creating opportunities

Montrose Quarry Extension

Groundwater Dependent Ecosystem Assessment: Field summary

Prepared for Prepared for Boral Resources (VIC) Pty Ltd

June 2025

Montrose Quarry Extension

Groundwater Dependent Ecosystem Assessment: Field summary

Boral Resources (VIC) Pty Ltd

E250014 1

June 2025

Version	Date	Prepared by	Reviewed by	Comments
1	8 April 2025	Amy Hughes	Andrea McPherson	Working draft
2	20 June 2025	Amy Hughes	Glenn Passfield	Final

Approved by

Signature:

Email: gpassfield@emmconsulting.com.au

Glenn Passfield
Associate Director
20 June 2025

Suite 9.01 Level 9
454 Collins Street
Melbourne VIC 3000
ABN: 28 141 736 558

Executive summary

ES1 Introduction

EMM Consulting Pty Limited (EMM) has been engaged by Boral Resources (VIC) Pty Ltd (Boral) to prepare this Groundwater Dependent Ecosystems (GDEs) assessment to identify the extent of the ecohydrological function of GDEs within the Montrose Quarry Extension (the project). The project boundary (Boral land), survey area and study area are presented in Figure 1.1.

This GDE assessment field report summarises findings and results from the GDE field survey undertaken in February 2025, including assessment of on-site conditions and GDE measurement results.

ES2 Objectives

The objective of the GDE assessment is to provide a detailed field-based investigation, using a multiple lines of evidence approach, to characterise the nature of GDEs that may be subject to impact as a result of groundwater drawdown.

This assessment was undertaken following the well-established methods and assessments outlined in the GDE toolbox (Richardson S. *et al.* 2011) and IESC guidelines (2019, 2023), and includes:

- Vegetation type and condition assessment at 12 locations to assess baseline conditions.
- Assessment of three mature trees for pre-dawn and midday leaf water potential (LWP) at 12 locations and collection of twig samples for stable isotope analysis.
- Construction of six auger holes to refusal (max depth achieved 3.5 metres below ground level (mbgl)), to investigate the geological and hydrogeological characteristics underlying the area.
- Undertaking soil logging/lithological descriptions and sampling at approximately 0.25–1 metre (m) intervals for stable isotope analysis and measurement of Soil Moisture Potential (SMP).
- Sampling groundwater bores and surface water for stable isotope analysis.
- Stable isotope analysis completed by the ANU Stable Isotope Analysis Laboratory to compare the isotopic signatures of tree xylem, soil moisture, surface water, and groundwater to identify the source, or sources of moisture utilised by trees within the assessment areas.
- Interpretation of data produced from the field-based investigation and laboratory isotope data alongside scientific literature and expert advice to develop an understanding of potential casual pathway linkages between the key water effecting activities on the groundwater system, and associated GDEs.
- Development of ecohydrological conceptual models to visually represent conclusions drawn from data interpretation and provide the basis for the risk assessment, to be included in the GDE Impact Assessment.

ES3 Findings

The results of the field survey do not suggest any GDEs exist within the project area. The risk of terrestrial ecosystems at the Montrose Quarry project area is low to negligible.

A summary of the results to date is provided below:

- Monitoring bore data including depth to water and salinity indicated at least initially, negligible likelihood of ecosystem dependency on groundwater (Class 5) at four bore locations and high likelihood (Class 2) at five bore locations using a modified version of the Froend & Loomes (2004) classification (Section 5.6.1).
- The Riparian scrub/swampy riparian woodland complex areas surrounding the creek vegetation has high LWP values, meaning high water availability, and low to average stress. The predominant species, Messmate Stringybark and Swamp Gum have approximate root depths of 5–10 m and GHD's numerical groundwater model suggested that groundwater depth within these areas is likely to be less than 5 m, allowing tree roots to utilise groundwater if needed. However, there is a correlation between LWP and SMP at 0.5 mbgl within GDE 1 and to 1.5 mbgl within GDE 10, indicative of soil moisture use. The isotope results did not indicate vegetation within this Ecological Vegetation Classes (EVC) is utilising groundwater and it is likely that vegetation is preferencing soil moisture water over other sources.
- Within the Herb-rich foothill forest areas closer to the quarry, vegetation has low to extremely low LWP values, indicating less water availability, average to high stress, and roots accessing soil moisture as indicated in GDE 12 with a clear correlation between LWP and SMP to 1.5 mbgl. The isotope results did not indicate vegetation within this EVC is utilising groundwater and it is likely that vegetation is preferencing soil moisture.
- Across the project area, evidence of dieback within the canopy layer and subcanopy layer was observed (Section 5.3).
- Since the site investigation in February 2025, a large bushfire has impacted the site with yet unknown impacts to the site ecosystems.

ES4 Conclusions

The results from this field investigation suggest there are no GDEs within the project area, based on the environment assessed during February 2025.

The preliminary GDE potential map identified high potential GDE areas predominantly surrounding Bungalook Creek line since the DTGW within this area is <5 mbgl and therefore more accessible to vegetation. However, the field results from this investigation indicate that this preliminary assessment is likely to be incorrect. The SMP results indicate that the project area has available soil moisture within at least the top 3 mbgl. Nutrient levels are typically higher within the upper soil layers with nutrient levels that tend to decrease rapidly with depth (McLendon et al. 2007). The majority of species typically develop dense roots in the top 0.8 m of soil and the rest of the root system in the top 2 m of soil in order to increase the uptake of nutrients (Orellana et al. 2012). Some GDE species tend to develop deeper root systems when the soil moisture and nutrients are not readily available. The soil moisture and therefore nutrients, surrounding Bungalook Creek appears to be available to vegetation within the project area and is most likely the source of the water for vegetation along the creek line. The isotope results also agree with the above interpretations with no isotope cluster correlation identified between the vegetation and groundwater isotopes, with the vegetation appearing to be more isotopically similar to the soil water isotope data.

It is likely that the vegetation to the south of the property is relying on the soil moisture that is likely sustained by rain fall and creek flows, when creek seepage occurs. It is recommended to minimise impacts and changes to the current creek flows which will help to maintain vegetation condition in this region.

TABLE OF CONTENTS

Appendices

Tables

Figures

Abbreviations

Abbreviation	Term
ANU	Australian National University
DEECCW	Department of Environment, Energy, Climate Change and Water
DELWP	Department of Environment, Land, Water and Planning
DO	Dissolved oxygen
EC	Electrical conductivity
EEA Act	*Environment Effects Act 1978*
ERI	Ecohydrological Rehydration Index
EMM	EMM Consulting Pty Limited
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EVC	Ecological Vegetation Classes
EWP	Environmental watering provisions
FFG Act	*Flora and Fauna Guarantee Act 1988*
GDE	Groundwater Dependent Ecosystems
GMWL	Global Meteoric Water Line
IESC	Independent Expert Scientific Committee
km	Kilometre
LMWL	Local Meteoric Water Line
LWP	Leaf Water Potential
m AHD	metres Australian Height Datum
mbgl	metres below ground level
MDVC	Mount Dandenong Volcanics Complex
MNES	Matters of National Environmental Significance
SMP	Soil Moisture Potential
SWL	Standing water level
TEC	Threatened Ecological Communities
VIC	Victoria

1 Introduction

EMM Consulting Pty Limited (EMM) has been engaged by Boral Resources (VIC) Pty Ltd (Boral) to prepare this Groundwater Dependent Ecosystems (GDEs) assessment to identify the extent of the ecohydrological function of GDEs within the Montrose Quarry Extension (the project).

The Montrose Quarry has been operating since the 1950s and is located at 56 Canterbury Road, Montrose, approximately 32 kilometres (km) east of Melbourne at the foothills of the Dandenong Ranges (refer to GHD 2023a). EMM understands that Boral plan to extend the existing extraction boundary of the Montrose Quarry to increase its operational life by approximately 40 years. Currently the deepest point of the quarry pit is around 17 metres Australian Height Datum (m AHD) which is more than 100 metres below the ground level (mbgl). Seepage and pooling of groundwater occurs at the base of the quarry and is pumped out. The presence of the quarry is likely to cause drawdown of the water table towards Bungalook Creek (GHD 2023a). The project boundary (Boral land), survey area and study area are presented in Figure 1.1.

A surface water and groundwater assessment were undertaken in preparation for the approvals required for the project and it was found that it may cause local groundwater drawdown and disconnection between Bungalook Creek and groundwater (GHD 2023b).

This GDE assessment field report summarises findings and results received to date from the GDE field survey undertaken in February 2025, including assessment of on-site conditions and GDE measurement results.

1.1 Background

A GDE assessment report for Montrose Quarry was conducted by GHD (2024) to determine if Bungalook Creek and/or other ecological values are GDEs and whether they will be potentially affected by predicted changes to groundwater levels and creek flow relating to the project.

GHD provided a baseline understanding of potential GDEs, where they may occur, a classification of ecosystem type and a conceptualisation of groundwater and surface water interactions with GDEs and other ecological values.

GHD (2024) concluded the following:

- Boral's Montrose Quarry serves as a local low point in the regional groundwater system, leading to seepage and pooling of groundwater at the bottom of the quarry.
- Under current conditions, Bungalook Creek ceases to flow during the dry months, however, the proposed extension of the quarry is predicted to create drawdown of groundwater along the creek that will increase the seepage of surface water flow, resulting in the creek having an increase in cease to flow events.
- Groundwater drawdown and a decrease in surface water flow could result in impacts to GDEs and ecological values particularly within areas of groundwater that is <10 mbgl.
- The GDEs and other ecological values included several flora and fauna species that may be present and are threatened under State or Commonwealth legislation.
- It was concluded that surface water flow loss is expected to cause a residual risk to adjacent and receiving ecological values, however with the implementation of mitigation measures the risk is considered low.
- A medium residual risk remained to the Burrowing Crayfish that relies on surface water as the risk will increase as operations proceed.

- Medium risks to GDEs were identified within shallow groundwater areas due to a decrease in groundwater levels that could cause a decline in the health of deep-rooted eucalypts and understory trees that may relying on groundwater, which could in turn affect threatened flora and fauna species that rely on these trees.

GHD (2024) made the following recommendations related to mitigation measures, addressing information gaps and ecological monitoring:

- An arborist be consulted before implementing irrigation of native vegetation.
- Before relocating the licenced discharge point, a hydrological/water balance assessment should be conducted.
- Further investigate potential refuge pools and their locations.
- Further hydrological tracer studies be conducted to gain a better understanding of sources of water used by trees within the project area.
- Ecological monitoring be established.

EMM (2024) conducted a peer review of the GHD (2024) groundwater impact assessment and supporting numerical groundwater flow modelling and the groundwater dependent ecosystem assessment. The following main review points, as an outcome of the EMM review included:

- The groundwater flow system and surface water-groundwater connectivity is poorly understood including recharge and discharge mechanisms of Bungalook Creek.
- The predicted drawdown effects needed to be more specific including the use of a conceptual groundwater contour map instead of a regional depth to water table map based on regional mapping only.
- Contradictions were found between the groundwater conceptual model and ecological model regarding the potential for GDEs within the area.
- Further GDE surveys and studies were recommended to be undertaken to understand the ecological water requirements and dependence on groundwater of potential terrestrial GDEs (e.g. using such methods as isotope analysis, leaf water potentials, and soil moisture potentials).

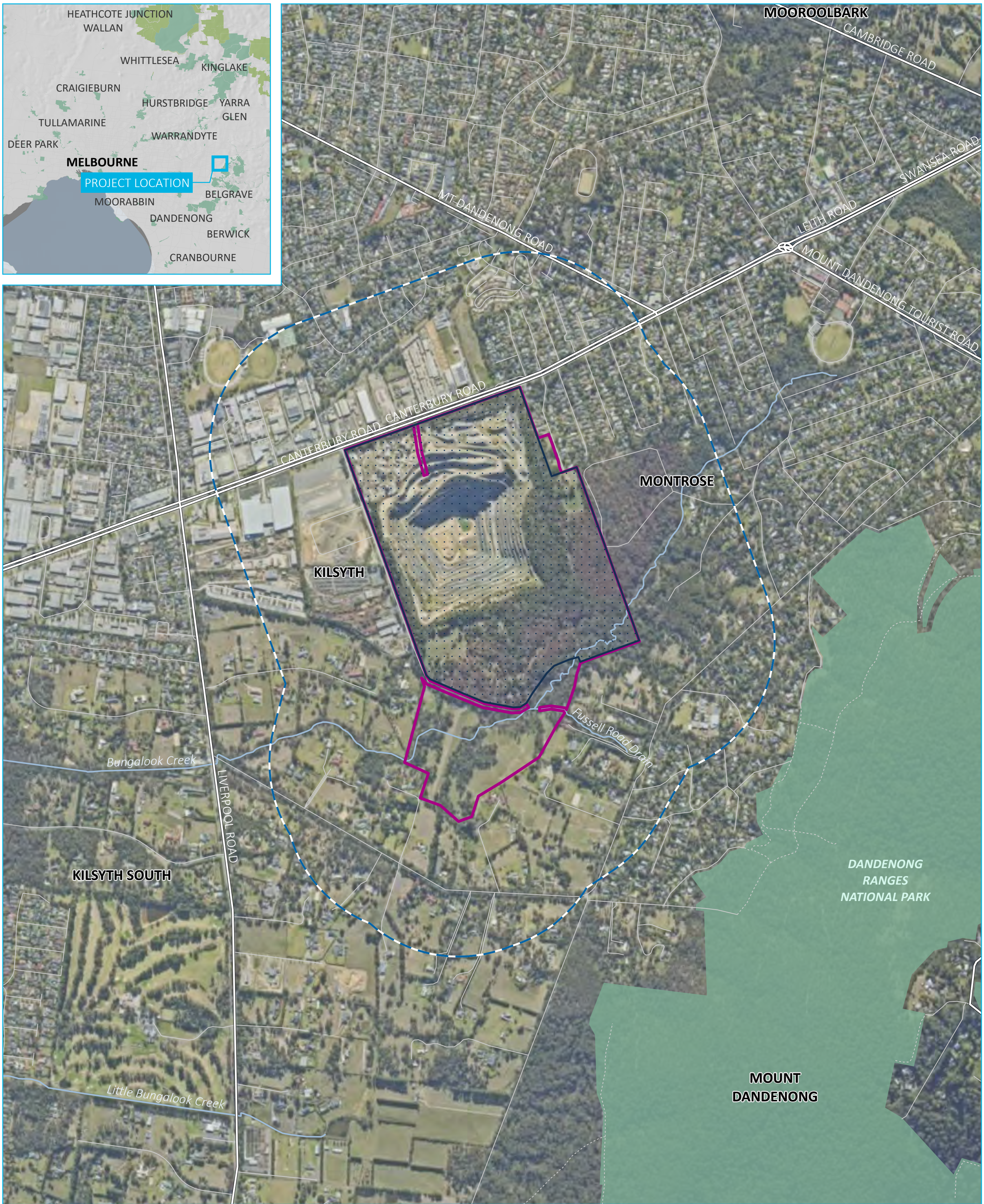
1.2 Project objectives

The objective of the GDE assessment is to provide a detailed field-based investigation, using a multiple lines of evidence approach, to characterise the nature, groundwater dependence and risk posed to the potential GDEs caused by the project's predicted groundwater drawdown.

This assessment was undertaken following the well-established methods and assessments outlined in the GDE toolbox (Richardson S. *et al.* 2011) and IESC guidelines (2019, 2023), and includes:

- Vegetation type and condition assessment at 12 locations to assess baseline 'current' conditions to compare back to for future field assessments.
- Assessment of three mature trees for pre-dawn and midday leaf water potential (LWP) at 12 locations to assist in understanding tree water status and ability to access soil moisture; and collection of twig samples for stable isotope analysis.
- Construction of six auger holes to refusal (max depth achieved 3.5 mbgl), to investigate the geological and hydrogeological characteristics underlying the area.

- Undertaking soil logging/lithological descriptions and sampling at approximately 0.25–1 metre (m) interval for stable isotope analysis and measurement of Soil Moisture Potential (SMP), also referred to as matric potential, to inform moisture availability down the soil profile.
- Sampling groundwater bores and surface water for stable isotope analysis.
- Stable isotope analysis completed by the ANU Stable Isotope Analysis Laboratory to compare the isotopic signatures of tree xylem, soil moisture, surface water, and groundwater to identify the source, or sources of moisture utilised by trees within the assessment areas.
- Interpretation of data produced from the field-based investigation and laboratory isotope data alongside scientific literature and expert advice to develop an understanding of potential casual pathway linkages between the key water effecting activities on the groundwater system, and associated potential GDEs.
- Development of ecohydrological conceptual models to visually represent conclusions drawn from data interpretation and provide the basis for the risk assessment, to be included in the GDE Impact Assessment.



\\emm.local\xdrive\2025\E250014 - Montrose Quarry Extension GDE\GIS\02_Maps\GDE001_ProjectLocation\GDE001_ProjectLocation_20250618_03.aprx 18/06/2025

Source: EMM (2025); Boral (2025); ABS (2021); DEECA (2023); GA (2009); MetroMap (2025)

KEY

- Project boundary – Boral land
- Survey area
- Study area

Existing environment

- Major road
- Minor road
- Vehicular track
- Named watercourse
- National park/reserve

INSET KEY

- Major road
- State forest
- National park/reserve

Project location

Montrose Quarry Extension
GDE Assessment: Field Summary
Figure 1.1

EMM
creating opportunities

2 Legislation and guidelines

GDEs are defined as "ecosystems that need access to groundwater to meet all or some of their water requirements to maintain their communities of plants and animals, ecological processes and ecosystem services" (NSW Government 2025).

The relevant legislation (and guidelines Table 2.1) that may be triggered due to impacts to GDEs includes:

- The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), administered by the Australian Commonwealth government; and protects Matters of National Environmental Significance (MNES, otherwise known as protected matters), which include animals, plants, habitats or places and Threatened Ecological Communities.

- The Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) establishes a legal and administrative structure to enable and promote the conservation of Victoria's native flora and fauna.

- The *Environment Effects Act 1978* (EEA Act), administered by the Victoria government, the potential for extensive or major effects on the use and environmental values of water resources due to changes in water quality, function, or regional groundwater levels, or the health or biodiversity of aquatic estuarine or marine ecosystems, over the long term.

Impacts to GDEs may have direct and indirect effects to native vegetation, protected state matters and MNES. While there is limited current legislative mechanisms for the protection of GDEs, the concern is in relation to the various environmentally significant ecosystems such as Threatened Ecological Communities and/or habitat of threatened species that GDEs maybe linked to.

Groundwater dependence can be highly variable between species as the individual species will be exposed to species-specific needs, climate, soil type, seasonal variation and landscape characteristics, leading to variations in groundwater access and reliance (Richard and NSW Government, 2025). Therefore, species will have adapted to varying levels of dependence within their tolerances. As such potential GDE species need to be considered holistically in a multiple lines of evidence (Richards et al 2011a; 2011b) approach where one factor may not be enough to sway the result if a species and/or community is a GDE whether they are obligate Phreatophytes.

Table 2.1 Relevant guidelines and details

Guideline	Reference	Details
GDE toolbox	Richardson et al. (2011a; 2011b)	Part 1 of the GDE toolbox presents an assessment framework for protecting GDEs, whilst Part 2 provides practicable and technically robust assessment tools to identify GDEs. Environmental watering provisions (EWP) for a habitat should be expressed with measurable indicators that are spatially and temporally explicit. A targeted monitoring program should be designed to test whether EWPs meet the agreed ecological objective. The following stages are identified for assessing impacts and appropriate mitigations for GDE habitats: • Stage 1: identification of ecosystems that may use groundwater, conceptualisation of groundwater systems and relation to GDEs, review of landscape and topography. • Stage 2: characterising potential reliance of GDE on groundwater by acquiring a multitude of variables such as water level, hydraulic gradients and fluxes, as well as geochemical and isotope analysis. Collection of time-series data to understand use over seasons. Linked ecological and hydrogeological monitoring should be established to correctly monitor and mitigate for changes to a GDE habitat. • Stage 3: identify potential threats or changes to the groundwater system and dependent ecosystems.

Guideline	Reference	Details
State Ministerial Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems	DEECCW (2015)	Department of Environment, Energy, Climate Change and Water ((DEECCW) have created guidelines for groundwater licensing and the protection of high value groundwater dependent ecosystems. It provides guidance on assessing the risk posed to high value GDEs and categorises the risk into high, medium and low risk levels. The likelihood of the proposed groundwater extraction interacting with a feature is determined by aquifer type, depth to groundwater and surface water connectivity. The consequence of the proposed groundwater extraction affecting high value GDEs is determined by the degree of predicted groundwater drawdown. Likelihood and consequence are then assessed to determine the risk evaluation.
Independent Expert Scientific Committee (IESC) Guidelines Explanatory Note for assessing groundwater-dependent ecosystems	Doody et al. (2019)	This reference is an explanatory note written to supplement the IESC Information Guidelines to prepare impact assessments under the EPBC Act for coal seam gas and large coal mining developments. The document provides information on designation of GDEs and the common threats and impacts from large coal seam gas and/or coal mining developments on GDEs, and provides a framework following six main stages: 1. Defining the project impact area. 2. Identify GDEs and potential risks. 3. Assessing level of groundwater dependence. 4. Identifying the baseline ecological condition and value of each GDE. 5. Assessing likelihood, frequency and magnitude of potential impacts on GDEs. 6. Prioritising options to avoid or mitigate impacts on GDEs. The explanatory note identifies the need to compile a management plan that draws on all information and present the casual impact pathways between the project and the relevant GDEs.

3 Environmental context

3.1 Vegetation communities and dominant species

GHD (2024) conducted a preliminary ecological site assessment on 23 August 2023 to confirm and map dominant Ecological Vegetation Classes (EVCs), describe each EVC, identify suitable habitat for threatened species and their likelihood of occurrence, and record their location if found.

Eight EVCs were identified and three EVCs were considered to be potential GDEs.

- EVC 17: Riparian Scrub/Swampy Riparian Woodland Complex was located along Bungalook Creek and dominated by Swampy Riparian Woodland areas. The dominant species were Messmate Stringybark (*Eucalyptus obliqua)* and Swamp Gum *(Eucalyptus ovata)* with approximate root depths of 5–10 m. The Riparian Scrub areas were dominated by Scented Paperback *(Melaleuca squarrosa)* and Prickly Tea-tree *(Leptospermum continentale*). This EVC is listed as vulnerable and a potential GDE.

- EVC 23: Herb-rich Foothill Forest was located within the proposed quarry extension area and was dominated by Messmate Stringybark *(Eucalyptus obliqua)* and occasional Bundy *(Eucalyptus goniocalyx)* and Narrow-leaf Peppermint *(Eucalyptus radiata)*. This EVC is listed as depleted.

- EVC 29: Damp Forest was located along the Bungalook Creek and was dominated by Messmate Stringybark (*Eucalyptus obliqua)* and Swamp Gum *(Eucalyptus ovata)*. Ground ferns were abundant within this EVC. This EVC is listed as least concern and a potential GDE.

- EVC 53: Swamp Scrub was located along Bungalook Creek and occurred in small pockets within damp areas. This EVC is dominated by tall Scented Paperback *(Melaleuca squarrosa)*.

- EVC 83: Swampy Riparian Woodland was located along Bungalook Creek and dominated with Messmate Stringybark *(Eucalyptus obliqua)* and Swamp Gum *(Eucalyptus ovata)*. This EVC is listed as endangered and potential GDE.

- ECV 821: Tall Marsh was located along Bungalook Creek and dominated by *Phragmites australis* and *Typha* spp. This EVC has no bioregional conservation status however listed as potential GDE.

- ECV 819: Potential Spike-sedge Wetland was located midstream along drainage lines on private property abutting Bungalook Creek. The dominant species was Spike Sedge *(Eleocharis acuta)*.

- EVC 938: Shrubby Gully Forest was located along Bungalook Creek and dominated by Messmate Stringybark *(Eucalyptus obliqua)* and Mana Gum *(Eucalyptus viminalia*).

Damp Forest and Riparian Scrub/Swamp Riparian Woodland Complex were the two most dominant EVCs identified within the project area. Messmate Stringybark *(Eucalyptus obliqua*) had an approximate height of 30 m and Swamp Gum *(Eucalyptus ovata)* had an approximate height of 20 m. It was reported that the typical root depth for these species is expected to be 5–10 m.

Species with deep roots have the potential to source some water directly from the groundwater. Species along the waterline of Bungalook Creek are likely to also source water directly from surface water and replenishment of soil moisture through creek seepage and rainfall infiltration.

GHD (2024) reported that no threatened ecological communities (TECs) were identified within the study area and no *Flora and Fauna Guarantee Act* (FFG) listed communities correlate with the EVCs observed within the study area. One EPBC Act listed and 12 FFG Act listed flora species had suitable habitats within the study area, however the likelihood of occurrence is considered low. Most of the species identified were terrestrial dry or damp species unlikely to use groundwater with the exception of Netted Brake (*Pteris epaleata*) and Bulging Hence (*Senecio campylocarpus*) which have higher water requirements. Targeted surveys were conducted for these two threatened species and were not identified to be within the study area therefore were not considered further. The other 11 possible threatened species were considered to be ecosystem dependent therefore if groundwater drawdown affected trees, these understory trees or shrubs could also suffer, however, the indirect impacts were beyond the scope of the GHD (2024) study.

GHD (2024) stated that groundwater drawdowns were predicted beneath vegetated land and included the Dr Ken Leversha Reserve which is located adjacent to the quarry.

3.2 Hydrogeological setting

A surface water and groundwater assessment report for Boral Montrose Quarry was conducted by GHD (2023) to quantify the potential impacts of the extension on groundwater and the flow regimes in the nearby Bungalook Creek. The findings are as follows:

- The oldest formation was identified within the project area to be lower Silurian age to lower Devonian age turbiditic sediments. The Melbourne Formation was identified to the east and west of the quarry. A simplified stratigraphy is outlined in Table 3.1.
- Two aquifers exist at the project site including Alluvial sediments and Mount Dandenong Volcanics Complex (MDVC). The MDVC is made up of the Mount Evelyn Rhyodacite and the Coldstream Rhyolite which are grouped into a single fractured rock aquifer system.
- Monitoring bores exist to the south and east of the quarry and have had three monitoring rounds conducted. A summary of the monitoring bores is provided in Table 3.2.
- Groundwater levels along Bungalook Creek are expected to be less than 5 m deep and greater than 10 m to the east and north of the quarry.
- It is assumed that existing disturbance to the groundwater environment has been caused by historical and current quarry operations.
- Streamflow in Bungalook Creek is likely to recharge the water table with minimal baseflow.
- Drawdown from operations is “likely”.
- Further extension has the potential to cause local disconnection between the streambed and underlying groundwater, within areas where the creek has a baseflow component from the surrounding aquifer.

A numerical groundwater modelling report was produced by GHD (2025) to quantify the magnitude, spatial extent and duration of potential groundwater related change arising from the proposed expansion.

Two scenarios were investigated, with the first scenario showing drawdown results from a baseflow fed Bungalook Creek only. It was predicted that the largest drawdown would be around the quarry with a cone of depression extending across Bungalook Creek which would become locally disconnected from the water table since predicted drawdown is expected to be 25–30 m over 40 years.

Scenario two assumed that surface water flow persisted within Bungalow Creek and predicted a 10 m or less drawdown along Bungalook Creek which a reduced drawdown impact compared to scenario one as it includes leakage from Bungalook Creek when the water table is lowered below the stream level. However, this leakage would lead to less streamflow reaching the downstream section of Bungalook Creek, resulting in localised drawdown along the creek.

Table 3.1 Site stratigraphy (GHD 2023)

Age	Stage	Representative formation	Lithological description	Comment
Quaternary			Undifferentiated alluvial, swamp, and colluvial deposits.	Alluvial mapped in present day drainage lines.
	Lower	Newer Volcanics	Olivine basalts	Not present near quarry.
Tertiary	Upper	Brighton Group	Sands, clays, silts	
	Middle	Newport Fm	Glauconitic and carbonaceous silts, clays, shelly sands and marls	
	Lower	Old volcanics	Olivine basalts	
		Werribee Fm	Sands, silts, clays	
Unconformity				
Devonian	Upper	Mount Dandenong Volcanics Group	Acid extrusive and intrusive	Mount Evelyn Rhyodacite and Coldstream Rhyolite are mapped in the quarry.
	Unconformity			
	Lower	Lilydale Lmst	Limestone, well bedded	Not present near quarry.
		Humevale Fm	Massive to thinly bedded siltstones and greywackes	Mapped to the west of the quarry in the Bayswater and Croydon areas.
Silurian	Upper	Melbourne Fm/Dargile Fm	Sandstone and interbedded siltstones and shales	Mapped in the Heathmont/Ringwood area, a few kilometres to the west of the quarry.
	Middle to Lower	Anderson Creek Fm	Siltstone and interbedded sandstones (and metamorphic)	

Table 3.2 Summary of monitoring bores (GHD 2023)

Bore ID	Easting (GDA94)	Northing (GDA94)	RL TOC (mAHD)	Total depth (m)	Top of screen	Screened lithology
MB1	353190	5812474	169.08	65.5	5.3, 59.5	Sand, Rhyodacite
MB2	353461	5812749	171.69	70.5	3.1, 64.5	Silty CLAY, Rhyodacite
MB3	353488	5812661	158.51	8.3	5.0	Silty CLAY
MB4	353008	5812326	161.63	100.0	90	Rhyodacite
MB5a	353110	5812265	151.86	60.0	54	Rhyodacite
MB5b	353114	5812267	152.16	5.0	3	Rhyodacite
MB6	353615	5812597	167.62	67.5	61.5	Rhyodacite
MB7	353848	5812477	190.66	50.0	44	Rhyodacite
MB8	353316	5813128	212.70	130.0	121	Rhyodacite
MB9	354211	5813557	181.34	49.0	46	Rhyodacite
AH1	353230	5812406	150.92	1.86	1.36	Sandy CLAY
AH2	353306	5812411	150.88	1.75	1.25	Sandy CLAY
A2	353312.5	5812481	153.50	3.1	1.5	Clayey SAND
A5	353310.7	5182482	153.51	8.0	6.0	SAND
B2	353307.8	5812495	154.19	3.0	1.5	Clayey SAND
B5	353307.8	5812498	154.30	8.0	6.0	Rhyodacite
C2	353301.1	5812523	155.76	12.0	10.0	Rhyodacite

3.3 Assessment period climatic conditions

The assessment was completed over four days between 24 to 27 February 2025. Rainfall data from the Croydon (Dorset Golf Course) weather station (data up to 24 February 2025, BOM station 086234 approximately 3.6 km west of the project) shows low to moderate rainfall from August 2024 to February 2025 (Figure 3.1). The highest rainfall within this period occurred during October 2024 (total 82.4 mm). During the field program, no rain was observed.

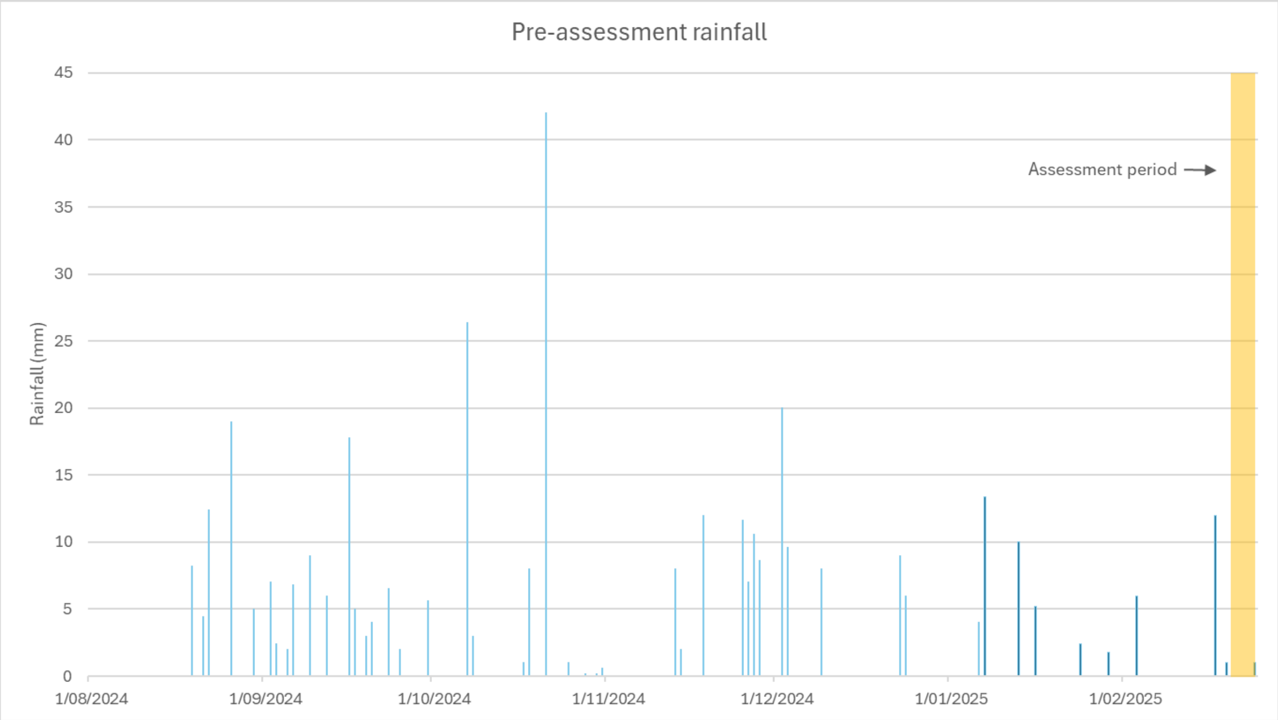


Figure 3.1 Pre-assessment rainfall measured at the Croydon (Dorset Golf Course) weather station (BOM station 086234)

4 Conceptualisation of GDEs

The conceptualisation of GDEs is essential for understanding whether a GDE could potentially be exposed to the water-related effects of the project. The Australian GDE Toolbox (Richardson et al, 2011) outlines the process of conceptualisation which involves a flora and fauna description of the ecosystem and the hydrological regime that supports it.

The conceptualisation assists in identifying whether any exposure pathway exists within the project area. A GDE is potentially affected when the hydrological regime is modified due to the project's construction or operation.

The effect of drawdown on GDEs is a function of rooting depths, vegetation tolerances, climate and GDE seasonal requirements, which are all reasonably unknown elements.

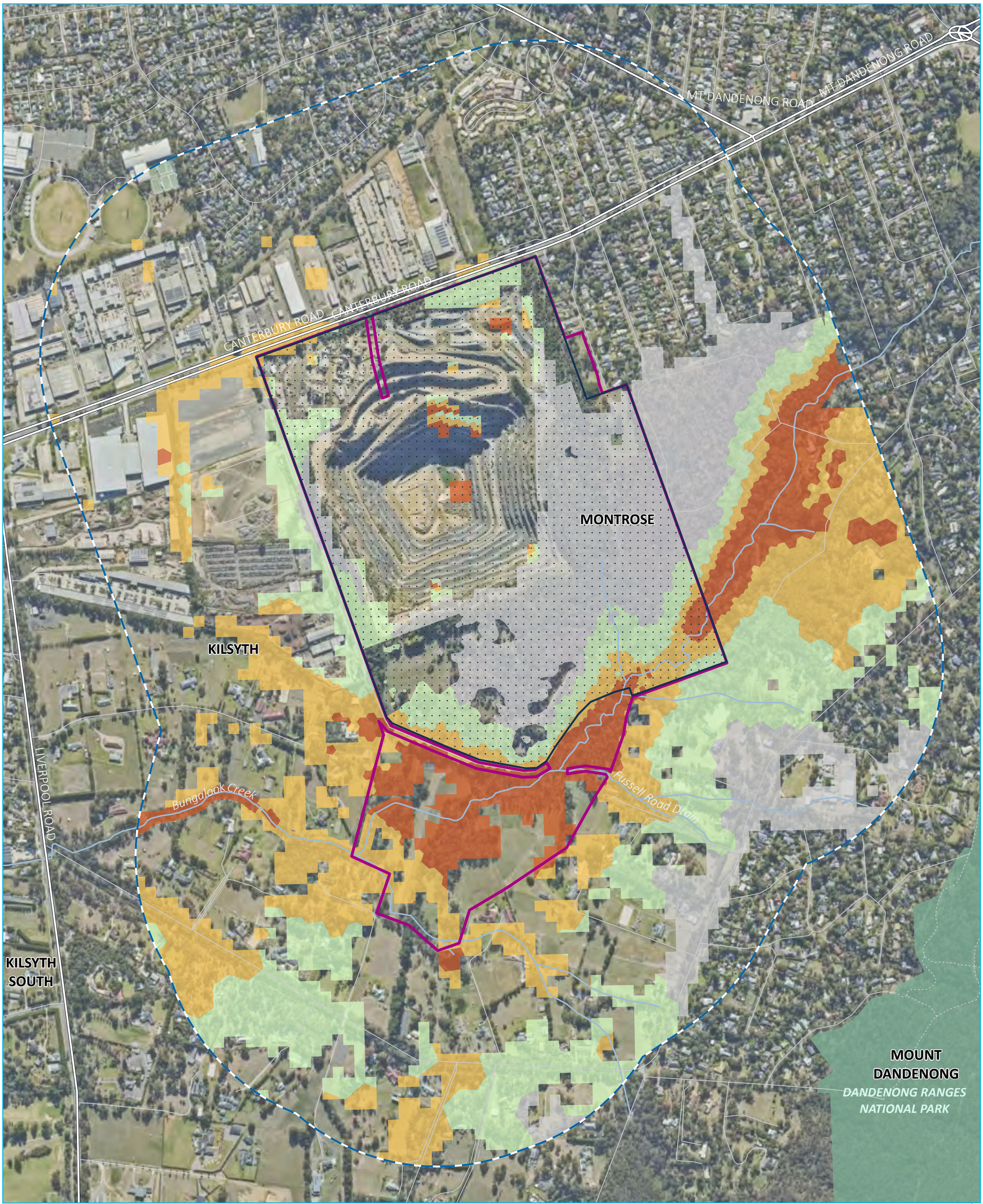
4.1 Preliminary conceptual models

Preliminary conceptualisation of potential GDEs for the Montrose Quarry extension area was created to characterise the hydrological regime for each EVC. To estimate the areas of potential GDEs, many factors need to be taken into consideration such as location, dominant species, depth to groundwater, topography, soils, geology and springs.

For this preliminary conceptualisation, a ground-truthed vegetation map provided by GHD (2024) was used with the Native Vegetation – Modelled 2005 Ecological Vegetation Classes layer from the Department of Environment, Land, Water & Planning (DELWP 2018) filling in the areas not able to be mapped by GHD. These two layers were used to determine the location and extent of each EVC within the project area. Estimated tree rooting depth for each EVC was then added. Rooting depth is dependent on several factors such as tree species, substrate, water and nutrient availability, and climate. Maximum rooting depth is expected to be variable and dependent on on-site geology, water quality, and depth to capillary fringe (Eamus D, 2006), therefore rooting depth is a particularly difficult parameter to predict and measure. A depth to groundwater model was provided by GHD (2025) which was used to intersect the Native Vegetation layer to determine the preliminary areas of potential GDEs. The depth to groundwater layer was divided into the following categories:

- <5 m – High potential GDEs
- 5–10 m – Moderate potential GDEs
- 10–20 m – Low potential GDEs
- >20 m – Negligible GDEs.

The preliminary GDE potential map created for the project area identified high potential GDE areas predominantly surrounding Bungalook Creek line. A large area considered to have no potential for containing GDEs was identified directly south and east of the quarry. The preliminary GDE potential areas can be found in Figure 4.1.



Source: EMM (2025); Boral (2025); DEECA (2023); MetroMap (2025)

\\emm.local\xdrive\2025\E250014 - Montrose Quarry Extension GDE\GIS\02_Maps\GDE002_PreliminaryGDEpotential\GDE002_PreliminaryGDEpotential_20250618_06.aprx 18/06/2025

KEY

Project boundary – Boral land
Survey area
Study area

Preliminary GDE potential
High (0-5 mbgl)
Moderate (5-10 mbgl)
Low (10-20 mbgl)
Not GDE (>20 mbgl)

Existing environment
Major road
Minor road
Vehicular track
Watercourse/drainage line
National park/reserve

Preliminary GDE potential

Montrose Quarry Extension
GDE Assessment: Field Summary
Figure 4.1

EMM
creating opportunities

5 Applied methods

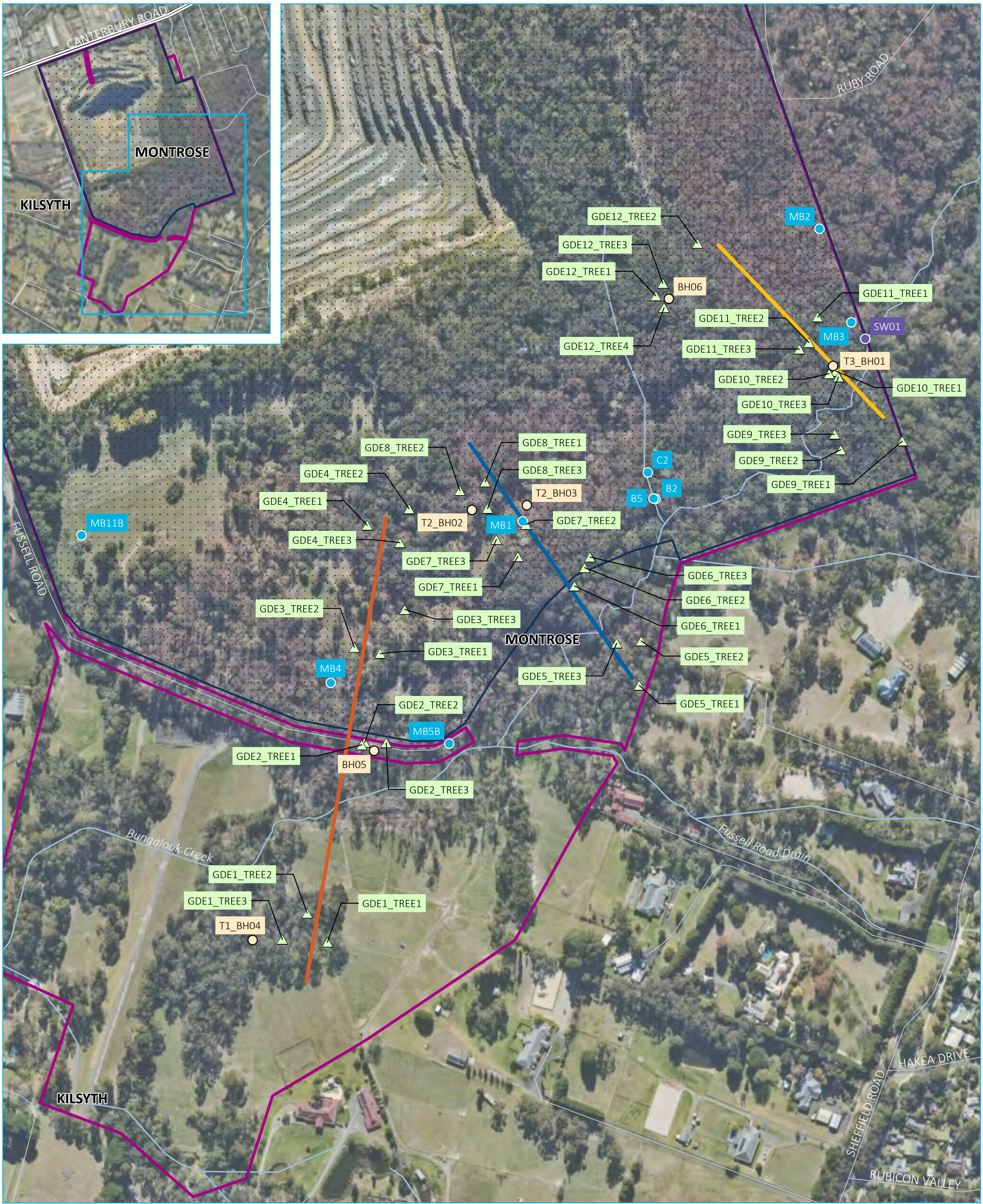
5.1 Preplanning and site selection

The GDE assessment locations were selected to ensure comprehensive coverage across the project area, targeting key areas of concern. Three transects were chosen within areas of varying EVCs, assumed depths to groundwater and GDE potential. The spatial distribution of these locations across different geomorphic positions allowed for a robust comparison of conditions, ensuring that the assessment captured a representative range of environmental conditions and potential causal pathways. Table 5.1 summarises the locations and methods applied at each site. The locations of each site, and tree assessed are shown spatially in Figure 5.1.

Table 5.1 GDE assessment locations

Assessment site	Location/geomorphic position	Number of trees sampled for pre-dawn/ midday LWP	Species sampled	Borehole and SMP sampling information
Transect 1				
GDE 1	• South of Bungalook Creek, south of the project. • Approximate depth to groundwater of 0–5 mbgl. • Grassy forest EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Ovata*	Auger hole to 3.5 mbgl with associated samples, auguring arrested due to refusal on hard clay.
GDE 2	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater of 5–10 mbgl. • Valley heath forest EVC with estimated rooting depth of 5–20 m. • Riparian scrub/swampy riparian woodland complex EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Obliqua*	Auger hole to 1.5 mbgl with associated samples, auguring arrested due to refusal on large tree root.
GDE 3	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater of 15–25 mbgl. • Valley heathy forest EVC with estimated rooting depth of 5–20 m. • Herb-rich foothill forest EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Goniocalyx*	Not sampled.
GDE 4	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater of 25–50 mbgl. • Herb-rich foothill forest EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Goniocalyx*	Not sampled.
Transect 2				
GDE 5	• South of Bungalook Creek, south of the project. • Approximate depth to groundwater of 0–5 mbgl. • Riparian scrub/swampy riparian woodland complex EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Obliqua*	Not sampled.

Assessment site	Location/geomorphic position	Number of trees sampled for pre-dawn/ midday LWP	Species sampled	Borehole and SMP sampling information
GDE 6	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 5–10 mbgl. • Riparian scrub/swampy riparian woodland complex EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Radiata* • *Eucalyptus Ovata*	Not sampled.
GDE 7	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 15–25 mbgl. • Riparian scrub/swampy riparian woodland complex EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Radiata* • *Eucalyptus Obliqua*	Auger hole to 1 mbgl with associated samples, auguring arrested due to refusal on hard clay.
GDE 8	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 25–50 mbgl. • Herb-rich foothill forest/Riparian scrub/swampy riparian woodland complex EVCs with estimated rooting depths of 5–10 m.	3/2	• *Eucalyptus Radiata*	Auger hole to 2 mbgl with associated samples, auguring arrested due to refusal on hard clay.
Transect 3				
GDE 9	• South of Bungalook Creek, south-east of the project. • Approximate depth to groundwater 5–15 mbgl. • Riparian scrub/swampy riparian woodland complex EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Baxteri* • *Eucalyptus Ovata*	Not sampled.
GDE 10	• North of Bungalook Creek, south-east of the project. • Approximate depth to groundwater 0–5 mbgl. • Riparian scrub/swampy riparian woodland complex EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Ovata*	Auger hole to 1.5 mbgl with associated samples, auguring arrested due to refusal on hard clay.
GDE 11	• North of Bungalook Creek, south-east of the project. • Approximate depth to groundwater 5–15 mbgl. • Riparian scrub/swampy riparian woodland complex EVC with estimated rooting depth of 5–10 m.	3/3	• *Eucalyptus Baxteri* • *Eucalyptus Radiata*	Not sampled.
GDE 12	• North of Bungalook Creek, south-east of the project. • Approximate depth to groundwater 25–50 mbgl. • Herb-rich foothill forest EVC with estimated rooting depth of 5–10 m.	3/2	• *Eucalyptus Obliqua*	Auger hole to 1.5 mbgl with associated samples, auguring arrested due to refusal on hard clay.



\\emm.local\xdrive\2025\E250014 - Montrose Quarry Extension GDE\GIS\02_Maps\GDE003_GDEassessmentLocations\GDE003_GDEassessmentLocations_20250618_04.aprx 18/06/2025

Source: EMM (2025); Boral (2025); DEECA (2023); MetroMap (2025)

0 100 200 m
GDA2020 MGA Zone 55
N

KEY

Project boundary – Boral land
Survey area
Survey/sampling location
Groundwater sampling
Surface water sampling
Soil sampling
GDE/tree assessment

GDE survey transect
Transect 1
Transect 2
Transect 3

Existing environment
Major road
Minor road
Watercourse/drainage line

GDE assessment locations

Montrose Quarry Extension
GDE Assessment: Field Summary
Figure 5.1

EMM
creating opportunities

5.2 Leaf Water Potential

Leaf Water Potential (LWP) is defined as the amount of work that must be done per unit quantity of water to transport that water from the moisture held in soil to leaf stomata. LWP consists of the balance between osmotic potential, turgor pressure, and matric potential; it is a function of soil water availability, evaporative demand, and soil conductivity.

Due to a lack of transpiration, LWP will equilibrate with the wettest portion of the soil that contains a significant amount of root material. Pre-dawn (prior to sunrise) LWP will shift to a lower status as soil dries out on a seasonal basis (Eamus 2006a). Measurement of LWP pre-dawn thus gives an indication of the water availability to trees at each assessment site and provides an indication as to whether trees are tapping saturated zones of the soil profile where water is freely accessible, or utilising moisture that is more tightly bound to soil particles.

Midday LWP is typically at a time LWP is at a minimum or most negative and is influenced by atmospheric evaporative demand, photosynthetically available radiation, and soil moisture. LWP during midday can be related to stomatal closure (closing of pores or stomata on leaf surfaces to conserve water). Depending on water availability, trees under water stress are able to close stomata in order to protect themselves during dry periods, whereas trees under low water stress are able to keep normal stomatal regulation.

LWP was measured pre-dawn and midday as per standard protocol and as an indicator of the strength of hydraulic gradient developed within the xylem pathway of the tree in order for the tree uptake soil water (AQ2 2023). These values can provide insight into the trees ability to access different source waters.

Ecohydrological Rehydration Index (ERI) = (midday LWP – pre-dawn LWP)/midday LWP is an index that indicates a trees ability to handle drought or dry conditions. ERI values collected over time can inform trees that are currently experiencing drought conditions and trees that may have increasingly or decreasingly favourable conditions. An ERI value of greater than 0.66 indicates high levels of diurnal hydration, low stress and high tree health, whereas an ERI value of less than 0.33 indicates poor hydration, high water stress and the risk of hydraulic failure.

Survey localities were visited pre-dawn and midday with leaves collected from the canopy using a 9 m extension pole fitted with a lopping head, where required. Leaves were collected from mature canopy trees within each assessment site in localities that were within several hundred metres from a vehicle track to assist collection of samples in low light within a limited sampling window. Collected branches were bagged in reflective plastic to avoid moisture loss and sun exposure. LWP was measured on-site within half an hour of harvest. Suitable leaf material was trimmed with a fine blade and inserted into an appropriate grommet for sealing within a Model 1515D Plant Pressure Chamber (PMS Instruments 2024). The chamber was sealed and gradually pressurised with nitrogen until the first drop of leaf water emerged from the petiole. Readings were taken using units measured in megapascals (MPa) for direct comparison to SMP measurements. In total, 36 trees were assessed for LWP across the 12 assessment sites.

The following categories in Figure 5.2 have been applied as a measure of relative water availability.

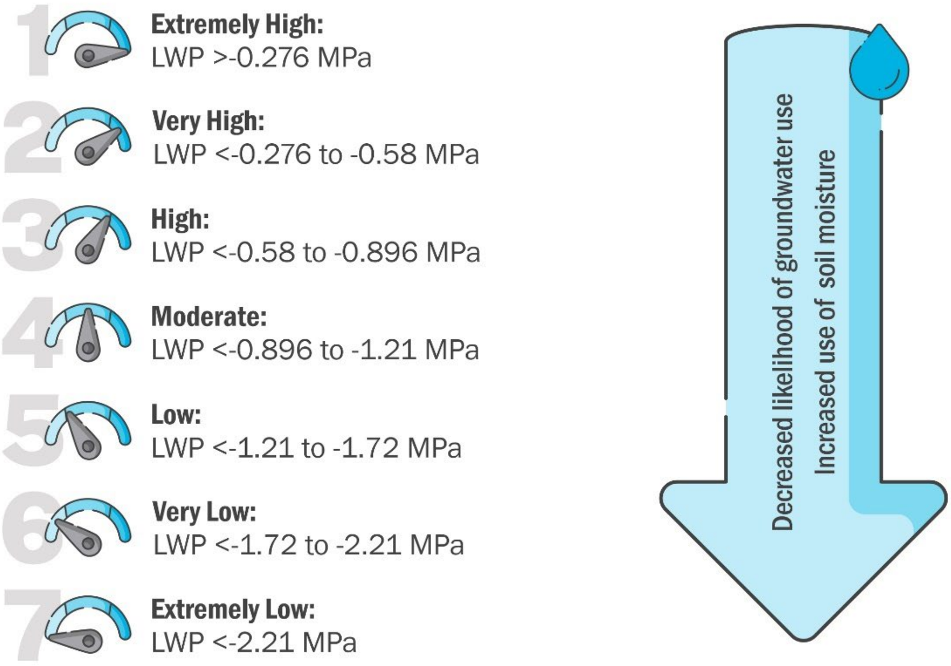


Figure 5.2 LWP as a measure of water availability

While the defining values of these categories are arbitrary in nature, they are intended to provide an indication of the likely degree and nature of groundwater dependence or interaction. The 'Extremely High' category would indicate the potential for interaction with an extremely fresh source of groundwater, with the degree of groundwater interaction decreasing through to the 'Moderate' category that may indicate either utilisation of soil moisture from the vadose zone or interaction with saline groundwater. Categories of 'Low' to 'Extremely Low' are considered unlikely to be utilising groundwater to any degree, regardless of salinity. It should also be stressed that soil moisture in the 'Extremely High' category can also be supplied directly from unsaturated portions of the soil profile depending on moisture availability and the soils physical properties, which can be assessed by measuring SMP. It is important to note that LWP alone only indicates water availability, and not where the water is coming from.

5.3 Vegetation assessment

Vegetation assessments were undertaken by a terrestrial ecologist to establish a baseline and enable comparison with future field assessments. Each sampled tree was identified by species, the height was measured, and a photo was taken. At each GDE assessment site, a quaternary assessment was completed to verify the EVC of the site, and the following data was collected:

- dominant tree species in canopy and subcanopy
- dominant species in shrub and ground layers
- average tree height in the canopy and subcanopy
- estimate of tree canopy cover in the dominant layer
- photos in a north, east, south, and west direction.

An assessment of tree canopy and subcanopy condition was undertaken at each GDE assessment site using the scale outlined in Table 5.2.

Table 5.2 Canopy condition scale

Condition	Classification
Healthy	>90% foliage present (canopy essentially intact); no epicormic growth; no-to-minor evidence of leaf discolouration; no-to-minor evidence of insect damage.
Slightly stressed	75–90% foliage present (some minor canopy loss); some epicormic growth; no-to-minor evidence of leaf discolouration (potentially some dead/dying leaves); no-to-minor evidence of insect damage.
Stressed	50–75% foliage present (moderate canopy loss); minor-moderate epicormic growth; moderate evidence of leaf discolouration (dead/dying leaves); moderate evidence of insect damage.
Very stressed	<50% foliage present (major canopy loss); moderate-high epicormic growth; moderate-high evidence of leaf discolouration (dead and dying leaves); moderate-high evidence of wide-scale insect damage.

5.4 Auger sampling and Soil Moisture Potential (SMP)

A hand auger was utilised to collect shallow soil samples at regular depths down the soil profile at selected sites where possible. Sites for auger placement were spread spatially across the potential impact zones to represent variability and diversity of soil types, hydrological conditions, and ecological characteristics across the area.

At each sampling site, the aim was to collect soil samples to the maximum depth of the auger of penetration with penetration often arrested by compacted clay substrate or large tree roots. Within each auger hole, the following observations were taken at regular depth intervals or where changes to soil structure were apparent:

- soil structure, colour, and texture
- presence of root matter
- soil moisture/water and areas of saturation.

Soil sampling was undertaken at regular intervals down the soil profile to analyse for SMP. Sample collection was generally spaced at 0.25 m intervals down the auger profile with additional samples taken where changes in soil structure/texture, moisture content, or zones of tree roots were detected. As the samples were collected, they were immediately sealed in airtight plastic vials and placed on ice, for later measurement for SMP.

SMP, which includes the matric (water availability) and osmotic (salinity) potential, is a measure of the energy required to extract moisture from soil. Water only has capacity to move down a hydraulic gradient from soil to root (Gardner 1960). Areas in the soil profile that have a SMP that is equal to or less negative than measured pre-dawn LWP will be accessible as a source of moisture by the tree. It is widely agreed in ecohydrology and plant physiology fields that large, mature trees are unable to extract moisture from regions in the soil profile where the total SMP is significantly below LWP measured in pre-dawn leaf material (Feikema et al. 2010; Lamontagne et al. 2005; Thorburn et al. 1994; Mensforth et al. 1994; Holland et al. 2009; and Doody et al. 2015). For crops, the maximum suction roots can apply to a soil/rock before a plant wilts due to negative water supply is approximately -15 bars or -1.5 MPa (or -217.55 psi). This wilting point is considered relatively consistent between all plant species, although many Australian plants have adapted to conditions of low water availability and can persist strongly in soil conditions where moisture potential is below standard wilting point (Eamus 2006a). As a general measure however, where measured LWP is below standard wilting point, it indicates plant water deficit, and the tree is unlikely to be supported by a saturated water source regardless of groundwater salinity.

The measurement of SMP was completed with a Dew Point Potentiometer (WP4C) (Meter Group Inc 2021). The WP4C meter uses the chilled mirror dew point technique with the sample equilibrated within the headspace of a sealed chamber that contains a mirror and a means of detecting condensation on the mirror. A single 7 ml soil sample was inserted into the WP4C meter using a stainless-steel measuring tray. SMP samples were measured in megapascal pressure units (MPa).

5.5 Isotope analysis

Trees may utilise water from a range of sources including the phreatic zone (saturated zone), the vadose zone (unsaturated zone), and surface water. The stable isotopes of water, oxygen 18 ($\delta^{18}O$) and deuterium ($\delta^{2}H$) are useful tools to help define the predominant source of water used by terrestrial vegetation. The method relies on a comparison between the stable isotope ratios of water contained in plant xylem (from a twig) with stable isotope ratios found in the various sources of water including soil moisture, shallow groundwater tables, or surface water and compared to the meteoric water line.

To compare the isotopic signature of tree xylem to various potential water sources, water samples were collected from various sources including surface water (located in the Bungalook Creek), soil water collected from soil samples and extracted using laboratory methods that preserve the isotopic composition for analysis and groundwater from monitoring bores MB1, MB2, MB3, MB4, MB5b, MB11b, C2, B2 and B5.

5.6 Other data considerations

5.6.1 Rapid assessment of GDE occurrence

A review of groundwater depths and salinity from the project groundwater bores has been used to understand the dependency an ecosystem may have on groundwater based on a modified version of the Froend & Loomes (2004) classification system, where ecosystems range from Class 1 to Class 5, with Class 1 ecosystems being dependant and thus most sensitive to groundwater. This classification system is shown in Table 5.3.

Table 5.3 GDE classification system (adapted from Froend & Loomes 2004)

		Groundwater salinity (mg/L)				
Depth of water table (mbgl)		<3,000	3,000–7,000	7,000–14,000	14,000–35,000	>35,000
	0–1	Class 1	Class 2	Class 3	Class 4	Class 5
	1–5	Class 2	Class 2	Class 3	Class 4	Class 5
	5–10	Class 3	Class 3	Class 3	Class 4	Class 5
	10–15	Class 4	Class 4	Class 4	Class 4	Class 5
	>15	Class 5	Class 5	Class 5	Class 5	Class 5

Class 1 = very high likelihood of groundwater use.

Class 2 = high likelihood.

Class 3 = moderate likelihood.

Class 4 = low likelihood.

Class 5 = negligible likelihood.

A review of aquifer type, depth to groundwater, and surface water connectivity was also conducted to determine the likelihood of groundwater interaction with potential GDEs as the predicated changes of groundwater drawdown could impacts upon potential these ecosystems. The rapid risk evaluation matrix is shown in Table 5.4 which is currently applied by Victorian Regulators when assessing the potential impacts of groundwater extraction on high-valued GDEs when considering groundwater license applications.

The GHD model scenario which only includes groundwater baseflow contributions to Bungalow Creek shows modelled predicted drawdown at the end of extraction period (40 years), in the range of 30 to 25 m perpendicular with the creek (Figure 5.3 (Figure 39 and 41)). The modelled drawdown is reduced when Bungalow Creek is simulated with the addition of surface water flow contributions (Figure 5.3 (Figure 45)), however the impact is still greater than a 2 m change over an extended period.

Table 5.4 Risk evaluation (from Environment, Climate Change and Water 2015)

		Consequence - water table decline (m)		
Likelihood Depth to water table (mbgl)		**Minor (<0.1)**	**Moderate (0.1–2)**	**Significant (2)**
	Unlikely (>6)	Low	Low	High
	Possible (2–6)	Low	Medium	High
	Certain (<2 m)	Medium	High	High

Table 5.5 summarises the parameters of groundwater monitoring bores sampled at the project and their respective GDE classification using the desktop approach when applying the rapid Froend & Loomes framework. The electrical conductivity (EC) of the monitoring bores ranged from 139 to 1,772 µS/cm. The standing water level (SWL) of each bore ranged from 2.5 to 19.69 mbgl. The risk evaluation matrix was used on each groundwater monitoring bore location to indicate the degree of risk within the area. Since the predicted groundwater drawdown is greater than 2 m (significant consequence as defined by Table 5.4) all areas are considered to be at high risk.

Table 5.5 Groundwater bore summary and GDE Classification

Bore	Sample date	Field pH	Field EC (µS/cm)	SWL (mbgl)	GDE Class (Froend & Loomes 2004)	Comment
MB1	25/02/2025	6.91	1,065	19.52	Class 5	Water table depth > 15 mbgl, probability of GDE is low to unlikely.
MB2	25/02/2025	6.65	593.8	17.60	Class 5	Water table depth >15 mbgl, probability of GDE is low to unlikely.
MB3	25/02/2025	4.99	1,160	4.48	Class 2	Water table depth between 1–5 mbgl and salinity level of <3,000 mg/L, probability of GDE is high.
MB4	25/02/2025	8.60	1,772	18.42	Class 5	Water table depth >15 mbgl, probability of GDE is low to unlikely.
MB5b	25/02/2025	6.82	1,411	4.78	Class 2	Water table depth between 1–5 mbgl and salinity level of <3,000 mg/L, probability of GDE is high.
MB11b	25/02/2025	6.38	139	19.69	Class 5	Water table depth >15 mbgl, probability of GDE is low to unlikely.
C2	26/02/2025	7.06	284.3	4.00	Class 2	Water table depth between 1–5 mbgl and salinity level of <3,000 mg/L, probability of GDE is high.

Bore	Sample date	Field pH	Field EC (µS/cm)	SWL (mbgl)	GDE Class (Froend & Loomes 2004)	Comment
B2	26/02/2025	7.66	4.00	2.5	Class 2	Water table depth between 1–5 mbgl and salinity level of <3,000 mg/L, probability of GDE is high.
B5	26/02/2025	6.93	1,157	2.5	Class 2	Water table depth between 1–5 mbgl and salinity level of <3,000 mg/L, probability of GDE is high.

5.7 Data reconciliation and interpretation

The biophysical measurement of LWP provided an initial assessment parameter, which was then directly compared to downhole SMP measurements to determine the likelihood of groundwater dependence and likely zone of water uptake by the root system. LWP values for trees with rooting zones in equilibrium with a source of fresh groundwater will typically present LWP values >-2 MPa with the likelihood of groundwater dependence decreasing as the LWPs become increasingly negative. Groundwater salinity complicates the interpretation of LWP measurements due to influence of a negative osmotic force. Generally, groundwater dependence is ruled out where LWP values fall below -1.5 MPa; this would be equivalent to the osmotic force generated by groundwater with salinity >30,000 µS/cm which is considered an unsuitable source of moisture for most trees.

For trees presenting LWP values >-1.5 MPa, assessment of downhole SMP from soil auger sampling determines the likelihood that moisture for transpiration is being supplied from the upper soil profile, as opposed to deeper groundwater sources. As described in Section 5.4, water only has capacity to move down a hydraulic gradient from soil to root meaning that only those portions of the soil profile that have a SMP that is equal to or less negative than measured pre-dawn LWP will be accessible as a source of moisture from the vadose zone for water to move into the plant (Gardner 1960).

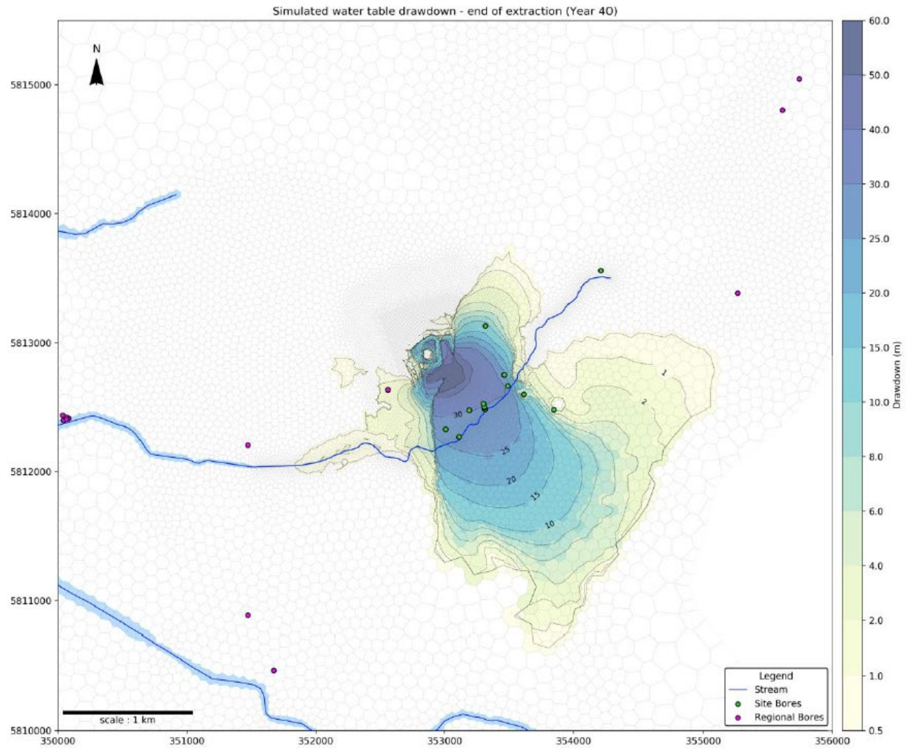


Figure 39 Simulated water table drawdown at end of extraction (baseflow only)

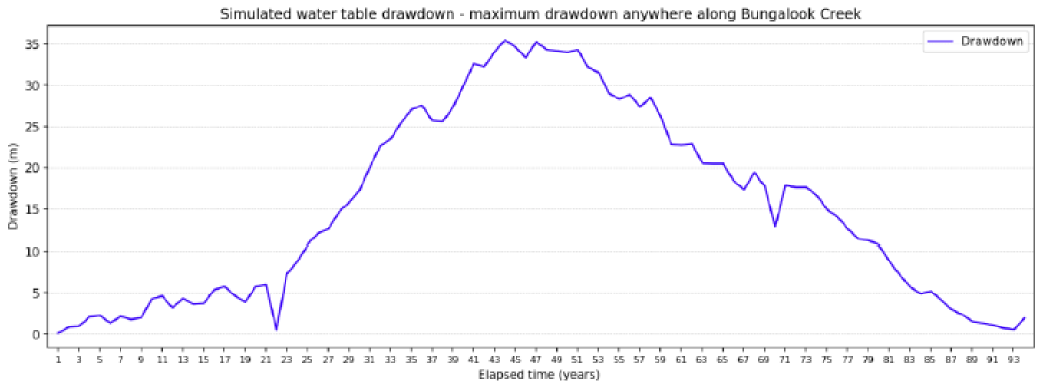


Figure 41 Bungalook Creek maximum drawdown hydrograph (baseflow only)

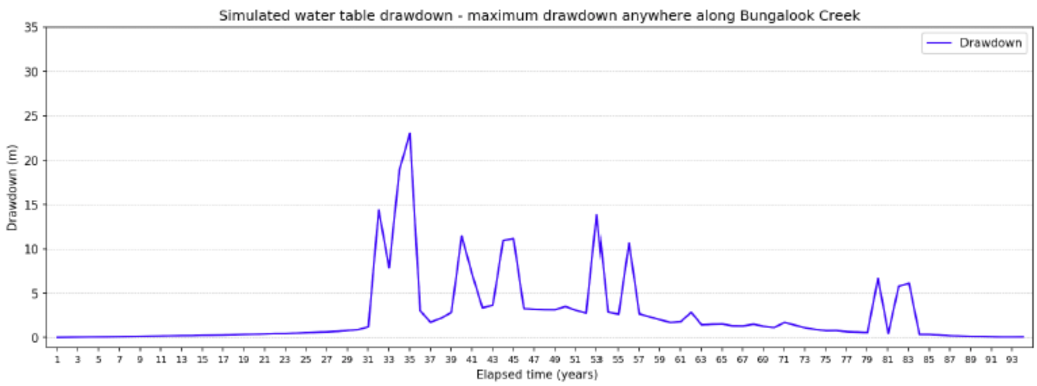


Figure 45 Bungalook Creek maximum drawdown hydrograph (with surface water flow)

Figure 5.3 Summary results from the GHD (2025) simulated water table drawdown impact at the end of extraction in relation to Bungalook Creek

6 Results

Tabulated LWP results for all leaf samples are in Appendix A, tabulated SMP results for all soil samples are in Appendix B and tabulated isotope data is in Appendix C. A summary of the interpreted results are provided below.

6.1 Leaf Water Potential

The LWP statistical values for the 12 assessment sites (shown spatially in Figure 5.1) are shown in Figure 6.1 as box and whisker plots, with the average, median, 25th, 75th, minimum, and maximum values shown. Extremely High to Extremely Low LWP ranges, as outlined in Section 5.2, have been plotted on the figure to aid with interpretation.

LWP values for slightly more than half (58%) of the trees across the assessment sites were above wilting point (-1.5 MPa). A total of seven GDE assessment sites has LWP values within the Moderate to Very High range, with the remaining five GDE assessment sites in the Low to Extremely Low range.

Site GDE 10 observed the highest overall LWP value within the Very High range. One tree in GDE 5 observed a LWP value in the Extremely High range (*Eucalyptus Ovata*) and GDE 1 observed LWP values in the High to Moderate range.

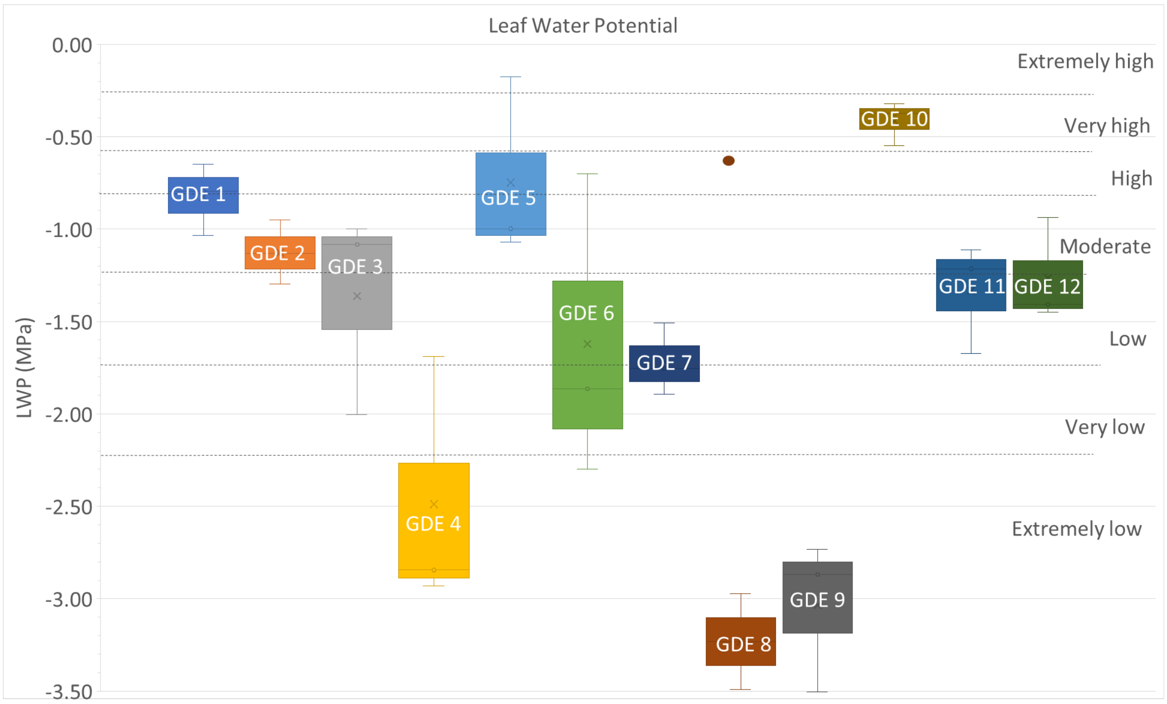


Figure 6.1 LWP Box and whisker plots

As an indicator of the strength of hydraulic gradient developed within the xylem pathway of the tree in order for the tree to uptake soil water, the Ecohydrological Rehydration Index (ERI) was calculated using the midday LWP and pre-dawn LWP measurements. The ERI statistical values for the 12 assessment sites are shown in Figure 6.2 as box and whisker plots, with average, median, 25th percentile, 75th percentile, minimum and maximum values shown.

Low water stress is indicated for GDE 1, GDE 5, and GDE 10 located next to or close to Bungalook Creek. Most GDE assessment sites are indicated to be experiencing average water stress, however GDE 9 ERI results suggested this area is experiencing high water stress.

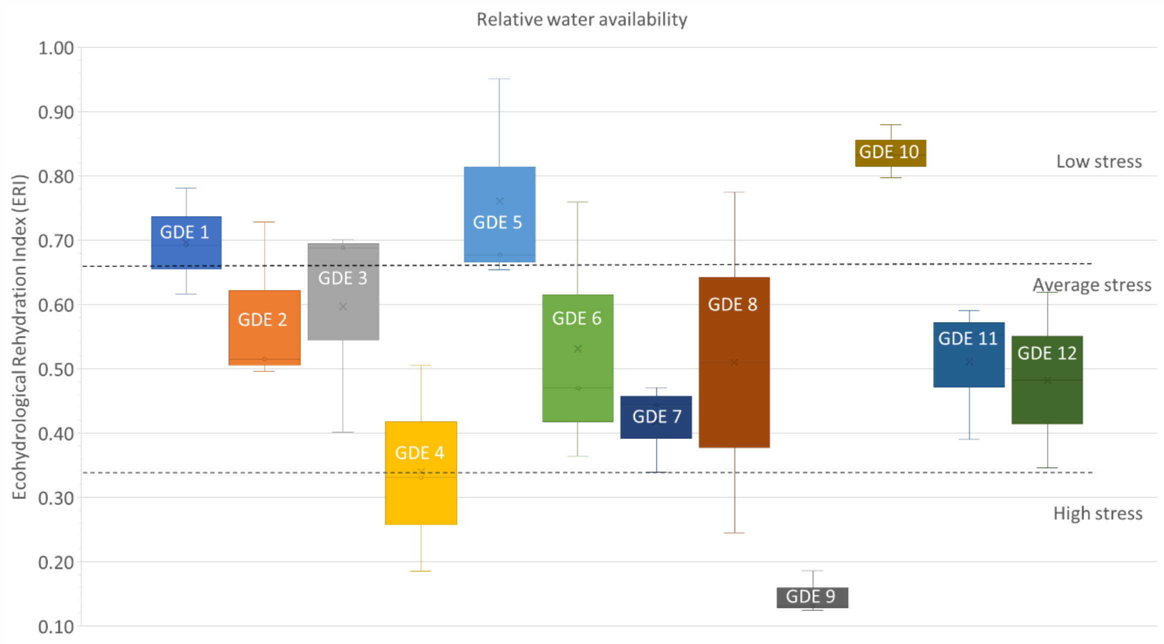


Figure 6.2 ERI Box and whisker plots

6.2 Vegetation assessment

The project area was observed to have varying disturbance including historically cleared areas with some of the GDE locations at the edge of cleared patches. The vegetation along the transect lines generally changed from Swampy woodland EVC in the low-lying southern extent, to Herb rich foothill forest EVC to the north. The Herb rich areas to the north are characterised by dense shrubby understorey of Sweet Pittosporum (*Pittosporum undulatum)*, an environmental weed when outside its natural range that competes with native species, shading out competition and altering soil nutrient loads. There was little to no evidence of Eucalyptus recruitment in areas where Sweet Pittosporum was prevalent. Terrestrial description of each potential GDE assessment site along with a condition classification is outlined below:

- GDE 1: Relatively small patch (approx. 2.5 hectares (ha)) of Swampy woodland with surrounding vegetation cleared and regularly mowed. Dominant species were observed to be Swamp gum *(Eucalyptus ovata)* in the canopy and Swamp paperbark *(Melaleuca ericifolia)* and Black wattle *(Acacia melanoxylon)* in the understory. A high level of recruitment was observed of canopy species. Canopy trees predominantly appeared healthy, however there was some evidence of dieback with some crowns of canopy species in poor condition. The site was given a condition classification of *Slightly Stressed* (refer to Table 5.2).

- GDE 2: Located on an edge between 'Tall marsh' and 'Herb rich foothill forest' Ecological Vegetation Classes with a track intersecting through the foothill forest just above the swamp boundary. Downhill side (south) contains damp areas dominated by Cumbungi *(Typha sp.)* and Common reed *(Phragmites australis)*. Uphill contains tall open woodland (average of 21 m tall) dominated by Messmate (*Eucalyptus obliqua*) where high levels of dieback were observed in the canopy and subcanopy layers with no evidence of Eucalypt recruitment. Sweet Pittosporum (*Pittosporum undulatum*) was dominant in the understory. The site was given a condition classification of *Stressed*.

- GDE 3: A patch of vegetation located in a relatively disturbed area with cleared tracks and historic paddock areas surrounding. Eucalypt woodland (average of 18 m tall) dominated by Messmate (*E. obliqua*) and co-dominated by Long-leaved box (*E. goniocalyx*). High levels of dieback within the canopy and subcanopy layers was observed, with exotic Radiata pine (*Pinus radiata*) present and Sweet Pittosporum (*Pittosporum undulatum*) dominant in understory. No recruitment of the canopy layer was observed. The site was given a condition classification of *Stressed*.

- GDE 4: Tall Eucalypt woodland (average of 20 m tall), dominated by Messmate (*E. obliqua*) with co-dominant Narrow-leaved peppermint (*Eucalyptus radiata*). The understory contained dense Sweet Pittosporum (*Pittosporum undulatum*). Some dieback was observed in the canopy layer with a low percentage of living tree crowns appearing stressed. The site was given a condition classification of *Healthy*.

Transect 2:

- GDE 5: Tall Eucalypt forest (average of 22 m tall) in low-lying area adjacent to the creek line. The canopy was dominated by Swamp gum (*Eucalyptus ovata*) with tall Black wattle (Acacia melanoxylon) in the subcanopy layer. Prickly currant-bush (*Coprosma quadrifida*) dominated the shrub layer. Some dieback was observed in the canopy layer but overall the site was in good condition. Some storm damage was apparent with the tops of trees and limbs fallen in places. The site was given a condition classification of *Healthy*.

- GDE 6: The site was located near the bottom of the slope and consisted of a tall Eucalypt forest (average of 25 m tall) dominated by Messmate (*E. obliqua*) with Black wattle (*Acacia melanoxylon*) present in the subcanopy layer. The shrub layer was dominated by dense Sweet Pittosporum (*Pittosporum undulatum*). Some dieback in the canopy layer on the downhill side of the survey point was observed, and some dieback in the subcanopy layer on the uphill side of the survey point was observed. The site was given a condition classification of *Slightly Stressed*.

- GDE 7: The site was located on mid slope and consisted of a tall Eucalypt forest (average 22 m tall) dominated by Messmate (*E. obliqua*) and Narrow-leaved peppermint (*E. radiata*). Black wattle (*Acacia melanoxylon*) was present in the subcanopy layer and dense Sweet Pittosporum (*Pittosporum undulatum*) dominated the shrub layer. In the immediate area of the survey point which was located on the edge of a cleared patch to the north-west, the canopy appeared healthy. The site was given a condition classification of *Healthy*.

- GDE 8: Trees to the north of the survey point were very tall with no lower branches therefore sample trees were located south of the mapped GDE 8 location. The site contained tall Eucalypt forest (average of 22 m tall) towards the top of slope and was dominated by Messmate (*E. obliqua*) and Narrow-leaved peppermint (*E. radiata*). Black wattle (Acacia melanoxylon) dominated the subcanopy layer and dense Sweet Pittosporum (*Pittosporum undulatum*) dominated the shrub layer. Some evidence of dieback within the canopy layer was observed. Some crowns were knocked out of trees and broken limbs observed suggesting storm damage. The site was given a condition classification of *Slightly Stressed*.

Transect 3:

- GDE 9: A tall Eucalypt forest (average of 26 m tall) was present and dominated by Brown stringybark (*Eucalyptus baxteri*) with tall layer of Cedar wattle (*Acacia elata*) and Cherry ballart (*Exocarpos cupressiformis*) in the subcanopy layer. Minimal branches were available for sampling from the canopy layer. The low tree and shrub layer were dominated by Sweet Pittosporum (*Pittosporum undulatum*). High levels of dieback were evident in the canopy and subcanopy layers, particularly to the south of the sample point. The site was given a condition classification of *Stressed*.

- GDE 10: A tall Eucalypt forest (average 25 m tall) was present in a low-lying area beside the creek with a dense ground layer of Austral bracken (*Pteridium esculentum*) and Thatch saw sedge (*Gahnia radula*). The canopy dominated by Swamp gum (E. ovata) with Messmate (E. obliqua) also present. A small amount of dieback was observed in the canopy crowns with dieback evident in lower limbs of tall trees. The site was given a condition classification of *Slightly Stressed*.

- GDE 11: A tall Eucalypt forest (average of 26 m tall) was present and dominated by Brown stringybark (*E. baxteri*) and Messmate (*E. obliqua*). The canopy crown was predominantly healthy however high levels of dieback in the subcanopy layer were observed. The subcanopy was either dead or in poor condition for approximately 80% of the Eucalypts in this layer at the survey point. Other signs of stress in the subcanopy layer were evident such as epicormic growth on trunks. Little evidence of Eucalypt recruitment was observed. Sweet Pittosporum (*Pittosporum undulatum*) was dense in shrub layer. The site was given a condition classification of *Stressed*.

- GDE 12: A tall Eucalypt forest (average of 26 m tall) was present and dominated by Messmate (*E. obliqua*) and Brown stringybark (*E. baxteri*). The canopy layer contained predominantly healthy crowns with some dieback on the down slope side to the south-east of the survey point and a moderate level of dieback was observed in the subcanopy layer. The site was given a condition classification of *Slightly Stressed.*

6.3 Auger sampling and Soil Moisture Potential

As per Section 5.4 and Section 5.7, the purpose of the auger sampling and SMP measurements is to identify whether sufficient moisture is available in the upper unsaturated portion of the soil profile (i.e. vadose zone) to support shallow root uptake, or whether the vegetation is utilising deeper groundwater sources (below the depth of auger sampling and towards the capillary fringe zone), when assessed in conjunction with the LWP results.

Soil logs are provided in the following sections to show representations of the major elements of the soil profile including location of major soil intervals and the depth of groundwater, if intersected. SMP was measured for each soil sample and the results of these analyses are plotted directly on the auger lithological profiles along with the range of LWPs measured at each assessment site, to aid in root water uptake assessment.

6.3.1 Transect 1 sites

Two auger holes were attempted in the clayey sands, gravelly clayey sands, sandy clays, and hard clays at sites GDE 1 and GDE 2. Logs for these sites show the following:

- The auger hole at site GDE 01 (BH04) was arrested at 3.5 mbgl after refusal on hard clay. The soil down the profile was noted to be slightly moist to approximately 1 mbgl, turning moist to 3.5 mbgl. There is a correlation between LWP and SMP at 0.5 mbgl (Figure 6.3), inferring this is a zone of water uptake for the trees assessed at this site. From 0.5 mbgl to 3.5 mbgl the soil moisture is above the LWP value range indicating there is more water availability in the soil than may be needed by the vegetation at this site. Soil moisture below 3.5 mbgl cannot be determined and isotope analysis will be used to help interpret depths below this point.

- Due to refusal on large tree root, auguring was arrested at 1.5 mbgl at site GDE 02. At these shallow depths, the SMP is strongly negative and much more negative than the LWP indicating root water uptake is not occurring at these shallow depths (Figure 6.4). Further isotope analysis to confirm the moisture sources below 1.5 mbgl are discussed in Section 6.4.

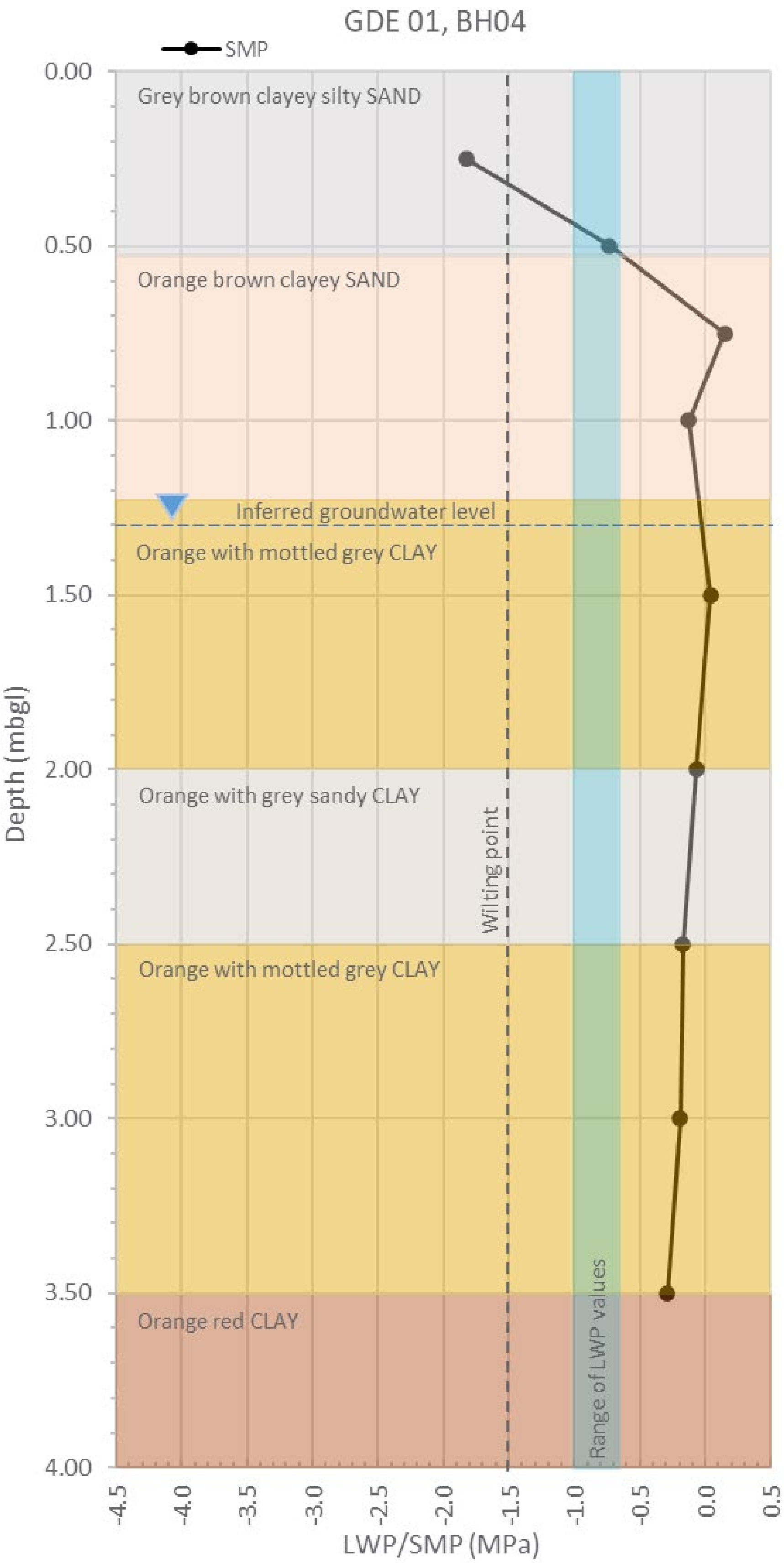


Figure 6.3 **BH04 profile from Transect 1, site GDE 01**

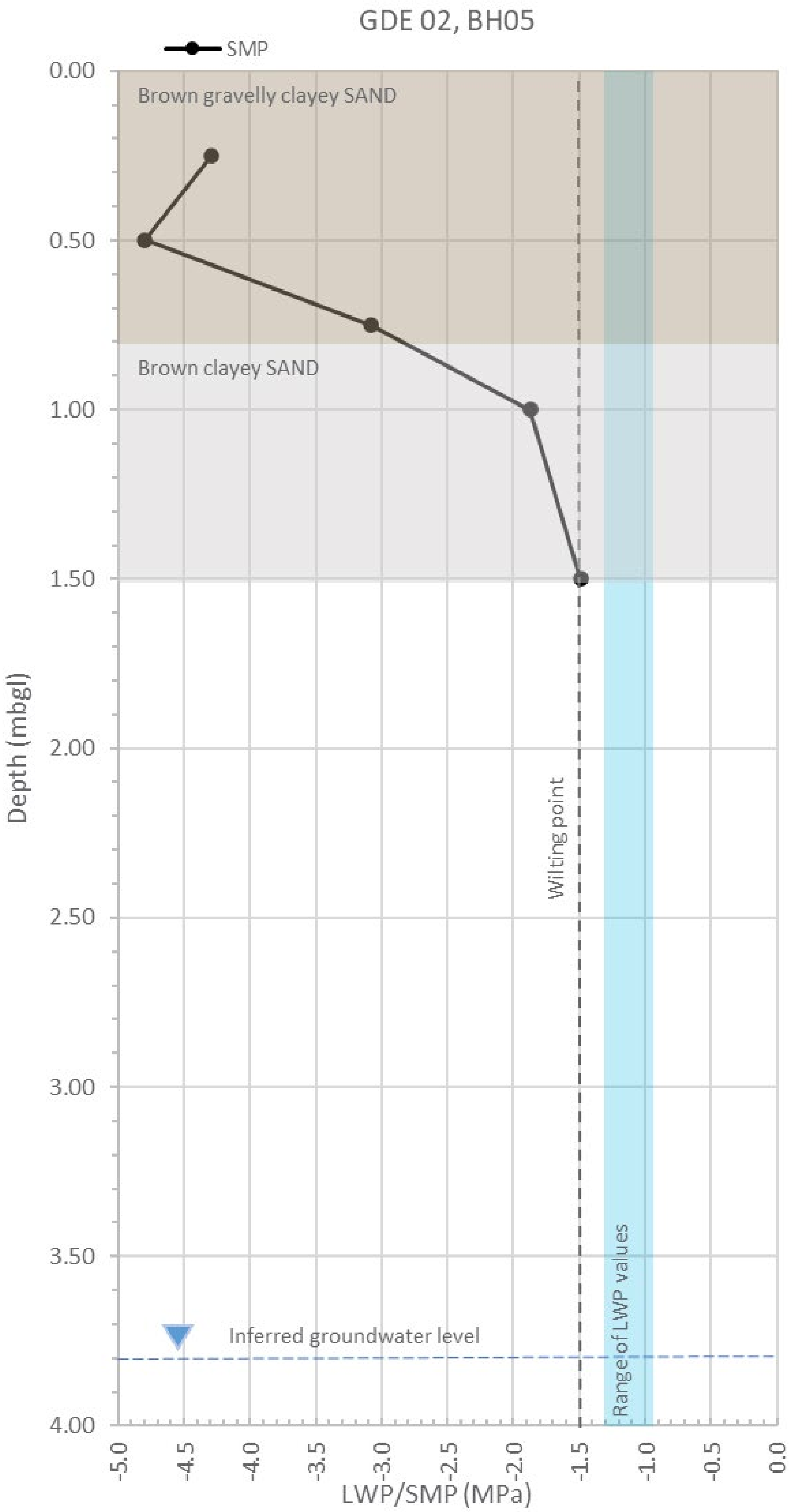


Figure 6.4 BH05 profile from Transect 1, site GDE 02

6.3.2 Transect 2 sites

Two auger holes were attempted in the clayey sands, sandy clays, and hard clays at sites GDE 8 and GDE 7. Logs for these sites show the following.

- The auger hole at site GDE 07 (BH03) was arrested at 1.0 mbgl after refusal on hard clay. The soil was noted to be moist from approximately 0.75 mbgl to 1.0 mbgl. LWP is more negative than SMP across the profile (Figure 6.5), inferring this is a shallow zone of water uptake for the trees assessed at this site. The soil moisture within the shallower depths of the profile is above the LWP value range indicating more water availability in the soil than may be needed by the vegetation at this site. Soil moisture below 1.0 mbgl cannot be determined and isotope analysis will be used to help interpret depths below this point.

- The auger hole at site GDE 08 (BH02) was arrested at 2.0 mbgl after refusal on hard clay. The soil was noted to be moist from approximately 1.0 mbgl to 2.0 mbgl. There is no correlation between LWP and SMP throughout the soil profile (Figure 6.6), and there is a significant difference in LWP values between tree 1 (t1) and tree 2 (t2) (Extremely Low) compared to tree 3 (t3) (High). The SMP values in the soil profile are significantly higher than LWP values for t1 and t2, indicating that soil moisture is available to the vegetation, if the LWP values are not erroneous. The SMP values are lower than the LWP value for t3, indicating that this tree has high water availability and may be accessing water from deeper in the soil profile, or groundwater. Isotope analysis is required to determine the source of water stress (t1 and t2) and source of moisture utilised by vegetation in this area.

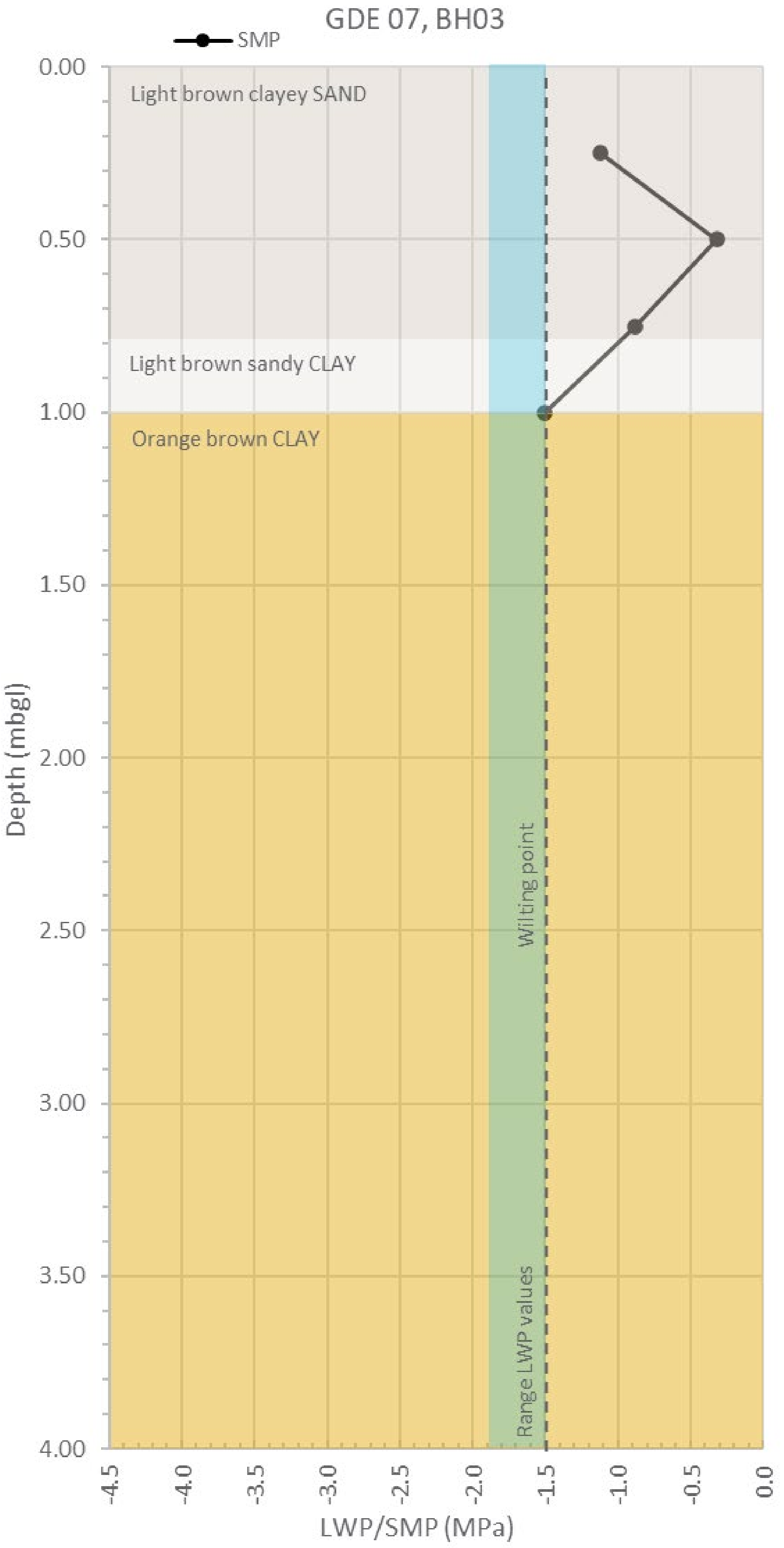


Figure 6.5 BH03 profile from Transect 2, site GDE 07

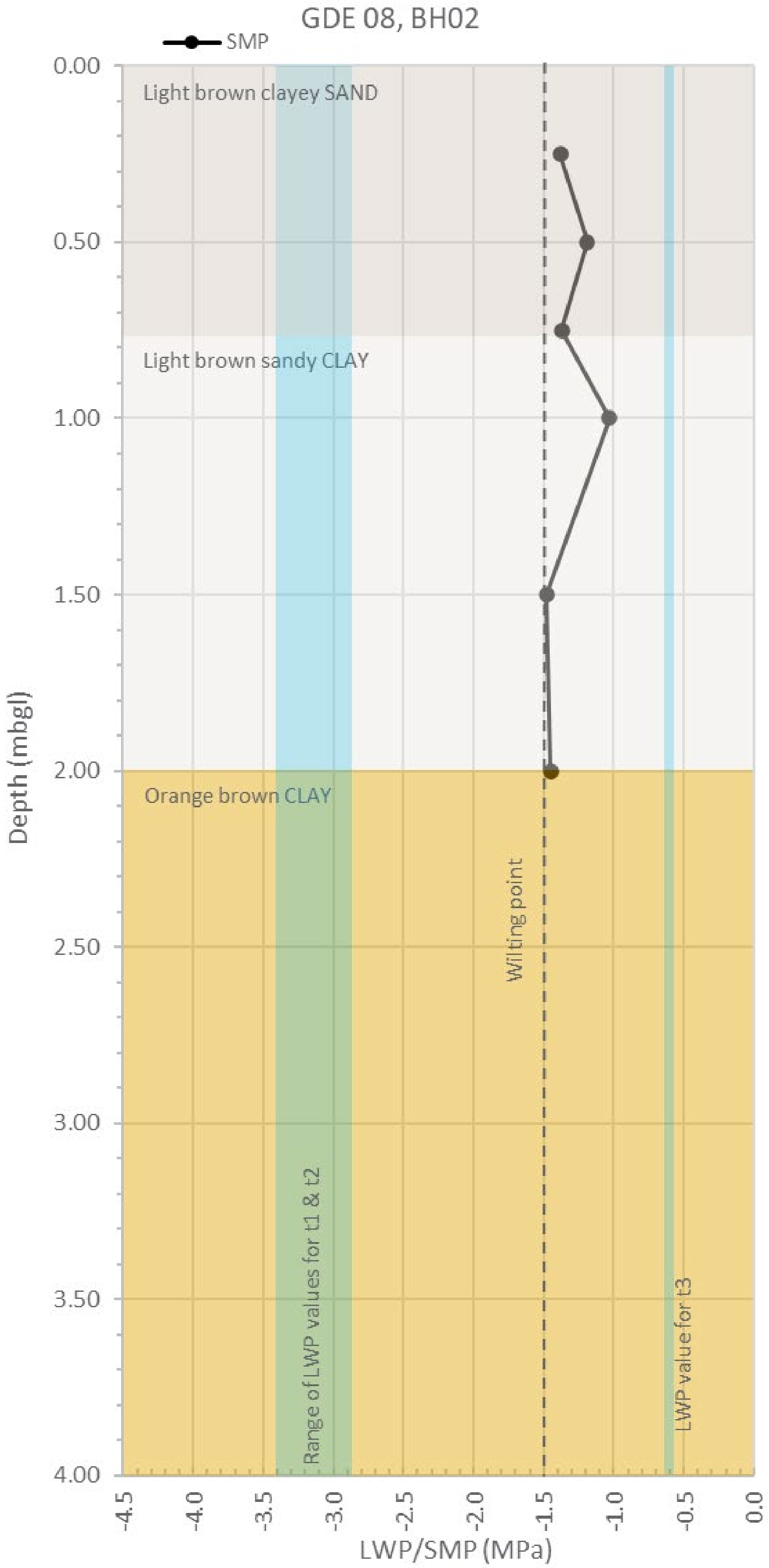


Figure 6.6 BH02 profile from Transect 2, site GDE 08

6.3.3 Transect 3 sites

Two auger holes were attempted in the clayey sands, gravelly clayey sands, sandy clays, and hard clays at sites GDE 10 and GDE 12. Logs for these sites show the following:

- The auger hole at site GDE 10 (BH01) was arrested at 1.5 mbgl after refusal on hard clay. The soil was noted to be slightly moist from throughout the soil profile. There is a clear correlation between LWP and SMP throughout the soil profile (Figure 6.7), inferring that the soil moisture within the top 1.5 mbgl is a zone of water uptake for the trees assessed at this site. Soil moisture below 1.5 mbgl cannot be determined and isotope analysis will be used to help interpret depths below this point.

- The auger hole at site GDE 12 (BH06) was arrested at 1.5 mbgl after refusal on hard clay. The soil down the profile was noted to be slightly moist from approximately 0.5 mbgl to 1.0 mbgl and moist from 1.0 mbgl to 1.5 mbgl. There is a clear correlation between LWP and SMP from 0.75 mbgl to 1.5 mbgl (Figure 6.8), inferring this is a zone of water uptake for the trees assessed at this site. Soil moisture below 1.5 mbgl cannot be determined and isotope analysis will be used to help interpret depths below this point.

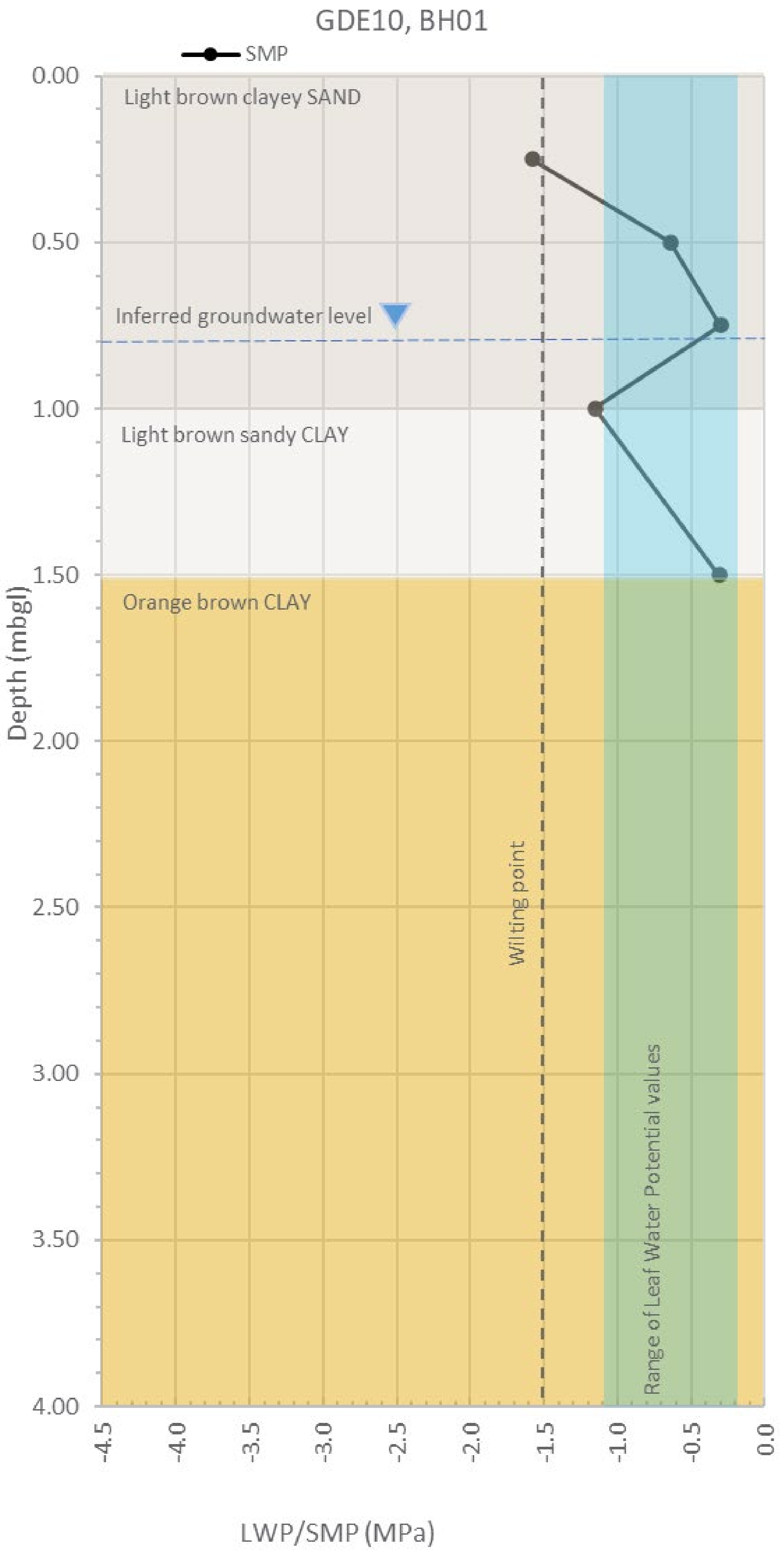


Figure 6.7 BH01 profile from Transect 3, site GDE 10

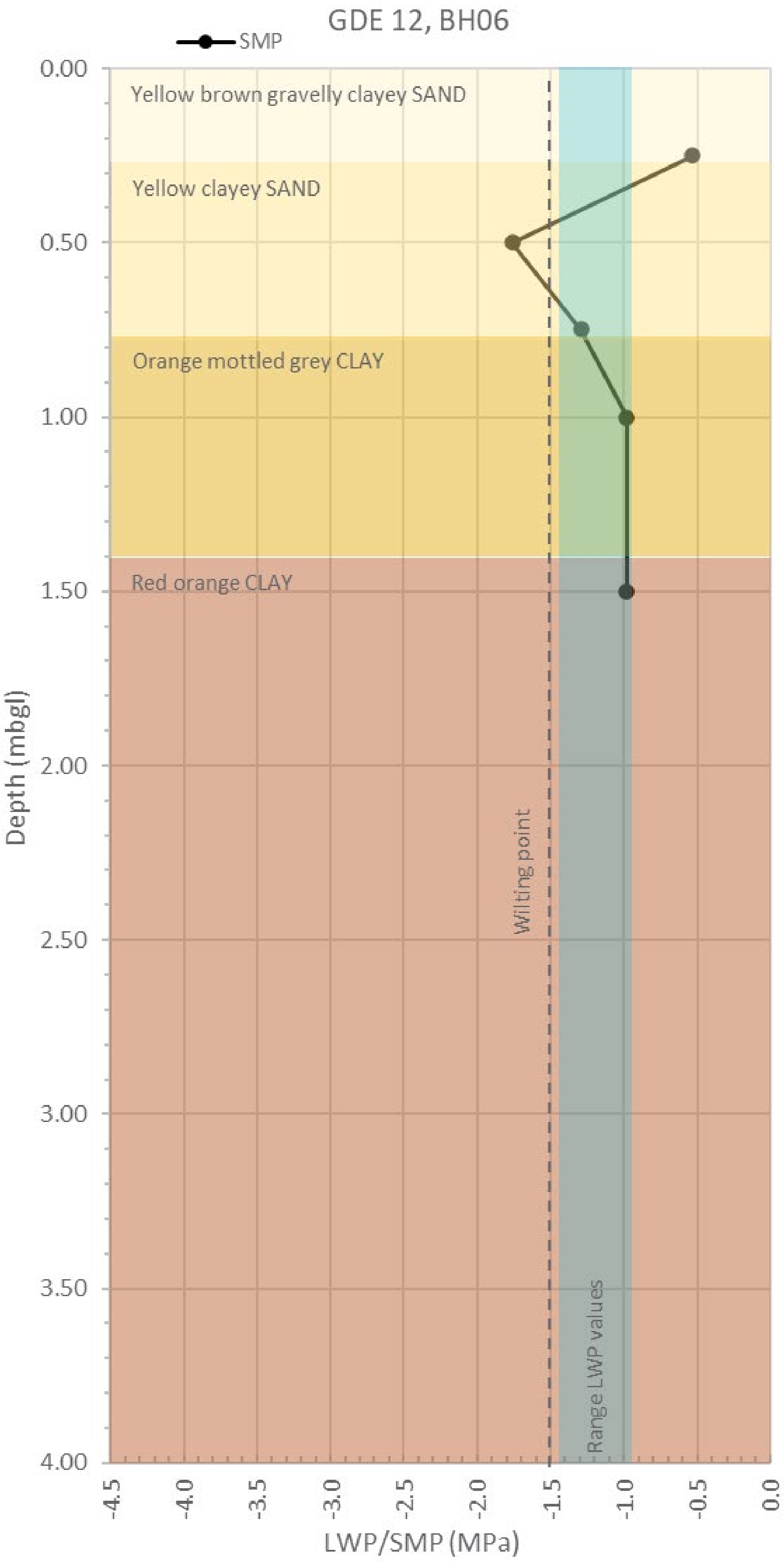


Figure 6.8 BH06 profile from Transect 3, site GDE 12

6.3.4 Groundwater and surface water sampling

Groundwater bores sampled during the February 2025 GDE assessment included MB1, MB2, MB3, MB4, MB5b, MB11b, C2, B2, and B5, and are summarised in Table 6.1. A surface water sample was collected from the eastern side of the project area from Bungalook Creek. The creek line within the western side of the project area was observed to be dry. All samples were collected with a bailer.

Table 6.1 Groundwater and surface water sampling summary

Sample source	Sample ID	SWL (mbTOC)[1]	Temp (°C)	pH	EC (µS/cm)	Redox (mV)	DO (mg/L)	Comments	Sample date	Isotope analysis
Groundwater	MB1	19.520	14.4	6.91	1065	96.3	31.4	Clear, colourless, no odour	25/02/2025	Yes
	MB2	17.601	14.2	6.65	593.8	89.4	40.3	Clear, colourless, slight sulfur odour	25/02/2025	Yes
	MB3	4.479	14.2	4.99	1160	92.2	36.6	Cloudy, colourless, slight sulfur odour	25/02/2025	Yes
	MB4	18.415	14.8	8.6	1772	71	42.2	Cloudy, colourless, no odour	25/02/2025	Yes
	MB5b	4.775	15.4	6.82	1411	99.9	48.5	Slightly cloudy, colourless, no odour	25/02/2025	Yes
	MB11b	19.699	15.7	6.38	139	22.7	52.6	Slightly cloudy, colourless, no odour	25/02/2025	Yes
	C2	4.000	14.7	7.06	284.3	191.1	71	Clear, colourless, no odour	26/02/2025	Yes
	B2	2.500	16	7.66	n/a	192.1	85.6	Brown, turbid, no odour	26/02/2025	Yes
	B5	2.500	14.9	6.93	1157	204.7	44.5	Clear, colourless, no odour	26/02/2025	Yes
Surface water	SW01	-	15.4	6.98	639	72.3	41.7	Cloudy, slightly brown, no odour	25/02/2025	Yes

1. mbTOC = meters below Top of Casing. 2. °C = degrees Celsius. 3. µS/cm = microSiemens per centimetre. 4. mV = millivolts.
5. mg/L = milligrams per litre. n/a. limited sample volume therefore unable to obtain EC reading.

6.4 Isotopes

Figure 6.10 plots stable isotope signatures ($\delta^{18}O$ $\delta^{2}H$) for values relating to surface water, groundwater, soil moisture and plant xylem water. Data interpretation is supported by isotopic data from Melbourne Airport which defines a Local Meteoric Water Line (LMWL; the local annual average relationship between hydrogen and oxygen isotope ratios in natural meteoric waters) and global rainfall defined by the Global Meteoric Water Line (GMWL). The water lines provide a reference to identify evaporative processes, which will generally result in $\delta^{18}O$ isotope values that plot below the LMWL trend.

Essentially the closer the points are to the LMWL the younger the isotopes are, suggesting they are closely linked to recent rainfall and atmospheric conditions. Whereas when the points move to the right of the LMWL, the isotopes are older and more likely to relate to groundwater that has been separated from the surface climate. In this context, samples which plot closer to the top right corner of the graph means that the samples have been exposed to more evaporative enrichment (Local Evaporation Line) which could be through surface evaporation process and or transpiration. Soil water uptake by plant roots occurs predominantly without significant isotopic fractionation, so the stable isotope composition of water in twig xylem reflects that of water taken up by roots (Dawson, Mambelli, Plamboeck, Templer, & Tu, 2002; Penna et al., 2018). Therefore, comparison of the stable isotope composition of plant xylem water with that of possible water sources (Figure 6.9) can help identify the uptake of different water sources (Ogle, Tucker, & Cable, 2014).

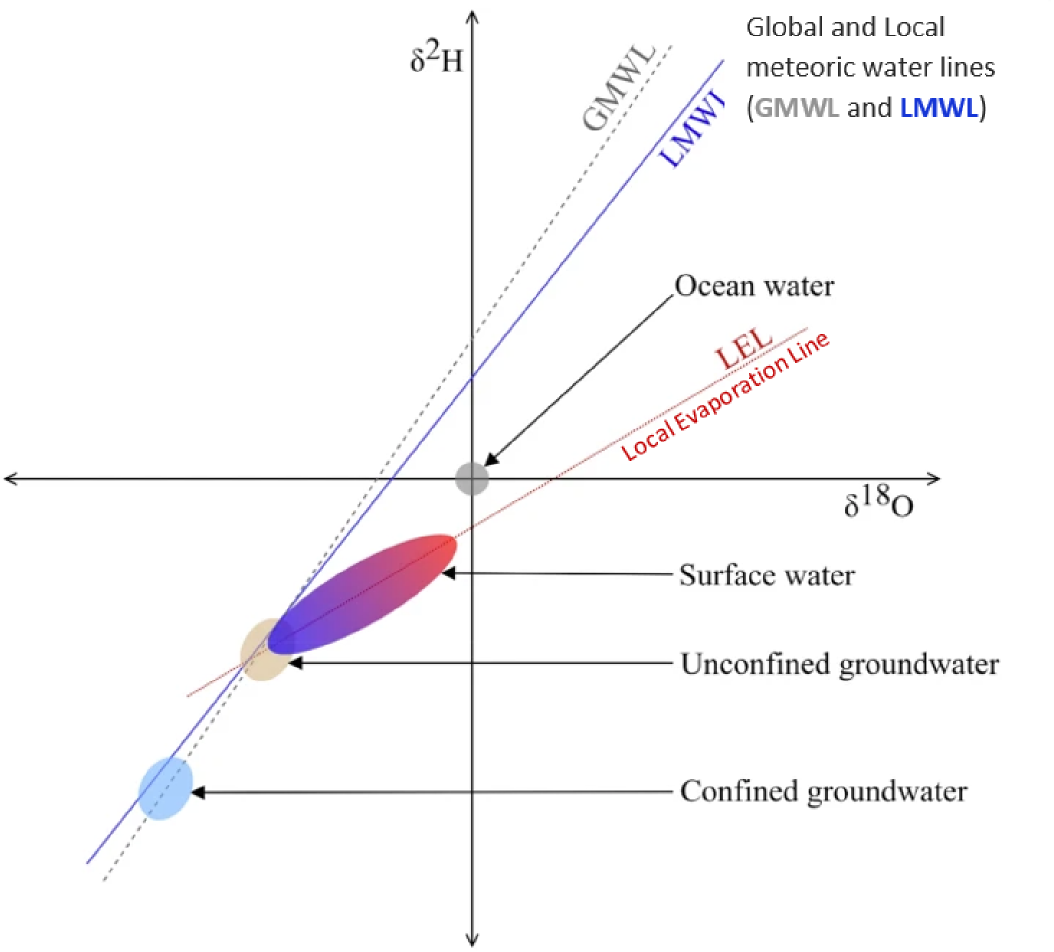


Figure 6.9 Example distribution groundwater and the surface water within the isotope ratio (modified from de Wet *et. al.*, 2020)

In Figure 6.10, stable isotope signatures of deuterium (^2H) and oxygen-18 (^{18}O) for all values sampled for including twig xylem water, soil moisture, surface water, and groundwater are compared to determine the origin of water uptake by tree xylem. The local meteoric water line (Melbourne), being the local average relationship between hydrogen and oxygen isotope ratios in natural meteoric waters and the global meteoric water line (GMWL) are also shown. Groundwater, surface water, soil and twig data were all collected in February 2025.

Precipitation, groundwater and surface water typically plot along the LMWL suggesting that these waters have a meteoric origin with minimal evaporation influence. In contrast, water in the unsaturated soil zone typically has a stable isotope (oxygen and hydrogen) composition that does not overlap with the LMWL but instead plots below/to the right of the LMWL and with a characteristic slope of less than 8. This occurs because water in the unsaturated soil zone is exposed to evaporation during its movement through the soil and while in the shallow soil layer, causing its oxygen and hydrogen isotopic composition to be altered by evaporative fractionalisation.

Surface water and groundwater samples had $\delta^{18}O$ and δ^2H values that plotted close and above the LMWL. Referring to Table 6.2, the Groundwater linear regression between the $\delta^{18}O$ and δ^2H values had a slope of 8.06, closely matching the Global Meteoric Water Line, suggesting minimal evaporation and indicating recharge primarily from meteoric sources and possibly under cooler climates (given the groundwater samples are slightly enriched in δ^2H) . Water from the unsaturated soil zone had a low slope of 4.8, suggesting it has undergone evaporative enrichment. Twig xylem water had very low slopes of 3.7 and all twig water isotopic compositions plotted below the LMWL lines, suggesting that the twig water has been evaporatively enrichened, and even more so than soil water. Twig xylem water, $\delta^{18}O$ and δ^2H values indicated that the tree samples did not exclusively take up groundwater but made extensive use of water sourced from the unsaturated soil zone.

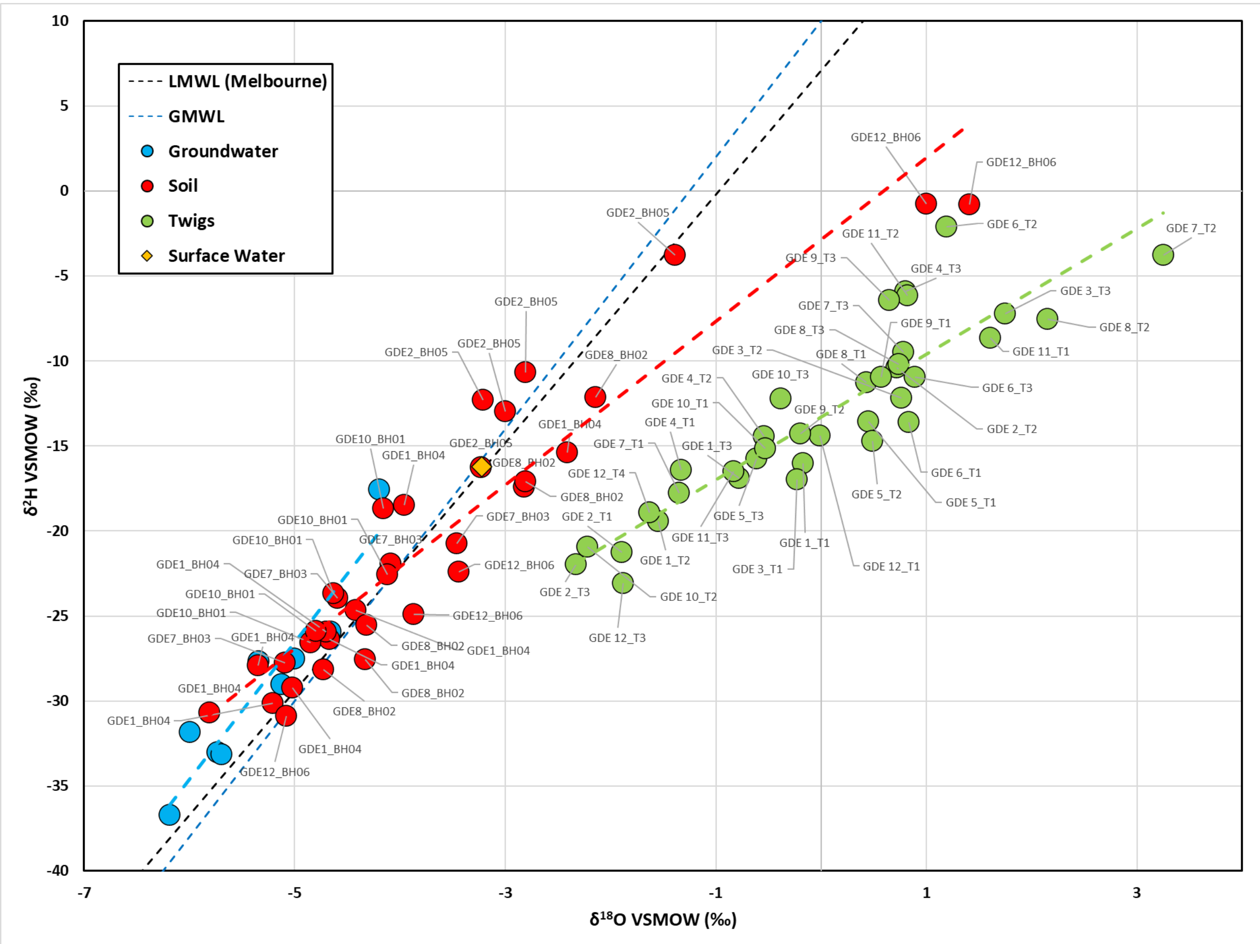


Figure 6.10 Stable isotope scatter of surface water, groundwater, soil and twig samples (February 2025)

The combination of low slope of tree xylem isotope data (slope = 3.7), consistent plotting of all xylem stable isotope values to the right-hand side of the LMWL and GMWL and the lack of groundwater and xylem isotope cluster overlap, indicates strong evaporative enrichment and suggests that the trees are not accessing groundwater, and therefore unlikely to be groundwater dependent ecosystems. Instead, the similarity in the slope of the stable isotopic compositions between the tree xylem and unsaturated soil water (slope = 4.8) indicates that water uptake is primarily from the enriched soil water from the unsaturated zone. Given that the xylem stable isotopic slope (3.7) is lower than that of the sampled unsaturated zone soil moisture (0.25–3.0 m) isotopic slope (4.8), it is likely the trees are accessing water from the sampled range as well as from deeper, more evaporatively enriched older soil water within the unsaturated zone.

Table 6.2 Comparison of linear regression parameters for the relationship between δ18O and δ2H isotopic composition of groundwater, soil water and twig water

Water source	slope
GMWL	8
LMWL	7.3
Groundwater	8.06
Soil water	4.8
Twig xylem	3.7

GDE 1 is located south of Bungalook Creek in an area with shallow groundwater (<5 mbgl), and the plant xylem isotope analysis shows no cluster correlation between plant water use and groundwater isotope signatures, indicating that vegetation at this site is not using groundwater (Figure D1, Appendix D). Instead, the isotope results align more closely with surface water and shallow soil moisture (up to 0.5 m depth). While there is some correlation between deeper soil moisture (below 0.5 m) and groundwater indicating some interaction, the plants appear to preferentially use the shallow, nutrient-rich soil moisture rather than access groundwater. The ecohydrological setting at GDE 1 is similar to that observed at GDE 5 and GDE 9.

GDE 10 is located north of Bungalook Creek also within an area of shallow groundwater, <5 mbgl, and there is no correlation between plant xylem isotope results and groundwater isotope results indicating the vegetation is not utilising groundwater (Figure D5, Appendix D). Like GDE 1, GDE 10 soil isotope results have a correlation between groundwater and soil moisture however, the vegetation is not accessing the deeper groundwater system.

6.5 Ecohydrological conceptual model of potential GDEs

Based on the information acquired to date including past studies, an ecohydrological conceptual model was developed for the project area and is provided in Figure 6.11. The model shows the potential GDE locations and their relationship to groundwater along an idealised cross section between the quarry and Bungalook Creek. Despite the shallow water table identified at GDE 1, GDE 5 and GDE 10, the isotope results, SMP measurements and vegetation assessment all indicate that vegetation within these areas are not accessing groundwater and are preferentially utilising the higher nutrient soil moisture. Soil moisture is likely predominantly recharged by rainfall infiltration however around the creek areas, surface water recharge is also possible. Referring to Figure 6.11, other components of the updated conceptual model include:

- The water table is likely a subdued reflection of topography, with groundwater levels ranging between 30 mbgl directly south of the quarry, to within 5 mbgl adjacent to Bungalook Creek.
- The quarry is a regional sink, with groundwater flowing radially towards the workings.

- During times of higher rainfall, when groundwater levels maybe even shallower, trees close to Bungalook Creek may access groundwater, however this would still likely be sourced from recent creek recharge post rainfall events.
- Root water update may occur at shallower depths during the wetter periods, when soil water is replenished, as indicated by the dry/wet season insert graphic.
- Baseflow to the creek is thought to be minimal based on measured groundwater levels.
- It is understood that water is pumped out of the quarry to maintain dry working conditions, which would be a combination of groundwater inflow, runoff and direct rainfall.
- Maintaining creek flows is likely still important to ensure groundwater and soil stores are replenished along Bungalook Creek during the wet season.

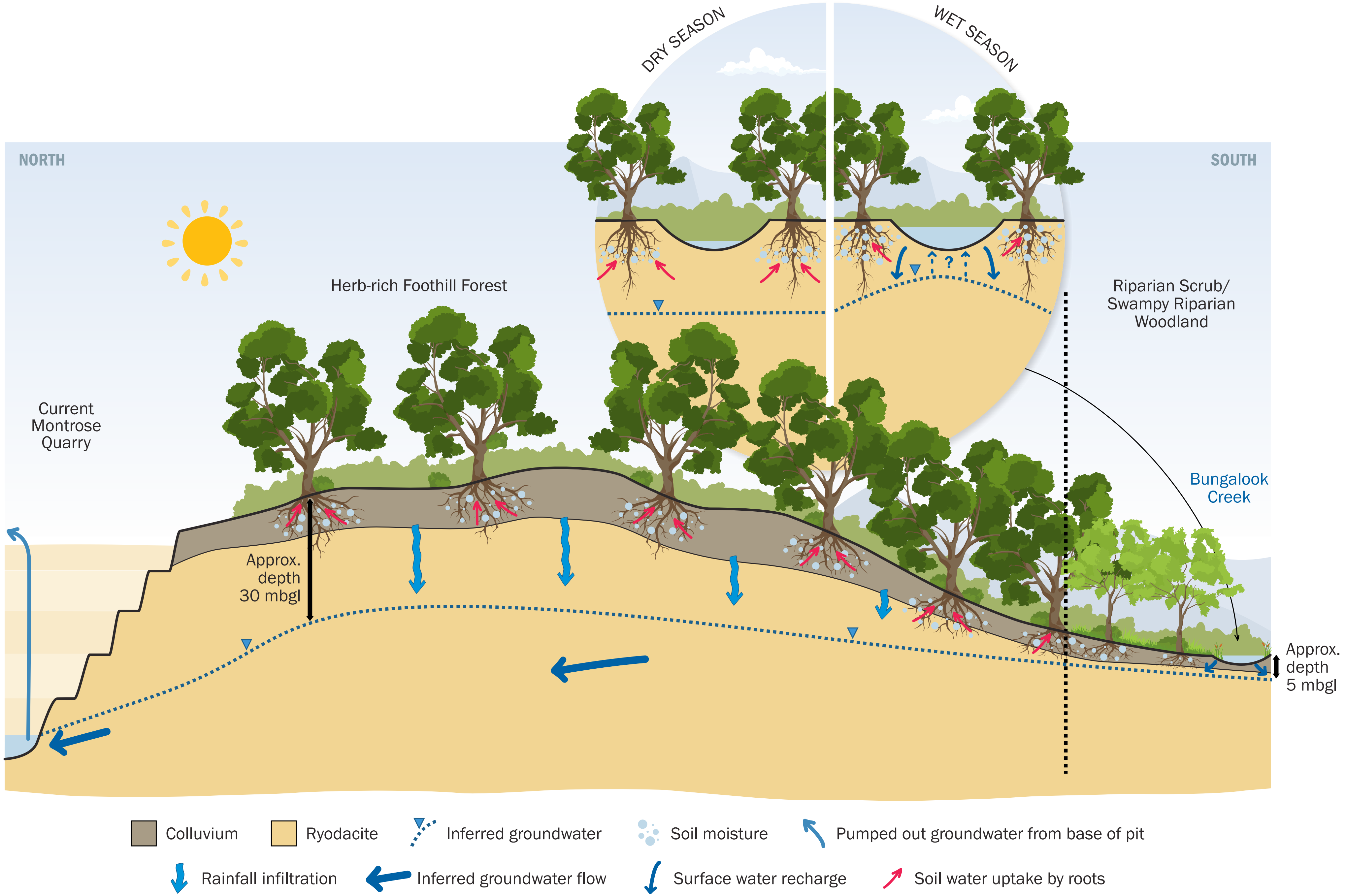


Figure 6.11 Ecohydrogeological conceptual model

6.6 GDE potential summary

The following Table 6.3 summarises the results of the GDE assessment and describes the GDE likelihood based on the current available information. The information presented is based on the current results and conditions at the time of the survey, using the multiple lines of evidence approach.

Table 6.3 GDE summary results review

Assessment site	Location/geomorphic position/desktop GDE potential	Initial Class Ranking[1]	LWP	ERI (relative water availability)	Vegetation condition	SMP	Isotopes	Post field assessment GDE potential
GDE 1	• South of Bungalook Creek, south of the project. • Approximate depth to groundwater 0–5 mbgl. • Grassy forest EVC. • **Mapped high potential GDE.**	Class 2 DTGW <5 mbgl Nearest borehole EC - <3,000 mg/L	High to Moderate	Low to average stress	• Canopy tress predominantly appeared healthy; however, some evidence of dieback was noted with some crowns of canopy species in poor condition. • Slightly Stressed.	• Arrested at 3.5 mbgl after refusal on hard clay. • There is a correlation between LWP and SMP at 0.5 mbgl inferring a zone of water uptake for trees at this site. Water is available to vegetation from 0.5 mbgl to 3.5 mbgl.	All twig isotope data is separated from all groundwater isotope results. Twig isotopes are closest to the surface water isotope and the shallow soil samples of BH04. There is a correlation between groundwater isotopes and soil moisture below 0.5 m suggesting recharge occurs rapidly through the soil profile to groundwater.	Likely a low level of dependence on groundwater and relying more on accessing soil moisture. The GDE assessment site had been classified initially as Class 2 since the DTGW is shallow. High LWP values suggests water is available to vegetation, however, SMP indicated a zone of water uptake within the soil between 0.5 and 3.5 mbgl and the isotope results did not indicate cluster correlation between vegetation and groundwater. The vegetation condition was also reported to be slightly stressed. This indicates the vegetation is preferencing soil moisture over the groundwater source at the time of sampling. **Low potential GDE**

[1] Froend & Loomes 2004.

Assessment site	Location/geomorphic position/desktop GDE potential	Initial Class Ranking[1]	LWP	ERI (relative water availability)	Vegetation condition	SMP	Isotopes	Post field assessment GDE potential
GDE 2	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 5–10 mbgl. • Valley heath forest and Riparian scrub/swampy riparian woodland complex EVCs. • **Mapped moderate to high potential GDE.**	Class 2 DTGW <5 mbgl Nearest borehole EC - <3,000 mg/L	Moderate	Low to average stress	• High levels of dieback were noted in the canopy and subcanopy layers with no evidence of Eucalypt recruitment. • Stressed.	• Arrested at 1.5 mbgl after refusal on a large tree root. • No link determined between LWP and SMP in the shallow profile therefore this site will rely on the isotope analysis.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water.	Likely a low level of dependence on groundwater and relying more on accessing soil moisture. The GDE assessment site had been initially classified as Class 2 since the DTGW is shallow. SMP values were inconclusive, however, high levels of dieback were observed, and the isotope results did not indicate a correlation between vegetation and groundwater. This indicates the vegetation is preferencing soil moisture over the groundwater source. **Low potential GDE**
GDE 3	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 15–25 mbgl. • Valley heathy forest/Herb-rich foothill forest EVCs. • **Mapped low to negligible potential GDE.**	Class 5 DTGW >15 mbgl Nearest borehole EC - <3,000 mg/L	Moderate to Low	Low to average stress	• Relatively disturbed area. High levels of dieback within the canopy and subcanopy layers were noted. No recruitment of the canopy layer was observed. • Stressed.	No soil samples collected, however, BH03 has the same geology, EVC and DTGW therefore it can be inferred that this location is similar to GDE 3. There is a correlation between LWP and SMP at 1.0 mbgl inferring a zone of water uptake for trees at this site.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been classified initially as Class 5 since the DTGW is deep. The LWP values indicated a low to average vegetation stress and the vegetation assessment indicated a stressed ecosystem. The isotope results did not indicate a correlation between vegetation and groundwater. **Negligible potential GDE**

Assessment site	Location/geomorphic position/desktop GDE potential	Initial Class Ranking[1]	LWP	ERI (relative water availability)	Vegetation condition	SMP	Isotopes	Post field assessment GDE potential
GDE 4	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 25–50 mbgl. • Herb-rich foothill forest EVC. • **Mapped negligible potential GDE.**	Class 5 DTGW >15 mbgl Nearest borehole EC - <3,000 mg/L	Extremely low	Average to high stress	• Some dieback was observed in the canopy layer. A low percentage of living tree crowns appearing stressed. • Healthy.	No soil samples collected, however, BH02 has the same geology, EVC and similar DTGW therefore it can be inferred that this location is similar to GDE 8. Soil moisture is available to vegetation however a highly variable range of LWP requires isotope results for clarification.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been initially classified as Class 5 since DTGW is deep and has an extremely low LWP, and average to high stress. The isotope results did not indicate a correlation between vegetation and groundwater. **Negligible potential GDE**
GDE 5	• South of Bungalook Creek, south of the project. • Approximate depth to groundwater 0–5 mbgl. • Riparian scrub/swampy riparian woodland complex EVC. • **Mapped high potential GDE.**	Class 2 DTGW <5 mbgl Nearest borehole EC - <3,000 mg/L	High to Moderate	Low stress	• Some dieback was observed in the canopy layer but the majority of the site appeared in good condition. Some storm damage was apparent. • Healthy.	No soil samples collected.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water.	Likely a low level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been classified initially as Class 2 and has high to moderate LWP. Low stress and healthy vegetation were identified within this GDE assessment site. The isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture (with an abundant supply) over the groundwater source. **Low potential GDE**

Assessment site	Location/geomorphic position/desktop GDE potential	Initial Class Ranking[1]	LWP	ERI (relative water availability)	Vegetation condition	SMP	Isotopes	Post field assessment GDE potential
GDE 6	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 5–10 mbgl. • Riparian scrub/swampy riparian woodland complex EVC. • **Mapped moderate potential GDE.**	Class 3 DTGW 5–10 mbgl Nearest borehole EC - <3000 mg/L	Low to Very low	Low to average stress	• Some dieback in the canopy layer on the downhill side of the survey point was observed, and some dieback in the subcanopy layer on the uphill side was observed. • Slightly stressed.	No soil samples collected.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been initially classified as Class 3, has low to very low LWP values and reported to contain slightly stressed vegetation. The isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture, albeit with difficulty, over the groundwater source. **Negligible potential GDE**
GDE 7	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 15–25 mbgl. • Riparian scrub/swampy riparian woodland complex EVC. • **Mapped negligible potential GDE.**	Class 5 DTGW >15 mbgl Nearest borehole EC - <3,000 mg/L	Low to Very low	Average stress	• The survey point was located on the edge of a cleared patch to the north-west and the canopy appeared healthy. • Healthy.	• Arrested at 1.0 mbgl after refusal on hard clay. • There is a correlation between LWP and SMP at 1.0 mbgl inferring a zone of water uptake for trees at this site. Water is available to vegetation from 0.25 mbgl to 1.0 mbgl.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data have experienced more evaporative fractionalisation than the soil moisture isotopes indicating the source could be deeper in the soil profile.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been initially classified as Class 5 since DTGW is deep and has low to very low LWP values. SMP results indicated water availability in the soil for vegetation and the isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture. **Negligible potential GDE**

Assessment site	Location/geomorphic position/desktop GDE potential	Initial Class Ranking[1]	LWP	ERI (relative water availability)	Vegetation condition	SMP	Isotopes	Post field assessment GDE potential
GDE 8	• North of Bungalook Creek, south of the project. • Approximate depth to groundwater 25–50 mbgl. • Herb-rich foothill forest/Riparian scrub/swampy riparian woodland complex EVCs. • **Mapped negligible potential GDE.**	Class 5 DTGW >15 mbgl Nearest borehole EC - <3,000 mg/L	Highly variable range, however most within the Very low to Extremely low	Low to high stress	• Some evidence of dieback within the canopy layer was observed. Some crowns knocked out of trees and brock limbs suggest storm damage. • Slightly Stressed.	• Arrested at 2.0 mbgl after refusal on hard clay. • There is no correlation between LWP and SMP. Soil moisture is available to vegetation however a highly variable range of LWP requires isotope results for clarification.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data have experienced more evaporative fractionalisation than the soil moisture isotopes indicating the source could be deeper in the soil profile.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been initially classified as Class 5 since DTGW is deep and has very low to extremely low LWP values. SMP results indicated water availability in the soil for vegetation and the isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture. **Negligible potential GDE**
GDE 9	• South of Bungalook Creek, south-east of the project. • Approximate depth to groundwater of 5–10 mbgl. • Riparian scrub/swampy riparian woodland complex EVC. • **Mapped moderate potential GDE.**	Class 3 DTGW 5–10 mbgl Nearest borehole EC - <3000 mg/L	Extremely low	High stress	• High levels of dieback were evident in the canopy and subcanopy layers, particularly to the south of the sample point. • Stressed.	No soil samples collected.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site has extremely low LWP and appears highly stressed. High levels of dieback were observed during the site investigation particularly to the south away from the quarry. Results suggest an external issue causing an unhealthy ecosystem at this site. The isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture over the groundwater source. **Negligible potential GDE**

Assessment site	Location/geomorphic position/desktop GDE potential	Initial Class Ranking[1]	LWP	ERI (relative water availability)	Vegetation condition	SMP	Isotopes	Post field assessment GDE potential
GDE 10	• North of Bungalook Creek, south-east of the project. • Approximate depth to groundwater of 0–5 mbgl. • Riparian scrub/swampy riparian woodland complex EVC. • **Mapped high potential GDE.**	Class 2 DTGW <5 mbgl Nearest borehole EC - <3,000 mg/L	Very high	Low stress	• Small amount of dieback observed in the canopy crowns with dieback evident in lower limbs of tall trees. • Slightly stressed.	• Arrested at 1.5 mbgl after refusal on hard clay. • There is a clear correlation between LWP and SMP from 0.5 mbgl to 1.5 mbgl inferring a zone of water uptake for trees at this site.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water. There is a correlation between groundwater isotopes and soil moisture below 0.5 m suggesting soil moisture recharge by groundwater.	Likely a low level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been initially classified as Class 2 since the DTGW is shallow. The LWP values are very high, however, the vegetation was reported to be slightly stressed. SMP results indicated water availability in the soil for vegetation and the isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture. **Low potential GDE**
GDE 11	• North of Bungalook Creek, south-east of the project. • Approximate depth to groundwater 10–15 mbgl. • Riparian scrub/swampy riparian woodland complex EVC. • **Mapped moderate potential GDE.**	Class 4 DTGW 10–15 mbgl Nearest borehole EC - <3,000 mg/L	Moderate to low	Average stress	• The subcanopy was dead or in poor condition for approximately 80% of the Eucalypts. Epicormic growth, a sign of stress, was observed on trunks. Little evidence of Eucalypt recruitment was observed. • Stressed.	No soil samples collected.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to soil moisture isotopes and surface water.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been initially classified as Class 4 since the DTGW is reasonably deep. The LWP values are moderate to low and the vegetation has been reported to be stressed. The isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture. **Negligible potential GDE**

Assessment site	Location/geomorphic position/desktop GDE potential	Initial Class Ranking[1]	LWP	ERI (relative water availability)	Vegetation condition	SMP	Isotopes	Post field assessment GDE potential
GDE 12	• North of Bungalook Creek, south-east of the project. • Approximate depth to groundwater 25–50 mbgl. • Herb-rich foothill forest EVC. • **Mapped negligible potential GDE.**	Class 5 DTGW >15 mbgl Nearest borehole EC - <3,000 mg/L	Moderate to low	Average stress	• Predominantly healthy crowns in canopy layer with some dieback observed down slope side to the south-east of survey point. Moderate level of dieback in the subcanopy layer. • Slightly stressed.	• The auger hole was arrested at 1.5 mbgl after refusal on hard clay. • There is a clear correlation between LWP and SMP from 0.75 mbgl to 1.5 mbgl inferring a zone of water uptake for trees at this site.	All twig isotope data is separated from all groundwater isotope results. Twig isotope data is closer to deeper soil moisture from BH06 and surface water.	Likely a negligible level of dependence on groundwater and relying on accessing soil moisture. The GDE assessment site had been initially classified as Class 5 since the DTGW is deep. The LWP values are moderate to low and the vegetation is slightly stressed. SMP results indicated water availability in the soil for vegetation and the isotope results did not indicate a correlation between vegetation and groundwater suggesting vegetation is preferencing soil moisture. **Negligible potential GDE**

\\emm.local\xdrive\2025\E250014 - Montrose Quarry Extension GDE\GIS\02_Maps\GDE004_UpdatedGDEpotential\GDE004_UpdatedGDEpotential_20250618_03.aprx 18/06/2025

Source: EMM (2025); DEECA (2023); MetroMap (2025)

KEY

Project boundary – Boral land
Survey area
Study area

Updated GDE potential
Low
Negligible

Existing environment
Major road
Minor road
Vehicular track
Watercourse/drainage line
National park/reserve

Updated GDE potential

Montrose Quarry Extension
GDE Assessment: Field Summary
Figure 6.12

EMM
creating opportunities

7 Conclusion

The results of the field survey do not suggest any GDEs exist within the project area. The risk of terrestrial ecosystems at the Montrose Quarry project area is low to negligible.

A summary of the results to date is provided below:

- Monitoring bore data including depth to water and salinity indicated at least initially, negligible likelihood of ecosystem dependency on groundwater (Class 5) at four bore locations and high likelihood (Class 2) at five bore locations using a modified version of the Froend & Loomes (2004) classification (Section 5.6.1).

- The Riparian scrub/swampy riparian woodland complex areas surrounding the creek vegetation has high LWP values, meaning high water availability, and low to average stress. The predominant species, Messmate Stringybark and Swamp Gum have approximate root depths of 5–10 m and GHD's numerical groundwater model suggested that groundwater depth within these areas is likely to be less than 5 m, allowing tree roots to utilise groundwater if needed. However, there is a correlation between LWP and SMP at 0.5 mbgl within GDE 1 and to 1.5 mbgl within GDE 10, indicative of soil moisture use. The isotope results did not indicate vegetation within this EVC is utilising groundwater and it is likely that vegetation is preferencing soil moisture water over other sources.

- Within the Herb-rich foothill forest areas closer to the quarry, vegetation has low to extremely low LWP values, indicating less water availability, average to high stress, and roots accessing soil moisture as indicated in GDE 12 with a clear correlation between LWP and SMP to 1.5 mbgl. The isotope results did not indicate vegetation within this EVC is utilising groundwater and it is likely that vegetation is preferencing soil moisture.

- Across the project area, evidence of dieback within the canopy layer and subcanopy layer was observed (Section 5.3).

- Since the site investigation in February 2025, a large bushfire has impacted the site with yet unknown impacts to the site ecosystems.

7.1 Discussion

The results from this field investigation suggest there are no GDEs within the project area, based on the environment assessed during February 2025.

The preliminary GDE potential map identified high potential areas primarily along Bungalook Creek, based on the assumption that groundwater is shallow (<5 mbgl) and therefore accessible to vegetation. However, field results from this investigation suggest that this assessment is likely incorrect. SMP data indicate that vegetation is accessing available moisture within at least the top 3 m of the soil profile, rather than relying on groundwater. Nutrient levels are typically higher within the upper soil layers with nutrient levels that tend to decrease rapidly with depth (McLendon et al. 2007). The majority of species typically develope dense roots in the top 0.8 m of soil and the rest of the root system in the top 2 m of soil in order to increase the uptake of nutrients (Orellana et al. 2012). Some GDE species tend to develop deeper root systems when the soil moisture and nutrients are not readily available. The soil moisture and therefore nutrients, surrounding Bungalook Creek appears to be available to vegetation within the project area and is most likely the source of the water for vegetation along the creek line. The isotope results also agree with the above interpretations with no isotope cluster correlation identified between the vegetation and groundwater isotopes, with the vegetation appearing to be more isotopically similar to the soil water isotope data.

7.2 Recommendations

It is likely that the vegetation to the south of the property is relying on the soil moisture that is likely sustained by rain fall and creek flows, when creek seepage occurs. It is recommended to minimise impacts and changes to the current creek flows which will help to maintain vegetation condition in this region.

References

AQ2 (2023). *West Musgrave Ecoydrological Conceptual Model report.*

Dansgaard, W. (1964). Stable isotopes in precipitation. *Tellus*, 16, 436–468.

Dawson, T. E., Mambelli, S., Plamboeck, A. H., Templer, P. H., & Tu, K. P. (2002). Stable isotopes in plant ecology. *Annual Review of Ecology and Systematics*, 33, 507–559. https://doi.org/10.1146/annurev.ecolsys.33.020602.095451.

de Wet, R.F., West, A.G. & Harris, C. (2020) Seasonal variation in tap water δ^2H and δ^{18}O isotopes reveals two tap water worlds. *Sci Rep* 10, 13544. https://doi.org/10.1038/s41598-020-70317-2.

Department of Environment, Land, Water & Planning (2018) Native Vegetation – Modelled 2005 Ecological Vegetation Classes layer.

Doody et al. (2019). Independent Expert Scientific Committee (IESC) *Guidelines Explanatory Note for assessing groundwater-dependent ecosystems.*

Eamus, D., Froend, F., Loomes, R., & Murray, B. (2006). A functional methodology for determining the groundwater regime needed to maintain the health of groundwater dependent vegetation. *Australian Journal of Botany 54*, 97-114.

Environment, Climate Change and Water (2015). *Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems.* Water Act. Victorian Government.

Flanagan LB, Orchard TE, Tremel TN, Rood SB. Using stable isotopes to quantify water sources for trees and shrubs in a riparian cottonwood ecosystem in flood and drought years. *Hydrological Processes*. 2019;1–14. https:// doi.org/10.1002/hyp.13560.

Froend R. & Loomes R (2004). *Approach to determination of ecological water requirement of groundwater dependent ecosystems in Western Australia - A report to the Department of Environment*, Edith Cowan University, Perth.

Gardner, W. R. (1960). Dynamic aspects of water availability to plants. *Soil Science*, (89) 63-73.

GHD (2024). *Groundwater Dependent Ecosystem Assessment for Montrose Quarry, Assessment Report.*

GHD (2023a). *Montrose Quarry Staging Plan and Rehabilitation Concept.*

GHD (2025). *Numerical Groundwater Modelling Report,* Boral Montrose Quarry.

GHD (2023b). *Surface Water and Groundwater Assessment,* Montrose Quarry.

Holland, K. L., Tyerman, S. D., J., M. L., & R., W. G. (2006). Holland, K. L, Tyerman S. D., Mensforth L. J., and Walker G. R. G.R. Tree water sources over shallow, saline groundwater in the lower River Murray, south-eastern Australia: implications for groundwater recharge mechanisms. *Australian Journal of Botany*, (54.2) 193-205.

Hollins. S. E et al. (2018). *Science of the Total Environment 645, 630-645.*

McLendon. T., Hubbard. P. J and Martin. D. W. 2007. Partitioning the use of precipitation and groundwater derived moisture by vegetation in an arid ecosystem in California. *Journal of Arid Environments*, 986-1001.

Mensforth, L., Thorburn, P., Tyerman, S., & & Walker, G. (1994). Sources of water used by riparian Eucalyptus camaldulensis overlying highly saline groundwater. *Oecologia*, 100(1), 21-28.

NSW Government (2025) Groundwater dependent ecosystems, NSW Government date accessed 04/04/2025 https://water.dpie.nsw.gov.au/our-work/science-data-and-modelling/groundwater-management-and-science/groundwater-and-the-environment#:~:text=Groundwater%20dependent%20terrestrial%20vegetation%20(Phreatophytes,groundwater%20as%20a%20water%20source.

Orellana. F., Verma. P., Loheide II. S. P. and Daly. E. 2012. Monitoring and modelling water-vegetation interactions in groundwater-dependent ecosystems, *Reviews of Geophysics*, 50.

Peng, H., Mayer, B., Harris, S., & Krouse, H. R. (2004). A 10-yr record of stable isotope ratios of hydrogen and oxygen in precipitation at Calgary, Alberta, Canada. *Tellus*, 56B, 147–159.

Penna, D., Hopp, L., Scandellara, F., Allen, S. T., Benettin, P., Beyer, M., … Kirchner, J. W. (2018). Ideas and perspectives: Tracing terrestrial ecosystem water fluxes using hydrogen and oxygen stable isotopes – challenges and opportunities from an interdisciplinary perspective. *Biogeosciences*, 15, 6399–6415. https://doi.org/10.5194/bg-15-6399- 2018.

PMS Instrument Company. (2019). Model 1515D Pressure Chamber Operating Manual. Retrieved from https://www.pmsinstrument.com/wp-content/uploads/PMS_Model_1515D_Operating_Instructions.pdf.

Richardson, S., Irvine, E., Froend, R., B. P., Barber, S., & Bonneville, B. (2011). *Australian groundwater dependent ecosystems toolbox part 1: assessment framework.* Canberra: Waterlines report. National Water Commission.

Sprenger, M., Tetzlaff, D., Buttle, J., Carey, S. K., McNamara, J. P., Laudon, H., … Soulsby, C. (2018). Storage, mixing, and fluxes of water in the critical zone across northern environments inferred by stable isotopes of soil water. Hydrological Processes, 32, 1720–1737. https:// doi.org/10.1002/hyp.13135.

Thorburn, P. J., & R, a. W. (1994). Variations in stream water uptake by Eucalyptus camaldulensis with differing access to stream water. *Oecologia*, 100, 293-301.

WP4C Operation Manual. (2021). Retrieved from Meter Group: 20588_WP4C_Manual_Web.pdf (metergroup.com).

Appendix A

Leaf Water Potential measurements

ID	GDE location	Tree #	Date	Tree height (m)	Species	Pre-dawn LWP (bar)			Average	LWP (Mpa)	Midday LWP (bar)			Average	LWP (Mpa)	Ecohydrological Rehydration Index (ERI)	Isotope twig sample (Y/N)	Date collected
						Reading #1	Reading #2	Reading #3			Reading #1	Reading #2	Reading #3					
T1_GDE4_t2	GDE_4	t2	25/02/2025	11.3	*Eucalyptus Goniocalyx*	-27.98	-28.43	-28.93	-28.45	-2.845	-34.9	-34.5	-35.36	-34.92	-3.492	0.185	Yes	25/02/2025
T1_GDE4_t1	GDE_4	t1	25/02/2025	13.0	*Eucalyptus Goniocalyx*	-16.62	-18.5	-15.55	-16.89	-1.689	-33.09	-33.89	-35.32	-34.10	-3.410	0.505	Yes	25/02/2025
T1_GDE4_t3	GDE_4	t3	25/02/2025	18.0	*Eucalyptus Goniocalyx*	-29.06	-30.13	-28.69	-29.29	-2.929	-42.00	-42.90	-46.40	-43.77	-4.377	0.331	Yes	25/02/2025
T1_GDE3_t1	GDE_3	t1	25/02/2025	20.0	*Eucalyptus Goniocalyx*	-9.57	-9.44	-10.92	-9.98	-0.998	-32.87	-32.58	-34.65	-33.37	-3.337	0.701	Yes	25/02/2025
T1_GDE3_t2	GDE_3	t2	25/02/2025	17.0	*Eucalyptus Goniocalyx*	-9.43	-12.02	-11.08	-10.84	-1.084	-34.48	-34.76	-35.07	-34.77	-3.477	0.688	Yes	25/02/2025
T1_GDE3_t3	GDE_3	t3	25/02/2025	12.0	*Eucalyptus Goniocalyx*	-20.40	-19.19	-20.51	-20.03	-2.003	-34.34	-33.30	-32.8	-33.48	-3.348	0.402	Yes	25/02/2025
T1_GDE1_t1	GDE_1	t1	25/02/2025	16.5	*Eucalyptus Ovata*	-7.54	-8.12	-8.15	-7.94	-0.794	-18.60	-28.98	-29.9	-25.83	-2.583	0.693	Yes	25/02/2025
T1_GDE1_t2	GDE_1	t2	25/02/2025	21.0	*Eucalyptus Ovata*	-10.12	-10.15	-10.76	-10.34	-1.034	-26.82	-27.01	-27.14	-26.99	-2.699	0.617	Yes	25/02/2025
T1_GDE1_t3	GDE_1	t3	25/02/2025	22.0	*Eucalyptus Ovata*	-6.39	-6.29	-6.79	-6.49	-0.649	-28.91	-29.99	-29.89	-29.60	-2.960	0.781	Yes	25/02/2025
T1_GDE2_t1	GDE_2	t1	25/02/2025	24.0	*Eucalyptus Obliqua*	-11.25	-10.34	-12.37	-11.32	-1.132	-22.59	-23.80	-23.62	-23.34	-2.334	0.515	Yes	25/02/2025
T1_GDE2_t2	GDE_2	t2	25/02/2025	23.0	*Eucalyptus Obliqua*	-14.49	-12.28	-12.16	-12.98	-1.298	-25.62	-25.80	-25.85	-25.76	-2.576	0.496	Yes	25/02/2025
T1_GDE2_t3	GDE_2	t3	25/02/2025	17.0	*Eucalyptus Obliqua*	-9.94	-8.45	-10.16	-9.52	-0.952	-35.17	-34.44	-35.30	-34.97	-3.497	0.728	Yes	25/02/2025
T2_GDE8_t1	GDE_8	t1	26/02/2025	20.0	*Eucalyptus Radiata*	-27.69	-30.70	-30.80	-29.73	-2.973	-37.95	-40.09	-40.11	-39.38	-3.938	0.245	Yes	26/02/2025
T2_GDE8_t2	GDE_8	t2	26/02/2025	20.0	*Eucalyptus Radiata*	-35.69	-33.35	-35.75	-34.93	-3.493				#DIV/0!	#DIV/0!	#DIV/0!	Yes	26/02/2025
T2_GDE8_t3	GDE_8	t3	26/02/2025	18.0	*Eucalyptus Radiata*	-17.90	-17.12	16.66	-6.12	-0.612	-27.46	-26.31	-27.63	-27.13	-2.713	0.774	Yes	26/02/2025
T2_GDE7_t1	GDE_7	t1	26/02/2025	23.0	*Eucalyptus Obliqua*	-17.44	-16.73	-18.42	-17.53	-1.753	-33.08	-32.64	-33.65	-33.12	-3.312	0.471	Yes	26/02/2025
T2_GDE7_t2	GDE_7	t2	26/02/2025	14.0	*Eucalyptus Obliqua*	-18.78	-18.17	-19.89	-18.95	-1.895	-29.98	-27.56	-28.43	-28.66	-2.866	0.339	Yes	26/02/2025
T2_GDE7_t3	GDE_7	t3	26/02/2025	15.0	*Eucalyptus Radiata*	-15.79	-15.73	-13.70	-15.07	-1.507	-27.46	-26.31	-27.63	-27.13	-2.713	0.444	Yes	26/02/2025
T2_GDE6_t1	GDE_6	t1	26/02/2025	27.5	*Eucalyptus Ovata*	-7.19	-6.40	-7.39	-6.99	-0.699	-28.71	-28.01	-30.33	-29.02	-2.902	0.759	Yes	26/02/2025
T2_GDE6_t2	GDE_6	t2	26/02/2025	24.0	*Eucalyptus Radiata*	-23.71	-22.39	-22.89	-23.00	-2.300	-36.22	-35.40	-36.89	-36.17	-3.617	0.364	Yes	26/02/2025
T2_GDE6_t3	GDE_6	t3	26/02/2025	17.0	*Eucalyptus Radiata*	-18.49	-18.51	-18.91	-18.64	-1.864	-33.14	-36.14	-36.22	-35.17	-3.517	0.470	Yes	26/02/2025
T2_GDE5_t1	GDE_5	t1	26/02/2025	15.0	*Eucalyptus Ovata*	-11.32	-9.47	-9.14	-9.98	-0.998	-32.76	-29.90	-30.09	-30.92	-3.092	0.677	Yes	26/02/2025
T2_GDE5_t2	GDE_5	t2	26/02/2025	19.0	*Eucalyptus Ovata*	-11.22	-10.32	-10.53	-10.69	-1.069	-31.11	-31.46	-30.08	-30.88	-3.088	0.654	Yes	26/02/2025
T2_GDE5_t3	GDE_5	t3	26/02/2025	18.5	*Eucalyptus Ovata*	-5.82	-5.46	5.99	-1.76	-0.176	-35.87	-36.02	-35.55	-35.81	-3.581	0.951	Yes	26/02/2025
T3_GDE9_t2	GDE_9	t2	27/02/2025	6.0	*Eucalyptus Baxteri*	-27.80	-29.73	-28.51	-28.68	-2.868	-35.45	-35.12	-35.17	-35.25	-3.525	0.186	Yes	27/02/2025
T3_GDE9_t1	GDE_9	t1	27/02/2025	12.0	*Eucalyptus Baxteri*	-34.09	-36.01	-34.99	-35.03	-3.503	-40.00	-40.00	-40.00	-40.00	-4.000	0.124	Yes	27/02/2025
T3_GDE9_t3	GDE_9	t3	27/02/2025	23.0	*Eucalyptus Ovata*	-27.75	-26.83	-27.42	-27.33	-2.733	-31.62	-31.38	-31.48	-31.49	-3.149	0.132	Yes	27/02/2025
T3_GDE10_t3	GDE_10	t3	27/02/2025	22.5	*Eucalyptus Ovata*	-7.49	-3.75	-5.18	-5.47	-0.547	-29.19	-26.12	-25.69	-27.00	-2.700	0.797	Yes	27/02/2025
T3_GDE10_t1	GDE_10	t1	27/02/2025	26.5	*Eucalyptus Ovata*	-4.22	-4.03	-2.99	-3.75	-0.375	-20.36	-23.44	-23.11	-22.30	-2.230	0.832	Yes	27/02/2025
T3_GDE10_t2	GDE_10	t2	27/02/2025	15.0	*Eucalyptus Ovata*	-2.24	-3.36	-4.06	-3.22	-0.322	-27.58	-26.82	-25.91	-26.77	-2.677	0.880	Yes	27/02/2025
T3_GDE11_t3	GDE_11	t3	27/02/2025	21.0	*Eucalyptus Baxteri*	-10.04	-12.02	-11.34	-11.13	-1.113	-27.02	-27.22	-27.39	-27.21	-2.721	0.591	Yes	27/02/2025
T3_GDE11_t2	GDE_11	t2	27/02/2025	20.0	*Eucalyptus Radiata*	-11.92	-12.30	-12.22	-12.15	-1.215	-27.36	-26.39	-27.80	-27.18	-2.718	0.553	Yes	27/02/2025
T3_GDE11_t1	GDE_11	t1	27/02/2025	15.0	*Eucalyptus Baxteri*	-17.69	-16.24	-16.25	-16.73	-1.673	-27.43	-27.60	-27.24	-27.42	-2.742	0.390	Yes	27/02/2025
T3_GDE12_t1	GDE_12	t1	27/02/2025	14.6	*Eucalyptus Obliqua*	-14.01	-14.20	-13.99	-14.07	-1.407	-25.18	-18.97	-20.33	-21.49	-2.149	0.346	Yes	27/02/2025
T3_GDE12_t2	GDE_12	t2	27/02/2025	15.0	*Eucalyptus Obliqua*	-13.56	-14.52	-15.43	-14.50	-1.450				#DIV/0!	#DIV/0!	#DIV/0!	No (T3_GDE12_t4)	27/02/2025
T3_GDE12_t3	GDE_12	t3	27/02/2025	18.0	*Eucalyptus Obliqua*	-9.18	-9.60	-9.30	-9.36	-0.936	-24.48	-24.10	-25.06	-24.55	-2.455	0.619	Yes	27/02/2025

Relative water availablility classification	
Extremely high	> -0.276
Very High	<-0.276 to -0.580
High	<-0.580 to -0.896
Moderate	<-0.896 to -1.21
Low	<-1.21 to -1.72
Very Low	<-1.72 to 2.21
Extremely Low	<-2.21

Hydration values

Low stress / high tree health	>0.66
Average stress / moderate tree health	0.66 to 0.33
High stress / risk of hydraulic failure	<0.33

Appendix B

Soil Moisture Potential measurements

EMM

creating opportunities

PROJECT	ID	GDE_Auger/Bore ID	Location	Auger/Bore ID	Depth	Date	Mpa	pF	Temp
E250014	T3_BH01	T3_BH01_0.25	GDE 10	T3_BH01_0.25_250226	0.25	26/02/2025	-1.58	4.21	24.4
E250014	T3_BH01	T3_BH01_0.5	GDE 10	T3_BH01_0.5_250226	0.50	26/02/2025	-0.64	3.82	24.5
E250014	T3_BH01	T3_BH01_0.75	GDE 10	T3_BH01_0.75_250226	0.75	26/02/2025	-0.30	3.50	24.4
E250014	T3_BH01	T3_BH01_1.0	GDE 10	T3_BH01_1.0_250226	1.00	26/02/2025	-1.15	4.08	24.5
		T3_BH01_1.0				QA/QC	-0.65	3.83	24.4
E250014	T3_BH01	T3_BH01_1.5	GDE 10	T3_BH01_1.5_250226	1.50	26/02/2025	-0.31	3.51	24.5
E250014	T2_BH02	T2_BH02_0.25	GDE 08	T2_BH02_0.25_250226	0.25	26/02/2025	-1.38	4.16	24.3
E250014	T2_BH02	T2_BH02_0.5	GDE 08	T2_BH02_0.5_250226	0.50	26/02/2025	-1.19	4.09	24.3
E250014	T2_BH02	T2_BH02_0.75	GDE 08	T2_BH02_0.75_250226	0.75	26/02/2025	-1.37	4.15	24.4
E250014	T2_BH02	T2_BH02_1.0	GDE 08	T2_BH02_1.0_250226	1.00	26/02/2025	-1.03	4.03	24.5
E250014	T2_BH02	T2_BH02_1.5	GDE 08	T2_BH02_1.5_250226	1.50	26/02/2025	-1.48	4.19	24.4
		T2_BH02_1.5				QA/QC	-1.41	4.16	24.5
E250014	T2_BH02	T2_BH02_2.0	GDE 08	T2_BH02_2.0_250226	2.00	26/02/2025	-1.45	4.18	24.4
E250014	T2_BH03	T2_BH03_0.25	GDE 07	T2_BH03_0.25_250226	0.25	26/02/2025	-1.12	4.06	24.5
E250014	T2_BH03	T2_BH03_0.5	GDE 07	T2_BH03_0.5_250226	0.50	26/02/2025	-0.32	3.53	24.5
E250014	T2_BH03	T2_BH03_0.75	GDE 07	T2_BH03_0.75_250226	0.75	26/02/2025	-0.88	3.96	24.4
E250014	T2_BH03	T2_BH03_1.0	GDE 07	T2_BH03_1.0_250226	1.00	26/02/2025	-1.50	4.19	24.5
E250014	T1_BH04	T1_BH04_0.25	GDE 01	T1_BH04_0.25_250227	0.25	27/02/2025	-1.82	4.27	24.5
E250014	T1_BH04	T1_BH04_0.5	GDE 01	T1_BH04_0.5_250227	0.50	27/02/2025	-0.73	3.88	24.7
E250014	T1_BH04	T1_BH04_0.75	GDE 01	T1_BH04_0.75_250227	0.75	27/02/2025	0.15	0.00	24.5
		T1_BH04_0.75				QA/QC	-1.28	4.12	24.4
E250014	T1_BH04	T1_BH04_1.0	GDE 01	T1_BH04_1.0_250227	1.00	27/02/2025	-0.13	3.12	24.5
E250014	T1_BH04	T1_BH04_1.5	GDE 01	T1_BH04_1.5_250227	1.50	27/02/2025	0.04	0.00	24.4
E250014	T1_BH04	T1_BH04_2.0	GDE 01	T1_BH04_2.0_250227	2.00	27/02/2025	-0.07	2.84	24.6
E250014	T1_BH04	T1_BH04_2.5	GDE 01	T1_BH04_2.5_250227	2.50	27/02/2025	-0.17	3.25	24.6
E250014	T1_BH04	T1_BH04_3.0	GDE 01	T1_BH04_3.0_250227	3.00	27/02/2025	-0.19	3.29	24.5
E250014	T1_BH04	T1_BH04_3.5	GDE 01	T1_BH04_3.5_250227	3.50	27/02/2025	-0.29	3.48	24.5
E250014	T1_BH05	T1_BH05_0.25	GDE 02	T1_BH05_0.25_250227	0.25	27/02/2025	-4.29	4.65	24.5
E250014	T1_BH05	T1_BH05_0.5	GDE 02	T1_BH05_0.5_250227	0.50	27/02/2025	-4.80	4.70	24.6
E250014	T1_BH05	T1_BH05_0.75	GDE 02	T1_BH05_0.75_250227	0.75	27/02/2025	-3.08	4.50	24.5
E250014	T1_BH05	T1_BH05_1.0	GDE 02	T1_BH05_1.0_250227	1.00	27/02/2025	-1.87	4.29	24.5
E250014	T1_BH05	T1_BH05_1.5	GDE 02	T1_BH05_1.5_250227	1.50	27/02/2025	-1.49	4.19	24.6
E250014	T3_BH06	T3_BH06_0.25	GDE 12	T3_BH06_0.25_250227	0.25	27/02/2025	-0.53	3.74	24.5
E250014	T3_BH06	T3_BH06_0.5	GDE 12	T3_BH06_0.5_250227	0.50	27/02/2025	-1.76	4.26	24.4
		T3_BH06_0.5				QA/QC	-1.18	4.09	24.5
E250014	T3_BH06	T3_BH06_0.75	GDE 12	T3_BH06_0.75_250227	0.75	27/02/2025	-1.29	4.12	24.4
		T3_BH06_0.75				QA/QC	-0.64	3.82	24.5
E250014	T3_BH06	T3_BH06_1.0	GDE 12	T3_BH06_1.0_250227	1.00	27/02/2025	-0.98	4.00	24.4
E250014	T3_BH06	T3_BH06_1.5	GDE 12	T3_BH06_1.5_250227	1.50	27/02/2025	-0.98	4.01	24.6

Lithology	Moisture
Clayey SAND, light brown, fine grained, low plasticity clay, slightly moist, loose, minor organics (rootlets)	s moist
Clayey SAND, light brown, fine grained, low plasticity clay, slightly moist, loose, minor organics (rootlets)	
Clayey SAND, light brown, fine grained, low plasticity clay, slightly moist, loose, minor organics (rootlets)	
Clayey SAND, light brown, fine grained, low plasticity clay, slightly moist, loose, minor organics (rootlets)	
Sandy CLAY, light brown, low plasticity, fine gained sand, slightly moist, loose to firm	
Clayey SAND, light brown, fine grained, low plasticity clay, dry, loose, minor organics (rootlets)	
Clayey SAND, light brown, fine grained, low plasticity clay, dry, loose, minor organics (rootlets)	
Clayey SAND, light brown, fine grained, low plasticity clay, dry, loose, minor organics (rootlets)	
Sandy CLAY, orange brown, low plasticity, fine gained sand, moist, loose	
Sandy CLAY, orange with grey mottling, low plasticity, fine gained sand, moist, firm	
Sandy CLAY, orange with grey mottling, low plasticity, fine gained sand, moist, firm	
Clayey SAND, grey brown, fine grained, low plasticity clay, dry, loose, minor organics (rootlets)	
Clayey SAND, grey brown, fine grained, low plasticity clay, dry, loose, minor organics (rootlets)	
Clayey SAND, grey brown, fine grained, low plasticity clay, moist, loose, minor organics (rootlets)	
Sandy CLAY, orange brown, low plasticity, fine gained sand, moist, firm	
Clayey silty SAND, grey brown, fine grained, low plasticity clay, slightly moist, loose, minor organics (rootlets)	
Clayey silty SAND, grey brown, fine grained, low plasticity clay, slightly moist, loose, minor organics (rootlets)	
Clayey SAND, orange brown, fine grained, low plasticity clay, slightly moist, loose.	
Clayey SAND, orange brown, fine grained, low plasticity clay, slightly moist, loose.	
CLAY, orange with mottled grey, low plasticity, fine grained sand, moist, firm.	
CLAY, orange with mottled grey, low plasticity, fine grained sand, moist, firm.	
Sandy CLAY, orange with grey, low plasticity, fine grained sand, slightly moist, loose.	
CLAY, orange with mottled grey, medium plasticity, moist, loose to firm.	
CLAY, orange with mottled grey, medium plasticity, moist, loose to firm.	
Gravelly clayey SAND, brown, fine grained, low plasticity clay, approx. 20 mm angular gravels, slightly moist, loose, minor organics (rootlets)	
Gravelly clayey SAND, brown, fine grained, low plasticity clay, approx. 20 mm angular gravels, slightly moist, loose, minor organics (rootlets)	
Gravelly clayey SAND, brown, fine grained, low plasticity clay, approx. 20 mm angular gravels, slightly moist, loose, minor organics (rootlets)	
Clayey SAND, brown, fine grained, low plasticity clay,inclusions of approx. 20 mm angular gravels, slightly moist, loose, minor organics (rootlets)	
Clayey SAND, brown, fine grained, low plasticity clay,inclusions of approx. 20 mm angular gravels, slightly moist, loose, minor organics (rootlets)	
Gravelly clayey SAND, yellow brown, fine grained, low plasticity clay, approx. 20 mm angular gravels, dry, loose, minor organics (rootlets)	
Clayey SAND, yellow, fine grained, low plasticity clay, slightly moist, loose.	
Clayey SAND, yellow, fine grained, low plasticity clay, slightly moist, loose.	
CLAY, orange mottled grey, low plasticity, moist, firm.	
CLAY, red orange mottled grey, low plasticity, moist, firm.	

Appendix C

Water isotope results

EMM
creating opportunities

Data processed by Hilary SW, Farquhar Laboratory, RSB, ANU 14th March 2025

Sample	δ^2H VSMOW	δ^{18}O VSMOW
SW01 240225	-16.24	-3.22
c2 250226	-17.56	-4.20
mb11b 250225	-33.03	-5.73
mb3 250225	-27.69	-5.34
mb5b 250225	-31.82	-5.99
b2 250226	-27.51	-5.00
mb4 250225	-36.72	-6.19
mb1 250225	-33.13	-5.69
mb2 250225	-25.92	-4.65
b5 250226	-29.03	-5.12

Montrose Quarry GDE isotope data EMM
Processed May 2025 Farquhar Laboratory Research school of Biology ANU

Sample	δ^{2}H VSMOW	δ^{18}O VSMOW
Soils		
T1_BH04_0.25	-15.37	-2.41
T1_BH04_0.5	-18.47	-3.96
T1_BH04_0.75	-24.65	-4.42
T1_BH04_1.0	-26.36	-4.67
T1_BH04_1.5	-29.23	-5.02
T1_BH04_2.0	-30.12	-5.21
T1_BH04_2.5	-25.93	-4.7
T1_BH04_3.0	-27.92	-5.35
T1_BH04_3.5	-30.68	-5.81
T1_BH05_0.25	-3.77	-1.39
T1_BH05_0.5	-12.31	-3.21
T1_BH05_0.75	-10.65	-2.81
T1_BH05_1.0	-12.95	-3
T1_BH05_1.5	-16.26	-3.23
T2_BH02_0.25	-12.15	-2.14
T2_BH02_0.5	-17.41	-2.82
T2_BH02_0.75	-17.1	-2.81
T2_BH02_1.0	-25.54	-4.32
T2_BH02_1.5	-28.14	-4.73
T2_BH02_2.0	-27.57	-4.33
T2_BH03_0.25	-20.73	-3.46
T2_BH03_0.5	-27.76	-5.09
T2_BH03_0.75	-21.93	-4.09
T2_BH03_1.0	-23.96	-4.59
T3_BH01_0.25	-18.67	-4.16
T3_BH01_0.5	-23.69	-4.63
T3_BH01_0.75	-26.57	-4.85
T3_BH01_1.0	-22.57	-4.12
T3_BH01_1.5	-25.89	-4.8
T3_BH06_0.25	-0.74	1
T3_BH06_0.5	-0.81	1.41
T3_BH06_0.75	-22.42	-3.44
T3_BH06_1.0	-24.91	-3.87
T3_BH06_1.5	-30.89	-5.08
Twigs		
T1_GDE1_T1	-16.01	-0.17
T1_GDE1_T2	-19.43	-1.55
T1_GDE1_T3	-16.9	-0.78
T1_GDE2_T1	-21.25	-1.89
T1_GDE2_T2	-10.4	0.72
T1_GDE2_T3	-21.97	-2.33
T1_GDE3_T1	-16.99	-0.23
T1_GDE3_T2	-12.19	0.76
T1_GDE3_T3	-7.23	1.75
T1_GDE4_T1	-16.42	-1.33
T1_GDE4_T2	-14.42	-0.54

T1_GDE4_T3	-5.9	0.8
T2_GDE10_T2	-20.92	-2.22
T2_GDE5_T1	-13.55	0.45
T2_GDE5_T2	-14.71	0.49
T2_GDE5_T3	-15.74	-0.61
T2_GDE6_T1	-13.61	0.83
T2_GDE6_T2	-2.12	1.19
T2_GDE6_T3	-10.94	0.89
T2_GDE7_T1	-17.77	-1.35
T2_GDE7_T2	-3.79	3.25
T2_GDE7_T3	-9.49	0.78
T2_GDE8_T1	-11.27	0.43
T2_GDE8_T2	-7.54	2.15
T2_GDE8_T3	-10.19	0.74
T3_GDE10_T1	-15.14	-0.53
T3_GDE10_T3	-12.21	-0.38
T3_GDE11_T1	-8.64	1.61
T3_GDE11_T2	-6.16	0.82
T3_GDE11_T3	-16.5	-0.83
T3_GDE12_T1	-14.41	-0.01
T3_GDE12_T3	-23.09	-1.88
T3_GDE12_T4	-18.93	-1.63
T3_GDE9_T1	-10.93	0.57
T3_GDE9_T2	-14.28	-0.2
T3_GDE9_T3	-6.43	0.65

Appendix D
Isotope graphs

creating opportunities

Suite 9.01 Level 9
454 Collins Street
Melbourne VIC 3000
ABN: 28 141 736 558
03 9993 1900
www.emmconsulting.com.au

Isotope results

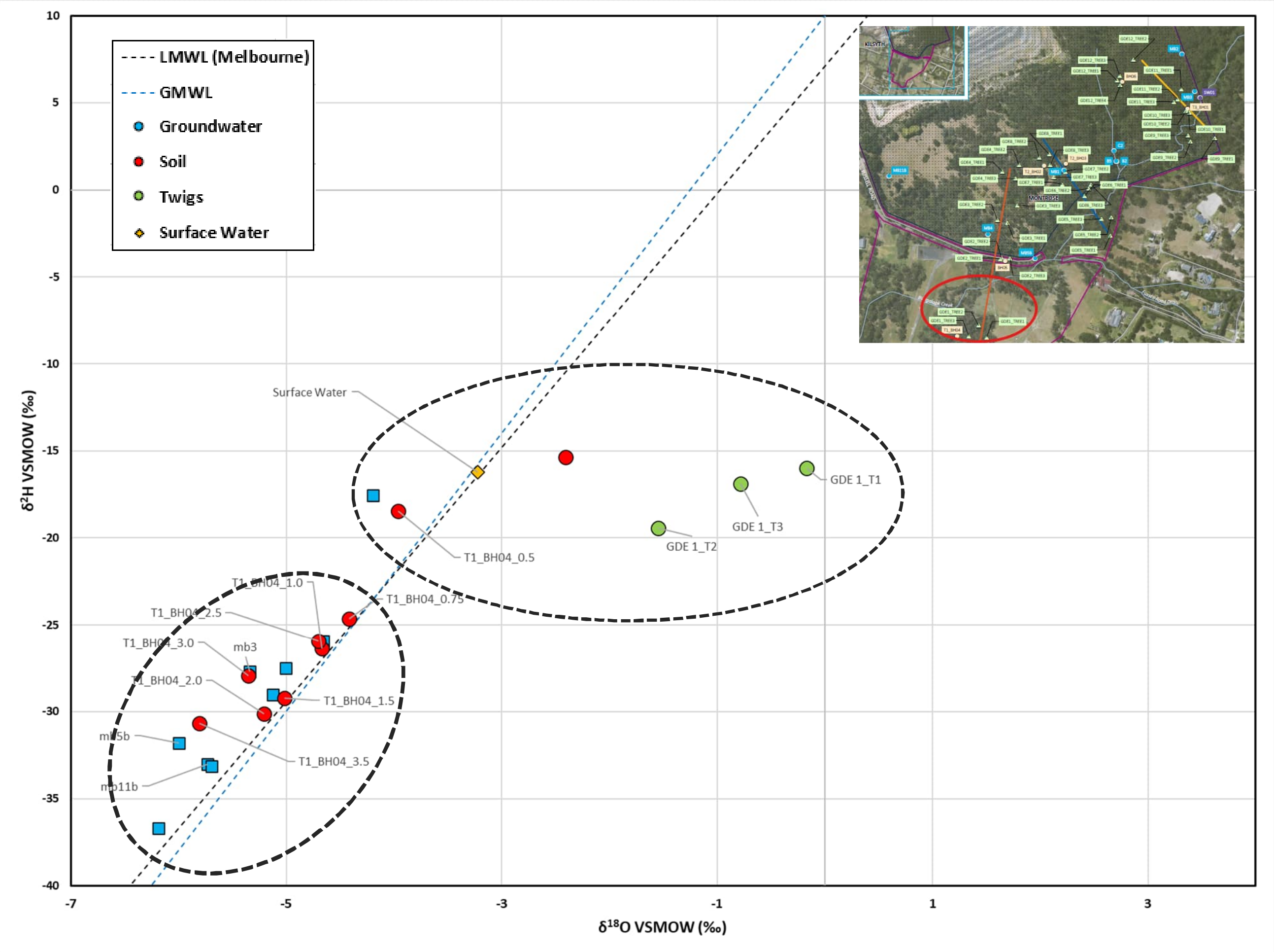


Figure D1 GDE 1 isotope results

GDE 1 is located on the southern side of Bungalook Creek with a depth to groundwater (DTGW) of <5 mbgl. The isotope analysis indicates that the vegetation in this area is preferentially utilising the soil moisture over the groundwater. The top 0.5 m of the soil profile correlates with the surface water and shallow soil moisture isotopes however lower down in the soil profile there is a correlation between the groundwater isotope results and soil isotope results indicating groundwater could be contributing to the soil moisture within these layers.

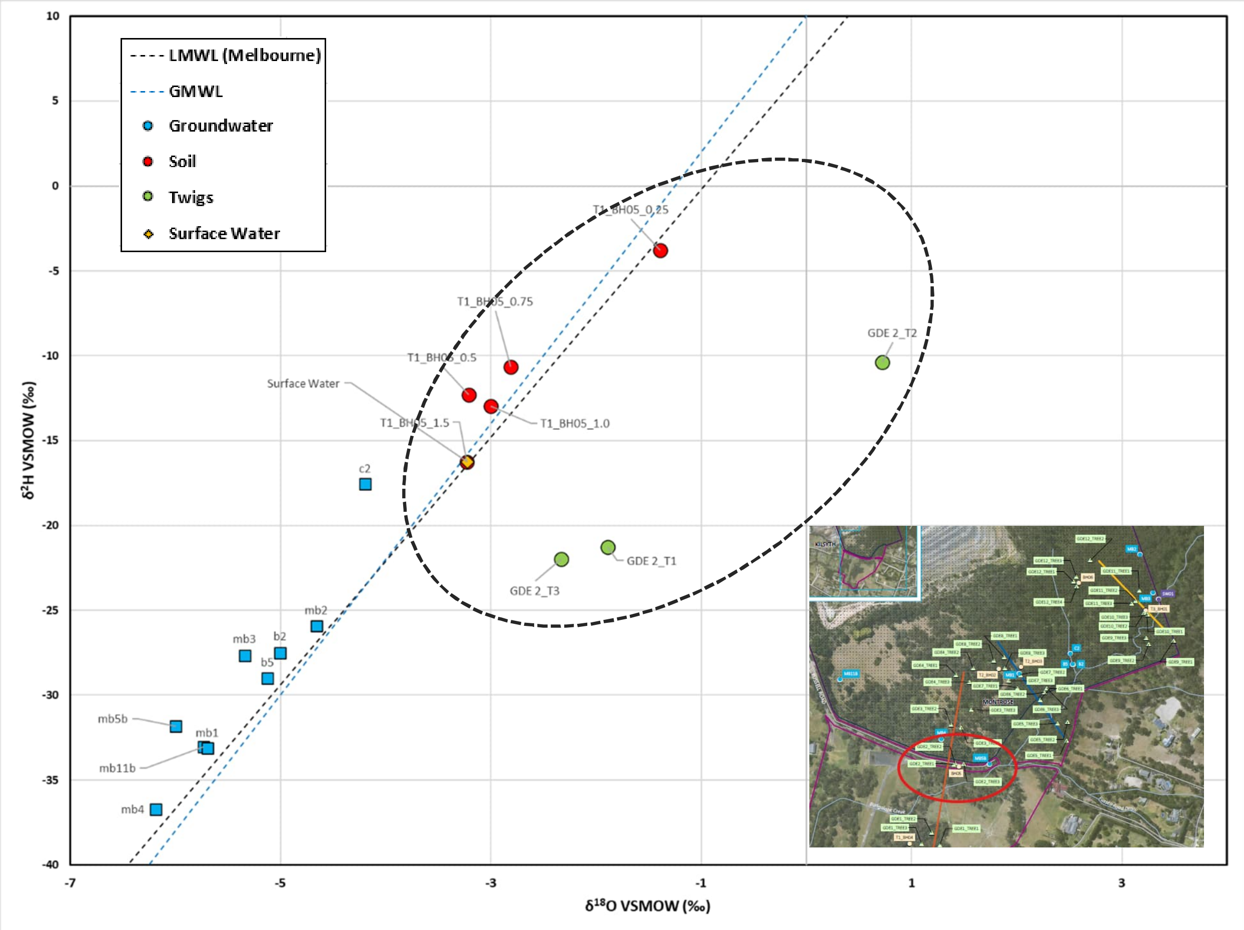


Figure D2 GDE 2 isotope results

GDE 2 is located on the northern side of Bungalook Creek with a DTGW between 5-10 mbgl. The isotope results indicate the soil moisture is potentially replenished mainly by precipitation rather than surface water and groundwater at this location. There is also no correlation between vegetation and groundwater use at GDE 2.

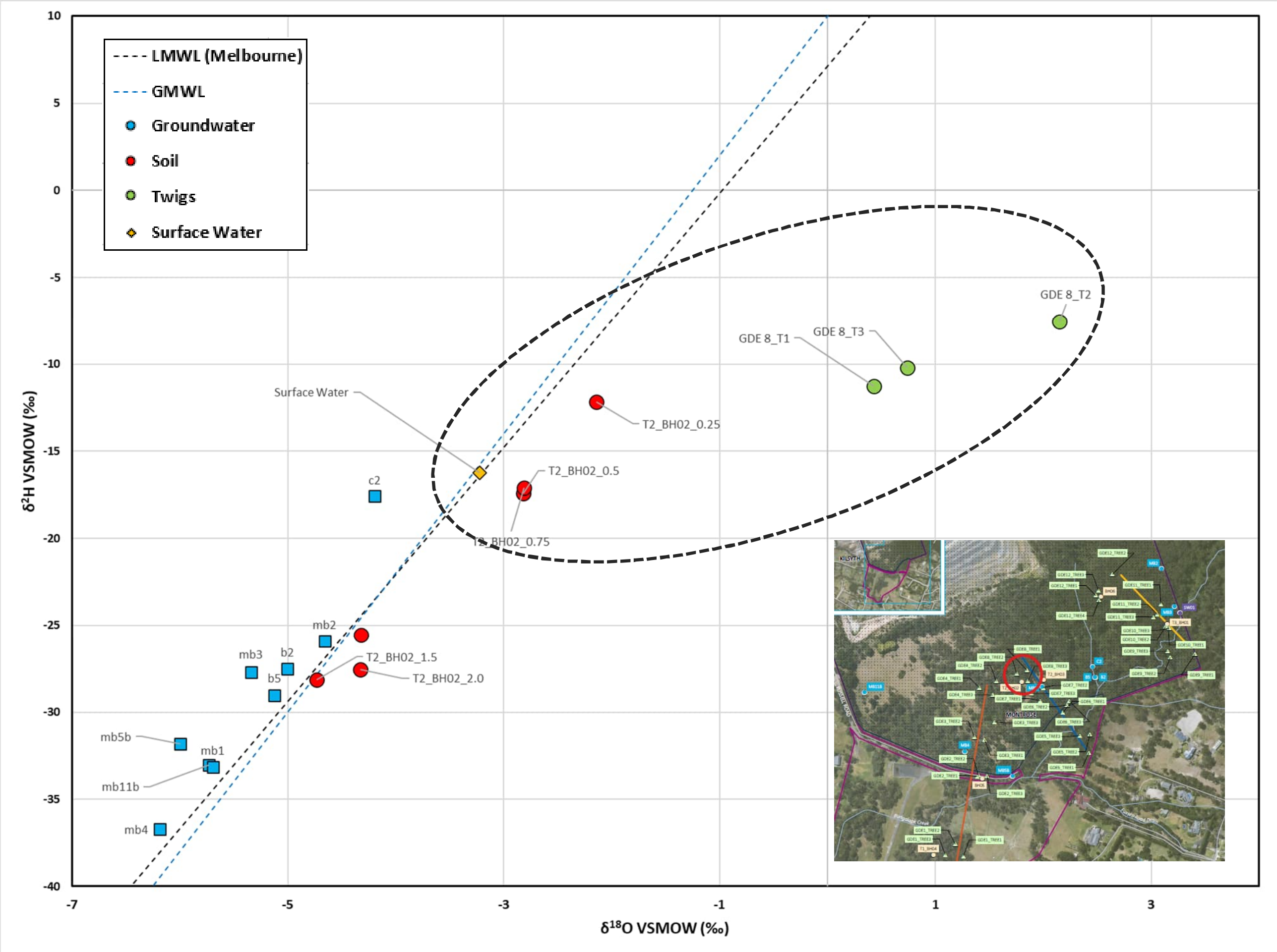


Figure D3 GDE 8 isotope results

GDE 8 is located south of the Montrose Quarry with a DTGW between 25-50 mbgl. The isotope results indicate that vegetation is more closely related to soil moisture and surface water than groundwater and there is no indication that vegetation at this site is using groundwater. However, the plant xylem isotopes have been altered more by evaporative fractionalisation than the soil sample isotopes which could indicate the source of the soil moisture is further down in the soil profile than where the soil samples have been collected from.

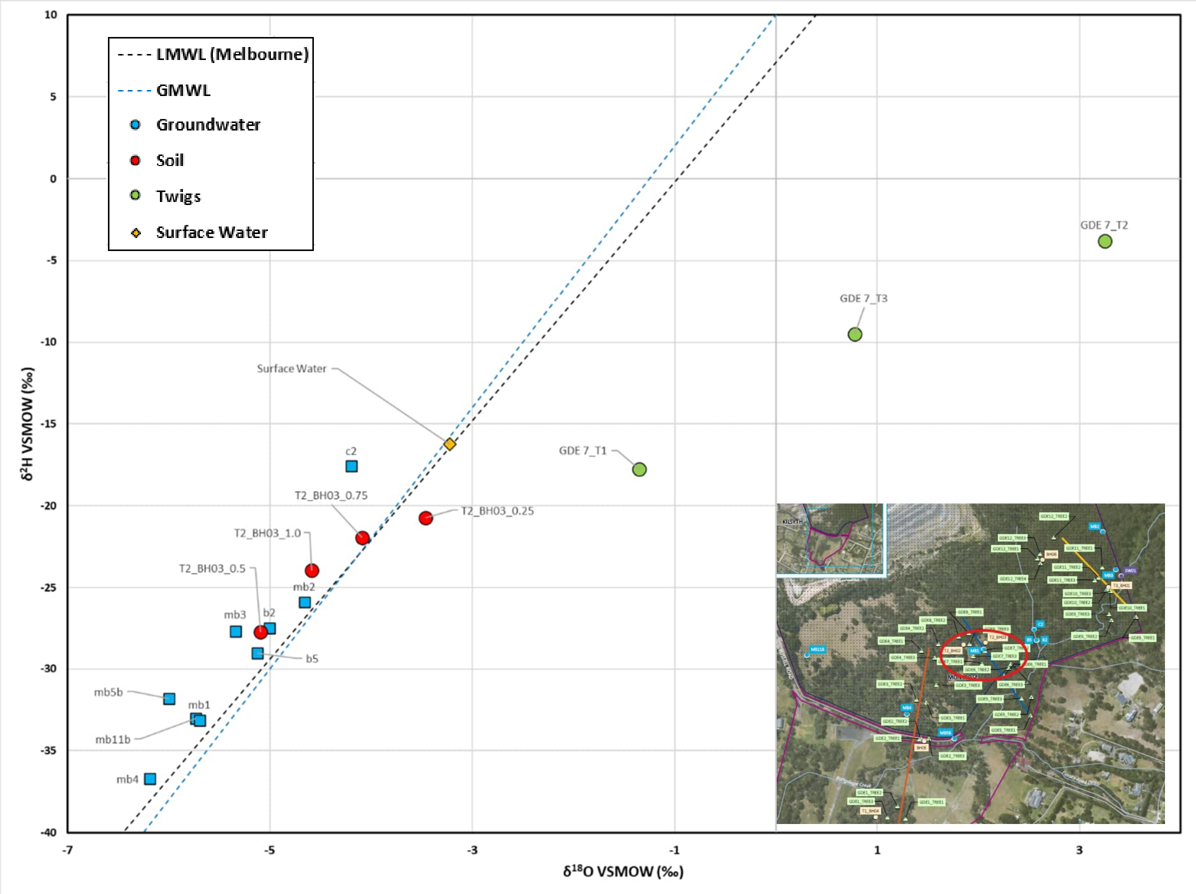


Figure D4 GDE 7 isotope results

GDE 7 is south of GDE 8 with a DTGW between 15-25 mbgl. The isotope results indicate there is no correlation between vegetation and groundwater therefore it is likely that vegetation within this area is utilising soil moisture. However, the plant xylem isotopes have been altered more by evaporative fractionalisation than the soil sample isotopes which could indicate the source of the soil moisture is further down in the soil profile than where the soil samples have been collected from.

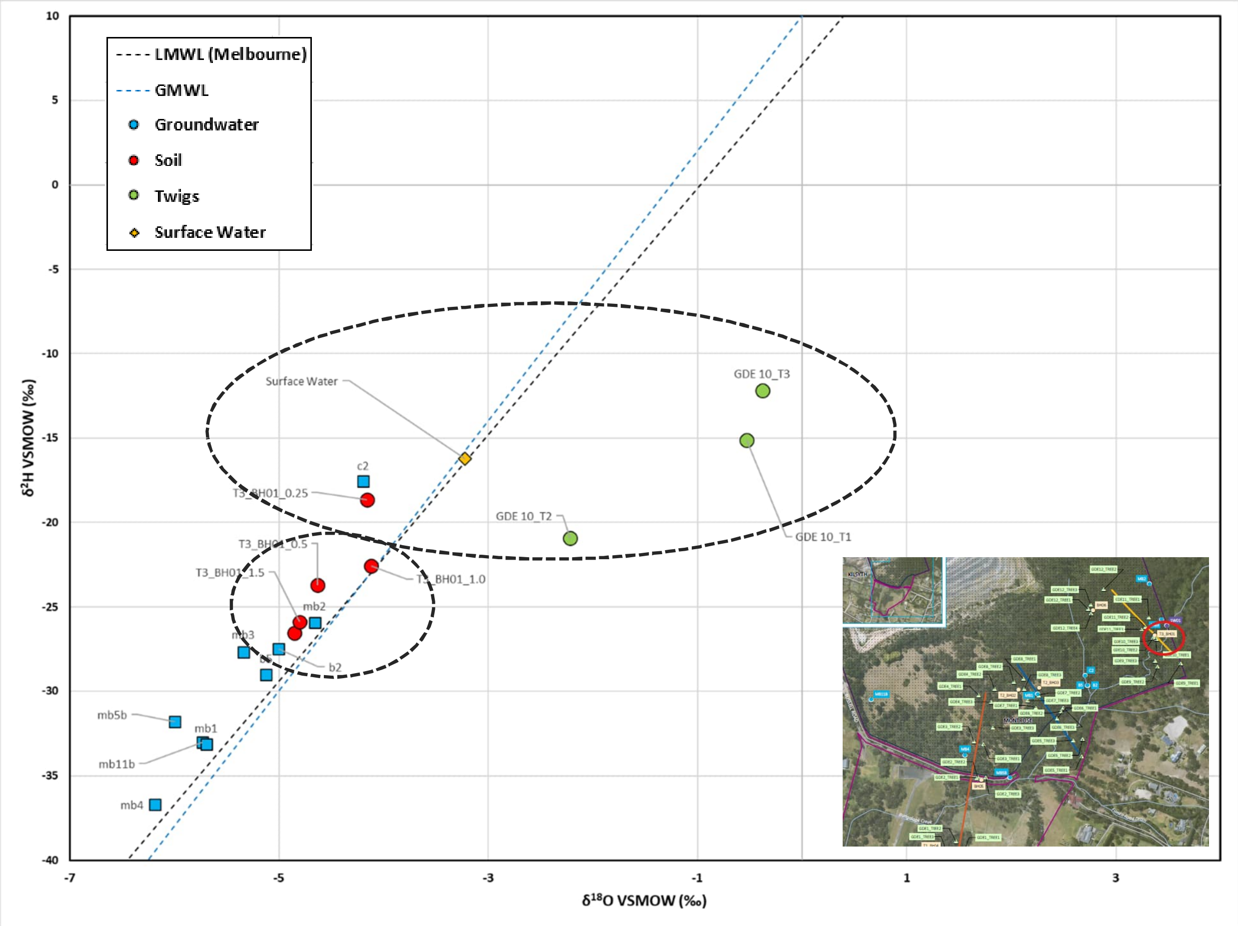


Figure D5 GDE 10 isotope results

GDE 10 is location south of Bungalook Creek with a DTGW <5 mbgl. The isotope results suggest that vegetation is utilising soil moisture which is being replenished by precipitation and surface water in the upper soil profile. However, like GDE 1 there is an indication that the lower soil profile could be receiving water from groundwater. The vegetation is preferentially utilising soil moisture over the groundwater.

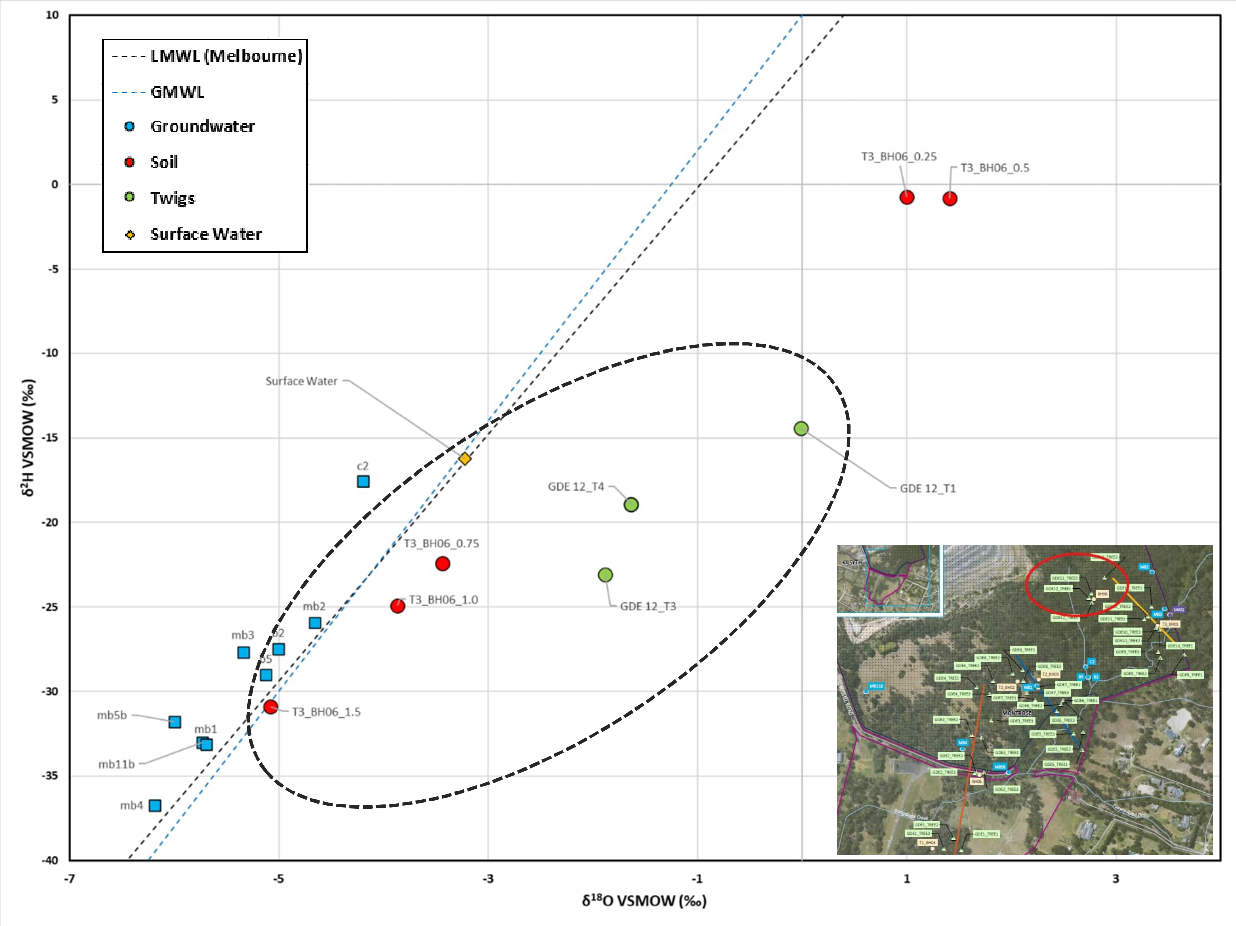


Figure D6 GDE 12 isotope results

GDE 12 is located south of the Montrose Quarry with a DTGW between 25-50 mbgl. The isotope results indicate that the vegetation is preferentially utilising soil moisture over groundwater, potentially from 0.75 mbgl to deeper in the soil profile. There is no correlation between plant xylem isotope data and groundwater isotope data.

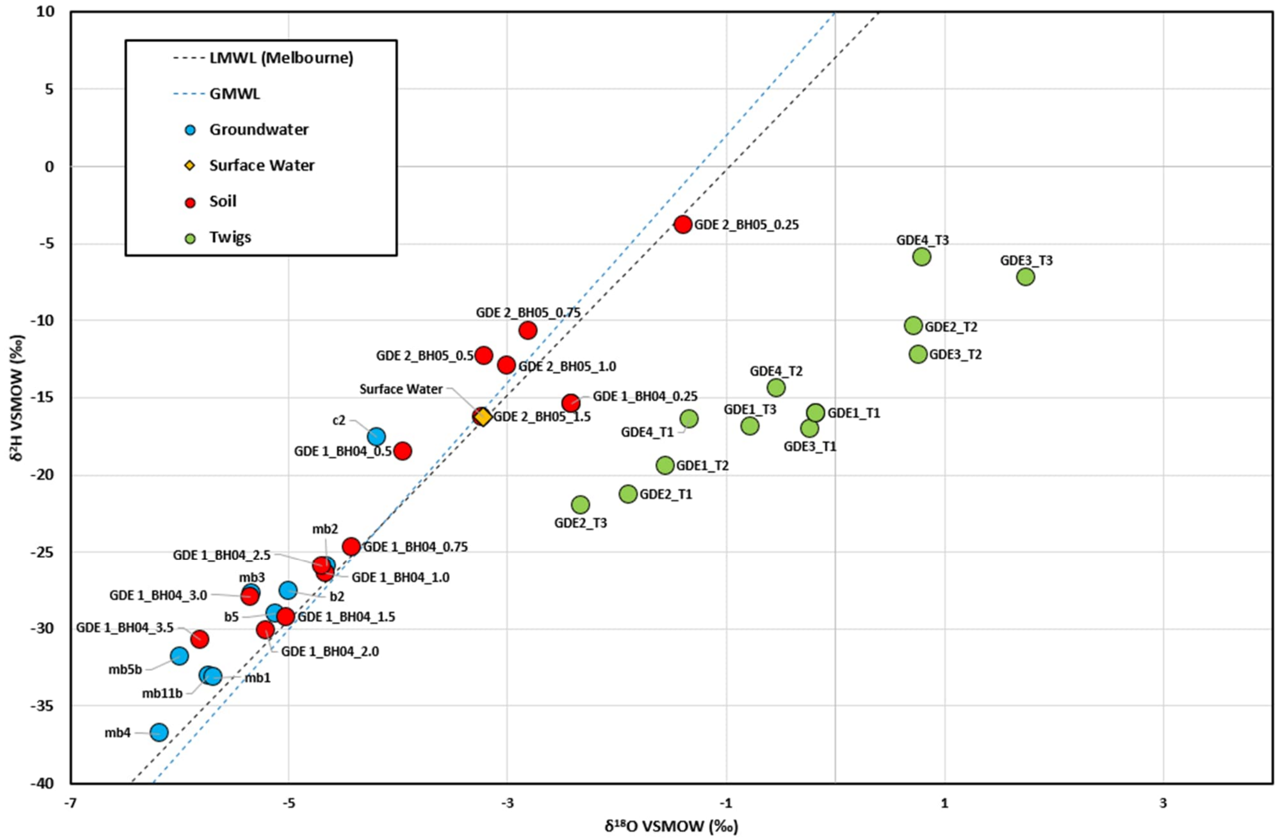


Figure D7 Transect 1 isotope results

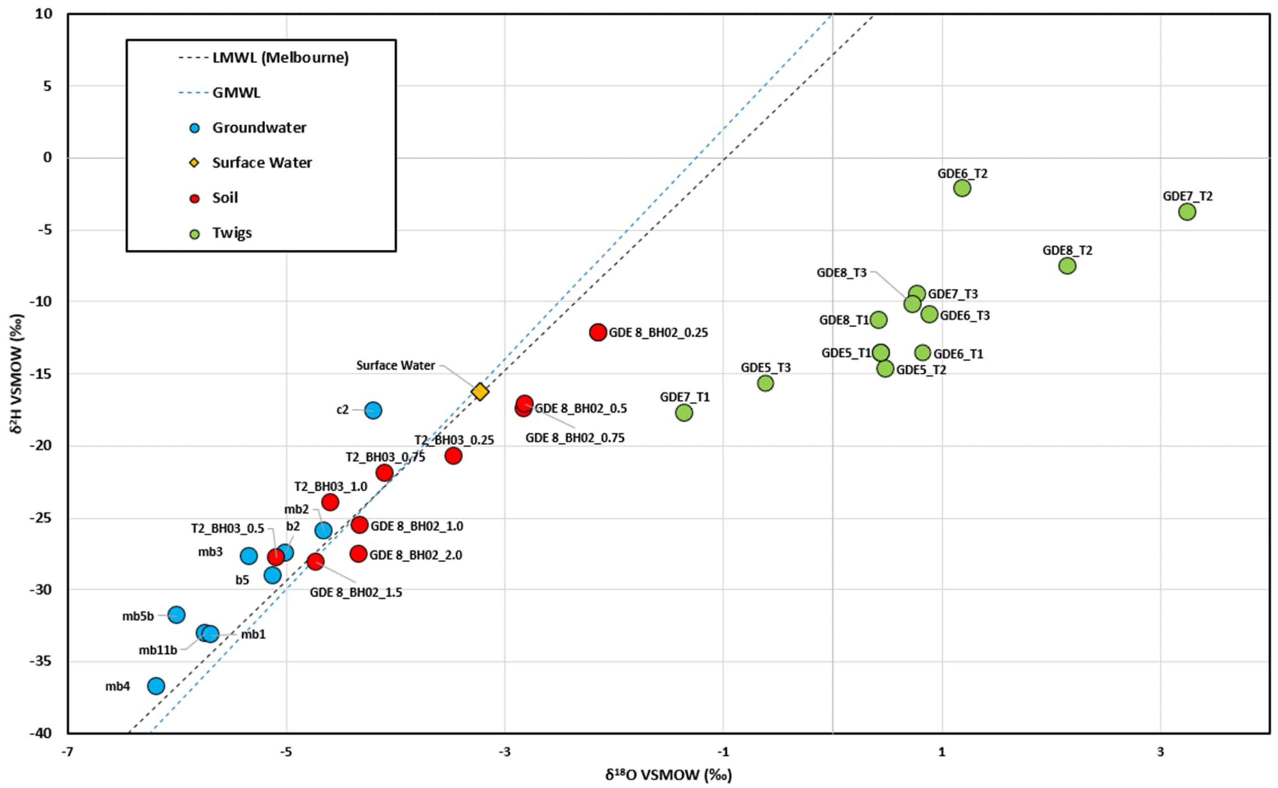


Figure D8 Transect 2 isotope results

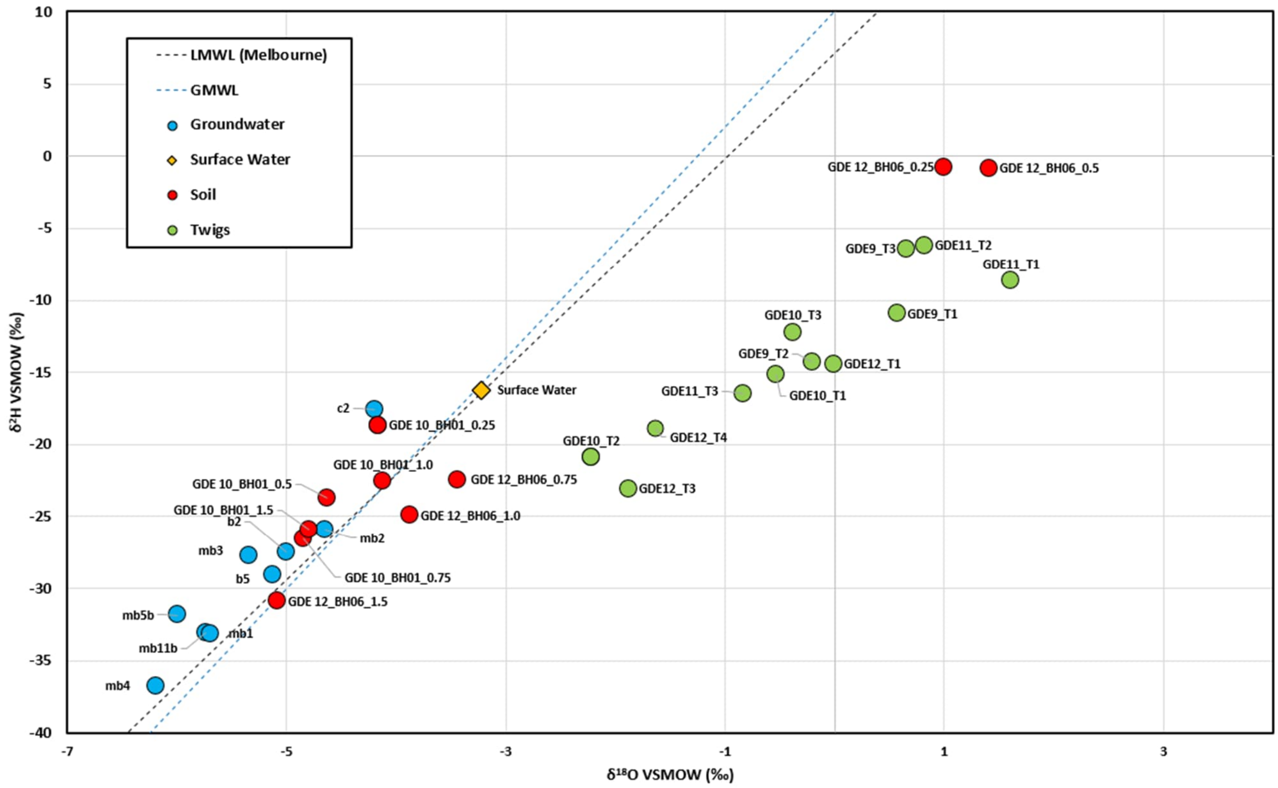


Figure D9 Transect 3 isotope results

Table D1 summarises the slopes of deuterium (^2H) and oxygen-18 (^{18}O) for soil moisture and twig water across the three transects, along with interpretations of water uptake depth and evaporative effects.

Table D1 Stable isotope slope comparison of soil moisture and twig water by transect with interpretations of water uptake

Transect	Slope		Comments
	Soil	Twig	
T1	6.43	3.83	Soil in transect 1 has a higher slope then soil overall, indicating less evaporative enrichment. The difference between soil and twig slopes suggests that trees at transect 1 are accessing water in deeper unsaturated zones beyond the sampled depth.
T2	5.30	3.43	In transect 2, twig slope is lower than the corresponding soil water slope, suggesting water uptake from slightly deeper soil layers that have experienced evaporation. Twig water xylem stable isotope signature is very low suggesting strong evaporative effects.
T3	4.24	4.31	Soil at transect 3 has a much lower slope then soil overall indicated more evaporative enrichment. Slopes of soil and twigs in transect 3 very closely match suggesting soil water uptake occurs in the sampled range (0-2.0m).

www.emmconsulting.com.au