Biota Environmental Sciences

Winu Project Infiltration Pond Impact Assessment

Prepared for

Rio Tinto Winu Pty Ltd

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Winu Project Infiltration Pond EIA

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1.0 Executive Summary

Rio Tinto Winu Pty Limited (RTW) plans to develop a new copper-gold mine, referred to as the Winu Project, approximately 320 km east of Port Hedland in the Pilbara region of Western Australia, within both the Nyangumarta and Martu Peoples' Native Title Determination Areas.

The project involves mine pit dewatering and surplus water management, which will involve controlled discharge of excess water to a designated infiltration area. Biota Environmental Sciences (Biota) was commissioned by RTW to provide an impact assessment of the proposed infiltration area, to primarily assess the potential impact to vegetation and flora from water table mounding associated with the proposed discharge.

Groundwater mounding and surface water expression is a challenge associated with managed recharge in mining, particularly where it can impact sensitive ecosystems. Apart from the direct ground disturbance impacts from land clearing for construction of infiltration infrastructure such as infiltration ponds or bore fields, other potential indirect and surrounding impacts associated with water table mounding include changes to vegetation structure, increased abundance of weeds, plant decline from waterlogging stress and salinisation.

Strategies considered for disposing of surplus water include:

1) Discharge into Managed Aquifer Recharge (MAR) bore field nominally consisting of 15 injection sites into the deeper-lying sandstone aquifer (partly saturated); and
2) The construction of two large infiltration ponds in the surficial sand (currently unsaturated).

Reinjection (MAR) Bore field

Based on the worst-case scenario (Life of Mine P90 surplus volume estimates), groundwater mounding associated with injection is predicted to not reach the surficial sand aquifer, even during the peak injection year (Year 9), with depth to water remaining well below the base of the surficial sand aquifer, not exceeding 35 metres below ground level (mbgl).

The literature review has found that the expected maximum rooting depth for vegetation of the study area (as described in Section 2.1) is approximately 10 mbgl, and as such no vegetation or individual plant (tree) species within the Project area will be influenced by groundwater mounding at this extent and depth.

Other groundwater dependent ecosystems, such as subterranean habitats, were considered within this assessment. Recent studies (Biota 2020, Biota 2022) have indicated that potential impacts on subterranean fauna are not considered significant due to the lack of evidence for either troglofaunal or stygofauna within the development envelope and the low likelihood of significant habitat for either ecological group being present.

Infiltration Pond

Direct Impact
Direct ground disturbance for pond construction is expected to clear 18.7 ha of native vegetation, comprising 5.4 ha of P1 vegetation and 13.3 ha of P2 vegetation.

There will be no direct impact to any recorded sites of significant flora. The entire direct impact area (18.7 ha) represents the 'Shrub and Spinifex on Sandplain' fauna habitat, which is associated with significant fauna species such as the Bilby and Brush-tailed Mulgara. Given that there is over 34,400 ha of this habitat type mapped within the surrounding area (Biota 2025a), the direct impact to the habitat from clearing for the construction of the ponds represents a very small proportion (0.05%) of the known local extent.

Indirect Impacts
The model developed to predict groundwater mounding outcomes looked at the 'worst-case scenario', using the total life of mine P90 surplus volume estimate from the project water balance (47.3GL) and the peak surplus volumes estimated for Year 9 (4.0GL). The predicted extent of the groundwater mounding resulting from the infiltration ponds includes:

- 14.6 ha within an area where the water table is less than 1 m from the surface;
- 10.9 ha within an area where the water table is 1-2 m from the surface;
- 32.0 ha within an area where the water table is 2-5 m from the surface; and
- 101.9 ha within an area where the water table is 5-10 m from the surface.

Three vegetation types (P1, P2, and D2) occur within the predicted 10 m mounding zones, and these vegetation types may be affected by indirect impacts due to the predicted groundwater mounding:

- Within the P2 vegetation type, 2 ha were within areas where groundwater will be less than 1 m from the surface and 26.2 ha is located within areas where groundwater is modelled to be at least 5 m from the surface.
- Within the P1 vegetation type, 1.2 ha was mapped within areas where groundwater will be less than 1 m from the surface and 13.9 ha is located within areas where groundwater is modelled to be at least 5 m from the surface.
- A very small portion of the D2 vegetation type is within the 10m mounding extent (1.8 ha), but all in areas where mounding is modelled to be greater than 7 m from the surface.
- The D1 vegetation represents 1.1 ha of the study area and occurs where water table mounding is modelled to be more than 30 m from the surface.

Further information on the potential impacts for flora, vegetation and fauna habitats across various mounding contours is provided in Section 7.4 (Table 7.1 and Table 7.2).

Two habitat types were recorded within the study area, 'Shrub and spinifex on sandplain' and 'Inland sand dunes'. Of these two habitats, only 'Shrub and spinifex on sandplain' habitat was recorded within predicted groundwater mounding contours that were less than 2 mbgl. The potential indirect impact will likely affect less than 0.1% of the known mapped extent of this habitat type within the surrounding area.

Most flora species from all potentially affected vegetation types are of growth forms with relatively shallow root systems and are therefore unlikely to be significantly affected by groundwater mounding.

A small number of tall shrub and tree species associated with the P1 and P2 vegetation types, which are within the 3.1 ha area where the groundwater mounding may occur less than 1 m from the surface, are most vulnerable. The majority of these tall shrub/tree species were recorded in very low abundance (less than 1% cover), with only *Acacia ancistrocarpa* slightly more abundant (7-15% cover), therefore putting a relatively higher number of *Acacia ancistrocarpa* individuals at risk from mounding impacts. However, an understanding of *Acacia ancistrocarpa* and its dimorphic root system has proven this species can adapt well to hydrological change.

A change in the characteristics of the ecohydrological unit is also likely to occur within the small area of mounding extent near the surface, with the site transitioning from EHU 5 (Lowland sand plains) to EHU 9 (Lowland receiving areas). Consideration of the ecohydrological characteristics and vegetation composition of EHU 9 may provide a useful model for management of the study area during the infiltration period.

Two conservation significant flora species are located within the study area, but at locations where the predicted groundwater mounding is greater than 7 m from the surface. *Goodenia hartiana* (P2) and *Indigofera ammobia* (P3) are both described as low shrubs, with an expected shallow root depth that is unlikely to exceed 1-2 m. Given that both these species are relatively shallow rooted, it is unlikely that these species would be at risk from the predicted mounding.

Summary

Overall, it is likely that the final operating strategy (in development) for managing surplus water, will include a combination of both reinjection MAR bores (as the primary discharging method), as well as infiltration ponds to manage any excess that may occur (i.e. emergencies, unexpected shutdowns). Based on this combined scenario, the MAR bore field will maintain groundwater mounding well below 30 mbgl. Apart from the direct impact from clearing to construct the infiltration infrastructure (ponds and water bores etc.) there will be no indirect impacts to environmental values from groundwater mounding.

2.0 Introduction

Rio Tinto Winu Pty Limited (RTW) plans to develop a new copper-gold mine, referred to as the Winu Project, approximately 320 km east of Port Hedland in the Pilbara region of Western Australia, within both the Nyangumarta and Martu Peoples' Native Title Determination Areas. (Figure 2.1).

The project involves mine pit dewatering and surplus water management, which will involve controlled discharge of excess water to a designated infiltration area. Biota Environmental Sciences (Biota) was commissioned by RTW to provide an impact assessment of the proposed infiltration area, to assess the potential impact to environmental values (primarily vegetation and flora) from water table mounding associated with the proposed infiltration strategy.

2.1 Spatial Scope of the Project

The Winu project area comprises the following spatial elements (Figure 2.1):

- The development envelope (DE) represents approximately 23,650 hectares (ha) (as of 30 April 2025).
- The survey area represents the consolidated vegetation and fauna habitat survey extent across the broader Winu Project and covers approximately 44,478 ha. While not all survey areas are part of the DE, all spatial data collected during these surveys are relevant to the Project and its impact assessment. A list of previous surveys relevant to this report are provided in Section 2.3.
- The study area represents the zone of predicted groundwater mounding extent (modelled to the 35 mbgl contour line for the infiltration pond scenario – refer to Section 5.4.2.1) and occupies an area of approximately 532 ha surrounding the Winu infiltration area. The Winu infiltration area is not a bounded area, but rather a general location for the proposed infiltration strategy.

2.2 Study Objectives

The main objective of this study was to undertake an impact assessment of proposed infiltration strategies and their potential impact on environmental values, primarily vegetation and flora, specifically to:

- review vegetation, flora and fauna surveys and technical studies of the study area and surrounds;
- review project hydrological studies, including modelling of predicted infiltration mound extent within the study area;
- assess the species composition of vegetation within the study area and investigate key species (or groups) within the potentially affected vegetation, to determine known responses to long-term saturation during controlled infiltration, as well as responses to a sudden decline in groundwater levels (i.e. following cessation of infiltration, at closure);
- assess other potential indirect impacts that may result from long-term saturation during controlled infiltration; and

- quantify the potential impacts to environmental values within the study area.

The review and impact assessment has been undertaken with reference to EPA guidance:

- EPA Statement of environmental principles, factors, objectives and aims of EIA Environmental Protection Authority April 2023 (EPA 2023).
- EPA Instructions: How to prepare an environmental review document Environmental Protection Authority March 2024 (EPA 2024).
- Technical Guidance: Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016a); and
- Environmental Factor Guideline: Flora and Vegetation (EPA 2016b).

2.3 Previous Studies

The vegetation and flora data consolidated in this report were collated from multiple studies undertaken across the Winu Project. Key studies included:

- Paterson Flora, Vegetation and Fauna Habitat Survey (Astron 2018);
- Paterson Reconnaissance Flora, Vegetation and Fauna Survey (Astron 2019a);
- Paterson Road Corridor Reconnaissance Flora and Vegetation and Level 1 Fauna Survey (Astron 2019b);
- Winu Detailed Flora and Vegetation Survey Interim Report (Biota 2019);
- Winu Detailed Flora and Vegetation Survey (Biota 2021a);
- Winu Detailed Flora and Vegetation Assessment (Western Botanical 2023a); and
- Winu Consolidated detailed flora and vegetation assessment (Western Botanical 2023b, 2025).

Winu Project fauna and fauna habitat data was also used in this assessment included:

- Winu Project Bilby Abundance Study (Biota 2020);
- Winu Project Fauna Assessment (Biota 2021b);
- Winu Project Area Extension Targeted Fauna Survey (Biota 2022);
- Winu Project Bilby Population Abundance Study (Biota 2023a);
- Winu Project Water Borefield Targeted Fauna Survey (Biota 2023b);
- Winu Project Native Vegetation Clearing Permit Fauna Clearance Survey (Biota 2023c);
- Winu Biological Gap Analysis (Biota 2023d);
- Winu Terrestrial Fauna Interim Consolidation Report (Biota 2023e);
- Winu Project Bilby Population Abundance Study (Biota 2024);
- Winu Fauna Consolidation Report (Biota 2025a); and
- Winu Targeted Night Parrot Survey (Biota 2025b).
- Winu Project Stygofauna Assessment (Biota 2025c).

Groundwater and Surface Water assessments and associated data used as part of this impact assessment included:

- Winu Project Surplus Water Management PFS (Worley 2025a);

- Winu Project Area H3 Hydrogeological Assessment (Worley 2025b);
- Winu Project Operational Surface Water Management Plan Update 2023 (Worley 2024a); and
- Winu Project Water Balance (Worley 2025c).

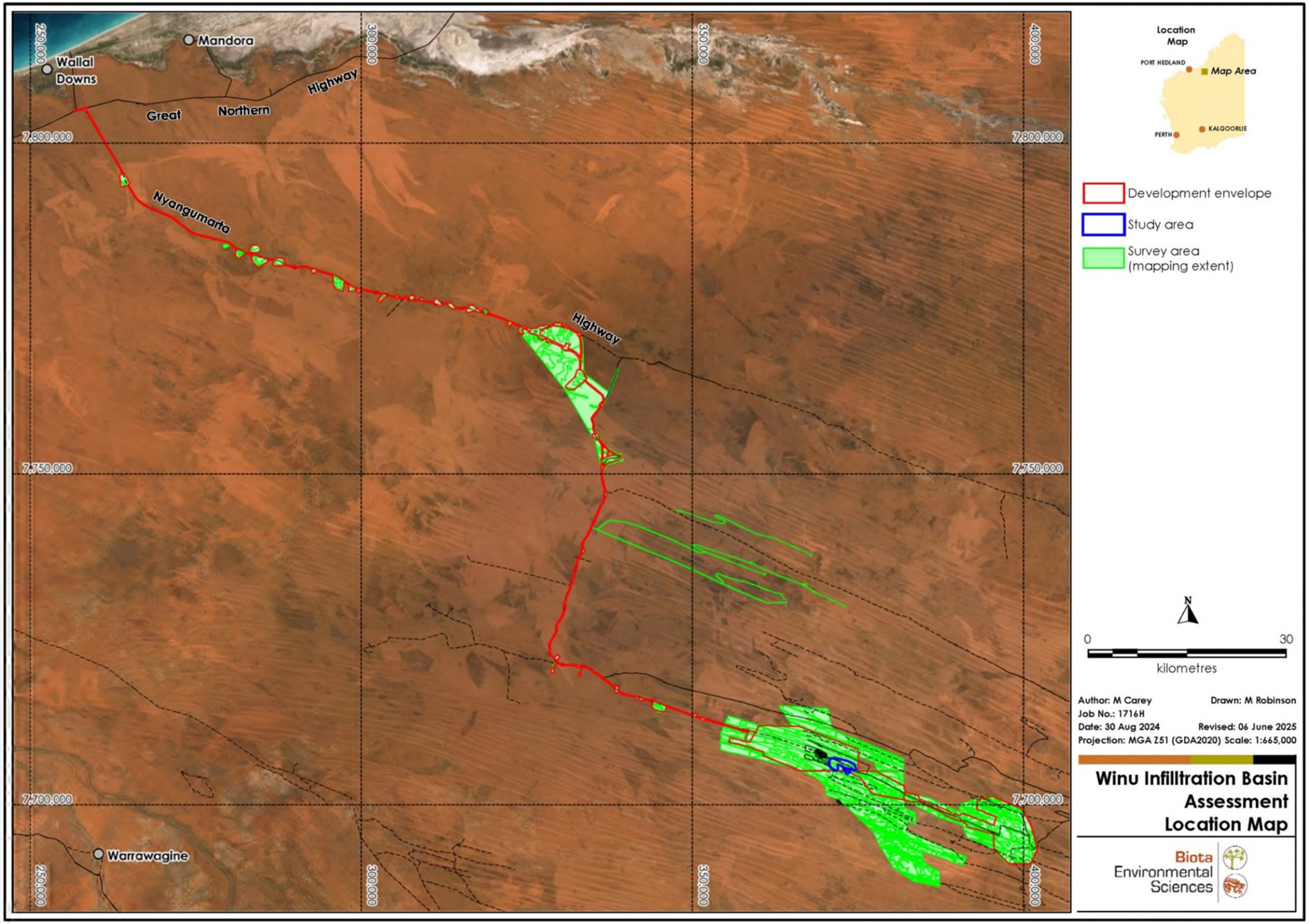

Figure 2.1: **Location of the project development envelope.**

3.0 Existing Environment

3.1 IBRA Bioregion and Subregion

The Interim Biogeographic Regionalisation of Australia (IBRA) identifies 89 bioregions across Australia (Environment Australia 2000).

The study area is located within the Great Sandy Desert IBRA bioregion and the Mackay subregion.

The Mackay subregion (18,636,695 ha) comprises the "tropical inland 'red-centre' desert and includes the 'Percival' and 'Auld' palaeoriver systems. Mainly tree steppe grading to shrub steppe in south; comprising open hummock grassland of *Triodia pungens* and *Triodia schinzii* with scattered trees of *Owenia reticulata* and bloodwood (*Corymbia* spp.), and shrubs of Acacia spp., *Grevillea wickhamii* and *G. refracta*, on Quaternary red longitudinal sand dune fields. The climate is arid tropical with summer rainfall, and monsoonal influences are apparent in the northwestern sector of this region" (Kendrick 2003).

3.2 Climate

The study area is located within the Eremaean biogeographic region, Australia's arid biome (Beard 1990 and Ebach and Murphy 2020). The area experiences desert conditions, with 12 dry months a year, summer rainfall from tropical thunderstorms and extreme evaporation rates.

Mean monthly rainfall and mean maximum and minimum temperatures (2003-2023) (Telfer Aero No. 13030, located approximately 100 km south of Winu mine) are presented in Figure 3.1.

Average annual rainfall totals 365.8 mm, with most rain falling between November and March. Tropical thunderstorms occur one to four times a year and can bring up to 120 mm of rain in one event. Outside this summer wet season, rain is often minimal for several months. Summer months also record the highest temperatures, with each month between November and February recording 12-18 days over 40 ^{o}C (Grigg 2009).

Potential evaporation (Class A pan) exceeds rainfall in every month and totals approximately 4,000 mm per year, ten-fold the annual rainfall rate (Bureau of Meteorology 2024) (Figure 3.2).

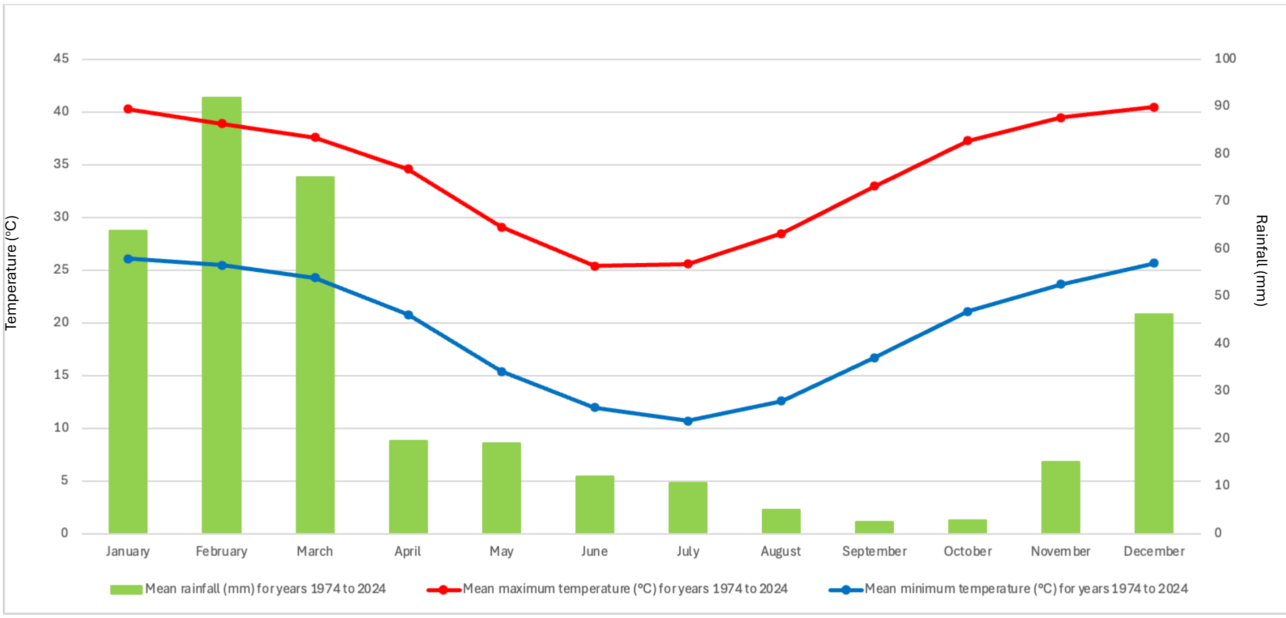

Figure 3.1: **Mean monthly rainfall and max/min temperatures (Telfer Aero Weather Station, BoM 2024).**

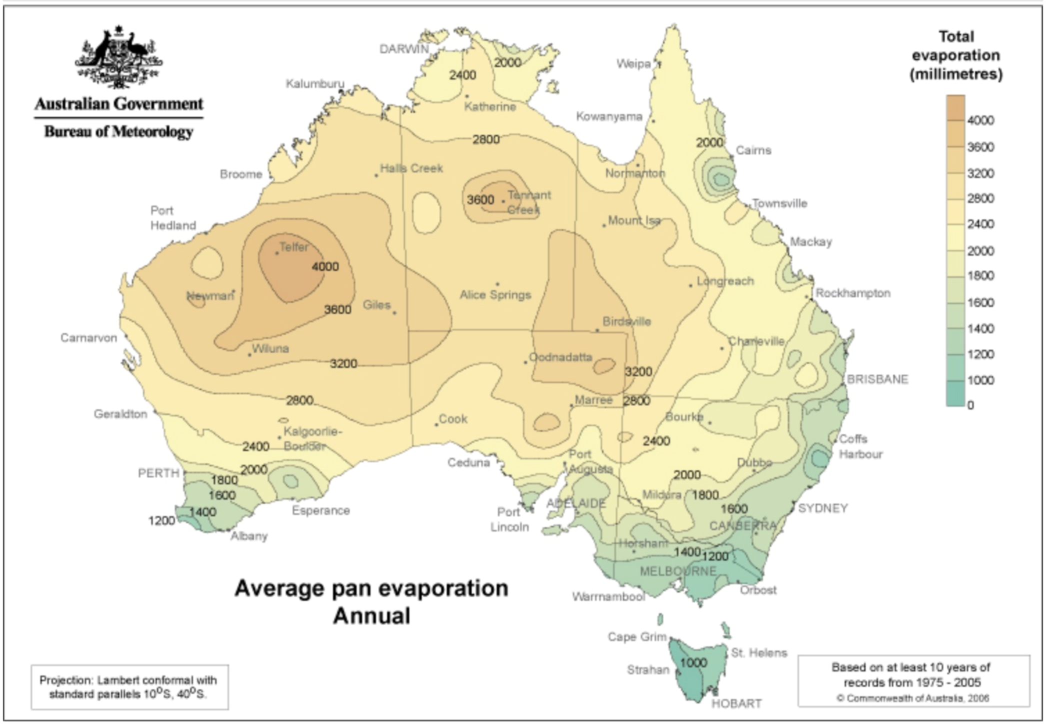

Figure 3.2: **Average annual evaporation (BoM 2024).**

3.3 Geology, Landforms and Topography

Consistent with old sedimentary basins, the geomorphology of the region comprises recent unconsolidated sediment (mostly wind-blown sand dunes and water-shifted alluvia) over thick sedimentary rocks (van Etten 2020).

The Winu deposit lies within metamorphosed sandstone, siltstone and lesser mafic rocks, which are considered correlatives of the upper Malu Formation of the Yeneena Basin and host to the large Telfer gold-copper deposit. The copper-gold mineralisation occurs in a series of lodes with strike lengths between 350 m and 750 m, northerly trends and moderate easterly dips. The host rocks are covered by at least 50 m of younger, unmineralized rocks, sand and soil (RTW 2023).

The Winu Project is located within the Great Sandy Desert, a landscape dominated by red sand dunefields overlying sandstones. The dunefields of the Great Sandy Desert are predominantly stable linear dunes with swales opening locally into sandplains. Within the study area, dunefield lineation generally trends northwest-southeast.

Among these dunefields are some small claypans and depressions. Calcrete and evaporite surfaces associated with occluded palaeodrainage systems traverse the swales and feature chains of salt lakes and salt pans. There are also exposures of ironstone gravels, isolated residual sandstone hills and some breakaways capped by laterite duricrust (Beard 1968, Beard and Webb 1974, van Etten 2020).

3.4 Land Systems

Land systems mapped and described by the Department of Primary Industries and Regional Development (DPIRD) are used to categorise zones into biophysical resources based on landform, soil and vegetation (van Vreeswyk et al. 2004). There are six land systems within the development envelope and the ‘Little Sandy’ land system covers the entire study area:

- Little Sandy: Sandplains with linear and reticulate dunes supporting shrubby spinifex grasslands. The study area is entirely within this little sandy system.

3.5 Hydrogeology

With the results from drilling programs between 2019 and 2024 the study area has been divided into seven (7) hydrostratigraphic units (HSU) based on lithology and their hydrogeological function (Worley 2025b).

The lithologies intersected at Winu, and described in Worley (2025b) comprise:

- Quaternary aeolian sands generally 5 to 10 m thick, however, can be up to 30 m thick under dunes and largely unsaturated
- Silcrete/ferricrete up to 20 m thick and largely unsaturated
- Unconfined Sandstone up to 60 m thick – partially saturated. The water table near Winu occurs around 50 to 60 mbgl, near the base of the unconfined aquifer.
    - Department of Water (DoW, 2012) describes this aquifer as the Wallal Aquifer (unconfined) groundwater resource, largely unsaturated
    - Referred to herein as the “Unconfined Sandstone aquifer’
- Permian Mudstone occurs to the west. Regional interpretations of Czarnota et al. (2009), report the depth to basement to the west of the Anketell Shelf as generally less than 250 m, whilst the interpretation by Alavi (2013) notes a depth of up to 500 m.
    - This unit pinches out to the east and is a discontinuous, low permeability confining unit (aquitard), incorporating clay, claystone, diamictite, and conglomerate (fine-grained, matrix supported) facies.
- Proterozoic metasediments include metasiltstone and metasandstone, typically thicker than 300 m, classified as a fractured rock aquifer and includes both an upper

'weathered' and lower 'fresh' (unweathered) profiles. Secondary porosity and permeability occur in the metasediments due to weathering, fracturing, and faulting.
    - Mafic intrusive units encountered at several locations are considered relatively sparsely distributed and unlikely to act as significant confining units. However, locally, they may behave as partially impermeable flow barriers and partly compartmentalise groundwater flow.
- Granitoid igneous intrusions surround Winu to the north, northeast, and south hosted within the Proterozoic metasediments. These are interpreted to act as a low permeability facies and inhibit groundwater flow in the metasediment aquifer, where present.

A conceptual cross section across the Winu area, showing the spatial configuration of the various units, is included in Figure 3.3.

3.5.1 Groundwater Depth

At the MIA, the depth to groundwater is typically greater than 50 mbgl. The upper Cenozoic stratum is typically unsaturated, with no perching shallow (less than 10 mbgl) groundwater observed (Worley 2024b). Groundwater contours indicate that the regional hydraulic gradient is 0.0016 to the north-northwest, from the MIA to the coast (Worley 2024b).

3.5.2 Groundwater Quality

Advisian (2023) describes groundwater quality as good, slightly alkaline (pH of 7.5) and moderately saline (approximately 2,500 S/cm). Groundwater inflow chemistry, as summarised in Table 3.1, is based on evaluation of 90 groundwater samples collected from 22 bores (Advisian 2023). All parameters are within typical ranges for the region.

3.5.3 Groundwater Dependent Ecosystems

Based on the groundwater dependent ecosystems (GDE) atlas, the region is considered to have a moderate to low potential for GDEs, with the nearest mapped GDE more than 20 km north of the mine area (Worley 2024b).

3.5.4 Soaks and Groundwater Dependent Vegetation

Worley (2024) noted that ephemeral soaks formed in the region are the result of surface water runoff and perching shallow groundwater. Rio Tinto (2020) conducted remote sensing analysis to identify areas of potential groundwater dependent vegetation and/or soaks surrounding the MIA. Toramah Soak, located approximately 54 km west-northwest of the study area, was the only site in the locality to record a persistently moist subsurface. Remote sensing analysis found that Toramah had healthy vegetation, with low to moderate levels of cover (Rio Tinto 2020, (Rio Tinto 2020b, Worley 2024b). No vegetation detected by remote sensing or water/moisture persistence values indicated connectivity to regional scale aquifers (Rio Tinto 2020).

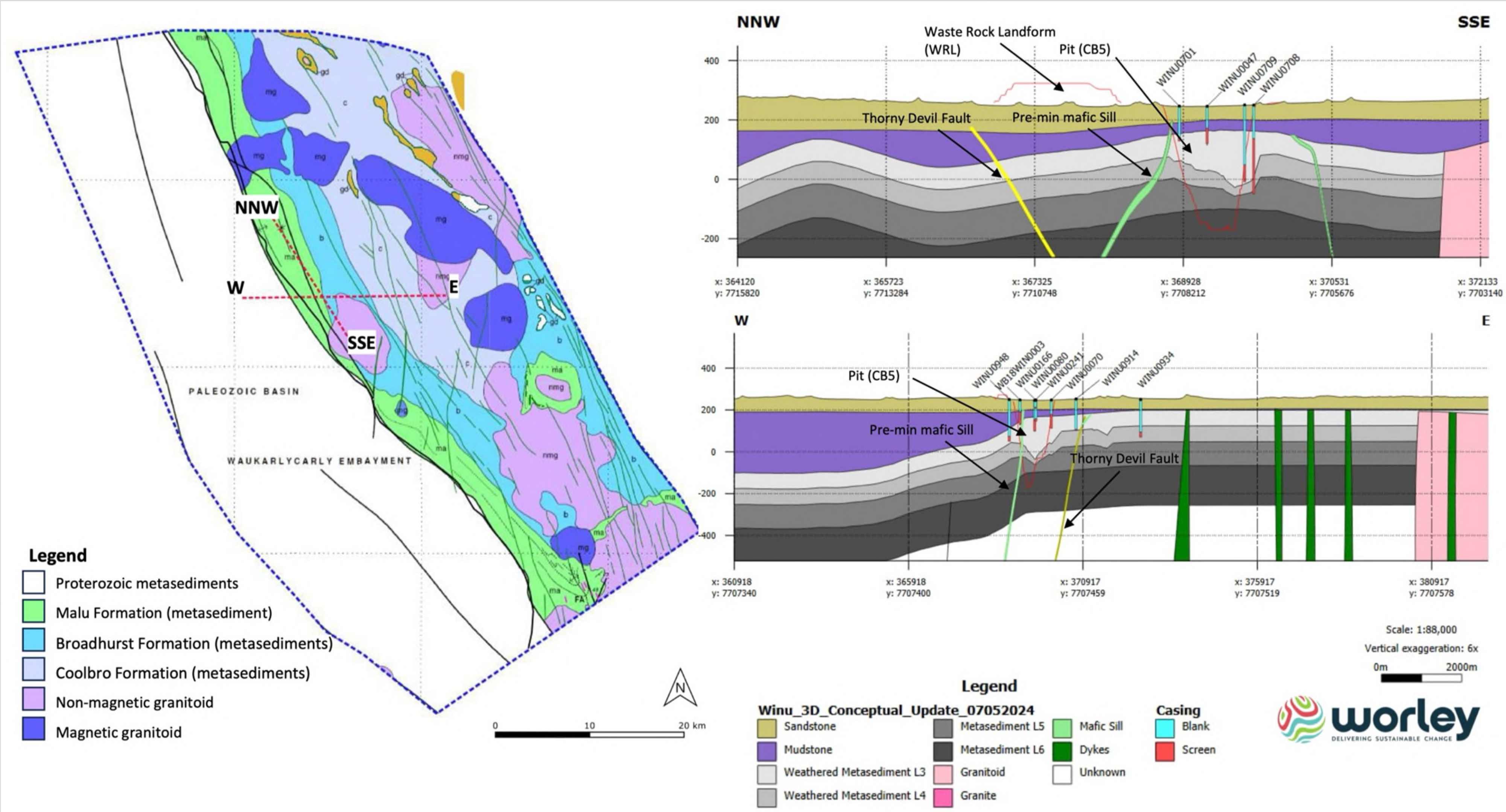

Figure 3.3: **Winu Project hydrogeological conceptualisation (source: Worley 2025b).**

Table 3.1: Summary of groundwater chemistry statistics (Source: Advisian 2023).

Parameter	Unit	25th Percentile	Average	Median (Best Estimate)	75th Percentile
Temperature	°C	25	25	25	25
pH	s.u.	7.4	7.5	7.61	7.93
Total Alkalinity	mg/L as CaCO3	90	188	119	253
Ca	mg/L	12	24	17	34
Na	mg/L	77	163	119	236
K	mg/L	6	8	8	10
Mg	mg/L	6	11	8	14
SO4	mg/L	15	49	35	68
Cl	mg/L	61	180	140	218
F	mg/L	0.3	0.5	0.4	0.5
Nitrate	mg/L as N	0.043	3.33	3.05	5.605
Nitrite	mg/L as N	0.005	0.043	0.005	0.005
Ammonia	mg/L as N	0.005	0.16	0.02	0.098
P	mg/L	0.03	0.129	0.07	0.14
Al	mg/L	0.005	0.021	0.005	0.02
Sb	mg/L	0.0001	0.0001	0.0001	0.0001
As	mg/L	0.0005	0.0015	0.0005	0.002
Ba	mg/L	-	-	-	-
B	mg/L	-	-	-	-
Cd	mg/L	0.00005	0.000051	0.00005	0.00005
Co	mg/L	-	-	-	-
Cr	mg/L	0.0005	0.0009	0.0005	0.001
Cu	mg/L	0.0005	0.0032	0.0005	0.0017
Fe	mg/L	0.025	0.115	0.025	0.025
Pb	mg/L	0.0005	0.0005	0.0005	0.0005
Mn	mg/L	0.001	0.1395	0.012	0.1665
Mo	mg/L	0.0005	0.0064	0.002	0.008
Hg	mg/L	0.00002	0.00002	0.00002	0.00002
Ni	mg/L	0.0005	0.00152	0.0005	0.002
Se	mg/L	0.005	0.005	0.005	0.005
Si	mg/L	14	19.1	18.3	27.5
Sr	mg/L	0.336	0.326	0.336	0.336
Ag	mg/L	0.000005	0.000009	0.000005	0.000005
U	mg/L	0.000025	0.00005	0.000025	0.000025
V	mg/L	-	-	-	-
Zn	mg/L	0.0025	0.0074	0.0025	0.008

- analyte not measured. Value below limit of detection. One-half the limit of detection shown.

3.6 Hydrology

The Great Sandy Desert region experiences little to no surface water runoff. There are no major surface water courses in the region and any surface water features tend to be ephemeral and sparse (V&C Semeniuk Research Group 2020, Worley 2024b). Surface water features in the vicinity of the proposal are summarised in Table 3.2. All soaks are understood to have significant cultural value and have been used by the Nyangumarta, Martu and/or other Aboriginal people for drinking water and cultural purposes.

The mine area and its surrounds include a series of depressions along interdunal corridors, each forming relatively small, individual catchments (Golder 2020). Rainfall has been observed to pond in these topographic lows, where it either evaporates or infiltrates the soil. Infrequent floods may result in inundation due to low channel grades and the internally draining interdunal depressions, however this is not expected to result in the formation of flow paths and creeks (Golder 2022). Ground cover is generally porous/ permeable and sandy, resulting in rapid infiltration, with no anticipated runoff (Golder 2022).

Table 3.2: Surface water features in the vicinity of the Winu Project (Source: Golder 2022)

Surface Water Feature	Distance from mine (km)
Winu Soak	22
Toramah Soak	54
Djimakarra Soak	45
Bulgamulgardy Soak	93
Oakover River	100
Mandora Salt Marsh Ramsar wetland area	>100
Lake Waukarlycarly	60

3.7 Vegetation and Flora

3.7.1 Beard's Regional Vegetation Mapping

Broad-scale vegetation mapping for the locality has been prepared at the 1:1,000,000 scale based on the work of J.S. Beard for the Pilbara (Beard 1975) and Great Sandy Desert (Beard 1968). The broader Winu proposal extends across five pre-European vegetation associations (Beard et al. 2013), of which only one association occurs within the study area, the 'Great Sandy Desert 134', which is described below:

> "Great Sandy Desert (134) – Mosaic. Hummock grasslands, open low tree steppe; Desert Bloodwood and Feathertop Spinifex (Triodia schinzii) on sandhills / Hummock grasslands, shrub steppe; mixed shrubs over spinifex between sandhills. Extent remaining 13,595,888 ha."

3.7.2 Vegetation in the Study Area

Several flora and vegetation surveys within the Winu survey area were undertaken between 2018-2023 by Astron Environmental Services (Astron 2018, 2019a, 2019b), Biota Environmental Sciences (Biota 2019, 2021a, 2023d) and Western Botanical (Western

Botanical 2023b, 2023a, 2025). Consolidated vegetation mapping is presented in Western Botanical (2025) and thirty vegetation types have been described and mapped within the Winu survey area. These vegetation types have been described at the association level (level V as per the National Vegetation Information System; NVIS.

Of these thirty units, four are located within the study area (vegetation type D1, D2, P1, and P2) (Table 3.3 and Figure 3.4). All four vegetation types are similar in terms of floristic composition and include the soft spinifex species *Triodia schinzii* as the dominant hummock grass (see Sections 3.7.2.1 to 3.7.2.4). The landform of D1 and D2 is broadly described as liner sand dunes, while the landforms of P1 and P2 are described as interdunal plains.

No Threatened or Priority Ecological Communities were found within the study area or more broadly within the Winu proposal survey area. Vegetation types D2 and P1 support Priority flora (see Section 3.7.3) and are considered locally significant (Biota 2021a).

No evidence of groundwater dependent vegetation has been identified during vegetation surveys (Biota 2021a). Vegetation dependence on groundwater is considered unlikely in the study area and more broadly across the survey area. The depth to groundwater exceeds 40 m within areas associated with the unconfined aquifer and 50 m within area associated with the confined aquifer (Golder 2022). The condition of all of the intact vegetation mapped within the study area was considered to be 'Excellent'[1] (Western Botanical 2023b, 2025).

Table 3.3: Vegetation types within the study area (from Western Botanical (2023b, 2025).

Landform	Vegetation Code	Vegetation Association Description	Total area surveyed (ha)	Total area in DE	Total area within indicative footprint
Linear Sand Dunes	D1	*Corymbia chippendalei* Low Open Woodland over *Triodia schinzii*	2,934.97	1951.228	716.52
	D2	*Owenia reticulata* scattered low trees over *Triodia schinzii*	3,426.52	1098.957	77.354
Interdunal Plains	P1	*Acacia platycarpa* (*Acacia tumida* var. *kulparn*) open shrubland over *Triodia schinzii*	10,594.37	6823.15	1988.896
	P2	*Acacia ancistrocarpa* tall Shrubland over *Triodia schinzii*	5,916.89	1978.025	563.398

3.7.2.1 D1 Vegetation

Vegetation type D1 (Plate 3.1) is associated with tall (approximately 20m) linear dunes (Figure 3.4), and is described as having an upper-stratum of *Corymbia chippendalei*, and occasional *Owenia reticulata*, over a mid-stratum dominated by *Acacia platycarpa*, *Acacia tumida* var. *kulparn* and *Crotalaria cunninghamii* subsp. *cunninghamii*, over a lower-stratum of *Acacia sabulosa*, *Triodia schinzii*, and *Gompholobium simplicifolium*.

Only a very small portion of the D1 is mapped within the study area (1.1 ha).

[1] Based on the ranking scale presented in the EPA Technical Guidance (EPA 2016a).

Species recorded within D1 that are associated with life forms with expected 'deep' roots (greater than 2 m), which could be affected by groundwater mounding, include:

- *Corymbia chippendalei;*
- *Owenia reticulata;*
- *Acacia platycarpa;*
- *Acacia tumida var. kulparn;*
- *Grevillea stenobotrya;* and
- *Thinicola incana*.


Plate 3.1: Typical D1 Vegetation (Biota 2021).

3.7.2.2 D2 Vegetation

Vegetation type D2 (Plate 3.2) was associated with the extensive sand dunes and swales landform (Figure 3.4), and is described as *Owenia reticulata*, *Erythrophleum arenarium*[2] scattered low trees over *Acacia platycarpa*, (*A. tumida* var. *kulparn*, *A sabulosa*, *Petalostylis cassioides*, *Grevillea stenobotrya*, *Thinicola incana*) open shrubland over *Dampiera cinerea*, *Dicrastylis doranii*, *Gompholobium simplicifolium* low open shrubland over *Triodia schinzii* open hummock grassland.

Species recorded within D2 that are associated with life forms with expected 'deep' roots (greater than 2 m), which could be affected by groundwater mounding, include:

- *Erythrophleum arenarium;*
- *Owenia reticulata;*
- *Acacia platycarpa* 'Desert Form Non-Pruinose';
- *Acacia sabulosa;*
- *Acacia tumida var. kulparn;*
- *Thinicola incana;* and
- *Grevillea stenobotrya*.

[2] Note that this was referred to as *Erythrophleum chlorostachys* in previous mapping, however a recent taxonomic revision of Australia *Erythrophleum* has been undertaken and *Erythrophleum arenarium* now recognised as the species that commonly occurs through the Great Sandy Desert (Barrett and Barrett 2023).


Plate 3.2: Typical D2 Vegetation (right image has been recently burnt) (Biota 2021).

3.7.2.3 P1 Vegetation

Vegetation type P1 (Plate 3.3) is associated with the extensive interdune sandplains landform (Figure 3.4), and is described as *Owenia reticulata*, *Erythrophleum arenarium* scattered low trees over *Acacia platycarpa* open shrubland over *Jacksonia aculeata*, *Androcalva loxophylla*, *Dicrastylis cordifolia*, *Gompholobium simplicifolium*, (*Seringia exastia*) low shrubland over *Triodia schinzii* open hummock grassland.

Species recorded within P1 that are associated with life forms with expected deep roots (greater than 2 m) include:

- *Erythrophleum arenarium;*
- *Owenia reticulata;* and
- *Acacia platycarpa* 'Desert Form Non-Pruinose'.

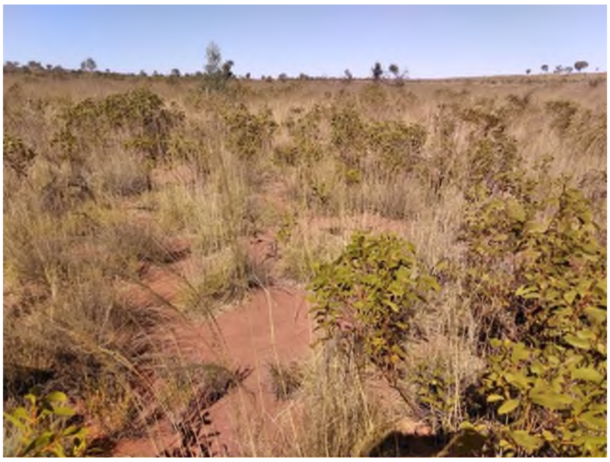


Plate 3.3: Typical P1 Vegetation (Biota 2021).

3.7.2.4 P2 Vegetation

Vegetation type P2 (Plate 3.4) is associated with the extensive interdune sandplains landform (Figure 3.4), and is described as *Owenia reticulata*, *Erythrophleum arenarium* scattered low trees over *Acacia ancistrocarpa*, (*Hakea macrocarpa*), tall shrubland over *Sorghum plumosum* var. *plumosum*, *Aristida holathera* var. *holathera*, *Amphipogon sericeus* scattered tussock grasses to very open tussock grassland over *Triodia schinzii* open hummock grassland.

Species recorded within P2 that are associated with life forms with deep roots (greater than 2 m) include:

- *Acacia ancistrocarpa;*
- *Erythrophleum arenarium;*
- *Hakea macrocarpa;* and
- *Owenia reticulata*.

Plate 3.4: Typical P2 Vegetation (Biota 2021).

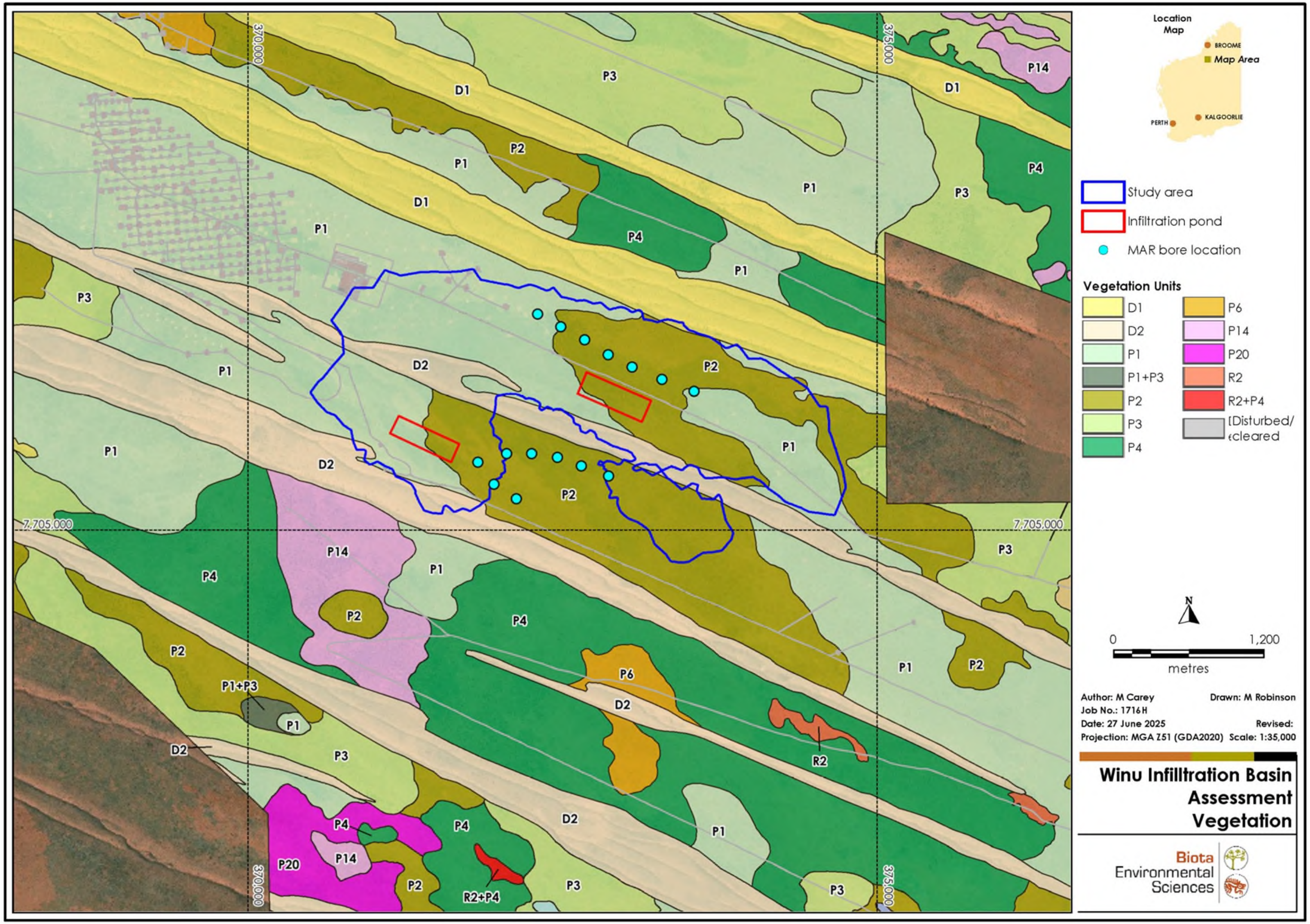

Figure 3.4: **Vegetation types of the study area and surrounds.**

3.7.3 Flora

A total of 302 native flora species were recorded within the Winu survey area, eleven of which are conservation significant (Western Botanical 2023b, 2025). Of these, two significant flora species were recorded within the study area, *Goodenia hartiana* (Priority 2) and *Indigofera ammobia* (Priority 3). Regional distributions for both species are present in Figure 3.5, Figure 3.6 and Figure 3.7.

Another priority species, *Corynotheca asperata* (P3), was recorded in small populations, typically on mid to lower slopes of sand dunes associated with the D1 and the D2 vegetation types, however none were recorded with in these vegetation types within the study area (Figure 3.7). Of those locations recorded, 44 were encountered outside the Project development envelope.

3.7.3.1 *Goodenia hartiana* (Priority 2)

This species (Figure 3.5, Plate 3.5 and Plate 3.6) is an erect to spreading, multi-stemmed perennial, herb or shrub (sub-shrub) that occurs on sand, sand dune swales, sandhills (WA Herbarium 2024). It is represented in the WA Herbarium by 26 voucher specimens from a range of almost 250 km in the Great Sandy Desert.

A total of 193 known locations of *Goodenia hartiana* (P2) were recorded within study area, from almost 6,000 records across the Project area (3.2%).

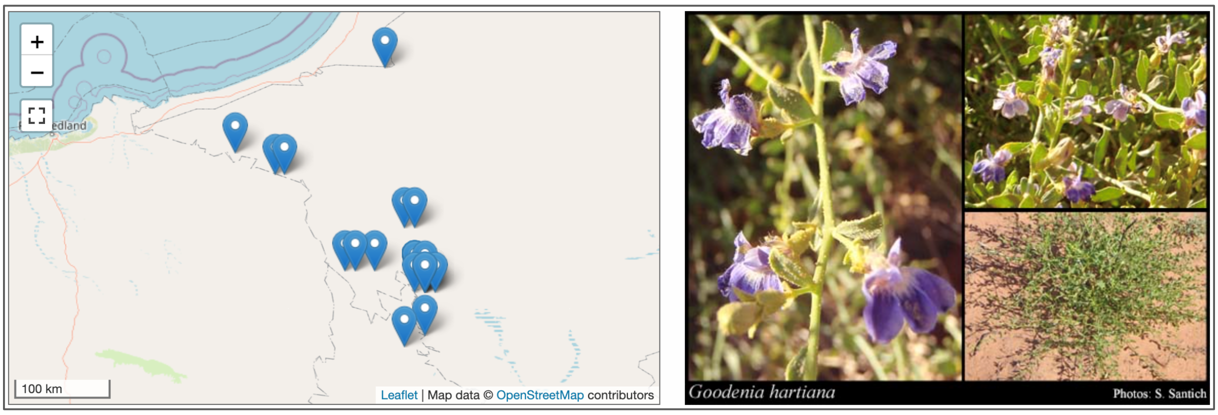

Figure 3.5 ***Goodenia hartiana*** **(P2) distribution and image (WA Herbarium 2024).**

Plate 3.5: Goodenia hartiana flower (Biota 2021).

Plate 3.6: Purple and white-flowered forms (Biota 2021).

3.7.3.2 *Indigofera ammobia* (Priority 3)

This low shrub has an open habit, very fine narrow leaves and small pink flowers (Plate 3.5, Plate 3.7 and Plate 3.8). It is represented in the WA Herbarium by 18 voucher specimens distributed across a range of more than 900 km, from near Shay Gap in the Pilbara, to Durack River Station in the Kimberley and Bilbarrd in the Great Sandy Desert (DBCA 2024). There are also vouchered records on AVH from the Northern Territory, which extend the known distribution to over 1,400 km (CHAH 2019).

Only two known locations of *Indigofera ammobia* (P3) were recorded within study area.

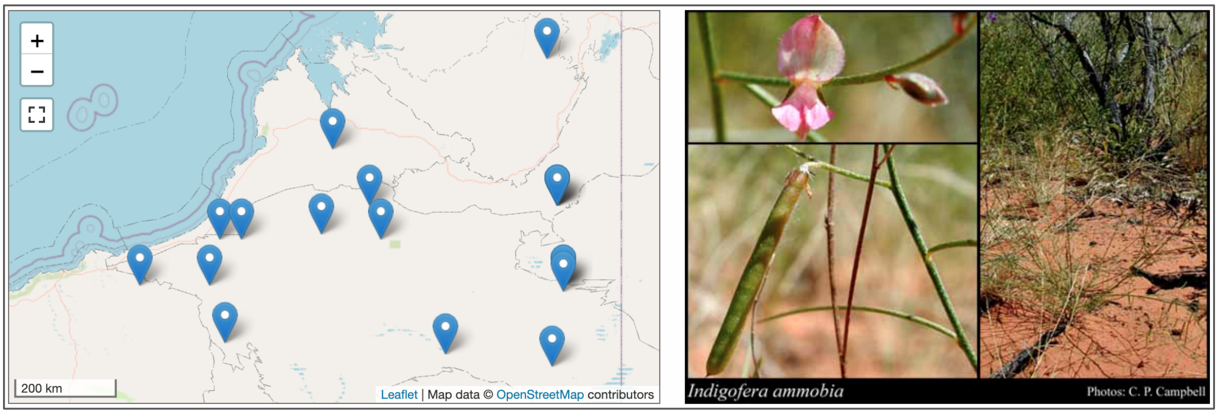

Figure 3.6: Indigofera ammobia (P3) distribution and image (WA Herbarium 2024).

Plate 3.7: *Indigofera ammobia* form (Biota 2021).

Plate 3.8: *Indigofera ammobia* flower and fruit (Biota 2021).

3.7.3.3 Weeds

Weeds are largely absent across the survey area, Four weed species have been recorded: **Cenchrus ciliaris* (Buffel Grass), **Citrullus amarus* (Bitter Melon), **Dactyloctenium aegyptium* (Coast Button Grass) and **Solanum lycopersicum* (Tomato) (Western Botanical 2023b). Of these, the **Cenchrus ciliaris* and **Solanum lycopersicum* were encountered at the Winu Camp and removed immediately. The **Citrullus amarus* and **Dactyloctenium aegyptium* were predominantly encountered at the Wallal Tanks area, within the pastural lease area on the Nyangumarta Highway. A review of the quadrat and releve data found no weed species were recorded from sites within the study area and its surrounds. All study area sites recorded vegetation in Excellent condition.

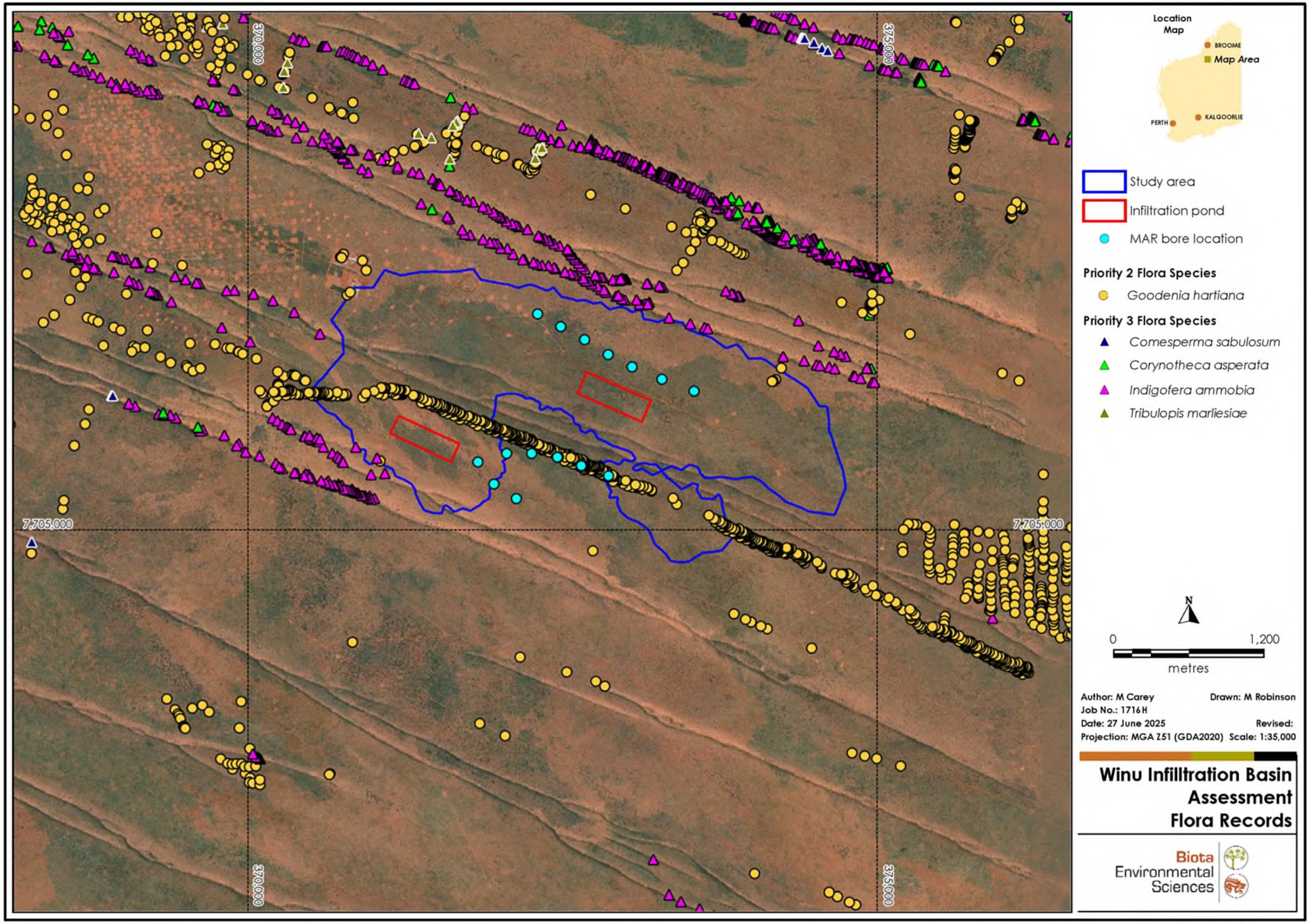

Figure 3.7: Priority flora of the study area and surrounds.

3.8 Terrestrial Fauna Habitats

Five broad fauna habitat types have been mapped across the survey area, two of which occur within the study area (Biota 2023e):

- Inland Sand Dunes (associated with vegetation type D1 and D2); and
- Shrub and Spinifex on Sandplain (associated with vegetation type P1 and P2).

Both fauna habitat types are presented in Figure 3.8.

3.8.1 Inland Sand Dunes

The substrate of this habitat type consists of red loose sand, with the vegetation dominated by *Erythrophleum arenarium* and *Owenia reticulata* low woodland and scattered trees over mixed *Acacia* low open shrublands over open hummock grasslands dominated by *Triodia schinzii* (Plate 3.9). Species associated with this habitat include fossorial species and dune specialists, including:

- Fossorial skink, *Eremiascincus pallidus*. Prefers loose substrates of dunes and was only recorded from the dune sites.
- Sand slider *Lerista vermicularis*. Endemic to the Great Sandy Desert where it inhabits crests of sand-ridges. This species was recorded only from the dune sites, where it was abundant.
- Northern Marsupial Mole*, Notoryctes caurinus* (State listed Priority 4). Prefers dune habitats, particularly interconnected dunes that provide dispersal opportunity.
- Bilby, *Macrotis lagotis* (State and Commonwealth listed as Vulnerable). Recorded on sand dunes where *Acacia monticola* was also present.


Plate 3.9: Typical Inland Sand Dunes habitat (Biota 2023e).

3.8.2 Shrub and Spinifex on Sandplain

This was the dominant habitat type of the development envelope, and the broad plains landforms comprise pink to red pindan soils. This habitat varied in condition, with some areas recently burnt, and supported occasional trees of *Erythrophleum arenarium* and *Owenia reticulata* over open to moderately dense mixed shrublands, typically dominated by wattles (*Acacia* spp.), over hummock grasslands of *Triodia schinzii* and *T. epactia* (Plate 3.10).

Some areas recovering from recent fires were dominated by successional species such as *Eragrostis* spp., *Scaevola parvifolia* and *Ptilotus calostachyus*, but will likely return to the species assemblage described above over time. This habitat support a diversity of burrowing species that are associated with spinifex grass, including mammals that forage on seeds or species that utilise shrubs and spinifex for cover and/or foraging. Species associated with this habitat include:

- Bilby, *Macrotis lagotis* (State and Commonwealth listed as Vulnerable); and
- Brush-tailed Mulgara, *Dasycercus blythi* (State listed Priority 4).

Plate 3.10: Typical shrub and spinifex on sandplain habitat (Biota 2023e).

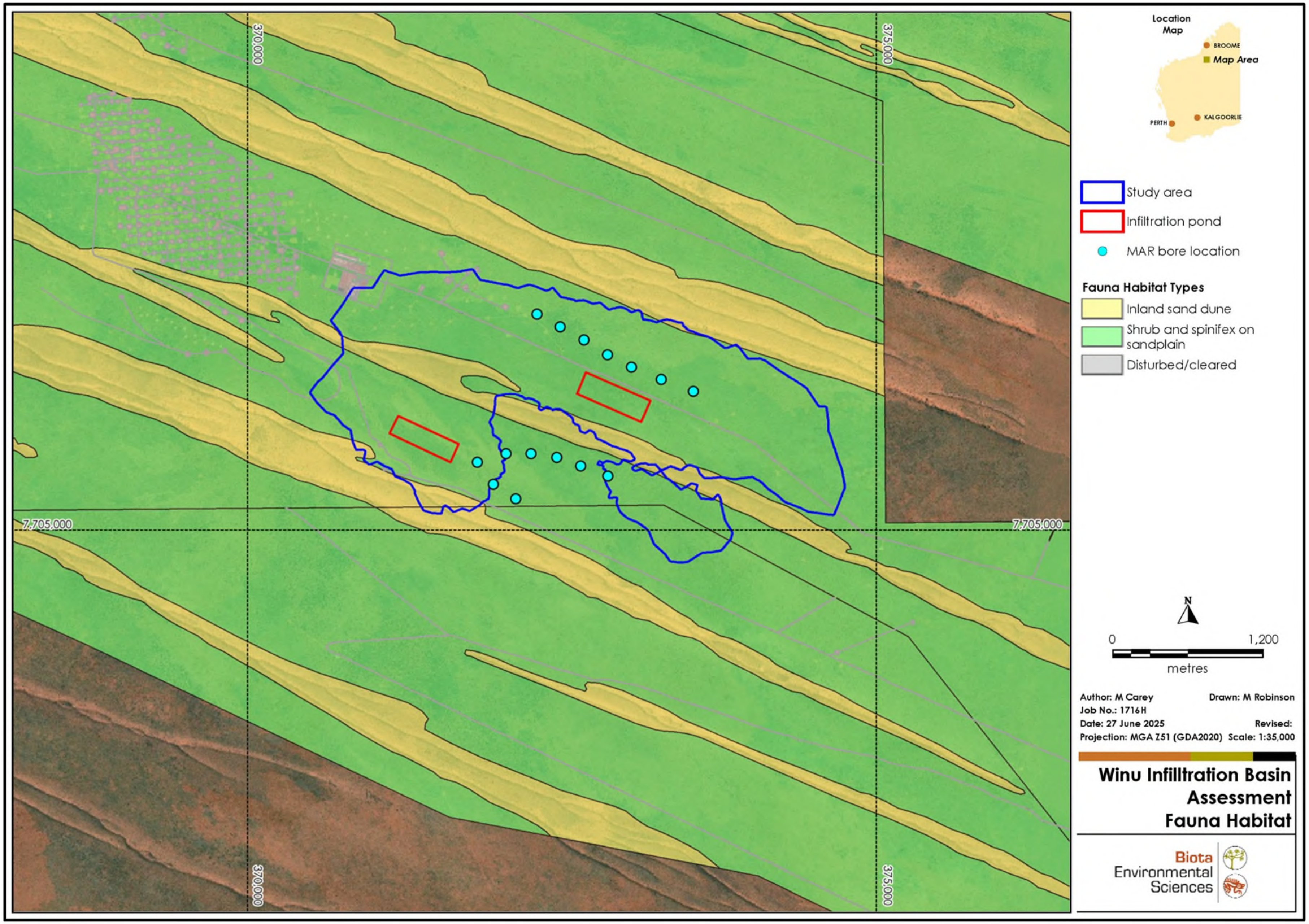

Figure 3.8: Fauna habitat of the study area and surrounds.

3.9 Subterranean Fauna Habitats

The mine infrastructure area (MIA)and Rimfire borefield areas sit within the Mackay subregion. The MIA lies in between the Percival and Wallal palaeodrainage lines and shows no evidence of any association to calcrete deposits. Rimfire is between two major paleovalleys, the Percival and Wallal paleovalleys.

Within the MIA, the sandstone and tillite geological units appeared porous. These units have some small spaces that may represent habitat for both troglofauna and stygofauna. The prospectivity for this unit was assessed as Moderate (Biota 2020). The other geological units within the MIA were assessed as Low and would not be suitable habitat for subterranean fauna.

3.9.1 Troglofauna

The subterranean survey conducted by Biota (2022) across 84 trap sites in the MIA, recorded no troglobitic fauna, consistent with the conclusions of the desktop studies.

3.9.2 Stygofauna

The basic subterranean survey conducted by Biota (2022) of the MIA recorded no stygofauna from any of the samples collected within the MIA (Biota 2022). In total, 25 sites were sampled for stygofauna, of which 20 were deemed optimal for sampling.

3.9.3 Potential Impact

Potential impacts on Subterranean Fauna are not considered significant due to the lack of evidence for either troglofaunal or stygofauna within the Development Envelope and the low likelihood of significant habitat for either ecological group being present. Subterranean fauna surveys conducted by Biota (2022) concluded that it is unlikely that any disturbance caused by the Winu Project would be of subregional significance on Subterranean Fauna within the Great Sandy Desert bioregion.

4.0 Literature Review: Vegetation Response to Hydrological Processes

4.1 Ecohydrological Units

Key landforms of the Pilbara region have been delineated using an ecohydrological conceptualisation approach, developed by MWH Australia (MWH 2015). Using topography, geology, geomorphology, drainage and vegetation datasets, inferences have been made about the relative importance of different water balance components across a range of landscape mosaics. Although this approach has been developed for the Pilbara region, and the study area is technically within the Great Sandy Desert, the setting is broadly similar and the framework is thereby applicable here.

In combination, these datasets provide a basis for describing ecohydrological regimes in different Pilbara landscapes, with the following five broadscale ecohydrological factors formulated for classifying ecohydrological units (MWH 2015):

- Landscape position and land surface types, including slope and soil characteristics;
- Surface drainage/redistribution patterns and processes;
- Connectivity and interactions between surface and groundwater systems;
- Major vegetation types and their water use behavior; and
- Occurrence and type of wetland habitats (e.g. pools, springs, ephemeral lakes/claypans, rockholes).

MWH (2015) described nine ecohydrological units based on consideration of these factors, (Figure 4.1), with the study area is represented by EHU 5 (Lowland Sandplains), based on the characteristics summarised in Table 4.1 and conceptualised in Figure 4.2 (MWH 2015):

- EHU 5: Lowland sandplains – level to gently undulating surfaces with occasional linear dunes. Little organised drainage but some tracts receive run-on from upland units.

Vegetation within the EHU5 lowland sandplain system is described as xerophytic, only accessing stored soil moisture from incident rainfall events. Groundwater levels within these units are greater than 10 m from the surface and beyond the vegetation root zone, suggesting no groundwater dependence from lowland sandplains vegetation.

Drainage within these units is generally indistinct, with a permeable sandy surface providing easy infiltration and minimal runoff. The sandplain units are also characterised by deep sandy soil profiles, which provide for xerophytic vegetation water use. Such plant water use is generally sourced from moisture in the soil and not directly from the water table.

In these semi-arid environments, very little rainfall is lost to deep drainage (Allison et al. 1994, Yair et al. 1997, Gee et al. 2004), with water that percolates beyond the root zone of grasses (e.g. *Triodia schinzii*) and small shrubs, then utilised by the roots of tall shrubs and trees (Grigg et al. 2008).

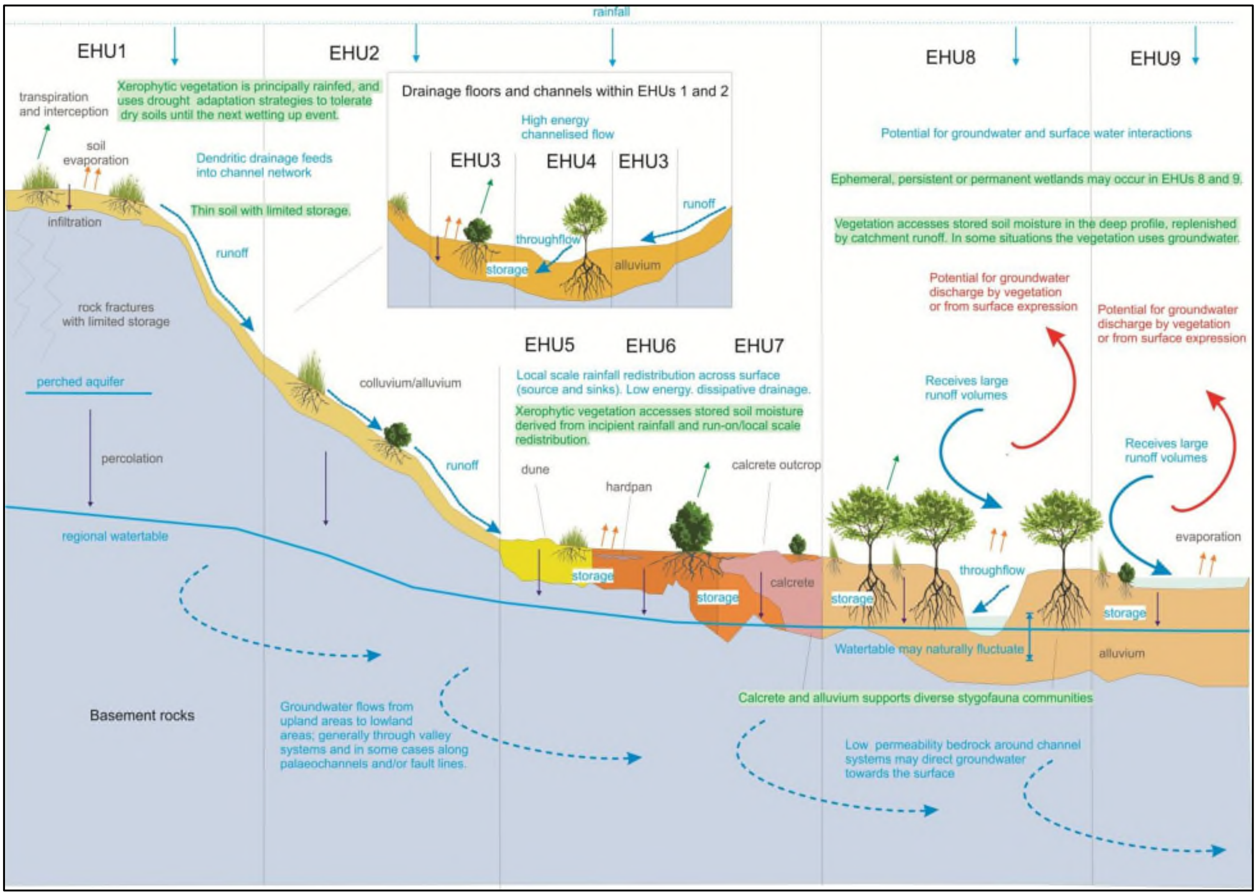

Figure 4.1: **Landscape arrangement of EHUs (Source: MWH 2015).**

Table 4.1: **Ecohydrological Unit 5 characteristics (Source: MHW 2015).**

EHU Characteristic	Description
Landscape position, land surface and soils	Lowland sandplains - landform characterised by level or gently undulating plains up to 10 km in extent. Deep sandy soils of aeolian origin. May have significant water storage capacity. Uncommonly features linear dunes up to about 15 m in height.
Surface drainage/ redistribution patterns and processes	Areas with minimal internal (localised) water redistribution. Poorly organised drainage. High rainfall infiltration and recharge. Runoff is minimal and if it does occur is generally localised, with accumulation in swales or depressions. Sandplains may receive and infiltrate inflows from channels deriving from up-gradient areas.
Connectivity and interactions between surface and groundwater systems	Diffuse recharge zones. Groundwater systems are generally deep and not accessed by vegetation. This EHU may include important zones of recharge, with associated groundwater mounding. Possibility of transient or more persistent perched groundwater at localised scales, depending on regolith characteristics.
Major vegetation types and their water use strategies	Xerophytic vegetation (principally rainfed). Vegetation includes hummock grasslands, with Acacia spp. and other shrubs, occasional mallee Eucalypts. Generally distinctive vegetation communities relative to other EHUs. Tracts receiving run-on include Acacia and Eremophila shrublands.
Occurrence and type of aquatic habitats	None
Dominant landscape water balance processes	Rainfall => Infiltration => Storage => Evapotranspiration and groundwater recharge

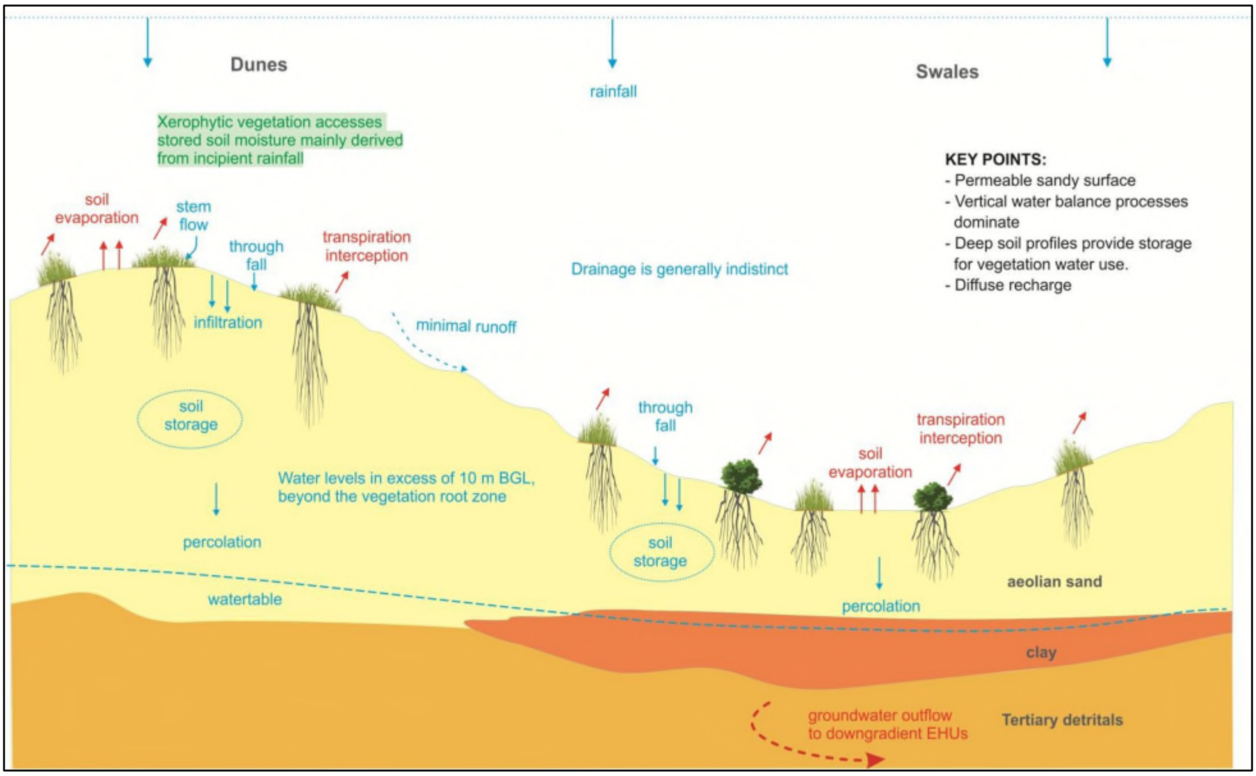

Figure 4.2: EHU5 Lowland sandplain conceptualisation (MHW 2015).

4.2 Ecohydrological Plant Types

The diversity of landscapes in the northwest of Australia has also driven plants to adapt to a range of hydrological regimes. Key ecohydrological plant types found in the landscapes of the Great Sandy Desert and Pilbara regions include:

- Xerophyte: Terrestrial plants dependent on water stored in the soil profile to meet some or all of their water requirements. Soil water is generally recharged via the direct infiltration of rainfall (Richards and Caldwell 1987).
- Surface Flow Dependent: Plants that requires additional water derived from surface water flows, and are generally associated with riparian systems (Astron 2019c).
- Sheet Flow Dependent: Vegetation typically outside drainage lines on shallow sloping areas (Mabutt and Fanning 1987, Ludwig et al. 1997). Sheet flow dependent plants often occur in groves (such as the Acacia aneura complex) (Miller et al. 2002).
- Halophyte: Plants that can survive and thrive under hostile environmental conditions with high concentration of salts in the surface soil layers (Marchesini et al. 2014).
- Phreatophyte: Terrestrial plants that are dependent on the presence of groundwater to meet some or all of their water requirements (Orellana et al. 2012). Facultative phreatophytes are considered partially dependent, while obligate phreatophytes are entirely reliant on groundwater.

As stated previously, the hummock grasslands and shrublands that are typical of study area represent vegetation types dominated by xerophytes such as *Triodia* and *Acacia* species. Xerophytes have adapted to very dry conditions, relying on soil moisture for their water requirements, and not reliant (or dependent) on groundwater or shallow water tables.

4.3 Root Dynamics in Water-Limited Environments

In arid environments, groundwater can only be accessed by plants when the water table is generally less than 10-12 m from the surface (Cook and Eamus 2018).
Species from dry environments that are known to access groundwater at depth include *Eucalyptus camaldulensis* and *E. victrix*, both of which are considered groundwater dependent (obligate and facultative phreatophytes respectively). These, and other groundwater dependent species, do not occur in the study area, where groundwater is approximately 50 m below the surface (Golder 2022, Worley 2024b).

Plant species associated with the study area are predominantly xerophytes, as they rely on soil moisture from rain events for their water source and do not depend on deeper groundwater supplies. It is therefore important to better understand the root systems of these xerophyte plants to assess the potential impacts that groundwater mounding may have on these roots.

Schenk and Jackson (2002) conducted a global study in water-limited environments to measure sizes and shapes of root systems. A dataset was developed from more than 1,300 records of root systems from plants in deserts, scrublands, grasslands and savannas. Maximum rooting depths and maximum lateral root spreads were measured and correlated. The study found that a large proportion of the variance in root system sizes can be predicted from above-ground plant sizes, growth form and climatic variables.

Schenk and Jackson (2002) found that root system size decreased with aridity for all plant growth forms, with root systems tending to be shallower and wider in dry, hot climates and deeper and narrower in cold, wet climates. Shrubs were also found to be more shallowly rooted under climates with typically summer rainfall (Figure 4.3). The Winu study area typically experiences summer rainfall events, suggesting that species from the abundant shrub strata have relatively shallower root systems.

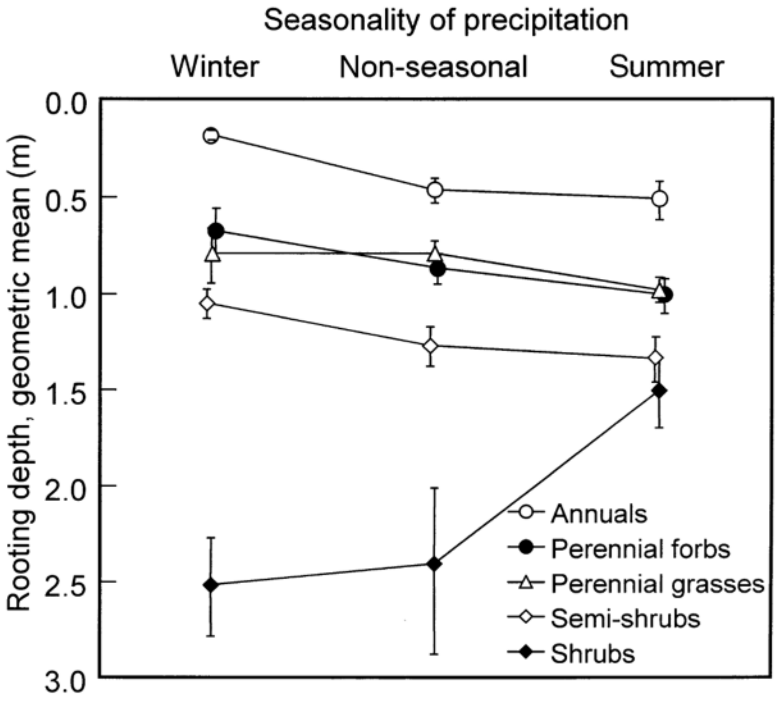

Figure 4.3: **Geometric means (± 1 SE) of absolute maximum rooting depths for five plant growth form categories in climates with > 50 and < 500 mm mean annual precipitation (grouped by seasonality) (Source: Schenk and Jackson 2002).**

4.3.1 Root Depth and Lateral Spread Across Growth Forms

Many species in dry environments have both lateral roots to access nutrients and water close to the surface, and sinker roots to access more reliable, deeply stored soil moisture (Grigg 2009). The combination of lateral and sinker roots also allows for hydraulic redistribution of water from deeper reserves to maintain lateral root function during dry periods. Despite potential losses to the dry surface soil, hydraulic redistribution facilitates the rapid development of fine roots and utilisation of rainfall events (Grigg 2009).
The ability for plants to develop fine lateral roots to adapt to changes in soil moisture conditions may also provide a useful adaption mechanism in areas subject to modified soil moisture conditions, such as groundwater mounding or irrigation.

Schenk and Jackson (2002) found that rooting depth and lateral root spread in arid environments generally increased for plant growth forms as their size and life span increased (Figure 4.4 and Figure 4.5). Rooting depths also showed a positive relationship with annual rainfall for all growth forms (Figure 4.6) (Schenk and Jackson 2002).

The relatively strong relationship between above-ground plant size and root systems is primarily due in part to larger plants needing more roots to supply a greater leaf area (Schenk and Jackson 2002). Perennial grasses and forbs had the shallowest root systems (Figure 4.4 and Figure 4.5). Tall shrubs had significantly larger rooting depths and lateral root spread than small shrubs (referred to as semi-shrubs in Schenk and Jackson 2002). Taller shrubs also tended to have deeper root systems with lateral spreads similar to depths, and small shrub root systems tended to be shallower and spreading only to about half their depth (Figure 4.4 and Figure 4.5).

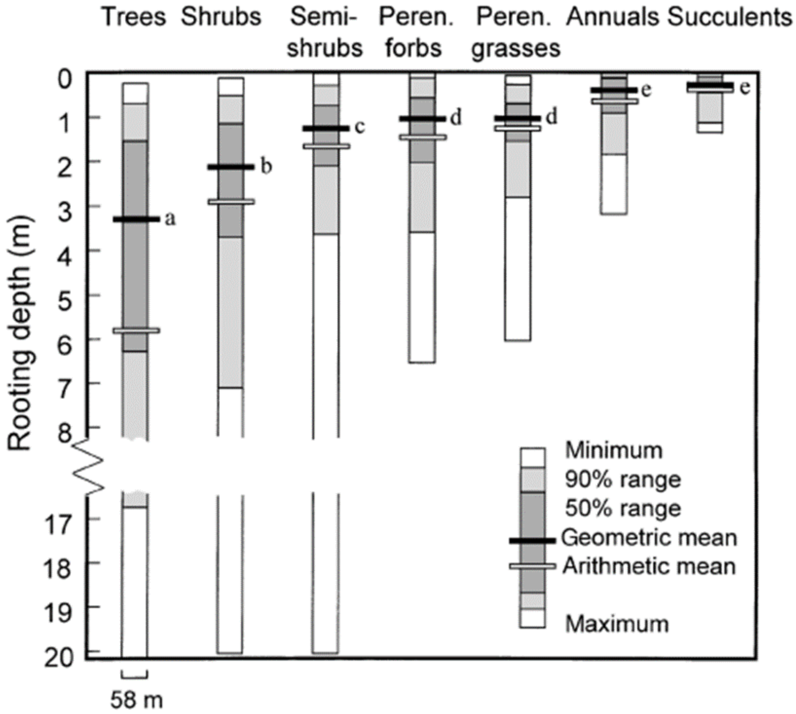

Figure 4.4: **Rooting depths of plant growth forms (Source: Schenk and Jackson 2002).**

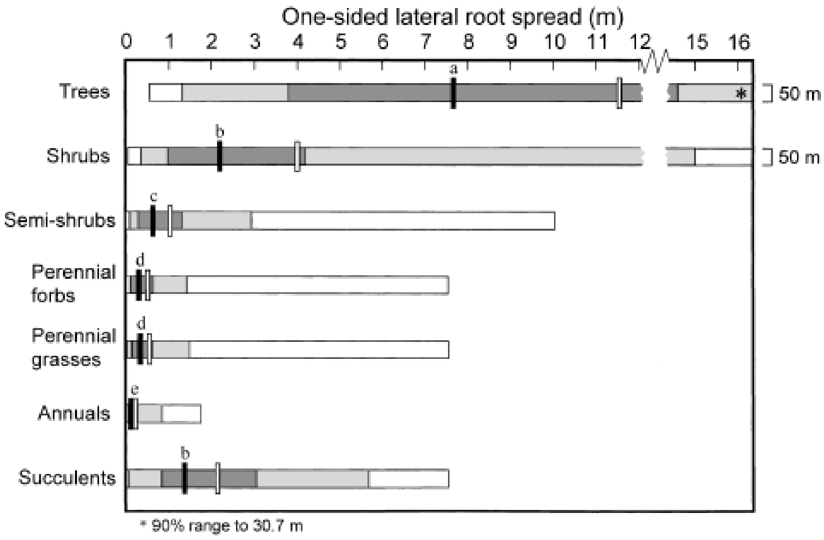

Figure 4.5: Lateral root spreads of plant growth forms (Source: Schenk and Jackson 2002).

Large lateral root spread in dry environments is thought to be related to the lower plant densities, which provides opportunities for lateral roots to explore the soil in interspaces between plants, which would enable plants to maximise uptake of shallow soil water from small rainfall events (Walter 1963, Sala and Lauenroth 1982). Lateral roots are also more efficient at anchoring plants with large aboveground sizes than deep, vertical roots (Ennos 1993).

Schenk and Jackson (2002) also suggest that in water-limited environments, ecosystem level rooting depths may also be affected by the proportion of deep and shallow rooted growth forms along a rainfall gradient. Along a rainfall gradient, shrubs and semi-shrubs tend to dominate the driest ecosystems, where they are typically more deeply rooted than herbaceous plants. Their proportion in the vegetation generally decreases with increasing rainfall (Figure 4.7).

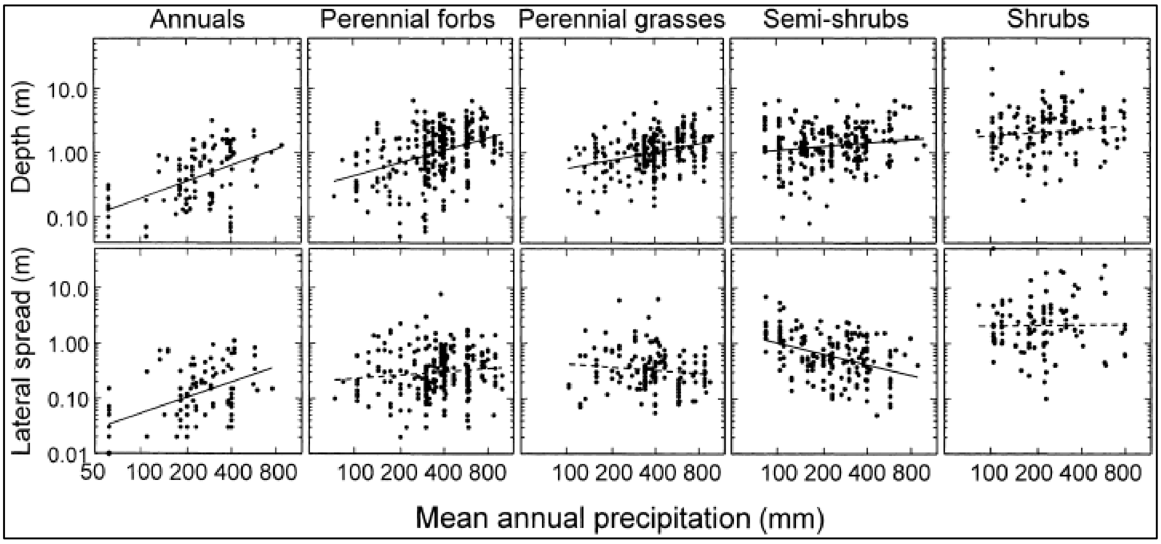

Figure 4.6: Maximum rooting depths and lateral root spreads for plant growth forms and mean annual precipitation (Source: Schenk and Jackson 2002).

Note, data for trees are not shown, due to sample size and root sizes showed no significant relationship with rainfall.

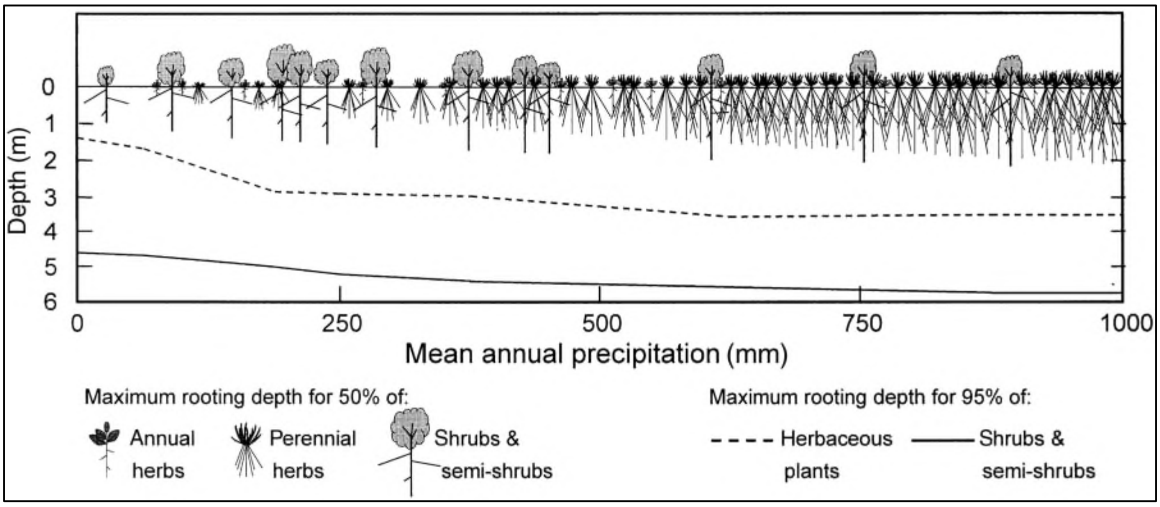

Figure 4.7: **Schematic diagram of the relationship between mean annual precipitation and ecosystem-level rooting depths (Source: Schenk and Jackson 2002).**

Note, the changing root depth along the gradient for all growth forms, and the changing plant density and changing proportions of annual herbs, perennial herbs and semi-shrubs/shrubs along the gradient, from deserts and shrublands dominated by woody plants to grasslands dominated by herbaceous plants.

4.3.2 Root Morphology of Acacia ancistrocarpa

Acacia ancistrocarpa is a common shrub in Western Australian deserts and is a dominant tall shrub species from the study area. It displays a dimorphic root system, with numerous lateral roots (5-12) on the top 0.4 m below the surface and one primary sinker root descending approximately 2 m (Grigg 2009, Grigg et al. 2010) (Plate 4.1).

Plate 4.1: **Natural interdune *Acacia ancistrocarpa* with exposed root system (Source: Grigg 2009).**

Grigg (2009) investigated the hydrological response of *Acacia ancistrocarpa* to increased soil moisture, by measuring sap flow movement in sinker and lateral roots in natural environments and degraded mine rehabilitation sites, where sinker roots were stunted/restricted from poor growth media.

Grigg (2009) and Grigg et al. (2010) found that in sites where the sinker roots were stunted/ restricted, less water was accessed by the primary sinker roots and a greater proportion of soil moisture was sourced from the wide-spreading lateral roots and the secondary sinker root network. The greater reliance on this wide-spreading network to obtain sufficient water means that each plant requires a greater 'footprint' area and a lower density of plants in these areas.

Acacia ancistrocarpa abundance at the study area ranges from 0.1% cover to up to 15% cover within shrubland patches, consistent with those findings.

4.3.3 Triodia and Soil Moisture

Studies of *Triodia* spp. leaf water potentials between dune and interdune systems on the Great Sandy Desert indicate that soil moisture reserves diminished more quickly from the root zone of interdune species (Grigg et al. 2008, Grigg 2009). Rapid declines in water potential in the wet season indicated that soil moisture reserves in the interdune were less than that of the dunes. However, the slightly greater proportion of clay silt in the interdune may hold more water per unit volume of soil.

4.3.4 Flood Tolerance

Little is known about the flooding/waterlogging tolerance of arid zone species. Most woody plants have not adapted to waterlogged soil conditions for extended periods of time. In general, plants that develop adventitious roots can usually survive flooding better than those that do not. Trees and other plants growing in poorly drained soil often develop shallow root systems that concentrate in aerated soil surface (Kramer and Boyer 1995).
Seedling pot trials of *Panicum decompositum*, a widespread perennial grass found throughout the Pilbara, found that while flooding reduced seedling growth and shoot:root ratios, most plant attributes were not significantly affected (Geurts et al. 2005). Effects were further reduced when seedlings were older, indicating some intrinsic tolerance of flooded conditions.

Argus (2018) investigated impacts of prolonged flooding from mine dewatering discharge on two co-occurring riparian eucalypts, *Eucalyptus camaldulensis* subsp. *refulgens* and *E. victrix*. The study found *E. victrix* seedlings are particularly vulnerable to extended flooding, while *E. camaldulensis* seedlings are comparatively very tolerant owing to greater capacity to alter root morphology.

Mature eucalypt trees, regardless of species, can also be severely affected by flooding if the entire root system is subject to prolonged saturation and hypoxic conditions. In terms of potential impacts resulting from mine pit dewatering and discharge, Argus (2018) found that the immediate impacts from flooding were highly localised and unlikely to affect a significant proportion of riparian eucalypts.

4.3.5 Monitoring

Sloan et al. (2023) conducted a review of managed aquifer recharge in mining and determined that water levels around recharge infrastructure must be regularly monitored and remodelled during infiltration to ensure the water table remains within an acceptable range. Sloan et al. (2023) also noted the importance of vegetation monitoring programs to closely observe any decline in vegetation health due to recharge, citing BHP Billiton (2016) as an example.

5.0 Proposed Infiltration Strategy

Water balance modelling for the Winu Project identified periods of surplus water from mine pit dewatering over the life of mine (Advisian 2023, Worley 2025a, 2025c). Strategies considered for disposing of surplus water include: 1) the construction of two large infiltration ponds in the surficial sand (currently unsaturated); and 2) discharge into MAR borefield nominally consisting of 15 injection sites into the deeper-lying sandstone aquifer (partly saturated).

The effectiveness and potential groundwater mounding extent for both strategies was assessed. A numerical model was developed by Worley (2025a) using MODFLOW-USG to simulate the long-terms effects of surplus water disposal over the life of mine.

To assess against a worst-case scenario, the total Life of Mine P90 surplus volume estimates were used from the Project's water balance (47.3 GL, or 47 L/s), with peak surplus in Year 9 (4.0 GLpa) (Worley 2025a).

The proposed infiltration approach and the outcomes of initial modelling is presented below.

5.1 Infiltration Descriptions

Based on the outcomes of the Project water balance assessment (Worley 2025c), and using a nominal processing rate of 10.0 Mtpa, the mine will be in a water surplus throughout the life of mine. The volumes of excess water per year included in the design of the surplus management strategy have been adopted from the P90 quantities (Worley 2025c).

The strategies for surplus water management investigated by Worley (2025a) in their "Surplus Water Management PFS" include:

- Infiltration into predominantly unsaturated surficial sands via infiltration ponds (pond strategy). This requires the construction of two large infiltration ponds with perimeter and central embankments within the dunefields; and
- Infiltration into a partially saturated Permian Sandstone aquifer situated underneath surficial sands and silcrete (the latter forming an intervening low permeability layer – aquitard). This requires boreholes to be drilled through the aquitard into the sandstone aquifer and is referred to as the reinjection (MAR) strategy.

5.2 Location and Layout

Several potential locations for the infiltration area were assessed against sensitive environmental and heritage constraints, with an area located approximately 2-2.5 km southeast of the mine pit identified as the preferred location (Figure 5.1).

The location of the infiltration pond requires a deep sand profile, at least 11-12 m deep (ideally 15-16 m), which extends at least 2.5 km from the infiltration site. The proposed MAR bore field will be in the vicinity of the ponds and will consist of approximately 15 injection sites in the deeper-lying sandstone aquifer (partly saturated).

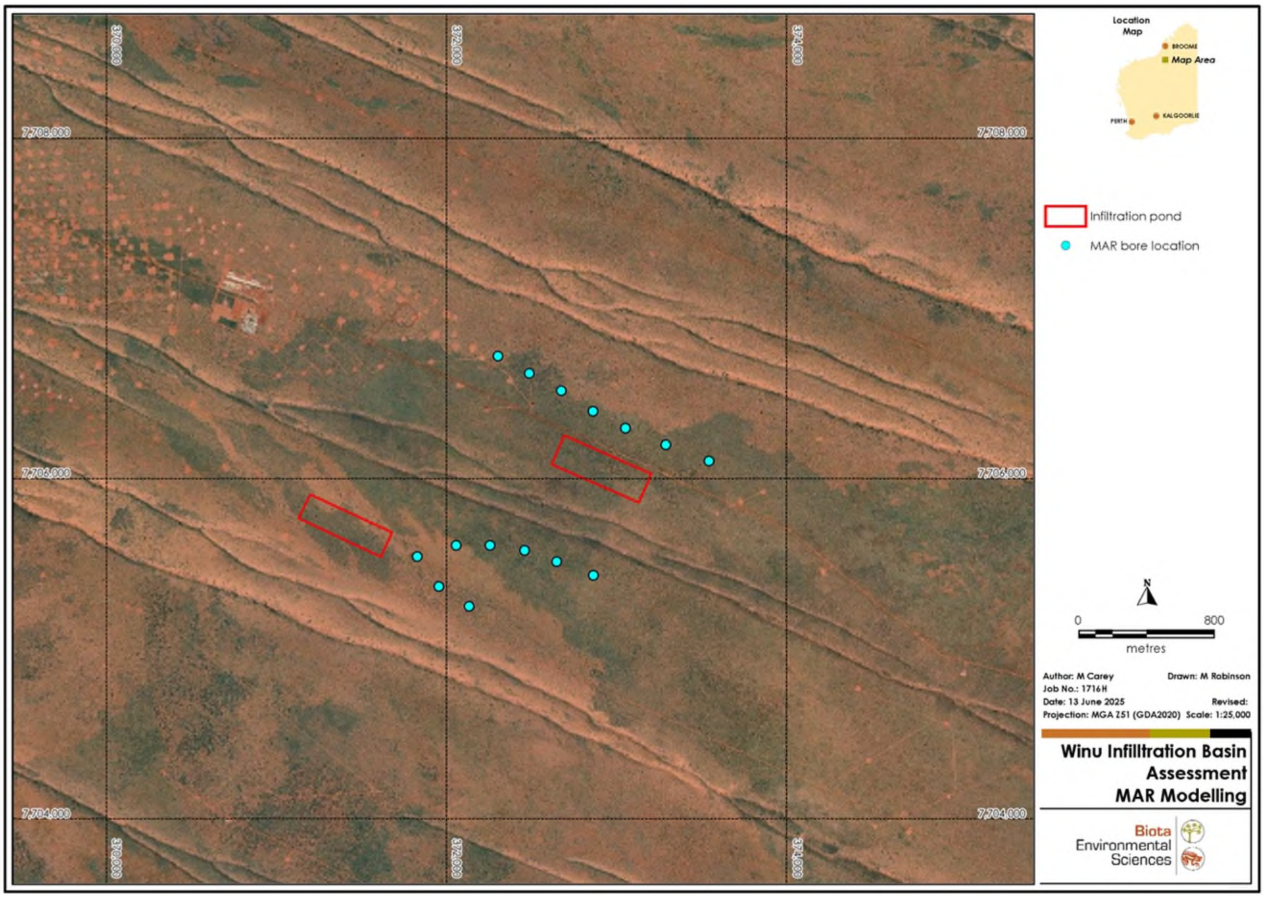

Figure 5.1: **Winu Project proposed infiltration area – infiltration strategy layout.**

5.3 Design Considerations

5.3.1 Infiltration Pond

The infiltration ponds were initially designed by Advisian (2023, 2024) to minimise the risk of:

- overtopping of the infiltration pond due to storage capacity exceedance;
- recirculation of infiltrated water back into the mine pit; or
- forming a surface expression of groundwater or near surface groundwater table.

The ponds will be positioned to align with the existing dunefields, to also minimise disturbance to the local topography.

The indicative design specifications provide for a base length of approximately 500 m and a base width of 150 m. Each pond includes two cells (to allow for maintenance) with perimeter and central embankments (Figure 5.2). The average pond depth is designed for approximately 1.5 m, which provides for a 1 m operating water depth and 0.5 m freeboard between the operating water level and the crest of the embankment. The design also protects against floodwaters in the 1% Annual Exceedance Probability event (Advisian 2023).

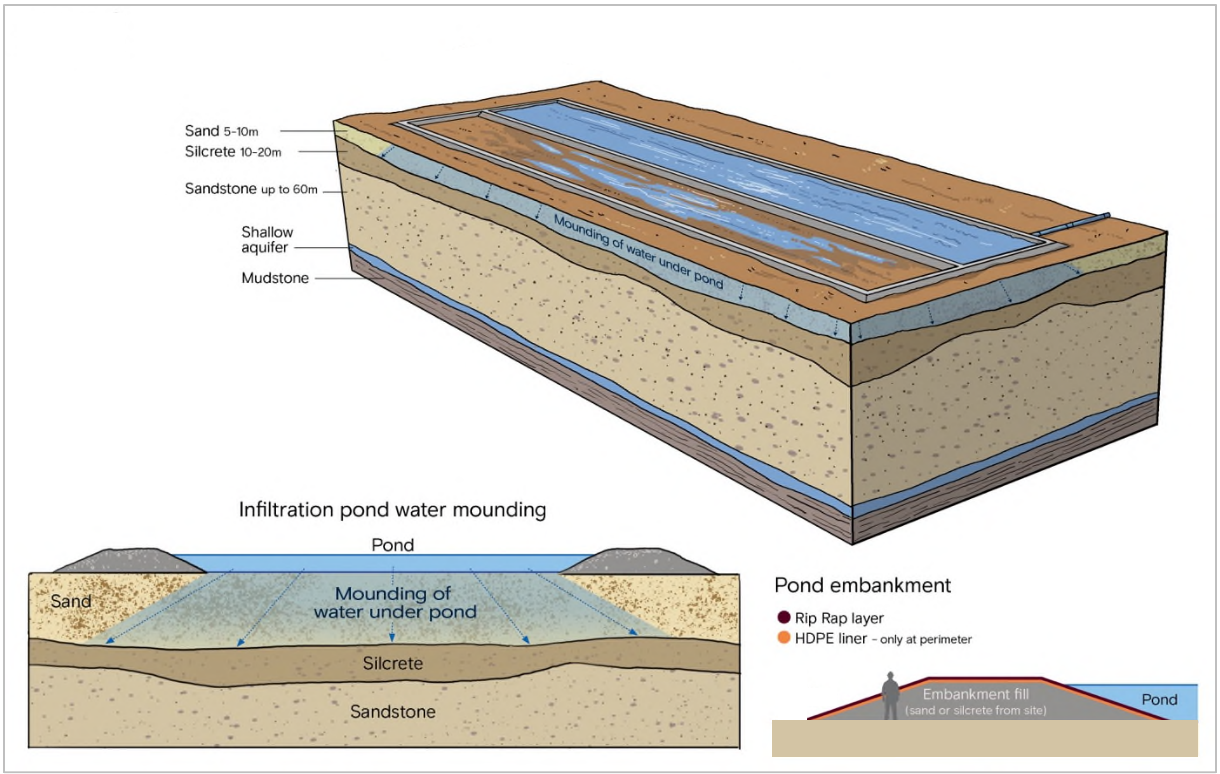

Figure 5.2: **Winu Project infiltration pond conceptual layout.**

5.3.2 MAR Bore Field

There will be a nominal 15 proposed MAR bore locations. While they are conceptual, they will be selected within existing heritage approved land and a nominal spacing of 200 m between each bore.

MAR bores will inject surplus water into the sandstone aquifer (Figure 5.3), with no injection into the surficial sand aquifer to occur. The MAR bores will be capable of injecting 0.3 to 8.5 L/s each, with the average injection rate per MAR bore over the life of mine for P90 case expected to be 3.1 L/s.

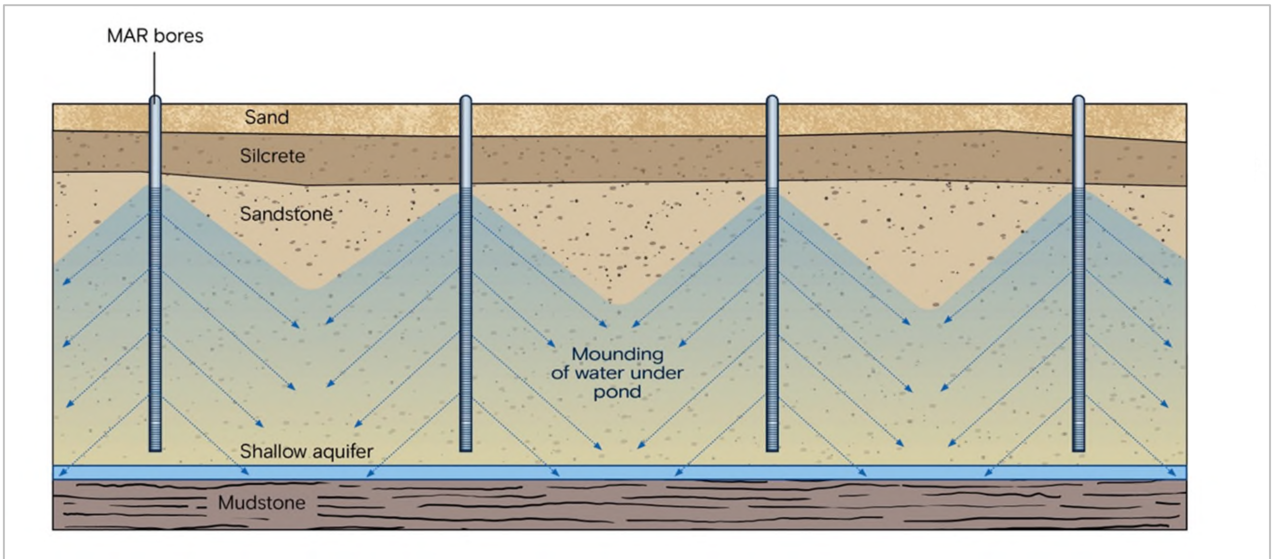

Figure 5.3: **Winu Project MAR bore field conceptual layout.**

5.4 Water Mounding

5.4.1 Excess Water Inflow Model

A mine water balance model was developed, based on the latest mine plan and estimated dewatering rates (Worley 2025c). The median results from this modelling show the mine will be in a water surplus from years 1 to 16 (Figure 5.4), with additional periods of excess water management likely required during sporadic high rainfall events occurring throughout the life of mine.

The results of water balance modelling were then used to develop annual estimates of excess water from mine pit dewatering, to be disposed of via infiltration.

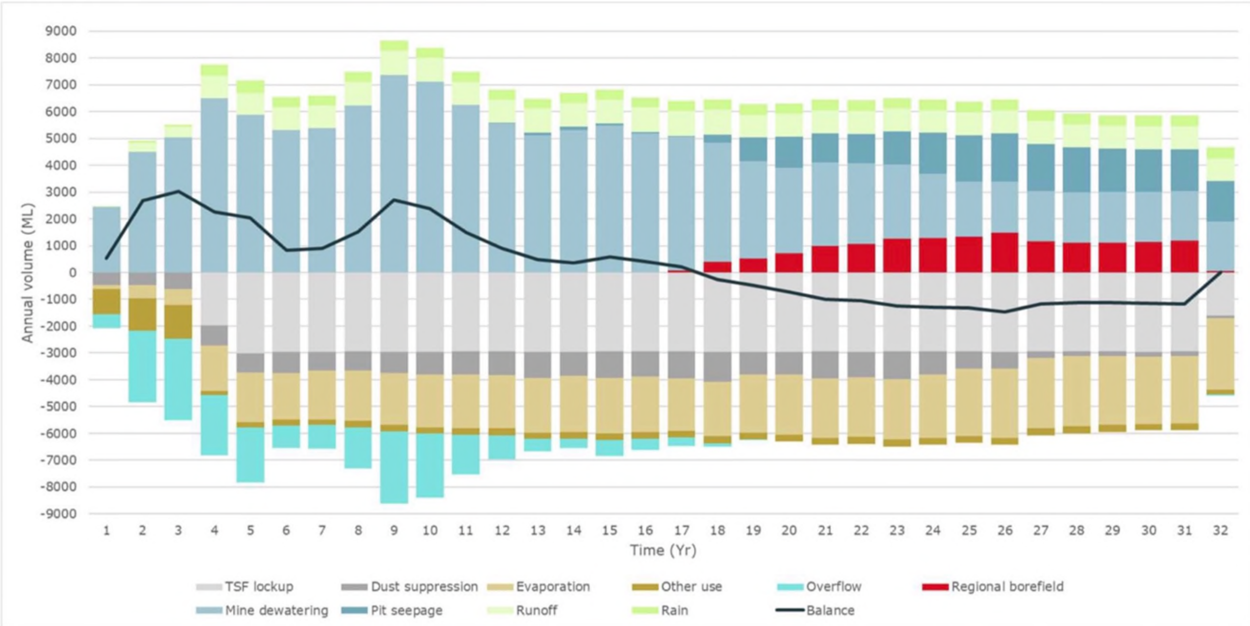

Figure 5.4: Annual excess water inflow rates (ML/month) (Source: Advisian 2023).

5.4.2 Infiltration Model and Groundwater Mounding

A predictive groundwater flow model was then used to estimate mounding from both proposed infiltration approaches. Using the water balance model, a numerical groundwater model was developed in MODFLOW-USG to simulate infiltration (Worley 2025a).

A numerical model was developed to simulate the long-terms effects of surplus water disposal over the life of mine, and to compare the infiltration strategies for surplus water management:

- Infiltration Pond: infiltration into predominantly unsaturated surficial sands via infiltration ponds,
- Reinjection (MAR) Bore field: Boreholes drilled through the aquitard into the sandstone aquifer.

5.4.2.1 Model outcomes – Infiltration Pond

Results from the numerical modelling indicate that surplus water managed through infiltration ponds will comply with the P90 surplus water demands (Worley 2025a) (Figure 5.5):

- Two groundwater mounds will develop around the ponds within the surficial sand aquifer, but most of the water volume is predicted to seep down to the sandstone aquifer.
- The mounds in the surficial sand aquifer at Year 9 of the mining operation, when the required infiltration volume is predicted to be the largest (4 GL/a), covers a relatively small footprint.
- Mounding of the deeper sandstone aquifer will occur over a larger footprint, with the groundwater mound supplying some of the infiltrated water to flow back to the mining pit.
- In total, over the life of mine, the average back inflow into the pit from infiltration ponds is predicted to be 11 L/s or 23% of total infiltrated water.
- From peak infiltration in Year 9 the surplus volume will gradually reduce which will also result in a smaller infiltration mound footprint over time.

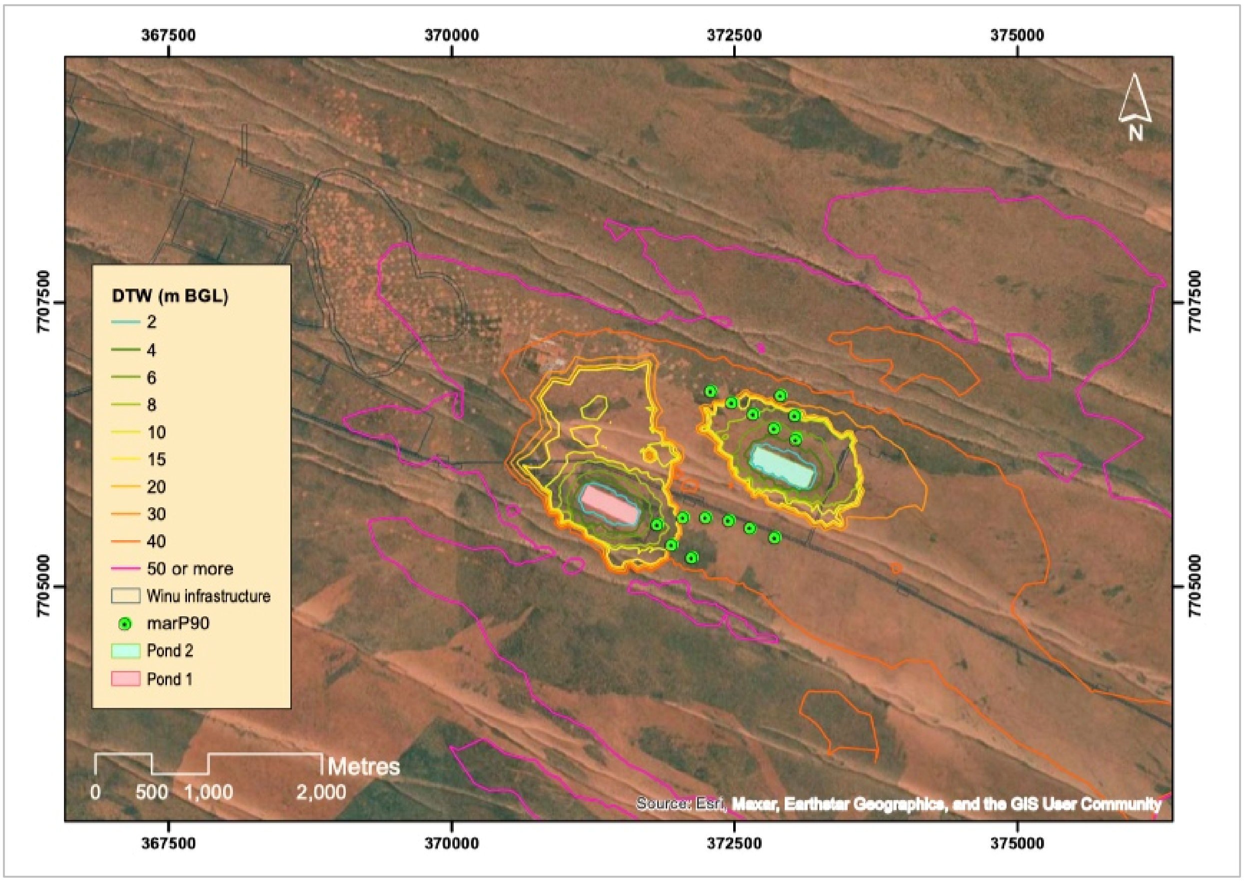

Figure 5.5: Modelled depth to water (mbgl) at Year 9 (Infiltration Pond) (Source: Worley 2025a).

5.4.2.2 Model outcomes – Reinjection (MAR) Bore Field

Groundwater mounding associated with reinjection is predicted to not reach the surficial sand aquifer, even during the peak injection year (Year 9), with depth to water remaining well below the base of the surficial sand aquifer, and remaining more than 30 mbgl (Worley 2025a) (Figure 5.6).

During 32 years of mining the effect on groundwater levels will remain irrelevant to the surficial sand aquifer, which is predicted to remain practically unsaturated.

Over the life of the mine, on average 15 L/s of injected water is predicted to be captured by the mining pit which is situated 2,200 to 2,500 m downgradient from the MAR bore fields, representing approximately 31% of total infiltrating water.

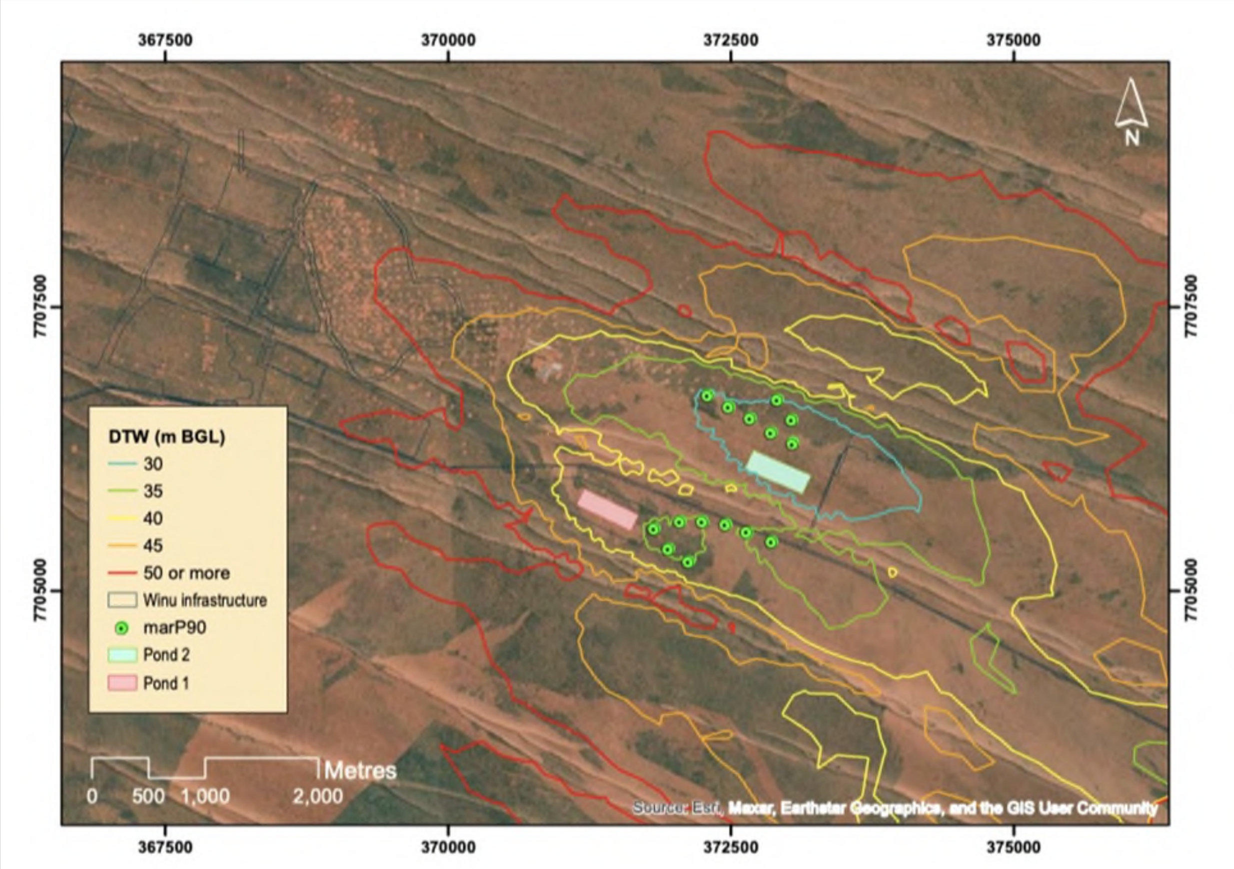

Figure 5.6: **Modelled depth to water (mbgl) at Year 9 (MAR Bore Field) (Source: Worley 2025a).**

5.4.3 Water Quality at the Infiltration Ponds

In an earlier assessment of infiltration options at the Winu Project, Advisian (2023, 2024) found that water quality results from local groundwater bores indicate that water reporting to the infiltration ponds is expected to be slightly alkaline with a pH of 7.8 and moderately saline (approximately 2,500 µS/cm) (Advisian 2023, 2024). The water appears cloudy, with high reported suspended solids (26 mg/L), which Advisian (2023) note is expected to settle once the water is stagnant. The iron content is elevated, which is expected to oxidise rapidly at the given pH, once in contact with oxygen. Advisian (2023) consider the oxidised iron (and other metals) have caused the elevated suspended solids value.

Sediment loads are a primary concern when discharging groundwater with elevated suspended solids values to infiltration ponds (Advisian 2023). If surplus water is pumped directly from the dewatering bores to the infiltration pond, at a peak inflow (11 ML/d), it is expected that approximately 290 kg/d of solids would settle in the pond, which will need to be removed every few years (Advisian 2023).

6.0 Potential Impact Pathways

Groundwater mounding and expression at the surface is a common challenge associated with managed recharge in mining, particularly where it can impact sensitive ecosystems. In Section 6.1 to Section 6.5 below, the potential impacts relating to the current study are discussed.

It is important to note that the extent to which any of these potential impacts affect vegetation will largely depend on the magnitude of the mounding effect (Section 7.1). Where the depth to the water table is large and root contact is unlikely, mounding may have little to no impact on vegetation. However, if the water table is nearer the surface and into the root zone, impacts are likely.

6.1 Changes to Vegetation Structure

Increased soil moisture availability in desert environments can trigger a pulse of biological activity, primary production and reproduction (Grigg 2009). Increases in soil moisture can have a positive effect on growth of cryptogamic crust organisms (Cable and Huxman 2004), soil microbes (Cui and Caldwell 1997), condition of shallow rooted species such as grasses (Sala and Lauenroth 1982), as well as woody shrubs and trees, and seed production and germination (Beatley 1974, Schwinning et al. 2003).

However, perceived positive effects may also result in negative impacts at closure with the cessation of infiltration/recharge activities. This may occur because the increase in growth may result in the inability of the root system to meet the demands of a canopy with a high leaf area after the water table recovers to pre-mining levels. Species classified as phreatophytes are deemed most likely to be subject to decline or mortality due to ‘unbalanced growth’ (Astron 2019c), and the study area does not contain these plant types.

6.2 Weeds

Increased soil moisture may also favour other adaptable plant species that can take advantage of the change in conditions. Such species may include local weeds, which are by their nature opportunistic.

6.3 Greater Lateral Root Footprint

Changed hydrological conditions could lead to greater reliance on a wide-spreading lateral root network to obtain sufficient water means that each plant requires a greater ‘footprint’ area, with related lower density of plants. Grigg (2009) found that in sites where the sinker roots were stunted or restricted, less water was accessed by the primary sinker roots and a greater proportion of soil moisture was sourced from the lateral root network.

6.4 Waterlogging

Waterlogging impacts usually arise where a large proportion of the root system is below the water table or saturation zone. Soil aeration is physiologically important to plants, with oxygen required for normal plant metabolism and plant growth. Flooding of the capillary pore spaces in the soil can result in roots suffering severe oxygen deficiency and lead to declines in condition or loss of individual plants.

6.5 Salinisation

More severe impacts from mounding will arise if the groundwater entering the root zone is saline, with most species highly sensitive to salt exposure. Salinisation of soils may also occur through capillary rise if the underlying groundwater is highly saline or by mobilisation of salt already held in soil by rising groundwater. Specific soil salinity tolerance for plant species native to the northwest Australia is largely unknown, however, soils with an electrical conductivity of soil saturated paste extract (ECe) above 2 dS m -1 to 4 dS m -1 are considered salt affected (Moore 2001) and only highly salt tolerant species such as saltbush and samphires occur in areas where the soil ECe exceeds 16 dS m-1 (Astron 2019c).

Due to the moderately saline nature of the water table at the study area, any elevation of water levels to the root zone is unlikely to expose vegetation to highly saline water.

7.0 Impact Assessment

Modelling outcomes indicated that groundwater mounding associated with the reinjection (MAR) bore field will not reach the surficial sand aquifer, even during the peak injection year (P90, Year 9), and will remain more than 30 mbgl (Worley 2025a). As such, the MAR bore field is not expected to affect flora and vegetation values. Based on the literature review (Section 4.0), no vegetation or individual species within the Study area will be influenced by groundwater mounding that occurs more than 30 mbgl.

Modelling outcomes did find that mounding from the infiltration pond would occur within the expected rooting zone of the local vegetation. As such, this impact assessment will primarily focus on the impacts to environmental values associated with groundwater modelling from the infiltration pond.

It should be noted that the final operating strategy (in development) for managing surplus water from mine pit dewatering, will include a combination of both reinjection MAR bores, as the primary discharging method, as well as infiltration ponds to manage any excess that may occur (i.e. emergencies, unexpected shutdowns). Based on this scenario, it is likely that the MAR bore field will maintain groundwater mounding well below 30 mbgl. For the impact assessment, the worst-case scenario is presented, however the likelihood of this scenario occurring during the life of the mine is very low.

To assess direct and indirect impacts to environmental values that are primarily associated with groundwater mounding, the proposed indicative clearing footprint for the Project has been removed from the impact assessment calculations.

7.1 Groundwater Mound Extent

Although the study area extends to a mounding contour of 35 mbgl, the literature review has found that the expected maximum rooting depth for vegetation of the study area is approximately 10 mbgl.

The predicted extent of groundwater mounding to within 10 mbgl from the infiltration ponds is approximately 532.2 ha, representing a range of water table depths to surface within the study area extent:

- 14.6 ha where the water table is less than 1 m from the surface;
- 10.9 ha where the water table is 1-2 m from the surface;
- 32.0 ha where the water table is 2-5 m from the surface; and
- 101.9 ha where the water table is 5-10 m from the surface.

7.2 Vegetation Types Affected

The vegetation types within the 0-10 m mounding contour extent are presented in Figure 7.1. Key life forms and species from within these vegetation types and their height range (and expected rooting depths) are presented in Table 7.3 and Table 7.4.

Three vegetation types occur within the 0-10 m mounding contour:

- D2 - Owenia reticulata, Erythrophleum arenaria scattered low trees over Acacia platycarpa, open shrubland over Dampiera cinerea, Dicrastylis doranii, Gompholobium simplicifolium low open shrubland over Triodia schinzii open hummock grassland.
- P1 - Owenia reticulata, Erythrophleum arenaria scattered low trees over Acacia platycarpa open shrubland over Jacksonia aculeata, low shrubland over Triodia schinzii open hummock grassland
- P2 - Owenia reticulata, Erythrophleum arenaria scattered low trees over Acacia ancistrocarpa, tall shrubland over Sorghum plumosum var. plumosum, Aristida holathera var. holathera, Amphipogon sericeus scattered tussock grasses to very open tussock grassland over Triodia schinzii open hummock grassland.

One additional vegetation type was found within the study area

- D1 - *Corymbia chippendalei*, and occasional *Owenia reticulata*, over a mid-stratum dominated by *Acacia platycarpa*, *Acacia tumida* var. *kulparn* and *Crotalaria cunninghamii* subsp. *cunninghamii*, *over a lower-stratum of Acacia sabulosa, Triodia schinzii, and Gompholobium* simplicifolium.

Of the vegetation types recorded, D2, P1 and P2 will be the focus of the impact assessment below as they are found within the groundwater mounding contours that were less than 10 mbgl.

7.3 Direct Impacts

Ground disturbance for pond construction is expected to directly clear 18.7 ha of native vegetation (8.4 ha for Pond 1, and 10.3 ha for Pond 2) (Table 7.1). The vegetation types to be cleared include 5.4 ha of P1 vegetation and 13.3 ha of P2 vegetation. Both vegetation types are well represented locally, with P1 mapped 10,594 ha and P2 mapped across approximately 5,916 ha of the broader project area (see Section 3.7.2 for a description of these units and their local mapped extent).

The area of direct impact is dominated by xerophytic vegetation and does not include any phreatophytic (groundwater dependent) species. There will be no direct impact to any recorded flora of conservation significance, and no disturbance to sites with conservation significant fauna records (Figure 7.2).

The entire direct impact area (18.7 ha) represents the ‘Shrub and Spinifex on Sandplain’ fauna habitat (Figure 7.3), which is mapped across 34,416 ha within the survey area, representing 0.05% of the known survey extent for this habitat type.

7.4 Indirect Impacts

7.4.1 Vegetation and Flora

Table 7.1 and Figure 7.1 show the areas of potential indirect disturbance due to groundwater mounding from the infiltration pond discharge scenario within the study area, split into the four mapped vegetation types of the study area.

Overall, there was 124.8 ha of vegetation mapped within the 10 mbgl contour boundary that was not within the proposed indicative footprint. Of this area, only 3.1 ha (2.5%) is within groundwater contours that are less than 1m from the surface and a further 8.4 ha are within groundwater contours that are less than 2m from the surface. Vegetation within contours that are less that 5 mbgl represents a total area of 40.1 ha, which is made up of 13.9 ha of P1 vegetation and 26.2 ha of P2 vegetation. The area of indirect impact within groundwater contours less than 5 mbgl represents 0.1% of the locally mapped extent of P1 vegetation and 0.4% of the locally mapped extent of P2 vegetation.

Within the 10 mbgl mounding contour (which is the expected maximum rooting depth for vegetation of the study area), the P2 and P1 vegetation types have the largest area of potential indirect impact, with 79.1 ha and 43.9 ha respectively, with D2 only representing 1.8 ha of the area within the 10 mbgl contour boundary.

Modelling results indicate that only 1.2 ha of P1 vegetation and only 2 ha of P2 vegetation were within areas where groundwater was predicted to be less than 1 m from the surface, and where the risk of indirect impacts from groundwater mounding would be greater.

The majority (90.7%) of the P1 vegetation within the 10 mbgl contours occurs where groundwater modelled at least 2 m from the surface, suggesting that significant indirect impacts are unlikely.

The predicted indirect impact area for the P2 vegetation within the 10 mbgl contours type totals 79 ha, with the majority (90.5%) occurring where groundwater is modelled to be at least 2 m from the surface.

D2 vegetation type represents a relatively small proportion of the study area, within areas where groundwater mounding is between 7-10 mbgl (for 1.8 ha) and between 10-30m (for 49.1 ha). D1 also represents a very small proportion (1.1 ha) of the study area, within mounding contours that are greater than 30 mbgl. It is very unlikely that D1 and D2 will be indirectly impacted by groundwater mounding at the Project area.

Two conservation significant flora species, *Goodenia hartiana* (P2) and *Indigofera ammobia* (P3) occur within the study area. *Goodenia hartiana* was recorded within mounding contours between 7-10 mbgl and *Indigofera ammobia* was recorded in very low numbers within groundwater contours that were predicted to be deeper than 10 mbgl. Given the growth form of both species (low shrubs), and an expected shallow root system, indirect impacts from groundwater mounding for either species is considered very unlikely (Table 7.1 and Figure 7.2).

Table 7.1: Direct and potential indirect impact to flora and vegetation within the study area.

	Vegetation types (ha) in the study area					Significant species, number of locations (number of plants)	
	P1	P2	D1	D2	Total	*Goodenia hartiana (P2)*	*Indigofera ammobia (P3)*
Direct Impact							
Land clearing	5.4	13.3	-	-	18.7	-	-
Total	**5.4**	**13.3**	**0**	**0**	**18.7**	**0**	**0**
Indirect Impact (groundwater mounding)							
<1 m	1.2	2.0	-	-	3.1	-	-
1-2 m	2.9	5.6	-	-	8.4	-	-
2-5 m	9.8	18.7	-	-	28.5	-	-
5-7 m	9.9	24.8	-	-	34.7	-	-
7-10 m^	20.1	28.1	-	1.8	50.1	80 (2,999)	-
10-35 m*	179.7	112.3	1.1	49.1	342.3	113 (3,237)	2 (3)
Total	**223.7**	**191.5**	**1.1**	**50.9**	**467.2**	**193 (6,236)**	**2 (3)**

Note, 46.3 ha of land, which is either already cleared or is within the indicative footprint, has been excluded from this impact assessment.
^10m mounding extent is primarily discussed in impact assessment as this depth represents the expected rooting depth of vegetation in the Project area
*35m contours represented the extent of the study area

7.4.2 Fauna Habitat

Of the two habitat types within the study area, only 'Shrub and spinifex on sandplain' habitat may be indirectly impacted by groundwater mounding from the infiltration pond discharge scenario. Approximately 11.6 ha of 'Shrub and spinifex on sandplain' habitat was recorded within predicted groundwater mounding contours that were less than 2 mbgl (Table 7.3). Given this habitat type has been mapped locally over approximately 34,416 ha (Biota 2025), the potential indirect impact will likely affect just 0.03% of the known mapped extent in the surrounding area.

It is likely that only habitat within mounding contours less than 1 mbgl (3.1 ha of shrub and spinifex on sandplain habitat) may be affected by groundwater mounding.

Inland sand dune habitat, although mapped within the study area will not be impacted by potential groundwater mounding. Apart from a very small portion of habitat that is within groundwater contours between 7-10 mbgl, all other areas of this habitat are found within potential mounding contours that are deeper than 10 mbgl.

Table 7.2: Direct and potential indirect impact to fauna habitat within the study area.

	Shrub and Spinifex on Sandplain	Inland Sand Dune	Total
Direct Impact			
Land clearing	18.7	-	18.7
Total	**18.7**	**0**	**18.7**
Indirect Impact			
<1 m	3.1	-	3.1
1-2 m	8.4	-	8.4
2-5 m	28.5	-	28.5
5-7 m	34.7	-	34.7
7-10 m^	48.3	1.8	50.1
10-35 m*	292.1	50.2	342.3
Total	**415.1**	**52.0**	**467.2**

Note, 46.3 ha of land, which is either already cleared or is within the indicative footprint, has been excluded from this impact assessment.

^10m mounding extent is primarily discussed in impact assessment as this depth represents the expected rooting depth of vegetation in the Project area

*35m contours represented the extent of the study area

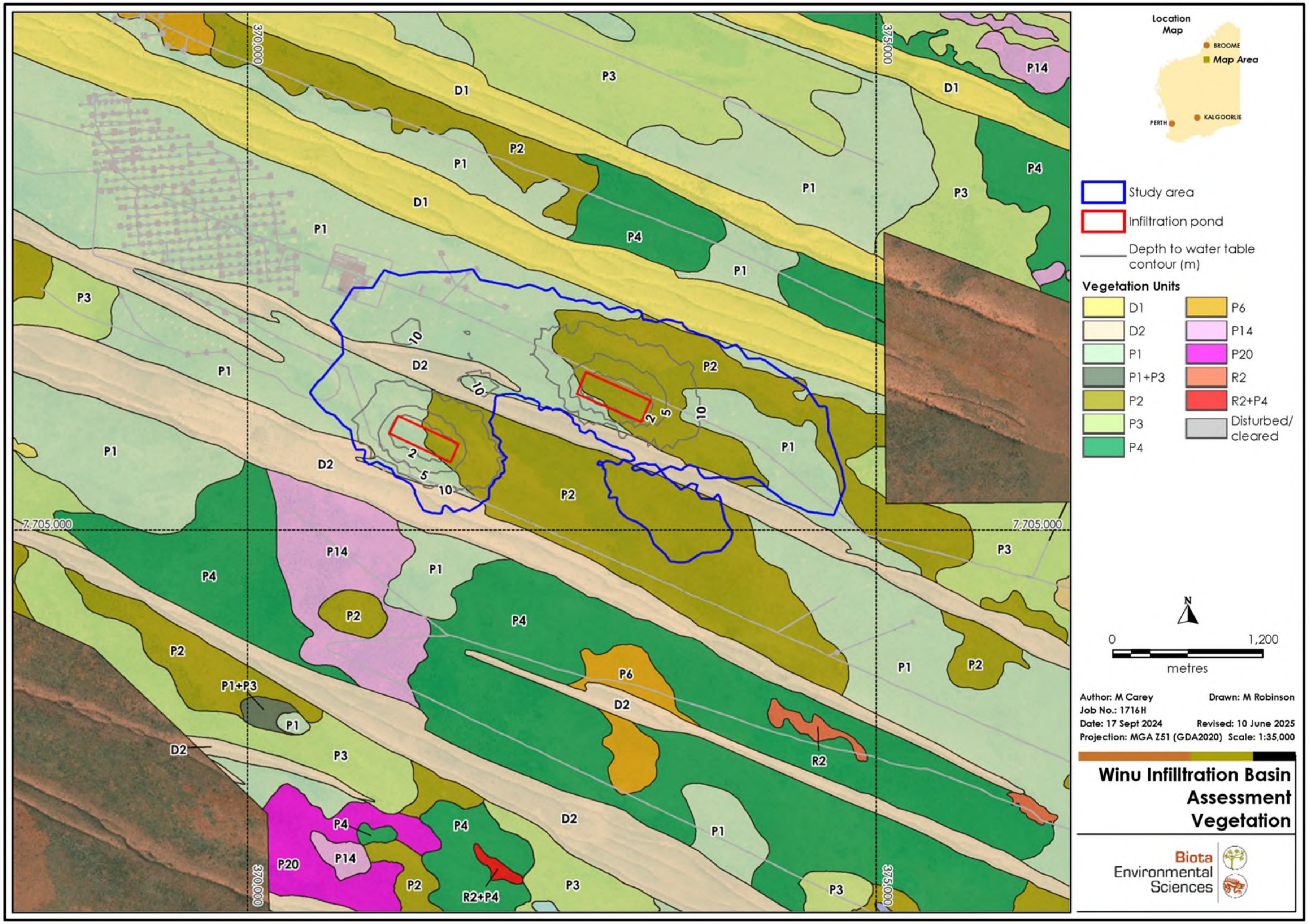

Figure 7.1: **Vegetation types within the study area (predicted groundwater mounding contours up to 10 m below surface).**

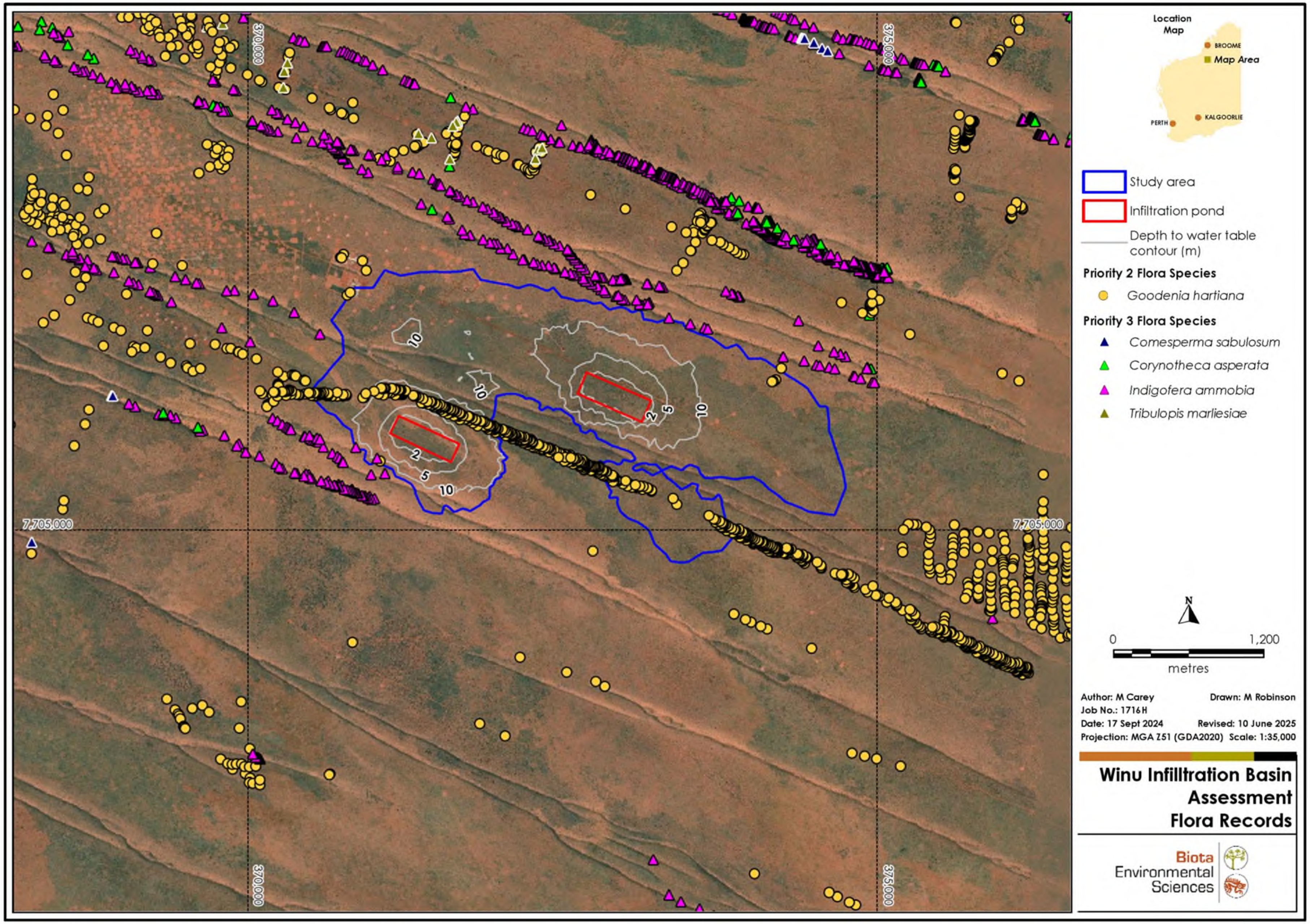

Figure 7.2: **Priority flora records within the study area (predicted groundwater mounding contours up to 10 m below surface).**

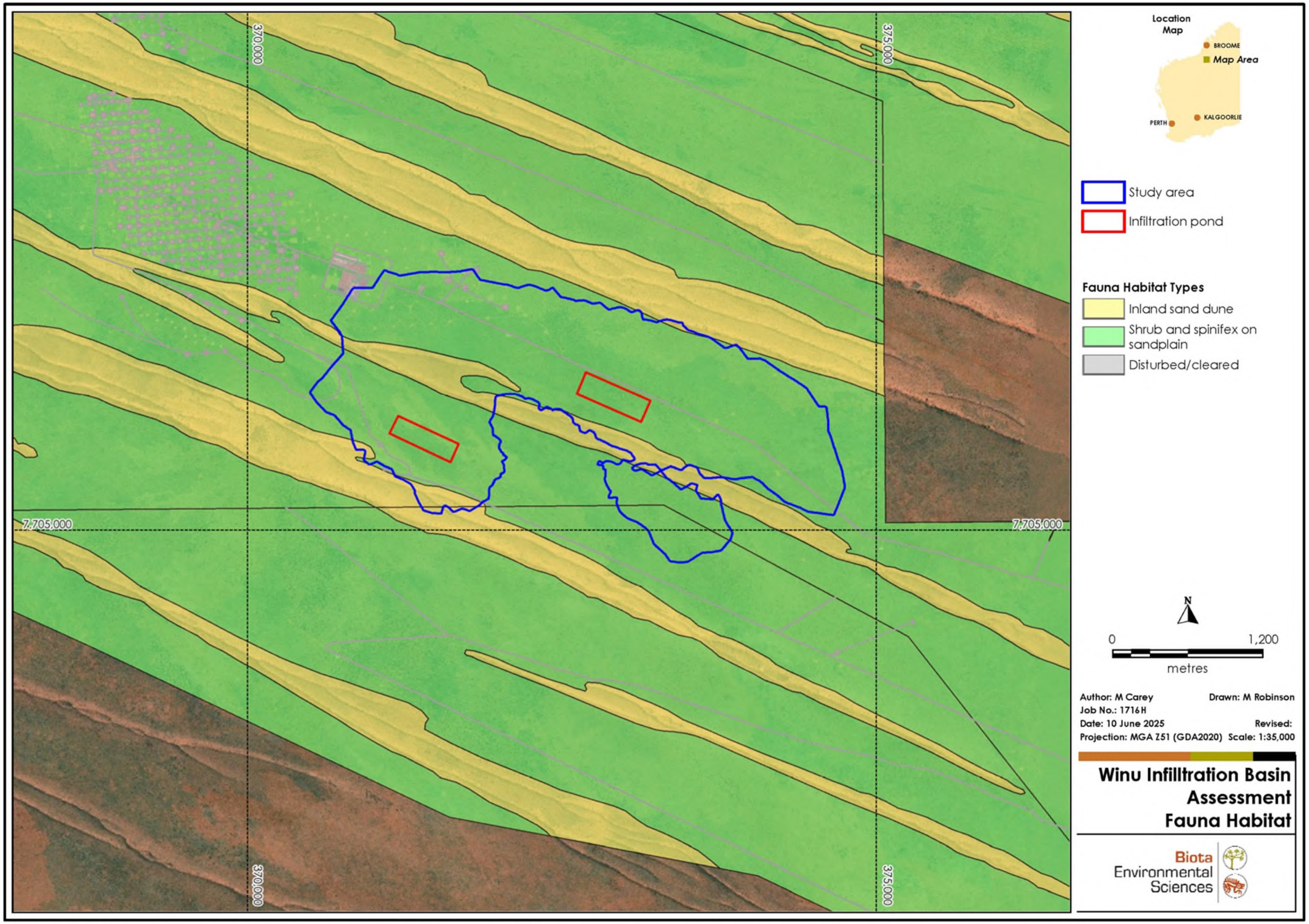

Figure 7.3: **Habitat within the study area.**

7.4.3 Plant Life Forms and Rooting Depths

The composition of the dominant plant life forms represented within the vegetation types of the study area is summarised in Table 7.3.

Across all vegetation types within the study area, shrub species were the most abundant (ranging from 29-50% of the total species composition), followed by grass-like forms such as spinifex (*Triodia*) hummocks (19-24% composition), trees (2-4% composition) and tall shrubs (6-12% composition) represented a relatively small proportion of the total species composition for all vegetation types. All species composition values are based on data from available quadrat records (Western Botanical 2023b, 2025).

Table 7.3: Life forms recorded within vegetation types of the study area.

	Vegetation Types of the Study Area*					
	D2		P1		P2	
Life Form	No. of Species	Proportion (%)	No. of Species	Proportion (%)	No. of Species	Proportion (%)
Annual	2	4	3	5	3	5
Grass and grass-like	10	20	11	19	13	24
Perennial herb	7	14	5	9	6	11
Low Shrub	2	4	10	18	9	16
Shrub	25	50	20	35	16	29
Tall Shrub	3	6	7	12	6	11
Tree	1	2	1	2	2	4
Total	**50**	**100**	**57**	**100**	**55**	**100**

*Vegetation D1 was excluded from this assessment as this vegetation type was only found at groundwater mounding contours that were deeper than 30 mbgl. There are no impacts to species and lifeforms within D1 vegetation.

Based on a review of current knowledge of rooting depths in arid environments (Section 4.0), an expected rooting depth has been proposed for the plant life forms of the study area, which ranked from shallowest to deepest rooted comprises:

- Annual: approximately 0.5 m expected rooting depth.
- Grass-like: approximately 0.9 m expected rooting depth.
- Perennial herb: approximately 1.0 m expected rooting depth.
- Low shrub: approximately 1.5 m expected rooting depth.
- Shrub: approximately 2.1 m expected rooting depth.
- Tall shrub: approximately 3.0 m expected rooting depth.
- Tree: approximately 3.0 m expected rooting depth.

An impact assessment has been made of all the species recorded from the three vegetation types associated with the 10 m mounding extent (D1, D2, P1 and P2). All recorded species have been ranked based on their susceptibility to groundwater mounding, using their dominance within the vegetation type, their life form and expected rooting depth (Table 7.4). Species highlighted in bold in Table 7.4 are at most risk of indirect impacts due to a combination of their relative abundance in the vegetation types and deeper roots.

Table 7.4: Assessment of key species associated with vegetation within the mounding zone.

Species	Life Form (based on Florabase descriptions)	Cover (%)	Height (cm)^	Vegetation Type*		
				D2	P1	P2
Amphipogon sericeus	Grass	0.1-0.5	30-50			
Aristida holathera var. *holathera*	Grass	0.1-1.0	30-50			
Sorghum plumosum var. *plumosum*	Grass	0.1-1.0	100-180			
Triodia schinzii	Grass	8-10	30-40			
Androcalva loxophylla	Low shrub	0.1-1.0	45-120			
Acacia platycarpa 'Desert Form Non-Pruinose'	Shrub	0.1-6.0	70-120			
Acacia sabulosa	Shrub	1.5	180			
Acacia tumida var. *kulparn*	Shrub	0.1-4.0	170			
Dampiera cinerea	Shrub	0.1-3.0	30-50			
Dicrastylis cordifolia	Shrub	0.1-1.0	25-40			
Dicrastylis doranii	Shrub	0.1-6.0	40-50			
Gompholobium simplicifolium	Shrub	0.1-2.5	50-90			
Jacksonia aculeata	Shrub	0.1-5.0	40-70			
Seringia exastia	Shrub	0.1-3.0	40-70			
Thinicola incana	Shrub	0.1	190			
Petalostylis cassioides	Shrub	0.1-5.0	50-110			
Acacia ancistrocarpa	**Tall shrub**	**0.1-20.0**	**200-280**			
Erythrophleum arenaria	**Tall shrub**	**0.1-1.0**	**120-350**			
Hakea macrocarpa	**Tall shrub**	**0.1-1.0**	**180-210**			
Owenia reticulata	**Tree**	**0.1-2.0**	**180-400**			
Grevillea stenobotrya	Tall shrub	0.1	140-300			
Trigastrotheca molluginea	Annual	0.1	15-30			
Eragrostis eriopoda	Grass	0.1	30-40			
Eriachne aristidea	Grass	0.1	20-40			
Eriachne helmsii	Grass	0.1	40-50			
Eriachne lanata	Grass	0.1-3.0	40-60			
Goodenia armitiana	Perennial herb	0.1-8.0	25-40			
Sida sp. Western sand dunes (P.K. Latz 11980)	Perennial herb	0.1	50			
Spermacoce occidentalis	Perennial herb	0.1	20			
Halgania solanacea var. *solanacea*	Low shrub	0.1-0.5	30-40			
Indigofera boviperda subsp. *eremaea*	Low shrub	0.1-1.0	40-45			
Scaevola parvifolia subsp. *parvifolia*	Low shrub	0.1-1.0	10-40			
Acacia anaticeps	Shrub	0.1-3.0	60-70			
Acacia platycarpa 'Desert Form Pruinose'	Shrub	0.1-7.0	70-140			
Bonamia erecta	Shrub	0.1-12.0	25-50			
Calytrix carinata	Shrub	0.1	50-170			
Cyanostegia cyanocalyx	Shrub	0.1	60			
Dodonaea coriacea	Shrub	0.1	40-110			
Grevillea eriostachya	Shrub	0.1-1.0	50-170			
Gyrostemon tepperi	Shrub	0.1	40-120			
Indigofera ammobia (P3)	Shrub	0.1	50			
Dodonaea hispidula var. *arida*	Tall shrub	0.1-1.0	120-250			

Species	Life Form (based on Florabase descriptions)	Cover (%)	Height (cm)^	Vegetation Type*		
				D2	P1	P2
Grevillea wickhamii subsp. hispidula	Tall shrub	0.1-5.0	100-320			
Euphorbia myrtoides	Annual herb	0.1	5			
Polycarpaea corymbosa var. *corymbosa*	Annual herb	0.1	20			
Polygala isingii	Annual herb	0.1	10-20			
Setaria surgens	Annual grass	0.1	30			
Abildgaardia oxystachya	Sedge	0.1	5-10			
Panicum australiense var. *australiense*	Grass	0.1	10-15			
Aristida inaequiglumis	Grass	0.1-1.0	70			
Aristida sp.	Grass	0.1	30			
Eragrostis aff. eriopoda	Grass	0.1	30			
Eragrostis sp.	Grass	0.1	10			
Eriachne obtusa	Grass	0.1-0.5	15-45			
Paractaenum refractum	Annual grass	0.1	40			
Paraneurachne muelleri	Grass	0.1	20-30			
Leptosema anomalum	Low shrub	0.1	20-30			
Cassytha capillaris	Perennial climber	0.1	20-90			
Bonamia alatisemina	Perennial herb	0.1	10-30			
Euploca diversifolia	Perennial herb	0.1	20			
Euploca vestita	Perennial herb	0.1	25			
Sida sp. Pindan (B.G. Thomson 3398)	Low shrub	0.1	30-50			
Swainsona microphylla	Perennial herb	0.1	50			
Goodenia azurea subsp. hesperia	Low shrub	0.1-1.0	30-50			
Goodenia hartiana (P2)	Low shrub	0.1-0.5	30-50			
Hibiscus leptocladus	Low shrub	0.1	10-50			
Ptilotus arthrolasius	Low shrub	0.1-0.5	30-70			
Ptilotus calostachyus	Low shrub	0.1-1.0	50-70			
Trichodesma zeylanicum var. zeylanicum	Low shrub	0.1	80			
Orianthera centralis	Low shrub	0.1	30-50			
Codonocarpus cotinifolius	Tall shrub	0.1	90			
Corchorus sidoides subsp. vermicularis	Shrub	0.1	20-40			
Dampiera candicans	Shrub	0.1	25-80			
Newcastelia cladotricha	Shrub	0.1	40-70			
Newcastelia spodiotricha	Shrub	0.5	70			
Ptilotus astrolasius	Shrub	0.1	30-50			
Senna curvistyla	Shrub	0.1	50			
Synostemon arenosus (P3)	Shrub	0.5	30			
Tephrosia arenicola	Shrub	0.1	50			
Acacia drepanocarpa subsp. latifolia	Shrub	0.1-2.0	100-180			
Acacia colei	Tall Shrub	0.1	220			
Acacia sericophylla	Tall Shrub	0.1-2	50-240			
Corymbia zygophylla	Tree	0.1	280			

*Dark green cells represent listed dominant species within the vegetation type description. Medium green cells represent other associated species noted within each vegetation description. Light green cells represent species listed from quadrat records, occasionally present in vegetation. White cells represent species not recorded in the vegetation type.

^ Height range (cm) for plants recorded within quadrats within D2, P1 and P2 vegetation types.D1 has not been included as vegetation is only represented with 1.1 ha within groundwater levels that are deeper than 30 mbgl

The P2 vegetation type includes eight listed dominant species, four of which are grass forms with expected shallow root depths (0.9 m) and four species that are tall shrub/tree forms with expected deeper roots (approximately 3.0 m). Two shrub species also associated with the P2 vegetation type have an expected root depth of approximately 2 m.

It is unlikely that the dominant shallow-rooted grass life forms of the P2 vegetation type (*Amphipogon sericeus, Aristida holathera* var. *holathera, Sorghum plumosum* var. *plumosum* and *Triodia schinzii*) will be affected in even the greatest mound contour; 18.5 ha with a water table less than 1 m from the surface.

The tall shrubs and tree species dominant in the P2 vegetation (*Acacia ancistrocarpa, Erythrophleum arenaria, Hakea macrocarpa and Owenia reticulata*) may experience waterlogging conditions where the water table contour mound is modelled to be less than 2m from the surface; an area which represents 18.6 ha of the P2 vegetation type within the study area. These tall shrub and tree species are likely to be impacted within other parts of the study area where the water table is predicted to be greater than 2 m from the surface; representing 262.7 ha of the vegetation type in the 10 m mounding extent.

The remaining shrub species also associated with the P2 vegetation (*Dampiera cinerea, Dicrastylis cordifolia*) are smaller shrub life forms, with an expected rooting depth of approximately 2 m, which can likely persist in groundwater that is greater than 2m from the surface.

Interestingly, P2 occurs within the greatest predicted mounding areas, where the water table will be less than 2 m from the surface. P2 also has the highest proportion of dominant grass species of all the vegetation types in the study area. Grasses are generally associated with shallower spreading root systems that tolerate a shallower water table. An abundance of grasses in the areas where the mounding is closest to the surface is beneficial as these groups can take advantage of the wetter environment and provide fast cover and protection from potential opportunistic weed species wanting to also take advantage of the wetter conditions.

In the P1 vegetation type description (Section 7.2), the dominant plant species described were shrub and tall shrub species, with only two shallow-rooted species listed as dominant (one grass and one forb; Table 7.4). Because P1 vegetation occurs in areas where the water table is modelled to be less than 2 m from the surface, it is unlikely that impacts to the grass and herb species will occur. It is also unlikely that the shrubs, which have an expected rooting depth of more than 2 m, will be impacted, given the opportunity for lateral root spread near the surface. The tallest shrub and tree species of the P1 vegetation type, which may have an expected root depth that extends beyond 3 m includes *Acacia ancistrocarpa, Erythrophleum arenaria, Hakea macrocarpa, Owenia reticulata* and *Grevillea stenobotrya,* which are therefore at greater risk of potential waterlogging impacts (Table 7.4).

Similarly, the D1 and D2 vegetation type only occurs in areas where groundwater is predicted to be at least 5 m from the surface. The dominant taxa described for the D2 vegetation type consists of shrubs and tall shrubs/trees (Section 7.2), but given the depth of the mounding is predicted to be at least 5 m from the surface, this is unlikely to have any impact on shrub and tree species.

7.4.4 Potential Change in Ecohydrological Unit

Another interesting, temporary transition in ecohydrological units may also occur because of prolonged infiltration and water table mounding. The ecohydrological unit currently assigned to the study area (EHU 5) is likely to transition and begin to align more with a EHU 9: Lowland receiving areas (drainage termini in the form of ephemeral lakes, claypans and flats) (MWH 2015) (Figure 7.4 and Table 7.5).

Consideration of the ecohydrological characteristics and vegetation composition of EHU 9 may provide a useful model for management of the study area during the infiltration period.

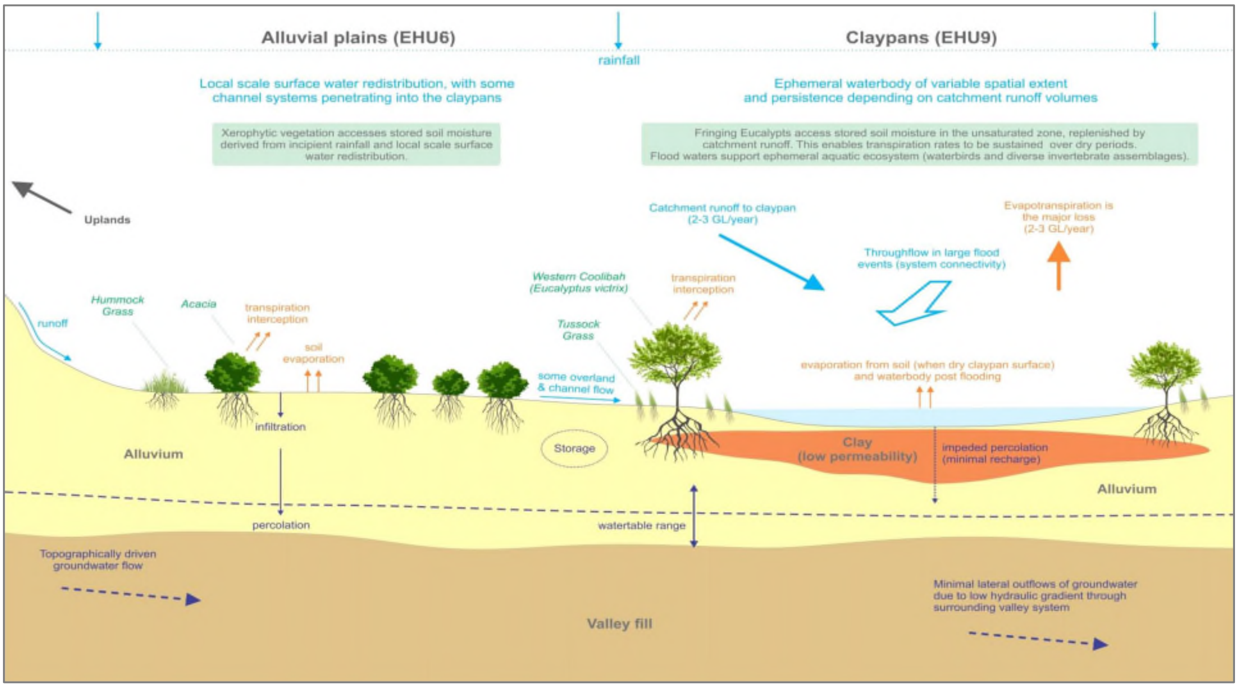

Figure 7.4: Ecohydrological conceptualisation of the Claypans (source: MWH 2015)

Table 7.5: Ecohydrological Unit 9 characteristics (Source: MWH 2015)

EHU Characteristic	Description
Landscape position, land surface and soils	Lowland receiving areas - drainage termini in the form of ephemeral lakes, claypans and flats. Deep silty and clay textured soils. Variable surface salinity (resulting from evaporites). Soils may be underlain by calcrete/ silcrete hardpans of variable depth.
Dominant landscape water balance processes	Inflows => Ponding => Infiltration=> Storage=> Soil evaporation=> Evapotranspiration=> Groundwater recharge=> Groundwater discharge (localised)
Dominant surface drainage/connectivity processes	Drainage termini receive inflows from up-gradient drainage systems. Transient to persistent ponding may occur as dictated by flooding regimes, with spillovers possible in large flooding events. Sediment accumulation and evaporative concentration of salts.
Level of connectivity to groundwater systems	Depth to groundwater may vary from shallow (less than 5 m) to deep (>20m). Groundwater may be fresh, brackish or saline. Groundwater systems can be accessible to vegetation in some situations. Evaporative discharge of shallow groundwater may occur.
Major Vegetation Types	Fringed or occupied by distinctive vegetation communities such as Samphire. Regularly inundated areas may be largely devoid of vegetation. Vegetation adapted to waterlogging, flooding and salinity stressors.

EHU Characteristic	Description
	Potential to support groundwater dependent ecosystems (GDEs), depending on the level of surface and groundwater connectivity. However, this is likely to be uncommon.

7.5 Impact Summary

While it is unlikely that any of the dominant species listed will be significantly impacted by mounding, tall shrub and tree species associated within P2 are more vulnerable within the 18.5 ha area where water table mounding may be less than 1 m from the surface. The key at-risk species for these areas are summarised in Table 7.6.

The distribution of three of the four tall shrub/tree species recorded within P2 are described as 'scattered low trees' and recorded less than 1% cover across all sampling locations. Only *Acacia ancistrocarpa* was described with a slightly higher cover class, representing 7-15% of foliar cover within flora sampling sites.

Because *Acacia ancistrocarpa* has the highest recorded cover of tall shrub and tree species in the study area within the predicted shallow water table contours (less than 2 m from the surface), it is likely that more individuals of this species may be affected by impacts associated with water table mounding within the P2 vegetation type. However, studies into *Acacia ancistrocarpa* by Grigg (2009) have shown this species to be extremely resilient and capable to adapting to a range of soil depth and moisture conditions.

Table 7.6: Tall shrubs and tree species associated with the vegetation within the 0-10 m mounding zone.

Species	Life Form	Cover Range (Height Range)		
		D2	P1	P2
Acacia ancistrocarpa	Tall shrub	Not recorded	0.1% (200 cm)	7-15% (250-280 cm)
Erythrophleum arenaria	Tall shrub	1% (250-260 cm)	0.5-3% (240-280 cm)	0.1-0.5% (120-250 cm)
Hakea macrocarpa	Tall shrub	Not recorded	0.1% (210 cm)	0.5-1% (30-110 cm)
Owenia reticulata	Tree	0.1% (180 cm)	0.5% (350 cm)	0.5% (400 cm)

8.0 Conclusions

Based on a review of current literature and an assessment of the flora and vegetation characteristics of the Winu project survey area, the following conclusions can be made of the potential impacts from the proposed discharge scenarios:

Infiltration ponds:

- Direct ground disturbance for pond construction is expected to clear 18.7 ha of native vegetation, comprising 8.4 ha of P1 vegetation and 10.3 ha of P2 vegetation.
- There will be no direct impact to any recorded sites of significant flora. The entire direct impact area (18.7 ha) represents the 'Shrub and Spinifex on Sandplain' fauna habitat, which is associated with significant fauna species such as the Bilby and Brush-tailed Mulgara.
- Three vegetation types (P1, P2, and D2) occur within the predicted 10 m mounding zones, and these vegetation types may be affected by indirect impacts due to the predicted groundwater mounding:
    - Within the P2 vegetation type, 2 ha were within areas where groundwater will be less than 1 m from the surface and 26.2 ha is located within areas where groundwater is modelled to be at least 5 m from the surface.
    - Within the P1 vegetation type, 1.2 ha were recorded within areas where groundwater will be less than 1 m from the surface and 13.9 ha is located within areas where groundwater is modelled to be at least 5 m from the surface.
    - A very small portion of the D2 vegetation type is within the 10m mounding extent (1.8 ha), but all in areas where mounding is modelled to be greater than 7 m from the surface.
    - The D1 vegetation represents 1.1 ha of the study area and occurs where water table mounding is modelled to be more than 30 m from the surface.
- Of the two habitat types within the study area, only 'Shrub and spinifex on sandplain' habitat was recorded within predicted groundwater mounding contours that were less than 2 mbgl. The potential indirect impact will likely affect less than 0.1% of the known mapped extent of this habitat type within the surrounding area.
- Most flora species from all potentially affected vegetation types are of growth forms with relatively shallow root systems and are therefore unlikely to be significantly affected by groundwater mounding.
- A small number of tall shrub and tree species associated with the P1 and P2 vegetation types, which are within the 3.1 ha area where the groundwater mounding may occur less than 1 m from the surface, are most vulnerable. The majority of these tall shrub/tree species were recorded in very low abundance (less than 1% cover), with only *Acacia ancistrocarpa* slightly more abundant (7-15% cover), therefore putting a relatively higher number of *Acacia ancistrocarpa* individuals at risk from mounding impacts. However, an understanding of *Acacia ancistrocarpa* and its dimorphic root system has proven this species can adapt well to hydrological change (Section 4.3).
- A change in the characteristics of the ecohydrological unit is also likely to occur within the small area of mounding extent near the surface, with the site transitioning from EHU 5 (Lowland sand plains) to EHU 9 (Lowland receiving areas). Consideration of the ecohydrological characteristics and vegetation composition of EHU 9 may provide a useful model for management of the study area during the infiltration period.

- Two conservation significant flora species are located within the study area, but at locations where the predicted groundwater mounding is greater than 7 m from the surface. *Goodenia hartiana* (P2) and *Indigofera ammobia* (P3) are both described as low shrubs, with an expected shallow root depth that is unlikely to exceed 1-2 m. Given that both these species are relatively shallow rooted, it is unlikely that these species would be at risk from the predicted mounding.

Reinjection (MAR) Bore field:

- The outcomes from the MAR modelling indicate that there will be no mounding within 30 m of the surface, and as such no vegetation or individual plant (tree) species within the Study area will be influenced by groundwater mounding at this extent and depth. The literature review found that the expected maximum rooting depth for vegetation of the study area is approximately 10 mbgl.
- Other groundwater dependent ecosystems, such as subterranean habitats, were considered for changes at depth. Recent studies (Biota 2020, Biota 2022) have indicated that potential impacts on subterranean fauna are not considered significant due to the lack of evidence for either troglofaunal or stygofauna within the aquifer and the low likelihood of significant habitat for either ecological group being present.

The final operating strategy (in development) for managing surplus water from mine pit dewatering, will likely include a combination of both reinjection MAR bores (as the primary discharging method), as well as infiltration ponds to manage any excess that may occur (i.e. emergencies, unexpected shutdowns). Based on this combined scenario, it is likely that the MAR bore field will maintain groundwater mounding well below 30 mbgl. Apart from the direct impact from clearing to construct the infiltration infrastructure (ponds and water bores etc.) there will be no indirect impacts to environmental values from groundwater mounding.

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