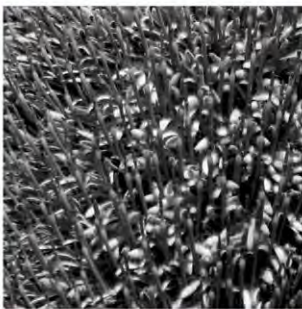
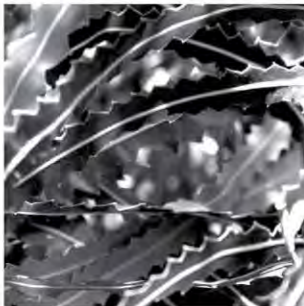




Glacier Valley Extension Flora and Vegetation Survey, North Star Project

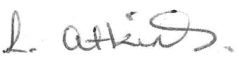



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SUMMARY

The North Star Magnetite Project is located in the Pilbara Region of Western Australia. It is being developed by an unincorporated joint venture between FMG Iron Bridge (which is a joint venture between Fortescue Metals Group [Fortescue] and Baosteel) and Formosa through an operating company known as IB Operations Pty Ltd (IBO). Fortescue is the leading partner in developing the project.

Fortescue appointed Ecoscape to conduct a detailed flora and vegetation survey of the Glacier Valley extension area, south of the North Star deposit, to build on previous data and support an environmental impact assessment. The Glacier Valley survey area occupies 4,820.37 ha within the Pilbara bioregion of Western Australia, in the Shire of East Pilbara.

The desktop assessment identified:

- a number of flora and vegetation surveys have been conducted in the nearby vicinity of the Glacier Valley survey area, but none within, with the exception of targeted conservation significant flora searches
- 47 conservation significant flora species were identified from combined database searches, including 22 that are known to occur within 40 km of the survey area. The Threatened Flora species *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp4) was known from a population within the survey area and a further 12 conservation significant flora species were considered to possibly occur within the study area based on a likelihood assessment.
- there are no TECs or PECs known within 40 km of the study area.

Ecoscape conducted a two phase detailed flora and vegetation survey of the study area during May and August 2018. The seasonal conditions were considered average prior to the phase one survey with significant rainfall during January 2018, followed by below average rainfall between February and April.

Ecoscape established 60 new floristic quadrats within the survey area during the combined 2018 surveys area plus an additional eight regional quadrats.

A total of 218 vascular flora species were identified within the survey area, including:

- three conservation significant flora species: *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp4) (TF), *Ptilotus mollis* (P4) and *Triodia basitricha* (P3)
- four introduced species (weeds): *Aerva javanica*, *Calotropis procera*, *Cenchrus ciliaris* and *Flaveria trinervia*. *Calotropis procera* is listed as a Declared Pest plant.

Eleven vegetation types, derived from a combination of structural composition and floristic analysis, were recorded. Of these, six were associated with the hills, three were associated with riparian areas (including gorges) and two were associated with valley floors or flats. The vegetation types considered of significance were:

- vegetation type **EvAtCc**, dominated by *Eucalyptus victrix*, is associated with riparian areas and potentially representative of a Groundwater Dependant Ecosystem. Additionally, an area dominated by *Eucalyptus camaldulensis* is known to occur within a restricted heritage area and is likely to represent a Groundwater Dependant Ecosystem.
- two vegetation types has small extents within the survey area of less than one percent including **CfAtEm**, (3.17 ha 0.07%) and **AeTb** (21.18 ha, 0.44%), these may be considered of local significance.

The vegetation condition ranged from Excellent to Good, with the majority (94.8%) in Excellent Condition.

1 INTRODUCTION

1.1 PROJECT BACKGROUND

The North Star Magnetite Project is located in the Pilbara Region of Western Australia. It is being developed by an unincorporated joint venture between FMG Iron Bridge (which is a joint venture between Fortescue Metals Group [Fortescue] and Baosteel) and Formosa through an operating company known as IB Operations Pty Ltd (IBO). Fortescue is the leading partner in developing the project.

The North Star Magnetite Project is being developed in stages. Stage 1, which has been completed, was a small scale pilot plant. Stage 2 is a full scale plant and will include expanded mining and processing operations. Environmental approvals have been granted for this project under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2012-6619) and Western Australian *Environmental Protection Act 1986* (Ministerial Statement 993).

The Glacier Valley ore body extension lies to the south of the North Star deposit. IBO requires a Detailed terrestrial flora and vegetation survey in the Glacier Valley extension area to build on previous data and support an environmental impact assessment.

1.2 PROJECT PURPOSE

IBO appointed Ecoscape to conduct a Detailed terrestrial flora and vegetation survey of the Glacier Valley extension area (the 'survey area'), including consolidating existing survey data from adjacent survey areas. The survey area encompasses unsurveyed area of mining tenement M45/1244 and extends southwards to survey the entire ridgeline which hosts the North Star and Glacier Valley ore bodies. A portion of the intended survey area is on exploration licence E45/4025 currently held by Wodgina Lithium Pty Ltd.

The overarching project objective is to prepare a comprehensive and consolidated flora and vegetation assessment report for the Glacier Valley survey area.

1.2.1 PROJECT SCOPE

The project scope was to:

- develop a field plan for the proposed surveys, taking into account:
 - a regional assessment in addition to tenements included in the survey area
 - optimal survey timing
 - records and distributions of species and communities from publicly available databases, Fortescue and IBO records and contractors own records, in particular those that have few records or restricted distributions
 - significance of species and communities at individual, population, local and regional scale
 - occurrences and potential occurrences of sheet-flow dependent, groundwater dependent and riparian vegetation communities
- undertake a Detailed terrestrial flora and vegetation survey comprising of:
 - an assessment of previous floristic and vegetation data
 - a desktop assessment including database and literature searches
 - a comprehensive flora inventory
 - vegetation mapping that takes into account mapping of adjacent areas to provide consolidated vegetation types and allow a regional assessment of potential impacts to vegetation
 - an assessment of significance of flora and vegetation within the survey area and compared with surrounding areas
 - a regional floristic analysis
 - a comprehensive report including desktop and field survey results, including assessments of significance at local and regional scales.

The field survey required:

- establishment of quadrats and scoring over two phases of survey
- identification and mapping of introduced species
- delineation (mapping) and vegetation type characterisation at NVIS Level V
- identification, accurate mapping and description of significant vegetation including groundwater dependent and riparian communities
- vegetation condition mapping comparable with previous assessments
- targeted searches for conservation significant flora and verification of nearby records in adjacent areas.

1.3 SURVEY AREA

The survey area occupies 4,820.37 ha within the Pilbara bioregion of Western Australia, in the Shire of East Pilbara, approximately 110 kilometres (km) south of Port Hedland (**Figure 1**).

The Glacier Valley ore body extension lies to the south of the North Star deposit. A number of environmental surveys have been conducted in the area of and surrounding the North Star Mine, and in associated infrastructure corridors, none of which correspond with the Glacier Valley survey area. The relevant flora and vegetation surveys are:

- *North Star Access Corridor Flora, Vegetation, Vertebrate Fauna and Fauna Habitat Assessment* (Ecologia Environment 2012a)
- *North Star Vegetation and Flora Assessment* (Ecologia Environment 2012b); mine area immediately adjacent to the north of the Glacier Valley survey area
- *North Star Filtration Plant Relocation Flora and Fauna Desktop Assessment* (Ecologia Environment 2014),
- *North Star Aerodrome Flora Level 2 and Fauna Level 1 Assessment* (Ecologia Environment 2015a),
- *North Star Alternate Access Road Flora and Vegetation Assessment* (Coffey Environments 2014a).

1.4 STATUTORY FRAMEWORK AND GUIDANCES

This assessment was conducted in accordance with Commonwealth and State legislation and guidelines:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- Western Australian *Wildlife Conservation Act 1950* (WC Act)
- Western Australian *Environmental Protection Act 1986* (EP Act)
- Western Australian *Biodiversity Conservation Act 2016* (BC Act), partly enacted
- Department of Environment Water Heritage and the Arts (2009) *Matters of National Environmental Significance. Significant impact guidelines 1.1 - Environment Protection and Biodiversity Conservation Act 1999*.

In addition, the Minister for the Environment has published lists of flora species in need of special protection because they are considered rare, likely to become extinct, or are presumed extinct. The current listings were published in the *Government Gazette* on 16 January 2018 (Government of Western Australia 2018c) and were taken into account.

As well as those listed above, the assessment complied with the EPA requirements for environmental survey and reporting in Western Australia, as outlined in:

- EPA (2016c) *Technical Guidance - Flora and Vegetation Surveys for Environmental Impact Assessment*, known as *Flora and Vegetation Technical Guidance*
- EPA (2016b) *Statement of Environmental Principles, Factors and Objectives*.

Fortescue's internal management Guidelines and Procedures were also complied with, primarily *Flora and Vegetation Assessment Guidelines* (100-GU-EN-0005) (Fortescue 2014).

1.4.1 WESTERN AUSTRALIAN BIODIVERSITY CONSERVATION ACT 2016

The Western Australian *Biodiversity Conservation Act 2016* (BC Act, the Act), parts of which were enacted on 21 September 2016, provides for the conservation, protection and ecologically sustainable use of biodiversity and biodiversity components in Western Australia. The BC Act replaces the *Wildlife Conservation Act 1950*. The parts of the BC Act currently in effect are listed on the DBCA website (DBCAs 2017, accessed 17 September 2017).

Threatened species (both flora and fauna) that meet the categories listed within the Act are highly protected and require authorisation by the Ministerial to take or disturb. These are known as Threatened Flora and Threatened Fauna. The conservation categories of critically endangered, endangered and vulnerable have been aligned with those detailed in the EPBC Act, as below.

Flora and fauna species may be listed as being of special conservation interest if they have a naturally low population, restricted natural range, are subject to or recovering from a significant population decline or reduction of range or are of special interest, and the Minister considers that taking may result in depletion of the species. Migratory species and those subject to international agreement are also listed under the Act. These are known as specially protected species in the Act.

Threatened Ecological Communities are also protected under the Act and are categorised using the same criteria as threatened species.

At the time of writing this report, only some sections of the BC Act have been enacted, with the remaining sections yet to be proclaimed including those relating to penalties for breaches of the Act's provisions. As species of conservation interest (Specially Protected Species) and Threatened Ecological Communities are not included in the WC Act, there is currently no specific legal protection afforded to these within Western Australia beyond the usual protection of unlisted species and native vegetation under the Native Vegetation Clearing Regulations (Government of Western Australia 2004), unless they are protected under the Commonwealth EPBC Act.

1.4.2 WESTERN AUSTRALIAN ENVIRONMENTAL PROTECTION ACT 1986

The Western Australian *Environmental Protection Act 1986* was created to provide for an Environmental Protection Authority (the EPA) that has the responsibility for:

- prevention, control and abatement of pollution and environmental harm
- conservation, preservation, protection, enhancement and management of the environment
- matters incidental to or connected with the above.

The EPA is responsible for providing the guidance and policy under which environmental assessments are conducted. It conducts environmental impact assessments (based on the information included in environmental assessments and provided by the proponent), initiates measures to protect the environment and provides advice to the Minister responsible for environmental matters.

1.4.3 COMMONWEALTH ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

At a Commonwealth level, Threatened taxa are protected under the EPBC Act, which lists species and ecological communities that are considered Critically Endangered, Endangered, Vulnerable, Conservation Dependent, Extinct, or Extinct in the Wild (detailed in **Table 14** in **Appendix One**).

1.4.4 FLORA

1.4.4.1 Threatened and Priority Flora

Conservation significant flora species are those that are listed as TF (Threatened Flora) and (within Western Australia) as PF (Priority Flora). TF species are listed as threatened by the Western Australian DBCA, formerly known as DPaW, and protected under the provisions of the BC Act. Some State-listed TF are provided with additional protection as they are also listed under the Commonwealth EPBC Act.

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 these have a greater level of protection than unlisted species.

There are seven categories covering State-listed TF and PF species (DPaW 2017) which are outlined in **Table 15** in **Appendix One**. PF for Western Australia are regularly reviewed by DBCA whenever new information becomes available, with species status altered or removed from the list when data indicates that they no longer meet the requirements outlined in **Table 15**.

1.4.4.2 Other Significant Flora

According to the *Flora and Vegetation Technical Guidance* (EPA 2016c) other than being listed as Threatened or Priority Flora, a species can be considered as significant if it is considered to be:

- locally endemic or association with a restricted habitat type (e.g. GDEs or SFDV as above)
- a new species or has anomalous features that indicate a potential new species
- at the extremes of range, recently discovered range extensions (generally considered greater than 100 km or in a different bioregion), or isolated outliers of the main range)
- unusual species, including restricted subspecies, varieties or naturally occurring hybrids
- relictual status, being representative of taxonomic groups that no longer occur widely in the broader landscape.

1.4.4.3 Introduced Flora

Introduced plant species, known as weeds, are plants that are not indigenous to an area and have been introduced either directly or indirectly (unintentionally) through human activity. Species are regarded as introduced if they are listed as 'alien' on *FloraBase* (Western Australian Herbarium [WAH] 1998b-2017).

Weeds of National Significance (WONS)

At a national level there are thirty-two weed species listed as Weeds of National Significance (WONS) (Weeds Australia 2012). The Commonwealth *National Weeds Strategy: A Strategic Approach to Weed Problems of National Significance* (2012) describes broad goals and objectives to manage these species.

Declared Pest Plants

The Western Australian Organism List (WAOL) details organisms listed as Declared Pests under the *Biosecurity and Agriculture Management Act 2007* (BAM Act). Under the BAM Act, Declared Pests are listed as one of the three categories, or exempt:

- C1 (exclusion), that applies to pests not established in Western Australia; control measures are to be taken to prevent their entry and establishment
- C2 (eradication), that applies to pests that are present in Western Australia but in low numbers or in limited areas where eradication is still a possibility
- C3 (management), that applies to established pests where it is not feasible or desirable to manage them in order to limit their damage
- exempt (no category).

1.4.5 ECOLOGICAL COMMUNITIES AND VEGETATION

1.4.5.1 Threatened and Priority Ecological Communities

Nationally Listed Threatened Ecological Communities

Ecological communities are naturally occurring biological assemblages associated with a particular type of habitat (Department of Environment and Conservation 2010; Government of Western Australia 2016). At Commonwealth level, Threatened Flora and Threatened Ecological Communities (TECs) are protected under the Commonwealth EPBC Act. An ecological community may be categorised into one of the three sub-categories:

- Critically Endangered, if it is facing an extremely high risk of extinction in the wild in the immediate future.
- Endangered, if it is not critically endangered and is facing a very high risk of extinction in the wild in the near future.
- Vulnerable, if it is not critically endangered or endangered, and is facing a high risk of extinction in the wild in the medium-term future.

State Listed Threatened Ecological Communities

The Western Australian DBCA also maintains a list of TECs which are further categorised into three subcategories much like those of the EPBC Act. The full details of DBCA criteria are shown in **Table 16** in **Appendix One**.

State Listed Priority Ecological Communities

DBCA maintains a list of Priority Ecological Communities (PECs). PECs include potential TECs that do not meet survey criteria, or that are not adequately defined.

1.4.5.2 Other Significant Vegetation

Groundwater Dependent Ecosystems

Groundwater Definition

Groundwater is water that is found in the saturated zone of the soil, where all soil pores are filled with water. The water table is the upper surface of the saturated zone in an unconfined aquifer. Groundwater may also occur as a perched aquifer located above unsaturated rock formations as a result of a discontinuous permeable layer or held under pressure in a confined aquifer (Goulburn-Murray Water 2010).

Groundwater Dependent Ecosystems Definition

Groundwater Dependent Ecosystems (GDEs) have been defined as ecosystems that are dependent on groundwater for their survival at some stage or stages of their lifecycle, however groundwater use cannot be equated with groundwater dependence (Eamus 2009b). In some contexts, GDEs are also known as Groundwater Dependent Vegetation.

Hatton and Evans (1998) identified four types of GDEs based on their geographic setting: terrestrial vegetation (vegetation communities and dependent fauna that have seasonal or episodic dependence on groundwater), river base flow systems (aquatic and riparian ecosystems that exist in or adjacent to streams that are fed by groundwater base flow), aquifer and cave ecosystems, and wetlands.

Eamus *et al.* (2006) identified three primary classes based on type of groundwater reliance:

1. Aquifer and cave ecosystems.
2. All ecosystems dependent on the surface expression of groundwater:
 - a) river base flows
 - b) wetlands, swamplands
 - c) seagrass beds in estuaries
 - d) floodplains
 - e) mound springs
 - f) riparian vegetation
 - g) saline discharge to lakes
 - h) low lying forests.
3. All ecosystems dependent on the subsurface presence of groundwater, often accessed via the capillary fringe (non-saturated zone above the water table) when roots penetrate this zone:
 - a) River Red Gum (*Eucalyptus camaldulensis*) forests
 - b) Banksia woodlands
 - c) Riparian vegetation in the wet/dry tropics.

GDEs in the Pilbara are generally determined to be vegetation associated with riparian areas. GDEs dependent on the surface expression of groundwater (Eamus *et al.* 2006 class 2) includes vegetation associated with wetlands (permanent or semi-permanent pools) within riparian areas, and generally includes *Melaleuca argentea* in association with other species described below. GDEs associated with the subsurface presence of groundwater (Eamus *et al.* 2006 class 3) includes riparian vegetation characterised by the phreatophytic species described below.

Direct impacts on GDEs i.e. clearing, and indirect impacts, including from dewatering and reinjection, frequently feature as being a significant environmental impact in mining approvals documents e.g. (Office of the Appeals Convenor 2016a; 2016b; Rio Tinto 2016).

Phreatophytic Species

Phreatophytic species (phreatophytes) rely on groundwater sources for water intake (Maunsell Australia Pty Ltd 2006); essentially the water requirements of phreatophytes are greater than can be provided from the surface soil profile (e.g. riparian vegetation) or they are dependent on free water availability (e.g. wetland species). They frequently show low tolerance to extended water stress due to a lack of physiological and/or morphological adaptation to drought, and respond to significant water deficit by a decline in health and eventual death (*ibid.*).

The EPA defines phreatophytes as species that utilise groundwater (EPA 2018).

Obligate phreatophytes are dependent on free access to water (i.e. they are wetland species) whereas facultative phreatophytes can switch their water source between the soil surface profile in times of rain, to groundwater in times of drought when the soil surface profile (vadosphere) is depleted (Grierson 2010).

Phreatophytes likely to occur in the survey area include:

- *Eucalyptus camaldulensis* subsp. *refulgens*, which is regarded as a facultative phreatophyte that is dependent on groundwater for part of its lifecycle and/or in times of drought. This species has been reported to be tolerant of groundwater falls of up to 4 m per year (Maunsell Australia Pty Ltd 2006), has both lateral and sinker roots and is tolerant of waterlogging (Grierson 2010).
- *Eucalyptus victrix*, which may be regarded as a facultative phreatophyte. It is considered to be relatively drought tolerant and likely to be tolerant of gradual declines to the water table (to a degree) (Maunsell Australia Pty Ltd 2006). *Eucalyptus victrix* has lateral and sinker roots (i.e. a dimorphic root system) but is not tolerant of waterlogging (Grierson 2010). There is some conjecture that this species is actually a vadophyte (i.e. relies on water from within the soil surface profile, and is independent of groundwater; Equinox Environmental 2017) or, at best, weakly phreatophytic (Resource and Environmental Management Pty Ltd 2007). Depth to groundwater is likely to be an important indicator of groundwater dependence (Equinox Environmental 2017).
- wetland species such as *Melaleuca argentea*, which is an obligate phreatophyte (EPA 2018).

Vegetation containing *Eucalyptus camaldulensis* subsp. *refulgens* and *Melaleuca argentea* is generally considered to represent a GDE.

Vegetation characterised by *Eucalyptus victrix* is considered to potentially represent a GDE as there is supporting evidence that, in some circumstances, this species does not always depend on groundwater (Batini 2009; Eamus 2009a; EPA & Hamersley Iron Pty Ltd 2010; Equinox Environmental 2017; Resource and Environmental Management Pty Ltd 2007).

Atlas of Groundwater Dependent Ecosystems

The *Groundwater Dependent Ecosystems Atlas* (Australian Government & BoM 2018) indicates the presence of known GDEs and Inflow Dependent Ecosystems (IDEs) in Australia.

An Inflow Dependent Ecosystem is one in which the vegetation within the landscape is likely to be accessing water in addition to rainfall, from soil or surface water or groundwater, assessed using remotely sensed data. The likelihood of a landscape using additional water is rated from one to 10 (low to high), with a rating above six indicating that a landscape is likely to be inflow dependent (Australian Government & BoM 2018).

Other Significant Vegetation

According to the *Flora and Vegetation Technical Guidance* (EPA 2016c), other than being listed as a TEC or PEC, vegetation can be considered as significant if it is considered to have:

- restricted distribution
- a degree of historical impact from threatening processes
- a role as a refuge
- provides an important function required to maintain ecological integrity of a significant ecosystem.

1.4.6 ENVIRONMENTALLY SENSITIVE AREAS

There are a number of areas around Western Australia identified as being of environmental significance within which the exemptions to the Native Clearing Regulations do not apply. These are referred to as Environmentally Sensitive Areas (ESAs), and are declared under section 51B of the EP Act and described in the Environmental Protection (Environmentally Sensitive Areas) Notice (Government of Western Australia 2005).

1.4.7 CONSERVATION ESTATE

The National Reserve System is a network of protected areas managed for conservation under international guidelines. The objective of placing areas of bushland into the Conservation Estate is to achieve and maintain a comprehensive, adequate and representative reserve system for Western Australia. The Conservation and Parks Commission is the vesting body for conservation lands, forest and marine reserves that are managed by DBCA (Government of Western Australia 2018b).

2 DESKTOP ASSESSMENT (EXISTING ENVIRONMENT)

2.1 PHYSICAL ENVIRONMENT

2.1.1 CLIMATE

The survey area is located within the Pilbara region, 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. The remaining 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). The survey area is within the dry inland area.

Monthly maximum temperatures range from an average of 25°C in July to 37°C in January, while minimum temperatures are experienced in these same months, with an average of 12°C in July and 25°C in January (McKenzie *et al.* 2009). December and January are the hottest months in inland areas, while coastal areas often experience their highest temperatures later in February or March due to the dampening effect of the ocean (Leighton 2004).

Annual rainfall in the Pilbara has substantial yearly variation, but generally follows an inland to coastal and southern to northern increasing trend (Leighton 2004). 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) (McKenzie *et al.* 2009), and winter rainfall is highly variable, generally decreasing from the coast through to inland areas (Leighton 2004).

According to the Köppen-Geiger climate classification, the survey area has a hot desert climate (Class BWh) (Peel *et al.* 2007). This classification includes arid regions where annual evaporation exceeds annual precipitation, and with a mean annual temperature $\geq 18^{\circ}\text{C}$.

Figure 2 outlines the monthly rainfall and temperature averages for the Marble Bar Bureau of Meteorology (BoM) station, located approximately 75 km east of the survey area, derived from data collected from 2000 onwards and figures for the year including and prior to the field surveys (BoM 2018a, accessed 19 June 2018).

On average, Marble Bar has 392.3 mm of rainfall, over 75% of which falls over summer (December to March period). Rainfall is variable over the years, with higher rainfall associated with cyclones (December to April) and occasional southern winter cold front events e.g. June 2013 when 202 mm of rain was recorded (BoM 2018a, accessed 19 June 2018).

Marble Bar is considered to be one of the hottest towns in Australia, with a mean December temperature of 41.8° C and an annual average of 35.6° C. The coldest month is July with an average minimum of 12.2° C and an annual average minimum of 20.9° C (BoM 2018a, accessed 19 June 2018).

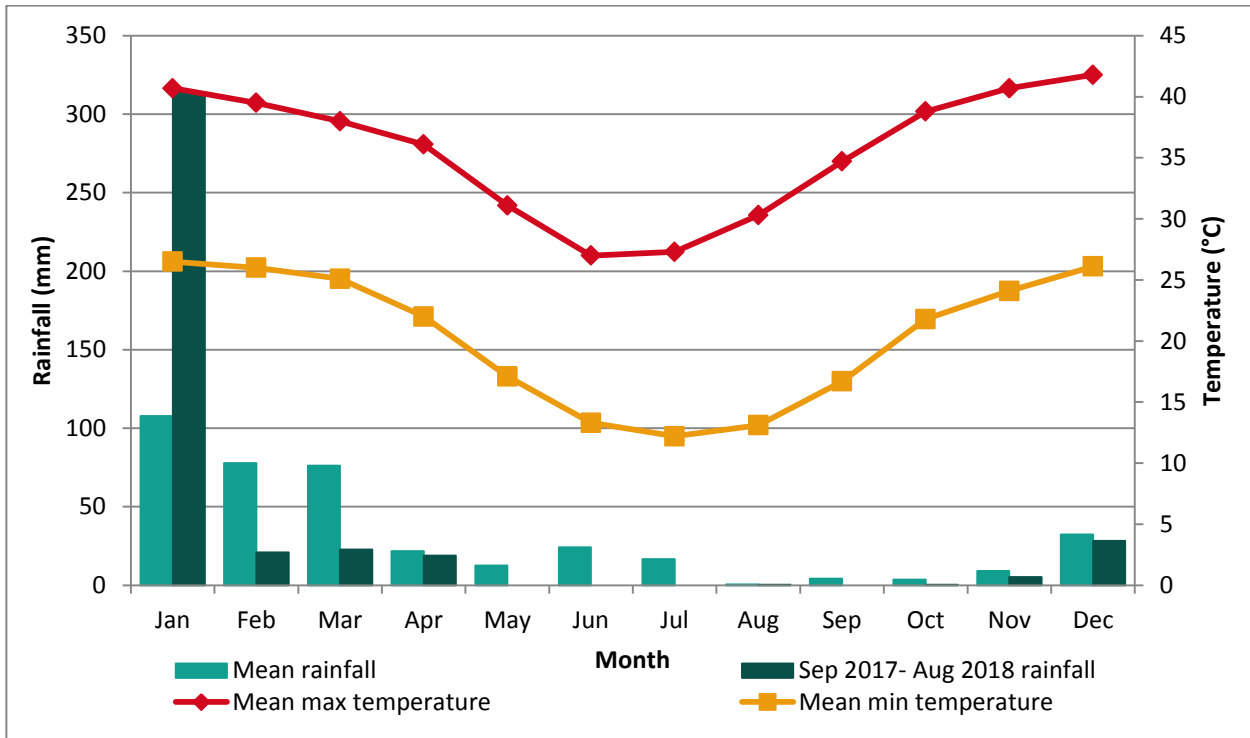


Figure 2: Rainfall and temperature data for Marble Bar BoM station (2018a)

2.1.2 LAND SYSTEMS

As part of the rangeland resource surveys, the then-Department of Agriculture comprehensively described and mapped the biophysical resources of the Pilbara together with an evaluation of the condition of the soils and vegetation (from an agricultural perspective) throughout (Van Vreeswyk *et al.* 2004). As part of this process an inventory of land types, land systems and land units with particular use capabilities, habitats or conservation values were established to assist in land use planning. The land systems occurring within the survey area are listed in **Table 1** and shown on **Map 1**.

Table 1: Land Systems of the Pilbara occurring within the survey area (Van Vreeswyk *et al.* 2004)

Land system	Description	Extent (ha)	Proportion (%)
Capricorn	Rugged sandstone hills, ridges, stony footslopes and interfluves supporting low acacia shrublands or hard spinifex grasslands with scattered shrubs.	1486	30.9
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex and occasionally soft spinifex grasslands with scattered shrubs.	1521	31.6
Talga	Hills and ridges of greenstone and chert and stony plains supporting hard and soft spinifex grasslands.	1808	37.5

2.1.3 GEOLOGY

Regional geological mapping covering the survey area is associated with the Marble Bar map sheet (SF50-08) of the 1:250,000 Geological Series of Western Australia (Hickman 2010). Seven geological units intersect the survey area as outlined in **Table 2**.

Table 2: Geological units that intersect the survey area (according to Hickman 2010)

Code	Unit Name	Description	Extent (ha)	Prop. (%)
A-CEst-gm	Strelley Monzogranite	Hornblende?biotite monzogranite, granophyric monzogranite, and subvolcanic granitoid intrusions; metamorphosed	277	5.8%
A-DA-xo-a	Dalton Suite	Mafic and ultramafic intrusive rocks; metamorphosed	1217	25.3%
A-SScp-ci	Pincunah Banded-Iron Member	Banded iron-formation; jaspilitic; minor layered chert and shale; metamorphosed	413	8.6%
A-SSc-xf-s	Kangaroo Caves Formation	Felsic and mafic volcanic rocks, and siliciclastic sedimentary rocks; metamorphosed	882	18.3%
A-SSk-b	Kunagunarrina Formation	Basaltic volcanic rocks, with minor komatiite, siliciclastic sedimentary rocks, and chert; metamorphosed	733	15.2%
A-SSI-s	Leilira Formation	Siliciclastic sedimentary rocks, minor felsic volcanic rocks, and chert; metamorphosed	1109	23.0%
A-SS-od	Sulphur Springs Group	Dolerite; metamorphosed	183	3.8%

2.1.4 WATERWAYS, HYDROLOGY AND WETLANDS

There are no significant waterways associated with the survey area which is located at the watershed of the Turner River, within the Port Hedland Coast river region (on the western side of the survey area) and De Grey River river region on the eastern side of the catchment (*Groundwater Dependent Ecosystems Atlas*, Australian Government & BoM 2018).

Both rivers flow in a general northwards direction before entering the ocean west of Port Hedland (Turner River) and northeast of Port Hedland (De Grey River).

There are no wetlands associated with the survey area.

2.1.5 CONSERVATION ESTATE

The survey area is not associated with any lands vested for conservation. There are no conservation lands within 50 km of the survey area.

2.1.6 RESTRICTED FEATURES

Restricted geological features, soil types and hydrology are poorly defined in the *Flora and Vegetation Technical Guidance* (EPA 2016c), however, the *Guidance* states they should be targeted for survey.

2.2 BIOLOGICAL ENVIRONMENT

2.2.1 BIOREGION

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) (Australian Government & DotEE 2017).

The survey area is located entirely within the Chichester subregion of the wider Pilbara biogeographic region (includes four subregions; Chichester, Fortescue Plains, Hamersley and Roebourne) described in the *2002 Biodiversity Audit of Western Australia's 53 Biogeographical Subregions* (McKenzie *et al.* 2003) as:

Chichester (PIL1, Kendrick & McKenzie 2002)

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 9,044,560 ha.

2.2.2 REGIONAL 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 1:250,000 in the south-west and at a scale of 1:1 000,000 in less developed areas. The vegetation survey of Western Australia maps and explanatory memoirs (1974-1981) are credited to J.S. Beard (or Beard with various co-authors).

Beard's vegetation maps attempt 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. They have since been developed in digital form by Shepherd *et al.* (2002), and updated by the Department of Agriculture and Food Western Australia (Department of Agriculture and Food Western Australia [DAFWA] 2012).

The survey area is mapped as occurring within one pre-European vegetation association: 82 (**Map 2**), described as Hummock grasslands, low tree steppe; snappy gum over *Triodia wiseana*. Vegetation association 82 has a pre-European extent of 2,565,901 ha (DAFWA 2012), of which 99.51% remains (Government of Western Australia 2018a). The total extent of the Pilbara bioregion is 17,823,125.84 ha.

2.2.3 SIGNIFICANT VEGETATION

2.2.3.1 Threatened and Priority Ecological Communities

No TECs or PECs are known from near the survey area (Australian Government & DotEE 2018, 40 km buffer applied to approximate survey area; DPaW 2007-2018).

2.2.3.2 Groundwater Dependent Ecosystems

According to the *Groundwater Dependent Ecosystems Atlas*, the survey area includes areas mapped as being low and moderate potential terrestrial GDE (national assessment) and contains small pools mapped as being unclassified potential aquatic GDE (regional study) (Australian Government & BoM 2018).

The survey area is, for the most part, mapped as having an IDE likelihood of 7, which is considered moderate and is more likely than not to be an IDE (Australian Government & BoM 2018).

2.2.3.3 Significant Vegetation Identified During Previous Surveys

Significant vegetation types from within the North Star area and nearby, and the documents within which they were identified, are described below.

Ecologia Environment (2015b), in *North Star Slurry and Infrastructure Corridors Conservation Significant Flora and Vegetation Assessment*, identified three vegetation types that were significant as they represented GDEs: GDE1 (+/- *Eucalyptus camaldulensis* isolated low trees to sparse low woodland, over *Melaleuca argentea* open low woodland (+/- *Melaleuca glomerata*), over sparse **Cenchrus ciliaris* tussock grassland and *Triodia epactia* hummock grassland), GDE2 (*Eucalyptus camaldulensis* and *Eucalyptus victrix* low woodland, over *Acacia trachycarpa* and *Melaleuca glomerata* tall open shrubland, over **Cenchrus ciliaris* open tussock grassland and *Triodia epactia* open hummock grassland) and GDE3 (*Melaleuca argentea* open low woodland, over *Acacia trachycarpa* open tall shrubland, over *Triodia epactia* hummock grassland).

Woodman Environmental Consulting (2013), in *Abydos Direct Shipping Ore Project Stage 2 Flora and Vegetation Impact Assessment*, identified a gorge with groundwater dependent tree species (*Melaleuca argentea* and *Eucalyptus camaldulensis*) as being significant but did not identify a specific vegetation unit within it.

Ecologia Environment (2012a), in *North Star Access Corridor Flora, Vegetation, Vertebrate Fauna and Fauna Habitat Assessment*, identified two vegetation units as being significant:

- GwTb (*Grevillea wickhamii* and *Corchorus parviflorus* sparse shrubland, over *Triodia basedowii* open hummock grassland) as locally significant as it provided habitat for a species that was a significant range extension (*Eriachne melicacea*)
- MaCb, (*Melaleuca argentea* open low woodland, over *Acacia tumida* var. *pilbarensis* mid shrubland, over *Cyperus blakeanus* open sedgeland) considered to be a GDE.

Ecologia Environment (2012b), in *North Star Vegetation and Flora Assessment*, identified a number of vegetation units that were considered to be of significance including:

- four vegetation units that correlated with a now TF-listed species (*Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp4)) that meet the requirements to be significant as a key habitat for threatened species, particularly vegetation unit AaTw4 (*Acacia acradenia* and *Acacia inaequilatera* sparse mid shrubland over *Triodia wiseana* and *Triodia lanigera* hummock grassland) and also units SpTI (*Solanum phlomoides* isolated low shrubs, over *Triodia lanigera* open hummock grassland), TI (*Triodia lanigera* open hummock grassland) and GwTe (*Grevillea wickhamii* sparse mid shrubland over *Triodia epactia* or *Triodia schinzii* open hummock grassland)
- locally significant vegetation units GaTw (*Gossypium australe* sparse mid shrubland over *Triodia wiseana* open hummock grassland) associated with basalt dykes and FpAtCo (*Ficus platypoda* open woodland over *Acacia tumida* and *Gossypium robinsonii* sparse tall shrubland over *Cymbopogon obtectus* and *Eriachne mucronata* sparse tussock grassland) associated with escarpment springs; both were poorly represented and restricted to particular habitats.

Coffey Environments (2007), in the report titled *Supplementary Vegetation and Flora Survey of the Port Hedland to Cloudbreak Rail Corridor and Associated Borrow Pits and Infrastructure*, identified vegetation type ChaW2 (*Corymbia hamersleyana* Low Open Woodland over Mixed Open to Mid Dense Hummock Grassland) as being of “very high conservation significance” and “considered poorly represented in the Pilbara bioregion”, however, the report also stated that it was recorded from “numerous locations and habitats in the central Abydos Plain”.

2.2.4 SIGNIFICANT FLORA

2.2.4.1 Database Searches

A search of the Western Australian DBCA databases (search reference 11-0518FL, survey area supplied as a shapefile) and *NatureMap* (DPaW 2007-2018, accessed 2 May 2018) was undertaken for Western Australian-listed TF and PF within a 40 km radius of the survey area.

Combined, these searches identified 47 conservation significant vascular flora species. One is TF (*Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4)), 15 are listed as P1, 6 are P2, 20 are P3, and 5 are P4 (**Table 20** and **Table 21** in **Appendix Two**). Previously recorded locations are shown on **Map 3**.

Table 20 and **Table 21** list all identified TF and PF vascular flora and their habitats, as well as their likelihood of occurrence. The likelihood of a species occurring in the survey area is based on the following attributes, as listed on *FloraBase* (WAH 1998b-2017; 2017), tailored to Pilbara populations, *Rare and Priority Plants of the Pilbara mobile app edition* (Rio Tinto & DPaW 2015) and including information from recent nearby surveys.

The attributes were:

- broad soil type usually associated with the species
- broad landform usually associated with the species
- usual vegetation (characteristic species) with which the species is usually associated

- species having previously been recorded from within approximately 40 km of the survey area (considered as 'nearby').

The likelihood rating is assigned using the following categories:

- Recorded
- Possible: it may occur within the survey area (but was not recorded); broadly, 2-4 of the required attributes (but always including records from nearby) are present in the survey area
- Unlikely: it could occur but is not expected; 1-3 of the required attributes are present in the survey area but:
 - it is not known from nearby, or
 - it is known from nearby but has no other required attributes, or
 - it is known from nearby but has at least one well-defined attribute that does not occur in the survey area (e.g. it is associated with a specific landform or soil type that does not occur in the survey area)
- Highly Unlikely: the species characteristics include none of the required attributes of soil, landform, associated vegetation and having previously been recorded nearby, or a critical element (often landform) is not within the survey area and as such it almost certainly does not occur within the survey area.

Except for targeted searches for *Pityrodia* sp. Marble Bar (that has been recorded within the survey area), there are no previous botanical surveys that are known to have been conducted within the survey area.

The likelihood assessment, conducted prior to any field surveys using broad information (e.g. land systems, landforms, soils, likely vegetation types and including surveyor familiarity with the general area), identified 12 species as having a 'possible' occurrence within the survey area.

2.2.4.2 Fortescue Database

Fortescue maintains a database of conservation significant flora and other flora of conservation interest associated with its operational and exploration tenements. This database consists of DBCA database search results requested for flora and vegetation assessments and the results of field surveys it has commissioned. The resultant list, and associated location data, provides a comprehensive understanding of the conservation significant flora and other flora of conservation interest (e.g. significant range extensions, unusual forms) within and close to Fortescue's areas of interest. Fortescue's significant flora records for the survey area and surrounds are provided in **Table 3**. Of these only *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) occurs within the survey area (highlighted).

Table 3: Significant flora listed on the Fortescue database (species within survey area highlighted)

Family	Species	EPBC status	DBCA status
Malvaceae	<i>Abutilon</i> sp. Pritzelianum (S. van Leeuwen 5095)	None	Priority 1
Fabaceae	<i>Acacia glaucocaesia</i>	None	Priority 3
Cyperaceae	<i>Bulbostylis burbridgeae</i>	None	Priority 4
Euphorbiaceae	<i>Euphorbia clementii</i>	None	Priority 2
Amaranthaceae	<i>Gomphrena leptophylla</i>	None	Priority 3
Goodeniaceae	<i>Goodenia nuda</i>	None	Priority 4
Apocynaceae	<i>Gymnanthera cunninghamii</i>	None	Priority 3
Boraginaceae	<i>Heliotropium muticum</i>	None	Priority 3
Solanaceae	<i>Nicotiana umbratica</i>	None	Priority 3
Phyllanthaceae	<i>Phyllanthus hebecarpus</i>	None	Priority 3
Lamiaceae	<i>Pityrodia</i> sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4)	Endangered	Schedule 2 (WC Act) - Endangered
Amaranthaceae	<i>Ptilotus mollis</i>	None	Priority 4

2.2.4.3 Previous Surveys

Significant flora other than species listed as TF and PF were identified during previous surveys of the tenement and nearby. Flora species considered significant, as identified during the literature review, were:

- *Eriachne melicacea*, considered a significant range extension: identified from the North Star access road (Ecologia Environment 2012a)
- *Sida macropoda*, considered to have a disjunct population with the main population approximately 700 km distant in the Kimberley region: locally common near Goldsworthy (Onshore Environmental Consultants 2013)
- *Stemodia* sp. Shay Gap (B. Cook 7) is undescribed but locally common in the Goldsworthy area (Onshore Environmental Consultants 2013).

2.3 LITERATURE REVIEW

The following documents have been reviewed for relevance to the current investigation:

- Woodman Environmental Consulting (2017), *Corunna Downs Intersection Works Flora and Vegetation Assessment*, prepared for Atlas Iron Ltd
- Ecologia Environment (2016), *Iron Bridge North Star Stage 2 Pityrodia sp. Marble Bar Regional Survey 2015*, unpublished report for FMG Iron Bridge (Aust) Pty Ltd
- Ecologia Environment (2015b), *North Star Slurry and Infrastructure Corridors Conservation Significant Flora and Vegetation Assessment*, unpublished report for Iron Bridge and Fortescue Metals Group
- Ecologia Environment (2015a), *North Star Aerodrome Flora Level 2 and Fauna Level 1 Assessment*, unpublished report for Iron Bridge and Fortescue Metals Group
- Ecologia Environment (2014), *North Star Filtration Plant Relocation Flora and Fauna Desktop Assessment*, unpublished report for Fortescue Metals Group
- Coffey Environments (2014b) *Significant Species Management Plan Abydos DSO Project*, unpublished report for Atlas Iron Limited
- Coffey Environments (2014a), *North Star Alternate Access Road Flora and Vegetation Assessment*, unpublished report for Fortescue Metals Group
- Onshore Environmental Consultants (2013), *Flora and vegetation survey and fauna assessment: Cundaline Northern Ridge*, report for BHP Billiton Iron Ore Pty Ltd
- Woodman Environmental Consulting (2013), *Abydos Direct Shipping Ore Project Stage 2 Flora and Vegetation Impact Assessment*, unpublished report for Atlas Iron Limited

- Ecologia Environment (2012a), *North Star Access Corridor Flora, Vegetation, Vertebrate Fauna and Fauna Habitat Assessment*, unpublished report for Fortescue Metals Group Ltd
- Ecologia Environment (2012b), *North Star Vegetation and Flora Assessment*, unpublished report for Fortescue Metals Group Ltd
- Ecologia Environment (2012c), *Pityrodia sp. Marble Bar Targeted Flora Survey*, unpublished report for Fortescue Metals Group Ltd
- Woodman Environmental Consulting (2011), *Mount Dove Direct Shipping Ore Project Flora and Vegetation Studies*, unpublished report for Atlas Iron Limited
- Matiske Consulting Pty Ltd (2010a), *Assessment of flora and vegetation on the Airstrip Expansion Area*, prepared for Millenium Minerals Limited
- Matiske Consulting Pty Ltd (2010b), *Assessment of flora and vegetation on the All Nations Lease Area*, prepared for Millenium Minerals Limited
- Matiske Consulting Pty Ltd (2010c), *Assessment of flora and vegetation on the Barton Lease Area*, prepared for Millenium Minerals Limited
- Matiske Consulting Pty Ltd (2010d), *Assessment of flora and vegetation on the Golden Gate and associated Lease Areas*, prepared for Millenium Minerals Limited
- Matiske Consulting Pty Ltd (2010e), *Assessment of flora and vegetation on the Little Wonder Lease Area*, prepared for Millenium Minerals Limited
- Matiske Consulting Pty Ltd (2010f), *Assessment of flora and vegetation on the Otways Lease Area*, prepared for Millenium Minerals Limited
- Matiske Consulting Pty Ltd (2010g), *Assessment of flora and vegetation on the Shearers Lease Area*, prepared for Millenium Minerals Limited
- Coffey Environments (2007), *Supplementary Vegetation and Flora Survey of the Port Hedland to Cloudbreak Rail Corridor and Associated Borrow Pits and Infrastructure*, prepared for Fortescue Metals Group Ltd, August 2007, Report No. 2007/186: Version 1
- Tinley, K.L. (1991). *Ecological Survey of Abydos-Woodstock Reserve, Pilbara Region, Western Australia: vegetation, habitats and biogeographic context*. Records of the Western Australian Museum Supplement No. 37, pp. 30-77.

3 METHODS

3.1 DETAILED FLORA AND VEGETATION SURVEY

The assessment was conducted as a detailed flora and vegetation survey, incorporating desktop study and targeted survey, as described in the *Flora and Vegetation Technical Guidance* (EPA 2016c).

According to the *Flora and Vegetation Technical Guidance*:

- the purpose of the desktop study (referred to as 'Existing Environment' in this report) is to gather contextual information on the survey area. It should incorporate literature reviews (including previous surveys), database searches and spatial information. One of the aims of the desktop study is to identify flora and vegetation of conservation and other significance, and associated habitat, that may occur in the survey area.
- the purpose of the detailed survey (i.e. the field survey component) is to provide adequate local and regional context relative to the values of flora and vegetation of the survey and adequately address the EPA's objectives. The survey requires comprehensive survey design, including optimal survey timing, and may require multiple sampling events. Multiple quadrats are required throughout each preliminary vegetation type, with three quadrats recorded from each vegetation type. Field survey techniques can include a combination of quadrats, relevés (although not as a primary sampling technique), transects, traverses and opportunistic surveys.
- the purpose of the targeted survey component is to gather comprehensive information on significant flora and/or vegetation, and includes systematic searches of all potentially suitable habitat.

3.1.1 FLORA AND VEGETATION FIELD SURVEY

The field survey was conducted as a two phase detailed flora and vegetation survey. Two personnel undertook each survey with the primary (phase one) survey conducted by Jared Nelson (flora collecting permit SL012269) and Andrew Fry (SL012267) during 7-17 May 2018. The supplementary (phase two) survey was conducted by Stephen Kern (SL012270, DRF permit 76-1718) and Daniel Roberts (SL012273) during 8-14 August 2018.

Following the requirements of the *Flora and Vegetation Technical Guidance* (EPA 2016c), the field survey was conducted by sampling using unmarked quadrats and relevés (as described below). Quadrats were located in representative vegetation of Good and better condition, and sampled vegetation over an area of 2,500 m² (generally 50 m x 50 m). Relevés, which are unmeasured areas the equivalent of quadrats, were recorded in areas of lesser condition vegetation.

According to the *Flora and Vegetation Technical Guidance* (EPA 2016c), a Detailed flora and vegetation survey requires a minimum of three quadrats per mapped vegetation type.

Opportunistic observations were conducted to contribute to a complete species inventory. The survey also included searches for conservation significant flora.

On ground observations, supported by aerial photography, were used to describe the vegetation of the survey area.

3.1.2 FIELD SURVEY TIMING

The field surveys were conducted during May and August, 2018. This corresponds with the recommended timing, as described in the *Flora and Vegetation Technical Guidance* (EPA 2016c), of vegetation surveys in the Eremaean province having the primary survey 6-8 weeks post wet season (March-June) and the supplementary survey during the dry season following winter rains if available.

Floristic Quadrats

Floristic quadrat ('quadrat') locations were selected using aerial photography, environmental values and field observations to represent the vegetation values existing at the site. The quadrats sampled were 50 m x 50 m in size, or equivalent area in linear habitats, and were not permanently marked.

The following information was collected from within each quadrat sampled:

- co-ordinates of the site, recorded in GDA 94 datum to an accuracy usually within 5 m for all four corners (or either end in the case of linear vegetation types)
- photograph to adequately represent the vegetation present, typically from the northwest corner facing southeast except for linear vegetation types
- identification of surveyors
- date
- unique site number
- soil type, colour and rocky substrate
- landform (habitat)
- percentage leaf litter and estimated depth
- percentage bare ground
- estimated fire age (unless known)
- vegetation condition (assessed against the scale included in the *Flora and Vegetation Technical Guidance*) and seasonal conditions
- evidence of disturbance including grazing, human disturbance, weed invasion, frequent fire
- vegetation description based on height and estimated cover of dominant and characteristic species at NVIS Level V
- flora inventory including average height and estimated cover of all vascular flora species within the quadrat.

Vegetation Description and Classification

Vegetation was described from each of the quadrats using the height and estimated cover of dominant and characteristic species of each stratum based on the National Vegetation Information System (NVIS; Executive Steering Committee for Australian Vegetation Information [ESCAVI] 2003), included in **Table 17** and **Table 18** in **Appendix One**, recorded at Level V. Up to three species per stratum from each stratum (upper, mid and ground) were used to formulate vegetation descriptions for each quadrat and each vegetation type.

Vegetation type descriptions were created by combining quadrat descriptions and modifying, where necessary, based on the wider vegetation. Vegetation codes for these were formulated using the first letter of genus and species names of the dominant species of each stratum e.g. **AiT^w1** = *Acacia inaequilatera* mid sparse shrubland over *Triodia wiseana* low hummock grassland. Where the dominant species make up more than one version of the same code they are distinguished by a number at the end of the code e.g. **AiT^w2** = *Acacia inaequilatera*, *Acacia bivenosa* and *Grevillea wickhamii* mid open shrubland over *Triodia wiseana* and *Acacia spondylophylla* mid hummock grassland/sparse low shrubland.

Vegetation types were interpreted in the field based on the dominant and characteristic species of the three main strata as was recorded from within quadrats and relevés, and later reviewed following floristic analysis. Vegetation boundaries were hand drawn on printed aerial imagery during the field survey and digitised upon return to the office.

Vegetation Condition and Mapping

Vegetation condition was assessed continuously throughout the survey area and at each quadrat using the Vegetation Condition Scale for the Eremaean and Northern Botanical Provinces included in the *Flora and Vegetation Technical Guidance* (EPA 2016c), included in **Table 19** in **Appendix One**.

The spatial extent of the varying vegetation condition was mapped using GIS and vegetation condition maps are provided in this report.

Conservation Significant Flora Searches (Targeted Searches)

Accessible areas of potentially suitable habitat for potentially occurring conservation significant flora, as identified during the desktop study, were comprehensively searched for conservation significant flora.

Range Extensions

Taxa recorded during the current survey that are outside of their known distribution were identified as range extensions. Known taxa records (WAH 1998a-2018) were used as a guide to determine if each taxon recorded in the survey area was representative of a range extension (in this case defined as greater than 100 km from nearest record) or outlier population.

Introduced Species

All introduced flora (weeds) were recorded from within quadrats or recorded opportunistically for inclusion in the flora inventory (species list).

3.1.3 STATISTICAL ANALYSIS

3.1.3.1 Floristic Analysis

PATN© software (Belbin & Collins 2006) was used to undertake statistical analysis to generate floristic groups using the data collected from the floristic quadrats, in order to better understand local significance of floristic units. PATN analysis has been used for several local floristic analyses including Gibson *et al.* (1994) for the Swan Coastal Plain and various Pilbara surveys (e.g. Ecoscape 2012).

PATN is a multivariate analysis tool that generates estimates of association (resemblance, affinity, distance) between sets of objects described by a suite of variables (attributes), and classifies the objects into groups and condenses the information and displays the patterns in the data graphically.

PATN offers a choice of data transformations prior to multivariate analysis.

Floristic groups, identified using a dendrogram output of the analysis, are used as a tool to inform vegetation type groups at various levels and scales. Floristic quadrat data is used for the analysis.

For Ecoscape's regional analysis, the Kulczynski similarity coefficient was the appropriate association to use as it has proven to be a good estimation of association for ecological applications (Belbin & Collins 2006). This was followed by Flexible UPMGA (Un-weighted Pair Group Using Arithmetic Averaging) fusion to produce clusters of related objects (species); these are the floristic groups that are displayed as a dendrogram. The survey area analysis was conducted using the square root of cover values for each species, but using the Bray Curtis similarity index instead of Kulczynski coefficient as this provides a cover-weighted similarity result, and has been used in previous surveys (e.g. Ecologia Environment 2012b).

Interpretation of these purely floristic groups into recognisable and mappable on-ground units is a tool used to identify broad vegetation types. Generally, quadrats that are closely floristically related on the dendrogram form identifiable vegetation units, however, as presence-absence data is usually used in the analysis and there is no weighting given to dominant species, at times the floristic groups are not easily related to on-ground vegetation types. Vegetation types are therefore determined as a combination of floristic analysis and on-ground interpretation using dominant and characteristic species (structural vegetation types).

The analyses were performed using data of all species (perennial and ephemeral). The cover weighted (Bray Curtis) analysis was performed using a single square root transformation of the percent cover data.

A regional floristic analysis was performed using data from the following surveys:

- North Star access corridor (Ecologia Environment 2012a)
- North Star Mine area (Ecologia Environment 2012b)
- North Star Filtration area (Ecologia Environment 2014)
- North Star Aerodrome (Ecologia Environment 2015a).

A revision of previous regional datasets was undertaken and species names were updated where applicable. Additionally, species that were not identified to species level were excluded.

PATN analysis was conducted using all data combined in order to determine if:

- the floristics correlated with the structural vegetation types as determined during the field survey, identifying discrete groups that were not apparent using purely structural vegetation types
- the floristics identified discrete geographic groupings of vegetation types
- there were sufficient (i.e. three) quadrats recorded from within each combined structural/floristic vegetation type
- for regional data, if the vegetation of the survey area is floristically representative of a wider area
- for regional data, consolidation of vegetation units between different surveys.

PATN analysis was also conducted separately for each tenement to provide additional floristic detail.

3.1.3.2 Adequacy of Sampling

In order to demonstrate adequacy of sampling, a species accumulation curve was generated by the computer programme Species Diversity and Richness (Pisces Conservation Ltd 2010) using five random selections of sample order, and using only quadrat data.

Adequacy of sampling is also assessed in terms of representation of various attributes, including vegetation types and representation of land systems.

4 RESULTS

4.1 FLORA

4.1.1 FLORA INVENTORY

The flora inventory was compiled using the data collected from 60 floristic quadrats within the survey area plus opportunistic observations. Of the floristic quadrats, 45 were established during phase one (May 2018) and 16 were established during phase two (August 2018). Thirty-four of the quadrats established during phase one were rescored during phase two. Eight additional regional quadrats were recorded during phase one, data from these is included for the regional analysis but excluded from flora inventory of the survey area.

A total of 218 vascular flora taxa (inclusive of species, subspecies, varieties and forms) from 48 families and 107 genera were recorded from the survey area. Two taxa could not be identified to species level due to lack of reproductive material. Four of the flora taxa recorded were introduced (weeds).

The most commonly represented families were Fabaceae with 46 taxa, followed by Poaceae (25 taxa including one introduced) and Malvaceae (19 taxa), Amaranthaceae (13 taxa including one weed), Cyperaceae (11 taxa) and Asteraceae (10 taxa including one introduced).

The most commonly represented genera were *Acacia* with 20 taxa, *Ptilotus* (9 taxa), *Euphorbia*, *Senna*, *Tephrosia* and *Triodia* (six taxa each).

The number of flora taxa recorded per quadrat ranged from five (GV18020) to 63 (GV18036). Average species diversity was 23.02 flora taxa per quadrat. The most frequently recorded flora taxa were *Triodia wiseana* (55 quadrats), *Corchorus parviflorus* (39), *Acacia inaequilatera*, *A. bivenosa* (36 each) and *A. acradenia* (35).

Flora species, presented as a site by species table, is included in **Appendix Three (Table 22)**. Quadrat details are presented in **Appendix Five**.

4.1.2 FLORA OF CONSERVATION SIGNIFICANCE

Locations of significant flora are shown on **Map 4** and provided in **Appendix Six**.


4.1.2.1 Threatened Flora

Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) is listed under the Commonwealth EPBC Act as Endangered, and as Schedule 2 (Flora that are considered likely to become extinct or rare, as endangered flora) under the Western Australian WC Act. *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) is well documented as occurring within IB Operation's North Star tenements (Ecologia Environment 2012c; 2015c; 2016; Ecoscape 2016; Fortescue Metals Group Limited 2015).

All *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) populations already known with the survey area and mine development envelope from previous studies were reconfirmed during the study (populations 9, 12 and 47). One additional plant was found within 200 m of the single plant associated with population number 12. Eight new populations were recorded during the field survey including six within the survey area (totalling 261 plants) and two to the north of the survey area (totalling seven plants). Plants observed during May were either vegetative or in the early bud stage of flower development, whilst in August many of the plants were flowering (**Table 4**).

A summary of the populations recorded during the field survey is provided in **Table 5**.

Table 4: *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) details

<i>Pityrodia</i> sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4)		
Threatened Flora	<p>Description (from Ecoscape 2016; Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)</p>	<p>Habitat (from Ecoscape 2016; Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)</p>
	<p><i>Pityrodia</i> sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) is an erect woody shrub to 1.5 m high with densely tomentose leaves and pink tubular flowers.</p>	<p>Occurs on steep rocky conglomerate, slopes and areas with outcropping rock, most frequently south-facing.</p> <p>Vegetation types: <i>Acacia</i> shrublands characterised by <i>A. acradenia</i>, <i>A. inaequilatera</i>, <i>A. tumida</i>, <i>A. orthocarpa</i>, <i>A. stellaticeps</i>, with <i>Grevillea wickhamii</i> or <i>Solanum phlomoides</i>; hummock grasslands characterised by <i>Triodia lanigera</i>¹, <i>T. wiseana</i>, <i>T. schinzii</i>, <i>T. epactia</i>.</p> <p>Distribution: Pilbara IBRA region, Chichester subregion</p>
	<p>Survey Results</p>	<p>Photograph</p>
	<p>Records: 261 plants within the survey from combined populations, an additional seven plants recorded from new populations outside the survey area</p> <p>Populations²: Seven within the study area, ranging in size from two plants to 138 plants. Two additional populations recorded outside the survey area</p> <p>Habitat: Occurs in five vegetation types:</p> <ul style="list-style-type: none"> • AaTw¹ • AbTw • AeTb • EITw • EvAtCc 	

¹ May be *Triodia chichesterensis* (P3) that was described in Anderson *et al.* (2017).

² Populations are defined as groups of plants separated by at least 500 m or a significant landscape feature (EPA 2016c).

Table 5: Summary of *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) populations within the survey area and additional new populations recorded outside.

Location	Population Reference	No. Plants	Notes
Inside Survey Area			
Far west of survey area, just north of quadrat GV18067	New, undocumented	3	Small population on high slopes
Western end of survey area, near GV18068	New, undocumented	45	Steep rocky hillslope
Central west of survey area, corresponding with quadrat GV18063	New, undocumented	138	Recorded from the slopes surrounding a high hill
Near section known as 'the drop' (a steep descent along the vehicle access track) near the central northern boundary of the survey area (near GV18050)	New, undocumented	4	Four plants recorded from a 10 m radius.
Eastern section of the survey area, near GV18028	New, undocumented	4	Four plants recorded from a 10 m radius.
Near northern boundary of survey area, west of access road, north of GV18065	New, undocumented	65	Many juvenile plants (<50 cm) included in the total count
Previously known location near north eastern boundary of the survey area near GV18025	Population 12	2	Previously documented during Phase 1
Outside Survey Area			
North of survey area, west of main access road	New, undocumented	6	Six plants recorded from a 20 m radius.
North of survey area, directly adjacent to main road between Japal Village and the Mine Site	New, undocumented	1	Isolated individual growing on road verge, flagged with green and white environment tape

4.1.2.2 Priority Flora

Two PF species were recorded during the field surveys:

- *Ptilotus mollis* (P4), described in **Table 6**
- *Triodia basitricha* (P3), described in **Table 7**.

Table 6: *Ptilotus mollis* details





<i>Ptilotus mollis</i>									
	<table border="1"> <thead> <tr> <th>Description (from Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)</th> <th>Habitat (from Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)</th> </tr> </thead> <tbody> <tr> <td><i>Ptilotus mollis</i> is a compact woolly erect or sprawling shrub to 0.9 m high, with pink flowers.</td> <td>Occurs on steep rocky sites generally in full sun. Distribution: Pilbara and Little Sandy Desert IBRA regions, Pilbara Chichester, Hamersley and Roebourne subregions</td> </tr> <tr> <th>Survey Results</th> <th>Photograph</th> </tr> <tr> <td> <p>Records: estimated 1008 plants within survey area from combined populations plus 33 plants outside survey area.</p> <p>Populations: Nine populations within the survey area plus one new population outside survey area</p> <p>Habitat: Occurs in five vegetation types:</p> <ul style="list-style-type: none"> • AaTw¹ • AbTw • AiTw • AoTw • EITw </td> <td>  </td> </tr> </tbody> </table>	Description (from Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)	Habitat (from Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)	<i>Ptilotus mollis</i> is a compact woolly erect or sprawling shrub to 0.9 m high, with pink flowers.	Occurs on steep rocky sites generally in full sun. Distribution: Pilbara and Little Sandy Desert IBRA regions, Pilbara Chichester, Hamersley and Roebourne subregions	Survey Results	Photograph	<p>Records: estimated 1008 plants within survey area from combined populations plus 33 plants outside survey area.</p> <p>Populations: Nine populations within the survey area plus one new population outside survey area</p> <p>Habitat: Occurs in five vegetation types:</p> <ul style="list-style-type: none"> • AaTw¹ • AbTw • AiTw • AoTw • EITw 	
Description (from Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)	Habitat (from Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)								
<i>Ptilotus mollis</i> is a compact woolly erect or sprawling shrub to 0.9 m high, with pink flowers.	Occurs on steep rocky sites generally in full sun. Distribution: Pilbara and Little Sandy Desert IBRA regions, Pilbara Chichester, Hamersley and Roebourne subregions								
Survey Results	Photograph								
<p>Records: estimated 1008 plants within survey area from combined populations plus 33 plants outside survey area.</p> <p>Populations: Nine populations within the survey area plus one new population outside survey area</p> <p>Habitat: Occurs in five vegetation types:</p> <ul style="list-style-type: none"> • AaTw¹ • AbTw • AiTw • AoTw • EITw 									
Priority 4									

Table 7: *Triodia basitricha* details

<i>Triodia basitricha</i>		
Priority 3	Description (from Rio Tinto & DPaW 2015; WAH 2018; WAH & DBCA 2018)	Habitat (WAH 2018; WAH & DBCA 2018)
	<p><i>Triodia basitricha</i> is a perennial tussock grass to approximately 40 cm high. The old leaf bases are curly.</p> <p>Several previous collections of this taxon from the surrounding region that are held at the WA Herbarium were previously identified as <i>Triodia bitextura</i></p>	<p>Occurs on low hills.</p> <p>Distribution: Pilbara and Gascoyne IBRA regions, Pilbara Chichester, Fortescue and Hamersley subregions</p>
	Survey Results	Photograph
	<p>Records: Recorded from 14 locations within the survey area totalling at least 2600 plants. At least 3000 additional plants are located outside the survey area. These are likely underestimates of the population size, as the species commonly occurs as a dominant component of the vegetation structure and many areas of suitable habitat had been recently burnt.</p> <p>Populations: Many of the locations are likely representative on one large, continuous population that extends north of the survey area. A separate population was recorded from a regional quadrat (GV18043), to the east of the survey area.</p> <p>Habitat: Occurs in seven vegetation types:</p> <ul style="list-style-type: none"> • AaTw¹ • AaTw² • AeTb • AiTw • AoTw • CfAtEm • EITw 	

4.1.2.3 Verification of Previous Records Within Previously Surveyed Areas

Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) has been subject to a number of specific searches and modelling, followed by verification surveys, to identify all populations and distribution (Ecologia Environment 2012c; 2015c; 2016; Ecoscape 2016; Fortescue Metals Group Limited 2015). This species is perennial, large and distinctive, and can commonly be spotted from a distance. It is known to resprout following fire, as well as produce seedlings following disturbance (Ecoscape 2016). All of the *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) populations already known with the survey area and mine development envelope from previous studies were reconfirmed during the survey (populations 9, 12 and 47). One additional plant was found within 200 m of the single plant associated with population number 12.

4.1.2.4 Significant Flora

Two flora taxa may be of significance according to the *Flora and Vegetation Technical Guidance* (EPA 2016c), based on range extensions to known distributions, outlined in **Table 8**.

Table 8: Significant flora

Taxon	Significant Attribute
<i>Acacia aptaneura</i>	Minor northern range extension of approximately 20 km
<i>Goodenia cusackiana</i>	Northern range extension of approximately 100 km based on NatureMap, however has been recorded during previous nearby surveys (Ecologia Environment 2012b)


4.1.2.5 Flora of Taxonomic Interest




A collection identified as *Themeda avenacea* (GV18036-12) appears to have substantially smaller reproductive parts than the more typical specimens (most of which are from the Kimberley). However, it does closely resemble at least one existing WA Herbarium collection from Spear Hill (S. van Leeuwen PBS 0415), 37 km southwest of Marble Bar that has been verified as *Themeda avenacea*. This taxon was recorded from two floristic quadrats (GV18036 and GV18064), both of which corresponded with the **EvAtCc** vegetation type.

4.1.3 INTRODUCED FLORA

Four introduced flora (weeds) were recorded from within the survey area. Species descriptions are provided in **Table 9**. None of the recorded species are listed as WONS (Weeds Australia 2012). **Calotropis procera* is a Declared Pest plant listed under the BAM Act, included in the exempt category. Locations of significant weeds, i.e. Declared Pest plants, are shown on **Map 5**.

Table 9: Introduced flora (weed) descriptions

Description and notes	Survey results	Photo
<p>*<i>Aerva javanica</i> (Kapok Bush) Perennial herb to 1.6 m high (but usually less) with greyish white flowers throughout much of the year (WAH 1998b-2018). Usually associated with disturbed areas and drainage lines, and is found throughout much of northern Western Australia. *<i>Aerva javanica</i> is rated as 'High' ecological impact and 'Rapid' invasiveness (DPaW 2016).</p>	<p>Records: seven including from five quadrats and two opportunistic records. Typically small populations from drainage lines.</p> <p>Impact: not significant.</p>	

Description and notes	Survey results	Photo
<p>*<i>Calotropis procera</i> (Calotrope, Rubber Bush)</p> <p>Shrub or tree to 4 m high with cream/white and purple flowers throughout much of the year (WAH 1998b-2018).</p> <p>*<i>Calotropis procera</i> (Calotrope, Rubber Bush), whilst a Declared Pest plant, is included in the exempt category, therefore there are no management requirements for this species. CSIRO/DBCA consider that this species is 'probably beyond containment' (Webber <i>et al.</i> 2017), indicating that management should focus on asset protection within the Pilbara IBRA region rather than a general recommendation to manage all infestations (p46), although the same document also recommends local eradication and containment (p72)..</p>	<p>Records: a single population from a drainage line near the south eastern boundary of the survey area</p> <p>Impact: moderate impact in a restricted area.</p>	
<p>*<i>Cenchrus ciliaris</i> (Buffel Grass)</p> <p>*<i>Cenchrus ciliaris</i> is a perennial tussock-forming grass to 1 m high (WAH 1998b-2018). It is generally associated with drainage lines and floodplains, and is more common in grazed areas. *<i>Cenchrus ciliaris</i> was either deliberately planted for pasture or accidentally introduced (Van Vreeswyk <i>et al.</i> 2004), and has been known from the Pilbara bioregion since the early 1900s (Keighery 2010).</p> <p>*<i>Cenchrus ciliaris</i> is rated as 'High' ecological impact and 'Rapid' invasiveness (DPaW 2016).</p>	<p>Records: five records from quadrats in the survey area. All occurring within the EvAtCc vegetation type characteristic of drainage lines</p> <p>Impact: moderate within a restricted area.</p>	
<p>*<i>Flaveria trinervia</i> (Speedy Weed)</p> <p>*<i>Flaveria trinervia</i> is an annual herb with distinctive red stems and three-veined leaves and is found throughout much of northern Western Australia. It is listed on <i>FloraBase</i> (WAH 1998b-2018) as 'alien' (introduced), however Hussey <i>et al.</i> (2007) and the Pilbara Ranking Summary (of the Weed Prioritisation Process) (DPaW 2016) do not list this species, indicating there is debate in relation to *<i>Flaveria trinervia</i> being native or introduced.</p>	<p>Records: two records from quadrats in the survey area. Both occurring within the EvAtCc vegetation type characteristic of drainage lines</p> <p>Impact: minor</p>	

4.2 VEGETATION



Eleven vegetation types were recorded from within the survey area (**Table 10**). The formulation of vegetation types took into account floristic analysis and vegetation species and structure (i.e. both floristic composition and structural vegetation classifications). The extents of the vegetation types and representative quadrat locations are shown on **Map 4**.



Six of the vegetation types correspond with hills including slopes crests and ridges (**AaTw1**, **AbTw**, **AeTb**, **AiTw**, **AoTw** and **EITw**), three correspond with drainage lines or gorges (**CfAtEm**, **ChAaTl** and **EvAtCc**) and two correspond with flats or valley floors (**AaTw2** and **ChAiTa**).

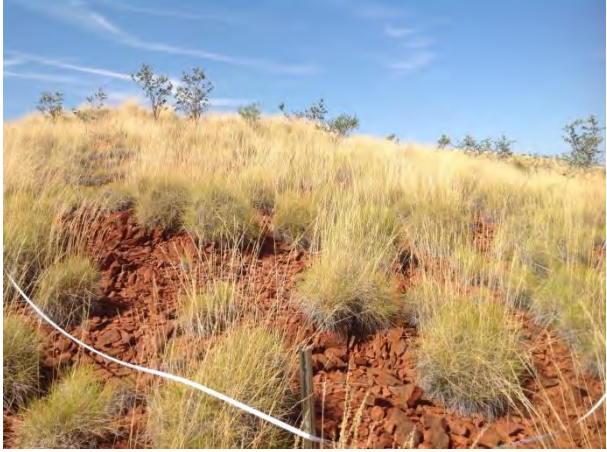

Table 10: Vegetation types


* r= regional quadrat



Bold indicates represented by photograph



Landform	Mapping Unit	Vegetation Type	Floristic Quadrats*	Representative Photograph	Other Characteristic Species	Area (ha) and Extent (%) of Survey area
High hill crests/slopes; ironstone/chert	AaTw ¹	<i>Acacia acradenia</i> , <i>Acacia inaequilatera</i> and <i>Grevillea wickhamii</i> tall sparse shrubland over <i>Triodia wiseana</i> and <i>Triodia brizoides</i> low hummock grassland M ^ <i>Acacia acradenia</i> , <i>Acacia inaequilatera</i> , <i>Grevillea wickhamii</i> ^ shrub\4\r; G+ ^ <i>Triodia wiseana</i> , <i>Triodia brizoides</i> ^ hummock grass\1\c	GV18002 GV18014 GV18025 GV18029 GV18050 GV18062 GV18066		<i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> <i>Triodia basitricha</i>	691.75 14.37%
Valley floor, slopes; basalt/colluvium	AaTw ²	<i>Acacia acradenia</i> , <i>Acacia inaequilatera</i> and <i>Acacia bivenosa</i> tall open shrubland over <i>Triodia wiseana</i> and <i>Triodia epactia</i> mid hummock grassland with <i>Corymbia hamersleyana</i> scattered low trees U ^ <i>Corymbia hamersleyana</i> ^ tree\6\bi; M+ ^ <i>Acacia acradenia</i> , ^ <i>Acacia inaequilatera</i> , <i>Acacia bivenosa</i> ^ shrub\4\i; G ^ <i>Triodia wiseana</i> , <i>Triodia epactia</i> ^ hummock grass\2\c	GV18009 GV18010 GV18015 GV18022 GV18024 GV18044r GV18060 GV18061		<i>Indigofera monophylla</i> <i>Cassytha capillaris</i> <i>Corchorus parviflorus</i> <i>Solanum phlomoides</i> <i>Bonamia pilbarensis</i> <i>Eriachne mucronata</i> <i>Ptilotus astrolasius</i> <i>Petalostylis labicheoides</i> <i>Boerhavia coccinea</i> <i>Grevillea wickhamii</i> <i>Hakea lorea</i> subsp <i>lorea</i>	739.56 15.36%

Landform	Mapping Unit	Vegetation Type	Floristic Quadrats*	Representative Photograph	Other Characteristic Species	Area (ha) and Extent (%) of Survey area
Valley Floors	AaTw2/ ChAiTa	Mosaic of two vegetation types	N/A			198.15 4.11%
Hills (shrub rich); mixed substrate	AbTw	<p><i>Acacia bivenosa</i> and <i>Acacia inaequilatera</i> mid sparse shrubland over <i>Triodia wiseana</i> and <i>Triodia brizoides</i> mid hummock grassland</p> <p>M+ ^ <i>Acacia bivenosa</i>, <i>Acacia inaequilatera</i> ^ shrub\3\r;G ^ <i>Triodia wiseana</i>, ^ <i>Triodia brizoides</i> ^ hummock grass\2\c</p>	GV18003 GV18007 GV18039 GV18041r GV18049 GV18065 GV18067 GV18068		<p><i>Acacia hilliania</i> <i>Acacia maitlandii</i> <i>Acacia stellaticeps</i> <i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i></p>	452.27 9.39%
Hills; quartz	AeTb	<p><i>Acacia eriopoda</i> and <i>Grevillea wickhamii</i> subsp. <i>aprica</i> tall sparse shrubland over <i>Triodia basitricha</i> and <i>Triodia wiseana</i> mid hummock grassland</p> <p>M+ ^ <i>Acacia eriopoda</i>, <i>Grevillea wickhamii</i> subsp. <i>aprica</i> ^ shrub\4\r;G ^ <i>Triodia basitricha</i>, <i>Triodia wiseana</i> ^ hummock grass\2\c</p>	GV18056 GV18057		<p><i>Cheilanthes brownii</i> <i>Cymbopogon ambiguus</i> <i>Cyperus cunninghamii</i> subsp. <i>cunninghamii</i> <i>Eriachne mucronata</i> <i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> <i>Senna venusta</i> <i>Triumfetta maconochieana</i> <i>Triumfetta propinqua</i></p>	21.18 0.44%

Landform	Mapping Unit	Vegetation Type	Floristic Quadrats*	Representative Photograph	Other Characteristic Species	Area (ha) and Extent (%) of Survey area
Hills; basalt	AiTw	<p><i>Acacia inaequilatera</i> mid sparse shrubland over <i>Triodia wiseana</i> low hummock grassland</p> <p>M+ ^ <i>Acacia inaequilatera</i> ^ shrub\3\r;G ^ <i>Triodia wiseana</i> ^ hummock grass\1\c</p>	<p>GV18012 GV18018 GV18020 GV18021 GV18043r GV18046r</p>		<p><i>Triodia basitricha</i> <i>Triodia brizoides</i></p>	<p>1323.03 27.48%</p>
Ridge, upper slope/ironstone	AoTw	<p><i>Acacia orthocarpa</i> and <i>Grevillea wickhamii</i> mid open shrubland over <i>Triodia wiseana</i> and <i>Triodia basitricha</i> mid hummock grassland</p> <p>M+ ^ <i>Acacia orthocarpa</i>, <i>Grevillea wickhamii</i> ^ shrub\3\i;G ^ <i>Triodia wiseana</i>, ^ <i>Triodia basitricha</i> ^ hummock grass\2\c</p>	<p>GV18032 GV18033 GV18034 GV18035 GV18037 GV18038 GV18048r</p>		<p><i>Acacia tumida</i> var. <i>pilbarensis</i> <i>Corymbia hamersleyana</i> <i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> <i>Triodia epactia</i></p>	<p>157.94 3.28%</p>

Landform	Mapping Unit	Vegetation Type	Floristic Quadrats*	Representative Photograph	Other Characteristic Species	Area (ha) and Extent (%) of Survey area
Gorge (upper slope); ironstone	CfAtEm	<p><i>Corymbia ferriticola</i>, <i>Terminalia circumalata</i> and <i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> low open woodland over <i>Acacia tumida</i> var. <i>pilbarensis</i>, <i>Acacia pruinocarpa</i> and <i>Ehretia saligna</i> var. <i>saligna</i> tall open shrubland over <i>Eriachne mucronata</i> and <i>Triodia wiseana</i> mid open tussock grassland/hummock grassland</p> <p>U+ ^ <i>Corymbia ferriticola</i>, <i>Terminalia circumalata</i>, <i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> ^tree\6\r;M ^ ^ <i>Acacia tumida</i> var. <i>pilbarensis</i>, <i>Acacia pruinocarpa</i>, <i>Ehretia saligna</i> var. <i>saligna</i> ^shrub\4\i;G ^ <i>Eriachne mucronata</i>, <i>Triodia wiseana</i> ^tussock grass, hummock grass\2\c</p>	<p>GV18027 GV18051 GV18054 GV18052</p>		<p><i>Cyperus cunninghamii</i> subsp. <i>cunninghamii</i> <i>Themeda triandra</i> <i>Triodia longiceps</i></p>	<p>3.17 0.07%</p>

Landform	Mapping Unit	Vegetation Type	Floristic Quadrats*	Representative Photograph	Other Characteristic Species	Area (ha) and Extent (%) of Survey area
Minor drainage; alluvium	ChAaTl	<p><i>Acacia acradenia</i>, <i>Grevillea wickhamii</i> and <i>Petalostylis labicheoides</i> tall open shrubland over <i>Triodia longiceps</i> mid open hummock grassland with <i>Corymbia hamersleyana</i> low scattered trees</p> <p>U ^ <i>Corymbia hamersleyana</i> ^tree\6\bi;M+ ^ <i>Acacia acradenia</i>, <i>Grevillea wickhamii</i>, <i>Petalostylis labicheoides</i> ^,shrub\4\i;G ^ <i>Triodia longiceps</i> ^hummock grass\2\i</p>	<p>GV18001 GV18006 GV18013</p>		<p><i>Cajanus cinereus</i> <i>Stemodia grossa</i> <i>Triodia wiseana</i></p>	<p>179.04 3.72%</p>
Valley; calcrete	ChAiTa	<p><i>Corymbia hamersleyana</i> open woodland over <i>Acacia inaequilatera</i> tall sparse shrubland over <i>Triodia angusta</i> and <i>Triodia wiseana</i> low hummock grassland</p> <p>U+ ^ <i>Corymbia hamersleyana</i> ^tree\6\r;M ^ <i>Acacia inaequilatera</i> ^shrub\4\r;G ^ <i>Triodia angusta</i>, ^ <i>Triodia wiseana</i> ^hummock grass\1\c</p>	<p>GV18005 GV18008 GV18017 GV18023 GV18042r</p>		<p><i>Acacia stellaticeps</i> <i>Goodenia stobbsiana</i></p>	<p>121.86 2.53%</p>

Landform	Mapping Unit	Vegetation Type	Floristic Quadrats*	Representative Photograph	Other Characteristic Species	Area (ha) and Extent (%) of Survey area
Hills (mid-upper slope); rocky (mixed)	EITw	<p><i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> low open woodland over <i>Triodia wiseana</i> and <i>Triodia brizoides</i> low open hummock grassland</p> <p>U+ ^ <i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> ^tree\6\r;G ^ <i>Triodia wiseana</i>, <i>Triodia brizoides</i> ^hummock grass\1\i</p>	<p>GV18011 GV18026 GV18030 GV18031 GV18040 GV18047r GV18055 GV18058 GV18059 GV18063</p>		<p><i>Acacia acradenia</i> <i>Acacia eriopoda</i> <i>Acacia inaequilatera</i> <i>Grevillea wickhamii</i> <i>Triodia epactia</i></p>	<p>793.58 16.48%</p>
Riparian (larger drainage); alluvium	EvAtCc	<p><i>Eucalyptus victrix</i> mid woodland over <i>Acacia tumida</i> var. <i>pilbarensis</i>, <i>Melaleuca glomerata</i> and <i>Acacia ampliceps</i> tall open shrubland over *<i>Cenchrus ciliaris</i> and <i>Triodia longiceps</i> low open tussock grassland/hummock grassland/sedgeland</p> <p>U+ ^ <i>Eucalyptus victrix</i> ^tree\7\i;M ^ <i>Acacia tumida</i> var. <i>pilbarensis</i>, <i>Melaleuca glomerata</i>, <i>Acacia ampliceps</i> ^shrub\4\i;G ^ <i>Cenchrus ciliaris</i>, ^ <i>Triodia longiceps</i>, <i>Cyperus vaginatus</i> ^tussock grass, hummock grass, sedge\1\i</p>	<p>GV18004 GV18016 GV18019 GV18028 GV18036 GV18045r GV18053 GV18064</p>		<p><i>Acacia pyrifolia</i> var. <i>pyrifolia</i> <i>Flueggea virosa</i> subsp. <i>melanthesoides</i> <i>Gossypium robinsonii</i> <i>Melaleuca linophylla</i> <i>Petalostylis labicheoides</i> <i>Streptoglossa decurrens</i> <i>Triodia epactia</i></p>	<p>133.84 2.78%</p>

4.2.1 FLORISTIC ANALYSIS

4.2.1.1 Survey Area and 2018 Regional Quadrats

Floristic analysis, conducted using the combined phase one and phase two floristic datasets, indicated that there were three floristic supergroups (**Appendix Four**). One of these supergroups completely corresponds with riparian vegetation of drainage lines and gorges (vegetation types **CfAtEm**, **ChAaTI** and **EvAtCc**). The second supergroup encompasses six vegetation types, mostly associated with lower hills and valley floors. The third supergroup strongly corresponds with two vegetation types (**AeTb** and **AoTw**) associated with high hills.

The riparian vegetation associated with larger drainage lines (creeks) and characterised by *Eucalyptus victrix* formed a discrete floristic group that corresponded entirely with the structural vegetation classification. Of note, Ecoscape is aware that there is a vegetation type characterised by *Eucalyptus camaldulensis* within the survey area; this could not be accessed and recorded due to potential representatives occurring entirely within indigenous heritage areas for which permission to access was not granted. It is likely that this vegetation type would have been floristically within this supergroup.

Five of the mapped vegetation types represent highly distinct floristic units with strong clustering of quadrats within the dendrogram output including **AeTb**, **AoTw**, **CfAtEm**, **ChAaTI**, **EvAtCc**. The remaining vegetation types are described as follows:

- **AaTw¹** quadrats are distributed within the second supergroup, but do not cluster together. Therefore this vegetation type is not a distinct floristic unit
- **AaTw²** is a distinct floristic unit, with the exception of quadrat GV18022 which is an outlier
- **AiT^w** is a reasonable floristic unit with the exception of quadrats GV18018 and GV1821 which are outliers
- **AbT^w** is a distinct floristic unit with the exception of quadrats GV18041 and GV18065 which are outliers
- **ChAiTa** is a distinct floristic unit with the exception of quadrat GV18008 which is an outlier
- **EIT^w** quadrats are distributed within the second supergroup. Six of the quadrats cluster together, but the remaining four are outliers

The eight regional quadrats established during phase one (May 2018) were dispersed within the survey area quadrats, indicating that the vegetation within the survey area is floristically representative of the wider (regional) area.

4.2.1.2 Regional Floristic Analysis

Floristic analysis, conducted using quadrat data supplied by Fortescue for adjacent and nearby (local-regional) areas (Ecologia Environment 2012a, mine area; 2012b, access corridor; 2014; filtration area; 2015a; aerodrome) was also conducted to determine wider regional representativeness of the quadrats recorded during this survey.

There were significant limitations associated with this data including:

- taxonomic issues that could not be resolved (e.g. taxa not occurring in the Pilbara, Western Australia or significant range extensions and therefore potentially erroneously named, taxa recently subject to taxonomic review). Where taxonomic issues could not be resolved, taxa were not included in the analysis.
- variation, including higher numbers of species and greater proportion of annuals, potentially due to seasonal conditions or fire
- anomalous location data; where these could not be resolved, the quadrats were not included in the analysis
- repeats, where quadrat data was used in more than one survey and had been renamed
- quadrats that had not been included in the floristic analysis for their project but have had a vegetation type assigned to them that may not have been based on floristics.

The regional floristic analysis identified:

- vegetation types assigned by Ecologia Environment did not floristically group together using the analysis conducted by Ecoscape, nor group with ostensibly similar vegetation as described by Ecoscape. Ecologia Environment used cover weighted site by species but did not provide the weighting scale in the methods,

thus similar analysis could not be reliably conducted. Therefore Ecoscape used presence-absence data for the regional analysis.

- both Ecoscape's and Ecologia Environment's vegetation types were generally associated with topography and substrate
- Ecoscape's quadrats tended to group together rather than being spread through the dendrogram matrix.

These findings indicate that:

- the Glacier Valley survey area is only broadly floristically similar to the surrounding area, with Ecologia Environment vegetation types in close geographical proximity being the most similar. This pattern is also extended for the further away quadrats within the access corridor floristically separated from quadrats within the mine area, which is closer to Glacier Valley. Few of the Glacier Valley quadrats are floristically similar to access corridor quadrats.
- seasonal variation or fire effects may be a significant limitation for consolidating vegetation types between surveys; surveyor variation within the Ecologia Environment quadrats and from Ecoscape may also be a significant limitation in this process
- the major drainage in the Glacier Valley survey area (vegetation type **EvAtCc**) is more floristically aligned with more minor drainages in the local and regional area (i.e. vegetation types characterised by *Acacia pyrifolia*)
- Ecoscape vegetation type **CfAtEm** is largely unique.

The regional floristics dendrograms are included in **Appendix Four**.

4.2.2 SIGNIFICANT VEGETATION

No TECs or PECs are known to occur within 40 km of the survey area and no vegetation resembling currently described TECs or PECs was recorded during the field surveys.

Vegetation type **EvAtCc** occupies 133.8 ha (2.78% of the survey area), and corresponds with mid-sized drainage lines throughout the survey area. This vegetation type represents a potential GDE as it is characterised by *Eucalyptus victrix* which is regarded as a facultative phreatophyte although, in some circumstances, it appears not to access or be dependent on groundwater (see **Section 1.4.5.2**).

Another unrecorded vegetation type dominated by *Eucalyptus camaldulensis* is known to occur in the survey area, however, it occurs entirely within Aboriginal Heritage areas for which access permission had not been granted. The extent of this vegetation type is therefore currently undocumented and the vegetation not described in detail. *Eucalyptus camaldulensis* is a facultative phreatophyte known to be dependent on groundwater at various times, and therefore vegetation with this species is representative of a GDE.

Vegetation having a restricted distribution is also considered as significant according to the *Flora and Vegetation Technical Guidance* (EPA 2016c). The following two vegetation types were represented by a small extent of less than one percent of the survey area.

- **CfAtEm**, characterised by *Corymbia ferricola*, *Eucalyptus leucophloia* subsp. *leucophloia* and *Terminalia circumalata*, is associated with a landform of restricted distribution (gorge with large boulders) and small extent. **CfAtEm** occupies 3.17 ha (0.07% of the survey area)
- **AeTb**, characterised by *Acacia eriopoda* and *Triodia basitricha* (listed as Priority 3) is associated with rocky hills. **AeTb** occupies 21.18 ha (0.44% of the survey area). There was not sufficient vegetation to record more than two spatially separated quadrats.

No other vegetation is considered to have significance according to the *Flora and Vegetation Technical Guidance* (EPA 2016c).

4.2.3 VEGETATION CONDITION

The majority of the floristic quadrats (90.0%) were rated Excellent, with minimal evidence of disturbance. Similarly, the majority of the survey area was mapped as in Excellent vegetation condition (94.81%). The remainder of floristic quadrats were rated as Very Good or Good condition and were drainage lines affected

by weeds (particularly **Cenchrus ciliaris*) and, to some degree, grazing. No vegetation was recorded as being in less than Good condition.

The vegetation condition extents of the survey area are shown in **Table 11**. Vegetation condition mapping is included on **Map 5**.

Table 11: Vegetation condition extents

Vegetation Condition	No. of Quadrats	Extent (ha)	Extent (%)
Excellent	54	4,565.43	94.81
Very Good	3	219.77	4.56
Good	3	30.19	0.62

4.2.4 VEGETATION RECONCILIATION

A reconciliation of vegetation types between the Glacier Valley survey area and the adjacent North Star Mine Area (Ecologia Environment 2012b) is provided in **Table 12**. This reconciliation identifies that three of the vegetation types within the Glacier Valley survey area are not represented within the North Star Mine Area.

Table 12: Vegetation type reconciliation between the Glacier Valley survey area and the North Star Mine Area

Ecotope vegetation type	Ecotope vegetation description	Ecologia Environment vegetation type	Ecologia Environment vegetation description
AaTw¹	<i>Acacia acradenia</i> , <i>Acacia inaequilatera</i> and <i>Grevillea wickhamii</i> tall sparse shrubland over <i>Triodia wiseana</i> and <i>Triodia brizoides</i> low hummock grassland	AaTw ²	<i>Acacia acradenia</i> open mid shrubland, over <i>Triodia wiseana</i> hummock grassland
AaTw²	<i>Acacia acradenia</i> , <i>Acacia inaequilatera</i> and <i>Acacia bivenosa</i> tall open shrubland over <i>Triodia wiseana</i> and <i>Triodia epactia</i> mid hummock grassland with <i>Corymbia hamersleyana</i> scattered low trees	AaTw ³	<i>Acacia acradenia</i> , <i>Acacia tumida</i> and <i>Grevillea wickhamii</i> open shrubland, over <i>Triodia wiseana</i> hummock grassland
AbTw	<i>Acacia bivenosa</i> and <i>Acacia inaequilatera</i> mid sparse shrubland over <i>Triodia wiseana</i> and <i>Triodia brizoides</i> mid hummock grassland	-	
AeTb	<i>Acacia eriopoda</i> and <i>Grevillea wickhamii</i> subsp. <i>aprica</i> tall sparse shrubland over <i>Triodia basitricha</i> and <i>Triodia wiseana</i> mid hummock grassland	-	
AiTw¹	<i>Acacia inaequilatera</i> mid sparse shrubland over <i>Triodia wiseana</i> low hummock grassland	Tw ⁴	<i>Triodia wiseana</i> hummock grassland
AoTw	<i>Acacia orthocarpa</i> and <i>Grevillea wickhamii</i> mid open shrubland over <i>Triodia wiseana</i> and <i>Triodia basitricha</i> mid hummock grassland	AoTw	<i>Acacia orthocarpa</i> open tall shrubland, over <i>Triodia wiseana</i> open hummock grassland
CfAtEm	<i>Corymbia ferritcola</i> low open woodland over <i>Acacia tumida</i> var. <i>pilbarensis</i> , <i>Acacia pruinocarpa</i> and <i>Ehretia saligna</i> var. <i>saligna</i> tall open shrubland over <i>Eriachne mucronata</i> mid tussock grass	AtEm	<i>Acacia tumida</i> , <i>Acacia orthocarpa</i> and <i>Grevillea wickhamii</i> open shrubland, over <i>Eriachne mucronata</i> isolated tussock grasses
ChAaTI	<i>Acacia acradenia</i> , <i>Grevillea wickhamii</i> and <i>Petalostylis labicheoides</i> tall open shrubland over <i>Triodia longiceps</i> mid open hummock grassland with <i>Corymbia hamersleyana</i> low scattered trees	ApTp	<i>Acacia pyrifolia</i> , <i>Acacia acradenia</i> and <i>Tephrosia rosea</i> mid shrubland, over <i>Triodia pungens</i> open hummock grassland

Ecospa vegetation type	Ecospa vegetation description	Ecologia Environment vegetation type	Ecologia Environment vegetation description
ChAiTa	<i>Corymbia hamersleyana</i> open woodland over <i>Acacia inaequilatera</i> tall sparse shrubland over <i>Triodia angusta</i> and <i>Triodia wiseana</i> low hummock grassland	Tw3	<i>Triodia wiseana</i> and <i>Triodia basedowii</i> hummock grassland
EIAtEm	<i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> and <i>Terminalia circumalata</i> low open woodland over <i>Acacia tumida</i> var. <i>pilbarensis</i> tall open shrubland over <i>Eriachne mucronata</i> and <i>Triodia wiseana</i> low open tussock grassland/hummock grassland	-	
EITw	<i>Eucalyptus leucophloia</i> subsp. <i>leucophloia</i> low open woodland over <i>Triodia wiseana</i> and <i>Triodia brizoides</i> low open hummock grassland	EIApTw	<i>Eucalyptus leucophloia</i> isolated trees, over <i>Acacia ptychophylla</i> sparse shrubland, over <i>Triodia wiseana</i> open hummock grassland
EvAtCc	<i>Eucalyptus victrix</i> mid woodland over <i>Acacia tumida</i> var. <i>pilbarensis</i> , <i>Melaleuca glomerata</i> and <i>Acacia amplexiceps</i> tall open shrubland over * <i>Cenchrus ciliaris</i> and <i>Triodia longiceps</i> low open tussock grassland/hummock grassland/sedgeland	EvCc	± <i>Eucalyptus victrix</i> ± <i>Eucalyptus camaldulensis</i> open mid woodland, over <i>Cenchrus ciliaris</i> tussock grassland

4.2.1 ADEQUACY OF SURVEY

A species accumulation curve (**Figure 3**) was generated to display adequacy of sampling: if the curve has reached (or nearly reached) an asymptote, it is considered likely that most species have been recorded from the study area. The species accumulation curve, based on quadrat data, appears to be approaching an asymptote. A Bootstrap estimate of species richness calculated that 222.9 taxa could be expected to occur within the survey area based on this data, which is only slightly higher than the total number of flora taxa recorded (218) when opportunistic collections are included. Therefore, it is considered likely that the majority of taxa present during the survey timeframes were recorded.

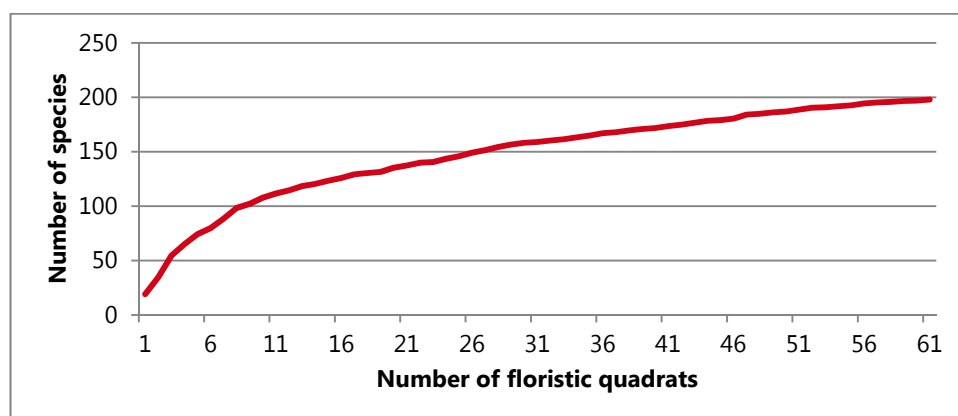


Figure 3: Species accumulation curve

4.1 SURVEY LIMITATIONS

Survey design: The survey was quadrat based. A minimum of three quadrats was recorded per mapped vegetation type where sufficient area was available. Vegetation types with less than three quadrats are geographically restricted in extent.

Survey type: Two phase detailed flora and vegetation survey with targeted conservation significant flora searches. The survey area is largely uncleared and has the potential to include conservation significant species that may be directly or indirectly impacted by potential mining and ancillary activities.

Type of vegetation classification system: Vegetation classified at NVIS Level V (ESCAVI 2003) using largely structural vegetation types defined using dominant and characteristic species and vegetation structure as recorded during the field surveys.

Table 13: Botanical Limitations

Possible limitations	Constraints (yes/no): Significant, moderate or negligible	Comment
Availability of contextual information at a regional and local scale	No	A significant number of reports were available to provide local and regional context (Section 2.3)
Competency/experience of the team conducting the survey, including experience in the bioregion surveyed	No	Field surveys were conducted by teams of two personnel led by an experienced botanist. The May field survey was led by Jared Nelson and the September field survey by Stephen Kern, both with over 10 years' experience with flora and vegetation surveys in the Pilbara, assisted by personnel with at least five years' relevant experience. Plant identification was largely undertaken by Stephen Kern.
Proportion of the flora recorded and/or collected, and any identification issues	No	Two of 218 taxa (0.92%) recorded during the field survey were not identified to species level due to lack of reproductive material. None are likely to be of conservation significance. The species accumulation curve, when taking opportunistic observation records, indicates that most species are likely to have been recorded.
Was the appropriate area fully surveyed (effort and extent)	No	The area was fully and adequately surveyed at sufficient intensity over two phases in 2018. A helicopter was provided in order to access areas that could not be easily reached on foot.
Access restrictions within the survey area	Negligible	General access due to lack of track access and rugged terrain (partly alleviated by access to a helicopter for part of the survey). <i>Eucalyptus camaldulensis</i> vegetation type/s not accessible due to occurrences occurring in heritage sites.

Possible limitations	Constraints (yes/no): Significant, moderate or negligible	Comment
Survey timing, rainfall, season of survey	Moderate	<p>The survey was conducted over two phases, in May and August 2018. The first phase coincided with the primary survey period (post wet season) and the second phase coincided with the supplementary survey period (dry season), as outlined for Eremaean Botanical Provinces in the <i>Flora and Vegetation Technical Guidance</i> (EPA 2016c). Mean rainfall and monthly rainfall for the 12 months prior to the last survey are shown in Figure 2. The May 2018 survey followed a period of below average rainfall with 62.6 mm from February to April at Marble Bar, representing 35.6% of the mean rainfall for that period. However, Marble Bar received heavy rainfalls during January 2018, totalling 314 mm. There was no rainfall recorded at Marble Bar between the May 2018 and August 2018 survey periods during a timeframe that is typically dry.</p> <p>Rainfall deciles for the May survey (Figure 4, left) indicate that the three months prior to the field survey had average or below average rainfall. The three months prior to the August field survey (Figure 4, right) were average based on the BoM modelling, during what is typically a dry period. It is possible that below average rainfall may have impacted the number of ephemeral flora taxa recorded.</p>
Disturbance that may have affected the results of the survey e.g. fire, flood, clearing	Negligible	<p>A bushfire during July 2018 impacted a substantial proportion of the survey area. However, the phase one survey had already accessed much of this area during May 2018. Fifteen of the phase one quadrats were burnt by this fire.</p>

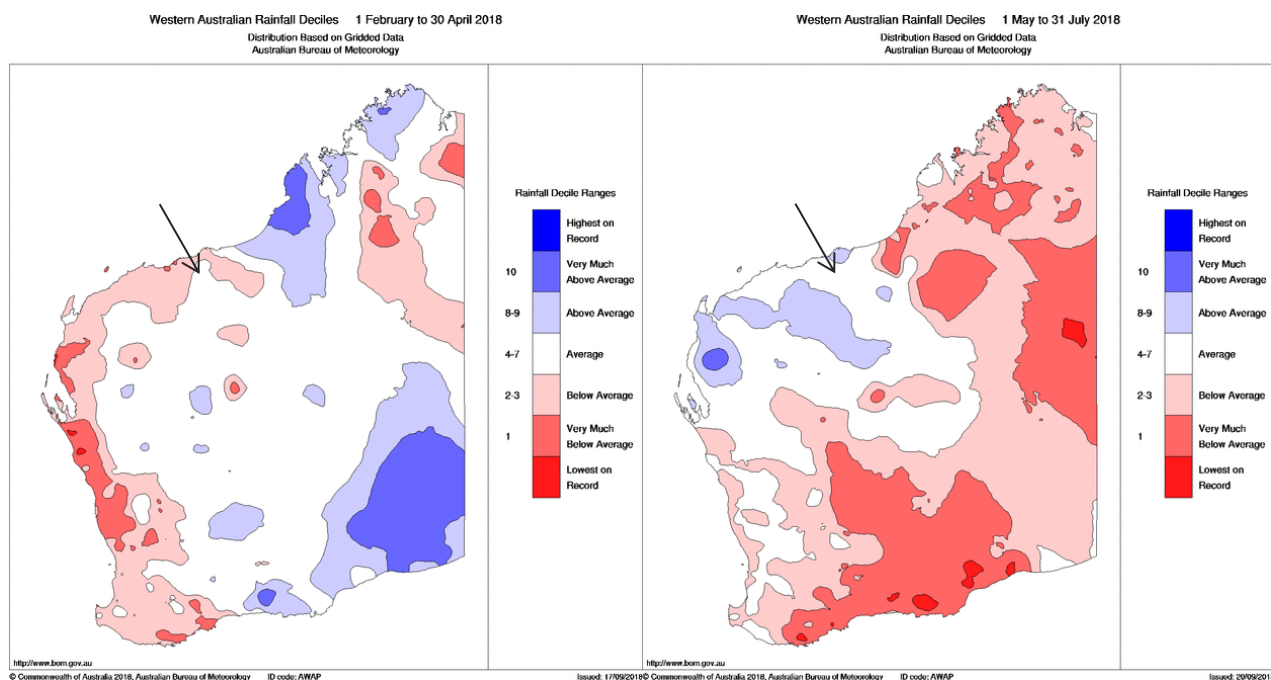


Figure 4: Rainfall deciles for three months prior to May 2018 (left) and August 2018 (right) survey timeframes (BoM 2018b); approximate survey area indicated by arrow

5 DISCUSSION

5.1 FLORA

5.1.1 FLORA INVENTORY

There were 218 vascular flora taxa were recorded within the survey area from 60 quadrats and opportunistic observations. The species accumulation curve, calculated using only quadrat data, and estimates of species richness suggest that the majority of flora taxa were recorded during the 2018 survey timeframe. However, it is anticipated that additional ephemeral flora species would be recorded following periods of higher rainfall.

In comparison to the Glacier Valley survey area, there were 453 flora taxa recorded within the adjacent North Star Mine area (Ecologia Environment 2012b). However, that survey area was substantially larger with more vegetation types (33 vegetation types compared with 11 at Glacier Valley).

5.1.2 CONSERVATION SIGNIFICANT FLORA

5.1.2.1 Threatened Flora

Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) is listed under the Commonwealth EPBC Act as Endangered, and as Schedule 2 (Flora that are considered likely to become extinct or rare, as endangered flora) under the Western Australian WC Act.

Seven populations of *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) were recorded from the Glacier Valley survey area, totalling 261 plants. All except one of these populations had not previously been documented. An additional two unrecorded locations of this species were recorded outside of the survey area with a total of seven plants.

This species has been the subject of intensive survey effort and targeted searches (Ecologia Environment 2012b; 2012c; 2015c; 2016). According to Fortescue's *Pityrodia* sp. Marble Bar Research and Conservation Plan (Ecoscape 2016) there were a total of 9,848 plants of this taxon known prior to the Glacier Valley survey from all combined locations. The total number of new plants recorded from this survey was 267 (including plants outside the Glacier Valley survey area), increasing the total number of known plants to 10,115. The 261 plants that were recorded within the Glacier Valley survey area therefore represent 2.58% of the total known population of *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4). The known distribution of *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) in relation to the Glacier Valley survey area is shown in **Map 3**.

Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) was recorded from the **AaTw¹, AbTw, AeTb, EITw, EvAtCc** vegetation types, which represent 43.5% of the survey area combined. Of these vegetation types, **EvAtCc** is not considered to represent typical habitat for this species, however, the single location within this vegetation type is at the base of a steep rocky area which does represent typical habitat.

Whilst mature plants can often be spotted from several hundred metres, if unobscured by the landscape, smaller plants are often obscured by spinifex. Many of the populations encountered were small, with less than 10 plants. Because of the large area of potential habitat present that has not been ground truthed, it is considered that there is a high possibility of additional populations occurring within the Glacier Valley survey area.

5.1.2.2 Priority Flora

Two PF were recorded from within the study area during the current survey:

- *Ptilotus mollis* (P4); there are 37 records on *NatureMap* (DBCA 2007-2018) for this species, predominantly scattered across the Pilbara Bioregion
- *Triodia basitricha* (P3); there are 21 records on *NatureMap* (DBCA 2007-2018) for this species, most of which occur within the central area of the Pilbara bioregion. Based on ground truthing, the population extends substantially into the adjacent North Star Mine area (north of Glacier Valley). It is presumed that

this taxon corresponds with records previously identified as *T. bitextura* as *T. basitricha* had not been formally described or documented at the time of that survey.

As both of the above PF are relatively widely distributed within the Pilbara bioregion, it is not expected that potential impacts on these species from any development within the Glacier Valley survey area will be significant.

The combined database searches identified 47 conservation significant flora taxa (**Table 20, Table 21**), of which 22 have been recorded within 40 km of the Glacier Valley survey area (**Table 20**). Three of these taxa were recorded during the field assessments (described above). Of the remaining taxa, 10 were considered from the desktop assessment to have a possible occurrence within the survey area based on habitat available. Further analysis of likelihood of occurrence of these species, indicates that seven (indicated in bold) remain as having a possible occurrence:

- *Acacia leeuweniana* (P1); this species is considered unlikely to occur, firstly due to the absence of granite outcrops (only minor granite areas observed on flats) and secondly because of its relatively large habit, increasing the likelihood of detection if present
- *Acacia levata* (P3); as with *A. leeuweniana*, due to the relative absence of granite outcrops and large habit of this species, it is considered unlikely to occur within the survey area
- ***Euphorbia clementii*** (P2); this species was recorded within the adjacent North Star mine area (Ecologia Environment 2012b) and potential habitat exists within the Glacier Valley survey area (valley floors and drainage lines). Additionally, *Euphorbia clementii* is relatively inconspicuous (hard to spot) and resembles several other *Euphorbia* spp. known from the region. Due to the combination of these factors, it remains possible that this species could occur within the Glacier Valley survey area.
- ***Fimbristylis sieberiana*** (P3); there is suitable habitat within the survey area that was not ground truthed. Consequently it remains possible that this species could occur within the Glacier Valley survey area
- ***Gomphrena leptophylla*** (P3); this species has been recorded from a variety of habitats, some of which correspond with habitat occurring within the survey. Additionally, this species is an annual herb, possibly not detectable following periods of below average rainfall such as the 2018 season. It therefore remains possible that this species could occur within the survey area.
- ***Goodenia nuda*** (P4); this species is widespread across the Pilbara (and occurs in other bioregions) and is inconspicuous if not in flower. It was recorded within the adjacent North Star mine area (Ecologia Environment 2012b). Suitable habitat (drainage lines and flats) exists within the survey area and it remains possible that this species could occur.
- ***Gymnanthera cunninghamii*** (P3); this species was recorded within the adjacent North Star mine area (Ecologia Environment 2012b) and suitable habitat (such as drainage lines) exists within the survey area. Whilst this species is relatively easy to detect due to its large habit, it remains possible that this species could occur within suitable habitat that was not ground truthed.
- ***Nicotiana umbratica*** (P3); this species has been recorded from habitats such as gorges, which are known to occur within the survey area. Additionally, this species is an annual herb, possibly not detectable following periods of below average rainfall such as the 2018 season. It therefore remains possible that this species could occur within the survey area, including in areas that were not ground truthed.
- *Terminalia supranitifolia* (P3); this species is a large shrub or tree, typical from basalt or dolerite boulder piles. This habitat was not encountered during the survey and it is considered unlikely that this species could occur within the survey area.
- ***Triodia chichesterensis*** (P3); this species has been recorded from a variety of habitats and it is possible that suitable habitat exists within the survey area. It therefore remains possible that this species could occur within the survey area.

5.1.3 LOCAL AND REGIONAL SIGNIFICANCE OF FLORA

Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) is locally endemic with a known range that extends less than 50 km. No other species recorded are considered locally endemic to the region.

5.1.4 INTRODUCED SPECIES

Four introduced species (weeds) were recorded from within the survey area: **Aerva javanica*, **Calotropis procera*, **Cenchrus ciliaris* and **Flaveria trinervia*. None of these are listed as WONS species. **Calotropis procera* is listed as a Declared Pest Plant under the BAM Act. It is included in the exempt category, therefore there are no management requirements for this species.

Two species (**Aerva javanica* and **Cenchrus ciliaris*) have high ecological impact and rapid invasiveness according to DPaW's weed prioritisation ranking (DPaW 2016).

The relative impact of each introduced species within the survey area is as follows:

- **Aerva javanica*; scattered populations were recorded from the survey area at low density, considered low overall impact
- **Calotropis procera*; one population was recorded near the south eastern boundary of the study area, considered moderate impact within a restricted area.
- **Cenchrus ciliaris*; commonly a dominant species of the **EvAtCc** vegetation type, therefore considered moderate impact within restricted areas of riparian habitats.
- **Flaveria trinervia*; recorded from only two **EvAtCc** quadrats at low density, considered minor impact within the survey area.

5.2 VEGETATION

5.2.1 VEGETATION TYPES

Eleven vegetation types were recorded from the survey area, six of these were associated with hills, three were associated with drainage lines or gorges and two occurred within flats of valley floors. The floristic analysis indicated that five of the vegetation types represent distinct floristic units, four vegetation types are mostly distinct (with the exception of a few outliers) and two are only broadly grouped.

5.2.2 CONSERVATION SIGNIFICANT VEGETATION

No TECs or PECs are known to occur within the vicinity of the survey area. None of the vegetation types recorded within the survey area are considered similar to any currently described TECs or PECs.

5.2.3 SIGNIFICANT VEGETATION

Based on the criteria provided in the *Flora and Vegetation Technical Guidance*, a number of vegetation types may be considered as significant. These are discussed below.

5.2.3.1 Groundwater Dependent Ecosystems

GDE mapping (Australian Government & BoM 2017), indicates that the Glacier Valley survey area corresponds with areas considered 'low' or 'moderate' potential for groundwater interaction. The only species recorded that is considered to be characteristic of a groundwater dependent ecosystem was *Eucalyptus camaldulensis* subsp. *refulgens*. This species is known to be a dominant species within the heritage area on the boundary of the study area (**Map 4**), which is therefore considered likely to be indicative of a groundwater dependant ecosystem. Isolated trees were occasionally observed within the **EvAtCc** vegetation type, though not at a high enough density to consider those areas as groundwater dependant.

5.2.3.2 Potential Groundwater Dependent Ecosystems

Vegetation type **EvAtCc** (*Eucalyptus victrix* mid woodland over *Acacia tumida* var. *pilbarensis*, *Melaleuca glomerata* and *Acacia ampliceps* tall open shrubland over **Cenchrus ciliaris* and *Triodia longiceps* low open tussock grassland/hummock grassland/sedgeland) was dominated by *Eucalyptus victrix* that is considered to be a facultative phreatophyte, although there is some evidence that in some circumstances this species is not dependent on groundwater (see **Section 1.4.5.2**). The **EvAtCc** vegetation type was associated with mid-order drainage lines within the survey area, with a total extent of 133.8 ha (2.78%).

5.2.4 LOCAL AND REGIONAL SIGNIFICANCE OF VEGETATION

Two of vegetation types within the study area had small extents relative to other vegetation types, indicating that they may be locally significant. These were:

- **CfAtEm**, occupying 3.17 ha (0.07% of the survey area)
- **AeTb**, occupying 21.18 ha (0.44% of the survey area).

Aside from their small extent, they are not considered as significant unless they are significant for reasons other than their size (see above).

5.2.5 VEGETATION CONDITION

The vegetation condition over the five tenement areas varied from Excellent to Good, with the majority of vegetation (94.8%) mapped as Excellent condition. The presence and density of weeds was the primary factor influencing vegetation condition, particularly **Cenchrus ciliaris*. Impacts of grazing by cattle or other hooved animals was also observed within several drainage lines, affecting the vegetation condition rating.

6 CONCLUSIONS

6.1 FACTOR CONSIDERATIONS

Considerations for EIA for the factor *Flora and Vegetation* (EPA 2016a) include, but are not necessarily limited to:

- application of the mitigation hierarchy to avoid and minimise impacts to flora and vegetation, where possible
- the flora and vegetation affected by the proposal
- the potential impacts and the activities that will cause them, including direct and indirect impacts
- the implications of cumulative impacts
- whether surveys and analyses have been undertaken to a standard consistent with guidance
- the scale at which impacts to flora and vegetation are considered
- the significance of the flora and vegetation, and the risk to the flora and vegetation
- the current state of knowledge of flora and vegetation and the level of confidence underpinning the predicted residual impacts
- whether proposed management and mitigation approaches are technically and practically feasible
- whether the proposal area will be revegetated in a manner that promotes biological diversity and ecological integrity.

Various issues are frequently of significance within the environmental impact assessment process. These issues, and the potential impact from the proposed works, are summarised below.

6.1.1 HABITAT LOSS, DEGRADATION AND FRAGMENTATION

The single pre-European vegetation association associated with the survey area has more than 99% of the original extent remaining. The small scale of clearing for mining within these tenements is unlikely to have a significant effect on the pre-European vegetation association extent.

While degradation of the survey area will undoubtedly occur with the proposed mining development within the survey area, the scale of degradation is unlikely to be significant. Due to the large remaining extents, fragmentation is unlikely to be a significant issue for the vegetation. None of the vegetation types recorded are of conservation significance.

6.1.2 INVASIVE SPECIES

Four introduced species were recorded from the survey area tenements; one is a Declared Pest plant (**Calotropis procera*), none are WONS species.

Buffel Grass (**Cenchrus ciliaris*), introduced as pastoral species, has significantly affected vegetation condition, mainly in riparian vegetation types. The presence and impact of this species is not a result of mining activities, and mining is unlikely to significantly increase the impact.

Other introduced species currently occur sporadically and are having little effect on vegetation condition (with the exception of the single location of **Calotropis procera*). Whilst mining activities may increase their extent, density and impact it is possible, with management, to minimise these effects.

6.1.3 FIRE REGIMES

Fire occurs naturally in the landscape as a result of lightning strike and vegetation has evolved to recover rapidly. Fire has also been used by Traditional Owners to flush game and generate new growth that attracts herbivores, and has been used by pastoralists to generate new growth that is more palatable to livestock.

Any proposed mining activities are unlikely to alter the frequency, intensity or extent of fires.

6.1.4 CHANGING CLIMATE

Climate change in the Pilbara region of Western Australia is likely to increased frequency and intensity of cyclones and be responsible for increases in temperature (Western Australian Government 2012).

Climate change impacts on native flora and vegetation may be of importance as a cumulative impact when taking all changing factors into account, however, on its own, climate change is unlikely to be a significant factor in the survey area. Given the small scale of potential works (mines, associated infrastructure and plant), any effects on the flora and vegetation cumulatively with climate change are unlikely to be significant.

6.1.5 STATE OF KNOWLEDGE

All other flora species are well known and it is unlikely that any flora knowledge gaps of the survey areas are likely to be of significance. *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) is a Threatened Flora species that is not formally described, though considered taxonomically distinct. Whilst it is geographically restricted, its distribution has been well documented by previous surveys, including targeted searches.

It is unlikely that any knowledge gaps relating to the vegetation of the survey areas are likely to be of significance.

It is considered the 'application of general ecological principles' are likely to be a reasonable guide to understanding the flora and vegetation of the survey area.

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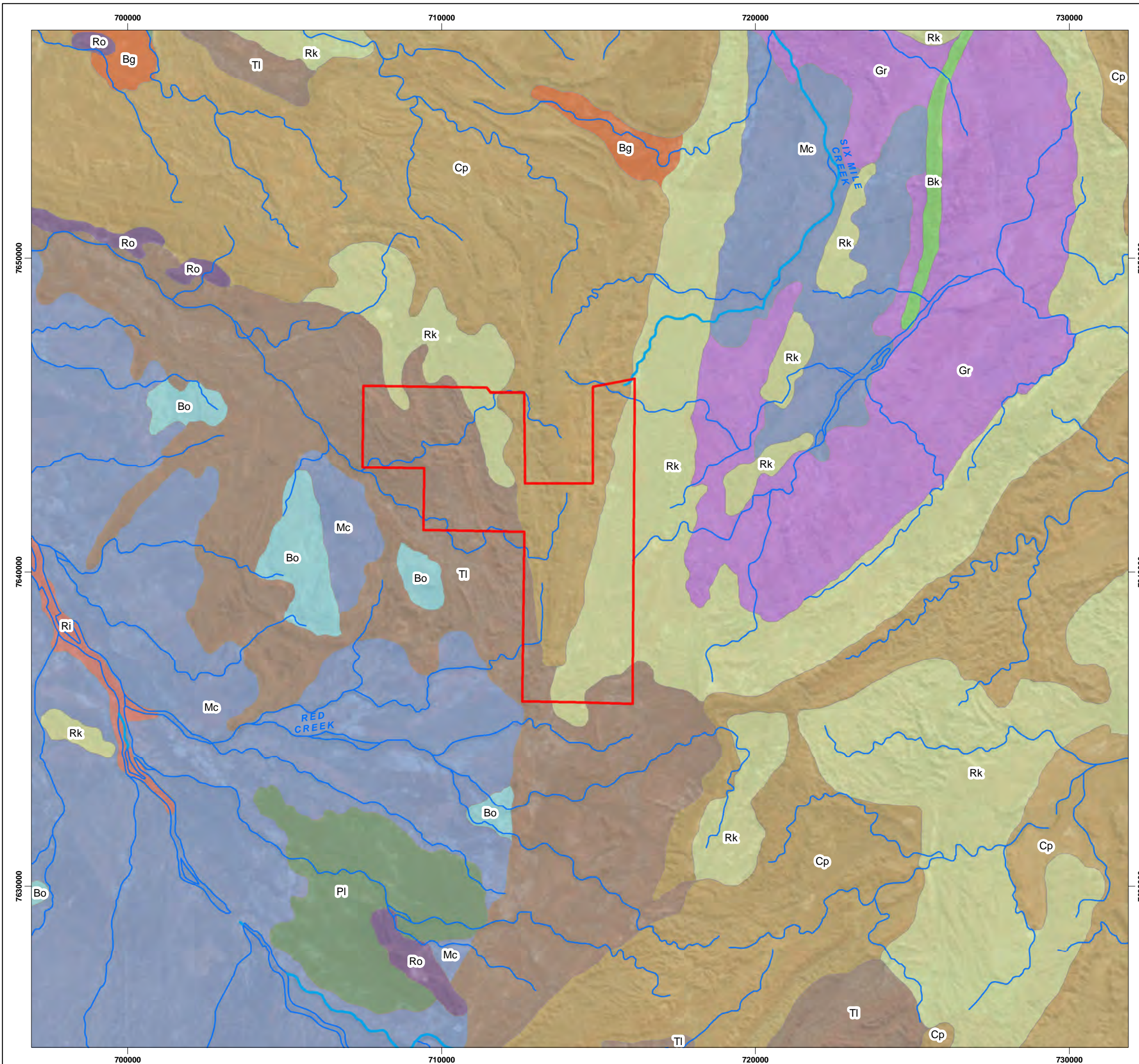
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MAPS



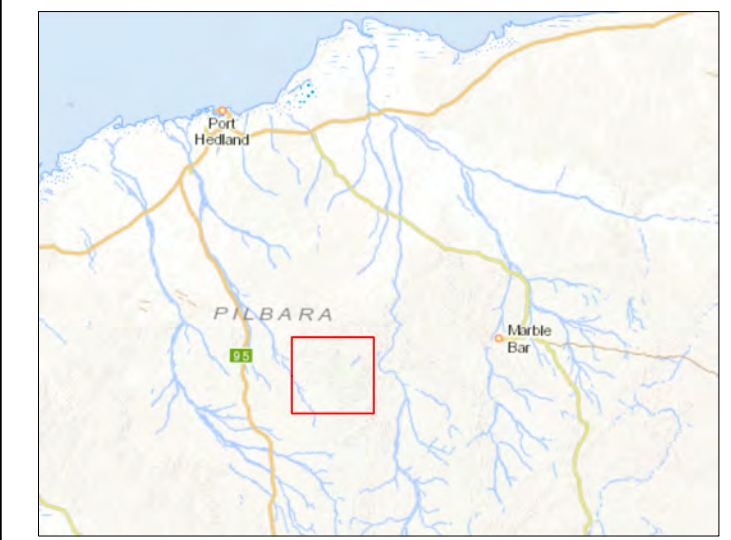
Legend

- Survey Area
- Rivers
- Creek
- Watercourse Areas

Land Systems

- Bg, Boolgeeda System
- Bk, Black System
- Bo, Boolaloo System
- Cp, Capricorn System
- Gr, Granitic System
- Mc, Macroy System
- Pl, Platform System
- Ri, River System
- Rk, Rocklea System
- Ro, Robe System
- Tl, Talga System
- Ua, Uaroo System

DATASOURCES:
 SOURCE DATA: MRWA ROAD CENTERLINES (2012)
 SERVICE LAYERS: NATMAP COLOUR TOPOGRAPHIC BASEMAP SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER

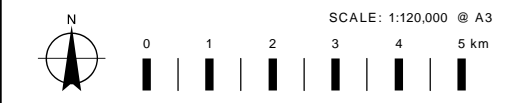


LAND SYSTEMS UNDERLYING THE STUDY AREA

GLACIER VALLEY EXTENSION FLORA AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

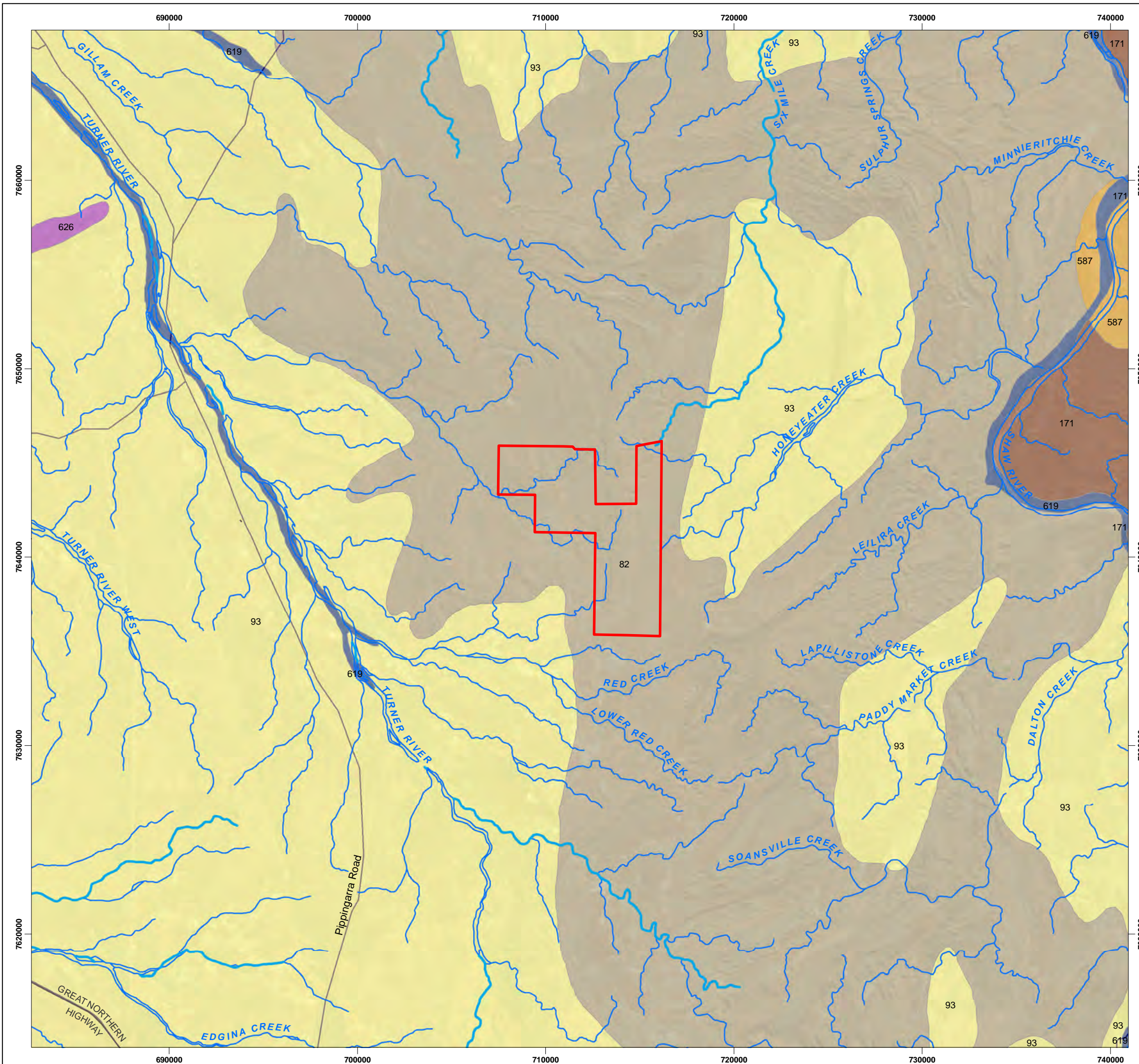
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 PROJECTION: TRANSVERSE MERCATOR
 DATUM: GDA 1994
 UNITS: METER



PROJECT NO: 4148-18

REV	AUTHOR	APPROVED	DATE
0	DR	AF	02/03/2018

MAP 01



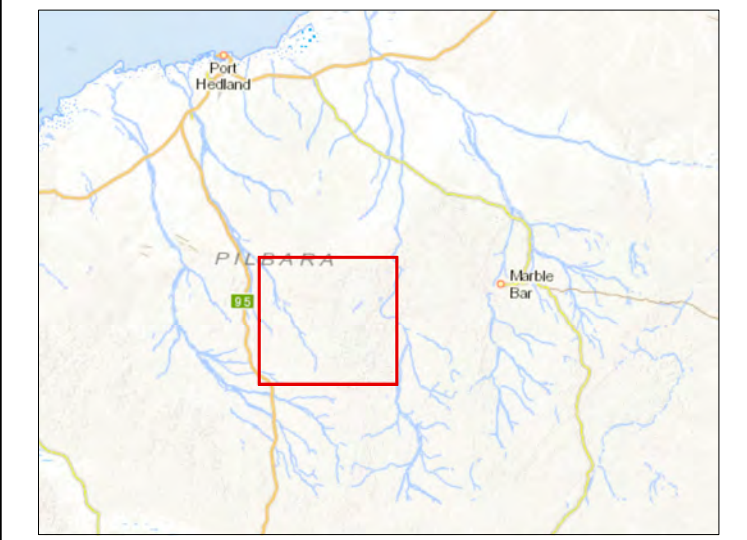
LEGEND

- Survey Area
- Rivers
- Creek
- Watercourse Areas
- Roads

Vegetation Association

- 82: Hummock grasslands, low tree steppe; snappy gum over *Triodia wiseana*
- 93: Hummock grasslands, shrub steppe; kanji over soft spinifex
- 171: Hummock grasslands, low tree steppe; snappy gum over soft spinifex and *Triodia brizoides*
- 587: Mosaic: Hummock grasslands, open low tree-steppe; snappy gum over *Triodia wiseana* / Hummock grasslands, shrub-steppe; kanji over *Triodia pungens*
- 619: Medium woodland; river gum (*Eucalyptus camaldulensis*)
- 626: Hummock grasslands, shrub-steppe; kanji over soft spinifex and *Triodia brizoides*

DATASOURCES:
 SOURCE DATA: MRWA ROAD CENTERLINES
 SERVICE LAYERS: NATMAP COLOUR TOPOGRAPHIC BASEMAP SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR, GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGIRD, IGN, AND THE GIS USER COMMUNITY



PRE-EUROPEAN VEGETATION ASSOCIATIONS

GLACIER VALLEY EXTENSION FLORA AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

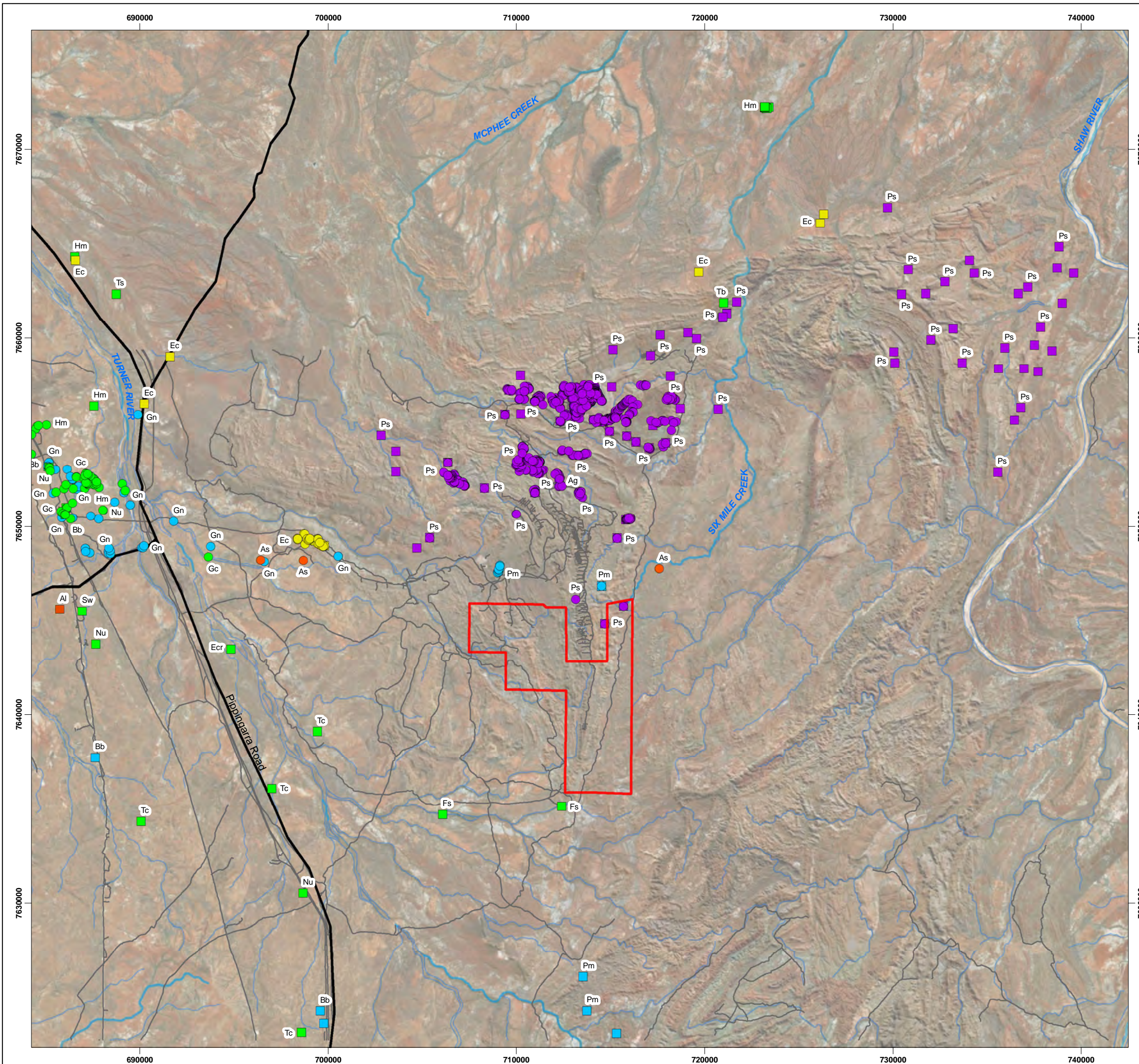
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 DATUM: GDA 1994
 UNITS: METER

SCALE: 1:200,000 @ A3

PROJECT NO: 4148-18

REV	AUTHOR	APPROVED	DATE
0	DR	AF	02/03/2018

MAP
02



LEGEND

- Survey Area
- Roads
- FMG Tracks and Roads
- Rivers
- Watercourse
- Watercourse Areas
- Threatened Flora
- Priority 1
- Priority 2
- Priority 3
- Priority 4

DBC Flora Databases

- Threatened Flora
- Priority 1
- Priority 2
- Priority 3
- Priority 4

Fortescue Flora Database

- Threatened Flora
- Priority 1

- Species Labels**
- | | |
|---|--|
| As: <i>Abutilon</i> sp. <i>Pritzelianum</i> (S. van Leeuwen 5095): Priority 1 | Hm: <i>Heliotropium muticum</i> : Priority 3 |
| Ag: <i>Acacia glaucoacaesia</i> : Priority 3 | Nu: <i>Nicotiana umbratica</i> : Priority 3 |
| Al: <i>Acacia leeuweniana</i> : Priority 1 | Ph: <i>Phyllanthus hebecarpus</i> : Priority 3 |
| Alav: <i>Acacia levata</i> : Priority 3 | Ps: <i>Pityrodia</i> sp. Marble Bar (G. Woodman and D. Coultas DCSC-Opp 07): Priority 1 - Endangered |
| Bb: <i>Bulbostylis burbridgeae</i> : Priority 4 | Pm: <i>Ptilotus mollis</i> : Priority 4 |
| Cm: <i>Cochlospermum macnamarae</i> : Priority 1 | Ri: <i>Rothia indica subsp. australis</i> : Priority 3 |
| Ecr: <i>Eragrostis crateriformis</i> : Priority 3 | Ss: <i>Schoenus</i> sp. Marble Bar (D. Coultas and S. Coultas DCSC-Opp 07): Priority 1 |
| Ec: <i>Euphorbia clementii</i> : Priority 2 | Sw: <i>Stylidium weeliwoilli</i> : Priority 3 |
| Fs: <i>Fimbristylis sieberiana</i> : Priority 3 | Ts: <i>Terminalia supranitifolia</i> : Priority 3 |
| Gf: <i>Gomphrena leptophylla</i> : Priority 3 | Tb: <i>Triodia basitricha</i> : Priority 3 |
| Gn: <i>Goodenia nuda</i> : Priority 4 | Tc: <i>Triodia chichesterensis</i> : Priority 3 |
| Gc: <i>Gymnanthera cunninghamii</i> : Priority 3 | |
| Hmu: <i>Heliotropium murinum</i> : Priority 3 | |

DATASOURCES:
 SOURCE DATA: MRWA ROAD CENTERLINES (2012), DAFWA LAND SYSTEMS MAPPING (2014).
 AERIAL:
 SERVICE LAYERS: NATMAP COLOUR TOPOGRAPHIC BASEMAP SOURCE: ESRI, DIGITALGLOBE, GEOEYE.



**DATABASE SEARCH RESULTS
 FLORA & COMMUNITIES**

GLACIER VALLEY EXTENSION FLORA
 AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

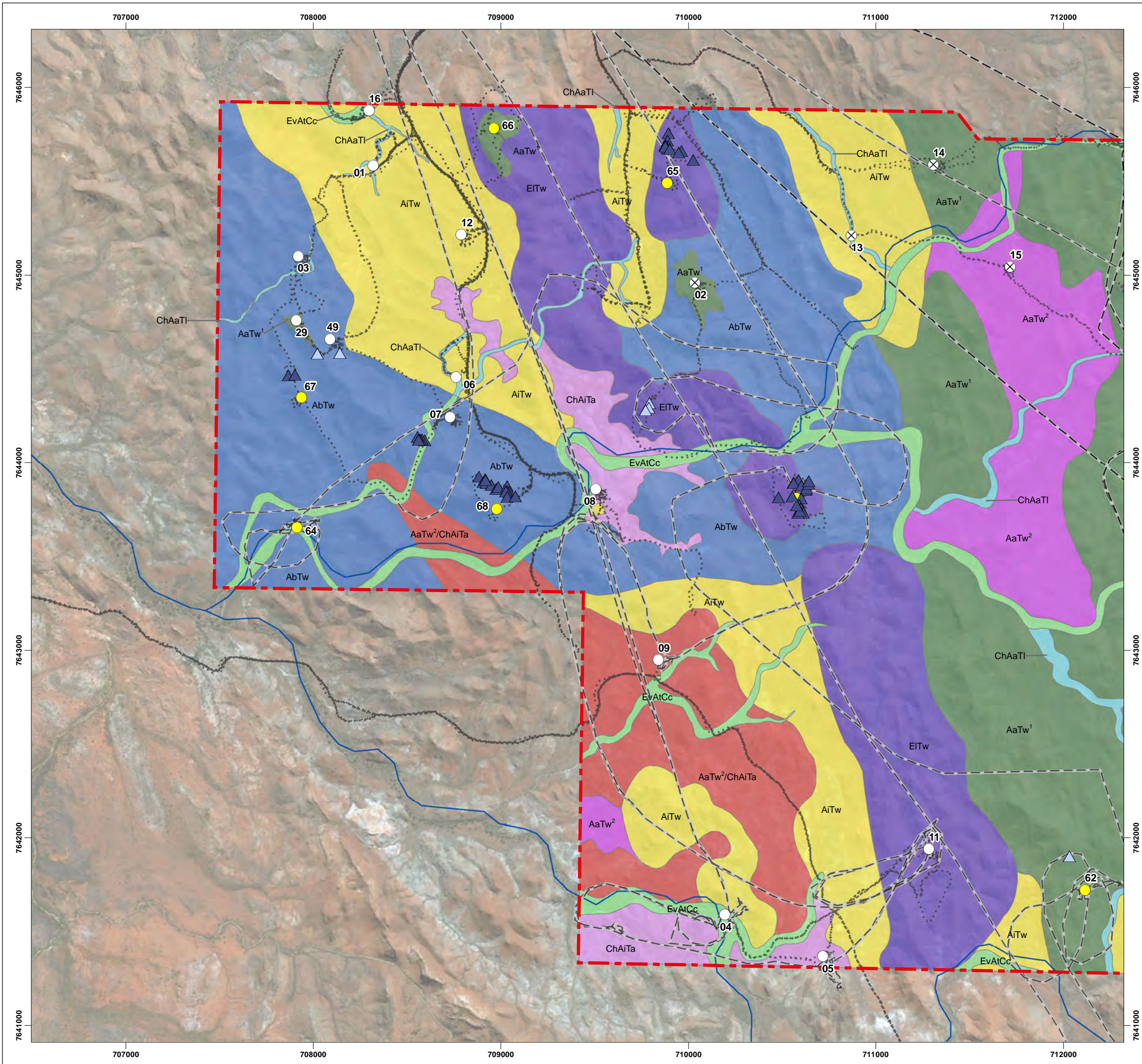
COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
 PROJECTION: TRANSVERSE MERCATOR
 DATUM: GDA 1994
 UNITS: METER

SCALE: 1:200,000 @ A3

PROJECT NO: 4148-18

REV	AUTHOR	APPROVED	DATE
0	DR	AF	02/03/2018

**MAP
03**



LEGEND

Survey Area
 Survey Tracks
 Helicopter Tracks
 Quadrat - scored Phase 2 only
 Quadrat - scored Phase 1 and 2
 Quadrat - scored Phase 1 only

Vegetation Types

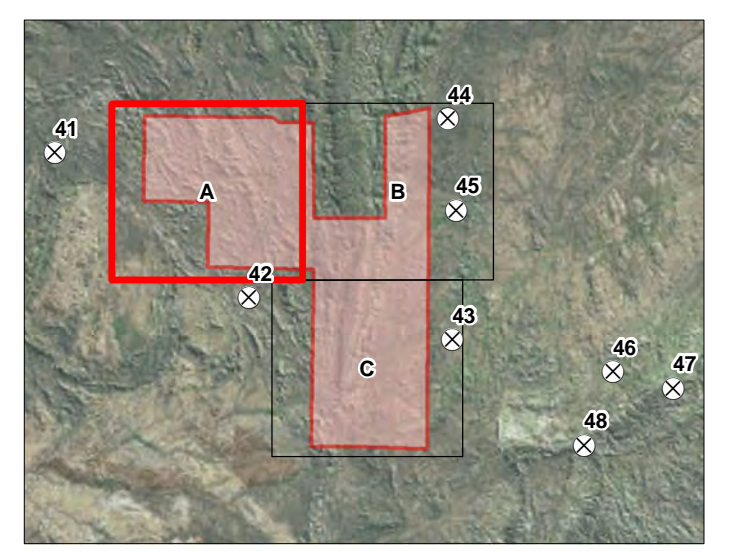
- AaTw¹
- AaTw²
- AaTw²/ChAiTa
- AbTw
- AiTw
- AoTw
- ChAaTI
- ChAiTa
- EITw
- EvAtCc

Conservation Significant Flora Locations

- Pityrodia* sp. Marble Bar (G. Woodman and D. Coultas GWDC Opp 4) - TF
- Ptilotus mollis* - P4

Ecoscape 2018 Records

DATASOURCES:
 SERVICE LAYERS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AERGRID, IGN, AND THE GIS USER COMMUNITY



**VEGETATION TYPES AND
 CONSERVATION SIGNIFICANT
 FLORA LOCATIONS**
 GLACIER VALLEY EXTENSION
 FLORA AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

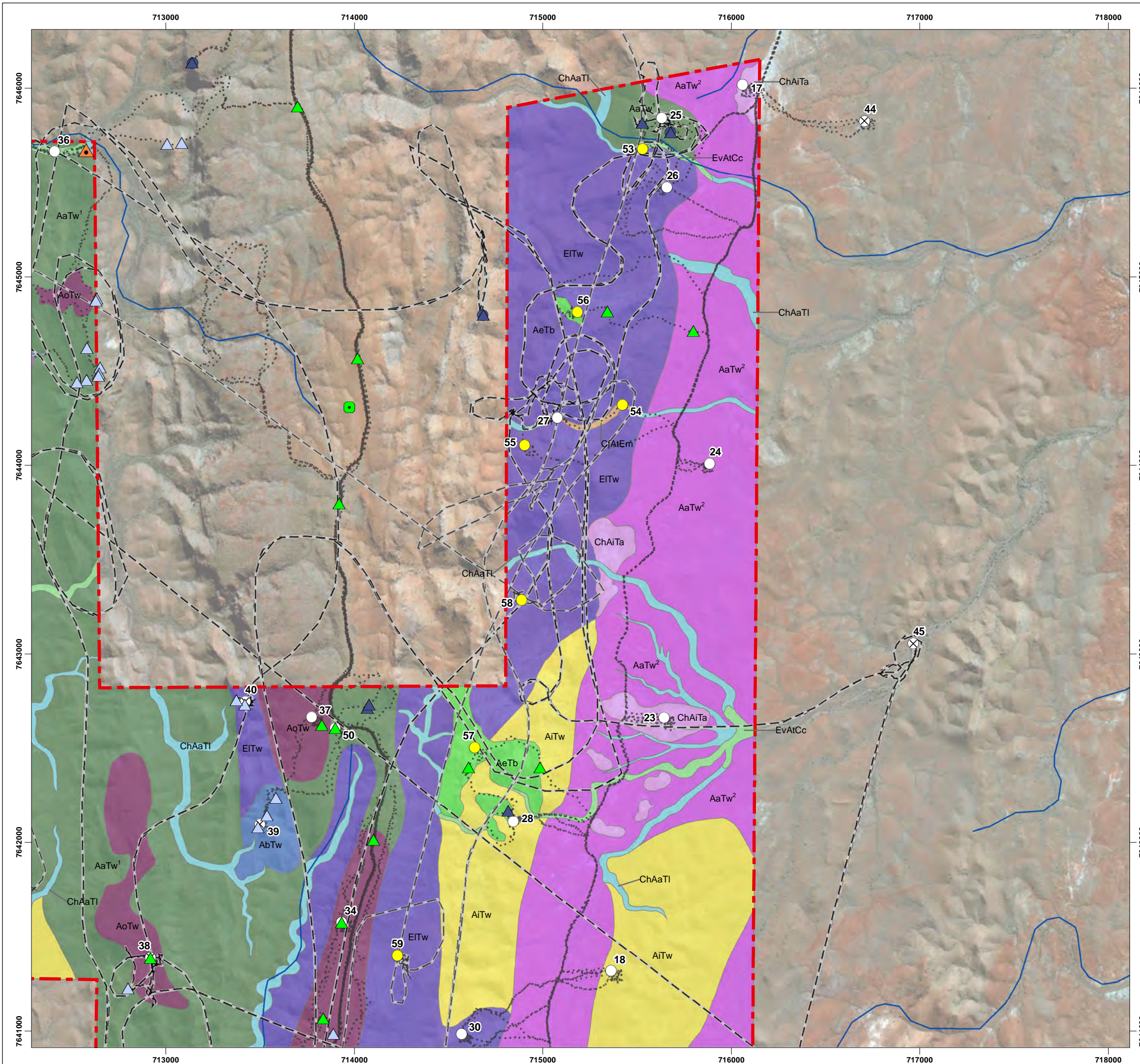
COORDINATE SYSTEM: GDA 1984 MGA ZONE 50
 PROJECTION: TRANSVERSE MERCATOR
 DATUM: GDA 1984
 UNITS: METER



REV	AUTHOR	APPROVED	DATE
00	JN	SK	12/10/2018

PROJECT NO: 4148-18

**MAP
 4A**



LEGEND

Survey Area
 Survey Tracks
 Helicopter Tracks
 Quadrat - scored Phase 2 only
 Quadrat - scored Phase 1 and 2
 Quadrat - scored Phase 1 only
Eucalyptus camaldulensis surrounding permanent pool

Vegetation Types

- AaTw¹
- AaTw²
- AbTw
- AeTb
- AiTw
- AoTw
- CfAtEm
- ChAaTI
- ChAiTa
- EITw
- EvAtCc

Conservation Significant Flora Locations

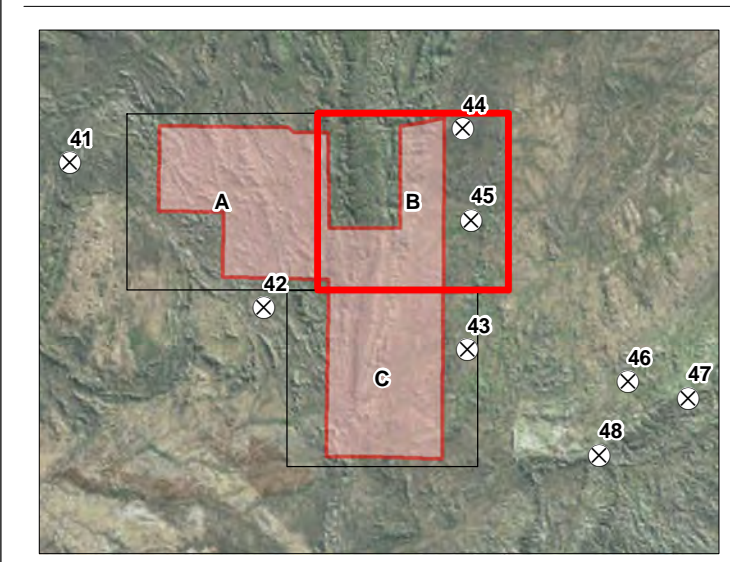
Ecoscape 2018 Records

- Pityrodia* sp. Marble Bar (G. Woodman and D. Coultas GWDC Opp 4) - TF
- Triodia basitricha* - P3
- Ptilotus mollis* - P4

Previous Significant Flora Locations

- Pityrodia* sp. Marble Bar (G. Woodman and D. Coultas GWDC Opp 4) - TF
- Triodia bitextura* - (inferred to be *T. basitricha* - P3)

DATASOURCES:
 SERVICE LAYERS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRIID, IGN, AND THE GIS USER COMMUNITY



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**VEGETATION TYPES AND
 CONSERVATION SIGNIFICANT
 FLORA LOCATIONS**

GLACIER VALLEY EXTENSION
 FLORA AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

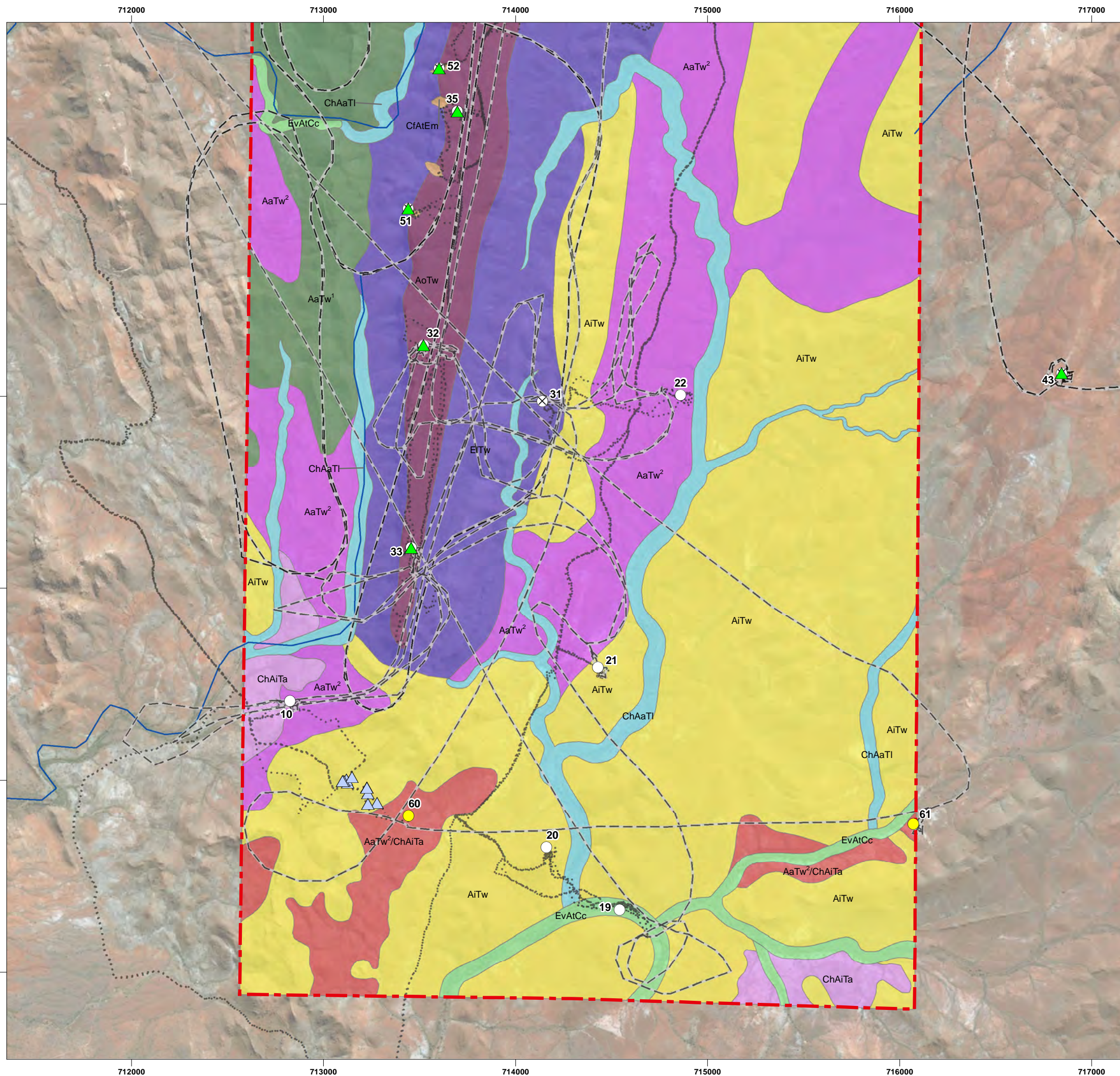
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 PROJECTION: TRANSVERSE MERCATOR
 DATUM: GDA 1984
 UNITS: METER

SCALE: 1:20,000 @ A3

PROJECT NO: 4148-18

REV	AUTHOR	APPROVED	DATE
00	JN	SK	12/10/2018

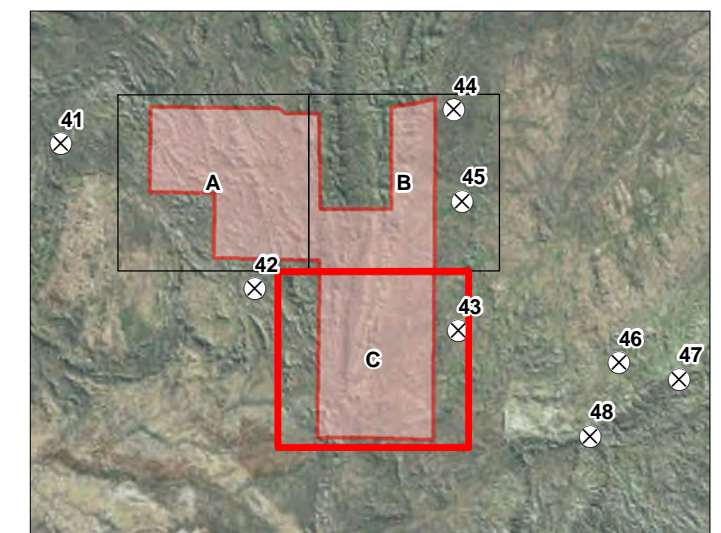
**MAP
 4B**



LEGEND

- Survey Area
 - Survey Tracks
 - Helicopter Tracks
 - Quadrat - scored Phase 2 only
 - Quadrat - scored Phase 1 and 2
 - Quadrat - scored Phase 1 only
- Vegetation Types**
- AaTw¹
 - AaTw²
 - AaTw²/ChAiTa
 - AiTw
 - AoTw
 - CfAiEm
 - ChAaTI
 - ChAiTa
 - EITw
 - EvAtCc
- Conservation Significant Flora Locations**
- Ecoscape 2018 Records**
- Triodia basitricha* - P3
 - Ptilotus mollis* - P4

DATASOURCES:
 SERVICE LAYERS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AERGRID, IGN, AND THE GIS USER COMMUNITY

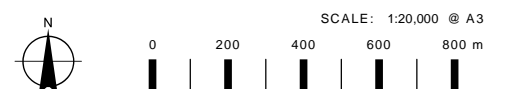


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**VEGETATION TYPES AND
 CONSERVATION SIGNIFICANT
 FLORA LOCATIONS**
 GLACIER VALLEY EXTENSION
 FLORA AND VEGETATION SURVEY

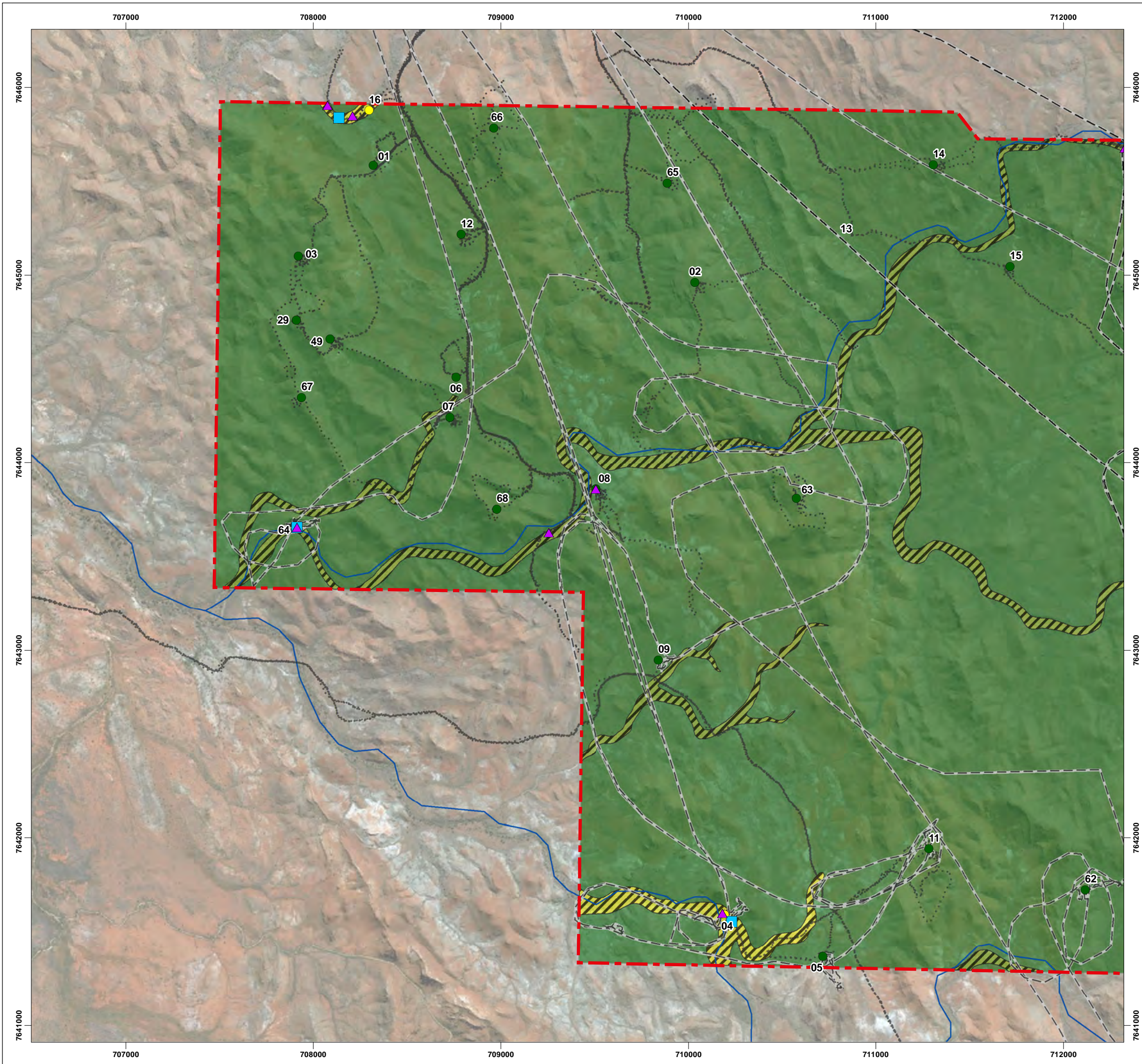
CLIENT: IB OPERATIONS PTY LTD

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



REV	AUTHOR	APPROVED	DATE
00	JN	SK	12/10/2018

**MAP
 4C**



LEGEND

Survey Area
 Helicopter Tracks
 Survey Tracks

Vegetation Types with at least one weed species as a dominant/characteristic species

EvAtCc - *Cenchrus ciliaris

Vegetation Condition

- Excellent
- Very Good
- Good
- Poor (n/a)
- Degraded (n/a)

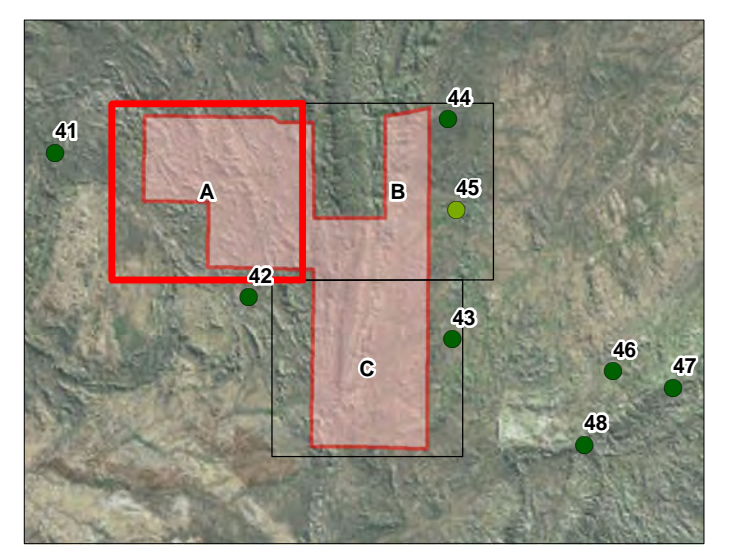
Vegetation Condition Mapping

- Excellent
- Very Good
- Good
- Poor (n/a)
- Degraded (n/a)

Weed Locations

- *Aerva javanica
- *Cenchrus ciliaris

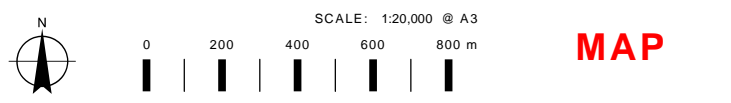
DATASOURCES:
 SERVICE LAYERS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRIID, IGN, AND THE GIS USER COMMUNITY



VEGETATION CONDITION AND SIGNIFICANT WEED LOCATIONS
 GLACIER VALLEY EXTENSION
 FLORA AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

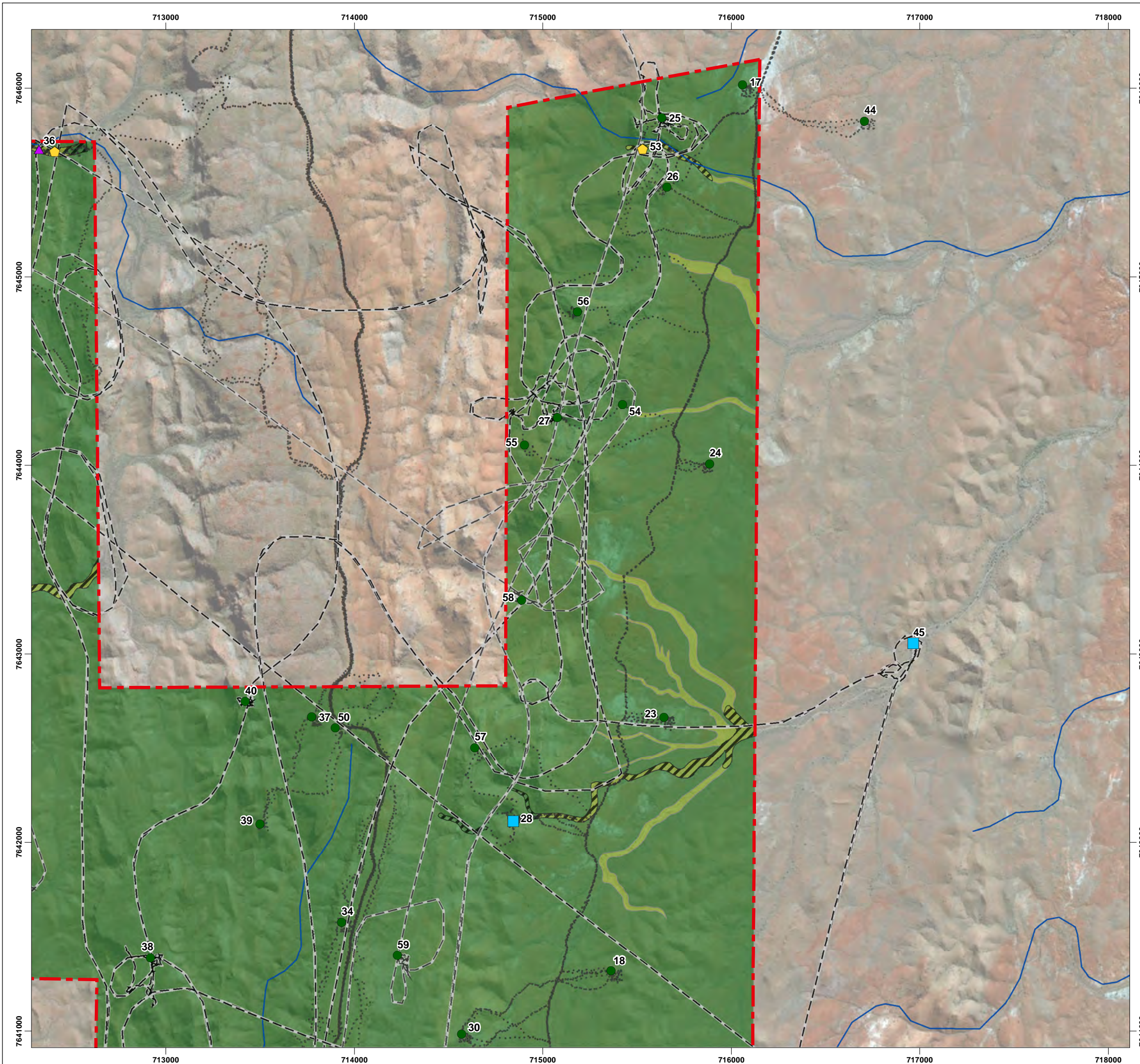
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 PROJECTION: TRANSVERSE MERCATOR
 DATUM: GDA 1994
 UNITS: METER



REV	AUTHOR	APPROVED	DATE
00	JN	SK	12/10/2018

PROJECT NO: 4148-18

MAP
5A



LEGEND

Survey Area
 Helicopter Tracks
 Survey Tracks

Vegetation Types with at least one weed species as a dominant/characteristic species

EvAtCc - **Cenchrus ciliaris*

Quadrats

Vegetation Condition

- Excellent
- Very Good
- Good
- Poor (n/a)
- Degraded (n/a)

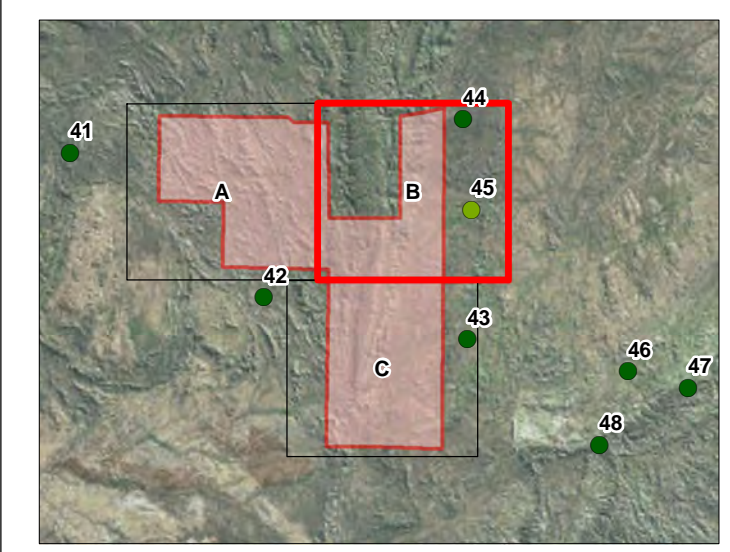
Vegetation Condition Mapping

- Excellent
- Very Good
- Good
- Poor (n/a)
- Degraded (n/a)

Weed Locations

- **Aerva javanica*
- **Cenchrus ciliaris*
- **Flaveria trinervia*

DATASOURCES:
 SERVICE LAYERS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRIID, IGN, AND THE GIS USER COMMUNITY

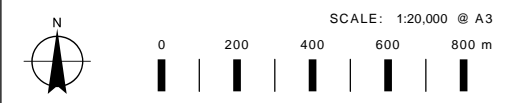


**VEGETATION CONDITION AND
 SIGNIFICANT WEED
 LOCATIONS**

GLACIER VALLEY EXTENSION
 FLORA AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

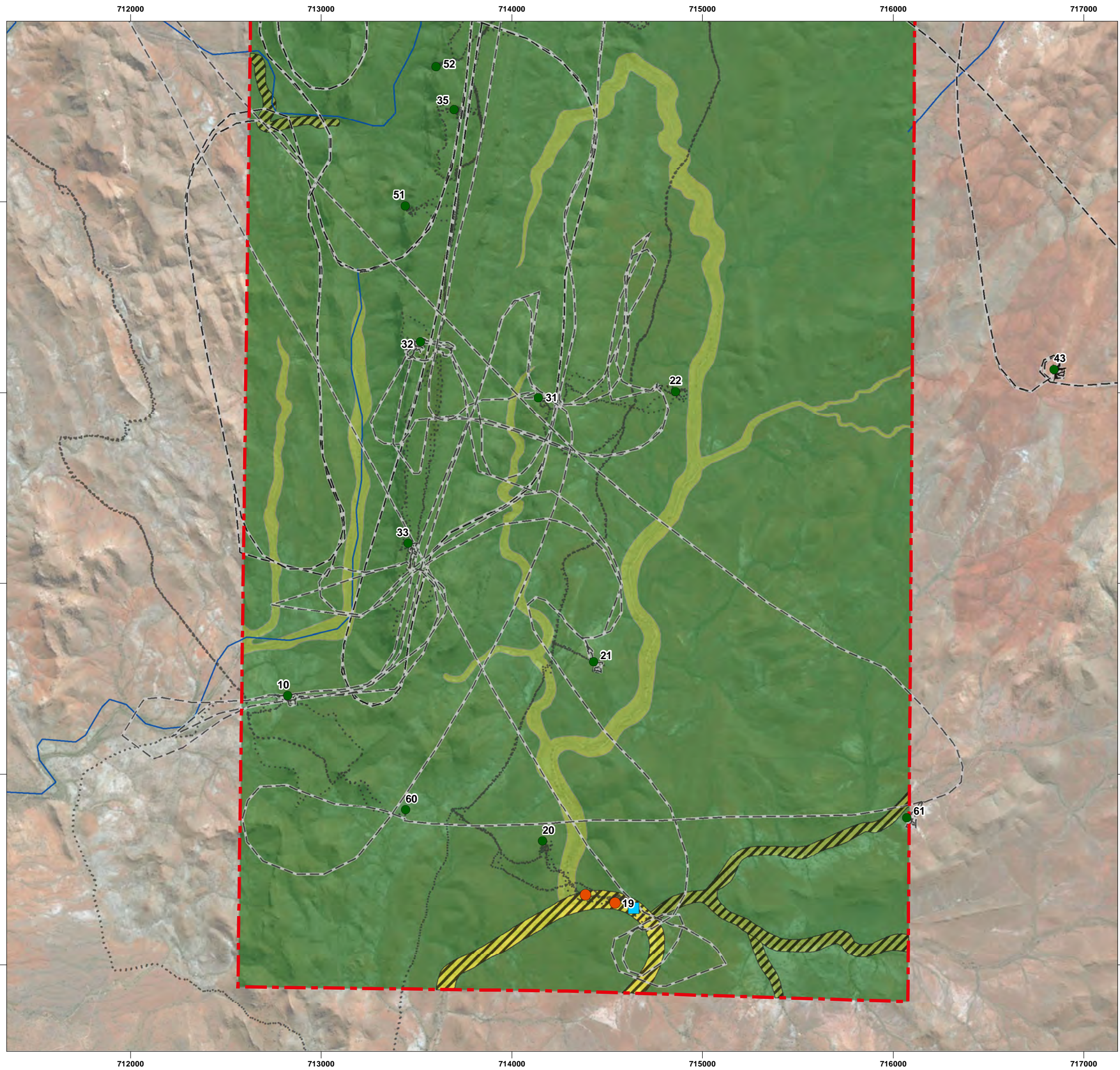
COORDINATE SYSTEM: GDA 1994 MGA ZONE 50
 PROJECTION: TRANSVERSE MERCATOR
 DATUM: GDA 1994
 UNITS: METER



PROJECT NO: 4148-18

REV	AUTHOR	APPROVED	DATE
00	JN	SK	12/10/2018

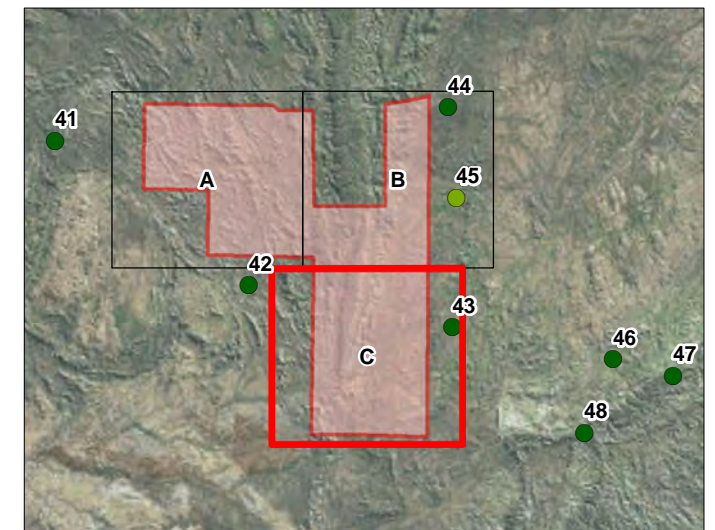
**MAP
 5B**



LEGEND

- Survey Area
- Helicopter Tracks
- Survey Tracks
- Quadrats**
- Vegetation Condition**
- Excellent
- Very Good
- Good
- Poor (n/a)
- Degraded (n/a)
- Vegetation Types with at least one weed species as a dominant/characteristic species**
- EvAtCc - *Cenchrus ciliaris
- Vegetation Condition Mapping**
- Excellent
- Very Good
- Good
- Poor (n/a)
- Degraded (n/a)
- Weed Locations**
- *Calotropis procera
- *Cenchrus ciliaris

DATASOURCES:
 SERVICE LAYERS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRIID, IGN, AND THE GIS USER COMMUNITY

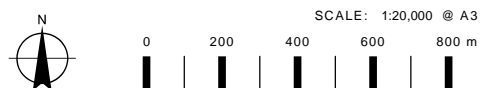


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**VEGETATION CONDITION AND
 SIGNIFICANT WEED
 LOCATIONS**
 GLACIER VALLEY EXTENSION
 FLORA AND VEGETATION SURVEY

CLIENT: IB OPERATIONS PTY LTD

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



REV	AUTHOR	APPROVED	DATE
00	JN	SK	12/10/2018

**MAP
 5C**

APPENDIX ONE DEFINITIONS AND CRITERIA

Table 14: EPBC Act categories for flora and fauna

EPBC ACT 1999 category	Definition
Extinct	A native species is eligible to be included in the extinct category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
Extinct in the wild	A native species is eligible to be included in the extinct in the wild category at a particular time if, at that time: (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
Critically Endangered (CE)	A native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered (EN)	A native species is eligible to be included in the endangered category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Vulnerable (VU)	A native species is eligible to be included in the vulnerable category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
Conservation Dependent	A native species is eligible to be included in the conservation dependent category at a particular time if, at that time: (a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

Table 15: Conservation codes for Western Australian flora and fauna (DPaW 2017)

Conservation Codes for Western Australian Flora and Fauna	
T	<p>Threatened species* Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, and listed under Schedules 1 to 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora (which may also be referred to as Declared Rare Flora).</p> <ul style="list-style-type: none"> • Threatened fauna is that subset of 'Specially Protected Fauna' declared to be 'likely to become extinct' pursuant to section 14(4) of the Wildlife Conservation Act. • Threatened flora is flora that has been declared to be 'likely to become extinct or is rare, or is otherwise in need of special protection' pursuant to section 23F(2) of the Wildlife Conservation Act. <p>The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.</p>
CR	<p>Critically Endangered species Threatened species considered to be facing an extremely high risk of extinction in the wild. Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, in Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.</p>
EN	<p>Endangered species Threatened species considered to be facing a very high risk of extinction in the wild. Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, in Schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.</p>
VU	<p>Vulnerable species Threatened species considered to be facing a high risk of extinction in the wild. Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, in Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.</p>
EX	<p>Presumed extinct species Species which have been adequately searched for and there is no reasonable doubt that the last individual has died. Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, in Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.</p>
IA	<p>Migratory birds protected under an international agreement Birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and the Bonn Convention, relating to the protection of migratory birds. Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, in Schedule 5 of the Wildlife Conservation (Specially Protected Fauna) Notice.</p>
CD	<p>Conservation Dependent fauna Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened. Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, in Schedule 6 of the Wildlife Conservation (Specially Protected Fauna) Notice</p>
OS	<p>Other specially protected fauna Fauna otherwise in need of special protection to ensure their conservation. Published as Specially Protected under the <i>Wildlife Conservation Act 1950</i>, in Schedule 7 of the Wildlife Conservation (Specially Protected Fauna) Notice</p>
P	<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 flora or fauna. 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 list 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.</p>
P1	<p>Priority One: 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 or 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 localities 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.</p>
P2	<p>Priority Two: 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 localities 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.</p>
P3	<p>Priority Three: 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 localities 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 localities 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.</p>

Conservation Codes for Western Australian Flora and Fauna	
P4	<p>Priority Four: Rare, Near Threatened and other species in need of monitoring</p> <p>(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.</p> <p>(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.</p> <p>(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.</p>
<p>¹The definition of flora includes algae, fungi and lichens.</p> <p>²Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population).</p>	

Table 16: DBCA definitions and criteria for TECs and PECs (Department of Environment and Conservation 2013)

Criteria	Definition
Threatened Ecological Communities	
Presumed Totally Destroyed (PD)	<p>An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future.</p> <p>An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies (A or B):</p> <ul style="list-style-type: none"> A. Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats or B. All occurrences recorded within the last 50 years have since been destroyed
Critically Endangered (CR)	<p>An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.</p> <p>An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C):</p> <ul style="list-style-type: none"> A. The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply (i or ii): <ul style="list-style-type: none"> i. geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 10 years); ii. modification throughout its range is continuing such that in the immediate future (within approximately 10 years) the community is unlikely to be capable of being substantially rehabilitated. B. Current distribution is limited, and one or more of the following apply (i, ii or iii): <ul style="list-style-type: none"> i. geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years); ii. there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes; iii. there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes. C. The ecological community exists only as highly modified occurrences that may be capable of being rehabilitated if such work begins in the immediate future (within approximately 10 years).
Endangered (EN)	<p>An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future.</p> <p>An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B, or C):</p> <ul style="list-style-type: none"> A. The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply (i or ii): <ul style="list-style-type: none"> i. the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term future (within approximately 20 years); ii. modification throughout its range is continuing such that in the short term future (within approximately 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated. B. Current distribution is limited, and one or more of the following apply (i, ii or iii): <ul style="list-style-type: none"> i. geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years); ii. there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes; iii. there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes. <p>The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within approximately 20 years).</p>

Criteria	Definition
Vulnerable (VU)	<p>An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range.</p> <p>An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B or C):</p> <ul style="list-style-type: none"> A. The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated. B. The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations. C. The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long term future because of existing or impending threatening processes.
Priority ecological communities	
Priority One	<p><i>Poorly known ecological communities</i></p> <p>Ecological communities with apparently few, small occurrences, all or most not actively managed for conservation (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) and for which current threats exist. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.</p>
Priority Two	<p><i>Poorly known ecological communities</i></p> <p>Communities that are known from few small occurrences, all or most of which are actively managed for conservation (e.g. within national parks, conservation parks, nature reserves, state forest, unallocated Crown land, water reserves, etc.) and not under imminent threat of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities, but do not meet adequacy of survey requirements, and / or are not well defined, and appear to be under threat from known threatening processes.</p>
Priority Three	<p><i>Poorly known ecological communities</i></p> <ul style="list-style-type: none"> i. Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or; ii. Communities known from a few widespread occurrences, which are either large or within significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or; iii. Communities made up of large, and/or widespread occurrences, that may or may not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes. <p>Communities may be included if they are comparatively well known from several localities, but do not meet adequacy of survey requirements and / or are not well defined, and known threatening processes exist that could affect them.</p>
Priority Four	<p>Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list. These communities require regular monitoring.</p> <ul style="list-style-type: none"> i. Rare. Ecological communities known from few occurrences 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 communities are usually represented on conservation lands. ii. Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable. iii. Ecological communities that have been removed from the list of threatened communities during the past five years.
Priority Five	<p><i>Conservation Dependent Ecological Communities</i></p> <p>Ecological Communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.</p>

Table 17: NVIS structural formation terminology, terrestrial vegetation (ESCAVI 2003)

Cover characteristics								
Foliage cover *	70-100	30-70	10-30	<10	» 0 (scattered)	0-5 (clumped)	unknown	
Cover code	d	c	i	r	bi	bc	unknown	
Growth Form	Height Ranges (m)	Structural Formation Classes						
tree, palm	<10,10-30, >30	closed forest	open forest	woodland	open woodland	isolated trees	isolated clumps of trees	tree, palm
tree mallee	<3, <10, 10-30	closed mallee forest	open mallee forest	mallee woodland	open mallee woodland	isolated mallee trees	isolated clumps of mallee trees	tree mallee
shrub, cycad, grass-tree, tree-fern	<1,1-2,>2	closed shrubland	shrubland	open shrubland	sparse shrubland	isolated shrubs	isolated clumps of shrubs	shrub, cycad, grass-tree, tree-fern
mallee shrub	<3, <10, 10-30	closed mallee shrubland	mallee shrubland	open mallee shrubland	sparse mallee shrubland	isolated mallee shrubs	isolated clumps of mallee shrubs	mallee shrub
heath shrub	<1,1-2,>2	closed heathland	heathland	open heathland	sparse heathland	isolated heath shrubs	isolated clumps of heath shrubs	heath shrub
chenopod shrub	<1,1-2,>2	closed chenopod shrubland	chenopod shrubland	open chenopod shrubland	sparse chenopod shrubland	isolated chenopod shrubs	isolated clumps of chenopod shrubs	chenopod shrub
samphire shrub	<0.5,>0.5	closed samphire shrubland	samphire shrubland	open samphire shrubland	sparse samphire shrubland	isolated samphire shrubs	isolated clumps of samphire shrubs	samphire shrub
hummock grass	<2,>2	closed hummock grassland	hummock grassland	open hummock grassland	sparse hummock grassland	isolated hummock grasses	isolated clumps of hummock grasses	hummock grass
tussock grass	<0.5,>0.5	closed tussock grassland	tussock grassland	open tussock grassland	sparse tussock grassland	isolated tussock grasses	isolated clumps of tussock grasses	tussock grass
other grass	<0.5,>0.5	closed grassland	grassland	open grassland	sparse grassland	isolated grasses	isolated clumps of grasses	other grass
sedge	<0.5,>0.5	closed sedgeland	sedgeland	open sedgeland	sparse sedgeland	isolated sedges	isolated clumps of sedges	sedge
rush	<0.5,>0.5	closed rushland	rushland	open rushland	sparse rushland	isolated rushes	isolated clumps of rushes	rush
herb	<0.5,>0.5	closed herbland	herbland	open herbland	sparse herbland	isolated herbs	isolated clumps of herbs	herb
fern	<1,1-2,>2	closed fernland	fernland	open fernland	sparse fernland	isolated ferns	isolated clumps of ferns	fern
bryophyte	<0.5	closed bryophyte-land	bryophyte-land	open bryophyteland	sparse bryophyteland	isolated bryophytes	isolated clumps of bryophytes	bryophyte
lichen	<0.5	closed lichenland	lichenland	open lichenland	sparse lichenland	isolated lichens	isolated clumps of lichens	lichen
vine	<10,10-30, >30	closed vineland	vineland	open vineland	sparse vineland	isolated vines	isolated clumps of vines	vine

Table 18: NVIS height classes (ESCAVI 2003)

Height		Growth form				
Height Class	Height Range (m)	Tree, vine (M & U), palm (single-stemmed)	Shrub, heath shrub, chenopod shrub, ferns, samphire shrub, cycad, tree-fern, grass-tree, palm (multi-stemmed)	Tree mallee, mallee shrub	Tussock grass, hummock grass, other grass, sedge, rush, forbs, vine (G)	Bryophyte, lichen, seagrass, aquatic
8	>30	tall	NA	NA	NA	NA
7	10-30	mid	NA	tall	NA	NA
6	<10	low	NA	mid	NA	NA
5	<3	NA	NA	low	NA	NA
4	>2	NA	tall	NA	tall	NA
3	1-2	NA	mid	NA	tall	NA
2	0.5-1	NA	low	NA	mid	tall
1	<0.5	NA	low	NA	low	low

Source: (based on Walker & Hopkins 1990)

Table 19: Vegetation condition scale for the Eremaean and Northern Botanical Provinces (EPA 2016c)

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.

APPENDIX TWO DESKTOP ASSESSMENT RESULTS

Table 20: Conservation significant flora occurring within 40 km of the survey area

Taxa recorded during the field surveys or previously are highlighted in darker blue; taxa with a 'possible' likelihood are highlighted in lighter blue.

Species	WA Cons. Code	Habitat	Likelihood
<i>Acacia leeuweniana</i>	P1	Granite outcrop, skeletal sandy loam, gravelly sand. Rock outcrops. <i>Acacia retivenea</i> , <i>Terminalia circumalata</i> , <i>Triodia pungens</i> , <i>Acacia tumida</i>	Possible
<i>Acacia levata</i>	P3	Granitic sand or sandy loam. Hillslopes, plain, granite outcrop. <i>Acacia stellaticeps</i> , <i>Triodia pungens</i> , <i>Triodia lanigera</i> , <i>Acacia translucens</i> , <i>Acacia hilliana</i>	Possible
<i>Bulbostylis burbidgeae</i>	P4	Granite outcrop. Granite outcrop, cliff bases. <i>Triodia epactia</i>	Unlikely
<i>Cochlospermum macnamarae</i>	P1	Granite rocks, skeletal soil. Low hills. <i>Triodia</i> , <i>A. tumida</i> .	Unlikely
<i>Eragrostis crateriformis</i>	P3	Clay loam, clay, granite outcrop, cracking clay. Creek banks, depressions, granite outcrop, clay pan. <i>Acacia pyrifolia</i> , <i>Acacia trachycarpa</i> , <i>Acacia tumida</i> , <i>Cenchrus ciliaris</i> , <i>Eucalyptus victrix</i> , <i>Corymbia hamersleyana</i> , <i>Acacia bivenosa</i> , <i>Acacia synchronicia</i> , <i>Triodia epactia</i> , <i>Triodia longiceps</i> , <i>Eucalyptus leucophloia</i> , <i>Chrysopogon fallax</i> , <i>Triodia wiseana</i> , <i>Flueggea virosa</i>	Unlikely
<i>Euphorbia clementii</i>	P2	Red clay loam, colluvium, granitic. Sandplain, outwash fans, lower slope. <i>Triodia epactia</i> , <i>Acacia inaequilatera</i> , <i>Corymbia hamersleyana</i> , <i>Acacia tumida</i> , <i>Triodia basedowii</i> , <i>Triodia lanigera</i>	Possible
<i>Fimbristylis sieberiana</i>	P3	Riparian areas (edges of rivers) and edges of pools in gorges. <i>Eucalyptus camaldulensis</i> , <i>E. victrix</i> , sedges.	Possible
<i>Gomphrena leptophylla</i>	P3	Sand, sandy clay, loam, granite, quartz, alluvium. Flats, creeks, salt pan edges, marshes, stony hills, floodplain. <i>Triodia lanigera</i>	Possible
<i>Goodenia nuda</i>	P4	Alluvium, clay. Drainage lines, floodplain. <i>Eucalyptus victrix</i> , <i>E. leucophloia</i> , Mulga, grasses.	Possible
<i>Gymnanthera cunninghamii</i>	P3	Sand, alluvium, clayey sand, basalt, ironstone, clay loam, limestone. Creekline, scree, floodplain. <i>Eucalyptus victrix</i> , <i>Eucalyptus camaldulensis</i> , <i>Triodia pungens</i>	Possible
<i>Heliotropium murinum</i>	P3	Sand, granitic sand. Plain. <i>Corymbia hamersleyana</i> , <i>Acacia inaequilatera</i> , <i>Triodia epactia</i> , <i>Triodia lanigera</i> , <i>Triodia pungens</i>	Unlikely
<i>Heliotropium muticum</i>	P3	Sand, sandy loam, granitic sand. Sandplain. <i>Acacia bivenosa</i> , <i>Acacia stellaticeps</i> , <i>Acacia inaequilatera</i> , <i>Triodia epactia</i> , <i>Corymbia hamersleyana</i> , <i>Corymbia flavescens</i> , <i>Acacia tumida</i> , <i>Triodia pungens</i> , <i>Acacia pyrifolia</i> , <i>Acacia trachycarpa</i>	Unlikely
<i>Nicotiana umbratica</i>	P3	Skeletal soils, ironstone, granite. Sheltered areas, creeklines, gorges, rocky outcrops, steep slopes, hills. <i>Eucalyptus victrix</i> , <i>Eucalyptus leucophloia</i> , Mulga, <i>Acacia arida</i>	Possible
<i>Phyllanthus hebecarpus</i>	P3	Granite outcrop, alluvium. Granite outcrop, creek, outwash. <i>Terminalia circumalata</i> , <i>Acacia tumida</i> , <i>Acacia retivenea</i> , <i>Triodia epactia</i>	Unlikely
<i>Pityrodia</i> sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4)	TF (Endangered)	Ironstone, sandstone. Steep slope, slopes. <i>Terminalia circumalata</i> , <i>Acacia tumida</i> , <i>Triodia longiceps</i>	Known (recorded)
<i>Ptilotus mollis</i>	P4	Ironstone, clay loam. Stony hills, scree, crest. <i>Eucalyptus leucophloia</i> , <i>Corymbia hamersleyana</i> , <i>Eucalyptus kingsmillii</i> , <i>Acacia bivenosa</i> , <i>Acacia synchronicia</i> , <i>Triodia basedowii</i> , <i>Triodia pungens</i>	(Possible – desktop) Known (recorded)

Species	WA Cons. Code	Habitat	Likelihood
<i>Rothia indica</i> subsp. <i>australis</i>	P3	Sand, clay loam. Sandhills, flats, creekline. <i>Pluchea ferdinandi-muelleri</i> , <i>Corchorus lasiocarpus</i> , <i>Triodia longiceps</i> , <i>Triodia lanigera</i> , <i>Gyrocarpus americanus</i> , <i>Triodia epactia</i> , <i>Cenchrus ciliaris</i> , <i>Corymbia flavescens</i> , <i>Chrysopogon fallax</i> , <i>Eucalyptus victrix</i>	Unlikely
<i>Schoenus</i> sp. Marble Bar (D. Coultas & S. Coultas DCSC- Opp 07)	P1	Granite seepage. <i>Eragrostis cumingii</i> .	Unlikely
<i>Stylidium weeliwoffi</i>	P3	Alluvium, clay, sand, wet soil. Watercourses, plains. <i>Eucalyptus victrix</i> , <i>Eucalyptus camaldulensis</i> , Mulga	Unlikely
<i>Terminalia supranitifolia</i>	P3	Sand, basalt, clay loam. Hilltop, basalt boulders, breakaway. <i>Triodia epactia</i> , <i>Triodia wiseana</i> , <i>Acacia acradenia</i> , <i>Acacia bivenosa</i> , <i>Grevillea wickhamii</i> , <i>Rhagodia eremaea</i>	Possible
<i>Triodia basitricha</i>	P3	Ironstone. Stony plain, stony crest, low hills. <i>Acacia</i> shrubland over <i>Triodia basitricha</i> , <i>Eucalyptus leucophloia</i> over <i>Triodia</i> (dominant)	(Possible – desktop) Known (recorded) +
<i>Triodia chichesterensis</i>	P3	Quartz, granite, basalt. Ridges, flat plain, hills. <i>Triodia</i> grassland. <i>Acacia inaequilatera</i> woodland	Possible

'+' = subject to confirmation

Table 21: Conservation significant flora that may occur as identified by DBCA place name searches ('^' = TP list) or other non-GIS sources

Species	WA Cons. code	Habitat	Likelihood
<i>Abutilon</i> sp. Pritzelianum (S. van Leeuwen 5095)	P1	Alluvium, sand, red clay. Creek, sandplain, coastal dunes, floodplain. <i>Eucalyptus camaldulensis</i> ; <i>Acacia ancistrocarpa</i> , <i>Acacia inaequilatera</i> , <i>Triodia epactia</i> ; <i>Eragrostis eriopoda</i> grassland; <i>Sida</i> spp. low shrubland; <i>Triodia</i> grassland	Highly unlikely
<i>Acacia aphanoclada</i> ^	P1	Stony soils. Ridges and rises. <i>Triodia wiseana</i> , <i>Eucalyptus leucophloia</i> , <i>A. inaequilatera</i> .	Unlikely
<i>Acacia cyperophylla</i> var. <i>omearana</i> ^	P1	Alluvium, stony sand. Drainage lines. <i>Melaleuca argentea</i> , <i>Eucalyptus victrix</i> , <i>E. camaldulensis</i> , <i>Acacia tumida</i>	Unlikely
<i>Acacia fecunda</i> ^	P1	Quartz gibber, Mosquito Creek sedimentary rocks. Creeks, drainage lines, gullies. <i>Eucalyptus leucophloia</i> , <i>Acacia</i> spp.	Unlikely
<i>Acacia glaucocaesia</i>	P3	Red loam, sandy loam, clay, stony loam. Creek; floodplain; plain. <i>Acacia bivenosa</i> ; <i>Bauhinia cunninghamii</i> ; <i>Eucalyptus camaldulensis</i> ; <i>Corymbia hamersleyana</i>	Unlikely
<i>Acacia monticola</i> × <i>tumida</i> var. <i>kulpam</i> (formerly <i>Acacia</i> sp. Broome (B.R. Maslin 4918))	P3	Rocky red sand. Gully, coastal cliff top. <i>Corymbia zygophylla</i> , <i>Corymbia greeniana</i> , <i>Acacia tumida</i>	Unlikely
<i>Acacia</i> sp. Marble Bar (J.G. & M.H. Simmons 3499) ^	P1	Sandy soil. Water courses.	Unlikely
<i>Acacia</i> sp. Nullagine (B.R. Maslin 4955) ^	P1	Clay. <i>Acacia trachycarpa</i> .	Unlikely
<i>Atriplex spinulosa</i> ^	P1	Gibber plains, clay. Creeks. <i>Triodia longiceps</i> .	Unlikely
<i>Bonamia oblongifolia</i>	P1	Sand, gravel, pindan. Plain, swampy, pindan plain. <i>Eucalyptus miniata</i> , <i>Lophostemon grandiflorus</i>	Highly unlikely
<i>Cladium procerum</i> ^	P2	Alluvium. Creeks, gorges. <i>Eucalyptus victrix</i> , <i>E. camaldulensis</i> , <i>Typha</i> .	Highly unlikely
<i>Corchorus</i> sp. Yarrie (J. Bull & D. Roberts CAL 01.05) ^	P1	Minor drainage line/gully. Skeletal loam. <i>Eucalyptus camaldulensis</i> , <i>Corymbia flavescens</i> , <i>Acacia coleii</i> , <i>Cyperus vaginatus</i> .	Unlikely
<i>Croton aridus</i>	P3	Red sand, pindan. Sandplain, ridges. <i>Corymbia zygophylla</i> , <i>Acacia ancistrocarpa</i> , <i>Triodia epactia</i> , <i>Triodia schinzii</i> ; <i>Gyrocarpus americanus</i>	Unlikely
<i>Dipteracanthus chichesterensis</i> ^	P1	Basalt. Tablelands. <i>Acacia xiphophylla</i> , <i>Triodia wiseana</i> , <i>T. epactia</i> .	Highly unlikely
<i>Eragrostis surreyana</i> ^	P3	Alluvium, clay, sandy clay, seasonally wet areas. Drainage lines, floodplains. <i>Eucalyptus victrix</i> , <i>E. camaldulensis</i> , <i>Melaleuca</i> spp.	Highly unlikely
<i>Eremophila spongiocarpa</i> ^	P1	Subsaline clay loams. Marsh. Samphire, Mulga, <i>Acacia synchronica</i> .	Unlikely

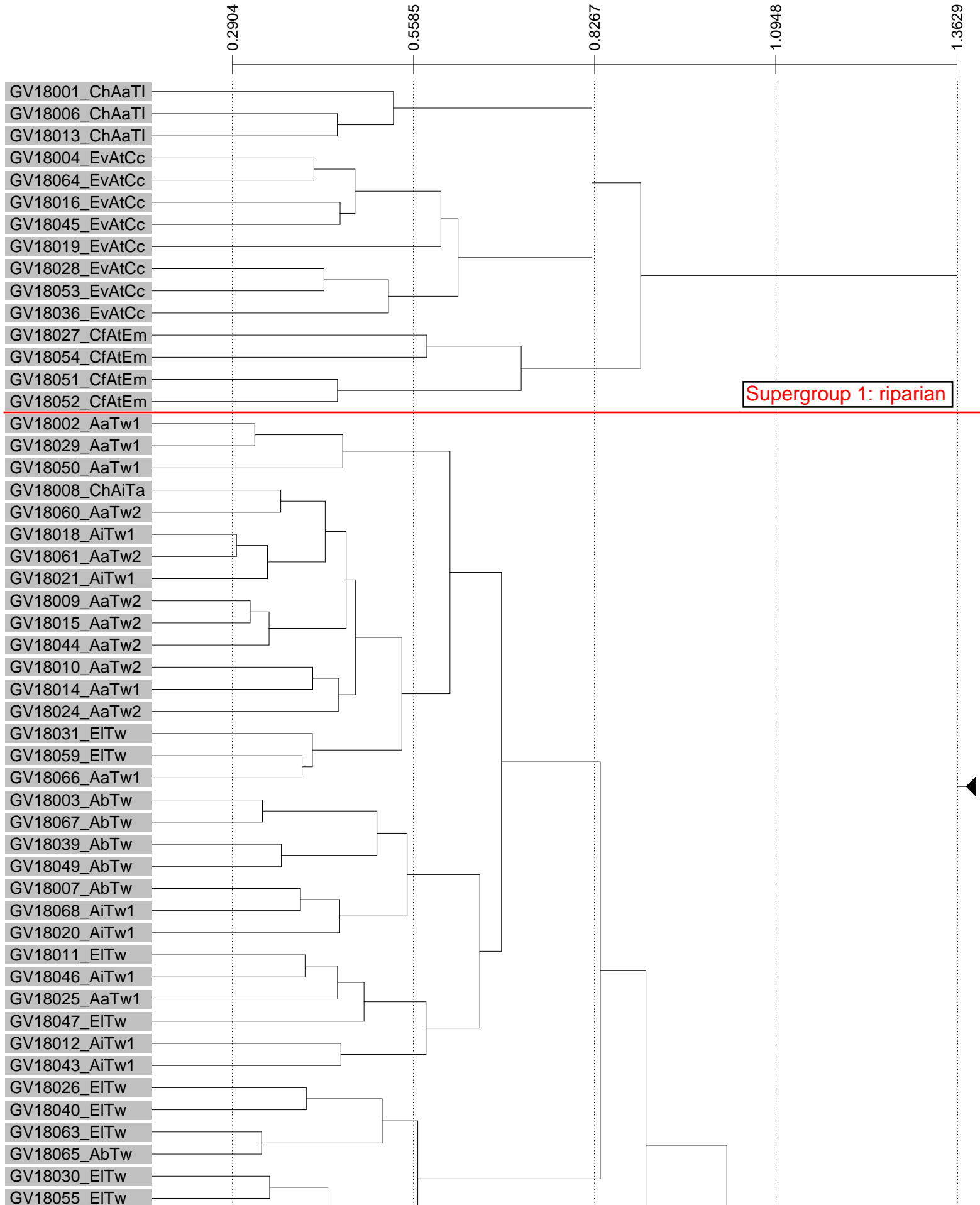
Species	WA Cons. code	Habitat	Likelihood
<i>Eremophila youngii</i> subsp. <i>lepidota</i> ^	P4	Sandy clay, sandy loam. Drainage line, floodplain. Mulga, chenopods.	Highly unlikely
<i>Euphorbia inappendiculata</i> var. <i>inappendiculata</i>	P2	Silty clay, cracking clay. Flat plain, elevated plain. <i>Aristida latifolia</i> , <i>Astrelba elymoides</i> , <i>Chrysopogon fallax</i> ; <i>Acacia xiphophylla</i> ;	Highly unlikely
<i>Fimbristylis</i> sp. Shay Gap (K.R. Newbey 10293)	P1	Sand, alluvium, basalt. Creek, pool edge. <i>Eucalyptus victrix</i>	Highly unlikely
<i>Glycine falcata</i> ^	P3	Loam, cracking clay. Plain. Grassland.	Highly unlikely
<i>Gomphrena pusilla</i>	P2	Beach sand, limestone, sandstone. Foredune. <i>Crotalaria cunninghamii</i> ; <i>Terminalia petiolaris</i>	Highly unlikely
<i>Goodenia</i> sp. East Pilbara (A.A. Mitchell PRP 727) ^	P3	Clay, loam, calcrete, ironstone. Low rises, plains, creeklines. <i>Triodia</i> , scattered trees.	Highly unlikely
<i>Heliotropium parviantrum</i>	P1	Sand. Plain, flats, rocky slopes. <i>Triodia</i>	Highly unlikely
<i>Indigofera ammobia</i>	P3	Red sand. Sand dunes. <i>Triodia melvillei</i>	Highly unlikely
<i>Indigofera ixocarpa</i> ^	P2	Skeletal soil, ironstone, alluvium. Creeks, gullies, high hills. <i>Eucalyptus leucophloia</i> , Mulga.	Highly unlikely
<i>Ipomoea racemigera</i> ^	P2	Alluvium, sand. Creeklines. <i>Eucalyptus camaldulensis</i> , <i>E. victrix</i> .	Highly unlikely
<i>Seringia katatona</i> (formerly <i>Keraudrenia katatona</i>)	P3	Red sand. Dunes, Pindan. <i>Grevillea eriostachya</i> , <i>Corymbia greeniana</i> ; <i>Triodia schinzii</i> ; <i>Acacia eriopoda</i>	Highly unlikely
<i>Oldenlandia</i> sp. Hamersley Station (A.A. Mitchell PRP 1479) ^	P3	Cracking clay, basalt. Plains, floodplains. Grassland, herbland.	Highly unlikely
<i>Olearia mucronata</i> ^	P3	Ironstone, clay. Scree, cliffs, low hills. <i>Eucalyptus leucophloia</i> , Mulga, <i>Grevillea berryana</i> , <i>Triodia</i> .	Highly unlikely
<i>Paspalidium retiglume</i> ^	P2	Clay, cracking clay. Plains. Grasslands, herblands.	Highly unlikely
<i>Polymeria distigma</i>	P3	Sand, cracking clay. Coastal plain, sandplain, cracking clay plain. <i>Acacia eriopoda</i> ; <i>Terminalia ferdinandiana</i> ; <i>Astrelba pectinata</i>	Highly unlikely
<i>Pterocaulon intermedium</i>	P3	Sand, loam. Plain. <i>Acacia stellaticeps</i> , <i>Triodia secunda</i> , <i>Triodia epactia</i>	Highly unlikely
<i>Ptilotus wilsonii</i> ^	P1	Calcrete. Lower slope. <i>Eucalyptus leucophloia</i> , <i>Triodia longiceps</i> , <i>T. brizoides</i> .	Unlikely
<i>Rhynchosia bungarensis</i> ^	P4	Alluvium, basalt, clay. Creeklines, gullies, boulder piles, floodplain. <i>Eucalyptus victrix</i> , <i>Acacia</i> spp.	Highly unlikely
<i>Solanum albotellatum</i> ^	P3	Cracking clays. Floodplains. Grassland, <i>Acacia xiphophylla</i> .	Highly unlikely
<i>Solanum</i> sp. Mosquito Creek (A.A. Mitchell et al. AAM 10795) PN ^	P1	Semi saline clay pan, red clay. Clay pans, creeks and flats, hills. <i>Eucalyptus leucophloia</i> , <i>Triodia longiceps</i> .	Highly unlikely
<i>Tephrosia rosea</i> var. Port Hedland (A.S. George 1114) Also previously known as <i>Tephrosia rosea</i> var. <i>venulosa</i>	P1	Sand, sandy loam. Coastal dunes, plains. <i>Acacia coriacea</i> ; <i>Triodia epactia</i> ; <i>Spinifex longifolius</i> ; <i>Acacia stellaticeps</i> ; <i>*Cenchrus ciliaris</i>	Highly unlikely
<i>Teucrium pilbaranum</i> ^	P2	Cracking clay, calcrete. Plain, drainage. Herblands, <i>Acacia</i> , grasslands.	Unlikely
<i>Tribulus minutus</i> ^	P1	Calcrete. Stony rise.	Unlikely

APPENDIX THREE FLORA INVENTORY

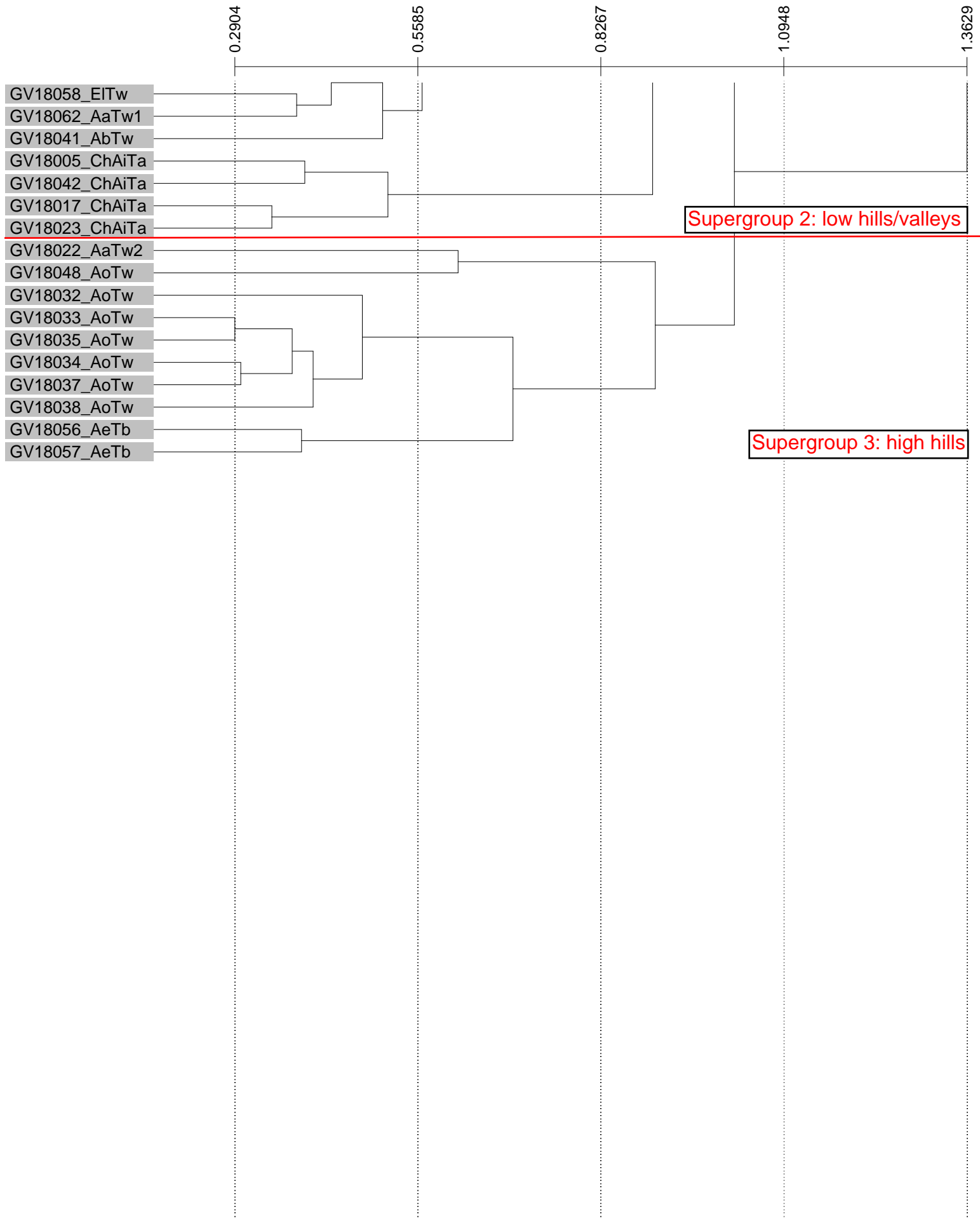
Table 22: Flora inventory (site x species)

APPENDIX FOUR FLORISTIC ANALYSIS

Column Fusion Dendrogram

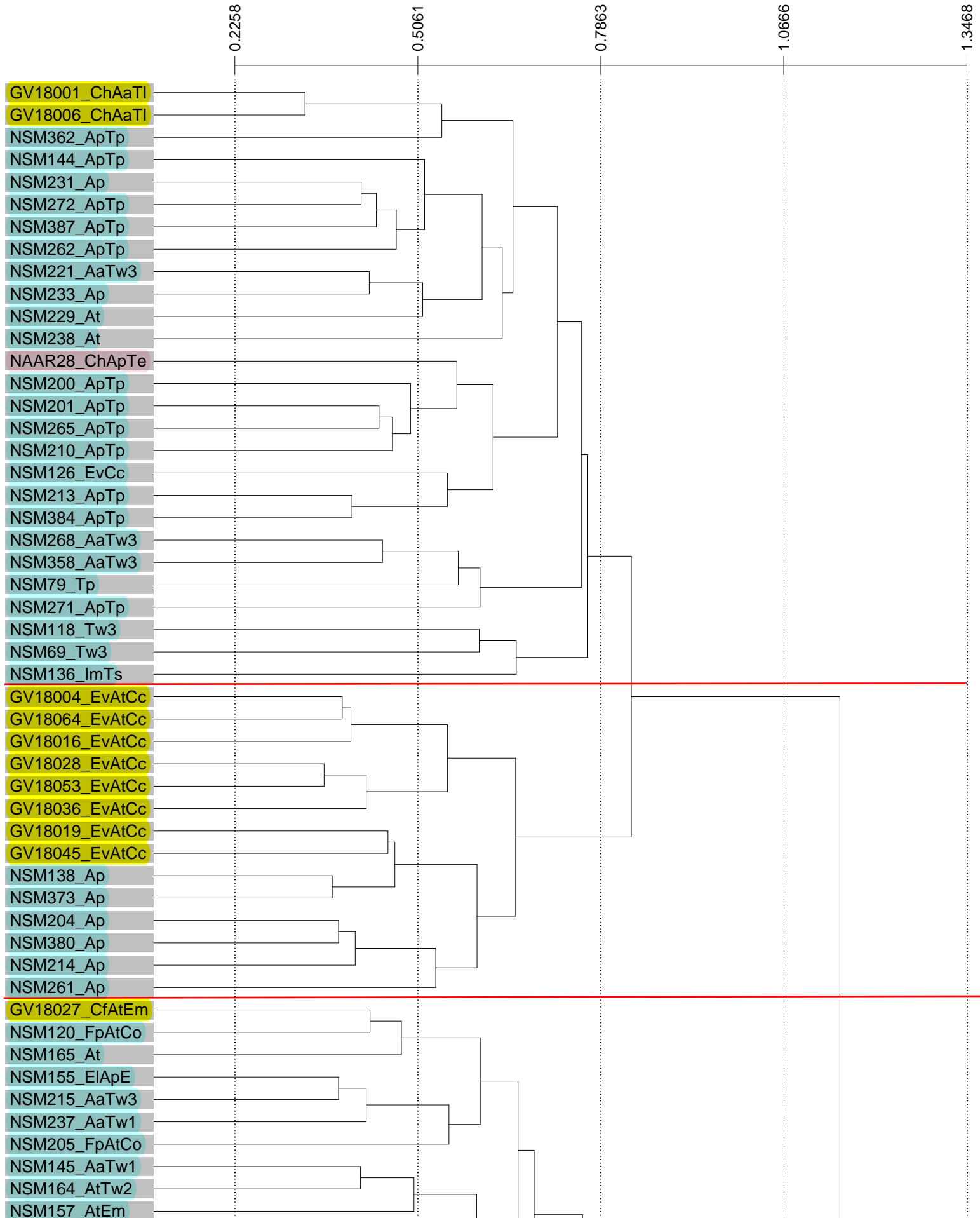


Column Fusion Dendrogram

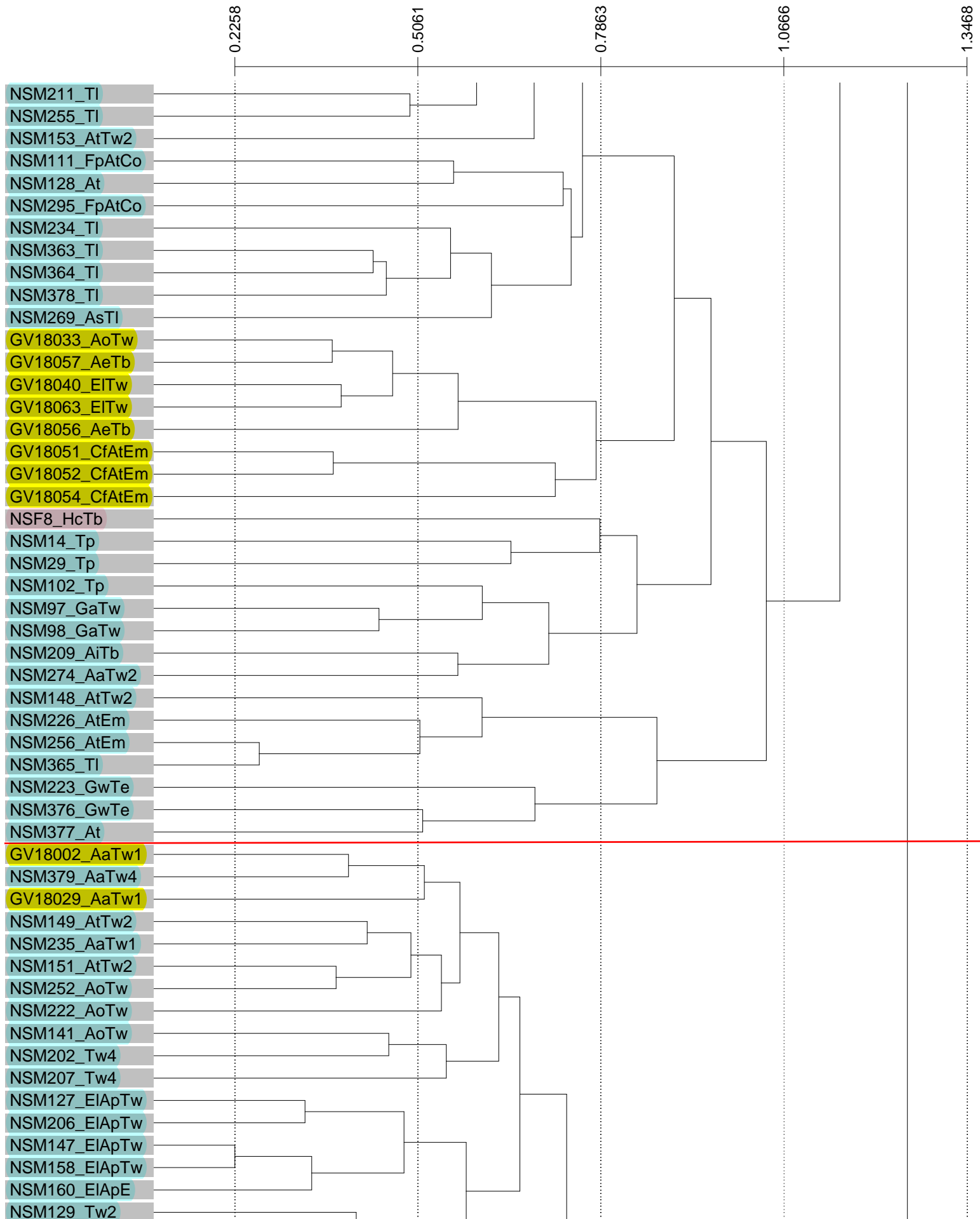


Column Fusion Dendrogram

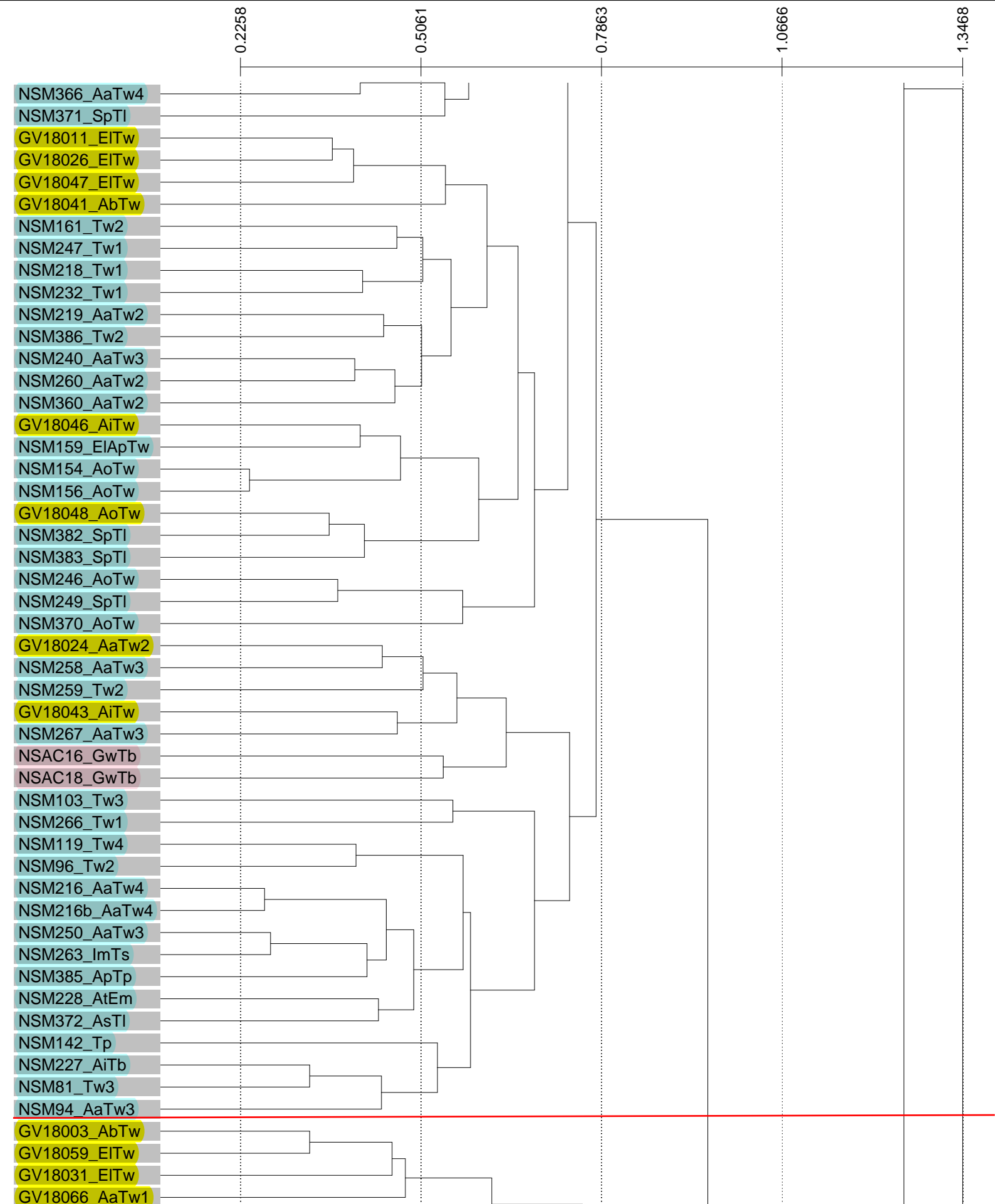
yellow = Glacier Valley, blue = NS mine area, pink = access corridor/filtration survey area



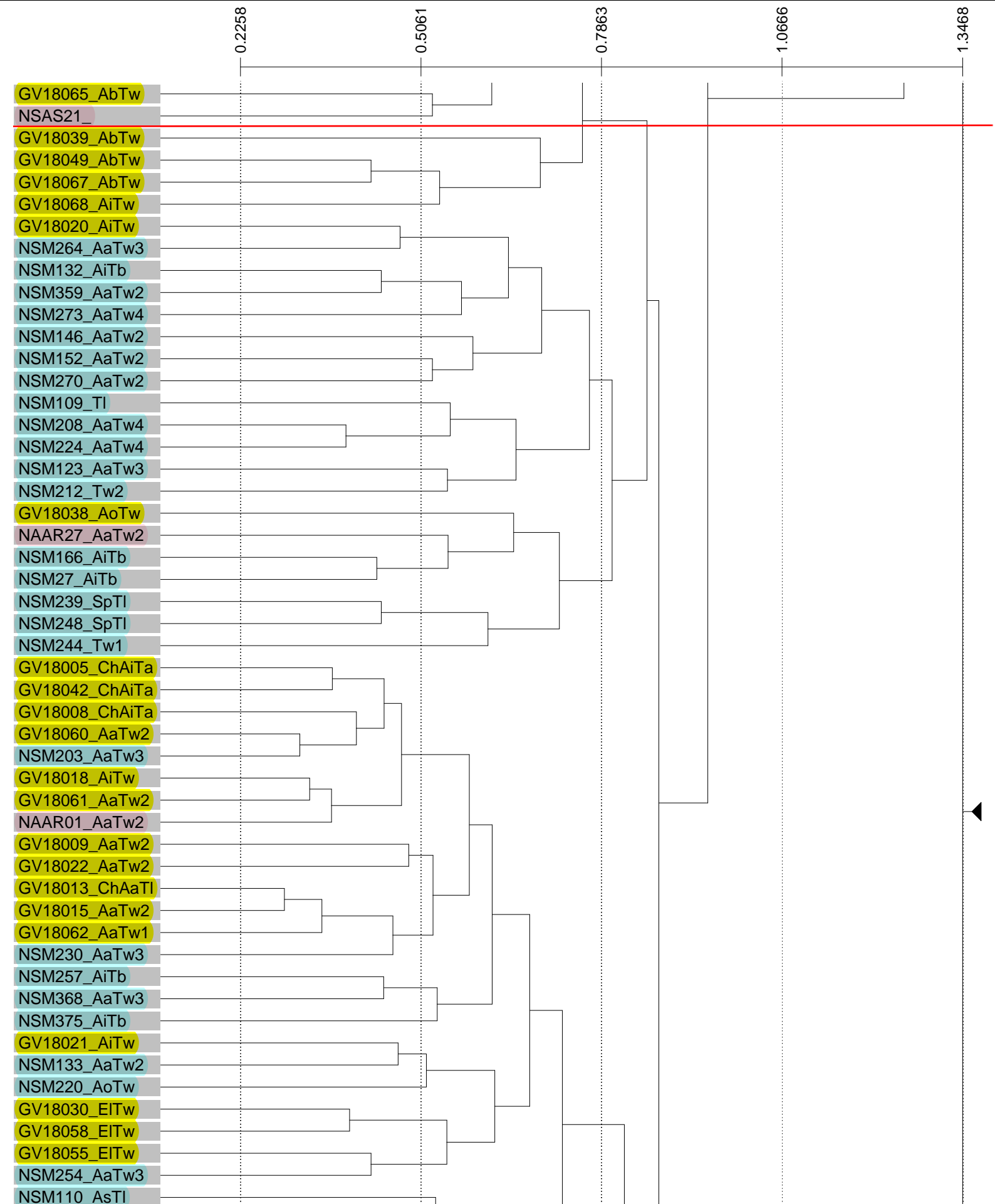
Column Fusion Dendrogram



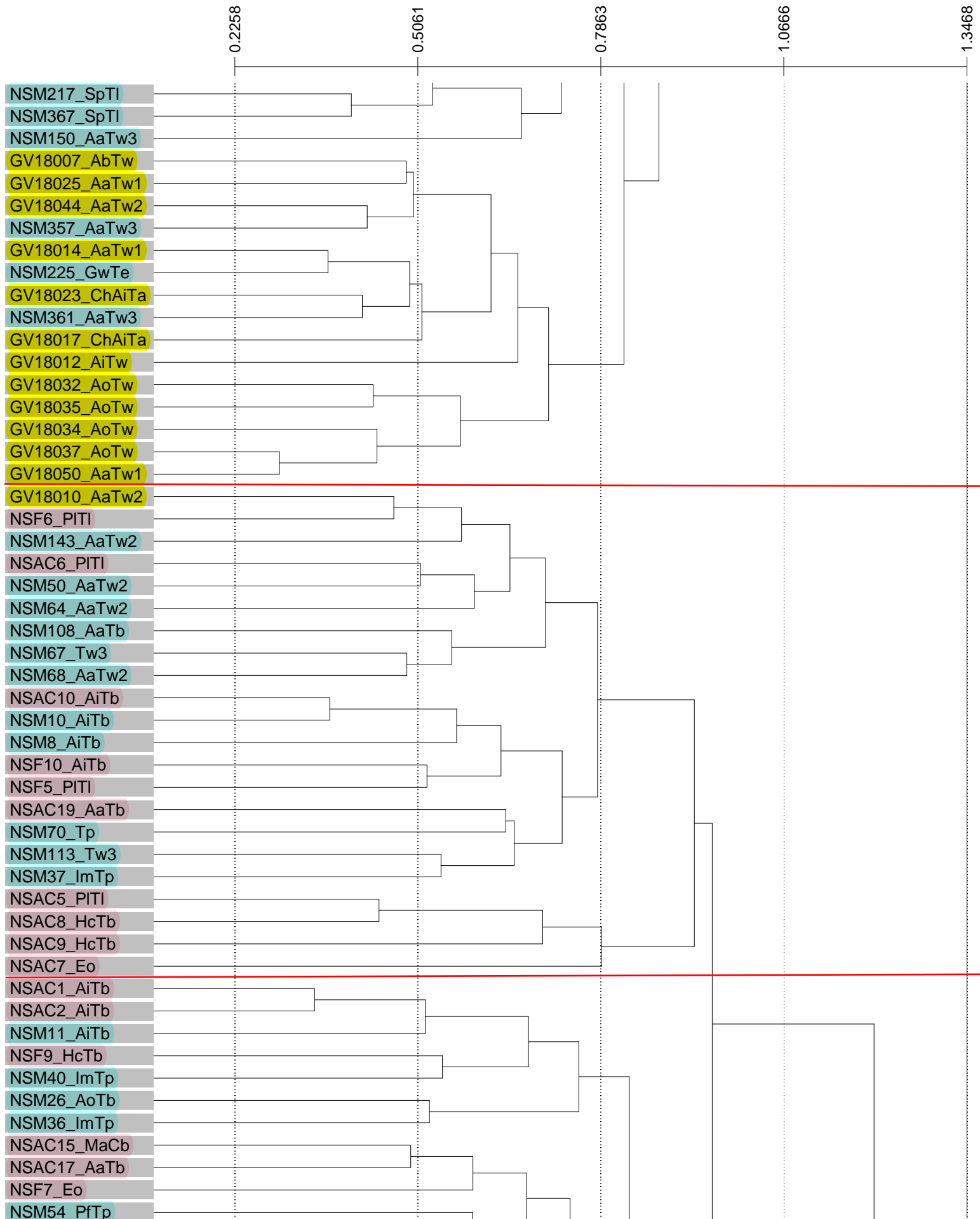
Column Fusion Dendrogram



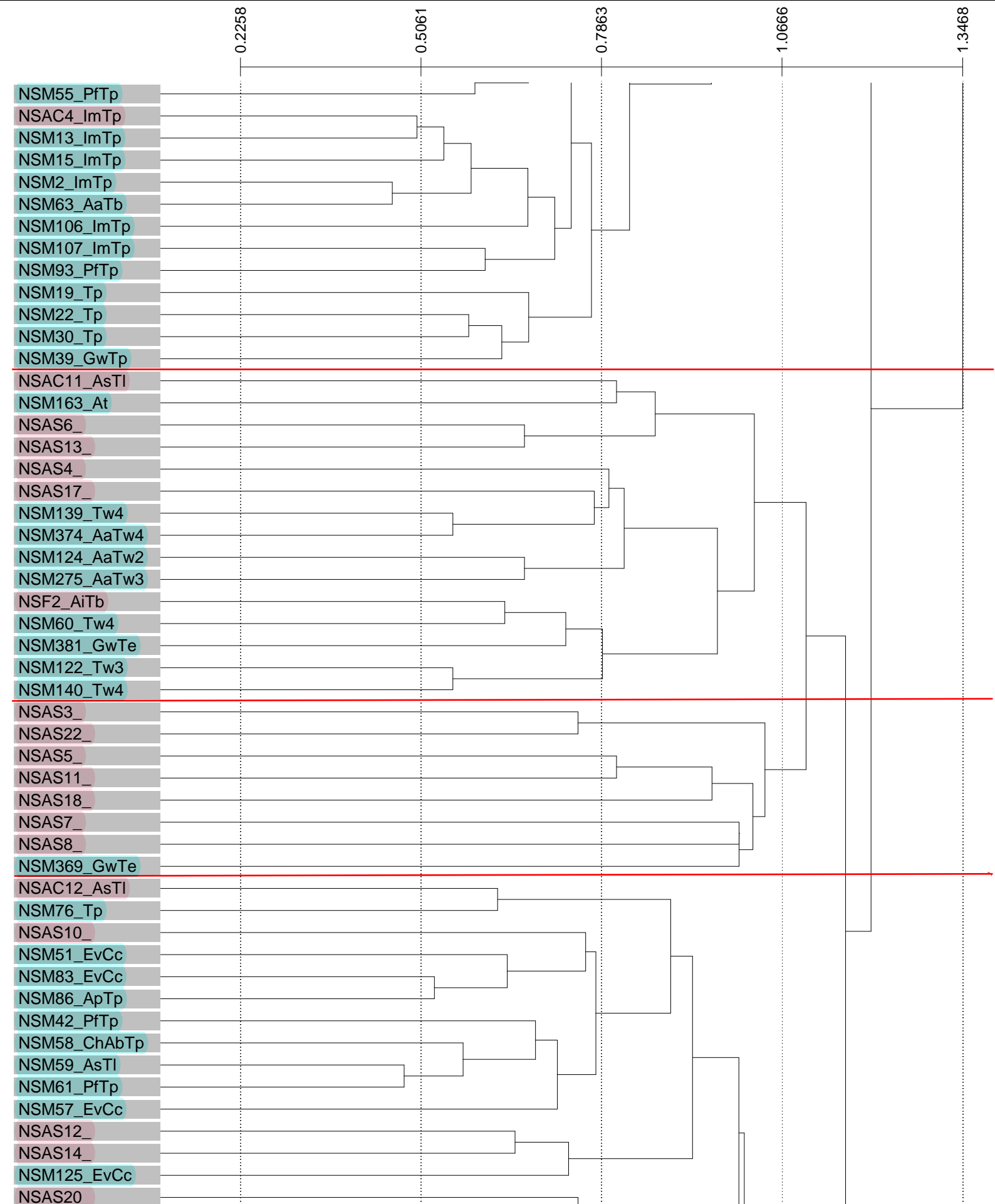
Column Fusion Dendrogram



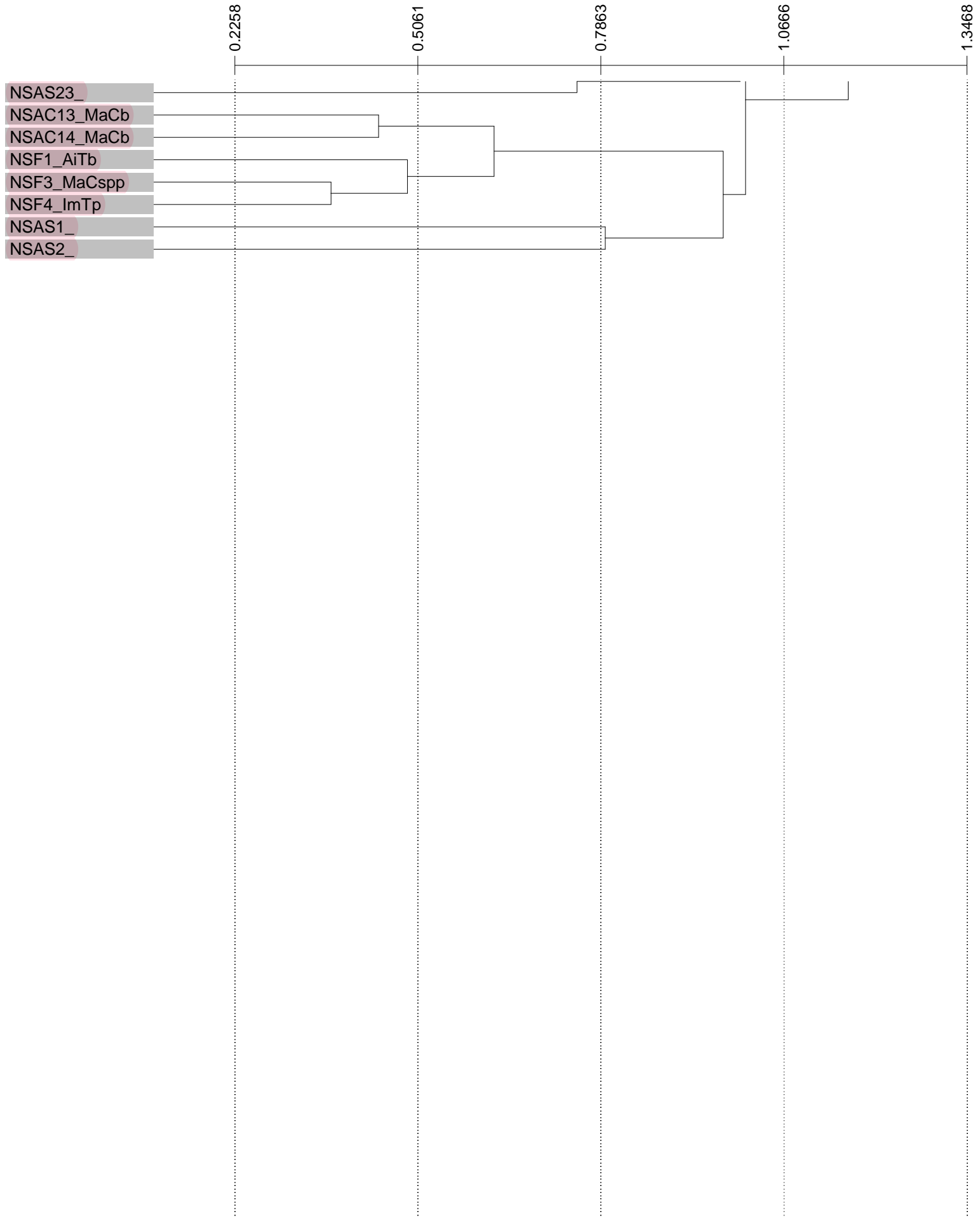
Column Fusion Dendrogram



Column Fusion Dendrogram



Column Fusion Dendrogram



APPENDIX FIVE QUADRAT DETAILS