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Lake Mackay Sulphate of Potash Project

Detailed Flora and Vegetation Assessment at Lake Mackay

Prepared for
Agrimin Limited
by Strategen

January 2018

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ENVIRONMENTAL

Lake Mackay Sulphate of Potash Project

Detailed Flora and Vegetation Assessment at Lake Mackay

Strategen is a trading name of
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January 2018

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Client: Agrimin Ltd

Report Version	Revision No.	Purpose	Strategen author/reviewer	Submitted to Client	
				Form	Date
Draft Report	Rev A	For client review	A Dalton / R Firth	Electronic (email)	15 Dec 2017
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Filename: AGI17841_01 R001 Rev C - 19 January 2018

Executive summary

Strategen Environmental was commissioned by Agrimin Limited (Agrimin) to undertake a Detailed Flora and Vegetation Survey for the Lake Mackay Sulphate of Potash Project.

The objective of this assessment was to conduct a Detailed flora and vegetation assessment in the proposed western infrastructure area, along with targeted searches in this area and the proposed southern infrastructure area for potential conservation significant flora species at Lake Mackay. The purpose of this assessment was to provide Agrimin with preliminary data to support environmental approvals for the Sulphate of Potash Project.

A total of 60 native vascular plant taxa from 42 plant genera and 26 plant families were recorded from quadrats within the survey area. The majority of taxa were recorded within the Poaceae (12 taxa) and the Chenopodiaceae (8 taxa) families. The most diverse genera were *Tecticornia* (Chenopodiaceae family) and *Eragrostis* (Poaceae family).

A review of the Department of Biodiversity, Conservation and Attractions (DBCA) threatened flora database and EPBC Protected Matters Search Tool (PMST) did not identify any Threatened/EPBC listed species, however, twelve taxa listed as Priority flora were identified as potentially occurring in the Survey Area from the database searches and desktop review. Of these 12 conservation significant flora, three are considered Likely to occur - *Goodenia virgata* (P2), *Goodenia modesta* (P3) and *Stackhousia clementii* (P3) and three are considered to possibly occur – *Tecticornia globulifera* (P1), *Thysanotus* sp. Desert East of Newman (P2) and *Dampiera atriplicina* (P2).

No Threatened flora species pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or gazetted as Threatened pursuant to the *Wildlife Conservation Act 1950* were recorded during the survey.

No Priority listed flora were recorded during the survey, however, if further targeted searches were undertaken within the survey area beyond the proposed disturbance footprint, Priority flora would likely be recorded.

Five specimens collected in the western and southern survey area belong to five unknown and potentially new taxa; *Tecticornia* aff. *calyptrata* [M. Stone LM01.05], *Tecticornia* aff. *calyptrata* [M. Stone LM01.06], *Tecticornia* aff. *calyptrata* [M. Stone LM02.03], *Tecticornia* aff. *calyptrata* [A. Dalton LM OP.03] and *Tecticornia* aff. *halocnemoides* subsp. *longispicata* [M. Stone LM01.04]. These taxa are therefore potentially conservation significant.

No introduced species were recorded during the survey and subsequently no species are listed as Weeds of National Significance (WONS) or Declared under the *Biodiversity and Agriculture Management Act 2007* (BAM Act).

Three vegetation associations were identified in the proposed western infrastructure area. The majority of the vegetation in the survey area was considered to be in Excellent condition.

None of the three vegetation associations recorded during the survey are of conservation significance. None of the vegetation in the survey area is considered to represent Federal or State listed Threatened Ecological Communities or Priority Listed Ecological Communities.

The vegetation associations and their associated landforms are considered common and widespread across and surrounding the survey area around Lake Mackay and more broadly across the region.

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1. Introduction

This report presents the findings of a Detailed flora and vegetation assessment and targeted survey undertaken for the proposed Sulphate of Potash (SOP) Project at Lake Mackay (Figure 1). A first-phase flora and vegetation assessment was previously undertaken in September 2016 by Ecologia (Ecologia survey), followed by a second-phase detailed flora and vegetation assessment in April 2017 by 360 Environmental (360 survey) in the proposed southern infrastructure area (southern survey area [previously referred to as the western survey area]).

This current assessment comprised a detailed flora and vegetation assessment in an additional proposed western infrastructure area (western survey area), along with targeted searches for conservation significant flora in this western survey area and in the previously surveyed southern survey area (survey area [Figure 1]).

1.1 Background

Strategen Environmental was commissioned by Agrimin Limited (Agrimin) to undertake a detailed flora and vegetation assessment for the Lake Mackay (the lake) SOP. Lake Mackay is a seasonally inundated salt lake located in the Great Sandy Desert on the Western Australian (WA) and Northern Territory (NT) border, with most of the lake located in WA.

The proposed development comprises 12 tenements in Western Australia covering most of the lake for a combined area of approximately 347,722 ha (Figure 1). The survey effort focused on two proposed infrastructure development areas (adjacent to the western boundary of the lake and to the southern boundary of the lake).

The purpose of this assessment was to provide Agrimin with data to support environmental approvals for the proposed development.

1.2 Scope

The scope of this Detailed flora and vegetation survey was to undertake a field assessment of flora and vegetation values within the survey area according to standards set out in *Guidance Statement 51 – Terrestrial flora and vegetation surveys for environmental impact assessment in Western Australia* (GS 51) (EPA 2004) and 'Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment' (EPA 2016).

The objectives were to:

- conduct a desktop review of the survey area prior to the field survey work to identify all floristic constraints which may be in, or nearby, the survey area
- identify and review any existing reports
- conduct a series of targeted searches in areas of suitable habitat for Threatened and/or Priority flora identified as likely to occur (based on previous surveys and habitat present)
- assess the survey area's plant species diversity, density, composition, structure and weed cover, recording the percentage of each in nominated quadrats
- define and map the native vegetation communities present within the western survey area
- map vegetation condition within the western survey area
- provide recommendations on the local and regional significance of the vegetation communities
- prepare a report summarising the findings.

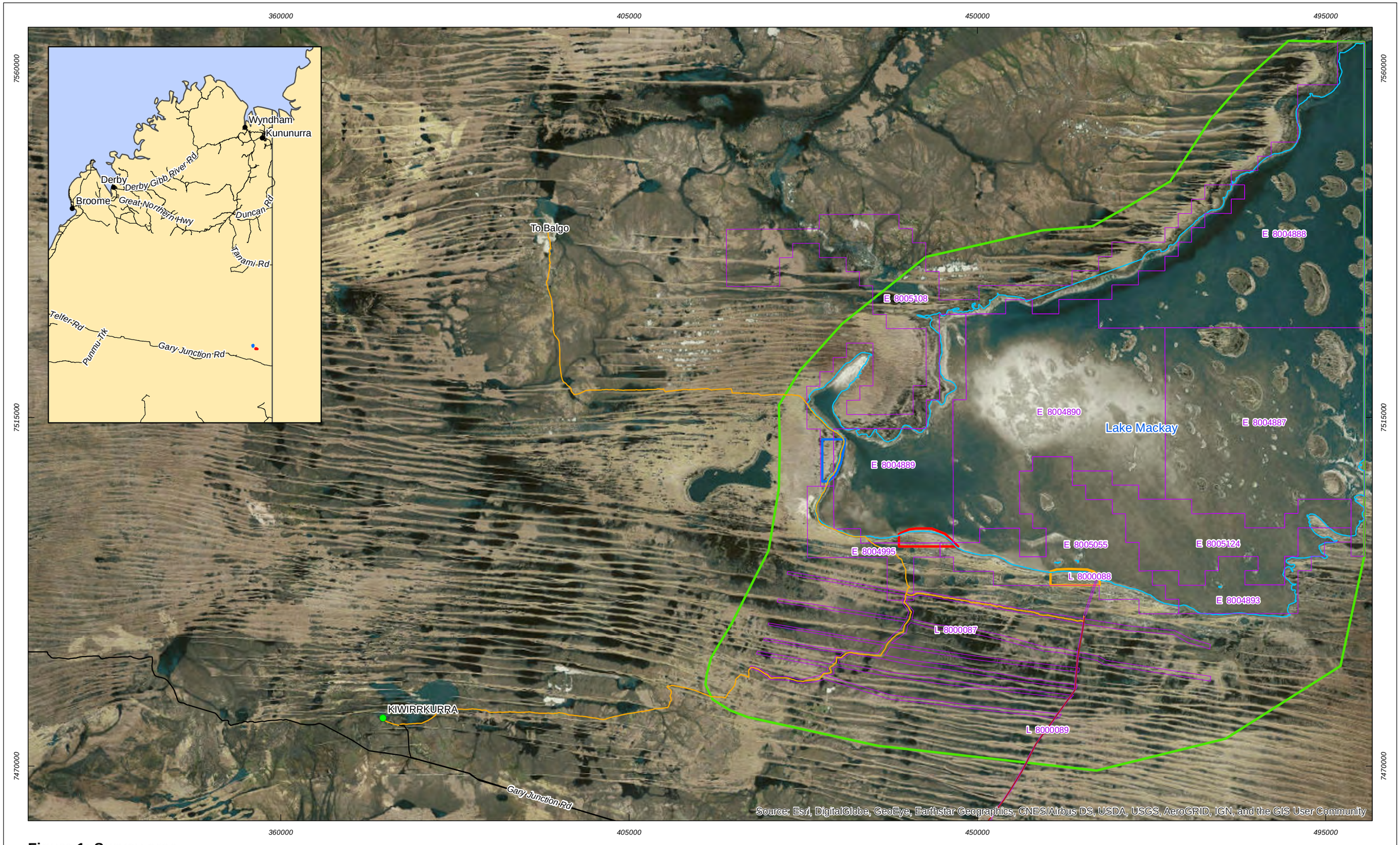

Figure 1: Survey area

Scale 1:450,000 at A3

0 5 10 15 km

Coordinate System: GDA 1994 MGA Zone 52
Note that positional errors may occur in some areas
Date: 22/01/2018
Author: JCrute
Source: Aerial image: ESRI, approx. 2014. Infrastructure areas: Client 11/2017. Survey area: Client 12/2017.
Path: Q:\Consult\2017\AGI\AGI17481\01_GIS_documents\ArcMap_documents\AGI17481_G009_RevF.mxd

Legend

- Existing tracks
- Proposed tracks
- Lake Mackay
- Mining tenement
- Existing roads
- Study area
- Eastern infrastructure area
- Proposed southern infrastructure area
- Proposed western infrastructure area

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2. Context

2.1 Legislative context

Flora in WA is protected formally and informally by various legislative and non-legislative measures, which are as follows:

Legislative measures:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) – Australian Government
- *Biodiversity Conservation Act 2016* (BC Act)
- *WA Environmental Protection Act 1986* (EP Act)
- *Biosecurity and Agriculture Management Act 2007* (BAM Act).

Non-legislative measures:

- WA Department of Biodiversity, Conservation and Attractions (DBCA) (formerly DPaW) Priority lists for flora and ecological communities
- Weeds of National Significance (WONS)
- Recognition of locally significant populations by DBCA
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) – Australian Government.

2.1.1 Conservation significant flora and ecological communities

Conservation significant flora and ecological communities are determined at a state and federal legislative level. Threatened species are listed under the EPBC Act at the Australian Government level and under the WC Act at the State level (Appendix 1). Priority species are listed by the Department of Biodiversity, Conservation and Attractions (DBCA) and include species of 'significant conservation value' (Appendix 1).

Threatened Ecological Communities (TECs) are listed under both the EPBC Act and EP Act (Appendix 1). Priority Ecological Communities (PECs) are listed by DBCA and include species of significant conservation value (Appendix 1).

A TEC is defined under the EP Act as an ecological community listed, designated or declared under a written law or a law of the Australian Government as Threatened, Endangered or Vulnerable. There are four State categories of TECs (DEC 2010).

- presumed totally destroyed (PD)
- critically endangered (CR)
- endangered (EN)
- vulnerable (VU).

2.1.2 Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESAs) are protected under the EP Act, and include the following:

- World Heritage areas
- areas included on the National Estate Register
- defined wetlands and associated buffers
- vegetation within 50 m of a listed Threatened species
- TECs.

2.1.3 Protection of native vegetation

Native vegetation is defined under the EP Act as "indigenous aquatic or terrestrial vegetation, and includes dead vegetation unless that dead vegetation is of a class declared by regulation to be excluded from this definition but does not include vegetation in a plantation".

This definition of native vegetation does not include vegetation that was intentionally sown, planted or propagated unless either of the following applies:

(a) the vegetation was sown, planted or propagated as required under the EP Act or another written law

(b) the vegetation is declared to be native under Regulation 4 of the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*.

Regulation 4 prescribes the kinds of intentionally planted indigenous vegetation that are "native vegetation" and which therefore require a clearing permit or exemption to clear and includes:

(a) planting that was funded (fully or partly)
   i. by a person who was not the owner of the land
   ii. for the purpose of biodiversity conservation or land conservation

(b) intentionally planted vegetation that has one of the following:
   i. a conservation covenant or agreement to reserve under section 30B of the *Soil and Land Conservation Act 1945*
   ii. a covenant to conserve under section 21A of the *National Trust of Australia (WA) Act 1964*
   iii. restrictive covenant to conserve under section 129B of the *Transfer of Land Act 1983*
   iv. some other form of binding or undertaking to establish and maintain, or maintain, the vegetation.

Native vegetation can only be cleared with a clearing permit, unless for some circumstances where exemptions apply pursuant to the EP Act and the Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (the Regulations). Clearing permits issued pursuant to the Regulations may be issued as area permits or purpose permits. Exemptions for clearing under Regulation 5 of the Regulations do not apply within ESAs.

Flora within WA that is considered to be under threat may be classed as either Threatened flora or Priority flora. Where flora has been gazetted as Threatened flora under the WC Act, the taking of such flora without the written consent of the Minister is an offence. The WC Act defines "to take" flora as to gather, pluck, cut, pull up, destroy, dig up, remove or injure the flora or to cause or permit the same to be done by any means. DBCA (2017) contains the current list of Threatened flora in WA.

Priority flora are considered to be species which are potentially under threat, but for which there is insufficient information available concerning their distribution and/or populations to make a proper evaluation of their conservation status. DBCA categorises Priority flora according to their conservation priority using five categories, P1 (highest conservation significance) to P5 (lowest conservation significance), to denote the conservation priority status of such species. Priority flora species are regularly reviewed and may have their priority status changed when more information on the species becomes available. Appendix 1 defines levels of Threatened and Priority flora (DEC 2010).

At the national level, the EPBC Act lists Threatened species as extinct, extinct in the wild, critically endangered, endangered, vulnerable, or conservation dependent. Appendix 1 defines each of these categories of Threatened species. The EPBC Act prohibits an action that has or will have a significant impact on a listed Threatened species without approval from the Australian Government Minister for the Environment. The current EPBC Act list of Threatened flora may be found on the DEE (2017) website.

2.1.4 Introduced species

Declared Pests

The BAM Act provides for management and control of listed organisms, including introduced flora species (weeds). Under the BAM Act, land managers are required to manage populations of declared pests as outlined under the relevant category. Species listed as declared pests under the BAM Act are classified under three categories:

- C1 Exclusion: Pests assigned under this category are not established in Western Australia, and control measures are to be taken to prevent them entering and establishing in the State
- C2 Eradication: Pests assigned under this category are present in Western Australia in low enough numbers or in sufficiently limited areas that their eradication is still a possibility
- C3 Management: Pests assigned under this category are established in Western Australia, but it is feasible, or desirable, to manage them in order to limit their damage. Control measures can prevent a C3 pest from increasing in population size or density or moving from an area in which it is established into an area that is currently free of that pest.

Weeds of National Significance

The Australian government, along with the WA and NT governments has endorsed 32 Weeds of National Significance (WONS). Four major criteria were used in determining WONS:

- the invasiveness of a weed species
- a weed's impact
- the potential for spread of a weed
- socio-economic impacts.

Each WONS has a nation strategy and coordinator responsible for implementing the strategy. WONS are regards as priority weeds in Australia because of their invasiveness, potential for spread and economic and environmental impacts (Thorp and Lynch 2000).

2.2 Environmental setting

2.2.1 Soils and topography

The survey area is located within the Great Sandy Desert biogeographic region of WA (Hearn *et al.* 2002). The Great Sandy Desert's dominant soils of its dunefields and sandplains are red deep sands and red sandy earths, with some red loamy earths and shallow gravels in depressions between dunes (Tille 2006). Hilly areas typically comprise red loamy earths, with red shallow loams, red shallow sands, stony soils and shallow gravels (Tille 2006).

Two soil units have been mapped within the survey areas using the Digital Atlas of Australian Soils (Bureau of Rural Sciences 2009). These are described in Table 1 and mapped in Figure 2.

Table 1: Soil units and their occurrence in the survey area

Soils	Description	Extent in western survey area (ha)	Extent in southern survey area (ha)
AB56	Plains extensively covered with longitudinal dunes; some hilly residuals with rock outcrops	-	305.50
SV12	Plains studded with salt pans, seasonal lakes, calcrete (kunkar) platforms; and fringing dunes	1239.56	1097.94

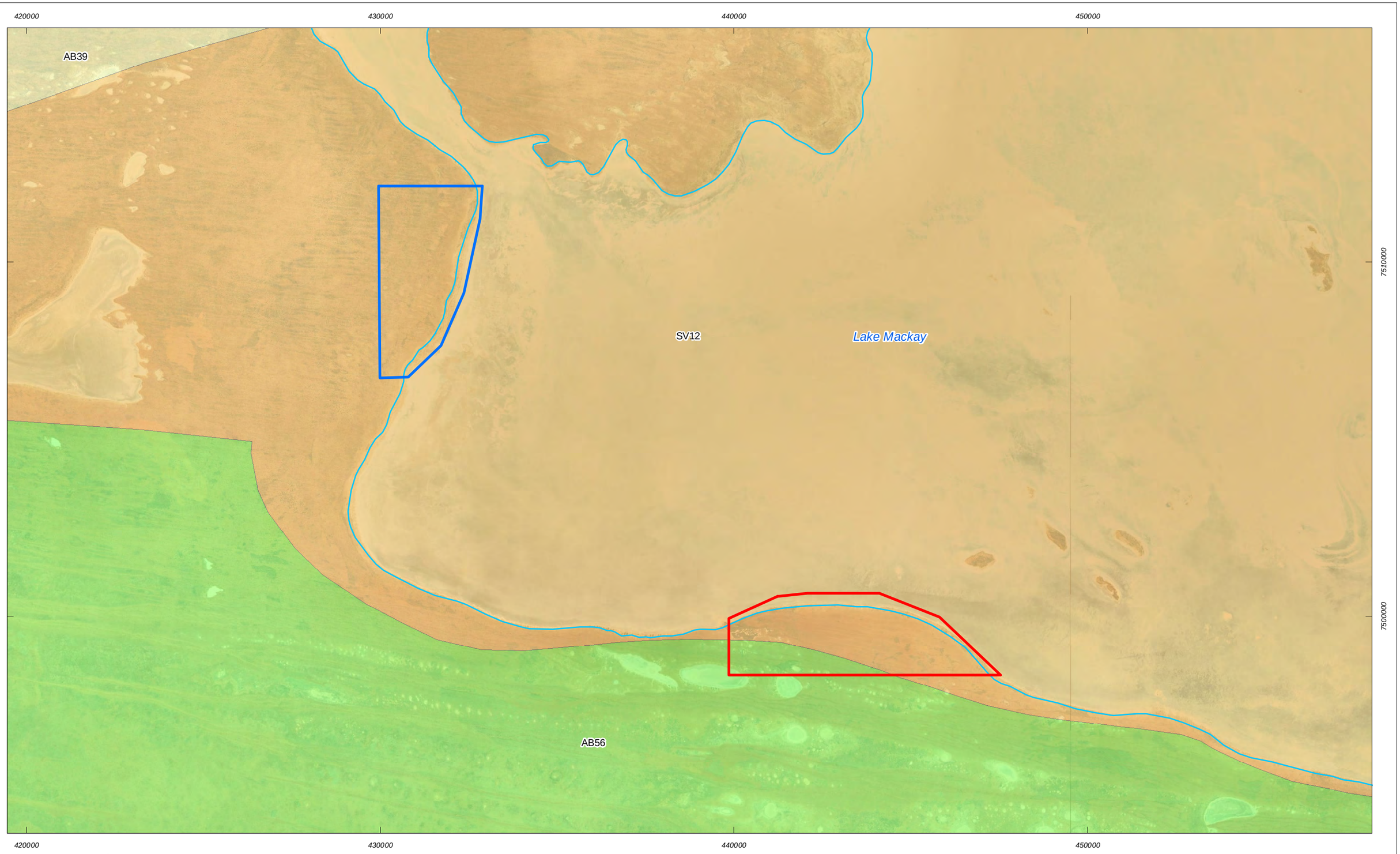

Figure 2: Land Systems

Legend

- Lake Mackay
- Proposed southern infrastructure area
- Proposed western infrastructure area

Soil Landscape Mapping Unit

- AB39
- AB56
- SV12

Scale 1:100,000 at A3

0 1,100 2,200 3,300 m

N

Coordinate System: GDA 1994 MGA Zone 52
Note that positional errors may occur in some areas
Date: 20/12/2017
Author: JCrute
Source: Soil: DAFWA, 2017.
Path: Q:\Consult\2017\AGI\AGI17481\01_GIS_documents\ArcMap_documents\AGI17481_G005_RevC.mxd

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2.2.2 Climate

The Great Sandy Desert Bioregion experiences an arid tropical climate in the north, grading into a temperate-subtropical climate in the south, where dry conditions with hot summers and mild winters occur (Tille 2006).

The nearest and most relevant Bureau of Meteorology (BoM) weather station for the survey area is Walungurru Airport (Station No. 0015664), approximately 120 km south-east of southern section of the survey area. The Walungurru Airport station receives a mean minimum temperature that ranges from 10.4°C to 26°C and mean maximum that ranges from 23.2°C to 39.4°C. The annual average rainfall is 306.1 mm (BoM 2017).

Walungurru Airport station recorded 696 mm of rain in the 12 months prior to the survey (November 2016 – October 2017) which is 390.1 mm above the long term average rainfall for the same period (Figure 3). In the three months prior to the survey (August – October 2017) 40.6 mm of rainfall was recorded which is below the 94.6 mm average rainfall for the same period (BoM 2017).

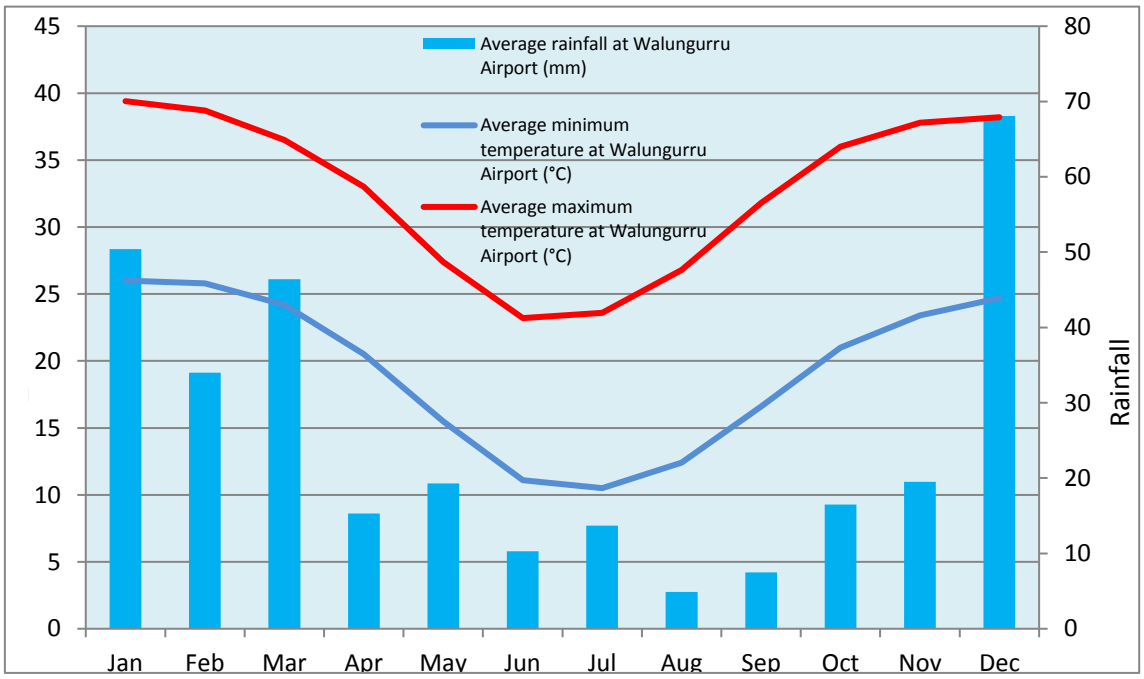

Figure 3: Mean monthly climatic data (temperature and rainfall) for Lake Mackay

Temperature and rainfall are now recorded at the Agrimin camp site which is much closer and more relevant than the Walungurru Airport station. Consequently, we have tabulated these for temperature (a week prior to the survey) and rainfall (Table 2).

Table 2: Rainfall and maximum and minimum temperatures for the Agrimin campsite in November 2017

Date	3/11	4/11	5/11	6/11	7/11	8/11	9/11	10/11	11/11	12/11	13/11	14/11	15/11
Rainfall (mm)						0.5			2		3		
Max Temp (° C)	35	42	41	44	40	35	37	25	35	37	41	42	38
Min Temp (° C)	15	15	15	15	15	18	18	18	15	18	20	22	24

2.2.3 Regional vegetation

Vegetation occurring within the region was initially mapped at a broad scale (1:1 000 000) by Beard during the 1970s. This dataset has formed the basis of several regional mapping systems, including physiographic regions defined by Beard (1981) which led to the delineation of botanical districts as described in Beard (1990); the biogeographical region dataset (Interim Biogeographic Regionalisation for Australia, IBRA) for Western Australia (DEE 2016).

Broad vegetation types

Mapping of the vegetation of the Great Sandy Desert region of WA was completed on a broad scale (1:1000 000) by Beard (1976). These vegetation types were later reassessed by Shepherd *et al.* (2001) to account for clearing in the intensive land use zones, dividing some larger vegetation units into smaller units to reflect the National Information System (NVIS) standards.

This mapping forms the basis of the vegetation extent statistics released annually by DBCA. According to Shepherd *et al.* (2001) the survey area occurs within two vegetation units. These are described along with their representation in the survey area in Table 3.

Table 3: Broad vegetation types in the survey area

Vegetation types	Description	Extent in western survey area (ha)	Extent in southern survey area (ha)
125 - Great Sandy Desert	Bare areas; salt lakes	128.24	339.48
2041 - Great Sandy Desert	Succulent steppe with scrub; teatree over saltflats	111.32	1064.13

IBRA subregion

IBRA describes a system of 89 'biogeographic regions' (bioregions) and 403 subregions covering the entirety of the Australian continent (Thackway & Cresswell 1995). Bioregions are defined on the basis of climate, geology, landforms, vegetation and fauna (Environment Australia 2000).

The survey is situated entirely within the Great Sandy Desert Mackay subregion (Figure 4). The climate is characterised as arid tropical with summer rainfall. This subregion comprises tropical inland 'red centre' desert and includes 'Percival' and 'Auld' palaeo-river systems. It is defined by tree steppe grading to shrub steppe in the south, with open hummock grasslands (*Triodia pungens* and *T. schinzii)* with scattered trees of *Owenia reticulata* and Bloodwood (*Corymbia spp.*). Shrublands consist of *Acacia spp., Grevillea wickenhamii* and *G. refracta*, on Quaternary red longitudinal sand dune fields overlying Jurassic and Cretaceous sandstones of the Canning and Armadeus Basins. Gently undulating, laterised uplands support shrub steppe such as *Acacia pachycarpa* shrublands over *Triodia pungens* hummock grasslands. Calcrete and evaporate surfaces are associated with occluded palaeo-drainage systems that traverse the desert. These include extensive salt lake chains with samphire low *Melaleuca* shrublands (*Melaleuca glomerata* and *M. Lasiandra*) (Kendrick 2001).

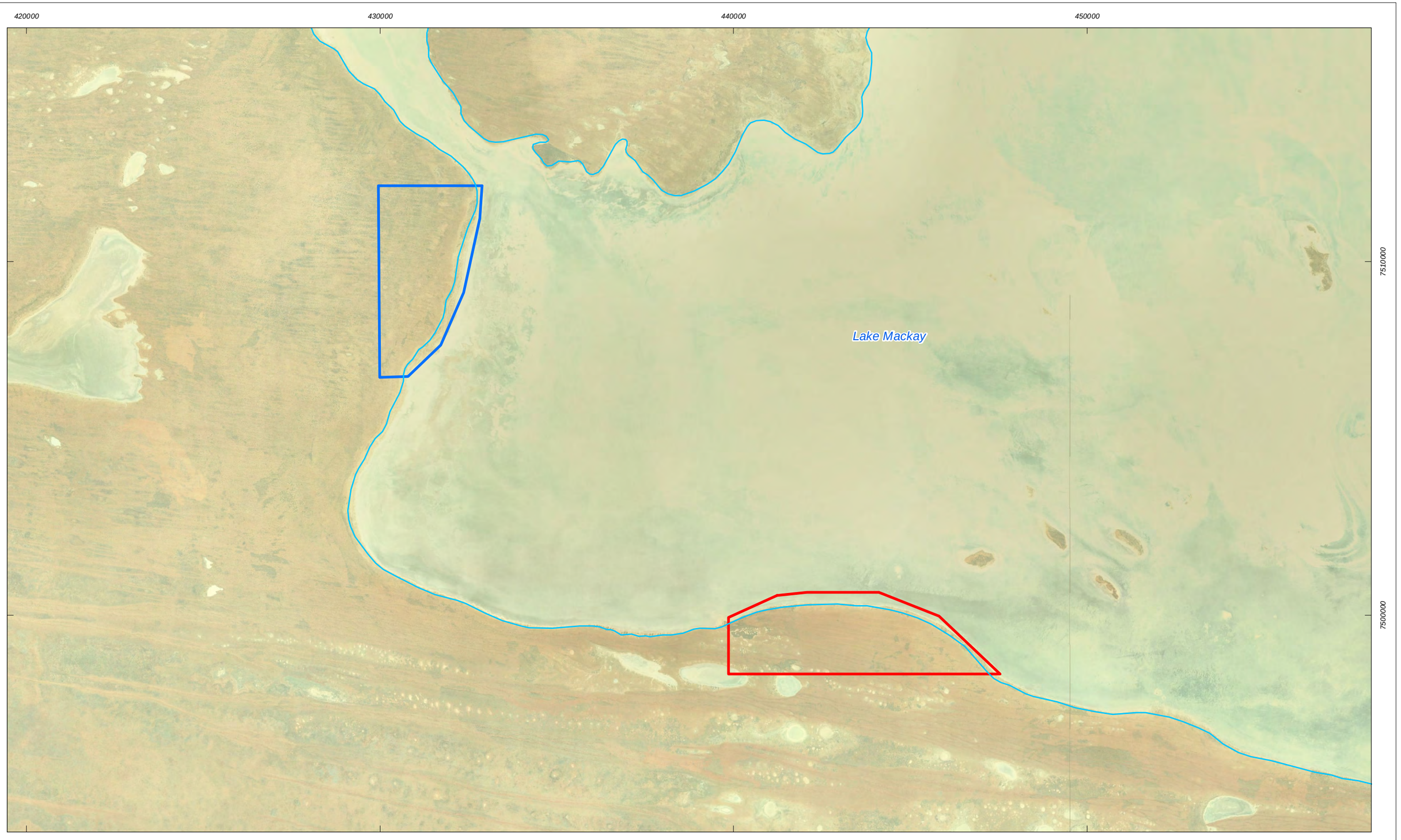

Figure 4: IBRA Regions and Subregions

Scale 1:100,000 at A3

0 1,100 2,200 3,300 m

N

Coordinate System: GDA 1994 MGA Zone 52
Note that positional errors may occur in some areas
Date: 20/12/2017
Author: JCrute
Source: IBRA: DoEE, 2017.

Legend

- Lake Mackay
- Proposed southern infrastructure area
- Proposed western infrastructure area

IBRA Region and Subegion

- Great Sandy Desert, Subregion Mackay

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2.2.4 Geology

The Canning Province of the Great Sandy Desert bioregion is situated over phanerozoic sedimentary rocks of the canning basin (2006). The inland forms of the Great Sandy Desert are predominantly east to west running linear dunes with swales opening locally onto sandplains. Some undulating plains and uplands occur. Among the dunes are areas of small claypans and isolated residual sandstone hills as well as area of ironstone gravels and some breakaways capped by laterite duricrust (Tille 2006).

Three geological units have been mapped in the survey area as parts of the Geological Series of W A. These are presented in Table 4.

Table 4: Geology in the survey area

Geological code	Description	Extent in western survey area (ha)	Extent in southern survey area (ha)
Dunes 38496	Dunes, sandplain with dunes and swales; may include numerous interdune claypans; residual and aeolian sand with minor silt and clay; aeolian red quartz sand, clay and silt, in places gypsiferous; yellow hummocky sand	1105.73	807.38
Calcrete 38497	Pisolitic, nodular or massive calcrete; ferruginous inclusions; calcerous cementing of bedrock and transported materials; locally with intercalated chalecony; as low mounds in playa lakes, or as valley calcrete; locally dissected and karstified	-	290.28
Lake deposits 38492	Lacustrine or residual mud, clay, silt and sand, commonly gypsiferous and/or saline; playa, claypan, and swamp deposits; peat; peaty sand and clay; halitic and gypsiferous evaporites	133.835	305.72

3. Methods

3.1 Desktop assessment

A desktop assessment was conducted using Florabase, DBCA and the Department of the Environment and Energy (DEE) databases to identify the possible occurrence of TECs, PECs and Threatened and Priority flora potentially occurring within the survey area.

A database search request was also submitted to the Threatened Communities Branch of DBCA to identify any potential Declared Rare Flora (DRF), TECs or PECs within a 60 km radial buffer around the survey area.

The WA Atlas database was also queried to identify any ESAs occurring within proximity to the survey area (Landgate 2016).

A limited number of publicly available flora and vegetation surveys are available for the Lake Mackay area, therefore, only a small number of relevant botanical surveys were considered suitable for the desktop assessment. These relevant botanical surveys include:

- second phase detailed flora and vegetation assessment (360 Environmental 2017)
- single phase level 2 flora and vegetation assessment (Ecologia 2017)
- level 1 flora and vegetation assessment – Theseus project (Outback Ecology 2012)
- biological resources of the Kiwirrkurra region (Desert Wildlife Services 2010).

3.2 Field assessment

The field survey was conducted according to standards set out in *Guidance Statement 51 – Terrestrial flora and vegetation surveys for environmental impact assessment in Western Australia* (GS 51) (EPA 2004) and 'Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment' (EPA 2016).

This detailed flora and vegetation assessment and targeted survey was undertaken by two botanists from Strategen on 10-15 November 2017. Table 5 identifies staff involved in the field surveys, their role and qualifications.

The survey was conducted by sampling flora within bounded 50 m x 50 m quadrats in the western survey area (the southern survey area was previously surveyed by Ecologia and 360 Environmental), supplemented by a series of traverses along which changes in vegetation type and disturbance were periodically noted, and additional plant species were recorded opportunistically. Standardised quadrats allow the vegetation to be consistently sampled and characterised facilitating multivariate analysis of vegetation associations. Both methods contributed to the delineation of fine scale vegetation units and a floristic inventory of the survey area.

In addition to quadrat sampling in the western survey area, targeted searches were carried out by traversing transect lines in both the western and southern survey areas where potential conservation significant flora species could occur. Approximately 300 km were traversed during the targeted searches. Survey effort for the targeted searches are illustrated in Figure 5a and 5b.

Table 5: Personnel

Name	Role	Flora collection permit
Ms. M. Stone Strategen (Senior Botanist)	Planning, fieldwork, plant identification, data interpretation	SL012169
Ms. A. Dalton Strategen (Botanist)	Planning, fieldwork, plant identification, data interpretation and report preparation	SL012195

Quadrat based sampling

A total of 10 50 m x 50 m quadrats were established and sampled in the western survey area. Additionally, two transects, each consisting of six 3 m x 3 m quadrats (12 quadrats) were established in transitional vegetation associated with the lake margin to adequately describe the vegetation from the upper lake margin profile to the edge of the playa. Two 3 m x 3 m quadrats were placed in each zone of vegetation (lower, mid and upper) along a 100 m long transect. The distance of each quadrat along the 100 m transect was recorded, and varied in each transect. This approach is consistent with recommended survey intensity for salt lakes as described in the Technical Guidance (EPA 2016). Quadrat locations were selected using a combination of aerial photography, topographic features, landforms, and field observations to represent the diversity of vegetation and the habitats present.

All quadrats were marked at the north-west corner, and at each the following data was recorded:

- GPS location
- topography
- soil type and colour
- outcropping rocks and their type
- percentage cover and average height of each vegetation stratum.

For each vascular plant species, the average height and percent cover were recorded.

All plant specimens collected during the field surveys were identified using appropriate reference material or through comparisons with pressed specimens housed at the Western Australian Herbarium where necessary. Nomenclature of the species recorded is in accordance with Western Australian Herbarium standards.

Systematic targeted searches

Priority flora species identified in the desktop review were targeted during the field survey using previously recorded locations as well as known habitat preferences. Searches consisted of a series of transects spaced 50 m apart in the western survey area (Figure 5a) and transects ranging from 50 m to 100 m apart in the southern survey area (Figure 5b). In both the western and southern survey areas, transects were placed in the proposed mine infrastructure areas (proposed disturbance area) within the survey area, which are those most likely to be impacted by disturbance. For each population of potential conservation significant flora identified in the field survey, the following were recorded:

- co-ordinate locations (using handheld GPS units)
- abundance/population size
- date and time
- reproductive condition and any interesting features (i.e. health)
- brief vegetation association description.

For each new population of significant flora recorded during the survey, a suitable specimen was taken and lodged at the Western Australian Herbarium (WAH) and Threatened (Declared Rare) Flora report forms were completed.

426000 429000 432000 435000

7512000

7509000

Lake Mackay

Figure 5a: Targeted survey transects (Proposed western infrastructure area)

Scale 1:30,000 at A3

0 300 600 900 1,200 1,500 m

N

Coordinate System: GDA 1994 MGA Zone 52
Note that positional errors may occur in some areas
Date: 20/12/2017
Author: JCrute
Source: Survey area: AGI 11/2017.
Path: Q:\Consult\2017\AGI\AGI17481\01_GIS_documents\ArcMap_documents\AGI17481_G011_RevD.mxd

Legend

- Targeted survey transects
- Proposed western infrastructure area

Mine design

- Communications tower
- Camp
- Processing plant
- Causeway link to on-lake infrastructure
- Airstrip
- Road
- Solar heating system
- Stockpile
- Truck facilities
- Vehicle facilities
- Wastewater treatment plant

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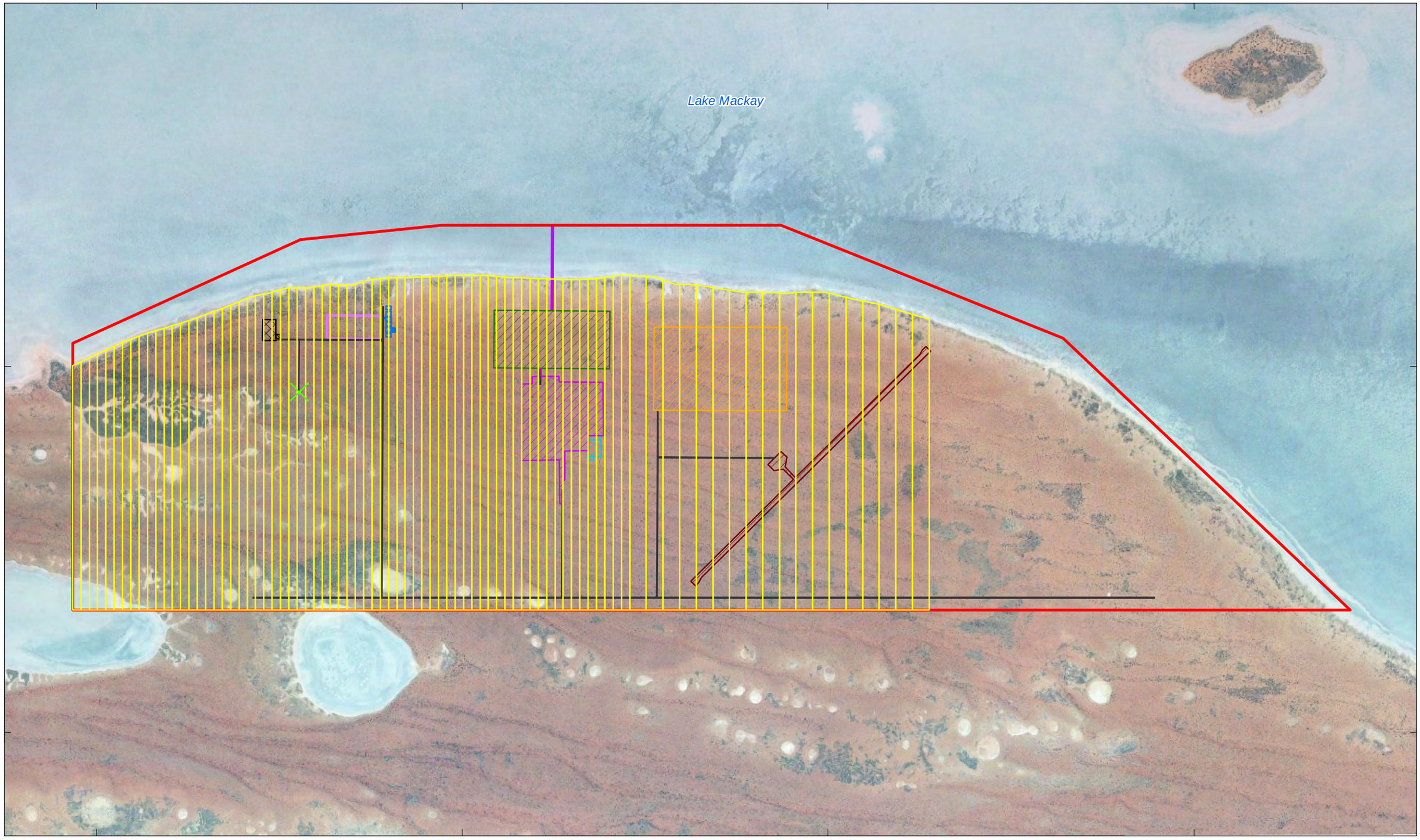
440000 442200 444400 446600

7499800

7497600

Lake Mackay



440000 442200 444400 446600

Figure 5b: Targeted survey transects (Proposed southern infrastructure area)

Scale 1:22,000 at A3

0 220 440 660 880 m

Coordinate System: GDA 1994 MGA Zone 52
Note that positional errors may occur in some areas
Date: 20/12/2017
Author: JCrute
Source: Survey area: AGI 11/2017.
Path: Q:\Consult\2017\AGI\AGI17481\01_GIS_documents\ArcMap_documents\AGI17481_G012_RevD.mxd

N

Legend

- Targeted survey transects
- Proposed southern infrastructure area

Mine layout

- Airstrip
- Camp
- Causeway link to on-lake infrastructure
- Communications tower
- Processing plant
- Road
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Specimen collection and identification

At least one specimen per taxon was collected during the field survey. Specimen identification was undertaken with reference to current taxonomic literature and herbarium reference specimens. The taxonomy was completed by senior taxonomist Sharnya Thomson, with assistance from other taxonomic specialists from the WAH (Mike Hislop and Kelly Shepherd).

The species list was checked against FloraBase (WAH 2017) to determine the species' conservation status. Threatened and Priority flora were verified against the EPBC Act listing of threatened species to determine commonwealth status.

Introduced species were checked against the BAM Act Declared Plants list to determine if any are Declared Plants, as with the WONS list (Thorp and Lynch 2000).

3.2.1 Data analysis and vegetation mapping

Due to the uniform distribution of vegetation within the survey area; quadrat data were grouped into a 'species by site' matrix to delineate individual vegetation types (VTs) present within the survey area. Aerial photography interpretation and field notes taken during the survey were then used to develop VT mapping polygon boundaries over the survey area. These polygon boundaries were then digitised using Geographic Information System (GIS) software.

Quadrat cover data was pre-treated with square root transformation and a dendrogram was then computed using hierarchical agglomerative cluster analysis. The dendrogram created from the cluster analysis was used to assist in the interpretation of the vegetation communities occurring within the survey area, which were delineated primarily by overall floristic similarity. VT descriptions (though floristic in origin) have been adapted from the National Vegetation Information System (NVIS) Australian Vegetation Attribute Manual Version 6.0 (ESCAVI 2003), a system of describing structural vegetation units (based on dominant taxa). This model follows nationally-agreed guidelines to describe and represent vegetation types, so that comparable and consistent data is produced nation-wide. For the purposes of this report, a VT is considered equivalent to a NVIS sub-association as described in ESCAVI (2003).

Vegetation mapping is the delineation of plant communities or vegetation units based on distinctive characteristics that these communities share such as the vegetation structure, dominant species and species composition. Extrapolative vegetation mapping based on aerial imagery, in addition to ground-truth data provided by quadrat assessments and vegetation mapping points, was used to map the vegetation of the study area at a scale of 1:30000.

Vegetation condition was recorded at all quadrats, and opportunistically during traverses across the survey area during the field assessment. Vegetation condition was described using the vegetation condition scale developed by Trudgen (1998) (Table 10). Vegetation condition polygon boundaries were developed using this information in conjunction with aerial photography interpretation, and were digitised as for vegetation type mapping polygon boundaries.

The sampling adequacy was assessed by conducting a species accumulation curve analysis (note that the analysis was undertaken using only systematic site data [quadrat data]). The species accumulation curve analyses the accumulation rates of new species and survey effort. That is, as the number of quadrats increases, the number of newly recorded species should increase until the accumulation of new species declines (i.e. the graph reaches an asymptote). This indicates that most species have been recorded and that the area has been adequately surveyed (the species accumulation curve can be a useful tool in estimating total species richness). At the point where there is a minimal increase in species richness with continued sampling effort, the sample size is considered adequate. The accumulation curve was based on presence/absence data and the sample order being random with a maximum 999 permutations. One estimator curve Chao2 was generated using version PC-ORD version 7.02 (McCune and Mefford 2016). The Chao 2 Mean curve aids in predicting the true total number of species that would be observed as the number of sites tends to infinity.

3.2.2 Survey limitations and constraints

Table 6 outlines and evaluates the flora and vegetation assessment against a range of potential limitations that may influence the assessment. Based on this evaluation, the assessment has been subject to constraints that could potentially affect the thoroughness of the assessment and the conclusions reached. The survey was conducted outside of the recommended period for the Eremaean botanical province in accordance with the Technical Guidance (EPA 2016).

Table 6: Flora and vegetation survey potential limitations and constraints

Potential limitation	Impact on assessment	Comment
Sources of information and availability of contextual information (i.e. pre-existing background versus new material).	**Low**	Vegetation mapping has been previously mapped by Shepherd *et al.* (2001) at a broad scale (1:1000 000), based on mapping by Beard (1976). Additionally, two recent flora and vegetation surveys were conducted in the study area.
Scope (i.e. what life forms, etc., were sampled).	**Moderate**	While outside the optimum surveying period for the region, the uniform distribution of vegetation within the survey areas has resulted in species which define vegetation types being identified.
Proportion of flora collected and identified (based on sampling, timing and intensity).	**Low**	The proportion of flora surveyed was adequate. The species accumulation curve analysis suggests that approximately 80% of the taxa expected to be present were recorded within quadrats. Most of the survey area was traversed on foot and flora species were recorded systematically and by opportunistic observations.
Completeness and further work which might be needed (i.e. was the relevant survey area fully surveyed).	**Low**	Due to the size of the survey area, limited access and limited time, the entire survey area was not able to be traversed. However, sufficient sampling was made within the survey area to identify the vegetation types within it.
Mapping reliability.	**Nil**	Aerial photography of a suitable scale was used to map the survey area. Sites were chosen from these aerials, along with the previous surveys in the study area by Ecologia and 360 Environmental to reflect changes in community structure. Opportunistic sites were also used if differences were observed during on ground reconnaissance. Vegetation types were assigned to each site based on topography, soil type and presence/absence and percent foliage cover of vegetation.
Timing, weather, season, cycle.	**Moderate**	The primary survey period for flora and vegetation surveys in the Eremaean Province is 6-8 weeks post wet season, ideally between March - June (EPA 2016). A supplementary survey can be undertaken in the dry season after winter rainfall (EPA 2016). The timing of the survey was outside of the optimal timing for flora surveys in this region, and is a possible constraint.
Disturbances (fire, flood, accidental human intervention, etc.).	**Nil**	The survey area and regional surrounds have been subjected to limited disturbance and there were no natural or human interventions that constrained the survey.
Intensity (in retrospect, was the intensity adequate).	**Low**	The survey area was traversed on foot and all differences in vegetation structure were recorded appropriately. The vegetation types recorded were represented by at least three sampled quadrats per vegetation type, as recommended for a detailed survey (EPA 2016).
Resources (i.e. were there adequate resources to complete the survey to the required standard).	**Nil**	The available resources were adequate to complete the survey.

Potential limitation	Impact on assessment	Comment
Access problems (i.e. ability to access survey area).	**Moderate**	There was limited access to the survey area due to its remoteness and lack of existing access tracks. Where access was not available by car, sites were accessed by helicopter or traversed by foot.
Experience levels (e.g. degree of expertise in species identification to taxon level).	**Nil**	The survey personnel have the appropriate training in sampling and identifying the flora of the region. The survey was conducted by Botanists with 8 and 2 years' botanical experience in arid WA. Where necessary, external expertise was sought by taxonomic specialists at the WAH.