BY2	Reporting	Consolidated baseline monitoring report delivered to DELWP, DCCEEW and published on website	One-off task at conclusion of BY2 (beginning of IY1)
	BY1 and BY2	Review	Review of monitoring methodology and parameters	One-off task at conclusion of BY2 (beginning of IY1)
Construction	IY1	Meteorological (rainfall, temp. and, for Mt Buller, evapotranspiration)	Automated data from Mt Buller BoM Station 083024 and Mt Stirling Weather Station	As per Pre-construction
	IY1	Meteorological (snow depth)	Buller Ski Lifts snow gauge monitoring from three sites	As per Pre-construction
	IY1	Surface water flow (stage height)	Boggy Creek Weir 1 Boggy Creek Weir 2	As per Pre-construction

Project phase	Year	Parameter/Data	Description	Frequency
	IY1	Surface water extraction (pumped metering)	Boggy Creek Weir 2	As per Pre-construction
	IY1	Surface water quality and inspection	Sampling, inspection, manual measurements and laboratory analysis of surface water	As per Pre-construction
	IY1	Groundwater level	Automated water level logging	As per Pre-construction
	IY1	Groundwater quality and inspection	Sampling, inspection, manual measurements and laboratory analysis of groundwater	As per Pre-construction
	IY1	Reporting	Annual monitoring report delivered to DELWP, DCCEEW and published on website	One-off requirement in winter (beginning of IY2)
	IY1	Review	Review of monitoring methodology and parameters	One-off task in winter (beginning of IY2)
Post-construction (Operation)	IY2 and ongoing	Meteorological (rainfall, temp. and, for Mt Buller, evapotranspiration)	Automated data from Mt Buller BoM Station 083024 and Mt Stirling Weather Station	As per Pre-construction
	IY2 and ongoing	Meteorological (snow depth)	Buller Ski Lifts snow gauge monitoring from three sites	As per Pre-construction
	IY2 and ongoing	Surface water flow (stage height)	Boggy Creek Weir 1 Boggy Creek Weir 2	As per Pre-construction
	IY2 and ongoing	Surface water extraction (pumped metering)	Boggy Creek Weir 2	As per Pre-construction
	IY2 and ongoing	Water storage drainage and discharge volumes	Water storage drainage and environmental watering discharge point	Weekly, outside of the declared snow season
	IY2 and ongoing	Surface water quality and inspection	Sampling, inspection, manual measurements and laboratory analysis of surface water	Twice yearly (once in November and once in February), with optional third sampling in April
	IY2 and ongoing	Groundwater level	Automated water level logging	As per Pre-construction
	IY2 and ongoing	Groundwater quality and inspection	Sampling, inspection, manual measurements and laboratory analysis of groundwater	Twice yearly (once in October and once in February), with optional third sampling in April
	IY2 and ongoing	Reporting	Annual monitoring report delivered to DELWP, DCCEEW and published on website	Annual requirement in winter (beginning of following monitoring year)
	IY2 and ongoing	Review	Review of monitoring methodology and frequencies	Once every three years in winter (beginning of following monitoring year)

2.5.2 Ecological monitoring schedule

Ecological surveys are conducted annually in summer, between mid-December and mid-February. The ecological monitoring will continue throughout the life of the water storage (subject to review), as specified in Table 2.

Table 2 Schedule and summary of ecological monitoring

Project phase	Year	Parameter/Data	Description	Frequency
Pre-construction	BY1 and BY2	Control sites (unaffected Alpine Bogs)	Selection of control sites comprising Alpine Bogs with catchment areas outside the water storage footprint	One-off task in first summer
	BY1 and BY2	Floristics	A full combined flora species list for all control and impact sites and a list of flora species considered to be bog dependent	One-off task in first summer
	BY1 and BY2	Fixed transects	Establishment of 3-5 transects per Alpine Bog (dependent on the size of the Bog), for use as line and belt transects	One-off task in first summer
	BY1 and BY2	Fixed photo points	Establishment of photo point locations at both ends of each transect	One-off task in first summer
	BY1 and BY2	Photos	Recording of pre-construction photos from fixed photo points	Annual in summer
	BY1 and BY2	Bog extent	Measurement of pre-construction extent (dimensions and area) of Alpine Bogs using line transects, on-ground mapping and aerial imaging	Annual in summer
	BY1 and BY2	Bog composition	Measurement of the richness and cover of bog-dependent flora in control and impact sites using line and belt transects	Annual in summer
	BY1 and BY2	Encroachment	Measurement of the cover of non-bog-dependent flora and weeds in control and impact sites using line and belt transects	Annual in summer
	BY1 and BY2	Bog structure	Measurement of Peat Moss cover in control and impact sites using line and belt transects	Annual in summer
	BY1 and BY2	Reporting	Consolidated baseline monitoring report delivered to DELWP, DCCEE and published on website	One-off task at conclusion of BY2 (beginning of IY1)

Project phase	Year	Parameter/Data	Description	Frequency
	BY1 and BY2	Review	Review of monitoring methodology, review of bog-dependent flora list and confirmation that control sites are suitably similar to impact sites so that valid post-construction comparisons can be made	One off task at conclusion of BY2 (beginning of IY1)
Construction	IY1	Photos	Recording of construction phase photos from fixed photo points	Annual in summer
	IY1	Bog extent	Measurement of construction phase extent (dimensions and area) of Alpine Bogs using line transects, on-ground mapping and aerial imaging	Annual in summer
	IY1	Bog composition	Measurement of the richness and cover of bog-dependent flora in control and impact sites using line and belt transects	Annual in summer
	IY1	Encroachment	Measurement of the cover of non-bog-dependent flora and weeds in control and impact sites using line and belt transects	Annual in summer
	IY1	Bog structure	Measurement of Peat Moss cover in control and impact sites using line and belt transects	Annual in summer
	IY1	Reporting	Annual monitoring report delivered to DELWP, DCCEEW and published on website	One-off requirement in winter (beginning of IY2)
	IY1	Review	Review of monitoring methodology and frequencies	One-off task in winter (beginning of IY2)
Post-construction (Operation)	IY2 and ongoing	Photos	Recording of post-construction photos from fixed photo points	Annual in summer
	IY2 and ongoing	Bog extent	Measurement of post-construction extent (dimensions and area) of Alpine Bogs using line transects, on-ground mapping and aerial imaging	Annual in summer
	IY2 and ongoing	Bog composition	Measurement of the richness and cover of bog-dependent flora in control and impact sites using line and belt transects	Annual in summer
	IY2 and ongoing	Encroachment	Measurement of the cover of non-bog-dependent flora and weeds in control and impact sites using line and belt transects	Annual in summer

Project phase	Year	Parameter/Data	Description	Frequency
	IY2 and ongoing	Bog structure	Measurement of Peat Moss cover in control and impact sites using line and belt transects	Annual in summer
	IY2 and ongoing	Reporting	Annual monitoring report delivered to DELWP, DCCEEW and published on website	Annual requirement in winter (beginning of following monitoring year)
	IY2 and ongoing	Review	Review of monitoring methodology and frequencies	Once every three years in winter (beginning of following monitoring year)

2.6 Quality assurance and quality control

The monitoring must include a quality assurance/quality control (QA/QC) program as part of its field procedures, based on relevant Australian Standards (Standards Australia 2005) and standard industry practice. The QA/QC program to be implemented is outlined in the SOPs for climatological monitoring (Appendix 3), hydrological monitoring (Appendix 4) and ecological monitoring (Appendix 5). The QA/QC program includes use of laboratories certified by the National Association of Testing Authorities (NATA) and use of suitably experienced field personnel (e.g. botanists) to undertake ecological monitoring.

2.7 Data management and analysis

All data collected during the monitoring is stored in digital format on the RMB's servers, with a secure third-party cloud-based backup. At a minimum, the RMB is responsible for maintaining the following five datasets:

- A climatological dataset in Microsoft Excel format. This spreadsheet contains relevant climatological records for Mount Buller and Mount Stirling from BY1 onwards.
- A hydrological dataset in Microsoft Excel format. This spreadsheet contains surface water and groundwater quality and quantity data for Mount Buller from BY1 onwards.
- An ecological dataset in Microsoft Excel format. This spreadsheet contains ecological data for impact sites and control sites from BY1 onwards.
- A spatial dataset in ESRI Shapefile format, referenced to a suitable coordinate system (e.g. Geocentric Datum of Australia 2020). This dataset contains relevant Alpine Bog boundaries from BY1 onwards, locations of monitoring infrastructure (e.g. photo points, transects, weather stations, snow gauges, boreholes and surface water monitoring sites) and locations of other relevant observations (e.g. novel weeds).
- A folder of all photo point photos in Joint Photographic Experts Group (JPEG or JPG) format. These photos are unmodified and labelled with the photo point name and monitoring year.

The spreadsheets are maintained in 'long' data format, as opposed to 'wide' data format. This allows for data to be easily added in subsequent years and for the data to be more readily analysed. The following approaches are used to examine and analyse the data:

- Graphical presentation of trends in climatological, hydrological, and ecological parameters over time. Where relevant, Mount Buller impact sites, Mount Buller control sites and Mount Stirling control sites are displayed separately to provide a visual indication of potential differences in responses.

- Statistical analysis using a range of techniques, such as Linear Mixed-effects Models (LMMs) and Analysis of Variance (ANOVA). Robust statistical tests, such as Repeated Measures ANOVA, have been chosen. The focus is on detecting changes in the difference between impact and control sites. Where relevant, Mount Buller and Mount Stirling control sites are analysed separately to verify that Mount Buller control sites have not been compromised.
- Correlation and multiple regression analysis, with the aim of developing and improving models that define the relationship between climatological, hydrological, and ecological parameters. These models assist in detecting or pre-empting ecological change and in determining an appropriate adaptive management response.

2.8 Reporting schedule

Annual monitoring reports will be completed each year by 31 August (refer to Section 7 for further details).

3. Climatological monitoring

3.1 Objective of climatological monitoring

Climatological monitoring provides landscape-scale climatological data for use in hydrological and ecological modelling. Climatological parameters, such as precipitation and evapotranspiration, are landscape-scale parameters that are unlikely to have been affected by construction of the water storage. The climatological dataset therefore serves two main purposes:

- Climatological parameters are proxy control groups for surface water flows and groundwater levels. The HEMAMP's hydrological models use climatological parameters (rainfall, snow depth and evapotranspiration) to predict the groundwater levels and surface water flows that would be expected from the Boggy Creek catchment under 'normal' (baseline) conditions.
- Climatological parameters provide a means of 'standardising' results at control sites across Mount Buller and Mount Stirling. The HEMAMP's ecological models can be adapted to use climatological parameters (rainfall and temperature) as covariates.

Ultimately, climatological monitoring allows for more informed adaptive management actions to be taken.

3.2 Climatological monitoring sites

3.2.1 Weather stations

The BoM has been collecting meteorological data at Mount Buller since 1948. Currently, the BoM maintains an automated weather station at Tirol Flat (Station Number 083024; 37°8'41.8" S, 146°26'22.0" E), approximately 500 metres west-northwest of the water storage (Figure 2 and Figure 5).

In November 2018, the RMB reinstated a weather station at Weather Station Ramble, Mount Stirling, approximately 100-400 metres from the Mount Stirling control sites (Figure 3). The Mount Stirling weather station is off grid, meaning that it relies on a solar panel, battery, and modem to capture and transmit data. In winter, the battery capacity can decrease substantially due to cold temperatures and the solar recharge capacity can be adversely affected by snow and/or overhanging trees covering the solar panel. As technology improves and becomes more readily available, the RMB is committed to periodic upgrades of this weather station to minimise interruptions to the Mount Stirling meteorological dataset. In May 2022, the weather station was upgraded with a new modem (4G/5G as opposed to 3G), solar panels (two 160W 12V monocrystalline panels) and battery (160Ah 12V deep cycle battery).

3.2.2 Snow gauges

Buller Ski Lifts has been recording daily snow depths during the snow season at Mount Buller since 1979. Buller Ski Lifts currently records snow depths at three locations, which have been in continuous use since 1987. The snow gauge locations are at Tirol Flat, Boggy Creek and Family Run, which are within 200-600 metres of the Alpine Bogs on the northern slopes of Mount Buller (Figure 2 and Figure 5). At each location, a gauge sits on the snow surface and measures the depth of the snowpack.

The three monitoring sites reflect different snow conditions across the resort, with the Tirol Flat and Boggy Creek gauges reflective of the conditions at the water storage site. The three monitoring locations are described below, based on historical records:

- Tirol Flat is located in the vicinity of the BoM weather station. The monitoring site is located above the tree line and generally receives the least amount of snow. It has sunlight all day, is prone to scouring from wind effect and is the first to lose all its snow during the spring snowmelt (in line with it being on the north side of the mountain). It is not unusual for the Tirol Flat gauge to have no snow on it during a significant snowfall due to the effects of wind.
- Boggy Creek is located at the top of the Boggy Creek T-Bar. This gauge is above the tree line and receives sunlight all day. It experiences little or no wind affect and receives considerably more snow than the Tirol Flat gauge.
- Family Run is located on the southern side of the upper part of Family Run and is below the tree line. The site receives sunlight for most of the day and historically receives the most snow. It is the last gauge to lose its snow in spring.

All the snow gauging stations are marked and fenced. They are in locations that are not affected by snowmaking or wind deposition. All gauges are above the lowest skiable point (1,375 m) and are at a similar altitude (between 1,689 metres and 1,731 metres). The Tirol Flat and Boggy Creek gauges, which are within the PCF, were temporarily dismantled during construction and reinstated before winter 2020.

3.3 Climatological monitoring requirements

The SOP for climatological monitoring (Appendix 3) outlines the way in which the climatological datasets are collated, curated, and prepared, including the way in which missing values are treated and data are transformed from daily to monthly resolution for inclusion in the HEMAMP's models.

3.3.1 Rainfall, temperature, and evapotranspiration

The BoM weather station at Mount Buller and RMB weather station at Mount Stirling record daily rainfall totals and temperatures (highs and lows), along with other meteorological parameters, such as wind speed. Using these parameters, the BoM also calculates daily evapotranspiration totals for Mount Buller.

At least once per year, the RMB downloads rainfall and temperature data for both weather stations and evapotranspiration data for Mount Buller. These daily datasets are collated for June to May (the monitoring year) and added to the HEMAMP climatological dataset for further analysis (e.g. use in the HEMAMP's models).

3.3.2 Snow depth

Buller Ski Lifts records daily snow depths each year during the snow season (typically from early June to early October). At each of the three monitoring locations, a fixed gauge measures the total depth of the snowpack. Buller Ski Lifts records the snow depth and cleans the gauge off at approximately 5:30 am each day during the snow season.

At the end of the snow season, Buller Ski Lifts supplies the snow depth monitoring data to the RMB to support the HEMAMP. The RMB adds the snow depth data to the HEMAMP climatological dataset for further analysis (e.g. use in the HEMAMP's models). The dataset includes daily snow depths for each of the three snow gauges and a mean daily snow depth across the three snow gauges.

4. Surface water monitoring

4.1 Mount Buller water supply

Water requirements of Mount Buller Resort are determined by the need to serve potable demand and non-potable demands (such as snowmaking activities) across the resort. The annual demand for potable and non-potable water is strongly dependent upon seasonal conditions.

The Mount Buller water supply system receives water from two main sources:

- Licenced diversions from Boggy Creek (and its tributaries).
- Class A recycled water from the Mount Buller Wastewater Treatment Plant.

Boggy Creek is the only source of potable water for the village. In addition, the same supply is transferred to a raw water storage and used for snowmaking. Water from the wastewater treatment plant is also transferred to the raw water storage and used for snowmaking. A third source comprises a temporary diversion from the Howqua River into Sun Valley Reservoir.

Boggy Creek forms part of the Delatite River catchment, which is a tributary of the Goulburn River. The Boggy Creek catchment is located on the northern side of Mount Buller and is bound by two spur lines running north. The catchment is above 1,250 metres elevation and is mainly covered by snow during the winter period (mid-June to mid-October). The topography of the catchment is steep and vegetated, and lies in montane, sub-alpine and alpine areas.

The catchment is relatively inaccessible and is an area where vehicle access is controlled. In winter, the water sourced from the catchment is direct rainfall runoff, snowmelt, or spring fed streamflow. In summer, the majority of the flow in the river is spring fed streamflow (i.e. groundwater seepage or baseflow).

Diversions from the Boggy Creek catchment occur at three locations. These are:

- The Headwaters of Boggy Creek, where a side hill trench across the northeast aspect of Mount Buller collects water that has originated from Alpine Bogs. This water can be gravity fed into Burnt Hut Reservoir.
- Two Catchment Weirs that collect water from several small gullies within the Boggy Creek catchment. This water is gravity fed into the Mount Buller system.
- Two Boggy Creek Weirs (Boggy Creek Weir 1 and Boggy Creek Weir 2) that divert water from Boggy Creek. Weir 1 gravity feeds into Boggy 1 Tank and Weir 2 requires water to be pumped from the creek into Boggy 1 Tank.

4.2 Objective of surface water monitoring

The objective of the surface water monitoring program is twofold:

- Characterise water use and quality.
- Quantify total flows generated by the Boggy Creek catchment.

4.3 Surface water monitoring network

At the commencement of baseline monitoring, there was one streamflow monitoring site within Boggy Creek and its tributaries. This infrastructure was installed at Boggy Creek Weir 2 during the 2014/15 summer period. Relying on one monitoring site places limitations on the assumptions that can be made regarding flow contributions from different parts of the Boggy Creek catchment. Additional monitoring locations were therefore required.

A network of surface water monitoring infrastructure (Figure 2 and Figure 5) allows for more intricate hydrological modelling. In addition to the pre-existing surface water monitoring at Boggy Creek Weir 2, surface water monitoring infrastructure was installed at Boggy Creek Weir 1 (Pickups 1 and 2) in December 2018. During construction of the water storage in 2019-2020, further surface water monitoring infrastructure was installed at the water storage discharge point.

4.3.1.1 Water storage discharge point

The headwaters of Boggy Creek are within the Alpine Bogs immediately downslope of the water storage. Within and between the Alpine Bogs is an aqueduct, referred to as the Headwaters Diversion. This aqueduct has a weir structure but is considered unsuitable for monitoring because:

- The existing weir structure is in poor condition (it is being bypassed in some areas).
- There is leakage from the unlined channel.
- The upstream catchment flows only partially cover the extent of the Alpine Bogs.

To monitor surface water near the headwaters of Boggy Creek, monitoring infrastructure was therefore installed at the water storage discharge point during construction. This infrastructure is in an enclosed concrete pit at the northern edge of the water storage earth embankment. The quality and volume of water from the following sources is monitored at this site:

- The groundwater de-watering (drainage) system below the water storage.
- Discharge from the water storage to the environmental watering system.
- Discharge from the water storage to the aqueduct.

4.3.1.2 Boggy Creek Weir 1

Boggy Creek Weir 1 is located approximately 700 metres downstream of the Alpine Bogs that are at the headwaters of Boggy Creek. Weir 1 has two input points, Pickups 1 and 2, which provide suitable locations for gauging of surface water flows from the eastern and western sub-catchments of Boggy Creek respectively. Weir 1 is above gravity-fed off-takes for the Mount Buller water supply, which means that there is a reduced influence of water extraction at this monitoring location.

The eastern sub-catchment (which delivers to Pickup 1) is comparatively more modified than the western sub-catchment (which delivers to Pickup 2). The eastern sub-catchment has many more roads, tracks, and artificial drains. The eastern sub-catchment also has more water infrastructure, such as pipelines, tanks and the Burnt Hut Reservoir. Weir 1 Pickup 2 is therefore subject to fewer external influences that may complicate surface water modelling.

Monitoring at Weir 1 allows for more detailed breakdown of sub-catchment hydrology and the influence of external factors, such as pre-existing infrastructure.

4.3.1.3 Boggy Creek Weir 2

Boggy Creek Weir 2 is located approximately 800 metres downstream of Weir 1 and the confluence of the eastern and western sub-catchments. This site also represents the licenced water supply diversion point from Boggy Creek, which requires metering to enable the RMB to demonstrate compliance with its licence conditions.

The installation of flow monitoring equipment at Weir 2 provides the opportunity to model the hydrology of the broader Boggy Creek catchment and gain a better understanding of the influence of water extraction.

4.4 Monitoring equipment

4.4.1 Surface water flows

Stream gauges with automated data loggers have been installed in the weir structures to enable automated water level (stage height) monitoring. Such devices can measure water levels at frequencies varying from seconds through to months. Daily water levels are currently being recorded daily and these water levels are converted to flows by following the SOP for hydrological monitoring (Appendix 4).

Discharge into and extraction from the Boggy Creek catchment is monitored using flow meters installed at the water storage discharge point and at Weir 2. The flow meter at Weir 2 is accompanied by an automated data logger while the flow meter at the water storage discharge point requires manual reading and recording.

4.4.2 Surface water quality

Water quality sampling is undertaken at each surface water monitoring site in accordance with EPA Victoria's Guide to the Sampling and Analysis of Waters, Wastewaters, Soils and Wastes (EPA 2000) and the SOP for hydrological monitoring (Appendix 4). Equipment required for this water sampling is specified in the SOP.

4.5 Monitoring requirements

Surface water monitoring requirements are detailed in the SOP for hydrological monitoring (Appendix 4).

4.5.1 Surface water flows

Surface water levels are automatically recorded at Boggy Creek Weir 1 (Pickup 1 and 2) and Weir 2 on a daily basis (at six-hour frequency) using data loggers. Flows at the water storage discharge point are recorded manually on a weekly basis outside of the declared snow season (the enclosed concrete pit is inaccessible when covered in snow).

Flows are recorded in the hydrological dataset spreadsheet as a rate expressed in megalitres per day or per week. Ultimately, for incorporation in the HEMAMP's hydrological models, these data are converted into monthly flows expressed in mean megalitres per day. There is no attempt to fill or reconstruct missing data.

4.5.2 Surface water quality

Surface water quality is analysed at surface water monitoring locations twice per year, assuming water is present and can be sampled (which may not be the case at the water storage drainage and environmental watering system). Water samples are tested for the following quality parameters:

- Electrical conductivity (EC)
- Total Dissolved Solids (TDS)
- pH (field)

- Nutrients (Total P, N)
- Major ions (Ca, Mg, Na, K, Cl, SO₄, HCO₃, CO₃ and NO₃)
- Turbidity
- Suspended Solids.

Laboratory results for these parameters are incorporated into the hydrological dataset spreadsheet for trend analysis and assessment against adaptive management triggers.

4.6 Asset maintenance

4.6.1 Inventory

An asset inventory must be maintained for the long-term operation of the monitoring network, particularly when maintenance works or expansion of the network is required. The documentation of assets facilitates purchasing, repairs, maintenance histories and performance specification. The asset inventory includes as a minimum:

- Metering records
- Faults
- Installed monitoring equipment specifications
- Transducer/data logger type (make and model)
- Setting depth
- Specifications for ordering
- Range
- Calibration details.

4.6.2 Inspections and maintenance

The RMB is responsible for maintaining operational monitoring sites. This includes regular inspections and repair or re-survey, where required.

The physical condition of weirs, stream gauges and flow meters is inspected and recorded on a weekly basis outside of the declared snow season. Deterioration of weir performance can be caused by several factors, including vandalism, blockages, sedimentation and structural collapse. Maintenance is prompted from visual inspection and assessment during a site visit, but also where anomalous monitoring results (for example, no stream flow) are noted.

A more detailed functional inspection is undertaken during each water quality visit (i.e. at least twice per year). During detailed inspections, the following is completed:

- Confirmation of data storage capacity (depending upon logging frequencies, data loggers can store several months of data).
- Check of battery life.
- Check of communications cabling.
- Manual flow gauge measurement (to check for instrument drift).

In addition, monitoring equipment is tested and calibrated every two years or as determined by the manufacturer's requirements.

4.7 Surface water models

4.7.1 Surface water model inputs

Prior to construction of the water storage, surface water flows in Boggy Creek appeared to be seasonal, with peak flows likely to have been in winter-spring and low flows likely to have been in summer-autumn (GHD 2014; Biosis 2019c). Characterising the seasonality of Boggy Creek's pre-construction flows is complicated by a short streamflow record (only 8 months) and the already modified nature of the Boggy Creek catchment before construction of the water storage began (e.g. with existing drainage infrastructure and artificial water extraction). Nevertheless, in the short record that does exist, mean monthly surface water flow showed a relatively strong linear correlation with the following climatological parameters at Mount Buller:

- Total monthly rainfall, with a lag of one month.
- Mean monthly snow depth, with a lag of two months.
- Total monthly evapotranspiration, with a lag of three months.

As expected, surface water flow is positively correlated with precipitation (rainfall and snow depth) and negatively correlated with evapotranspiration. Higher surface water flows were associated with higher rainfall, greater snow depth and lower evapotranspiration. Results of this correlation analysis are shown in Table 3. While all correlations are moderately strong or very strong, not all are statistically significant, based on t-tests with a 5% statistical significance threshold ($\alpha = 0.05$).

Table 3 Summary of surface water and climate correlation analysis

Climatological parameter	Test statistics	Mean monthly flow (ML/day) at surface water sites		
		Weir 1 Pickup 1	Weir 1 Pickup 2	Weir 2
Total monthly rainfall (mm)	Lag (months)	6	1	1
	Pearson correlation (r)	0.6666	0.8526	0.6113
	Degrees of Freedom (DF)	6	6	6
	P-value	0.0711	0.0072	0.1074
Mean monthly snow depth (m)	Lag (months)	6	2	2
	Pearson correlation (r)	0.8400	0.9327	0.6995
	Degrees of Freedom (DF)	6	6	6
	P-value	0.0091	0.0007	0.0535
Total monthly evapotranspiration (mm)	Lag (months)	6	3	3
	Pearson correlation (r)	-0.6149	-0.8095	-0.7413
	Degrees of Freedom (DF)	6	6	6
	P-value	0.1047	0.0149	0.0353

Note: Non-significant P-values are shown in bold.

The one- to three-month lag refers to a delayed response and was observed at Boggy Creek Weir 1 Pickup 2 and Weir 2, but not at Weir 1 Pickup 1. At Pickup 2 and Weir 2, it took up to three months for surface water flows to respond to precipitation and evapotranspiration. A delayed response is expected and explainable. There is a relatively short lag of one month between rainfall and the resultant surface water runoff. The response is probably not immediate because the surface water monitoring sites are located up to 1.5 kilometres downslope of the catchment headwaters and, over this distance, there is no doubt some interaction between surface water and groundwater (with infiltration into groundwater and discharge from springs). The lag of two months between snow depth and surface water flows is likely to be attributable to the time required for snowmelt. The extent to which rain and snow (precipitation) becomes surface water runoff is also likely to be influenced by evapotranspiration rates in the lead up to the precipitation events. Higher evapotranspiration rates at the top of the catchment result in less runoff into Boggy Creek three months later.

While similarly strong correlations existed between climatological parameters and surface water flows at Weir 1 Pickup 1, all correlations had a lag of a lag of six months. Such an extended delay in the surface water response to precipitation and evapotranspiration is not readily explainable. The delayed response at Pickup 1 may be a genuine hydrological response. Pickups 1 and 2 capture runoff from the eastern and western sides (sub-catchments) of the Boggy Creek catchment respectively and both ultimately drain into Weir 2. The eastern sub-catchment (which delivers to Pickup 1) is comparatively more modified than the western sub-catchment (which delivers to Pickup 2). The eastern sub-catchment has many more roads, tracks, and artificial drains. The eastern sub-catchment is also the location of water infrastructure, including the Burnt Hut Reservoir and Baldy Turret tank. Burnt Hut Reservoir is known to have a slow leak and it was discovered in November 2021 that Baldy Turret had been regularly discharging 20 to 30 kilolitres of water per week (Baldy Turret tank is explained in more detail in Section 5.7.3). These leaks and other modifications to the eastern sub-catchment may be the reason for a much more delayed response at Pickup 1. Alternatively, the six-month lag at Pickup 1 may simply be a spurious correlation resulting from the short pre-construction surface water dataset, which is only eight months long.

The strongest pre-construction correlations between surface water flows and climatological parameters were at Pickup 2, which receives water from the less modified western side of the Boggy Creek catchment, before water extraction from the catchment occurs. When water extractions are considered, strong correlations also existed at Weir 2, which receives water from Pickups 1 and 2 and therefore better represents the catchment as a whole. The correlations between surface water flow at Weir 2 (expressed as a mean monthly flow in megalitres per day), total monthly rainfall, mean monthly snow depth and total monthly evapotranspiration are shown in Chart 1 and Chart 2. Note that evapotranspiration is shown on a reverse axis to better represent its relationship with overall catchment hydrology (i.e. increased evapotranspiration represents less surface water runoff).

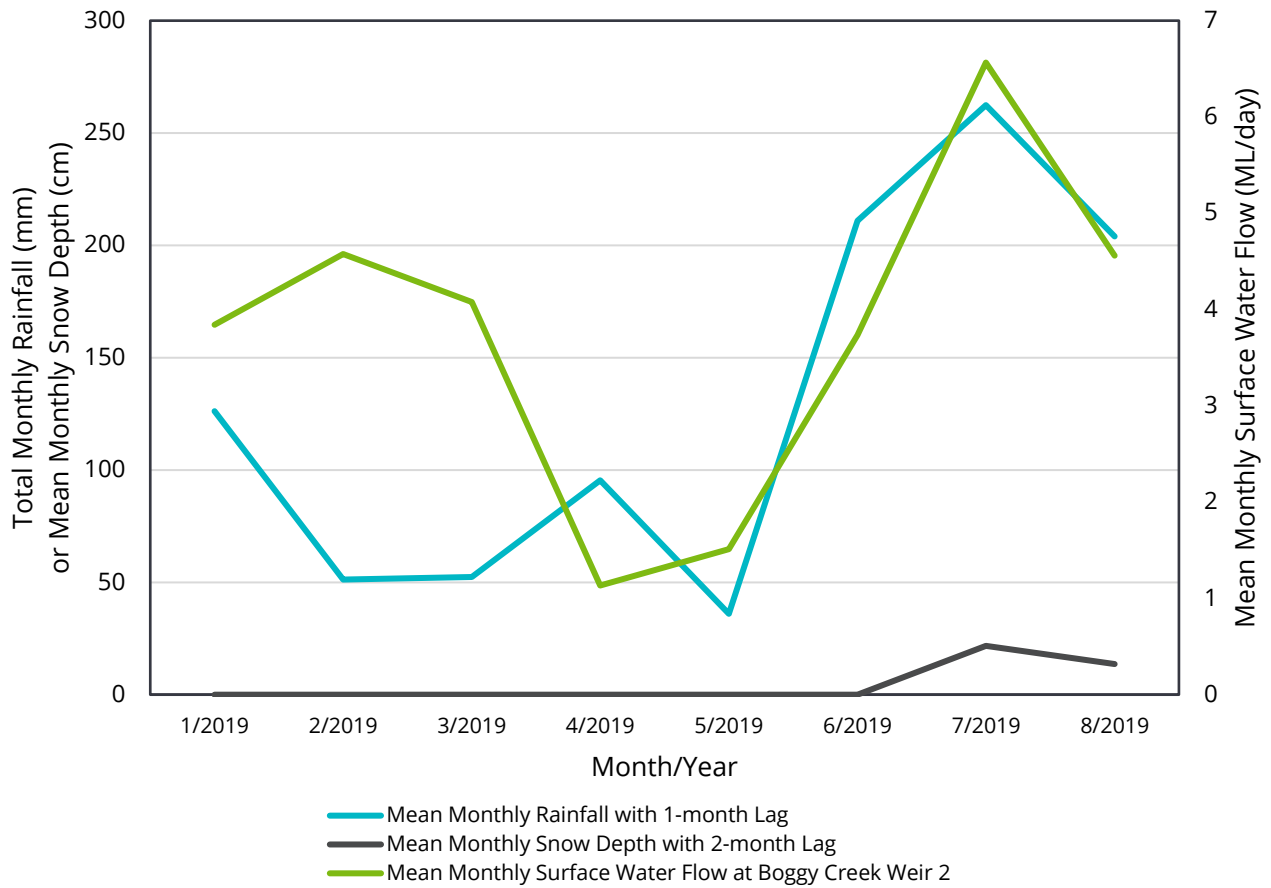


Chart 1 Mean monthly surface water flow (megalitres per day) at Mount Buller Boggy Creek Weir 2, plotted against total monthly rainfall (millimetres) and mean monthly snow depth (centimetres) at Mount Buller from one and two months earlier respectively

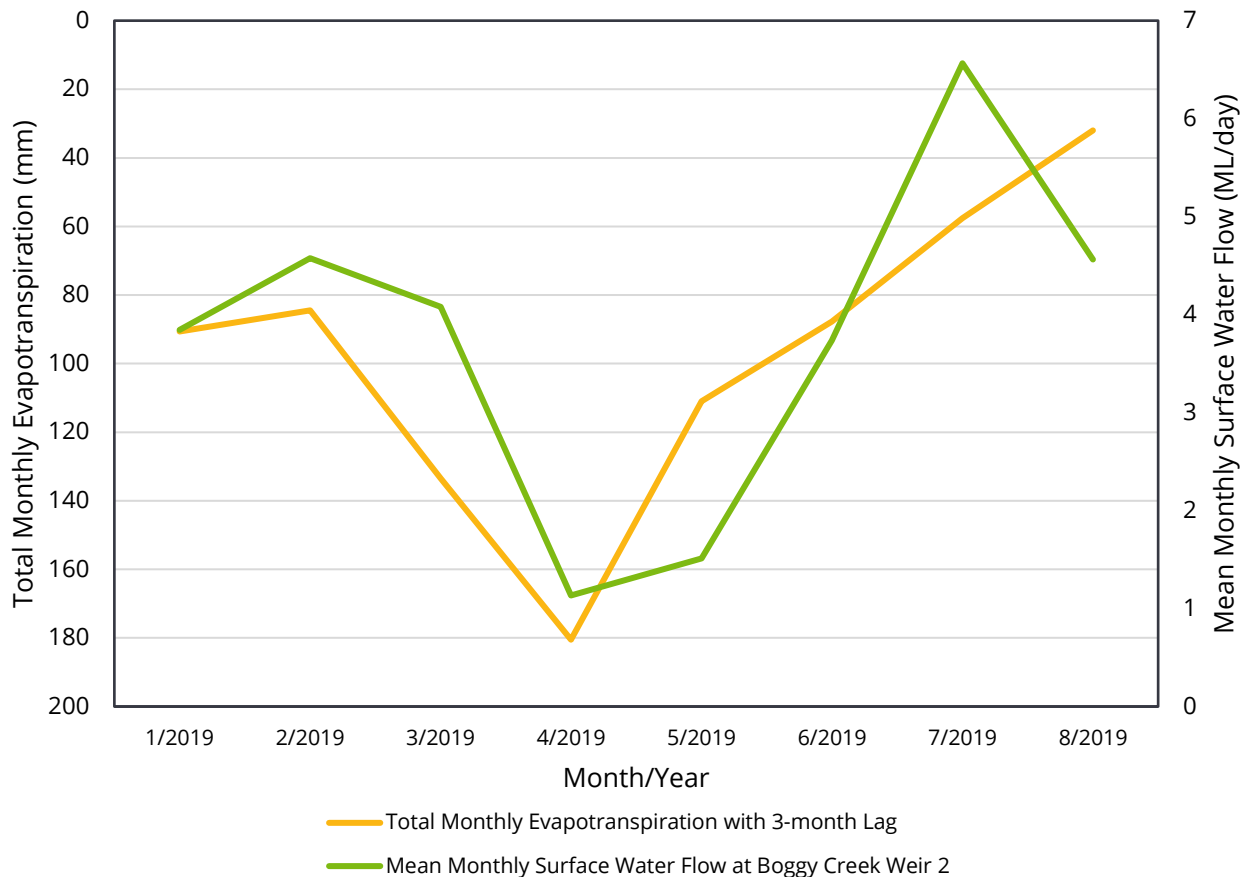


Chart 2 Mean monthly surface water flow (megalitres per day) at Mount Buller Boggy Creek Weir 2, plotted against total monthly evapotranspiration (millimetres) from three months earlier at Mount Buller

4.7.2 Surface water model calibration and validation

Multiple linear regression was used to define the pre-construction (baseline) linear relationship between surface water, rainfall, snow depth and evapotranspiration at each of the three baseline surface water monitoring sites (Weir 1 Pickup 1, Weir 1 Pickup 2 and Weir 2). The linear models take the following form:

$$\text{Surface Water} \sim \text{Rainfall} + \text{Snow Depth} + \text{Evapotranspiration}$$

The components of the models are explained as follows:

- ‘Surface Water’ refers to the mean volume of water available per day over the course of a month at each of the three pre-construction surface water monitoring sites on Boggy Creek. The volume of water available in each day is the sum of the volume of water artificially extracted during the course of the day and the remaining volume of water that spilt over the weir at the monitoring location that same day. There are three surface water models, as follows:
 - There is one model for Weir 2, which represents overall surface water hydrology for the broader Boggy Creek catchment.
 - There are separate models for Pickups 1 and 2 at Weir 1. These models provide more localised results for the eastern and western Boggy Creek sub-catchments respectively. However, the model for Pickup 1 has severe limitations (see Section 4.7.3).
- ‘Rainfall’ is total monthly rainfall (millimetres) for Mount Buller, derived from the BoM weather station.

- ‘Snow Depth’ is the mean monthly snow depth (centimetres) across the three snow gauges monitored by Buller Ski Lifts.
- ‘Evapotranspiration’ is total monthly evapotranspiration (millimetres) at Mount Buller, as determined by the BoM with reference to meteorological parameters collected at the BoM weather station.

When defining the parameters of a model, some baseline data would normally be used for calibration of the model and a separate portion of the data would be withheld to validate the performance of the model as a predictive tool. However, no baseline surface water data were withheld for validation of the surface water models because the baseline surface water dataset was too short, with only 8 months of observations for each monitoring location. Ideally, at least one complete year of pre-construction surface water data would have been available for calibration of the models. With only eight months of pre-construction surface water data and no data for the spring period, there are limitations on the inferences that can be drawn from the models (discussed further in Section 4.7.3). All data needed to be retained for model calibration so as not to further limit the application of the models.

For the purposes of the HEMAMP, the best surface water model is the one that explains the most variability in surface water (the dependent variable) using the fewest climatological parameters (explanatory variables). In practice, there is often a trade-off between these two demands. For each of the three models, the three-variable form outlined above, and all its subsets were examined as potential model candidates. Criteria for selecting the best model included the Adjusted R^2 , ANOVA results, Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (BIC).

A comparison of these criteria for each of the models and their subsets suggested that the complete model, with all three explanatory variables, was most suitable for Pickups 1 and 2. In these cases, the complete model had a greater Adjusted R^2 and more favourable AIC and BIC than any of the subset models. The choice of best surface water model for Weir 2 was more challenging. Adjusted R^2 values suggested that a simplified model with snow depth and evapotranspiration as explanatory variables explained the greatest variability in surface water flows. However, ANOVA results suggested that neither variable made a significant contribution to the hydrological model for Weir 2. An even more simplified model, expressed in terms of evapotranspiration only, had a slightly reduced Adjusted R^2 but a statistically significant relationship and more favourable AIC and BIC, suggesting that it would be a better predictive tool with new climatological data. The hydrological model for Weir 2 was therefore defined with reference to evapotranspiration only, although all other model subsets have been retained for further investigation, if needed in future.

Models with a greater number of explanatory variables generally have a greater risk of collinearity, where two or more explanatory variables are strongly correlated with each other. Collinearity may compromise estimates of model coefficients or inflate confidence intervals (Quinn and Keough 2002). Collinearity was tested by plotting explanatory variables against each other and by calculating Pearson correlation coefficients (r), Variance Inflation Factors (VIFs) and tolerance values. These tests suggested that there was low collinearity between rainfall, snow depth and evapotranspiration. Inclusion of all three explanatory in the hydrological models for Pickups 1 and 2 was therefore appropriate.

The three calibrated surface water hydrological models are defined as follows (subscript refers to monthly lag):

- $Pickup\ 1_t = 0.0395 \times Rainfall_{t-6} + 0.0990 \times Snow\ Depth_{t-6} + 0.0413 \times Evapotranspiration_{t-6} - 7.7296$
- $Pickup\ 2_t = 0.0013 \times Rainfall_{t-1} + 0.0288 \times Snow\ Depth_{t-2} - 0.0030 \times Evapotranspiration_{t-3} + 0.5394$
- $Weir\ 2_t = -0.0283 \times Evapotranspiration_{t-3} + 6.5018$

Results of the multiple linear regression analysis are provided in Table 4. Note that the regression for all models is statistically significant.

The model for Pickup 1 explains 92% of the variability in surface water flows during the calibration period and is therefore superficially a very strong predictive tool (R^2 of 0.9242). However, the coefficient (slope) for its relationship with evapotranspiration is positive. The correlation between surface water runoff and evapotranspiration should be negative (greater evapotranspiration results in less surface water runoff). These results, coupled with the unusual six-month lag, suggest that the model for Pickup 1 is probably over-fitted to the relatively short calibration period and describes a spurious correlation between pre-construction surface water and climatological parameters. This model should be used with extreme caution, if not discarded. It has been included here for the purposes of facilitating further investigation (if required in the future) and continual improvement, but should not be used for predictive purposes or assessment of adaptive management triggers.

For the pre-construction calibration period, the model for Pickup 2 explains 97% of the variability in surface water flows at Pickup 2 (R^2 of 0.9680) and the model for Weir 2 explains 55% of the variability in surface water flows at Weir 2 (R^2 of 0.5495). These results suggest that the Pickup 2 model may be a very strong predictive tool, while the Weir 2 model is likely to be a moderately strong predictive tool. The strength of each model must be interpreted within the limits of their calibration (discussed further in 4.7.3). The reduced performance of the Weir 2 model may be because Weir 2 is influenced by artificial water extractions (although water extraction volumes were factored into the model) and receives surface water runoff from both Pickup 1 (from the more modified eastern side of the Boggy Creek catchment) and Pickup 2 (from the less modified western side of the Boggy Creek catchment). This may weaken the relationship between surface water flow and climate parameters. Weir 2 is also furthest from the headwaters of the Boggy Creek catchment, which is where the climatological parameters are monitored. The greater geographical separation introduces a greater possibility of unknown or extraneous variables influencing surface water flows at Weir 2.

Table 4 Summary of surface water models developed by multiple linear regression

Test statistics	Surface water model: mean monthly flow (ML/day) at Mount Buller surface water sites		
	Weir 1 Pickup 1	Weir 1 Pickup 2	Weir 2
Rainfall: total monthly rainfall (mm) at Mount Buller with specified lag			
Lag (months)	6	1	-
Coefficient	0.0395	0.0013	-
Standard Error	0.0117	0.0007	-
t-statistic	3.3674	1.7623	-
P-value	0.0281	0.1528	-
Snow depth: mean monthly snow depth (cm) across three gauges at Mount Buller with specified lag			
Lag (months)	6	2	-
Coefficient	0.0990	0.0288	-
Standard Error	0.0220	0.0078	-
t-statistic	4.5021	3.6851	-
P-value	0.0108	0.0211	-

Test statistics	Surface water model: mean monthly flow (ML/day) at Mount Buller surface water sites		
	Weir 1 Pickup 1	Weir 1 Pickup 2	Weir 2
Evapotranspiration: total monthly evapotranspiration (mm) at Mount Buller with specified lag			
Lag (months)	6	3	3
Coefficient	0.0413	-0.0030	-0.0283
Standard Error	0.0225	0.0012	0.0105
t-statistic	1.8392	-2.5143	-2.7051
P-value	0.1397	0.0658	0.0353
Intercept: regression equation constant			
Intercept value	-7.7296	0.5394	6.5018
Standard Error	3.4413	0.1707	1.1106
t-statistic	-2.2461	3.1610	5.8542
P-value	0.0880	0.0342	0.0011
Regression statistics			
R ²	0.9242	0.9680	0.5495
Adjusted R ²	0.8673	0.9440	0.4744
Standard Error	1.8893	0.1058	1.2628
Observations	8	8	8
F-statistic	16.2558	40.3441	7.3175
P-value	0.0105	0.0019	0.0353

Note: Non-significant P-values are shown in bold.

4.7.3 Surface water model application

The surface water models are intended to be a tool for detecting potential changes in surface water flows that may have been caused by construction and operation of the water storage. Ultimately, the models may assist in pre-empting potential ecological change to the Alpine Bogs that rely on surface water and assist in defining adaptive management actions that may be required.

However, the surface water models come with important limitations related to their short calibration period, including the following:

- The model for Pickup 1 may describe a spurious correlation between pre-construction surface water flows and climatological parameters. There may be genuine hydrological reasons for the six-month lag (e.g. artificial surface water inputs from leaks at Burnt Hut Reservoir and Baldy Turret tank) but, equally, the strong correlations at a six-month lag may simply be due to the short calibration period.

Either way, this model is likely to be compromised and should not be used to assess adaptive management triggers.

- The model for Pickup 2 has an exceptionally high R^2 value of 0.9680. While this indicates that the model explains almost all the variability in the surface water dataset during the pre-construction calibration period, it also indicates that the model may be over-fitted to the short calibration period and not perform as well as expected as a predictive model with new climatological data. The AIC and BIC values for this model suggest that it should be a strong predictive tool, but some caution should still be applied when interpreting results from this model.
- Weir 2 receives water from Pickups 1 and 2. This means that the model for Weir 2 is likely to be partially influenced by the same factors that may have compromised the model for Pickup 1, such as artificial surface water inputs. However, unlike the model for Pickup 1, the model for Weir 2 does not appear to describe a spurious six-month lagged correlation between surface water flows and climatological parameters. This model is still a useful tool but should be interpreted in the context of artificial surface water extractions and potential artificial surface water inputs.
- Ideally, the calibration period for the surface water models would be as long as possible and capture as much variability in all parameters as possible. The models will not necessarily be reliable predictive tools when used for extrapolation i.e. when climatological inputs are outside the limits observed within the pre-construction calibration period. As a result, the short calibration period of the surface water models makes these models less reliable than the groundwater models, which are based on almost 4 years of pre-construction data. In addition, the short calibration period for the surface water models did not include spring, which limits the inferences that can be made for surface water flows during this season.

It may be possible to augment the calibration period and improve the reliability of the surface water models in the future. For example, if many years elapse since construction of the water storage and little to no ecological change in the Alpine Bogs has been detected or is suspected, there may be justification for adding the initial post-construction years to the calibration period for the surface water models. This would assume that no lagged ecological response had occurred, suggesting that no appreciable impact had yet occurred to the surface water systems in the initial post-construction years.

The possibility of an augmented calibration period will be explored as the models undergo continual improvement, which is part of the HEMAMP's adaptive management component. These models will be built into the hydrology dataset spreadsheet so that new post-construction surface water results can be checked with the pre-construction models and abnormal surface water results highlighted for further action (refer to adaptive management triggers in Section 8.2).

5. Groundwater monitoring

5.1 Mount Buller groundwater

GHD (2016b) conducted several subsurface investigations into the geology of the PCF and surrounds. These investigations confirmed that granite forms the basement rock throughout most of the study area. Granite closer to the surface has become weathered and formed granitic soils or 'grus'. In addition, the granite is capped in places with a relatively complex lithological profile comprising sediments and volcanics (including basalts). Also present are colluvium deposits, including cobbles and boulders of high-strength sandstone, and swamp deposits, including organic-rich carbonaceous clays and silts that have lithified to weak mudstones with minor coal seams.

When saturated, these lithologies represent aquifers to varying degrees. Both the granite and older volcanic basalt represent fractured rock aquifers where groundwater is stored and transmitted by fractures, joints, and other discontinuities within the rockmass. Due to the nature of their emplacement, granites tend to be massive rock masses, with low fracture densities, compared to the extrusive older volcanic basalt, where fracture density is generally higher (GHD 2016b).

Groundwater flow systems within the granite are likely to be complex. Flow within the slightly weathered to fresh granite would likely be dominated by secondary porosity mechanisms. With increased weathering or reworking of extremely weathered granite (granitic soils), groundwater flow may be analogous to porous media flow (GHD 2016b).

The carbonaceous mudstone unit tends to be fine grained and therefore it is likely to act like an aquitard, forming either a perching bed or confining layer for the underlying saturated granite (granite rock and granitic soils). The colluvium is likely to behave as a porous media continuum when saturated (GHD 2016b).

5.2 Objective of groundwater monitoring

The objective of the groundwater monitoring component is to obtain sufficient data to identify relationships between the quantity and quality of groundwater and the groundwater system's response to climate, construction of the water storage and on-going operations. This enables the system's response to be related to the condition of downslope Alpine Bogs, thereby informing the implementation of management responses such as watering of Alpine Bogs to maintain or improve their condition.

The groundwater monitoring would have two phases:

- Phase 1 aims to characterise groundwater level behaviour and its relationship with vegetation condition. These data will inform the design of adaptive management if deemed necessary.
- Phase 2 focuses on characterising the long-term condition of the site and the efficacy of any adaptive management that may occur.

Phase 1 of the groundwater monitoring component commenced in November 2014.

5.3 Groundwater monitoring network

5.3.1 Groundwater monitoring method

Groundwater levels and quality are monitored using a network of bores installed in and around the PCF in 2014 and 2015. These boreholes provide for both water sample collection and monitoring of groundwater levels.

5.3.2 Groundwater bore network

The groundwater monitoring network originally included 17 bores established in 2014 or 2015. However, nine of these bores were within the footprint of the water storage or its earth embankment and therefore could not be readily maintained or monitored during or after construction of the water storage. A further three bores were near other bores and/or relatively shallow, therefore providing limited additional information on groundwater trends. Based on recommendations from GHD, the following five bores have been the focus of groundwater monitoring since HEMAMP monitoring commenced: BH06; BH09; BH16; BH17; and BH18 (Table 5; Figure 2 and Figure 5).

In April or May 2020, BH09 was inadvertently buried during construction of the water storage. It was relocated and restored in March 2022. During this time, no groundwater monitoring was conducted at BH09. BH10 was used as a temporary substitute.

In November 2021, it was discovered that water was being regularly discharged from Baldy Turret tank in proximity to BH18. The regular discharge was caused by an error in the automatic refilling of the water tank. Up until this time, it is estimated that approximately 10 kilolitres of water was being discharged at this location at each refilling of the water tank, which occurred twice per week in summer and three times per week in winter (up to 1.3 megalitres of water per annum). It is unknown when this error commenced but it is possible that results from BH18 have been compromised by artificial inputs of water for an extended period, potentially since monitoring began. The error was rectified, and regular discharges ceased in November 2021.

Table 5 Summary of groundwater bore monitoring network

Bore ID	Zone 55 co-ordinates		Reduced Level (m AHD) ¹	Total Depth (m bgl) ²	Screen (m bgl) ²		
	Easting	Northing			Top	Bottom	Screened lithology
BH06	449,429.0	5,888,787	1,727	9	6	9	Granite, weathered to sands with clay bands (water losses during coring)
BH09	449,611.8	5,888,835	1,714	6	3	6	Granite (sandy clay / clayey sands)
BH16	449,459.4	5,888,860.5	1,715	2.1	1.1	2.1	Clayey gravelly sand and silty gravel
BH17	449,701.4	5,888,866.6	1,727	2.2	1.2	2.2	Clayey sand
BH18	449,922.4	5,888,830.6	1,711	2.15	1.15	2.15	Clayey sand

Notes: (1) Reduced Level derived from LiDAR data (not instrument surveyed) and measured in metres Australian Height Datum (m AHD). (2) Total Depth and Screen measured as metres below ground level (m bgl).

5.3.3 Monitoring bore construction

The monitoring bores are:

- Registered with Goulburn-Murray Water under the Victorian *Water Act 1989*.
- Constructed consistent with the NUDLC (2012) guidelines.
- 50 mm PVC cased bores, completed with appropriate seals.
- Completed with a secure, flush-mounted gatic™ cover which provides a safe, tamper-proof installation.
- Consistent with safety in design considerations.
- Maintained in operational condition.
- Kept secure from unauthorised access.
- Clearly identified on the bore casing or headworks.

5.4 Monitoring equipment

5.4.1 Groundwater level

Pressure transducers and data loggers are installed in the five groundwater monitoring bores. The bores are non-vented, meaning that their transducers are absolute pressure sensors that measure the pressure of the water column and atmospheric pressure. Data from these sensors therefore need to be corrected for atmospheric pressure to obtain groundwater level measurements. In addition to the absolute pressure sensor, BH06 includes an atmospheric (barometric) pressure sensor, which collects concurrent atmospheric pressure measurements that can then be used to correct groundwater level data from all five bores. The quality of groundwater level data is assured twice yearly when manual depth measurements are taken during sampling for groundwater quality.

5.4.2 Groundwater quality

Sampling of groundwater quality occurs at each of the five bores using manual bailing methods, following EPA (2000) guidance on sampling of groundwater (where relevant) and the SOP for hydrological monitoring (Appendix 4). The bores are purged of standing water (minimum three casing volumes, where possible) prior to sampling using a dedicated, disposable bailer to eliminate cross contamination.

Field water quality parameters are measured during the sampling process using a calibrated water quality meter. Groundwater samples are collected and sent to a primary laboratory and a secondary laboratory for quality assurance and quality control. Both laboratories are registered with the National Association of Testing Authorities.

5.5 Monitoring requirements

Groundwater monitoring requirements are detailed in the SOP for hydrological monitoring (Appendix 4).

5.5.1 Groundwater levels

Raw groundwater levels are recorded on a daily basis (at six-hour frequency). Atmospheric pressures are recorded concurrently and are used for providing corrected groundwater levels, as outlined in the SOP for hydrological monitoring (Appendix 4). Mean daily groundwater levels for each monitoring bore are recorded

in the hydrology dataset spreadsheet and ultimately converted to a monthly mean groundwater level for use in the HEMAMP's hydrological models.

5.5.2 Groundwater quality

Groundwater quality is analysed at least twice per year (once in November and once in February), with an optional additional sampling taking place in April. Groundwater sampling currently analyses the following:

- Temperature (°C; field)
- pH (field)
- Dissolved oxygen (field)
- Oxidation reduction potential (ORP; field)
- Electrical conductivity (EC; field and laboratory)
- Total Dissolved Solids (TDS; laboratory)
- Suspended solids (laboratory)
- Turbidity (laboratory)
- Nutrients (total P, N; laboratory)
- Major ions (Ca, Mg, Na, K, Cl, SO₄, HCO₃, CO₃ and NO₃; laboratory).

Laboratory results for these parameters are incorporated into the hydrological dataset spreadsheet for trend analysis and assessment against adaptive management triggers.

5.6 Asset maintenance

5.6.1 Inventory

An asset inventory will be maintained for the long-term operation of the monitoring network, particularly to track maintenance works or expansion of the network as required. The asset inventory will include, as a minimum:

- Monitoring bore records
- Lithological logs and bore construction details
- Installed monitoring equipment specifications
- Transducer/data logger type (make and model)
- Setting depth
- Specifications for ordering
- Range
- Calibration details.

5.6.2 Inspections and maintenance

The RMB is responsible for maintaining operational monitoring bores. This includes periodical inspection and repair or re-survey of monitoring bores where required.

Regular maintenance actions include rust proofing of the bore covers, maintenance of bore access (e.g. preventing over-growth of vegetation) and testing and re-calibrating of pressure transducers and data loggers. These maintenance actions are performed four times per monitoring year, as follows:

- In October, after the declared snow season, monitoring bores are relocated in situ and marked with a stake so that they can be more readily found in November and February following rapid spring vegetation growth. Maintenance actions are also performed.
- During groundwater sampling events in November and February of each monitoring year, the condition of the bores is assessed, and maintenance actions performed (as required).
- A final check of the monitoring bores takes place in April each year before the declared snow season. During this check, the stake is removed (so as not to pose a hazard during the snow season) and an optional groundwater sampling event may take place.

Testing and re-calibrating of automated pressure transducers and data loggers will take place during each of the four annual inspections and involve the follows:

- Confirmation of data storage capacity (depending upon logging frequencies, data loggers can store several months of data).
- Check of battery life.
- Calibration/'zeroing' in air.
- Check of suspending wires.
- Check of desiccants (if vented loggers are ever applied).
- Manual water level measurement (to check for instrument drift).

Deterioration of monitoring bore performance can be caused by a number of other factors, including vandalism, sedimentation, invasion by plant roots and structural collapse. Maintenance to address these causes is prompted by visual inspection and assessment during a site visit, but also when anomalous monitoring results occur.

5.7 Groundwater models

Hydrological models have been developed to define the relationship between climatological parameters and groundwater levels in the Boggy Creek catchment before construction of the water storage occurred. There are individual hydrological models for each of the five HEMAMP monitoring boreholes and one overall model for the Boggy Creek catchment, which uses the average (mean) depth to water table from each of the five boreholes.

5.7.1 Groundwater model inputs

Groundwater levels in the vicinity of the Alpine Bogs at Mount Buller are seasonal. Baseline monitoring results show that depth to the water table is greatest in autumn (March to April) and shallowest in spring (September to October) at the five monitoring boreholes (GHD 2014; Biosis 2019c). Mean monthly depth to the water table before construction therefore showed a relatively strong linear correlation with the following climatological parameters at Mount Buller:

- Total monthly rainfall, with a lag of up to four months.
- Mean monthly snow depth, with a lag of up to three months.
- Total monthly evapotranspiration, with a lag of up to four months.

The lag refers to a delayed response. It took up to three or four months for groundwater levels to respond to rainfall, snowfall, and evapotranspiration in the years before construction of the water storage. This is expected, as it can take some time for precipitation to be absorbed by soils and infiltrate into the sub-surface soils and geology. The extent to which precipitation infiltrates the sub-surface is also likely to be influenced by evapotranspiration rates at the surface in the lead up to the precipitation events.

On average, baseline groundwater levels were most strongly correlated with precipitation (rainfall and snow depth) from two months earlier and with evapotranspiration from three months earlier. Results of this correlation analysis are shown in Table 6. Note that all correlations are statistically significant, based on t-tests with a 5% statistical significance threshold ($\alpha = 0.05$).

Table 6 Summary of groundwater and climate correlation analysis

Climatological parameter	Test statistics	Mean depth (m) to water table at monitoring bores					
		BH06	BH09	BH16	BH17	BH18	All Bores (Mean)
Total monthly rainfall (mm)	Lag (months)	2	1	4	2	0	2
	Pearson correlation (r)	-0.5945	-0.5625	-0.5022	-0.3911	-0.6463	-0.5675
	Degrees of Freedom (DF)	46	46	46	46	46	46
	P-value	<0.0001	<0.0001	0.0003	0.0060	<<0.0001	<0.0001
Mean monthly snow depth (m)	Lag (months)	2	2	3	2	0	2
	Pearson correlation (r)	-0.7050	-0.6353	-0.5804	-0.4291	-0.5104	-0.6503
	Degrees of Freedom (DF)	46	46	46	46	46	46
	P-value	<<0.0001	<<0.0001	<0.0001	0.0023	0.0002	<<0.0001
Total monthly evapo-transpiration (mm)	Lag (months)	3	3	4	3	1	3
	Pearson correlation (r)	0.7577	0.7690	0.7855	0.6865	0.8366	0.7900
	Degrees of Freedom (DF)	46	46	46	46	46	46
	P-value	<<0.0001	<<0.0001	<<0.0001	<<0.0001	<<0.0001	<<0.0001

As expected, depth to water table across all monitoring bores is negatively correlated with precipitation (rainfall and snow depth) and positively correlated with evapotranspiration (Table 6). Depth to the water table decreases (i.e. groundwater levels increase) with increased precipitation and reduced evapotranspiration. In other words, precipitation recharges the water table and brings it closer to the surface, while higher evapotranspiration rates lower the water table further from the surface. The correlations between depth to water table (expressed as a mean monthly depth across all monitoring bores), total monthly rainfall, mean monthly snow depth and total monthly evapotranspiration are displayed in Chart 3 and Chart 4. Note that

depth to the water table and evapotranspiration are shown on reverse axes to better represent their relationship with the overall catchment hydrology (i.e. increased depth to water table or increased evapotranspiration represents less water in the catchment).

One might expect non-linear correlations between depth to the water table and precipitation or evapotranspiration. Indeed, slightly stronger correlations with precipitation or evapotranspiration are achieved when groundwater data from some monitoring bores undergo a natural logarithm or natural exponential transformation respectively. Pearson correlation coefficients are up to 0.04 further from zero. While data transformations improve correlations for most monitoring bores, it is not universal across all bores and any improvements are minor. The data transformations add unnecessary complexity to an otherwise simple linear relationship and were therefore not pursued further.

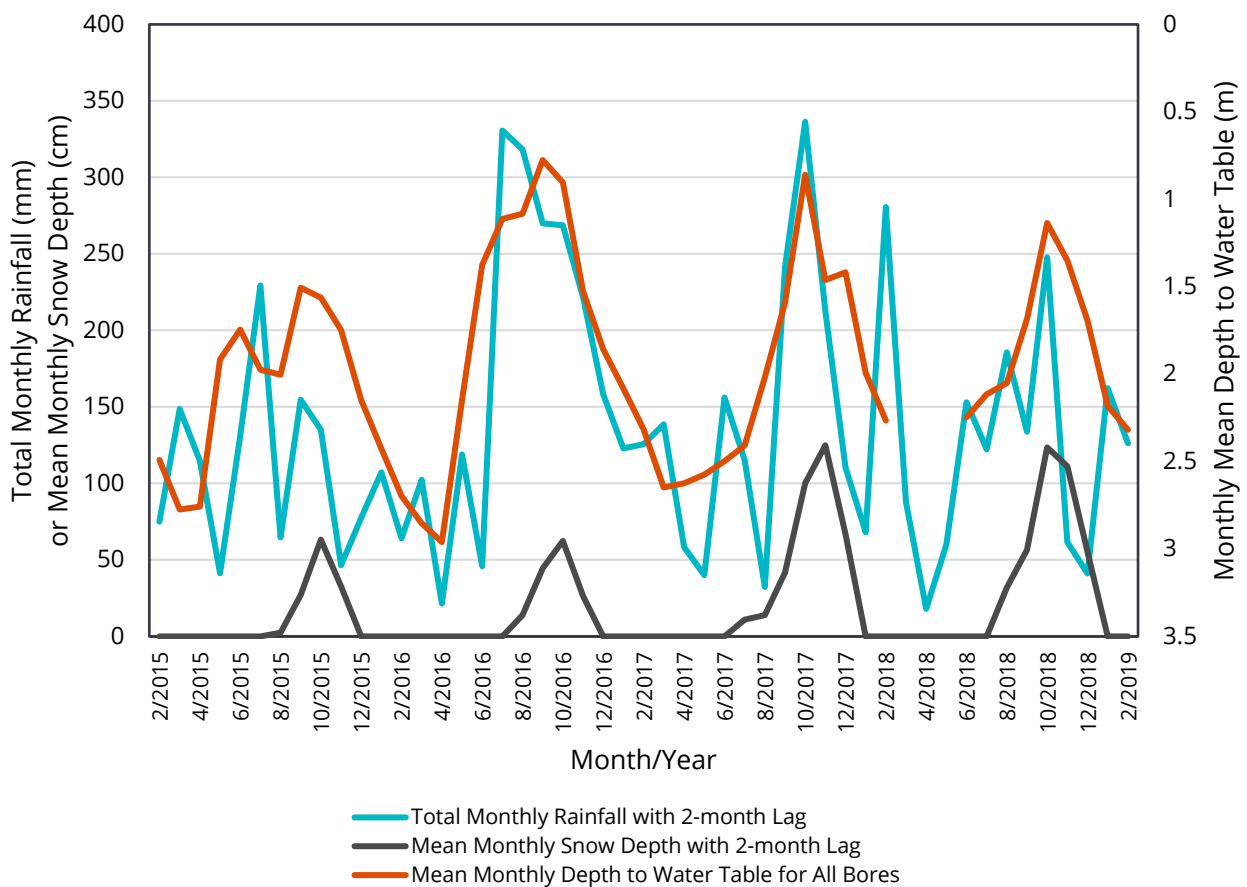


Chart 3 Mean monthly depth (metres) to water table across five monitoring bores at Mount Buller, plotted against total monthly rainfall (millimetres) and mean monthly snow depth (centimetres) from two months earlier at Mount Buller

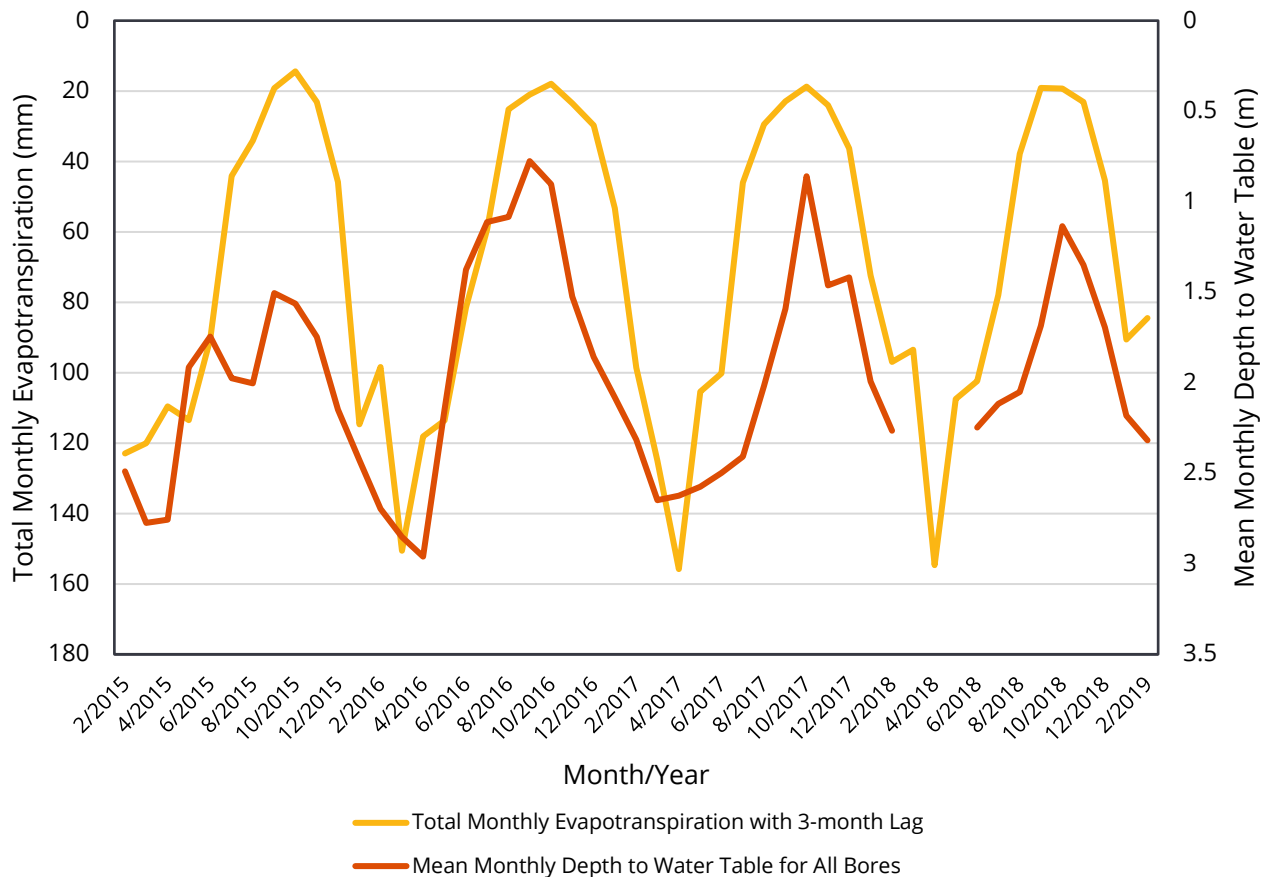


Chart 4 Mean monthly depth (metres) to water table across five monitoring bores at Mount Buller, plotted against total monthly evapotranspiration (millimetres) from three months earlier at Mount Buller

5.7.2 Groundwater model calibration and validation

Multiple linear regression was used to define the pre-construction (baseline) linear relationship between groundwater, rainfall, snow depth and evapotranspiration at each of the five monitoring bores and across the average (mean) of all monitoring bores. The linear models take the following form:

$$\text{Groundwater} \sim \text{Rainfall} + \text{Snow Depth} + \text{Evapotranspiration}$$

The components of the models are explained as follows:

- ‘Groundwater’ refers to the mean monthly depth to water table at individual monitoring bores and as an average (mean) across all five monitoring bores. This means that there are six groundwater models, as follows:
 - There is one overall groundwater model that captures all monitoring bores and is designed to provide an overview of the broader Boggy Creek catchment. When comparing pre-construction and post-construction groundwater hydrology, this should be the model that is used in the first instance.
 - Individual models for the each of the five monitoring bores provide localised results for parts of the Boggy Creek catchment and allow for more targeted monitoring and management.
- ‘Rainfall’ is total monthly rainfall (millimetres) for Mount Buller, derived from the BoM weather station.

- ‘Snow Depth’ is the mean monthly snow depth (centimetres) across the three snow gauges monitored by Buller Ski Lifts.
- ‘Evapotranspiration’ is total monthly evapotranspiration (millimetres) at Mount Buller, as determined by the BoM with reference to meteorological parameters collected at the BoM weather station.

When defining the parameters of a model, some baseline data would normally be used for calibration of the model and a separate portion of the data would be withheld to validate the performance of the model as a predictive tool. However, no baseline groundwater data were withheld for validation of the groundwater models because the baseline groundwater dataset was considered too short, with only 46 to 48 monthly observations (depending on the monitoring bore in question). It is generally recommended that the number of observations contributing to calibration of the model be at least six to ten times the number of predictor variables in the model (Kutner *et al.* 2005), although others suggest that the number of observations should be much larger than this (e.g. Green 1991). In this case, three predictor variables would demand at least 18 to 30 observations. For the purposes of detecting potential post-impact hydrological changes, it was more important that the groundwater models captured as much baseline variability as possible. Validation of model performance with a subset of baseline data would be more important if the models were used purely to reconstruct a longer baseline hydrological record using climatological parameters as proxies.

For the purposes of the HEMAMP, the best groundwater model is the one that explains the most variability in groundwater (the dependent variable) using the fewest climatological parameters (explanatory variables). In practice, there is often a trade-off between these two demands. For each of the six models, the three-variable form outlined above, and all its subsets were examined as potential model candidates. Criteria for selecting the best model included the Adjusted R^2 , ANOVA results, Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (BIC). A comparison of these criteria for each of the models and their subsets suggested that the complete model, with all three explanatory variables, was most suitable for BH06, BH09, BH16 and the overall model for all monitoring bores. In these cases, the complete model had a greater Adjusted R^2 and more favourable AIC and BIC than any of the subset models. ANOVA results suggested that rainfall and snow depth did not make a significant contribution to the hydrological model for BH17, and snow depth did not make a significant contribution to the model for BH18. The hydrological models for these locations were therefore better defined without including these variables.

Models with a greater number of explanatory variables generally have a greater risk of collinearity, where two or more explanatory variables are strongly correlated with each other. Collinearity may compromise estimates of model coefficients or inflate confidence intervals (Quinn and Keough 2002). Collinearity was tested by plotting explanatory variables against each other and by calculating Pearson correlation coefficients (r), Variance Inflation Factors (VIFs) and tolerance values. These tests suggested that there was low collinearity between rainfall, snow depth and evapotranspiration. Inclusion of all three explanatory variables in the hydrological models for BH06, BH09, BH16 and all bores was therefore appropriate.

The six calibrated groundwater hydrological models are defined as follows (subscript refers to monthly lag):

- $BH06_t = -0.0054 \times Rainfall_{t-2} - 0.0131 \times Snow\ Depth_{t-2} + 0.0145 \times Evapotranspiration_{t-3} + 6.9443$
- $BH09_t = -0.0045 \times Rainfall_{t-1} - 0.0097 \times Snow\ Depth_{t-2} + 0.0082 \times Evapotranspiration_{t-3} + 2.0065$
- $BH16_t = -0.0009 \times Rainfall_{t-4} - 0.0013 \times Snow\ Depth_{t-3} + 0.0030 \times Evapotranspiration_{t-4} + 0.2033$
- $BH17_t = 0.0025 \times Evapotranspiration_{t-3} - 0.0305$
- $BH18_t = -0.0017 \times Rainfall_t + 0.0070 \times Evapotranspiration_{t-1} + 0.5582$
- $All\ Bores_t = -0.0019 \times Rainfall_{t-2} - 0.0034 \times Snow\ Depth_{t-2} + 0.0073 \times Evapotranspiration_{t-3} + 1.8116$

Results of the multiple linear regression analysis are provided in Table 7. Note that the regression for all models is statistically significant. Except for the hydrological model for BH17, all models explain between 73% and 79% of the variability in groundwater levels and are therefore strong predictive tools (R^2 between 0.7274 and 0.7863). The hydrological model for BH17 explains 47% of the variability in groundwater levels at that bore location, making it only a moderately strong predictive tool (R^2 of 0.4713).

The reduced performance of the BH17 model is likely to be because the water table was consistently shallow at this location during the baseline calibration period and showed little variability. The water table was regularly at the surface (i.e. the depth to the water table was zero metres), especially in early calibration years (2015 and 2016). Rainfall and snow depth had a reduced influence on groundwater levels at BH17 compared with other locations, which is why these variables were not included in the BH17 model. With low variability in the dependent variable and only one explanatory variable, it is unsurprising that the performance of the BH17 model is reduced.

Table 7 Summary of groundwater models developed by multiple linear regression

Test statistics	Groundwater model: mean depth (m) to water table at Mount Buller monitoring bores					
	BH06	BH09	BH16	BH17	BH18	All Bores (Mean)
Rainfall: total monthly rainfall (mm) at Mount Buller with specified lag						
Lag (months)	2	1	4	-	0	2
Coefficient	-0.0054	-0.0045	-0.0009	-	-0.0017	-0.0019
Standard Error	0.0014	0.0008	0.0002	-	0.0004	0.0006
t-statistic	-3.8723	-5.7121	-4.2237	-	-3.9411	-3.2465
P-value	0.0004	<<0.0001	0.0001	-	0.0003	0.0023
Snow depth: mean monthly snow depth (cm) across three gauges at Mount Buller with specified lag						
Lag (months)	2	2	3	-	-	2
Coefficient	-0.0131	-0.0097	-0.0013	-	-	-0.0034
Standard Error	0.0040	0.0023	0.0006	-	-	0.0017
t-statistic	-3.3163	-4.1375	-2.1011	-	-	-2.0212
P-value	0.0018	0.0002	0.0417	-	-	0.0497
Evapotranspiration: total monthly evapotranspiration (mm) at Mount Buller with specified lag						
Lag (months)	3	3	4	3	1	3
Coefficient	0.0145	0.0082	0.0030	0.0025	0.0070	0.0073
Standard Error	0.0034	0.0021	0.0005	0.0004	0.0008	0.0015
t-statistic	4.1995	3.9127	5.5240	6.2627	8.4009	4.9527
P-value	0.0001	0.0003	<<0.0001	<<0.0001	<<0.0001	<0.0001

Test statistics	Groundwater model: mean depth (m) to water table at Mount Buller monitoring bores					
	BH06	BH09	BH16	BH17	BH18	All Bores (Mean)
Intercept: regression equation constant						
Intercept value	6.9443	2.0065	0.2033	-0.0305	0.5582	1.8116
Standard Error	0.3852	0.2496	0.0631	0.0308	0.1066	0.1688
t-statistic	18.0266	8.0382	3.2198	-0.9895	5.2389	10.7293
P-value	<<0.0001	<<0.0001	0.0025	0.3278	<<0.0001	<<0.0001
Regression statistics						
R²	0.7453	0.7863	0.7379	0.4713	0.7796	0.7274
Adjusted R²	0.7280	0.7717	0.7192	0.4593	0.7693	0.7079
Standard Error	0.7347	0.4220	0.1135	0.1102	0.2284	0.3080
Observations	48	48	46	46	46	46
F-statistic	42.9242	53.9700	39.4130	39.2211	76.0310	37.3555
P-value	<<0.0001	<<0.0001	<<0.0001	<<0.0001	<<0.0001	<<0.0001

Note: Non-significant P-values are shown in bold.

5.7.3 Groundwater model application

The groundwater models provide a means of detecting change in groundwater levels that may be brought about by the water storage and, ultimately, a means of pre-empting potential ecological change to the Alpine Bogs that rely on the groundwater source. These models will be built into the hydrology dataset spreadsheet so that new post-construction groundwater results can be checked with the pre-construction (baseline) models and abnormal groundwater results highlighted for further action (refer to adaptive management triggers in Section 8.2).

The overall groundwater model, which captures all monitoring bores, provides an overview of the broader Boggy Creek catchment. When comparing pre-construction and post-construction groundwater hydrology, this should be the model that is used in the first instance. Individual models for the each of the five monitoring bores provide localised results for parts of the Boggy Creek catchment and allow for more targeted monitoring and management, if required.

Each groundwater model is a strong predictive tool but should be used with caution, especially if climatological inputs into the models are outside the limits observed within the baseline calibration period (i.e. extrapolation). Further limitations exist in the application of the groundwater models for BH17 and BH18, as follows:

- As noted above, the predictive strength of BH17 model is only moderately strong and relatively weak compared with the other groundwater models, due to low variability in the dependent variable during the calibration period and reliance on only one explanatory variable (evapotranspiration).

- While the BH18 model is founded on a strong baseline relationship between hydrological and climatological parameters, results from this model will need to be interpreted with caution because the relationship may have been influenced by artificial inputs of water at this location during the baseline calibration period.
 - In November 2021, it was discovered that water was being regularly discharged from the Baldy Turret tank, from the overflow pipe approximately 20 metres upslope of BH18. The regular discharge was caused by an error in the automatic refilling of the water tank.
 - It is estimated that approximately 10 kilolitres of water was being discharged at this location at each refilling of the water tank, which occurred twice per week in summer and three times per week in winter (up to 1.3 megalitres of water per annum).
 - We do not know when this error commenced and therefore whether it would have affected the baseline calibration period (2015 to 2019). BH18 is the only monitoring bore that showed very little (if any) lagged response to climatological parameters during the baseline period, which suggests that it may have indeed been affected by artificial water inputs during this period.
 - If the baseline calibration period was affected, the BH18 model may need to be re-calibrated to compensate for the artificial addition of up to 1.3 megalitres of water per annum. If this re-calibration cannot occur, the results from the BH18 model may be compromised and BH18 may need to be removed from the overall groundwater model.

The groundwater models will undergo continual improvement as part of the HEMAMP's adaptive management component. For example, if many years elapse since construction of the water storage and little to no ecological change in the Alpine Bogs has been detected or is suspected, we may consider adding the initial post-construction years to the groundwater models. This would assume that no lagged ecological response had occurred, suggesting that no appreciable impact had yet occurred to the groundwater systems in the initial post-construction years. The additional data from the initial post-construction years could be used for further model calibration or, ideally, for model validation, which was not possible with pre-construction data alone.

6. Ecological monitoring

6.1 Objective of ecological monitoring

The ecological monitoring component aims to assess the extent and condition of Alpine Bogs at impact sites relative to the extent and condition of Alpine Bogs at control sites. Ecological monitoring focuses on the extent of the bogs, their floristic composition, their structural health and encroachment of weeds and other atypical species. These parameters are assessed with reference to specific performance criteria and trigger points for adaptive management actions (Sections 2.2 and 8.2). Ultimately, the aim of ecological monitoring is to inform the implementation of adaptive management measures to minimise the potential indirect impacts of the water storage on Alpine Bogs.

Table 8 Link between ecological monitoring and performance criteria

Target criterion	Metric	Method	Sample size	Frequency
Extent	<ul style="list-style-type: none"> Bog dimensions (m) Bog area (ha) 	Line transects, on-ground mapping and aerial imaging	Three to five transects per Alpine Bog	Annual (summer)
Composition	<ul style="list-style-type: none"> Richness of bog-dependent flora (# spp.) Cover of bog-dependent flora (%) 	Line transects (point intersections) and belt transects (quadrats)	Three to five transects per Alpine Bog with point intersections at 20 cm intervals and quadrats at 4 m intervals	
Encroachment	<ul style="list-style-type: none"> Cover of non-bog-dependent flora (%) Cover of weeds (%) 			
Structure	<ul style="list-style-type: none"> Peat Moss cover (%) 			

6.1.1 Ecological parameters to be monitored

Ecological monitoring considers the following parameters, which are directly related to the HEMAMP's performance criteria and adaptive management thresholds:

- Bog extent: area and dimensions of Alpine Bogs.
- Bog composition: richness and cover of bog-dependent flora.
- Encroachment by weeds and other atypical species: cover of weeds and cover of non-bog-dependent flora.
- Bog structure: Peat Moss cover.

6.1.2 Ecological monitoring frequency

As Alpine Bogs are highly sensitive ecosystems, it is essential that field methods are designed to avoid or minimise impacts that may result from the monitoring procedure itself. For this reason, ecological monitoring takes place annually rather than seasonally, to avoid excessive trampling of the Alpine Bogs.

The methods specified in this HEMAMP use a combination of:

- Repeatable and systematic monitoring using belt transects and line transects.
- On-ground reference photo points.
- On-ground mapping of bog extent using a Differential Global Positioning System (DGPS) or equivalent.
- High resolution aerial imagery.

Annual monitoring using these methods is frequent enough to detect changes in Alpine Bogs and to inform adaptive management actions. Vegetative changes to Alpine Bogs are slow and gradual enough for annual monitoring to be sufficient (A Tolsma, pers. comm., July 2016) and this has been reflected in monitoring results to date.

The frequency of ecological monitoring will be subject to reporting and review requirements (Section 7). If reviews reveal that annual monitoring is too frequent (e.g. because no changes are being detected and/or the monitoring procedure is itself impacting on the Alpine Bogs), the frequency of ecological monitoring may be reduced (subject to agreement from DELWP and DCCEE). Greater reliance may be placed on less intrusive monitoring methods, such as monitoring by way of aerial imagery.

6.2 Site selection, establishment and maintenance

Identical methods and survey intensity will be conducted each year, in accordance with the SOP for ecological monitoring (Appendix 5). However, some additional actions were required to establish the monitoring sites during the baseline monitoring years (BY1 and BY2) and some additional actions will be required from time to time to maintain the ecological monitoring infrastructure. These additional actions are outlined in the following sub-sections.

6.2.1 Selection of control sites

The monitoring program includes seven Alpine Bogs with catchment areas that are entirely outside of the footprint of the water storage and earth embankment. These have been designated as control sites. The control sites include:

- Four Alpine Bogs on the northern slopes of Mount Buller (Bogs 1, 2, 4.1/5/7 and 11.1), with a total combined areas of 1.115 hectares of Alpine Bog as at February 2019 or BY2 (Figure 2).
- Three Alpine Bogs on Mount Stirling (Bogs S1, S2 and S3), with a total combined area of 0.903 hectares as at February 2019 or BY2 (Figure 3).

Control sites on Mount Stirling are far enough from the water storage and other infrastructure to ensure that resort activities (including construction and operation of the water storage) have no measurable impact on the extent or condition of the sites.

6.2.2 Full floristic assessment of all control and impact sites

A comprehensive and combined species list was collected for all Alpine Bogs included in the monitoring program over BY1 and BY2. The species list uses Victorian Biodiversity Atlas nomenclature and is updated each year with taxonomic changes and any new species that are encountered during monitoring.

In addition, a continual effort is made to improve upon species identifications where possible. For example, a concerted effort was made to collect, photograph, and identify all bryophytes (in this case, liverworts and mosses) in IY2. An informal herbarium is being maintained to assist with plant identifications in subsequent

years. This is particularly useful when important plant material (e.g. flowers or seeds) may not be available in the field each year.

6.2.3 Creation of bog-dependent flora species list

From the full species list, a subset of species considered dependent on, and characteristic of the Alpine Bogs has been determined and this list is used to assess extent and composition criteria. The list draws heavily upon the diagnostic bog species outlined in the Diagnostic Key to Alpine Bogs (DoE 2013; Appendix 5) and the EPBC Act policy statement for Alpine Bogs (DEWHA 2009). The list of bog-dependent flora is as follows:

- Silver Astelia *Astelia alpina* var. *novae-hollandiae*
- Alpine Baeckea *Baeckea gunniana*
- Mountain Baeckea *Baeckea utilis* s.l. (which includes Subalpine Baeckea *Baeckea latifolia* and Mountain Baeckea *Baeckea utilis* s.s., two species that cannot be reliably distinguished at Mount Buller)
- Alpine Bottlebrush *Callistemon pityoides*
- Spreading Rope-rush *Empodisma minus*
- Swamp Heath *Epacris paludosa*
- Candle Heath *Richea continentis*
- Peat Moss *Sphagnum* spp.

Introduced species and native species not on the above list are non-bog-dependent for the purposes of assessing performance criteria. The exceptions are Bidgee-widgee *Acaena novae-zelandiae*, Alpine Water-fern *Blechnum penna-marina* subsp. *alpina*, Tall Sedge *Carex appressa* and all bryophyte species other than Peat Moss. These species are considered 'neutral' for the purposes of mapping Alpine Bog boundaries (the cover of these species is not included in total vegetation cover because they are typical of Alpine Bogs at Mount Buller and Mount Stirling but not strictly 'bog-dependent').

6.2.4 Full aerial imaging of control and impact sites

High resolution aerial imagery of the Alpine Bogs and immediate surrounds was captured on 20 and 21 February 2019 using a DJI Phantom 4 Pro Unmanned Aerial Vehicle (UAV), equipped with a DJI Phantom 4 Pro FC6310 8.8 camera for capturing red-green-blue (RGB) imagery and a Parrot Sequoia 4.0 camera for capturing near infrared (NIR) imagery.

The UAV was flown in accordance with Civil Aviation Safety Authority (CASA) regulations. The flights were undertaken in clear conditions (10-16°C), with no cloud cover, low wind speeds (generally less than 10 km/h) and within a few days of on-ground mapping being conducted. Imagery was captured around the middle of the day to minimise shadow. The average Ground Sampling Distance (GSD), which represents the average pixel size of the imagery when projected onto the ground, was 1.63 to 1.67 centimetres for RGB imagery and 5.98 to 6.27 centimetres for NIR imagery. The data were georeferenced using ground control points (the locations of which have been recorded). Flight paths and other metadata have also been recorded for repeatability in future years.

In total, imagery was captured for approximately 30 hectares of Mount Buller and 20 hectares of Mount Stirling. The data were post-processed to produce RGB and multispectral orthomosaics and a digital surface model (DSM) of the Alpine Bogs. This baseline imagery may be used in future impact years if a less intrusive method for monitoring the size of the Alpine Bogs is required.

Before aerial imagery is adopted as an alternative monitoring method (subject to approval from DELWP and DCCEEW), the RMB will analyse, review, and compare mapping of Alpine Bogs from aerial imagery with

existing on-ground mapping to determine the suitability of remote monitoring as a replacement for on-ground monitoring.

6.2.5 Establishment of fixed transects

Permanent transects have been established at each Alpine Bog (impact and control sites) to assess extent, composition, encroachment, and structure of each Alpine Bog. The same transects are used as line transects (for point intersection sampling), belt transects (for quadrat sampling) and photo points. The transects were established as follows:

- Each Alpine Bog has three to five transects, depending on the size of the Alpine Bog (Figure 4).
- To minimise trampling, transects were aligned across the narrow dimensions of the Alpine Bog, rather than across the longest dimension, and areas dominated by tall shrubs were avoided where possible (although this was challenging at some sites).
- At the time of establishment, each transect traversed the entire width of the Alpine Bog, starting 1.5-4 metres outside the Bog and ending 1.5-4 metres outside the Bog. Due to floristic changes at some control and impact sites, the start and/or end of some transects are now within the Alpine Bogs themselves. This has occurred due to vigorous growth of bog-dependent species (relative to non-bog-dependent species) or colonisation of surrounding vegetation by bog-dependent species.
- Transect lengths (in metres) are divisible by four to facilitate quadrat sampling at regular 4-metre intervals.
- The start and end points of transects have been recorded using DGPS and marked with small wooden pegs that do not protrude above the height of the vegetation, to avoid creating a risk to skiers and passers-by. A galvanised nail was embedded in the top of each peg to allow the pegs to be relocated with a metal-detector, if needed.

As DGPS technology and locational accuracy improves, the locations of wooden pegs will be progressively re-mapped to ensure that this spatial dataset remains as accurate as possible. In addition, photos will be periodically taken of the wooden pegs and their surrounds, to assist with relocating and replacing wooden pegs, if necessary. The pegs are periodically sprayed pink, which also assists in relocating them each year.

6.2.6 Establishment of fixed photo points

Photo point locations have been established at both ends of each fixed transect, providing 6-10 photo points per Alpine Bog. In addition to providing a visual documentation of any changes to the Alpine Bogs, the photos also assist in relocating transect end pegs.

6.3 Monitoring methods

Detailed ecological monitoring methods are outlined in the Standard Operating Procedure (SOP) for ecological monitoring (Appendix 5). A summary of the ecological monitoring methods and their purpose is provided in the following sub-sections.

6.3.1 Line transects (point intersections)

The fixed transects are used as line transects, which facilitate monitoring of extent, composition, encroachment, and structure of Alpine Bogs, but particularly extent, encroachment and structure. At each transect, a measuring tape is extended from the start peg (designated as 0 centimetres) to the end peg. A 5-millimetre diameter steel pin (approximately 1.1 metres long) is inserted vertically into the vegetation at 20-centimetre intervals along the tape, starting at 20 centimetres. At each interval, the following observations are

recorded using the digital ecology data collection spreadsheet (in Microsoft Excel format) that has been specifically designed for this project:

- The ground condition (substrate) at the base of the pin.
- All species of flora touching the pin along any part of the pin's length.
- The condition of each species touching the pin, categorised as dead or alive.

The types of species recorded (i.e. bog-dependent species or not) and the position at which they are recorded provide an indication of the extent of the Alpine Bog. It allows demarcation of the boundary of the Alpine Bog in at least six locations (if three transects are deployed) and in up to ten locations for larger Bogs (if five transects are deployed), thereby allowing approximate dimensions of the Alpine Bog to be determined.

The frequency at which species are recorded provides an indication of the structure of the Alpine Bogs and any encroachment of atypical or weed species. It allows for the 'cover' of bog-dependent species, non-bog-dependent species, weeds, and Peat Moss to be estimated. Estimating cover with point intersections is less subjective than simple visual estimates, which means that the data are less biased by an individual observer and more suited to vegetation monitoring for detection of change. This means that the data should be more accurate and the estimates of change over time more reliable. Assessing on a continuous scale as opposed to broad categories (as is the case for the widely used Braun-Blanquet or Domin scales) also increases the resolution of the data so that relatively smaller changes can be detected.

Some subjectivity exists in the determination of a plant's condition as dead or alive. A species is recorded as dead where all individuals of that species that are touching the pin are dead. An individual plant is dead when all material belonging to that individual is dead. Dead plant material is inferred by a clear lack of photosynthesising tissue. This can be complicated for some species, as photosynthetic tissue is not always green. For example, photosynthetic tissue of Peat Moss can range in colour from dark green to yellow to pink. Peat Moss is therefore only considered to be dead when it has a 'dirty' brown or grey appearance.

When calculating plant covers for the purposes of assessing the HEMAMP's performance criteria and adaptive management triggers, all individuals are counted, regardless of whether they are dead or alive. The potential subjectivity associated with plant condition is one reason for this. Another reason is that dead individuals still have an inherent cover (albeit reduced, if they have lost leaves), until they become detached and are recorded as organic litter. Ultimately, the individual may appear dead (due to lack of photosynthetic tissue) but actually recover. The purpose of recording plant condition is to pre-empt potential future decline in cover.

6.3.2 Belt transects (quadrats)

The fixed transects are used as belt transects, which facilitate monitoring of the composition of Alpine Bogs. More specifically, belt transects allow for accurate estimation of the species richness of bog-dependent flora.

A 1-metre x 1-metre quadrat (Plate 2) is placed at 4-metre intervals along each transect, starting and ending 4 metres from the ends of the transect. The centre of the quadrat is placed at the 4-metre interval mark. All flora species within the quadrat and their condition (dead or alive,) are recorded using the digital ecology data collection spreadsheet (in Microsoft Excel format). The covers of species are not recorded.

When combined with point intersection data, quadrat data provides a measure of the species richness of bog-dependent flora. Point intersection data captures the most dominant flora species. The inclusion of quadrat data increases the likelihood of detecting small or rare species, including any novel weed species that may need eradicating.

6.3.3 Photo points

The ends of the fixed transects are used as photo points, from which photos are taken annually to allow for qualitative assessment of changes (if any) to the extent, composition, encroachment and structure of Alpine Bogs.

6.3.4 On-ground mapping

The boundary of each Alpine Bog (at impact and control sites) is mapped on foot using a DGPS. In BY1 and BY2, this mapping was to an accuracy of 3 metres or better in most instances, but accuracy was reduced to up to 5 metres in some areas with an overhanging tree canopy, particularly at Mount Stirling. In IY1 and IY2, improvements to DGPS technology (e.g. satellite availability and satellite-delivered correction services, particularly Trimble RTX) allowed for sub-2-metre accuracy in most instances (especially at Mount Buller sites) and generally no worse than 3-metre accuracy (e.g. at Mount Stirling sites with overhanging tree canopies). Further improvements to DGPS technology resulted in consistent sub-metre accuracy at all monitoring sites in IY3 and this accuracy is expected to continue in future monitoring years.

Annual on-ground mapping provides measures of the area of each Alpine Bog, which enable changes to extent to be detected. Since on-ground mapping can be subjective and may cause excessive trampling of Alpine Bogs, on-ground mapping may be replaced by mapping using aerial imagery, if reviews show that remote monitoring by aerial imagery is valid.

6.3.5 Aerial imaging

Aerial imaging was conducted in BY2 (pre-construction) and may be analysed, reviewed, and compared with existing on-ground mapping to verify that monitoring through aerial imaging is valid. Aerial imagery would be analysed to determine whether it is a valid method for estimation of:

- The extent (area) of Alpine Bogs (extent criterion).
- The cover of bog-dependent and non-bog-dependent flora species (composition and encroachment criteria).
- The cover of weeds (encroachment criterion).
- The cover of Peat Moss (structure criterion).

Assuming aerial imaging is found to be valid, it will provide an ecological monitoring contingency if reviews reveal that on-ground monitoring is disturbing the Alpine Bogs and less intrusive monitoring methods are required.

While it appears that five years of monitoring (particularly transect monitoring) has caused some disturbance to the Alpine Bogs, it is not yet severe enough to warrant stopping on-ground monitoring altogether. If aerial imaging by UAV were undertaken again in future years, flights would be subject to weather conditions or satellite imagery may be used as an alternative.

6.4 Ecological models

The ecological monitoring program follows a 'Beyond BACI' (Before-After-Control-Impact) design and data analysis has been set up accordingly (Underwood 1992 and 1994). Linear Mixed-effects Models (LMMs) and Analysis of Variance (ANOVA) are used to test the statistical significance of the effect of the period (before/after) and treatment (control/impact) on a given response variable (e.g. area of Alpine Bogs or cover of weeds).

LMMs are fitted using the 'lme4' package in the R statistical and graphical environment (R Development Core Team 2022) using the Restricted Maximum Likelihood (REML) method. The models are in the following form:

$$\text{Response} \sim \text{Period} * \text{Site Class} + (1 | \text{Year}) + (1 | \text{Sample})$$

The various components of the models are explained as follows:

- Response:
 - The response variable is the ecological monitoring parameter of interest, such as the area of Alpine Bogs or cover of weeds, non-bog-dependent flora, bog-dependent flora, or Peat Moss.
 - We are interested in detecting whether there has been a statistically significant change in the response variable at impact sites relative to control sites in the period after the impact commenced.
- Period and Site Class:
 - Period refers to the time before (i.e. BY1 and BY2) or after (i.e. IY1 and IY2) the potential impact commenced (i.e. before or after construction of the water storage started).
 - Site Class refers to the 'treatment' that the Alpine Bogs have received. The Alpine Bogs belong to one of two Site Classes – control sites or impact sites.
 - Period and Site Class are the fixed effects in the model. They are the BACI effect that we are monitoring.
- 1 | Year and 1 | Sample:
 - The model also includes Year (BY1, BY2, IY1 etc.) and Sample (Bog 1, Bog 2, Bog 4.1/5/7 etc.) as random effects (i.e. random temporal and spatial variables).
 - The Sample-to-Sample variation represents localised spatial variability within each Site Class (e.g. the variation between Mount Buller and Mount Stirling control sites, brought about by climatological differences, may represent some of the random effect within control sites).
 - The Year-to-Year variation represents temporal variability that applies to all Samples, regardless of Site Class (i.e. the random temporal effect that applies equally to control and impact sites, causing the same fluctuations at both Site Classes from year-to-year).

We are interested in determining whether there is a statistically significant interaction between Period and Site Class (sometimes called a BA*CI interaction or BACI contrast). If the coefficient for the BA*CI interaction (i.e. the estimate of the BACI contrast) is statistically significant, it suggests that there is a significant difference in the response of control and impact sites to the impact. In other words, there is a statistically significant difference between the control and impact sites after the impact, compared with the control and impact sites before the impact.

The statistical significance of the BA*CI interaction (BACI contrast) is determined by two-way ANOVA using Type III Sums of Squares and the Kenward-Roger approximation for Degrees of Freedom (DF). Estimated Marginal Means (EMMs) provides an estimate of the BACI contrast and an indication of the variability or Standard Error (SE) in the dataset.

Examining SE is important and requires an ecological understanding of the dataset. If ANOVA suggests that the BA*CI interaction is not statistically significant, this may be because construction of the water storage has genuinely had no detectable effect on impact sites, or it may be because the datasets are too variable (SE is too high) for an effect to be detectable.

Statistical tests are undertaken in the R statistical and graphical environment (R Development Core Team 2020) and a 5% statistical significance threshold ($\alpha = 0.05$). LMMs were fitted and ANOVA conducted using the 'lmerTest' package, while EMMs were computed and analysed using the 'emmeans' package.

7. Reporting

7.1 Annual monitoring report

The RMB will prepare an annual report covering all elements of the HEMAMP, including the following:

- Details of compliance with the conditions of development approval.
- The results of the climatological, hydrological, and ecological monitoring over the previous 12 months.
- A comparison of the results of the climatological, hydrological, and ecological monitoring from the previous 12 months with historic monitoring data, including the baseline data.
- A description of any long-term trend in climatological, hydrological and ecological monitoring since the inception of the monitoring (i.e. since collection of baseline data commenced).
- Assessment of monitoring results against the defined performance criteria, whether adaptive management triggers have been reached and the consequences if they have.
- Strategic recommendations for proactive and adaptive management of the Alpine Bogs for the following 12 months and following 5 years.
- Recommendations for the ongoing monitoring of the Alpine Bogs under the HEMAMP, including any recommendations to adapt elements of the monitoring program as data are analysed and interpreted.

The annual report will be submitted to DELWP and DCCEEW. The RMB will provide the Departments with the report by 31 August each year and will publish the report on its website for public access. The Departments will review the annual report and may provide advice on the approach that the RMB should take for adaptive and proactive management of the Alpine Bogs.

7.2 Review

The first two years of monitoring (BY1 and BY2, from June 2017 to May 2019) involved collection of baseline data (Biosis 2019c). The HEMAMP protocol was subsequently reviewed and updated to incorporate recommendations arising from baseline monitoring and recommendations from the pre-construction Environmental Risk Assessment (Biosis 2019b). This resulted in publication of Version 4 of the HEMAMP protocol.

Three years of monitoring and management have since elapsed (IY1, IY2 and IY3, from June 2019 to May 2022). In this time, further recommendations for improvements to the HEMAMP protocol have been made. These recommendations have come from annual monitoring reports, an independent peer review conducted in the early stages of IY3, and a joint DELWP/DAWE government review undertaken in the middle of IY3. This version of the HEMAMP protocol (Version 5) addresses these reviews and recommendations.

Ongoing periodic reviews will be needed for the HEMAMP to remain adaptive. At a minimum, the HEMAMP should be reviewed every three years or as otherwise agreed with DELWP and DCCEEW. The purpose of the reviews will be to evaluate the effectiveness of the monitoring program, with consideration of the:

- Frequency and timing of field surveys.
- Sample size and selection of sample and control sites.

- Cost effectiveness of monitoring activities and assets.
- Survey methods, including whether survey methods are causing disturbance to Alpine Bogs.
- Data management and analysis procedures.
- Statistical power and sensitivity.
- Communication of findings to DELWP, DCCEEW and the broader community.
- Utility of the monitoring procedures for triggering management responses.

The reviews will also specify the timing of the next review, if further review is considered necessary. Any recommended changes to the monitoring program will be subject to the RMB receiving approval from DELWP and DCCEEW. It is expected that these reviews will be conducted along with regular site inspections and meetings with representatives of DELWP and DCCEEW, as outlined in the ERP Addendum.

8. Adaptive management actions

The footprints of the water storage and earth embankment have reduced the catchment areas of Bogs 4.2, 6, 8/9/10, 11.2, 12 and 13, thereby potentially causing these Alpine Bogs to dry (Figure 5). Adaptive management actions therefore focus on returning water to these bogs through the design and management considerations outlined below. Priority will be given to those bogs (priority Alpine Bogs) that are likely to experience the greatest reductions in catchment area (Bogs 4.2, 6, 8/9/10, 11.2 and 12). Additional management responses, such as weed management, pest animal control and revegetation, are also considered below.

8.1 Design and construction considerations

Design of the water storage incorporated considerations for drainage and a watering system to avoid, minimise and mitigate impacts to the Alpine Bogs and to facilitate adaptive management if required. These features will be maintained throughout the life of the water storage.

8.1.1 Drainage

Drainage and landscaping around the periphery of the water storage and access tracks has been constructed to direct water runoff along the natural flow paths towards downslope Alpine Bogs. Overflow and perimeter drains also divert water towards the Alpine Bogs (incorporating appropriate sediment protection).

The water storage and earth embankment incorporate an internal drainage system to control groundwater pressure. Groundwater seepage under the footprint of the water storage is collected to a centralised discharge point (Figure 2 and Figure 5) and redistributed through a drainage outlet pipe under natural groundwater pressure to the aqueduct that runs through the downslope Alpine Bogs. The drainage outlet pipe is also connected to the watering system to provide contributions to the Alpine Bogs, if required.

8.1.2 Watering system

A watering system was installed during the construction phase to allow for environmental watering of priority Alpine Bogs (Bogs 4.2, 6, 8, 9, 10, 11.2 and 12). The watering system incorporates an underground infiltration soakage trench, surrounded by aggregate and geocloth, allowing both overland surface water and groundwater flows to recharge existing groundwater springs. Potential sediment mobilisation into the Alpine Bogs is reduced by the infiltration soakage trench as the water is filtered through an aggregate and geocloth layer prior to discharge. The watering system includes filtration mechanisms to ensure that environmental water delivered to downslope Alpine Bogs is of high quality, with low sediment load and no weed propagules. The surface water monitoring program includes monitoring of water quality at the watering system, to ensure that the quality of water delivered to downslope Alpine Bogs is maintained.

Operational control of the watering system is achieved by valves allowing discharge to either the western or eastern Alpine Bogs (sub-catchments). Importantly, environmental watering does not take place near (within 20 metres of) the water storage earth embankment so as not to compromise the geotechnical stability of the embankment. Pipeline alignments and construction depths are located sensitively to avoid or minimise the potential for interception or redirection of groundwater.

The watering system has been designed so that the method of delivery of water to Alpine Bogs mimics the natural groundwater seepage and baseflow discharge patterns. Through close monitoring and interpretation of the hydrological models, the frequency and timing of water delivery will attempt to match the natural system, although there may be a lag of a few months.

8.2 Triggers for adaptive management

This HEMAMP aims to maintain the extent and condition of Alpine Bogs at impact sites, relative to the extent and condition of the Alpine Bogs at control sites. Triggers for management responses have been designed to provide certainty around the type and timing of adaptive management actions that should be taken in response to monitoring results. The aim of these triggers is to enable pre-emptive and timely intervention to maintain the status quo of the Alpine Bogs at impact sites, relative to control sites.

In response to key recommendations of an independent peer review conducted in 2021, a ‘traffic light’ approach to adaptive management triggers has been adopted, where the level of management intervention is escalated as the risk of adverse impacts on the ecological values of the impact sites increases. The ‘traffic light’ trigger system is outlined in Table 9 and discussed in the following sub-sections. This system formalises the way in which HEMAMP monitoring results and recommendations have been reported to date (since the baseline monitoring years).

All trigger levels relate to changes observed or measured at impact sites relative to control sites. These are changes that are most likely to be caused by construction and operation of the water storage. Broad landscape scale changes, such as those brought about by a drying and warming climate, are unlikely to trigger adaptive management if they affect impact and control sites similarly.

There may be scope for environmental watering to protect Alpine Bogs at impact sites from the effects of a changing climate. However, it would be unrealistic for the RMB to commit to protecting Alpine Bogs against the effects of climate change for the lifetime of the water storage, given that these effects are unlikely to be purely hydrological in nature and unlikely to be entirely avoidable through environmental watering. The RMB’s commitment to environmental watering will nevertheless ensure that Alpine Bogs at impact sites retain their resilience to landscape scale environmental change.

Table 9 Triggers and responses for adaptive management of Alpine Bogs at impact sites

Thresholds	Monitoring results	Management actions
‘Green’ trigger level		
Ecological thresholds	Extent – Reduction of $\leq 5\%$ in extent (area) of Alpine Bogs at impact sites relative to control sites.	Continue annual HEMAMP monitoring and reporting, unless otherwise agreed with DELWP and DCCEE. As part of HEMAMP monitoring and reporting, conduct in-depth analysis beyond the performance criteria to detect underlying or unusual trends e.g. novel weeds or mortality of key species. Implement weed management actions to eradicate any novel weeds. Continue with all other weed and pest control obligations in accordance with the Victorian <i>Catchment and Land Protection Act 1994</i> (CaLP Act).
	Composition – Reduction of $\leq 5\%$ in total bog-dependent species richness at impact sites relative to control sites.	
	Encroachment – Increase of $\leq 5\%$ in cover of non-bog-dependent species at impact sites relative to control sites. Total weed cover at impact sites is $\leq 2.5\%$.	
	Structure – Reduction of $\leq 5\%$ in cover of Peat Moss at impact sites relative to control sites.	
Hydrological thresholds	Surface water flows – Reduction of $\leq 10\%$ in mean annual surface water flows to Boggy Creek over two consecutive years, relative to levels predicted by the overall surface water model.	
	Groundwater levels – Reduction of $\leq 10\%$ in mean annual groundwater levels over two consecutive years, relative to levels predicted by the overall groundwater model.	

Thresholds	Monitoring results	Management actions
	Surface water quality – No outliers when compared with baseline surface water quality i.e. no surface water quality parameters outside the baseline IQR by ≥ 1.5 times the IQR.	
	Groundwater quality – No outliers when compared with baseline groundwater quality i.e. no groundwater quality parameters outside the baseline IQR by ≥ 1.5 times the IQR.	
'Amber' trigger level		
Ecological thresholds	<p>Extent – Reduction of $>5\%$ but $\leq 10\%$ in extent (area) of Alpine Bogs at impact sites relative to control sites.</p> <p>Composition – Reduction of $>5\%$ but $\leq 10\%$ in total bog-dependent species richness at impact sites relative to control sites.</p> <p>Encroachment – Increase of $>5\%$ but $\leq 10\%$ in cover of non-bog-dependent species at impact sites relative to control sites. Total weed cover at impact sites is $>2.5\%$ but $\leq 5\%$.</p> <p>Structure – Reduction of $>5\%$ but $\leq 10\%$ in cover of Peat Moss at impact sites relative to control sites.</p>	Further investigation is required to determine appropriate pre-emptive management actions. Further investigation may include more detailed and/or more frequent monitoring. Pre-emptive management actions may include environmental watering, weed management, sediment control, revegetation and/or pest animal control, depending on the likely underlying causes. Management actions should be documented, so that they can be adapted or improved, where necessary.
Hydrological thresholds	<p>Surface water flows – Reduction of $>10\%$ but $\leq 50\%$ in mean annual surface water flows to Boggy Creek over two consecutive years, relative to levels predicted by the overall surface water model.</p> <p>Groundwater levels – Reduction of $>10\%$ but $\leq 50\%$ in mean annual groundwater levels over two consecutive years, relative to levels predicted by the overall groundwater model.</p> <p>Surface water quality – One or more mild outliers when compared with baseline surface water quality i.e. one or more surface water quality parameters outside the baseline IQR by ≥ 1.5 and ≤ 3 times the IQR.</p>	
	Groundwater quality – One or more mild outliers when compared with baseline groundwater quality i.e. one or more groundwater quality parameters outside the baseline IQR by ≥ 1.5 and ≤ 3 times the IQR.	

Thresholds	Monitoring results	Management actions
'Red' trigger level		
Ecological thresholds	Extent – Reduction of >10% in extent (area) of Alpine Bogs at impact sites relative to control sites.	Depending on underlying causes, weed management, pest animal control, revegetation, environmental watering and/or water quality remediation will be required. Management actions will need to be accompanied by more detailed and/or more frequent monitoring, so that the actions can be adapted or improved, where necessary. These monitoring results may constitute a breach of conditions of approval for the project, in which case DCCEE and/or DELWP will need to be notified.
	Composition – Reduction of >10% in total bog-dependent species richness at impact sites relative to control sites.	
	Encroachment – Increase of >10% in cover of non-bog-dependent species at impact sites relative to control sites. Total weed cover at impact sites is >5%.	
	Structure – Reduction of >10% in cover of Peat Moss at impact sites relative to control sites.	
Hydrological thresholds	Surface water flows – Reduction of >50% in mean annual surface water flows to Boggy Creek, over two consecutive years, relative to levels predicted by the overall surface water model.	Environmental watering should commence and be accompanied by more frequent analysis of hydrological monitoring results and the hydrological models, to inform the environmental watering.
	Groundwater levels – Reduction of >50% in mean annual groundwater levels over two consecutive years, relative to levels predicted by the overall groundwater model.	
	Surface water quality – One or more extreme outliers when compared with baseline surface water quality i.e. one or more surface water quality parameters outside the baseline IQR by ≥ 3 times the IQR.	Exact management actions will depend on the contaminant that is detected. Immediate implementation of all or part of the water quality remediation strategy will be needed.
	Groundwater quality – One or more extreme outliers when compared with baseline groundwater quality i.e. one or more groundwater quality parameters outside the baseline IQR by ≥ 3 times the IQR.	

8.2.1 Ecological thresholds

Ecological thresholds are derived from the HEMAMP's performance criteria and relate to the extent and condition of Alpine Bogs at impact sites, relative to control sites. All but one of the performance criteria refer to a 10% change at impact sites, relative to control sites. The exception is the criterion relating to weed encroachment, which requires that weed cover does not exceed 5% at the impact sites. Relative changes of up to 10% were set and approved because:

- This magnitude of change was considered to be readily detectable by current monitoring techniques.
- This magnitude of change was considered to have a good probability of being reversible by targeted management actions.
- If ultimately irreversible, this magnitude of change (but no more) was deemed to be acceptable.

It is important to note that, except for weed encroachment, the performance criteria and ecological thresholds are relative. This means that a decline in extent or condition of impact sites may not trigger any of

the ecological thresholds if the same decline occurs concurrently at the control sites. The performance criteria and ecological thresholds are also expressed in terms of all impact sites collectively. Ecological monitoring to date has shown that small changes at the scale of an individual Alpine Bog can occur relatively rapidly and randomly (e.g. from one year to the next), disconnected from any apparent impact event. In contrast, broader ecological changes to all impact sites collectively, relative to control sites, are more noteworthy and are the focus of the HEMAMP's ecological monitoring and thresholds for adaptive management.

8.2.2 Hydrological thresholds

Thresholds for water quality parameters relate to whether a water quality result would be considered an outlier with reference to baseline water quality results and a common definition of outliers. Outliers are defined according to the Inter-Quartile Range (IQR) of baseline water quality results. The lower quartile is the median value in the lower half of the baseline dataset, including the median value of the entire baseline dataset. The upper quartile is the median value in the upper half of the baseline dataset, including the median value of the entire baseline dataset. The difference between the lower and upper quartiles is the IQR. The threshold for a mild outlier (and the 'amber' trigger level) is a result that is outside the IQR by a value that is 1.5 to 3 times the IQR. The threshold for an extreme outlier (and the 'red' trigger level) is a result that is outside the IQR by a value that is more than 3 times the IQR.

Thresholds for surface water flows and groundwater levels have been set with reference to the HEMAMP's hydrological models, which have been developed for the Boggy Creek catchment. The models are designed to provide an early warning system for pre-empting possible decline in the ecological condition of Alpine Bogs at impact sites.

The hydrological models describe the pre-construction (baseline) relationship between landscape-scale climatological parameters (which should have remained unaffected by the water storage) and hydrological parameters of the Boggy Creek catchment (which may be affected by the water storage). The models can be used to predict the expected hydrological monitoring results, based on the climatological monitoring results of the previous one to four months. If the hydrological monitoring results appear to have diverged from the model predictions, we may have reason to believe that the water storage has had an impact on the catchment's hydrology. Depending on the magnitude of the impact and whether it meets hydrological thresholds, corrective actions may be required.

Ideally, the hydrological thresholds would be set with reference to a long validation period (during which the predictive performance of the hydrological models would be tested) and with reference to the prediction intervals of the hydrological models (a measure of confidence in the predictions of the models, similar to confidence intervals). For example, with a long validation period, the thresholds could be set such that the 'red' trigger level is reached when a hydrological monitoring result falls below the 90% prediction interval of the model, on the basis that such a result never occurred during the validation period.

In the absence of a validation period for the hydrological models, hydrological thresholds were set with reference to long-term climatological trends. Reliable rainfall records for Mount Buller date back to 1985. On two occasions since 1985, total annual rainfall has been more than 10% below the long-term mean (or median) in two or more consecutive years. There has been one occasion where total annual rainfall has been more than 50% below the long-term mean (or median) for two or more consecutive years. These have therefore been historically uncommon events, and all occurred before the calibration period for the hydrological models.

It has been assumed that similar divergence of groundwater levels and surface water flows from expected or predicted results would be similarly infrequent and therefore warrant action. In other words, the 'amber' trigger is met when annual hydrological observations are more than 10% below expected values for two or

more consecutive years and the 'red' trigger is met when annual hydrological observations are more than 50% below expected values for two or more consecutive years.

Because these hydrological thresholds are not directly related to the prediction intervals (confidence) of the hydrological models and have not been tested during a validation period, the thresholds should be applied with some caution. In particular, the following should be noted:

- As is the case for all models, the hydrological models are imperfect, particularly if they are used for extrapolation i.e. models may not be very strong predictors during extreme events that did not occur during the calibration period. Where possible, prediction intervals should be used to interpret results.
- The hydrological thresholds refer to an annual result occurring in two consecutive years. This is to account for the inherent variability that can occur in hydrological systems from month to month. An unusually dry month may be cancelled out by an unusually wet month and not trigger one of the hydrological thresholds. That said, the timing and variability of natural water delivery to the Alpine Bogs over the course of a monitoring year may need to be considered. For example, pre-emptive management may be needed if summers are found to be getting drier than expected by the hydrological models.

Reductions in surface water flows or groundwater levels need to occur over two consecutive years before management actions, such as environmental watering, are implemented. In this respect, management responses to hydrological triggers will be reactive to hydrological monitoring results but are still intended to be proactive in pre-empting potential changes to the ecological condition or extent of Alpine Bogs. It is expected that the hydrological models and triggers will be improved over time. For example, there may be scope to use initial post-construction years as a validation period for the hydrological models, assuming many years have elapsed since construction and little to no ecological change (lagged or otherwise) in the Alpine Bogs has been detected or is suspected.

8.2.3 'Green' trigger level

The 'green' trigger level denotes that the extent and condition of impact sites, relative to control sites, is currently being maintained and is likely to be maintained in the near future (next 12 months). It also suggests that the hydrology of the Boggy Creek catchment is as expected, based on the precipitation and evapotranspiration that has been experienced, and that water quality parameters are not unusual (outliers) when compared with baseline water quality.

The 'green' trigger level indicates that the objectives and performance criteria of the HEMAMP are being achieved (see Section 2.2). Annual HEMAMP monitoring and reporting should continue, unless otherwise agreed with DELWP and DCCEE. The SOP for ecological monitoring (Appendix 5) specifies in-depth analysis that should take place beyond a simple assessment against the performance criteria and adaptive management triggers. In-depth analysis is required to detect underlying or unusual trends e.g. novel weeds or mortality of key species. Any novel weed species must be eradicated (i.e. reduced to less than 1% cover). Control of all other weeds and pest animals should continue in accordance with obligations under the *Victorian Catchment and Land Protection Act 1994* (CaLP Act).

8.2.4 'Amber' trigger level

The 'amber' trigger level signifies one or both of the following:

- The extent and/or condition of impact sites, relative to control sites, has declined and is unlikely to be maintained in the near future (e.g. next 12 months).

- Water quality, surface water flows and/or groundwater levels in the Boggy Creek catchment are less than expected, which may result in a decline in the ecological condition and/or extent of impact sites, if not already.

While the objectives and performance criteria of the HEMAMP are being achieved for the time being, the ecology and/or hydrology of impact sites has declined to the point where pre-emptive management intervention is likely to be required to avoid further decline.

The ecological 'amber' thresholds are halfway towards non-compliance with one or more of the HEMAMP's performance criteria (outlined in Section 2.2). The hydrological 'amber' thresholds are an indication that surface water flows and/or groundwater levels have diverged from climatological parameters in a way that was probably uncommon in pre-construction years. Alternatively, the hydrological 'amber' thresholds indicate that there are one or more mild outliers amongst the water quality data, when compared with baseline water quality. It is therefore important to begin reversing these small ecological and/or hydrological changes as soon as they are detected and before non-compliance occurs. Importantly, further investigation is the initial response to an 'amber' threshold being met (see Section 8.3). This minimises the risk of inappropriate or improperly timed management actions being implemented.

8.2.5 'Red' trigger level

The 'red' trigger level indicates one or both of the following:

- The extent and/or condition of impact sites, relative to control sites, has declined to the point that the objectives and performance criteria of the HEMAMP are not being achieved (see Section 2.2).
- Water quality, surface water flows and/or groundwater levels in the Boggy Creek catchment are substantially less than expected, which is likely to result in a decline in the ecological condition and/or extent of impact sites, if not already.

The 'red' trigger level denotes actual or imminent non-compliance with the HEMAMP's performance criteria and therefore necessitates immediate action. The management actions that are implemented will target the precise ecological or hydrological thresholds that have been breached. For example, weed management will occur if weeds are proliferating and the 'encroachment' threshold has been met. Similarly, environmental watering will occur if the 'groundwater levels' threshold has been met.

As always, these management actions will be accompanied by further investigations to try to determine the underlying causes of the 'red' trigger level and coordinate appropriate and targeted management actions. The underlying causes may be inter-related, and a combination of management actions may be needed. For example, weeds may be proliferating due to a drying substrate and/or pest animal activity. The substrate may be drying due to the pest animal activity. In the short-term, weed management may therefore be accompanied by pest animal control. In the medium-term, environmental watering and/or revegetation may be required to re-establish bog-dependent flora and allow them to out-compete weeds.

Importantly, if the 'red' trigger level is reached, it may constitute a breach of one or more conditions of approval for the project, such as Condition 2 of the EPBC Act Approval (Appendix 2). DCCEEW and/or DELWP will need to be notified.

8.3 Adaptive management actions and responses

The following sub-sections outline management actions that should be undertaken in response to monitoring resulting indicating that certain ecological and/or hydrological thresholds have been met (Table 9). These management actions should be read in conjunction with the ERP Addendum (Biosis 2022). Importantly, the management actions should be adaptive and change according to the latest monitoring results. Over time, as

more site-specific climatological, hydrological and ecological data are collected, there will be greater scope to pre-empt ecological decline at impact sites and prevent it from occurring.

8.3.1 Further investigation

The first step in any adaptive management will be further investigation to determine why a threshold may have been breached and to respond accordingly. Certain management actions have the potential to damage the Alpine Bogs if they are inappropriately timed or delivered. For example, water could be delivered to the Alpine Bogs when it is not needed, resulting in localised erosion.

Further investigation may show that a false positive or false negative has occurred, meaning that no specific response is necessary. Conversely, further investigation may reveal that the underlying causes for the threshold being met are more complicated than first thought and necessitate a multi-faceted response involving a variety of management actions. For example, weed management may need to be accompanied by revegetation to 'fill' vegetation voids, which may need to be accompanied by pest animal control to minimise herbivory on establishing plants.

Further investigation may also include more intensive monitoring. For example, a more frequent monitoring feedback loop will be needed if environmental watering commences. Hydrological monitoring results (surface water flow data and groundwater depth data) will need to be downloaded more regularly (at least monthly) and incorporated into the hydrological model to assess whether environmental watering is having the intended effect on local hydrology.

8.3.2 Weed management

Once established, weeds can alter hydrology, changing conditions to further favour weed invasion. The HEMAMP incorporates annual monitoring of weeds and allows for early detection and control of any weed encroachment. Indeed, it is through the HEMAMP that one novel weed species was detected in 2021 and control measures promptly commenced.

Due to the sensitivity of Alpine Bogs (and wetland ecosystems in general), effective weed control can be difficult to achieve without collateral damage to existing native vegetation and fauna (DoE 2015). Chemical treatments should be limited, which places constraints on how effective weed control can be. For this reason, the ERP Addendum includes a weed control hierarchy, which prioritises manual removal, heat treatment and smothering of weeds over chemical treatments (Biosis 2022). It also allows for the trialling of alternative weed control methods, if they would be more suitable or appropriate and still fulfil the aims of the weed control hierarchy.

The ERP Addendum's weed control hierarchy and list of priority weed species should be adopted when undertaking weed management as part of this HEMAMP.

8.3.3 Pest animal control

The impact of deer and rabbits on Alpine Bog vegetation is regularly recorded during HEMAMP ecological monitoring. Direct impacts from these pest animals include browsing, wallowing, digging, and trampling. They also have the ability to exacerbate other impacts, such as weeds proliferation (e.g. weed invasion into Alpine Bogs has been observed to occur along deer tracks) and drying of the peat substrate (e.g. rabbit diggings and deer tracks can lead to the formation of incised channels, which drain water away).

Pest animal control will be needed to ensure that other management actions are successful. Pest animal control techniques are outlined in the ERP Addendum (Biosis 2022).

8.3.4 Revegetation

Revegetation of Alpine Bogs may be needed to minimise the risk of further weed invasion after weed control works, to re-establish peat substrates that have been covered in sediment or washed away and/or to re-introduce bog-dependent flora that may have been lost. The ERP Addendum provides requirements for species selection, tubestock management and planting techniques for revegetation in the Alpine Bogs (Biosis 2022). Importantly, the genetic provenance of all plants must be from Mount Buller. Only native species that are typical of the Alpine Bog vegetation at Mount Buller will be planted (bog-dependent and bog 'neutral' species). The Diagnostic Key to Alpine Bogs provides further information on typical Alpine Bog species (Appendix 5).

8.3.5 Environmental watering

Construction of the water storage project included construction of drainage and watering systems designed to deliver water from the water storage to priority Alpine Bogs (Bogs 4.2, 6, 8/9/10, 11.2 and 12), if needed and in accordance with water storage safety guidelines (ANCOLD 2003). A hydrological model has been developed and hydrological thresholds set for when environmental watering should occur. If the hydrological model detects drying of the Alpine Bogs that exceeds natural seasonal fluctuations, further investigation will be undertaken to ascertain the source and magnitude of the risk. This will assist in determining where environmental watering should occur, how much water should be delivered and over what timeframe.

Water will be delivered to the eastern and/or western branches of the environmental watering system (eastern and/or western sub-catchments of Boggy Creek), depending on where the drying has been detected. The amount of environmental water that is delivered will be proportionate to the divergence that has occurred in the hydrological model. The precise amount of water and the timeframe over which it is delivered will require close monitoring of amounts discharged from the environmental watering system and how these amounts affect surface water flows and groundwater levels. This will require increased frequency of data collation from the surface water and groundwater data loggers and inputting of this data into the hydrological model to verify whether the divergence is being reversed i.e. a feedback loop.

The feedback loop may have some delay, given that groundwater shows a lagged response to precipitation and evapotranspiration of up to four months, depending on the location. The lag in the feedback loop may not be as long because the environmental watering system will be delivering water directly to the water table. The lack of a lengthy lag in the relationship between climatological parameters and groundwater levels at BH18 (presumably due to artificial water inputs) suggests that groundwater levels can be artificially recharged relatively rapidly. Nevertheless, the potential for a lagged feedback loop means that the increased monitoring intensity would need to continue for at least a few months. It also means that the intervention should not be overly reactionary i.e. environmental watering should not be increased just because an immediate effect on groundwater has not occurred.

Importantly, the aim of environmental watering is not to restore groundwater and/or surface water to pre-construction levels but to restore the relationship between hydrological parameters (groundwater and surface water) and climatological parameters (precipitation and evapotranspiration) defined by the hydrological models. The aim is to pre-empt and prevent any consequent ecological change at Alpine Bog impact sites.

The RMB is committed to the project meeting environmental needs, as a first priority. This means that demands for environmental water for Alpine Bogs will take priority over other demands, such as demands for snowmaking or potable water, for the lifetime of the water storage facility. The RMB cannot guarantee that there will always be a minimum volume of water present in the water storage for environmental watering purposes because the volume of water that is present will ultimately depend on increasingly variable environmental (climatic) conditions. Nevertheless, when there is water available, the RMB is committed to environmental watering taking precedence over other water uses.

8.3.6 Water quality remediation

Water quality remediation may be needed if monitoring results indicate that one or more water quality parameters is an outlier when compared with baseline water quality. Immediate further investigation will be needed to determine the source of the contamination, if unknown. Where possible, the source of contamination must be isolated and removed. For example, if sedimentation appears to be the source of the contamination, existing sediment controls will need to be inspected and additional sediment controls added. The ERP Addendum provides details on installation and maintenance of sediment and erosion controls (Biosis 2022).

If containment and/or removal of the source of contamination is not possible, water treatment may be needed to remove the contaminant from the surface water and/or groundwater. If water treatment is not possible, an action of last resort may be dilution of the contamination by the addition of water through the environmental watering system.

8.4 Recovery targets

The recovery target for all adaptive management actions is the 'green' trigger level. Adaptive management actions will be considered successful and may be scaled back when all ecological and hydrological thresholds are within the 'green' trigger level.

From an ecological perspective, the 'green' trigger level represents Alpine Bogs in a very high condition state. The 'green' trigger level indicates that the extent and condition of the Alpine Bog impact sites is comparable to that of the unaffected control sites. In the case of weed cover, the 'green' trigger level denotes very low weed cover and lower weed cover than has ever been recorded at the impact sites, including during baseline monitoring years.

Timeframes for recovery are expressed in terms of an escalation matrix, as follows:

- If one or more of the thresholds is within the 'amber' trigger level, it should be expected that those thresholds return to the 'green' trigger level within 3 years. If there is no return to the 'green' trigger level within three years, management actions and effort will need to be increased.
- If one or more of the thresholds is within the 'red' trigger level, it should be expected that those thresholds return to the 'amber' trigger level within 2 years. If there is no return to the 'amber' trigger level within three years, management actions and effort will need to be increased.

The recovery timeframes of 2-3 years are necessary to allow for timing of monitoring events, delivery of monitoring results (the feedback loop) and a lag in the ecological and/or hydrological response.

8.5 Risks and contingencies

All environmental management plans have inherent risks associated with their implementation. There are risks, albeit of low to moderate severity, that this monitoring and adaptive management program may not achieve its overall objective of maintaining the current extent and condition of Alpine Bogs at impact sites, relative to control sites. Risks to the program can be placed into four general categories, which are outlined and evaluated in Table 10. The risks have been evaluated according to the risk matrix shown in Table 11, which is based upon DCCEE guidelines (DSEWPac 2014).

The project has fully incorporated mechanisms (watering system infrastructure and priority water allocation to Alpine Bogs) to mitigate plausible risks associated with the project. Residual risks have been assessed, with consideration of baseline monitoring data and control measures, as part of a pre-construction Environmental Risk Assessment (Biosis 2019b). Mitigation actions to address residual risks have been tailored to suit specific

requirements such as timing, frequency, duration, and volumes of water to be provided and understanding of any such specific requirements will be informed by results of ongoing monitoring. External risks (those not associated with the water storage, such as long-term climate change) will also be better understood based on before (baseline) and after monitoring. However, risk mitigation for the water storage is not designed to address risks that are not associated with the water storage project itself.

Table 10 Evaluation of risks associated with implementation of the HEMAMP

Risk	Minimisation	Consequence	Likelihood	Severity
<p>(1) Risk that monitoring fails to detect changes in Alpine Bogs that exceed thresholds for corrective actions</p>	<p>Annual monitoring is designed to be robust and repeatable. Since monitoring started, a complete ecological dataset has been gathered. Gaps in climatological and hydrological datasets have been appropriately filled so that they contribute to our understanding of Alpine Bog extent and condition. The BACI monitoring design that has been adopted minimises the risk of statistical error (false negative and positives). The ecological and hydrological thresholds take into consideration limitations of statistical power. There is a high level of confidence that the monitoring program will be able to detect change at the thresholds for pre-emptive management to commence.</p>	<p>High</p>	<p>Rare</p>	<p>Low</p>
<p>(2) Risk that required management actions are not delivered when needed</p>	<p>Assuming that changes are detected (see Risk 1), the only instance in which management actions would not be delivered when required would be if the RMB lacked adequate resources. The RMB has fully costed the HEMAMP and is committed to its implementation. Demands for environmental water for Alpine Bogs will take priority over other demands, such as demands for snowmaking or potable water, for the lifetime of the water storage facility. There is a residual risk that no water will available at all due to environmental conditions (severe protracted drought). This risk is considered unlikely (given the hydrological records for the area) and cannot be controlled.</p>	<p>High</p>	<p>Unlikely</p>	<p>Moderate</p>

Risk	Minimisation	Consequence	Likelihood	Severity
(3) Risk that Alpine Bogs do not respond to management actions	<p>Environmental watering of Alpine Bogs, via a dedicated watering system, is not known to have taken place previously in Australia. However, the requirement for water to sustain these ecosystems is well understood. Restoration of Alpine Bogs (e.g. following fire) typically focuses on re-instating their hydrology by impeding water, slowing erosion and allowing peat and Peat Moss to recover (e.g. Good <i>et al.</i> 2010). In this respect, damage to Alpine Bogs through hydrological change and its collateral effects (e.g. weed incursion) can be reversed. There is a high level of confidence that Alpine Bogs at impact sites can be maintained by environmental watering, weed management, pest animal control and, if required, revegetation. Experience with one borehole at Mount Buller (BH18) suggests that groundwater can be recharged artificially. In the unlikely event that the extent and/or condition of Alpine Bogs does not respond to environmental watering, a groundwater management plan will be developed in consultation with DELWP and DCCEEW. The plan may include changes to the environmental watering system.</p>	Moderate	Unlikely	Low
(4) New Alpine Bogs arise, are not detected and are subsequently affected by the project or another development	<p>Changes to hydrology downslope of the water storage may give rise to the formation, migration and/or expansion of Alpine Bogs in new areas. As demonstrated during baseline monitoring (Biosis 2019c), it is unlikely that any new Alpine Bogs on the northern slopes of Mount Buller would go undetected given the frequency and scale of ecological monitoring. Discovery of new Alpine Bogs will be documented in annual HEMAMP monitoring reports. A preliminary assessment will determine if the catchment area of the new Alpine Bogs is influenced by the water storage and earth embankment and, if so, the new Alpine Bog may be added to the ecological monitoring program.</p>	Moderate	Unlikely	Low

Table 11 Risk matrix used to evaluate risks to HEMAMP implementation

Likelihood x Consequence = Severity		Consequence				
		Minor: incident of environmental damage that can be reversed	Moderate: isolated but substantial instances of environmental damage, reversible with intensive efforts	High: substantial incidents of environmental damage that could be reversed with intensive efforts	Major: major loss of environmental amenity and real danger of continuing	Critical: severe widespread loss of environmental amenity and irrecoverable environmental damage
Likelihood	Highly likely: expected to occur in most circumstances	Moderate	High	High	Extreme	Extreme
	Likely: will probably occur during the life of the project	Low	Moderate	High	High	Extreme
	Possible: might occur during the life of the project	Low	Moderate	Moderate	High	Extreme
	Unlikely: could occur during the life of the project but doubtful	Low	Low	Moderate	High	High
	Rare: may occur in exceptional circumstances	Low	Low	Low	Moderate	High

9. Conclusion

This HEMAMP protocol (Version 5) is designed to protect and maintain the extent and condition of Alpine Bogs that are downslope of the water storage. The HEMAMP adopts a quasi-experimental design to monitor hydrology and the widely accepted 'Beyond BACI' design to monitor the ecology of Alpine Bogs at impact sites and control sites.

The focus of the monitoring is to enable early identification of potential changes to the hydrology, extent, structure and composition of the local Alpine Bogs throughout the lifetime of the water storage facility. This will enable proactive and adaptive management actions to be developed, implemented, and reviewed on an ongoing basis.

The RMB has the experience and resource capabilities required to implement the HEMAMP and has a successful history of implementing other large-scale environmental monitoring and adaptive management programs. The RMB is committed to the performance criteria specified in this HEMAMP and will prioritise the environmental demands of the project over all other demands.

Successful implementation of this HEMAMP will maintain the Alpine Bogs on the northern slopes of Mount Buller for the lifetime of the water storage facility.

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Figures

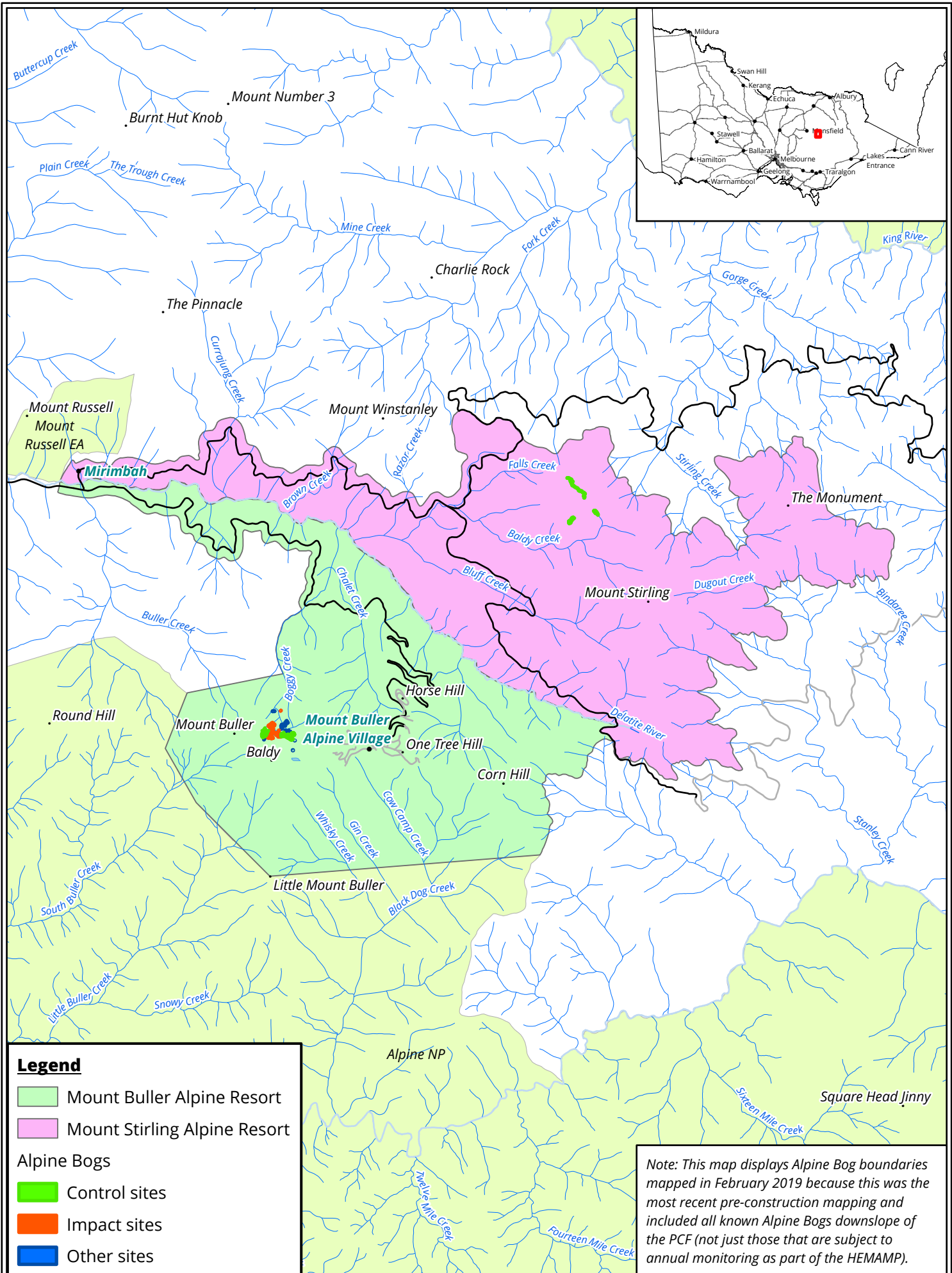
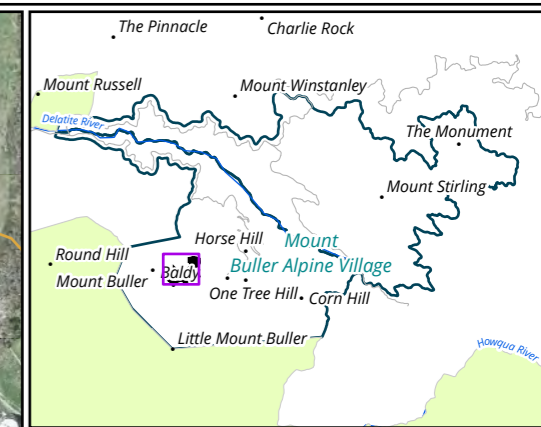
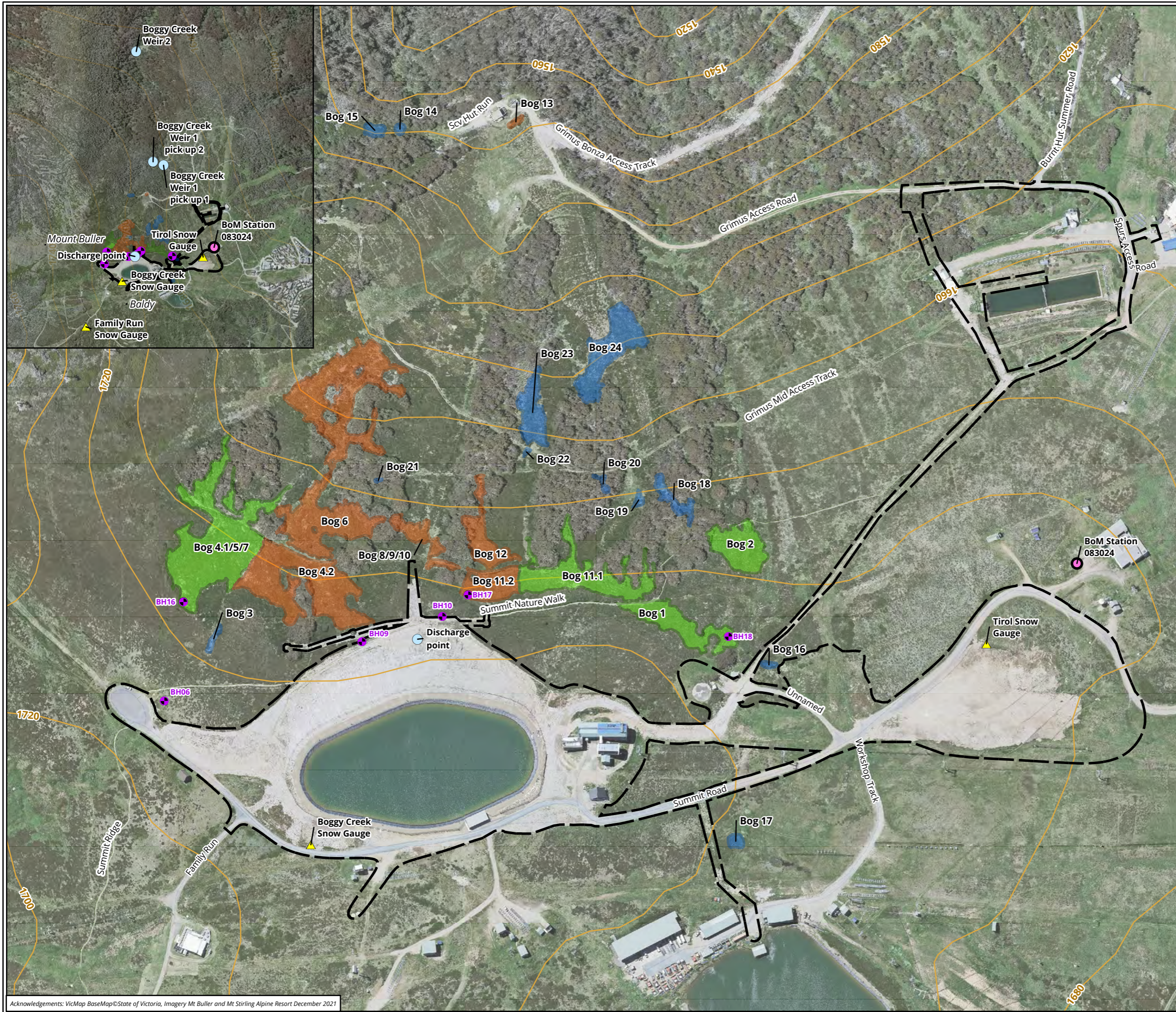


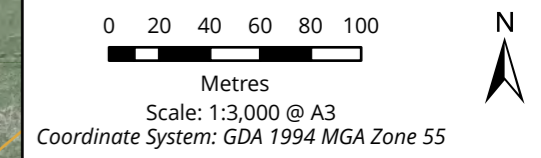
Figure 1 Location of the Mount Buller and Mount Stirling Alpine Resorts, Victoria

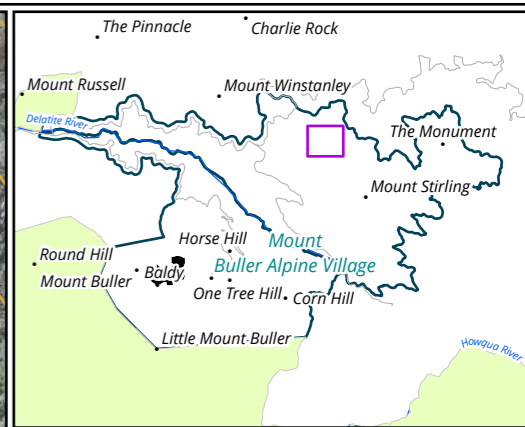
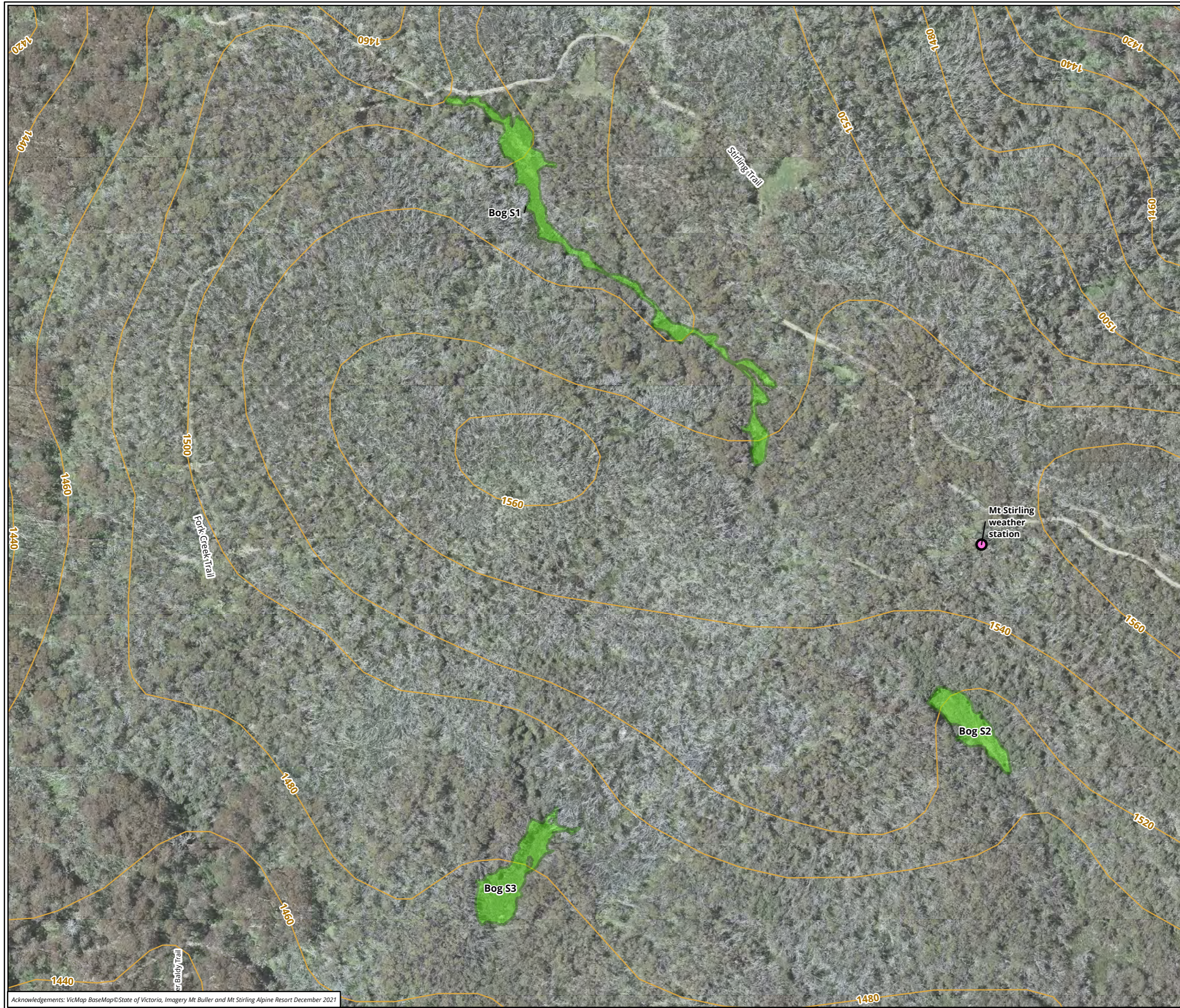


- Legend**
- Project Construction Footprint (PCF)
 - Ecological monitoring (Alpine Bogs)**
 - Control site (2019)
 - Impact site (2019)
 - Other site (2019)
 - Climatological monitoring**
 - Snow gauge
 - Weather station
 - Hydrological monitoring**
 - Groundwater bore
 - Surface water monitoring location

Note: This map displays Alpine Bog boundaries mapped in February 2019 because this was the most recent pre-construction mapping and included all known Alpine Bogs downslope of the PCF (not just those that are subject to annual monitoring as part of the HEMAMP). This map shows locations for groundwater boreholes and surface water sites, as mapped in 2022 with 1 cm on-ground accuracy.

Figure 2 Location of Alpine Bogs subject to monitoring at Mount Buller Alpine Resort

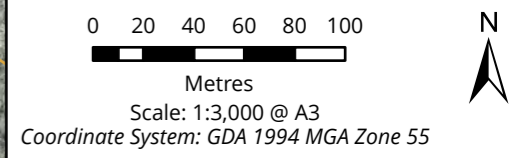




- Legend**
- Ecological monitoring (Alpine Bogs)**
 - Control site (2019)
 - Climatological monitoring**
 - Weather station

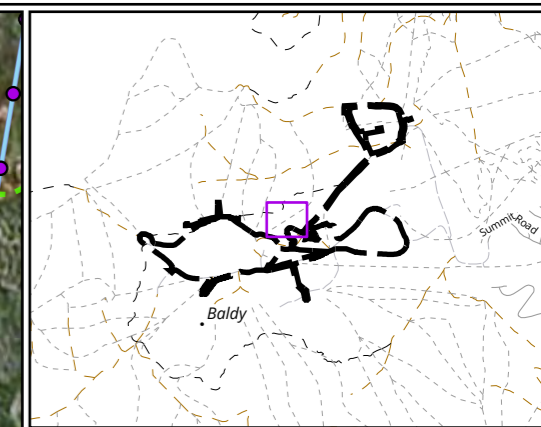
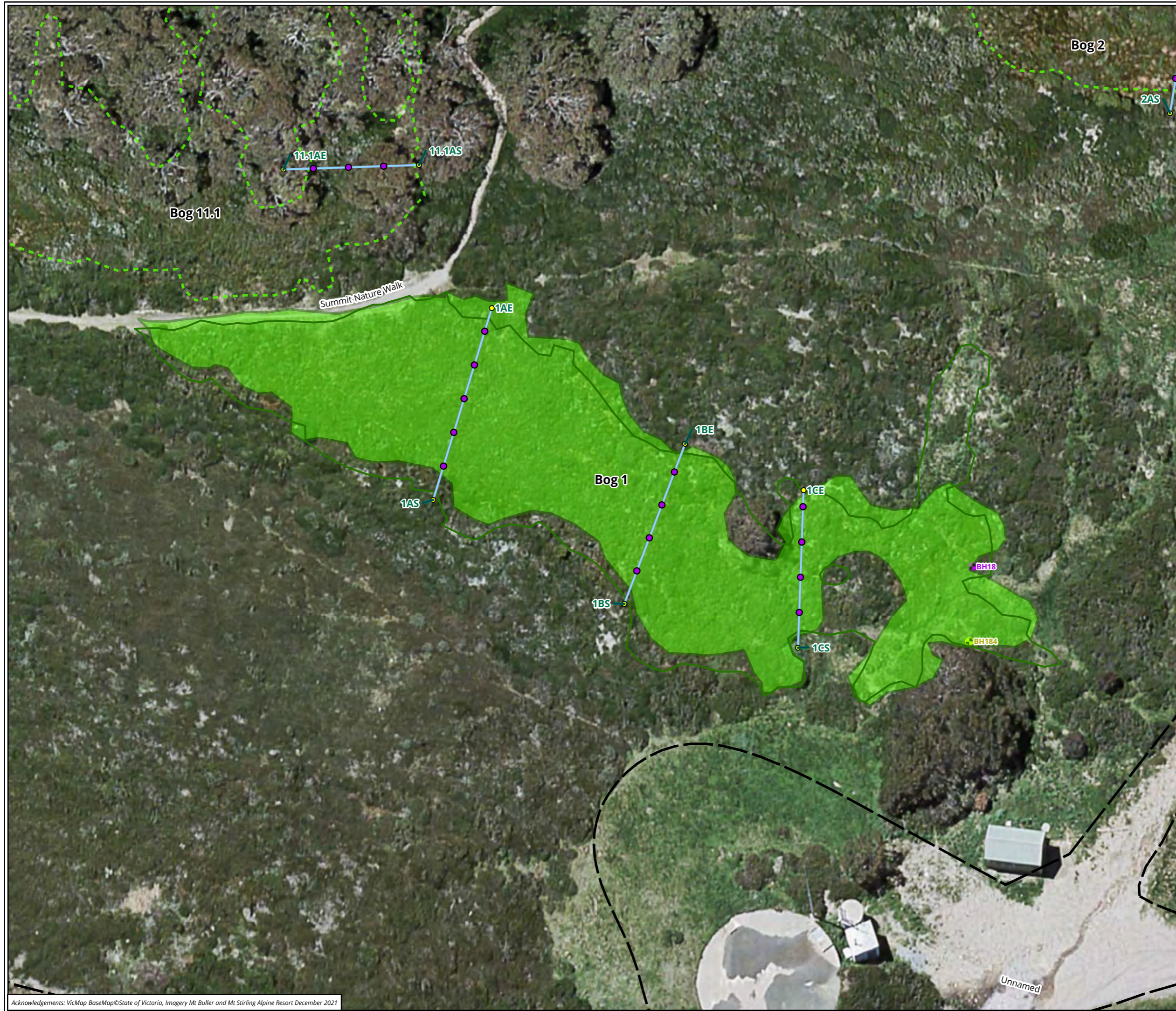
Note: This map displays Alpine Bog boundaries mapped in February 2019 because this was the most recent pre-construction mapping

Figure 3 Location of Alpine Bogs subject to monitoring at Mount Stirling Alpine Resort



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F3_HEMAMP_Alpine_Bogs_Stirling
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

Acknowledgements: VicMap BaseMap © State of Victoria, Imagery Mt Buller and Mt Stirling Alpine Resort December 2021



Legend









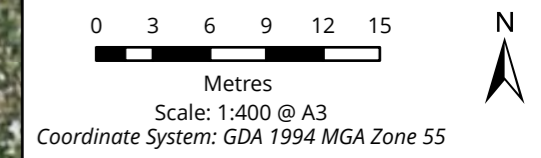
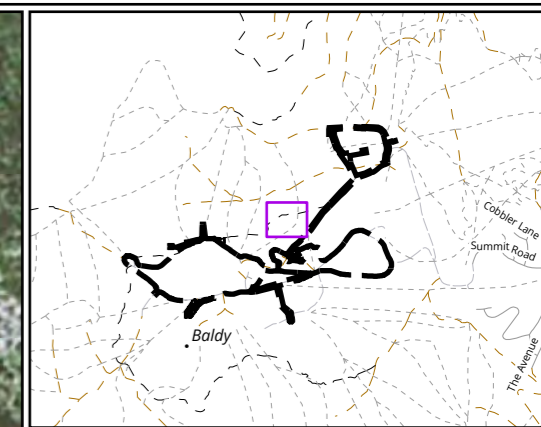
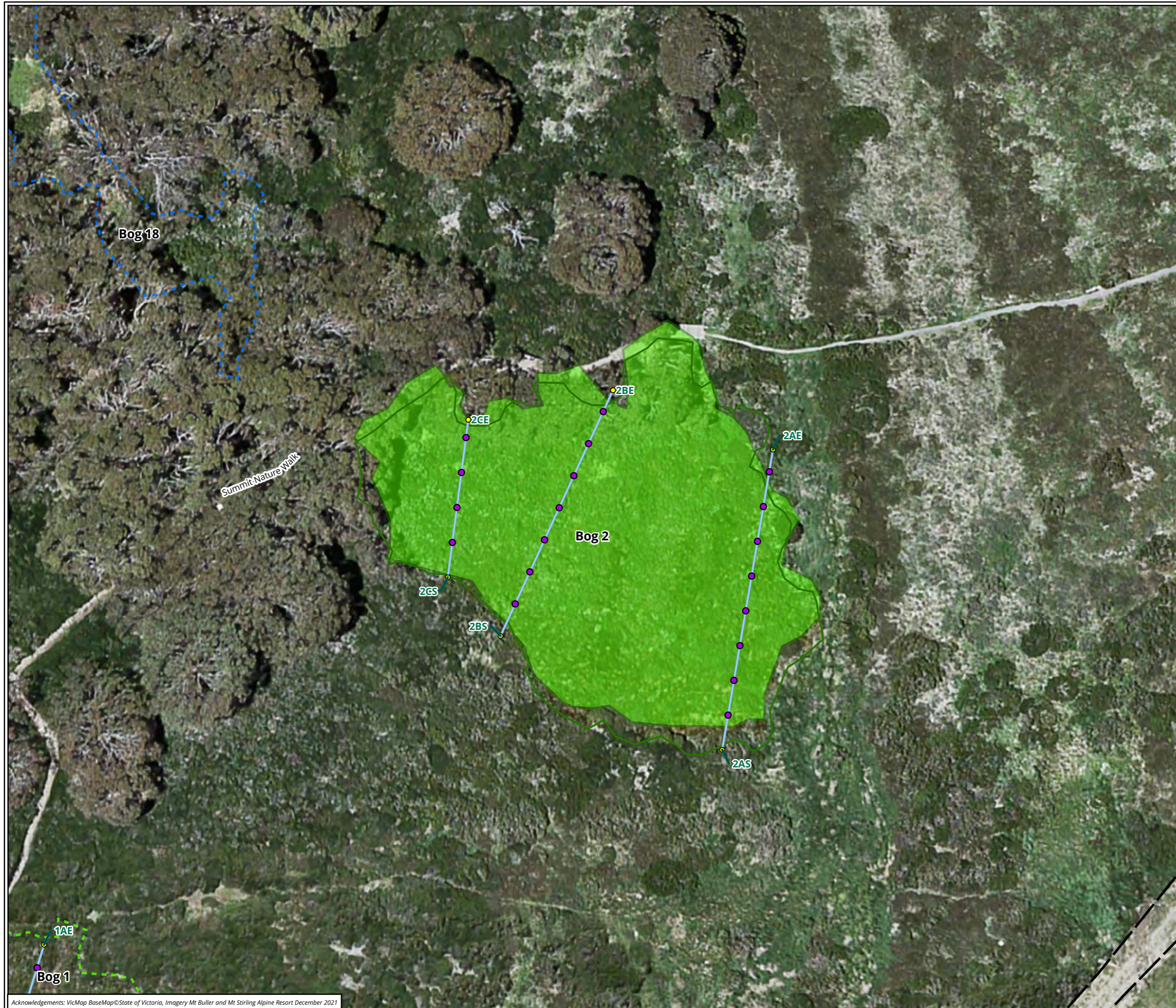
-  Project Construction Footprint (PCF)
- Ecological monitoring (Alpine Bogs)**
-  Transects
-  Quadrats
-  Photo points
- Alpine Bog**
-  Control site (2018)
-  Control site (2019)
- Hydrological monitoring**
-  Groundwater bore
-  Other groundwater boreholes

Figure 4a Bog 1 (control site)



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx



- Legend**
- Project Construction Footprint (PCF)
 - Ecological monitoring (Alpine Bogs)**
 - Transects
 - Quadrats
 - Photo points
 - Alpine Bog**
 - Control site (2018)
 - Control site (2019)

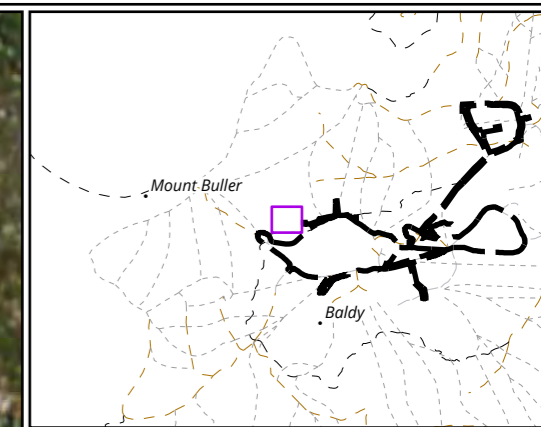
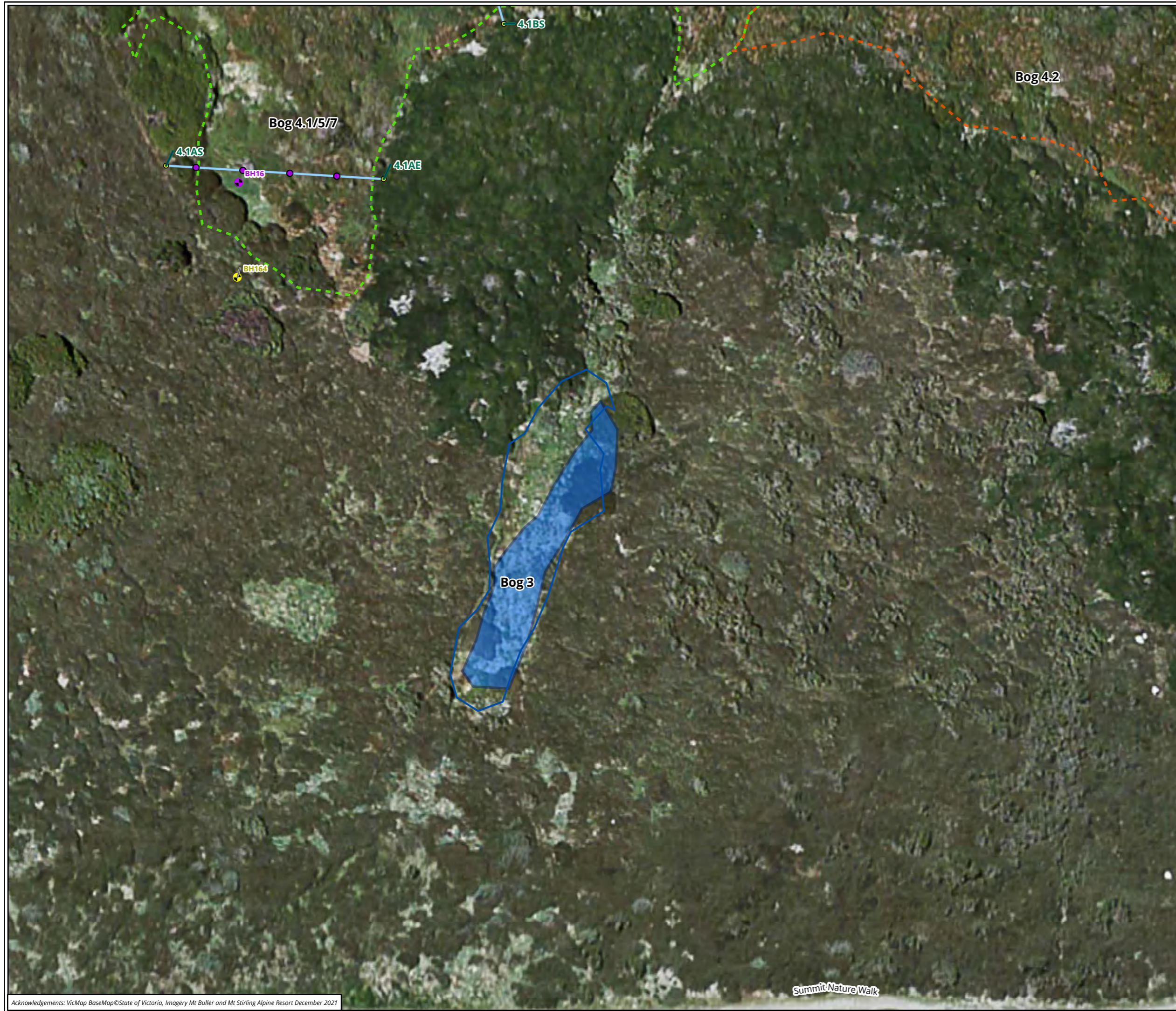
Figure 4b Bog 2 (control site)

0 3 6 9 12 15
 Metres
 Scale: 1:400 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F4_HEMAMP_Alpine_Bogs
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Ecological monitoring (Alpine Bogs)**
- Transects
 - Quadrats
 - Photo points
- Alpine Bog**
- Other site (2018)
 - Other site (2019)
- Hydrological monitoring**
- Groundwater bore
 - Other groundwater boreholes

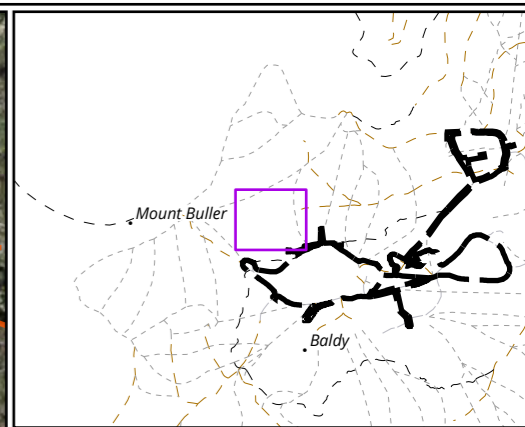
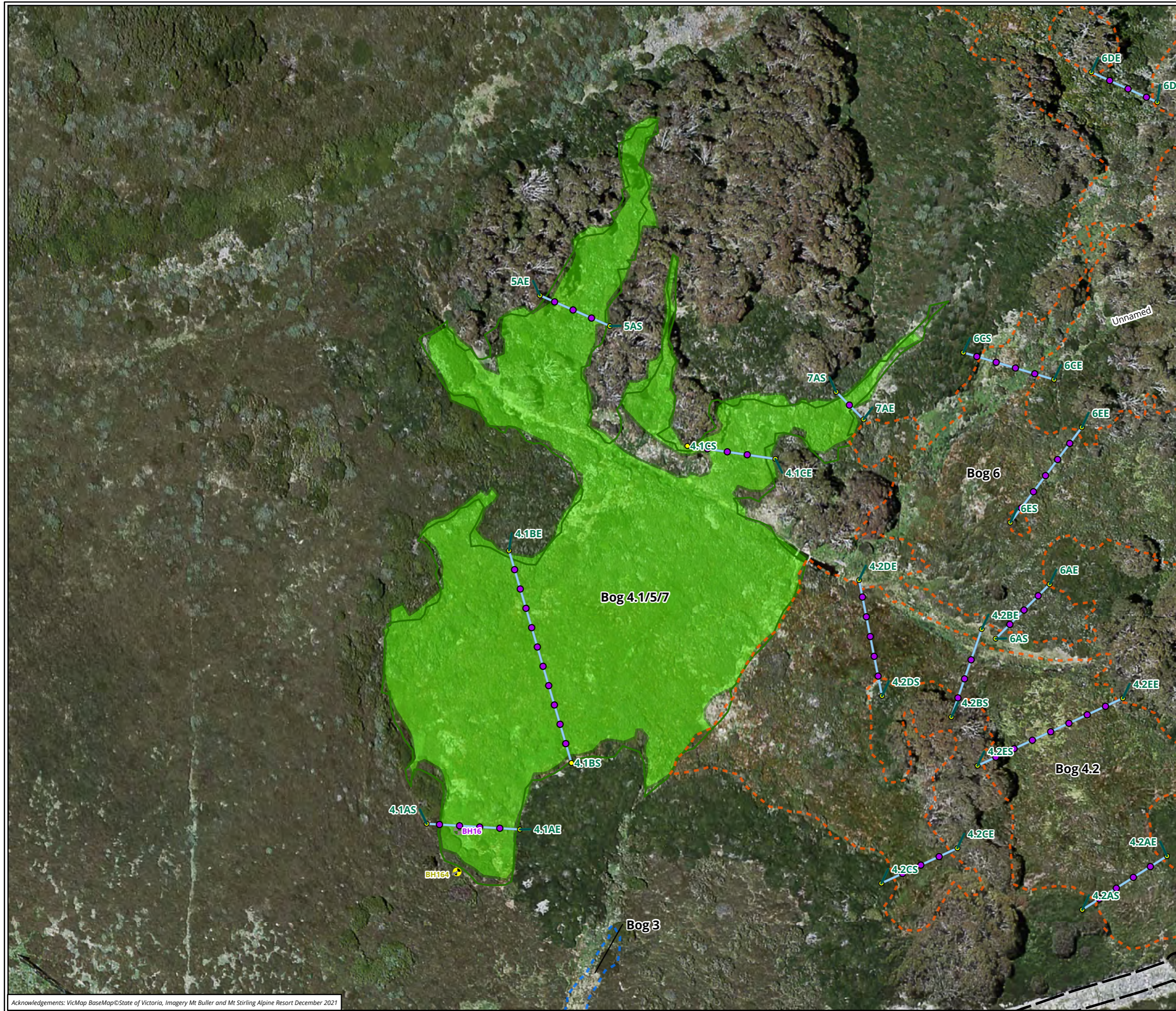
Figure 4c Bog 3 (other site)

0 2 4 6 8 10
Metres

Scale: 1:300 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022 ,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\
33202_HEMAMP_Update.aprx



- Legend**
- Project Construction Footprint (PCF)
 - Ecological monitoring (Alpine Bogs)**
 - Transects
 - Quadrats
 - Photo points
 - Alpine Bog**
 - Control site (2018)
 - Control site (2019)
 - Hydrological monitoring**
 - Groundwater bore
 - Other groundwater boreholes

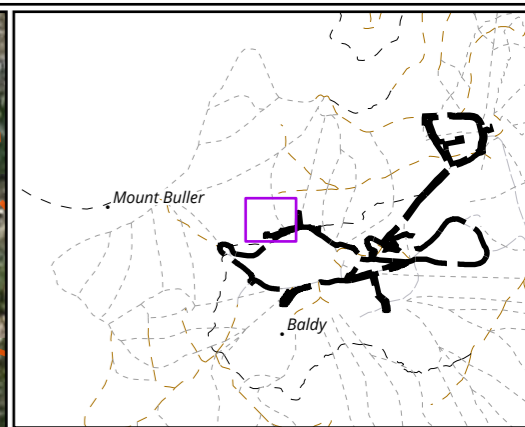
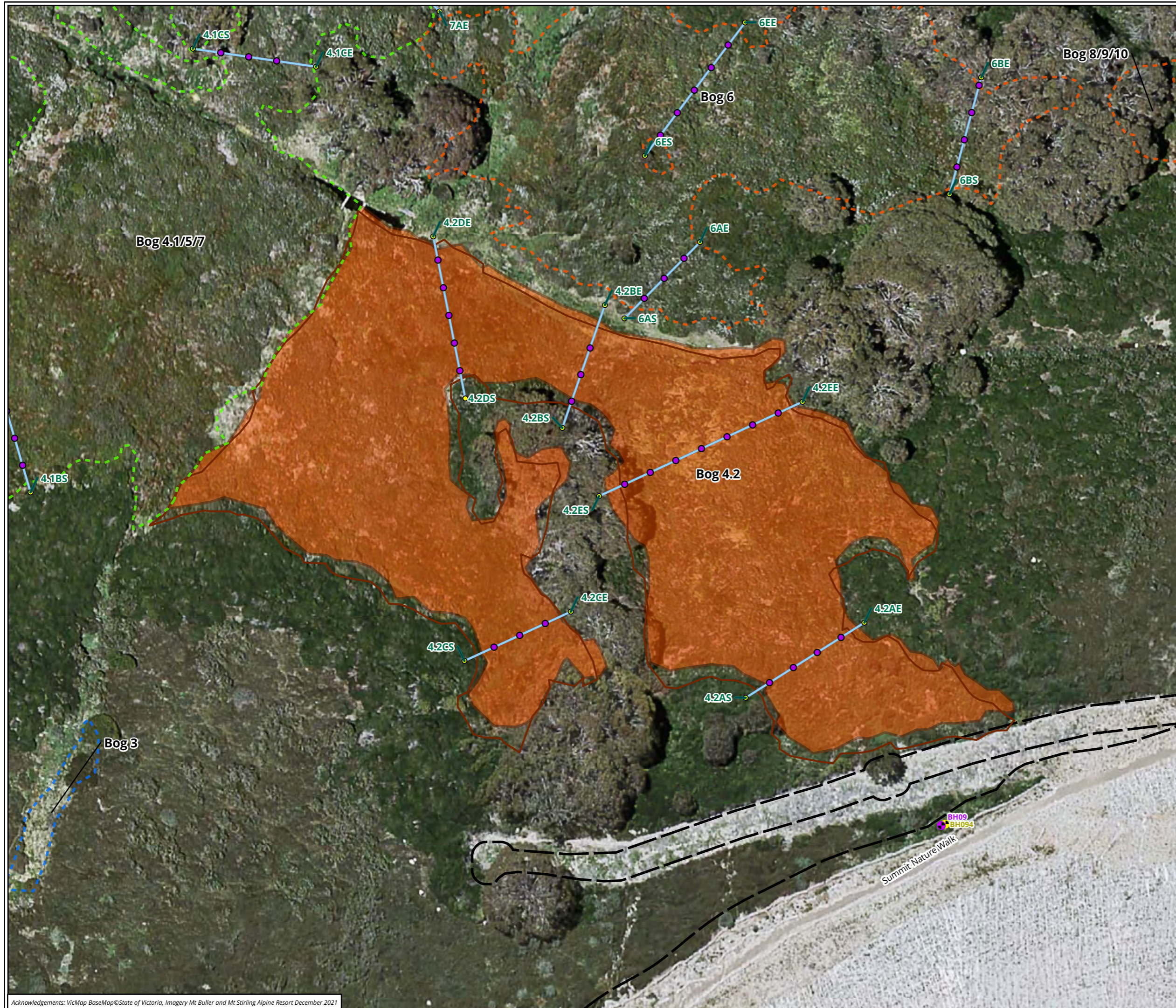
Figure 4d Bog 4.1/5/7 (control site)

0 5.5 11 16.5 22 27.5
Metres
Scale: 1:700 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022,
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- Legend**
- Project Construction Footprint (PCF)
 - Ecological monitoring (Alpine Bogs)**
 - Transects
 - Quadrats
 - Photo points
 - Alpine Bog**
 - Impact site (2018)
 - Impact site (2019)
 - Hydrological monitoring**
 - Groundwater bore
 - Other groundwater boreholes

Figure 4e Bog 4.2 (impact site)

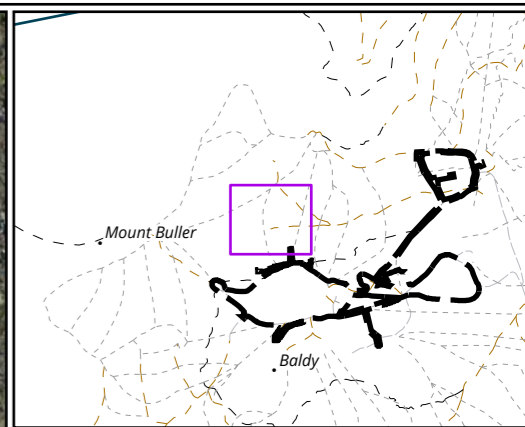
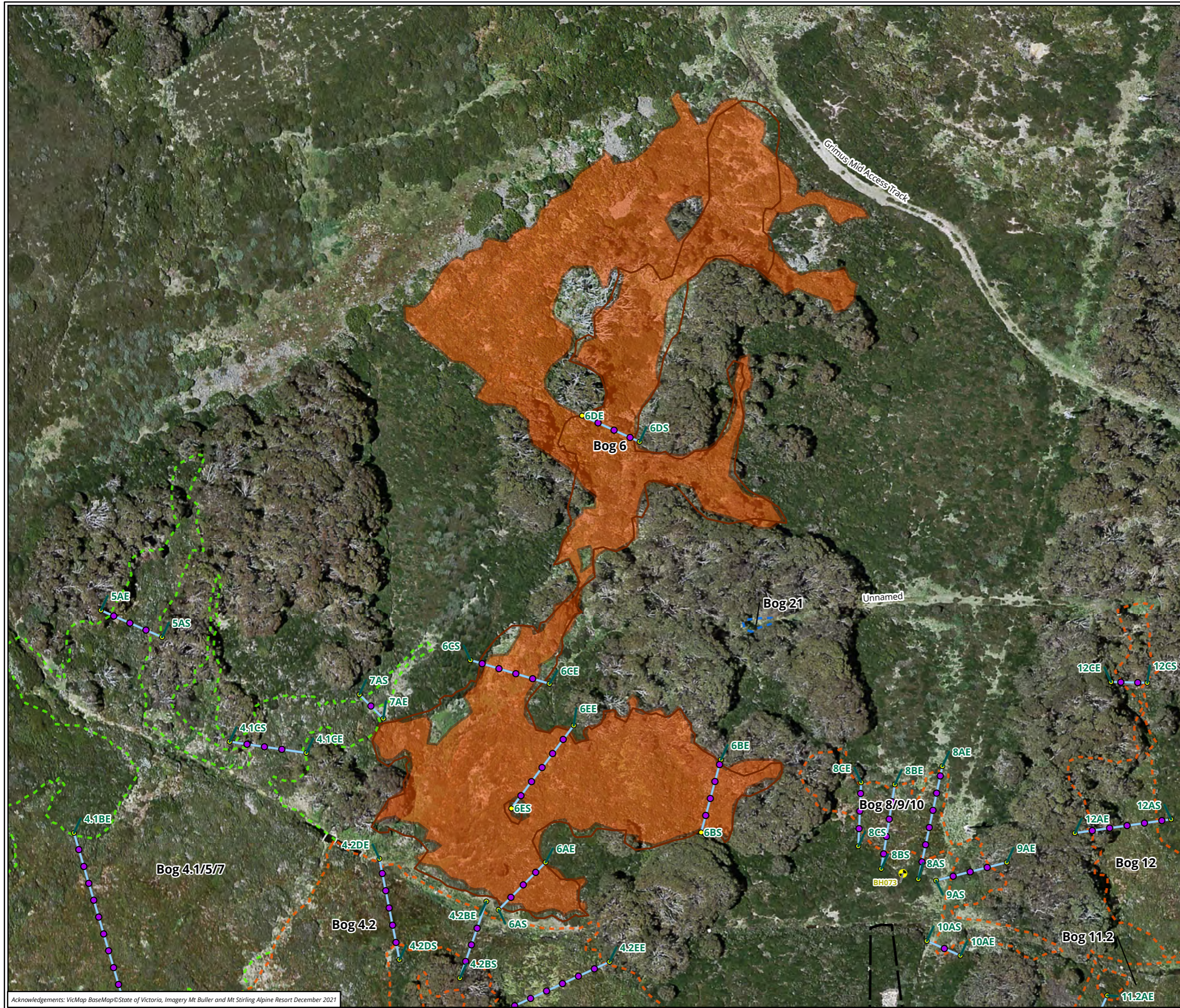


Scale: 1:500 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F4_HEMAMP_Alpine_Bogs
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Project Construction Footprint (PCF)
 - Ecological monitoring (Alpine Bogs)**
 - Transects
 - Quadrats
 - Photo points
 - Alpine Bog**
 - Impact site (2018)
 - Impact site (2019)
 - Hydrological monitoring**
 - Other groundwater boreholes

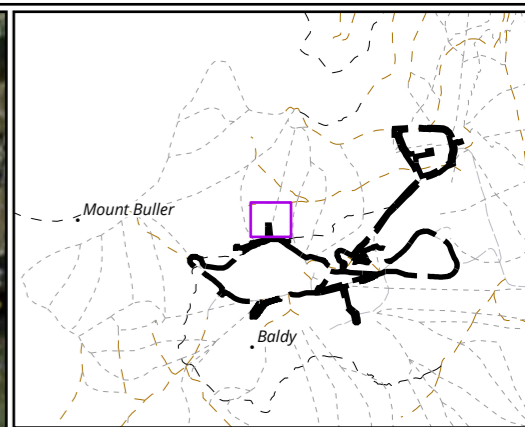
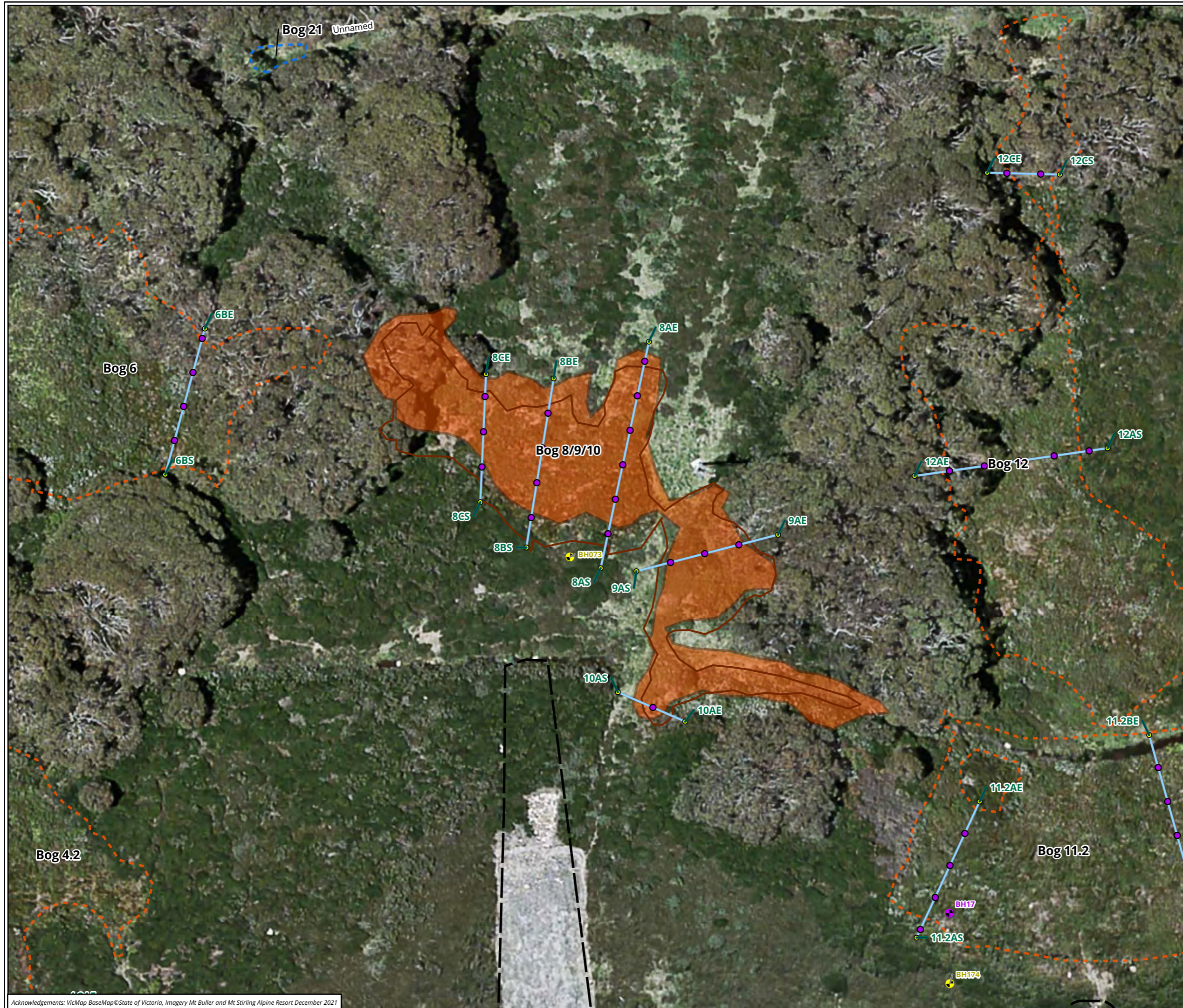
Figure 4f Bog 6 (impact site)

0 6 12 18 24 30
Metres
Scale: 1:800 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Legend

- Project Construction Footprint (PCF)
- Ecological monitoring (Alpine Bogs)**
- Transects
- Quadrats
- Photo points
- Alpine Bog**
- Impact site (2018)
- Impact site (2019)
- Hydrological monitoring**
- Groundwater bore
- Other groundwater boreholes

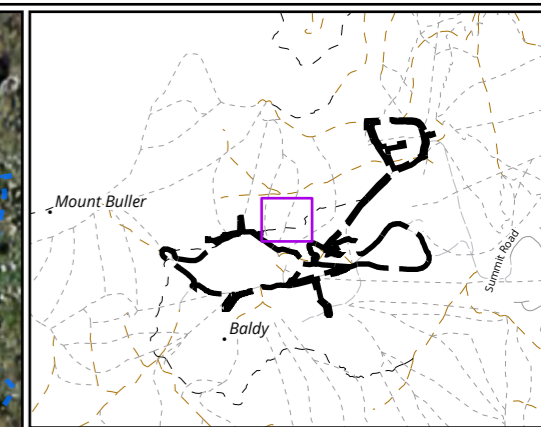
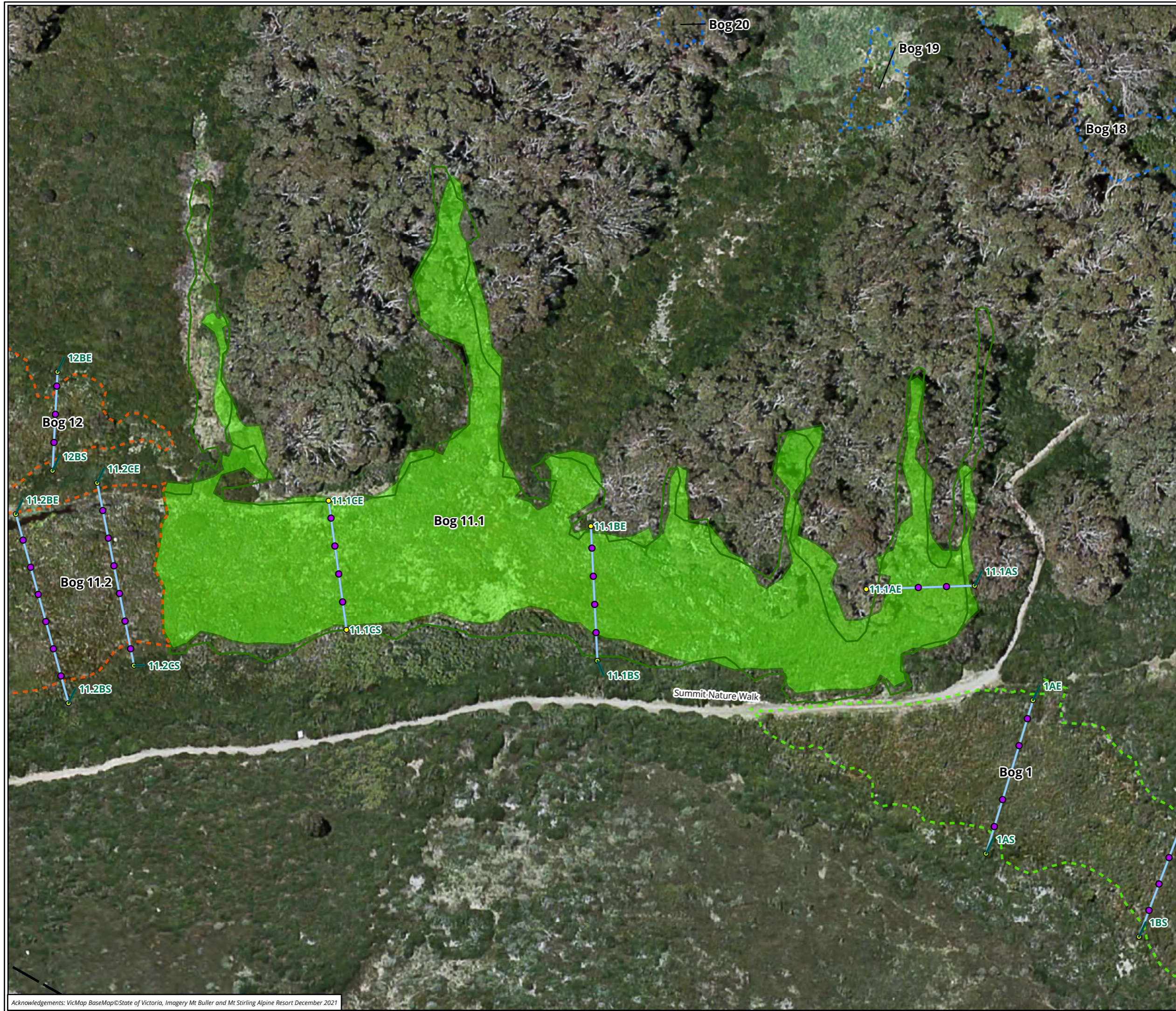
Figure 4g Bog 8/9/10 (impact site)

0 3 6 9 12 15
Metres
Scale: 1:400 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Legend

- Project Construction Footprint (PCF)
- Ecological monitoring (Alpine Bogs)**
 - Transects
 - Quadrats
 - Photo points
- Alpine Bog**
 - Control site (2018)
 - Control site (2019)

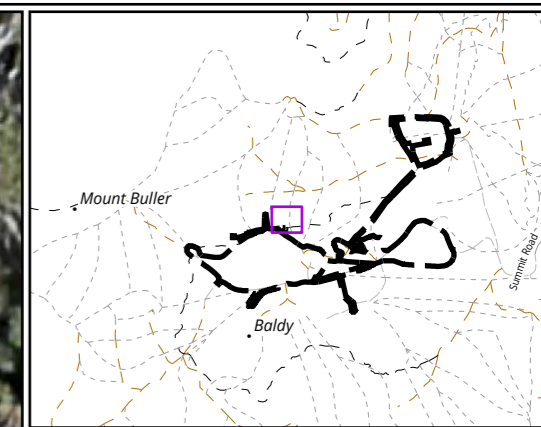
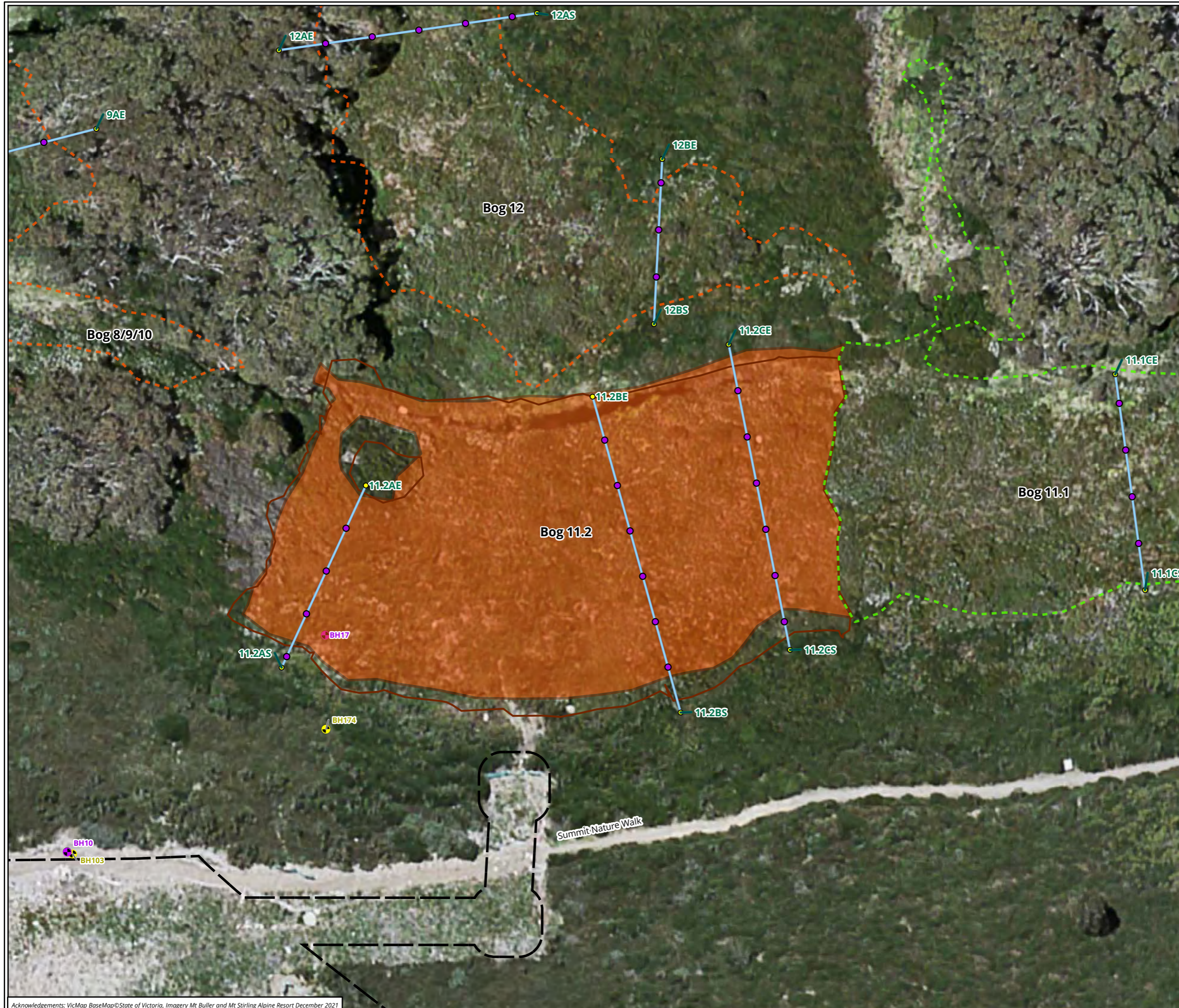
Figure 4h Bog 11.1 (control site)

0 4 8 12 16 20
Metres
Scale: 1:500 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Project Construction Footprint (PCF)
 - Ecological monitoring (Alpine Bogs)**
 - Transects
 - Quadrats
 - Photo points
 - Alpine Bog**
 - Impact site (2018)
 - Impact site (2019)
 - Hydrological monitoring**
 - Groundwater bore
 - Other groundwater boreholes

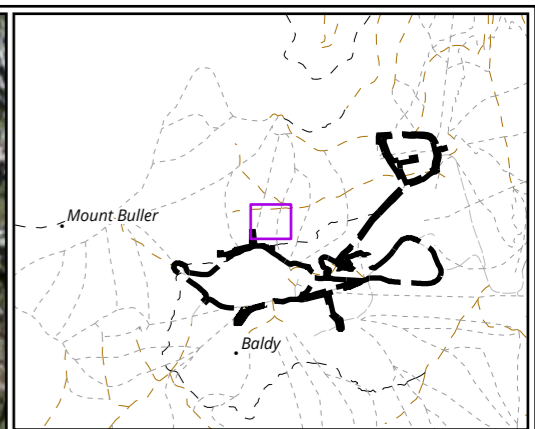
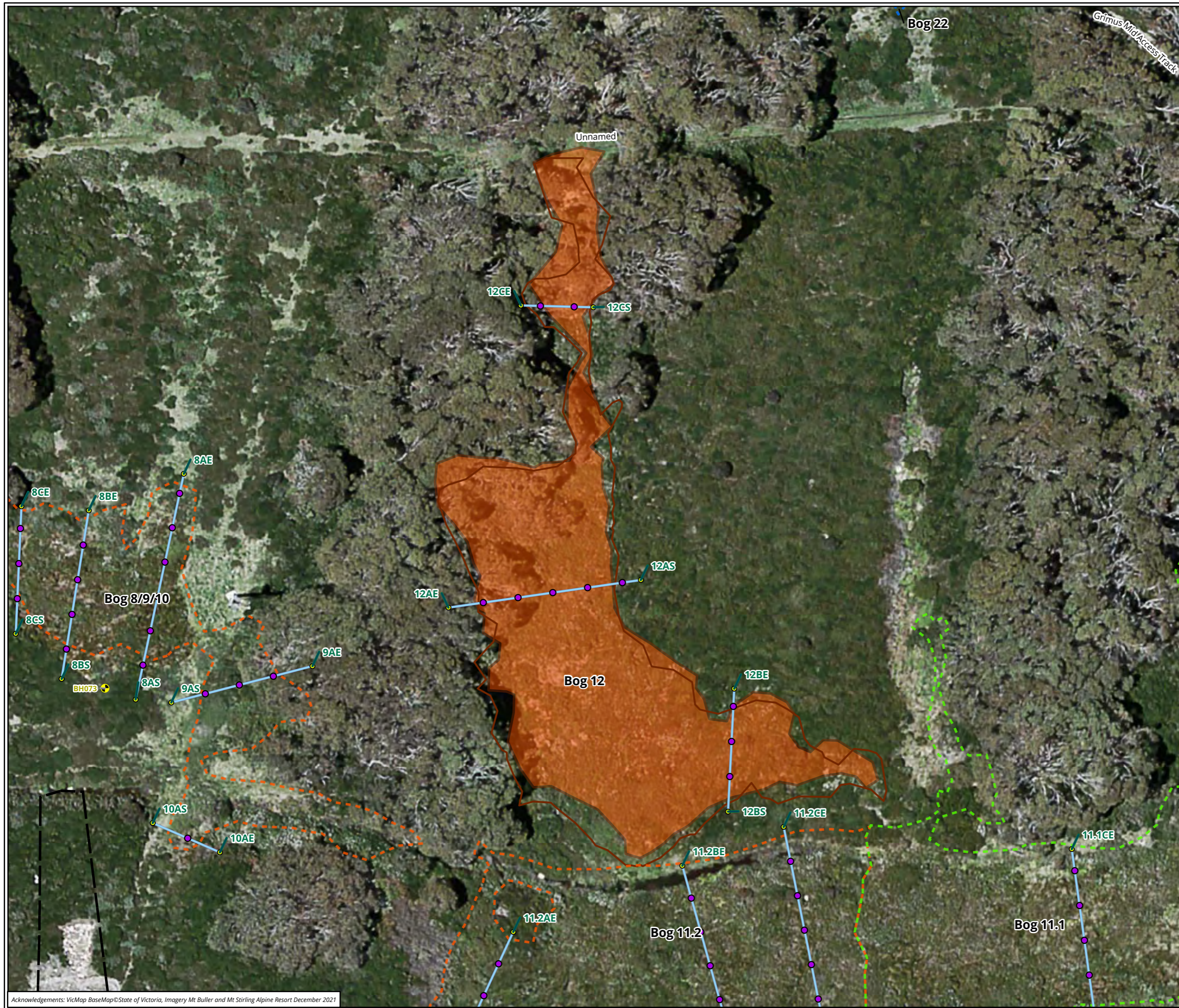
Figure 4i Bog 11.2 (impact site)

0 2 4 6 8 10
Metres
Scale: 1:300 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Project Construction Footprint (PCF)
 - Ecological monitoring (Alpine Bogs)**
 - Transects
 - Quadrats
 - Photo points
 - Alpine Bog**
 - Impact site (2018)
 - Impact site (2019)
 - Hydrological monitoring**
 - Other groundwater boreholes

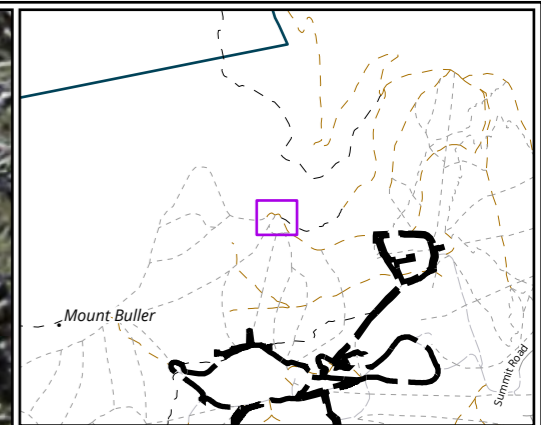
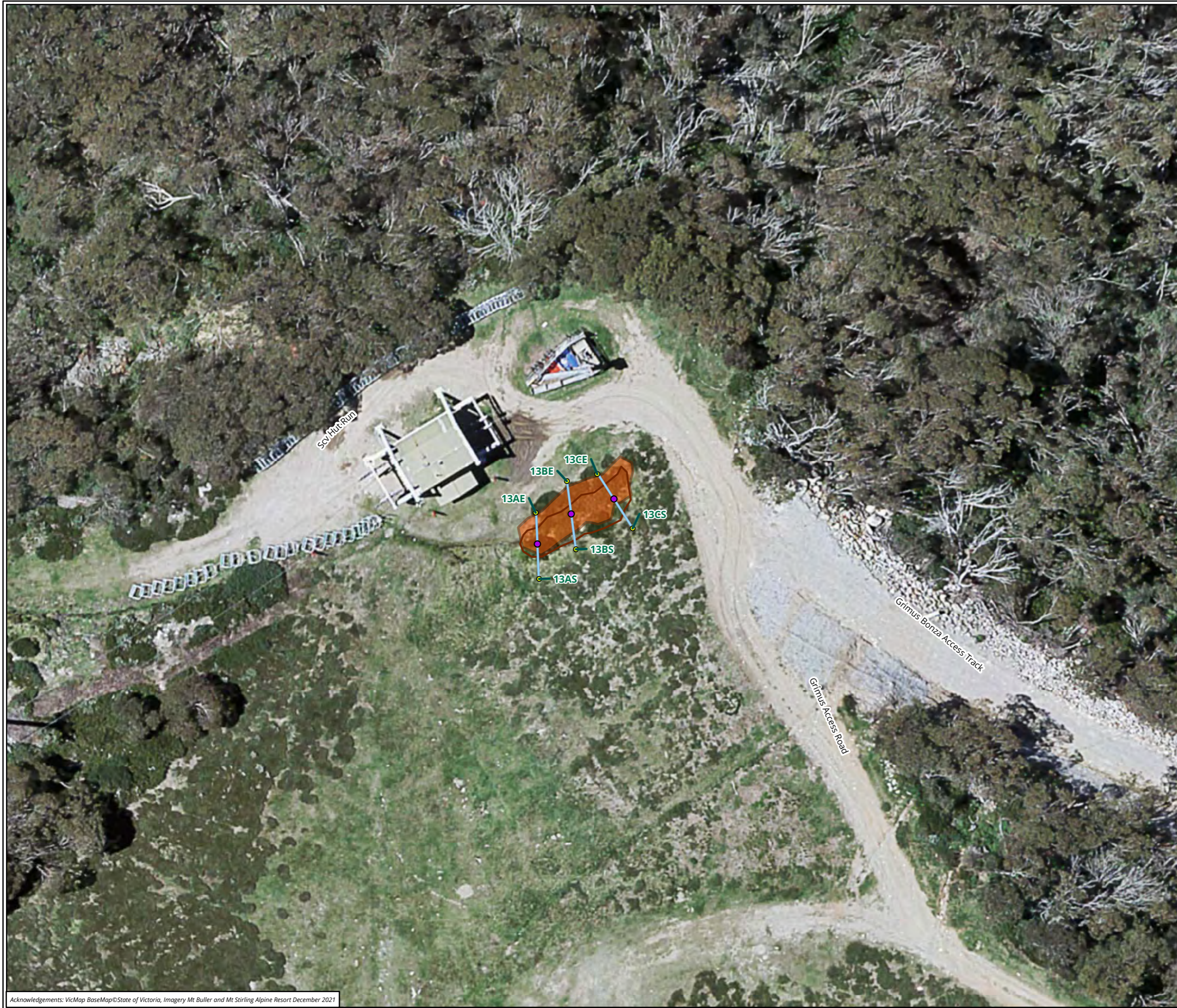
Figure 4j Bog 12 (impact site)

0 3 6 9 12 15
 Metres
 Scale: 1:400 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
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Legend

Ecological monitoring (Alpine Bogs)

- Transects
- Quadrats
- Photo points

Alpine Bog

- Impact site (2018)
- Impact site (2019)

Figure 4k Bog 13 (impact site)



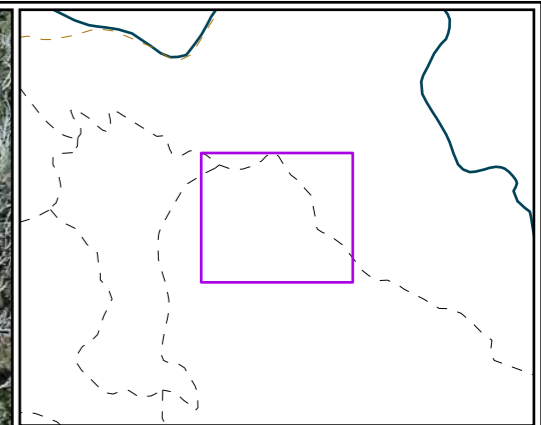
Metres

Scale: 1:400 @ A3

Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022 ,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
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 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx



Legend

Ecological monitoring (Alpine Bogs)

- Transects
- Quadrats
- Photo points

Alpine Bog

- Control site (2018)
- Control site (2019)

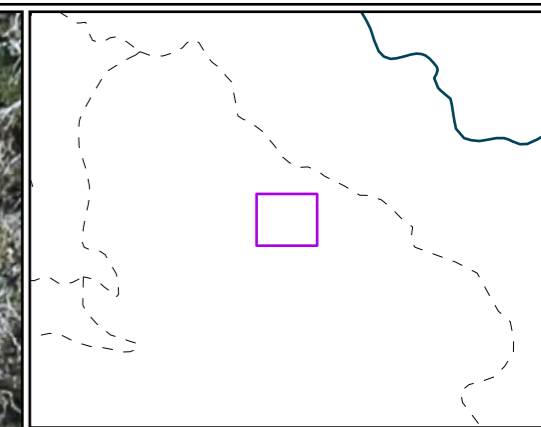
Figure 4I Bog S1 (control site)

0 10 20 30 40 50
 Metres
 Scale: 1:1,500 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022 ,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
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- Legend**
- Ecological monitoring (Alpine Bogs)**
- Transects
 - Quadrats
 - Photo points
- Alpine Bog**
- Control site (2018)
 - Control site (2019)

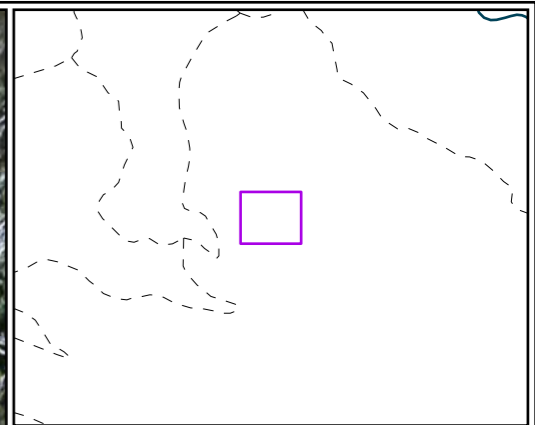
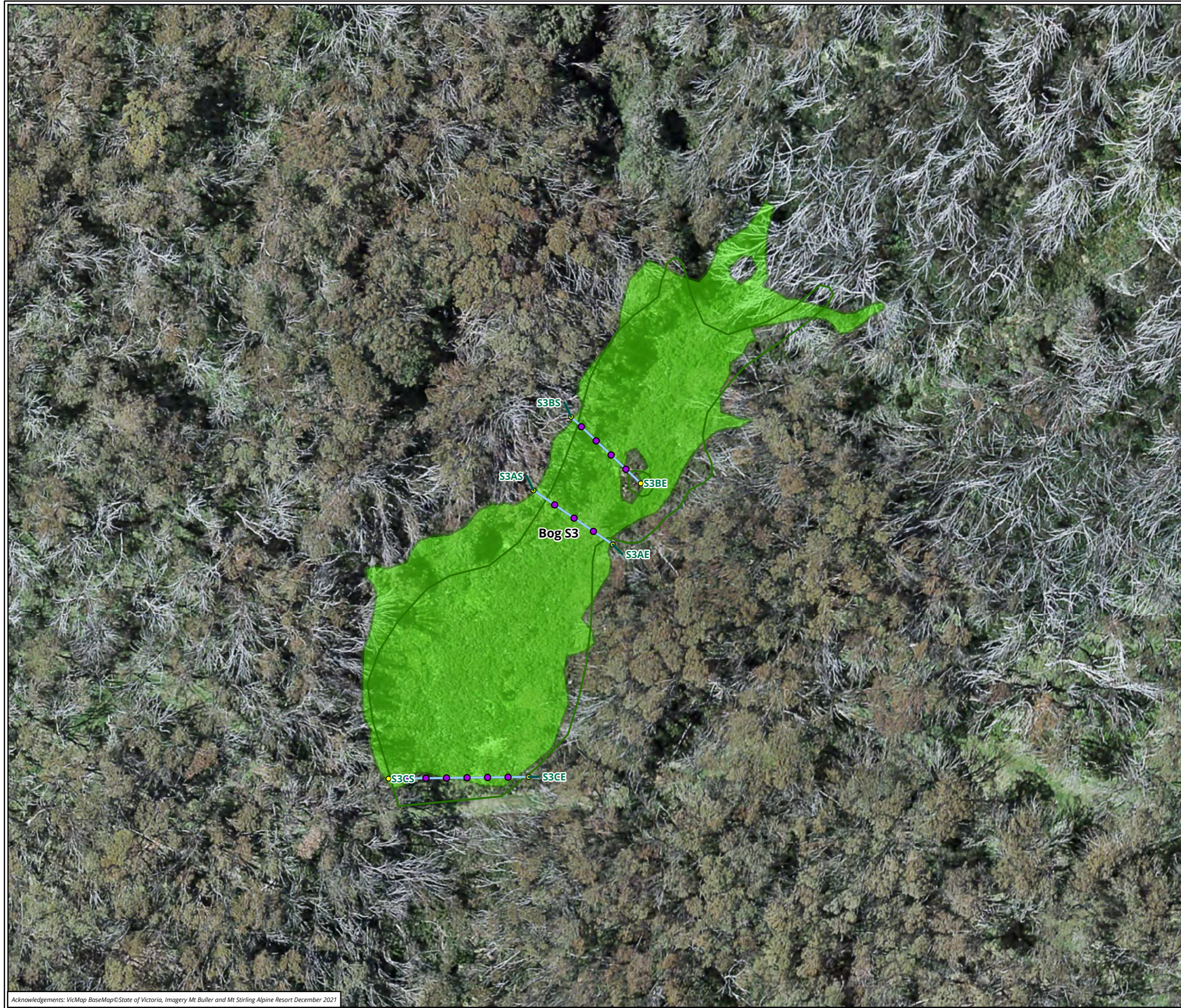
Figure 4m Bog S2 (control site)

0 4.5 9 13.5 18 22.5
 Metres
 Scale: 1:600 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022 ,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
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- Legend**
- Ecological monitoring (Alpine Bogs)**
- Transects
 - Quadrats
 - Photo points
- Alpine Bog**
- Control site (2018)
 - Control site (2019)

Figure 4n Bog S3 (control site)

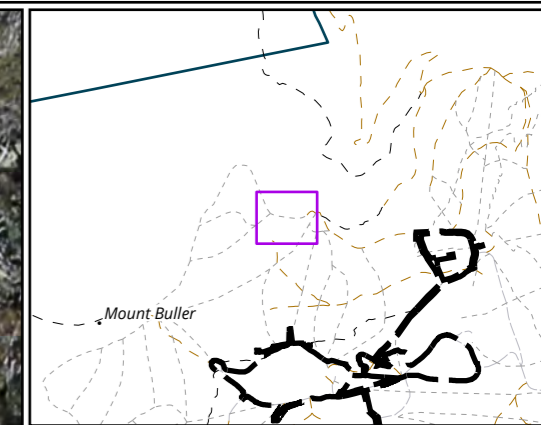
0 4.5 9 13.5 18 22.5
Metres

Scale: 1:600 @ A3
Coordinate System: GDA 1994 MGA Zone 55



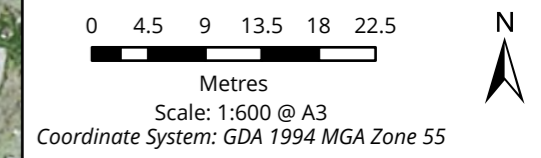
Matter: 33202/29064,
Date: 28 July 2022 ,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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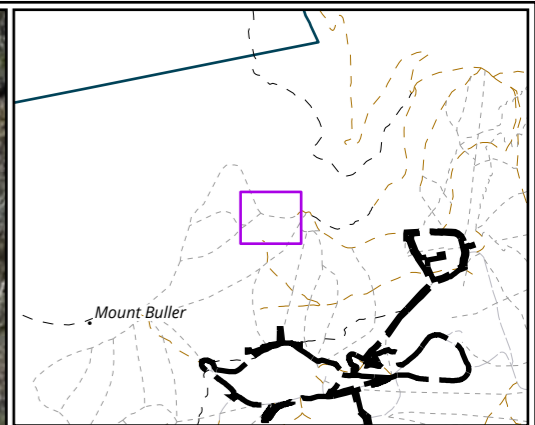
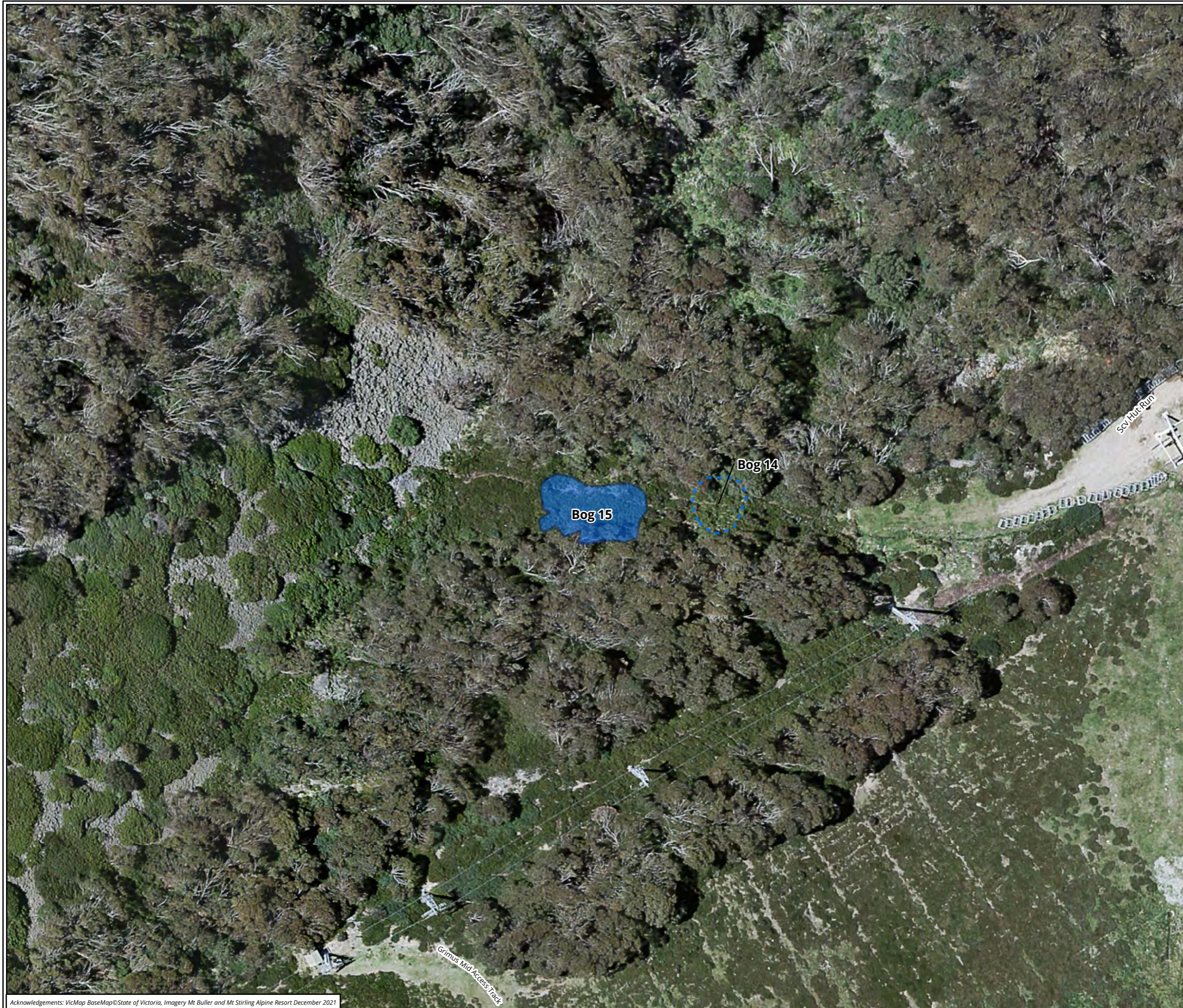


- Legend**
- Ecological monitoring (Alpine Bogs)**
- Transects
 - Quadrats
 - Photo points
- Alpine Bog**
- Other site (2019)

Figure 4o Bog 14 (other site)



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F4_HEMAMP_Alpine_Bogs
 Project: P:\33200s\33202\Mapping\
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Legend

Alpine Bog


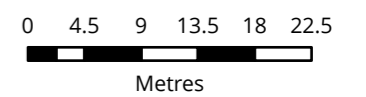
 Other site (2019)

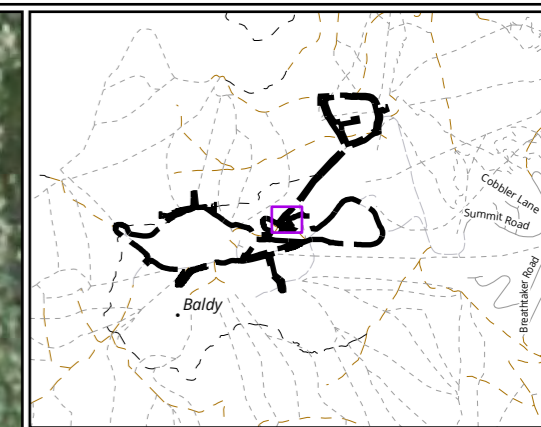
Figure 4p Bog 15 (other site)



Scale: 1:600 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022 ,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\
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Legend






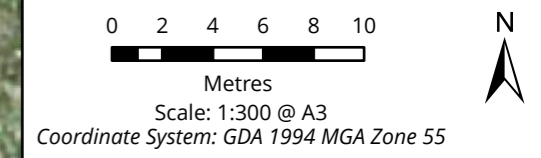
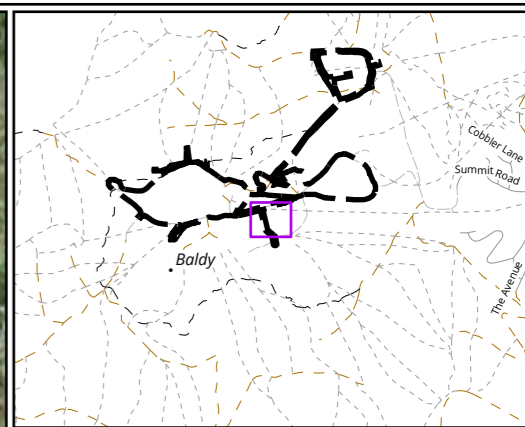
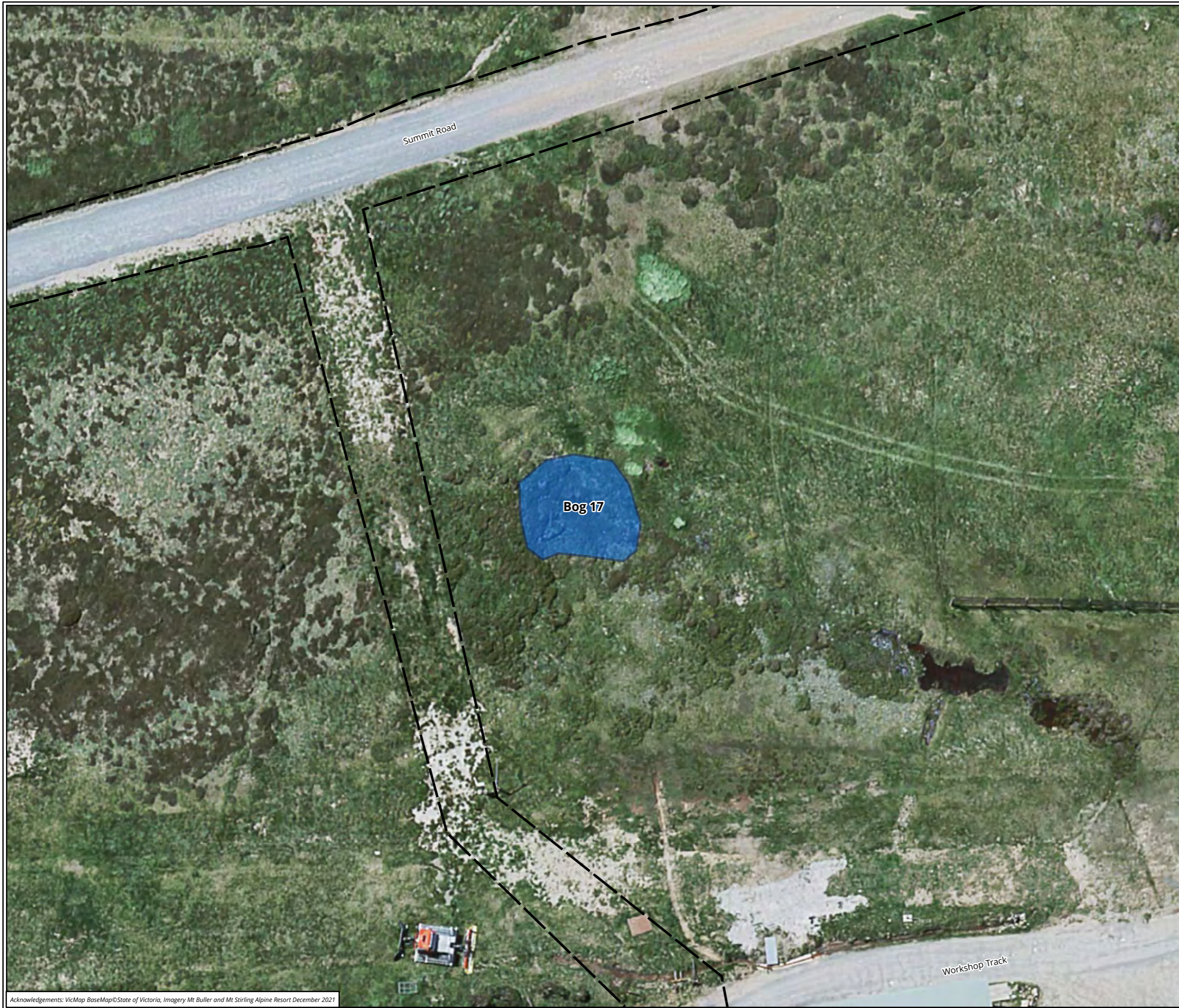
-  Project Construction Footprint (PCF)
-  Alpine Bog
 -  Other site (2019)
- Hydrological monitoring**
 -  Groundwater bore
 -  Other groundwater boreholes

Figure 4q Bog 16 (other site)



Matter: 33202/29064,
Date: 28 July 2022 ,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
-  Project Construction Footprint (PCF)
 - Alpine Bog**
 -  Other site (2019)

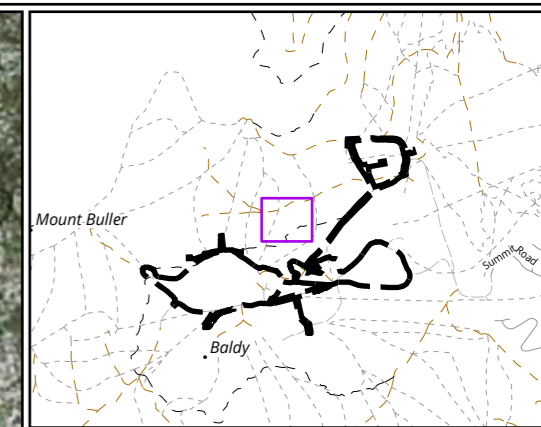
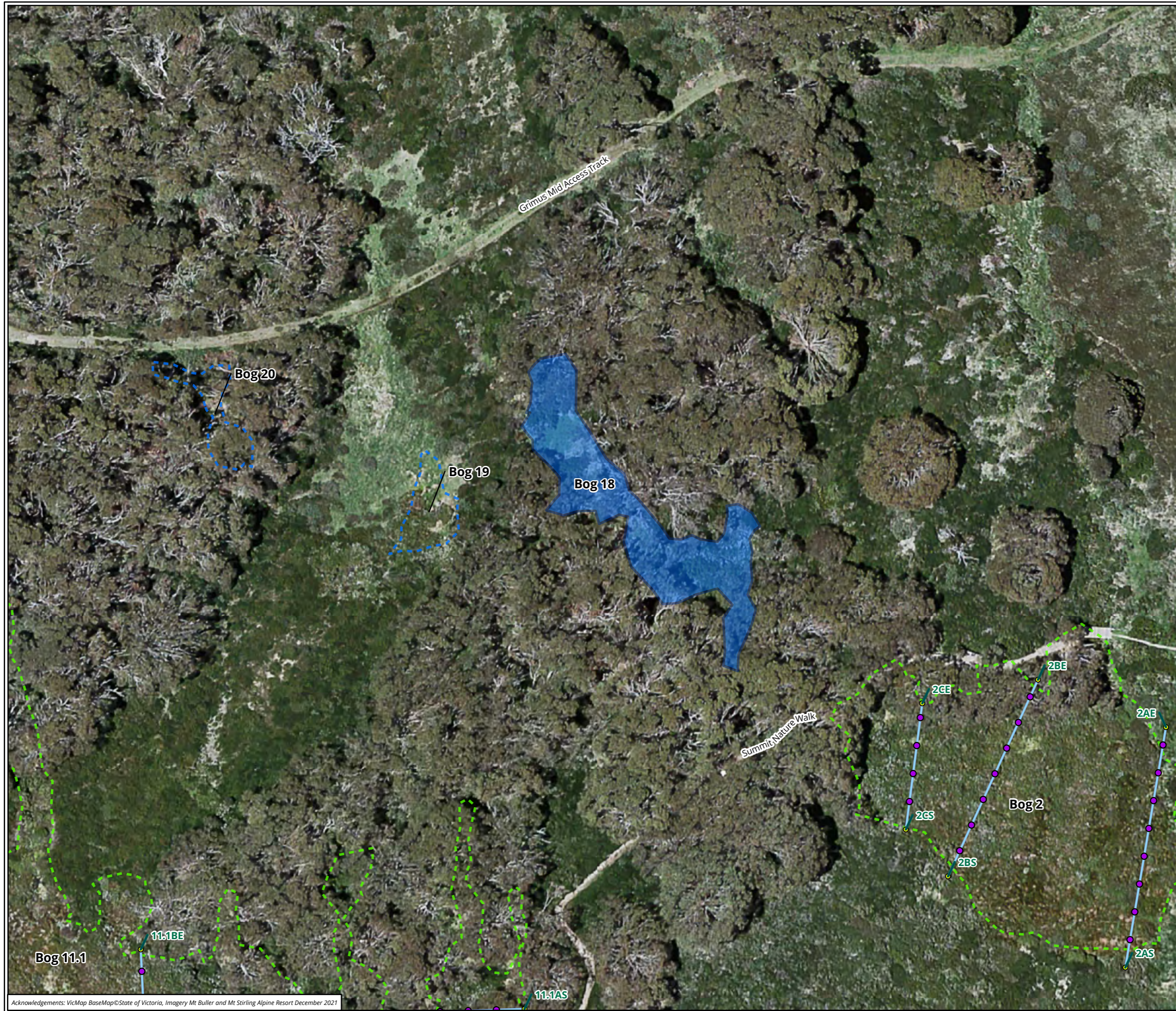
Figure 4r Bog 17 (other site)

0 3 6 9 12 15
 Metres
 Scale: 1:400 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
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 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Ecological monitoring (Alpine Bogs)**
- Transects
 - Quadrats
 - Photo points
- Alpine Bog**
- Other site (new in 2019)

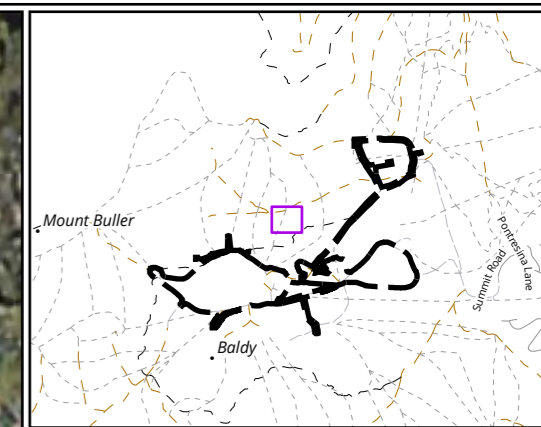
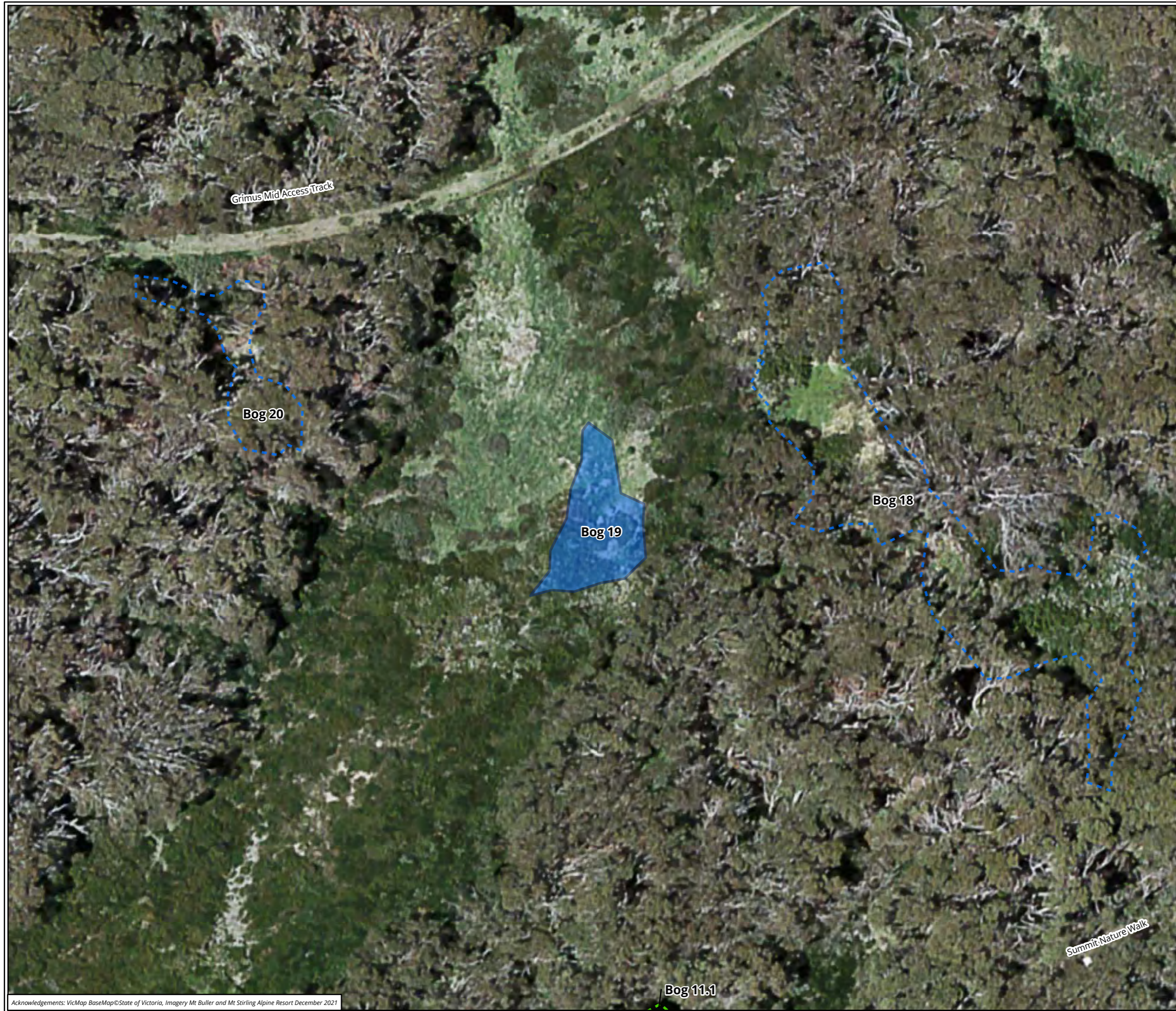
Figure 4s Bog 18 (new in 2019)

0 4 8 12 16 20
Metres
Scale: 1:500 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Legend

Alpine Bog

- Other site (new in 2019)

Figure 4t Bog 19 (new in 2019)



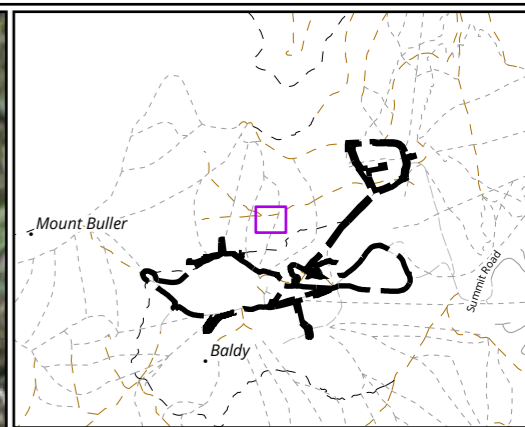
Scale: 1:300 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022 ,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\
33202_HEMAMP_Update.aprx

Summit Nature Walk

Bog 11.1



Legend

Alpine Bog

- Other site (new in 2019)

Figure 4u Bog 20 (new in 2019)



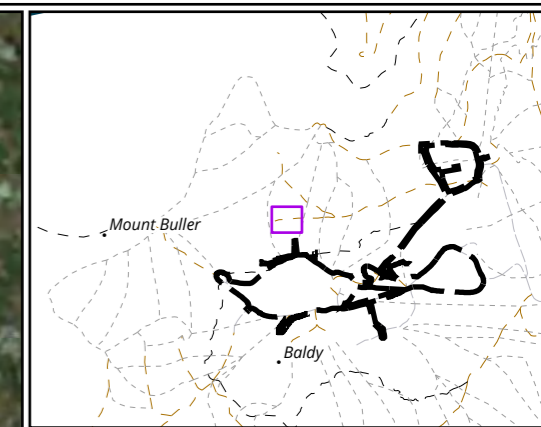
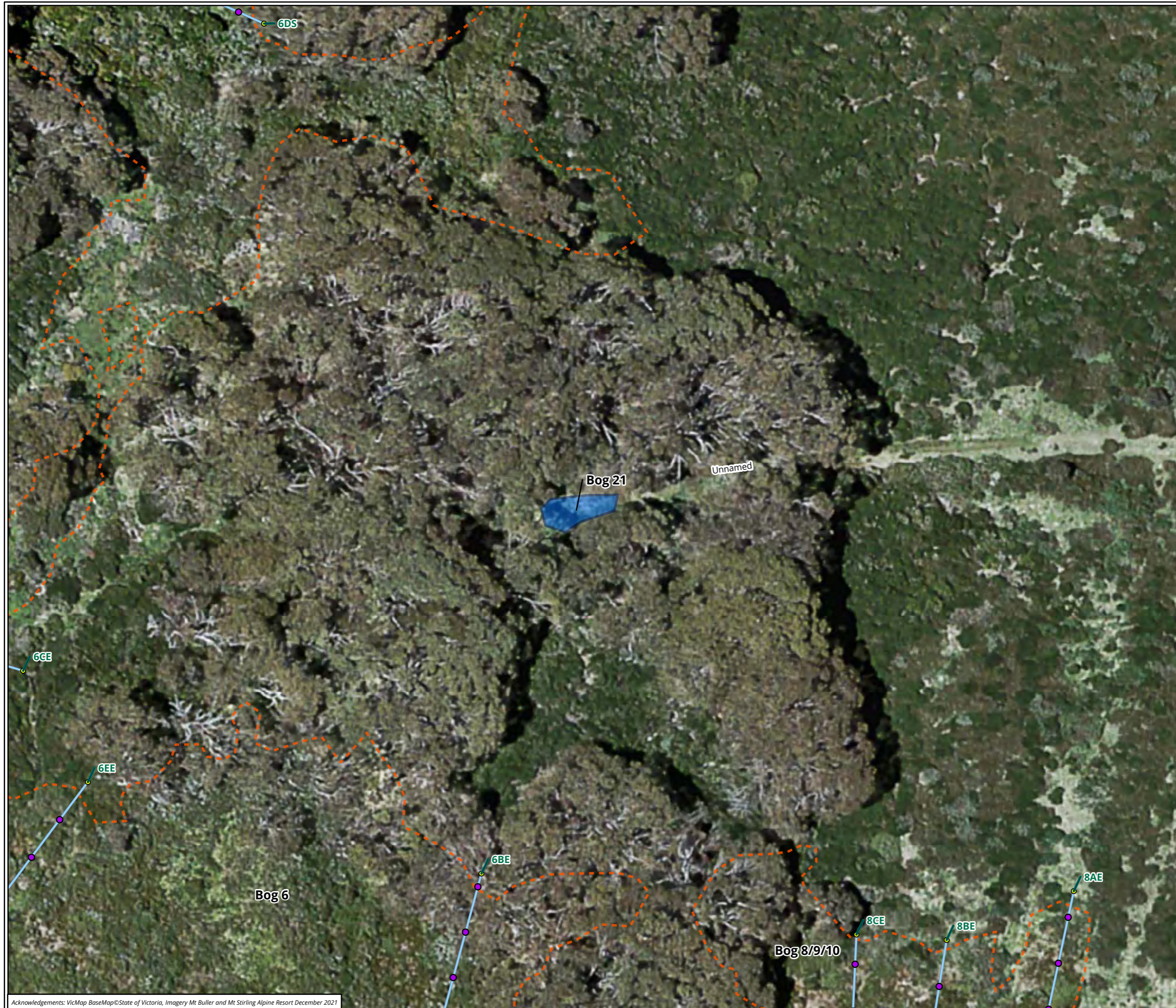
Metres

Scale: 1:300 @ A3

Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022 ,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
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- Legend**
- Ecological monitoring (Alpine Bogs)**
- Transects
 - Quadrats
 - Photo points
- Alpine Bog**
- Other site (new in 2019)

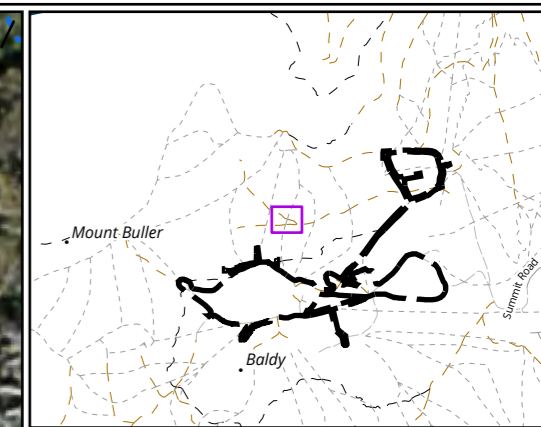
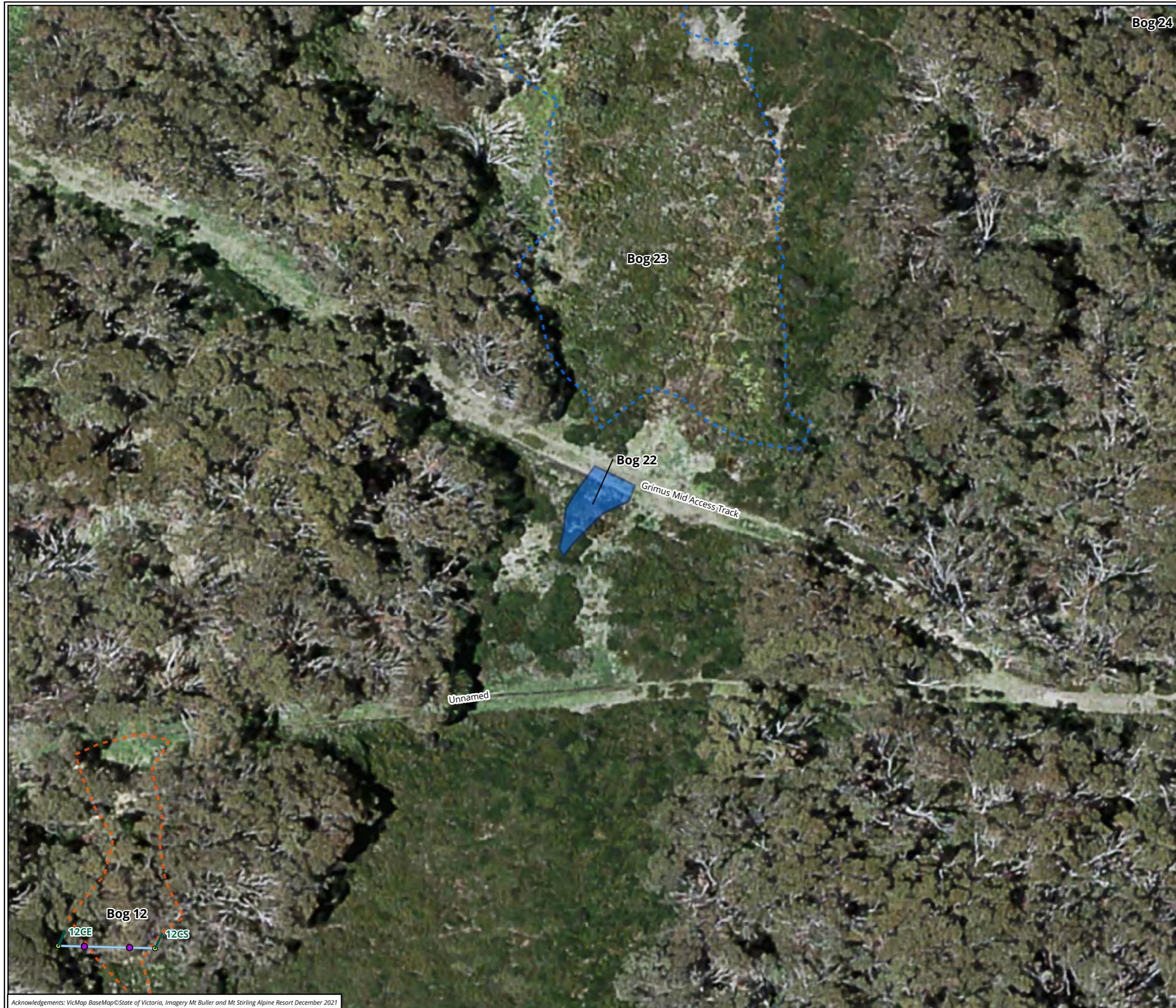
Figure 4v Bog 21 (new in 2019)

0 2 4 6 8 10
 Metres
 Scale: 1:300 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022 ,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F4_HEMAMP_Alpine_Bogs
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- Legend**
- Ecological monitoring (Alpine Bogs)**
- Transects
 - Quadrats
 - Photo points
- Alpine Bog**
- Other site (new in 2019)

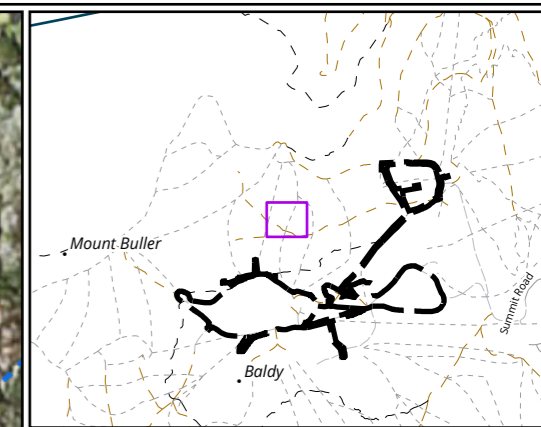
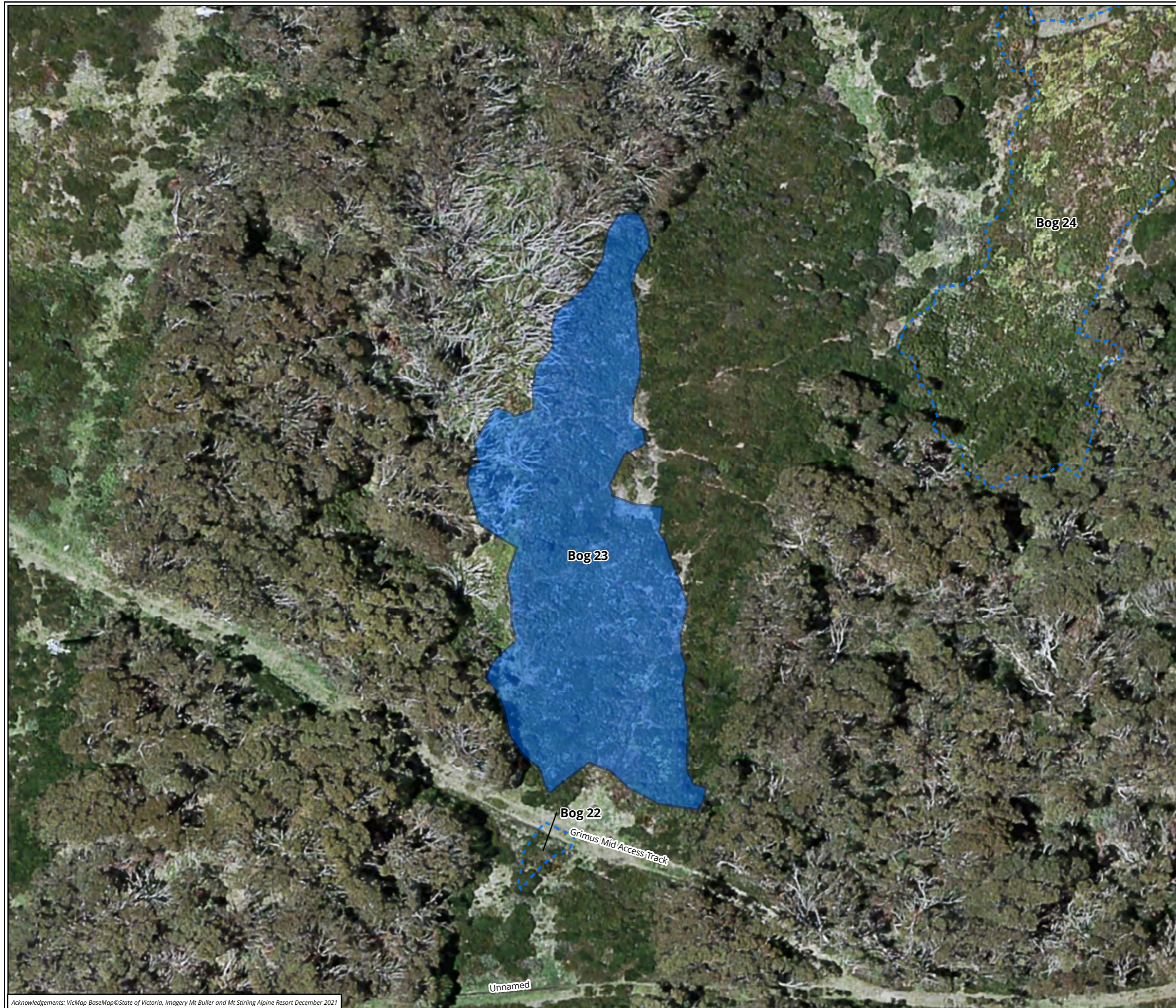
Figure 4w Bog 22 (new in 2019)

0 2 4 6 8 10
 Metres
 Scale: 1:300 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



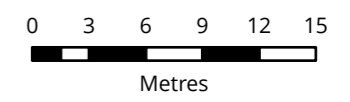
Matter: 33202/29064,
 Date: 28 July 2022 ,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F4_HEMAMP_Alpine_Bogs
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Legend
Alpine Bog
 Other site (new in 2019)

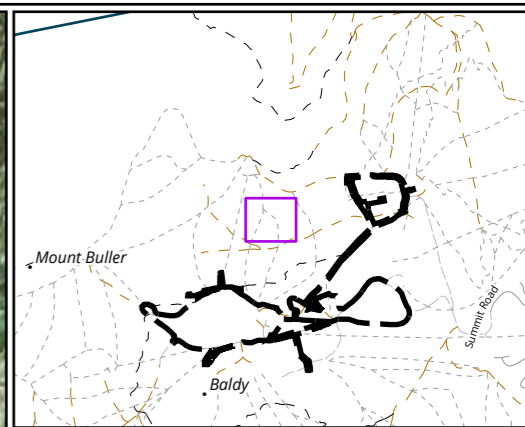
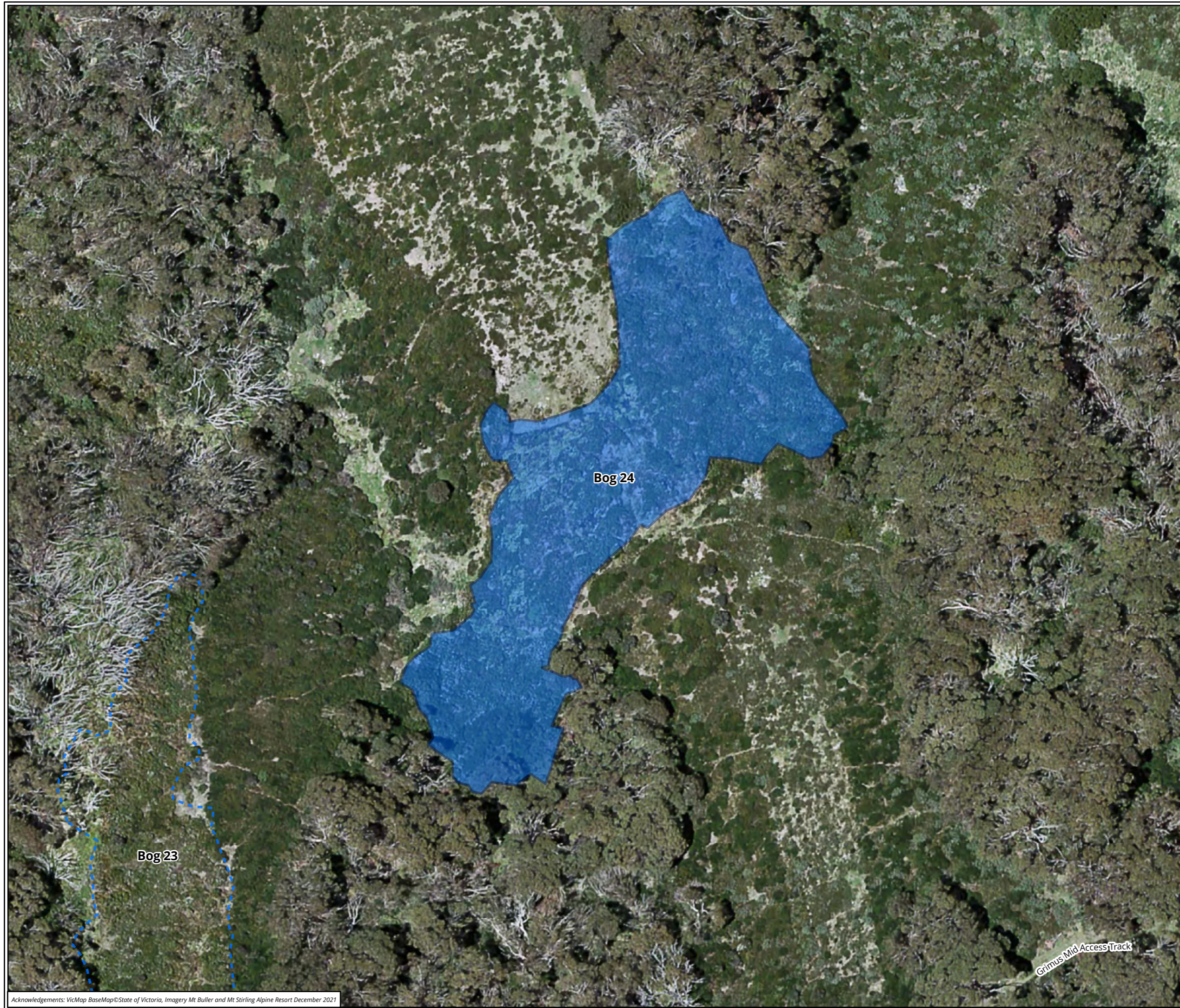
Figure 4x Bog 23 (new in 2019)



Scale: 1:400 @ A3
 Coordinate System: GDA 1994 MGA Zone 55




Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F4_HEMAMP_Alpine_Bogs
 Project: P:\33200s\33202\Mapping\
 33202_HEMAMP_Update.aprx



Legend

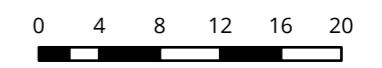
Alpine Bog

-  Other site (new in 2019)

Bog 24

Bog 23

Figure 4y Bog 24 (new in 2019)

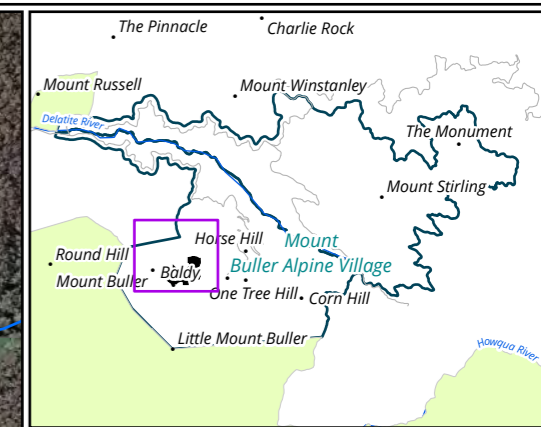
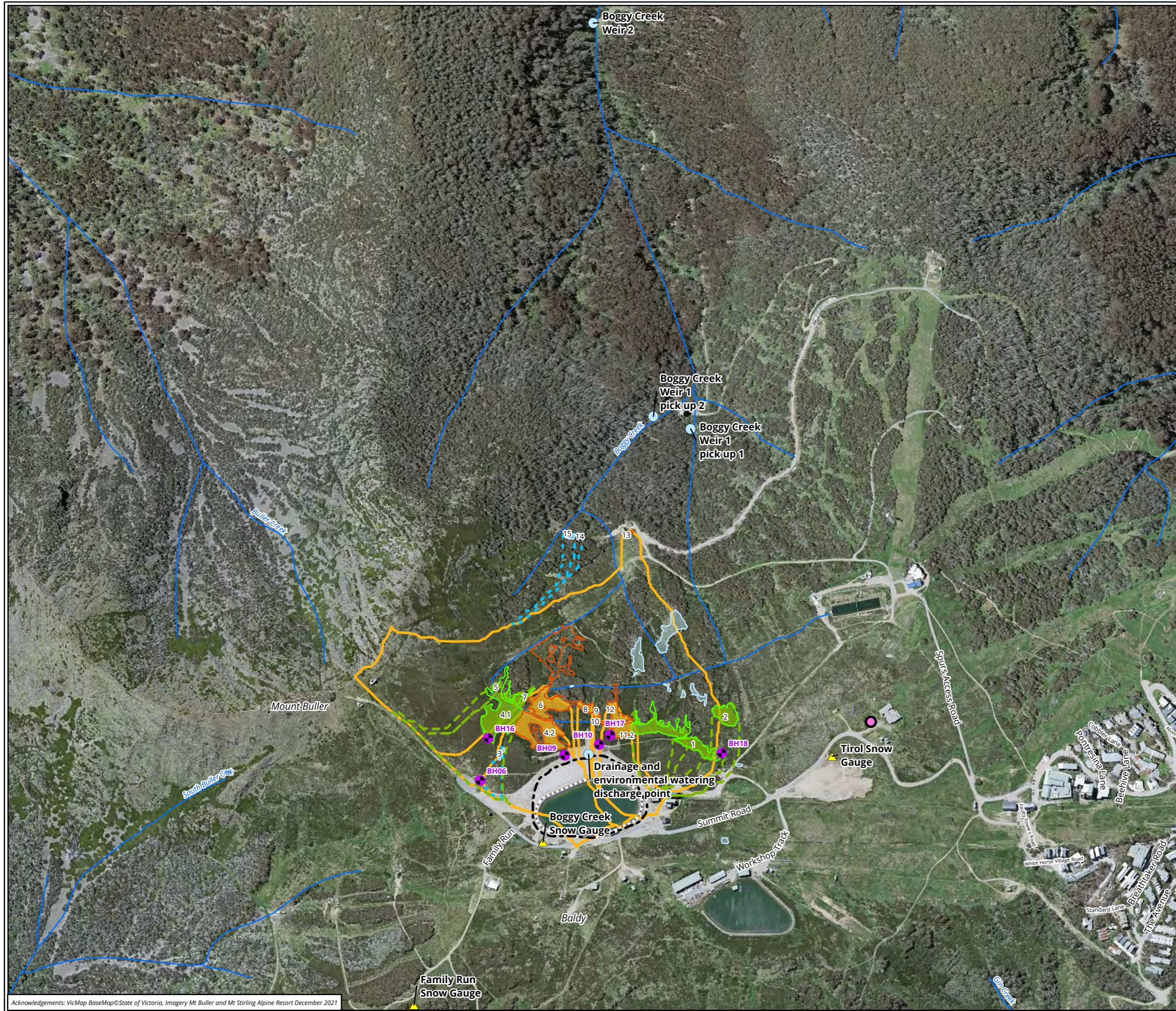


Scale: 1:500 @ A3
Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
Date: 28 July 2022 ,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F4_HEMAMP_Alpine_Bogs
Project: P:\33200s\33202\Mapping\
33202_HEMAMP_Update.aprx

Grimus Mid Access Track



- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Snow gauge
 - Surface water monitoring location
 - BoM Station
- Alpine Bogs (Biosis 2019)**
- Impact sites
 - Control sites
 - Other sites
- Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
- Alpine Bogs**
- Impact sites
 - Control sites
 - Other sites
- Alpine Bog catchment areas**
- Impact sites
 - Control sites
 - Other sites

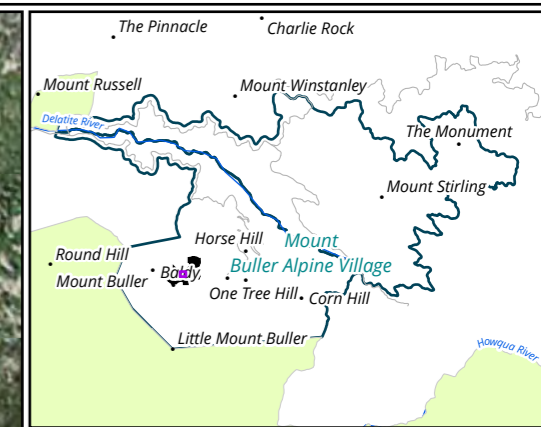
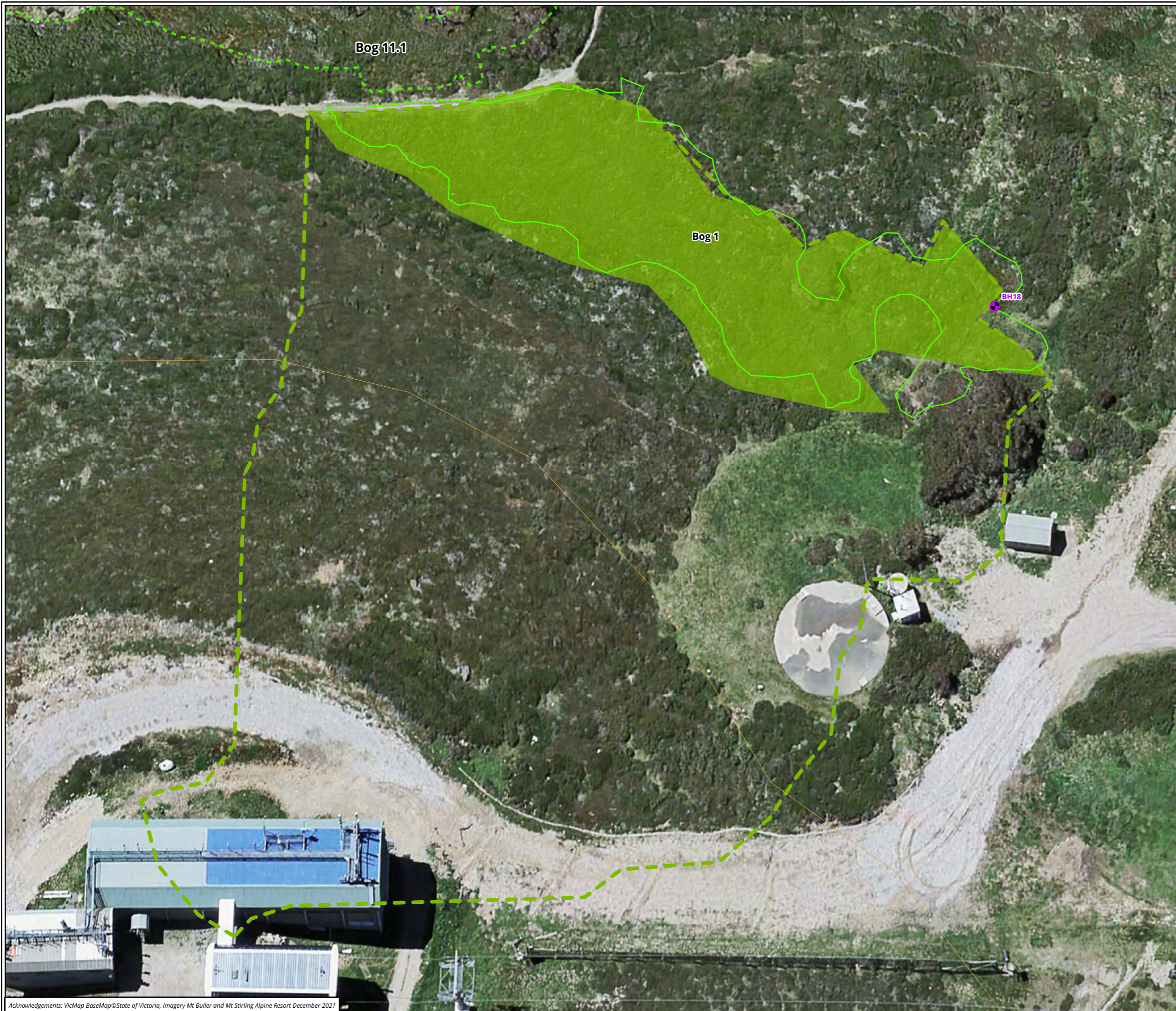
Figure 5 Catchment areas of alpine bogs subject to monitoring at Mount Buller Alpine Resort

0 50 100 150 200 250
 Metres
 Scale: 1:7,000 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F5_HEMAMP_Alpine_Bog_catchments
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Groundwater bore
 - Alpine Bogs (Biosis 2019)**
 - Control site
 - Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
 - Alpine Bogs**
 - Control site
 - Alpine Bog catchment areas**
 - Control site

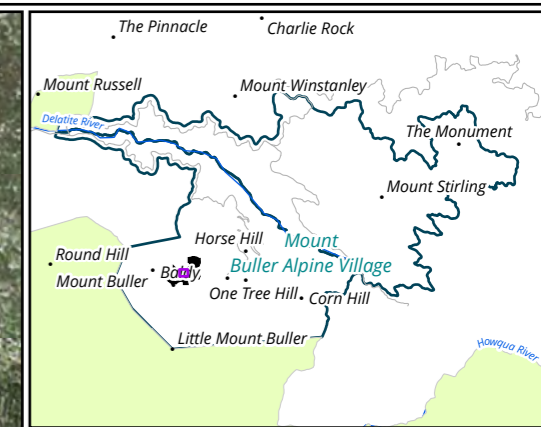
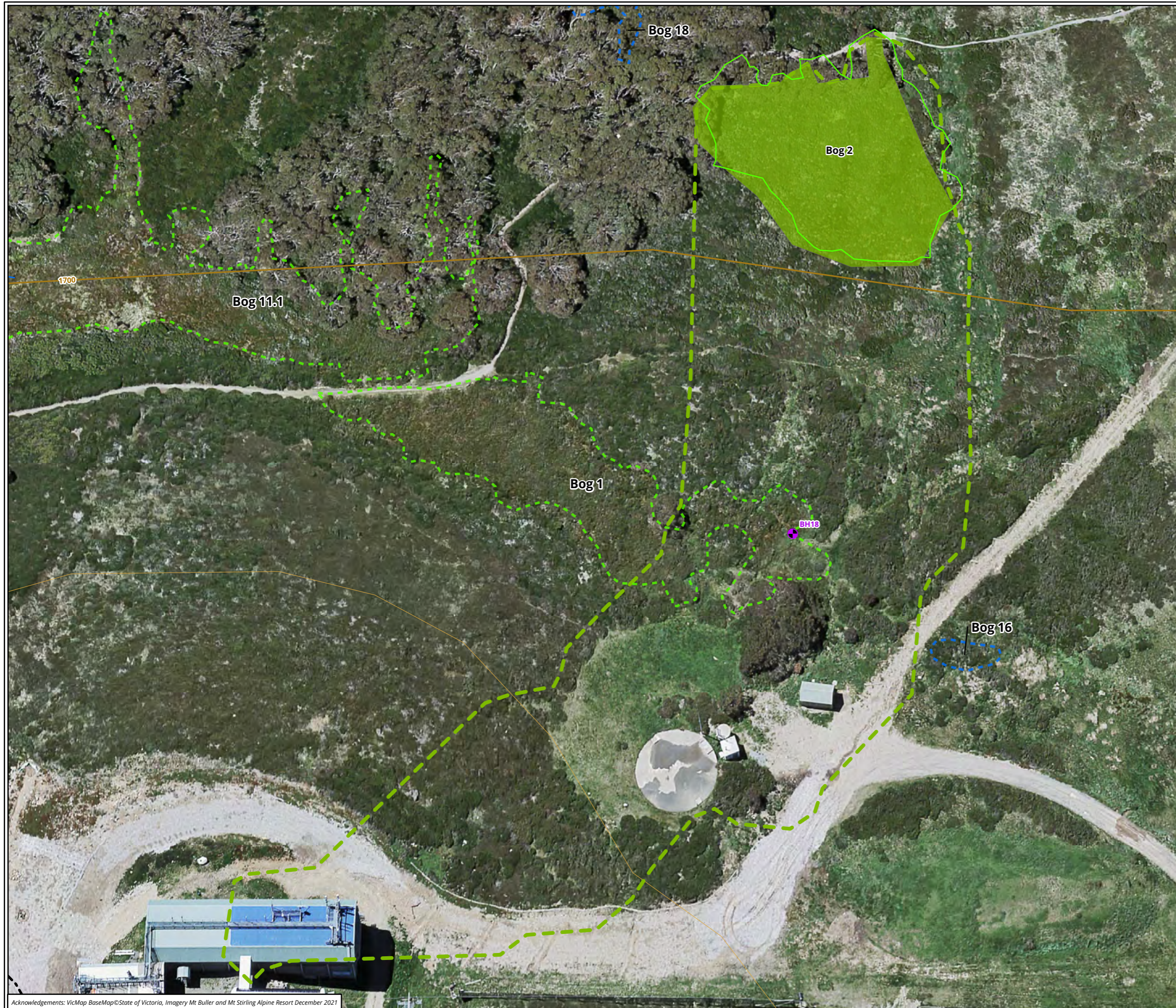
Figure 6a Catchment area of Bog 1 (Control site)

0 4 8 12 16 20
 Metres
 Scale: 1:500 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F6_HEMAMP_Bog_catchments_details
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Earth embankment footprint
 - Groundwater bore
 - Alpine Bogs (Biosis 2019)**
 - Control site
 - Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
 - Alpine Bogs**
 - Control site
 - Alpine Bog catchment areas**
 - Control site

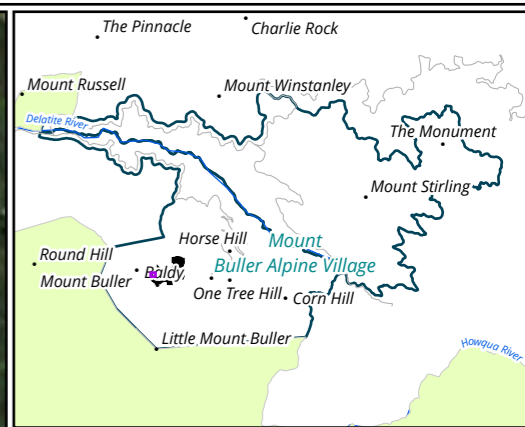
Figure 6b Catchment area of Bog 2 (Control site)

0 5.5 11 16.5 22 27.5
 Metres
 Scale: 1:700 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



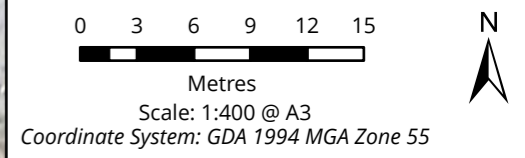
Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F6_HEMAMP_Bog_catchments_details
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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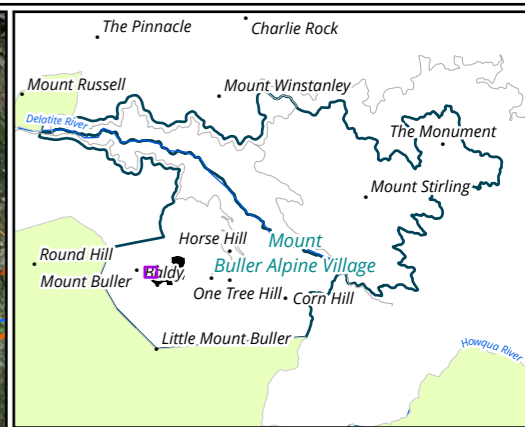
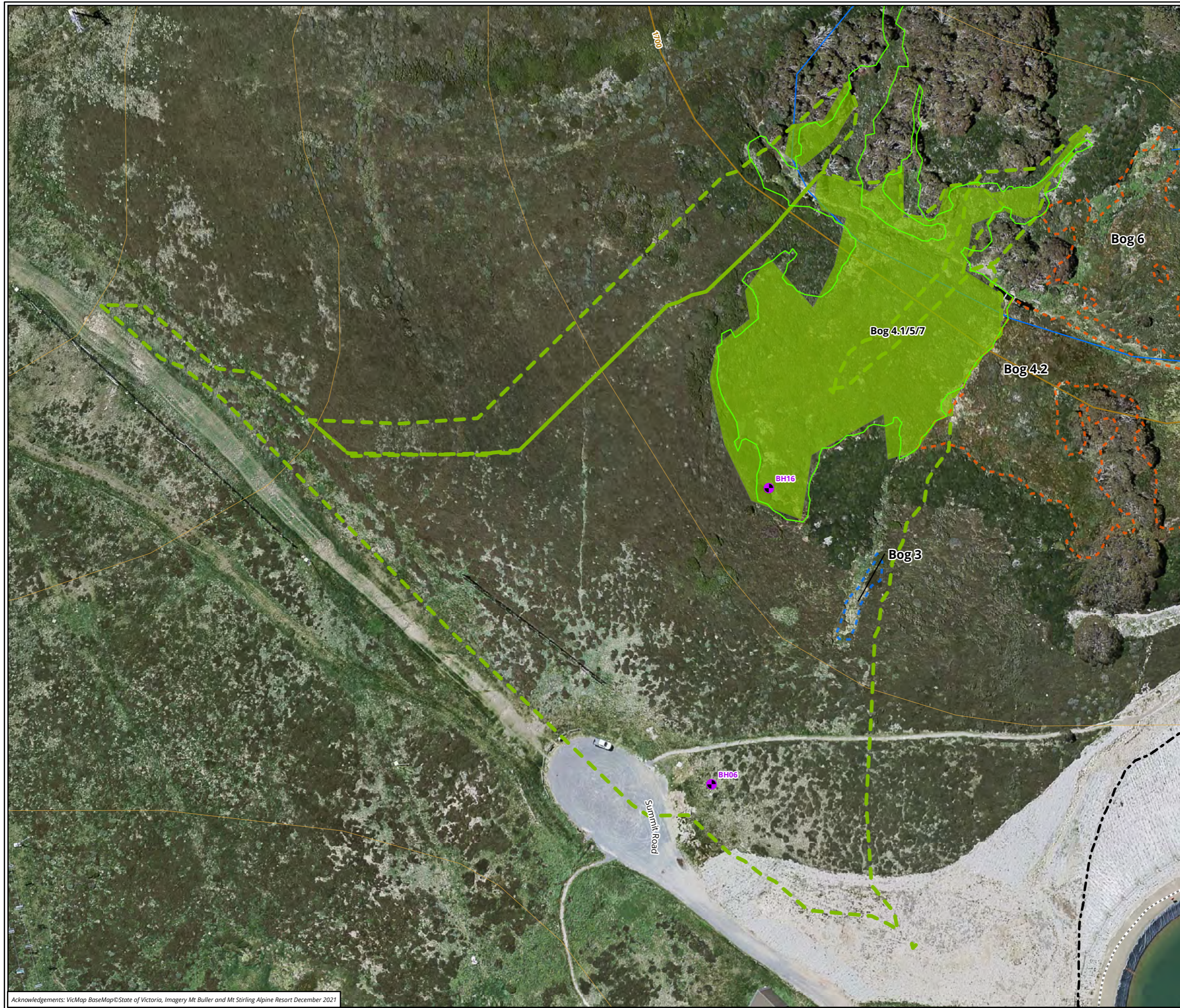


- Legend**
- Groundwater bore
 - Alpine Bogs (Biosis 2019)**
 - Other site
 - Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
 - Other site
 - Alpine Bogs**
 - Other site
 - Alpine Bog catchment areas**
 - Other site

Figure 6c Catchment area of Bog 3 (Other site)

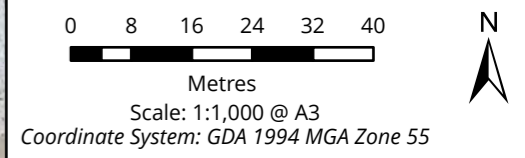


Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F6_HEMAMP_Bog_catchments_details
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx



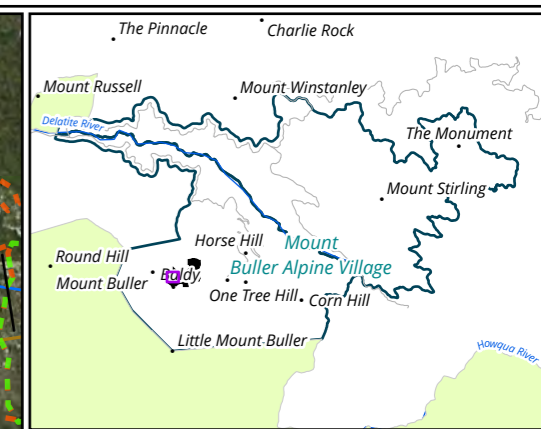
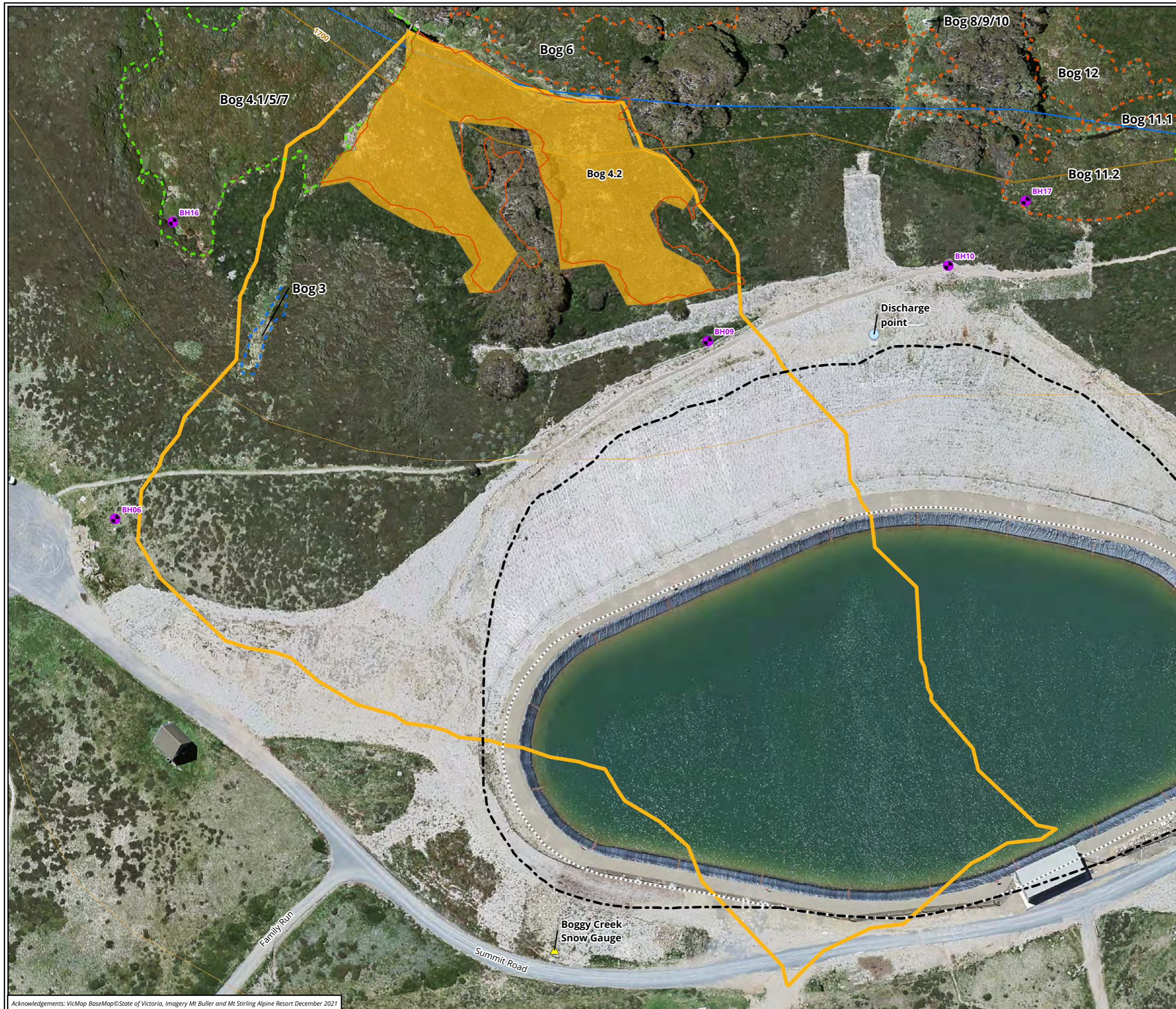
- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Alpine Bogs (Biosis 2019)**
 - Control site
 - Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
 - Alpine Bogs**
 - Control site
 - Alpine Bog catchment areas**
 - Control site

Figure 6d Catchment area of Bog 4.1/5/7 (Control site)



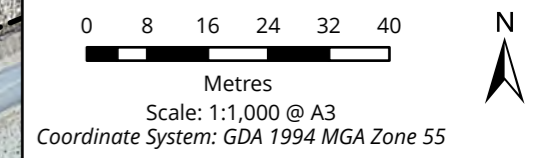
Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F6_HEMAMP_Bog_catchments_details
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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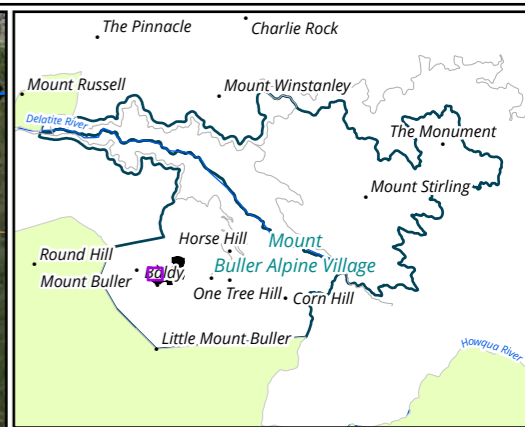
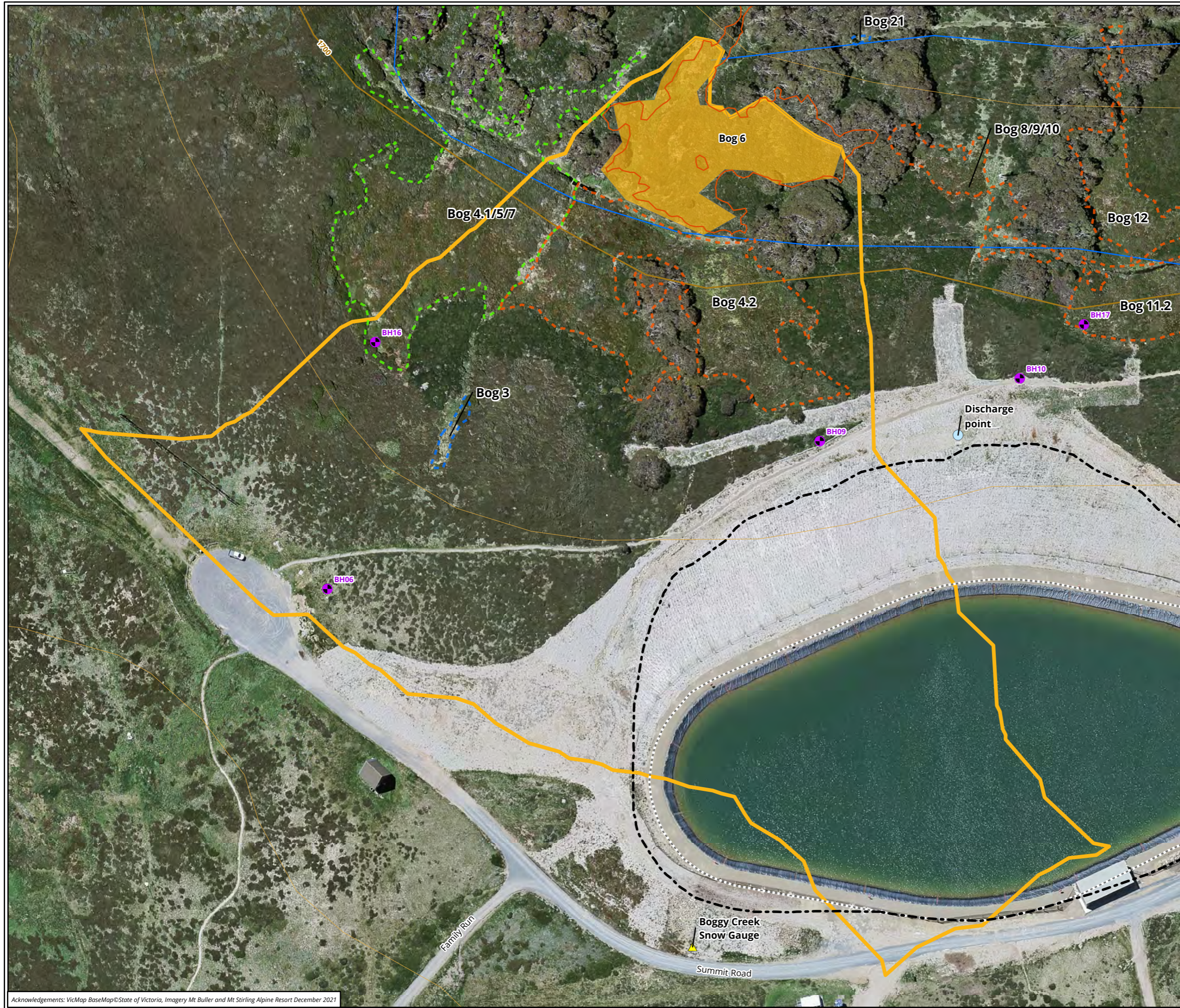


- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Snow gauge
 - Surface water monitoring location
- Alpine Bogs (Biosis 2019)**
- Impact site
- Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
- Impact site
 - Impact site

Figure 6e Catchment area of Bog 4.2 (Impact site)

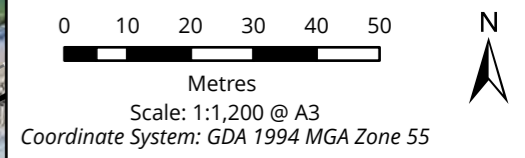


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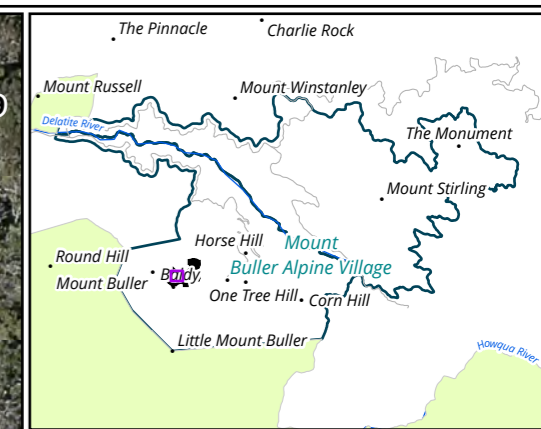
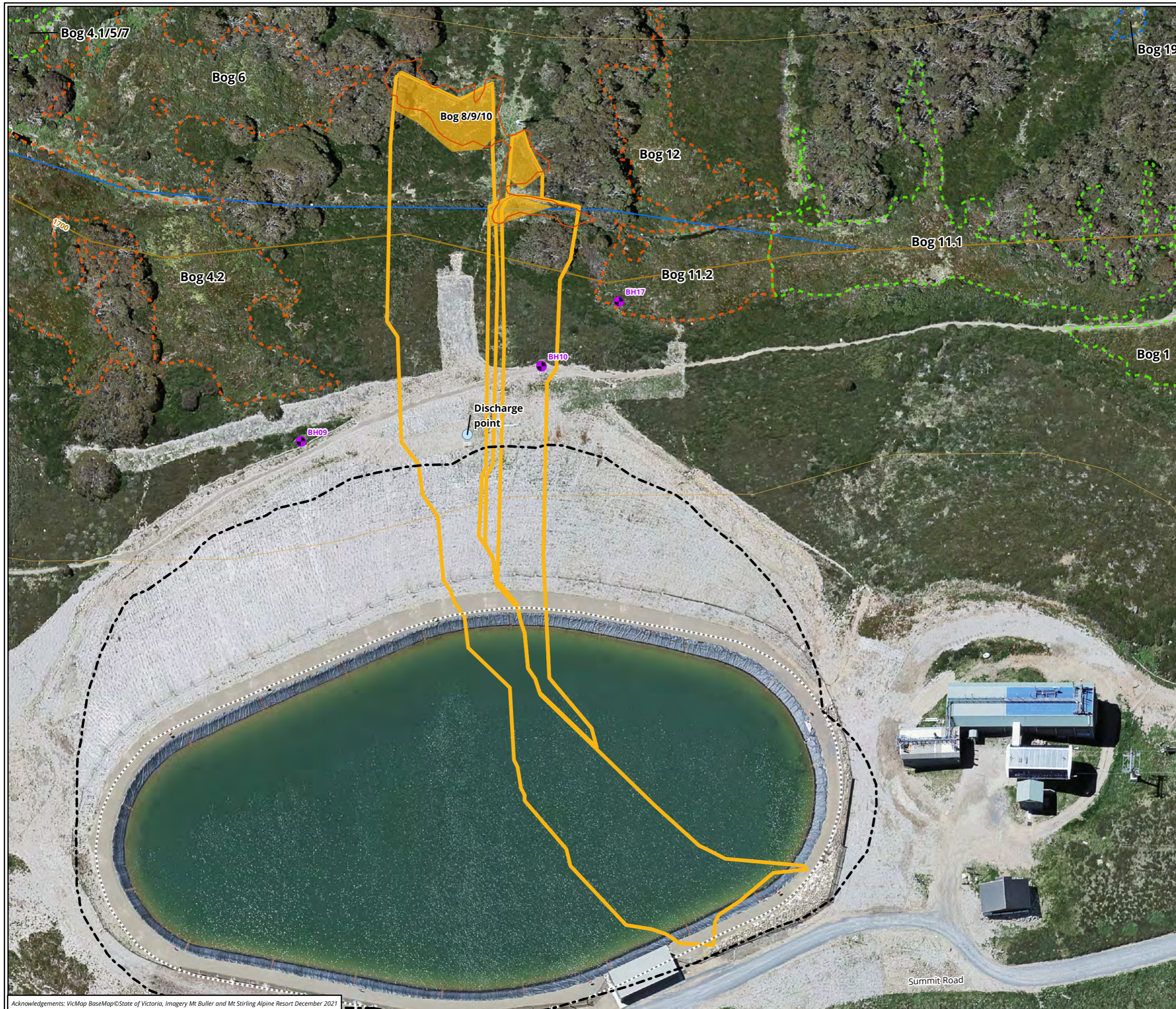
- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Snow gauge
 - Surface water monitoring location
- Alpine Bogs (Biosis 2019)**
- Impact site
- Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
- Impact site
- Alpine Bogs**
- Impact site
- Alpine Bog catchment areas**
- Impact site

Figure 6f Catchment area of Bog 6 (Impact site)



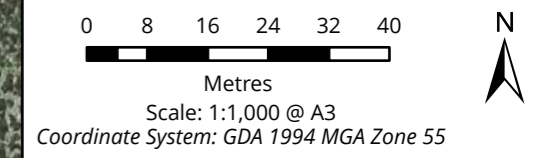
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Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F6_HEMAMP_Bog_catchments_details
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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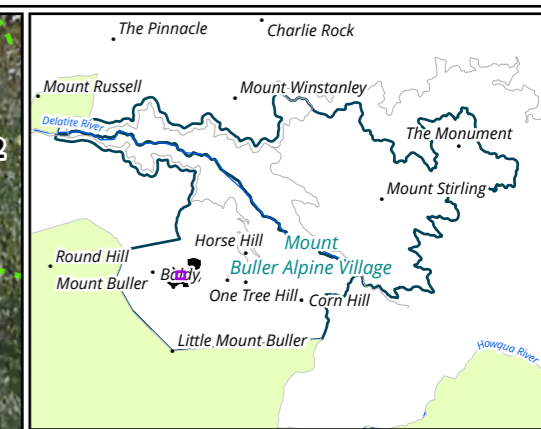
- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Surface water monitoring location
- Alpine Bogs (Biosis 2019)**
- Impact site
- Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
- Impact site
- Alpine Bogs**
- Impact site
- Alpine Bog catchment areas**
- Impact site

Figure 6g Catchment area of Bog 8/9/10 (Impact site)



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
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 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Alpine Bogs (Biosis 2019)**
 - Control site
 - Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
 - Alpine Bogs**
 - Control site
 - Alpine Bog catchment areas**
 - Control site

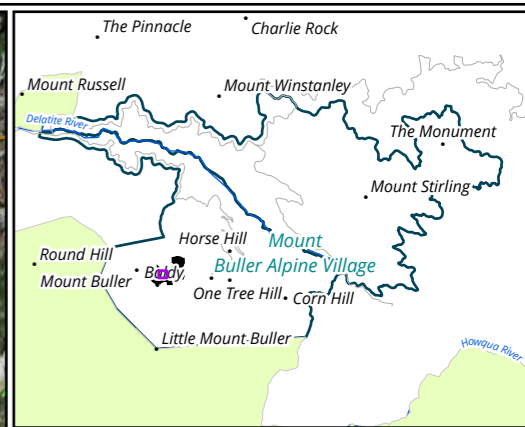
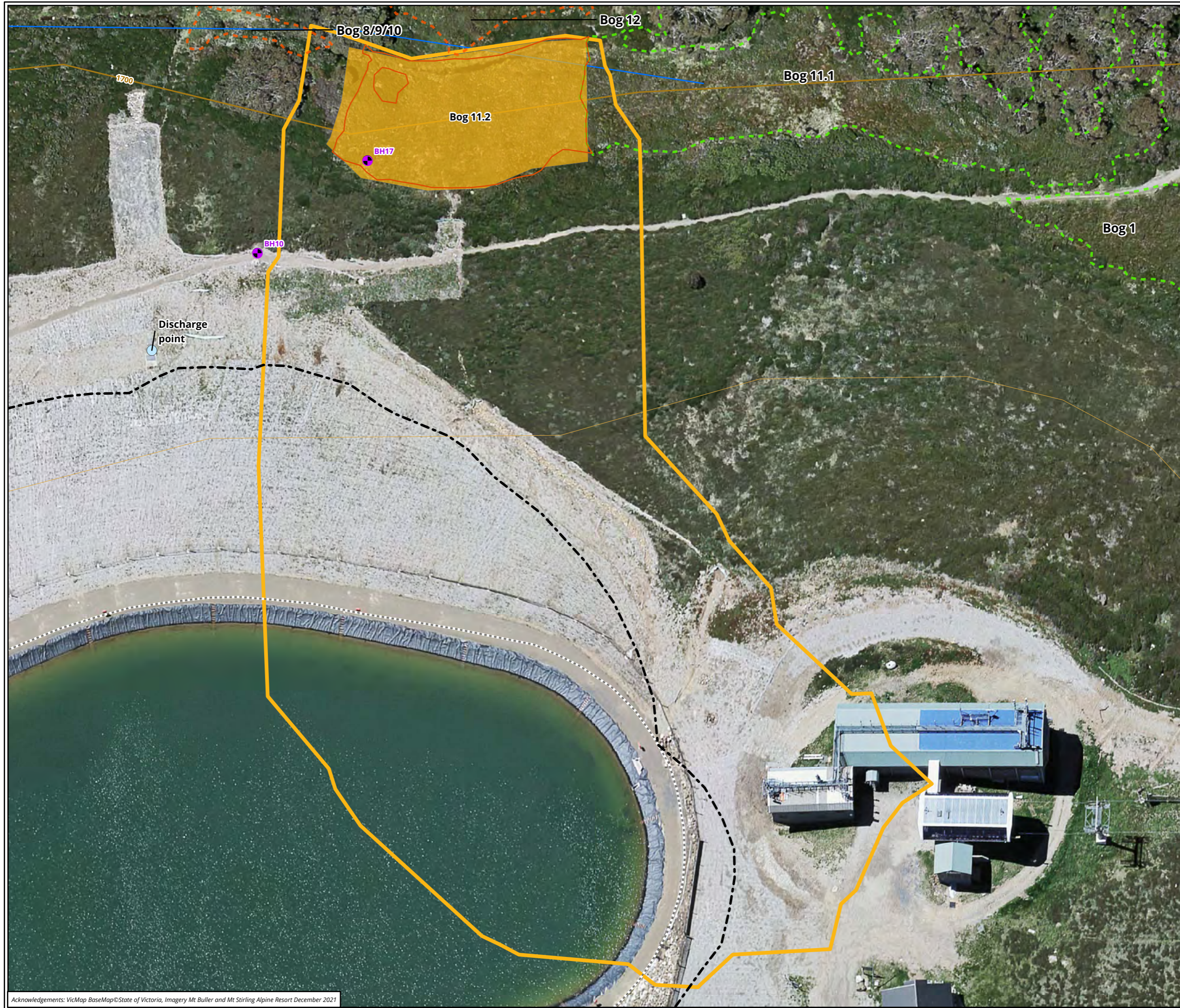
Figure 6h Catchment area of Bog 11.1 (Control site)

0 5.5 11 16.5 22 27.5
 Metres
 Scale: 1:700 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F6_HEMAMP_Bog_catchments_details
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Surface water monitoring location
- Alpine Bogs (Biosis 2019)**
- Impact site
- Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
- Impact site
- Alpine Bogs**
- Impact site
- Alpine Bog catchment areas**
- Impact site

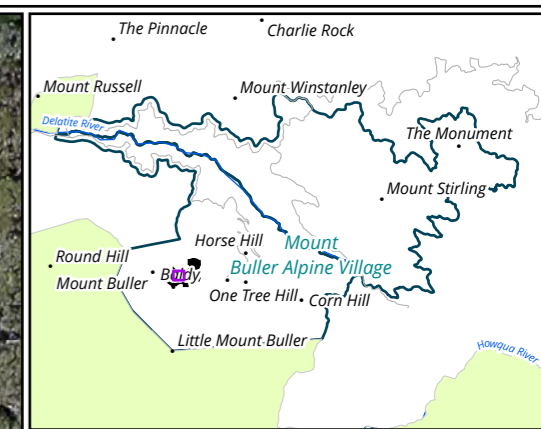
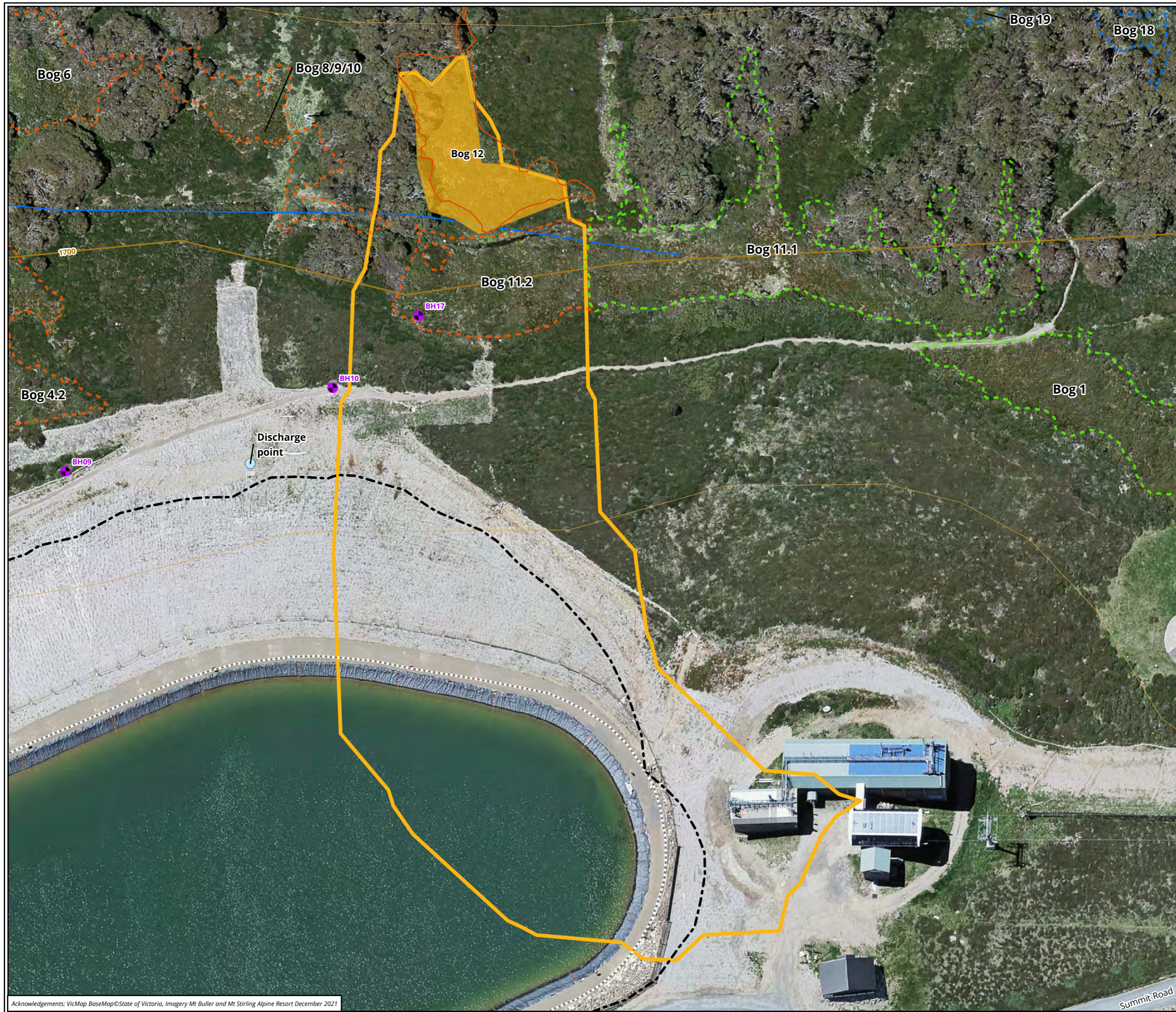
Figure 6i Catchment area of Bog 11.2 (Impact site)

0 5.5 11 16.5 22 27.5
 Metres
 Scale: 1:700 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F6_HEMAMP_Bog_catchments_details
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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- Legend**
- Earth embankment footprint
 - Water storage footprint
 - Groundwater bore
 - Surface water monitoring location
- Alpine Bogs (Biosis 2019)**
- Impact site
- Alpine Bogs and Alpine Bog catchment areas (GHD 2015)**
- Impact site
- Alpine Bogs**
- Impact site
- Alpine Bog catchment areas**
- Impact site

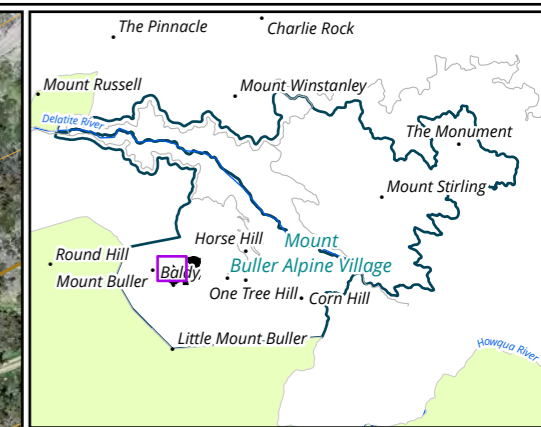
Figure 6j Catchment area of Bog 12 (Impact site)

0 7 14 21 28 35
 Metres
 Scale: 1:900 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F6_HEMAMP_Bog_catchments_details
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Legend

- Earth embankment footprint
- Water storage footprint
- Groundwater bore
- Snow gauge
- Surface water monitoring location

Alpine Bogs (Biosis 2019)

- Impact site

Alpine Bogs and Alpine Bog catchment areas (GHD 2015)

Alpine Bogs

- Impact site

Alpine Bog catchment areas

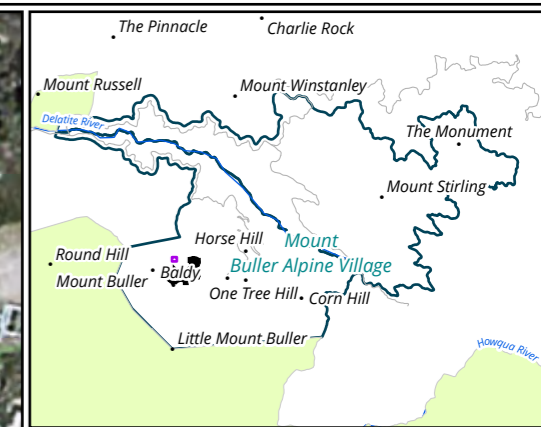
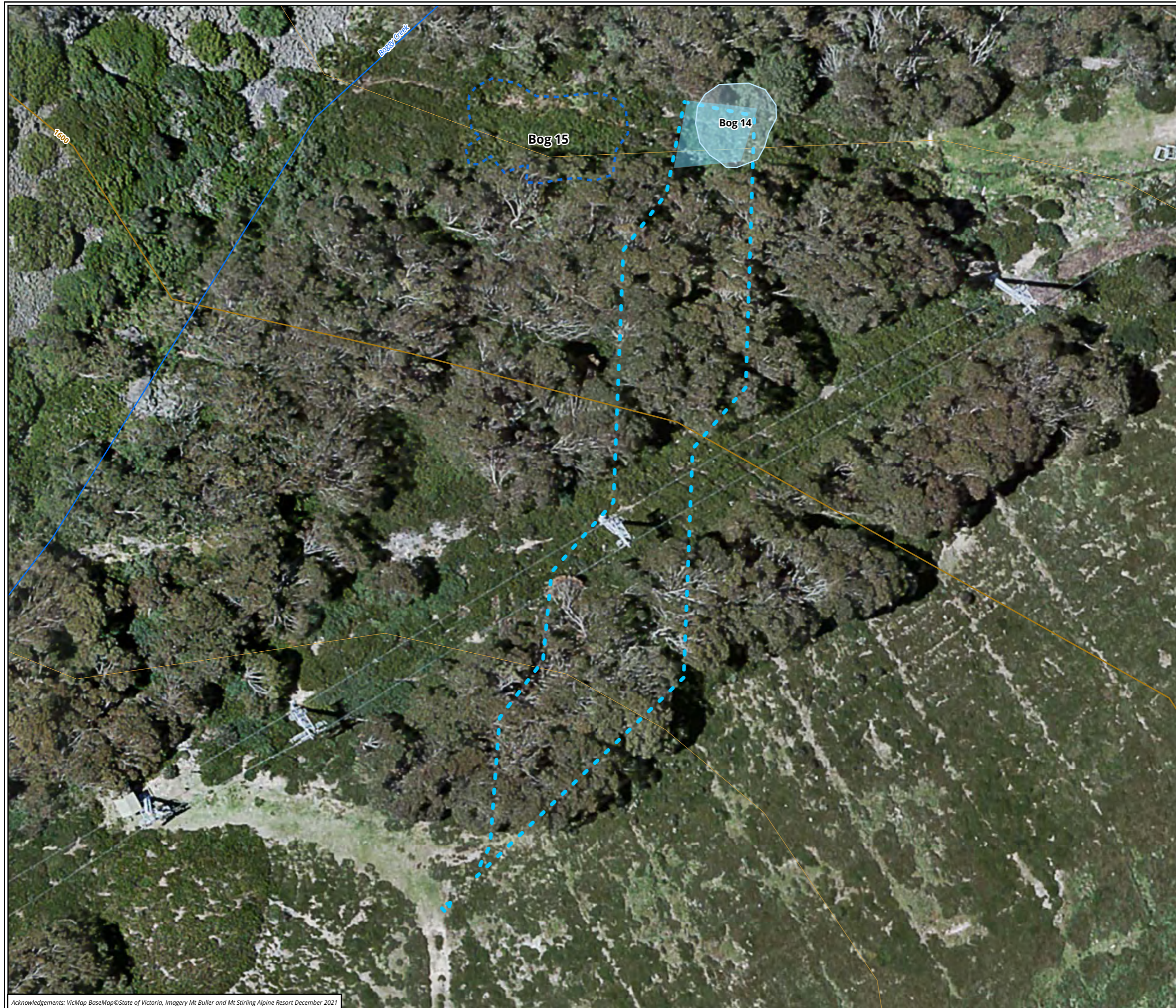
- Impact site

Figure 6k Catchment area of Bog 13 (Impact site)

0 10 20 30 40 50
Metres
Scale: 1:2,400 @ A3
Coordinate System: GDA 1994 MGA Zone 55

Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F6_HEMAMP_Bog_catchments_details
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Legend

Alpine Bogs (Biosis 2019)
 Other site

Alpine Bogs and Alpine Bog catchment areas (GHD 2015)
 Other site

Alpine Bogs
 Other site

Alpine Bog catchment areas
 Other site

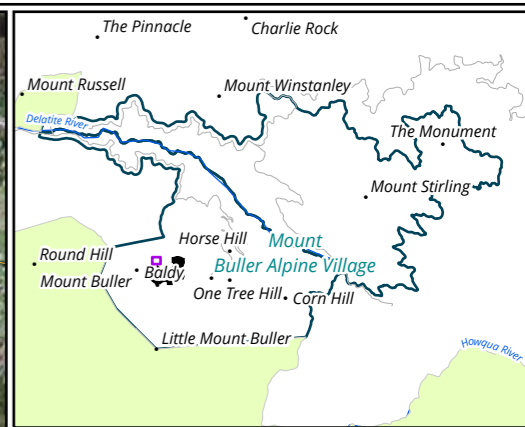
Figure 6I Catchment area of Bog 14 (Other site)

0 3 6 9 12 15
 Metres
 Scale: 1:400 @ A3
 Coordinate System: GDA 1994 MGA Zone 55



Matter: 33202/29064,
 Date: 28 July 2022 ,
 Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
 Layout: 33202_F6_HEMAMP_Bog_catchments_details
 Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Legend

Alpine Bogs (Biosis 2019)

- Other site

Alpine Bogs and Alpine Bog catchment areas (GHD 2015)

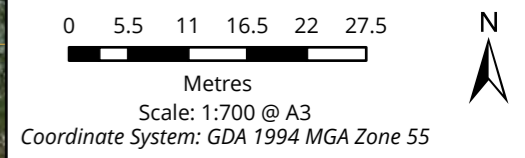
Alpine Bogs

- Other site

Alpine Bog catchment areas

- Other site

Figure 6m Catchment area of Bog 15 (Other site)



Matter: 33202/29064,
Date: 28 July 2022,
Prepared for: MG, Prepared by: SKM, Last edited by: smitchell
Layout: 33202_F6_HEMAMP_Bog_catchments_details
Project: P:\33200s\33202\Mapping\33202_HEMAMP_Update.aprx

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Appendices

Appendix 1 Planning Permit PA1600138



Permit No.: PA1600138

Alpine Resorts Planning Scheme

Responsible Authority: Minister for Planning

ADDRESS OF THE LAND:

(PART) CROWN ALLOTMENT 5A SECTION A PARISH OF
CHANGUE EAST,
MT BULLER ALPINE RESORT
MT BULLER

THE PERMIT ALLOWS:

Use of the land for a water storage facility (utility
installation) and associated native vegetation
removal in accordance with the endorsed plans

THE FOLLOWING CONDITIONS APPLY TO THIS PERMIT

Additional documents/reports

1. Before the commencement of any works, including vegetation removal and bulk excavation (but excluding works necessary to be undertaken specifically to address the environmental risk assessment requirements of condition 1a), the following documents or reports must be submitted to and be to the satisfaction of the Secretary (Secretary as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*) of Department of Environment, Land, Water and Planning (DELWP) and the Goulburn Broken Catchment Management Authority (CMA). When approved, the document(s) will be endorsed and will then form part of the permit. Three copies (including an electronic copy) must be provided. The document(s) must include the following:
 - a) An environmental risk assessment based on the detailed design for the project. The risk assessment must include an assessment of environmental and geotechnical risks from construction and operation of the project infrastructure including the risks to the Alpine Bog associated with changes to hydrology and the environmental watering program.
2. Before the commencement of any works, including vegetation removal, bulk excavation, (but excluding works necessary to be undertaken specifically to address the environmental risk assessment), the following documents or reports must be submitted to and be approved by the Responsible Authority. When approved, the document(s) will be endorsed and will then form part of the permit. Three copies (including an electronic copy) must be provided. The document(s) must include the following:
 - a) The Hydrological and Ecological Management and Monitoring Program (HEMAMP) dated 28 April 2017, and prepared by Biosis and GHD, must be updated to incorporate the findings and recommendations of the environmental risk assessment as required by condition 1a of this permit.

- b) The detailed offset management plan, as required by condition 20 of this permit;
- c) Evidence that the offsets have been secured, in accordance with condition 21 of this permit;
- d) The Site Environmental Management Plan (SEMP), dated December 2016, and prepared by Environmental Resources Management Australia (ERM), must be updated to include revised construction timeframes.

Endorsed Plans

- 3. The use and native vegetation removal as shown on the endorsed plans must not be altered without the written consent of the Responsible Authority.
- 4. All construction is to remain within the Project Construction Footprint (PCF) as identified and approved to help limit the potential effects to biodiversity values to those already identified, to the satisfaction of the Responsible Authority. (Any measures to reduce other risks must not result in a larger PCF).
- 5. Once the works and native vegetation removal have started, they must be continued and completed to the satisfaction of the Responsible Authority.
- 6. All buildings and works associated with the permitted use and native vegetation removal must be maintained in good order and appearance to the satisfaction of the Responsible Authority.

All External Activities to Cease

- 7. Without the prior written consent of the Responsible Authority, no earthworks, site restoration, revegetation or other related outdoor construction activities may commence prior to the end of the declared snow season and all such activities must cease prior to the start of the snow season.

Hydrological and Ecological Management and Monitoring Program (HEMAMP) and Ongoing Monitoring Report

- 8. The endorsed Hydrological and Ecological Management and Monitoring Program (HEMAMP), as required by this permit, must be implemented and completed to the satisfaction of the Department of Environment, Land, Water and Planning (DELWP) Secretary (Secretary as constituted under Part 2 of the *Conservation, Forests and Lands Act 1987*). A monitoring report, together with its independent review (commissioned by the proponent at no cost to DELWP), and revisions to the HEMAMP must be submitted to the DELWP Secretary annually, until the DELWP Secretary formally advises the permit holder in writing that the monitoring reports are no longer required. The HEMAMP must address risks that are identified in response to Condition 1a of this permit, as well as advice from DELWP (Environment) in the context of annual monitoring reports.
- 9. The Mount Buller and Mount Stirling Resort Management Board (RMB) must inform the Land Manager (DELWP) of known major risks or failure to effectively implement the HEMAMP and of the risk management systems that it has in place to address those risks.

Landscaping and Rehabilitation Plan

- 10. All existing vegetation to be retained as shown on the endorsed plans must be suitably marked and photographed (with a copy provided to the Responsible Authority) before any development starts on the site and that vegetation must not be removed, destroyed or lopped without the written consent of the Responsible Authority.
- 11. Before the commencement of the use hereby permitted by this permit, all landscaping and rehabilitation works as shown on the endorsed Ecological Rehabilitation Plan report (including the attached Landscape Masterplan), dated 8 December 2016, and prepared by Biosis and Tract, must be implemented and completed to the satisfaction of the

Responsible Authority. Any dead or diseased trees must be replaced to the satisfaction of the Responsible Authority.

12. Should the water storage facility not be completed or is decommissioned in the future, the land must be reinstated and rehabilitated to the satisfaction of the Responsible Authority.

Geotechnical

13. The proposed works must be undertaken in accordance with the recommendations (Sections 4.1 and 4.2) of the endorsed 'Geotechnical Risk Assessment' report, dated December 2016, and prepared by GHD, to the satisfaction of the Responsible Authority.

Site Management, Stockpiling, Material Storage and Waste

14. Stockpiles of soil, building materials or waste are not to be located on top of areas of native vegetation.
15. All earth-moving equipment and other machinery must be cleaned of soil and plant material before entering and leaving the site to prevent the spread of weeds and pathogens.
16. All stockpiling and building material storage, fencing and signage must ensure safe pedestrian access.
17. All materials and waste must be appropriately managed, contained and removed, to the satisfaction of the Responsible Authority.

Site Environmental Management Plan

18. All construction activity and site rehabilitation works must be conducted in accordance with the endorsed Site Environmental Management Plan (SEMP), dated December 2016, and prepared by Environmental Resources Management Australia (ERM) or as revised, to the satisfaction of the Responsible Authority. All contractors working on the site must be provided with a copy of the endorsed SEMP and must retain a copy of the SEMP on-site at all times during the construction period.

Department of Environment, Land, Water and Planning (Hume Region)

19. Before the commencement of any works, the permit holder must advise all persons undertaking the vegetation removal or works on site of all relevant permit conditions and associated statutory requirement or approvals.
20. Before the commencement of any works, including vegetation removal, bulk excavation and site preparation works, a detailed offset management plan including proposed management activities, monitoring, reporting, funding and management arrangements, must be submitted to and be approved by the Responsible Authority.
21. Before the commencement of any works, including vegetation removal, bulk excavation and site preparation works, evidence that the required offset (including the approved alternative specific offset component) has been secured, must be provided to the satisfaction of the Responsible Authority. The offsets must be secured with an ongoing Crown land offset agreement to the satisfaction of the DELWP Secretary and in accordance with the offset rules of the Native Vegetation Credit Register. If more permanent arrangements come into place, the agreement will be updated to reflect these arrangements.
22. To offset the removal of 6.177 hectares of native vegetation the permit holder must secure a native vegetation offset, in accordance with the Permitted clearing of native vegetation – Biodiversity assessment guidelines and the Native vegetation gain scoring manual (Department of Environment and Primary Industries 2013) as specified below.

23. A general offset of 1.102 general biodiversity equivalence units with the following attributes:
- a) Be located within the Mt Buller/Mt Stirling Alpine Resort or Goulburn Broken Catchment Management Authority boundary.
 - b) Have a strategic biodiversity score of at least 0.774.
24. The specific offsets required must contribute a gain of:
- a) 7.446 specific biodiversity equivalence units for Alpine Bog Skink.
 - b) 7.212 specific biodiversity equivalence units for Snow Aciphyll.
 - c) 7.896 specific biodiversity equivalence units for Mountain Aciphyll.
 - d) 8.332 specific biodiversity equivalence units for Mountain Daisy.
 - e) 2.312 specific biodiversity equivalence units for Alpine Marsh Marigold.
 - f) 8.400 specific biodiversity equivalence units for Carpet Sedge.
 - g) 6.442 specific biodiversity equivalence units for Broad-leaf Flower-rush.
 - h) 5.650 specific biodiversity equivalence units for Sticky Fleabane.
 - i) 7.337 specific biodiversity equivalence units for Fog Club-sedge.
 - j) 8.391 specific biodiversity equivalence units for Tussock Woodrush.
 - k) 6.636 specific biodiversity equivalence units for Veined Plantain.
 - l) 8.468 specific biodiversity equivalence units for Gunn's Alpine Buttercup.
 - m) 1.274 specific biodiversity equivalence units for Felted Buttercup.
 - n) 6.059 specific biodiversity equivalence units for Mossy Knawel.
 - o) 1.218 specific biodiversity equivalence units for Alpine Stackhousia.
 - p) 7.172 specific biodiversity equivalence units for Green Billy-buttons.
 - q) 5.955 specific biodiversity equivalence units for Mountain Wallaby-grass.
 - r) 0.796 specific biodiversity equivalence units for Planarian.
25. All works must be undertaken in accordance with the Site Environmental Management Plan (SEMP) – December 2016, and prepared by Environmental Resources Management Australia (ERM) or as revised in conjunction with the Responsible Authority.
26. All contractors working on the site must be provided with a copy of the SEMP for ongoing guidance and works prescriptions during the construction period.
27. All proposed actions in the endorsed Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP), or as revised are to be undertaken to the satisfaction of the Responsible Authority.

Cultural Heritage Management Plan

28. Where it is suspected that works may impact on Aboriginal cultural heritage objects or places, works must be undertaken in accordance with the approved Cultural Heritage Management Plan CHMP 12912, to the satisfaction of the Responsible Authority.

AusNet

29. The applicant must enter into an agreement with AusNet Electricity Services Pty Ltd for supply of electricity to each lot on the endorsed plan.

30. The applicant must enter into an agreement with AusNet Electricity Services Pty Ltd for the rearrangement of the existing electricity supply system.
31. The applicant must enter into an agreement with AusNet Electricity Services Pty Ltd for rearrangement of the points of supply to any existing installations affected by any private electric power line which would cross a boundary created by the subdivision, or by such means as may be agreed by AusNet Electricity Services Pty Ltd.
32. The applicant must provide easements satisfactory to AusNet Electricity Services Pty Ltd for the purpose of "Power Line" in the favour of "AusNet Electricity Services Pty Ltd" pursuant to Section 88 of the Electricity Industry Act 2000, where easements have not been otherwise provided, for all existing AusNet Electricity Services Pty Ltd electric power lines and for any new power lines required to service the lots on the endorsed plan and/or abutting land.
33. The applicant must obtain for the use of AusNet Electricity Services Pty Ltd any other easement required to service the lots.
34. The applicant must adjust the position of any existing AusNet Electricity Services Pty Ltd easement to accord with the position of the electricity line(s) as determined by survey.
35. The applicant must set aside on the plan of subdivision Reserves for the use of AusNet Electricity Services Pty Ltd for electric substations.
36. The applicant must provide survey plans for any electric substations required by AusNet Electricity Services Pty Ltd and for associated power lines and cables and executes leases for a period of 30 years, at a nominal rental with a right to extend the lease for a further 30 years. AusNet Electricity Services Pty Ltd requires that such leases are to be noted on the title by way of a caveat or a notification under Section 88 (2) of the Transfer of Land Act prior to the registration of the plan of subdivision.
37. The applicant must provide to AusNet Electricity Services Pty Ltd a copy of the plan of subdivision submitted for certification that shows any amendments that have been required.
38. The applicant must agree to provide alternative electricity supply to lot owners and/or each lot until such time as permanent supply is available to the development by AusNet Electricity Services Pty Ltd. Individual generators must be provided at each supply point. The generator for temporary supply must be installed in such a manner as to comply with the Electricity Safety Act 1998.
39. The applicant must ensure that all necessary auditing is completed to the satisfaction of AusNet Electricity Services Pty Ltd to allow the new network assets to be safely connected to the distribution network.

Goulburn Murray Water

40. All construction and ongoing activities must be in accordance with sediment control principles outlined in 'Construction Techniques for Sediment Pollution Control' (Environment Protection Authority, 1991).
41. No buildings or works may be erected or carried out within 30 metres of a waterway.
42. The proposed water storage facility should be Bunded and be fully lined with 2mm High-Density Polyethylene (HDPE).
43. The proposed water storage facility will be classed as 'Hazardous' due to wall height (21 metres) and volume (100ML). Therefore, prior to commencement of site preparation works, a construction and operating licence (works licence) must be obtained.

Permit Expiry

44. The permit will expire if:

- a) The use does not start within four (4) years of the date of this permit.
- b) The use is discontinued for a period of two (2) years.
- c) The native vegetation permitted to be removed is not removed within two (2) years of the date of this permit.

45. In accordance with section 69 of the *Planning Environment Act 1987*, the Responsible Authority may extend:

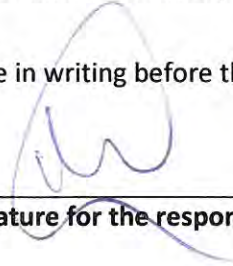
The commencement date referred to if a request is made in writing before the permit expires or within six (6) months afterwards.

Date Issued:

18/1/18

Signature for the responsible authority

Note: Under Part 4, Division 1A of the Planning and Environment Act 1987, a permit may be amended. Please check with the responsible authority that this permit is the current permit and can be acted upon.



Notes:

- If protected flora listed under the Flora & Fauna Guarantee Act 1988 (FFG Act) is to be removed a permit issued in accordance with the FFG Act must first be obtained.
- The permit holder must consult with Hume Region biodiversity staff in relation to impacts on the Flora and Fauna Guarantee (FFG) and Environmental Protection and Biodiversity Conservation (EPBC) listed species - Broad toothed Rat. Agreed measures should be developed to minimise and mitigate the impact of the proposed development on this species, prior to works starting. Agreed measures should be to the satisfaction of the DELWP (Hume Region) and the Responsible Authority to be notified when this has occurred.

Goulburn Murray Water

- The proposed water storage facility will be classed as 'Hazardous' due to wall height (21 metres) and volume (100ML). Therefore, prior to commencement of site preparation works, a construction and operating licence (works licence) must be obtained. Applications can be made by contacting Goulburn Murray Water on 1800 013 357 or by following the link the <http://www.g-mwater.com.au/customer-services/forms>
- If water is to be taken and used for dust suppression, application must be made to GMW. Applications for a Licence to Take and Use Water can be made to Goulburn Murray Water's Diversion Operations on 1800 013 357.

IMPORTANT INFORMATION ABOUT THIS PERMIT

WHAT HAS BEEN DECIDED?

The responsible authority has issued a permit. (Note: This is not a permit granted under Division 5 or 6 of Part 4 of the **Planning and Environment Act 1987**.)

CAN THE RESPONSIBLE AUTHORITY AMEND THIS PERMIT?

The responsible authority may amend this permit under Division 1A of Part 4 of the **Planning and Environment Act 1987**.

WHEN DOES A PERMIT BEGIN?

A permit operates:

- * from the date specified in the permit; or
- * if no date is specified, from -
 - (i) the date of the decision of the Victorian Civil and Administrative Tribunal, if the permit was issued at the direction of the Tribunal; or
 - (ii) the date on which it was issued, in any other case.

WHEN DOES A PERMIT EXPIRE?

1. A permit for the development of land expires if -
 - * the development or any stage of it does not start within the time specified in the permit; or
 - * the development requires the certification of a plan of subdivision or consolidation under the **Subdivision Act 1988** and a plan is not certified within two years of the issue of a permit, unless the permit contains a different provision; or
 - * the development or any stage of it is not completed within the time specified in the permit, or, if no time is specified, within two years after the issue of the permit or in the case of a subdivision or consolidation within five years of the certification of the plan of subdivision or consolidation under the **Subdivision Act 1988**.
2. A permit for the use of land expires if -
 - * the use does not start within the time specified in the permit, or if no time is specified, within two years of the issue of the permit; or
 - * the use is discontinued for a period of two years.
3. A permit for the development and use of land expires if -
 - * the development or any stage of it does not start within the time specified in the permit; or
 - * the development or any stage of it is not completed within the time specified in the permit, or, if no time is specified, within two years after the issue of the permit; or
 - * the use does not start within the time specified in the permit, or, if no time is specified, within two years after the completion of the development; or
 - * the use is discontinued for a period of two years.
4. If a permit for the use of land or the development and use of land or relating to any of the circumstances mentioned in Section 6A(2) of the **Planning and Environment Act 1987**, or to any combination of use, development or any of those circumstances requires the certification of a plan under the **Subdivision Act 1988**, unless the permit contains a different provision-
 - * the use or development of any stage is to be taken to have started when the plan is certified; and
 - * the permit expires if the plan is not certified within two years of the issue of the permit.
5. The expiry of a permit does not affect the validity of anything done under that permit before the expiry.

WHAT ABOUT REVIEWS?

- * The person who applied for the permit may apply for a review of any condition in the permit unless it was granted at the direction of the Victorian Civil and Administrative Tribunal, in which case no right of review exists.
- * An application for review must be lodged within 60 days after the permit was issued, unless a notice of decision to grant a permit has been issued previously, in which case the application for review must be lodged within 60 days after the giving of that notice.
- * An application for review is lodged with the Victorian Civil and Administrative Tribunal.
- * An application for review must be made on the relevant form which can be obtained from the Victorian Civil and Administrative Tribunal, and be accompanied by the applicable fee.
- * An application for review must state the grounds upon which it is based.
- * A copy of an application for review must also be served on the responsible authority.
- * Details about applications for review and the fees payable can be obtained from the Victorian Civil and Administrative Tribunal.

Appendix 2 EPBC Act Approval 2014/7303



Approval

**Mt Buller Sustainable Water Security Project – Off-stream Storage, Victoria
(EPBC 2014/7303)**

This decision is made under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999*.

Proposed action

person to whom the approval is granted	Mount Buller and Mount Stirling Alpine Resort Management Board
proponent's ABN	44 867 982 534
proposed action	To construct and operate a 100 megalitre capacity off-stream water storage and ancillary infrastructure within the Mt Buller Alpine Resort Ski Area, Victoria [See EPBC Act referral 2014/7303].

Approval decision

Controlling Provision	Decision
Listed threatened species and communities (sections 18 & 18A)	Approve


conditions of approval

This approval is subject to the conditions specified below.

expiry date of approval

This approval has effect until 1 June 2068.

Decision-maker

name and position	James Barker Assistant Secretary Assessments and Governance Branch
signature	
date of decision	25 / 6 / 2018

Conditions attached to the approval

Disturbance areas

1. The approval holder must only undertake the action in the **project area** shown in Annexure A.
2. For the life of the approval, the approval holder must achieve the following outcomes (relative to baseline monitoring and control sites):
 - a. no **direct impacts** to **Alpine bogs**;
 - b. no more than a 10 per cent (0.090 hectare) reduction in the total combined area of **indirectly affected areas** of **Alpine bogs**;
 - c. no more than a 10 per cent reduction in the total 'bog-dependent' native flora **species richness** of **indirectly affected areas** of **Alpine bogs**;
 - d. no more than a 10 per cent increase in the cover of 'non-bog dependent' species within **indirectly affected areas** of **Alpine bogs**; and
 - e. no more than a 10 per cent reduction in the average cover of sphagnum moss (*Sphagnum* spp) within **indirectly affected areas** of **Alpine bogs**.

Pre-disturbance surveys

3. The approval holder must undertake **pre-disturbance surveys** in the **project area** to identify any new or new occurrences/extent of **EPBC Act** listed threatened species or ecological communities. **Pre-disturbance surveys** must be supervised by a **suitably qualified person** and undertaken in accordance with the **Department's survey guidelines** in effect at the time of the survey or other equivalent survey methodology approved by the **Department**.
4. If new or new occurrences/extent of **EPBC Act** listed threatened species or ecological communities not previously identified are found in the **project area** during **pre-disturbance surveys** or during **construction**, the approval holder must:
 - a. immediately cease work;
 - b. notify the **Department** in writing within 48 hours of finding the **EPBC Act** listed threatened species and/or ecological communities; and
 - c. not **re-commence** or **commence the action** without written agreement from the **Minister**.
5. If new or new occurrences/extent of **EPBC Act** listed threatened species or ecological communities not previously identified are found in the **project area** during **pre-disturbance surveys** or during **construction**, the approval holder must outline in writing the number or extent and quality of the **EPBC Act** listed threatened species and ecological communities present, and how potential impacts to these **EPBC Act** listed threatened species and/or ecological communities will be avoided, mitigated and/or compensated for, for the **Minister's** approval. Once approved, the approved avoidance, mitigation and/or compensation measures must be implemented.

Hydrological and Ecological Monitoring and Adaptive Management Program

6. The approval holder must implement the **Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP)** for the life of the approval. If monitoring results indicate that the outcomes in condition 2 has not been achieved or is not likely to be achieved, the approval holder must:
 - a. investigate why the outcome has not or will not be achieved
 - b. advise the **Department** within 14 days of receiving the monitoring results (including a summary of the provision of the investigation required under condition 6a); and
 - c. develop corrective actions, revised monitoring, mitigation, management measures and/or compensation measures to be included in the **HEMAMP**.
7. Any revised measure(s) to be included in the **HEMAMP** required under condition 6, must be peer reviewed by a **suitably qualified expert**. The peer review must be submitted to the **Minister** together with the revised **HEMAMP**, and a statement from the **suitably qualified expert** stating that the peer review adequately evaluated measures proposed.
8. Within three (3) months following the third anniversary of **commencement of the action**, the approval holder must assess the effectiveness of the monitoring, mitigation, and management measures in the **HEMAMP** in achieving the outcome in condition 2(b). The assessment must be undertaken by a **suitably qualified independent expert**. The findings of the assessment must immediately be made publicly available on the approval holder's website, and be provided to the **Department** within five (5) days of publishing.
9. If the **Minister** at any time is not satisfied that the outcomes in condition 2 have been achieved or are likely to be achieved, the **Minister** may (in writing) require the approval holder to submit a new plan or program for the **Minister's** approval to reduce, mitigate, remediate or compensate impacts to **Alpine bogs**, within a designated timeframe. The **Minister** may request that the plan or program be prepared or reviewed by a person designated or agreed to by the **Minister**. If the **Minister** approves the plan or program, then the approved plan or program must be implemented.

Note: To avoid doubt, any proposed compensation measures must be additional to that required under condition 12.

Ecological Rehabilitation Plan

10. Information obtained during **pre-disturbance surveys** required under condition 3 must be used to inform the implementation of the **Ecological Rehabilitation Plan**. Any changes to the plan must be submitted to the **Department** for the **Minister's** written approval prior to the **commencement** of the rehabilitation works.
11. Within one (1) month following completion of **construction**, or following approval by the **Minister** as required under condition 9, the approval holder must **commence** rehabilitation of the **project area** in accordance with the **Ecological Rehabilitation Plan**.

Offset Areas

12. Prior to the **commencement of the action**, to compensate for the potential reduction in the total combined area of up to 0.090 ha of **indirectly affected areas** of **Alpine bogs**, the approval holder must **legally secure** 0.381 hectares of **Alpine bogs** at Mt Stirling as identified in the **Offset Strategy**, or another offset agreed to by the **Minister** in writing.

13. Within three (3) months of **legally securing** the offset required under condition 12, the approval holder must submit an Offset Management Plan, for the written approval of the **Minister**. Once approved, the approved Offset Management Plan must be implemented for the life of this approval. The Offset Management Plan must:
- a. be prepared by a **suitably qualified expert**
 - b. provide the **Department** with a written description and map to clearly define the location and boundaries of the offset area(s). This must be accompanied with the **offset attributes** and **shapefiles**
 - c. include timeframes and key milestones for implementation of offsets.
 - d. detail management actions and regeneration and revegetation strategies to be undertaken on the offset area(s) to improve and extend the ecological quality of **Alpine bogs**, including:
 - i. a discussion of how measures outlined take into account relevant **conservation advice** and are consistent with the measures in relevant **recovery plans** and **threat abatement plans**
 - ii. a description and timeframe of measures that will be implemented to improve the condition and extent of **Alpine bogs** within the offset area(s);
 - iii. performance and completion criteria for evaluating the management of the offset areas, and criteria for triggering remedial action;
 - iv. a program to monitor and report on the effectiveness of these measures, and progress against the performance and completion criteria;
 - v. a description of potential risks to the successful implementation of the plan, a description of the measures that will be implemented to mitigate against these risks and a description of the contingency measures that will be implemented if defined triggers arise; and
 - vi. details of who is responsible for monitoring, reviewing and implementing the plan.

Administrative conditions

14. Within 20 business days after the **commencement of the action**, the **approval holder** must advise the **Department** in writing of the actual date of **commencement of the action**.
15. The approval holder must maintain accurate records substantiating all activities associated with or relevant to the conditions of approval and make them available upon request to the **Department**. Such records may be subject to audit by the **Department** or an independent auditor in accordance with section 458 of the **EPBC Act**, or used to verify compliance with the conditions of approval. Summaries of audits will be posted on the **Department's** website. The results of audits may also be publicised through the general media.
16. Within one (1) month of every 12 month anniversary of **commencement**, the approval holder must publish a report on their website addressing compliance with each of the conditions of this approval, including implementation of any management plans as specified in the conditions and any monitoring results required. Any monitoring program results or peer-reviews must be publicly available on the approval holder's website and remain on the approval holder's website for the life of the approval. Documentary evidence providing proof of the date of publication and details of non-compliance with any of the conditions of this approval must be provided to the **Department** at the same time as the compliance report is published.

17. Upon the direction of the **Minister**, the approval holder must ensure that an independent audit of compliance with the conditions of approval is conducted and a report submitted to the **Minister**. The independent auditor must be approved by the **Minister** prior to the commencement of the audit. Audit criteria must be agreed to by the **Minister** and the audit report must address the criteria to the satisfaction of the **Minister**.
18. If, at any time after five (5) years from the date of this approval, the approval holder has not **commenced** the action, then the approval holder must not **commence** the action without the written agreement of the **Minister**.
19. Unless otherwise agreed to in writing by the **Minister**, the approval holder must publish all reports and agreements referred to in conditions 7, 8, 10, and 13 on their website. Each report and agreement must be published on the website within one (1) month of being approved by the **Minister**.

Definitions

Alpine bogs means the **EPBC Act** listed threatened ecological community *Alpine Sphagnum Bogs and Associated Fens*.

Commencement of the action (also **commence**, **re-commence**, **commenced**) means the first instance of **construction**.

Conservation advice means a conservation advice approved by the Minister under the **EPBC Act**.

Construction means the erection of a structure that is or is to be fixed to the ground and wholly or partially fabricated on-site; the alteration, maintenance, or repair; preliminary site preparation work which involved breaking of the ground; clearing vegetation; the laying of pipes and other prefabricated materials in the ground, and any associated excavation works; but excluding the installation of fences and signage.

Department means the Australian Government Department administering the **EPBC Act**.

Department's survey guidelines means Survey Guidelines for Australia's Threatened Frogs, Threatened Birds, Threatened Fish, Threatened Mammals, Threatened Reptiles and Threatened Bats: <http://www.environment.gov.au/epbc/guidelines-policies.html>

Direct impact means any clearing such as the cutting down, felling, thinning, logging, removing, poisoning, ringbarking, uprooting or burning of native vegetation, but does not include measure for weed, pest management.

Ecological Rehabilitation Plan refers to the document titled '*Mount Buller Sustainable Water Security Project – Off-stream Storage Ecological Rehabilitation Plan. Final Report. 8 December 2016*', or subsequent versions as approved by the **Minister**.

EPBC Act is the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP) refers to the document titled '*Mount Buller Sustainable Water Security Project – Off-stream Storage Hydrological and Ecological Monitoring and Adaptive Management Plan. Final Report. 21 September 2017*'.

Indirectly affected areas refers to 0.898 hectares of **Alpine bogs** 4.2, 6, 8, 9, 10, 11.2 and 12 as shown in Annexure B and occurring in the catchment area that may be **indirectly impacted** by the action.

Legally secure/securing means to secure a legal agreement under section 18B of the *Victorian Crown Land (Reserves) Act 1978* or the *Victorian Planning and Environment Act 1987*, to provide enduring protection for the site against development incompatible with conservation.

Minister means the Commonwealth Minister administering the **EPBC Act** and includes a delegate of the Minister.

Mountain Pygmy-possums means the **EPBC Act** listed species Mountain Pygmy-possum (*Burramys parvus*).

Offset attributes means an '.xls' file capturing relevant attributes of the offset area, including:

- i. **EPBC Act** reference number;
- ii. physical address of the offset area;
- iii. coordinates of the boundary points in decimal degrees;
- iv. **EPBC Act** listed threatened species that the offset compensates for;
- v. any additional protected matters that are benefiting from the offset; and
- vi. size of the offset in hectares.

Offset Strategy refers to the document titled *Mount Buller Sustainable Water Security Project – Off-stream Storage EPBC Act Offset Strategy. Draft Report. 5 October 2017*.

Pre-disturbance surveys means surveys that are undertaken within the **project area** to determine the occurrence of any **EPBC Act** listed threatened species (or their habitat) and/or ecological communities prior to the **commencement of the action**.

Project area is the area shown in Annexure A and described as 'project construction footprint'.

Recovery plans means a recovery plan made or adopted by the **Minister** under the **EPBC Act**.

Shapefiles means an Esri compatible file containing '.shp', '.shx' and '.dbf' files and any other relevant file extensions capturing attributes including at least the **EPBC Act** reference number and **EPBC Act** protected matters present at the relevant site.

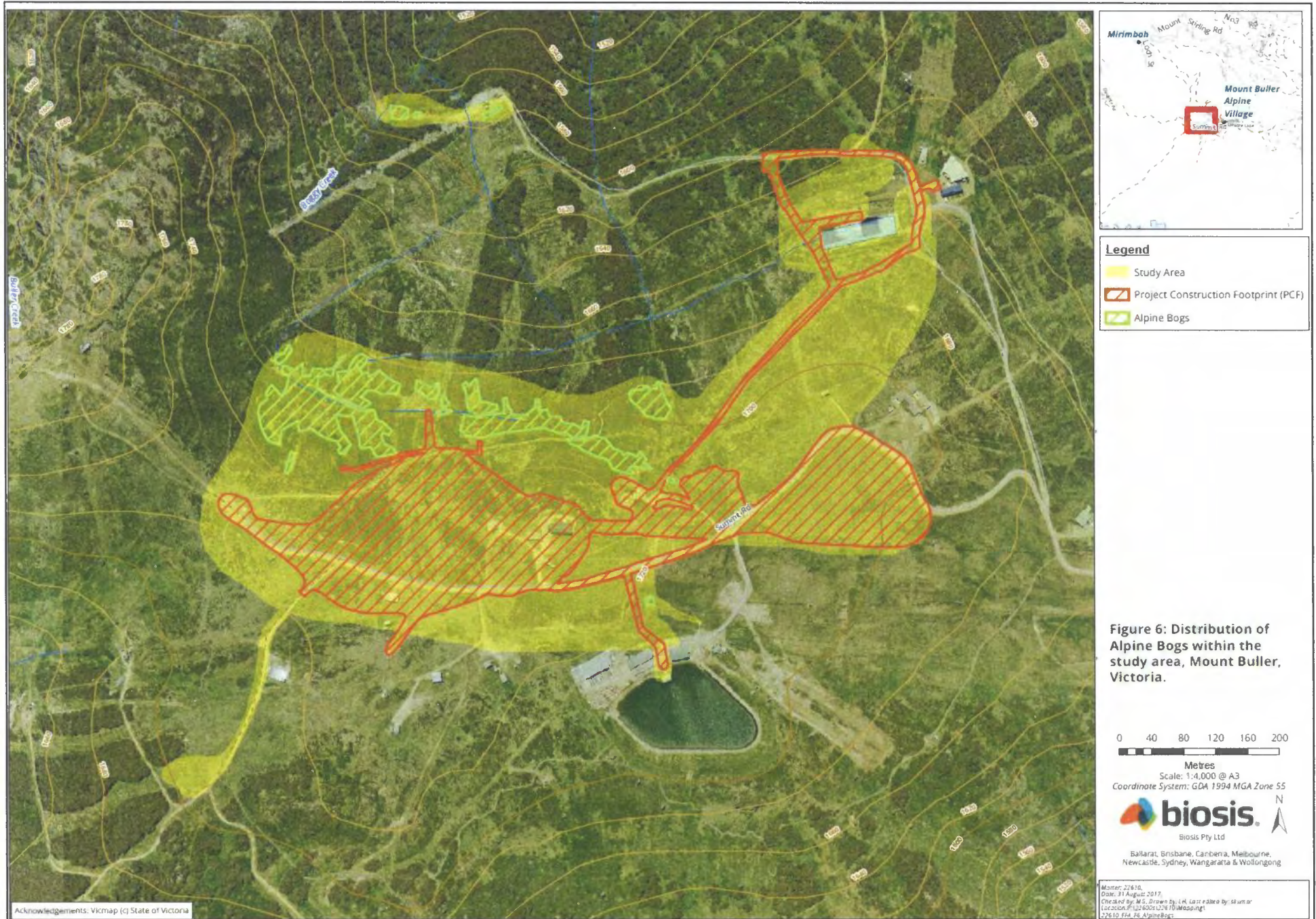
Species richness means the number of different species represented in the **indirectly affected areas**.

Suitably qualified independent expert means a person who is approved by the **Department**, and who is independent, is not an employee of the approval holder, and who has relevant tertiary qualifications and a minimum of five years demonstrated experience relevant to the review of management plans, strategies or monitoring programs.

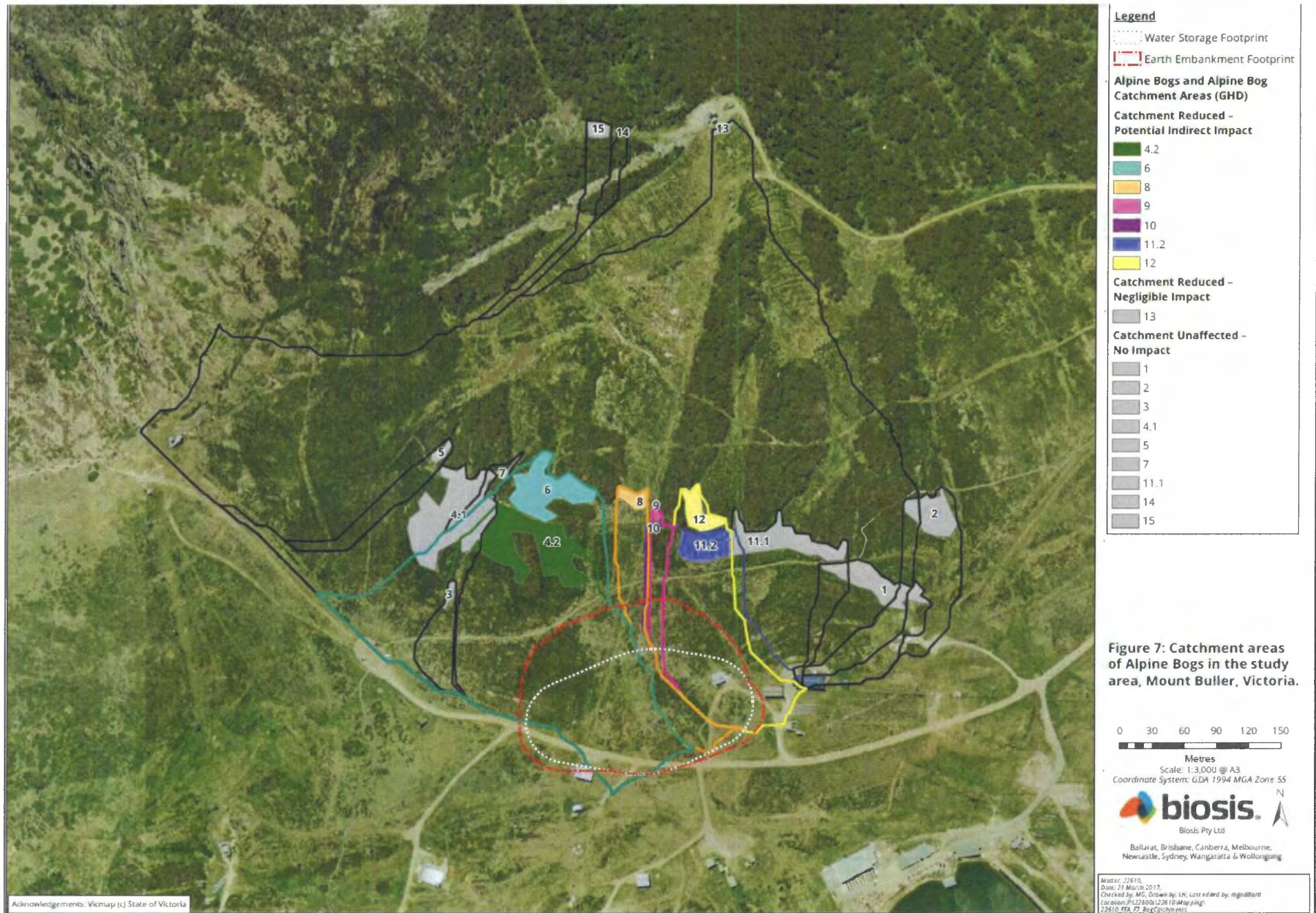
Suitably qualified expert means a person with tertiary qualification and a minimum of five years demonstrated experience relevant to the nominated subject matter/s and who can provide authoritative assessment advice and analysis about performance relevant to the subject matters using relevant protocols, standards, methods or literature.

Threat abatement plans means a threat abatement plan made or adopted by the **Minister** under the **EPBC Act**.

Annexure A: Project area and distribution of Alpine Bogs



Annexure B: Indirectly impacted Alpine bogs



Appendix 3 SOP for climatological monitoring

Standard Operating Procedure for Climatological Monitoring

This standard operating procedure has been prepared by the Mount Buller and Mount Stirling Alpine Resort Management Board (RMB) for the climatological monitoring component of the Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP).

1 Mount Stirling Weather Station

The Mount Stirling Weather Station is in the vicinity of Signpost 31 on Weather Station Ramble at 1520m elevation approximately 100-400 metres from the Mount Stirling control sites (Figure 1). It was initially established in the mid 1980's and was upgraded in November 2018 to provide data for the HEMAMP (Figure 2). The weather station is a 'Weather Maestro' from Envirodata – a robust, premium, Australian-made data logger, designed for reliability and longevity in remote environmental sites with harsh weather conditions. It collects daily rainfall and temperature data for HEMAMP monitoring. Data is provided via an online subscription with Envirodata. The weather station is serviced every two years or as needed by the supplier at the request of the RMB.

The station logs the following data at 9am every morning: maximum wind speed km/h, average wind speed km/h, average wind direction degrees, average wind direction, maximum relative humidity %, minimum relative humidity %, average relative humidity %, maximum air temperature degrees c, minimum air temperature degrees c, average air temperature degrees c, maximum rain gauge mm, total rain gauge mm, maximum barometric pressure hPa, minimum barometric pressure hPa, average barometric pressure hPa, minimum battery voltage V, total communications mins, standard deviation wind speed km/h, average wind direction degrees, average wind direction, theta wind direction degrees, maximum peak wind gust km/h, vector wind speed km/h, vector wind direction degrees, minimum dew point degrees c, maximum dew point degrees c, average dew point degrees c, average load current mA, average solar voltage V, and average charge current mA.

The Mount Stirling weather station is off grid, meaning that it relies on the solar panel, battery and modem to capture and transmit data. In winter, the battery capacity can decrease substantially due to cold temperatures and the solar recharge capacity can be adversely affected by snow and/or overhanging trees covering the solar panel. As technology improves and becomes more readily available, the RMB is committed to periodic upgrades of this weather station to minimise interruptions to the Mount Stirling meteorological dataset. In May 2022, the weather station was upgraded with a new modem (4G/5G as opposed to 3G), solar panels (two 160W 12V monocrystalline panels) and battery (160Ah 12V deep cycle battery). It is accessible by 4WD on management vehicle only tracks during the summer months and by snowmobile by Mount Stirling Ski Patrol staff during the snow season.



Figure 1 Mt Stirling Weather Station Location



Figure 2 Mt Stirling Weather Station

Table 1 Annual monitoring procedure Mount Stirling Weather Station

Task	Description	Location	Timing	Responsibility
1. Annual online subscription	<ul style="list-style-type: none"> <input type="checkbox"/> Update annual subscription to WeatherMation LIVE <input type="checkbox"/> Contact admin@environdata.com.au <input type="checkbox"/> 2022 contacts: Matthew Proberts and Jolinda Murray matthew@environdata.com.au jolinda@environdata.com.au 	RMB Office	January	RMB
2. Servicing	<ul style="list-style-type: none"> <input type="checkbox"/> Service by Environdata (contact Matthew Proberts; May 2022 full service and upgrades) 	On site	April every 2 years or as needed	RMB
3. Maintenance	<ul style="list-style-type: none"> <input type="checkbox"/> Fortnightly maintenance checks by Mt Stirling Operations staff <input type="checkbox"/> Check all equipment for damage <input type="checkbox"/> Open logger box container and check cables <input type="checkbox"/> Clear out rain gauge of debris and leaf litter <input type="checkbox"/> Check online data – lack of data may indicate potential issues with sensors or gauges on site 	On site	Every 2 weeks	RMB
4. Data access and downloads	<ul style="list-style-type: none"> <input type="checkbox"/> Log into WeatherMation LIVE to view meteorological data and complete a raw data download: https://www.weathermation.net.au/WMLogin.aspx <input type="checkbox"/> Login: Louise.Perrin, password: uD!Q5?R4 <input type="checkbox"/> View data on the home screen <input type="checkbox"/> Go to Historical Data → Download Data <input type="checkbox"/> Select date range and include wind direction <input type="checkbox"/> Click ‘Download Daily Summary’ to generate excel spreadsheet of raw data 	Office	Monthly	RMB
5. Data storage and recording	<ul style="list-style-type: none"> <input type="checkbox"/> Save WeatherMation LIVE raw data download to Sharepoint: C:\Users\StirlingPatrol\Mt Buller Mt Stirling Resort Management\Mt Buller Mt Stirling Resort Management - Documents\Environmental\Plans & Strategies\HEMAMP\Climate Monitoring\Mt Stirling Weather Station INFO\Data <input type="checkbox"/> Use the naming convention already used for raw data downloads in the location <input type="checkbox"/> Then update ‘HEMAMP Meteorological Data’ excel document with the specific data required <input type="checkbox"/> ‘HEMAMP Meteorological Data’ excel document stored at C:\Users\StirlingPatrol\Mt Buller Mt Stirling Resort Management\Mt Buller Mt Stirling Resort Management - Documents\Environmental\Plans & Strategies\HEMAMP\Climate Monitoring 	Office	Monthly	RMB
6. Data reporting	<ul style="list-style-type: none"> <input type="checkbox"/> Interpret and report data annually in Section 3.5 Climate in the annual HEMAMP monitoring report. 		August	Consultant

2 Mount Buller Bureau of Meteorology (BoM) Weather Station 083024

The BoM has been collecting meteorological data at Mount Buller since 1948. Currently, the BoM maintains an automated weather station at Tirol Flat (Station Number 083024; 37°8'41.8" S, 146°26'22.0" E), approximately 500 metres west-northwest of the water storage.

Table 2 Annual monitoring procedure Mount Buller Weather Station

Task	Description	Location	Timing	Responsibility
1. Servicing and Maintenance	<input type="checkbox"/> Maintained and serviced by BoM representatives	On site	As needed	BoM
2. Data access	<input type="checkbox"/> Log into Mount Buller, Vic - Daily Weather Observations (bom.gov.au) to view meteorological data and complete a raw data download (including rainfall, temperature and evapotranspiration) <input type="checkbox"/> View data on the home screen and complete a download <input type="checkbox"/> Go to Other times and other places → Select desired month → Other formats → select plain text version → in pop up window, click open file to check data in excel format	RMB Office	Monthly	RMB
3. Data storage and recording	<input type="checkbox"/> Save BoM raw data download to Sharepoint: C:\Users\StirlingPatrol\Mt Buller Mt Stirling Resort Management\Mt Buller Mt Stirling Resort Management - Documents\Environmental\Plans & Strategies\HEMAMP\Climate Monitoring\Meteorological raw BOM data <input type="checkbox"/> Use the naming convention already used for raw data downloads in the location <input type="checkbox"/> Then update 'HEMAMP Meteorological Data' excel document with the specific data required <input type="checkbox"/> 'HEMAMP Meteorological Data' excel document stored at C:\Users\StirlingPatrol\Mt Buller Mt Stirling Resort Management\Mt Buller Mt Stirling Resort Management - Documents\Environmental\Plans & Strategies\HEMAMP\Climate Monitoring	RMB Office	Monthly	RMB
4. Data reporting	<input type="checkbox"/> Interpret and report data annually in Section 3.5 Climate in the annual HEMAMP monitoring report.		August	Consultant

3 Snow Depth Data

Buller Ski Lifts has been recording daily snow depths during the snow season at Mount Buller since 1979. Buller Ski Lifts currently records snow depths at three locations, which have been in continuous use since 1987. The snow gauge locations are at Tirol Flat, Boggy Creek and Family Run, which are within 200-600 metres of the Alpine Bogs on the northern slopes of Mount Buller. At each location, a gauge sits on the snow surface and measures the depth of the snowpack. Each gauge is safely accessible by Mount Buller Ski Patrol staff by snowmobile in variable snow conditions.

The three monitoring sites reflect different snow conditions across the resort, with the Tirol Flat and Boggy Creek gauges reflective of the conditions at the water storage site.

All the snow gauging stations are marked and fenced. They are in locations that are not affected by snowmaking or wind deposition. All gauges are above the lowest skiable point (1,375 m) and are at a similar altitude (between 1,689 metres and 1,731 metres). The Tirol Flat and Boggy Creek gauges, which are within the PCF, were temporarily dismantled during construction and reinstated before winter 2020.

Daily during the declared snow season (typically from June to September inclusive).

Table 3 Annual monitoring procedure Mount Buller snow depth

Task	Description	Location	Timing	Responsibility
1. Pre-season Check	<input type="checkbox"/> Check gauges are in position and depth marks are clearly visible	On site	Annually May	BSL
2. Data collection, recording and storage	<input type="checkbox"/> At 7:15 each morning, Mount Buller Ski Patrol staff access each gauge and record: Snowpack depth (permanent gauge), and 24 hours snowfall (measured on 50cm gauge placed on the snowpack) <input type="checkbox"/> Snowdepths are reported by staff through to the Mount Buller Ski Patrol base by radio <input type="checkbox"/> Mount Buller Ski Patrol Base Patroller records depths into Mt Buller_SnowDepths_2015_current year excel spreadsheet	On site	Daily during the snow season (typically from June to September inclusive)	BSL
5. Data transfer	<input type="checkbox"/> Email snow depth data spreadsheet to RMB hemamp@mtbuller.com.au	BSL Office	Annually by December	BSL
5. Data reporting	<input type="checkbox"/> Interpret and report data annually in Section 3.5 Climate in the annual HEMAMP monitoring report.		August	Consultant

Appendix 4 SOP for hydrological monitoring

Memorandum

28 July 2022

To	Louise Perrin (RMB)		
Copy to	Muhhumad Abdullah (RMB)		
From	Meg Turner	Tel	+61 3 8687 8862
Subject	Standard Operating Procedures for HEMAMP Water Monitoring	Project no.	12565989

Dear Louise,

This memorandum outlines a procedural checklist for Mt Buller and Mt Stirling Resort Management Board (RMB) personnel to follow in undertaking surface water and groundwater monitoring as part of the established Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP).

1. Surface water monitoring

1.1 Relevance to the HEMAMP monitoring

Surface water monitoring is required through the HEMAMP to inform whether post-construction stream conditions indicate that certain thresholds (trigger points outlined in the HEMAMP) for surface water have been met.

The intention of the HEMAMP monitoring is to identify changes to the sampling data over time; therefore sampling consistency is imperative to the analysis. It is important that the surface water sample point and depth is consistent each monitoring round, so that reliable comparisons can be made between monitoring events. Images are provided in this SOP to assist with this and the following section outlines further relevant considerations.

1.2 Stream sampling overview

The distribution of suspended matter is non-uniform in a stream. Being denser than water, the tendency for suspended matter to settle out is counteracted by turbulent transfer upward from the bed. As the velocity gradient, and therefore turbulence, is greatest near the side and bed of the stream, suspended matter will tend to accumulate in these areas. Depending upon the particle size, turbulence and water viscosity, the particle distribution may be more or less uniform with depth.

Generally, suspended solids with a particle size less than 60 μm are uniformly distributed, whereas larger particles will tend to accumulate near the streambed. However, for very deep rivers, there is evidence that even particles smaller than 10 μm are not uniformly distributed. Many inorganic elements such as phosphorus and heavy metals, and contaminants such as pesticides and herbicides, can be strongly adsorbed onto suspended solids and particular care must be taken when sampling streams carrying heavy sediment loads.

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1.3 Grab sampling method

A grab sample is a small sample collected at random at a specific time. Grab samples can be collected using a hand-held plastic scoop or bottle, depending on the depth of water, and if required, composited into a narrow-mouth plastic container. Care must be taken to minimise aeration.

To collect a grab sample:

1. Place container by hand directly into water body
 - Typically, for waters less than half a metre in depth, collect a grab sample at half the water depth.
 - For waters greater than half a metre in depth, a grab sample should be taken at 20 to 30 cm below the surface water.
2. Open end vertically down and fill with an arc motion with the bottle mouth facing upstream
3. Take care to avoid collecting surface films

For the Boggy Creek weir sampling locations, a sample collected from 10 cm to 15 cm below the surface is sufficient.

1.4 Sampling procedure

Table 1 Surface water sampling procedure

Step	Task	Notes
1	Remove calibration certificate from the Water Quality Meter (WQM) (e.g. YSI) case and store with field sheets. The calibration certificate should be scanned along with the field notes after sampling. The calibration certificate should be attached to the monitoring report.	If there is no calibration certificate with the WQM when it arrives, email the provider and they should be able to provide a copy electronically.
2	Label the laboratory supplied bottles.	Label before sampling, as labelling wet bottles is difficult. If the laboratory provided pre-labelled stickers, use these, otherwise use a permanent marker. Check that the label includes the client/project name (Mt Buller RMB) location (e.g. Boggy Creek 1 PU 1), date, initials of sampling personnel.
3	Rinse the WQM probe with deionised (DI) water, place in protective cover.	DI water can be ordered from the laboratory that provides the sample bottles. *Keep the monitor unit including screen of the WQM dry.
4	Turn on WQM and place in the water column at the sampling point; at the corner of the weir outlet in the flowing water (see figures 1, 3 and 5).	Lower just below the surface (to the start of the cord) to take readings from the same depth as the samples (see figure 6). Allow a minute or two for the WQM to adjust to the water temperature and record a measurement when the parameters have stabilised. Note: values will naturally continue to fluctuate. If values are continuously decreasing or continuously increasing this indicates the WQM is still adjusting. Wait until values have generally stabilised).
5	Record a WQM measurement and note the physical water characteristics	Remember to note the units of all parameters, particularly dissolved oxygen (DO) and electrical conductivity (EC). This is because the units of these parameters may vary. Typically, DO will be mg/L and EC will be µS/cm. Note the WQM reading on the purge sheet. Note the characteristics of the water include colour, turbidity, sediment, odour etc. This will be more consistent

Step	Task	Notes
		if using a clear measuring jug to scoop some water out from the sampling point.
6	Rinse the WQM probe with DI water and place in protective cap before storing.	Make sure the protective cap is moist to prevent the probe from drying out (there should be a sponge in the bottom of the protective cap – keep this damp).
7	Collect a sample from the sampling point.	When collecting duplicate and split samples, fill the same bottle types together, so that the same parameters are sampled consecutively. Make sure to note on the sampling sheet if any duplicate samples were taken and the primary sample that they relate to.
8	Place samples in an esky with ice.	Ensure that sampling bottle lids are securely fastened. Populate the Chain of Custody (COC) documentation once each sample is placed in the esky. Ensure all required analyses are included in the COC.
9	Take a photo of the site, showing the sampling point and water level/weir condition.	
10	Laboratory dispatch	Once all samples are collected, contact the relevant laboratory to arrange for sample collection. Ensure the COC is signed off by the receiver.
11	Laboratory receipt confirmation	Look out for the laboratory issued sample receipt notification (SRN), usually issued via email the day following sample dispatch. Review the SRN to confirm the analysis interpreted by the lab is as requested/intended.



Figure 1 Boggy Creek 1 PU 1 location
(arrow shows sample point)

Coordinates: 449,781 E, 5,889,496 N (UTM, zone 55)



Figure 2 Location of Boggy Creek 1 PU 1 – follow
grassed path past the overhead PVC pipe behind the tank



Figure 3 *Boggy Creek 1 PU 2 location (arrow shows sample point)*

Coordinates: 449,857 E, 5,889,488 N (UTM, zone 55)



Figure 4 *Location of Boggy Creek 1 PU 2 – follow the path to the right behind the tank*



Figure 5 *Boggy Creek 2
(arrow shows sample point)*

Coordinates: 449,677.79 E, 5,890,310.05 N (UTM, zone 55)



Figure 6 *Depth for WQM measurements*

2. Groundwater monitoring

2.1 Relevance to the HEMAMP monitoring

Groundwater monitoring is required through the HEMAMP to inform whether post-construction groundwater conditions indicate that certain thresholds (trigger points outlined in the HEMAMP) for groundwater have been met.

Note that bores should be located in situ immediately post winter (when the vegetation is low) and marked with a bright wooden stake so that they can be readily located in November and February. This will speed up the monitoring event and reduce the chance of missing bores.

2.2 Groundwater sampling overview

Groundwater sampling procedures, including the measurement of non-aqueous phase liquids, must conform with the requirements of EPA Victoria (2000) Publication 669.1: Groundwater Sampling Guidelines.

A fundamental component of groundwater sampling is well purging. The aim of this process is to remove 'stagnant' groundwater from the well so that groundwater representative of the surrounding hydrostratigraphic unit is obtained. Measuring stabilisation criteria such as pH, EC, DO, temperature and oxygen reduction potential (ORP, or Eh) provides an indication as to when stagnant water has been successfully purged and sampling can begin. A calibrated measuring instrument should be used and evidence of calibration should be retained on file. Where possible, these parameters should be measured using a flow through cell or similar device.

Parameter measurements should be recorded at regular intervals (i.e. every 1 litre where possible). A minimum of three measurements is required to confirm stabilisation, ideally over a minimum of 5 litres purged. Descriptions of the visual and olfactory characteristics of the groundwater should be recorded each time a measurement is recorded and should include details such as elapsed time, volume purged, colour, turbidity, odour, sheen etc. All measured stabilisation parameters and field observations should be recorded on a standard purging and sampling field sheet pro forma.

The parameters can be considered stable when three consecutive readings are within:

- 0.05 for pH
- $\pm 3\%$ for EC
- $\pm 10\%$ for DO
- ± 0.2 °C for temperature
- ± 10 mV for Eh / ORP

2.3 Groundwater level monitoring and sampling procedure

Table 2 Groundwater sampling procedure

Step	Task	Notes
1	Remove calibration certificate from WQM case and store with field sheets. The calibration certificate should be scanned along with the field notes after sampling.	If there is no calibration certificate with the WQM when it arrives, email the provider and they should be able to provide a copy electronically.
2	Label bottles.	Label before sampling, as labelling wet bottles is difficult. If the laboratory provided pre-labelled stickers, use these, otherwise use a permanent marker. Check that the label includes the client/project name (Mt Buller RMB) location (e.g. Boggy Creek 1 PU 1), date, initials of sampling personnel.

Step	Task	Notes
3	Rinse the WQM probe with DI water, place in protective cover and place in a clean bucket.	DI water can be ordered from the laboratory that provides the sample bottles.
4	Open the gatic cover of the groundwater bore and remove the j-plug.	
5	Turn on the interphase probe / water dipper and measure standing water level (SWL).	SWL should be measured to a consistent datum (e.g. top of PVC casing, or ground surface) and this should be recorded clearly If there is a datalogger in the well, measure SWL before and after removing the datalogger.
6	If datalogger is present, gently remove the datalogger and download to laptop.	Keep datalogger out of the well until sampling is completed. Dataloggers should be downloaded during each groundwater quality monitoring event. Battery life and storage capacity should be reviewed during each download event, and equipment should be upgraded or replaced if either memory or storage are below 20%
7	Measure the total depth of the bore	Confirm the total depth by lowering the interphase probe / water dipper so that it contacts the bottom of the well, while the measuring tape is taut. Measure the depth to the same datum as per the step above.
8	Determine how many purge volumes are in the well.	The following provides some general rules on calculating purge volumes: <ul style="list-style-type: none"> – 1 m of casing of 50 mm internal diameter = 2 L in well – 1 m long bailer of 50 mm outer diameter = 1 L per bail To estimate purged volumes, calculate the vertical water column from SWL to the total bore depth. Before sampling, aim to obtain 3 consecutive readings within the stabilised range on the purging record sheet, and/or remove 3 well volumes of water if there is enough water. *Check that the water is recharging while bailing by intermittently measuring SWL during bailing. If the bore goes dry, await recovery before sampling can commence.
9	If sampling via bailing technique, tie string to the bailer.	Tie off the other end of the string to something heavy/fixated at the ground surface (e.g. gatic lid, dipper) to prevent a lost bailer scenario.
10	Lower bailer into well. Pull up when the bailer has filled with water	
11	Empty bailer into bucket and rinse the bucket with the water	
12	Refill bailer, empty the bailer into the bucket and turn on the WQM.	Allow a minute or two for the WQM to adjust to the water temperature and take a measurement when parameters have stabilised Note: values will naturally continue to fluctuate. If values are continuously decreasing or continuously increasing this indicates the WQM is still adjusting. Wait until values have generally stabilised).
13	Take a WQM reading.	Remember to note the units of all parameters, particularly DO and EC. This is because the units of these parameters may vary. Typically, DO will be mg/L and EC will be $\mu\text{S/cm}$.

Step	Task	Notes
		<p>Note the WQM reading and the number of litres of water removed from the well on the record sheet.</p> <p>Note the physical characteristics of the water (colour, turbidity, sediment, odour etc.). This will be more consistent if using a clear jug to scoop some water out from the bucket.</p>
14	<p>Repeat steps 9 to 12, keeping count of the litres removed, until the required volume of water (calculated in step 8) has been removed.</p> <p>Every couple of bails, tip the WQM bucket (careful not to damage the WQM) and fill with new water for another reading. Alternatively, use multiple buckets.</p>	Record measurements at set intervals (e.g. every 2 or 3 litres). Empty the bucket and fill with new water before taking the next reading.
15	Collect samples directly from the bailer to avoid contamination of the sample.	<p>When collecting duplicate and split samples, fill the same bottle types together, so that the same parameters are sampled consecutively.</p> <p>Make sure to note on the sampling sheet if any duplicate samples were taken and the primary sample that they relate to.</p>
16	Place samples in an esky with ice.	Ensure that sampling bottle lids are securely fastened. Populate the Chain of Custody (COC) documentation once each sample is placed in the esky. Ensure all required analyses are included in the COC.
17	Replace the datalogger gently into the well. Close gatic cover.	Ensure datalogger cable/wireline is tort and that logger test is still running.
18	Rinse the WQM probe with DI water before storing in the storage cap.	
19	Take a photo of the site, showing the sampling point and gatic condition	
20	Laboratory dispatch	<p>Once all samples are collected, contact the relevant laboratory to arrange for sample collection.</p> <p>Groundwater samples must be issued to a National Association of Testing Authorities (NATA) accredited laboratory accredited for the testing program conducted.</p> <p>Ensure the COC is signed off by the receiver.</p>
21	Laboratory receipt confirmation	<p>Look out for the laboratory issued SRN, usually issued via email the day following sample dispatch.</p> <p>Review the SRN to confirm the analysis interpreted by the lab is as requested/intended.</p>

Bore integrity checks should be undertaken during groundwater monitoring events, to confirm that bore assets have not been damaged or destroyed. At a minimum, bore integrity checks should include the following checks:

- Bore security (locks, screw caps etc. in place and intact)
- Bore cap present and functional
- Datalogger and accessories in place (where relevant) and all components fastened tightly
- Total bore depth is as expected
- No visible pooling of surface water or ingress of surface contamination

- Bore construction does not present a hazard to site personnel or general public

If damage is observed, this should be reported and the issue rectified by A) Reinstatement works to repair damaged bores or B) Decommissioning of destroyed bore and installation of a replacement bore.

All bores need to be constructed, repaired and decommissioned in accordance with the Minimum Construction Requirements for Water Bores in Australia (NUDLC, 2020).



Figure 7 BH04 and BH04A

Coordinates: 449,692.8 E, 5,888,663 N (UTM, zone 55)



Figure 8 Location of BH04 and BH04A



Figure 9 BH06

Coordinates: 449,429.0 E, 5,888,787 N (UTM, zone 55)



Figure 10 BH06 is located on the eastern side of the carpark beneath the summit walk (pictured)



Figure 11 BH07

Coordinates: 449,658.3 E, 5,888,915 N (UTM, zone 55)

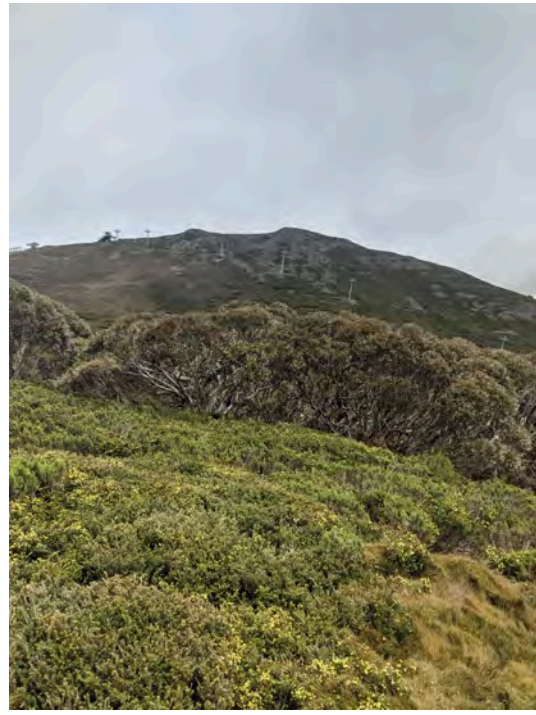


Figure 12 View from BH07 indicating location



Figure 13 BH09

Coordinates: 449,611.8 E, 5,888,835 N (UTM, zone 55)



Figure 14 View from BH09 indicating location



Figure 15 BH10

Coordinates: 449,679.9 E, 5,888,856 N (UTM, zone 55)



Figure 16 Location of BH10



Figure 17 BH16

Coordinates: 449,459 E, 5,888,860 N (UTM, zone 55)

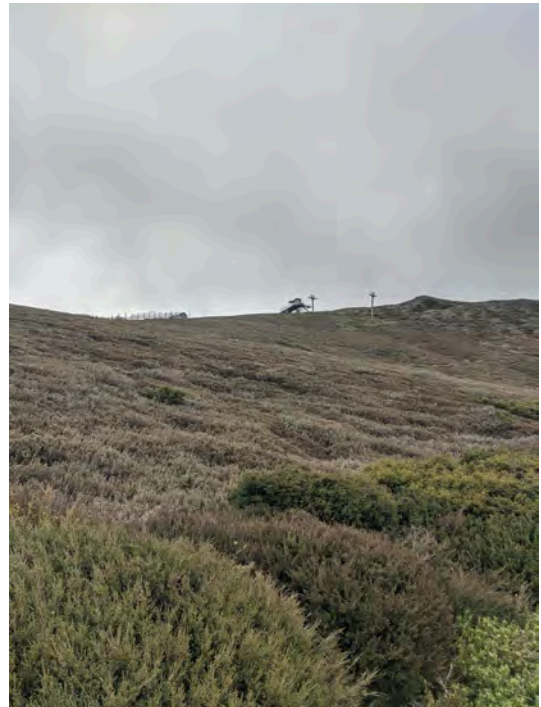


Figure 18 View from BH16 indicating location



Figure 19 **BH17**

Coordinates: 449,701 E, 5,888,866 N (UTM, zone 55)



Figure 20 **View from BH17 indicating location**



Figure 21 **BH18**

Coordinates: 449,922 E, 5,888,830 N (UTM, zone 55)



Figure 22 **Location of BH18**

3. Glossary of terms

Item	Description
COC	<p>Chain of custody.</p> <p>Chain of custody (often referred to as the COC) procedures are used to track samples, discourage tampering, and provide a sampling summary. The primary purpose of the COC is to show who is and has been in possession of the samples. Each time the sample is relinquished or received, the party involved signs the form and indicates the time and date.</p> <p>Chain of custody forms also include general information including sample names, sample locations, the type of sample, number of sample containers from each location and comments.</p>
DI water	Deionised water.
Field Duplicate / Blind duplicate	<p>Field or blind duplicates are duplicate samples that are sent as independent samples to the same laboratory for analysis, to assess the repeatability of the analytical results. Field blind duplicates are collected typically at a frequency of 1 in 20 samples (i.e. 5%).</p> <p>This sample is taken alongside a primary sample. The primary sample is called the "parent sample". The name of the parent sample of the duplicate is not given to the laboratory.</p>
Parent sample	The primary sample which a duplicate sample was taken with.
Primary laboratory	The laboratory which the primary samples, rinsates and field duplicates are sent to for analysis.
Primary sample	Sample from a location specified in the HEMAMP.
Rinsate	<p>Rinsate blanks monitor possible contamination that may be introduced by inadequate equipment decontamination. Rinsate blanks should be collected when cross contamination of the samples is likely to impact on the validity of the analytical results, for example where the investigation level for a contaminant is near the detection limit for the contaminant.</p> <p>After equipment has been decontaminated, deionised water should be run through or over that section of the equipment that is used to collect the samples. The deionised water should be collected, sealed and labelled as a sample. One rinsate blank should be collected per piece of sampling equipment per day in the field.</p>
Screen	A type of lining tube, with apertures, designed to permit the flow of water into a well while preventing the entry of aquifer or filter pack material.
Secondary laboratory	The laboratory which the split / inter-lab duplicate sample is sent to for analysis.
Split / Inter-lab duplicate	<p>Field splits are duplicate samples that are sent to different laboratories for analysis to assess the analytical proficiency of the laboratories. Field spikes are collected typically at a frequency of 1 in 20 samples (ie 5%).</p> <p>The split duplicate gets sent to a secondary laboratory.</p>
SWL	Standing water level
WQM	<p>Water Quality Meter</p> <p>Hand held device containing measurement probes used for field parameter measurements.</p>
YSI	<p>Yellow Springs Instruments.</p> <p>YSI is the brand name of a water quality probe used for field parameter measurements. The name "YSI" is colloquially used to refer to the water quality probe in the environmental monitoring industry.</p>

HEMAMP Surface Water and Groundwater Monitoring

Groundwater Monitoring Bores – Construction Details

Bore ID	Zone 55 UTM Coordinates		Total Depth (m bgl)	Screen (m bgl)		
	Easting	Northing		Top	Bottom	Screened Lithology
BH04	449,692.8	5,888,663	15.68	8.68	14.68	Carbonaceous Mudstone
BH04A	449,692.6	5,888,663	2.56	1.56	2.56	Basalt
BH06	449,429.0	5,888,787	9	6	9	Granite
BH07	449,658.3	5,888,915	1	0	1	Bog/Granitic Soil
BH09	449,611.8	5,888,835	6	3	6	Granite
BH10	449,679.9	5,888,856	9	6	9	Granite
BH16	449,459	5,888,860	2.1	1.1	2.1	Granitic Soils
BH17	449,701	5,888,866	2.2	1	2.2	Granitic Soils
BH18	449,922	5,888,830	2.15	1.15	2.15	Granitic Soils

Note that BH04, BH04A and BH10 (shaded grey) are not included in the sampling. Monitor the standing water level only.

Equipment Checklist

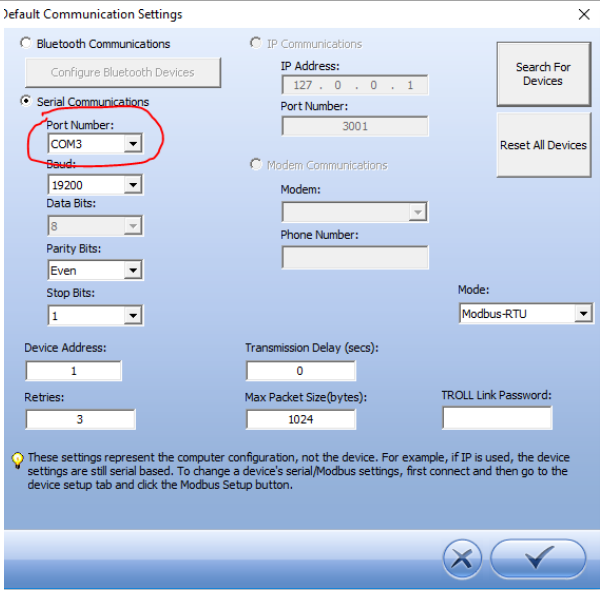
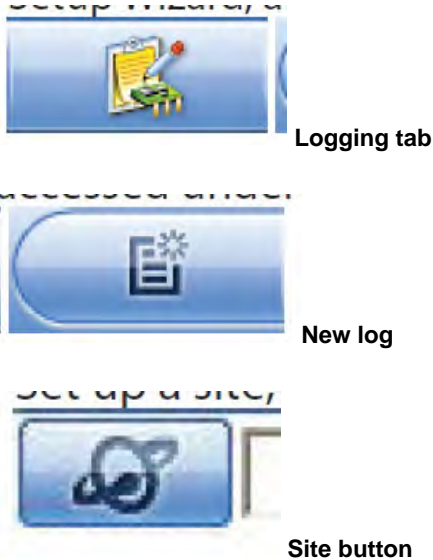
Table 1 Monitoring Equipment checklist

Item	Number	Used for surface water?	Used for groundwater?	Checklist
Laboratory Items				
Water Quality Meter (Eg. YSI probe)	1	Y	Y	
Sample bottles	The lab will decide in accordance with the analysis requested.	Y	Y	
Esky for storing bottles	Will be determined by the laboratory to fit the number of bottles.	Y	Y	
Deionised water	One 5 L bottle	Y	Y	
Nitrile gloves	1 box	Y	Y	
Supplied by Mt Buller				

Item	Number	Used for surface water?	Used for groundwater?	Checklist
Allan key (8 mm)	1 (one spare is useful too!)		Y	
Screw driver, nail lifter and other tools (useful for lifting stuck gatics)	1 each		Y	
Adapter for data logger download	1		Y	
Laptop for data logger download	1		Y	
Water level meter / interface probe	1		Y	
Bucket	1		Y	
Clear plastic measuring jug	1	Y	Y	
Bailers	7 (six bores plus one spare)		Y	
String for bailers	1 roll (at least 25 m needed)		Y	
Filters	9	Y	Y	
Hand pump for filters	1	Y	Y	
Ice or ice bricks	Enough to keep esky cool until the lab receives samples	Y	Y	
Permanent marker, pen/pencil and clipboard	1-2 of each	Y	Y	
First aid kit	1			
Site map	1	Y	Y	
Purging record sheet	14 (12 sampling locations plus two spare)	Y	Y	
COC form	1-2 (will need enough rows to fit all 12 sampling sites)	Y	Y	

Datalogger guide

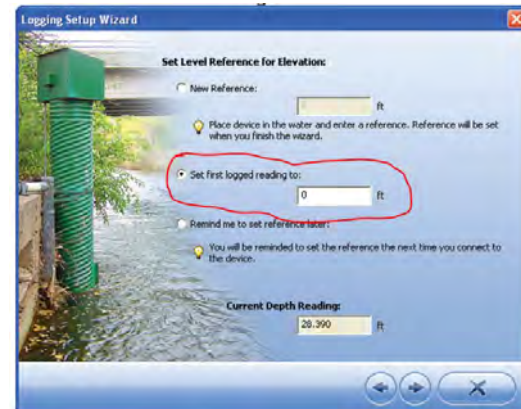
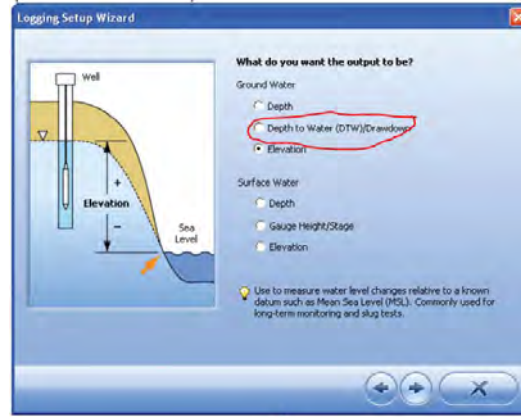
Table 1 Installation and set-up

Set-up and installation	
<p>Required software:</p> <ul style="list-style-type: none"> - Win Situ 5 	
Connecting to the datalogger	
<ul style="list-style-type: none"> - Connect datalogger to computer via USB using connection cable / adapter - Open up Win-Situ 5 on your laptop - Upon opening it will prompt you – “Connect to device now”, say OK - The program may not be set to look at the correct comms port, if this is the case it will say that it can't find a device. If it asks to try other factor settings, Say No to this - After saying no a dialog box will appear (see image to right) and the top left hand side it will have a drop down for comms ports, select a new one, click the tick button and select the connect button at the bottom right hand side of screen (as shown on bottom RH side of this slide) - Keep doing this until you find the correct comms port and the program successfully connects to the logger - If it asks you to sync to PC say yes 	
Data logger set-up	
<ul style="list-style-type: none"> - Go to the logging tab - Select new log - Select the site – if your site isn't there, add it using the site button - Give the log a meaningful name e.g. ID06-BH06 LT monitoring - Click the next arrow - Make sure all the parameters are selected and that the units are: <ul style="list-style-type: none"> - Temp oC - Depth m - Pressure kPa - Click next 	
Logging specifics	
<ul style="list-style-type: none"> - For the logging method select “Linear” - Set the appropriate sampling rate (we typically use 6 hrs but if monitoring for tidal fluctuations a higher 	

Set-up and installation

- frequency is required, please confirm with hydrogeologist)
- Select an automatic start at a sensible time so that logger is in the borehole before it starts taking readings

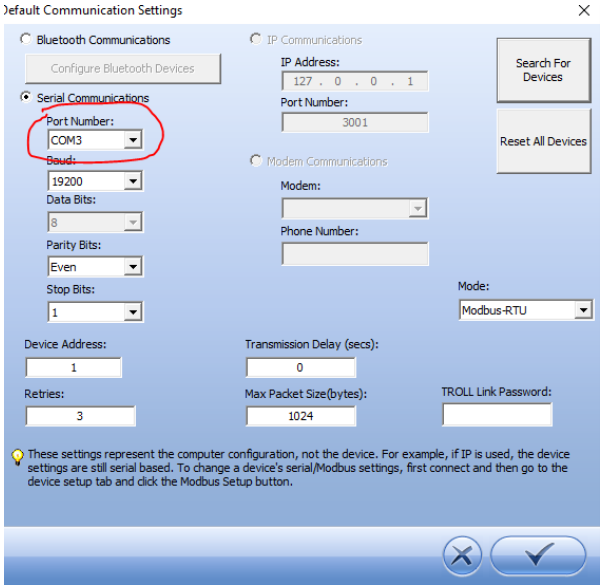


- Set the output to Depth to Water / drawdown as highlighted red
- Set first logged reading to zero (as shown in red) – this will measure the displacement from the water level at the time of deployment
- Set the specific gravity to be freshwater
- Check that everything looks correct on the summary page. If correct finalise logger set up



Deployment

- Disconnect logger from dock and attach cap back on
- Secure data logger to the steel wire at one end and the other to the J-screw cap
- **Before inserting logger into well, take a water level reading, this will be used as a reference when we post process the data later**
- Insert logger into well and place J-screw cap on well. Note that you want the data logger to be fully submerged, preferably by a couple of metres

Table 2 Data download

Downloading data	
Data logger retrieval	
<ul style="list-style-type: none"> – Undo J-screw cap on PVC pipe – Pull data logger out of well using the stainless steel cable that it is attached too – Once removed, take a water level reading (so we can check the logged reading against manual later) 	
Connecting to the logger	
<ul style="list-style-type: none"> – Take the cap off the data logger (cap should remain attached to the stainless steel cable) so you can connect to the logger – Connect data logger to your computer via connection cable/adaptor and USB – Open up Win-Situ 5 on your laptop – Upon opening it will prompt you – “Connect to device now”, say OK – The program may not be set to look at the correct comms port, if this is the case it will say that it can't find a device. If it asks to try other factor settings, Say No to this – After saying no a dialog box will appear (see image to right) and the top left hand side it will have a drop down for comms ports, select a new one, click the tick button and select the connect button at the bottom right hand side of screen (as shown on bottom RH side of this slide) – Keep doing this until you find the correct comms port and the program successfully connects to the logger – If it asks you to sync to PC say no 	
Data download	
<ul style="list-style-type: none"> – Once connected to the logger you should see the current parameter readings shown on the home screen – Go to the logging tab – Here you will see the logs on the datalogger – Click on the log that you want to download, it should become highlighted – Click on the download button – Select “Download all” – Once completed it will ask you if you want to view the data, say yes – You will be able to see a graph of the data on the right hand side and a list of data files on the left – on the logger file to the left under “site data”right click and select “export to csv” – a file will appear under export data on the left hand side for the log – The files under “site data” and “export data” for Winsitu are stored on your computer in Documents - Winsitu Data – Remove logger from the docking station and reattach cap, put the logger back down the bore 	 <p style="text-align: right;">Logging Tab</p>  <p style="text-align: right;">Download button</p>
Post-processing using Baromerge	

Downloading data

- Using the barologger data (BH06 has a barologger installed alongside the datalogger) to correct the water levels.
- Units usually kPa, unless project specific requirement for psi
- Date is just the date the baromerged file was made
- Increment depends on the logging interval – if hourly, select hourly (or the next finest interval eg. if 3-hourly, select hourly)
- Select logger file to merge – can select multiple at once
- Merged file appears in Winsitu Site Data folder
- There is no requirement for Mt Buller to select the tick box for Post Correction, but there is no harm in ticking the box

Appendix 5 SOP for ecological monitoring

Standard operating procedure for ecological monitoring

This is the Standard Operating Procedure (SOP) for the ecological monitoring component of the Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP) for the Mount Buller Sustainable Water Security Project. This SOP should be read in conjunction with the current HEMAMP protocol.

1 Ecological monitoring checklist

The procedure checklist presented in Table 1 provides a means of tracking the progress of ecological monitoring in a given monitoring year and assists in verifying that all ecological monitoring tasks have been completed. The checklist should be reviewed and items marked off as ecological monitoring progresses, preferably on a daily basis while on site (to ensure that data are complete and backed up).

Table 1 Annual ecological monitoring procedure checklist

Description	Location	Timing	Responsibility
1. Site visit planning			
<input type="checkbox"/> Plan for monitoring to commence around 26 January +/- one week. <input type="checkbox"/> Plan for transect monitoring to be completed by 23 February. <input type="checkbox"/> Plan for Alpine Bog mapping to be completed by 16 March. <input type="checkbox"/> Reserve appropriate accommodation and monitoring staff for these dates. <input type="checkbox"/> Plan order of monitoring site visits, taking into account access limitations in the given year (monitoring sites do not need visiting in any particular order).	Off-site (prior to arriving at monitoring sites).	By 20 December	RMB Environment Manager and consultant lead
2. Monitoring equipment preparation			
<input type="checkbox"/> Book and gather the monitoring equipment listed in Section 2 (Table 2). <input type="checkbox"/> Check that all monitoring equipment is in working order. <input type="checkbox"/> Update monitoring spreadsheet with any improvements suggested from previous year. <input type="checkbox"/> Test monitoring spreadsheet on tablet(s). <input type="checkbox"/> Load past photo point photos onto tablet(s). <input type="checkbox"/> Load past geospatial data onto tablet(s), including Alpine Bog boundaries, transect location, photo point locations and monitoring notes from previous years. <input type="checkbox"/> Set camera settings to required parameters.	Off-site (prior to arriving at monitoring sites).	By 10 January	RMB Environment Manager and consultant lead
3. Photo points			
Following the steps in Section 3 of this SOP, re-establish monitoring transects, take photos from the following photo points and ensure that these photos are backed up: <input type="checkbox"/> 1AS photo <input type="checkbox"/> 1AE photo <input type="checkbox"/> 1BS photo <input type="checkbox"/> 1BE photo <input type="checkbox"/> 1CS photo <input type="checkbox"/> 1CE photo <input type="checkbox"/> 2AS photo <input type="checkbox"/> 2AE photo	On-site at the ends of monitoring transects at control and impact sites.	By 23 February	RMB Environment Manager and consultant lead

Description		Location	Timing	Responsibility
<input type="checkbox"/> 2BS photo	<input type="checkbox"/> 2BE photo			
<input type="checkbox"/> 2CS photo	<input type="checkbox"/> 2CE photo			
<input type="checkbox"/> 4.1AS photo	<input type="checkbox"/> 4.1AE photo			
<input type="checkbox"/> 4.1BS photo	<input type="checkbox"/> 4.1BE photo			
<input type="checkbox"/> 4.1CS photo	<input type="checkbox"/> 4.1CE photo			
<input type="checkbox"/> 4.2AS photo	<input type="checkbox"/> 4.2AE photo			
<input type="checkbox"/> 4.2BS photo	<input type="checkbox"/> 4.2BE photo			
<input type="checkbox"/> 4.2CS photo	<input type="checkbox"/> 4.2CE photo			
<input type="checkbox"/> 4.2DS photo	<input type="checkbox"/> 4.2DE photo			
<input type="checkbox"/> 4.2ES photo	<input type="checkbox"/> 4.2EE photo			
<input type="checkbox"/> 5AS photo	<input type="checkbox"/> 5AE photo			
<input type="checkbox"/> 6AS photo	<input type="checkbox"/> 6AE photo			
<input type="checkbox"/> 6BS photo	<input type="checkbox"/> 6BE photo			
<input type="checkbox"/> 6CS photo	<input type="checkbox"/> 6CE photo			
<input type="checkbox"/> 6DS photo	<input type="checkbox"/> 6DE photo			
<input type="checkbox"/> 6ES photo	<input type="checkbox"/> 6EE photo			
<input type="checkbox"/> 7AS photo	<input type="checkbox"/> 7AE photo			
<input type="checkbox"/> 8AS photo	<input type="checkbox"/> 8AE photo			
<input type="checkbox"/> 8BS photo	<input type="checkbox"/> 8BE photo			
<input type="checkbox"/> 8CS photo	<input type="checkbox"/> 8CE photo			
<input type="checkbox"/> 9AS photo	<input type="checkbox"/> 9AE photo			
<input type="checkbox"/> 10AS photo	<input type="checkbox"/> 10AE photo			
<input type="checkbox"/> 11.1AS photo	<input type="checkbox"/> 11.1AE photo			
<input type="checkbox"/> 11.1BS photo	<input type="checkbox"/> 11.1BE photo			
<input type="checkbox"/> 11.1CS photo	<input type="checkbox"/> 11.1CE photo			
<input type="checkbox"/> 11.2AS photo	<input type="checkbox"/> 11.2AE photo			
<input type="checkbox"/> 11.2BS photo	<input type="checkbox"/> 11.2BE photo			
<input type="checkbox"/> 11.2CS photo	<input type="checkbox"/> 11.2CE photo			
<input type="checkbox"/> 12AS photo	<input type="checkbox"/> 12AE photo			
<input type="checkbox"/> 12BS photo	<input type="checkbox"/> 12BE photo			
<input type="checkbox"/> 12CS photo	<input type="checkbox"/> 12CE photo			
<input type="checkbox"/> 13AS photo	<input type="checkbox"/> 13AE photo			
<input type="checkbox"/> 13BS photo	<input type="checkbox"/> 13BE photo			
<input type="checkbox"/> 13CS photo	<input type="checkbox"/> 13CE photo			
<input type="checkbox"/> S1AS photo	<input type="checkbox"/> S1AE photo			
<input type="checkbox"/> S1BS photo	<input type="checkbox"/> S1BE photo			
<input type="checkbox"/> S1CS photo	<input type="checkbox"/> S1CE photo			
<input type="checkbox"/> S2AS photo	<input type="checkbox"/> S2AE photo			
<input type="checkbox"/> S2BS photo	<input type="checkbox"/> S2BE photo			
<input type="checkbox"/> S2CS photo	<input type="checkbox"/> S2CE photo			
<input type="checkbox"/> S3AS photo	<input type="checkbox"/> S3AE photo			
<input type="checkbox"/> S3BS photo	<input type="checkbox"/> S3BE photo			
<input type="checkbox"/> S3CS photo	<input type="checkbox"/> S3CE photo			
4. Point intercept and quadrat data				
Following the steps in Section 3 of this SOP, collect point intercept and quadrat data for the following transects and ensure that these data are backed up:		On-site along lengths of transects at control and impact sites.	By 23 February	RMB Environment Manager and consultant lead
<input type="checkbox"/> 1A point data	<input type="checkbox"/> 1A quadrat data			

Description		Location	Timing	Responsibility
<input type="checkbox"/> 1B point data	<input type="checkbox"/> 1B quadrat data			
<input type="checkbox"/> 1C point data	<input type="checkbox"/> 1C quadrat data			
<input type="checkbox"/> 2A point data	<input type="checkbox"/> 2A quadrat data			
<input type="checkbox"/> 2B point data	<input type="checkbox"/> 2B quadrat data			
<input type="checkbox"/> 2C point data	<input type="checkbox"/> 2C quadrat data			
<input type="checkbox"/> 4.1A point data	<input type="checkbox"/> 4.1A quadrat data			
<input type="checkbox"/> 4.1B point data	<input type="checkbox"/> 4.1B quadrat data			
<input type="checkbox"/> 4.1C point data	<input type="checkbox"/> 4.1C quadrat data			
<input type="checkbox"/> 4.2A point data	<input type="checkbox"/> 4.2A quadrat data			
<input type="checkbox"/> 4.2B point data	<input type="checkbox"/> 4.2B quadrat data			
<input type="checkbox"/> 4.2C point data	<input type="checkbox"/> 4.2C quadrat data			
<input type="checkbox"/> 4.2D point data	<input type="checkbox"/> 4.2D quadrat data			
<input type="checkbox"/> 4.2E point data	<input type="checkbox"/> 4.2E quadrat data			
<input type="checkbox"/> 5A point data	<input type="checkbox"/> 5A quadrat data			
<input type="checkbox"/> 6A point data	<input type="checkbox"/> 6A quadrat data			
<input type="checkbox"/> 6B point data	<input type="checkbox"/> 6B quadrat data			
<input type="checkbox"/> 6C point data	<input type="checkbox"/> 6C quadrat data			
<input type="checkbox"/> 6D point data	<input type="checkbox"/> 6D quadrat data			
<input type="checkbox"/> 6E point data	<input type="checkbox"/> 6E quadrat data			
<input type="checkbox"/> 7A point data	<input type="checkbox"/> 7A quadrat data			
<input type="checkbox"/> 8A point data	<input type="checkbox"/> 8A quadrat data			
<input type="checkbox"/> 8B point data	<input type="checkbox"/> 8B quadrat data			
<input type="checkbox"/> 8C point data	<input type="checkbox"/> 8C quadrat data			
<input type="checkbox"/> 9A point data	<input type="checkbox"/> 9A quadrat data			
<input type="checkbox"/> 10A point data	<input type="checkbox"/> 10A quadrat data			
<input type="checkbox"/> 11.1A point data	<input type="checkbox"/> 11.1A quadrat data			
<input type="checkbox"/> 11.1B point data	<input type="checkbox"/> 11.1B quadrat data			
<input type="checkbox"/> 11.1C point data	<input type="checkbox"/> 11.1C quadrat data			
<input type="checkbox"/> 11.2A point data	<input type="checkbox"/> 11.2A quadrat data			
<input type="checkbox"/> 11.2B point data	<input type="checkbox"/> 11.2B quadrat data			
<input type="checkbox"/> 11.2C point data	<input type="checkbox"/> 11.2C quadrat data			
<input type="checkbox"/> 12A point data	<input type="checkbox"/> 12A quadrat data			
<input type="checkbox"/> 12B point data	<input type="checkbox"/> 12B quadrat data			
<input type="checkbox"/> 12C point data	<input type="checkbox"/> 12C quadrat data			
<input type="checkbox"/> 13A point data	<input type="checkbox"/> 13A quadrat data			
<input type="checkbox"/> 13B point data	<input type="checkbox"/> 13B quadrat data			
<input type="checkbox"/> 13C point data	<input type="checkbox"/> 13C quadrat data			
<input type="checkbox"/> S1A point data	<input type="checkbox"/> S1A quadrat data			
<input type="checkbox"/> S1B point data	<input type="checkbox"/> S1B quadrat data			
<input type="checkbox"/> S1C point data	<input type="checkbox"/> S1C quadrat data			
<input type="checkbox"/> S2A point data	<input type="checkbox"/> S2A quadrat data			
<input type="checkbox"/> S2B point data	<input type="checkbox"/> S2B quadrat data			
<input type="checkbox"/> S2C point data	<input type="checkbox"/> S2C quadrat data			
<input type="checkbox"/> S3A point data	<input type="checkbox"/> S3A quadrat data			
<input type="checkbox"/> S3B point data	<input type="checkbox"/> S3B quadrat data			
<input type="checkbox"/> S3C point data	<input type="checkbox"/> S3C quadrat data			

Description	Location	Timing	Responsibility
5. Alpine Bog mapping			
<p>Following the steps in Section 4 of this SOP, map Alpine Bog boundaries and back up spatial data for the following Alpine Bog entities:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Bog 1 <input type="checkbox"/> Bog 2 <input type="checkbox"/> Bog 3 <input type="checkbox"/> Bog 4.2 <input type="checkbox"/> Bog 6 <input type="checkbox"/> Bog 11.1 <input type="checkbox"/> Bog 11.2 <input type="checkbox"/> Bog 12 <input type="checkbox"/> Bog 13 <input type="checkbox"/> Bog 4.1/5/7 <input type="checkbox"/> Bog 8/9/10 <input type="checkbox"/> Bog S1 <input type="checkbox"/> Bog S2 <input type="checkbox"/> Bog S3 	On-site at boundaries of Alpine Bog monitoring sites.	By 16 March	RMB Environment Manager and consultant lead
6. Ecological data collation			
<p>Following the steps in Section 5 of this SOP, collate the following ecological datasets, upload them to the RMB's servers and send them to a third-party cloud-based backup:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Ecological dataset in Microsoft Excel format. <input type="checkbox"/> Spatial dataset in ESRI Shapefile format, referenced to a suitable coordinate system. <input type="checkbox"/> Photo point photos in Joint Photographic Experts Group (JPEG or JPG) format. 	Off-site (after site visit).	By 31 May	RMB Environment Manager and consultant lead
8. Ecological data analysis and reporting			
<p>Following the steps in Section 6 of this SOP:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Analyse the ecological data, which will include updates to the ecological dataset spreadsheet. <input type="checkbox"/> Report on the results of the ecological data analysis. <input type="checkbox"/> Upload the updated ecological dataset in Microsoft Excel format to the RMB's servers and to the third-party cloud-based backup. 	Off-site (after site visit).	By 31 August	RMB Environment Manager and consultant lead

2 Ecological monitoring equipment

The equipment listed in Table 2 allows for the ecological monitoring component of the HEMAMP to be conducted safely, efficiently and accurately. Quantities of items are based on monitoring being conducted as two teams of two people working in proximity to each other i.e. within the same or adjacent monitoring sites (Alpine Bogs). The quantities include some redundancies in case equipment is lost or fails. Plate 1 shows the key transect, photo point and mapping equipment.

Table 2 Annual ecological monitoring equipment checklist

	Quantity	Item	Notes
Personal protective equipment			
<input type="checkbox"/>		Hat (wide brim)	
<input type="checkbox"/>		Sunglasses	
<input type="checkbox"/>		Clear safety glasses	
<input type="checkbox"/>		Sunscreen	
<input type="checkbox"/>		Protective gloves	Gloves for searching through prickly vegetation.
<input type="checkbox"/>		Long-sleeved shirts	
<input type="checkbox"/>		Long pants	
<input type="checkbox"/>		Gaiters	Cleaned before arrival on site.
<input type="checkbox"/>		Sturdy boots	Cleaned before arrival on site.
<input type="checkbox"/>		Beanie and scarf	
<input type="checkbox"/>		Warm jacket/jumper	
<input type="checkbox"/>		Warm gloves	
<input type="checkbox"/>		Thermals	
<input type="checkbox"/>		Rain jacket	
<input type="checkbox"/>		Rain pants	
<input type="checkbox"/>		Gumboots	Cleaned before arrival on site.
<input type="checkbox"/>		Large backpack	
<input type="checkbox"/>		Water bottles and/or water bladder	Minimum 2 litres.
Other safety equipment			
<input type="checkbox"/>		Safe Work and Environmental Method Statement (SWEMS)	
<input type="checkbox"/>		First aid kit (up to date)	Review and replenish contents before arrival on site.
<input type="checkbox"/>		4WD vehicle	Cleaned and maintained before arrival on site.
<input type="checkbox"/>	1/vehicle	Vehicle recovery kit	Cleaned and maintained before arrival on site.
<input type="checkbox"/>	1/vehicle	Phytoclean kit	
<input type="checkbox"/>		Insect repellent	
<input type="checkbox"/>	1/vehicle	10-litre vehicle water storage	Filled before arriving on site.
<input type="checkbox"/>		Electrolytes	
<input type="checkbox"/>		Cool storage with ice blocks	
<input type="checkbox"/>		In-car USB charger	
<input type="checkbox"/>	1/team	Compass	
<input type="checkbox"/>	1/team	Printed maps	
<input type="checkbox"/>	1	Satellite phone	Consider undertaking refresher training on satellite phone use before arriving on site.
<input type="checkbox"/>	1	Satellite GPS messenger (e.g. SPOT GPS)	Nominate and liaise with designated contacts before arriving on site.

	Quantity	Item	Notes
<input type="checkbox"/>	1	Emergency Position Indicating Radio Beacon (EPIRB)	Consider undertaking refresher training on EPIRB use before arriving on site.
<input type="checkbox"/>	1/team	Land manager contact details	
<input type="checkbox"/>	1/person	VicEmergency app	Establish watch zone for Mount Buller and Mount Stirling within at least 20 km radius.
Transect and photo point monitoring equipment			
<input type="checkbox"/>	1/tablet	Electronic field data collection spreadsheet	Verify and test spreadsheet before arrive on site. Create unique versions for each tablet.
<input type="checkbox"/>	2	GPS-enabled tablets	Pre-loaded with HEMAMP protocol (incl. this SOP), interactive maps of monitoring sites, labelled photo point photos from recent years, unique field data collection spreadsheet and flora list.
<input type="checkbox"/>	1	Printed SWEMS, HEMAMP, maps, photo point, data sheet and flora list booklet	Hard copy backup of HEMAMP protocol (incl. this SOP), maps, photos from recent monitoring years, physical data sheets and flora list.
<input type="checkbox"/>	1	Metal detector	
<input type="checkbox"/>	4	50-m tape measures with centimetre markings	
<input type="checkbox"/>	3	Small signboards (approx. 30 cm x 35 cm)	Whiteboards are suitable.
<input type="checkbox"/>	Many	Black whiteboard pens	Attach flagging tape to ends.
<input type="checkbox"/>	3	Signboard holding stakes (approx. 1 m long)	
<input type="checkbox"/>	4	Cameras or camera-enabled phones/tablets	Verify and test camera settings before arrival on site.
<input type="checkbox"/>	3	Steel pins (approx. 1.1 m long and 5 mm diameter)	Attach flagging tape to ends.
<input type="checkbox"/>	3	Lightweight 1 m x 1 m quadrats	At least one should ideally be collapsible.
<input type="checkbox"/>	2	Pairs of walkie talkies	Enables easier communication between the observer and data recorder.
<input type="checkbox"/>	2	Golf umbrellas	Protects data recorder and tablets from rain.
<input type="checkbox"/>	Many	Styluses	Attach flagging tape to ends.
<input type="checkbox"/>	Many	Pencils	Attach flagging tape to ends.
<input type="checkbox"/>	20	Replacement hardwood pegs (30-50 cm long)	
<input type="checkbox"/>	20+	Galvanised nails	
<input type="checkbox"/>	1	Mallet	Metal mallet for hammering pegs into ground.
<input type="checkbox"/>	2	Pink marking spray paint	
Plant identification equipment			
<input type="checkbox"/>	10+	A3 or A4 plastic plant sample bags	For vascular plant samples.
<input type="checkbox"/>	50+	A5 paper envelopes	For bryophyte samples.
<input type="checkbox"/>		Field guides and taxonomic keys	Including access to VicFlora.
<input type="checkbox"/>		Field herbaria	Scrapbooks of plant samples from previous years.
<input type="checkbox"/>	1	Scrapbook and clear tape	For new field herbarium.
<input type="checkbox"/>	1	Microscope	
<input type="checkbox"/>	2	Hand lens (10-30 x magnification)	
<input type="checkbox"/>	2	15 cm ruler with sub-mm markings	
<input type="checkbox"/>	2	Tweezers	
<input type="checkbox"/>	2	Pocket knife	
Mapping equipment			
<input type="checkbox"/>	2	DGPS with suitable correction settings	For example, Trimble R1 or Emlid Reach RS2.
<input type="checkbox"/>	1	Extendable DGPS survey pole	Ideally extendable from approx. 1.5 m to 4 m.

	Quantity	Item	Notes
<input type="checkbox"/>	1	Tablet paired with DGPS	Pre-loaded with interactive maps of monitoring sites and key to Alpine Bogs.
<input type="checkbox"/>	1	Printed key to Alpine Bogs	
Miscellaneous equipment			
<input type="checkbox"/>		Electrical power board	With a minimum of six sockets.
<input type="checkbox"/>	8	USB chargers and cables	
<input type="checkbox"/>	2	Portable USB battery packs	
<input type="checkbox"/>	2	Headlamps	
<input type="checkbox"/>		Flagging tape	Full roll.
<input type="checkbox"/>		String line	Full roll.
<input type="checkbox"/>		Duct tape	Full roll.



Plate 1: Important ecological monitoring equipment, including (from left to right, top to bottom): extendable DGPS survey pole; steel pin; DGPS; tablet with stylus; plant sample bag and envelope; signboard holding stake; 1 m x 1 m quadrat; 50-m tape measures; metal detector; golf umbrella; printed booklet with SWEMS, HEMAMP protocol, maps, photo points, data sheets, flora list and key to Alpine Bogs; galvanised nails; mallet; small signboard with whiteboard pen; and replacement hardwood pegs.

3 Transect monitoring

Transect monitoring is best conducted in groups of two people: one observer and one recorder. The use of two people allows for the transect line to be accurately set up, minimises trampling of the Alpine Bogs and increases the efficiency of data collection. As much as possible, the step-by-step procedure outlined below should be followed for collecting data at a given transect. The monitoring transects do not need to be completed in any particular order.

3.1 Set up the transect

1. Navigate to the start of the transect using a GPS enabled device (e.g. a tablet with pre-loaded interactive maps showing locations of monitoring sites). The starts and ends of transects are marked with permanent short wooden pegs. Note that it is preferable to locate the start peg first, as this minimises trampling of vegetation.
2. All monitoring equipment (backpacks, whiteboards etc.) should be left out of sight of photo point photos near the start or end of the transect. For consistency of photo point photos, it is important that no equipment or people are visible in the photos, except for the signboard, signboard holder and transect tape.
3. Locate the wooden peg that marks the start of the transect (see Plate 2). Photo point photos from previous years assist greatly in finding the location of the peg. All pegs protrude from the ground by 5-20 centimetres, depending on how exposed the location. All pegs have been previously sprayed pink (Plate 3), although the pink colouring may have worn off since the previous monitoring. If the start peg is difficult to find, it may be preferable to locate the end peg first, which will assist in locating the start peg.



Plate 2: Example of a wooden peg used to mark the starts and ends of transects.



Plate 3: Example of a wooden peg after having been coloured pink.

4. If the wooden peg cannot be located with reference to photo point photos, a DGPS and/or metal detector may assist. The top of each peg has a metal nail hammered into it, which should trigger a metal detector.
5. Once the start or end peg has been found, refer to the data collection spreadsheet to determine the length ('L') of the transect in question and refer to the map of monitoring sites and previous photo point photos to determine the approximate direction of the transect. In general, transects start uphill and end downhill.
6. Attach a flexible measuring tape to the wooden peg, noting that the start peg should be at 0 metres and the end peg should be at 'L' metres along the tape, where 'L' is the length of the transect.
 - a. If starting at the start peg (the preferred approach), the tape should be attached at the start peg using the hook at the end of the tape. One person may need to hold the hook in place until the tape is secured to the end peg.
 - b. If starting at the end peg (the alternative approach), the tape should ultimately be wound around the end peg at 'L' metres along the tape. However, one person may need to hold the tape above the vegetation until the tape is extended and hooked onto the start peg.
7. With the tape attached to the peg or with one person holding the tape at the peg location, the other person should walk to the opposite end of the transect with the tape in hand. It is important that the route that is taken to the other end of the transect is not directly along the transect line itself. Instead, an indirect, curved route should be taken. This is to avoid trampling vegetation along the transect, which would not only compromise monitoring results by moving vegetation before point intersect data are collected, but may also lead to long term degradation of the Alpine Bog vegetation.
 - a. If walking from the start peg to the end peg (the preferred approach), be sure to also carry a camera, signboard, signboard holder, whiteboard pen and tablet or photo point booklet to

the other end. This minimises the number of trips from each end of the transect and therefore minimises vegetation trampling. One person should remain at the start peg and assist in reeling out, straightening and securing the tape.

- b. If walking from the end peg to the start peg (the alternative approach), there should not be any need to carry additional equipment. One person should remain at the end peg and assist in reeling out, straightening and securing the tape.
- 8. Use photo point photos, the known length of the transect and the measuring tape to locate the other wooden peg at the end of the transect. Again, a DGPS and/or metal detector may assist if the end peg is difficult to locate.
- 9. Once the start and end pegs have been located, ensure that the tape is as straight as possible from start to end and reasonably taught. If not already, attach the tape to both pegs using the hook at the start peg and by wrapping the tape around the end peg. Ensure that the tape is attached as closely as possible to the 'L'-metre mark at the end peg.

3.2 Take photo point photos

- 10. Label the signboard with the name of the transect, followed by the letter 'E' (to denote 'end'). Use signboard labels from previous photos as a guide for how to label the signboard.
- 11. Using the signboard holder stake, position the signboard at 'L-4' metres along the transect line (i.e. 4 metres along the transect line from the end peg), approximately 1 metre off the ground (Plate 4).
 - a. Avoid trampling vegetation, especially along the transect line, while positioning the signboard.
 - b. If the signboard is not visible due to the height of vegetation, one person may need to hold the signboard in place and it may need to be held slightly higher than 1 metre (use previous photos as a guide as to whether this approach may need to be taken).
 - c. If a person needs to hold the signboard, try to ensure that the person holding the signboard is as hidden as possible from view and not overly obscuring the vegetation. The objective is to capture an image of the vegetation, not the people undertaking the monitoring.



Plate 4: Positioning the signboard at the 4-metre mark from the start of the transect.

12. Verify that the camera settings are correct. Camera settings are as follows (particular attention should be paid to those that are underlined, as they can easily be inadvertently changed between photos):
 - a. Landscape mode.
 - b. No optical or digital magnification.
 - c. Natural lighting (no flash).
 - d. ISO speed of ISO-40 to ISO-64, but very occasionally ISO-80 or higher.
 - e. An aperture (F stop) of f/1.9.
 - f. Variable exposure times (shutter speeds), depending on light levels.
 - g. Scale of 16:9 (minimum 4032 x 2268 pixels).
 - h. Resolution of 72 dpi.
 - i. Geolocation tags turned on.
 - j. No post-processing, enhancement or modification.
13. Standing with the camera positioned approximately 1.6 metres above the ground and directly above the wooden peg, take a photo of the length of the transect, noting the following (Plate 5):
 - a. The signboard should be in the centre of the field-of-view and in focus. The centring and focus of the photo can be easily missed. It is important to ensure that the lens is focused on the signboard to ensure consistency of photos between years and to ensure that vegetation in the mid- and foreground is in focus (rather than distant vegetation in the background being in focus).
 - b. The transect tape should be straight and run vertically up the middle of the photo. If the tape does not appear straight, it may need straightening or the camera may not be positioned above the wooden peg.
 - c. Some cameras allow for gridlines to be superimposed on the field of view, which can assist in centring the photo on the signboard and verifying that the camera is angled directly up the transect line.
 - d. No monitoring equipment or personnel should be visible in the photo, except for the transect tape, signboard and signboard holder. Care should also be taken to ensure that the camera lens is not inadvertently covered (e.g. by a finger).
14. Once the photo has been taken, compare it with photos taken in previous years from the same photo point. Pay attention to the relative size of the signboard, the straightness or angle of the transect tape and prominent features in the foreground and background. If the photo appears different, check the following before re-taking the photo:
 - a. The name and location of the photo point has been correctly identified.
 - b. Camera settings are correct (refer to Step 0).
 - c. The positioning and focus of the camera is correct (refer to Step 13).
15. Once the accuracy of the photo from the end peg has been verified, dismantle the signboard and signboard holder. Return to the start peg with all equipment except for the tape. Again, it is important that the route taken back to the start peg is not directly along the transect line. Instead, an indirect, curved route should be taken.
16. Re-label the signboard with the name of the transect, followed by the letter 'S' (to denote 'start'). Use signboard labels from previous photos as a guide for how to label the signboard.
17. Repeat Steps 11-14, this time positioning the signboard at 4 metres along the transect (i.e. 4 metres along the transect line from the start peg).
18. Once the accuracy of the photo from the start peg has been verified, dismantle the signboard and signboard holder.
19. Update the data collection spreadsheet to indicate that photo point photos have been taken for the transect. At the same time, the date and the initials of the recorder and observer should also be added to the metadata for the transect on the data collection spreadsheet.

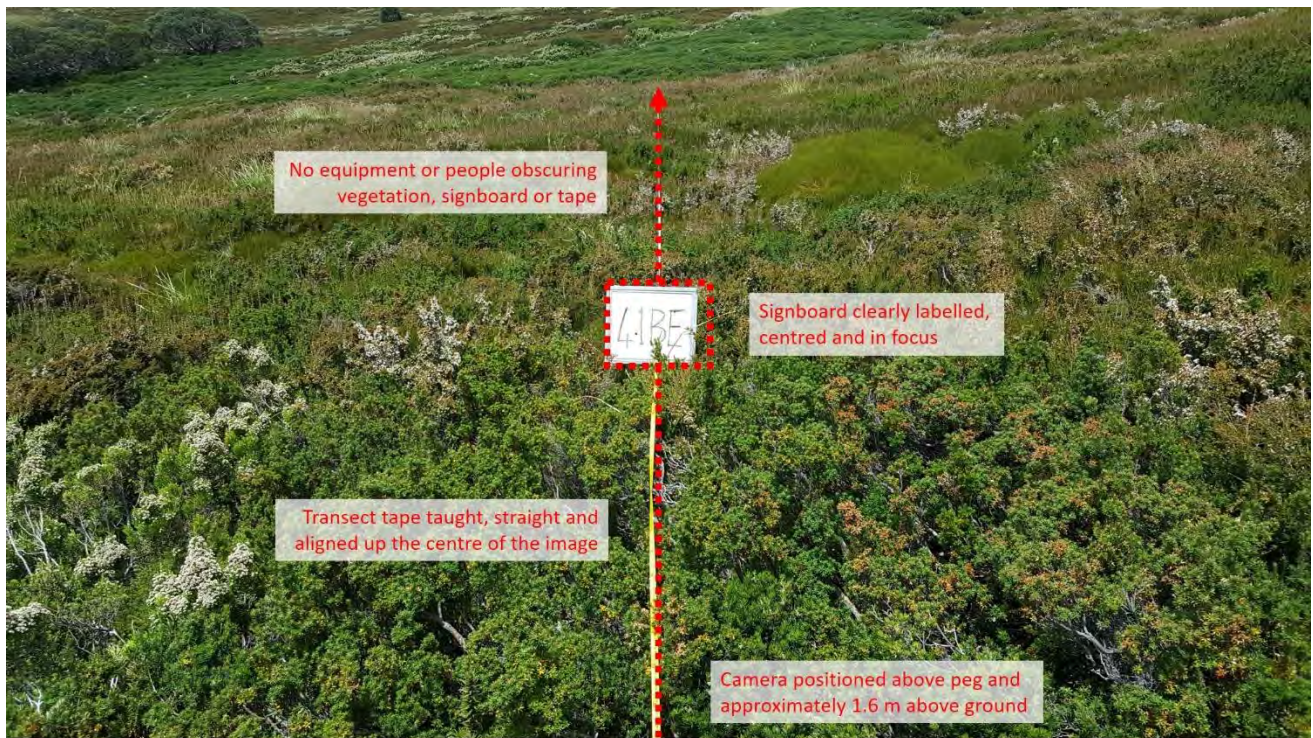


Plate 5: Annotated example of a well-executed photo point photo.

3.3 Record point intercept data

20. One person (the recorder) should position themselves with a tablet (pre-loaded with the field data collection spreadsheet) near the start of the transect. The following items may assist with data entry:
 - a. A stylus can improve usability of the spreadsheet and minimise the risk of incorrect data inadvertently being added.
 - b. If it is raining, a golf umbrella can assist in shielding the recorder and tablet from rain drops, which can interact with the tablet screen and also result in the addition of spurious data.
 - c. Walkie-talkies may assist with communication between the observer and recorder, especially on long transects (greater than 20 metres) and when rain or wind makes communication difficult.
21. The other person (the observer) should have sufficient training and/or experience to be able to identify the flora species along the transect. The observer must determine the species and ground condition that are present at 20-centimetre intervals ('points') along the transect, starting at 0.2 metres and ending at 'L minus 0.2' metres along the transect.
22. At each 20-centimetre point along the transect, the observer must insert a 1.1-metre long, 5-millimetre diameter steel pin vertically into the vegetation, such that the pin hits the ground or cannot descend further into the vegetation i.e. the pin encounters resistance (Plate 6). Once the pin is in position, the observer must communicate the following information to the recorder for entry into the field data collection spreadsheet:
 - a. Distance along the transect i.e. the 20-centimetre interval point.
 - b. All flora species that are touching the pin along any part of the pin's length. Attention should be paid to the following:
 - Only those species touching the pin should be recorded, not species that are above the pin.

- The observer should check the full length of the pin (Plate 7). If this requires vegetation to be moved out of the way, it should be done progressively from the top to the bottom of the pin, while communicating the names of species that were (and perhaps still are) touching the pin. This is to avoid missing species. In addition, care should be taken to avoid inadvertently recording species that have been moved against the pin by the observer. Similarly, movement of vegetation at the next 20-centimeter interval should be minimised.
 - If the species cannot be identified in the field (e.g. if high magnification is required), a temporary name should be added to the spreadsheet and a small sample of the species should be taken from nearby (rather than from the transect itself) for later identification.
- c. The condition of each species that is touching the pin, categorised as follows:
- Alive: where living plant material is present on any of the plants that are touching the pin and that belong to the species in question. Living plant material is inferred by the presence of photosynthesising tissue i.e. 'green' tissue. If two or more individuals of a species are touching the pin at a given transect point, only one individual needs to be considered 'alive' for the species to be recorded as 'alive'. Even if the branch or leaf that is touching the pin appears to be dead, the plant is considered as 'alive' if the branch or leaf that is touching the pin is attached to a part of the plant that is clearly alive.
 - Dead: where all individuals belonging to the species in question and touching the pin are dead. Dead individuals are inferred by a clear lack of photosynthesising tissue. If two or more individuals of a species are touching the pin at a given transect point, all individuals would need to be considered 'dead' for the species to be recorded as 'dead'. In addition, the entire plant that is touching the pin must be considered 'dead', not just the part of the plant that is touching the pin.
- d. The ground condition at the base of the pin, categorised as follows:
- Vegetation: attached plant material, whether dead or alive. This category is used where the base of the pin rests on vegetation, such as the woody stem of a shrub or the rosette leaves of a herb, in which case the species and condition of the vegetation are also recorded.
 - Litter: detached plant material, whether dead or alive. Note that a large branch that has broken from the main plant is considered to be 'litter'.
 - Rock: substrate comprising cobbles, boulders or bedrock i.e. anything with a particle size greater than 64 millimetres and therefore not easily erodible in an Alpine Bog context (EPA 2003).
 - Bare ground: substrate comprising silt, sand, gravel or pebbles i.e. anything with a particle size of 64 millimetres or less and therefore easily erodible in an Alpine Bog context (EPA 2003). Bare ground is further categorised as follows:
 - Bare ground (deer): where the bare ground is probably linked to deer activity, evidenced by the presence of a deer wallow, track, print and/or scat.
 - Bare ground (sedimentation): where the substrate appears to have originated from outside the bog (i.e. allochthonous) and is typically made up of inorganic fines such as clay. This sub-category generally targets sediment from the water storage project and can be determined by sight and feel (the clay-like consistency and colour of the sediment) and/or by tracing the source of the sediment uphill.
 - Bare ground (natural): attributed to all other instances of bare ground, typically where the substrate is a dark, organic-rich humus and/or peat.

- Water: running water (which is generally rare, except after rain) or a standing pool or puddle of water (which is generally more common).
 - Note that the above ground conditions are mutually exclusive i.e. only one ground condition should be recorded at any given point. The exception is for the 'deer' and 'sedimentation' sub-categories of bare ground. These sub-categories were added in IY2 and may co-occur with one of the other ground conditions e.g. where sediment has accumulated at the bottom of a standing pool of water, 'bare ground (sedimentation)' and 'water' would be recorded as the ground condition.
23. Once the observer reaches approximately 1 metre beyond each 4-metre interval along the transect (i.e. at 5, 9, 13, 17 etc. metres along the transect), the observer should pause point intercept observations and record quadrat observations at the 4-metre interval. Collecting point intercept and quadrat data concurrently minimises trampling of the Alpine Bog vegetation. However, at any given location along the transect, point intercept data should be collected before quadrat data because the quadrat is likely to disturb the positioning of the vegetation and therefore has the potential to compromise the point intercept data.



Plate 6: An observer inserting the steel pin with pink tape vertically into Alpine Bog vegetation at one of the 20-centimetre transect intervals. The steel pin is flagged at the top with pink tape.



Plate 7: Examples of the steel pin positioned vertically along a monitoring transect, with views progressively further down the pin from left to right.

3.4 Record quadrat data

24. At each 4-metre interval along the transect, the observer must position a 1-metre by 1-metre quadrat such that the centre of the quadrat is at the 4-metre interval mark (Plate 8). For example, a quadrat positioned at 4 metres along the transect will start at 3.5 metres, end at 4.5 metres and extend 0.5 metres each side of the transect tape.
25. Once the quadrat is in position, the observer must communicate the following information to the recorder for entry into the field data collection spreadsheet:
 - a. Distance along the transect i.e. each 4-metre interval.
 - b. All flora species that are within the quadrat, including above or below the quadrat. Attention should be paid to the following:
 - The observer should check the full area of the quadrat, recording everything above and below the quadrat frame. This includes overhanging trees (e.g. Snow Gum *Eucalyptus pauciflora*) and shrubs (e.g. Mountain Tea-tree *Leptospermum grandiflorum*, which may be above the observer).
 - If a species cannot be identified in the field (e.g. if high magnification is required), a temporary name should be added to the spreadsheet and a small sample of the species should be taken from nearby (preferably not from the quadrat or transect) for later identification.
 - c. The condition of each species, categorised as follows:
 - **Alive:** where living plant material is present on any of the plants that are within the quadrat and that belong to the species in question. Living plant material is inferred by the presence of photosynthesising tissue i.e. 'green' tissue. If two or more individuals of a species are within the quadrat, only one individual needs to be considered 'alive' for the species to be recorded as 'alive'. Even if the plant part that is within the

quadrat appears to be dead, the plant is considered as 'alive' if the plant part is attached to a plant that is clearly alive.

- **Dead:** where all individuals belonging to the species in question and within the quadrat are dead. Dead plant material is inferred by a clear lack of photosynthesising tissue. If two or more individuals of a species are within the quadrat, all individuals would need to be considered 'dead' for the species to be recorded as 'dead'. In addition, the entire plant must be considered 'dead', not just the part of the plant that is within the quadrat.



Plate 8: Example of a quadrat positioned at a 4-metre interval along a monitoring transect.

3.5 Data and infrastructure quality check

26. When the observer reaches the end of the transect and has finished communicating all point intercept and quadrat data, the recorder must perform a data quality check before the transect tape is detached from the wooden pegs.
27. The field data collection spreadsheet has been programmed to highlight certain missing or erroneous data in red. For example, cells at the top of the spreadsheet will be highlighted red if no ground condition has been recorded or if two mutually exclusive ground conditions have been recorded. The recorder must ensure that there are no red cells present in the field data collection spreadsheet.
28. If red cells are present (Plate 9), the recorder must request that the observer return to the location of the missing or erroneous data and re-communicate observations from that point/quadrat.
29. Before winding in the transect tape, the observer and recorder should examine the quality of the wooden pegs. The recorder should note any maintenance issues (e.g. loose or rotten pegs) in the field data collection spreadsheet. Loose or rotten pegs must be replaced as soon as possible to ensure that they are placed in exactly the same location. Ideally, replacement wooden pegs should be instated while the transect tape is still extended to assist in positioning the new peg in exactly the same location as the old peg.

30. Finally, any improvements that could be made to the data collection technique or methods should also be noted in the field data collection spreadsheet.

*Recorder:				
*Date:				
Bog:	1			
Transect	A			
Treatment	Control			
Data:	Point			
*Start photo required				
*End photo required				
Length: 24	Data has been entered into this column	Missing required condition	Data has been entered into this column	Data has been entered into this column
Species	0.2	0.4	0.6	0.8
Bare Ground (sedimentation)				
Bare Ground (deer)				
Bare Ground (natural)				
Litter	Present		Present	Present
Rock			Present	
Vegetation				
Water				
Baeckea gunniana				
Baeckea utilis s.s.				
Carex appressa				
Empodisma minus				
Epacris paludosa				
Hovea montana			Alive	Alive
Leionema phyllicifolium	Alive	Alive	Alive	
Ozothamnus cupressoides	Alive			
Poa costiniana				
Podolobium alpestre				
Richea continentis				
Stellaria pungens	Alive			Alive
Stylidium armeria subsp. armeria				

Plate 9: Example of a field data collection spreadsheet with red cells indicating missing or incorrect data, including missing metadata, a missing ground condition at 0.4 metres and a double-up of mutually exclusive ground conditions at 0.6 metres.

3.6 Dismantle the transect line

31. Once the quality check is complete, the tape can be detached from the pegs and wound in.
 32. The pegs must remain in place for future monitoring. If the pink spray paint has worn off the peg, consider re-spraying it.

3.7 Back up transect data

33. At the end of the day, the field data collection spreadsheet and all new photo point photos should be uploaded to the cloud as a backup.

3.8 Prepare for the next day of monitoring

34. In preparation for the next day of monitoring, charge all tablets, phones, cameras and safety devices overnight.

4 Alpine Bog mapping

Alpine Bog mapping is best conducted by a single person (the mapper) and, if possible, under clear skies (minimal cloud cover). The single person minimises trampling of vegetation, although at least one other person should be nearby for safety reasons. The other person(s) can be completing transect monitoring or other management activities (e.g. weed control) while mapping is taking place. Mapping under clear skies assists with DGPS connectivity to satellites and results in improved locational accuracy. As far as possible, the step-by-step procedure outlined below should be followed for mapping a given Alpine Bog. The Alpine Bogs do not need to be mapped in any particular order.

4.1 Set up equipment

1. Start by establishing satellite connections with the Differential Global Positioning System (DGPS) unit, which can take up to 15 minutes. This generally involves switching on the DGPS unit and positioning it in a location with a clear view of the sky (not within a building or vehicle and preferably not in an area of dense canopy cover).
2. While waiting for satellite connections to be established, check the following:
 - a. Ensure that the DGPS unit is paired with the tablet on which spatial/mapping data will be collected. The DGPS unit should be connected to the tablet via Bluetooth.
 - b. Ensure that the tablet's in-built GPS is disabled. It is important that the tablet is receiving locational information from the DGPS unit, rather than the in-built GPS, which is less accurate. At the very least, the application being used to collect spatial data should be sourcing locational information from the DGPS unit.
 - c. Ensure that the tablet and DGPS unit have sufficiently charged batteries (ideally more than 50% charge). Low battery may compromise locational accuracy. If necessary, plug the devices into a portable battery pack.
 - d. Ensure that the DGPS unit's correction settings are appropriate, as these can greatly affect locational accuracy. Without appropriate differential corrections, the locational accuracy of the DGPS unit may be no better than a standard GPS unit. Correction settings are generally verified using an application developed by the DGPS unit's manufacturer and available on the tablet. Settings may vary depending on the DGPS unit being used. In general, corrections received over the internet are faster and provide greater accuracy than corrections received from satellites. However, since the HEMAMP's Alpine Bog mapping started in 2018, improvements to satellite and DGPS technology have meant that the differences in accuracy between these two correction methods is now almost unnoticeable. In some cases, corrections via satellite may actually provide greater locational accuracy, especially in locations where mobile internet reception is poor (e.g. some parts of Mount Stirling).
3. Once Steps 1 and 2 have been completed, verify that the locational accuracy of the DGPS unit is better than 1 metre. When Alpine Bog mapping started in 2018, locational accuracy of up to 3 metres was common. With technological improvements since 2018, sub-metre accuracy should now be expected and achievable at all monitoring sites (including Mount Stirling). The locational accuracy of the DGPS should be verified using two applications on the tablet: the DGPS unit's application (used to check the DGPS unit's settings) and the mapping application (used to collect the spatial data). If sub-metre locational accuracy is not being achieved on either application, consider re-starting the DGPS unit and repeating Steps 1 and 2.
4. If sub-metre accuracy still cannot be achieved (which would be unusual), two contingencies must need considering:
 - a. Mapping may need to be postponed until weather conditions are more favourable. Cloudless skies are the most ideal conditions.

- b. A local base station may need to be established in proximity to the Alpine Bogs. The base station would typically be another DGPS unit that remains stationary as a reference point for the first DGPS unit. Establishing a base station with a known position can be very time-consuming (potentially several hours) and has never before been necessary. It should only be a last resort.
5. Once the DGPS unit and tablet are reporting sub-metre accuracy, spatial data collection can begin, using an interactive mapping application, pre-loaded with Alpine Bog mapping from previous years.

4.2 Map the Alpine Bog boundary

6. Using the tablet's interactive mapping application and Alpine Bog boundaries as previously mapped, navigate to the approximate edge of the Alpine Bog as previously mapped.
7. The Alpine Bog boundary must be mapped as a polygon feature with many vertices. Create a new Alpine Bog boundary polygon feature with the following metadata:
 - a. Bog number.
 - b. Date.
 - c. Notes on the locational accuracy achieved during mapping. This may be expressed as a range (e.g. 10-30 centimetres) and will need to be periodically updated as the mapping progresses.
8. The Alpine Bog polygon must then be mapped as a series of vertices in a clockwise direction, as follows:
 - a. Confirm that an Alpine Bog is still present in the vicinity using the Diagnostic Key to Alpine Bogs (see next page).

Key to the listed Alpine *Sphagnum* bogs and Associated Fens ecological community on the Australian mainland

The listed ecological community comprises two main components, *Sphagnum* bogs and their associated fens. Fens, or fen pools, are species-poor communities typically linked to bogs. They are dominated by sedges and frequently inundated. The bogs which surround or link to fens generally display greater species diversity, and it is this diversity which in part guides the following key.

1. Are you above 1000m in elevation and in the Australian Alps bioregion?
 Yes – go to 2
 No – Unlikely to be the listed community
2. Is live, hummock-forming *Sphagnum* present and abundant, or if burnt¹, can abundant pre-fire *Sphagnum* be inferred from burnt remnants?
 Yes – Is the listed community
 No, *Sphagnum* is minor or absent – go to 3
3. Does the site have a peat substrate evident?
 Yes, or unsure – go to 4
 No – Unlikely to be the listed community
4. Is *Sphagnum* present?
 Yes – go to 5
 No – go to 6
5. Is most of the non-*Sphagnum* vegetation cover composed of two or more of the diagnostic species listed below?
 Yes – Is the listed community.
 No – Not the listed community, but may be transitional or a degraded version²
6. Is most of the vegetation cover composed of 3 or more of the diagnostic species?
 Yes – Is the listed community, possibly degraded.
 No – Not the listed community, but may be transitional or a degraded version²

Diagnostic species other than *Sphagnum*:

- *Empodisma minus*
- *Epacris* spp (usually *E. paludosa*, *E. glacialis*, *E. celata* or *E. breviflora*)
- *Richea* spp (*R. continentis* or *R. victoriana*)
- *Baeckea* spp (usually *B. gunniana*, *B. latifolia* or *B. utilis*)
- *Astelia alpina*
- *Carpha nivicola*
- *Baloskion australe*
- *Carex gaudichaudiana*
- *Callistemon pityoides*
- *Hakea microcarpa*
- *Carex jackiana*³
- *Hierochloe redolens*³
- *Olearia algida*³

¹ If a site has been recently and severely burnt, *Sphagnum* and other key diagnostic species may be temporarily absent (live hummock-forming *Sphagnum* would normally comprise at least 20-30% cover). In this case, assessment of the site for the listed community should be delayed for at least 24 months. However, the presence of burnt hummocks over peat indicates the community is present.

² Clarification: no need to refer.

³ This key originally appeared in a draft version of the National Recovery Plan for the Alpine *Sphagnum* Bogs and Associated Fens. The key has been left unchanged except for the addition of these three species and this footnote. These species have been added by Biosis for the purposes of monitoring Alpine Bogs at Mount Buller and Mount Stirling, Victoria. At these locations, *Carex jackiana*, *Hierochloe redolens* and *Olearia algida* are restricted to Alpine Bogs and are therefore amongst the diagnostic species.

- b. Once presence of an Alpine Bog is established, the boundary of the Alpine Bog is mapped along the line on which bog-dependent flora are dominant on one side but not dominant on the other side i.e. where bog-dependent flora make up at least 50% of the vegetative cover on one side but less than 50% of the vegetative cover on the other side. It is important to note the following when assessing whether or not bog-dependent flora are dominant:
- The following flora species are considered 'bog-dependent':
 - Silver Astelia *Astelia alpina* var. *novae-hollandiae*
 - Alpine Baeckea *Baeckea gunniana*
 - Subalpine Baeckea *Baeckea latifolia*
 - Mountain Baeckea *Baeckea utilis* s.s.
 - Alpine Bottlebrush *Callistemon ptyoides*
 - Carpet Sedge *Carex jackiana*
 - Spreading Rope-rush *Empodisma minus*
 - Swamp Heath *Epacris paludosa*
 - Sweet Holy-grass *Hierochloa redolens*
 - Mountain Daisy-bush *Olearia algida*
 - Candle Heath *Richea continentis*
 - Peat Moss *Sphagnum* spp.
 - The following species are considered 'neutral' for the purposes of mapping Alpine Bog boundaries (the cover of these species is not included in total vegetation cover because they are typical of Alpine Bogs at Mount Buller and Mount Stirling but not strictly 'bog-dependent'):
 - Bidgee-widgee *Acaena novae-zelandiae*
 - Alpine Water-fern *Blechnum penna-marina* subsp. *alpina*
 - Tall Sedge *Carex appressa*
 - All bryophytes others than Peat Moss.
- c. Place the DGPS unit on or directly above the current Alpine Bog boundary (Plate 10). It is crucial that the DGPS unit is positioned on or directly above the boundary of the Alpine Bog because it is the location of the DGPS unit that is being recorded, not the location of the tablet or the mapper. This can be advantageous for minimising trampling of Alpine Bogs because the mapper can stand outside the Alpine Bog and use the extendable DGPS survey pole to position the DGPS unit above the Alpine Bog boundary, without any need to enter the Alpine Bog.
- d. The DGPS unit may need to be held still for a few seconds for sub-metre accuracy to be achieved. Once this has occurred, 'drop' a polygon vertex at the current location of the DGPS device. This should be done with the 'use my location' function or similar, rather than manually positioning the vertex at the location where you perceive the DGPS unit to be. Manual positioning of vertices will reduce the accuracy of the mapping and should be avoided, except where temporarily needed to avoid polygon lines becoming crossed (see Step 8e).
- e. While mapping the polygon, ensure that the polygon's lines never cross. If the polygon is completed at a moment when the polygon's lines cross, the polygon may be split at the points of intersection, making it very difficult to further edit the polygon and making the polygon an inaccurate representation of the true Alpine Bog extent. Crossed lines can be particularly problematic when initially starting the polygon. For this reason, when first starting the polygon, it is prudent to manually add several (e.g. 3-6) temporary vertices around the previous Alpine Bog boundary, to very roughly capture the previous Alpine Bog extent. As the mapper approaches one of these temporary vertices, the temporary vertex can be deleted and replaced with a vertex that represents the current Alpine Bog boundary.



Plate 10: Emlid RS2 DGPS unit, attached to an extendable DGPS survey pole and positioned on the boundary of an Alpine Bog, with non-bog-dependent species dominant in front of the DGPS unit (in the foreground) and bog-dependent species dominant behind the DGPS unit (in the background).

- f. In a clockwise direction, start to walk the boundary of the Alpine Bog, as identified using the Diagnostic Key to Alpine Bogs. Polygon vertices should be 'dropped' approximately every 0.5-2 metres (use previous mapping as a guide to mapping resolution). This may be achieved using a vertex 'streaming' function or similar. If a 'streaming' function is used, a 5-second streaming interval is recommended to allow for sufficient mapping resolution and it should be set up to only collect vertices when sub-metre accuracy is being achieved. Previous mapping was conducted in a clockwise direction because this direction was most compatible with the 'use my location' and 'streaming' functions. It is important that mapping continue in a clockwise direction for consistency.
- g. At regular intervals, update the notes on locational accuracy and be sure to 'complete' the polygon by tapping the 'done' icon (or similar). This will ensure that the polygon as mapped up to that point is saved locally to the tablet.

4.3 Note changes to Alpine Bog extent and management issues

9. While mapping the Alpine Bog boundary, compare the current Alpine Bog boundary with the boundary as mapped in previous years. This will highlight potential changes to the Alpine Bog boundary and provide an opportunity to investigate and document these changes more closely while at the location of the change (rather than having to return and cause further trampling of vegetation).
10. Where there appears to have been a loss in Alpine Bog extent (when compared with previous years), the loss of Alpine Bog should be mapped as follows:

- a. Where the loss has occurred at the edge of the Alpine Bog, the new Alpine Bog boundary will extend further inwards as an incursion towards the centre of the Alpine Bog. If the incursion is substantial, potential causes should be noted (see Step 11).
 - b. Where the loss has occurred inside the Alpine Bog (i.e. towards the middle of the Alpine Bog), a separate 'hole' or 'cut out' polygon will need to be mapped within the broader Alpine Bog polygon. This new and separate polygon should feature the same metadata as the broader Alpine Bog polygon. The bog number should be appended with the words 'hole' or 'cut out' to indicate that the area of this polygon will ultimately need deleting from the overall Alpine Bog area. Potential causes of the 'hole' should be noted (see Step 11).
 - c. Where the Alpine Bog has been fragmented, it should be mapped as two or more polygons. These separate polygons should have the same metadata (bog number and date) because their areas will ultimately be combined for Alpine Bog extent analysis. Potential causes of the fragmentation should be noted (see Step 11).
11. Important observations regarding Alpine Bog extent or management issues should be recorded in a consistent fashion using 'note' features or similar. These 'note' features should be accompanied by the following metadata:
- a. The type of observation e.g. 'floristic change', 'sedimentation', 'deer', 'weeds' etc. To aid in filtering this observational data at a later point, it is important that the labels that are used are consistent with labels used in previous years and in the current year. As a guide:
 - 'Floristic change' is generally used to indicate that there appears to have been a change to the composition of species present at a location. This is often used when the cause of the change is unknown. It may be used when there has been a local change in Alpine Bog extent that needs further investigation or may also be used to signal an area where there is likely to be a change (positive or negative) in Alpine Bog extent in the future.
 - 'Sedimentation' is used to indicate areas where sediment, which is likely to have originated from the Project Construction Footprint, has had an impact on bog-dependent species.
 - 'Rock/boulder' is used to mark the location of rocks or boulders that are likely to have originated from the Project Construction Footprint and to track the rehabilitation of these locations over time.
 - 'Deer' is used to denote damage to vegetation caused by deer, whether wallows, tracks, trampling and/or browsing (as evidenced from prints and scats).
 - 'Rabbits' is used to denote damage to vegetation caused by rabbits, whether burrows, diggings or browsing (as evidenced from drying vegetation and scats).
 - 'Horses' is used to denote damage to vegetation caused by horses (as evidenced from prints and scats).
 - 'Weeds' is used to mark serious weed invasions, particularly novel weeds and/or invasions that have reduced Alpine Bog extent.
 - b. Date.
 - c. Detailed notes on the observation and links/references to accompanying photos. If there appears to have been a reduction in Alpine Bog extent at the given location, there should be an explanation of what may have caused this (e.g. mortality of bog-dependent species or proliferation of weeds). Other information to assist monitoring and management actions may include the depth of sediment, the approximate size (area) and freshness of the deer wallow and the major weed species that are proliferating.

4.4 Back up spatial data

12. After mapping the entire Alpine Bog boundary and returning the starting position, ensure that there are no remaining temporary vertices, added to prevent the polygon's lines from crossing. Delete any that remain.
13. Update the polygon's metadata with any final observations about locational accuracy.
14. 'Complete' the polygon by tapping the 'done' icon (or similar).
15. As soon as mobile internet service is available, all spatial mapping data should be backed up by synchronising the interactive mapping application with the cloud.

4.5 Prepare for the next day of monitoring

35. In preparation for the next day of monitoring, charge all DGPS units, tablets, phones, cameras and safety devices overnight.

5 Ecological data collation

Ecological data collation should be performed in the office with a desktop computer that has access to the cloud-based data backups.

5.1 Extract and collate transect data

1. Follow the instructions in the 'Read Me' tab of the field data collection spreadsheet to extract the transect data from the spreadsheet.
2. Follow the instructions in the 'Read Me' tab of the ecological dataset spreadsheet to append the extracted transect data to all other transect data collected in previous years. This 'Read Me' tab also contains instructions for analysing the new data (see Section 13 of this SOP).
3. The ecological dataset spreadsheet must have the current date appended to the filename.

5.2 Calculate and collate Alpine Bog areas

4. There must be no post-processing of Alpine Bog boundaries (i.e. no editing of polygon lines or vertices after mapping has been completed in the field), except where:
 - a. 'Holes' or 'cut outs' have been mapped, in which case they will need to be extracted from the broader Alpine Bog polygons in which they have been mapped.
 - b. Two or more Alpine Bogs (e.g. Bogs 11.1 and 11.2) share a common boundary, in which case one boundary will likely need clipping to the other boundary.
5. Access the spatial mapping data via a desktop computer. The data should be available in the cloud.
6. Using the 'calculate geometry' function (or similar) in a suitable Geographic Information System (GIS) program, calculate the total area, perimeter and number of polygons (fragments) for each Alpine Bog.
7. Add the calculated totals to the ecological dataset spreadsheet, following the instructions in the 'Read Me' tab.
8. Export all spatial data (including Alpine Bog boundaries and any observational 'note' points) in ESRI Shapefile format referenced to a suitable coordinate system (e.g. GDA 2020).

5.3 Label and collate all photo point files

9. There must be no post-processing or compression of photo point photos (i.e. no editing of colours, brightness, contrast, size, resolution or aspect ratio).
10. Photo files should be labelled as '[Bog Number][Transect Letter][Peg Position]_HEMAMP_[Monitoring Year]' e.g. '1AS_HEMAMP_Y1' to denote the photo taken at the start of Transect 1A in Impact Year 1 (IY1). Note that the bog number, transect letter and peg position should already be labelled on the signboard that appears in the photo.
11. In a given monitoring year, there should be 94 photo point photos (one for each end of the 47 transects).

5.4 Share and back up all data

12. All ecological monitoring data must be uploaded to the RMB's servers as soon as possible and sent to a secure third-party cloud-based backup. There are three ecological monitoring datasets that must be retained on the RMB's servers:
 - a. The ecological dataset in Microsoft Excel format.
 - b. The spatial dataset in ESRI Shapefile format.

- c. The folder of all photo point photos in Joint Photographic Experts Group (JPEG or JPG) format.
- 13. To improve monitoring in subsequent years, it is recommended that the field data collection spreadsheet be updated with any suggested improvements and also uploaded to the RMB's servers.

6 Ecological data analysis and reporting

The steps outlined below are the minimum steps required for basic data analysis and reporting. These steps allow for assessment against the HEMAMP's performance criteria and adaptive management triggers. Further analysis will be required in any given year to properly investigate new trends or observations in Alpine Bog ecology and target pre-emptive management actions accordingly. To some extent, further in-depth analysis and investigation is built into the ecological dataset spreadsheet but other analyses may need to be considered, depending on current trends and results. Further analyses may include:

- Comparing control sites at Mount Buller with control sites at Mount Stirling.
- Examining site-specific results, to ascertain where the overall results may be coming from and to target adaptive management e.g. determining whether an increase in weed cover has occurred at one particular Alpine Bog.
- Analysing mortality (cover of dead vegetation).
- Investigating the cover and location of novel weed species.
- Reviewing extent of sedimentation and pest animal activity.

6.1 Prepare data for analysis

1. Follow the instructions in the 'Read Me' tab of the ecological dataset spreadsheet to prepare the point intercept, quadrat and mapping data for analysis.

6.2 Refresh tables, update graphs and perform data analysis

2. Follow the instructions in the 'Read Me' tab of the ecological dataset spreadsheet to refresh tables and update graphs. These tables and graphs form the basis for analysing trends in the data and reporting on results. The tables and graphs also provide a final means of verifying the quality of data that has been collected.
3. If the tables and graphs highlight spurious data or potential errors, these should be corrected as soon as possible before further data analysis is performed.
4. If no data errors are detected, further in-depth data analysis can occur. Follow the instructions in the 'Read Me' tab of the ecological dataset spreadsheet to test the statistical significance of the 'Before After Control Impact' (BACI) interaction in the R Statistical and Graphical Environment. This will require updating and running a script in the R Statistical and Graphical Environment.

6.3 Report results, share updated data and back up data

5. Relevant tables, graphs and data analyses should be included in the annual monitoring report. At a minimum, relevant results are those that are needed to make an assessment against the HEMAMP's performance criteria (the report must make an assessment against the performance criteria).
6. The ecological dataset spreadsheet will have been updated during the data analysis process. Upon publication of the monitoring report, the final ecological dataset in Microsoft Excel format must be uploaded to the RMB's servers and sent to a third-party cloud-based backup. For version control (to distinguish this dataset from all previous versions), the ecological dataset spreadsheet must have the current date appended to the filename.
7. To improve data analysis in subsequent years, it is recommended that the updated script for use in the R Statistical and Graphical Environment also be uploaded to the RMB's servers.