THEMEDA SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY

Fortescue

ecoscape

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SUMMARY

FMG Iron Bridge (Aust) Pty Ltd (FMGIB) is seeking to amend the North Star Magnetite Project with the extension of the mine development envelope (MDE). To support the proposed amendment, Fortescue requires additional assessment of a Priority 1 flora taxon, *Themeda* sp. Panorama (J. Nelson et al. NS 102), which is known to occur within the project's development envelope. Fortescue engaged Ecoscape to conduct species distribution modelling for the target species within the Pilbara bioregion and undertake a targeted flora survey.

The species distribution modelling was performed with MaxEnt software using known records of *Themeda* sp. Panorama (J. Nelson et al. NS 102) and 12 environmental variables, including four topographical variables, seven landform variables and one vegetation variable. The modelling predicted that suitable habitat supporting *Themeda* sp. Panorama (J. Nelson et al. NS 102) would occur within 100 km of North Star, mostly in the vicinity of the MDE. No suitable habitat was predicted to occur in the wider Pilbara region. Suitable habitat predicted with high probability was evaluated using aerial imagery to identity locations to target for the field survey. Preference was given to drainage features as most known records of *Themeda* sp. Panorama (J. Nelson et al. NS 102) occur within drainage lines.

The targeted flora survey was conducted over two phases during May and July 2024. Seasonal conditions were adequate for the identification of the target taxon due to above average rainfall in the months preceding the field survey. The key findings from the survey were:

- a total of 10,713 plants were recorded from 33 populations, including 29 new populations and four population extensions
- all populations were recorded within 80 km of North Star with an overall distribution of approximately 85 km east-west by 65 km north-south
- all records occur within mining tenements; no records occur within any conservation estate
- all populations were recorded from within drainage features, mostly in rugged sandstone and basaltic hills and in association with *Eucalyptus camaldulensis* subsp. *refulgens*, *E. victrix* and/or *Melaleuca argentea* woodland communities. Populations were also associated with drainage vegetation dominated by *Corymbia hamersleyana* and mixed *Acacia* shrubland communities.

Five of the populations recorded were opportunistically observed during traverses between target locations. These populations mostly corresponded with areas that had a lower probability score for suitable habitat as predicted by MaxEnt. However, the populations were recorded from drainage features, mostly in hilly terrain, which is the known habitat type. These results suggest that additional populations are likely to occur within the taxon's known distribution. Suitable habitat is also relatively widespread in the region (although only occupying a small proportion of the landscape), increasing the likelihood of additional populations occurring.

ACRONYMS AND ABBREVIATIONS

Table 1: Acronyms and abbreviations

Acronyms	
BC Act	Western Australian *Biodiversity Conservation Act 2016*
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWE	Commonwealth Department of Agriculture, Water and Environment (2020-2022, now DCCEEW)
DBCA	Western Australian Department of Biodiversity, Conservation and Attractions
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DEMIRS	Western Australian Department of Energy, Mines, Industry Regulation and Safety (formally DMIRS)
DPIRD	Western Australian Department of Primary Industries and Regional Development
DWER	Western Australian Department of Water and Environmental Regulation
Ecoscape	Ecoscape (Australia) Pty Ltd
EP Act	Western Australian *Environmental Protection Act 1986*
EPA	Western Australian Environmental Protection Authority
GDA 94	Geographic Datum of Australia 1994
GDE	Groundwater Dependent Ecosystem
GIS	Geographic Information System
GPS	Global Positioning System
FMGIB	FMG Iron Bridge
IBRA	Interim Biogeographic Regionalisation for Australia
MDE	Mine development envelope
MGA	Map Grid of Australia
P1, P2, P3, P4	Priority Flora rankings
PF	Priority Flora
sp.	Species (generally referring to an unidentified taxon or when a phrase name has been applied)
subsp.	Subspecies (infrataxon)
TF	Threatened Flora (formerly termed Declared Rare Flora, DRF, in Western Australia)
var.	Variety (infrataxon)
WAH	Western Australian Herbarium
*	Introduced flora species (i.e. weed)

1 INTRODUCTION

1.1 BACKGROUND

FMG Iron Bridge (Aust) Pty Ltd (FMGIB) operates the existing North Star Magnetite Project, (the Approved Proposal) located approximately 110 km southeast of Port Hedland in the Pilbara region of Western Australia. FMGIB is seeking to amend the Approved Proposal to include the North Star extension, which is an extension of the Mine Development Envelope (MDE), the Proposed Amendment. One Priority 1 flora species, *Themeda* sp. Panorama (J. Nelson et al. NS 102) (hereafter referred to as *Themeda* sp. Panorama), is known to occur within the disturbance footprints. Previous surveys have identified that 33% of known individuals occur within the combined indicative disturbance footprints of the Approved Proposal and Proposed Amendment. Fortescue requires further assessment of *Themeda* sp. Panorama to expand its known distribution and commissioned Ecoscape to undertake regional species distribution modelling for the Pilbara and targeted flora survey.

1.2 SURVEY AREA

The study area for the species distribution modelling was the extent of the Pilbara region excluding offshore islands (see **Section 2.4**). The survey area for the targeted flora survey was determined from the results of the modelling (**Section 4.1**) and is shown in **Figure 1**. The survey area encompasses areas surrounding the North Star MDE and extension area, and more regional areas where *Themeda* sp. Panorama was predicted to occur.

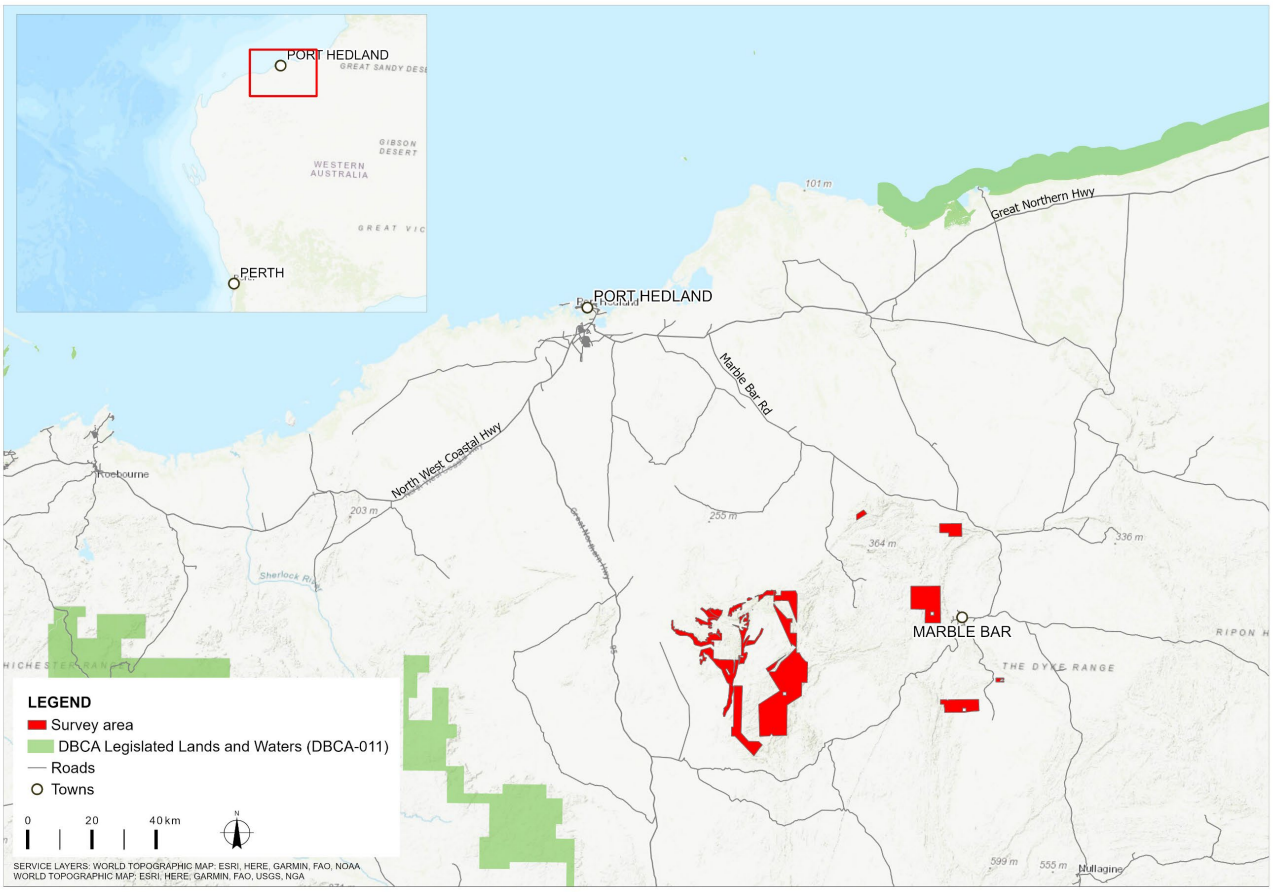

Figure 1: Survey area location

1.3 SURVEY REQUIREMENTS

The requirements of the survey were to:

- undertake desktop assessment and species distribution modelling for *Themeda* sp. Panorama to determine likely regional distribution within the Pilbara
- undertake targeted field surveys based on the results of the modelling in accordance with relevant aspects of the Environmental Protection Authority (EPA) *Technical Guidance - Flora and Vegetation Surveys for Environmental Impact Assessment* (known herein as the Flora and Vegetation Technical Guidance)
- provide a report detailing modelling approach, model results, targeted survey methodology, field survey results and discussion on species abundance and regional distribution.

1.4 COMPLIANCE

This assessment complied with EPA requirements for environmental survey and reporting in Western Australia, as outlined in:

- EPA (2016a) *Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment*
- EPA (2016b) *Environmental Factor Guideline – Flora and Vegetation*
- EPA (2021) *Statement of environmental principles, factors, objectives and aims of EIA*.

Fortescue's internal management guidelines and procedures were also complied with as required.

Additional details (definitions and criteria) relevant to these works are available in **Appendix One**.

2 METHODS

2.1 SURVEY AIMS

The aims of the Targeted flora survey were to:

- undertake desktop assessment and species distribution modelling for *Themeda* sp. Panorama to determine likely regional distribution within the Pilbara
- undertake systematic targeted searches for *Themeda* sp. Panorama in potentially suitable habitat identified by the modelling.

2.2 GUIDING PRINCIPLES

The flora and vegetation survey was conducted as a Targeted survey according to the Flora and Vegetation Technical Guidance (EPA 2016a). The EPA considers that a Targeted survey should be used to gather comprehensive information on significant flora. The EPA identifies the following requirements for a Targeted survey relevant to the scope of works (regional assessment):

- one or more site visits by an experienced botanist to locate and record details for individuals/populations
- surveys should be conducted when the targeted flora are most detectable and identifiable in the field
- potentially suitable habitats should be systematically searched.

2.3 HERBARIUM INVESTIGATION

Prior to conducting modelling and field survey, an investigation was undertaken at the WA Herbarium to identify whether there were any additional collections of *Themeda* sp. Panorama that may provide additional locations to target. All collections of *Themeda avenacea* were examined as well as any collections filed under '*Themeda* sp.'. No additional collections were identified.

2.4 MAXIMUM ENTROPY SPECIES DISTRIBUTION MODELLING

Specific locations to target during the field survey were identified by the species distribution modelling program MaxEnt (Phillips, Anderson & Schapire 2006). This model expresses a probability distribution where each grid cell has a predicted suitability of conditions for the species based on a set of environmental variables (such as elevation, geology and soil) and known species occurrence locations. The outcomes of the modelling will therefore identify areas most likely to support the species to be targeted during the field survey.

Data Inputs

MaxEnt requires two input datasets: species occurrence points and environmental predictors that are relevant to the species. Species occurrence points were known records of *Themeda* sp. Panorama featuring 655 points from Fortescue-commissioned botanical surveys, Ecoscape survey records, Trudgen et al. (2002) documented locations and WA Herbarium records. Environmental predictors selected for the modelling are shown in **Table 2** and comprise 12 layers representing topographical, landform and vegetation variables for the Pilbara region**.**

Digital elevation was acquired online from *EarthExplorer* (The United States Geological Survey 2022) using the SRTM 1 Arc-Second Global dataset. Slope, aspect and curvature were derived from the digital elevation layer in ArcGIS Desktop (ESRI 2023) using the Slope, Aspect and Curvature spatial analyst tools, respectively. All other environmental layers were sourced online from Data WA (Government of Western Australia 2023) and CSIRO Data Access Portal (CSIRO 2023) (shown in **Table 2**).

Pre-Processing

Pre-processing of the environmental layers was conducted in ArcGIS Desktop to ensure all layers had the same spatial characteristics (e.g. cell size, datum and geographic bounds). The geographic bounds were defined as the extent of the Pilbara bioregion (excluding offshore islands) as mapped in the Interim

Biogeographic Regionalisation for Australia dataset (DBCA 2012). All environmental layers were re-sampled to the spatial resolution of the digital elevation layer (cell size of 30.87 meters).

Spatial filtering (thinning out of records) was applied to the occurrence points to address sampling bias evident in the dataset. The oversampling of flora was apparent in areas near North Star where systematic targeted surveys have been undertaken for *Themeda* sp. Panorama. Minimising sampling bias through spatial filtering has been shown to improve the accuracy of predictions by reducing the degree to which models overfit to biases (Boria et al. 2014).

Records were spatially filtered to 500 m between points (resulting in 34 occurrence points) using the Delete Identical data management tool in ArcGIS. The 500 m distance was chosen as it is used to define the upper limit of population clustering for flora taxa (i.e. plants that are more than 500 m apart are considered separate populations) (DBCA 2017). Modelling was also performed with the data spatially filtered to 200 m (60 occurrence points) and 1,000 m (20 occurrence points) to compare model performance.

The settings used to run the model in MaxEnt are shown below in **Table 3.**

Table 2: MaxEnt variables

Environmental layers	Description	Reference
Topographic variables		
DEM	Topographical relief	SRTM 1 Arc-Second Global (The United States Geological Survey 2022)
Aspect	Terrain slope direction	Aspect (Spatial Analyst Tools) (ESRI 2023)
Slope	Terrain steepness	Slope (Spatial Analyst Tools) (ESRI 2023)
Curvature	Surface terrain curvature	Curvature (Spatial Analyst Tools) (ESRI 2023)
Landform variables		
Bedrock geology	Bedrock rock formation/structure	1:500 000 State interpreted bedrock geology (DMIRS-016) (DPIRD 2018a)
Surface geology	Surface rock formation/structure	Surface Geology of Australia – 1:1 000 000 scale (Raymond et al. 2012)
Regolith	Unconsolidated material above bedrock	Regolith of WA - 500 metre grid (DMIRS-017) (DPIRD 2018b)
Soil landscape	Land systems defined by a combination of vegetation, soil, landform and geology	Soil Landscape Mapping – Best Available (DPIRD-027) (DPIRD 2019a)
Soils	Australian soil types	Atlas of Australian Soils (digital) (CSIRO 2021)
Soil colour	RGB surface soil colour	Soil and Landscape Grid National Soil Attribute Maps - Soil Colour (3" resolution) - Release 1 (Malone 2022)
Soil depth	Depth of soil within a 0-2 m range	Soil and Landscape Grid National Soil Attribute Maps - Soil Depth (3" resolution) - Release 2 (model 2) (Malone 2020)
Vegetation		
Vegetation	Pre-European vegetation units	Pre-European Vegetation (DPIRD-006) (DPIRD 2019b)

Table 3: MaxEnt settings

Parameter	Value
Output format	Cloglog
Random test percentage	20
Regularisation multiplier	1
Background points	10000
Replicate run type	Subsample
Replicates	10
Maximum iterations	5000
Default prevalence	0.5

2.5 FIELD SURVEY

The methods utilised during the field survey followed those outlined in the Flora and Vegetation Technical Guidance (EPA 2016a), conducted as a two-phase Targeted flora survey.

Survey method details are outlined below.

2.5.1 TARGETED SEARCHES

Targeted searches were conducted as lengthy traverses on foot (several hundred meters to several kilometres) in areas of suitable habitat, including drainage lines, gullies, gorges, basalt boulder fields and rocky south-facing slopes at the base of cliffs. Specific locations targeted were selected prior to the field survey using the high probability scores (0.8 - 1.0) from the MaxEnt modelling in combination with aerial imagery to identify suitable habitat (see **Section 4.1**). Preference was given to drainage features when selecting target locations as most known records occur within these features. Additional targeting during the field survey was also undertaken in suitable habitat identified from observations during helicopter traverses between target locations.

The locations of *Themeda* sp. Panorama were recorded using handheld GPS devices (iPad) with the following data recorded:

- observer, date and time
- local abundance/population size and/or population boundary, including in nearby areas where possible (one tussock or clump was considered to represent one plant)
- landform and geology
- brief vegetation community description and associated species using relevé methodology (as per the Flora and Vegetation Technical Guidance)
- representative photos of individual plants and habitat (including surrounding vegetation)
- other details as relevant such as plant condition and vegetation condition using the vegetation condition scale for the Eremaean and Northern Botanical Provinces (**Table 4**)
- collection of representative specimens with at least one per population.

According to the Threatened and Priority Flora Report Form Field Manual (DBCA 2017), a population is defined as plants that occur within 500 m of each other. Therefore, plants occurring more than 500 m from another record were considered part of a new population.

The focus of the survey was to search for *Themeda* sp. Panorama, however, other conservation-listed flora were also recorded opportunistically when encountered.

Table 4: Vegetation Condition Scale for the Eremaean and Northern Botanical Provinces

Condition rating	Description
Excellent	Pristine or nearly so, no obvious signs of disturbance or damage caused by human activities since European settlement.
Very Good	Some relatively slight signs of damage caused by human activities since European settlement. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds, or occasional vehicle tracks.
Good	More obvious signs of damage caused by human activity since European settlement, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or slightly aggressive weeds.
Poor	Still retains basic vegetation structure or ability to regenerate it after very obvious impacts of human activities since European settlement, such as grazing, partial clearing, frequent fires or aggressive weeds.
Degraded	Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species present including very aggressive species.
Completely Degraded	Areas that are completely or almost completely without native species in the structure of their vegetation; i.e. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.

2.5.1.1 Permits

Kyla Pannell, James Tsakalos and Tracy de Vetter hold current flora collection licences for the purposes of taxonomic identification. Kyla Pannell holds a current collecting permit for Threatened Flora. Licence numbers are provided in **Section 4.2**.

None of the known records of *Themeda* sp. Panorama or target survey locations intersect any conservation areas and, therefore, additional permits were not required.

2.5.2 DATA MANAGEMENT AND ANALYSIS

2.5.2.1 Taxonomic Plant Identification

Themeda sp. Panorama specimens from each population and other plants that could not be identified with certainty in the field were collected using Western Australian Herbarium collecting protocols. Post-survey plant collection identification was undertaken by Ecoscape taxonomist Stephen Kern using relevant literature, taxonomic keys and reference specimens held at the WA Herbarium.

2.5.3 FIELD SURVEY TIMING

The field survey was conducted over two phases during 8-15 May and 5-12 July 2024. The phase one survey timing was within the primary season for botanical survey (March to June) according to the Flora and Vegetation Technical Guidance (EPA (2016a). The second phase was just outside this timeframe, however, seasonal conditions were adequate for the identification of *Themeda* sp. Panorama during both phases of survey following above average rainfall during March and June (see **Section 3.2.1**).

3 DESKTOP ASSESSMENT

3.1 BACKGROUND

Themeda sp. Panorama (J. Nelson et al. NS 102) was first identified as a potential new species in 2002 under the name *Themeda* sp. Panorama (Trudgen, Morgan & Griffin 2002), although it was not formally recognised by the WA plant census at this time. Additional collections were reported in 2018 and 2020 by Ecoscape under the names *Themeda* sp. and *Themeda* aff *avenacea* (Ecoscape 2018, Ecoscape 2020). Herbarium records also indicated that specimens collected in 1997 (Payne, A.L, PRP 1844) and 2006 (S. van Leeuwen et al., PBS 0416) were the same undescribed species reported by Trudgen et al. (2002) and Ecoscape (Ecoscape 2018, Ecoscape 2020). The taxon was formally added to the Western Australian plant census in 2020 under the phrase name *Themeda* sp. Panorama (J. Nelson et al. NS 102) (hereafter abbreviated to *Themeda* sp. Panorama) and listed as Priority 1 under the *Biodiversity Conservation Act 2016*. A draft publication to name it as a distinct species has been prepared with the proposed name *Themeda fehreae* (Jayasekara et al. 2023). In addition, collections lodged with the WA herbarium have been made of a taxon (currently not formally recognised) that may have affinities to *Themeda* sp. Panorama from the Bungaroo Creek region (P. Jayasekara pers. comm.).

Priority 1 taxa are poorly known species from one or a few locations which are potentially at risk. Populations are either very small, occur outside of conservation lands or are under threat of habitat destruction and degradation. P1 taxa may include species well known from one or more locations but are in urgent need of further survey (DBCA 2020).

Themeda sp. Panorama is a robust perennial tussock grass growing to 1 m tall with long greyish or bluish-green linear leaves (30-90 cm in length) (**Image 1** and **Image 2**). Flower culms are tall (110-150 cm) and straw coloured with lime-green inflorescence, flowering during late summer to early autumn. Suitable habitat includes drainage lines, gorges, basalt boulder fields and rocky south-facing slopes at the base of cliffs (Jayasekara et al. 2023).

Image 1: *Themeda* sp. Panorama form

Image 2: *Themeda* sp. Panorama habitat

3.1.1 DATABASE SEARCH

A database search was undertaken for *Themeda* sp. Panorama and a total of 655 records (totalling 15,182 individuals from 16 populations) were identified from Fortescue's database, Ecoscape survey records (2018, 2020), the Western Australian Herbarium and Trudgen et al. (2002) survey records. The identified records have a small distribution in the Pilbara region, approximately 80 km east-west by 35 km north-south, mostly near the North Star Magnetite Project area (**Map 1**). A small proportion of records are historical and may be unreliable, however the majority are considered current, dating between 2018 and 2023.

3.2 PHYSICAL ENVIRONMENT

3.2.1 CLIMATE

The survey area is the extent of the Pilbara region (excluding offshore islands) which includes two broad climatic zones. Coastal areas, as well as some higher rainfall inland areas, have a semi-desert tropical climate which experience 9-11 months of dry weather, with hot humid summers and warm winters. Inland areas have a dry desert climate, typically with higher temperatures and lower rainfall, and often experience up to 12 months of dry weather, with hot dry summers and mild winters (Leighton 2004).

According to the Köppen-Geiger climate classification, the survey area has a hot arid desert (Class BWh) climate (Peel, Finlayson & McMahon 2007). This classification is considered to represent a desert climate where annual rainfall is generally less than 200 mm or the region loses more water via evapotranspiration than it receives as rain, generally a result of hot, sunny weather without significant cloud. The mean average temperature exceeds 18°C, and summer temperatures are frequently over 40°C.

Annual rainfall in the Pilbara has substantial yearly variation, but generally follows an inland to coastal and southern to northern increasing trend. Tropical cyclones, many of which originate in the Timor Sea, along with local thunderstorms, produce much of the summer and early autumn rainfall. The driest months are in spring (September to October) and winter rainfall is highly variable, generally decreasing from the coast through to inland areas (Leighton 2004).

The closest the Bureau of Meteorology (BoM) station with long term records to the known locations of *Themeda* sp. Panorama is Marble Bar (BoM 2023a station 4106, operating since 2000), located approximately 80 km east of North Star. The mean annual rainfall is 400.3 mm, predominantly falling in the summer months (January to March) (**Figure 2**).

December is the hottest month with a mean maximum temperature of 42°C and minimum of 26.4°C. June is the coldest month with a mean maximum of 27.1°C and minimum of 13.3°C.

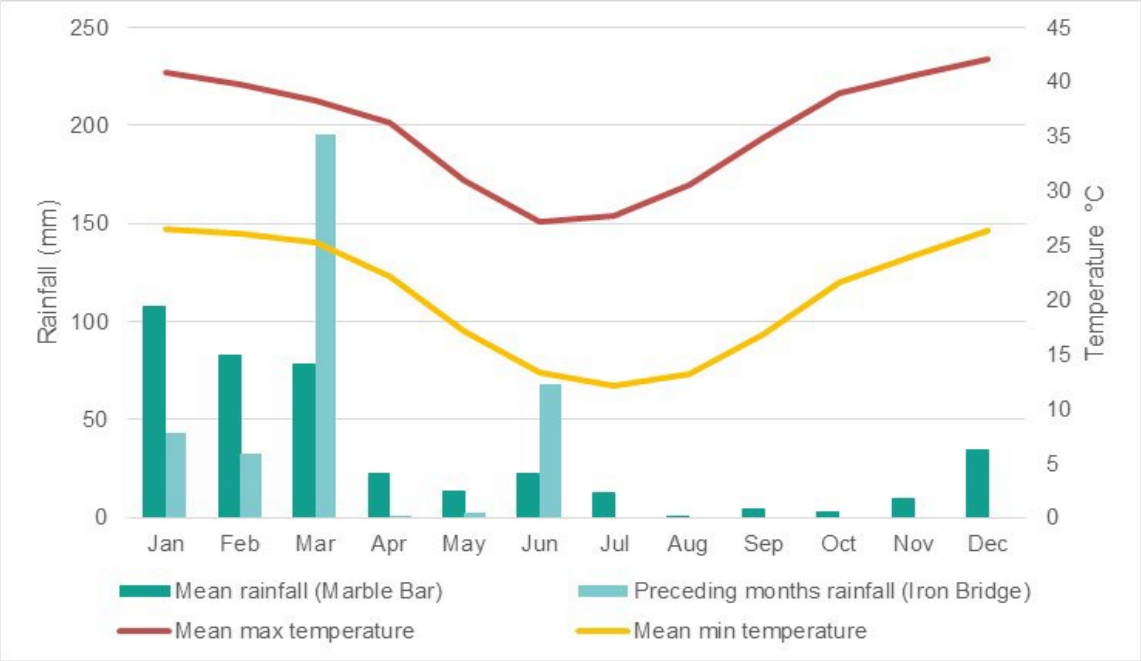

Figure 2: Rainfall and temperature data for the survey area (BoM 2023a)

Rainfall data for the months preceding the survey was supplied by Fortescue from the Iron Bridge North Star weather station, located in close proximity to the majority of the survey area. Long-term mean rainfall data was acquired from the nearest weather station with multi-decadal records (i.e. Marble Bar BoM station 4106).

3.2.2 LAND SYSTEMS

According to the Department of Primary Industries and Regional Development (DPIRD 2020) soil landscape mapping, 113 land systems occur within the Pilbara region. The largest land system by area is the Rocklea system, occupying 28,816.32 km^2 (or 16.18% of the Pilbara).

Table 5 below and **Map 2** show the land systems that correspond with known records of *Themeda* sp. Panorama within the survey area. The majority of records (82.14%) occur within the Capricorn system.

Table 5: Land systems (DPIRD 2020)

Land system	Description	% of records
Black system	Linear ridges of dolerite or basalt supporting hard spinifex grasslands, with unvegetated boulder slopes and rock piles along summits	0.31
Capricorn system	Rugged sandstone hills, ridges, stony footslopes and interfluves supporting low acacia shrublands or hard spinifex grasslands with scattered shrubs	82.14
Macroy system	Stony plains and occasional tor fields based on granite supporting hard and soft spinifex shrubby grasslands	0.15
Rocklea system	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex and occasionally soft spinifex grasslands with scattered shrubs	7.18
Talga system	Hills and ridges of greenstone and chert and stony plains supporting hard and soft spinifex grasslands	10.23

3.2.3 GEOLOGY

Detailed mapping of Australia's surface geology (1:1,000,000 scale) indicates that the Pilbara region is composed of 271 geological units (Raymond et al. 2012). Known records of *Themeda* sp. Panorama correspond with nine geological units with most records occurring within the Soanesville Group and Sulphur Springs Group (**Table 6** below and **Map 3**).

Table 6: Surface geology (Raymond et al. 2012)

Geological unit	Description	% of records
Dalton Suite	Gabbro, dolerite, dunite, peridotite, serpentine-chlorite schist, serpentinite, metaleucogabbro, metapyroxenite, ultramafic schist; metamorphosed.	0.31
Euro Basalt	Basalt, chert, dolerite, komatiitic basalt, komatiite, amphibolite, basaltic fragmental rock, gabbro, ultramafic to mafic schist, carbonate rock, felsic tuff, shale, sandstone, quartzite, metapyroxenite, serpentinite	0.46
Gorge Creek Group	Chert, ferruginous chert, banded iron formation, jaspilite; minor siltstone, shale, sandstone, pebbly sandstone, quartzite, polymictic conglomerate, felsic volcaniclastic rock, basalt, ultramafic schist, mafic schist	0.31
Nandingarra Granodiorite	An elliptical body of fine- to coarse-grained, equigranular biotite granodiorite, with lesser tonalite and monzogranite	0.15
Pincunah Banded-iron Member	Banded-iron formation; jaspilitic; minor layered chert and shale; metamorphosed	1.83
Soanesville Group	Conglomerate, arkosic sandstone, greywacke, lithic arenite, banded iron formation, shale, silicified shale (chert), sandstone, siltstone, quartzite, schist, basalt, mudstone, dacite, tuff, quartz-sericite schist; mafic schist	51.76
Sulphur Springs Group	Felsic to mafic volcanics and volcaniclastic rocks, chert, volcaniclastic sandstone, greywacke, shale, basalt, komatiitic basalt, amphibolite, mafic and ultramafic schist, banded iron formation, quartz-carbonate rock, siltstone.	42.44
Sulphur Springs Group - metadolerite	Metadolerite	2.44
Tambina Supersuite	Felsic intrusives; granodiorite, granite, monzogranite, syenogranite, quartz diorite, tonalitic orthogneiss, leucogranite, pegmatite, tonalite, schlieric leucogranite and diatexite	0.31

3.2.4 WETLANDS AND DRAINAGE

Seven drainage basins occur within the Pilbara region (Ashburton River, De Grey River, Fortescue River, Onslow Coast, Port Hedland Coast, Canning Basin and Sandy Desert) that are dominated by major non-

perennial river systems and smaller channels. Major rivers include the Ashburton River, Robe River, Fortescue River, Yule River, Shaw River, Nullagine River and Oakover River. All known records of *Themeda* sp. Panorama occur within or in close proximity to minor, non-perennial drainage lines within the Turner River, Strelley River, Shaw River and Coongan River catchments.

3.2.5 GROUNDWATER DEPENDENT ECOSYSTEMS

The Groundwater Dependent Ecosystems Atlas (BoM 2023b) indicates that known records of *Themeda* sp. Panorama correspond with mapped areas that have low to moderate potential for terrestrial Groundwater Dependent Ecosystems (GDEs) to occur. Most records (82.14%) occur within moderate potential GDE areas with an Inflow Dependent Ecosystem likelihood of 7.

3.2.6 CONSERVATION LANDS

Themeda sp. Panorama is not currently known to occur within any conservation estate within the Pilbara region. The nearest conservation estate to known records is Mungaroona Range Nature Reserve, located approximately 65 km to the southwest of the MDE.

3.3 BIOLOGICAL ENVIRONMENT

3.3.1 BIOGEOGRAPHIC REGION

Biogeographic regions are delineated on the basis of similar climate, geology, landforms, vegetation and fauna and are defined in the Interim Biogeographical Regionalisation for Australia (IBRA) (Department of Agriculture Water and the Environment 2020).

The survey area is the entire Pilbara IBRA region which includes four subregions (Chichester, Fortescue, Hamersley and Roebourne). All known records of *Themeda* sp. Panorama occur within the Chichester subregion (PIL1), described by Kendrick and McKenzie (2001) as:

> *The Chichester subregion (PIL 1) comprises the northern section of the Pilbara Craton. Undulating Archaean granite and basalt plains include significant areas of basaltic ranges. Plains support a shrub steppe, characterised by Acacia inaequilatera over Triodia wiseana (formerly Triodia pungens) hummock grasslands, while Eucalyptus leucophloia tree steppes occur on ranges. The climate is Semi-desert-tropical and receives 300mm of rainfall annually. Drainage occurs to the north via numerous rivers (e.g. De Grey, Oakover, Nullagine, Shaw, Yule, Sherlock). Subregional area is 9,044,560ha.*

3.3.2 PRE-EUROPEAN VEGETATION

During the 1970s, John Beard and associates conducted a systematic survey of native vegetation, describing the vegetation systems in Western Australia at a scale of 1:1,000,000 in the Pilbara bioregion.

Beard's vegetation maps attempted to depict the native vegetation as it was presumed to be at the time of settlement and is known as the pre-European vegetation type and extent. Beard's vegetation maps have since been developed in digital form by Shepherd, Beeston & Hopkins (2002), updated by DPIRD (2019b) and published by the DBCA (2019). This mapping indicates that the survey area intersects 88 pre-European vegetation units. Known records of *Themeda* sp. Panorama correspond with two pre-European vegetation units:

- Association 82: Hummock grassland with scattered bloodwoods & snappy gum; *Triodia* spp., *Corymbia dichromophloia, Eucalyptus leucophloia*
- Association 93: Hummock grassland with scattered shrubs or mallee; *Triodia* spp., *Acacia* spp., *Grevillea* spp., *Eucalyptus* spp.

The pre-European vegetation associations that correspond with known records of *Themeda* sp. Panorama and their pre-European and current extents are listed in **Table 7** below (DBCA 2019) and shown on **Map 4**.

Table 7: Pre-European vegetation association representation (DBCA 2019)

Region	Vegetation association	Original extent (ha)	Current extent (ha)	% remaining
Western Australia	82	2,565,901.28	2,553,206.19	99.51
	93	3,044,309.52	3,040,640.98	99.88
IBRA biogeographic region (Pilbara)	82	2,563,583.23	2,550,888.14	99.50
	93	3,042,114.27	3,038,471.67	99.88
IBRA biogeographic sub-region (Chichester)	82	360,666.90	360,322.69	99.90
	93	2,940,348.04	2,936,731.54	99.88

3.4 RELEVANT LITERATURE

The following documents have been identified as having relevance to the target species:

- Focused Vision (2023) *East Pilbara Generation Hub, Detailed Flora and Vegetation Survey* (Draft). A detailed flora survey of the proposed East Pilbara Generation Hub, located to the east of North Star. This survey area corresponds with known locations of *Themeda* sp. Panorama, although it was not identified by the survey.
- Ecologia (2023) *North Star Extension Targeted Flora Assessment*. The survey recorded 12,583 individuals of *Themeda* sp. Panorama, mostly from banks of major stony creeks. Suitable habitat also included sheltered gullies and steep rocky slopes with shallow soil. The survey suggests populations are likely to extend beyond the surveyed area along major creeks and may be associated with surface water flows.
- Jayasekara et al. (2023) *Themeda fehreae (Poaceae) a new species from the Pilbara Bioregion of north-western Western Australia* (Draft). A draft paper formally describing *Themeda* sp. Panorama (proposed to be *Themeda fehreae*).
- Spectrum Ecology (2021) *Targeted Flora and Vegetation Survey, Iron Bridge*. A targeted survey of Threatened and Priority 1 conservation-listed flora and Threatened Ecological Communities within the North Star Magnetite Project area. Three conservation-listed flora taxa were recorded during the survey. *Themeda* sp. Panorama was not identified during the desktop assessment (likely still not formally recognised at that stage) and therefore not targeted during the survey. The report did not identify any *Themeda* spp. of taxonomic interest.
- Ecoscape (2020) *North Star Extension Flora and Vegetation Survey*. The survey identified a species of taxonomic interest representing an undescribed species of *Themeda* (now *Themeda* sp. Panorama). The species was described as forming large tussocks and was recorded from drainage lines.
- Ecoscape (2018) *Glacier Valley Extension Flora and Vegetation Survey, North Star Project*. A detailed flora and vegetation survey of an area that corresponds with the known distribution of *Themeda* sp. Panorama. The survey reported a collection of *Themeda avenacea* that was of taxonomic interest (now known to represent *Themeda* sp. Panorama) in association with *Eucalyptus victrix* drainage line vegetation.
- Ecologia (2015) *North Star Aerodrome Flora Level 2 and Fauna Level 1 Assessment*. Includes a detailed flora and vegetation assessment of an area to the west of North Star. Of the nine vegetation types identified, three were associated with drainage lines. No *Themeda* sp. Panorama or *Themeda* spp. of interest were reported.
- Ecologia (2015) *North Star Stage 2 Slurry and Infrastructure Corridors - Conservation Significant Flora and Vegetation Assessment*. A survey of conservation-listed flora and vegetation within an area situated to the west of North Star. Twelve Priority-listed flora were recorded, however, no *Themeda* sp. Panorama or *Themeda* spp. of interest were reported.
- Coffey (2014) *North Star Alternate Access Road Flora and Vegetation Assessment*. A Detailed flora and vegetation survey of an alternate transport route to North Star. The survey area is located immediately to the west of the known distribution of *Themeda* sp. Panorama. Ten vegetation types were identified from the survey area. No *Themeda* sp. Panorama or *Themeda* spp. of interest were reported.
- Ecologia (2012) *North Star Vegetation and Flora Assessment*. A Detailed flora and vegetation survey of the North Star Magnetite Project which corresponds with known locations of *Themeda* sp. Panorama. The survey did not identify any *Themeda* spp. of taxonomic interest (noting that *Themeda* sp. Panorama was

not formally described at this time), however *T. avenacea* was recorded which is similar in appearance to *Themeda* sp. Panorama and considered likely to represent the latter taxon.

- Trudgen, M (2002) *A Flora and Vegetation Survey of the Proposed Mine Areas and Access Road for the Panorama Project*. First report of a new species of *Themeda* (now confirmed as *Themeda* sp. Panorama) which was recorded from a rock pile in a small creek in association with *Eucalyptus victrix*, *Acacia acradenia, Acacia pyrifolia*, *Cajanus cinereus*, *Triodia wiseana, Cyperus vaginatus* and *Stemodia grossa*.

4 RESULTS

4.1 MAXENT

The results of the modelling using 12 environmental variables and known locations of *Themeda* sp. Panorama are presented on **Map 5**. Predicted probabilities were classed into five groups to inform areas to be targeted. The value range "0.8-1.0" corresponds with the highest probability of suitable conditions for species occurrence. The results indicate that *Themeda* sp. Panorama is unlikely to occur in the broader region with high probability areas largely mapped within 30 km of North Star. Smaller isolated high probability areas were also mapped within the vicinity of Marble Bar. All predicted high probability areas occur within 100 km of North Star.

The overall model accuracy was 0.993 (± 0.005) based on the average test AUC (Area under the ROC Curve). When compared to the results of data spatially filtered to 200 m (AUC of 0.986) and 1000 m (AUC of 0.953), the 500 m model performed slightly better (indicated by the higher AUC value). The jackknife test of variable importance indicates that geology (surface and bedrock geology) and soil landscape are the strongest predictors of location for *Themeda* sp. Panorama (**Figure 3**). The full MaxEnt summary report is provided in **Appendix Two**.

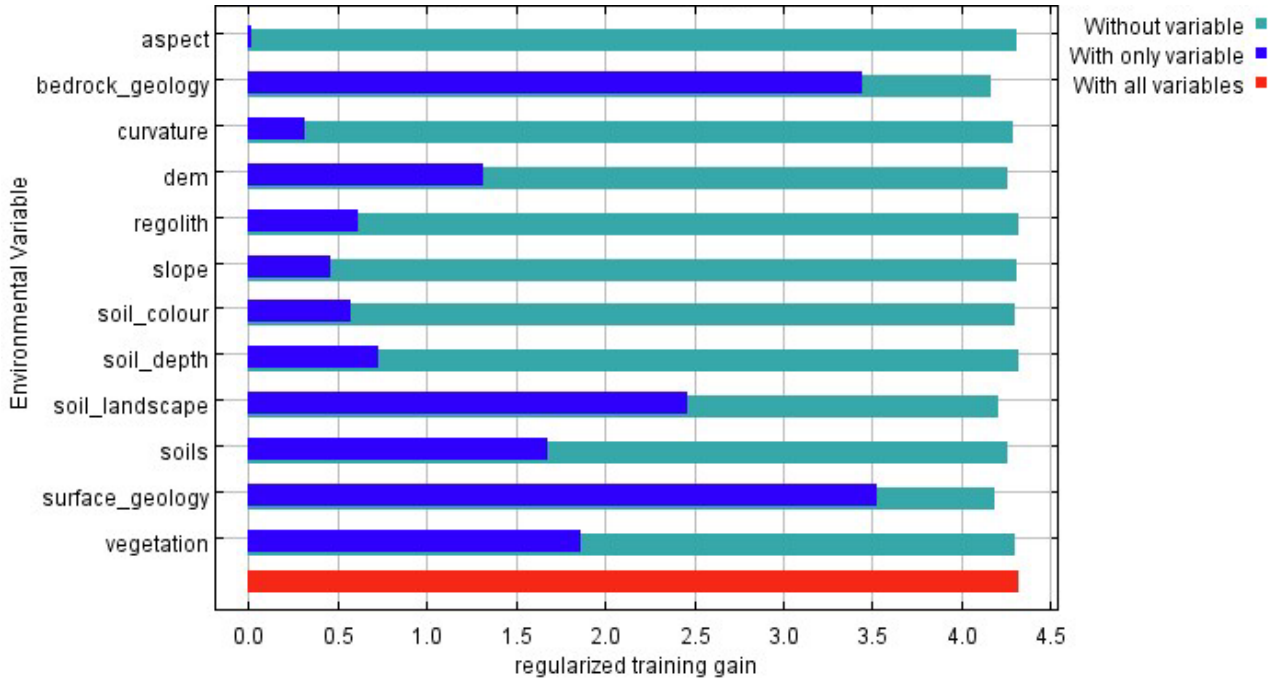

Figure 3: Jackknife of regularised training gain for *Themeda* sp. Panorama

Light blue indicates the impact on the model if the variable is not used. Dark blue indicates the impact on the model if it is the only variable used.

4.2 TARGETED SURVEY

The Targeted flora survey was conducted over two phases as follows:

- 8-15 May 2024: Kyla Pannell (Senior Botanist; Flora Collecting Permit FB62000261, Threatened Flora Collecting Permit TFL TFL161-2122) and Tracy de Vetter (Ecologist; Flora Collecting Permit FB62000546)
- 5-12 July 2024: Kyla Pannell (Senior Botanist), James Tsakalos (Senior Botanist; Flora Collecting Permit FB62000661), Sonya Bateman (Senior Spatial Ecologist) and Madeline West (Environmental Field Technician).

4.2.1 FLORA RESULTS

The field survey identified 33 populations of *Themeda* sp. Panorama with a total of 10,713 plants recorded (shown on **Map 6**). Detailed population descriptions are provided in **Table 10** in **Appendix Three**. A total of 222 sites were sampled over an area of approximately 666.34 km^2, encompassing the North Star Magnetite Project area and more regional areas between North Star and Marble Bar. Sample sites comprise 28 relevés where *Themeda* sp. Panorama was recorded and 194 waypoints where no plants were found (shown on **Map 7**).

Twenty-nine of the 33 populations recorded are new populations. Four populations (populations 23, 27, 28 and 29) are extensions of known populations. Population abundance ranged from a minimum of one plant in population 30 to a maximum of 3,035 plants in population 33 (located approximately 3.74 km northeast of the North Star MDE). All populations were recorded within 80 km of North Star with an overall distribution of approximately 85 km east-west by 65 km north-south.

None of the recorded populations fall within any conservation estate. All records occur within current mining tenements, most of which are under exploration licences (DEMIRS 2024).

Representative photographs on *Themeda* sp. Panorama recorded in the field are provided below.

Image 3: *Themeda* sp. Panorama habit (mature plants)

Image 4: *Themeda* sp. Panorama foliage showing green/blue-green leaves with whitish midrib

Image 5: *Themeda* sp. Panorama fruit

Records of *Themeda avenacea* suspected of being inaccurate were also inspected during the field survey as requested by Fortescue. One record corresponded with a recently burnt area and no plants were found. The other record was inspected at the location which corresponded with population 27 within a rocky gorge (see **Map 6**). Formal identification of the specimen confirmed it was *Themeda* sp. Panorama and not *T. avenacea.* It is considered highly likely that other records of *T. avenacea* in the local area are also inaccurate and should be regarded as *Themeda* sp. Panorama.

4.2.1 HABITAT ASSESSMENT

All populations of *Themeda* sp. Panorama recorded during the survey were identified within drainage features, including within channels, along banks and on lower slopes immediately adjacent to creeks. The majority of records occur in rugged sandstone and basaltic hills including within valleys, deeply dissected gorges and in gullies on hill slopes. Other geological associations include granite, quartzite, dolerite and sedimentary rock (shale, chert, siltstone, conglomerates, banded-iron formations and carbonate rock) (DEMIRS 2012; Hickman 2010). Drainage lines were predominantly rocky and composed of a mixture of pebbles and cobbles reflective of the surrounding geology with occasional boulders and outcropping of bedrock. Plants were also recorded from rocky creeks (and occasionally sandy creeks) situated on stony plains and low undulating stony plains lower in the landscape.

Vegetation corresponding with records of *Themeda* sp. Panorama was typical of drainage vegetation found throughout the Pilbara region. Most populations were recorded from groundwater dependent vegetation (GDV) and potential groundwater dependent vegetation (PGDV) communities dominated by *Eucalyptus camaldulensis* subsp. *refulgens*, *E. victrix* and/or *Melaleuca argentea*. Other drainage-type vegetation associations include woodland and shrubland communities dominated by *Corymbia hamersleyana* and *Acacia tumida* var. *pilbarensis*, *A. pyrifolia* var. *pyrifolia*, A. *acradenia* and *Petalostylis labicheoides.* A summary of the characteristic species associated with *Themeda* sp. Panorama is provided below with full vegetation descriptions for each population shown in **Table 10** in **Appendix Three**.

Associated Flora:

- Upper stratum:
  - *Corymbia hamersleyana*, *Eucalyptus victrix*, *Eucalyptus camaldulensis* subsp. *refulgens, Eucalyptus leucophloia* subsp. *leucophloia* and *Melaleuca argentea*
- Mid stratum:
  - *Acacia acradenia, Acacia ampliceps, Acacia bivenosa, Acacia eriopoda, Acacia pyrifolia* var. *pyrifolia, Acacia tumida* var. *pilbarensis, Carissa lanceolata, Grevillea wickhamii, Petalostylis labicheoides, Melaleuca glomerata* and *Melaleuca linophylla*
- Ground stratum:

- *Acacia spondylophylla, *Cenchrus ciliaris, *Cenchrus setiger, Corchorus parviflorus, Cymbopogon ambiguus, Cyperus vaginatus, Eriachne mucronata, Eriachne tenuiculmis, Tephrosia rosea* var. *clementii, Triodia epactia, Triodia longiceps, Triodia pungens* and *Triodia wiseana*.

Vegetation condition ranged from Good to Excellent with most populations found in undisturbed and isolated habitats. Where disturbance was recorded, the impacts were primarily from cattle activity and weed invasion.

Five populations (populations 2,3,4,5 and 6) were opportunistically recorded from the air during traverses between survey areas. As these populations were identified outside the approved Land Use Certificate (LUC) boundary, detailed habitat information and botanical specimens were not collected during the survey. However, *Themeda* sp. Panorama can be easily identified from a helicopter by experienced botanists and it was clear from aerial observations that the habitats were consistent with that recorded for other populations.

4.2.2 OTHER SIGNIFICANT FLORA

Other conservation-listed flora and significant weeds were recorded opportunistically during the field survey when encountered. One Priority Four-listed taxon, *Ptilotus mollis* (one record with 12 plants), was recorded approximately 19 km south of the North Star MDE and 11 records (51 plants) of **Calotropis procera* (a Declared Pest) were recorded in various locations across the surveyed area. No Threatened Flora (specifically, *Quoya zonalis*) were recorded during the field survey.

4.2.3 SURVEY LIMITATIONS AND CONSTRAINTS

There were no significant limitations or constraints that negatively impacted the outcomes of the Targeted survey. All target locations identified within the approved LUC were assessed during the field survey. A full summary of survey limitations is presented in **Table 8** below.

Table 8: Botanical limitations

Possible limitations	Constraints (yes/no): Significant, moderate or negligible	Comment
Availability of contextual information at a regional and local scale	Negligible	The target species is relatively poorly known, however, previous local surveys and a draft taxonomic paper were available to provide sufficient contextual information.
Competence/experience of the team conducting the survey, including experience in the bioregion surveyed	No	The lead botanist conducting the field survey has five years' experience conducting botanical surveys in the Pilbara region, including Targeted surveys.
Proportion of the flora recorded and/or collected, and any identification issues	No	Only one taxon was targeted for this survey and there were no identification issues with the collected specimens.
Was the appropriate area fully surveyed (effort and extent)	No	While the survey area was very large in extent, all target locations identified prior to survey were assessed where there were no access constraints and additional areas were also inspected to increase survey effort.
Access restrictions within the survey area	Negligible	Several target locations identified from the species distribution modelling corresponded with heritage-restricted areas or other restricted areas and were not accessed during the survey. This is considered a negligible constraint given that the approved area for survey was sufficiently large and target sites could be relocated to other suitable areas.

Possible limitations	Constraints (yes/no): Significant, moderate or negligible	Comment
Survey timing, rainfall, season of survey	No	The field survey was conducted during May and July which partly falls within the primary season for survey in the Pilbara bioregion. Seasonal conditions were adequate for the identification of the target taxon during both phases of survey due to above average rainfall in March and June. The taxon was also readily identifiable in the field.
Disturbance that may have affected the results of the survey e.g. fire, flood, clearing	Negligible	A small proportion of the survey area had been affected by recent fire (impacting three target locations[1]) and it was difficult to assess whether the target species was present or not due to the complete absence of vegetation. Habitat suitability was still assessed in these areas but no targeted searches were undertaken.

[1]Waypoints 64, 184 and 185 on **Map 7**.

5 DISCUSSION

The regional Targeted survey for *Themeda* sp. Panorama identified 29 new populations in the Pilbara bioregion and extended the distribution of four known populations within the vicinity of Iron Bridge North Star. A total of 10,713 plants were recorded during the field survey. When combined with existing records (including Fortescue-commissioned surveys), the total number of plants on record is 25,895 (representing an increase of 70.56%) with an approximate distribution of 85 km east-west by 65 km north-south.

All new records of *Themeda* sp. Panorama occur within current mining tenements (predominantly exploration), although only a few records were observed in close proximity to active mines or exploration activity. Most populations were found in undisturbed and isolated habitats. Where disturbance was recorded, the primary impacts were from weeds and cattle activity. No records to date occur within DBCA-managed conservation lands.

The preferred habitat of *Themeda* sp. Panorama appears to be rocky drainage lines (creeks, gullies and gorges) high in the landscape in rugged sandstone and basaltic hills, in association with *Eucalyptus, Corymbia* and/or *Melaleuca* woodland or *Acacia* shrubland communities. Suitable habitat also includes lower slopes of drainage lines and rocky or sandy creeks on stony plains/undulating plains lower in the landscape with similar vegetation associations. Other geological associations include granite, quartzite, dolerite and sedimentary rock (shale, chert, siltstone, conglomerates, banded-iron formations and carbonate rock). The vegetation associated with *Themeda* sp. Panorama is considered typical vegetation of drainage channels in the Pilbara region. While most populations were recorded from GDV and PGDV communities within medium to large drainage channels, populations were also found within *Corymbia hamersleyana*-dominated creeks and smaller shrubland-dominated creeks consisting of mixed *Acacia* species. Given that populations of *Themeda* sp. Panorama correspond with a variety of vegetation community types, it is considered more likely that landform, geology and soils are the primary predictors of habitat suitability.

Based on the results of this survey, the population size and distribution of *Themeda* sp. Panorama have been significantly extended within the Pilbara. It is also considered highly likely that additional populations exist within the known distribution given that *Themeda* sp. Panorama was recorded opportunistically at several locations when traversing between survey areas. Suitable habitat is also relatively widespread in the region (although only occupying a small proportion of the landscape), increasing the likelihood of additional populations occurring. Revised species distribution modelling and further field survey would be advantageous to extending its current known distribution.

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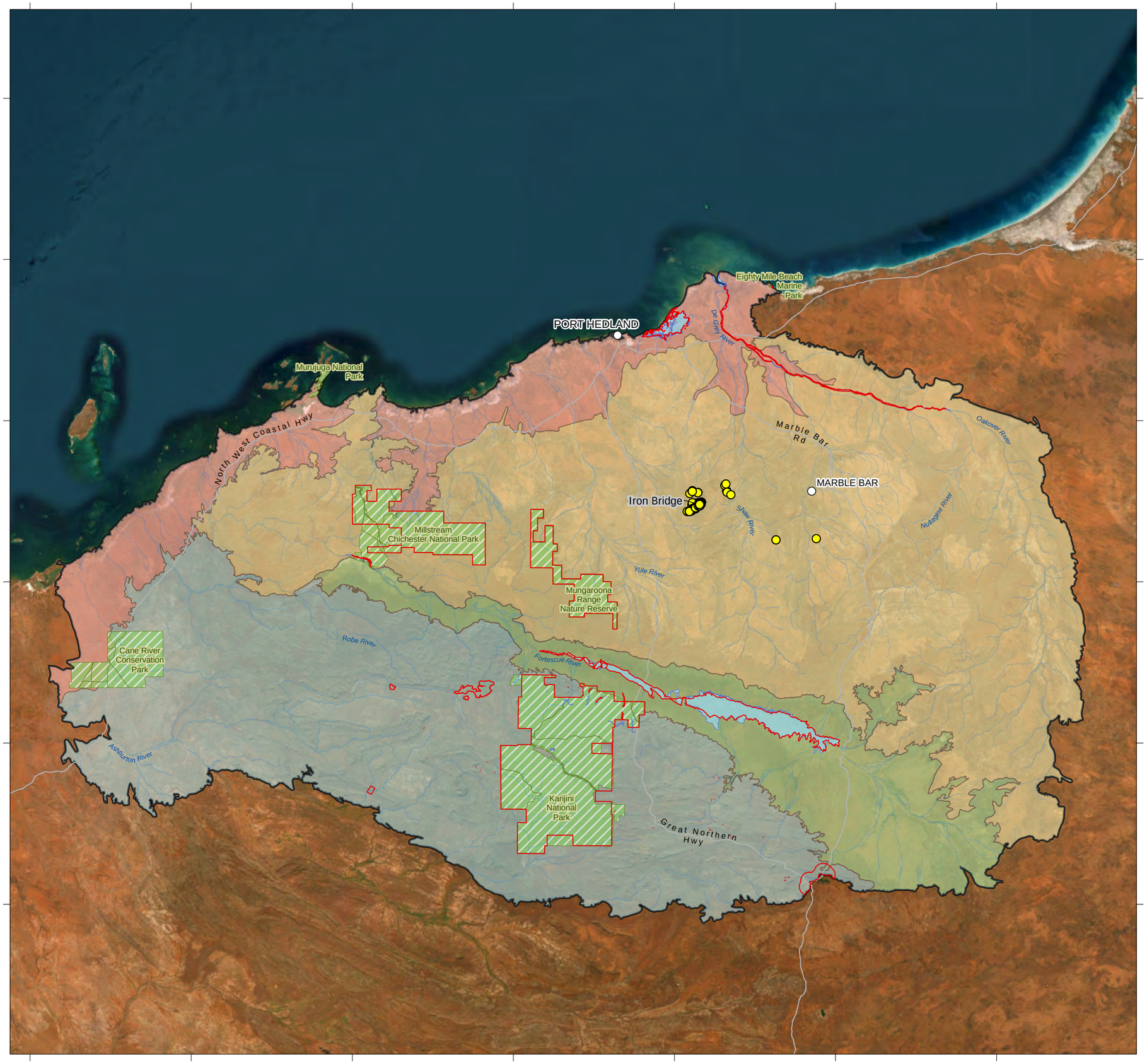
MAPS



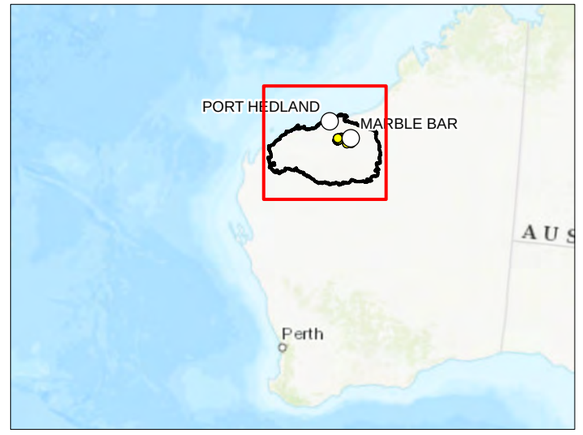
LEGEND

- *Themeda* sp. Panorama (J. Nelson et al. NS 102)
- Towns
- Roads
- Drainage Lines
- Survey area
- Parks and Reserves
- Environmentally Sensitive Areas
- Directory of Important Wetlands

IBRA Subregions

- Chichester
- Fortescue
- Hamersley
- Roebourne

DATA SOURCES:
SOURCE DATA: FLORA DATA (FORTESCUE 2023); CLEARING REGULATIONS - ENVIRONMENTALLY SENSITIVE AREAS (DWER-046) (DWER 2021); DBCA - LEGISLATED LANDS AND WATERS (DBCA-011) (DBCA 2022); ROAD NETWORK (MRWA 2023). SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015); IBRA 7 (DCCEEW 2023); DIRECTORY OF IMPORTANT WETLANDS IN AUSTRALIA - WESTERN AUSTRALIA (DBCA-045) (DBCA 2018)
BASEMAP: ESRI WORLD IMAGERY
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS



ecoscape

DATABASE SEARCH RESULTS

***THEMEDA* SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY**

FORTESCUE

COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

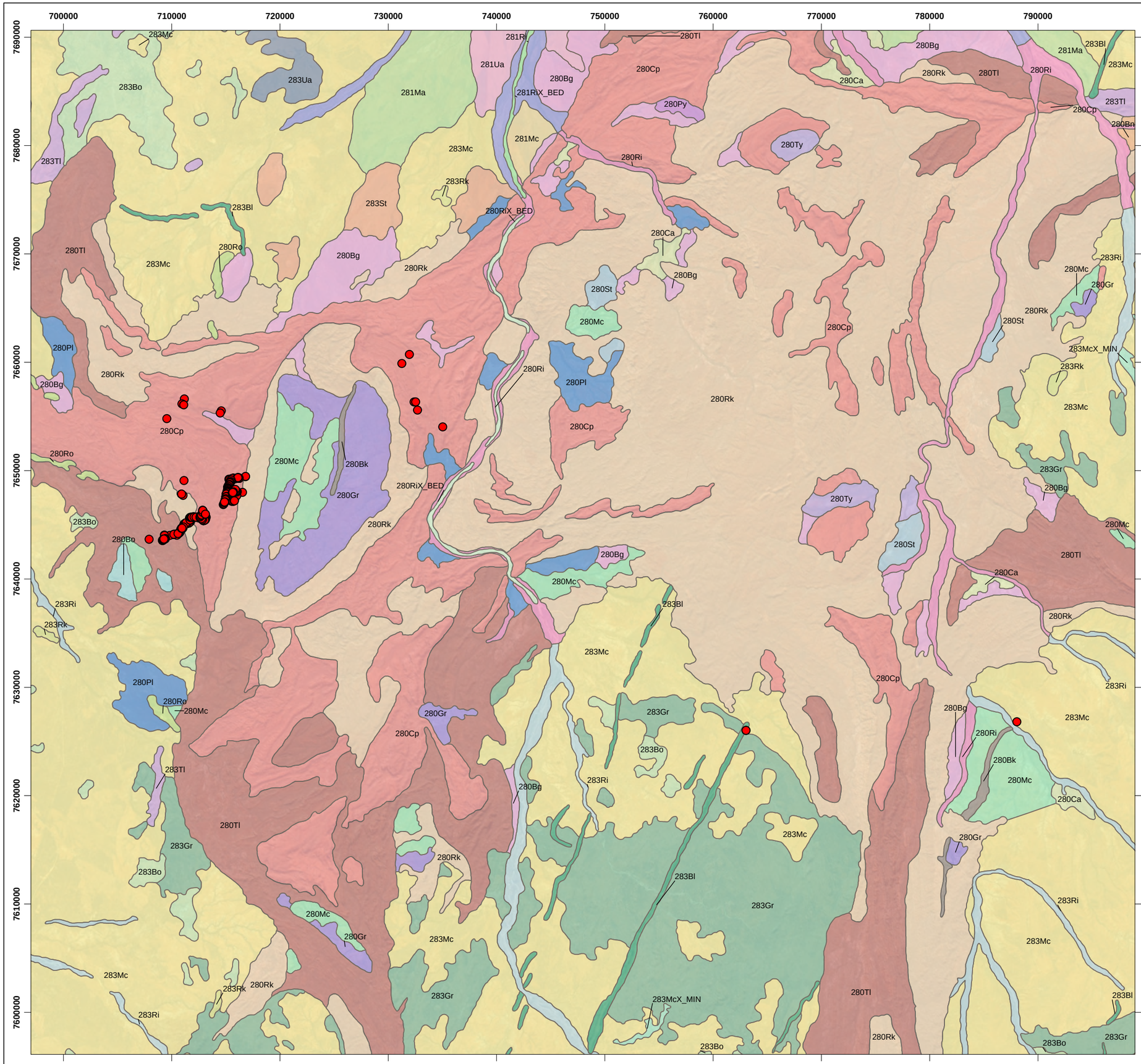
SCALE: 1:2,400,000@ A3

0 50 100 km

PROJECT NO: 4881-24

REV	AUTHOR	APPROVED	DATE
0	KP	NW	12/01/2024

MAP 1



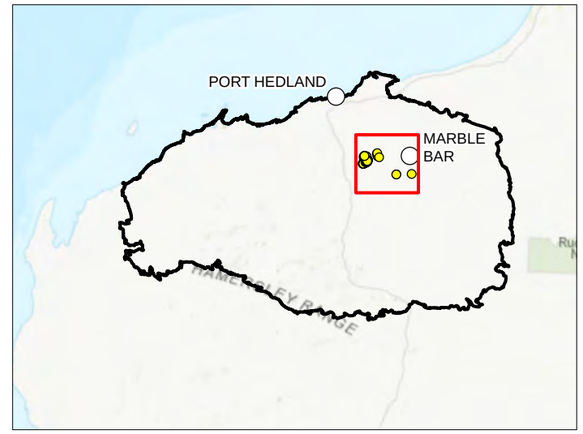
LEGEND

- *Themeda* sp. Panorama (J. Nelson et al. NS 102)

Soil Land Systems

- 280Bg
- 280Bk
- 280Bn
- 280Bo
- 280Ca
- 280Cp
- 280Gr
- 280Mc
- 280Pl
- 280Py
- 280Ri
- 280RiX_BED
- 280Rk
- 280Ro
- 280St
- 280Tl
- 280Ty
- 281Ma
- 281Mc
- 281Ri
- 281RiX_BED
- 281Ua
- 283Bl
- 283Bo
- 283Gr
- 283Mc
- 283McX_MIN
- 283Ri
- 283Rk
- 283St
- 283Tl
- 283Ua

DATA SOURCES:
SOURCE DATA: FLORA DATA (FORTESCUE 2023); ROAD NETWORK (MRWA 2023). SOIL-LANDSCAPE MAPPING WESTERN AUSTRALIA – BEST AVAILABLE SOILS (DPIRD-027) (DPIRD 2022).
BASEMAP: ESRI WORLD IMAGERY (2022); ESRI TOPOGRAPHIC
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS



ecoscape

SOIL LANDSCAPE MAPPING

THEMEDA SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY

FORTESCUE

COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

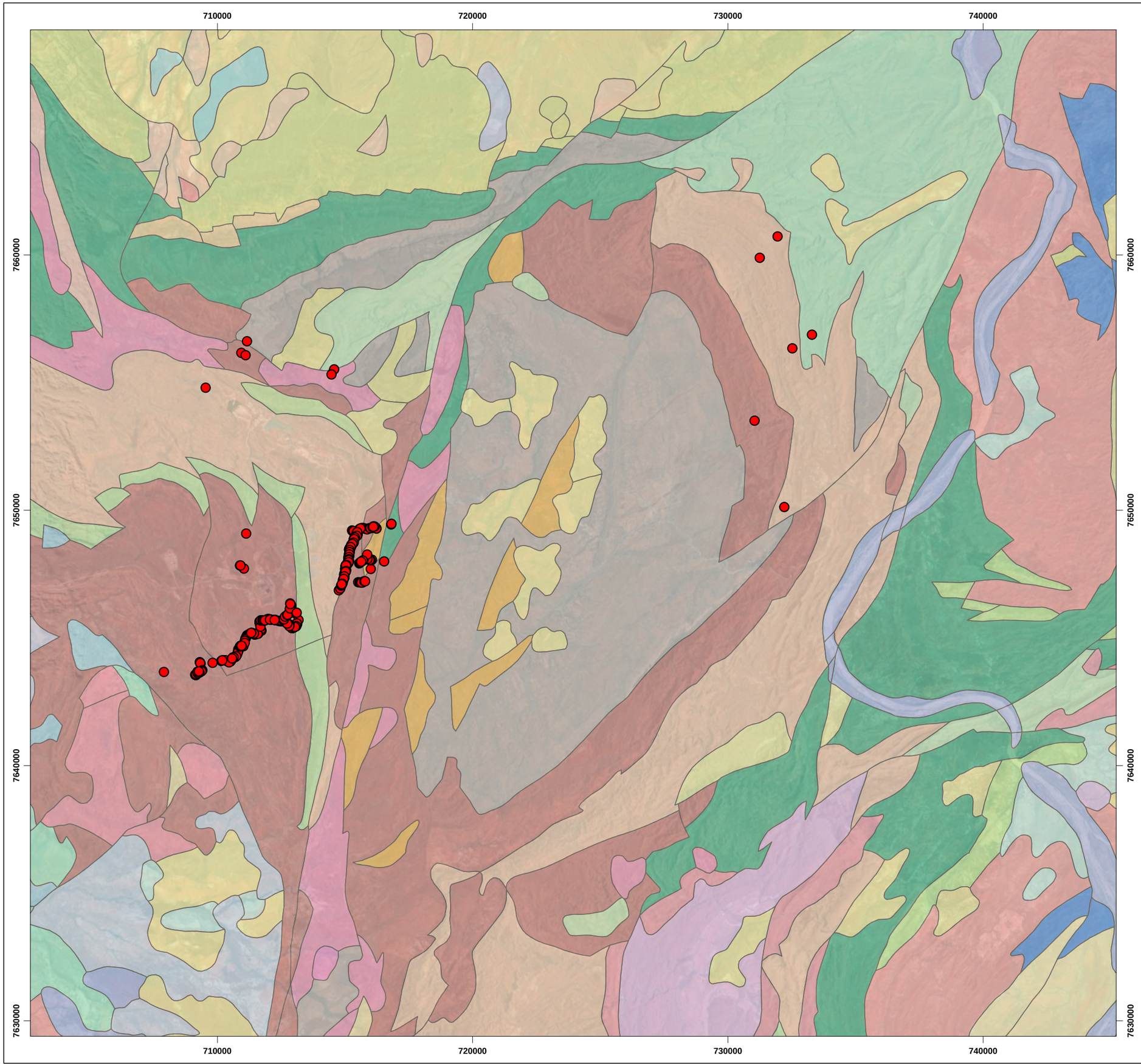
SCALE: 1:350,000 @ A3

0 7 14 km

PROJECT NO: 4881-24

REV	AUTHOR	APPROVED	DATE
0	KP	NW	08/01/2024

MAP 2



LEGEND

Themeda sp. Panorama (J. Nelson et al. NS 102)

Surface geology

- Callina Supersuite
- Cleland Supersuite
- Coolyia Creek Granodiorite
- Coongan Subgroup
- Coonterunah Subgroup
- Croydon Group
- Dalton Suite
- Euro Basalt
- Gorge Creek Group
- Hardey Formation
- Kavir Granodiorite
- Kelly Group - amphibolite
- Kelly Group - leucogabbro and dolerite
- Kylena Formation
- Lalla Rookh Sandstone
- Mount Roe Basalt
- Petroglyph Gneiss
- Pilbara Supergroup - basalt
- Pilbara Supergroup - ultramafic rocks
- Pincunah Banded-iron Member
- Pincunah Monzogranite
- Salgash Subgroup
- Sisters Supersuite
- Soanesville Group
- Strelley Monzogranite
- Sulphur Springs Group
- Sulphur Springs Group - diorite sills
- Sulphur Springs Group - metadolerite
- Talga Talga Subgroup
- Tambina Supersuite
- Woodstock Monzogranite
- alluvium 38485
- alluvium 38494
- calcrete 38497
- chert 74258
- colluvium 38491
- dolerite, gabbro 74265
- dolerite, metagabbro 74261
- ferruginous duricrust 38498
- metamorphosed mafic rocks 74327
- metamorphosed ultramafic to mafic rocks 74283
- sand plain 38499

DATA SOURCES:
SOURCE DATA: SURFACE GEOLOGY (RAYMOND ET AL. 2012)
IMAGERY: ESRI WORLD IMAGERY
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS

ecoscape

GEOLOGY

THEMEDA SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY

FORTESCUE

COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

SCALE: 1:146,000 @ A3

0 0 2 4 6 km

PROJECT NO: 4881-23

REV	AUTHOR	APPROVED	DATE
0	KP	SB	05/09/2024

MAP 3A

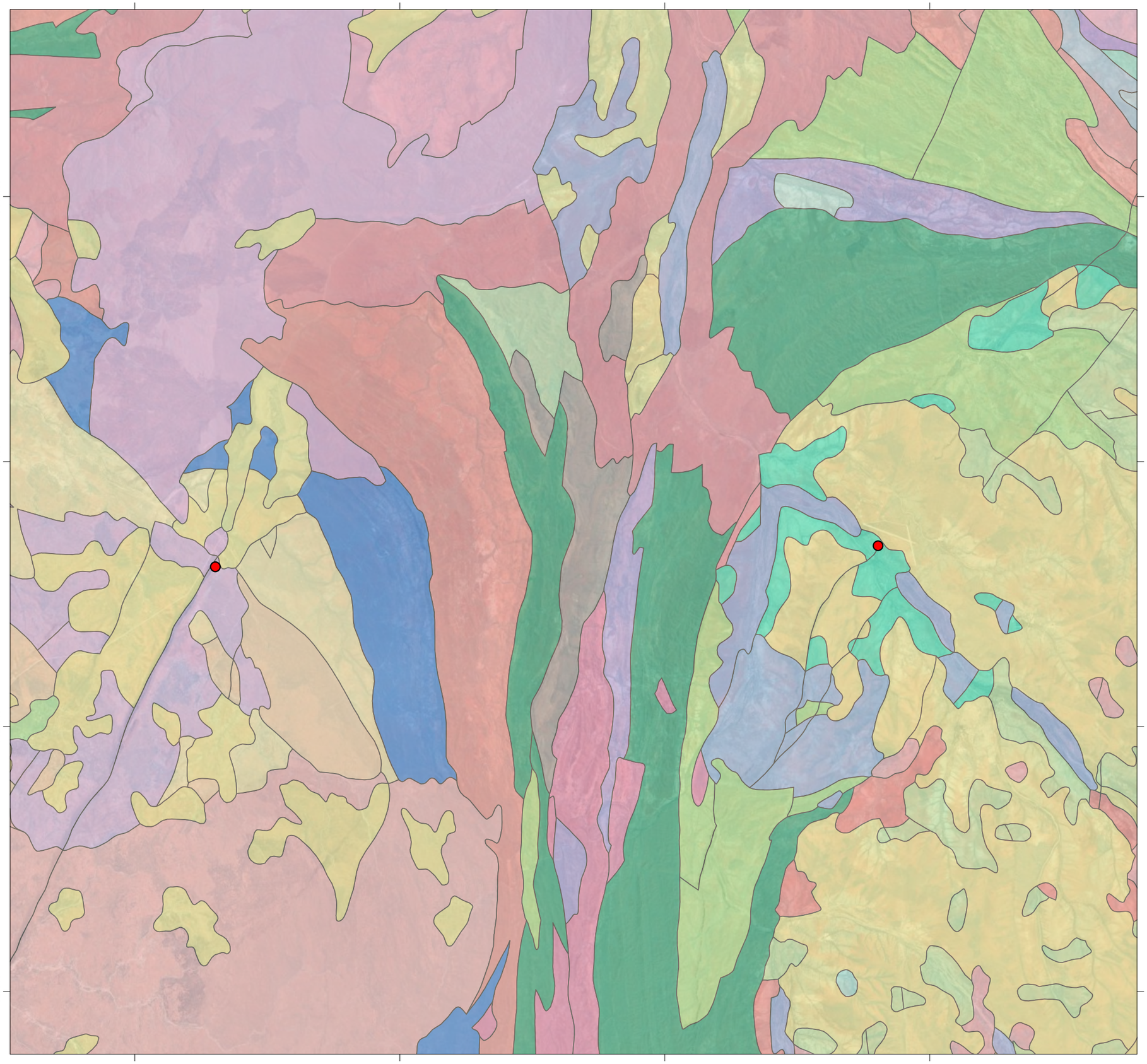
760000 770000 780000 790000

7640000

7630000

7620000

7610000



LEGEND

Themeda sp. Panorama (J. Nelson et al. NS 102)

Surface geology

- Bookargemoona Tonalite
- Callina Supersuite
- Carbana Monzogranite
- Cooglegong Monzogranite
- Coolyia Creek Granodiorite
- Coongan Subgroup
- Cotton Well Granodiorite
- Croydon Group
- Dalton Suite
- Emu Pool Supersuite
- Euro Basalt
- Fig Tree Gneiss
- Gorge Creek Group
- Hardey Formation
- Homeward Bound Granite
- Jenkin Granodiorite
- Kelly Group
- Kylena Formation
- Mondana Monzogranite
- Mount Roe Basalt
- Mulgandinnah Monzogranite
- Nandingarra Granodiorite
- North Shaw Tonalite
- Owens Gully Diorite
- Pear Creek Formation
- Salgash Subgroup
- Talga Talga Subgroup
- Tambina Supersuite
- Underwood Gneiss
- Warrawoona Group - ultramafic and mafic rocks
- alluvium 38485
- alluvium 38494
- calcrete 38497
- colluvium 38491

DATA SOURCES:
SOURCE DATA: SURFACE GEOLOGY (RAYMOND ET AL. 2012)
IMAGERY: ESRI WORLD IMAGERY
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS

ecoscape

GEOLOGY

***THEMEDA* SP. PANORAMA (J. NELSON ET AL. NS 102)**
DESKTOP MODELLING AND TARGETED SURVEY

FORTESCUE

COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

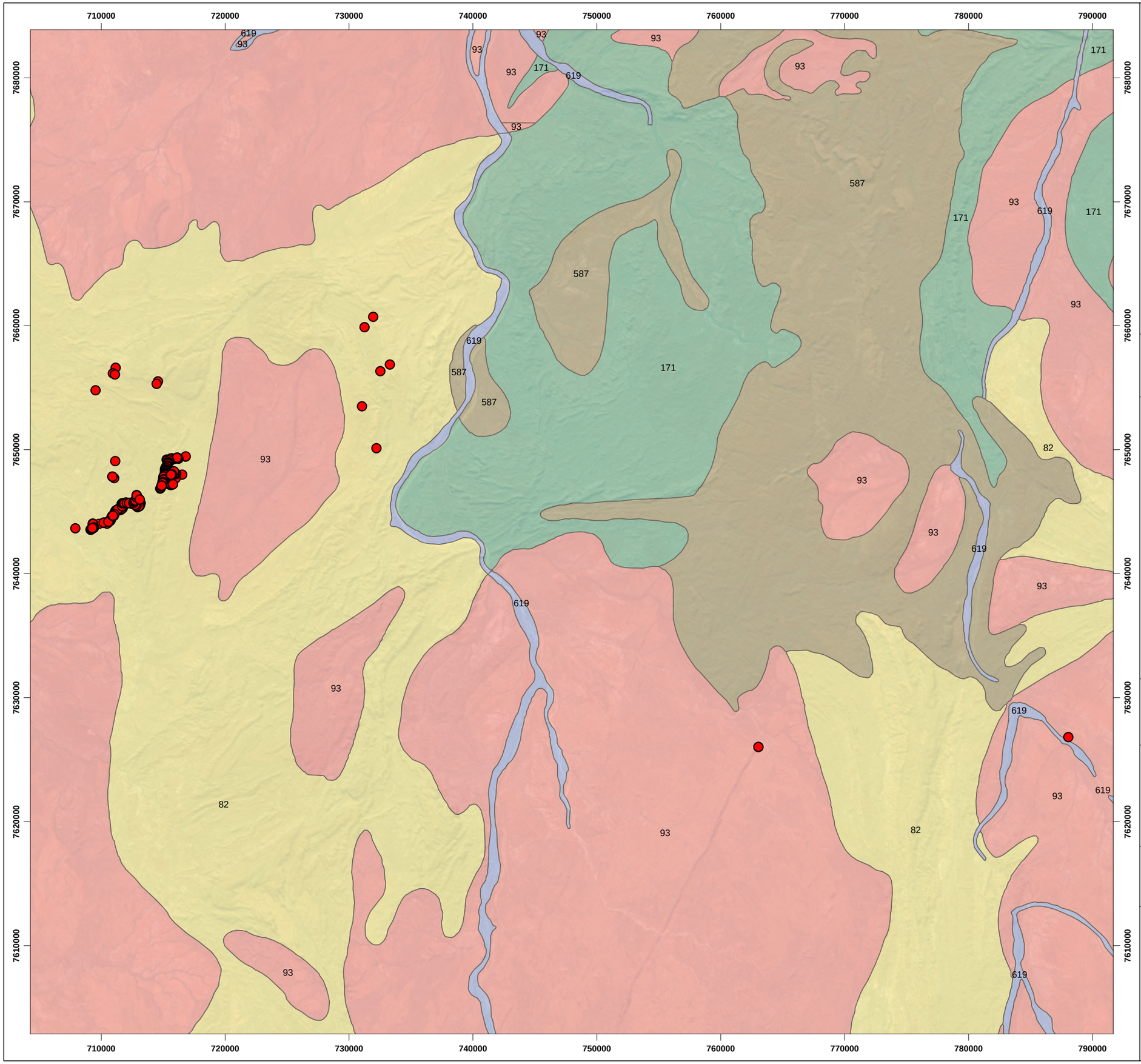
SCALE: 1:146,000 @ A3

0 0 2 4 6 km

PROJECT NO: 4881-23

REV	AUTHOR	APPROVED	DATE
0	KP	SB	05/09/2024

MAP
3B



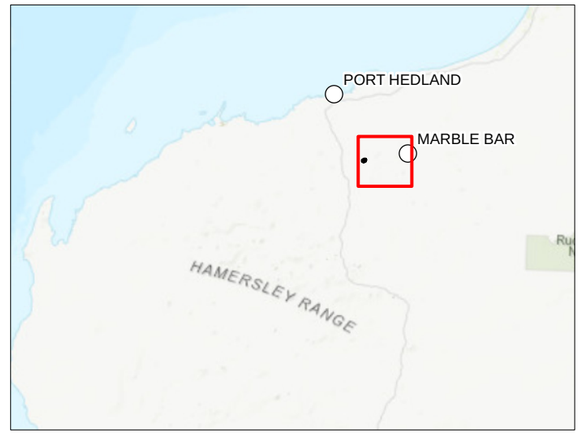
LEGEND

- *Themeda* sp. Panorama (J. Nelson et al. NS 102)

Pre-European Vegetation Units

- 171: Hummock grassland with scattered bloodwoods and snappy gum *Triodia* spp., *Corymbia dichromophloia, Eucalyptus leucophloia*
- 587: Sparse low tree-steppe / Sparse shrub-steppe
- 619: Wheatbelt; York gum, salmon gum etc. *Eucalyptus loxophleba, E. salmonophloia*. Goldfields; gimlet, redwood etc. *E. salubris, E. oleosa*. Riverine; rivergum *E. camaldulensis*. Tropical; messmate, woolybutt
- 82: Hummock grassland with scattered bloodwoods and snappy gum *Triodia spp., Corymbia dichromophloia, Eucalyptus leucophloia*
- 93: Hummock grassland with scattered shrubs or mallee *Triodia* spp. *Acacia* spp., *Grevillea* spp. *Eucalyptus* spp

DATA SOURCES:
SOURCE DATA: FLORA DATA (FORTESCUE 2023); ROAD NETWORK (MRWA 2023). PRE-EUROPEAN VEGETATION (DPIRD-006)(2019).
BASEMAP: ESRI WORLD IMAGERY (2022); ESRI TOPOGRAPHIC
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS



ecoscape

PRE-EUROPEAN VEGETATION

THEMEDA SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY

FORTESCUE

COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

SCALE: 1:300,000 @ A3

0 0 4 8 12 km

PROJECT NO: 4881-23

REV	AUTHOR	APPROVED	DATE
0	KP	SB	08/01/2024

MAP 4

680000 700000 720000 740000 760000 780000 800000 820000

7700000 7680000 7660000 7640000 7620000 7600000 7580000 7560000

INDEE
WALLAREENYA
Marble Bar Rd
MARBLE BAR
NULLAGINE
Great Northern Hwy
Marble Bar Rd

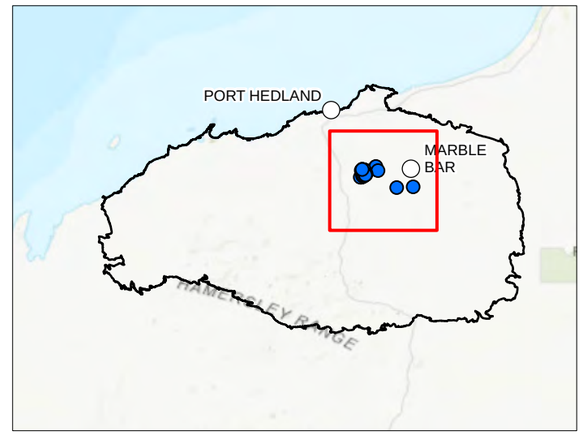
LEGEND

- *Themeda* sp. Panorama (J. Nelson et al. NS 102)
- Iron Bridge North Star
- Towns
- Roads
- North Star Extension

MaxEnt predicted probability

- 0.0-0.2
- 0.2-0.4
- 0.4-0.6
- 0.6-0.8
- 0.8-1.0

DATA SOURCES:
SOURCE DATA: FLORA DATA (FORTESCUE 2023); ROAD NETWORK (MRWA 2023); URBAN LOCATIONS (STREETPRO 2009)
BASEMAP: ESRI WORLD IMAGERY (2022)
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS



ecoscape

MAXIMUM ENTROPY MODELLING

THEMEDA SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY

FORTESCUE

COORDINATE SYSTEM: GCS GDA 1994
DATUM: GDA 1994
UNITS: DEGREE

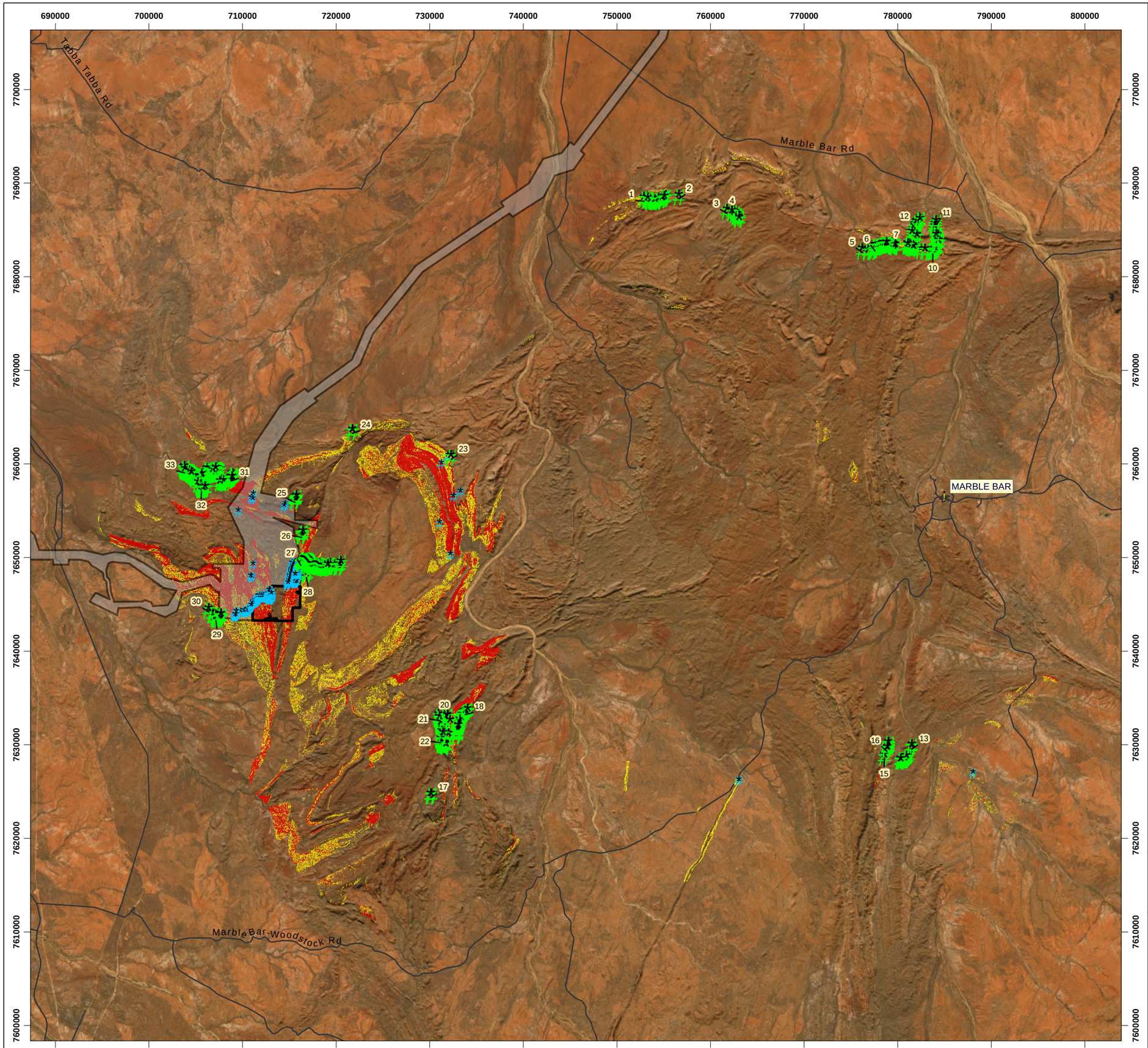
SCALE: 1:600,000 @ A3

0 0 12.5 25 km

PROJECT NO: 4881-24

REV	AUTHOR	APPROVED	DATE
0	KP	NW	09/01/2024

MAP 5



LEGEND

Survey Results

Themeda sp. Panorama (J. Nelson et al. NS 102) (P1)

Known records

Themeda sp. Panorama (J. Nelson et al. NS 102) (P1)

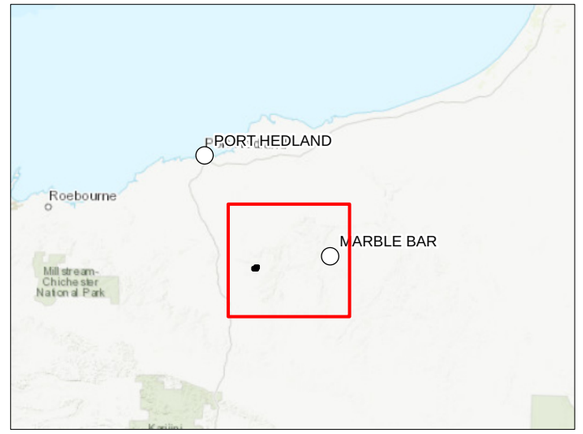
Predicted suitable habitat (MaxEnt)

- Medium probability (0.6 - 0.8)
- High probability (0.8 - 1.0)

North Star Magnetite Project

- NSE Proposed Amendment
- Mine Development Envelope
- Roads

DATA SOURCES:
SOURCE DATA: FLORA AND SPECIES DISTRIBUTION MODELLING DATA (FORTESCUE 2023, ECOSCAPE 2024); ROADS (MRWA 2024); OPERATING MINES (DEMIRS 2024)
BASEMAP: ESRI WORLD IMAGERY
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS



ecoscape

TARGETED SURVEY RESULTS

***THEMEDA* SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY**

FORTESCUE

COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

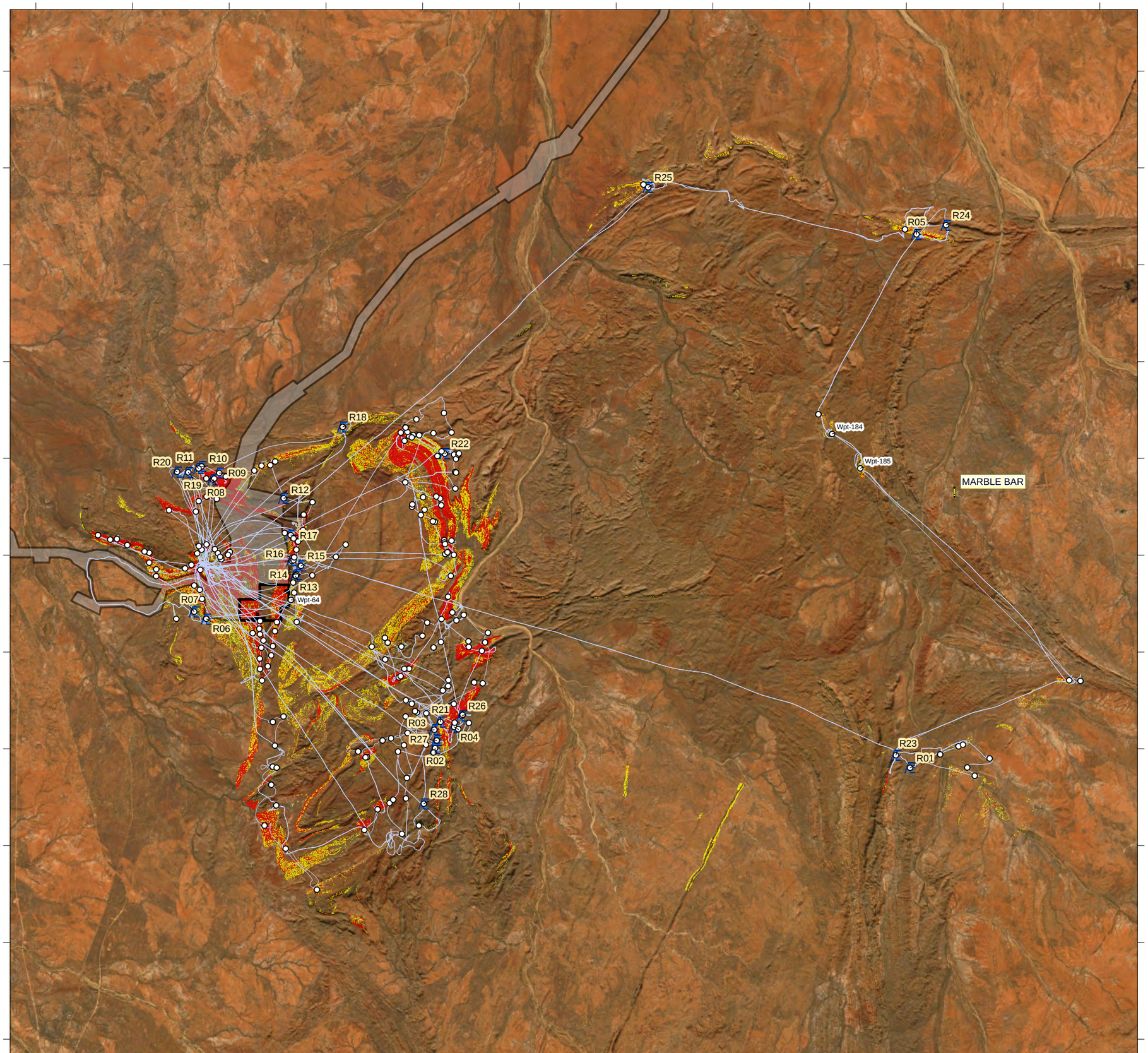
SCALE: 1:400,000 @ A3

0 0 7.5 15 km

PROJECT NO: 4881-24

REV	AUTHOR	APPROVED	DATE
0	KP	SB	09/08/2024

MAP 6



LEGEND

- Releves
- Waypoints
- Survey tracks
- Roads

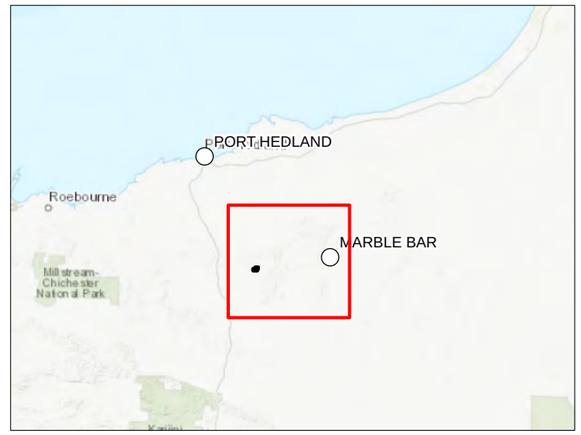
Predicted suitable habitat (MaxEnt)

- Medium probability (0.6 - 0.8)
- High probability (0.8 - 1.0)

North Star Magnetite Project

- NSE Proposed Amendment
- Mine Development Envelope

DATA SOURCES:
SOURCE DATA: FLORA AND SPECIES DISTRIBUTION MODELLING DATA (FORTESCUE 2023, ECOSCAPE 2024); ROADS (MRWA 2024); OPERATING MINES (DEMIRS 2024)
BASEMAP: ESRI WORLD IMAGERY
SERVICE LAYERS: WORLD TOPOGRAPHIC MAP: ESRI, HERE, GARMIN, FAO, NOAA, USGS
WORLD IMAGERY: EARTHSTAR GEOGRAPHICS



ecoscape

SURVEY EFFORT

***THEMEDA* SP. PANORAMA DESKTOP MODELLING AND TARGETED SURVEY**

FORTESCUE

COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

SCALE: 1:400,000 @ A3

0 0 7.5 15 km

PROJECT NO: 4881-24

REV	AUTHOR	APPROVED	DATE
0	KP	SB	09/08/2024

MAP 7

APPENDIX ONE DEFINITIONS AND CRITERIA

Priority-listed Flora

Flora are listed as PF where populations are geographically restricted or threatened by local processes, or where there is insufficient information to formally assign them to TF categories. Whilst PF are not specifically listed in the BC Act, some may qualify as being of special conservation interest and thereby have a greater level of protection than unlisted species.

There are three categories covering Western Australian-listed TF and four categories covering PF species which are outlined in **Table 9**. PF for Western Australia are regularly reviewed by the DBCA whenever new information becomes available, with species status altered or removed from the list when data indicates that they no longer meet these requirements.

Table 9: Conservation codes for Western Australian Priority Flora (DBCA 2019)

Conservation Codes for Western Australian Priority Flora	
P	**Priority species** Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened fauna or flora. Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring. Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.
1	**Priority 1: Poorly-known species** Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.
2	**Priority 2: Poorly-known species** Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.
3	**Priority 3: Poorly-known species** Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.
4	**Priority 4: Rare, Near Threatened and other species in need of monitoring** (a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent. (c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

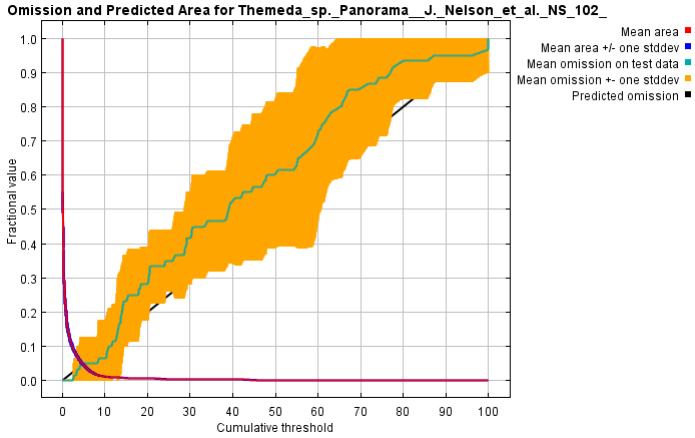
APPENDIX TWO MAXENT RESULTS

Replicated maxent model for Themeda_sp._Panorama__J._Nelson_et_al._NS_102_

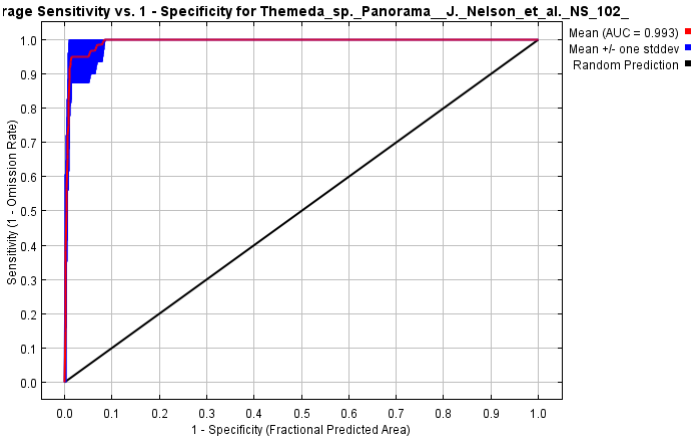
This page summarizes the results of 10 split-sample models for Themeda_sp._Panorama__J._Nelson_et_al._NS_102_, created Wed Jan 03 11:30:52 AWST 2024 using Maxent version 3.4.4. The individual models are here: [0] [1] [2] [3] [4] [5] [6] [7] [8] [9]

Analysis of omission/commission

The following picture shows the test omission rate and predicted area as a function of the cumulative threshold, averaged over the replicate runs. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold.

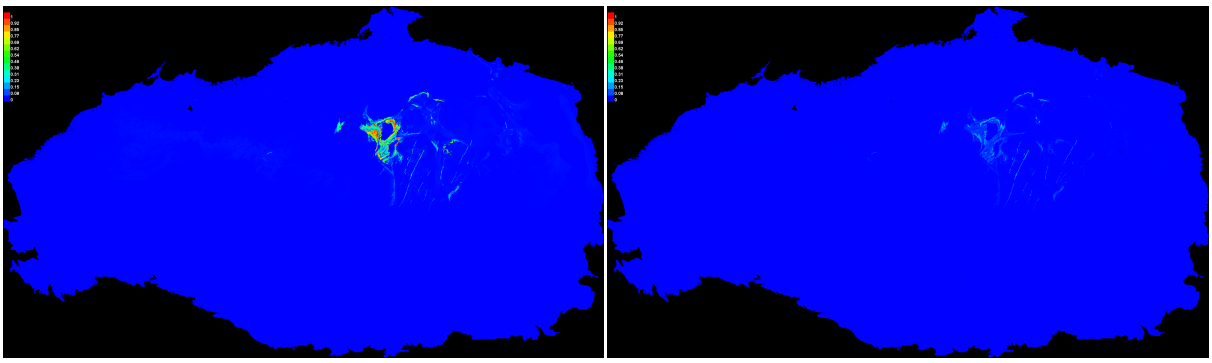


The next picture is the receiver operating characteristic (ROC) curve for the same data, again averaged over the replicate runs. Note that the specificity is defined using predicted area, rather than true commission (see the paper by Phillips, Anderson and Schapire cited on the help page for discussion of what this means). The average test AUC for the replicate runs is 0.993, and the standard deviation is 0.005.



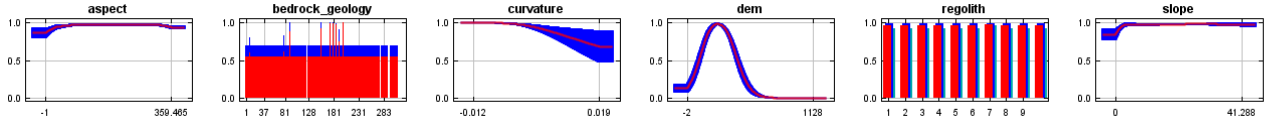
Pictures of the model

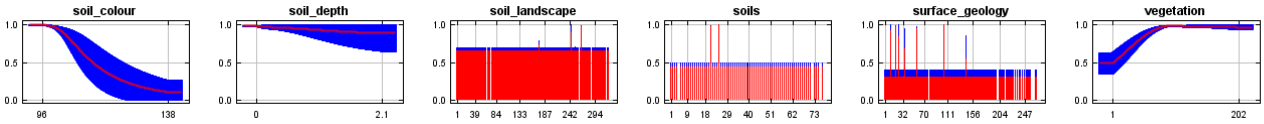
The following two pictures show the point-wise mean and standard deviation of the 10 output grids. Other available summary grids are min, max and median.



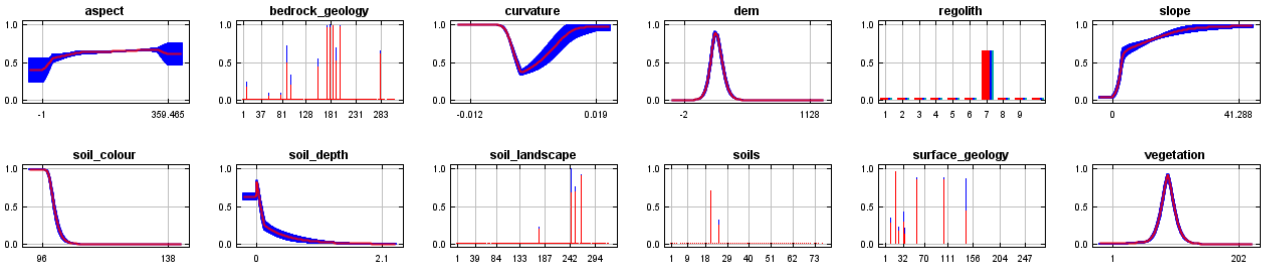
Response curves

These curves show how each environmental variable affects the Maxent prediction. The curves show how the predicted probability of presence changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. Click on a response curve to see a larger version. Note that the curves can be hard to interpret if you have strongly correlated variables, as the model may depend on the correlations in ways that are not evident in the curves. In other words, the curves show the marginal effect of changing exactly one variable, whereas the model may take advantage of sets of variables changing together. The curves show the mean response of the 10 replicate Maxent runs (red) and and the mean +/- one standard deviation (blue, two shades for categorical variables).





In contrast to the above marginal response curves, each of the following curves represents a different model, namely, a Maxent model created using only the corresponding variable. These plots reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables. They may be easier to interpret if there are strong correlations between variables.

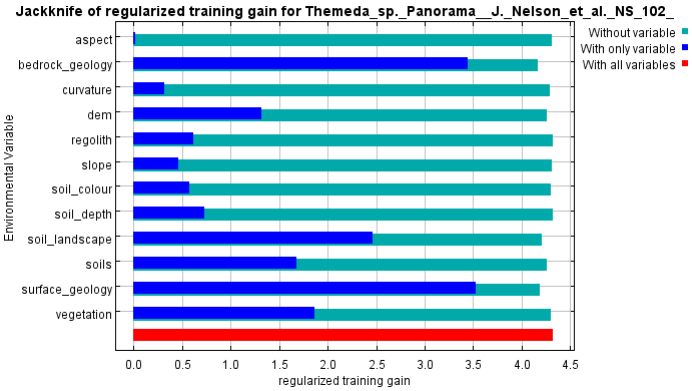


Analysis of variable contributions

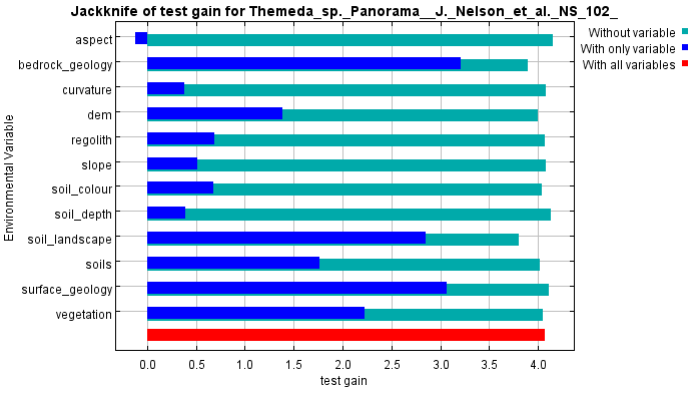
The following table gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. As with the variable jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated. Values shown are averages over replicate runs.

Variable	Percent contribution	Permutation importance
surface_geology	29.8	7.3
soils	27.2	3.1
soil_landscape	24.6	1.9
bedrock_geology	11.7	4.2
regolith	2	0
dem	1.3	64.5
vegetation	1.2	2.7
curvature	0.7	0.3
soil_depth	0.6	0.3
slope	0.4	0.5
soil_colour	0.3	14.5
aspect	0.2	0.5

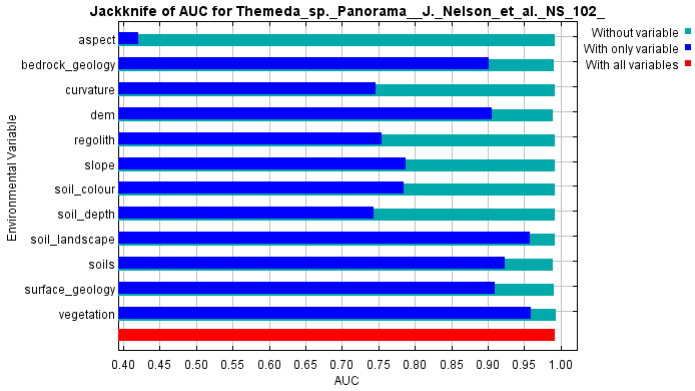
The following picture shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is surface_geology, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is bedrock_geology, which therefore appears to have the most information that isn't present in the other variables. Values shown are averages over replicate runs.



The next picture shows the same jackknife test, using test gain instead of training gain. Note that conclusions about which variables are most important can change, now that we're looking at test data.



Lastly, we have the same jackknife test, using AUC on test data.



Command line to repeat this species model: java density.MaxEnt nowarnings noprefixes -E "" -E Themeda_sp._Panorama__J._Nelson_et_al._NS_102_ responsecurves jackknife "outputdirectory=X:\01_Projects\4881-23 Themeda sp. Panorama surveys\Maps\Working\Spatial Files\Model 1" "samplesfile=X:\01_Projects\4881-23 Themeda sp. Panorama surveys\Maps\Working\Spatial Files_Themeda records\Records_filtered_500m.csv" "environmentallayers=X:\01_Projects\4881-23 Themeda sp. Panorama surveys\Maps\Working\Spatial Files_Environmental layers\ASCII" randomseed randomtestpoints=20 replicates=10 replicatetype=subsample nooutputgrids maximumiterations=5000 -t bedrock_geology -t regolith -t soil_landscape -t soils -t surface_geology

APPENDIX THREE FIELD SURVEY RESULTS

Table 10: Targeted survey results

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
1	310	R25	**Vegetation:** *Melaleuca argentea, Eucalyptus victrix* and *Corymbia hamersleyana* low open woodland over *Acacia tumida* var. *pilbarensis, Acacia eriopoda* and *Petalostylis labicheoides* tall shrubland over *Triodia epactia* and *Eriachne tenuiculmis* mid open hummock grassland/tussock grassland. **Vegetation condition:** Excellent **Site description:** rocky creek with brown sand and underlying geology of sandstone, quartz sandstone, siltstone and grey shale.		9.14
2	20		Not assessed (outside the LUC boundary)		11.17
3	50		Not assessed (outside the LUC boundary)		16.47
4	221		Not assessed (outside the LUC boundary)		17.59
5	20		Not assessed (outside the LUC boundary)		30.51
6	615		Not assessed (outside the LUC boundary)		31.70
7	140	R24	**Vegetation:** *Corymbia hamersleyana* and *Eucalyptus victrix* low woodland over *Acacia pyrifolia* var. *pyrifolia*, *Carissa lanceolata* and *Grevillea wickhamii* mid open shrubland over *Triodia epactia, Eriachne tenuiculmis* and *Chrysopogon fallax* mid open hummock grassland/tussock grassland. **Vegetation condition:** Excellent **Site description:** rocky creeks with brown sand and underlying geology of sandstone, siltstone, grey shale, basalt and chert.		32.88
9	4				35.69
10	268				36.32
11	86				35.11
12	601				33.53

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
8	531	R05	**Vegetation:** *Eucalyptus leucophloia* subsp. *leucophloia* low open woodland over *Acacia tumida* var. *pilbarensis* mid open shrubland over *Eriachne mucronata* low open tussock grassland **OR** *Corymbia hamersleyana* and *Eucalyptus victrix* low woodland over *Acacia pyrifolia* var. *pyrifolia*, *Carissa lanceolata* and *Grevillea wickhamii* mid open shrubland over *Triodia epactia, Eriachne tenuiculmis* and *Chrysopogon fallax* mid open hummock grassland/tussock grassland. **Vegetation condition:** Excellent **Site description:** moderately sloped rocky gully/rocky creek with orange clay soil/brown sand and underlying geology of sandstone, minor siltstone and grey shale.		34.28
13	40	R01	**Vegetation:** *Eucalyptus camaldulensis* subsp. *refulgens* low woodland over *Melaleuca glomerata* mid sparse shrubland over *Cyperus vaginatus, Themeda* sp. Panorama (J. Nelson et al. NS 102) and **Cenchrus ciliaris* low open sedgeland/tussock grassland. **Vegetation condition:** Good **Site description:** rocky creeks with brown sandy soil and underlying geology of basalt.		67.61
14	460				67.26
15	5	R23	**Vegetation:** *Eucalyptus victrix* and *Corymbia hamersleyana* mid open forest over *Acacia tumida* var. *pilbarensis*, *Grevillea wickhamii* and *Acacia pyrifolia* var. *pyrifolia* mid open shrubland over *Triodia epactia* mid hummock grassland. **Vegetation condition:** Excellent **Site description:** rocky creeks with brown sandy soil and underlying geology of basalt and mafic intrusive rocks.		65.09
16	81				65.18

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
17	20	R28	**Vegetation:** *Corymbia hamersleyana* low open woodland over *Acacia tumida* var. *pilbarensis* and *Petalostylis labicheoides* mid open shrubland over *Triodia epactia* mid open hummock grassland. **Vegetation condition:** Excellent **Site description:** steep rocky gully with brown clay loam soil and underlying geology of shale with minor siltstone, banded iron-formation, chert, sandstone and conglomerate.		26.57
18	1,049	R04 R26	**Vegetation:** *Eucalyptus victrix* mid open woodland over *Melaleuca linophylla, Acacia acradenia* and *Acacia pyrifolia* var. *pyrifolia* tall shrubland over *Triodia longiceps, Triodia wiseana* and *Themeda* sp. Panorama (J. Nelson et al. NS 102) mid open hummock grassland/tussock grassland. **Vegetation condition:** Excellent **Site description:** rocky creek with brown sand and underlying geology of basalt.		22.55
19	5	R21	**Vegetation:** *Acacia tumida* var. *pilbarensis* and *Acacia pyrifolia* var. *pyrifolia* tall shrubland over *Corchorus parviflorus, Triodia longiceps* and *Triodia epactia* low shrubland/mid hummock grassland. **Vegetation condition:** Excellent **Site description:** rocky creeks with brown sand and underlying geology of basalt or banded iron-formation, chert, siliciclastic sedimentary rocks and felsic volcanic rocks.		21.76
20	45				21.17

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
21	942	R27 R03	**Vegetation:** *Corymbia hamersleyana* low open woodland over *Acacia tumida* var. *pilbarensis* and *Acacia pyrifolia* var. *pyrifolia* tall shrubland over *Triodia wiseana* and *Themeda* sp. Panorama (J. Nelson et al. NS 102) mid open hummock grassland/tussock grassland **OR** *Grevillea wickhamii* and *Grevillea pyramidalis* mid isolated shrubs over *Themeda* sp. Panorama (J. Nelson et al. NS 102) and *Triodia wiseana* mid tussock/hummock grassland. **Vegetation condition:** Excellent **Site description:** rocky creek with brown sand and underlying geology of basalt and carbonate rocks.		21.46
22	402	R02	**Vegetation:** *Eucalyptus victrix* low woodland over *Acacia pyrifolia* var. *pyrifolia* and *Acacia tumida* var. *pilbarensis* mid sparse shrubland over *Cyperus vaginatus* and *Themeda* sp. Panorama (J. Nelson et al. NS 102) low open sedgeland/tussock grassland. **Vegetation condition:** Excellent **Site description:** rocky creek with brown sandy clay and underlying geology of basalt and carbonate rocks.		22.90
23	1	R22	**Vegetation:** *Eucalyptus camaldulensis* subsp. *refulgens* mid woodland over *Melaleuca linophylla, Melaleuca glomerata* and *Acacia ampliceps* tall shrubland over *Triodia longiceps* and *Cymbopogon ambiguus* mid open hummock grassland/tussock grassland. **Vegetation condition:** Very Good **Site description:** major rocky creek/gorge with brown sand and underlying geology of basalt.		14.04

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
24	100	R18	**Vegetation:** *Eucalyptus victrix, Eucalyptus camaldulensis* subsp. *refulgens* and *Melaleuca argentea* mid open forest over *Melaleuca linophylla, Melaleuca glomerata* and *Acacia ampliceps* tall shrubland over *Cyperus vaginatus* and *Triodia longiceps* mid open sedgeland/hummock grassland. **Vegetation condition:** Very Good **Site description:** major drainage channel with brown sandy-loam soil and underlying geology of basalt, quartz sandstone, minor conglomerate and chert.		5.10
25	67	R12	**Vegetation:** *Corymbia hamersleyana* low open woodland over *Acacia acradenia*, *Acacia tumida* var. *pilbarensis* and *Petalostylis labicheoides* tall shrubland over *Triodia longiceps*, *Triodia epactia* and *Acacia spondylophylla* mid hummock grassland/shrubland. **Vegetation condition:** Excellent **Site description:** rocky creek with brown loam soil and underlying geology of mafic and ultramafic rock.		0.05
26	20	R17	**Vegetation:** *Acacia acradenia, Petalostylis labicheoides* and *Acacia tumida* var. *pilbarensis* mid open shrubland over *Triodia epactia* and *Acacia spondylophylla* mid hummock grassland/shrubland with *Corymbia hamersleyana* low isolated trees. **Vegetation condition:** Excellent **Site description:** rocky creek with brown sandy loam and underlying geology of felsic and mafic volcanic rocks, siliciclastic sedimentary rocks; banded iron-formation, chert and shale.		0.75

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
27	1,191	R16 R15	**Vegetation:** *Eucalyptus victrix* mid woodland over *Melaleuca glomerata* and *Melaleuca linophylla t*all shrubland over *Triodia epactia, Themeda* sp. Panorama (J. Nelson et al. NS 102) and *Eriachne tenuiculmis* mid open hummock grassland/tussock grassland **OR** *Eucalyptus victrix* mid woodland over *Petalostylis labicheoides, Acacia tumida* var. *pilbarensis* and *Acacia pyrifolia* var. *pyrifolia* mid shrubland over *Triodia epactia, Eriachne tenuiculmis* and *Triodia wiseana* mid hummock grassland/tussock grassland. **Vegetation condition:** Very Good to Excellent **Site description:** rocky gorge or creek with brown sandy loam and underlying geology of volcanic rocks and siliciclastic sedimentary rocks.		1.17
28	11	R13 R14	**Vegetation:** *Acacia pyrifolia* var. *pyrifolia* and *Acacia tumida* var. *pilbarensis* tall shrubland over *Triodia epactia* and *Indigofera monophylla* mid hummock grassland/shrubland with *Corymbia hamersleyana* low isolated trees **OR** *Eucalyptus victrix* mid woodland over *Acacia tumida* var. *pilbarensis*, *Acacia pyrifolia* var. *pyrifolia* and *Acacia bivenosa* mid shrubland over *Cyperus vaginatus, Triodia longiceps* and *Tephrosia rosea* var. *clementii* mid sedgeland/hummock grassland/shrubland. **Vegetation condition:** Very Good to Excellent **Site description:** rocky creek with brown sandy loam soil and underlying geology of siliciclastic sedimentary rocks, minor felsic volcanic rocks and chert.		0.72
29	73	R06	**Vegetation:** *Eucalyptus victrix* mid woodland over *Acacia tumida* var. *pilbarensis*, *Acacia pyrifolia* var. *pyrifolia and Petalostylis labicheoides* tall shrubland over *Triodia longiceps*, *Cenchrus ciliaris* and *Cymbopogon ambiguus* mid hummock grassland/tussock grassland. **Vegetation condition:** Very Good **Site description:** rocky creek with brown sand and underlying geology of siliciclastic sedimentary rocks, minor felsic volcanic rocks and chert or mafic and ultramafic intrusive rocks.		0.28

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
30	1	R07	**Vegetation:** *Eucalyptus camaldulensis* subsp. r*efulgens and Eucalyptus victrix* mid woodland over *Acacia pyrifolia* var. *pyrifolia*, *Acacia bivenosa* and *Melaleuca glomerata* tall shrubland over **Cenchrus ciliaris*, *Triodia longiceps* and **Cenchrus setiger* mid tussock grassland/hummock grassland. **Vegetation condition:** Very Good **Site description:** rocky creek with brown sand and underlying geology of mafic and ultramafic intrusive rocks.		1.10
31	274	R08 R09	**Vegetation:** *Corymbia hamersleyana* low open woodland over *Acacia tumida* var. *pilbarensis, Petalostylis labicheoides* and *Grevillea wickhamii* tall shrubland over *Triodia longiceps* and *Triodia epactia* mid open hummock grassland **OR** *Petalostylis labicheoides, Acacia acradenia* and *Grevillea wickhamii* tall open shrubland over *Triodia wiseana* and *Themeda* sp. Panorama (J. Nelson et al. NS 102) mid hummock grassland/tussock grassland. **Vegetation condition:** Excellent **Site description:** rocky creek with red-brown sand and underlying geology of basaltic volcanic rocks with minor komatiite, siliciclastic sedimentary rocks and chert.		1.40
32	25	R20	**Vegetation:** *Eucalyptus camaldulensis* subsp. *refulgens* mid open forest over *Acacia tumida* var. *pilbarensis, Petalostylis labicheoides* and *Melaleuca linophylla* tall shrubland over *Triodia pungens, Triodia epactia* and *Eriachne tenuiculmis* low hummock grassland/tussock grassland. **Vegetation condition:** Very Good **Site description:** rocky creek with brown sandy loam and underlying geology of basalt**,** serpentinised peridotite, local dolerite and gabbro sills, minor felsic volcaniclastic rocks and chert.		3.20

Population number	Plant count[1]	Relevé number/s	Habitat description[2]	Site photograph	Distance from MDE[3] (km)
33	3,035	R20 R19 R11 R10	**Vegetation:** *Eucalyptus camaldulensis* subsp. *refulgens* mid open forest over *Acacia tumida* var. *pilbarensis, Petalostylis labicheoides* and *Melaleuca linophylla* tall shrubland over *Triodia pungens, Triodia epactia* and *Eriachne tenuiculmis* low hummock grassland/tussock grassland **OR** *Corymbia hamersleyana* low open woodland over *Acacia tumida* var. *pilbarensis, Grevillea wickhamii* and *Petalostylis labicheoides* tall shrubland over *Triodia pungens, Themeda* sp. Panorama (J. Nelson et al. NS 102) and *Corchorus parviflorus* mid hummock grassland/tussock grassland/shrubland. **Vegetation condition:** Very Good to Excellent **Site description:** minor and major rocky creeks with brown sandy loam and underlying geology of basalt**,** serpentinised peridotite, local dolerite and gabbro sills, minor felsic volcaniclastic rocks, siliciclastic sedimentary rocks and chert.		3.74

[1]*Themeda* sp. Panorama (J. Nelson et al. NS 102)

[2]Surface geology as per the 1:250,000 Geological Series Map for Port Hedland and Marble Bar (DEMIRS 2012; Hickman 2010)

[3]Average distance of all records in the population to the North Star mine development envelope