Appendix K Groundwater-Dependent Ecosystems Survey Report and Monitoring Plan (EcOz 2026)

GROUNDWATER-DEPENDENT ECOSYSTEM SURVEY REPORT AND MONITORING PLAN

Lei Lithium Project

Lithium Plus Minerals Ltd Pty



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EXECUTIVE SUMMARY

Lithium Plus Minerals Ltd (LPM) is seeking environmental approval for the Lei Lithium Project, approximately 30 km south of Darwin, Northern Territory. Groundwater extraction associated with underground mining is predicted to result in groundwater drawdown surrounding the mine. This report identifies and characterises groundwater-dependent ecosystems (GDEs) that could potentially be affected by this drawdown and establishes a framework for monitoring potential vegetation responses during project operation.

The assessment focused on terrestrial GDEs within the predicted groundwater drawdown extent. Eucalypt savanna woodland dominates the study area and based on available ecological literature, is generally sustained by soil moisture recharged during the wet season rather than being functionally dependent on groundwater. Accordingly, the assessment sought to identify localised vegetation communities that exhibited characteristics suggesting a greater likelihood of groundwater dependence.

Potential terrestrial GDEs were initially identified using a multi-year analysis of late dry-season Normalised Difference Moisture Index (NDMI) derived from Sentinel-2 satellite imagery for 2018–2025. Persistent elevated NDMI was used as a conservative landscape-scale indicator of vegetation retaining greater moisture during the late dry season. As elevated NDMI can also result from surface drainage, soil moisture storage, vegetation structure and other hydrological processes, the remote-sensing assessment was used to identify areas requiring field investigation rather than as evidence of groundwater dependence.

Four of the largest and most distinct high-NDMI, non-riparian vegetation patches within the predicted drawdown extent were selected for field verification. All occurred within or adjacent to shallow drainage depressions and generally supported denser or compositionally distinct vegetation than the surrounding Eucalypt woodland. However, field investigations found no seepage, permanent surface water, saturated soils, soil characteristics indicative of prolonged saturation, or vegetation communities strongly indicative of groundwater dependence. The elevated vegetation moisture at these locations was instead consistent with localised accumulation of surface water following rainfall and prolonged retention of soil moisture within shallow drainage depressions. Based on the desktop assessment, remote-sensing analysis and field investigations, no terrestrial GDEs were identified within the study area.

Notwithstanding this conclusion, a monitoring framework has been developed to detect potential vegetation responses to groundwater drawdown and provide an early indication of impacts that were not predicted by the assessment. Monitoring is based on annual late dry-season NDMI derived from Sentinel-2 imagery and incorporates two complementary approaches. The first uses a Before-After-Control-Impact (BACI) design to compare changes in vegetation moisture at fixed monitoring polygons within the drawdown cone against comparable control polygons outside the predicted influence of drawdown. The second provides landscape-scale surveillance across the entire undisturbed drawdown cone, compared with a nearby reference area.

The existing 2018–2025 Sentinel-2 record provides the pre-drawdown baseline. Following commencement of groundwater drawdown, annual October NDMI will be compared against this baseline and contemporaneous control conditions. A potential drawdown-related response would be indicated where vegetation moisture declines within the drawdown cone relative to both its pre-impact condition and matched control sites. Landscape-scale anomaly mapping will complement the BACI assessment by identifying persistent or spatially coherent vegetation drying elsewhere within the drawdown cone, including vegetation not initially identified as a potential GDE.

Where monitoring identifies a potential response, further investigation will consider aerial imagery, rainfall and fire history, groundwater levels and targeted field assessment to determine whether the observed vegetation change is attributable to groundwater drawdown or other environmental factors. Together, the site-based BACI assessment and landscape-scale surveillance provide a multiple-lines-of-evidence framework for detecting, investigating and interpreting potential ecological responses to groundwater extraction over the life of the project.

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1 INTRODUCTION

Lithium Plus Minerals Ltd (LPM) are seeking environmental approval for the Lei Lithium Project. Located 30 km (direct line) south of Darwin, Northern Territory, the project proposes to mine spodumene ore via underground mining methods to an approximate depth of 700 m below surface. The key project components include crushing, storage and transport of the ore, together with ancillary infrastructure and access roads.

Based on the referral submitted to the NT EPA in 2024, LPM are required to prepare a Supplementary Environmental Report (SER) that includes, *inter alia*, a requirement to develop a site-specific groundwater model that predicts groundwater drawdown levels, spatial extent and recovery time as a result of project activities. This modelling has been developed by CloudGMS (2026a, 2026b).

The SER also requires the groundwater modelling results to be used to assess the potential for groundwater extraction to affect groundwater-dependent ecosystems (GDEs). Of relevance is the potential for sustained groundwater drawdown to alter groundwater availability to ecosystems surrounding the mine that are wholly or partially dependent on groundwater. The likelihood and significance of any ecological response will depend on the magnitude, duration and spatial extent of drawdown, together with the degree of dependence and sensitivity of the ecosystems potentially affected GDEs.

Specifically, the SER must respond to the following three items:

> *8. Identify, describe and assess potential direct and indirect impacts and risks of the predicted groundwater extraction, including likely effects to groundwater-dependent ecosystems including springs, wetlands, vegetation, connected surface water systems, declared beneficial uses and other groundwater users.*
>
> *9. Describe the avoidance and mitigation measures to manage the impacts and risks of groundwater extraction identified by item 8.*
>
> *23. Describe ongoing monitoring, inspection and reporting of impacts on terrestrial ecosystem values to ensure their protection.*

1.1 Purpose

The purpose of this report is to provide detail on the GDEs that could be impacted by groundwater extraction from the project, and a plan to monitor the health of those GDEs.

To fulfil this purpose, this report presents a:

- Characterisation of GDEs in both the Top End setting and as relevant to the project.
- Map of potential GDEs based on analysis of remote-sensing imagery.
- Description of those potential GDEs based on a field survey.
- Plan for monitoring impacts to vegetation from project interactions with groundwater.

This report does not assess the significance of potential impacts from the project on GDEs – that is undertaken within the SER.

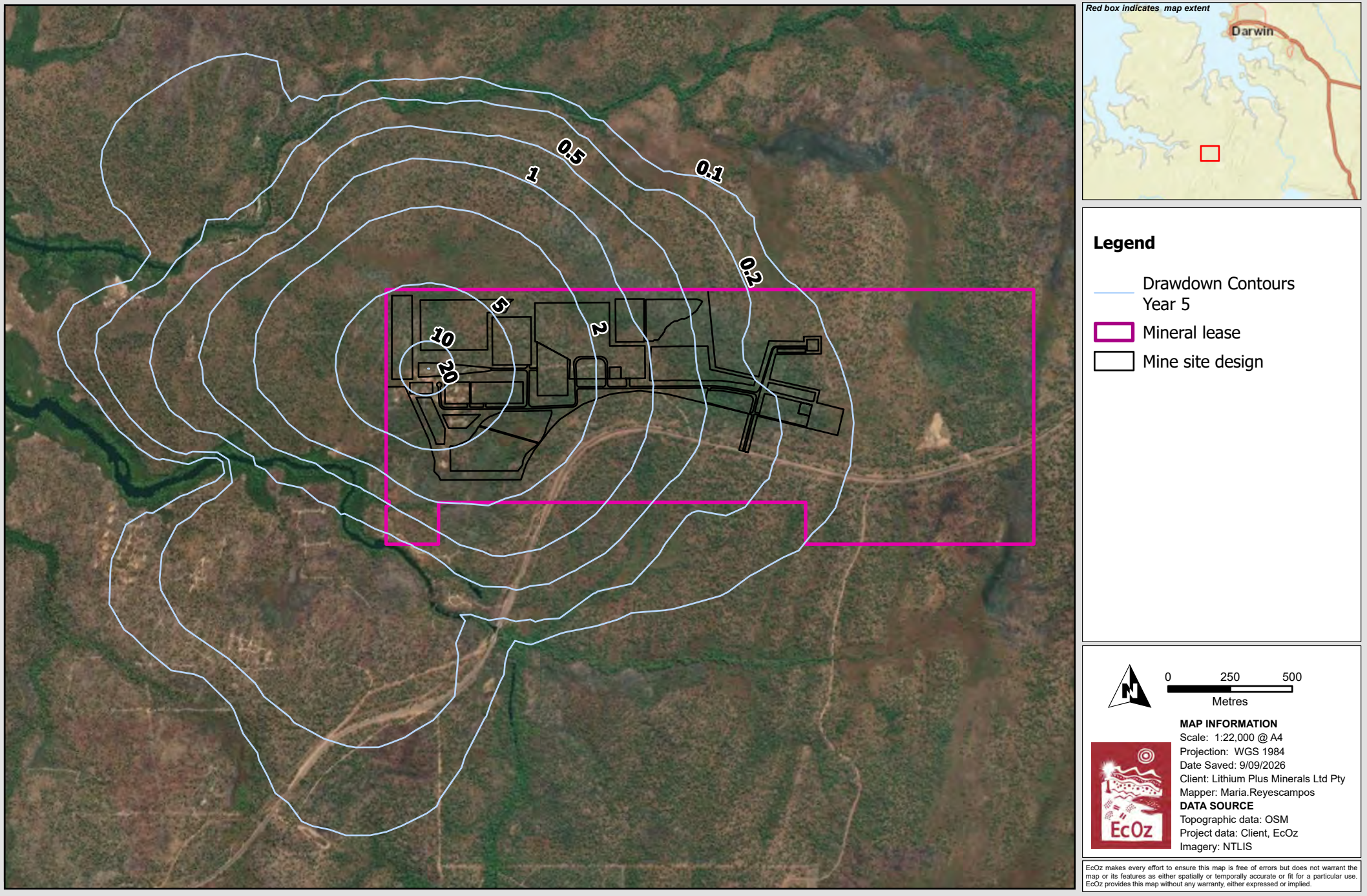
1.2 Project groundwater model

A Groundwater Assessment and Model Report (EcoLogical Australia 2026) has been prepared for the project. That report makes the following observations that are relevant to this study of GDEs (noting that the authors of that report have limited expertise regarding GDEs):

- Around Year 5 of groundwater extraction is when drawdown is expected to peak (see Figure 1-1), at which time:
    - The 10 m drawdown contour will have a maximum extent of 120 m from the pit (noting that this is wholly within the disturbance footprint of the site which will be cleared of native vegetation).
    - The 5 m drawdown contour will have a maximum extent of 400 m from the pit.
    - For up to 1 km from the pit, there will be a maximum drawdown of at least 1 m.

  The extent of modelled groundwater drawdown in Year 5 of extraction is referred to in this report as the *study area*.
- The bores recently drilled proximate to the project footprint indicate a relatively shallow aquifer, with water levels between 0 and 16 metres below ground level (mbgl).
- Groundwater levels are typically at the lowest point towards the end of the dry season (September) and their peak at the end of the wet (March). Groundwater levels increase following wet season rainfall, indicating that recharge occurs primarily through diffuse infiltration of rainfall during the monsoonal wet season.
- Based on seasonal trends in groundwater levels, it is unlikely that the mangroves would be considered dependant on groundwater.
- Mapping of surface water permanence shows that the higher reaches of the drainages are generally not permanent water sources, indicating little to no base flow to the rivers from the groundwater during dry periods.

Additional to this, the author of this report notes that the extent of mangroves along Charlotte River indicates it is tidal up so some rocky bars approximately 750 m downstream of the Fog Bay Road bridge (Figure 3-1).



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Layout: Figure 1-1. Map showing maximum modelled drawdown extents (in year 5 of extraction)

Figure 1-1. Map showing maximum modelled drawdown extents (in year 5 of extraction)

1.3 Groundwater-dependent ecosystems

1.3.1 Overview

GDEs are ecosystems which require access to groundwater on a permanent or intermittent basis to meet all, or some, of their water requirements to maintain their ecological communities, ecological processes and ecosystem services (Richardson et al. 2011). Eamus et al. (2006) recognise three broad classes of GDE:

I. Subterranean aquifer and cave ecosystems where stygofauna reside.

II. Aquatic ecosystems reliant on surface expression of groundwater. This includes baseflow rivers, streams and wetlands, springs and estuarine seagrasses.

III. Terrestrial ecosystems that rely on groundwater occurring within the effective rooting zone.

In the Top End, the presence of Class I and II GDEs can generally be identified with confidence based on the presence of caves, sinkholes, rivers, springs etc. However, as explained below, identifying Class III terrestrial ecosystem GDEs is problematic.

Studies of Eucalypt savannas – the dominant vegetation community in the Top End – suggest that these ecosystems are generally not functionally groundwater-dependent, instead relying on water stored within the soil profile following wet season recharge. Annual evapo-transpiration of these woodlands is approximately 900 to 1200 mm per year (Cook et al., 1998, Beringer et al., 2016), with tree transpiration between 300 and 350 mm per year (Hutley et al., 2000, Kelley et al., 2007), substantially less than annual rainfall of 1,500 to 2,000 mm, indicating that sufficient sub-soil moisture (1 to 5 m depth) is typically available to sustain transpiration throughout the dry season (Cook et al. 1998). Excavation of root systems in the Darwin region found limited evidence of tap roots extending to groundwater, with most root biomass occurring within the upper metre of soil and deeper sinker roots accessing subsoil moisture beneath ferricrete layers rather than the capillary fringe or water table (Eamus et al. 2000). Similarly, O'Grady et al. (1999) observed little seasonal variation in tree water use, concluding that transpiration was maintained by water stored within the soil profile. A reasonable interpretation of the literature is that the dominant Eucalypt species of the Top End are unlikely to represent groundwater-dependent vegetation because following wet season recharge, savanna soils likely retain adequate quantities of moisture that sustain vegetation transpiration throughout the dry season, with limited requirement to access the groundwater via the capillary fringe (Cook et al.,1998; O'Grady et al., 1999, Kelley et al., 2002).

Additional evidence is provided by fine-scale patterns in vegetation composition across local topographic and drainage gradients. *Eucalyptus tetrodonta* and *Eucalyptus miniata* trees typically occupy deeper, well-drained soils, transitioning to Bloodwood (*Corymbia spp.*) and subsequently *Melaleuca spp.* with relatively modest declines in elevation towards seasonally inundated and anoxic soils. These patterns indicate strong vegetation response to local hydrological conditions, with vegetation occupying lower landscape positions potentially having greater access to, or dependence on, groundwater.

Accordingly, for Class III terrestrial ecosystems, groundwater dependence should be distinguished from the ability of vegetation to utilise water stored within the soil profile. For the purposes of this assessment, terrestrial GDEs are considered to be ecosystems in which groundwater makes a material contribution to maintaining dominant tree species composition, structure or ecological function, such that a sustained reduction in groundwater availability would be expected to result in measurable ecological change. The ability of vegetation to access groundwater opportunistically does not, in itself, constitute groundwater dependence. Mapped terrestrial GDEs should therefore be regarded as areas of potential groundwater dependence requiring site-specific assessment, rather than confirmed groundwater-dependent vegetation.

1.3.2 Within the study area

Aquatic ecosystems

The Groundwater Dependent Ecosystems Atlas (BOM 2019) indicates a moderate potential for aquatic (Class II) GDEs along the Charlotte River in the south and south-west of the study area (Figure 1-1). This is consistent with the mapping approach adopted in the GDE Atlas, where major Top End watercourses are identified as potential aquatic GDEs.

Terrestrial ecosystems

Non-riparian vegetation within the study area is predominantly Eucalypt-dominated savanna woodland. The GDE Atlas maps a broad area of this savanna woodland as having a low to moderate potential to support terrestrial (Class III) GDEs. As outlined above, this broad-scale classification should not be interpreted as indicating that all vegetation within the mapped extent is groundwater-dependent. Rather, it identifies landscapes within which localised areas of vegetation with some degree of groundwater dependence may occur. The distribution and likely groundwater dependence of vegetation within the study area is considered in detail below.





Legend

Potential Terrestrial GDE

- Known GDE
- High potential GDE
- Moderate potential GDE
- Low potential GDE

0 250 500

Metres

MAP INFORMATION

Scale: 1:22,000 @ A4
Projection: WGS 1984
Date Saved: 9/09/2026
Client: Lithium Plus Minerals Ltd Pty
Mapper: Maria.Reyescampos

DATA SOURCE

Topographic data: OSM
Project data: Client, EcOz
Imagery: NTLIS

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Layout: Figure 1-2. Map of modelled GDE's within the Study Area as per the BOM GDE Atlas

Figure 1-2. Map of modelled GDE's within the Study Area as per the BOM GDE Atlas

2 GDE MAPPING

The study area is dominated by gentle rises and side-slopes supporting open Eucalypt woodland. These are interspersed with drainage systems occurring between low hills and rises, which typically support mixed-species open forest, and broader plains supporting Eucalypt woodland and open forest.Because no regional dataset exists that directly maps terrestrial groundwater dependence, the assessment undertaken in this report uses persistent late dry-season Normalised Difference Moisture Index (NDMI) as a landscape-scale indicator of vegetation moisture status. Persistent greenness during the late dry season is interpreted as an indicator that vegetation may have access to a reliable water source beyond that expected from seasonal rainfall storage in the upper soil horizons alone. This additional water source may include groundwater, but may also reflect deep soil moisture, a perched aquifer or other hydrological processes. Accordingly, late dry-season (August to September) NDMI is used as a landscape-scale screening tool to identify areas warranting further investigation, rather than as direct evidence of groundwater dependence.

Potential terrestrial GDEs within the modelled groundwater drawdown contours were identified using a multi-year assessment of late dry-season vegetation moisture derived from Sentinel-2 imagery processed within the Google Earth Engine platform. Surface reflectance imagery acquired annually in October (2018 to 2025, which is the breadth of Sentinel-2 data availability) was selected to coincide with the end of the dry season, when vegetation moisture across the Top End is typically at its annual minimum. At this time of year, vegetation with access to persistent water sources – including groundwater – is more likely to maintain elevated canopy moisture relative to the surrounding landscape. Remote-sensing approaches have been proven useful for identifying potential terrestrial GDEs using vegetation moisture indices and multi-temporal satellite imagery (Brim Box et al. 2022, Fildes et al. 2023, Kilgour and Dixon-Jain 2024).

The Normalised Difference Moisture Index (NDMI) is a dimensionless spectral index ranging theoretically from -1 to 1 that provides a relative measure of vegetation canopy moisture using the near-infrared and short-wave infrared bands of Sentinel-2 imagery. Higher NDMI values indicate greater vegetation water content, while lower values indicate drier or more moisture-stressed vegetation. By the end of the dry season in the Top End, vegetation with continued access to reliable moisture sources – including shallow groundwater – typically maintains higher NDMI values than the surrounding landscape, allowing potential terrestrial GDEs to be identified.

For each year between 2018 and 2025, cloud and cloud-shadow affected pixels were removed from Sentinel-2 Level-2A surface reflectance imagery before calculating the NDMI using the near-infrared (Band 8, NIR) and short-wave infrared (Band 11, SWIR) spectral bands as:

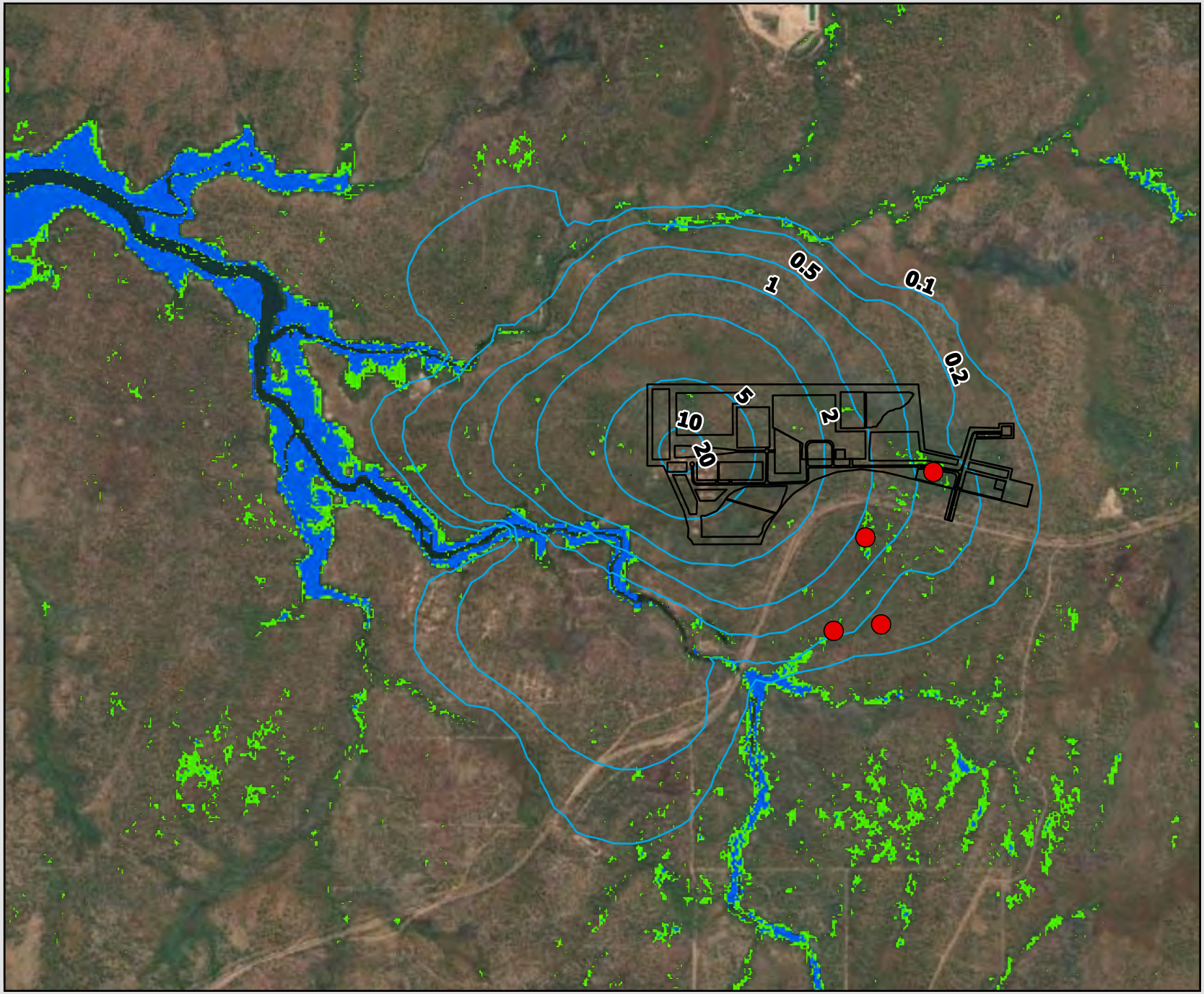
(Band 8 - Band 11) divided by (Band 8 + Band 11)

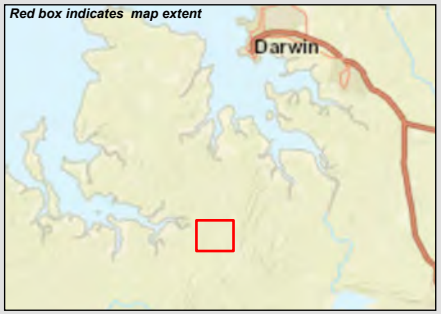
NDMI was produced as a 10 m spatial resolution raster, allowing relatively small areas of persistent vegetation moisture to be identified across the study area. Annual October NDMI images were then combined to produce a median late dry-season NDMI composite across the time series. The use of a multi-year median reduces the influence of interannual variability in seasonal rainfall, image acquisition conditions and short-term vegetation responses, providing a more robust representation of persistent vegetation moisture.

The median NDMI image was classified into three categories: NDMI values below 0.05, values between 0.05 and 0.15, and values greater than or equal to 0.15. NDMI is widely used as an indicator of vegetation moisture condition, and temporal patterns in vegetation moisture and greenness have been used in remote-sensing assessments to identify vegetation potentially dependent on groundwater. However, there are no generally applicable NDMI thresholds that distinguish groundwater-dependent from non-groundwater-dependent vegetation, as spectral responses vary with vegetation composition, soil and hydrological conditions and other landscape characteristics.

Accordingly, the thresholds adopted for this assessment are study-specific screening values rather than established ecological thresholds for groundwater dependence. They were selected based on examination of the distribution and spatial pattern of late dry-season NDMI across the study area. A value of 0.05 was adopted as a conservative lower threshold to capture vegetation exhibiting comparatively elevated late dry-season moisture, while a value of 0.15 was used to distinguish the most pronounced areas of persistent vegetation

moisture and prioritise these areas for field investigation. The thresholds therefore provide a means of identifying relative moisture anomalies within the local landscape rather than determining whether vegetation is groundwater dependent.





Legend

- Mine site design
- Drawdown Contours Year 5

October median NDMI

- 0.051 - 0.15
- 0.151 - 1
- Sites surveyed

0 250 500
Metres

MAP INFORMATION
Scale: 1:22,000 @ A4
Projection: WGS 1984
Date Saved: 9/09/2026
Client: Lithium Plus Minerals Ltd Pty
Mapper: Maria.Reyescampos
DATA SOURCE
Topographic data: OSM
Project data: Client, EcOz
Imagery: NTLIS

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Layout: Figure 2-1. Map of classified NDMI in relation to drawdown extents

Figure 2-1. Map of classified NDMI in relation to drawdown extents

3 GROUND-TRUTHING

3.1 Methodology

The NDMI imagery was assessed alongside the predicted groundwater drawdown contours and North Australian Fire Information (NAFI) fire scar mapping (May 2026) to identify potential terrestrial GDEs within the projected drawdown impact area.

The contours for Year 6 of the groundwater drawdown model were adopted because they represent the maximum predicted extent of groundwater drawdown (noting that Year 5 has the deepest drawdown in the vicinity of the mine). As explained in Section 2, potential GDEs were identified as areas exhibiting NDMI values greater than 0.15 relative to the surrounding vegetation. Riparian vegetation associated with mapped drainage lines was excluded from this assessment (see Section 1.3.1 for justification). Recent fire scar data were included to distinguish elevated NDMI responses associated with persistent vegetation moisture from those potentially influenced by recent fire history.

The remaining non-riparian vegetation patches were assessed within the 0.5 m drawdown contour. This is a conservative drawdown depth that was chosen on the assumption that a 0.2 m drawdown would likely fall within normal seasonal variability and that a 1 m contour would likely not. The four largest and most distinct patches within the predicted 0.5 m drawdown extents were selected for field verification, because they represented the highest likelihood locations for terrestrial GDEs within the study area. These potential GDE sites were designated VS.01 to VS.04 – see Figure 2-1 for locations.

From baseline and supplementary ecological surveys undertaken by EcOz for the project in 2023 and 2024, there is an established understanding of the vegetation communities within the study area. The existing datasets from these surveys were supplemented by targeted inspections of the abovementioned potential GDE sites on 5 July 2026, to determine whether they exhibited characteristics consistent with groundwater dependence. Field assessments at each site were standardised to Level 5 of the National Vegetation Information System (NVIS) and undertaken in accordance with the *Northern Territory Guidelines and Field Methodology for Vegetation Survey and Mapping* (Brocklehurst et al. 2007). Assessments considered vegetation composition and condition, landform, soil characteristics indicative of prolonged saturation, evidence of groundwater discharge (including seepage, springs and permanent surface water), and other ecological and geomorphic indicators of groundwater dependence. A representative photograph of each site is provided in Figure 3-2.

3.2 Results

The four vegetation sites were all situated within, or on the margins of, shallow drainage depressions where localised surface water accumulation and prolonged soil moisture would be expected following rainfall. Several sites supported a distinct vegetation assemblage and substantially denser midstorey than the surrounding *Eucalyptus*-dominated woodland. NAFI fire scar mapping indicated these areas have experienced less frequent burning in recent years than the surrounding landscape. This pattern is consistent with the comparatively moist conditions and denser vegetation within these drainage depressions reducing their susceptibility to fire.

VS.01 and VS.02 were the southernmost sites, located 200 m apart at the base of rocky slopes, on opposite sides of a broad shallow drainage depression. Both sites shared similar landform positions, with the patch bounded upslope by the lower edges of the rocky slopes and downslope by the open, grassed drainage.

VS.01 comprised *Eucalyptus*-dominated woodland with a dense understorey of *Pandanus spiralis* and *Lophostemon lactifluus*, and midstorey dominated by *Petalostigma pubescens*. VS.02 comprised a mixed *Eucalyptus/Corymbia* woodland with sparser midstorey because of recent fire, and an understorey dominated by *Lophostemon lactifluus.* The upper soil profile at both sites were slightly damp at the time of survey.

VS.03 represented the largest and most distinct vegetation patch identified during the desktop assessment. The site comprised a broad, gently sloping drainage depression between low stony rises, supporting a

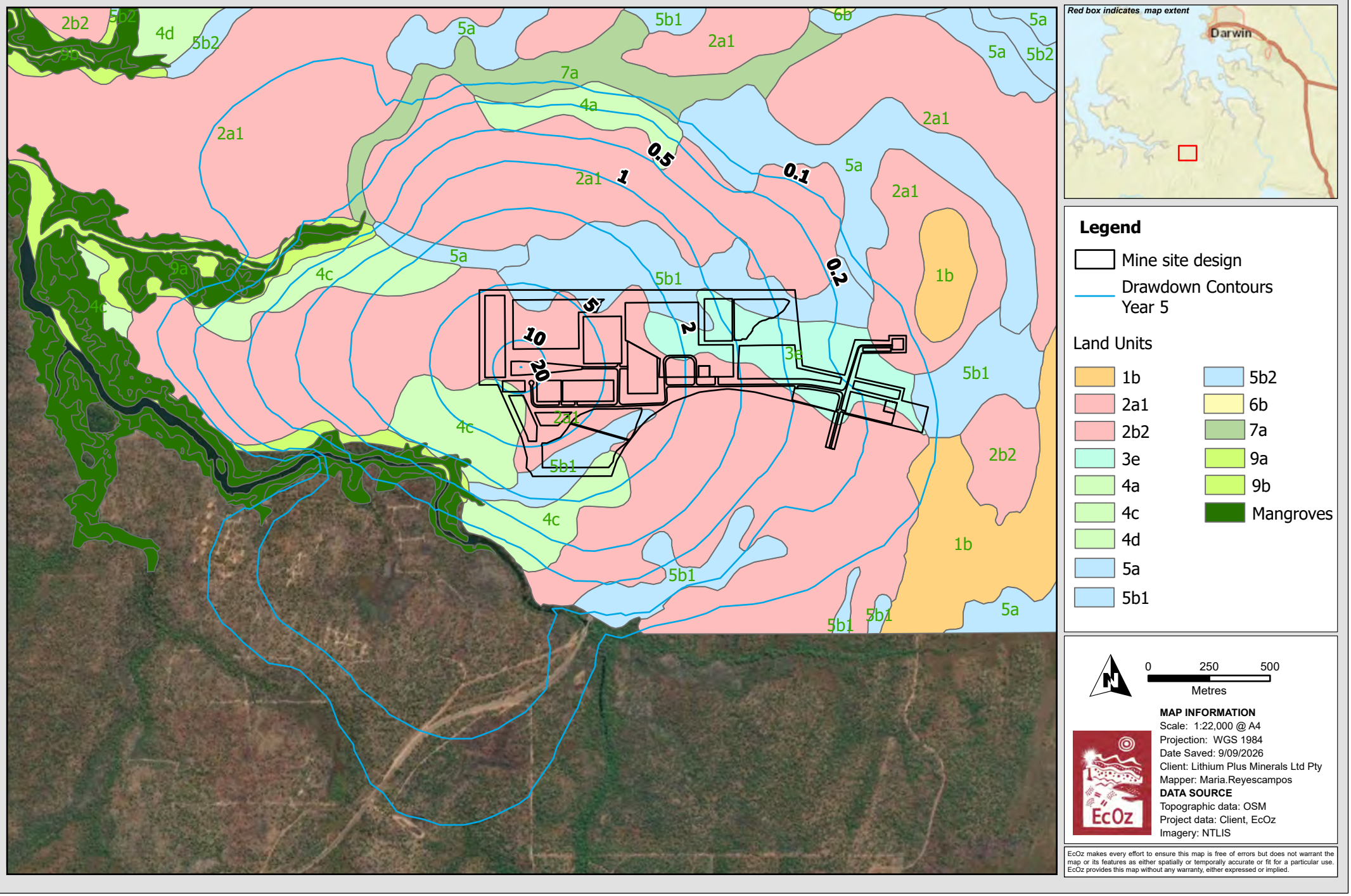
Corymbia-dominated woodland with a dense *Pandanus spiralis* midstory which included *Banksia dentata*, *Lophostemon lactifluus* and other species associated with seasonally-wetter environments. The upper soil profile was damp despite the assessment being undertaken in the middle of the dry season. In contrast, surface soils within the adjacent *Eucalyptus miniata*-dominated woodland were dry, indicating greater persistence of soil moisture within the drainage depression.

VS.04 was located on the northern side of Fog Bay Road, within a different drainage system than the other three sites. The site occupied a shallow drainage depression between adjacent slopes that opened onto a broader floodplain. Vegetation comprised *Erythrophleum chlorostachys*-dominated woodland, with *Corymbia polycarpa* and *Xanthostemon paradoxus* also present in the upper stratum. The relatively open midstorey comprised *Lophostemon lactifluus*, *Livistona humilis* and *Xanthostemon paradoxus*. *Pandanus spiralis* and *Banksia dentata* were also present, but at lower densities. The site had experienced recent fire in some areas; however, unburnt areas supported a moderately-dense grassy understorey similar to that of the adjacent floodplain, with *Lophostemon lactifluus* and recruitment of other midstorey species present.

Although the vegetation structure and composition of the four patches differed from the surrounding landscape, field investigations found no evidence to indicate that these sites were groundwater dependent. All four sites were associated with shallow surface-drainage depressions, and no seepage, permanent surface water, saturated soils, soil characteristics indicative of prolonged saturation, or vegetation communities strongly indicative of groundwater dependence were observed. Instead, the landscape position and field characteristics of the sites were consistent with localised accumulation of surface water following rainfall and greater persistence of soil moisture than in the surrounding, better-drained woodland.

These sites represented the largest and most distinct high-NDMI, non-riparian vegetation patches identified within the predicted drawdown extent and were therefore considered the highest-likelihood candidates for terrestrial GDEs. They were also considered representative of the smaller and less distinct patches exhibiting similar remotely sensed characteristics elsewhere within the study area. The elevated NDMI response, together with the observed vegetation composition and structure, landscape position and fire history, is therefore interpreted as reflecting localised surface-water accumulation and prolonged retention of soil moisture within shallow drainage depressions, rather than groundwater dependence.

Based on the desktop assessment, remote-sensing analysis and field investigations, no terrestrial GDEs were identified within the study area.



Path: Z:\01 EcOz_Documents\05 EcOz M-Files GIS\2025\EZ25048 - Lithium Plus Lei SER\1. Project Files\2. Report Maps\GDE Mapping_NA_260602.aprx
Layout: Figure 3-1. Map of land units and groundwater drawdown contours for Year 5

Figure 3-1. Map of land units and groundwater drawdown contours for Year 5

VS.01	VS.02
	
VS.03	**VS.04**
	

Figure 3-2. Representative images of surveyed patches

4 MONITORING PLAN

Potential impacts of groundwater drawdown on terrestrial GDEs will be monitored using a Before-After-Control-Impact (BACI) design based on annual late dry-season NDMI values derived from Sentinel-2 imagery. The monitoring program will use two parallel approaches to compare temporal changes in vegetation moisture.

The first approach will compare temporal changes in vegetation moisture within potential GDEs in the modelled groundwater drawdown cone, with those in analogous potential GDE vegetation outside the drawdown cone. The second approach will compare temporal changes in vegetation moisture across all undisturbed areas of the drawdown cone with an analogous area to the north-west of the drawdown cone.

This section provides a demonstration of how the monitoring plan could be implemented. Actual control and impact sites should be selected based upon the mine footprint.

4.1 GDE monitoring

4.1.1 Identification of control and impact sites

Potential GDEs within 5 km of the drawdown cone should be used as control to minimise any geographic variability in GDE attributes. NDMI mapping suggests that there are potential sites to the north, south-west and south-east of the drawdown cone within 5 km.

As a demonstration, potential GDE monitoring polygons were delineated from the 2018-2025 median October NDMI raster data as potential fixed monitoring units throughout the program. Using fixed polygons ensures that NDMI is extracted from the same spatial footprint each monitoring year. Polygons within the modelled drawdown cone are designated as impact sites, while comparable polygons outside the cone are designated as control sites. Control sites should be selected to match the impact sites as close as practicable in vegetation composition and structure, and drainage setting. The impact and control sites are designed to remain the same each year. Field surveys should be conducted to confirm the vegetation composition and structure of these potential GDEs.

The before-impact period will comprise annual October NDMI values from 2018 to 2025 (or until groundwater drawdown commences). For each year, cloud- and cloud shadow-affected pixels will be removed from Sentinel-2 Level 2A surface reflectance imagery before calculating NDMI. A median October NDMI composite will be produced for each year. NDMI pixel values should be extracted for each pixel within each fixed control and impact polygon, and then the mean and median NDMI for each polygon should be calculated. All image processing, cloud masking, NDMI calculation, polygon extraction and statistical analyses should be undertaken using the same workflow throughout the monitoring program to ensure methodological consistency among years.

An illustrative assessment of six potential impact polygons and six potential control polygons demonstrate that both groups exhibit comparable interannual variation in October NDMI during the pre-impact period (Figure 4-1). Although individual polygons display variability among years, the overall temporal patterns are similar between the impact and control groups, indicating that suitable control sites can be identified for the BACI analysis. These candidate impact and control sites are mapped in Figure 4-2.

4.1.2 Commencement of groundwater drawdown

Following the commencement of groundwater drawdown, the same analysis should be repeated using October Sentinel-2 imagery. Monitoring metrics will include the mean, median and variability within each polygon. The principal BACI comparison will assess whether the change in median NDMI between the before- and after-impact periods differs between impact and control sites.

A potential drawdown-related response would be indicated where NDMI declines within the drawdown cone relative to both the site-specific pre-impact baseline and the contemporaneous response observed at matched control sites. As a result, the analysis focuses on the interaction between monitoring period (before and after

drawdown) and exposure group (within and outside the drawdown cone), rather than interpreting a decline at an impact site in isolation.

The analysis will use a repeated-measures mixed-effects linear model to account for annual observations being repeatedly collected from the same monitoring polygons. Median NDMI will be the response variable, with monitoring period (before/after), treatment (control/ impact) and their interaction included as fixed effects and monitoring polygon included as a random effect. The BACI model will take the general form:

NDMI = monitoring period + treatment + monitoring period × treatment

The monitoring period × treatment interaction provides the primary statistical test of a groundwater-drawdown effect. A statistically-significant negative interaction ($p < 0.05$) would indicate that vegetation moisture within the drawdown cone declined more following groundwater drawdown than would be expected from natural interannual variation observed at the control sites. Effect sizes and 95% confidence intervals should also be reported to quantify the magnitude of any observed response.

Impact polygons may be further grouped by modelled drawdown zone for descriptive reporting and interpretation. However, the primary BACI test will remain a comparison between polygons inside and outside the predicted drawdown cone. Results can be presented for each drawdown zone to assess whether the magnitude of any observed change increases with predicted (or actual) drawdown.

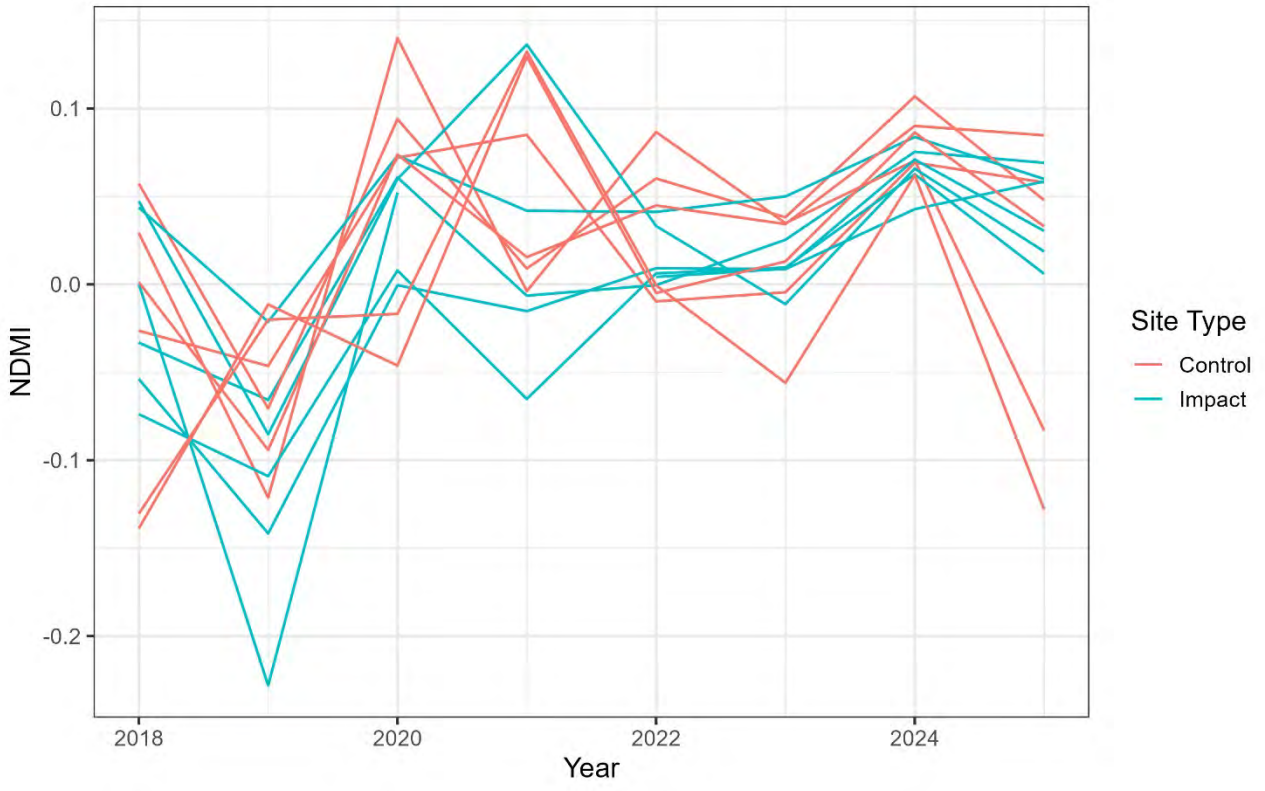
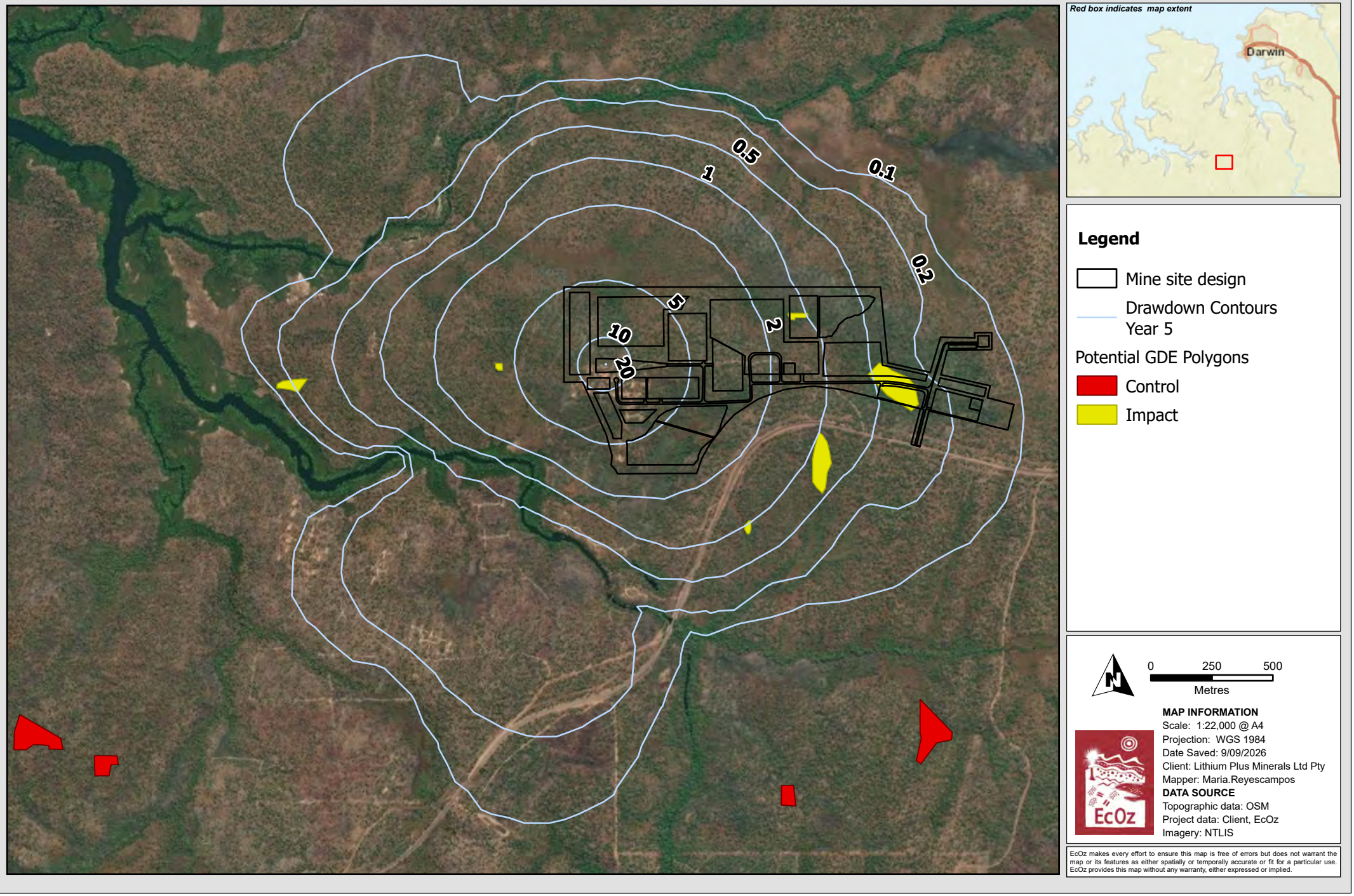


Figure 4-1. Graph of October NDMI from 2018 to 2025 of six candidate control and six impact polygons



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Layout: Figure 4-2. Map of potential control and impact GDE polygons in relation to the drawdown contours

Figure 4-2. Map of potential control and impact GDE polygons in relation to the drawdown contours

4.2 Landscape-scale monitoring

In addition to the BACI assessment of selected potential GDE monitoring sites, annual landscape-scale monitoring of vegetation moisture should be undertaken across the entire, undisturbed modelled groundwater drawdown cone. This assessment is intended to identify broad spatial patterns of vegetation drying that may not be detected through fixed monitoring sites alone and provides a complementary line of evidence for assessing potential groundwater drawdown impacts.

4.2.1 Identification of the reference area

A comparable reference area will be established outside the predicted influence of groundwater drawdown to provide a basis for interpreting observed changes within the drawdown cone. The reference area should comprise similar landforms, vegetation communities and climatic conditions to the impact area and be within 5 km to ensure comparable rainfall and seasonal conditions. An area to the north-west of the drawdown cone is likely to be similarly positioned in the landscape with relatively similar vegetation communities.

4.2.2 NDMI monitoring methodology and interpretation

Using the same annual October Sentinel-2 imagery and processing methodology adopted for the BACI assessment, NDMI will be calculated across the full extent of the maximum drawdown cone and a comparable reference area located outside the predicted influence of groundwater drawdown.

Annual NDMI rasters will be compared with the 2018 to 2025 baseline to quantify changes in vegetation moisture throughout the landscape. Spatial outputs will include annual NDMI maps, NDMI anomaly maps (current NDMI relative to the baseline median), and maps identifying areas exhibiting sustained reductions in late dry-season vegetation moisture. These outputs will allow visual identification of spatial patterns and potential hotspots of vegetation change across the entire study area.

Summary statistics – including mean, median and percentile NDMI values – may be calculated for the entire drawdown cone and reference area, as well as for individual modelled drawdown zones. These summaries provide a broad indication of whether vegetation moisture across the impact area is changing relative to the surrounding landscape. Because the assessment is undertaken at the landscape scale and does not involve independent replicated monitoring units, it should be interpreted as a surveillance and screening tool rather than a formal statistical test.

4.2.3 Investigation of potential impact areas

Areas exhibiting persistent or spatially coherent declines in NDMI relative to both the baseline period and the reference area should be investigated further through targeted interpretation of aerial imagery, review of rainfall and fire history, groundwater levels and field survey. This approach ensures that the monitoring program can detect unexpected vegetation responses across the entire drawdown cone – including areas of savanna woodland or other vegetation types that were not initially identified as potential GDEs.

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