



APPENDIX 19 – GROUNDWATER DEPENDENT ECOSYSTEM MONITORING AND MANAGEMENT PLAN

NEW LENTON COAL PTY LTD
NEW LENTON COAL PROJECT



3D Environmental
Landscape & Vegetation Science

Groundwater Dependent Ecosystem (GDE) Monitoring and Management Plan - New Lenton Project

Prepared by 3d Environmental

For

Bowen Coking Coal Ltd

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Client: Bowen Coking Coal Ltd

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List of Abbreviations

Abbreviation	Description
DCCEEW	Department of Climate Change, Energy, Environment and Water (Commonwealth)
DES	Department of Environment and Science (Qld)
DoEE	Department of Environment and Energy (Commonwealth)
EA	Environmental Authority
EIS	Environmental Impact Statement
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
EPBC Approval	Approval granted by the Commonwealth under the EPBC Act
EP Act (Water)	Environmental Protection Act (Qld) 1994
ESCP	Erosion and Sediment Control Plan
EWR	Environmental Water Requirement
GDE	Groundwater Dependent Ecosystem
GDEMMP	Groundwater Dependent Ecosystem Monitoring and Management Plan
GMMP	Groundwater Management and Monitoring Plan
LAI	Leaf Area Index
LWP	Leaf Water Potential
ML	Mining Lease
MNES	Matters of National Environmental Significance, as defined under the EPBC Act.
NDVI	Normalised Difference Vegetation Index
PER	Public Environment Report
REMP	Receiving Environment Monitoring Program
SMP	Soil Moisture Potential
WMP	Water Management Plan

Glossary

Alluvial aquifer	An aquifer comprising unconsolidated sediments deposited by flowing water usually occurring beneath or adjacent to the channel of a river.
Aquifer	A geological formation or structure that stores or transmits water to wells or springs. Aquifers typically supply economic volumes of groundwater.
Base flow	Streamflow derived from groundwater seepage into a stream.
Capillary fringe	The unsaturated zone above the water table containing water in direct contact with the water table though at pressures that are less than atmospheric. Water is usually held by soil pores against gravity by capillary tension.
Confined aquifer	A layer of soil or rock below the land surface that is saturated with water with impermeable material above and below providing confining layers with the water in the aquifer under pressure.
Perched groundwater system	A groundwater system or aquifer that sit above the regional aquifer due to a capture of infiltrating moisture on a discontinuous aquitard.
Phreatic zone	The zone of sub-surface saturation separated from the unsaturated zone in unconfined aquifers by the water table.
Phreatophyte	Plants whose roots extend downward to the water table to obtain groundwater or water within the capillary fringe.
Obligate phreatophyte	A plant that is completely dependent on access to groundwater for survival.
Evapotranspiration	The movement of water from the landscape to the atmosphere including the sum of evaporation from the land surface and transpiration from vegetation through stomata.
Facultative phreatophyte	A plant that occasionally or seasonally utilises groundwater to maintain high transpiration rates, usually when other water sources are not available.
Fractured rock aquifer	An aquifer in which water flows through and is stored in fractures in the rock caused by folding and faulting.
Fluvial	Relating to processes produced by or found in rivers.
Groundwater	Those areas in the sub-surface where all soil or rock interstitial porosity is saturated with water. Includes the saturated zone and the capillary fringe.
Water table	The upper surface of the saturated zone in the ground, where all the pore space is filled with water.
Groundwater dependent ecosystems (GDE)	Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al. 2011).
Infiltration	Passage of water into the soil by forces of gravity and capillarity, dependent on the properties of the soil and moisture content.
Leaf water potential (LWP)	The total potential for water in a leaf, consisting of the balance between osmotic potential (exerted from solutes), turgor pressure (hydrostatic pressure) and matric potential (the pressure exerted by the walls of capillaries and colloids in the cell wall).
Leaf area index (LAI)	The ratio of total one-sided area of leaves on a plant divided by the area of the canopy when projected vertically on to the ground.
Percolation	The downward movement of water through the soil due to gravity and hydraulic forces.
Permeability	A material's ability to allow a substance to pass through it, such as the ability of soil or rocks to conduct water under the influence of gravity and hydraulic forces.
Preferential flow	Movement of surface water rapidly from surface to aquifer along preferential flow paths, bypassing older moisture in the upper soil profile.
Unconfined aquifer	An aquifer whose upper surface is at atmospheric pressure, producing a water table, which can rise and fall in response to recharge by rainfall.

Soil water potential	A measure of the difference between the free energy state of soil water and that of pure water. Essentially a measure of the energy required to extract moisture from soil.
Stable isotope	An isotope that does not undergo radioactive decay.
Surface water	Movement of water above the earths' surface as runoff or in streams.
Transpiration	The process of water loss from leaves, through stomata, to the atmosphere.
Terrestrial GDE	Terrestrial vegetation supported by sub-surface expression of groundwater (i.e. tree has roots in the capillary fringe of groundwater table).
Vadose zone	The unsaturated zone, above the water table in unconfined aquifers.
Water Potential	The free energy potential of water as applied to soils, leaves plants and the atmosphere.

1.0 Introduction

1.1 Background

3d Environmental has been engaged by New Lenton Coal (NLC), a wholly owned subsidiary of Bowen Coking Coal Pty Ltd, to prepare a Groundwater Dependent Ecosystem (GDE) Monitoring and Management Plan (GDEMMP) for the proposed New Lenton Project (The Project). The Project is in the Northern Bowen Basin, Central Queensland, approximately 120 km southwest of Mackay and 50 km north of Moranbah within the Isaac Regional Council (IRC) local government area (LGA) (see **Figure 1**). NLC is proposing to develop open-cut coal mining pits on mining lease (ML) 70337, ML700053, and ML700054 (the New Lenton MLs) in a joint venture with MPC Lenton Pty Ltd (MPC), known as the Lenton Joint Venture (LJV). The LJV hold the operating Burton Mine MLs (ML70109 and ML70260) which adjoins the New Lenton MLs and are subject to an existing State approved Environmental Authority (EA).

3d Environmental undertook a groundwater-dependent ecosystem (GDE) assessment as a component of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) public environment report (PER) approval process for The Project (3d Environmental (2023a)). This assessment identified the presence of Terrestrial GDEs (TGDEs) associated with the riparian fringe of the Isaac River, occurring within the area of predicted groundwater drawdown, with some additional uncertainty relating to the seasonality and source of groundwater usage. The development of this GDEMMP is in response to this finding.

1.2 Purpose of the Management Plan

Preparation of this GDEMMP intends to address and manage the uncertainties associated with the environmental impacts of the Project on GDEs through the development of consistently applied monitoring actions, analysis and reporting of data trends, and development of ‘early warning’ triggers to identify a decline in GDE health. Corrective actions (mitigations) are described for implementation when statistically significant impacts on GDE function caused by mining activity are detected. The plan will be used as a reference for management actions before construction, during construction, and operation, extending through stages of project rehabilitation, decommissioning, and closure. As this plan applies to a specific two-year ‘baseline’ assessment phase of monitoring, an additional purpose is to provide increased certainty to the findings of the PER assessment (3d Environmental 2023a), ensuring that post-baseline GDE monitoring focuses specifically on ecosystems that are groundwater dependent.

1.3 Objectives

Objectives of this GDEMMP are described as follows:

1. Characterise GDEs that are likely to be impacted by The Project in terms of ecological function, interaction with surface water and interaction with groundwater as presented in 3d Environmental (2023a).
2. Provide a synopsis of the potential risks to GDE integrity posed by Project-related mining activities and resolve uncertainties in GDE response and function through longer-term temporal monitoring.

3. Identify biophysical parameters applicable to the monitoring of GDE function that can be repeated objectively and consistently throughout the mining project's life to measure GDE health.
4. Describe the most appropriate actions to measure changes to the biophysical function of GDEs that may indicate a decline in GDE health and provide a statistically robust framework that can demonstrate whether impacts to GDEs are associated with mining activities or influenced by natural variation.
5. Develop triggers that may be used to initiate the application of corrective actions. Further refinement can be completed as temporal data is comprehensively collected.
6. Develop a suite of applicable corrective actions to ameliorate impacts to GDEs and prevent or repair declining GDE health.

1.4 Relevant Legislation

A public environment report (PER) for The Project has been submitted to the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) for assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for Referral 2020/8778.

Environment Protection and Biodiversity Conservation Act 1999: In June 2013, the EPBC Act was amended to capture water resources (that relate to coal seam gas development and large coal mining development) as MNES. Under the amendment, water resources include groundwater, surface water, and organisms and ecosystems that depend on it to maintain ecological function and condition. These ecosystems that rely on groundwater are otherwise termed GDEs and are captured under the water trigger. The regulatory guideline Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources (DoEE 2013a) identify a 'significant impact' as 'an impact which is important, notable, or of consequence, having regard to its context or intensity'. On 22nd October 2020, the Minister for the Environment determined the Project to be a controlled action under the EPBC Act (EPBC 2020/8778). The controlling provisions are sections 18 and 18A (listed threatened species and communities), sections 20 and 20A (Listed migratory species), and sections 24D and 24E (a water resource in relation to coal seam gas development and large coal mining development).

1.5 Relationship with other plans and management controls

This GDEMMP interacts with the following impact assessments and plans, which directly aim to monitor, avoid and/or minimise impact on water and ecology:

1. **Surface Water Monitoring Program:** Surface water quality both within and surrounding the Project area will be undertaken with upstream, on-site, and downstream water quality locations to demonstrate that the Site Water Management System (SWMS) is effective in meeting its objective of minimal impact on receiving water quality, allowing or early detection of impacts and corrective actions. Surface water monitoring protocols will:
 - a) Ensure compliance with the EA for the Project.
 - b) provide valuable information on the performance of the water management system and
 - c) Facilitate adaptive management of water resources on-site.

1. **Receiving Environment Management Plan (REMP):** The REMP aims to identify, describe, and monitor any impacts to aquatic ecology and surface water quality values from discharges associated with approved mining activities. Preparation of The Project REMP will address EA requirements and the relevant guidelines and will specify the proposed monitoring program for the local receiving waters. The REMP is expected to include the upstream and downstream monitoring sites on the Isaac River and sites on Ti-Tree Creek, including the diversion (see **Figure 2**). The REMP will require, amongst other factors:
 - a) a description of the receiving environment during monitoring, including habitat conditions, baseline conditions, and climatic conditions, watercourse levels, and release events during an annual reporting period.
 - b) establishment of a set of objectives for water quality, sediment quality, and biological indicators, including a program for water quality sampling for a range of physicochemical, metals, and nutrient parameters
 - c) macroinvertebrate community assessment with statistical analysis
 - d) analysis of data, assessment of trends over time, and comparison of data from monitoring sites
 - e) an assessment of the project's impacts on the receiving environment and recommendations for site environmental management are needed.
2. **Groundwater Monitoring and Management Plan and Monitoring Network:** A groundwater monitoring and management plan (GMMP) has been prepared for the Project consistent with the relevant requirements of the Project's EA (SLR, 2024). The establishment and implementation of the GMMP will evolve and respond to the various Project stages to ensure the program remains reflective of the current mining regime, including pre-mining, construction, operations, and post-closure activities. The GMMP will include procedures and processes required to determine and assess the hydrogeological regime and develop trigger levels, contaminant limits, and groundwater level thresholds. Data collected as a component of the GMMP will be used to assess the potential impacts of mining activities on groundwater resources. Considerations for the GMMP include:
 - a) Initial phases: Collect representative groundwater level measurements and groundwater quality samples from each aquifer or groundwater unit identified as potentially impacted (directly and indirectly) by mining activities; identify baseline (pre-project) fluctuations and trends in groundwater levels and hydrochemistry; and derive the groundwater impact triggers and limits based on the baseline dataset and groundwater impact predictions.
 - b) Ongoing data collection and review: Regular reviews of groundwater data will assess the monitoring networks' suitability for continuing monitoring, enable verification and refinement of the groundwater modelling predictions from the Project's groundwater model, and collate and record the data into a groundwater monitoring database managed by the site environment department.
 - c) Groundwater Monitoring Network: A groundwater monitoring network has been established to measure and monitor groundwater levels and quality in groundwater units that potentially interact with mining activity.

In addition, this GDEMMP includes a subset of additional shallow monitoring bores to be installed into the Isaac River Alluvium to determine the seasonality and persistence of the perched

groundwater unit supporting Terrestrial GDEs. The location of the shallow monitoring points will be established as a component of this GDEMMP.

1.6 Structure of this Document

This GDEMMP intends to compile and expand knowledge on the ecohydrological function of relevant GDEs. The scope is to update monitoring requirements, including methods, timing, and interval, as the knowledge base increases with each subsequent monitoring survey event. A summary of the critical components of this GDEMMP is provided below:

- **Section 2:** A contextual description of the mining layout and project timeframes.
- **Section 3:** A general description of the existing environment to contextualise hydrogeological and ecological setting referring to detailed description provided in 3d Environmental (2023a).
- **Section 4:** Describes the hydro-ecological function of GDEs in the Project area, referring to detailed information in 3d Environmental (2023a).
- **Section 5:** Provides a summary of the significant risks to GDE health imposed by the Project, as presented in 3d Environmental (2023a).
- **Section 6:** Summarizes how the biotic impacts on GDEs may manifest in the environment.
- **Section 7:** The general approach to the monitoring program.
- **Section 8:** An overview of monitoring techniques and their application.
- **Section 9:** A summary of reporting requirements for each monitoring event and preparation of a baseline synopsis.
- **Section 10:** Approach to determining trigger thresholds for which impacts to GDEs are investigated and corrective actions applied where appropriate.
- **Section 11:** A discussion identifying potential corrective actions to ameliorate impacts to GDEs resulting from mining activities.
- **Appendix:** Provides the basis for risk assessment, a summary of monitoring methods, monitoring timing, and raw data from prior GDE surveys. The Appendix is structured to provide:
 - a) Appendix A. Mining stages and development plans
 - b) Appendix B. Summary of GDE sampling methods
 - c) Appendix C. Sampling localities from the PER assessment.
 - d) Appendix D. Shallow groundwater monitoring bores (preliminary investigations).
 - e) Appendix E. Soil moisture potential results from the PER Report (3d Environmental (2023a)),
 - f) Appendix F. Stable isotope results from PER Report (3d Environmental (2023a)).
 - g) Appendix G. Summary structural data from the February 2023 field assessment.
 - h) Appendix H. GDE monitoring two-year schedule.

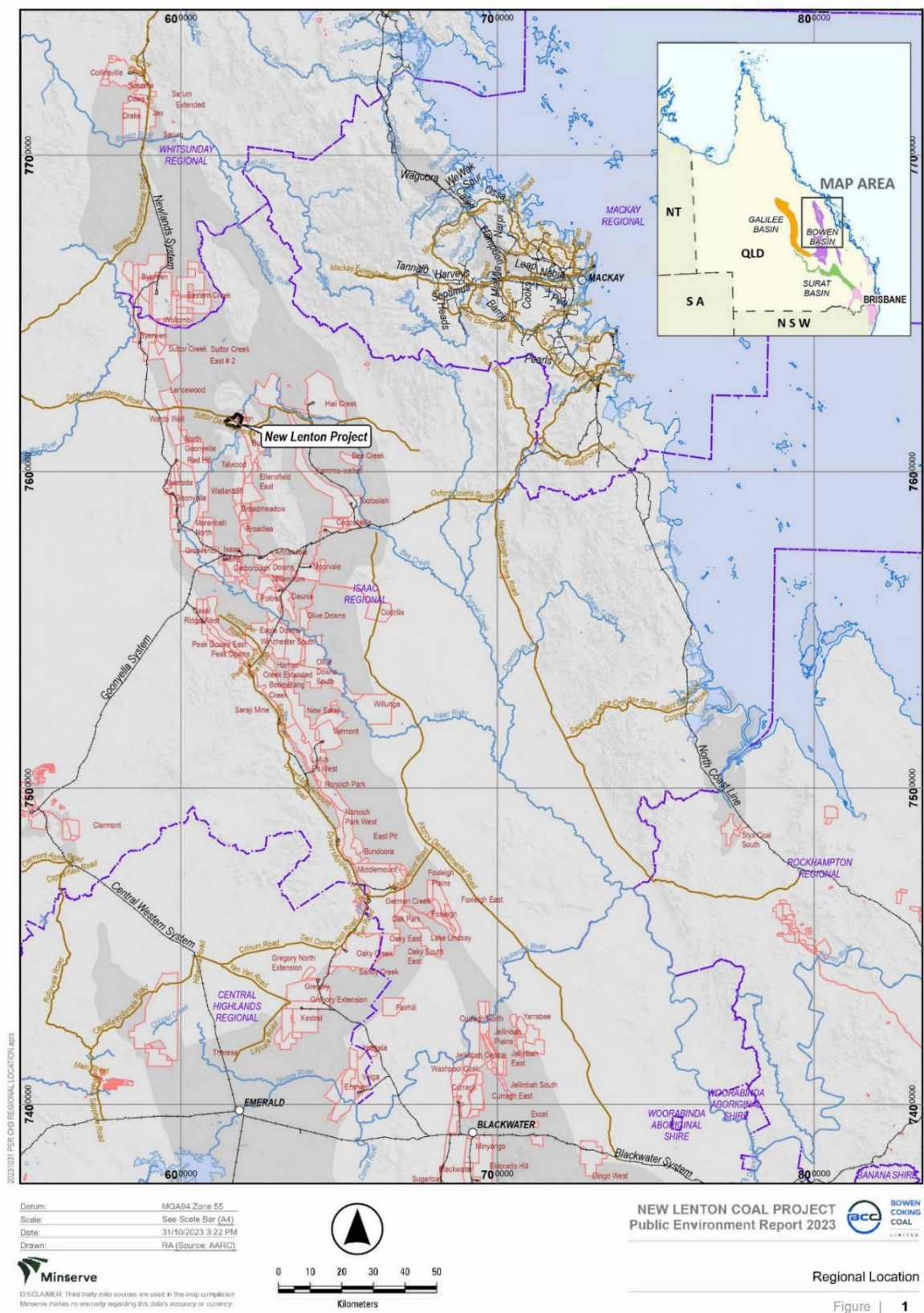


Figure 1. Project Location.

2.0 Project Description and Timing

2.1 Project Activities

NLC proposes developing open-cut coal mining pits on the New Lenton MLs with supporting infrastructure. Approximately 1.9 million tonnes per annum (Mtpa) of metallurgical run-of-mine (ROM) coal will be mined over 18 years, with a total of roughly 30 Mt over the life of the mine. In some years, including during ramp-up phases, less than 1.9 Mtpa ROM coal will be mined. Overburden will be placed in in-pit and out-of-pit overburden dumps, with a residual void remaining at the end of mine life. Supporting infrastructure includes:

- A mine infrastructure area (MIA).
- Haul roads.
- Realignment of a public road.
- Water management infrastructure.

ROM coal will be hauled to Burton Mine for washing in Burton Mine's coal handling and processing plant (CHPP). Product coal will be hauled to Burton Mine's train load out (TLO) facility and railed to Dalrymple Bay Coal Terminal (DBCT). Rejects from washing of Project ROM coal will be stored within Burton Mine's existing co-disposal areas within old mine voids. The proposed Project activities, which cover a total disturbance area of 886 ha, are shown in **Figure 2**, and comprise:

- Two mining pits, East Pit and West Pit
- In-pit and out-of-pit overburden dumps
- Mine Infrastructure Area (MIA)
- haul roads, including haul road connection with the Burton Mine haul roads and a bed-level crossing of the Isaac River
- Suttor Developmental Road (a public road) realignment, with a new bridge over the Isaac River
- mine-affected water dams, sediment dams, clean water diversion drains, and a mine-affected water (MAW) pipeline connecting with pipelines at Burton Mine
- diversion of Ti-Tree Creek, including a levee along the diversion
- Levee along the Isaac River

2.2 Project Stages and Timing

Mine stage plans, provided in **Appendix A**, describe the progression of mining as follows:

- Year 1 (Appendix A1): Mining of West Pit commences including clearing, grubbing, topsoil removal, pre-stripping of overburden and establishment of an out of pit overburden dump. Ti-Tree Creek diversion and levee will be constructed in the initial Project stage to allow mining of West Pit.
- Year 5 (Appendix A2): Mining of West Pit has been completed, mining of East Pit has commenced with associated out of pit dumps, and rehabilitation has been substantially progressed on the western out of pit dump. The Isaac River levee will be constructed between Year 1 and Year 5.

- Year 10 (Appendix A3): Mining of East Pit advances, backfill and rehabilitation of West Pit with overburden from East Pit, and substantial rehabilitation commences on the out of pit overburden dumps.
- Year 13 (Appendix A4): Further advance of the East pit including in-pit backfill. The West Pit has been completed with substantial rehabilitation of out of pit dumps and backfilling.
- The final landform (Appendix A5): The final landform, as approved by the Department of Environment and Science (DES) in the EA, shows the residual void area and rehabilitated out of pit and in-pit dumps and infrastructure areas.

3.0 Existing Environment

This section provides an overview of the local and regional setting, including climate, existing and surrounding landuse. For context, detailed information on the following features is described in the following sections of the New Lenton Groundwater Dependent Ecosystem Assessment (3d Environmental 2023a).

- Hydrogeological setting and the major groundwater bearing units (**Section 2.1** of 3d Environmental 2023a).
- Ecological characteristics of the site including potentially groundwater dependent regional ecosystems (REs) and species (**Section 2.2** of 3d Environmental 2023a).

3.1 Site Setting

The Project is located in the Northern Bowen Basin subregion of the Brigalow Belt North Bioregion, an ecologically complex area characterised by clay soils interspersed with Tertiary plateaus, sand plains, basalt plains, and some more expansive ranges formed on sandstone and granite. Typical vegetation is dominated by forests and woodlands of *Acacia harpophylla* (Brigalow), *Acacia shirleyi* (lancewood), eucalyptus woodlands, and grassland habitats. The region surrounding The Project area has been extensively cleared of native vegetation to accommodate pastoral activities. However, some intact tracts of woodland persist in rangelands to the north (Denham Range), east (Kerlong and Carborough Ranges) and west (Burton Range). Narrow fringes of continuous riparian vegetation have generally been retained along the more significant watercourses, occasionally buffered by broader areas of floodplain woodland. Coal mining has been a more recent activity in the region, emerging in the 1970s as a significant industrial activity. The Project interacts directly with the existing Burton Mine directly to the east and will utilize some of Burton Mine's existing infrastructure. The Project Description (Reach Environmental 2023) identified several coal mines and projects approved in the region, including the North Goonyella and Riverside mines approximately 15km to the west, separated from New Lenton by the Burton Range, and Hail Creek Mine 15km to the east, separated from the Project by the Carborough Range (**Figure 3**).

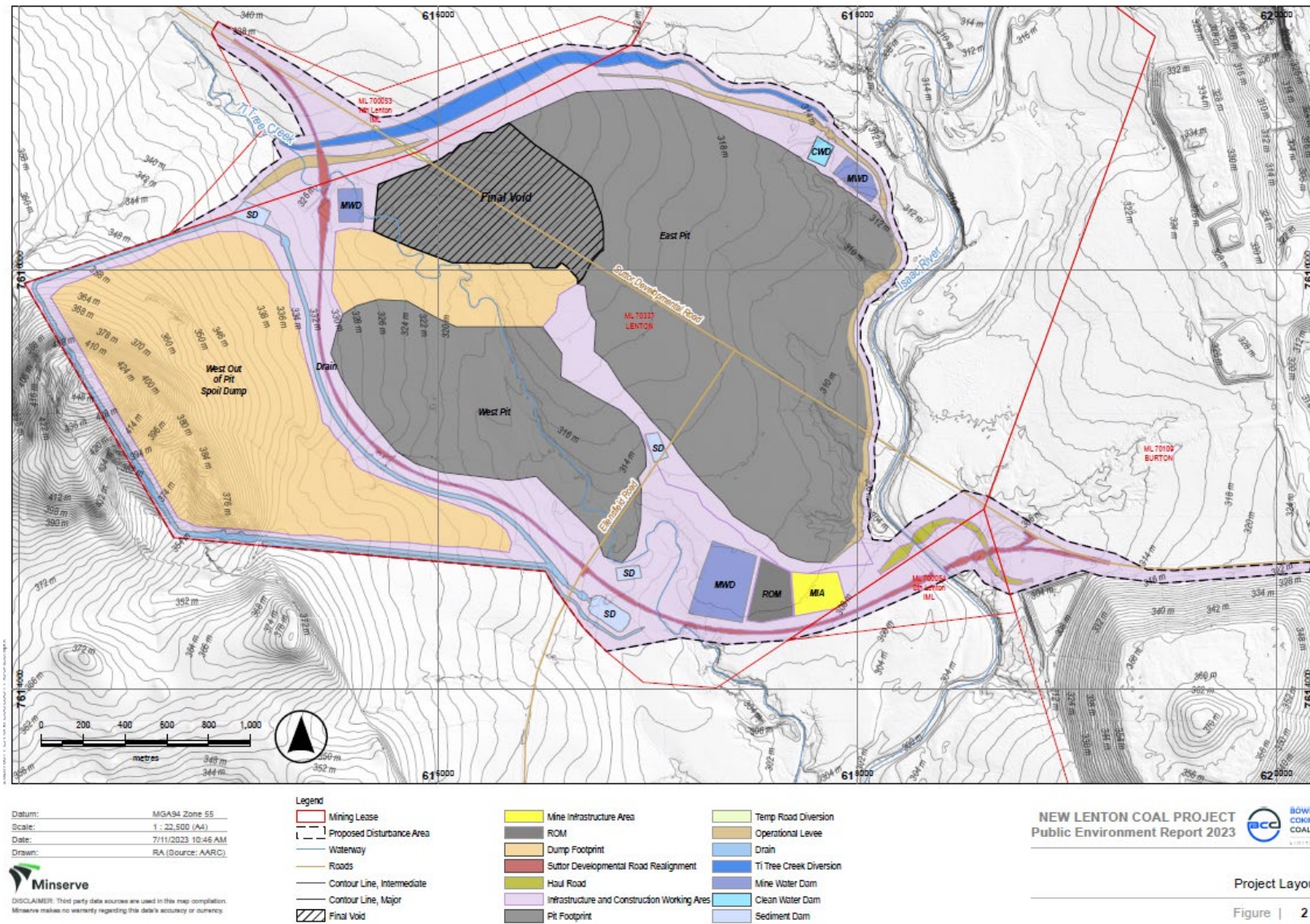


Figure 2. Project layout showing principal components of the mining operation.

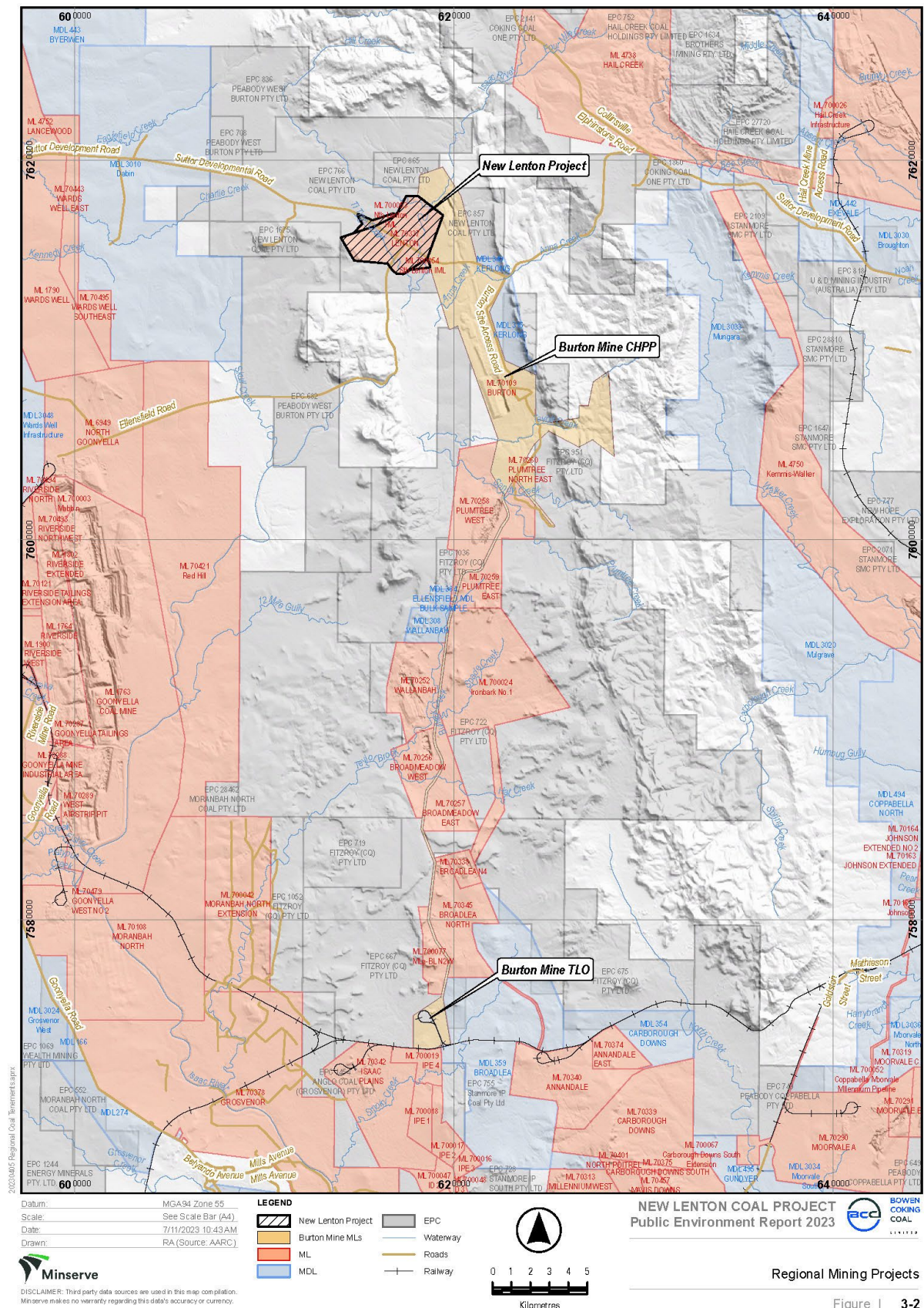


Figure 3. The location of the New Lenton Coal Project relative to regional mining projects.

3.2 Climatic Considerations

The region is sub-tropical, with average temperatures recorded in Moranbah of between 21.1°C and 34.8°C in the summer months and 8.9°C and 25.2 °C in the winter months. The nearest reliable public meteorological recording station to the Project Site is at the Moranbah Airport, which is 79km to the south and within a drier climatic region. However, point data from the SILO database (SILO 2023) at the location of the Burton Mine (-21.55° / 148.15°) provides a long-term local context. Long-term rainfall data (33 years of data between January 1990 and March 2023) indicates the average rainfall at the NLC Site is 758.8 mm (SILO 2023) with a pronounced wet season. Approximately 75% of annual rainfall occurs between November and March (BOM, 2024a). Plant growth in the region is limited by moisture rather than temperature (Hutchinson et al., 1992), which reflects in the evapotranspiration rates for the 2020 – 2023 period, with data indicating evapotranspiration is generally considerably higher than rainfall (SILO 2023). Exceptions to this occurred in May 2022, July 2022, and January 2023, where rainfall exceeded evapotranspiration, increasing rainfall penetration into the soil profile and recharging shallow unconfined groundwater tables. Annual evapotranspiration rates peak in December/January and are typically at their lowest in June / July (Figure 4).

The region has experienced several significant drought events, which are likely to have affected both surface flows and the recharge of groundwater systems. **Figure 5** demonstrates the primary climatic cycles in terms of Cumulative Rainfall Departure (CRD) (Weber & Stewart, 2004), representing a cumulative departure of monthly rainfall from the long-term mean monthly rainfall between January 1990 to February 2023 (SILO, 2023). Strongly decreasing rainfall trends between 1990 and 1996 and 2000 to 2007, representing significant drought periods, are strongly evident. Following a relatively stable/average rainfall period between 2013 and October 2017, rainfall volumes declined up to August 2021, followed by a solid upward trajectory in rainfall volume to the period of field assessment (February 2023). The analysis of cumulative rainfall departure is relevant to this assessment as shallow water tables generally follow similar trends, with rising water tables and increased occupation of surface waters coincident with increasing trends in the CRD curve.

3.3 Topography and Drainage

The Project Site is in the central part of the Permo-Triassic aged Bowen Basin, a broad sedimentary basin formed in the Permian / Triassic period with a variable cover of Quaternary and Tertiary period sediment and basic volcanic rocks (basalts). The Project area is characterised by gently undulating plains interrupted by narrow drainage features which drain toward the south characterise the Project Site. The broad rises form a variable cover of Pleistocene to Tertiary age cracking clay and residual silts and loams. Watercourses flow into the Isaac River, the most significant drainage feature in the region, which drains to the south, defines the eastern limits of the NLC mining operation and has developed a significant alluvial floodplain (Isaac River Alluvium). All watercourses flowing through the New Lenton Project study area are ephemeral, flowing only after high-intensity rainfall. For the more significant watercourse features such as the Isaac River, surface flows disappear quickly into the streambed sands as flows recede. The Project study area is bound to the east by the Kerlong and Carborough Ranges, which run in north-south orientation to the east of the Burton Mine, the Burton Range with passes to the west, and the Denham Range to the north, which are all formed on the Triassic age Clematis Sandstone.

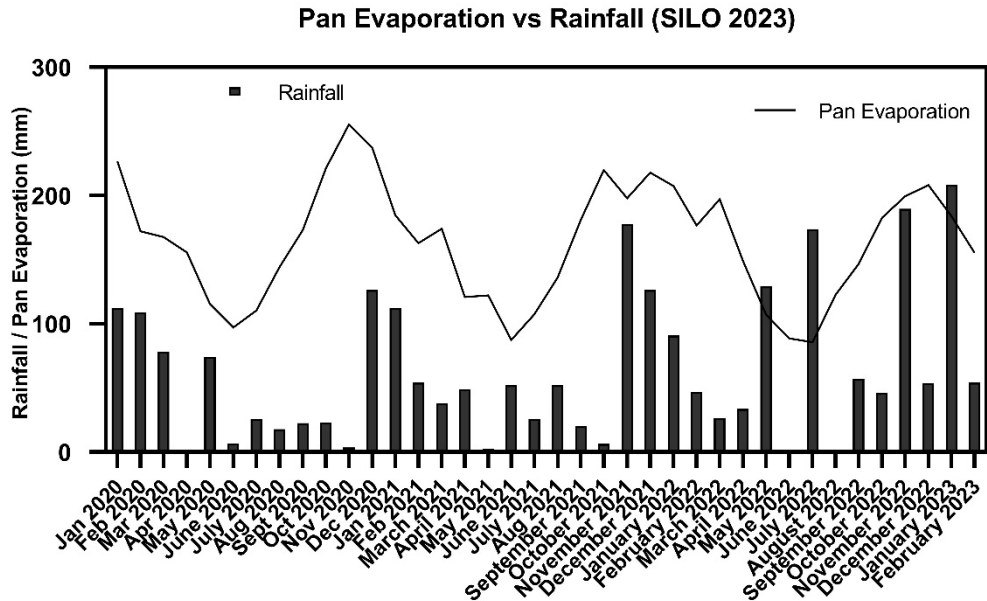


Figure 4. Evapotranspiration compared to rainfall for January 2020 to February 2023 (from SILO 2023).

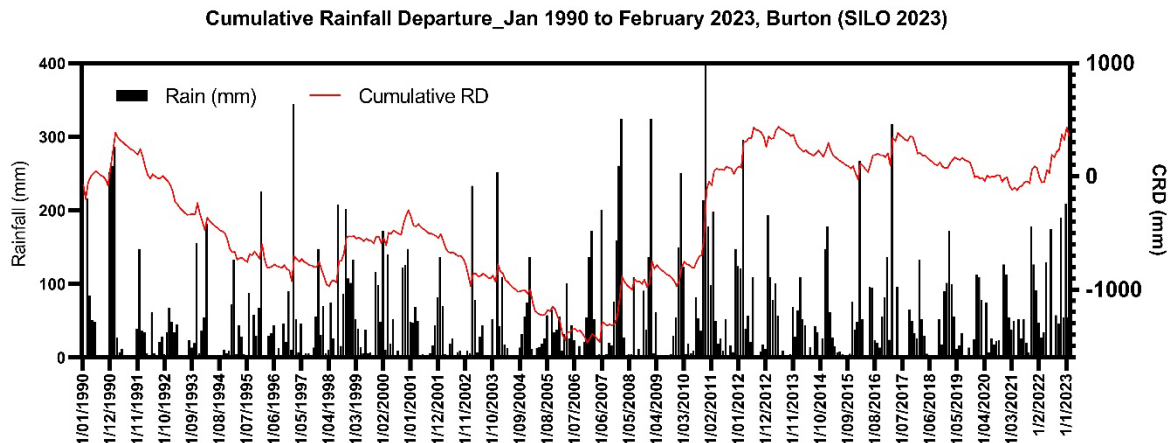


Figure 5. Cumulative Rainfall Departure demonstrating major and minor climatic fluctuations with a strong upward trajectory in rainfall volume from August 2021 to the period of field assessment (February 2023) (from SILO 2023).

3.4 Surface Geological Features

Triassic Sedimentary Rocks: The Rewan Formation (Rr), being formed by arenitic mudstone, siltstone, and some lithic sandstone, occurs over a broad portion of the Project study area and surrounds, with surface outcrop hidden by regolith cover. The Rewan Formation forms a thickness of up to 440m within the Project study area, although structural controls result in reduced thickness towards the east (SLR, 2023). The Rewan Formation is overlain by the Triassic age Clematis Group's medium to coarse-grained cross-bedded sandstones. The Clematis group outcrops to the north (Denham Range), east (Kerlong and Scarborough Range), and west (Burton Range) of the Project

study area, with the Burton Range intruding into the south-western boundary of ML 70337 (SLR, 2023).

Permian Sedimentary Rocks: The Rangel Coal Measures are the uppermost unit of coal-bearing strata in the Bowen Basin and the primary resource target within ML 70337 (SLR 2023). Thickness of coal seams is up to 8m for the Burton Rider and Leichardt / Vermont sequence with coal seams separated by an average of 20 to 25 m of sandstone, siltstone and mudstone interburden. The Rangel Coal measures are underlain by the Fort Cooper Coal Measures, separated by an average thickness of approximately 99 m of interburden and outcrops in the south of ML70337 (DNRM, 2018). The Burton Rider and Leichardt / Vermont sequence subcrop below regolith / alluvium in the south of ML 70337 and along an alignment running roughly parallel to and west of the Isaac River (GHD, 2019; SLR, 2023).

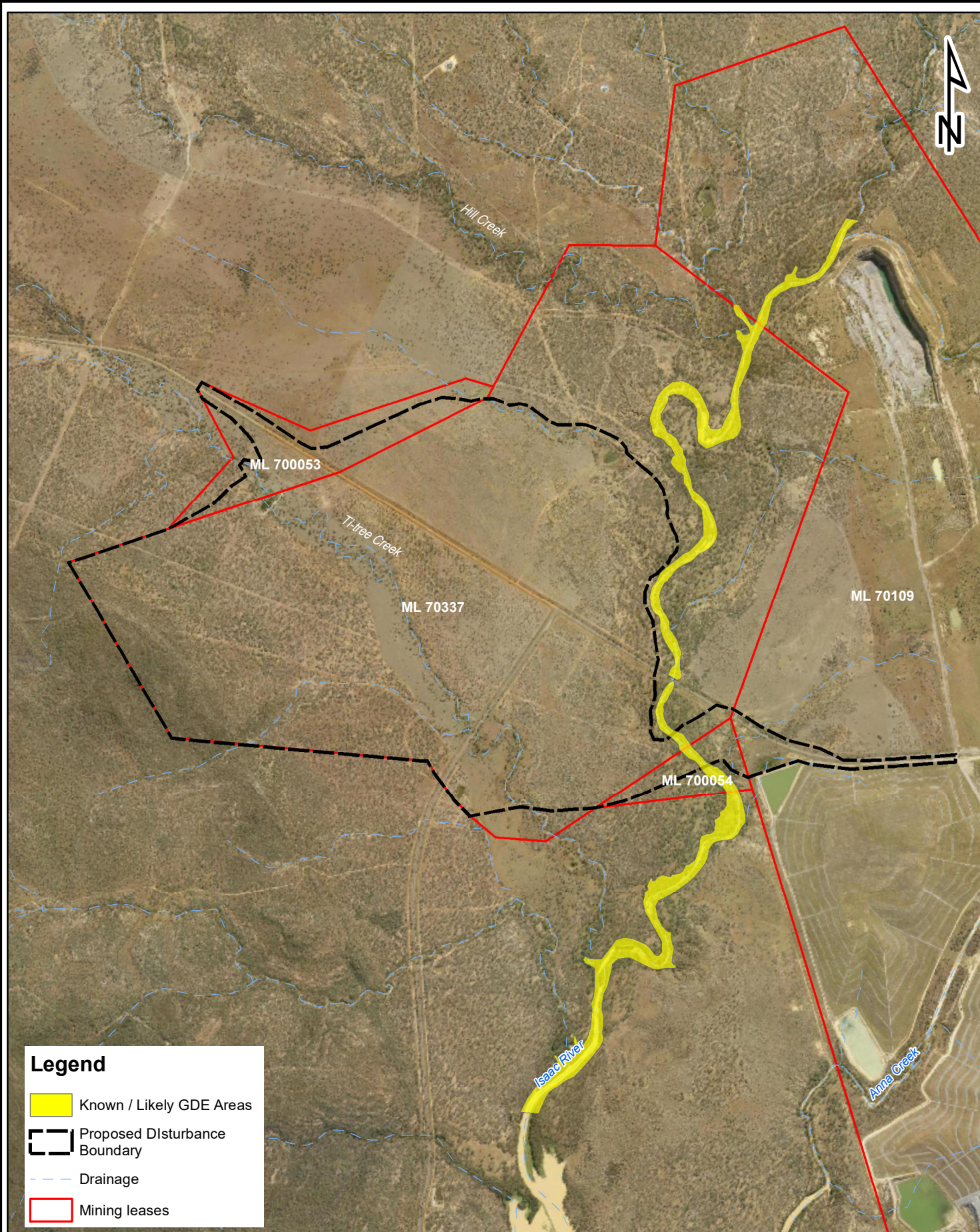
4.0 The Distribution and Hydro-ecological Function of GDEs at the New Lenton Mine

The potential occurrence of GDEs has been mapped at a national level by the Bureau of Meteorology (BOM), providing the GDE Atlas (BOM, 2024b). Further discussion of the GDE mapping presented in the GDE Atlas is provided in the PER Assessment Report (3d Environmental 2023a). Detailed descriptions of field-verified GDEs described in the New Lenton Project area, including block model conceptualisations and cross sections, have been developed and described in Section 5.0 of the New Lenton Project Groundwater Dependent Ecosystem Assessment Report (3d Environmental 2023a) and should be referred to for more detailed conceptual information.

Based on the field assessment completed by 3d Environmental (2023), riparian vegetation associated with the Isaac River floodplain and alluvium presents the only terrestrial GDE identified during the assessment. **Figure 7** shows the mapped location of GDEs relative to the Project disturbance area. Groundwater usage by vegetation away from the river margins decreases with distance and away from well-developed alluvial sediments. Groundwater usage is restricted by the shallow rooting depth of vegetation, depth to the groundwater table (particularly in the regolith), and groundwater salinity levels. Within the assessment area, the alluvial floodplain of the Isaac River forms a narrow sandy flood channel flanked by discontinuous upper and lower alluvial terraces, confined between gentle rises in regolith mantled by residual sediments. At the time of assessment, perched groundwater was intersected in shallow auger holes in fluvial sands beneath the sandy creek bed: these coarse river sands and associated groundwater extended as a unit laterally, subtending the riverbanks. The perched water recorded beneath the river terraces supports well-developed riparian vegetation that fringes the river, typically comprising RE11.3.25.

Recharge of the Isaac River alluvial groundwater system occurs during flood events where overbank flow pushes water laterally into the riverbanks and adjacent terraces. Lateral infiltration of surface flows into the alluvial terraces continues until the level of the surface water drops below the level of the recharged alluvial water table, after which recharged water may temporarily discharge back into the river channel as low volume seepage/baseflow in the short-term. An eco-hydrological conceptualisation of the Isaac River terrestrial GDE system, including a conceptualisation of Project impacts has been developed and presented in the New Lenton Groundwater Dependent Ecosystem Assessment (3d Environmental 2023a). These models infer a lack of any significant evidence that groundwater in the coal seams or regolith supports any GDEs in the New Lenton Project area to any significant degree.

A significant question applicable to this GDEMMP relates to the spatial extent and seasonal persistence of the perched groundwater, including its relationship and connectivity to the basal alluvial aquifer as defined by SLR (2023) and whether the basal alluvial aquifer is being utilised by riparian vegetation when the perched groundwater unit dries.



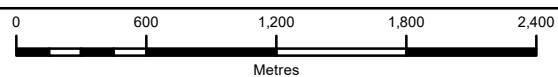
Legend

- Known / Likely GDE Areas
- Proposed Disturbance Boundary
- Drainage
- Mining leases

Figure 7. The mapped spatial extent of terrestrial GDEs fringing the Isaac River, from 3d Environmental (2023a).

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5.0 Major Risks to GDE Function

Sections 6.2 and 6.3 of the New Lenton Project Groundwater Dependent Ecosystem Assessment Report (3d Environmental 2023) develop a detailed assessment of the potential risks to GDEs. This document should be consulted if additional detail or specific information is required.

The most likely pathway for impact to Terrestrial GDEs will be through depressurisation/dewatering of the basal alluvial groundwater unit, which may result in faster drying of the soil profile and a reduced seasonal persistence of the perched groundwater system if the permeability of the intervening clays is sufficient to allow downward movement from the perched water to the basal alluvial system. **Section 6.3** of the New Lenton Project GDE Assessment Report (3d Environmental, 2023) conceptualises the impact scenario, which illustrates the drainage of the basal alluvial groundwater unit into the mining void and associated groundwater table drawdown. The model also indicates the position of the wet season bulge in the groundwater table resulting from wet season recharge and the potential for enhanced drying in the soil profile, leading to slightly reduced residence time for the perched system. While this represents the most likely impact pathway, the magnitude of the impact will depend on several factors, which include:

1. The degree of connectivity (if any) between the seasonally variable perched and the basal alluvial groundwater units.
2. The effectiveness of the hydraulic barrier effect of any intervening clay horizons that support perching and
3. Whether any vegetation associated with the mapped TGDE areas has developed deeper rooting systems that have penetrated through the perched into the basal alluvial unit.

This GDEMMP proposes monitoring protocols that will specifically address these questions.

To recognise that the level of risk to GDE function varies across the Project Area dependent on the interactions between groundwater drawdown and mapped terrestrial GDEs, four risk zones are identified as described in **Table 1** with spatial representation of Risk Zones provided in **Figure 8** (see **Section 6.6** of 3d Environmental 2023a).

Table 1. GDE Risk Zones based on degree of groundwater drawdown interacting with mapped Terrestrial GDEs.

Rank	GDE Risk Zone	Likelihood of Unmitigated Impact	Description
1	Zone 1 – Highest Risk	Likely	10m to 12m drawdown in the basal alluvial groundwater unit focused on mapped GDEs associated with the Isaac River.
2	Zone 2 –	Possible	>5 to <10m groundwater drawdown in the basal alluvial groundwater unit focused on mapped GDEs associated with the Isaac River.
3	Zone3_	Unlikely	2m to 5m drawdown in the basal alluvial groundwater unit focused on mapped GDEs associated with the Isaac River.
4	Zone4_Lowest Risk	Not Expected	<2m drawdown in the basal alluvial groundwater unit focused on mapped GDEs associated with the Isaac River.

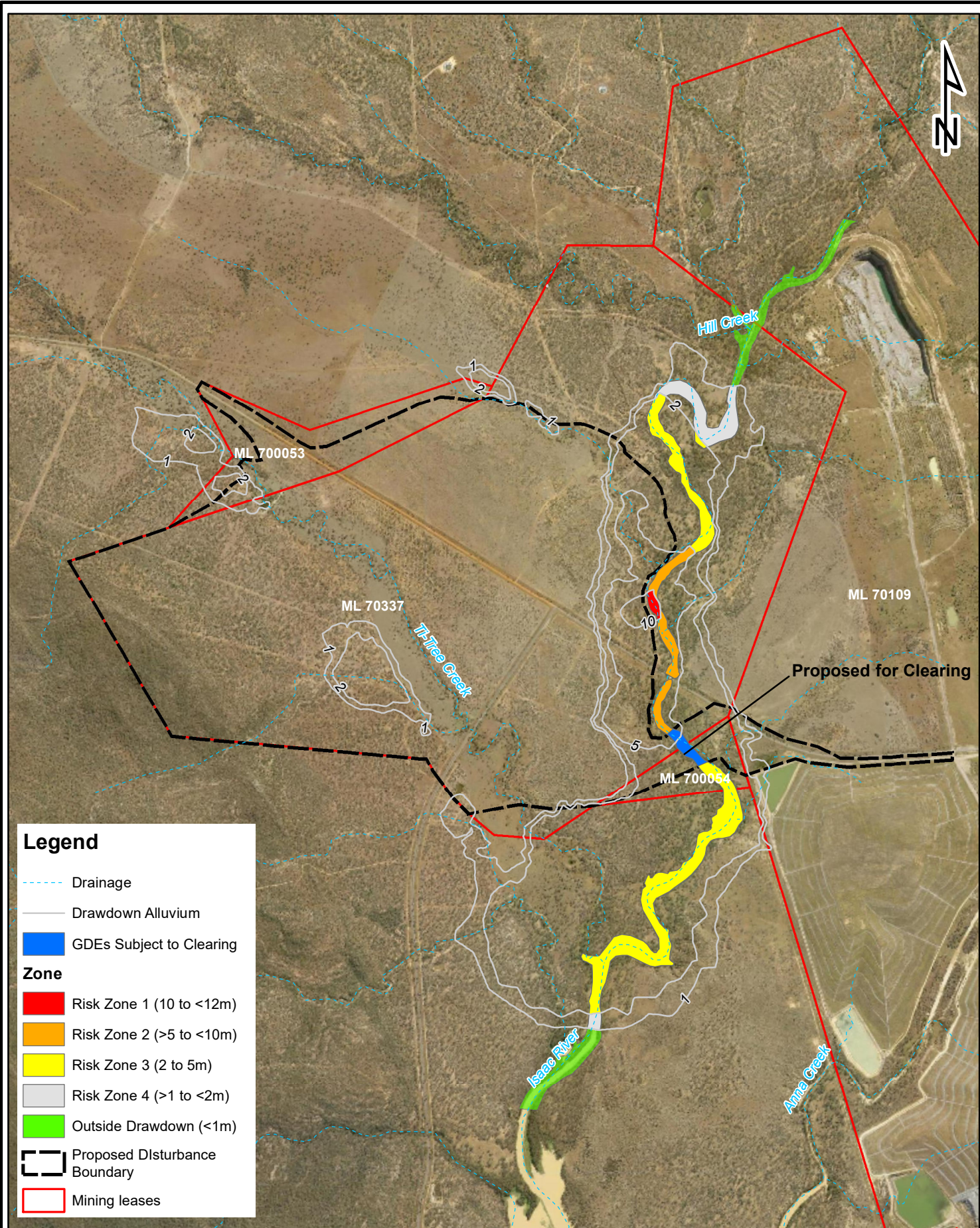
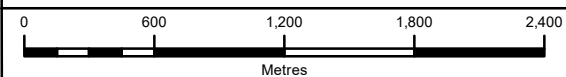


Figure 8. GDE Impact Risk Zones relative to confirmed TGDEs

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6.0 Biophysical Response to Reduced Water Availability / Quality

Eamus et al (2009) provides a conceptual assessment of the major stressors that contribute to declining GDE health. Reduced water availability is the major determinate of GDE health and the flow-on effects of this are outlined in **Figure 9**. Based on conceptualisations provided in **Section 6.3** and risk assessment completed in **Section 6.6** of 3d Environmental (2023a), an unmitigated 'moderate' risk of impact to GDE function is associated with the Risk Area 1 and Risk Area 2, where Terrestrial GDEs fringe the Isaac River. The unmitigated risk of impact can be linked to:

- A total or partial loss or reduction in volume or pressure of the aquifer being utilised by GDEs.
- Change in the chemical composition of an aquifer detrimentally affecting the health of a GDE.

In an unmitigated 'worst case' scenario when maximum drawdown coincides with a period of drought, the predicted impact would be of 'moderate' magnitude in Risk Zone 1 and Risk Zone 2, which in the context of the risk assessment detailed in **Section 6.6** of 3d Environmental (2023) would result in:

'Plant stress linked to mining activity that results in the reduction in volume and duration of groundwater supporting a GDE system that does not result in more than 25% dieback of mature canopy trees (defined as a canopy tree with DBH >60cm). Impact is reversible with mitigation.'

Any decrease in groundwater availability associated with drawdown of the aquifer being utilised by GDEs, and seasonal dryness extending into the summer months when transpiration is highest will likely be sufficient to trigger stomatal closure and reduction in Leaf Area Index (LAI)¹. Over an extended period with sustained conditions of drought, increasing levels of plant mortality may occur and in a general context, these adverse physiological responses may ultimately result in the conversion of a diverse, functioning habitat to a simplified system with reduced ecological value (Doody et al 2009). As detailed in **Figure 10**, the time taken for the first measurable impacts on vegetation due to reduction of moisture availability to manifest may take months, with habitat conversion due to dieback of the original canopy taking many years to decades with the rate of dieback dependent on climatic controls. However, detectable changes in vegetation health would likely be apparent within months to a few years. Many of the physical responses of vegetation to reduced water availability can also occur because of natural seasonal variation and hence any monitoring program must have capacity to distinguish what is natural variation from impacts that result from anthropogenic disturbance to the hydrogeological regime.

¹ Leaf Area Index is ratio of total one-sided area of leaves on a plant divided by the area of the canopy when projected vertically on to the ground.

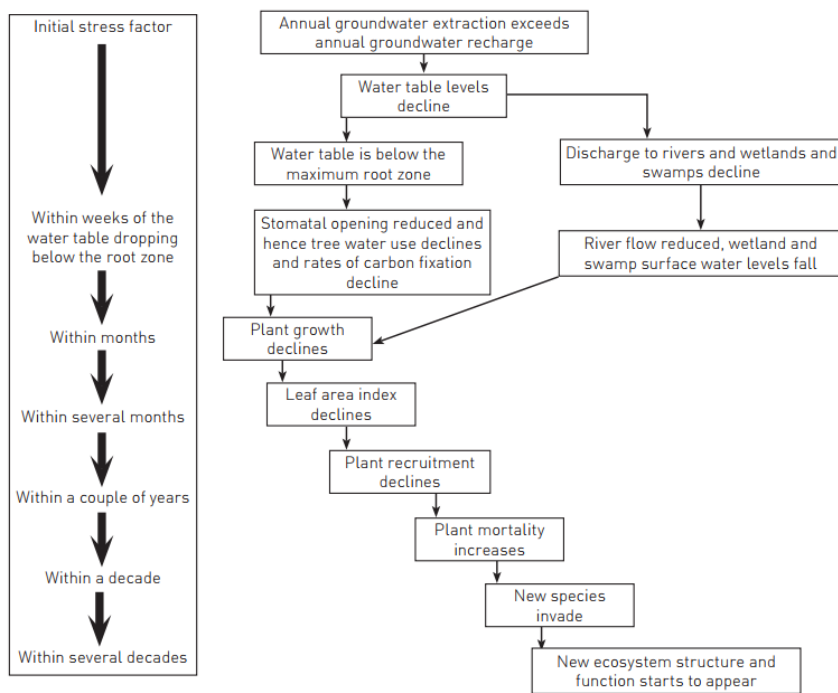


Figure 9. Schematic outline of the response of plants and communities of plants to reduced availability of groundwater from Eamus (2009).

7.0 Approach to Monitoring and Management Program

7.1 Overview

This document provides a framework for the management and monitoring of GDEs associated with the New Lenton Project Area including areas both within the area of predicted groundwater drawdown and areas outside the drawdown footprint where GDEs are attenuated upstream and downstream along the fringes of the Isaac River.

A sequential approach to monitoring and management has been applied which allows for adaptive implementation of monitoring and management protocols reliant on results of prior assessment activities. The major components of the GDEMMP include provision to:

- Apply monitoring and assessment techniques that support development of an environmental baseline for GDE function commencing prior to operations, including upstream and downstream control sites for GDE monitoring. An initial baseline assessment phase will be undertaken to add certainty to the findings of the PER assessment (3d Environmental 2023).
- Produce a statistically robust multi-parameter dataset that can be used to validate perturbations in GDE function that fall beyond thresholds of natural seasonal variation.
- Allow a flexible approach to monitoring which is subject to ongoing review and allows methods to be adapted based on results of lead-up monitoring and data analysis.
- Utilise biophysical and ecological parameters to establish:
 - an appropriate ecological trigger threshold, applied to indicate requirement for further investigation or corrective action; and

- an appropriate disturbance level threshold applied to indicate requirement for offsets should corrective actions not be successful.
- Develop a comprehensive suite of management actions and corrective measures which will be applied if a breach of trigger threshold is identified, noting that the suite of management actions implemented will depend on impacts identified, and all may not be required for any given breach of a trigger threshold.
- Assess the effectiveness of management actions and corrective measures, determine if significant residual impacts to MSES or MNES have occurred, and where significant residual impacts have occurred, provide offsets.

The approach is consistent with the GDE Toolbox approach (Richardson 2011a and 2011b) which recommends a sequential assessment, as outlined below:

- Stage 1 – GDE location, classification, and basic conceptualisation. The focus of Stage 1 is to gain a baseline understanding of where potential GDEs exist including classification of GDE type and ecohydrological function.
- Stage 2 – Characterisation of groundwater reliance. Stage 2 assessment builds on conceptual information provided in Stage 1 to characterise the degree of reliance of the GDE on groundwater.
- Stage 3 – Characterisation of ecological response to change: During Stage 3 assessment, knowledge of baseline ecohydrological function is utilised to describe and quantify likely changes to biophysical function and health of GDEs if impacts to groundwater regimes manifest.

The GDE characterisation undertaken by 3d Environmental (2023) as a component of the New Lenton Project PER meets the requirements of Stage 1, the outcomes of which are described in accordance with conceptual models provided in **Section 5.2** and **Section 6.3** of the PER report. Ongoing adjustment of the ecohydrological models may be required as the monitoring program develops, and ecological data is collected and analysed.

Stage 2 and Stage 3 of the monitoring program will rely on collection of temporal data to support characterisation of baseline ecohydrological function. Seasonal monitoring events will allow for baseline data to be acquired to predict trends in GDE function and identify impacts that extend beyond the range of natural variation.

7.2 Approach

The monitoring and management program has been separated into two stages:

- Two years of intensive data collection during which the GDE monitoring program will be refined, and investigative thresholds will be defined (see **Section 10**).
- The period after 2 years, comprising the remainder of operations and the post mining period, which will utilise data collected in the initial two years to re-assess the developed thresholds.

The process for establishing thresholds is described in **Section 10**, involving collection of data from the impact site (i.e., drawdown area) and two control sites located upstream and downstream from the mining impact area (i.e., outside the area of drawdown) on the Isaac River. The thresholds for impact are linked to vegetation health and provide a comparison between the control and impact sites. Should the established thresholds be exceeded, this will trigger an investigation that will make

use of other monitoring data (See **Section 10.2**) that considers the bio-physical function of groundwater dependent vegetation, groundwater, and surface water to determine the cause of a threshold exceedance. If drawdown of the groundwater table is found to be the cause of the threshold exceedance, then mitigation measures (see **Section 11**) will be implemented, and the effect of mitigation measures monitored. If mitigation measures are not effective, habitat quality data from a GDE habitat quality monitoring program, as prepared by AARC (2024) will be used to assess whether there has been a significant residual impact to riparian habitat and any threatened species that may be associated with it. The GDE habitat quality monitoring program has been established in conjunction implementation of this GDEMMP and draws upon assessment of biocondition and derived assessment of habitat quality prescribed in Eyre et al (2015) and DES (2020). Biocondition should be monitored:

- Biannually for two years to establish the seasonal baseline range of biocondition scores for habitats associated with GDE monitoring sites proposed within the GDEMMP.
- Every two years in the dry season following establishment of baseline biocondition scores.

If mitigation measures are not effective, data from the habitat quality monitoring program (AARC, 2024) will be used to assess whether there has been a significant residual impact.

The initial two years of intensive data collection aims to refine habitats for ongoing monitoring (i.e., focus on areas of confirmed groundwater dependency) and develop thresholds for monitoring and impact assessment, including provision of a dataset to support investigative action if decline in GDE health is detected. The initial event of the 2-year baseline is proposed to commence prior to Project approval, and preferably prior to Project operations involving removal of overburden intersecting alluvium in open cut pit mining areas, to allow monitoring data to be calibrated to a pre-disturbance threshold. For post baseline monitoring, while the process remains the same, sites that do not demonstrate groundwater dependence can be excised from the program, and thresholds may be amended to reflect alternative parameters for monitoring and / or the threshold values attached to those parameters.

8.0 Monitoring and Analysis Techniques

The GDE Toolbox – Part 2 (Richardson 2011b) provides a suite of technically robust tools to identify GDEs and determine their ecological water requirements. These tools are based on established methods repeated in studies within Australia and abroad, many of which are published in peer-reviewed scientific journals. Many of these tools were applied in the PER GDE characterisation (3d Environmental 2023a) and for the purpose of baseline characterisation, are recommended for inclusion as a component of ongoing monitoring. **Table 2** provides a list of tools used in the GDE characterisation and describes their purpose and ongoing relevance to monitoring. Several additional methods adapted from the GDE Toolbox have also been included, being recommended components of an ongoing monitoring program. Technical details of recommended assessment methods are provided in **Appendix B**.

Table 2. Assessment methods that will be applied during GDE monitoring.

Assessment Method	Utilised in PER GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
Conceptual modelling	Yes	Tool 2	Aims to conceptualise the interactions between biotic factors (e.g., trees) and abiotic (e.g., soil, surface water and groundwater). Conceptualisation formalises the understanding of the major components of a GDE system and allows impact pathways to be contextualised.	Conceptualisation and informing monitoring program design and implementation.
Leaf water potential	Yes	Tool 3	LWP provides the primary biophysical measure of tree water availability and defines a continuum between the relationship of soil, water and plant. Trees associated with high water availability will have a high (least negative) LWP. LWP provides an indication of which trees have access to a saturated or near saturated water source, although does not identify the nature of the source (i.e., groundwater, saturated pockets in the soil, surface water from stream pools).	Site based assessment with some application for seasonal monitoring to identify plant water deficits. Used in conjunction with Leaf Area Index (LAI).
Stable Isotopes of water in plants	Yes	Tool 4	The stable isotopic signature ($\delta^2\text{H}$ and $\delta^{18}\text{O}$) of the dominant water source for a tree will be imparted on its hydraulic architecture, typically measured in twigs. The stable isotope signature in twigs may be directly analogous to a single water source if that source provides a predominant contribution to a trees water requirement. It may also be a combination of a number or sources, requiring a mixing model to be employed to calculate relative contributions of each water source.	Identifies plant water sources. Monitoring application in the initial two-year baseline investigation to: 1. Determine the proportions of various water sources used by tree in response climate controls. 2. Determine how these contributions change over a seasonal cycle to fully evaluate the GDE risk profile.
Leaf Area Index	No	Tool 1, Tool 2	Leaf Area Index (LAI) is a ratio of the total leaf area within a canopy to the ground area covered by the canopy. It is a measure of canopy vigour and the	A fundamental application used in monitoring, in conjunction with remote sensing, to measure

Assessment Method	Utilised in PER GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
			rationale applied is that plants with access to permanent sources of water (i.e., groundwater) will have greater vigour and LAI than vegetation that has only periodic access to groundwater resources (e.g., Zolfagher 2014). LAI is likely to vary on a seasonal basis if the sustaining source of moisture is variable, or the groundwater is only seasonally utilised.	seasonal variation in vegetation health.
Remote sensing	No	Tool No 1	Assessment utilises the Normalised Difference Vegetation Index (NDVI) as a measure of canopy health and vigour, that can be directly correlated to LAI. It is a widely accepted method and with advances in satellite technology, has the capacity to assess the health of individual trees rather than landscapes.	Application for long-term monitoring once baseline conditions have been established.
Site based groundwater monitoring	Yes – for data from regional groundwater units including the Permian coal measures, weathered Tertiary sediments and the Isaac River alluvium.	Tool No 10, 13	Local installation of additional shallow groundwater monitoring bores targeted to assess the seasonality and persistence of the perched alluvial groundwater system which supports GDEs (see Appendix D). Additional monitoring bores will be proposed to specifically target groundwater / GDE interaction. Groundwater monitoring will include collection of EC and other water equality data.	Long term monitoring applications as a basis to draw correlations with biotic assessment parameters (e.g. LAI). Used to determine mechanisms of groundwater recharge into and discharge from the Isaac River.
Surface Water Monitoring	Yes - Ongoing monitoring under the developed REMP and EA surface water monitoring requirements.	Tool No 10	Ongoing monitoring of surface water flows and quality from dedicated monitoring points (see Section 2.2 of 3d Environmental 2023a).	Long term monitoring applications to draw correlations between surface flows and recharge of groundwater, particularly in the alluvial and Tertiary groundwater systems.
GDE Habitat Quality Monitoring Program	No – Habitat quality scores will need to be measured to characterise the pre-impact baseline ecological condition	n/a	A GDE habitat quality monitoring plan has been established by AARC (2024), as per methods detailed in Eyre et al (2015) and DES (2020). Sites proposed in the habitat quality monitoring program complement the proposed GDEMMP monitoring sites and include both riparian monitoring sites (within RE11.3.25) and representative sites within the mapped Poplar Box TEC.	Site based assessment with some application for seasonal monitoring to assess changes in habitat quality in the riparian zone. Monitoring undertaken to inform whether:

Assessment Method	Utilised in PER GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
	of known and potential GDEs.		Species specific habitat indices will also be assessed in line with Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3. (see Section 8.1).	• changes in GDE health have resulted in changes in biocondition or habitat quality for potentially impacted REs, TECs or listed species. • changes in biocondition or habitat quality are in exceedance of disturbance thresholds and require offsets. • remediation measures, if required, have benefited habitat quality

8.1 Site Selection and Application

Data collection will occur in all GDE Risk Areas. Proposed monitoring methods are in **Section 8.3** (statistical analysis), **Section 8.4** (stable isotopes), **Section 8.5** (NDVI analysis), **Section 8.6** (groundwater), and general procedural information is provided in **Appendix B** as listed below:

1. LWP and SMP provided in **Appendix B1**
2. Stable Isotope Analysis in **Appendix B2**
3. Measurement of field-based LAI in **Appendix B3**
4. NDVI assessment in **Appendix B4**

While the distribution of field-verified GDEs is a primary driver for the allocation of monitoring areas, overlap with field-verified TECs and GDE mapping represented in the GDE Atlas (BOM, 2024b) has also been given consideration, providing additional temporal context and certainty to the GDE assessment. While habitats consistent with the Poplar Box TEC (applicable patches of RE11.3.2) were assessed to not represent Terrestrial GDEs in the PER assessment (3d Environmental 2023), Advice to the Decision Maker from the IESC (2024-147: New Lenton Coal Project (EPBC 2020/8778) – New Development) has requested additional seasonal information on the moisture sources being utilised by TECs before groundwater dependence can be discounted.

Figure 10 shows the location of proposed GDE monitoring and TEC assessment sites relative to Risk Zones (from 3d Environmental 2023a) and groundwater drawdown contours (SLR 2023) while **Figure 11** shows proposed assessment sites relative to groundwater monitoring bores and REMP sites. Both maps show the extent of mapped Poplar Box TEC from AARC (2023). **Figure 12** also shows the location of GDE and TEC assessment sites relative to mapped GDEs from the BOM GDE Atlas (BOM 2024b) to provide additional context.

The purpose of each GDE monitoring locality, including Risk Zone, catchment, and target ecosystem, is summarised in **Table 3**. In contrast, **Table 4** provides details of the monitoring program, including parameters for assessment and the number of sites. The program includes GDE monitoring areas within areas of highest risk (Risk Zone 1) to lowest risk (Risk Zone 4), with control sites proposed for areas outside of the groundwater drawdown footprint. The proposed GDE monitoring areas overlap with GDE assessment sites from the PER (3d Environmental 2023a) and coincide with the location of groundwater monitoring bores where possible. The location of sampling points from the PER assessment is provided in **Appendix C**.

Field reconnaissance in September 2024 completed investigative auger sampling at four monitoring sites to confirm the potential location of shallow groundwater monitoring bores and monitor the seasonality and persistence of the perched groundwater unit. **Figure 11** shows the location of four potential shallow bores, and the results of investigative augers, including auger logs, are provided in **Appendix D**.

Table 3. Details of proposed GDEMMP monitoring localities.

GDEMP Monitoring Site	Catchment	Purpose	Assessment Area from from PER Study*	RE	TEC	Relevant Groundwater Monitoring Bores	No. of Shallow Monitoring Bores Proposed **
Risk Zone 1							
Site 1	Isaac River	Riparian TGDE	1	11.3.25	NA	GW19_37a	1
TEC1	Isaac River	TEC	NA	11.3.2	(Poplar box)	GW19_37a	0
Risk Zone 2							
Site 1A	Isaac River	Riparian TGDE	NA	11.3.25	NA	GW19_36	0
Site 1B	Isaac River	Riparian TGDE	NA	11.3.25	NA	None	0
TEC2	Isaac River	TEC	NA	11.3.2	(Poplar box)	GW19_37a	0
TEC3	Isaac River	TEC	NA	11.3.2	(Poplar box)	GW19_37a	0
Risk Zone 3							
Site 2A	Isaac River	Riparian TGDE	2	11.3.25	NA	GW06	1
Site 2B	Isaac River	Riparian TGDE	6	11.3.25	NA	None	1
Site 2C	Isaac River	Riparian TGDE	NA	11.3.25	NA	GW09	0
Site 2D	Isaac River	Riparian TGDE	7	11.3.25	NA	GW07	0
Risk Zone 4							
TEC4	Ti-Tree Creek	TEC	NA	11.3.2	(Poplar box)	GW19_37a	0
Risk Zone – Outside Drawdown							
Site 3A	Isaac River	Riparian TGDE	13	11.3.25	NA	GW19_33	1
Site 3B	Isaac River	Riparian TGDE	NA	11.3.25	NA	None	0

**Locations for shallow augers have been identified based on reconnaissance investigations in localities that are determined to be suitable based on landform, vegetation, and the presence of either perched groundwater or suitable groundwater host material (e.g., sandy sediments) that may hold perched groundwater seasonally. The final locations of the shallow augers may be subject to change based on constructability and access.

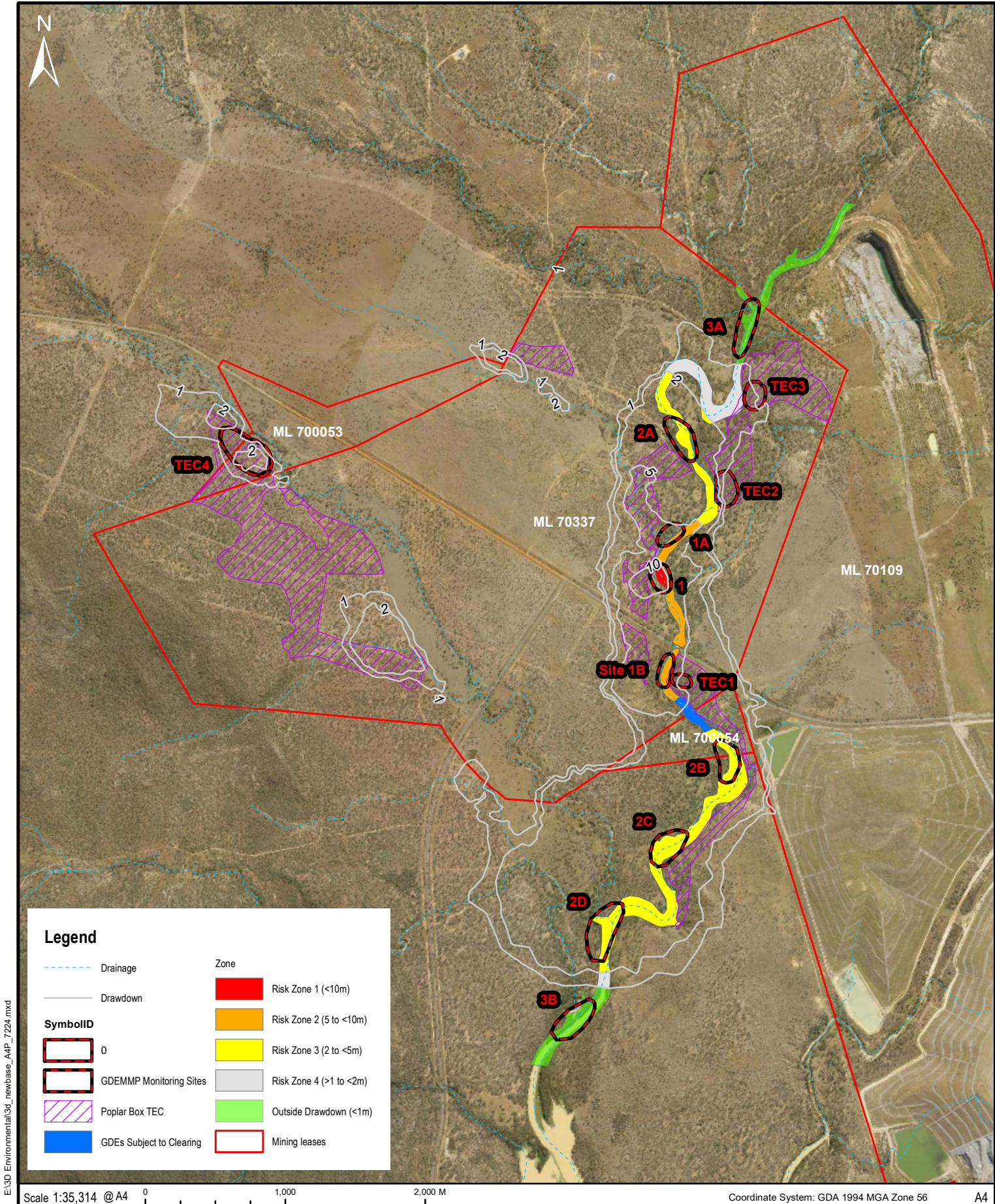


Figure 10. Location of proposed GDE and TEC assessment sites for ongoing monitoring in relation to groundwater drawdown contours, GDE risk zones and mapped occurrences of the Poplar Box TEC (AARC 2023).

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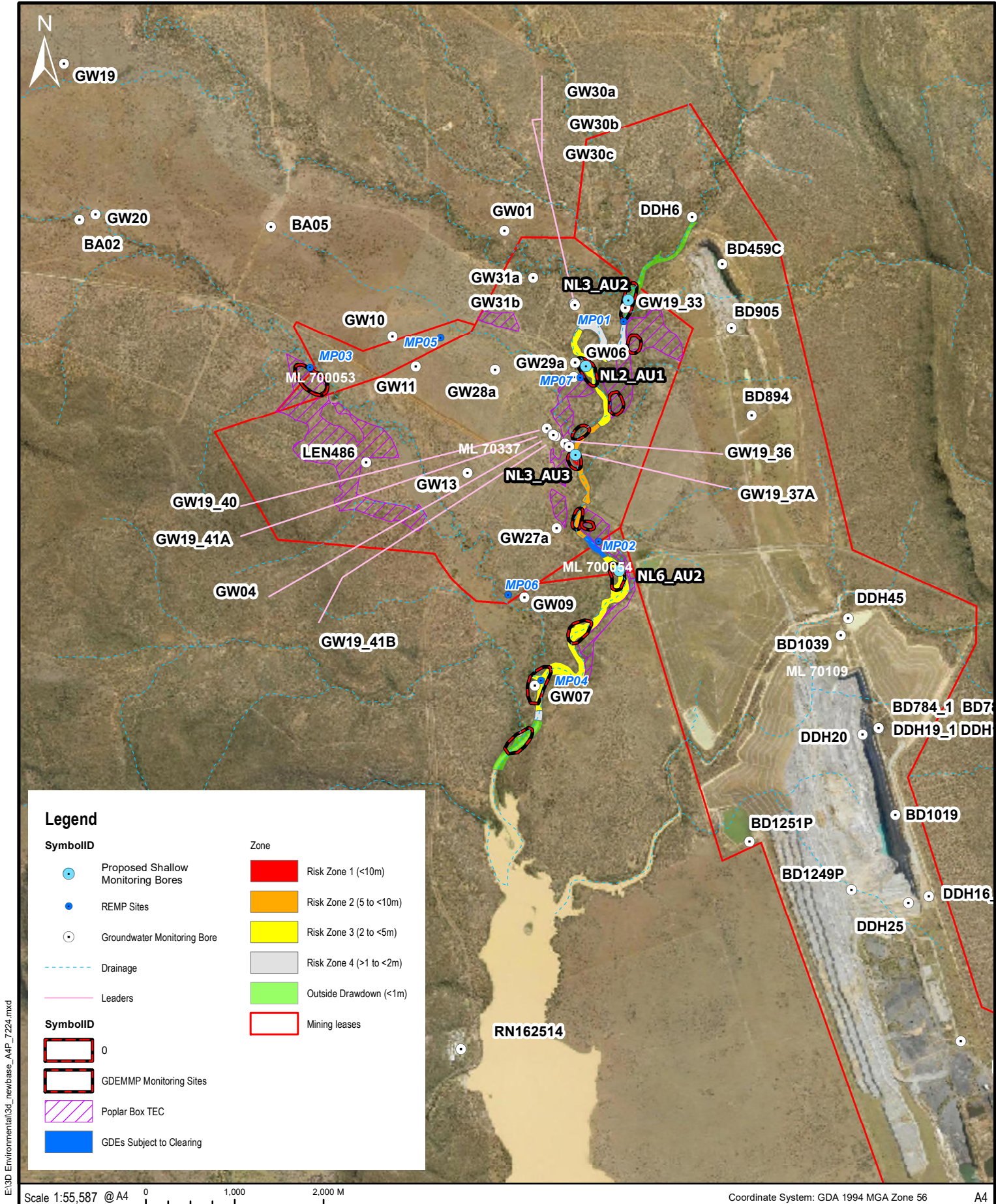


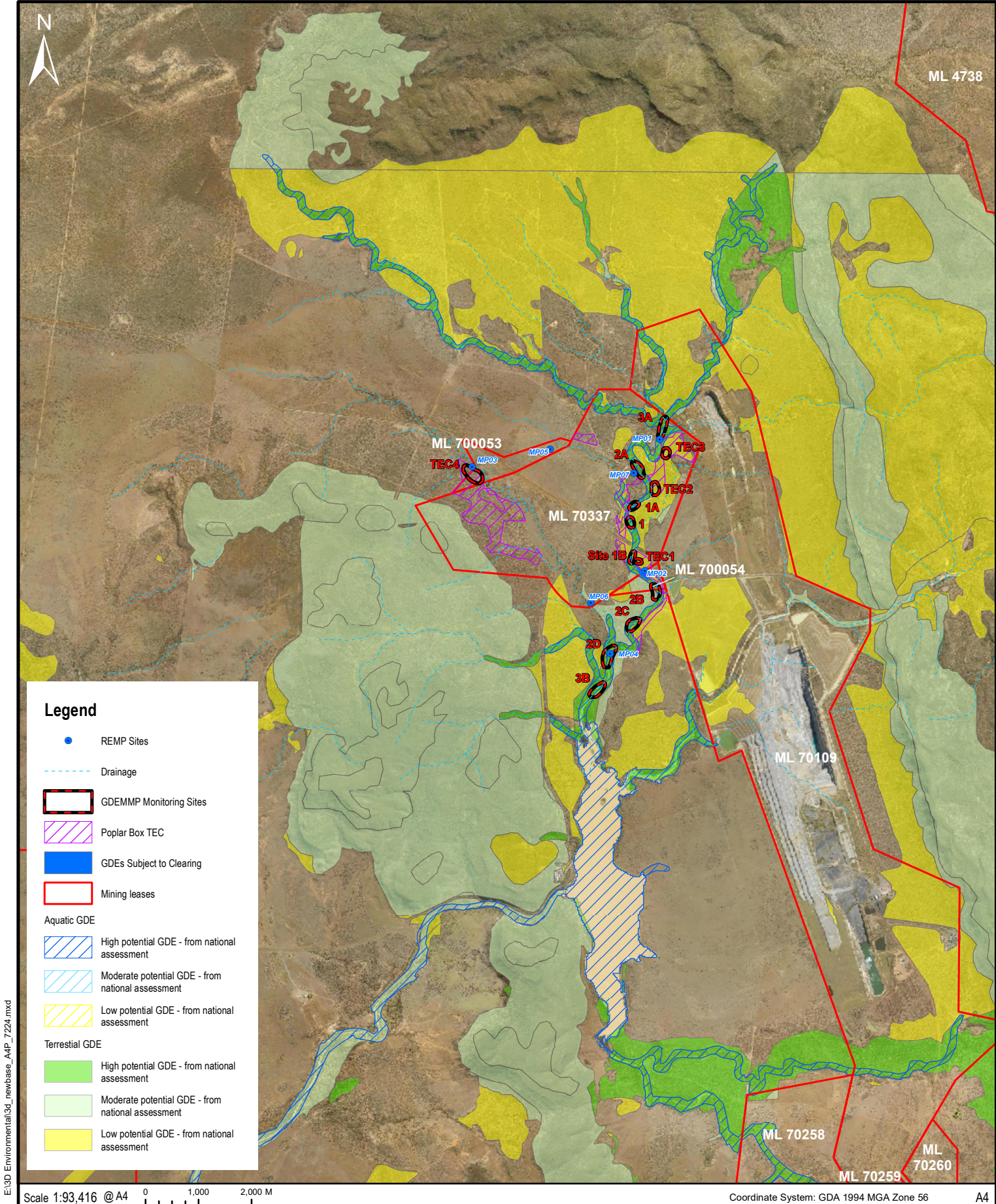
Figure 11. Location of proposed GDE and TEC assessment sites relative to groundwater monitoring bores, REMP sites, the extent of the Poplar Box TEC and GDE risk zones.

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Source: BOM GDE Atlas (2020).

Figure 12. The location of proposed GDE monitoring areas relative to potential GDE mapping produced in the GDE Atlas (BOM, 2024).

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Table 4. Proposed sampling intensity for for Terrestrial GDE and TEC sampling program

Sampling Method	Sampling Locality	Sampling Intensity
LAI	Risk Zone 1	A minimum of 8 permanently located LAI capture points within areas of maximum predicted groundwater drawdown: a) Four capture points within the area of field verified Terrestrial GDE associated at Site 1, within the vicinity of alluvial groundwater monitoring bore GW19_37A. b) Four capture points associated with monitoring site TEC1 located on the upper terrace of the Isaac River where areas of the Poplar Box Woodland TEC (RE11.3.2) has been identified. The most relevant groundwater monitoring bore is GW19_37A.
	Risk Zone 2	A minimum of 16 permanently located LAI capture points including: a) Eight capture points allocated to the field verified Terrestrial GDE associated with the frontage of the Isaac River at Site 1A and Site 1B. The most relevant groundwater monitoring bore is GW19_36. b) Eight capture points associated with monitoring sites TEC2 and TEC3 located on the upper terrace of the Isaac River where areas of the Poplar Box Woodland TEC (RE11.3.2) has been identified. The most relevant groundwater monitoring bore is GW19_37A.
	Risk Zone 3	A minimum of 16 permanently located LAI capture points distributed amongst the four allocated Terrestrial GDE monitoring sites, being Site 2A, Site 2B, Site 2C and Site 2D . The most relevant groundwater monitoring bores are GW06 (2A), GW09 (2C), and GW07 (2D).
	Risk Zone 4	A minimum of four permanently located LAI capture points at site TEC4 on Ti-Tree Creek within a broader expanse of mapped Poplar Box Woodland TEC (RE11.3.2).
	Outside Drawdown	A minimum of 8 permanently located LAI capture points outside the groundwater drawdown footprint within the area of field verified Terrestrial GDE associated with the frontage of the Isaac River. Relevant sites are Site 3A and Site 3B , with the most relevant groundwater monitoring bore being GW19_33 for GDE Monitoring Site 3A.
LWP	Risk Zone 1	A minimum of 8 permanently located trees for LWP sampling within areas of maximum predicted groundwater drawdown: a) Four LWP sampling trees within the area of field verified Terrestrial GDE associated within Site 1, within the vicinity of alluvial groundwater monitoring bore GW19_37A. b) Four LWP sampling trees associated with monitoring site TEC1 located on the upper terrace of the Isaac River where areas of the Poplar Box Woodland TEC (RE11.3.2) has been identified. The most relevant groundwater monitoring bore is GW19_37A.
	Risk Zone 2	A minimum of 16 permanently located LWP sampling trees including: c) Eight LWP sampling trees allocated to the field verified Terrestrial GDE associated with the frontage of the Isaac River at Site 1A and Site 1B. The most relevant groundwater monitoring bore is GW19_36. a) Eight LWP sampling trees associated with monitoring sites TEC2 and TEC3 located on the upper terrace of the Isaac River where areas of the Poplar Box Woodland TEC (RE11.3.2) has been identified. The most relevant groundwater monitoring bore is GW19_37A.
	Risk Area 3	a) A minimum of 16 permanently located LWP sampling trees distributed amongst the four allocated Terrestrial GDE monitoring sites, being Site 2A, Site 2B, Site 2C and Site 2D. The most relevant groundwater monitoring bores are GW06 (2A), GW09 (2C), and GW07 (2D).

Sampling Method	Sampling Locality	Sampling Intensity
	Risk Area 4	A minimum of four permanently located LWP sampling trees at site TEC4 on Ti-Tree Creek within a broader expanse of mapped Poplar Box Woodland TEC (RE11.3.2).
Stable Isotopes ²	All localities	The aim of the stable isotope program will be to determine the relative proportion of each moisture source being utilised by groundwater dependent vegetation and is to be completed as a component of the 2-year intensive data collection period. Further details of the purpose of the stable isotope sampling program are provided in Section 8.4 which details the methods to be applied. Sampling for stable isotopes will be completed for a minimum: a) Four trees within Risk Area 1 at Site 1. b) Eight trees in Risk Area 2 at Site 1A and Site 1B. c) 16 trees within Risk Area 3 at Site 2A, Site 2B, Site 2C and Site 2D. d) Eight trees in the area 'Outside Drawdown' at Site 3A and Site 3B. Stable isotope sampling will cover: e) Twigs from 36 representative trees across all risk areas including areas outside drawdown. f) Surface water from flows, if available at time of survey. g) Groundwater stored in riverbed (bank) sand aquifer in the river channel. h) Groundwater from alluvial monitoring bores collected during routine sampling events. i) Soil samples from a minimum of four shallow auger holes targeting perched groundwater supporting GDEs selected from Site 1 (Risk Zone 1), Site 2A, Site 2B (Risk Zone 3), and Site 3A (Outside Drawdown) as identified in reconnaissance investigations. Soil isotope sampling will preferentially target auger holes chosen for construction of monitoring bores to monitor the perched aquifer. j) Rainfall undertaken opportunistically. TEC sites (i.e., sites in the Poplar Box TEC) will not be sampled for stable isotopes unless specific properties, such as unexplained high water availability is noted in field assessment.
NDVI Capture	Approximately 100km ² capture to cover the relevant parts New Lenton disturbance footprint including the full extent of all GDE and TEC monitoring sites.	High resolution imagery from the WorldView 3 and WorldView 4 satellites (0.3m resolution, 4 -16 band multispectral) is recommended and will allow detailed monitoring of canopy vigour at extremely fine scale. The application of NDVI Imagery for the purpose of monitoring GDE / Vegetation health is discussed in Section 8.5. Localities will be established for permanent monitoring of NDVI to coincide with areas proposed for GDE monitoring. Established transects will be 100m length with measurement of NDVI completed at 1m centres along transect.
Groundwater Monitoring Bores	GDE monitoring bores as part of the dedicated groundwater monitoring program.	Monitoring bores which are applicable to monitoring of impacts to Terrestrial GDEs include existing bores GW19_37a, GW19_36, GW_06, GW_09, GW_07, GW19_33. A minimum of four additional dedicated shallow GDE monitoring bores should be installed to monitoring the persistence and seasonality of the perched groundwater selected from the following Terrestrial GDE monitoring sites, based on reconnaissance investigations: 1. Site 1 (Risk Zone 1) 2. Site 2A and Site 2B (Risk Zone 3). 3. Site 3A (Risk Zone 4). The capacity to construct groundwater monitoring bores at these locations will be dependent on ground conditions and presence of perched groundwater, or the potential for presence of perched groundwater. No

² Collection of LWP and the analysis of stable isotopes was completed in the PER assessment (3d Environmental 2023a) and hence can be augmented with the intensive data collection period.

Sampling Method	Sampling Locality	Sampling Intensity
		shallow groundwater monitoring bores will be constructed within the TEC sampling sites (i.e., those sampling the Poplar Box TEC). Monitoring of groundwater quality will be undertaken in accordance with the New Lenton groundwater monitoring program and will include parameters detailed in Section 10.2.4.

8.2 Interactions with Established Monitoring Programs and Parameters

The following interactions with monitoring programs that are either existing, or will be developed as a component of the Project approval process:

1. **Surface water:** Surface water quality and environmental flows will be measured as a component of the New Lenton SWMS (as required by the EA) and the REMP, allowing for early detection of any impacts on water quality and employment of appropriate corrective actions. In conjunction with other parameters, surface flow, and water quality datasets will inform the baseline characterisation of Terrestrial GDEs on the Isaac River and assess project impacts.
2. **GDE habitat quality:** A GDE habitat quality monitoring program has been developed to complement, although remain separate from, this GDEMMP (AARC 2024). Habitat quality sites, utilising methods prescribed in Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3 (DES 2020) to complement 'early warning' vegetation parameters assessed as a component of this GDE monitoring program. The GDE habitat quality monitoring program will assist measurement of the significance of Project related impacts to GDEs. At a minimum, the GDE habitat quality monitoring program should establish one permanently maintained habitat quality site for each of the nine proposed GDE Monitoring Sites, with complementary sites established to monitor TEC condition (TEC1 to TEC4).
3. **Groundwater:** Details of the GMMP are provided in SLR (2023). The program covers the operation of the existing monitoring bore network, plus any additional shallow bores established to monitor the seasonality of the perched alluvial groundwater system. The GMMP will be continued throughout the life of the project. Records of groundwater levels and water quality from monitoring bores will continue to provide baseline information for groundwater fluctuations in response to rainfall and surface flows in the Isaac River and associated tributaries. These measurements will be used to distinguish groundwater drawdown resulting from proposed mining activities from natural fluctuation and provide a basis for investigation related to the health and function of GDEs. Further information on the groundwater monitoring network, including existing and proposed bores and water quality parameters, is provided in **Section 8.6**.

8.3 Detection of Trends and Statistical Analysis

The BACI (Before After/Control Impact) provides a statistically robust survey design to test for environmental change in response to disturbance. The method takes a single impact site and a single control site (outside the impact area) before and after the management or impact has occurred to detect environmental change. Excluding TEC sites, the proposed monitoring program includes:

1. One monitoring site (comprising four trees and LAI capture points) within the zone of maximum groundwater drawdown (10 to 12mm) (Risk Area 1) (see **Table 1**).
2. Two monitoring areas within the area of groundwater drawdown ranging from >5m to <10m, though outside the area of predicted subsidence (Risk Area 2).
3. Four monitoring sites within the 2m to <5m modelled groundwater drawdown area (Risk Area 3).
4. Two control sites proposed outside the footprint of modelled groundwater drawdown (Risk Area 4).

Statistical analysis will need to consider interactions between multiple datasets to establish baseline conditions and allow identification of statistically significant deviations from these conditions that may be associated with New Lenton Project mining activities. The most critical interactions will be between biotic health (typically measured in LAI, LWP, and NDVI) and abiotic factors such as groundwater levels and salinity. Statistical tests applied to the analysis of data will depend on whether datasets are normally distributed and may include bivariate analysis of two datasets (e.g., NDVI and LAI) applying a Pearson or Spearman Correlation. 'T-tests' will be applied to identify significant differences in mean values between sampling localities. More complex statistical analysis may be applied if investigative actions are required, including multivariate analysis of variance (PERMANOVA) for interacting datasets.

The overriding purpose of the data collection and subsequent statistical analysis is to represent natural variation in the system applied to biotic factors and abiotic controls and allow appropriate trigger thresholds to be proposed, as further discussed in **Section 9.0**.

8.4 Application of Stable Isotopes to Determine Relative Contribution of Various Moisture Sources Utilised by Groundwater Dependent Vegetation.

The two-year intensive data collection period will refine existing information on the sources of water utilised by groundwater-dependent vegetation, including the relative contribution each moisture source makes to a tree's total water budget. While it may not be possible to determine these proportions precisely, it will be possible to identify the dominant sources of moisture utilised by trees at any sampling event. The process will involve:

1. Collecting stable xylem isotope samples from all trees is proposed as a permanent monitoring point (see **Table 4**) to determine isotopic signatures. To maximise the capacity to identify variations in moisture sources, trees proposed for sampling should be located at various geomorphic positions relative to the stream bank or targeted wetland.
2. The collection of soil samples for stable isotope analysis from a minimum of four dedicated auger holes is proposed as a permanent monitoring bore to measure groundwater levels in the perched alluvial groundwater system. Augers will be selected from Risk Area 1 (minimum one auger), Risk Area 2 (minimum one auger), Risk Area 3 (minimum one auger)

with a control outside the area of groundwater drawdown (minimum one auger). Soil augers should consider:

- a. A maximum depth of 6m or down to the intersection with the basement rock or groundwater strike is required.
- b. Be sampled at 0.5m intervals down the soil profile.
3. Collect groundwater in the riverbed (bank) aquifer associated with the Isaac River channel for stable isotope analysis.
4. The opportunistic collection of rainfall for stable isotope analysis.
5. Opportunistic collection of water from surface flows in the Isaac River for stable isotope analysis.
6. Collection of groundwater from groundwater monitoring bores identified in **Section 8.1**,

Table 4.

Sampling will need to be undertaken at minimum biannually, with rainfall and surface water collected opportunistically throughout the baseline assessment period.

While comparison of stable isotope signatures in biplots, as completed during the PER assessment (3d Environmental 2023), provides a rapid means to identify the predominant sources of moisture utilised by vegetation, analysis of time series (seasonal) datasets may provide a measure of the water source partitioning of trees (i.e., the proportions used of each potential moisture source) during the various seasons. The Line Conditioned Excess method (Petit and Froend 2018) provides the most straightforward analysis technique, which relies on the establishment of a local meteoric water line (LMWL) applying the method of Crosbie (2012), which can be used to identify stable isotope datasets that have undergone significant evaporative fractionation. To test for evaporative isotopic enrichment, the line-conditioned excess (or precipitation offset as per Evaristo et al., 2015) of soil moisture, xylem water, groundwater and other collected water sources will need to be calculated ($lc\ excess = [\delta^2H - a\ \delta^{18}O - b]/S$ where a and b are the slope and intercept of the LMWL, and S is the standard deviation of both δ^2H and $\delta^{18}O$ values). Where $lc\ excess$ values are close to zero, it indicates values similar to rainfall that have not been affected by high evaporation rates (as per Petit and Froend, 2018). By comparing the $lc\ excess$ for soil moisture, surface flows, stored groundwater in the channel, groundwater, and xylem water, it will be possible to identify which moisture sources are significantly different, providing a fingerprinting tool for the comparison of the $lc\ excess$ for xylem moisture to groundwater and other potential moisture sources will enable the 'degree of similarity' to be calculated, and identification of the dominant source of moisture utilised during typical seasonal variation. More importantly, it will make it possible to identify the variety of water sources utilised by trees that occur at various distances from the river channel and positions on the stream bank, allowing impacts to vegetation that result from groundwater vegetation to be predicted more accurately. The basis and process for stable isotope sampling and analysis is provided in **Appendix B2**, with raw data from stable isotope sampling undertaken during the PER assessment, which is provided in **Appendix F**.

8.5 Application of NDVI Analysis

The NDVI datasets will provide a permanent record of vegetation health captured biannually during the intensive data collection period, with capture requirements following the baseline assessment period subject to review and modification where appropriate. To provide analysis of vegetation health that can be repeated precisely between capture events, permanently placed 100m transects will be co-located with GDE monitoring areas detailed in **Table 3**. Measured 100m canopy transects

with permanent start and end points to coincide with relevant habitat quality sites, with the NDVI value sampled at 1m intervals along each transect (101 points total from start to endpoint). NDVI data will be extracted and plotted as a line graph representing seasonal variation between survey events (see **Appendix C4**). A minimum of 13 transects will be established, covering the nine GDE monitoring sites and the four TEC monitoring sites (see **Table 3**). The capacity to utilise remote sensing as a monitoring tool may also have utility in the more remote or inaccessible sites (e.g., Site 2D and Site 3B) in the southern extent of the study area where site access tracks are limited, enabling monitoring data to be collected when these sites are otherwise inaccessible due to weather constraints.

8.6 Groundwater Monitoring

The objective of the groundwater monitoring network design was to provide information to conceptualise the site hydrogeology and provide a monitoring network to establish baseline conditions. Of relevance to GDE function, the groundwater monitoring network will continue to provide baseline information concerning fluctuations in the groundwater table as a response to rainfall and surface flows and assist in the identification of drawdown in the alluvial groundwater systems (both basal alluvial aquifer and the perched groundwater system). Groundwater quality and salinity will form part of the ongoing suite of measured chemical parameters.

At a minimum, continuous groundwater level loggers should be installed in monitoring bores of most robust relevance to GDE Assessment, including additional bores installed to monitor the perched alluvial groundwater system inside and outside the groundwater drawdown footprint.

Groundwater Quality Parameters: In the context of GDE health, salinity and standing water level are the most critical chemical and physical monitoring parameters. There are currently no water quality guidelines for GDEs that rely on subsurface expression of groundwater. The suite of water quality parameters that are important for vegetation health should be considered as part of the groundwater monitoring program (Australian Government 2013) and would include:

1. Salinity
2. Dissolved oxygen
3. pH
4. nitrogen
5. phosphorus
6. organic carbon

9.0 Reporting, Periodic Review, Timing and Objectives

General program: This GDEMMP proposes methods to collect baseline ecological and biophysical data to facilitate an increased understanding of the ecohydrological function of GDEs mapped within the influence of the New Lenton Coal Project. During the compilation and analysis of monitoring data, identifying information gaps and data trends may indicate the need to update the GDEMMP approach and methods. To accommodate this requirement:

2. Reporting will be prepared at the completion of each monitoring event, which describes:
 - a. Methods employed.
 - b. Any factors that may have influenced data and monitoring results.
 - c. Data trends for each of the parameters measured.
 - d. Information gaps that may influence the assessment.

- e. Any correlation between datasets that characterise ecological function.
 - f. Trends that appear abnormal or indicative of an unexplained/unnatural decrease in ecological function warrant further investigation or corrective action.
3. Bi-annual monitoring (four events covering two wet seasons and two dry seasons) should be undertaken for two years, commencing prior to Project approval and preferably before operations involving removal of overburden intersecting alluvium in open cut mining areas.
 4. After four monitoring events (excluding the original GDE assessment associated with the PER), a consolidated report will be prepared which provides a synopsis of the data collected, including correlations between parameters and statistical analysis (where possible) to identify relationships between parameters and any significant changes to GDE health.
 5. Additionally, those GDE Monitoring Areas that can be shown through multiple lines of evidence (LWP, SMP, and Stable Isotopes) to conclusively not be utilising groundwater to any significant degree during the two-year baseline period can be excluded from any ongoing monitoring. This may include areas of the Poplar Box TEC that were assessed not to be dependent on groundwater during the PER assessment (3d Environmental 2023a).
 6. The PER assessment report (3d Environmental 2023) determined that areas of the Poplar Box TEC (RE11.3.2) are not dependent on groundwater. Monitoring of TEC sites in the baseline phase of this GDEMMP will apply the measurement of LWP and LAI only. Soil augering and analysis of stable isotopes will be required if high moisture availability (high LWP) is detected that cannot be accounted for by climatic conditions and recent rainfall.

The four-event intensive data collection period aims to determine the range of natural seasonal variation in the measured parameters, particularly LWP and LAI, which are fundamental indicators of plant stress. Correlation of these parameters to NDVI signature may allow future monitoring to be undertaken remotely on an 'on demand' basis, supplemented with field assessment should this be identified as appropriate. Additional field sampling assessments may be required if a significant departure from baseline is detected. **Appendix H** has incorporated Reporting and review requirements into a proposed two-year monitoring schedule.

Ongoing monitoring following baseline: Following completion of the two-year (four-event) intensive data collection program, NDVI will be captured on an annual basis during the height of the dry season (nominally October / November) to support ongoing monitoring of GDE health for five years. At the completion of five years, a data review will be completed to guide any further monitoring requirements.

NDVI threshold values will be calculated from correlations to LAI established during the baseline assessment. Statistically significant threshold exceedance events will be investigated to determine causal effects, with a robust evaluation completed where control sites do not record a similar threshold exceedance. The NDVI capture will require supplementation with field data measuring LAI and LWP at those areas identified for ongoing monitoring, including control and impact sites, on an annual basis at the peak of the dry season. The ongoing assessment will also include monitoring groundwater levels, water quality, and habitat quality, as per details provided in **Table 3** and **Table 4**.

Monitoring completion: A monitoring event that includes field assessment of monitoring parameters is to be undertaken at the completion of the mining operation. This event will consist of:

- A comparison to the baseline GDE dataset to identify any significant departure from pre-impact conditions.

- A summary memorandum detailing the ecological condition of the groundwater dependent vegetation at all dedicated monitoring sites will be provided, including control and impact and future monitoring requirements (if any).

Providing there has been no significant decline in ecological condition attributed to the mining operation, follow up field survey periods will be completed:

- Two years after completion of mining operations, timed to coincide with the driest portion of the year (typically September to November).
- Four years after completion of mining operations, timed to coincide with the driest portion of the year.
- A final survey event is held six years after the completion of the mining operation or when rehabilitation of the mine site has been successfully completed.

The capture of NDVI datasets should continue to be completed annually to cover the six years following mining completion. Considering the impact of groundwater drawdown on vegetation health can take several years to manifest, a period of six years, or until rehabilitation is successfully completed, should be a sufficient to capture any trend for declining vegetative health that is a result of mining activity.

10.0 Triggers for Investigative Action and Supporting Parameters

While groundwater is an abiotic control on the ecohydrological function of Terrestrial GDEs in the Project Area, the ecological attributes and condition of terrestrial vegetation define GDE habitat values. Analysis of vegetation indices will provide a baseline for GDE health and define trigger thresholds for initiation of investigative action. The vegetation indices used to define trigger thresholds, including potential parameters applied during investigative action, are described in the following sections. The management framework intends to be adaptive, with future capacity for updates dependent on the ongoing results of the baseline assessment and any information gaps identified. Data from the groundwater monitoring program, including water level and water quality data, will provide supporting information if vegetation threshold values are breached and investigative actions are necessary.

10.1 Vegetative Indices

Section 6.0 (Figure 10) identifies a decrease in LAI as an initial indicator of vegetative stress. LAI is a precursor to more intensive impacts on habitat values, including canopy dieback and conversion to an alternative ecological state that may manifest over a longer time frame. LAI varies on a seasonal basis depending on water availability, generally within weeks to months, with the highest values lagging slightly behind moisture recharge events. Doody et al. (2015) document typical annual LAI variation in the range of 14% to 35%, with LAI = 0.5 (i.e., 50% foliage to canopy ratio) identified as a potential threshold, indicative of critical water stress beyond which vegetation health rapidly declines. This value applies to the open forest of river red gum on the Murray River, and it may not have the same applicability as the GDEs at the New Lenton Project site. However, the LAI threshold can be adapted based on the results of pre-impact monitoring assessments. The process for thresholds based on LAI applies the following principles:

- Time series data of LAI from control and impact sites for two years is collected to establish and test thresholds applied to vegetation indices.

- Identify appropriate thresholds that will be applied as a trigger for investigation and provide a mechanism to review the appropriateness of the derived trigger.
- Statistical analysis of time series data to characterise seasonal differences in assessment parameters at control and impact sites to identify if a threshold breach occurs.

Applying a threshold value for LAI intends to provide an 'early warning,' which will trigger a requirement for the investigation to identify causal factors, allowing mitigations to be applied to restore vegetation health if a threshold breach links to mining activities. NDVI may similarly define a trigger threshold correlated to field-measured LAI and supported by a suitable data collection period. Where a threshold breach occurs, appropriate baseline data from a range of biotic and abiotic parameters will be available to provide a sound basis for investigation. **Figure 13** details the process and decision framework from initial data collection to corrective actions in case a threshold breach can be linked to mining activity. The initial two years of the assessment cover wet and dry season surveys to provide a baseline against which future vegetation condition trends can be assessed. The two-year baseline assessment and decision-making process are as follows:

1. Establish the proposed monitoring sites to capture LAI and supporting biophysical data (LWP and NDVI) at the proposed monitoring area in an initial GDE monitoring event before mining operations commence. The proposed location of the impact and control sites has been previously identified in **Section 8.1** and **Table 3**.
2. Establish an appropriate trigger threshold value based on the percentile method detailed in DSITI (2017). The proposed process for the establishment of the investigative trigger thresholds is:
 - a. Collect LAI data from the proposed impact and control sites (as per **Table 4**) at permanently located monitoring points in the initial GDE assessment.
 - b. Undertake statistical analysis (t-test) to compare dataset means and ensure the appropriateness of the control site for comparative purposes.
 - c. If a significant difference between the mean values of control and impact datasets is detected in the initial assessment, the location of the control site will be re-considered.
 - d. Assuming the control site's suitability, set the lower of the 10th percentile (or LAI of 0.5 as per Doody et al. 2015, whatever value is lowest) as a trigger value for investigative action.
3. Collect seasonal data from a follow-up assessment to provide an initial (1 year) baseline dataset considering seasonal variation.
4. Undertake two additional monitoring events in the following year (2025) to complete the two-year baseline dataset, allowing the appropriateness of applied thresholds to be tested and providing sufficient data for significant differences in means (t-test) to identify if a threshold breach occurs.

When threshold breaches are identified at each stage, decision pathways are provided, including requirements for investigative action and corrective measures where causal factors can be linked to mining activity. Corrective actions, including potential requirements for biodiversity offsets in a worst-case scenario, are discussed in **Section 11**.

Following the two-year baseline assessment, a statistical correlation between various assessment parameters will be analysed, particularly the relationship between LAI and NDVI, to allow ongoing monitoring to be completed remotely annually and trigger thresholds to be adapted. The full suite of parameters collected during the baseline assessment period, with their relevance and intended

application in both the baseline assessment and longer-term monitoring program, is provided in **Table 5**. Supporting parameters are further discussed in **Section 10.2**. After the two-year intensive data collection period, the process will follow the same method as shown in the flowchart in **Figure 13**. Instead of using LAI as a threshold parameter, however, NDVI may be applied if a suitable statistical correlation with LAI can be confirmed, with a field assessment of LAI and LWP completed either annually or every two years as a control measure, dependent on the strength of the LAI / NDVI correlation. Both NDVI and follow-up field assessment will be completed in the dry season at impact and control sites to determine if a threshold exceedance occurs, and if exceeded, trigger the flow chart process for investigation, mitigation (corrective action), and offsets as required. There is preliminary support for the assessment process described in the Commonwealth approved Isaac Downs Project GDE Baseline Assessment Report (3d Environmental 2023b). This assessment was prepared after the two-year baseline assessment period (November 2020 to March 2022) and confirmed the following correlations between monitoring parameters:

- The most significant data linkage relates to the correlation between LAI and NDVI. At the completion of the baseline assessment period, Pearson Correlation (r) identifies a statistically significant 'Moderate' positive correlation between these parameters ($r = 0.5469$; $p = 0.001$), confirming the complementary nature of these datasets.
- There is no significant correlation between LAI and LWP values, attributed to a substantial lag response where an increase in LWP may take several weeks to months to stimulate a commensurate rise in LAI.
- There is no statistically significant correlation between NDVI and LWP values. Like the described correlation between LAI and LWP, the lack of correlation relates to a lag response between high LWP values and subsequent response in vegetative productivity that would be evident in an increase in NDVI.

The assessment also successfully identified LAI impact threshold values for Isaac Downs Project Control Sites (LAI = 0.429), sites outside the groundwater drawdown area (LAI = 0.522), and sites within the drawdown area (LAI=0.41).

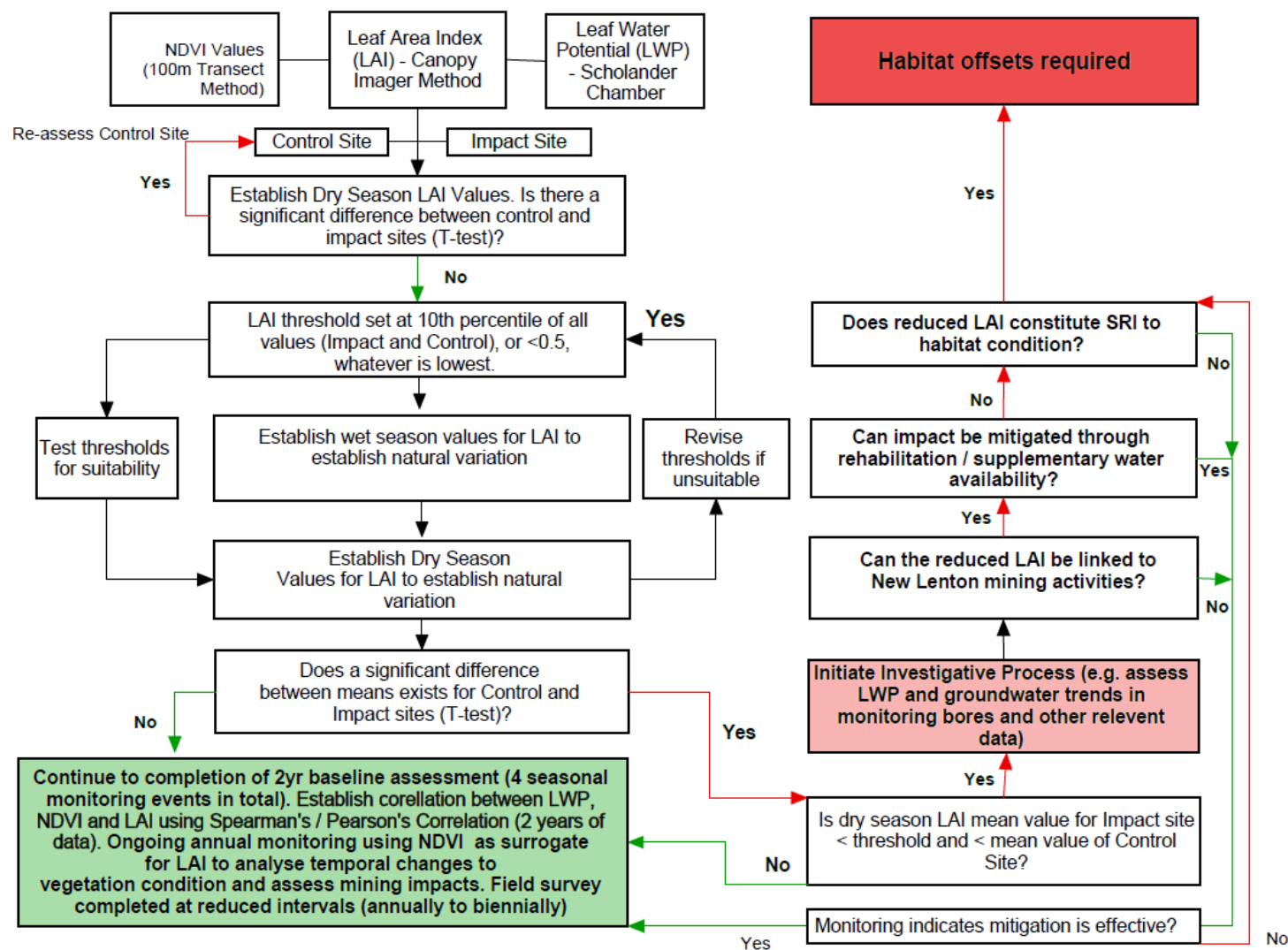


Figure 13. Decision process for application of investigative and corrective actions when trigger thresholds are exceeded for the initial 2-year baseline assessment.

10.2 Supporting Parameters

Supporting parameters will be measured to provide a component of the baseline dataset. They will then be drawn on to support the longer-term monitoring program and provide input into investigative action if required. Specifically, these supporting parameters will include LWP, stable isotopes, NDVI, and groundwater monitoring data.

10.2.1 Leaf water potential

LWP provides the primary biophysical measure of tree water availability and defines a continuum between soil, water, and plant relationships. The relationship between LWP and LAI requires seasonal monitoring to be more confidently defined, and any circumstance where LWP remains high, and LAI decreases dramatically indicates factors other than water availability may be influencing the relationship (e.g., insect defoliation). However, LWP measurements established during the two-year intensive data collection period will be a fundamental consideration for any future investigative action.

10.2.2 Normalised Difference Vegetation Index

NDVI is a measure of vegetation vigour, including a combination of greenness and biomass, which directly correlates to LAI. A correlation between field-based measurements of LAI and NDVI will be established over the 2-year intensive data collection period to allow GDE monitoring to be undertaken remotely at a landscape scale annually. While a statistically significant positive correlation between LAI and NDVI has been demonstrated for the Commonwealth approved Isaac Downs Project baseline assessment project (3d Environmental 2023b), verification will be required at a site-specific level for the New Lenton Project. Upon completion of the two-year baseline, trigger threshold values for investigative action will be calculated based on the correlation between LAI and NDVI. Ongoing annual monitoring will utilise high-resolution NDVI as a surrogate for field-based LAI / LWP measurements should a suitable correlation be identified, supported by field-based sampling in the dry season on an annual to biennial basis. Further information on the NDVI process is provided in **Appendix C4**.

10.2.3 Stable isotopes

The primary role of stable isotope investigations is to inform how sources of moisture utilised by trees vary on a seasonal basis. The process for identifying dominant water sources using stable isotopes is discussed in **Section 8.4**, with the dataset used to identify endpoints where vegetation is utilising groundwater alone, shifting in status to primary utilisation of soil moisture in the unsaturated zone, rainfall or surface water from river flows or wetlands. While stable isotope analysis provides insight into site ecological function, allowing characterisation of the risks to GDE function, its relevance to ongoing monitoring diminishes once a seasonal dataset is established. Stable isotope composition is not a direct indicator of plant health. Stable isotope analyses may be applied beyond baseline dataset collection to support investigative actions when a specific requirement or application is identified.

10.2.4 Groundwater levels and quality

The collection of groundwater monitoring data has been ongoing since the installation of groundwater monitoring bores to monitor groundwater levels in the Project area in 2014, providing several years' worth of water level and water quality data for baseline characterisation. Additional shallow groundwater monitoring bores are proposed, which will be helpful to:

- Determine the seasonality and persistence of the perched alluvial groundwater system that supports GDEs and its hydraulic linkage to the basal alluvial aquifer.
- Identify the degree to which the perched alluvial groundwater system and the basal alluvial groundwater unit are being utilised by vegetation (typically through analysis of stable isotopes) on a seasonal basis, and whether vegetation is using brackish to saline water from the basal alluvial groundwater system when the perched groundwater unit seasonally dries.
- Monitor linkages between the alluvial groundwater system recharge, surface flows, and rainfall.
- Establish water quality values, particularly for EC, and how recharge from the various sources may influence water quality.
- Identify ecological responses to aquifer recharge, including correlations between aquifer recharge, LAI, LWP, NDVI, and climate data.
- Monitor and quantify the impacts of mine pit development on drawdown in aquifers that support GDEs, particularly the basal alluvial groundwater system and the perched groundwater system that forms the floodplain of the Isaac River.

Water levels and quality can directly correlate to LAI to determine the relationship between groundwater and vegetation health. While Eamus (2006) defines 1500 $\mu\text{S}/\text{cm}$ as a measure where salinity becomes toxic to red gum, any impact on the seasonality and water quality of the alluvial aquifer will be directly imparted on LAI and supporting vegetative parameters. The ecological response of vegetation to falling groundwater levels cannot be accurately linked or quantified to specific thresholds as it will be influenced by several factors, including:

- The drawdown rate directly influences trees' capacity to adapt to a declining water table and reduced water availability.
- Water quality, as the response will be influenced by changes to salinity rather than by water levels alone.
- Surface water flows, including timing and duration of flooding.
- Site-specific adaptations to water stress inherent in the local groundwater dependent vegetation, including exposure to drought conditions.

Hence, thresholds for investigative action related to groundwater levels and quality are not proposed in this GDEMMP, which otherwise relies on vegetation indices, which define GDE health and function. The chosen vegetation parameter (LAI) will provide a rapid response to the detrimental impacts of groundwater drawdown (within weeks), with data from the groundwater monitoring program providing the basis for investigative action as required.

Groundwater Quality Parameters: The most critical chemical and physical groundwater monitoring parameters are salinity and standing water levels. There are currently no water quality guidelines for GDEs that rely on the subsurface expression of groundwater. The groundwater monitoring program will report on the following suite of parameters:

- Salinity

- Dissolved oxygen
- pH
- nitrogen
- phosphorus
- organic carbon

In addition, groundwater monitoring will continue to sample water levels and quality monthly in accordance with the currently operating groundwater monitoring program. Standing water levels in selected monitoring bores will be continuously monitored with pressure transducers.

Table 5. Assessment parameters, application, and analysis.

Data collection method	Purpose	Analysis methods / metrics
Primary Parameter		
LAI	Primary parameter used to measure plant stress and vegetation response to decreasing groundwater.	Threshold to be set at the lower of the 10th percentile for all LAI data from the initial dry season survey (or 0.5 from Doody et al 2015, whichever is lower). A threshold response for investigative action will be triggered when: 1. The LAI at the impact site falls below the threshold value. 2. T-test indicates significant differences between means of control and impact sites, and 3. Impact site has a lower mean LAI value. The initial establishment of the trigger threshold will be undertaken in the first dry season assessment to be undertaken and relies on the means between impact and control sites to be comparable at the initial survey.
Supporting Parameters		
LWP	A measurement of water availability to trees, which will provide an important correlate with LAI and a baseline dataset to support a future requirement for investigative action. Supporting data which can be used to determine if any future LAI threshold trigger events are related to plant water availability.	1. Pearson / Spearman's correlation to establish if there is a statistical relationship between LAI and LWP as a basis for inclusion in investigative action, if required. 2. Application of a T-test to identify if significant differences between means of control and impact sites exist during the initial dry season assessment.
NDVI	A remotely sensed measurement of vegetation productivity that describes the greenness and the relative density / health of forest biomass.	Confirming the relationship between NDVI, LAI and LWP through application of Pearson's / Spearman's correlation. Longer term application to remotely monitor GDE health at completion of the 2yr intensive data collection period supplemented with field survey.
Stable Isotopes of twig xylem, soil, groundwater and surface water.	Application as a tracer to identify the predominant sources of water utilised by trees. Useful to determine how tree / water interaction varies on a seasonal basis as groundwater	Biplot comparisons of stable isotope values ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) of tree xylem, groundwater and soil moisture to identify phase shifts.

Data collection method	Purpose	Analysis methods / metrics
	levels fluctuate. Most applicable in the baseline characterisation phase though may be useful supporting information if investigative actions are initiated.	Calculation of Ic-excess as per Section 8.4 to identify how the water sources of trees varies along the Isaac River frontage.
Groundwater monitoring data	The groundwater monitoring program, focused on the monitoring of the alluvial and Tertiary groundwater systems for the purpose of GDE health will: 1. Monitor linkages between recharge of the alluvial aquifer (both basal and perched systems), surface flows and rainfall. 2. Assist identification of the degree to which the alluvial groundwater system is utilised by vegetation on a seasonal basis. 3. Establish water quality values, and the influence of aquifer recharge events from various sources. 4. Identify ecological response to aquifer recharge including correlations between alluvial / Tertiary groundwater system recharge, LAI, LWP, NDVI and climate data. 5. Monitor and quantify the impacts mine void development on drawdown in groundwater systems that support GDEs fringing the Isaac River.	1. Water quality measurement (as per Section 10.2.4) associated with routine water sampling schedules. 2. Analysis of water levels and water quality in alluvial (basal and perched) and Tertiary groundwater systems against vegetative indices including LAI and LWP through correlation testing (Pearson / Spearman's). 3. Pressure transducers (data loggers) installed into selected monitoring bores to continuously record water level changes. Pressure transducers to be installed into all monitoring bores targeted to monitor water levels in the perched aquifer system.

11.0 Potential Corrective Actions and Adaptive Management

Corrective actions that halt or reverse impacts on GDEs are not well developed in the literature, and the suggested measures will require testing and monitoring to determine/confirm their effectiveness if they are to be applied. Where impacts to GDEs related to mining activities are identified, corrective actions may include treatment of affected vegetation through restoration of moisture supply or infill planting to restore canopy gaps created through vegetation dieback.

11.1 Restoration of Tree Water Supply

Direct water injection: While there have been few case studies that have applied direct injection into the root zone, Berens et al. (2009) investigated the direct injection of fresh water into a saline aquifer on the Murray and found that while the trial resulted in temporary freshening of the capillary fringe, it had limited influence on tree condition as the radial extent of freshening (approximately 10 m) did not intersect with the root zone of salinity stressed trees. Therefore, applying this technique is likely practical for localised areas only where impacts are detected in scattered trees or scattered groups of trees rather than used in broader scale impact mitigation.

Infiltration of surface water: Where mining-related impacts to the health of groundwater dependent vegetation are detected, it may be possible to restore water supply in critical portions of the tree root zone through enhancing natural infiltration, which may include:

- Construction of a shallow trench (1m) depth within the affected vegetation's drip zone (margins of canopy reach).
- Flooding the trench with fresh water, where it meets water quality objectives (e.g. supply of water from sediment ponds to where it meets low flow WQO of < 720 $\mu\text{S}/\text{cm}$).

Trench construction disturbs the upper soil profile and, if inappropriately placed, may damage tree root architecture. Ecological advice should be sought prior to trench construction to minimise adverse impacts.

11.2 Infill Planting

River red gum (*Eucalyptus camaldulensis*), Forest red gum (*Eucalyptus tereticornis*), and river oak (*Casuarina cunninghamiana*) are the dominant groundwater dependent species occupying the banks of Isaac River in Risk Zone 1 and, more broadly, along the Isaac River frontage. These major riparian species are likely to demonstrate groundwater reliance in the Project Area. Both river red gum and forest red gum are ecologically adaptable species, with forest red gum occurring on dry hillslopes and floodplains, and they are significant plantation species. Malik and Sharma (2004) found that the species has a solid capacity to extract moisture from the shallow soil profile (0 – 150cm) in the 426mm rainfall belt, and Kallarackel and Somen (1997) identified that growth rates are not limited by water deficit. As an initial measure, trials using locally sourced forest and river red gum seedlings should be undertaken to determine:

- If infill planting of forest red gum in canopy gaps has the capacity to ameliorate impacts caused by potential tree dieback.
- Whether trees planted in dry soil regimes have a greater capacity to withstand environmental stressors than older established trees that have adapted over long periods to specific ecological water requirements (EWRs).

Small-scale trials will commence upon approval of the GDEMMP by planting forest red gum and river red gum seedlings into existing canopy gaps. This will require some maintenance through drier periods until seedlings have been established. Trials do not need to be extensive and will focus on the species' capacity to survive by planting scattered trees into existing canopy gaps.

Flooding the trench with fresh water, where it meets water quality objectives (e.g. supply of water from sediment ponds to where it meets low flow WQO of $< 720 \mu\text{S}/\text{cm}$). Trench construction disturbs the upper soil profile and, if inappropriately placed, may damage tree root architecture. Ecological advice should be sought prior to trench construction to minimise adverse impacts.

11.3 Monitoring of Corrective Actions

Where injection of fresh water into the tree root zone is applied as a management measure, the effectiveness of the measures should be confirmed through:

- Measurement of pre-impact LWP and LAI of trees where treatment is applied. Pre-impact canopy health can also be measured using NDVI imagery captured before treatment.
- Repeat measurements for LAI and LWP taken at 1 month, three months, and six months following treatment to measure vegetative response.
- Ongoing annual monitoring of crown health of individual trees using high-resolution NDVI, supplemented with field measurements of LWP and LAI every two years.

Plantings will be checked for disease and loss of vigour:

- At least weekly for the first month, including any watering requirements to aid establishment.
- Monthly for the next five months, and
- Annually following the initial six months, in conjunction with the annual GDE monitoring program.

Records must be kept of the above works.

11.4 Triggers for Ecological Offset

Without positive results from mitigation measures, the requirement for biodiversity offsets will be assessed based on impacts on measured habitat conditions. Disturbance thresholds that indicate a requirement for offsetting of GDEs and listed species, including habitat for koala and greater glider, which may be significantly impacted by the Project's impacts on GDEs (AARC 2023), will be developed after completion of the 2-year baseline assessment, in consultation with the Department of Climate Change, Energy, the Environment and Water (DCCEEW), incorporated into an updated post-baseline GDEMMP (see **Appendix G**). Triggers and requirements for offsets will be guided by the baseline biocondition information gathered in the habitat quality assessment (AARC, 2024) using the QLD habitat quality assessment methodology (Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3) (DES 2020).

To adequately assess whether any detected reduction in habitat quality constitutes a threshold exceedance requiring an offset, it may be necessary to continue monitoring over an extended period (nominally two years). This will ensure that the original exceedance event represents a trend toward a longer-term decline in habitat condition or is a short-term perturbation that can be corrected with

the application of appropriate mitigation or a return to normal climatic regimes. Relevant EPBC Act-listed species are identified in the New Lenton Terrestrial Ecology Assessment (AARC 2023), and a habitat quality assessment program, as prepared by AARC (2024) should guide the assessment of the significance of impact.

Figure 13 provides the decision-making process that determines the level of action required. It indicates ecological offset as a final measure applied to compensate habitat loss. The management framework is intended to be adaptive, with future capacity for updating dependent on the ongoing results of the baseline assessment and any future information gaps identified.

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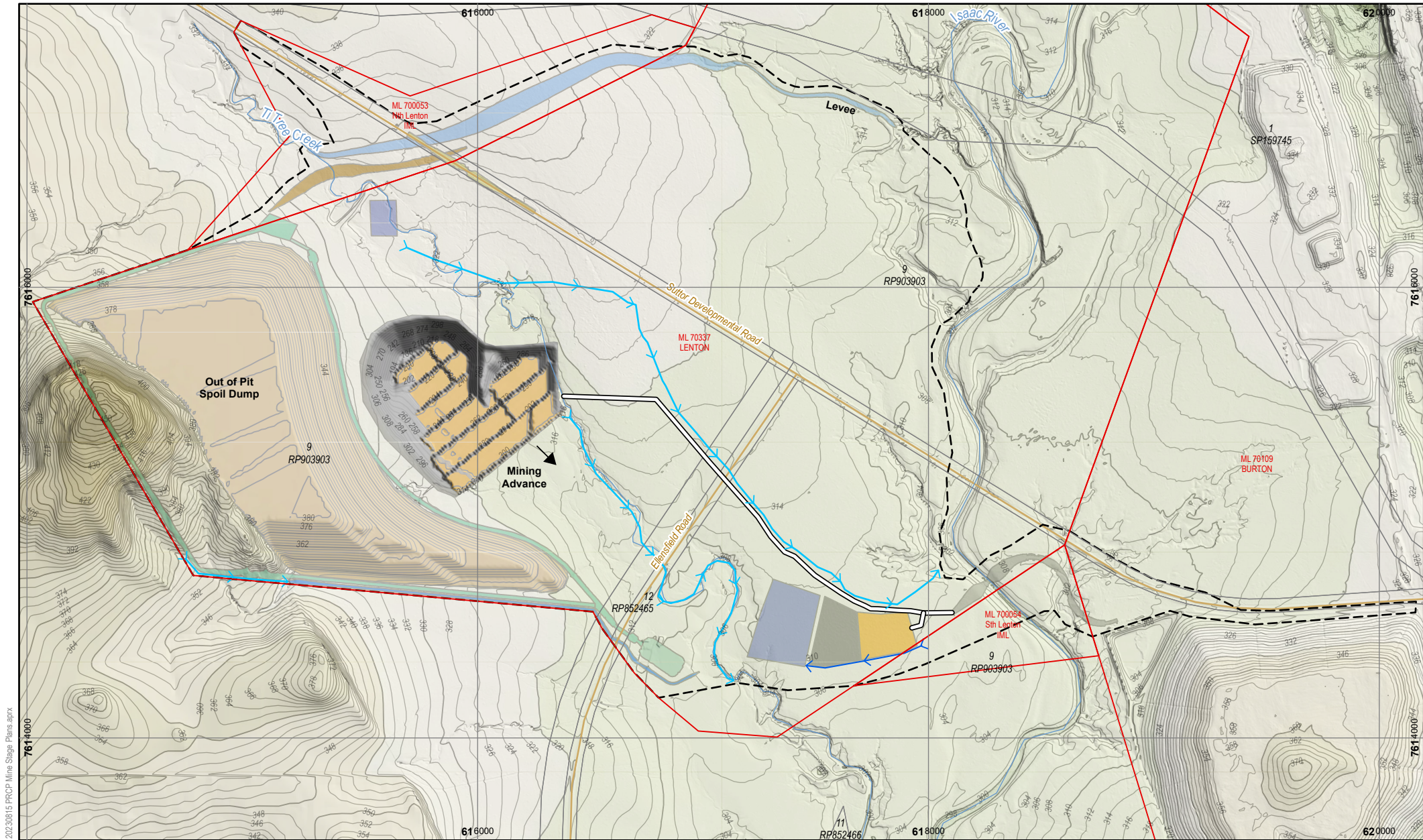
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13.0 Appendices

Appendix A. New Lenton Mining Stages

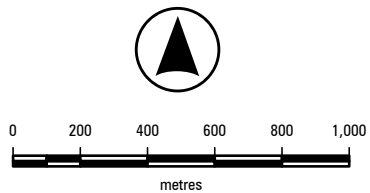


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DISCLAIMER: Third party data sources are used in this map compilation. Minserve makes no warranty regarding this data's accuracy or currency.



- LEGEND**
- Mining Lease
 - Cadastral Boundary
 - Proposed Disturbance Boundary
 - Mining Activity
 - Active Spoil Dump
 - Mining Advance
 - Pit Highwall

- WM Infrastructure**
- Clean Water Drain
 - Diversion
 - Haul Road
 - Levee
 - MIA
 - Mine Water Dam
 - ROM

- Sediment Dam
- Sediment Drain
- Temp. Road Diversion
- Clean Water Drain
- Mine Water Drain
- Haul Road

NEW LENTON COAL PROJECT
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Mine Stage Plan
 Year 1

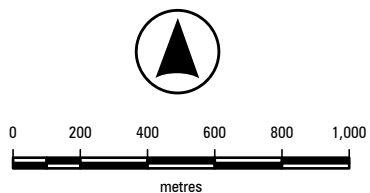


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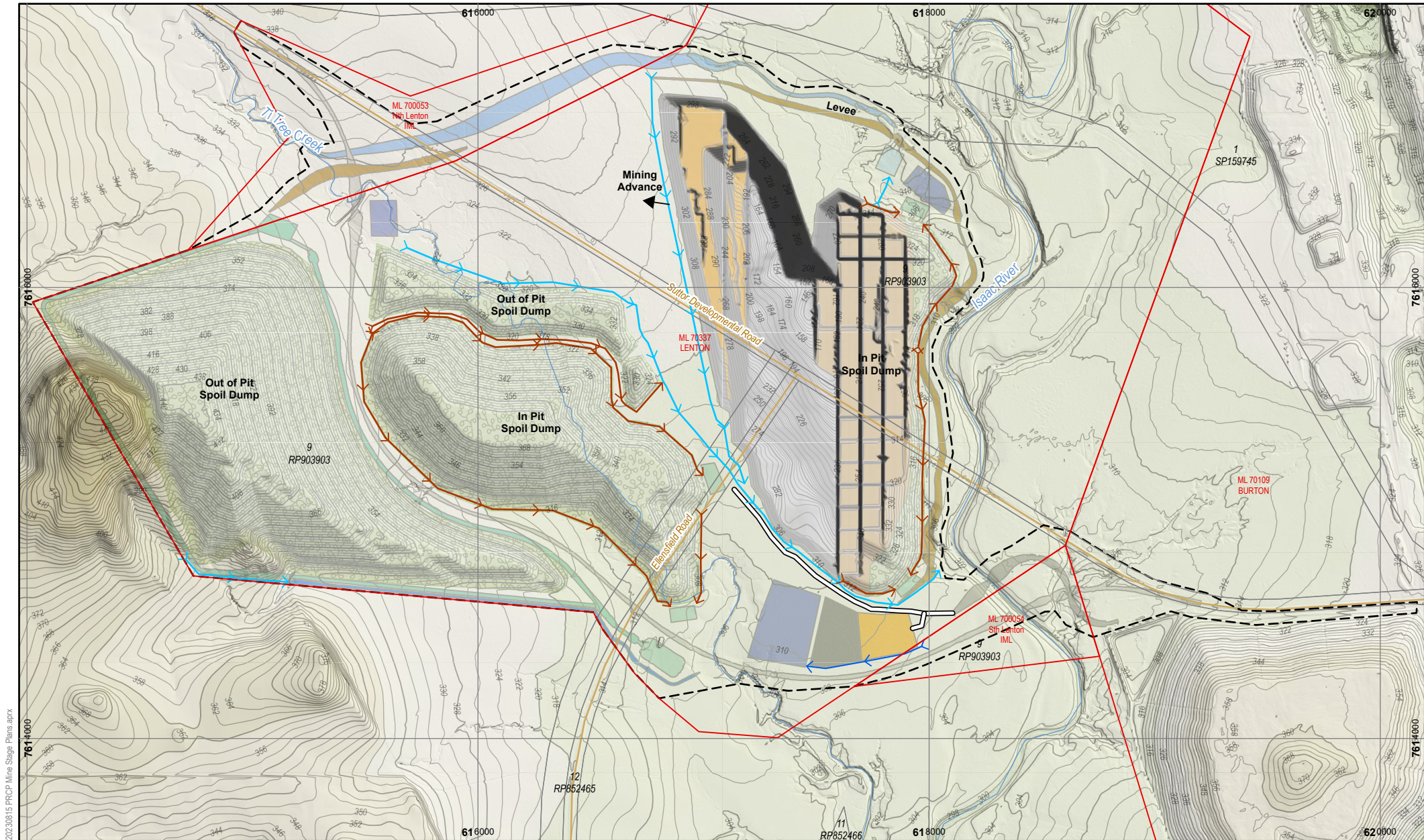
LEGEND		WM Infrastructure	
	Mining Lease		Clean Water Drain
	Cadastral Boundary		Clean Water Dam
	Proposed Disturbance Boundary		Sediment Drain
Mining Activities			Diversion
	Active Spoil Dump		Sediment Dam
	Mining Advance		Perm. Road Diversion
	Pit Highwall		Levee
	Pit Floor		MIA
	Rehabilitation		Mine Water Dam
			ROM
			Haul Road
			Haul Road
			Clean Water Drain
			Mine Water Drain
			Sediment Water Drain

NEW LENTON COAL PROJECT
 Public Environment Report 2023



Mine Stage Plan
 Year 5

Figure | 3-16

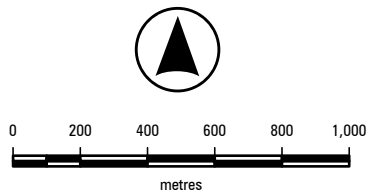


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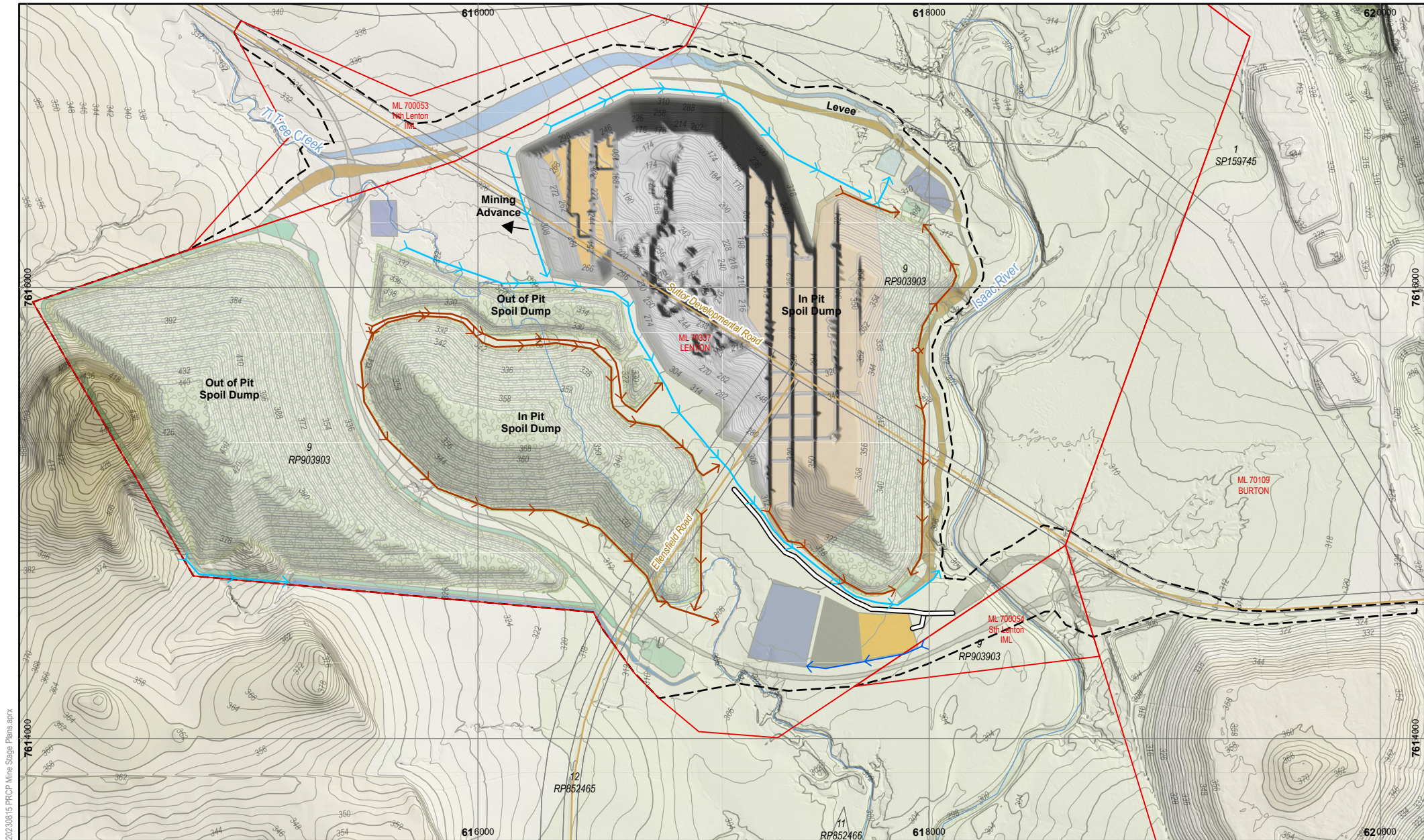
LEGEND		WM Infrastructure	
 	Mining Lease	 	Clean Water Drain
 	Cadastral Boundary	 	Clean Water Dam
 	Proposed Disturbance Boundary	 	Sediment Drain
 	Mining Activities	 	Diversion
 	Active Spoil Dump	 	Sediment Dam
 	Mining Advance	 	Perm. Road Diversion
 	Pit Highwall	 	Levee
 	Pit Floor	 	MIA
 	Rehabilitation	 	Mine Water Dam
		 	ROM
		 	Haul Road
		 	Haul Road
		 	Clean Water Drain
		 	Mine Water Drain
		 	Sediment Water Drain

NEW LENTON COAL PROJECT
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Mine Stage Plan
 Year 10

Figure | 3-17

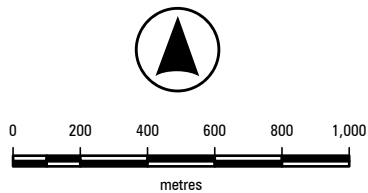


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- LEGEND**
- Mining Lease
 - Cadastral Boundary
 - Proposed Disturbance Boundary
 - Mining Activities**
 - Active Spoil Dump
 - Mining Advance
 - Pit Highwall
 - Pit Floor
 - Rehabilitation

- WM Infrastructure**
- Clean Water Drain
 - Clean Water Dam
 - Sediment Drain
 - Diversion
 - Sediment Dam
 - Perm. Road Diversion
 - Levee

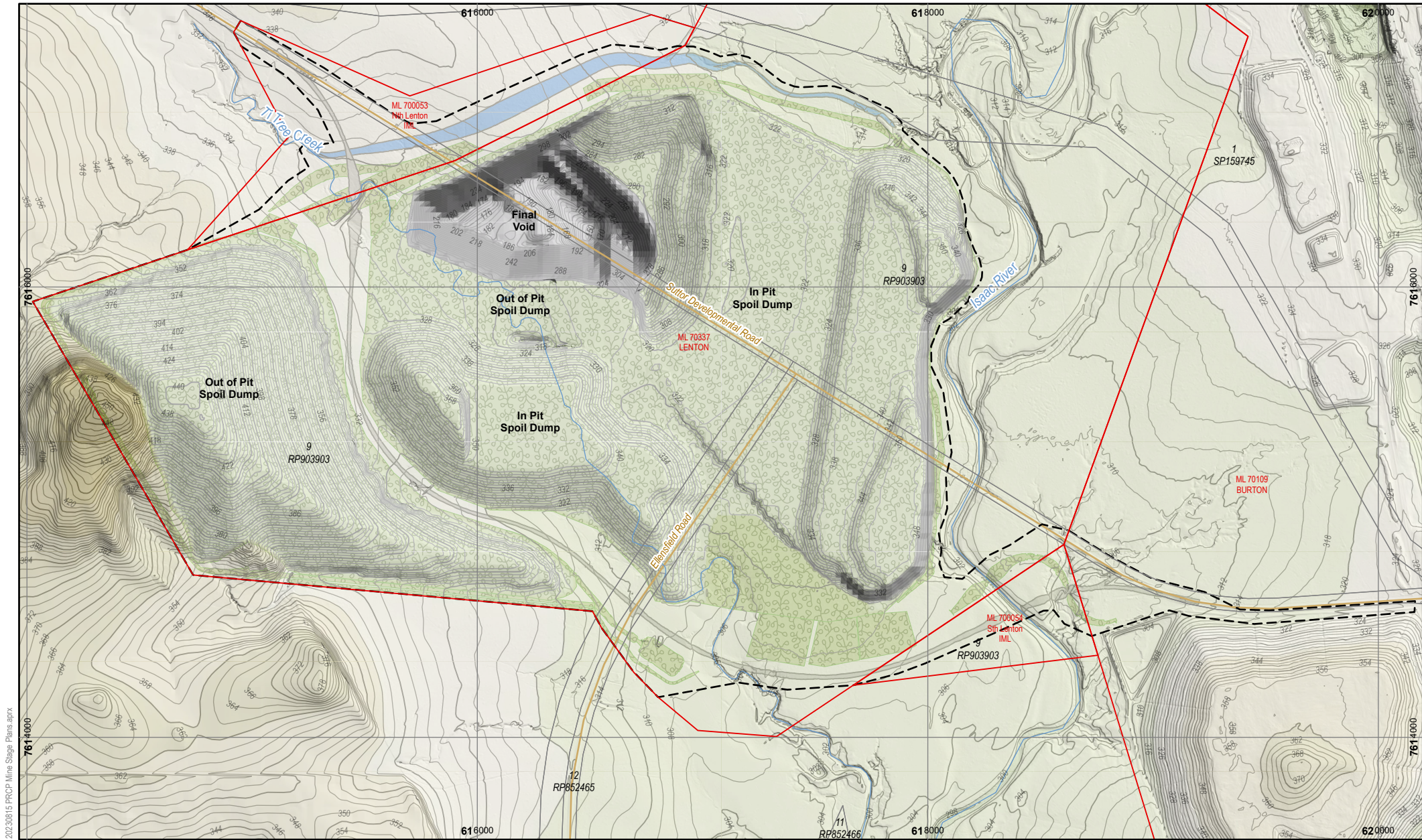
- MIA
- Mine Water Dam
- ROM
- Haul Road
- Haul Road
- Clean Water Drain
- Mine Water Drain
- Sediment Water Drain

NEW LENTON COAL PROJECT
 Public Environment Report 2023



Mine Stage Plan
 Year 13

Figure | 3-18

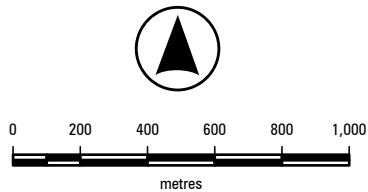


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- LEGEND**
- Mining Lease
 - Cadastral Boundary
 - Proposed Disturbance Boundary
 - Pit Highwall
 - Pit Floor and Low Wall
 - Rehabilitation
 - Permanent Road Diversion
 - Diversion

NEW LENTON COAL PROJECT
 Public Environment Report 2023



Final Landform

Figure | 3-19

Appendix B. Sampling Methods

B1. Leaf / Soil Moisture Potential

The measurement of leaf moisture potential will be targeted to specifically assess the interactions between tree roots and soil moisture / groundwater. These measurements will only be undertaken at the chosen localities on selected trees (as per **Section 8.1**) placed specifically to assess for these interactions.

Rationale

Leaf water potential is the total potential for water in a leaf consisting of the balance between osmotic potential, turgor pressure and matric potential. It 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. It is a function of soil water availability, evaporative demand and soil conductivity.

Measurement of leaf water potential is undertaken by collecting leaf samples at pre-dawn and using a Scholander pressure chamber (pressure bomb) to measure the pressure required to force water from the stem of the leaf. The results of the leaf water potential measurement are then compared to either the soil moisture potential at the same site collected at regular vertical intervals by drilling down to the water table and using a dewpoint potential meter.

It is assumed that trees will be using water from a source that requires the least energy (lowest water potential) to lift water from the soil, through plant xylem to the leaf for transpiration. This will be dependent to a large part on recent rainfall as well as the specific physical attributes of the soil that holds the rooting material. Heavy clays for example, may have a relatively high water content, although this water is hard to extract due to the cohesive forces of the fine particles which hold water very tightly. Clays will thus have a lower water potential than sand which has large pore spaces between the grains and much lower cohesive forces.

It must also be recognised that trees at the chosen monitoring sites may not be accessing water from one specific source exclusively. Moisture from several horizons within the soil profile may be contributing to tree water requirements, and the predominant source of water may vary on a seasonal basis. To maximise the likelihood of identifying trees that are predominantly using groundwater, it is important that assessments be undertaken in the seasonally driest part of the year.

Methodology

Leaf water potential needs to be measured pre-dawn (prior to sunrise). The basis of this requirement is that pre-dawn measurement provides an estimate of the water potential of the wettest part of the soil profile that contains a significant amount of root matter (Eamus et al 2006). It is assumed that pre-dawn leaf water potential will equilibrate overnight to the portion of the soil profile that has the highest water potential. Hence contemporaneous measurement of both pre-dawn leaf water potential from a canopy tree at a chosen monitoring locality and soil water potential from selected depth intervals down a co-located borehole will provide an indication of the predominant source of water (soil moisture or groundwater) being utilised by trees at the time of survey.

Measurement of Leaf Water Potential

Leaf water potential is measured pre-dawn (prior to 5.30 am in summer) using a Plant Water Potential Gauge (originally referred to as the Scholander pressure chamber or 'Pressure Bomb'). Measurement of leaf water potential requires:

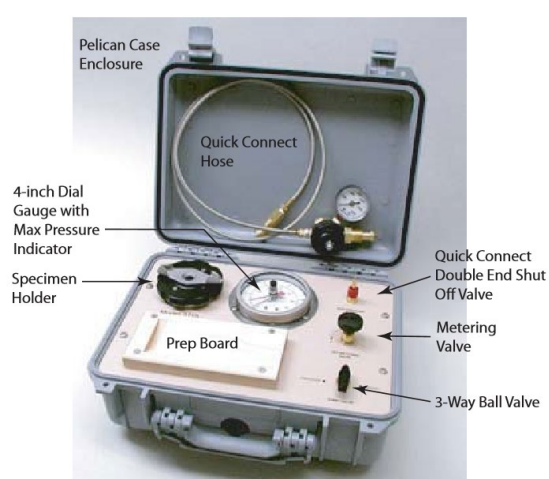
1. Collection of leaves from an accessible part of the tree crown.
2. Preparing of leaf material for insertion into the pressure bomb.
3. Measurement of Leaf Water Potential using the pressure bomb.

Collection of Leaf Material: Leaf material is to be collected from the highest accessible portion of the tree crown using an extension pole and attached lopper head (see **Section 8.5.2.2**). Leaf material should be selected that is disease free (as far as practical) and vigorous, preferably with indications of new leaf growth at the growing tips.

Preparation of Leaf Material: A representative sample of healthy leaf is removed from the collected material with sufficient leaf stem (petiole) to allow it to protrude outside the water potential meter (typically 1 to 2 cm). The stem is cut square with a sharp blade and immediately inserted into the water potential metre with the grommet sealed.

Use of the Plant Water Potential Gauge: The preferred Plant Water Potential gauge is the Model 3115 Plant Water Status Console due to its compactness and portability. The device is manufactured in USA (Soil Moisture Equipment Corp.) and distributed in Australia by ICT International (Armidale). The device fits into a 16 x 13 x 7inch Pelican Case and weighs approximately 11kgs which includes the compressed gas cylinder.

Additional Safety and Operational Measures: The Model 3115 console is accompanied with a detailed unit operation manual which describes in detail the required operational procedures. The unit operates on a compressed gas cylinder which should be professionally refilled with compressed N₂. As pressure is applied to the chamber, there is potential for the leaf petiole to be forcefully ejected from the chamber. Hence safety glasses will be required during unit operation.



B1. Model 3115 Plant Water Status Console with parts description.

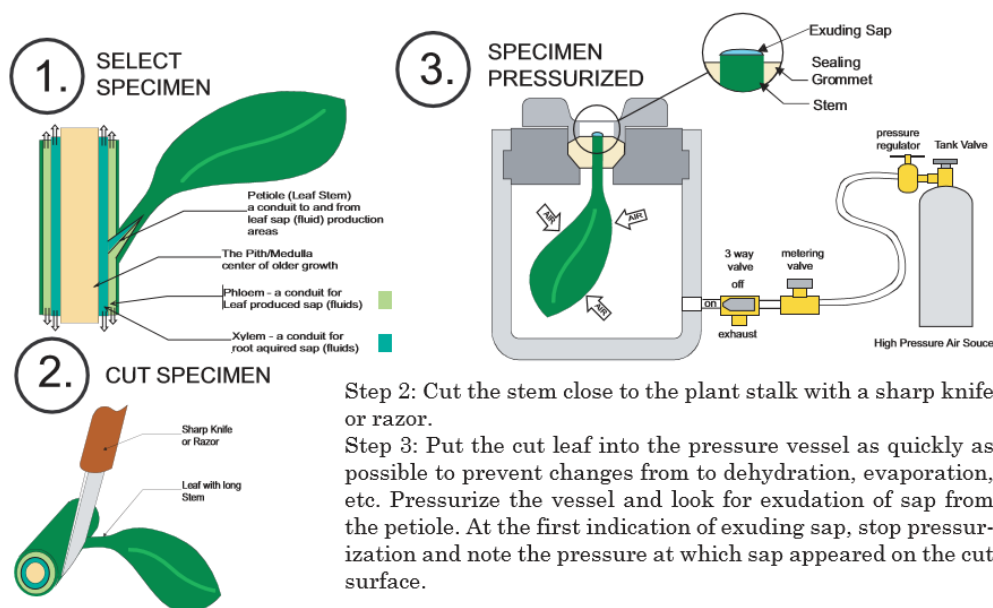
The Water Potential gauge measures leaf or stem water status by the following method:

1. A leaf or stem is collected from the tree that is targeted for assessment.

2. The petiole (leaf stem) is cut and placed in the pressure chamber with the cut stem protruding from the chamber at atmospheric pressure.
3. The vessel is sealed around the petiole and pressure applied via an external gas cylinder.
4. The protruding stem is observed and pressure readings recorded at the first point that water is noted to be exuding from the leaf.
5. The positive pressure applied to the leaf that forced water from the leaf stem is measured. This is the leaf water potential.

The process as supplied by Soil Moisture Equipment Corp (2006) is provided in **Figure 19** below.

Step 1: Select a representative sample specimen of the plant with sufficient length to fit into the pressure vessel.



Step 2: Cut the stem close to the plant stalk with a sharp knife or razor.

Step 3: Put the cut leaf into the pressure vessel as quickly as possible to prevent changes from dehydration, evaporation, etc. Pressurize the vessel and look for exudation of sap from the petiole. At the first indication of exuding sap, stop pressurization and note the pressure at which sap appeared on the cut surface.

B2. Diagrammatic illustration of the use of the Pressure Bomb as per Soil Moisture Equipment Corp. (2006).

Measurement of Soil Water Potential

Soil moisture potential should be measured, utilising a soil auger, in specific cases where results of LWP analysis require additional explanation. This would occur primarily as result of unexpectedly high, or unexpectedly low LWP measurements that cannot be contextualised based on seasonal conditions. The same sampling protocols applied to soil sampling for stable isotopes should be applied to assessment of soil moisture potential. This includes:

1. An initial soil sample taken within the top 10cm of the soil profile.
2. Subsequent sampling at 0.5m intervals down borehole to the top of the Permian basements.
3. Additional measurements taken whenever there is a noted change in soil texture within the soil core (i.e change from clay to sandy clay / loam).

Sampling should be undertaken with a portable hand auger with a maximum expected depth of 5m (BGMB3 is 4.5m depth).

The most convenient method of measuring soil moisture potential is with a portable Dew Point PotentiaMeter which enables measurement to be taken directly on site. Portable devices such as the WP4C uses the chilled mirror dew point technique to measure water potential with the sample being equilibrated with the headspace of a sealed chamber that contains a mirror and a means of detecting condensation on the mirror.

B3. The WP4C Dew Point PotentiaMeter available for hire from ICT International Pty Ltd.



The following protocols are to be followed:

1. A 7ml soil sample is inserted into the sample draw of the potentiaMeter in a 15ml stainless steel sample cup.
2. A soil sample takes between 10 -15mins to analyse.
3. Faster settings (fast mode) should be used for samples with limited water holding capacity such as sand.

The WPC4 unit will require 12V power inverter that plugs into the 12V port of a vehicle if measurements are to be taken in the field. Alternatively, samples can be collected in a sealed sample bag (with air removed) and measurements taken in an office or other areas where there is a reliable power source. The inverter should have a continuous output of at least 140 Watts.

Outputs

The water potential assessments of both leaf (target tree at site) and soil (from soil core) will provided the following data outputs:

1. Pre-dawn leaf water potential measurements of canopy / sub-canopy leaf samples taken with the Pressure Bomb (3115 unit). The output unit will be provided in MPA.
2. Soil moisture potential taken with the portable WPC4 Potentiometer at standard intervals along the drillhole core. The unit output will be measured in MPA consistent with leaf moisture potential. The intervals for measurement will be:
 - a. Top 10cm of the soil profile.
 - b. At 0.5m intervals from the soil surface to the top of the phreatic zones.
 - c. Where noticeable changes in soil texture or moisture content are noted during examination of the core.

The interval for measurement is purposefully coincident with the interval applied to soil sampling for stable isotopes. This will allow for more ready comparison of the results between differing sampling methods and applications.

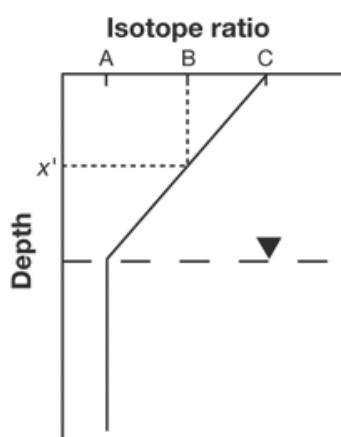
B2. Stable Isotope Analysis

The overarching aim of stable isotope analysis is to determine the degree to which trees utilise groundwater on either a permanent or seasonal basis. It will be applied during the initial phase of the baseline assessment to determine seasonal sources of moisture usage by selected trees, to be phased out once baseline water utilisation patterns are established (minimum of 2 years).

Rationale

Trees may utilise water from a range of sources including the phreatic zone, the vadose zone and surface water and the stable isotopes of water, oxygen 18 (^{18}O) and deuterium (^2H) may be a useful tool 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 or xylem core) with concentrations in the various sources of water including potential artesian water sources, and shallow soil moisture. The heavier isotopes of ^{18}O and ^2H fractionate differently to the lighter isotopes equivalents (^{16}O and ^1H). Rainfall has a typically large $\delta^{18}\text{O}$ and $\delta^2\text{H}$ as it is formed through the process of condensation which concentrates heavier isotopes. Surface water may have an extremely high $\delta^{18}\text{O}$ if it is subject to a period of strong evaporation, whilst isotopic composition of groundwater will vary dependent on the input source, although tends to be relatively stable as it is not exposed to processes of fractionation.

The isotopic signature of water measured in a trees xylem may result from a combination of sources with varying signatures. As per Eamus et al (2006) below (Figure B4), if an isotopic signature of 'A' is recorded, then water is being sourced from the phreatic zone, and for 'C' at the surface. If an isotopic signature of 'B' is recorded, this may represent water sourced from the middle of the vadose zone (at depth x), or may be a combination of water from a deeper phreatic source (A) or a shallow source (B). Hence there is potential for considerable uncertainty when mixed isotopic signatures occur and it may be necessary to apply a linear mixing model to aid the interpretation (as per Thorburn et al, 1993).



B4. Schematic representation of isotope ratios within soil and groundwater and application in identifying plant water sources (from Eamus et al. 2006).

For a robust application of stable isotopes signatures obtained from plant xylem and soil pore spaces, the following general protocols should be observed:

1. Sampling of plant and soil material will need to be completed during a single sampling event to ensure the results are directly comparable.
2. Sampling of plant xylem material would be completed most efficiently from twigs, collected whilst undertaking leaf water potential measurements. Leaves have tendency to concentrate isotopic concentrations during the process of transpiration and evaporation and hence should not be used.
3. The sampling program is best completed following a period of extended drought / dry conditions to maximise the potential that plants are utilising groundwater sources.
4. Sampling of soil pore water should be undertaken at consistent intervals throughout the vadose zone (the unsaturated zone above the groundwater table) down to the groundwater table. Soil samples are to be collected to the depth of the saturated zone or consolidated bedrock (whichever comes first). Sampling needs to extend beyond the saturated zone to consolidated bedrock in the case that a perched aquifer is identified.

Methodology

Sampling of Soil Pore Water for Stable Isotopes

Method: Soil sampling is to be undertaken at regular intervals along a retrieved soil core to capture signatures for possible isotopic end points (ground water and surface water) and a range of potential plant moisture sources within from the upper soil surface to the top of the phreatic zone. Mensforth et al (1994) completed soil sampling at 0.1m increments to 0.4m depth; 0.2m increments to 2m depth and 0.5m increments to the groundwater surface while others such as O'Grady et al (2006) applied sampling interval of 0.5m down the entire profile. The proposed sampling interval for this assessment is:

1. Initial soil sample taken within the top 10cm of the soil profile.
2. Subsequent soil sampled taken at 0.5m intervals down borehole to the top of the phreatic zone.
3. Additional soil samples take whenever there is a noted change in soil texture within the soil core (i.e change from clay to sandy clay / loam).

Soil sampling should be continued until either the unconfined groundwater table is intersected or the top of the Pleistocene surface halts auger penetration.

Soil sampling protocols: The following protocols for soil sampling are to be applied based on advice from ANU Stable Isotope Laboratory:

1. A minimum 50ml equivalent of soil is to be collected for each sample to be analysed.
2. Samples are to be immediately sealed to prevent evaporation in an airtight container (double bagging recommended).
3. Samples are to be labelled with the drill hole number and sampling depth / interval in a consistent format to aid data entry and recognition
4. Samples are to be kept on ice and transported to a freezer for temporary storage prior to dispatch to the laboratory (at the completion of each hole).

5. Frozen samples are to be dispatched in an a sealed (as airtight as possible) esky via overnight courier.

Equipment: The following equipment will be required by the site geologist / ecologist.

1. Stainless steel spatula for sample collection (paint scraper or putty knife sufficient).
2. Tape measure (15m extendable steel builders measure).
3. Sealable polypropylene containers (30 to 70ml adequate)
4. Permanent marking pens.
5. Esky for sample storage and dispatch.
6. A chest freezer will need to be accessed off site for storage.

Sampling of Xylem Water for Stable Isotopes

This will require twigs to be collected from the outer branches of mature Red Gum (or Poplar Box) trees that are the subject of the assessment. It is anticipated that up to 4 twig samples will be collected from individual trees directly adjacent to the assessment locality. At each site, the following sampling protocols should be observed: Method: Sampling of leaf twigs will be undertaken in conjunction with sampling of leaves for water

1. Outer branches of up to four trees, including the central tree at the assessment locality plus three adjacent trees are to be harvested for twig material.
2. Trees subject to assessment are to be marked with a GPS.
3. Outer branches from each tree will be harvested using an extendable aluminium pole and lopping head. The longest commercially available extension pole is 7.5m giving a maximum reach of approximately 10m.
4. Stem material that is the equivalent to one joint length of the small finger should be sourced (based on advice from ANU). Hence collected branches should contain some stem diameters of at least 10mm.
5. Selected stems are to be cut into maximum 5cm lengths and the bark stripped. One to two stems of 10mm diameter stems will be sufficient although more material will be required for smaller diameter stems.
6. Stems are to be sealed in wide mouth sample containers with leakproof polypropylene closure.
7. Samples should be immediately labelled with the tree number and placed in an iced storage vessel before being transported to a freezer for temporary storage prior to dispatch to the laboratory (at the completion of each hole).
8. Frozen samples are to be dispatched in an a sealed (as airtight as possible) esky via overnight courier.

Equipment: The following equipment will be required by the site geologist / ecologist.

1. An extendable 7.5m aluminium pruning pole with an attached lopper head.
2. High quality secateurs for cutting stem material.
3. 125ml wide mouth sample containers with a polypropylene seal cap (up to 16 required).
4. Permanent marking pens.
5. Esky for sample storage and dispatch. May be included with the frozen soil samples.
6. A chest freezer will need to be accessed off site for storage.

Groundwater sampling for stable isotopes

Method: Groundwater samples are to be collected from each groundwater monitoring bore using the low flow method. Groundwater sampling will follow methods described in the Geosciences Australia *Groundwater Sampling and Analysis – A Field Guide* (Sundaram, et al., 2009). Care should be taken not to oxygenate or agitate the sample during pumping or sample collection.

Samples for analysis of stable isotopes should be collected in laboratory prepared 28ml glass McCartney bottles or 15ml Vacutainers and kept cool during storage and transport.

Sample Despatch and personnel

Personnel: Samples are to be collected, bagged and stored by the supervising geologist / ecologist who will also be responsible for the sample dispatch to the receiving laboratory

Dispatch: Samples are to be dispatched directly to the ANU Stable Isotope Laboratory (address provided below).

Hilary Stuart-Williams
Stable Isotope Laboratory
Research School of Biology
R.N. Robertson Building (46)
The Australian National University Canberra ACT 0200 Australia

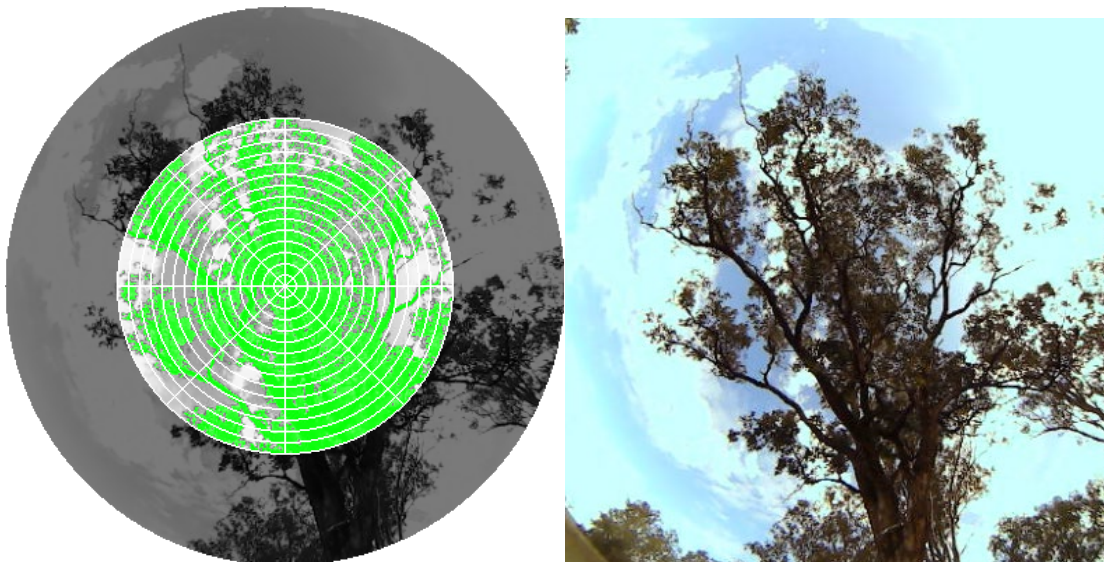
B3. Field Based Assessment of Leaf Area Index

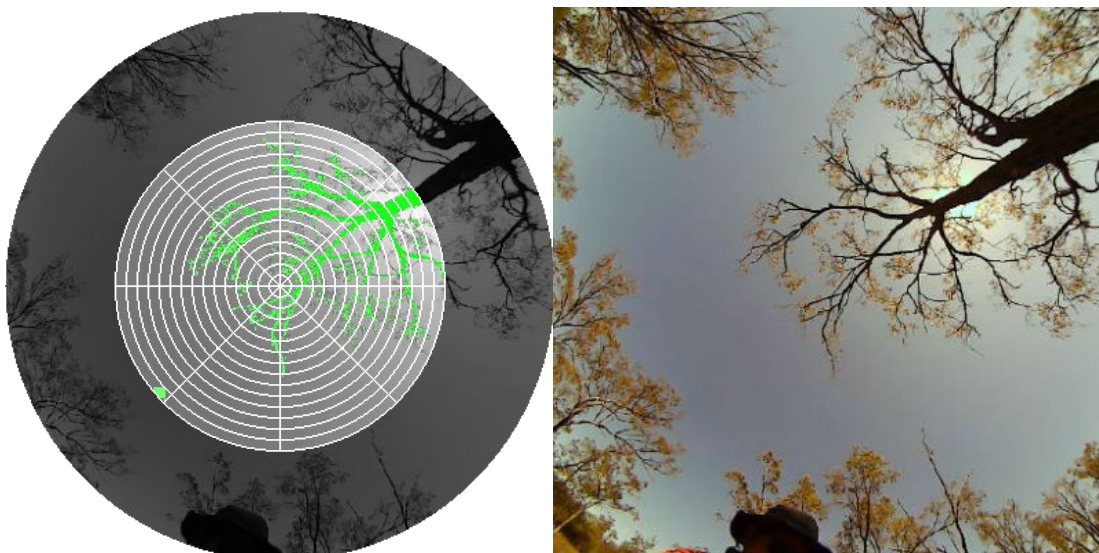
Leaf Area Index (LAI) is a ratio of the total leaf area within a canopy to the ground area covered by the canopy. It is a measure of canopy vigour and the rationale applied is that plants with access to permanent sources of water (i.e. groundwater) will have greater vigour and hence LAI than vegetation that has only periodic access to groundwater resources (e.g. Zolfagher 2014). If a previous permanent groundwater resource is withdrawn (as might occur in a CSG operation), then leaf fall will occur, and LAI will decrease.

Measurement of LAI is typically completed with a hemispherical lens, is labour intensive and utilises specialised software to analyse foliage cover. The CI-110 Plant Canopy Analyzer provides a self-leveling, wide-angled lens to capture hemispherical photographs for the analysis of leaf area index (LAI) and gap fraction analysis and photosynthetically active radiation (PAR). This instrument is integrated with the corresponding software program, and a GPS, allowing for fast and simple analysis, with immediate data available on site including:

- Leaf area index (LAI)
- Leaf angle distribution
- Extinction coefficients
- PAR LAI

The unit provides considerably greater accuracy in LAI measurement than standard hemispherical cameras and is time saving due to the immediate access of data. Raw data outputs are provided below demonstrating a *Eucalyptus populnea* with a canopy density of 83% and a Gap Fraction LAI of 0.8 compared to a stressed *Eucalyptus populnea* with a canopy density of 52% and a Gap Fraction LAI of 0.3 (second row). Zenith angle is set at 45° to filter out adjacent canopy trees and other interference.



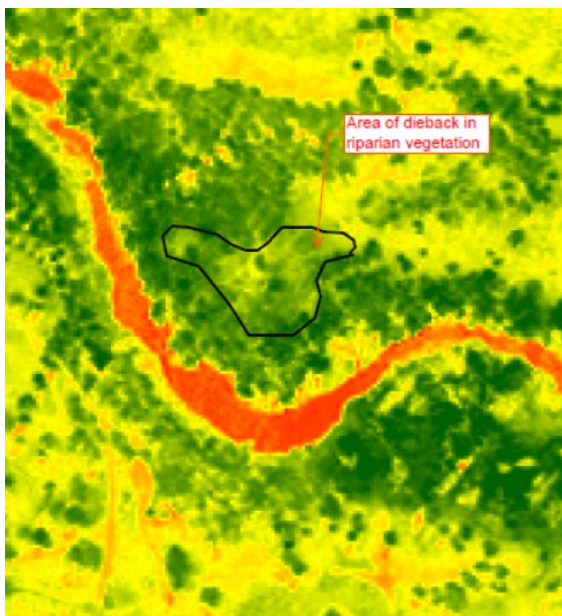


B5. Raw data outputs are provided below demonstrating a *Eucalyptus populnea* with a canopy density of 83% and a Gap Fraction LAI of 0.8 compared to a stressed *Eucalyptus populnea* with a canopy density of 52% and a Gap Fraction LAI of 0.3 (second row).

B4. Remote Sensing Methods

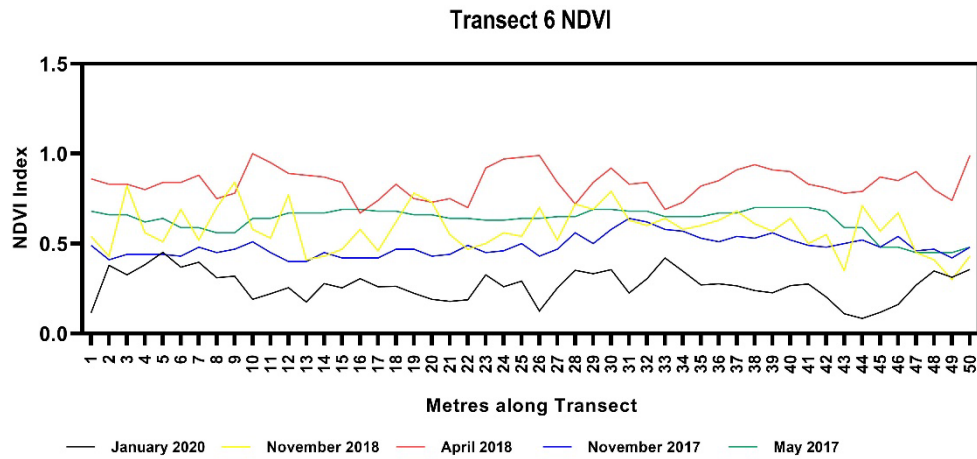
There are remote sensing based assessments used to calculate LAI (TERRA and AQUA satellites), although the spatial resolution of at 250 m x 250 m is not going to be useful for the application, due to the fragmented nature of the landscape with large areas of clearing interspersed amongst native woodland.

Recent availability of high-resolution satellite imagery (WorldView-3/WorldView-2 and GeoEye-1; 0.5m Resolution 4-band Pan) to map canopy and foliage dieback in habitats potentially affected by gas seeps. Assessment utilises the Normalised Difference Vegetation Index (NDVI) as a measure of canopy health and vigor. It is a widely accepted method and with advances in satellite technology, has the capacity to assess the health of individual trees rather than landscapes. The strength of the assessment is that it enables the health of riparian (and other GDE) vegetation to be monitored across the entire landscape, rather than just a limited number of individual sites. The landscape-scale capability also has an ability to overcome issues surrounding a lack of site access and provides a long-term monitoring record of vegetation health that can be utilised as reference when a need arises. Capture can be undertaken reactively and can be tasked with a days' notice, providing weather, particularly cloud cover is amenable. An example of high resolution NDVI Imagery showing dieback in riparian vegetation is provided in **A7** (capture date May 2017).



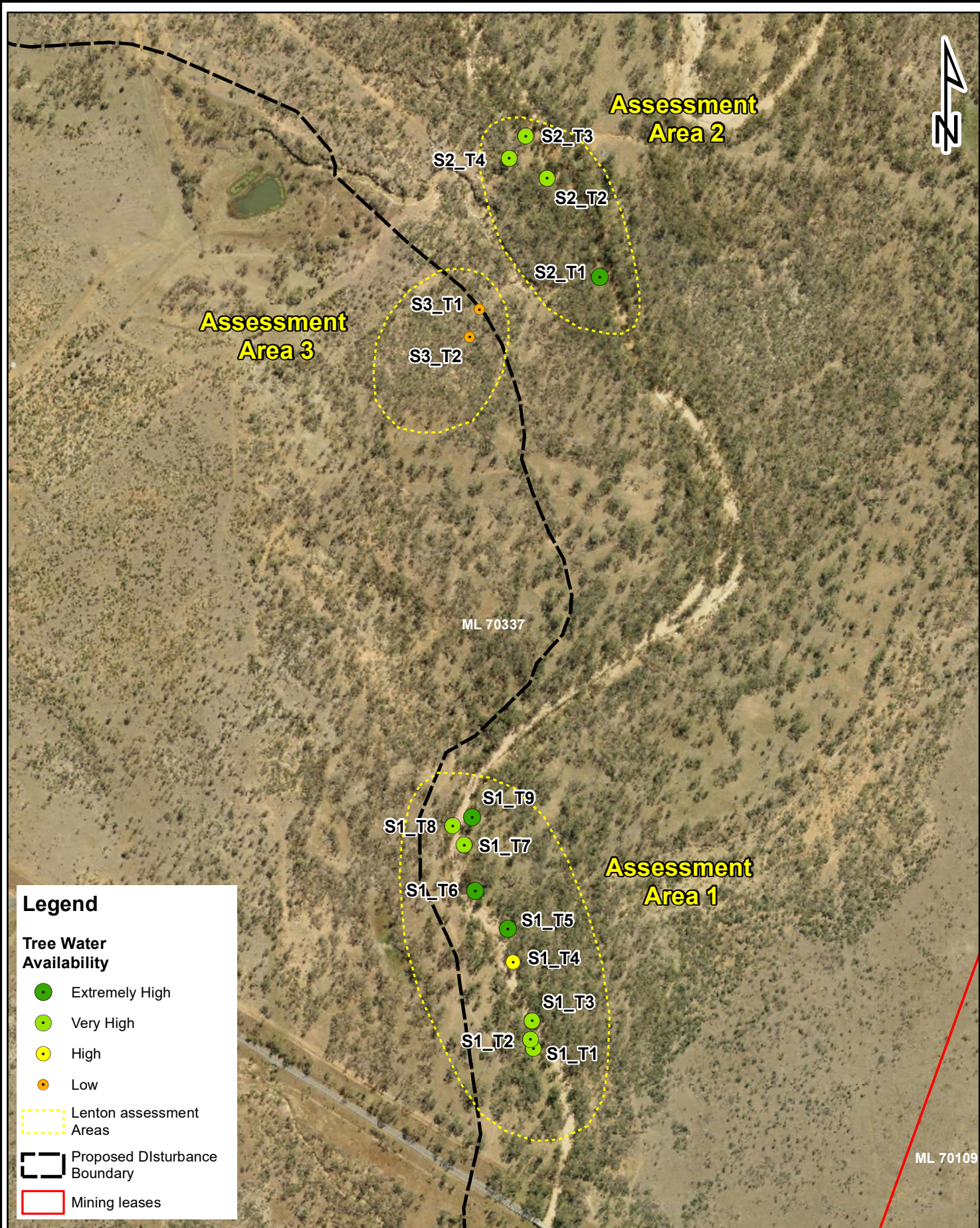
A7. Healthy vegetation in bright green grading to bare ground and water in red. Area of recent canopy dieback is indicated.

Measurements of NDVI values at set intervals along permanently established transects also provides a quantifiable and easily rectifiable measure of vegetation productivity that can be undertaken on a seasonal basis. This would form a component of the baseline dataset against which trends in vegetation productivity and fluctuations in groundwater regime can be correlated. Figure A8 provides an example of a vegetation transect that has been monitored for vegetation production for period of years, showing the strong decrease in vegetative productivity between May 2017 and January 2020.



A8. Seasonal variations in vegetation productivity, measured using NDVI, showing a decrease in vegetation health over a 2.5yr sampling period for a permanent monitoring transect in the Surat Basin.

Appendix C. Sampling Localities from the NEW Lenton GDE Assessment Report



Legend

Tree Water Availability

- Extremely High
- Very High
- High
- Low

 Lenton assessment Areas

 Proposed Disturbance Boundary

 Mining leases

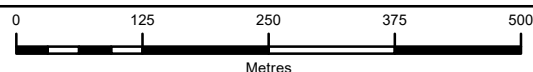
Extremely High	> - 0.276 mpa
Very High	< -0.276 to - 0.552 mpa
High	<-0.552 to -0.896 mpa
Moderate	<-0.896 to -1.24 mpa
Low	<-1.24 to -1.72 mpa
Very Low	<-1.72 to -2.21 mpa
Extremely Low	<-2.21 mpa

1:7,500

Appendix C1. Sampling detail at Assessment Area 1 to Assessment Area 3

Client

Bowen Basin Coking Coal



Scale

Drawn By DG

Checked DS

File Path

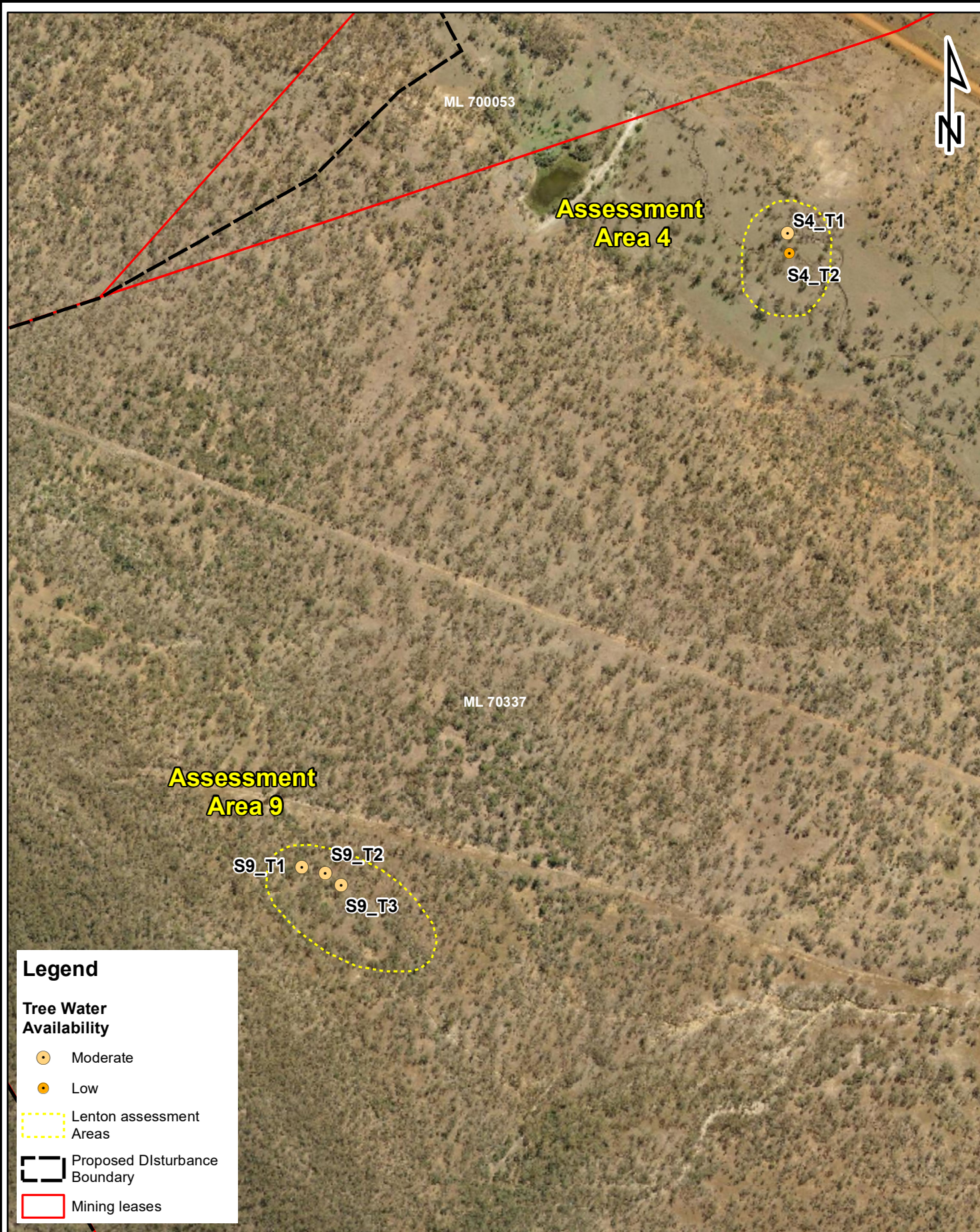


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A4



Legend

Tree Water Availability

- Moderate
- Low

 Lenton assessment Areas

 Proposed Disturbance Boundary

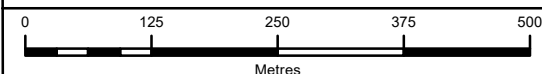
 Mining leases

Extremely High	> - 0.276 mpa
Very High	< -0.276 to - 0.552 mpa
High	<-0.552 to -0.896 mpa
Moderate	<-0.896 to -1.24 mpa
Low	<-1.24 to -1.72 mpa
Very Low	<-1.72 to -2.21 mpa
Extremely Low	<-2.21 mpa

Appendix C2. Sampling detail at Assessment Area 4 and Assessment Area 9

Client

Bowen Basin Coking Coal



Scale 1:7,500

Drawn By DG

Checked DS

File Path



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A4



Assessment Area 5

ML 70337

S5_T2

S5_T1

Legend

Tree Water Availability

-  Very High
-  High
-  Moderate
-  Low

 Lenton assessment Areas

 Proposed Disturbance Boundary

 Mining leases

S10_T2
S10_T1

S10_T3

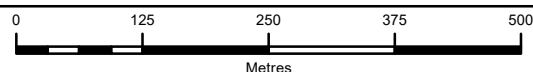
Assessment Area 10

Extremely High	> - 0.276 mpa
Very High	< -0.276 to - 0.552 mpa
High	<-0.552 to -0.896 mpa
Moderate	<-0.896 to -1.24 mpa
Low	<-1.24 to -1.72 mpa
Very Low	<-1.72 to -2.21 mpa
Extremely Low	<-2.21 mpa

Appendix C3. Sampling detail at Assessment Area 5 and Assesment Area 10

Client

Bowen Basin Coking Coal



Scale 1:7,500

Drawn By DG

Checked DS

File Path

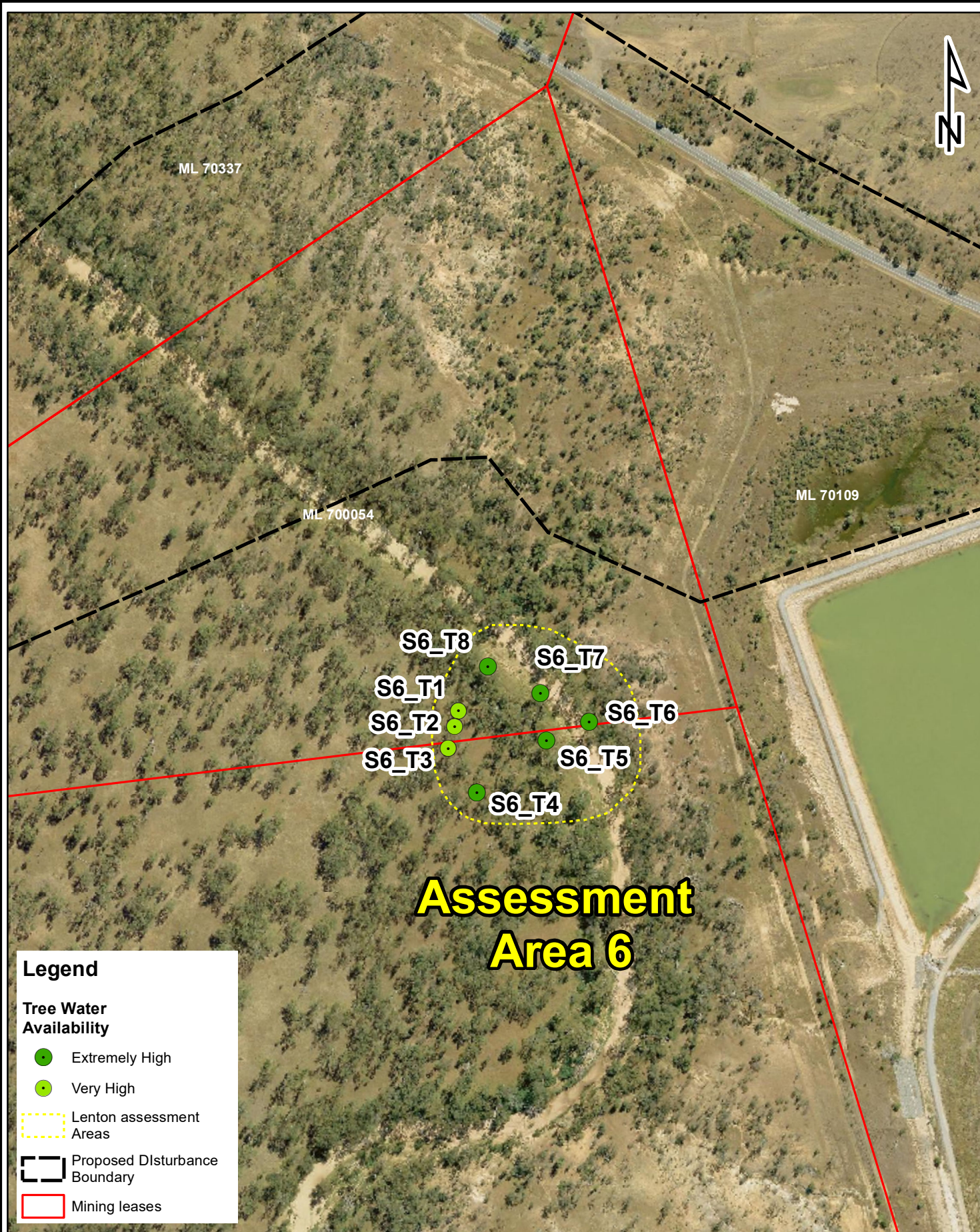


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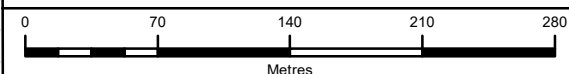
A4



Extremely High	> - 0.276 mpa
Very High	< -0.276 to - 0.552 mpa
High	<-0.552 to -0.896 mpa
Moderate	<-0.896 to -1.24 mpa
Low	<-1.24 to -1.72 mpa
Very Low	<-1.72 to -2.21 mpa
Extremely Low	<-2.21 mpa

Appendix C4. Sampling detail at Assessment Area 6

Client **Bowen Basin Coking Coal**



Scale 1:4,000

Drawn By DG

Checked DS

File Path



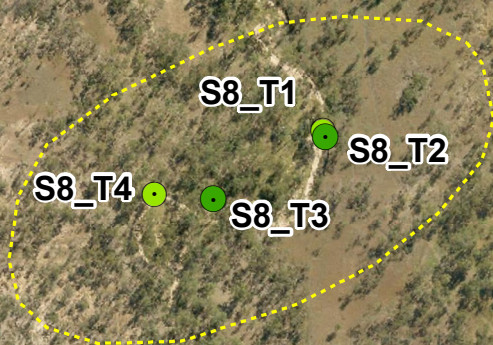
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Date
05-Jun-23

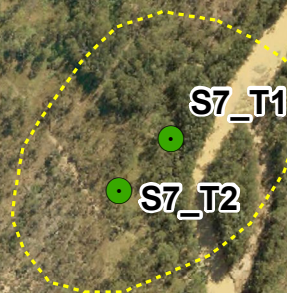
A4



Assessment Area 8



Assessment Area 7



Legend

Tree Water Availability

- Extremely High
- Very High

Lenton assessment Areas

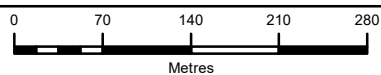
Mining leases

Extremely High	> - 0.276 mpa
Very High	< -0.276 to - 0.552 mpa
High	<-0.552 to -0.896 mpa
Moderate	<-0.896 to -1.24 mpa
Low	<-1.24 to -1.72 mpa
Very Low	<-1.72 to -2.21 mpa
Extremely Low	<-2.21 mpa

Appendix C5. Sampling detail at Assessment Area 7 and Assessment Area 8

Client

Bowen Basin Coking Coal



Scale 1:6,000

Drawn By DG

Checked DS

File Path

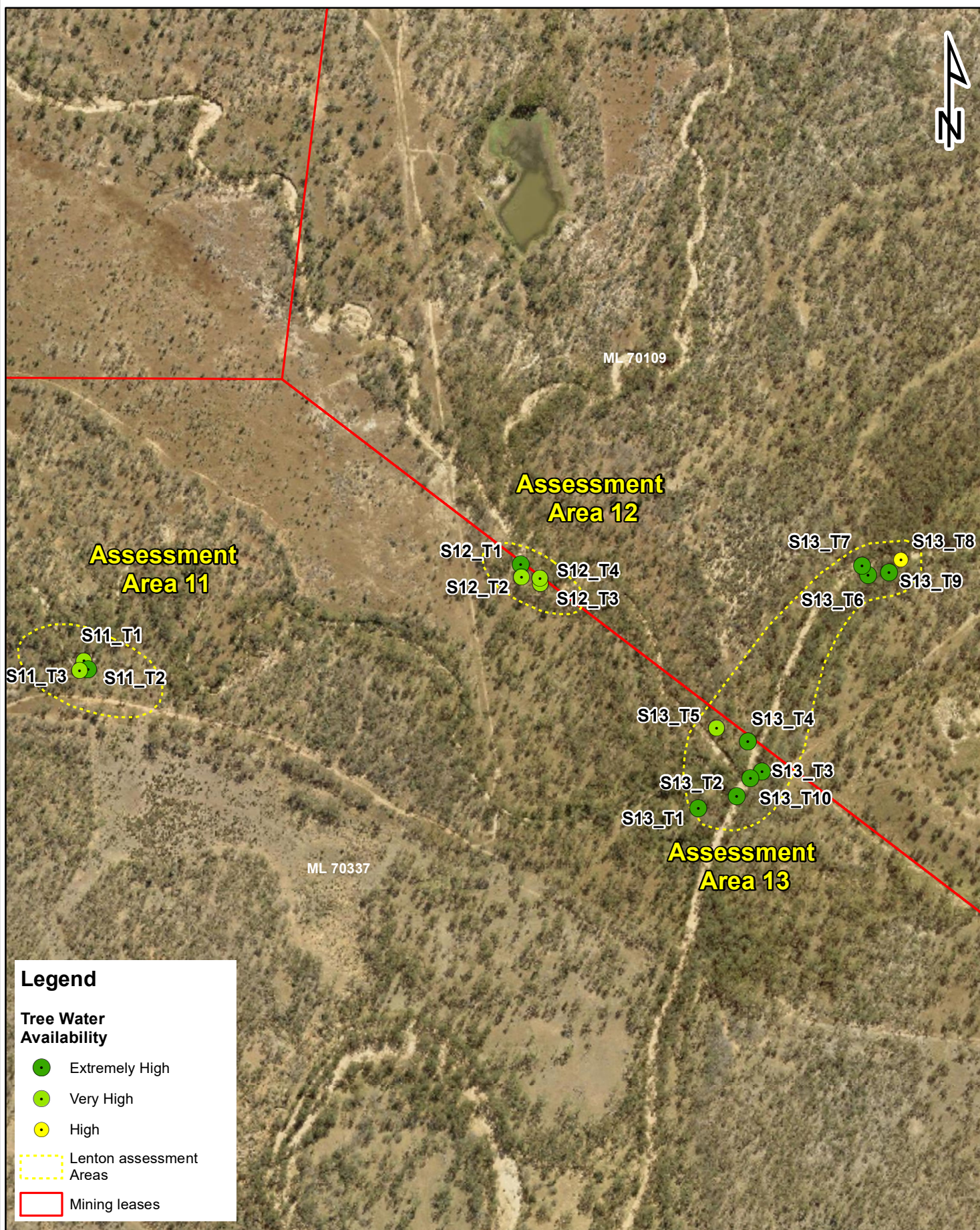


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A4



Legend

Tree Water Availability

-  Extremely High
-  Very High
-  High

 Lenton assessment Areas

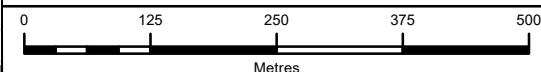
 Mining leases

Extremely High	> - 0.276 mpa
Very High	< -0.276 to - 0.552 mpa
High	<-0.552 to -0.896 mpa
Moderate	<-0.896 to -1.24 mpa
Low	<-1.24 to -1.72 mpa
Very Low	<-1.72 to -2.21 mpa
Extremely Low	<-2.21 mpa

Appendix C6. Sampling detail at Assessment Area 11 to Assessment Area 13

Client

Bowen Basin Coking Coal



Scale 1:7,500

Drawn By DG

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File Path



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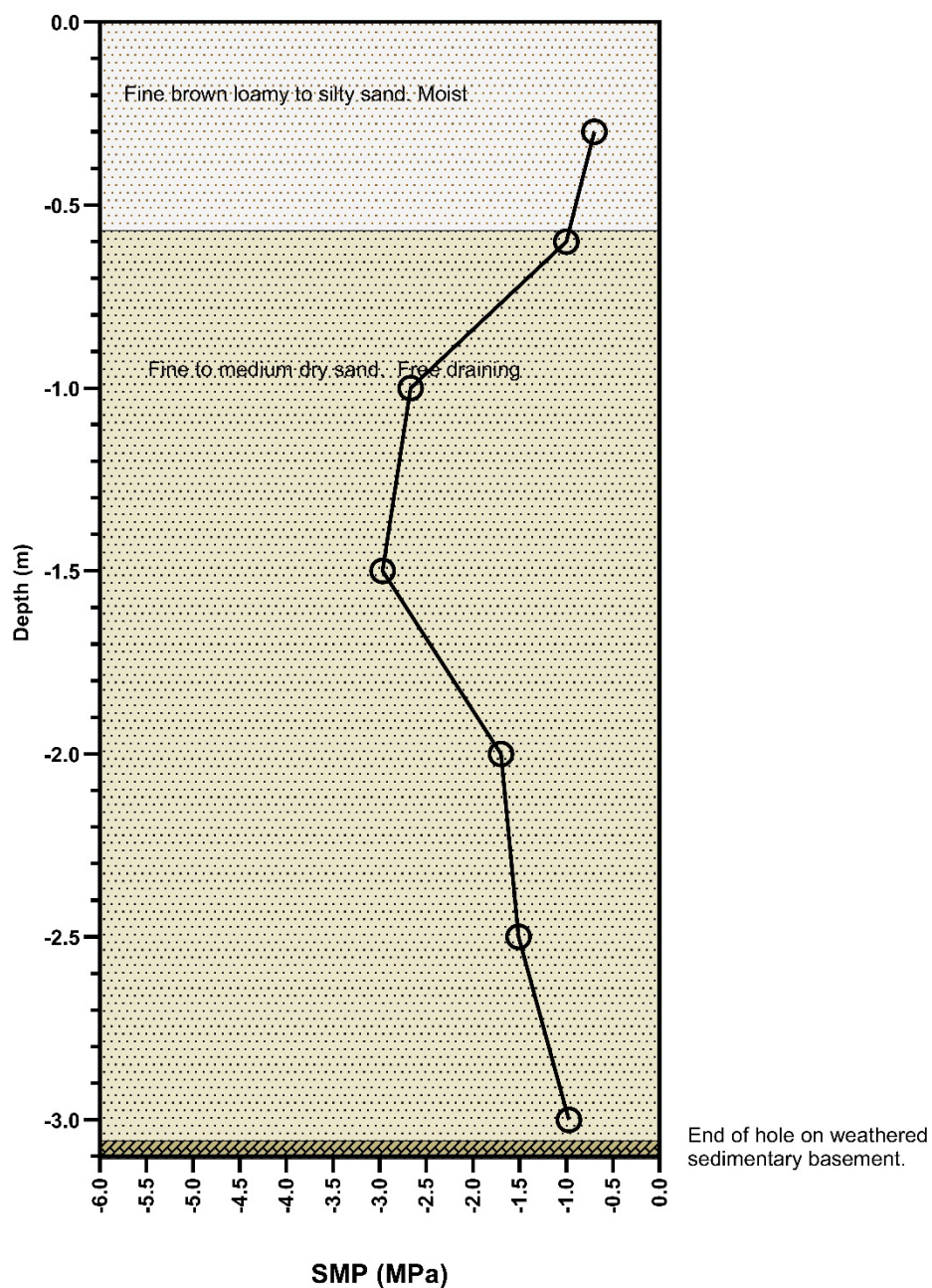
Date
05-Jun-23

A4

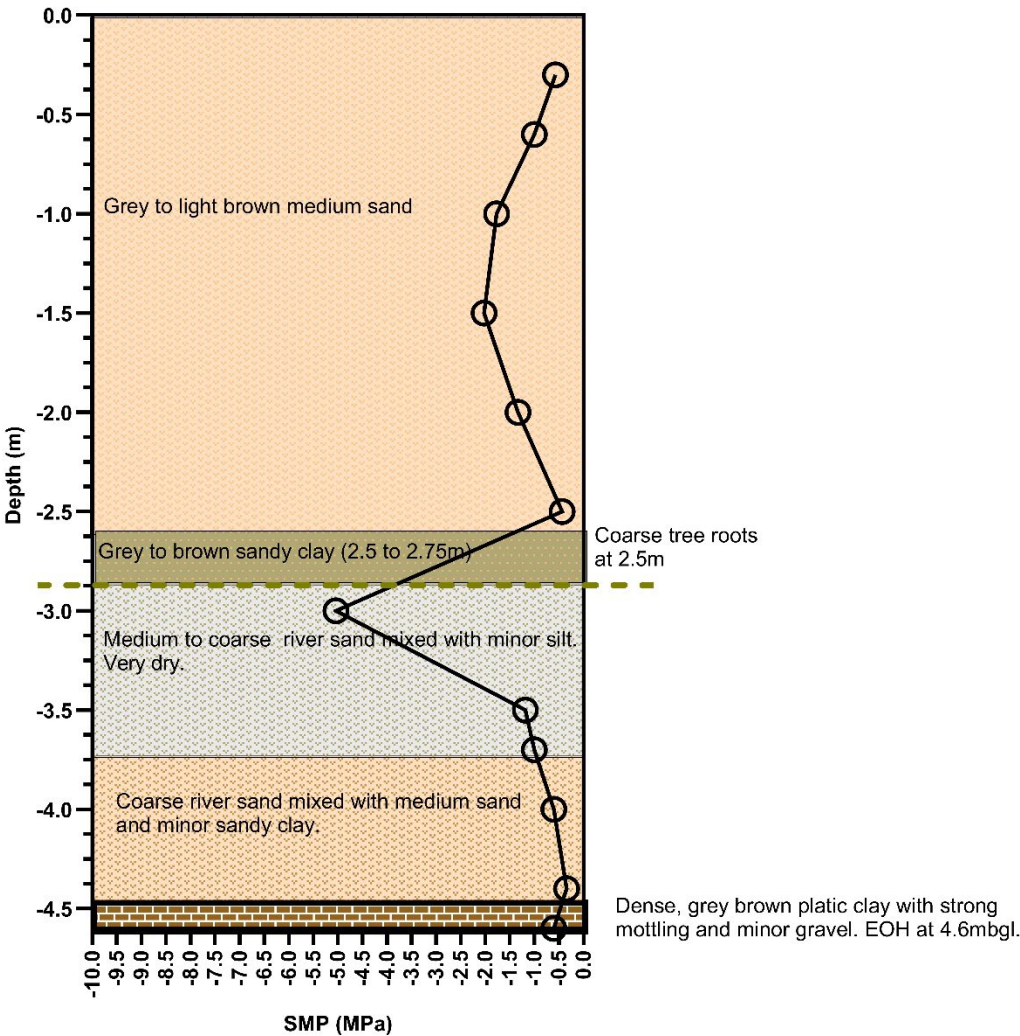
Appendix D. Shallow Groundwater Monitoring Bores (Preliminary Investigations).

Auger	Y	X	Total Depth (m)	Proposed Screen (m)	Sediment Screened	Material at Base of Hole_Perching Layer
NL2_AU1	-21.54881	148.141668	3	2.0 to 3.0	Coarse sand	Sedimentary basement.
NL1_AU3	-21.557876	148.140578	4.6	4.0 - 4.5	Coarse river sand.	Grey brown plastic clay with minor gravel
NL6_AU2	-21.569645	148.145456	5.5	4.5-5.4	Coarse river sand with minor clay interbeds	Grey brown plastic clay. Dense
NL3_AU2	-21.542012	148.146221	5.9	5.1 - 5.7	Coarse river sand. Minor Clay.	Grey plastic clay. Mottled

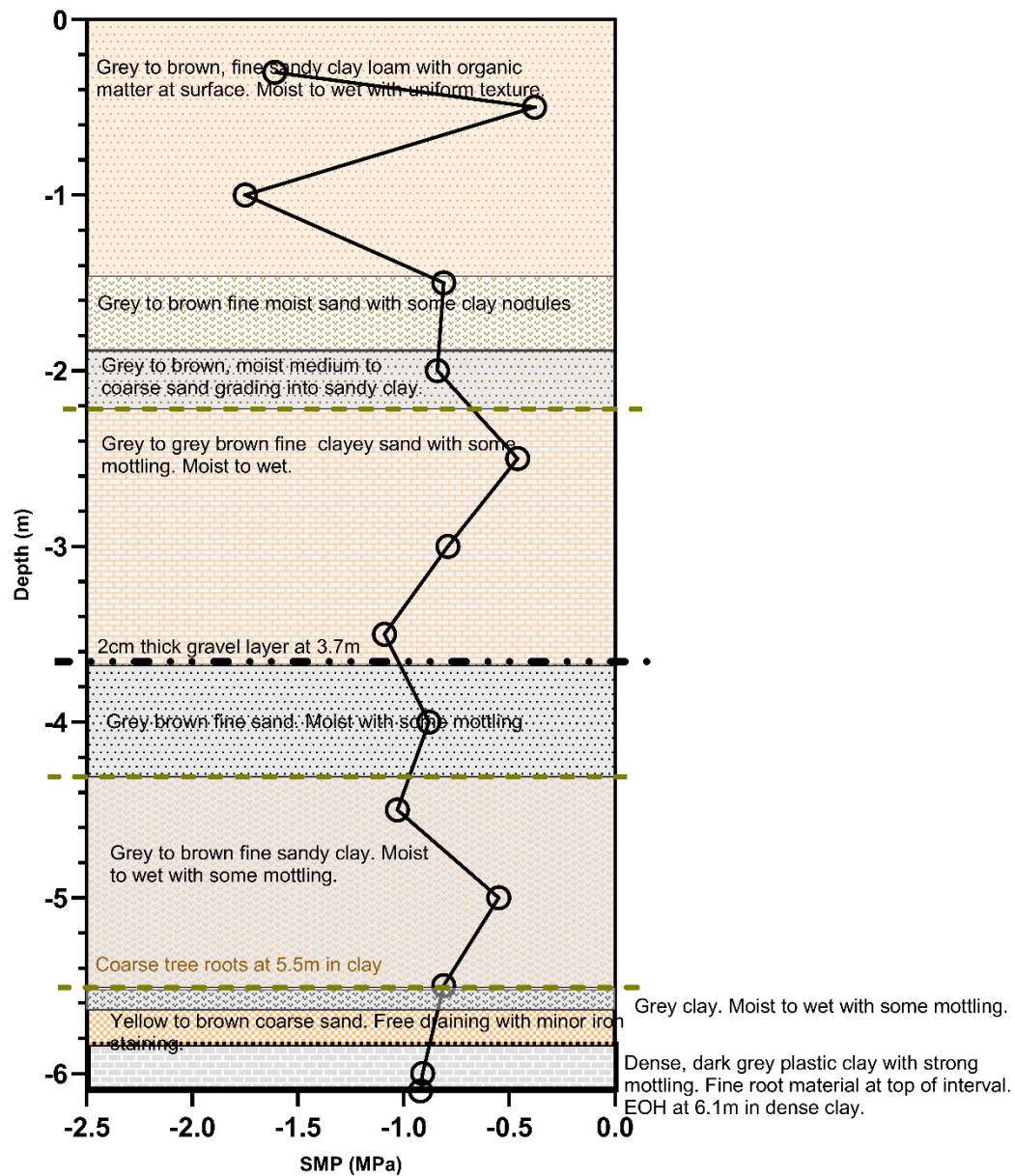
New Lenton Site NL2_AU1



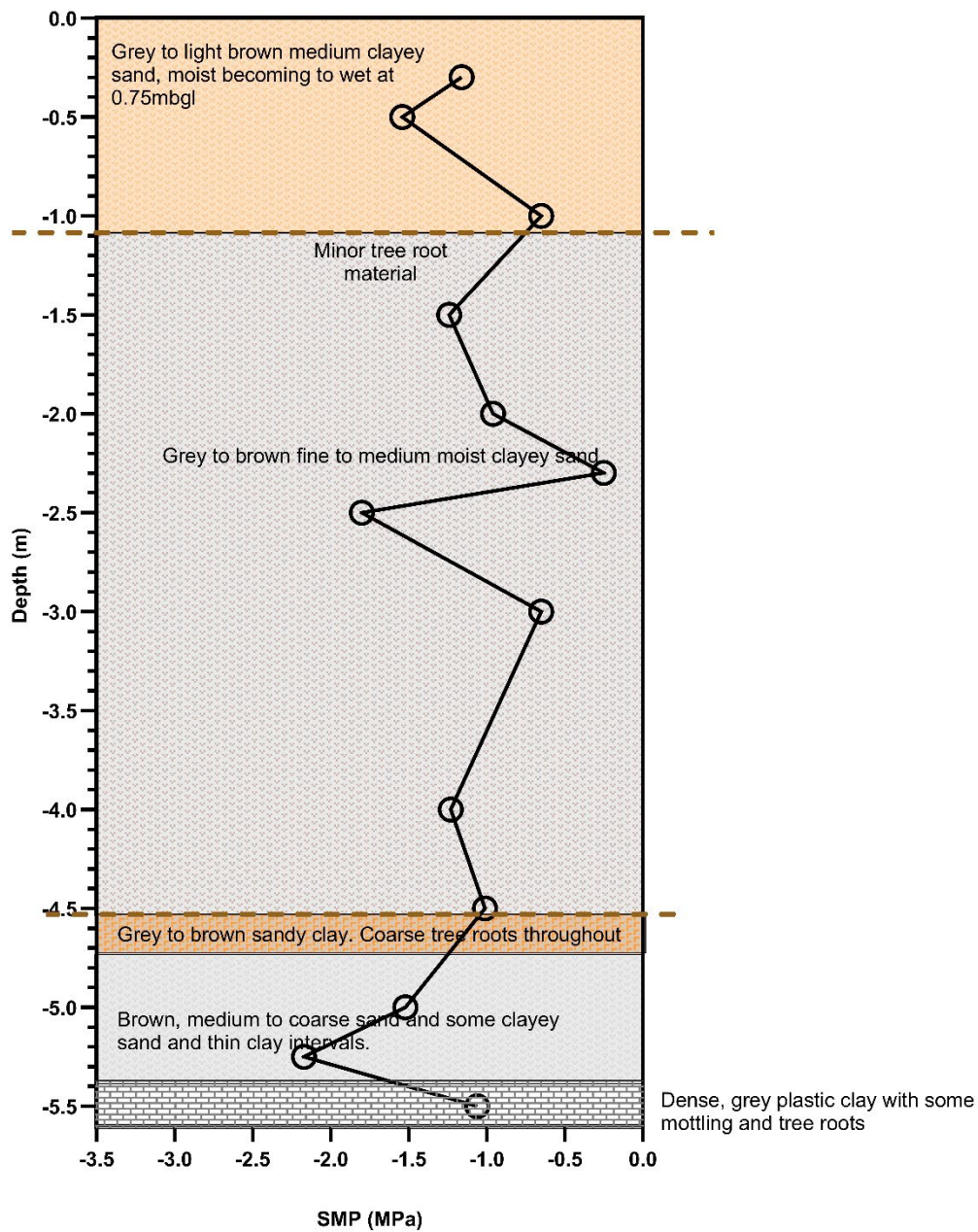
New Lenton Monitoring_NL1_AU3



New Lenton Monitoring_NL3_AU2



New Lenton Site NL6_AU2



Appendix E. Raw Data from Soil Moisture Potential (New Lenton GDE Assessment)

Sample	Type	Project	Date Sampled	SMP
S1_AU1_0.6	Soil	New Lenton	21.02.23	-0.06
S1_AU2_0.3	Soil	New Lenton	21.02.23	-0.12
S1_AU2_0.5	Soil	New Lenton	21.02.23	0
S1_AU2_0.75	Soil	New Lenton	21.02.23	-0.02
S1_AU2_1.0	Soil	New Lenton	21.02.23	-0.02
S1_AU2_1.5	Soil	New Lenton	21.02.23	-0.03
S1_AU2_1.75	Soil	New Lenton	21.02.23	-0.08
S1_AU2_2.0	Soil	New Lenton	21.02.23	-0.18
S1_AU2_2.5	Soil	New Lenton	21.02.23	-0.04
S1_AU2_3.3	Soil	New Lenton	21.02.23	-0.04
S1_AU2_3.5	Soil	New Lenton	21.02.23	-0.05
S1_AU2_3.75	Soil	New Lenton	21.02.23	-0.09
S12_AU1_0.1	Soil	New Lenton	25.02.23	-0.11
S12_AU1_0.3	Soil	New Lenton	25.02.23	-0.08
S12_AU1_0.75	Soil	New Lenton	25.02.23	-0.04
S12_AU1_1.0	Soil	New Lenton	25.02.23	-0.1
S12_AU1_1.5	Soil	New Lenton	25.02.23	-0.02
S13_AU1_1.3	Soil	New Lenton	26.02.23	-0.01
S13_AU1_1.5	Soil	New Lenton	26.02.23	-0.04
S13_AU2_0.2	Soil	New Lenton	26.02.23	-0.06
S13_AU2_0.3	Soil	New Lenton	26.02.23	-0.06
S13_AU2_0.5	Soil	New Lenton	26.02.23	-0.21
S13_AU2_0.8	Soil	New Lenton	26.02.23	-0.02
S13_AU2_1.0	Soil	New Lenton	26.02.23	-0.12
S13_AU2_1.3	Soil	New Lenton	26.02.23	-0.01
S13_AU2_1.5	Soil	New Lenton	26.02.23	0
S13_AU2_1.75	Soil	New Lenton	26.02.23	-0.17
S13_AU2_2.1	Soil	New Lenton	26.02.23	-0.01
S13_AU2_2.5	Soil	New Lenton	26.02.23	-0.1
S13_AU2_2.7	Soil	New Lenton	26.02.23	-0.01
S13_AU2_3.0	Soil	New Lenton	26.02.23	0

Sample	Type	Project	Date Sampled	SMP
S13_AU2_3.5	Soil	New Lenton	26.02.23	-0.02
S13_AU2_3.75	Soil	New Lenton	26.02.23	-0.13
S13_AU2_3.8	Soil	New Lenton	26.02.23	-0.07
S13_AU2_4.0	Soil	New Lenton	26.02.23	-0.02
S13_AU2_4.2	Soil	New Lenton	26.02.23	0
S6_AU1_1.2	Soil	New Lenton	24.02.23	-0.01
S6_AU2_0.1	Soil	New Lenton	24.02.23	-0.02
S6_AU2_0.3	Soil	New Lenton	24.02.23	-0.01
S6_AU2_0.6	Soil	New Lenton	24.02.23	0
S6_AU2_1.0	Soil	New Lenton	24.02.23	-0.07
S6_AU2_1.5	Soil	New Lenton	24.02.23	-0.05
S6_AU2_2.0	Soil	New Lenton	24.02.23	-0.05
S6_AU2_2.5	Soil	New Lenton	24.02.23	-0.08
S6_AU2_2.75	Soil	New Lenton	24.02.23	0
S6_AU2_3.0	Soil	New Lenton	24.02.23	0
S6_AU2_3.3	Soil	New Lenton	24.02.23	0
S8_AU1_0.2	Soil	New Lenton	24.02.23	-0.35
S8_AU1_0.85	Soil	New Lenton	24.02.23	0
S8_AU1_1.0	Soil	New Lenton	24.02.23	-0.03
S8_AU1_1.3	Soil	New Lenton	24.02.23	-0.1
S8_AU1_1.4	Soil	New Lenton	24.02.23	-0.32
S8_AU1_1.6	Soil	New Lenton	24.02.23	-0.05
S8_AU1_1.8	Soil	New Lenton	24.02.23	-0.02
S8_AU1_2.5	Soil	New Lenton	24.02.23	-0.37

Appendix F. Raw Data from Stable Isotope Analysis (New Lenton GDE Assessment)

Appendix G. LWP and Tree Structural Measurements from the New Lenton GDE Assessment (PER Report)

Tree Sample Point	Y	X	Species	DBH (cm)	Height (m)	Geomorphic Position	LWP	Tree Water Availability
S1_T1	-21.5604	148.1414	Eucalyptus tereticornis	80	21	5m above river channel and 15m from channel margins	-0.4	Very High
S1_T2	-21.5603	148.1414	Eucalyptus tereticornis	95	22	5m above river channel and 10m from channel margins	-0.45	Very High
S1_T3	-21.5601	148.1414	Casuarina cunninghamiana	65	18	On margins of sandy channel	-0.55	Very High
S1_T4	-21.5593	148.1411	Casuarina cunninghamiana	73	23	On margins of sandy channel	-0.65	High
S1_T5	-21.5588	148.1411	Eucalyptus tereticornis	60	20	5m from margins of sandy channel and approximately 3m above channel floor	-0.25	Extremely High
S1_T6	-21.5583	148.1406	Eucalyptus tereticornis	100	24	2m from margins of sandy channel and approximately 3m above channel floor	-0.15	Extremely High
S1_T7	-21.5577	148.1404	Eucalyptus tereticornis	150	26	2m above channel floor directly adjacent to river	-0.4	Very High
S1_T8	-21.5574	148.1402	Eucalyptus tereticornis	90	27	On margins of sandy channel	-0.45	Very High
S1_T9	-21.5573	148.1405	Eucalyptus tereticornis	70	15	10m from river channel and 5m above channel floor	-0.2	Extremely High
S2_T1	-21.55	148.1423	Eucalyptus tereticornis	100	18	Lower alluvial terrace adjacent to the Isaac River. 5m from channel margin and 3m above channel floor	-0.05	Extremely High
S2_T2	-21.5487	148.1415	Eucalyptus tereticornis	55	17	Lower alluvial terrace adjacent to the Isaac River. 15m from channel margin and 4m above channel floor	-0.4	Very High
S2_T3	-21.5481	148.1412	Eucalyptus tereticornis	60	23	Lower alluvial terrace adjacent to the Isaac River. 5m from channel margin and 4m above channel floor	-0.5	Very High
S2_T4	-21.5484	148.141	Eucalyptus tereticornis	110	24	Margins of Tertiary residuals approximately 30m from river channel	-0.45	Very High
S3_T1	-21.5505	148.1406	Eucalyptus populnea	50	16	>250m from river margins on elevated residual surface	-1.45	Low
S3_T2	-21.5509	148.1404	Eucalyptus populnea	55	15	>250m from river margins on elevated residual surface	-1.55	Low
S4_T1	-21.5527	148.1177	Eucalyptus orgadophila	65	13	On margins of ephemeral gully on heavy clay soils	-0.9	Moderate
S4_T2	-21.553	148.1178	Eucalyptus orgadophila	70	15	On margins of ephemeral gully on heavy clay soils	-1.4	Low
S5_T1	-21.5659	148.1283	Eucalyptus tereticornis	65	15	Directly on margins of ephemeral drainage line	-0.55	Very High
S5_T2	-21.5656	148.1281	Eucalyptus tereticornis	70	16	Directly on margins of ephemeral drainage line	-0.6	High
S6_T1	-21.5697	148.1449	Eucalyptus tereticornis	70	22	>100m from main channel of Isaac River	-0.3	Very High
S6_T2	-21.5698	148.1449	Eucalyptus tereticornis	75	22	>100m from main channel of Isaac River	-0.45	Very High

Tree Sample Point	Y	X	Species	DBH (cm)	Height (m)	Geomorphic Position	LWP	Tree Water Availability
S6_T3	-21.57	148.1448	Eucalyptus tereticornis	90	24	70m from main channel of Isaac River	-0.3	Very High
S6_T4	-21.5703	148.145	Eucalyptus tereticornis	75	21	60m from main channel of Isaac River	-0.1	Extremely High
S6_T5	-21.5699	148.1456	Eucalyptus tereticornis	130	24	30m from main channel of Isaac River on margins of T1 terrace	-0.05	Extremely High
S6_T6	-21.5698	148.1459	Eucalyptus tereticornis	140	30	On inner bench of river 4m above river channel	-0.1	Extremely High
S6_T7	-21.5696	148.1455	Eucalyptus tereticornis	110	23	3m from margins of the river channel on lower river terrace	-0.2	Extremely High
S6_T8	-21.5694	148.1451	Eucalyptus tereticornis	80	24	15m from river channel on margins of T1 terrace	-0.1	Extremely High
S7_T1	-21.581	148.1366	Eucalyptus tereticornis	80	26	20m from channel of Isaac River on lower T1 terrace	-0.1	Extremely High
S7_T2	-21.5814	148.1362	Eucalyptus populnea	80	23	50m from main channel of Isaac River on T1 terrace	-0.25	Extremely High
S8_T1	-21.5793	148.1341	Eucalyptus tereticornis	120	15	Directly on margins of ephemeral drainage line. Sandy channel	-0.35	Very High
S8_T2	-21.5793	148.1341	Eucalyptus tereticornis	70	23	15m from channel of ephemeral drainage line	-0.15	Extremely High
S8_T3	-21.5798	148.1333	Eucalyptus tereticornis	130	22	15m from channel of ephemeral drainage line	-0.25	Extremely High
S8_T4	-21.5798	148.1328	Eucalyptus tereticornis	80	20	Directly adjacent to overflow channel of ephemeral drainage line	-0.45	Very High
S9_T1	-21.5613	148.1108	Eucalyptus populnea	50	15	Lower limits of colluvial slope	-0.85	Moderate
S9_T2	-21.5614	148.1112	Eucalyptus crebra	45	17	Lower limits of colluvial slope	-0.95	Moderate
S9_T3	-21.5615	148.1114	Eucalyptus populnea	55	17	Lower limits of colluvial slope	-0.95	Moderate
S10_T1	-21.5743	148.1268	Eucalyptus populnea	55	15	> 0.5km from river margins on elevated residual surface	-0.95	Moderate
S10_T2	-21.5741	148.127	Eucalyptus populnea	45	16	> 0.5km from river margins on elevated residual surface	-1.4	Low
S10_T3	-21.574	148.1271	Eucalyptus populnea	45	16	> 0.5km from river margins on elevated residual surface	-1.1	Moderate
S11_T1	-21.5395	148.1375	Eucalyptus tereticornis	100	18	On lower alluvial terrace of drainage line 5m from sandy channel	-0.45	Very High
S11_T2	-21.5396	148.1375	Eucalyptus tereticornis	100	17	2m above channel floor on inner bench	-0.25	Extremely High
S11_T3	-21.5396	148.1374	Eucalyptus tereticornis	50	17	5m above channel floor on upper terrace	-0.45	Very High
S12_T1	-21.5381	148.1437	Eucalyptus tereticornis	50	15	5m from river channel on lower alluvial terrace	-0.25	Extremely High
S12_T2	-21.5383	148.1437	Eucalyptus tereticornis	80	23	10m from river channel on lower alluvial terrace	-0.5	Very High

Tree Sample Point	Y	X	Species	DBH (cm)	Height (m)	Geomorphic Position	LWP	Tree Water Availability
S12_T3	-21.5384	148.144	Eucalyptus tereticornis	80	20	3m above channel floor on inner bench of tributary creek	-0.5	Very High
S12_T4	-21.5383	148.144	Eucalyptus tereticornis	50	20	Inner bench 3m above sandy channel floor	-0.45	Very High
S13_T1	-21.5414	148.1463	Eucalyptus tereticornis	120	23	15m from river channel and 5m above channel floor	-0.1	Extremely High
S13_T2	-21.5412	148.1468	Casuarina cunninghamiana	80	23	Directly on river channel	-0.2	Extremely High
S13_T3	-21.5409	148.1472	Eucalyptus tereticornis	90	16	Top of upper terrace 5m above river channel	-0.25	Extremely High
S13_T4	-21.5405	148.147	Eucalyptus tereticornis	100	24	Top of upper terrace 8m above river channel	-0.2	Extremely High
S13_T5	-21.5403	148.1466	Eucalyptus tereticornis	120	25	3m above channel floor and 12m from channel margins	-0.3	Very High
S13_T6	-21.5383	148.1487	Eucalyptus tereticornis	80	16	2.5m above channel floor and 6m from sandy channel margins	-0.1	Extremely High
S13_T7	-21.5381	148.1486	Casuarina cunninghamiana	80	22	Directly on river channel floor	-0.15	Extremely High
S13_T8	-21.538	148.1492	Eucalyptus tereticornis	100	18	1m above channel floor and 3m from river channel margins	-0.8	High
S13_T9	-21.5382	148.149	Eucalyptus tereticornis	80	15	3.5m above river channel floor on inner bank of river	-0.15	Extremely High
S13_T10	-21.541	148.147	Eucalyptus tereticornis	55	16	2.5m above channel floor and 2.5m from sandy channel margins	-0.1	Extremely High

Appendix H. GDE Monitoring Program for Initial Two Years

Event	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
Monitoring Survey 1: Seasonal assessment undertaken in Dry Season (September to October 2024)	• Risk Zone 1 ○ Site 1 ○ TEC 1 • Risk Zone 2 ○ Site 1A ○ Site 1B ○ TEC 2 ○ TEC 3 • Risk Zone 3 ○ Site 2A ○ Site SB ○ Site 2C ○ Site 2D • Risk Zone 4 ○ TEC 4 • Outside Risk Zone ○ Site 3A ○ Site 3B	• LWP • Stable isotopes (trees, soils, surface water and water in channel sands) • Leaf Area Index • Soil moisture potentials (shallow monitoring bores)	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Establishment of shallow bores to monitor seasonality of groundwater in the perched groundwater system. Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 1.
Monitoring Survey 2: Seasonal assessment undertaken in Late Wet Season (March to May 2025)	• Risk Zone 1 ○ Site 1 ○ TEC 1 • Risk Zone 2 ○ Site 1A ○ Site 1B ○ TEC 2 ○ TEC 3 • Risk Zone 3 ○ Site 2A ○ Site SB ○ Site 2C ○ Site 2D • Risk Zone 4 ○ TEC 4 • Outside Risk Zone ○ Site 3A ○ Site 3B	• LWP • Stable isotopes (trees, soils, surface water and water in channel sands) • Leaf Area Index • Soil moisture potentials (shallow monitoring bores)	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from installed shallow monitoring bores.. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 2.
Monitoring Survey 3: Seasonal assessment undertaken in Late Dry Season	• Risk Zone 1 ○ Site 1 ○ TEC 1 • Risk Zone 2 ○ Site 1A	• LWP • Stable isotopes (trees, soils, surface water	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and	GDE Monitoring Report- Monitoring Event 3.

Event	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
(September to October 2025)	○ Site 1B ○ TEC 2 ○ TEC 3 • Risk Zone 3 ○ Site 2A ○ Site SB ○ Site 2C ○ Site 2D • Risk Zone 4 ○ TEC 4 • Outside Risk Zone ○ Site 3A ○ Site 3B	- and water in channel sands) • Leaf Area Index • Soil moisture potentials (shallow monitoring bores)		data from pressure transducers). Stable isotope composition of groundwater from installed shallow monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	
Monitoring Survey 4: Seasonal assessment undertaken in Late Wet Season (April to May 2026)	• Risk Zone 2 ○ Site 1A ○ Site 1B ○ TEC 2 ○ TEC 3 • Risk Zone 3 ○ Site 2A ○ Site SB ○ Site 2C ○ Site 2D • Risk Zone 4 ○ TEC 4 • Outside Risk Zone ○ Site 3A ○ Site 3B	• LWP • Stable isotopes (trees, soils, surface water and water in channel sands) • Leaf Area Index • Soil moisture potentials (shallow monitoring bores)	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from installed shallow monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 4.
2 Year Review - Baseline GDE Monitoring Assessment	NA	NA	NA	NA	– Compilation of data from all surveys – Analysis of baseline ecohydrological function of field verified GDE areas. – Refinement of GDE mapping, including excision of areas that are demonstrated to not be groundwater dependent for excision. – Correlation between LAI and

Event	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
					NDVI (plus other parameters) to provide a baseline for ongoing annual vegetation monitoring. – Identification of sources of water utilised by trees on a seasonal basis through analysis of stable isotope results for multiple parameters. – Assessment of seasonal persistence of perched alluvial groundwater. – Interaction between shallow perched groundwater system and basal alluvial groundwater reviewed by project hydrogeologist. – Review of risk assessment and identification of areas where risk profile is increased / diminished. – Revised GDEMMP issued based on results and outcomes of the 2-year baseline monitoring program.