REPORT

ABRA SUBTERRANEAN FAUNA LEVEL 2 ASSESSMENT

PREPARED FOR **GALENA MINERALS LTD**

August 2018

Amphipoda: Paramelitidae OES10

Stantec

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Executive Summary

Galena Mining Limited (Galena) proposes to develop the Abra Base Metals Project (the Project), a base metals deposit (Pb-Ag-Cu-Au) located within the Gascoyne Region of Western Australia (WA), 220 kilometres (km) north of Meekatharra and 180 km southwest of Newman. The Project will primarily involve underground mining of the ore, starting at 260 m bgl (below ground level), with the bulk of high grade ore occurring from 350 to 500 m bgl.

Development of the Project could potentially directly impact subterranean fauna through the physical removal of habitat by mining excavation, together with groundwater drawdown from the dewatering required to access the resource. This report presents the findings of the stygofauna and troglofauna surveys of the Abra Study Area and an environmental impact assessment (EIA) to support future applications for regulatory approval of the Project.

The main objectives of this assessment were to assess the subterranean fauna values in the context of the proposed Project footprint and surrounding areas and to investigate the potential environmental impacts and conservation risks for any species recorded within the Study Area, posed by the removal or modification of potential subterranean fauna habitat. The scope of this study encompassed a literature review, database searches and subterranean fauna sampling.

Survey Effort

The stygofauna sampling was undertaken in a staged approached. The first stage comprised a Level 1 low sample intensity (pilot) stygofauna survey of 15 samples to verify the stygofauna values associated with the deposit area. The second stage comprised a greater sample intensity (41 samples) to: 1) further confirm the stygofauna values in the deposit area; and 2) target sites in the broader area to provide greater context of the potential habitat surrounding the deposit. In total, 56 stygofauna net haul samples were collected from 40 sites. The sample phases were undertaken in March and May 2018.

A total of 27 troglofauna samples were collected from 25 sites to verify the troglofauna values in and around the Study Area. The 16 troglofauna litter traps were deployed over one survey phase for eight weeks from March 1 to April 4, 2018. The 11 scrape samples were collected as part of the stygofauna sampling of uncased holes undertaken in March and May 2018.

Stygofauna Assessment

The stygofauna findings and habitat assessment demonstrated that there will be no risk to the long-term conservation of any stygofauna species due to the proposed underground mining of the Abra base metal deposit. The subterranean habitat in the deposit area was found not to host any stygofauna values. Furthermore, the subterranean habitat in and near the deposit area was found to not be prospective for stygofauna as the overlying regolith was clay dominated and deep, extending to below the SWL, and considered to be an aquitard, offering limited interstitial pore space and hydrological exchange. The groundwater present represented a locally recharged, low permeability, mostly confined fractured rock aquifer system. The non-prospectivity of the habitat was verified by two rounds of sampling that failed to record any stygofauna from similar habitat in and around the deposit area.

Only one species, the oligochaete *Phreodrilus* OES25, was collected from within the potential groundwater dewatering drawdown impact zone associated with the proposed underground mining, from surficial colluvial habitat 800 m north of the deposit area. However, *Phreodrilus* OES25 was also recorded on multiple occasions from outside the potential groundwater drawdown impact zone, collected from three non-impact sites, up to 3.6 km from the deposit area. Within the Study Area, two additional stygofauna species, Paramelitidae OES10 and *Brevisomabathynella* OES30, were collected sympatrically on a single occasion, from outside the potential groundwater drawdown impact area, more than 1.5 km from the deposit area.

Within the Study Area, the three stygofauna species recorded were from sites in the north-eastern portion of the Study Area that intercepted surficial colluvial groundwater habitat near incised drainage channels of the 5 Mile Creek catchment. Within the broader region of the Study Area, stygofauna values are considered likely to progressively increase further downstream (northward) along 5 Mile Creek to the confluence zone with Ethel Creek, approximately 8 km north of the Study Area. The Ethel Creek calcrete/alluvial aquifer system is considered to represent the most favourable habitat present within the region of the Study Area and likely to host the highest stygofauna diversity (species richness and abundance) in the broader catchment, with stygofauna diversity considered likely to progressively decline

further upstream as habitat conditions become progressively less optimal. The more favourable habitat present within the Ethel Creek calcrete/alluvial aquifer system has not been extensively sampled due to the lack of suitable sites available. However, an amphipod species, *Bogidiella* OES11, and ostracod species, *Deminutiocandona neara*, have been collected more than 30 km north of the deposit area from the limited sampling that has occurred within Ethel Creek calcrete/alluvial aquifer system.

Troglofauna Assessment

Troglofauna do not represent an environmental factor for future regulatory approvals of the Project, in accordance with EPA (2016b), as no troglofauna species were recorded. The sampling results are consistent with the habitat characterisation that indicated that the Study Area does not provide prospective habitat for troglofauna.

Conclusion

The subterranean fauna assessment reported here has demonstrated that the subterranean habitat in the deposit area does not host any stygofauna or troglofauna values. The subterranean habitat in and near the deposit area was found to not be prospective for stygofauna or troglofauna with no subterranean fauna species collected from the deep clay dominated regolith, an aquitard confining the underlying low permeability fractured rock aquifer.

The overall findings of this assessment indicate that the proposed underground mining of the Abra base metal deposit will meet the relevant EPA objectives in that the proposal does not pose a threat to maintaining subterranean fauna representation, diversity, viability and ecological function at the species, population or assemblage level.

Galena Minerals Ltd

Abra Subterranean Fauna Level 2 Assessment

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1. Introduction

Galena Mining Limited (Galena) proposes to develop the Abra Base Metals Project (the Project), a base metals deposit (Pb-Ag-Cu-Au) located within the Gascoyne Region of Western Australia (WA), 220 kilometres (km) north of Meekatharra and 180 km southwest of Newman (**Figure 1-1**). The principal activities planned for the Project are (**Figure 1-2**):

- underground mine, including boxcut to establish the portal to the decline to access deposit, with mining of ore starting at 260 m bgl (below ground level), with bulk of high grade ore occurring from 350 to 500 m bgl;
- associated mining infrastructure such as on-site ore processing plant facility, waste rock landforms (WRL), a tailings storage facility (TSF), access and haul roads, and water management infrastructure (bunds, drains); and
- mining camp and airstrip.

Development of the Project could potentially directly impact subterranean fauna through the physical removal of habitat from mining excavation, together with groundwater drawdown from the dewatering required to access the resource. This report presents the findings of the stygofauna and troglofauna surveys of the Abra Study Area and an environmental impact assessment (EIA) to support future applications for regulatory approval of the Project.

1.1 Scope and Objectives

The main objectives of this assessment were to assess the subterranean fauna values in the context of the proposed Project footprint and surrounding areas and to investigate the potential environmental impacts and conservation risks for any species recorded within the Study Area, posed by the removal or modification of potential subterranean fauna habitat. The assessment was designed in accordance with the Western Australian Environmental Protection Authority (EPA) Technical Guidance Statements (2016a, b) that outline considerations and sampling methods for subterranean fauna in Western Australia. The specific objectives of the assessment were to:

- document the species richness, abundance and distribution of subterranean fauna species within the Study Area;
- evaluate the potential of habitat to support subterranean fauna within the Study Area;
- identify potential risks to obligate subterranean fauna from the proposed mining activities;
- consider the conservation significance of any subterranean fauna assemblage or species occurring within the Study Area to determine if subterranean fauna will represent a key environmental factor; and
- provide an EIA in relation to the proposed Project development.

The scope of this subterranean fauna assessment encompassed a literature review, database searches and Level 1 and targeted subterranean fauna survey.

The terms used in this report to define the various areas surveyed within and around the Project Study Area as part of this subterranean fauna assessment are:

- Abra deposit area — encompasses the area above the target Abra deposit;
- potential groundwater drawdown impact zone — within a 1 km radius of the Abra deposit;
- Study Area — designated area for biological EIA (flora and vegetation, fauna, and subterranean fauna) encompassing the mining resource exploration activity and infrastructure of proposed development; and
- northern reference area — includes three sites over 25 km north of the Study Area within and near the riparian zone of major tributaries, including Ethel Creek, of the upper Ashburton River.

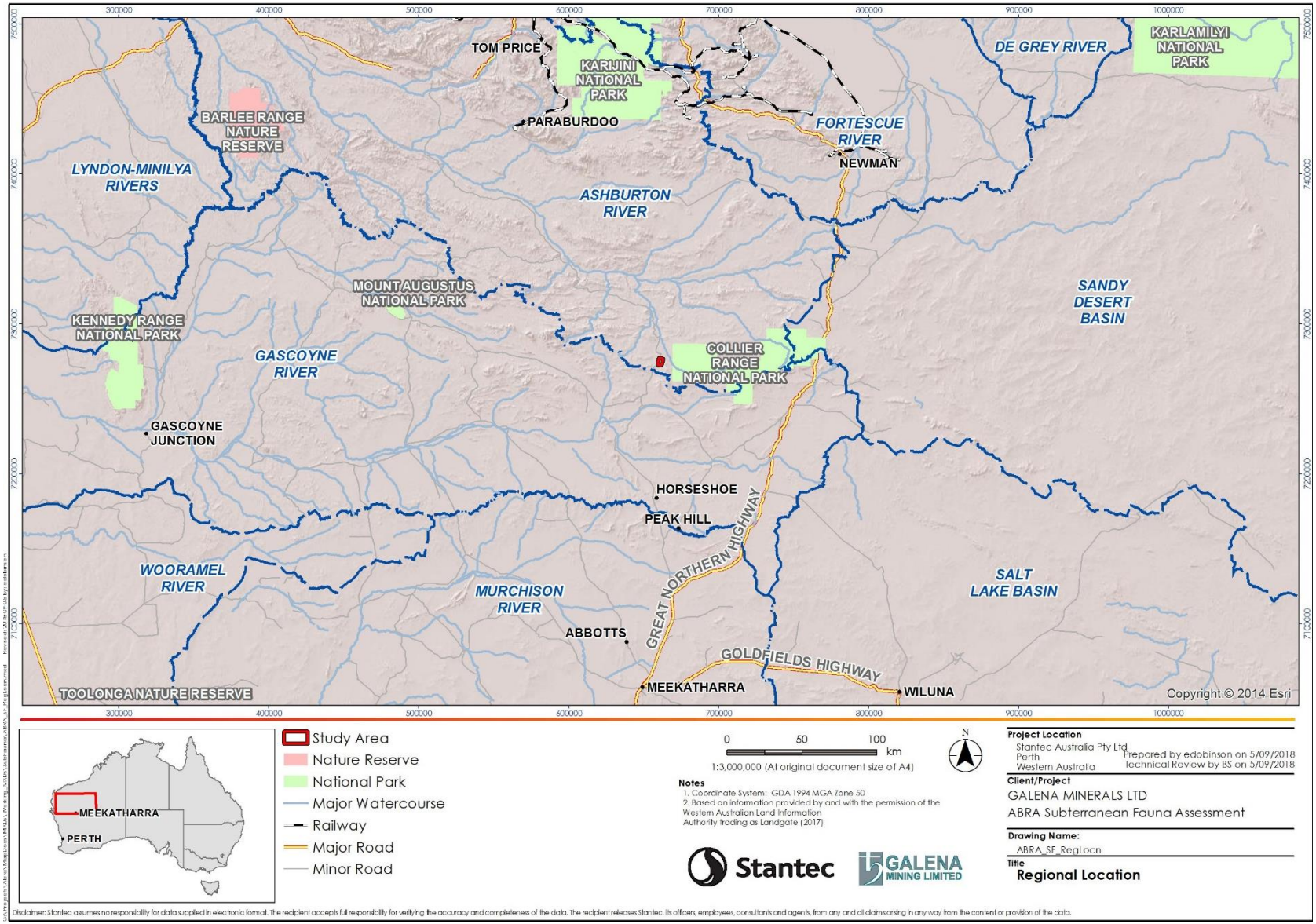

Figure 1-1: Regional location of the Abra Project, including drainage catchment areas.

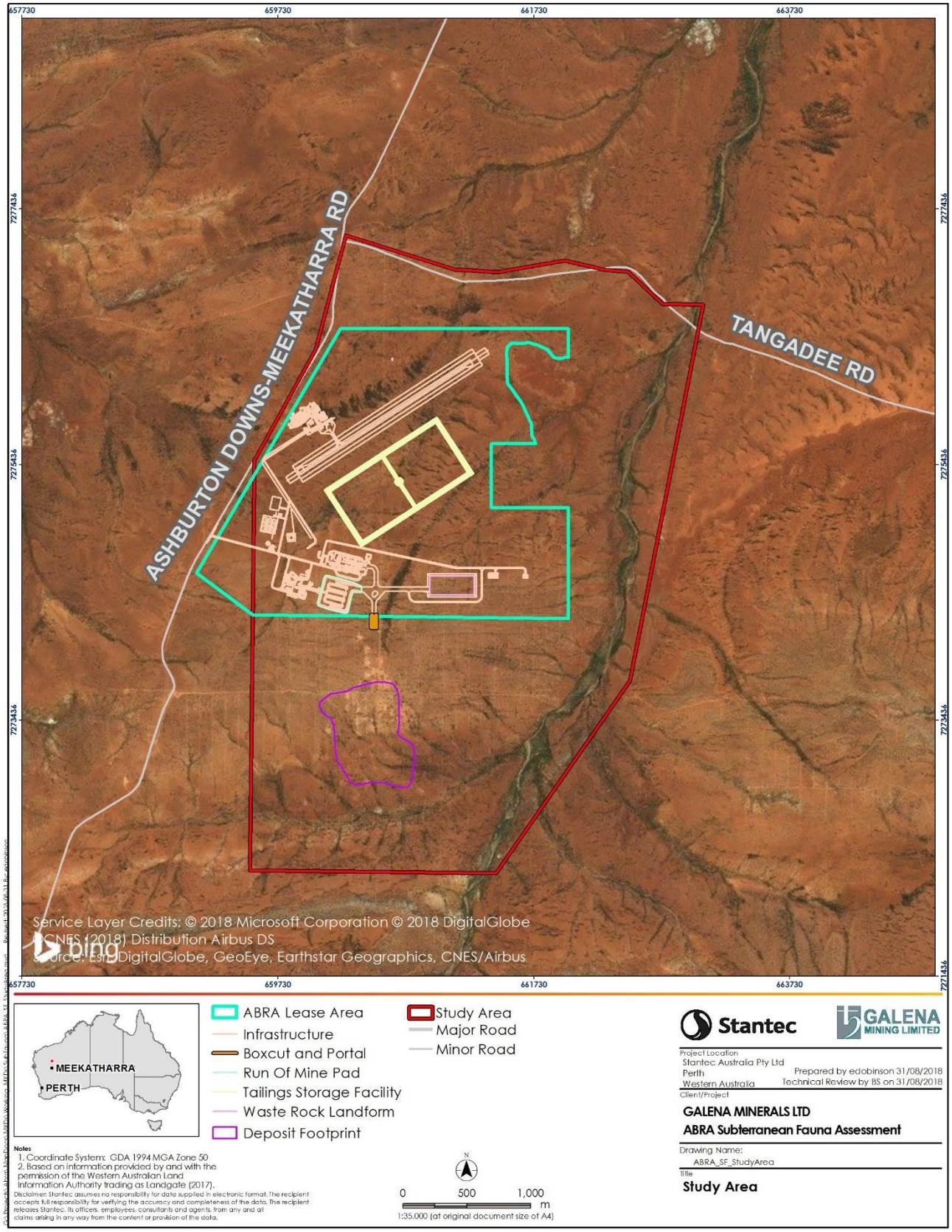

Figure 1-2: Proposed layout of the Abra Project.

2. Existing Environment

2.1 Biogeographic Region

The Project is in the Augustus subregion (GAS03) within the Gascoyne bioregion (**Figure 2-1**). The Augustus subregion is 10,687,739 ha in size and classified as a Desert and Xeric Shrubland ecoregion, characterised by rugged low Proterozoic sedimentary and granite ranges separated by wide flat valleys with extensive areas of alluvial valley fills (Desmond *et al.* 2001, DoEE 2013). Vegetation mainly consists of mulga woodland over *Triodia* species on shallow stony loams and rises, and mulga parkland on shallow earthy loams over hardpan on plains (Desmond *et al.* 2001).

The Gascoyne River is the main drainage system in the Augustus subregion, draining the entire southern portion of the subregion. The headwaters of both the Ashburton and Fortescue River systems originate in the northeastern portion of the subregion (**Figure 1-1**).

Stygofauna assemblages hosted in calcrete aquifer ecosystems are listed as vulnerable rare features for the Augustus subregion, but incorrectly as in the Carnegie drainage (Desmond *et al.* 2001) that occurs in the Carnegie subregion (GAS02) (Cowan 2001). Groundwater calcrete systems are present in all three of the Gascoyne bioregion's subregions, therefore the following would likely hold true as stated in the Gascoyne subregional description, stygofauna assemblages within calcrete environments are so far unknown, but indications are for a significant fauna (Kendrick 2001). Diverse subterranean fauna assemblages are known to inhabit many groundwater calcrete systems (Cooper *et al.* 2002, Humphreys 2008, Outback Ecology 2008, 2011b, 2012b, c, d, Subterranean Ecology 2011a).

2.2 Land Use

The majority of land within the Gascoyne is used for pastoral purposes, with leases covering 84% of the area (GDC 2015). Smaller areas serve horticultural or mining purposes (GDC 2015). Land within the Augustus subregion is mainly used for native pasture grazing, with smaller areas classified as unallocated Crown land (UCL), Crown and Aboriginal reserves (Desmond *et al.* 2001). The Study Area lies within the Mulgul Pastoral Lease with cattle grazing occurring across Galena's leases. The exploration lease E52/1455 is dissected by the Fortescue Cue Stock Route Reserve # 9698. The Department of Mines, Industry Regulation and Safety (DMIRS) has a management order over this reserve. Historical mining exploration activities have occurred over the Project area since 1976. The Project was previously known as the Mulgul which was acquired by Galena from Abra Mining Limited.

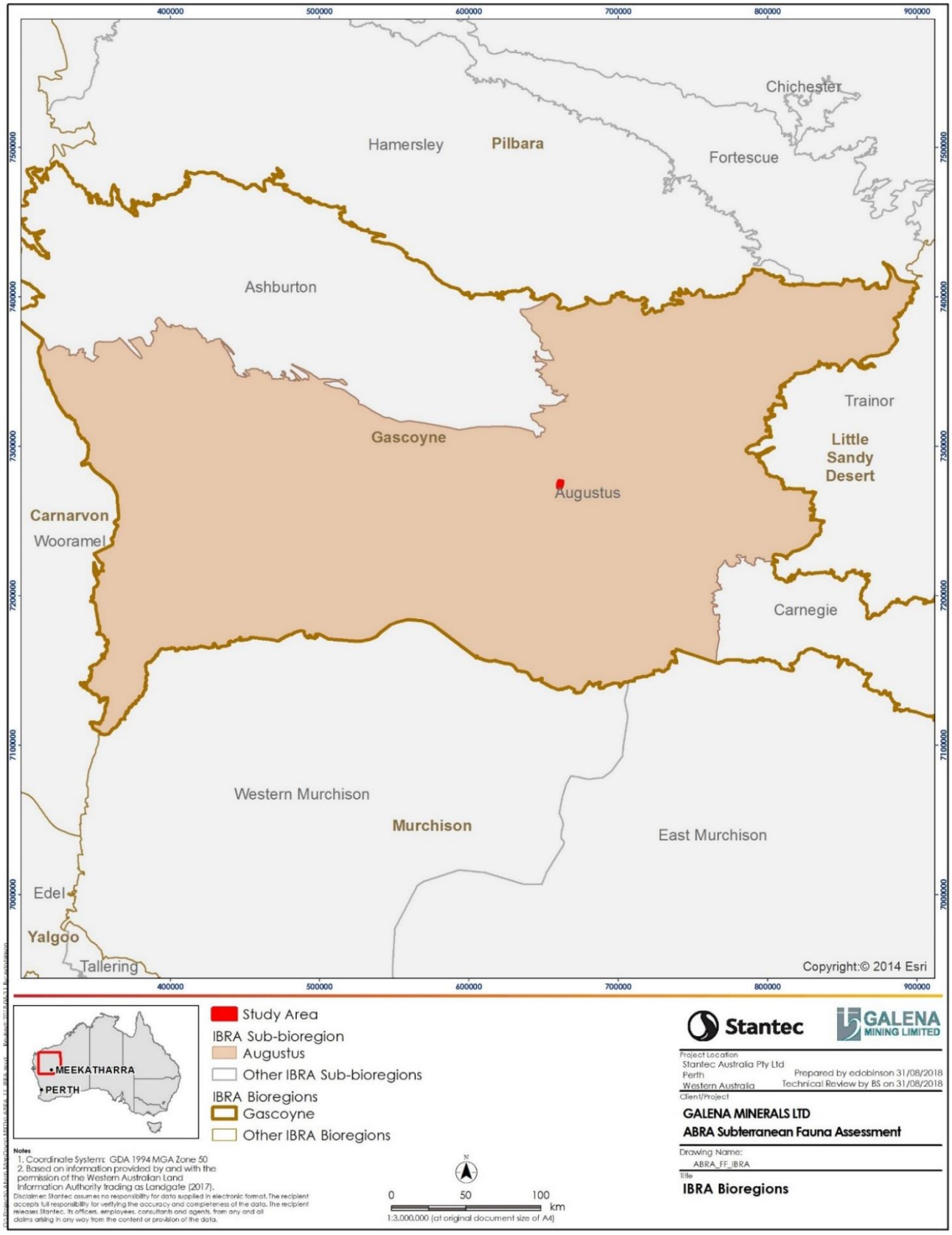

Figure 2-1: Location of the Project in relation to IBRA subregions.

2.3 Climate

The Gascoyne region typically receives low amounts of variable rainfall influenced by northern cyclonic events (GDC 2015). The Augustus subregion is a desert area that is generally characterised by bimodal rainfall (Desmond *et al.* 2001, GDC 2015). The nearest Bureau of Meteorology (BOM) weather stations to the Project, with reliable long-term and recent climatic data, are Three Rivers (station number 7080) and Newman Aero (station number 7176). Three Rivers station provided long term rainfall trends and is located approximately 75 km southeast of the Project, while Newman Aero is located approximately 175 km north-east of the Project.

The mean long-term annual rainfall (1907 to 2018) recorded at Three Rivers is 233 mm with the majority falling during the warmer months from January to March (Bureau of Meteorology 2018). In 2018, January and February received above-average rainfall with more than twice the average falling in February with 117 mm compared to the average of 45 mm (**Figure 2-2**). Much drier than average conditions prevailed from March to May with no rainfall received in May (**Figure 2-3**). In June, the station received a second above-average downpour, almost double (45 mm) the long-term average (24 mm). The 2018 rainfall data (when accessed September 3, 2018) was incomplete, with data available up to the end of July only.

The minimum and maximum temperatures recorded in 2018 were largely consistent with the mean temperatures recorded since 1997 at Newman Aero station, although the maximum and minimum temperatures were higher over the March to early May periods (Bureau of Meteorology 2018).

Subterranean fauna sampling commenced soon after above average summer rainfalls were received in the area (**Figure 2-3**). Therefore, favourable environmental conditions for subterranean fauna would have prevailed throughout the survey period.

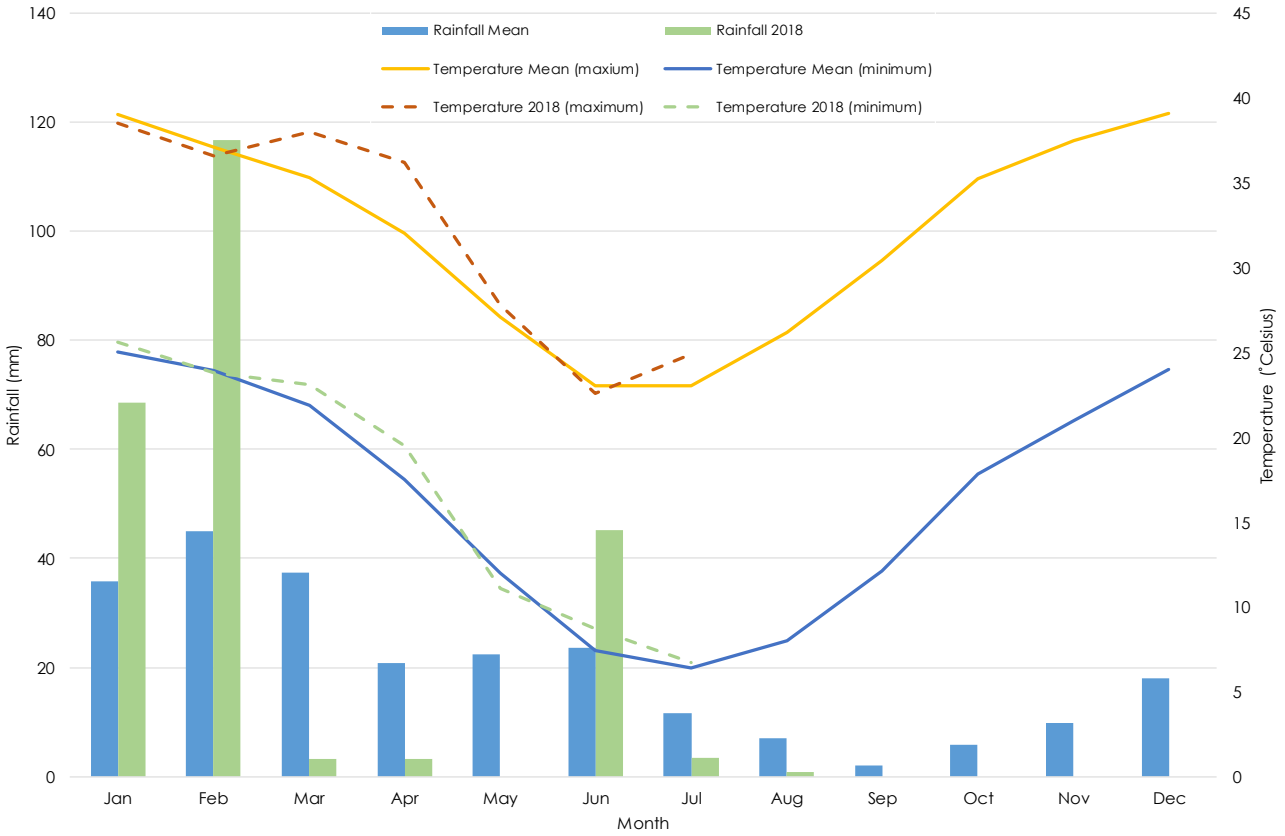

Figure 2-2: Monthly climate data relating to the Project area. Monthly rainfall data (1907 to 2018) recorded from Three Rivers weather station (7080) and monthly mean maximum and minimum temperatures (1997 to 2018) from Newman Aero station (7176) (Bureau of Meteorology 2018).

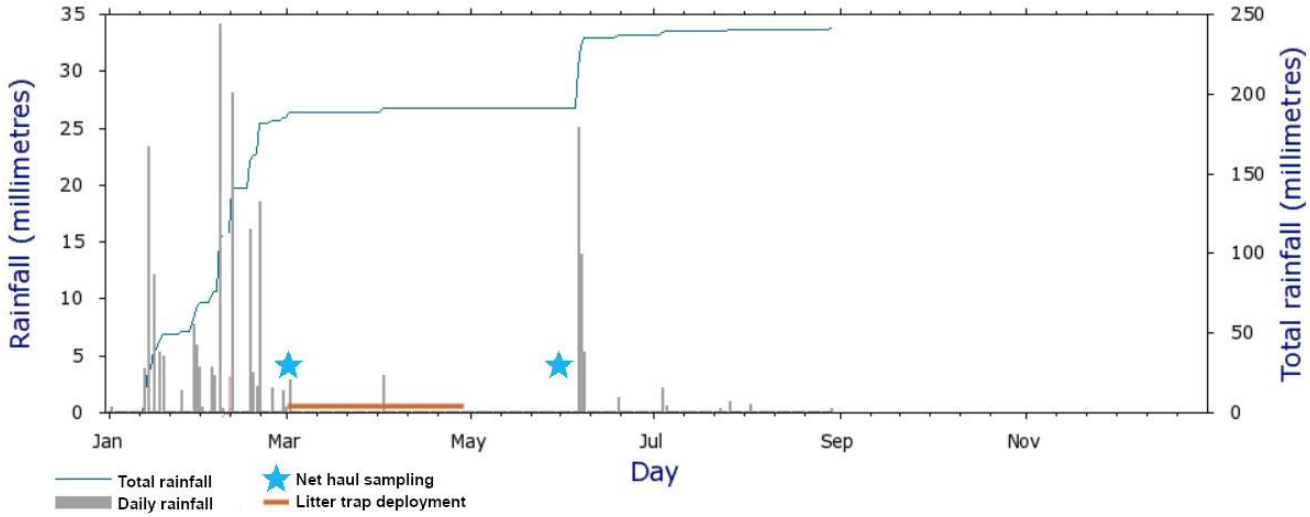

Figure 2-3: Sampling periods with daily rainfall data recorded for 2018 from Three Rivers weather station (7080) (Bureau of Meteorology 2018).

2.4 Geology

The Abra polymetallic prospect is a blind (no geochemical manifestation present at the surface) hydrothermal deposit hosted by metamorphosed sedimentary dolostone, sandstone, siltstone and conglomerates of the Edmund Basin within the east to west trending Jillawarra mineralised belt that extends for approximately 60 km in length by 15 km wide (Boddington 1990, Jianwei *et al.* 2015, Whitford *et al.* 1994) (**Figure 2-4**). The polymetallic deposit is the largest known base metal accumulation in the Capricorn Orogen with mineralisation occurring close to the junction of two major fault lines, the northeast trending Bujundunna Fault and the easterly trending Quarzite Well Fault (considered an extension of the Lyons River Fault system) (Jianwei *et al.* 2015) (**Figure 2-5**). The deposit mainly occurs within the Irregully Formation and in the lower alluvial-fan sediments of the Kiangi Creek Formation (also referred to as the Gap Well and West Creek Formations, respectively (AQ2 2018)), 200 to 500 mbgl, overlain by the deltaic to deep-marine facies of the Kiangi Creek Formation (Jianwei *et al.* 2015). The mushroom-shaped deposit formed during the sedimentation of the lower components of the Edmund Basin between circa 1,610 to 1,590 Ma. The major faults in the region, particularly the Lyons River-Quartzite Well Fault, appear to have focused the flow of hydrothermal fluids from the mantle (or mid to lower crust) into the upper crust formations, likely at numerous stages from circa 1,610 to 995 Ma (Jianwei *et al.* 2015, Rasmussen *et al.* 2010).

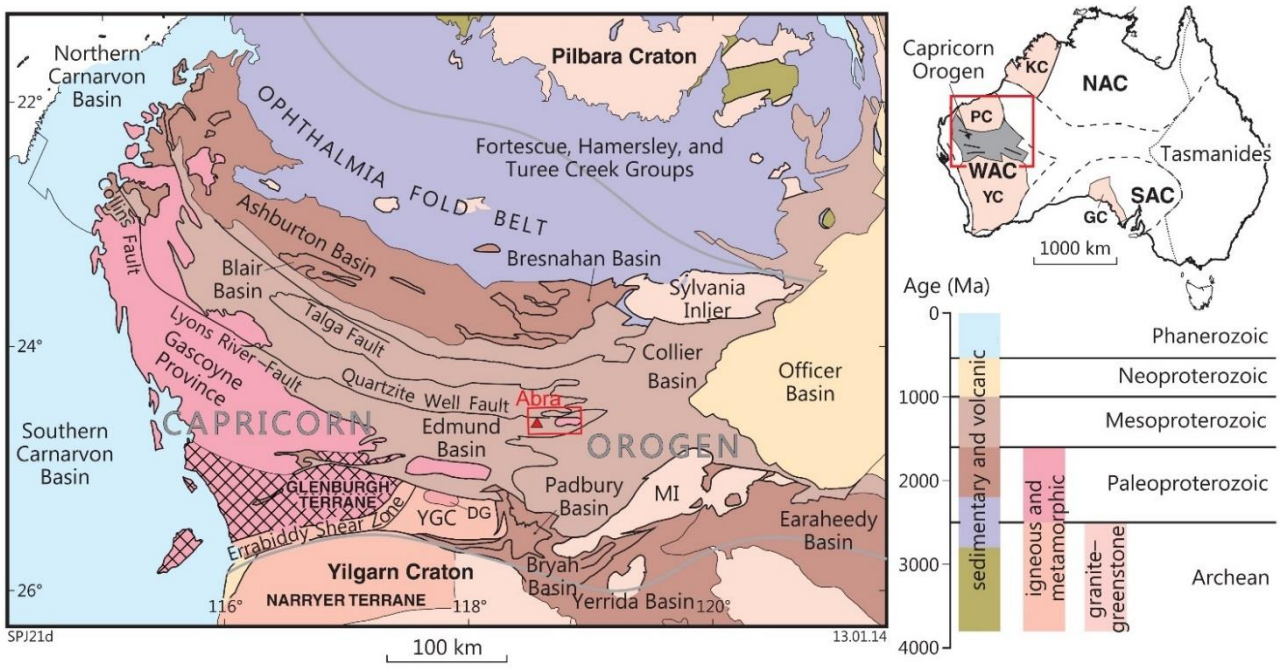

Figure 2-4: The regional geological context of the Abra deposit (source Jianwei *et al.* (2015)).

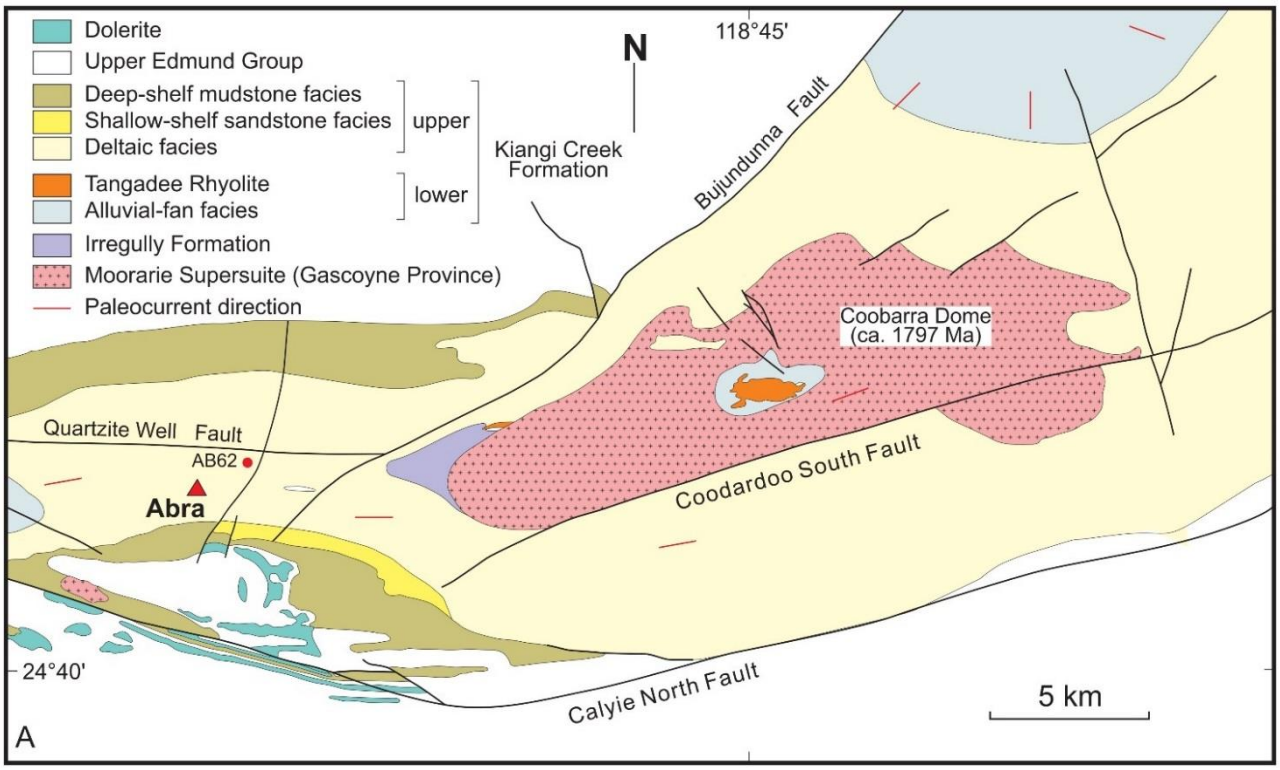

Figure 2-5: The location of the Abra deposit in relation to the Jillawarra Sub-basin bedrock geology showing major geological structures and depositional facies of the Kiangi Creek Formation (source Jianwei *et al.* (2015)).

2.5 Hydrology

The broader region surrounding the Project is characterised by rugged low ranges separated by wide flat valleys with extensive areas of alluvial valley fills (Desmond *et al.* 2001). The Project occurs in the upper headwaters of the Ashburton River, approximately six kilometres north of the catchment divide between the Gascoyne and Ashburton River systems (**Figure 1-1**). The Ashburton River and Ethel Creek, located immediately north and east of the survey area, respectively, are seasonal water courses with several permanent pools. A small tributary of Ethel Creek, 5 Mile Creek, runs south to north along the eastern boundary of the Study Area.

2.6 Hydrogeology

The groundwater present occurs in a low permeable, mostly confined fractured rock aquifer system (AQ2 2018). The physicochemical analysis of the groundwater indicated that aquifer was locally recharged with limited chemical alteration or evaporation since recharge events. The five hydrogeological units identified in the Study Area were (AQ2 2018):

1. Saprolite — Clay dominated with low permeability (0.001 m/d) so would act as an aquitard; widespread, depth variable ranging from 30 to 50 mbgl;
2. Saprock (including transition zone) — Low to moderate local permeability (ranging from 0.0004 to 0.3 m/d, typically 0.04 m/d) associated with relic geological structures (bedding, joints, fractures and mineral veins); widespread, depth variable ranging from 50 to 100 mbgl; likely to be semi-confined aquifer in places due to the overlying aquitard;
3. Upper Kiangi fractured rock aquifer — Low permeability (ranging from 0.0002 to 0.0003 m/d, typically 0.0001 m/d) with secondary porosity associated with fractured rock only; depth variable from 100 to 250 mbgl; considered to be confined by overlying low permeable rock mass;
4. Lower Kiangi fractured rock aquifer — Low permeability (ranging from 0.00007 to 0.00006 m/d, typically 0.00002 m/d) with limited secondary porosity associated with joints and minor dissolution in occasional veins only; joints and fractures extensively infilled with hydrothermal precipitate; depth variable from 250 to 700 mbgl; considered to be confined aquifer by overlying low permeable rock mass; and
5. Main fault zone fractured rock aquifer — Low permeability (0.001 m/d) with secondary porosity associated with fractured rock only near fault zone; zones are thin and not considered to be contiguous; depth variable from 50 mbgl (as relic structure in saprock) to 700 mbgl; considered to be mostly confined aquifer by overlying low permeable rock mass.

The storativity and hydraulic conductivity of the local fractured rock aquifer system is dependant on the degree of secondary porosity present as a result of fracturing intensity and weathering. The overlying saprolite is clay dominated, resulting in lower secondary porosity due to infilling of the interstitial spaces by finer clay sediments. The overlying clay-dominated strata is considered to act as a confining aquitard of the underlying fractured rock aquifer system. The results of the initial aquifer assessment indicate that the fractured rock aquifer system is very-low yielding with low inflow into underground mine workings resulting in limited predicted extent of groundwater drawdown (AQ2 2018).

3. Subterranean Fauna

3.1 Habitat

Prospective habitat for subterranean fauna (stygofauna and troglofauna) is dependent on the presence of voids of suitable size and connectivity to satisfy biological requirements. Subterranean fauna were previously believed to be mostly restricted to karst landscapes that provide a relatively high degree of secondary porosity, but in more recent times have been found to occur in various types of non-karstic geologies and aquifer systems that exhibit suitable voids for colonisation (Humphreys 2008). Stygofauna are now known to occur in non-karstic aquifers in coarse alluvial sediments, fractured rock, pisolites and thin rocky regoliths (Halse *et al.* 2014, Humphreys 2006, 2008, MWH 2016a, Outback Ecology 2014). Likewise, recent surveys have identified troglofauna from non-karstic geologies such as vuggy pisolite ore beds, and fractured and weathered rock formations in the Pilbara and Yilgarn regions (Barranco and Harvey 2008, Bennelongia 2009, Halse *et al.* 2002, MWH 2015b, Outback Ecology 2011b, Subterranean Ecology 2008b).

The extent of subterranean fauna habitat is dependent on the interconnection of sub-surface crevices, fractures and voids, within suitable geological and hydrogeological units and aquifer systems. In addition to allowing for the movement of subterranean fauna, adequate interconnected void spaces and associated high permeability can provide pathways for infiltration (vertical or lateral) of resources such as oxygen and nutrients, key factors influencing subterranean fauna persistence and distribution (Humphreys 2008, Strayer 1994). Geological, hydrological, and hydrogeological studies can give an indication of the extent of subterranean fauna habitat present by providing information on the geological units and structures present, as well as recharge zones, groundwater flow or aquifer characteristics.

3.2 Stygofauna

Stygofauna (groundwater fauna) are predominantly comprised of invertebrates, particularly crustaceans. Other invertebrate stygofauna groups can include gastropods, insects, water mites and worms. In Western Australia, studies have shown that the calcrete and alluvial aquifers associated with palaeodrainage channels of the arid and semi-arid zones can contain rich stygofauna communities. The Pilbara and to a lesser extent the Yilgarn, stand out as global hotspots for stygofauna diversity (Halse *et al.* 2014, Humphreys 2008). Stygofauna can be further classified according to their level of dependency on the subterranean environment:

- stygoxenes are animals that enter groundwaters passively or accidentally;
- stygophiles inhabit groundwaters on a permanent or temporary basis; and
- stygobites are obligate groundwater dwellers (and the focus of this stygofauna assessment).

Stygobites are restricted to their subterranean environment and as such are often classified as short range endemics. Short-range endemic species (SRE's) have geographically restricted ranges of less than 10,000 km^2 and are considered more vulnerable to extinction because of their limited distribution range (Harvey *et al.* 2011, Harvey 2002). Stygobites can often be distinguished from surface or soil dwelling animals by morphological characteristics typical of a subterranean existence, such as a reduction or absence of pigmentation, absence or reduction of eyes, and the presence of extended locomotory and sensory appendages (Humphreys 2008). They can also be defined by ecological parameters such as longer life history stages, and lower rates of metabolism and fecundity (Cooper *et al.* 2002, Danielopol and Pospisil 2000).

Ecologically, there are many factors that influence the distribution of stygofauna at a range of habitat and temporal scales (Boulton 2000). Some of the more influential factors at the microhabitat (sediment) scale include suitable interstitial pore size (i.e. provision of connected network of habitable cavities), inflow rates of energy resources (e.g. organic carbon, biofilm growth, prey), and water quality parameters such as temperature, pH, dissolved oxygen and organic carbon levels. At the mesohabitat (catchment) scale, factors include surface water flow patterns influencing infiltration zones and influx rates into the groundwater systems of energy resources or dissolved oxygen according to geomorphological features, as well as interactions with riparian vegetation and parafluvial sediments (Boulton *et al.* 1998, Schmidt *et al.* 2007).

3.3 Troglofauna

Troglofauna (air-breathing subterranean fauna) are often relictual forms related to surface dwelling (epigean) groups and can be distinguished by characteristics associated with a below-ground existence (Humphreys 2000b). Troglofauna can be divided into:

- troglophiles, which carry out most of their lifecycle underground but are able to survive in epigean habitats;
- trogloxenes, which can enter subsurface habitats passively or incidentally; and
- troglobites (the focus of this assessment), which are obligate or permanent subterranean inhabitants (Thurgate *et al.* 2001) that generally lack pigmentation, are blind (or have reduced eyes), have elongated limbs and may possess enhanced non-visual sensory adaptations (Culver and Sket 2000).

Troglofauna are found worldwide and historically had been generally classified as cave organisms (Culver and Sket 2000). However, the discovery of diverse troglofauna communities inhabiting sub-surface rock fractures in non-karst areas in Europe in the 1980s prompted broader consideration of potential habitat (Juberthie 2000). The most common environments in which troglofauna occur are those that support suitably sized and extensively connected crevices, small cavities or vugs associated with secondary porosity from erosion, fractures and shears zones, that remain relatively humid, an important condition considered to be a key requirement for troglofauna existence (EPA 2003). Like stygofauna, troglobites are restricted to their subterranean environment and often have locally-restricted distributions so most species are considered to be SRE's that are more vulnerable to extinction because of their limited distribution range (Harvey *et al.* 2011, Harvey 2002).

The most researched areas in Western Australia are the Cape Range and Barrow Island karst cave systems where large, diverse communities have been discovered(Hamilton-Smith and Eberhard 2000, Humphreys 1991, 2000a). However, extensive sampling in areas of the Pilbara Craton has identified diverse troglofauna assemblages from non-karstic geologies such as vuggy pisolite ore beds (Biota 2006, MWH 2014a, b). Diverse troglofauna assemblages are commonly collected from groundwater associated calcrete (i.e. non-pedogenic calcrete) and alluvial/colluvial geologies within palaeodrainage channels of the arid and semi-arid zones, particularly in the Pilbara and Yilgarn regions (Harrison *et al.* 2014, MWH 2015b, Outback Ecology 2011b, 2012a, c, Platnick 2008), but less so in the more arid interior of Australia (Outback Ecology 2011c). Less diverse troglofauna assemblages have also been recorded from weathered fractured rock (Outback Ecology 2011a, 2014) and metamorphic mafic rock systems (Bennelongia Environmental Consultants 2009). Continued studies are likely to increase the understanding of prospective troglofauna habitat in Western Australia. It is only recently that troglofauna have become a focus of environmental assessment in Western Australia, and there is still relatively little information on their distribution compared to stygofauna (Eberhard *et al.* 2007, Environmental Protection Authority 2016a).

3.4 Risks and Relevant Legislation

Development and operation of mines in Western Australia pose a number of risks to subterranean fauna and their habitat, which include:

- direct removal of, or disturbance to, habitats through mining excavation;
- lowering the groundwater table through groundwater abstraction for pit dewatering and supply; and
- altering water quality parameters, to levels which may exceed species tolerance limits.

Subterranean fauna are protected under State and Federal legislation, governed by three Acts:

- Wildlife Conservation Act 1950 (WA) (WC Act);
- Environmental Protection Act 1986 (WA) (EP Act); and
- Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act).

With this legislation in mind, the EPA developed the *Technical Guidance Subterranean Fauna Survey* (2016b)(equivalent to EPA (2013) EAG 12 *Environmental Assessment Guideline for Consideration of Subterranean Fauna in Environmental Impact Assessment in Western Australia*) and the *Technical Guidance Sampling Methods for Subterranean Fauna Survey* (2016a)(equivalent to EPA (2007) *Guidance Statement No. 54A Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia*) which outline considerations and sampling methods for subterranean fauna in Western Australia. These documents provide advice to proponents and the public on the requirements for environmental impact assessment (EIA) and management of subterranean fauna. The assessment reported here was designed in accordance with both the EPA (2016a, b) guidance documents.

Mining proposals that will potentially impact on groundwater, or hypogean habitats that support subterranean fauna, require a risk assessment to ensure mining operations do not threaten the viability of important species or communities. Proponents must demonstrate that any species existing within potential mine-related impact zones also occur outside this area. For taxa restricted to impact zones, a suitable management plan must be developed, which includes ongoing monitoring of subterranean fauna to ensure the persistence of the species.

3.5 Regulatory Survey Adequacy Guidelines

The EPA (2016a) stipulates that the appropriate level of survey depends on the likely presence of subterranean fauna, the degree of impact proposed, and adequacy to reliably inform decisions as part of the EIA process as to whether a proposal meets the EPA's objective and is tailored to the circumstances of the proposal.

For Level 1 low intensity (pilot) surveys the recommended survey intensity considered to provide a reliable verification of the habitat present hosting subterranean fauna is:

- Troglofauna — 10 to 15 samples; and
- Stygofauna — 6 to 10 samples.

If the findings from a desktop assessment and pilot survey indicate that a project area is not prospective for subterranean fauna then no further survey would be required. If a pilot survey does find that stygofauna and / or troglofauna species do occur within the target deposit habitat, thereby demonstrating that subterranean fauna are a potential environmental factor, then a Level 2 (baseline or comprehensive) survey would be required.

The EPA (2016b) recommends that for Level 2 stygofauna surveys in areas that have been demonstrated to host a stygofauna assemblage, a minimum of 40 net haul samples are to be collected over at least two survey seasons from within proposed impact areas. The minimum survey effort is considered to relate to proposed impacts across an interconnected habitat, not a collated impact survey effort of separate habitats that are each likely to host distinct stygofauna assemblages with no, or restricted, gene flow occurring among each system.

For Level 2 troglofauna surveys in areas that are likely to host 'significant troglofaunal values', a minimum of 60 litter trap samples deployed over two rounds for a minimum of six weeks each are recommended (EPA 2016b). The definition of 'significant values' is not specified or quantified but has been interpreted to relate to the presence of a relatively diverse troglofauna assemblage in or associated with the proposed development area.

4. Methods

4.1 Database searches and lists

Searches of both federal and state databases were undertaken as part of the desktop review to reveal if any stygofauna or troglofauna taxa had been previously recorded from within or near the Study Area, and to identify if any threatened or priority ecological communities (TEC's and PEC's) were in the vicinity. Search areas were either from a central point in the Study Area or a designated rectangular search area (**Table 4-1**). Database and internet information sources included:

- Department of Biodiversity, Conservation and Attractions (DBCA) TEC/PEC database was searched for TEC's and PEC's occurring within a 75 km radius of the Study Area;
- Western Australian Museum's (WAM) arachnid, crustacean, myriapod and oligochaete collection databases were searched for subterranean fauna;
- Atlas of Living Australia (ALA);
- Nature Map of Western Australia; and
- Stantec's Biolink Subterranean Fauna Database (SBSFD).

The following Federal and State government lists were also checked against the database results, to identify any threatened or priority subterranean fauna that may occur within the search area:

- WC Act Schedule Species List;
- EPBC Act TEC List; and
- EPBC Act Threatened Fauna List.

Table 4-1: Defined search parameters of database and internet sources.

Data Source	Search Area	Co-ordinates
DBCA TEC/PEC	75 km radius	Central point @ 24.628889 S, 118.586667°E
Nature Map		
Literature Review		
WAM Collections	200 by 120 km rectangle	NW corner @ 26.315579 S, 120.437015 E SE corner @ 25.670564 S, 120.216059 E
ALA		
SBSFD		

4.2 Literature Review

A literature review was conducted to gather existing information on subterranean fauna from within the vicinity of the Project Area. The review included technical reports, scientific journal articles and government publications. The areas of focus for the literature review were drainage and palaeochannel systems associated with and/or near to the Study Area, as well as calcrete systems associated with the Raeside palaeochannel within approxiamately 75 km of the Study Area.

4.3 Field Personnel and Licences

The field survey methods and sampling effort employed for the Abra subterranean fauna survey followed both the EPA (2016a, b) technical documents. The Regulation 17 licence to collect fauna for scientific purposes (*Wildlife Conservation Act 1950*, Regulation 17) was obtained from the DBCA prior to survey (Licence Number: 08-001836-1). Personnel involved in the field sampling were: Dr Nicholas Stevens and Samantha Lostrom.

4.4 Groundwater Properties

Groundwater properties can have an important influence on the occurrence and distribution of stygofauna. A number of basic groundwater physicochemical parameters (electrical conductivity (EC), pH, water temperature, dissolved oxygen (DO), and reduction-oxidation potential (Redox)) were recorded in the field from a water sample collected by a bailer from the upper one to two metres of the bore

column using a calibrated YSI water quality meter. The three more important parameters in regard to influencing stygofauna habitat are considered to be pH, DO and salinity.

Standing water level (SWL) was measured as metres below ground level (m bgl) using a Solinst 101 water level meter. The end of hole depth (EoH) was calculated from the number of rotations of the stygofauna sampling winch reel required to retrieve stygofauna nets.

4.5 Stygofauna Assessment

4.5.1 Net Haul Sampling

Stygofauna samples were taken from either exploration drill holes or bores (collectively referred to henceforth as sites) using haul nets, which have been found to be the most efficient retrieval method (Allford *et al.* 2008). The details of sites sampled are presented in **Appendix A**. Sampling was consistent with the procedures outlined in the EPA (2016b) technical document, as follows:

- samples were collected using two weighted haul nets with mesh sizes of 150 µm and 50 µm. Each net was fitted with a collection vial with a base mesh of 50 µm;
- the 150 µm net was lowered first, to near the bottom of the site;
- once at the bottom, the net was gently raised up and down to agitate the sediments;
- the net was then raised slowly, to minimise the 'bow wave' effect that may result in the loss of specimens, filtering the stygofauna from the water column on retrieval;
- once retrieved, the collection vial was removed, the contents emptied into a 250 ml polycarbonate vial, and preserved with 100% undenatured ethanol;
- this process was repeated three times alternating with three samples with the 50 µm net;
- to prevent cross-contamination, all sampling equipment was washed thoroughly with Decon 90 (2 to 5% concentration) and rinsed with potable water after each site;
- in the field, samples were placed into eskies with ice bricks prior to being transferred into a refrigerated environment on-site at the end of each survey day; and
- samples were couriered back to the Stantec laboratory in Perth, where they were stored in 100% ethanol and refrigerated at approximately minus 20°C.

4.5.2 Windmill Pump Sampling

Opportunistic samples were collected from two windmills present in the northern reference area. The method used to collect the pump sample involved filtering the direct outflow from the windmill through a 50 µm stygofauna net for 30 minutes. The sample was then processed in the same manner as the standard stygofauna net haul sample as detailed above in section 4.5.1.

4.5.3 Stygofauna Survey Effort

The stygofauna sampling was undertaken in a staged approached. The first stage comprised a Level 1 low sample intensity (pilot) stygofauna survey of 15 samples to verify the stygofauna values associated with the deposit area. The second stage comprised a greater sample intensity (41 samples) to: 1) further confirm the stygofauna values in the deposit area; and 2) to target sites in the broader area to provide greater context of the potential habitat surrounding the deposit. In total, 56 stygofauna net haul samples were collected from 40 sites (**Table 4-2**, **Figure 4-1**, **Appendix A**). The sample phases were undertaken in March and May 2018. Twenty samples (36%) were from within the proposed impact area and 36 samples (64%) were from non-impact areas.

The survey effort undertaken to verify the stygofauna values in the deposit area (20 samples) and in the broader area (36 samples) fulfils the recommended approach to stygofauna assessment, as recommended by the Western Australia EPA *Technical Guidance Sampling Methods for Subterranean Fauna Survey* (2016a). The survey intensity undertaken, in conjunction with the habitat present, is considered to be sufficient to enable a reliable characterisation to be made of the stygofauna values present in the deposit area and in relation to the proposed direct impact zones in accordance with EPA *Technical Guidance Subterranean Fauna Survey* (2016b).

Table 4-2: Total stygofauna sample effort.

Area		Impact		Non-Impact
		Mining	Groundwater Drawdown	
Overlying Deposit & Boxcut Portal		10		
Outside Deposit	<500m		10	
	>1km, <2km			17
	>2km			19
Totals		20		36

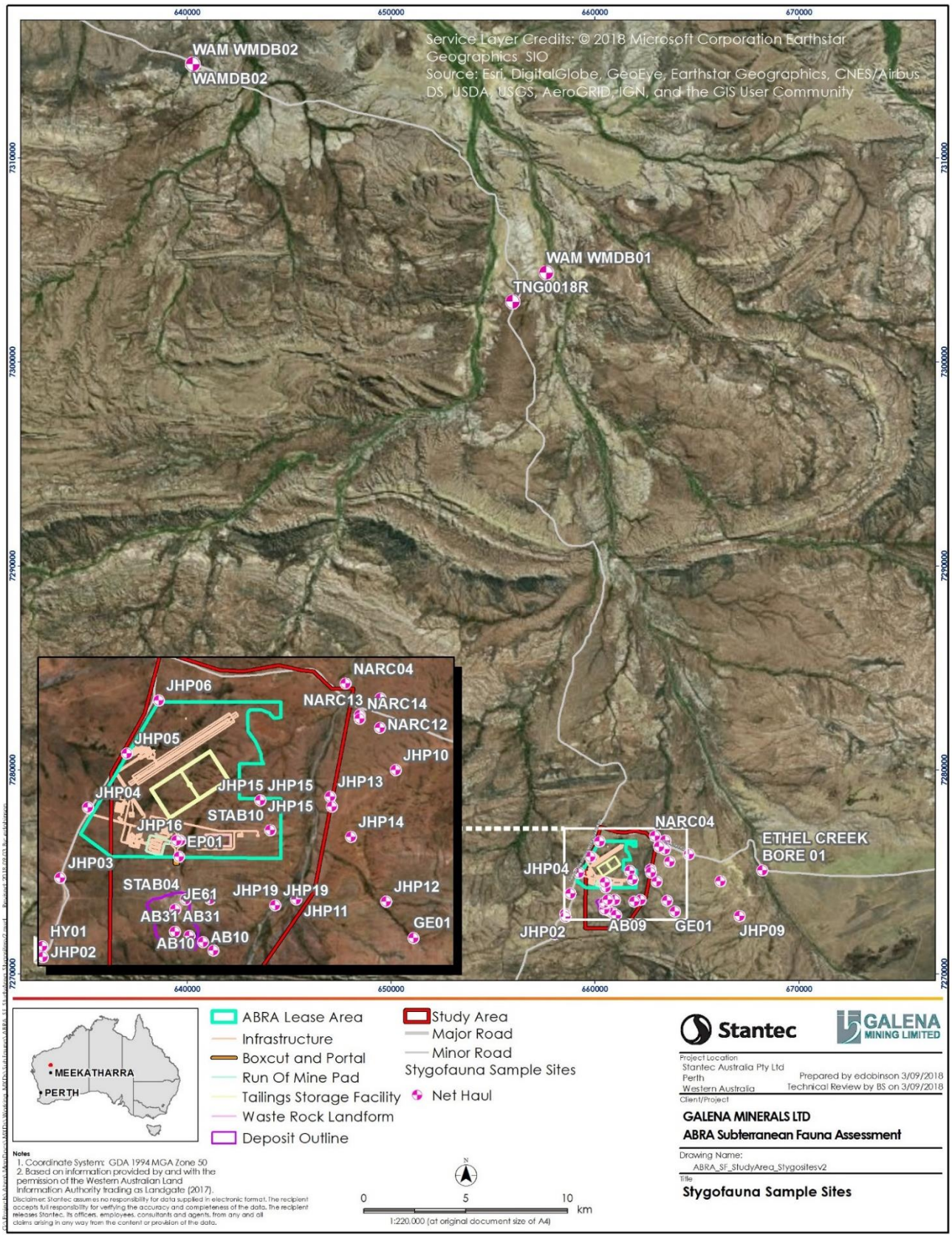

Figure 4-1: Stygofauna sample locations.

4.6 Troglofauna Survey

Troglofauna samples were taken from either exploration drill holes or bores (collectively referred to henceforth as sites) using litter traps and net haul scrapes. The details of sites sampled are presented in **Appendix A.**

4.6.1 Litter Traps

Troglofauna were sampled using litter traps as follows:

- litter traps were packed with sterilised organic material and sealed to maintain moist, sterile conditions prior to field deployment;
- traps were then moistened with water prior to deployment in sites;
- once installed in the sites, traps were left in place for eight weeks to allow adequate time for colonisation by troglofauna; and
- on retrieval, traps were sealed in zip lock bags, labelled, and couriered to the Stantec laboratory in Perth for sorting and identification.

In the laboratory, troglofauna specimens were extracted from the litter using Tullgren funnels. Litter was placed into funnels, and light and low heat was applied from overhead lamps to create a temperature gradient of approximately 14°C in the litter. This method was applied to encourage any troglofauna, which are light sensitive and prefer humid conditions, to migrate down through the litter as it dried. Troglofauna specimens then fell through a mesh layer into collection vials at the base of the funnels, containing 100% ethanol. After collection of troglofauna in the vials, the litter was removed from the funnels and manually searched under magnification for any troglofauna specimens that might be remaining (**Figure 4-2**).

Figure 4-2: Troglofauna collection and extraction methods: A) Litter trap; B) Tullgren funnels.

4.6.2 Net Haul Scraping

Net haul scraping has been found to be an efficient method for sampling for troglofauna that compliments troglofauna trapping (Halse and Pearson 2014, Outback Ecology 2011b, Subterranean Ecology 2008a). Net haul scraping involves the following:

- lowering a stygofauna net to the bottom of a dry site or at least 1 m below the standing water level if groundwater is present.
- scraping the net up along the uncased wall surface of the site on retrieval with the aim of dislodging and collecting any invertebrates that may be present.
- this process is repeated four times per site with each scrape sampling a different side of the wall surface of the site.

Scraping for troglofauna can also be conducted simultaneously when sampling uncased bores with water present for stygofauna so that the stygofauna sample also counts as a troglofauna scrape sample. The only difference is the sample effort is greater with six net hauls taken per sample rather than four. Stygofauna sampling of fully-cased bores are not regarded as net haul scrape samples, regardless of whether potential troglofauna taxa may have been collected.

All haul samples were preserved in 100% ethanol prior to shipment back to the Stantec laboratory in Perth for processing. To enhance preservation of specimens and their DNA, samples were kept cool onsite in eskies with ice bricks then refrigerated at the end of each survey day. All samples were then shipped back to Perth in eskies with ice bricks then placed in freezers (at minus 20 Celsius) to further promote fixation of DNA.

4.6.3 Troglofauna Survey Effort

A total of 27 troglofauna samples were collected from 25 sites to verify the troglofauna values in and around the Project Study Area. (**Table 4-3**, **Appendix A**). The 16 troglofauna litter traps were deployed over one survey phase for eight weeks from March 1 to April 4, 2018. The 11 scrape samples were collected as part of the stygofauna sampling of uncased holes undertaken in March and May 2018. Fifteen samples (56%) were from within the proposed impact area and 12 samples (44%) were from non-impact areas (**Figure 4-3**).

The survey effort undertaken meets the recommended number of 10 to 15 samples for a Level 1 low sample intensity (pilot) troglofauna survey to verify the troglofauna values present, as recommended by the Western Australia EPA *Technical Guidance Sampling Methods for Subterranean Fauna Survey* (2016a). The survey intensity undertaken, in conjunction with the habitat present, is considered to be of a sufficient quantity to enable a reliable characterisation to be made of the troglofauna values present in the Project Area and in relation to the proposed direct impact zones in accordance with EPA *Technical Guidance Subterranean Fauna Survey* (2016b).

Table 4-3: Total troglofauna sample effort. Numbers in parentheses indicate number of scrape samples.

Area		Impact		Non-Impact
		Mining	Groundwater Drawdown	
Deposit & Boxcut Portal		15 (2)		
Outside Deposit	>1km, <2km			4 (1)
	>2km			8 (8)
Totals		15 (2)		12 (9)

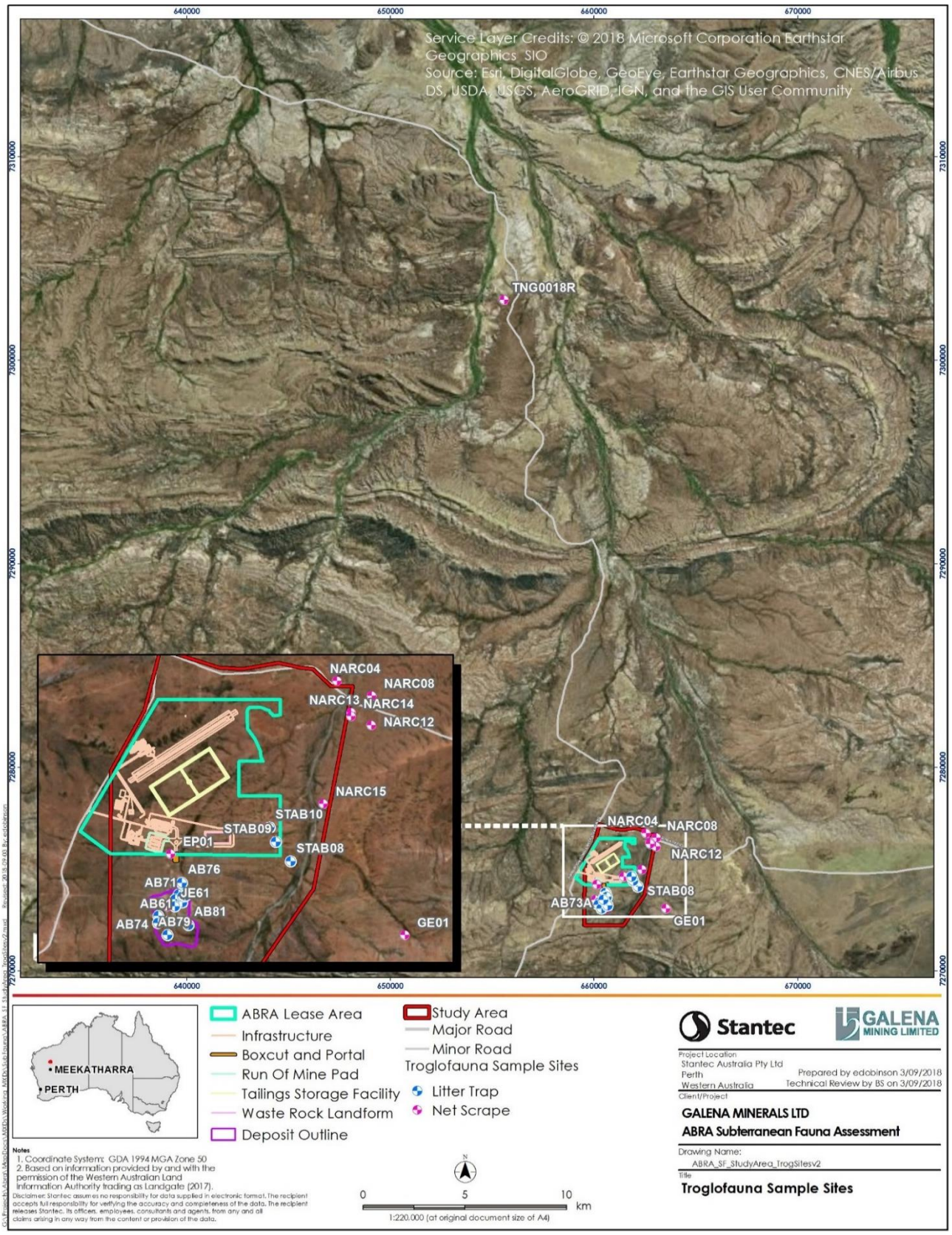

Figure 4-3: Troglofauna sample sites.

4.7 Sorting and Identification of Specimens

Preserved samples were sorted manually using Leica MZ6, MZ7.5, M80 and M205C stereomicroscopes by Dr Nicholas Stevens and Emma Dobinson. Once sorted, any potential subterranean fauna specimens found were preserved in 100% ethanol and stored at minus 20°C to ensure viability for future DNA analysis (if required). Taxa were identified by Dr Nicholas Stevens and Dr Erin Thomas of Stantec, using published and unpublished keys and taxon descriptions. Undescribed taxa were assigned morphospecies names based on morphological features. The taxonomy of the amphipod material collected were investigated with genetic analysis.

4.8 DNA Sequencing

Four representative specimens of two amphipod morphospecies collected from the Study Area and a northern reference sites were sent to Dr Remko Leijs from the South Australian Museum (SAM) for genetic analysis (**Appendix E**). The main aim of the molecular analysis was to test the robustness of identifications based on morphological characters, including juvenile specimens, investigate the haplotype diversity present, and align morphospecies with any described and/or previously sequenced taxa.

4.9 Diversity Analysis

The EstimateS software package (Colwell (2013) Version 9.1.0) was used to assess the survey adequacy by investigating the stygofauna species richness recorded within and around the Study Area (i.e. excluding the sample results from the northern reference area). The species richness was analysed using species accumulation rarefaction and extrapolation curves, and various species richness estimators (using incidence and abundance data).

The species richness analyes provide a statistical evaluation of the proportion of the stygofauna assemblage detected. A range in the number of species predicted to form the assemblage was developed using seven species richness estimators (ACE, Bootstrap, Chao1, Chao2, ICE, Jack 1 and Jack 2). Statistically, it is more robust to show the results of several estimators to provide a range in predicted richness rather than present only one prediction (Hortal *et al.* 2006).

4.10 Limitations of the Assessment

There were sufficient suitable sites available in and near the Study Area for stygofauna and troglofauna sampling. A number of sites sampled that were initially considered to be potential impact sites were later determined to occur outside the potential groundwater drawdown impact zone. The number of suitable reference sites from more optimal subterranean habitats (e.g. calcrete and alluvial) associated with Ethel Creek to the northeast within 10 km of the Study Area was limited, with only one site present, Ethel Creek Bore01. Three reference sites were found much further to the north, over 30 km away.

Specimens were identified to the lowest taxonomic level where possible. However, specimens may not always be identified to the level of species or morphospecies due to:

- loss or damage of important taxonomic features during collection and/or sorting of specimens;
- lack of adult specimens; or
- limitation in taxonomy, in that the current state of taxonomy for a particular group is insufficiently advanced, and/or relevant taxonomic keys and descriptions are lacking.

While every effort has been made to assess the taxonomy, distribution and conservation significance of the subterranean fauna collected using in-house data collections, publications, publicly available reports, and information provided by specialist taxonomists, some accounts may be limited if specialist information was unavailable.

5. Results

5.1 Database Searches and Literature Review

5.1.1 Database Searches

There were no threatened or priority subterranean fauna species previously noted within a 75 km radius of the Project or surrounds, based on a search of the DBCA's threatened and priority fauna database (DBCA 2018).

A search of the DBCA's threatened and ecological communities database did identify one priority ecological stygofauna community (PEC) within a 75 km radius of the Project. Mingah Springs calcrete groundwater assemblage PEC is hosted in the Gascoyne palaeodrainage channel on Mingah Spring Station, 40 km SSE of the Abra deposit (**Figure 5-1**, **Figure 5-2**). The Mingah Springs calcrete stygofauna PEC has been classified as priority 1, under the *Western Australian Wildlife Conservation Act (1950)*, due to the 'poorly known ecological communities' that are 'known from very few occurrences with a very restricted distribution'. The proposed development of the Project will not have any impact on the Mingah Springs calcrete stygofauna PEC that is located in the Gascoyne River drainage catchment.

A search of the WAM Arachnida, Insecta, Myriapoda and Oligochaeta databases did not identify any stygofauna or troglofauna records within the designated search area for the Project. However, within the WAM Crustacea database there were records of two ostracod species, *Deminutiocandona bicaudal* and *Deminutiocandona neara*, collected from two sites (Vernon 1 (=WAMDB02) and Vernon 3 (near WAM WMDB01), respectively) in the northern reference area, more than 30 km north of the Project, within calcrete habitat overlying siltstone, mudstone and sandstone sedimentary formations (**Figure 5-1**, **Figure 5-2**, **Table 5-1**, **Appendix B**).

A search of the DBCA's NatureMap database, and Atlas of Living Australia (ALA) for the Study Area did not return any listings of stygofauna or troglofauna species.

5.1.2 Stygofauna

No intensive stygofauna assessments are known to have been completed in the region surrounding the Study Area (≤75 km). However, a limited number of stygofauna samples have been collected in the surrounding region by Western Australian Museum or Department of Conservation and Land Management (now DBCA) staff, predominantly from calcrete associated aquifer systems, but also from alluvial habitats (**Figure 5-1**, **Figure 5-2**, **Appendix B**). Calcrete aquifer systems are recognized as providing optimal habitat for stygofauna in the Pilbara and Yilgarn, typically hosting more diverse stygofauna assemblages than alluvial, regolith or fractured rock associated aquifers (Allford *et al.* 2008, Environmental Protection Authority 2007, Humphreys 2008, Outback Ecology 2012d, Stantec 2017a). Relatively well-studied calcrete systems, Barwidgee, Hinkler Well, Lake Violet, Uramurdah, and Yeelirrie, that have formed in the northern Carey paleodrainage channel, each host diverse stygofauna assemblages in excess of 30 stygofauna species, with more than 70 species recorded from Yeelirrie, the most intensively sampled calcrete system in the region, if not Australia (Bennelongia 2015, MWH 2015b, Outback Ecology 2012b, d, Subterranean Ecology 2011b). The Ashburton and Gascoyne palaeodrainage channel calcrete systems have not been as extensively studied as the Carey calcrete systems, however, the limited sampling has demonstrated that stygofauna assemblages are present.

Genetic studies have indicated that calcrete systems can represent closed 'subterranean islands' in that the species of the stygofauna assemblage present are restricted in distribution to a particular calcrete (Cooper *et al.* 2002, Cooper *et al.* 2008, Guzik *et al.* 2008). The Lake Way calcrete systems have been shown to be unique in that genetic data has demonstrated that for some taxa, gene flow does occur among the close neighbouring calcrete systems, particularly among the northern lake-associated calcretes, with amphipod, Bathynellacea and dytiscid species distributions shown to extend from Millbillillie Bubble Well calcrete to Lake Violet and Uramurdah calcretes (Abrams *et al.* 2012, Outback Ecology 2012d). The genetic data was consistent with the hydrogeological assessment that found the surficial alluvial and colluvial aquifers associated with the main drainage pathways can provide hydraulic connections among the main calcrete aquifer systems.

There are times when evidence of stygofauna distribution can seemingly be at odds with hydrogeological data. Genetic studies have demonstrated in some cases that hydraulic connections do exist between aquifers that hydrogeological data had indicated were largely separate systems. As an example, genetic data showed that *Atopobathynella wattsi* has a distribution extending from the Lake Violet calcrete, on the northern shore of Lake Way, to the Hinkler Well calcrete, more than 12 km away on the western shore of Lake Way (Guzik *et al.* 2008). In a further example, the Browns Range Metamorphics and Gardiner Sandstone fractured rock aquifer systems in northern WA, each exhibited distinctly different

hydrogeological characteristics and were considered to be isolated from one another (Klohn Crippen Berger 2013). However, genetic analysis demonstrated that hydraulic connections did exist between the two fractured rock aquifer systems, with two bathynellicean species clearly shown to be distributed in both (Outback Ecology 2014).

Within the Gascoyne bioregion the calcrete habitats, as well as associated alluvial and colluvial aquifer systems, are known to host stygofauna, however, they have not yet been as extensively studied as many Yilgarn and Pilbara stygofauna assemblages.

5.1.3 Troglofauna

There were no troglofauna records found from the designated search area surrounding the Study Area. Typically, information on troglofauna is limited in comparison to stygofauna. However, studies have indicated a similar trend to stygofauna in that troglofauna are more commonly recorded from calcrete habitats, with less diverse, or often no troglofauna collected from fractured rock or colluvium habitats (MWH 2015a, 2016a, Outback Ecology 2014, Stantec 2018b). Studies undertaken in the Yilgarn region of calcrete habitats associated with Lake Way, Lake Maitland, and Yeelirrie, have shown that troglofauna occur in relatively low abundance and diversity compared to stygofauna (MWH 2015b, Outback Ecology 2011b, 2012a, c, Subterranean Ecology 2011b). Surveys of non-calcrete associated geology from the broader Yilgarn region have collected troglofauna from weathered and fractured banded ironstone formations (BIF) and mafic units (Bennelongia 2009, ecologia Environment 2008a, b, Environmental Protection Authority 2010, MWH 2016a, Stantec 2018c). In comparison, calcretes in the broader Yilgarn region are known to host more diverse troglofauna assemblages (MWH 2015b, Outback Ecology 2011b, 2012c, Stantec 2018a, Subterranean Ecology 2011a).

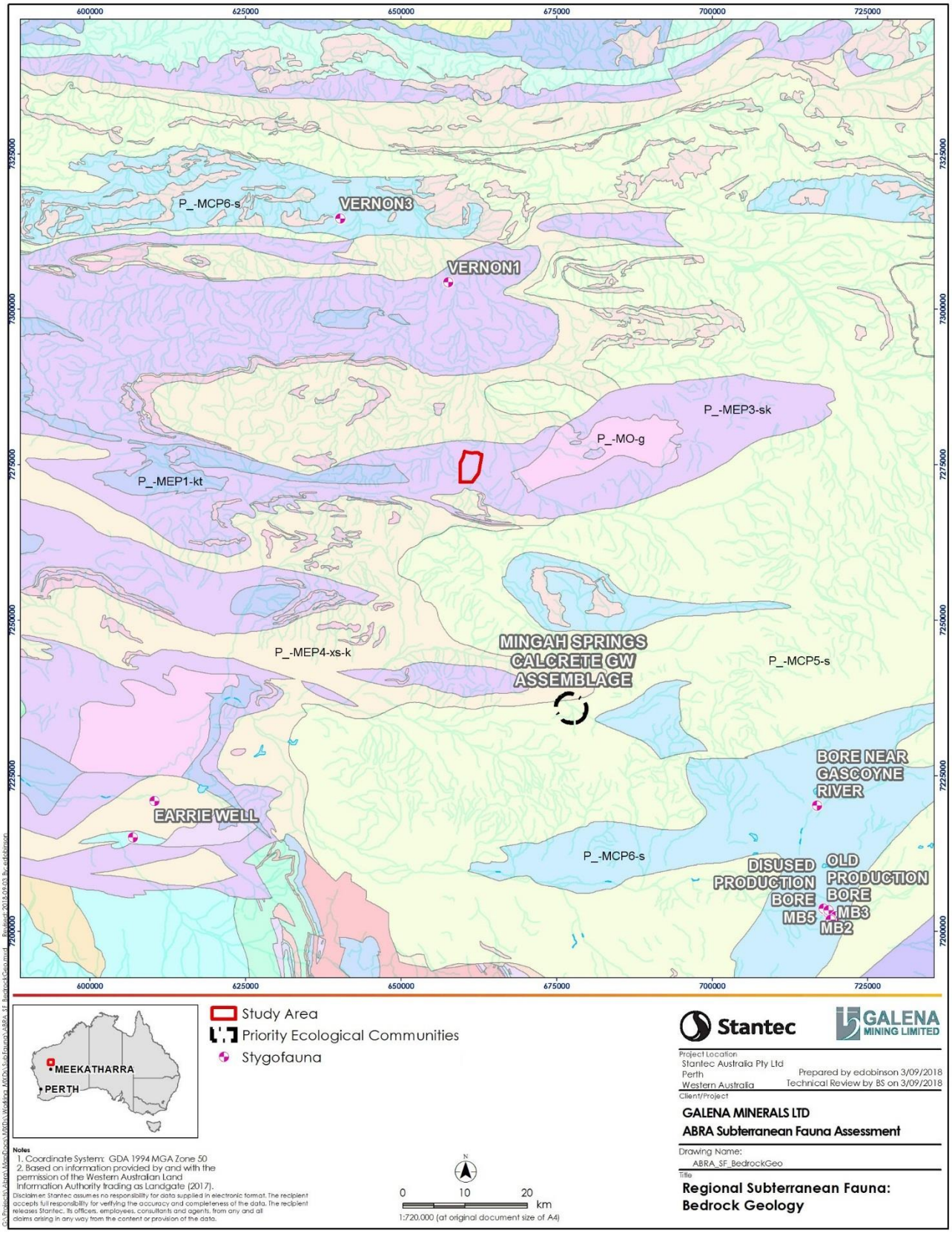

Figure 5-1: Locations of stygofauna records from literature and database searches for the region surrounding the Project in relation to bedrock geology (refer **Table 5-1** for descriptions of relevant geological codes).

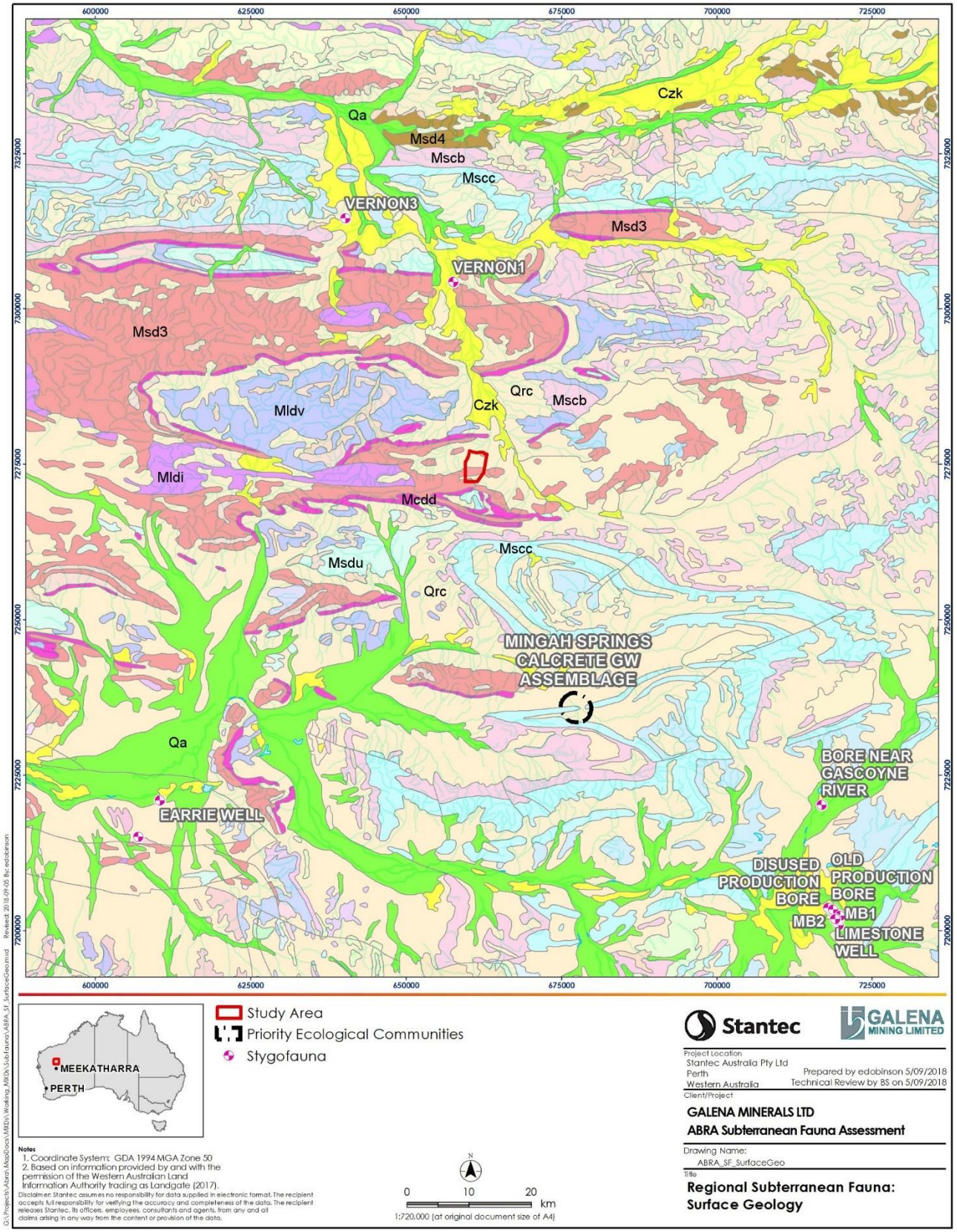

Figure 5-2: Locations of stygofauna records from literature and database searches for the region surrounding the Project in relation to surface geology (refer **Table 5-1** for descriptions of relevant geological codes).

Table 5-1: Description of geological codes relevant to Study Area in **Figures 5-1** and **Figure 5-2**.

Geology	Code	Unit Name	Description
Bedrock	P_-MCP5-s	Collier Group, Depositional package 5	Siltstone, mudstone, sandstone; minor dolostone, chert, and conglomerate. Includes Backdoor Formation and Calyie Formation
	P_-MCP6-s	Collier Group, Depositional package 6	Siltstone, mudstone, and fine-grained sandstone. Includes Ilgararie Formation
	P_-MEP1-kt	Edmund Group, Depositional package 1	Stromatolitic and non-stromatolitic dolostone, dolomitic siltstone, sandstone, siltstone, and conglomerate. Includes Yilgatherra Formation and Irregully Formation
	P_-MEP3-sk	Edmund Group, Depositional package 3	Siltstone and mudstone; sandstone, and dolostone, minor conglomerate. Includes Kiangi Creek Formation and Muntharra Formation
	P_-MEP4-xs-k	Edmund Group, Depositional package 4	Siltstone and mudstone; sandstone, dolostone, dolomitic mudstone, chert, and minor conglomerate. Includes Discovery Formation, Devil Creek Formation, Ullawarra Formation and Coodardoo Formation
	P_-MO-g	Moorarie Supersuite	Undivided; granite and minor gabbro
Surface	Czk	Calcrete	Pisolitic, nodular or massive calcrete; ferruginous inclusions; calcareous cementing of bedrock and transported materials; locally with intercalated chalcedony; as low mounds, in playa lakes, or as valley calcrete; locally dissected and karstified
	Mcdd	Discovery Formation	Massive to laminated (with occasional wavy laminations) black to cream chert
	Mldi	Irregully Formation	Sedimentary carbonate, argillaceous detrital sediment
	Mldv	Devil Creek Formation	Laminated and massive dolomite, interbedded shale, dolomitic breccia, chert and siltstone
	Mscb	Backdoor Formation	Shale, siltstone, minor fine-grained sandstone, chert, mudstone, dolostone.
	Mscc	Calyie Formation	Recrystallised fine to coarse sandstone, in places glauconitic, with lesser interbedded siltstone, granule to pebble conglomerate, shale, mudstone, dolostone, pebbly sandstone, minor chert and dolostone
	Msd3	Muntharra and Kiangi Creek Formations	Siltstone and mudstone; sandstone, dolostone, minor conglomerate
	Msdu	Ullawarra Formation	Shale, siltstone, minor fine-grained sandstone and claystone, locally calcareous
	Qa	Alluvium	Channel and flood plain alluvium; gravel, sand, silt, clay, locally calcreted
	Qrc	Colluvium	Colluvium, sheetwash, talus; gravel piedmonts and aprons over and around bedrock; clay-silt-sand with sheet and nodular kankar; alluvial and aeolian sand-silt-gravel in depressions and broad valleys in Canning Basin; local calcrete, reworked laterite

5.2 Subterranean Habitats

The attributes of the geological units present in and near the deposit area are not considered to represent prospective habitat for subterranean fauna due to the lack of suitable interconnected cavities in the upper clay dominated strata that confines the underlying limited local fractured rock aquifer system (refer section 5.2). The Abra deposit occurs 200 to 500 mbgl within the metamorphosed sedimentary dolostone, sandstone, siltstone and conglomerates of the Irregully Formation and the lower units of the Kiangi Creek Formation, which are overlain by the deltaic to deep-marine facies of the upper Kiangi Creek Formation (**Figure 5-3**). The geological units associated with the target deposit would not provide any habitat for subterranean fauna due to being too deep underground, buried by thick confining clay dominated units, as well as possessing low permeability with secondary porosity associated with the fractured rock only.

The thick sandstone, siltstone and conglomerate units overlying the deposit are fined grained and clay dominated, resulting in low permeability (**Figure 5-4**, **Figure 5-5**). The diamond drill core images from within the deposit area indicate that the unsaturated strata above the groundwater table (SWL ranging from 31 to 38 mbgl) lack voids of suitable size and connectivity to satisfy biological requirements for troglofauna to exist. The same is true below the water table with the upper 25 to 35 m of the saturated strata exhibiting low permeability, that appears to decline with increasing depth (AQ2 2018). Geological drill logs from the JHP series of sites drilled beyond the deposit area, but in and around the Study Area, further demonstrates that the upper strata are predominantly clay dominated and widespread in the area (**Appendix A.3**).

The overlying clay dominated strata is considered to represent an aquitard, confining the underlying very-low yielding fractured rock aquifer system (AQ2 2018). For stygofauna, confined to semi-confined fractured rock aquifer systems are not regarded as suitable habitat due to limited hydrological exchange that would restrict the influx of resources (i.e. oxygen and nutrients (in the form of organic matter)) into the aquifer system (Gibert *et al.* 1994, Strayer 1994, Vervier and Gibert 1991). Dissolved oxygen generally shows a decreasing trend with depth in groundwater. In Australia, stygofauna are generally found to occur within the upper 10 to 15 m of an unconfined aquifer system, below which dissolved oxygen and nutrients decline to levels that will not sustain long term persistence (Boulton *et al.* 2008, Humphreys 1999, Humphreys 2009, Outback Ecology 2012d).

Previous stygofauna sampling within the broader region (refer section 5.1.2) has demonstrated that the calcrete habitats, as well as the associated alluvial and, to a lesser extent, colluvial aquifer systems, fringing the calcrete systems, do host stygofauna (**Figure 5-2**). Within the Study Area, there are no calcrete or extensive alluvial aquifer systems. Instead, the groundwater present occurs in a locally recharged, low permeable, mostly confined fractured rock aquifer system. Most of the limited recharge would likely occur along the main, more deeply incised tributaries of 5 Mile Creek. In the northern part of the Study Area colluvial surface geological units are present and widespread, occurring in association with 5 Mile Creek and extending to and along the Ethel Creek calcrete/alluvial aquifer system. The colluvial and likely limited alluvial geological units present in close association with the main drainage channels in and around the north-eastern portion of the Study Area would represent the more prospective groundwater habitat for stygofauna.

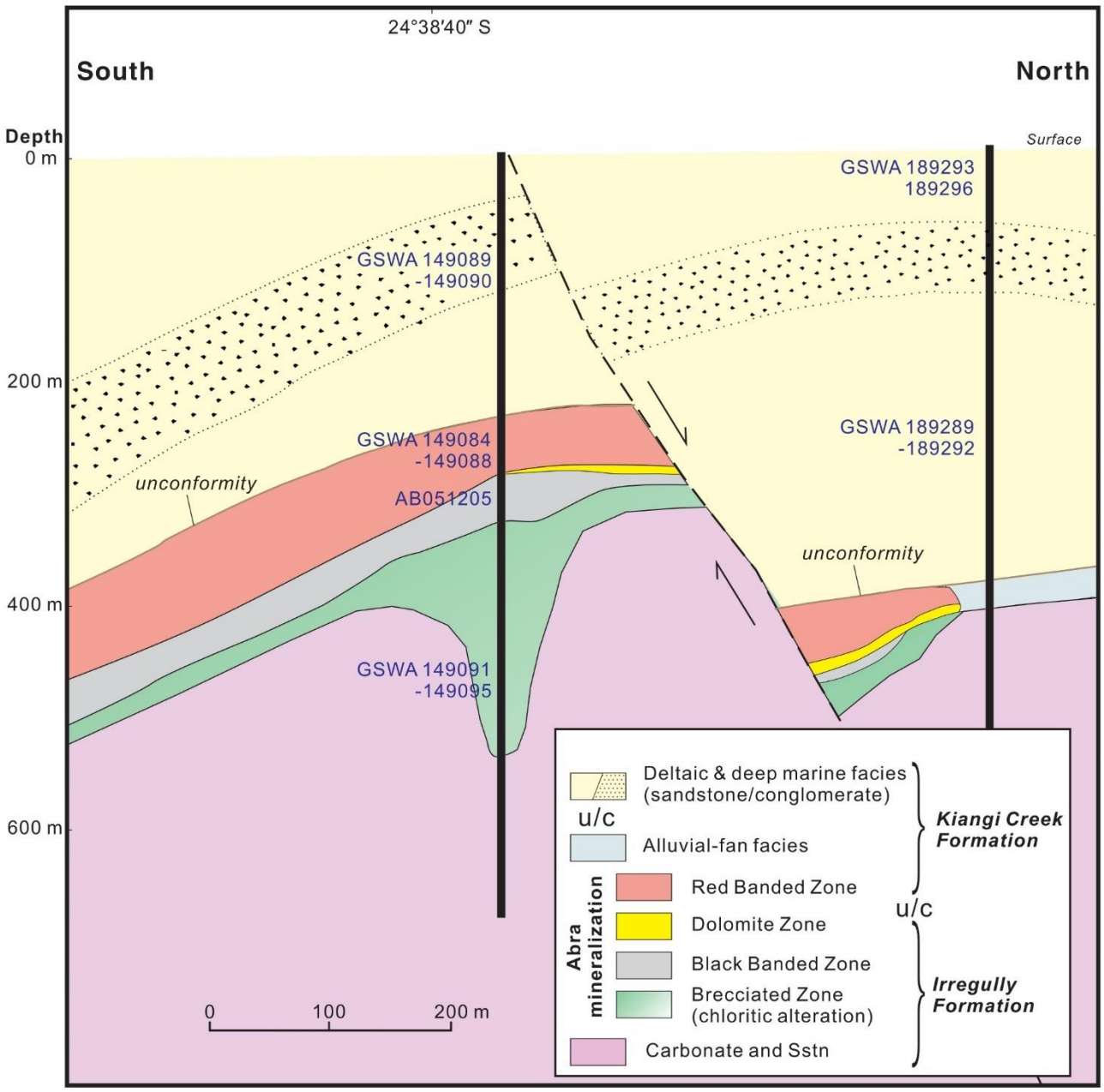

Figure 5-3: A cross section of the Abra deposit (from north to south) showing the geological units and structures present (source Jianwei *et al.* (2015)).

Figure 5-4: Diamond drill AB70 core images (0 to 65.7 mbgl) within northern part of deposit area (SWL in area ranges from 37 to 38 mbgl).

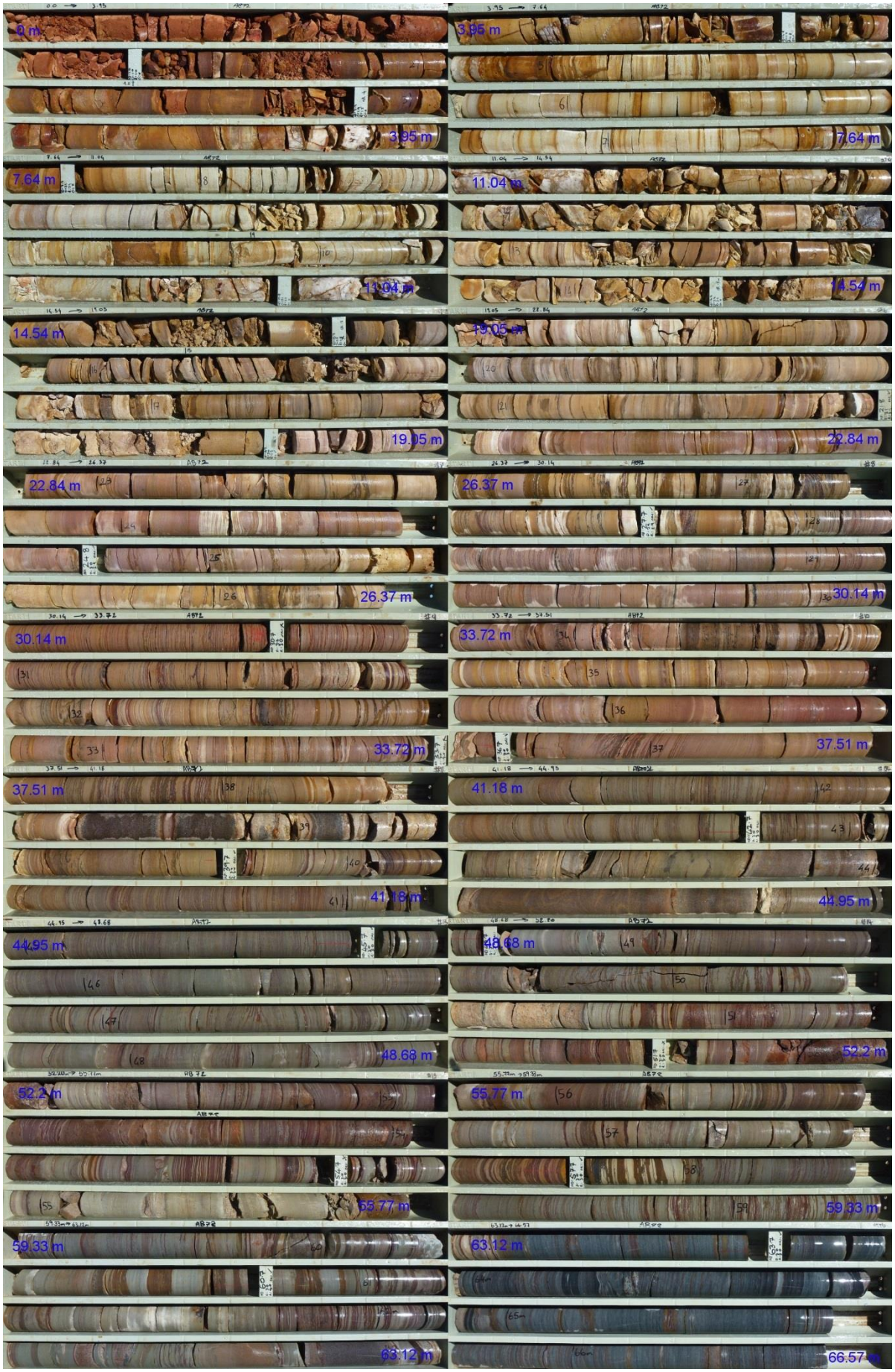

Figure 5-5: Diamond drill AB72 core images (0 to 66.57 mbgl) within central west part of deposit area (SWL in area ranges from 31 to 37 mbgl).

5.3 Groundwater Properties

5.3.1 Standing Water Level

The variation in standing water level (SWL), measured against the Australian Height Datum (AHD), generally reflected local topography. The recorded SWL indicated that the hydraulic gradient runs northwards from the deposit area, that is located higher in the landscape, towards the Ethel Creek drainage system. However, at the local scale the anisotropic permeability of the rocks will probably result in a more complex pattern of groundwater movement (Whitford *et al.* 1994). The SWL was progressively lower moving northwards, ranging from 520.6 to 516.8 AHD (21.1 to 38.1 mbgl) in and near the deposit area (elevation 539 to 558 AHD), to 509.5 to 512.4 AHD (15.6 to 19.5 mbgl), lower in the landscape bordering 5 Mile Creek near the northeastern corner of the Study Area (elevation 525 to 529 AHD) (**Appendix C**, **Table 5-2**). In the northern reference area the SWL ranged from 417.8 to 442.4 AHD (5.8 to 16.7 mbgl) in and near the riparian zones of the main tributaries of the upper Ashburton River, including Ethel Creek (elevation 434 to 459 AHD).

The depth to groundwater in and around the Study Area ranged from 13.3 to 44.5 mbgl, with the depth typically greater towards the southwest, and getting closer to the surface moving northwards (**Table 5-2**). The SWL ranged from 5.84 to 16.65 mbgl at sites near Ethel Creek in the northern reference area. The preliminary hydrogeological assessment of the deposit area indicated that the fractured rock aquifer is confined (refer section 5.2). Therefore, the SWL recorded from the stygofauna sites within and near the deposit area may not to be a true reflection of the actual groundwater levels present due to the piezometric head of the confined aquifer. Confined or semi-confined aquifers are not considered to provide suitable habitat for stygofauna due to the lack of interconnected habitable space and low hydraulic conductivity that restricts the influx of resources into the aquifers (Gibert *et al.* 1994, Humphreys 2008, Strayer 1994).

To the north of the deposit area, groundwater in colluvium geology (Qrc in **Figure 5-2**) is more likely to represent unconfined aquifer conditions with no overlying dominant confining layer present, particularly near to or in association with the more developed drainage lines in the area. In unconfined aquifer conditions, stygofauna diversity is considered to decline with increasing depth to groundwater, particularly greater than 30 mbgl (Halse *et al.* 2014).

5.3.2 Salinity

The groundwater salinity, measured as electrical conductivity (EC), in and near the Study Area was fresh, *sensu* Hammer (1986), averaging 848.6 µS/cm and ranging from 275 to 3,240 µS/cm (**Table 5-2, Appendix C**). There were no discernible trends evident in the distribution of salinity levels among sites sampled and all sites in and near the Study Area where stygofauna were present had salinities ranging from 438 to 811 µS/cm. The salinity levels at sites near Ethel Creek in the northern reference area were generally higher than levels in the Study Area, ranging from fresh to hyposaline, 2,731 to 6,037 µS/cm. The single stygofauna collected from the northern reference area was from WAM WMDB01 that recorded a salinity of 2,731 uS/cm. Stygofauna show a preference for salinities less than that of seawater (<35 ppt or <55 mS/cm) (Strayer 1994). However, some species can tolerate salinity levels up to 70 mS/cm, with fewer species, more commonly copepods, able to exist in salinities in excess of 70 mS/cm (Humphreys 2008, MWH 2015b, 2016b, Outback Ecology 2011b, 2012d). Stygofauna diversity is known to decline with increasing salinity above 5 mS/cm (MWH 2015b, 2016b, Outback Ecology 2011b, 2012b), a similar trend to surface aquatic species (Pinder *et al.* 2005, Pinder *et al.* 2002). The documented salinity levels from in and around the Study Area are well within the habitable range for stygofauna.

5.3.3 pH

The groundwater pH ranged from slightly acidic (6.1) to slightly alkaline (7.9) (Table 5-2**, Appendix C**). All sites where stygofauna were recorded were circumneutral, ranging from 6.5 to 7.6. Diverse stygofauna communities typically occur in calcareous habitats, characterised by circumneutral pH between 7.2 and 8.2 (Humphreys 2008). Acidic groundwaters, typically associated with igneous and metamorphic sedimentary rocks, generally provide less suitable conditions for stygofauna (Humphreys 2008), however, styobitic ostracods have been recorded in acidic groundwaters in the Pilbara region, where pH levels were as low as 4.4 (Reeves *et al.* 2007). Whilst stygofauna diversity may decline with increased acidity, the occurrence of some stygofauna taxa cannot always be discounted.

5.3.4 Dissolved Oxygen

Dissolved oxygen levels recorded from the Study Area ranged from 0.42 mg/L to 5.34 mg/L, indicating oxygenated groundwater conditions were present (**Table 5-2, Appendix C**). In subterranean environments, dissolved oxygen concentrations can be variable and patchy, often fluctuating between suboxic (<0.04 mg/L) to oxic (>3/mL) and varying over small and large spatial scales. Given the natural variability of these environments, stygofauna tend to be more resistant to low levels of oxygen compared to surface water aquatic species (Malard and Hervant 1999, Strayer 1994). Within the Project area, stygofauna were recorded from both oxic and almost suboxic conditions, ranging from 1.1 mg/L to 3.3 mg/L. Dissolved oxygen concentrations below 5 mg/L may often adversely affect surface aquatic biota, stygofauna however, have been documented from suboxic conditions well below 1 mg/L (Chapman and Kimstach 1996, Humphreys 2008). Stygofauna species richness and abundance do begin to decline at levels below 1.0 mg/L DO, with less than 0.5 mg/L representing a critical threshold for long term persistence (Hahn 2006). The oxygenated groundwater conditions present across the Study Area would provide suitable oxygenated conditions for stygofauna.

5.3.5 Groundwater Assessment

The fresh, oxygenated and neutral pH groundwater measured from the sites sampled indicate suitable conditions for stygofauna in the Study Area sampled. However, the confined to semi-confined aquifer conditions in and around the deposit area would likely preclude stygofauna.

Table 5-2: Minimum, maximum and mean of groundwater parameters recorded.

		Elevation (AHD)	SWL (AHD)	SWL (mbgl)	EC (uS/cm)	pH	DO (mg/L)
Northern Reference	**Min**	427	417.75	5.84	796	6.9	0.78
	Max	459	442.35	16.65	6037	7.26	2.98
	Mean	440	433.75	10.58	3188	7.05	2.05
	Number	4	3	3	3	3	3
Study Area	**Min**	524	504.33	10.58	275	6.1	0.42
	Max	569	527.53	44.45	3240	7.92	5.34
	Mean	541.6	516.79	25.46	848.61	7.17	2.11
	Number	47	44	44	47	45	47

5.4 Stygofauna Findings

5.4.1 Overview

A total of 18 stygofauna specimens, representing four species from three higher level taxonomic groups, Amphipoda, Bathynellacea, and Oligochaeta, were recorded from six of the 40 sites sampled (**Table 5-3**, **Figure 5-6**, **Appendix D**). No stygofauna were recorded from within the deposit area (**Figure 5-7**, **Figure 5-8**). Only one species, the oligochaete *Phreodrilus* OES25, was collected from within the potential groundwater dewatering drawdown impact zone associated with the proposed underground mining, approximately 800 m north of the deposit area (**Figure 5-9**, **Figure 5-10**). *Phreodrilus* OES25 was also recorded on multiple occasions from outside the potential groundwater drawdown impact zone, collected from three non-impact sites, up to 3.6 km from the deposit area.

The Amphipoda was the most species-rich group with 2 species recorded, *Bogidiella* OES11 and Paramelitidae OES10 (**Table 5-3**). A single specimen of *Bogidiella* OES11 was collected from the northern reference area, more than 30 km north of the deposit area, from a windmill pump sample (**Figure 5-9**). Genetic analysis confirmed that this damaged specimen was not a Paramelitidae species (**Appendix E**). Within the Study Area, seven specimens of Paramelitidae OES10 were collected from a single site, STAB10, from outside the potential groundwater drawdown impact area, more than 1.5 km from the deposit area (**Figure 5-10**). Four specimens were sent for genetic analysis but no sequence data was successfully obtained (**Appendix E**). A single specimen of *Brevisomabathynella* OES30 was also collected in the same sample (sympatrically) with Paramelitidae OES10.

5.4.2 Project Areas

The findings for each of the areas sampled are summarised as follows:

- Abra Deposit Area — No stygofauna collected, confirming that the deep clay-dominated regolith present across the area, which extends to over 50 m bgl and is characterised as an aquitard (AQ2 2018), does not provide suitable habitat for stygofauna.
- Potential groundwater drawdown impact zone (within 1 km of the deposit) — Only one species, *Phreodrilus* OES25, was recorded, approximately 800 m north of the deposit area from site JHP16. The regolith at JHP16 is not clay dominated, instead comprised primarily of weathered sandstone (medium grained) and subordinate siltstone (Robinson Drilling Company 1990) (**Appendix A.3**).
- Non-impact zone — Three stygofauna species, *Brevisomabathynella* OES30, Paramelitidae OES10, and *Phreodrilus* OES25, were recorded from four north-eastern sites more than 1.5 km from the deposit.
- Northern reference area — One stygofauna species, *Bogidiella* OES11, was collected from a windmill pump sample from the Ethel Creek calcrete aquifer.

5.4.3 Taxa Recorded

5.4.3.1 Amphipoda

Only one amphipod species, Paramelitidae OES10, was recorded from within the Study Area, collected more than 1.5 km from the deposit area from a single site within colluvial surface geology, in close association with 5 Mile Creek (**Figure 5-8**, **Figure 5-10**). A second amphipod species, *Bogidiella* OES11, was recorded as part of the study, but from the Ethel Creek calcrete aquifer within the northern reference area, more than 30 km north of the deposit area (**Figure 5-9**).

Stygobitic amphipod species are relatively commonly recorded in stygofauna studies from many of the Pilbara and northern Yilgarn calcrete systems (Bradford *et al.* 2013b, Bradford *et al.* 2010, Cooper *et al.* 2007, Guzik *et al.* 2011, Outback Ecology 2012b, d, Subterranean Ecology 2011a). Within well studied calcrete systems (e.g., Ethel Gorge, Hinkler Lake Violet, Laverton Downs, Sturt Meadows, Uramurdah and Yeelirrie) genetic studies have revealed amphipod species to often be relatively broadly distributed compared to other stygofauna species, with distributions extending over 15 km and up to 70 km (Bradford *et al.* 2013a, Guzik *et al.* 2011, MWH 2015b, Outback Ecology 2012d, Stantec 2017a, Subterranean Ecology 2011a).

Important contributing factors to the relatively broad distributions documented for many stygobitic amphipod species would be the relatively broad habitat preferences often exhibited. Species of stygobitic

amphipods known to inhabit calcrete aquifers have also been recorded from alluvial and colluvial regolith aquifers within the associated drainage system. In addition, they often display the ability to tolerate relatively wide variations in groundwater salinity, from fresh conditions (<5 mS/cm) at sites upstream of salt lake playas, to mesosaline conditions, often in excess of 50 mS/cm, from sites progressively closer to the hypersaline aquifers of the lake playa (MWH 2015b, Outback Ecology 2012b, d, Stantec 2018a, Subterranean Ecology 2011a).

The relatively broad distributions and habitat preferences documented for stygobitic amphipod species indicate that the distributions of both amphipod species, *Bogidiella* OES11 and Paramelitidae OES10, would be much broader than current records indicate. It is considered likely that the distribution of Paramelitidae OES10 extends further northwards of the Study Area, inhabiting the colluvial and alluvial groundwaters occurring in association with 5 Mile Creek, and potentially extending to and within the Ethel Creek calcrete/alluvial aquifer system.

5.4.3.2 Bathynellacea

A single specimen of the parabathynellid, *Brevisomabathynella* OES30, was collected from within the Study Area, more than 1.5 km from the deposit area at site Stab10 within colluvial surface geology, in close association with 5 Mile Creek (**Figure 5-8**, **Figure 5-10**). The species was collected sympatrically with the amphipod, Paramelitidae OES10.

All species of Bathynellacea globally are stygobitic and short range endemics (SRE), believed to have evolved to be obligate inhabitants of fresh groundwater systems during the late Permian, early Mesozoic eras, approximately 250 to 240 million years ago, prior to the breakup of Gondwana (Coineau and Camacho 2013). Parabathynellidae species are commonly recorded from calcrete, fractured rock and alluvial aquifer systems in Australia, with species known to exhibit linear distributions up to 5 to 10 km (Abrams *et al.* 2012, Guzik *et al.* 2008, Outback Ecology 2012d, 2014, Stantec 2018c, Subterranean Ecology 2011b). Similar to stygobitic amphipods, Parabathynellidae species can also exhibit relatively broad habitat preferences in terms of a species inhabiting both calcrete and associated alluvial/colluvial aquifer systems and the ability to tolerate relatively wide variations in groundwater salinity, from fresh to mesosaline conditions (MWH 2015b, Outback Ecology 2012b, d, Stantec 2017a, Subterranean Ecology 2011a).

The relatively broad distributions and habitat preferences documented for parabathynellid species suggest that the distribution of *Brevisomabathynella* OES30, would likely extend further northwards of the Study Area, inhabiting the colluvial and alluvial groundwaters occurring in association with 5 Mile Creek, and potentially extending to and within the Ethel Creek calcrete/alluvial aquifer system.

5.4.3.3 Oligochaeta

Phreodrilidae OES25 was collected from four sites and displayed a linear distribution of approximately 3.2 km (**Figure 5-9**, **Figure 5-10**). The species' distribution ranged from the potential groundwater drawdown impact site JHP16, 800 m north of the deposit area, to well beyond the potential groundwater drawdown impact area more than 3.6 km from the deposit to sites NARC13 and JHP14. All sites that Phreodrilidae OES25 has been recorded from occur within colluvial surface geology, often in close association with 5 Mile Creek (**Figure 5-8**).

Phreodrilidae species are commonly associated with groundwater systems and have been recorded in stygofauna surveys within the Pilbara, Western Desert, and Yilgarn regions (Biota Environmental Services 2010, Brown *et al.* 2015, Halse *et al.* 2002, Outback Ecology 2012d, 2013, Pinder 2001, 2008, Rockwater 2012, Subterranean Ecology 2012). While some species of Phreodrilidae have only been recorded from aquifers, other species have been recorded from a range of habitats including springs, spring-fed creeks and pools and large surface water systems (Pinder 2008). Although mostly aquatic, there can be some uncertainty as to the level of aquatic dependence of these worms, with one species having been recorded from ephemeral seepages on granite outcrops that dry out periodically (Pinder 2008). In addition, it is difficult to determine if species are stygobitic or stygophilic. Species recorded from both groundwater and surface water environments (e.g. *Phreodrilus peniculus*) are considered to be stygophilic (Pinder 2003). However, it is difficult to determine the groundwater dependence for a species recorded from a stygofauna assessment. In the arid zone it is considered likely that many taxa take refuge in groundwater environments until significant rainfall events occur. Some species are only known from a limited number of sites and often restricted in distribution to a single creek catchment, other species have been found to have widespread distributions that can occur across disjunct aquifers and drainage catchments (Biota Environmental Sciences 2010, Brown *et al.* 2015, Pinder 2008).

The documented broad distributions and breadth of occupied habitat niches shown by Phreodrilidae species indicate that the distribution of Phreodrilidae OES25 could likely extend throughout much of the Ethel Creek catchment area.

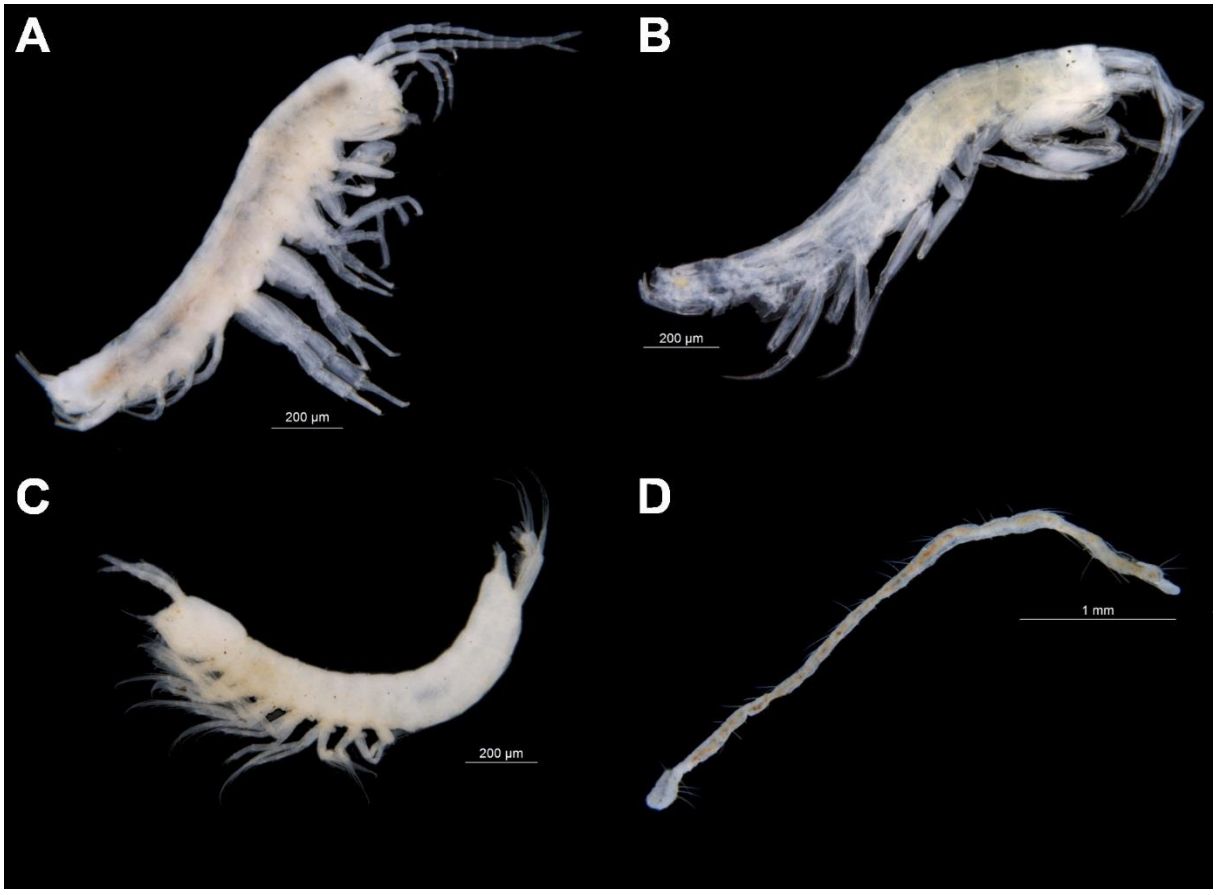

Figure 5-6: Stygofauna images. A) Paramelitidae OES10 (Amphipoda); B) *Bogidiella* OES11 (Amphipoda); C) *Brevisomabathynella* OES30 (Bathynellacea); D) *Phreodrilus* OES25 (Oligochaeta).

Table 5-3: Stygofauna diversity and distribution recorded.

Taxon	Impact		Non-Impact	Comments
	Inside Deposit Area	Groundwater Drawdown		
Amphipoda				
Bogidiella OES11			1	Not of conservation concern. Recorded from Ethel Creek calcrete system, more than 30 km north of deposit area. Genetic analysis confirmed genus identification.
Paramelitidae OES10			7	Not of conservation concern. Recorded from outside proposed impact area, more than 1.5 km from deposit area, near 5 Mile Creek, a major tributary of Ethel Creek. Specimens sent for genetic analysis failed to sequence. Collected sympatrically with *Brevisomabathynella* OES30.
Bathynellacea				
Brevisomabathynella OES30			1	Not of conservation concern. Recorded from outside proposed impact area, more than 1.5 km from deposit area, near 5 Mile Creek, a major tributary of Ethel Creek. Collected sympatrically with Paramelitidae OES10.
Oligochaeta				
Phreodrilus OES25		6	9	Not of conservation concern. The only species to be recorded from near proposed impact area; 230 m north of proposed portal and 760 m north of deposit. Species also recorded from outside proposed impact area, more than 3.6 km from deposit area, near 5 Mile Creek, a major tributary of Ethel Creek.

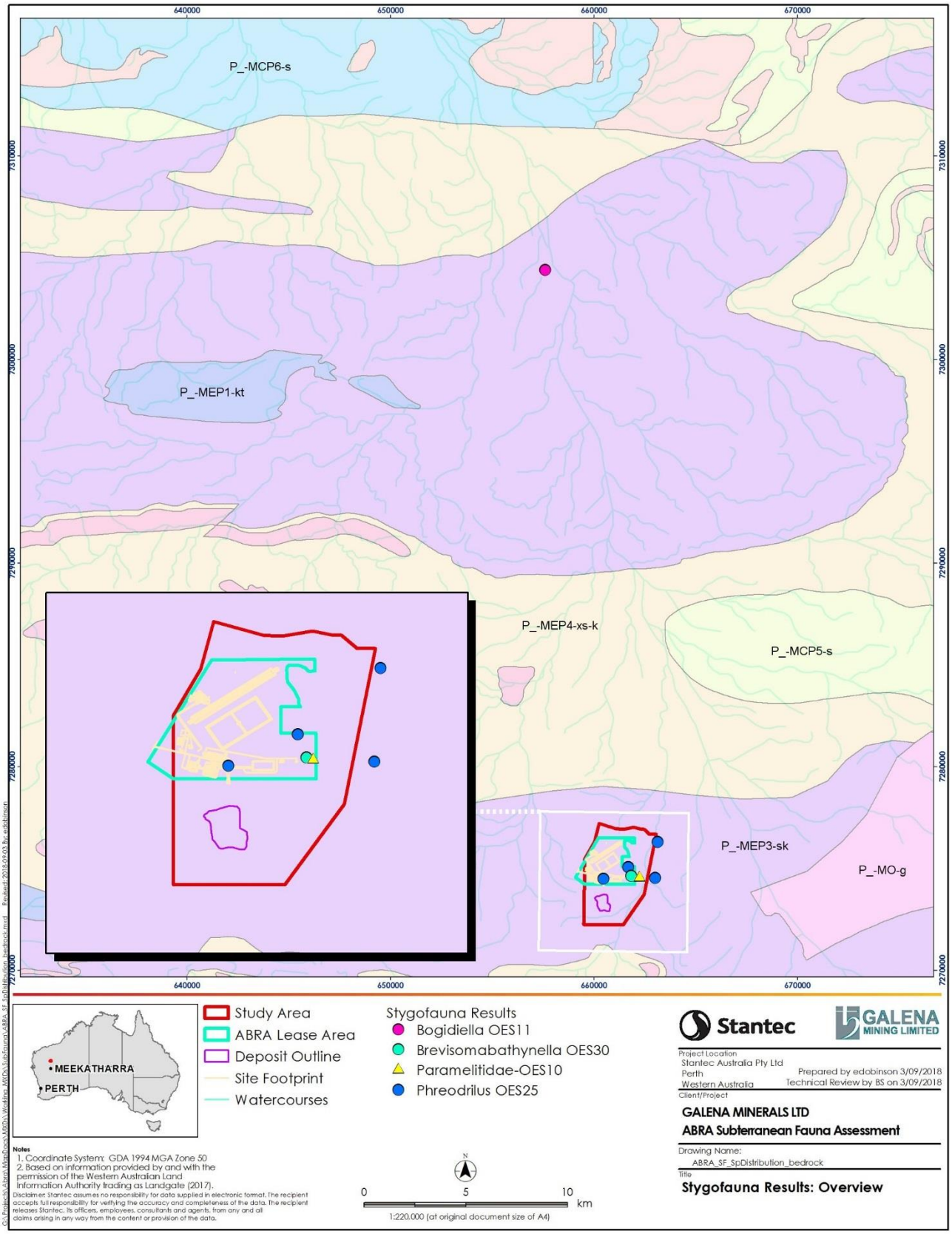

Figure 5-7: Presence / absence of stygofauna species recorded in relation to the bedrock geology (refer Table 5-1 for descriptions of relevant geological codes).

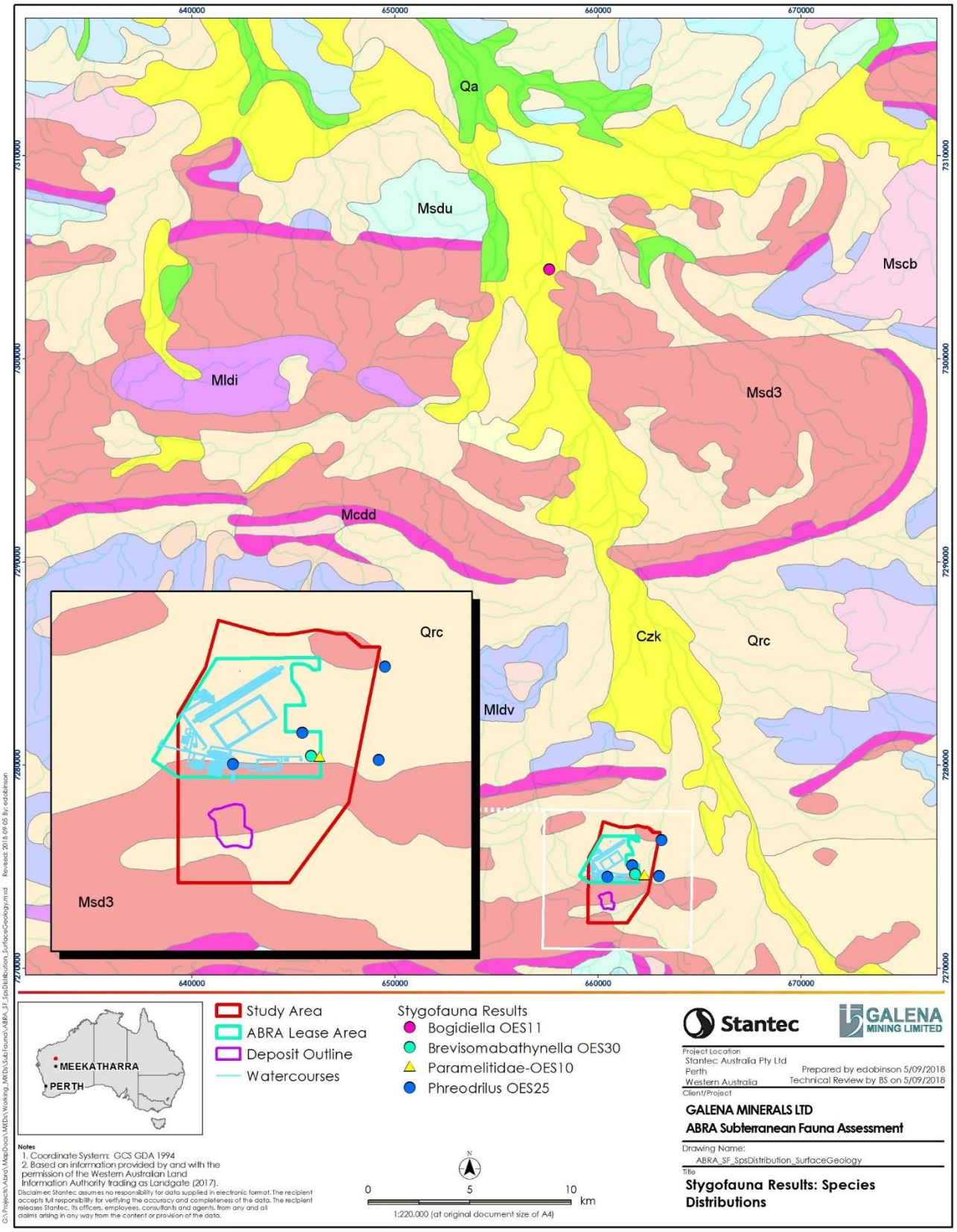

Figure 5-8: Presence / absence of stygofauna species recorded in relation to the surface geology (refer Table 5-1 for descriptions of relevant geological codes).

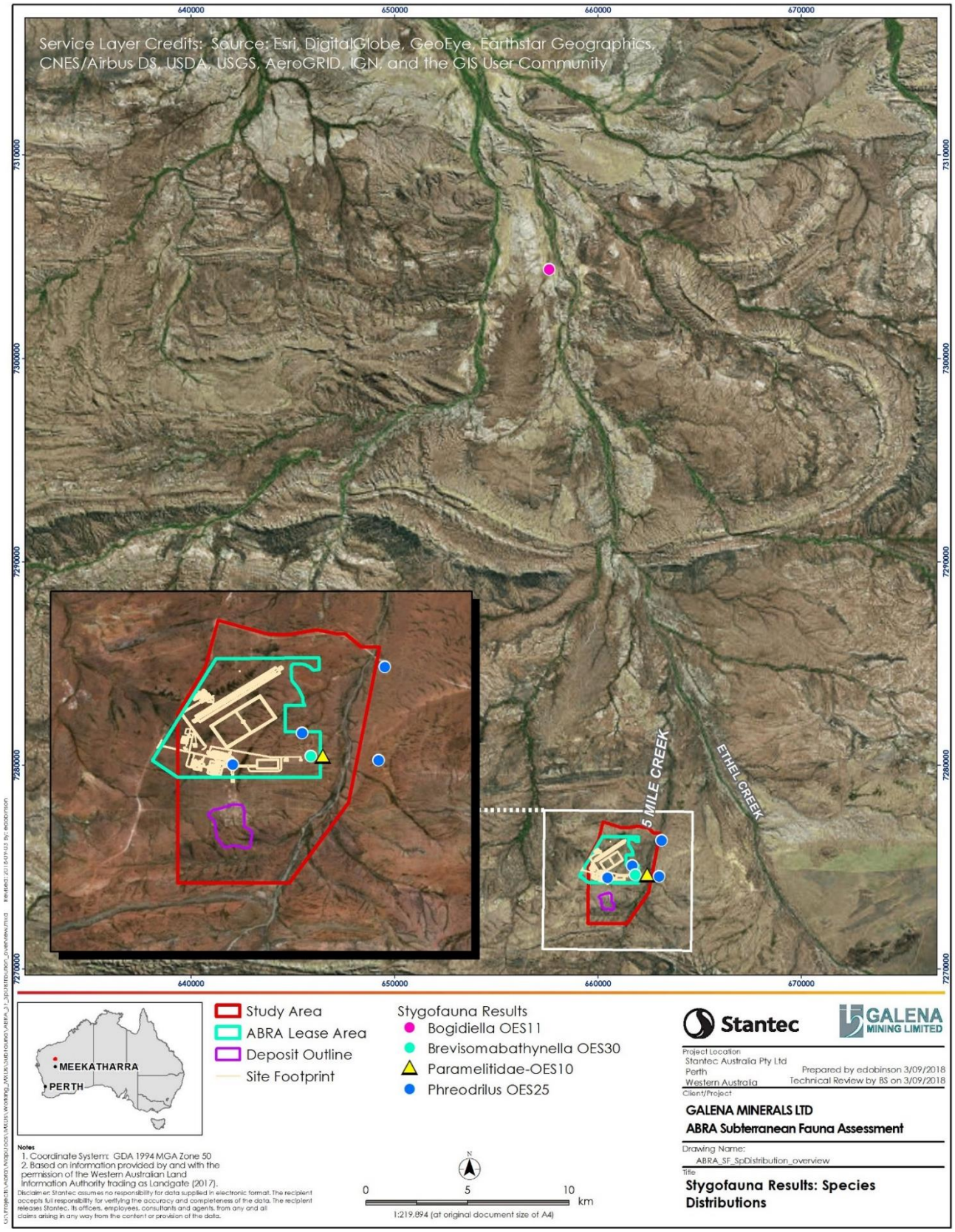

Figure 5-9: Distribution of stygofauna species recorded.

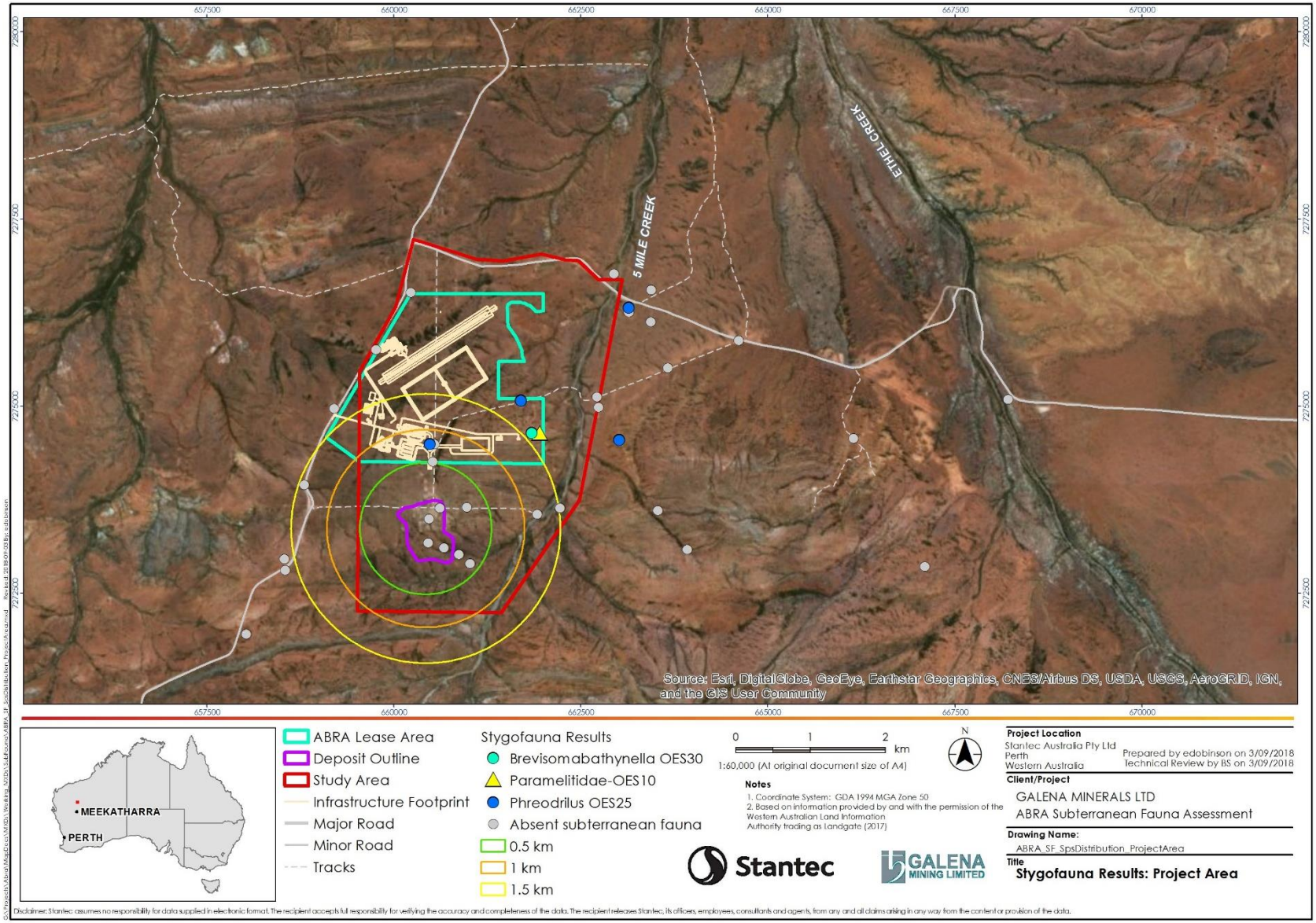

Figure 5-10: Distribution of stygofauna species recorded in and near the Study Area.

5.4.4 Stygofauna Species Richness Estimates and Survey Adequacy

The species richness predicted to occur within and around the Study Area (i.e. excluding the northern reference area) ranged from three to seven species (**Figure 5-11**, **Table 5-4**). The Chao 1 estimator was consistent with the observed number of species with three species predicted. The ICE estimator predicted the highest species richness that was more than double the observed richness with 7.2 species. Of the remaining estimators, Bootstrap, Chao 2, and ACE, predicted at least one extra species may occur, with Jack 1 and Jack 2 predicting two and three additional species, respectively. The three species recorded from the 52 samples collected are estimated to represent 42% to 100% of the total species predicted to occur within and around the Study Area.

The species accumulation curves for all diversity estimators were still strongly trending upwards with no indication of plateauing by the end of sampling (**Figure 5-11**). The trend is not unusual considering that the species richness estimators generally require higher sample numbers (often >100 samples) prior to the detection rate of new species starting to decline (MWH 2016c, Outback Ecology 2014, Stantec 2017a). Species accumulation curves for many stygofauna surveys in Australia (Eberhard *et al.* 2009, Stantec 2017a) and overseas, do not reach a plateau even after many years of intensive survey effort (Pipan and Culver 2007). The extrapolation of the observed species accumulation curve (S(ext)) indicates that increasing the survey effort by 200% (156 samples) may record one additional stygofauna species.

The species capture rate (3 species from 52 samples at an overall capture rate of 0.06 species per sample) is relatively consistent with the range in findings for other stygofauna assemblages recorded from other colluvial and fractured rock aquifer systems:

- Browns Range — 18 species from 160 samples (capture rate 0.11) (Outback Ecology 2014a);
- Leonora — 5 species from 100 samples (capture rate of 0.05) (Stantec 2018c);
- Yakabindie — 10 species from 221 samples (capture rate 0.05) (Stantec 2017b); and
- Camelot — one species from 61 samples (capture rate 0.02) (Stantec 2018a).

The species accumulation curves and comparison of capture rates with other similar studies, in terms of habitat hosted in colluvial and fractured rock aquifer systems, indicate that the survey intensity undertaken has been sufficient in evaluating the stygofauna values in and around the Study Area. The sampling effort undertaken to verify and target the stygofauna values in and around the deposit area fulfils the recommended approach to stygofauna assessment, as recommended by the Western Australia EPA *Technical Guidance Sampling Methods for Subterranean Fauna Survey* (2016a). The survey intensity undertaken, in conjunction with the assessment of the habitat present, is considered to provide a reliable characterisation of the stygofauna values present in the deposit area and in relation to the proposed direct impact zones, in accordance with EPA (2016a, b) guidelines.

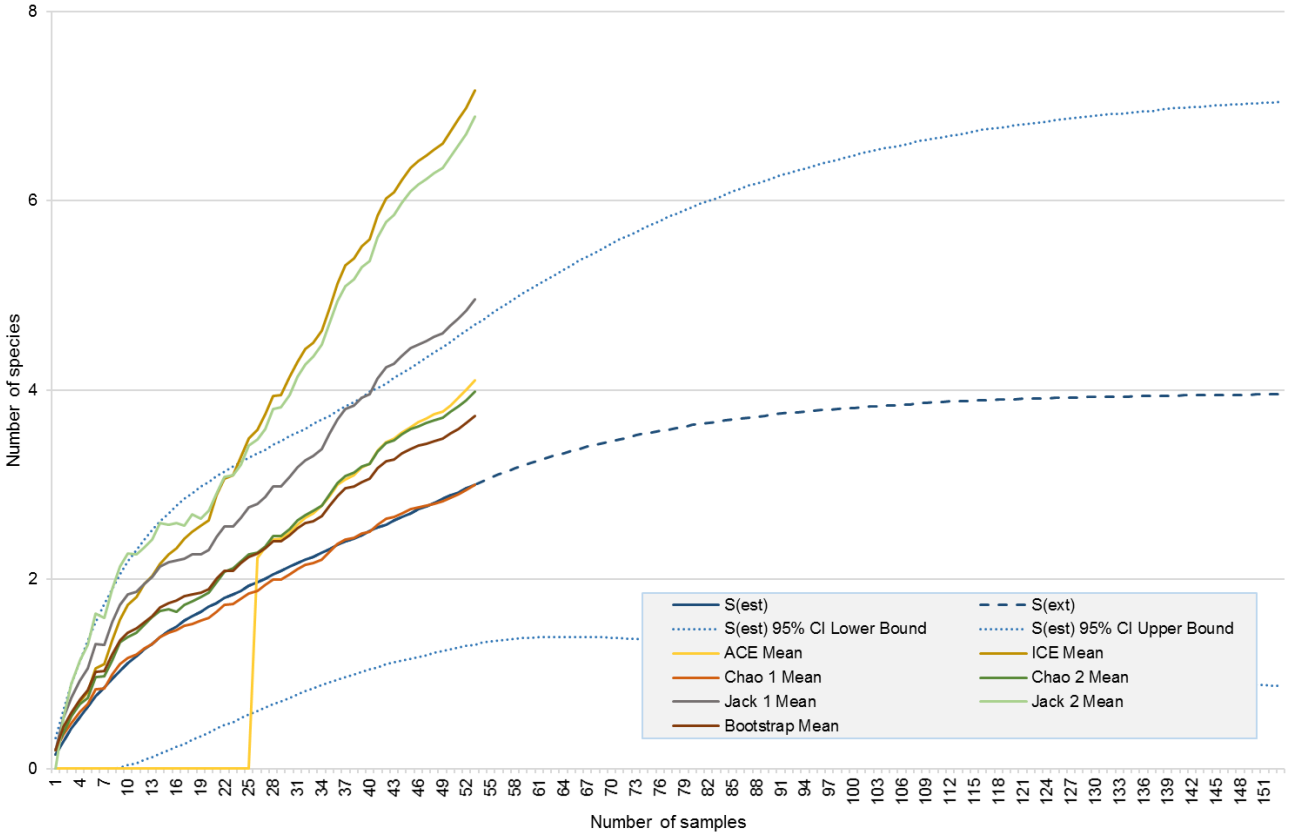

Figure 5-11: Stygofauna species accumulation curves for various diversity estimators and rarefaction curves for observed (S(est)) and extrapolated (S(ext) for the Project.

Table 5-4: Observed stygofauna species diversity from the Study Area compared to estimated diversity using EstimateS (Colwell 2013) diversity estimators.

Observed vs Estimated		Obs. & Pred. spp richness	% Predicted collected
Obs.	Sobs	3	
	Extrapolated (274 samples)	3.96	75.8%
Diversity estimators	Chao 1 Mean	3	100.0%
	Bootstrap Mean	3.73	80.4%
	Chao 2 Mean	3.98	75.4%
	ACE Mean	4.1	73.2%
	Jack 1 Mean	4.96	60.5%
	Jack 2 Mean	6.89	43.7%
	ICE Mean	7.17	41.8%
	Range	3 — 7.17	41.8 — 100%

5.5 Troglofauna Findings

No troglofauna species were recorded from the 27 samples collected from 25 sites located in and around the Study Area. The survey effort conducted is more than sufficient to provide a reliable indication of the prospectivity of the habitats sampled for hosting troglofauna. The sampling results are consistent with the habitat characterisation that indicated that the Study Area does not provide prospective habitat for troglofauna.

6. Impact Assessment

6.1 Proposed Impacts

6.1.1 Direct Impacts

The two main direct potential impacts on subterranean fauna associated with the development of the Project are:

- removal of habitat through excavation of the proposed underground mining; and
- drying out of habitat through the lowering of the groundwater table associated with underground mining dewatering.

The removal of habitat through mining excavation poses the greater risk to the conservation of stygofauna and troglofauna species relative to the lowering of the groundwater table only. Groundwater drawdowns are considered to have greater impacts on stygofauna compared to troglofauna because lowering of the groundwater table can directly reduce the extent of habitat available for stygofauna. Groundwater drawdown of 0.5 mbSWL is considered to represent the extent of the groundwater drawdown impact for both stygofauna and troglofauna. However, in the case of troglofauna, the lowering of the water table by less than 5 mbSWL is less likely to reduce the relative humidity of the overlying inhabited strata to such an extent to render them uninhabitable. In addition, troglofauna can migrate downwards to avoid uninhabitable conditions, provided suitable habitable voids are available for colonisation. Therefore, it is considered likely that troglofauna habitat would remain beyond a groundwater drawdown of 5 mbSWL.

6.1.2 Indirect Impacts

Potential indirect impacts posed by proposed mining developments that can impact subterranean habitats and lead to reduced abundance of species populations, include:

- reduction in influx of resources (e.g. nutrients, oxygen) through clearing of vegetation (reduced organic inputs) and changes to hydrological regimes as a result of mining associated landforms (e.g. pits, waste rock landforms, access infrastructure, etc);
- contamination through chemical seepage or fuel spills; and
- increase in sediment load in run-off from mining activities that could reduce surface-subsurface water exchange during flow periods (e.g., lessen input of resources) and alter groundwater chemistry (Marmonier 1991).

These potential indirect impacts to groundwater quality are not considered further here as part of this risk assessment because they can be greatly reduced or avoided through project design and best practice environmental management procedures. For example, limit clearing of vegetation to immediate areas of planned development footprint, avoid significant changes / diversions to main drainage flow paths present, and reduce sediment run-off from roads and landforms. In addition, the indirect impacts are considered difficult to assess, and likely to lead to the reduction in the abundance of subterranean fauna species rather than reduce the species richness. Appropriate management and mitigation measures will need to be addressed in the relevant approvals documentation and related environmental management plan in relation to potential indirect impacts.

6.2 Stygofauna

The stygofauna findings and habitat assessment has demonstrated that there will be no risk to the long term conservation of any stygofauna species due to the proposed underground mining of the Abra base

metal deposit. The subterranean habitat in the deposit area was found not to host any stygofauna values. The subterranean habitat in and near the deposit area was found to not be prospective for stygofauna as the overlying regolith was clay dominated and deep, extending to below the SWL, and considered to be an aquitard, offering limited interstitial pore space and hydrological exchange. The groundwater present represented a locally recharged, low permeable, mostly confined fractured rock aquifer system. The non-prospective habitat was verified by two rounds of sampling that failed to record any stygofauna species from similar habitat in and around the deposit area.

Only one stygofauna species, *Phreodrilus* OES25, was recorded from within the potential groundwater drawdown impact zone, from colluvial habitat 800 m north of the deposit area (**Figure 5-8**). However, the distribution of *Phreodrilus* OES25 was demonstrated to extend well beyond the potential impact zone up to 3.6 km from the deposit area. The remaining stygofauna species recorded were all collected from non-impact areas from colluvial geology in close association with incised drainage lines (**Figure 5-9**, **Figure 5-10**).

Stygofauna records from within the broader region, including from the northern reference area, have shown that stygofauna do occur along the main drainage systems in the calcrete habitats, and the fringing alluvial and, to a lesser extent, colluvial aquifers present (refer section 5.1.2) (**Figure 5-2**). However, there are no calcrete or extensive alluvial aquifer systems within the Study Area. The only prospective habitat is found in the northern part of the Study Area where colluvial surface geology occurs in association with 5 Mile Creek and its tributaries and from which stygofauna were collected. The colluvial habitat does extend northwards, away from the deposit, to the more prospective and widespread Ethel Creek calcrete/alluvial aquifer system, from which an amphipod species, *Bogidiella* OES11, and ostracod species, *Deminutiocandona neara*, have been collected (**Figure 5-8**).

The distributions of all the stygofauna species collected from the north-eastern portion of the Study Area are likely to extend northwards along 5 Mile Creek to the Ethel Creek calcrete/alluvial aquifer system, particularly when taking into consideration the relatively broad distributions and habitat preferences documented for other stygobitic amphipod, parabathynellid, and phreodrilid species (refer section 5.4.3). The Ethel Creek calcrete/alluvial aquifer system is considered to represent the most optimal habitat present within the region of the Study Area and likely to host the highest stygofauna diversity (species richness and abundance) in the broader catchment, with stygofauna diversity progressively declining further upstream as habitat conditions become progressively less optimal. The collection records of Paramelitidae OES10, *Brevisomabathynella* OES30, and Phreodrilidae OES25 from within surficial colluvial aquifer habitat in the north-eastern portion of the Study Area are likely to represent the southerly extent of each of the species' distribution. Unfortunately, there were not a sufficient number of suitable sample sites present northwards along 5 Mile Creek to the confluence zone with the Ethel Creek calcrete/alluvial aquifer system, approximately 8 km north of the Study Area, to empirically demonstrate that the stygofauna values in the area progressively increased further downstream along the main drainage lines.

6.3 Troglofauna

The development of the Project will not pose a conservation risk to any troglofauna species as the deposit area was found not to host any troglofauna values. The unsaturated subterranean habitat was found to not be prospective for troglofauna as the overlying regolith was clay dominated, offering limited interstitial pore space, and deep, extending to below the SWL. The non-prospective habitat was verified by 27 samples, collected over two sample rounds that failed to record any troglofauna species. The findings reported here demonstrated that troglofauna do not represent an environmental factor for future regulatory approvals of the Project, in accordance with EPA (2016b), as no troglofauna species were recorded. Therefore, no further troglofauna assessment is necessary to provide further information on the troglofauna values within the Project Study Area.

7. Conclusion

The subterranean fauna assessment reported here has demonstrated that the subterranean habitat in the deposit area does not host any stygofauna or troglofauna values. The subterranean habitat in and near the deposit area was found to not be prospective for stygofauna or troglofauna with no subterranean fauna species collected from the deep clay dominated regolith, an aquitard confining the underlying low permeable fractured rock aquifer. Three stygofauna species were recorded from surficial colluvial groundwater in the north-eastern portion of the Study Area, from sites near incised drainage channels of the 5 Mile Creek catchment. The recorded distributions of all three species occurred more than 1.5 km from the deposit area, outside the potential groundwater drawdown impact zone. Within the broader

region of the Study Area, stygofauna values are considered likely to progressively increase further downstream (northward) along 5 Mile Creek to the more optimal habitat present within the Ethel Creek calcrete/alluvial aquifer system.

Troglofauna do not represent an environmental factor for future regulatory approvals of the Project, in accordance with EPA (2016b), as no troglofauna species were recorded.

The overall findings of this assessment indicate that the proposed underground mining of the Abra base metal deposit will meet the relevant EPA objectives in that the proposal does not pose a threat to maintaining subterranean fauna representation, diversity, viability and ecological function at the species, population or assemblage level.

8. Glossary

alluvium – sediment deposited by a stream or river

aquatic – relating to water

aquifer – a body of permeable rock or sediment capable of storing groundwater

arid – a region characterised by a severe lack of available water, to the extent that the growth and development of biota is hindered or prevented

bedrock – consolidated rock attached to the earth's crust

biodiversity – the diversity of biota in a particular environment or region

calcrete – carbonate deposits that form in arid environments, as a result of groundwater evaporation

cave – a subsurface cavity of sufficient size that a human could enter

dissolved oxygen – a measure of the amount of gaseous oxygen dissolved in a solution; oxic = > 3 mg/L; dysoxic = 0.3 to 3.0 mg/L; suboxic = < 0.3 mg/L levels

distribution range – the overall geographic area that a species is known to occur in

divergence – degree of separation from a common ancestor

diversity – a combination of species richness and abundance

drawdown – the lowering of the adjacent water table or piezometric surface as a result of groundwater extraction

ecotone – zone of transition among different ecosystems

electrical conductivity – an estimate of the total dissolved salts in a solution, or salinity

endemic – having a distribution restricted to a particular geographic region

epigean – pertaining to the surface zone

fractured rock – a rock formation characterized by separation or discontinuity, usually as a result of geological stress (e.g. faulting)

geological ages (e.g. Cainozoic) – distinct time periods within the geological history of the earth

groundwater – water occurring below the ground surface

habitat – an ecological or environmental area that is inhabited by a particular animal or plant species

hypogean – pertaining to the subterranean zone

hyporheic zone – spatially fluctuating ecotone within the bed of a river or stream between surface and groundwater. Considered important component of groundwater ecosystems and involved in the 'interstitial highway', forming hyporheic corridor linking associated aquifers.

invertebrates – animals lacking vertebrae

karst – a region of limestone or other soluble rock, characterized by distinctive features such as caves, caverns, sinkholes, underground streams and springs

lineage – a group of organisms related by descent from a common ancestor

molecular – pertaining to the genetic characteristics of an organism or group

morphology – the specific form and structure of an organism or taxon

morphospecies – a general grouping of organisms that share similar morphological traits, but is not necessarily defined by a formal taxonomic rank

palaeoriver, palaeochannel, palaeodrainage – a remnant of a stream or river channel cut in older rock and filled by the sediments of younger overlying rock

pH – a measure of the hydrogen ion concentration of a soil or solution (values below pH of 6.5 are 'acidic', and those above pH 7.5 are 'alkaline')

relictual – having survived as a remnant

salinity – the concentration of all dissolved salts in a solution. The salinity level classification *sensu* Hammer (1986): freshwater = salinity less than 5 mS/cm (3 ppt); hyposaline = salinity ranging from 5–30 mS/cm (3–20 ppt); mesosaline = salinity ranging from 30–70 mS/cm (20–50 ppt); hypersaline = salinity equal to or greater than 70 mS/cm (50 ppt)

semi-arid – a climatic region that receives low annual rainfall (250 – 500 mm)

species – a formal taxonomic unit defining a group or population of organisms that share distinctive characters or traits, are reproductively viable and/or are otherwise identifiable as a related group

species richness – the number of species present in a particular habitat, ecosystem or region

species accumulation curve – a model used to estimate species diversity or richness

standing water level (SWL) – the depth to groundwater from a particular reference point (e.g. in a monitoring bore)

stygal – pertaining to groundwater habitat or biota

stygobite – an obligate aquatic species of groundwater habitats

stygobiont – another term used to describe obligate inhabitants of groundwater systems

stygofauna – a general term for aquatic groundwater fauna

stygophile – an aquatic species that temporarily or permanently inhabits groundwater habitats

stygoxene – an aquatic species that has no fixed affinity with groundwater habitats, but may nonetheless occur in groundwater habitats

sympatry / sympatric – two or more species that are considered to exist in the same or overlapping geographic area and may regularly interact with, or encounter, each another (without interbreeding)

taxon (singular), taxa (plural) – an identifiable group of organisms, usually based on a known or inferred relationship or a shared set of distinctive characteristics

troglobite – an obligate terrestrial species of subterranean habitats

troglofauna – a general term for terrestrial subterranean fauna

troglomorphic features – morphological characteristics resulting from an adaptation to subterranean habitats (e.g. a reduction in pigment)

troglophile – a terrestrial species that temporarily or permanently inhabits subterranean habitats

trogloxene – a terrestrial species that has no fixed affinity with subterranean habitats, but may nonetheless occur in subterranean habitats

void – a pore space in the rock or stratum

Yilgarn – pertaining to the Yilgarn Craton, a 65,000 km2 body of the earth's crust in south-western Australia that dates back to the Archaean period, 2.6 to 3.7 million years ago

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Appendices

Amphipoda: Paramelitidae OES10

Appendix A Subterranean Fauna Survey Effort and Site Details

A.1 Survey Effort and Site details

Table A-1: Stygofauna survey effort and site details.

Site Name	Latitude (S)	Longitude (E)	Sample Date	Collection Method	Bore Angle	Casing Type
AB09	24.64792	118.58761	31/05/2018	Net Haul	Vertical	PVC; slotted
AB10	24.64870	118.58955	01/03/2018	Net Haul	Vertical	PVC; slotted
AB10	24.64870	118.58955	31/05/2018	Net Haul	Vertical	PVC; slotted
AB31	24.64736	118.58552	01/03/2018	Net Haul	Inclined (70)	Steel
AB31	24.64736	118.58552	31/05/2018	Net Haul	Inclined (70)	Steel
ABRC001	24.63547	118.58617	01/03/2018	Net Haul	Vertical	PVC; slotted
EP01	24.63756	118.58596	01/06/2018	Net Haul	Vertical	None
Ethel Creek Bore01	24.62923	118.66183	28/05/2018	Net Haul	Vertical	PVC; slotted
GE01	24.64781	118.61968	29/05/2018	Net Haul	Vertical	None
HY01	24.64950	118.56655	30/05/2018	Net Haul	Vertical	PVC; slotted
JE61	24.64444	118.58555	01/03/2018	Net Haul	Vertical	None
JHP01	24.65860	118.56161	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP02	24.65088	118.56666	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP03	24.64053	118.56903	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP04	24.63126	118.57285	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP05	24.62415	118.57833	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP06	24.61716	118.58281	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP07	24.62250	118.62616	01/03/2018	Net Haul	Vertical	PVC; slotted
JHP07	24.62250	118.62616	29/05/2018	Net Haul	Vertical	PVC; slotted
JHP08	24.63417	118.64149	29/05/2018	Net Haul	Vertical	PVC; slotted
JHP09	24.64952	118.65106	29/05/2018	Net Haul	Vertical	PVC; slotted
JHP10	24.62590	118.61684	01/06/2018	Net Haul	Vertical	PVC; slotted
JHP11	24.64299	118.60283	29/05/2018	Net Haul	Vertical	PVC; slotted
JHP12	24.64312	118.61574	29/05/2018	Net Haul	Vertical	PVC; slotted
JHP13	24.62950	118.60753	01/03/2018	Net Haul	Vertical	PVC; slotted
JHP13	24.62950	118.60753	01/06/2018	Net Haul	Vertical	PVC; slotted
JHP14	24.63470	118.61056	29/05/2018	Net Haul	Vertical	PVC; slotted
JHP15	24.63009	118.59751	01/03/2018	Net Haul	Vertical	PVC; slotted
JHP15	24.63009	118.59751	01/03/2018	Net Haul	Vertical	PVC; slotted
JHP15	24.63009	118.59751	01/06/2018	Net Haul	Vertical	PVC; slotted
JHP15	24.63009	118.59751	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP16	24.63544	118.58559	01/03/2018	Net Haul	Vertical	PVC; slotted
JHP16	24.63544	118.58559	30/05/2018	Net Haul	Vertical	PVC; slotted
JHP18	24.64303	118.59051	01/03/2018	Net Haul	Vertical	PVC; slotted
JHP18	24.64303	118.59051	31/05/2018	Net Haul	Vertical	PVC; slotted
JHP19	24.64377	118.59985	01/03/2018	Net Haul	Vertical	PVC; slotted
JHP19	24.64377	118.59985	31/05/2018	Net Haul	Vertical	PVC; slotted
NARC04	24.61464	118.60958	30/05/2018	Net Haul	Inclined (70°)	None
NARC08	24.61655	118.61453	29/05/2018	Net Haul	Inclined (70°)	None
NARC12	24.62042	118.61453	29/05/2018	Net Haul	Inclined (70°)	None
NARC13	24.61875	118.61161	29/05/2018	Net Haul	Inclined (70°)	None
NARC14	24.61925	118.61161	29/05/2018	Net Haul	Inclined (70°)	None
NARC15	24.63077	118.60780	29/05/2018	Net Haul	Inclined (70°)	None
STAB04	24.64315	118.58700	01/03/2018	Net Haul	Vertical	PVC; slotted
STAB04	24.64315	118.58700	31/05/2018	Net Haul	Vertical	PVC; slotted
STAB06	24.64979	118.59107	01/03/2018	Net Haul	Vertical	PVC; slotted
STAB10	24.63398	118.59899	01/06/2018	Net Haul	Vertical	None
TNG0018R	24.37891	118.53781	31/05/2018	Net Haul	Vertical	None

Site Name	Latitude (S)	Longitude (E)	Sample Date	Collection Method	Bore Angle	Casing Type
WAM WMDB01	24.36580	118.55400	31/05/2018	Windmill Pump	Vertical	Steel
WAM WMDB02	24.27524	118.38197	31/05/2018	Windmill Pump	Vertical	Steel
WAMDB02	24.27524	118.38200	31/05/2018	Net Haul	Vertical	PVC; slotted

Table A-2: Troglofauna Survey Effort and Site Details.

Site Name	Latitude (S)	Longitude (E)	Sample Start Date	Sample End Date	Collection Method	Hole Angle	Casing Type
AB60	24.64354	118.58561	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB61	24.64388	118.58661	01/03/2018	27/04/2018	Litter Trap	Vertical	None
AB70	24.64312	118.58657	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB71	24.64305	118.58706	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB72	24.64573	118.58319	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB73A	24.64647	118.58469	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB74	24.64664	118.58315	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB76	24.64134	118.58653	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB77	24.64283	118.58658	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB78	24.64288	118.58607	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB79	24.64822	118.58451	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
AB81	24.64686	118.58751	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
JE61	24.64444	118.58555	01/03/2018	27/04/2018	Litter Trap	Vertical	None
STAB08	24.63836	118.60207	01/03/2018	27/04/2018	Litter Trap	Inclined (70°)	None
STAB09	24.63584	118.59992	01/03/2018	27/04/2018	Litter Trap	Vertical	None
STAB10	24.63398	118.59899	01/03/2018	27/04/2018	Litter Trap	Vertical	None
EP01	24.63756	118.58596	01/06/2018		Scrape	Vertical	None
GE01	24.64781	118.61968	29/05/2018		Scrape	Vertical	None
JE61	24.64444	118.58555	01/03/2018		Scrape	Vertical	None
NARC04	24.61464	118.60958	30/05/2018		Scrape	Inclined (70°)	None
NARC08	24.61655	118.61453	29/05/2018		Scrape	Inclined (70°)	None
NARC12	24.62042	118.61453	29/05/2018		Scrape	Inclined (70°)	None
NARC13	24.61875	118.61161	29/05/2018		Scrape	Inclined (70°)	None
NARC14	24.61925	118.61161	29/05/2018		Scrape	Inclined (70°)	None
NARC15	24.63077	118.60780	29/05/2018		Scrape	Inclined (70°)	None
STAB10	24.63398	118.59899	01/06/2018		Scrape	Vertical	None
TNG0018R	24.37891	118.53781	31/05/2018		Scrape	Vertical	None

A.2 Site Photos.

Figure A-1: Representative site photos: A) AB60; B) AB73A; C) AB79; D) AB81; E) Ethel Creek Bore01; F) GE01; G) JE61; H) JHP01.

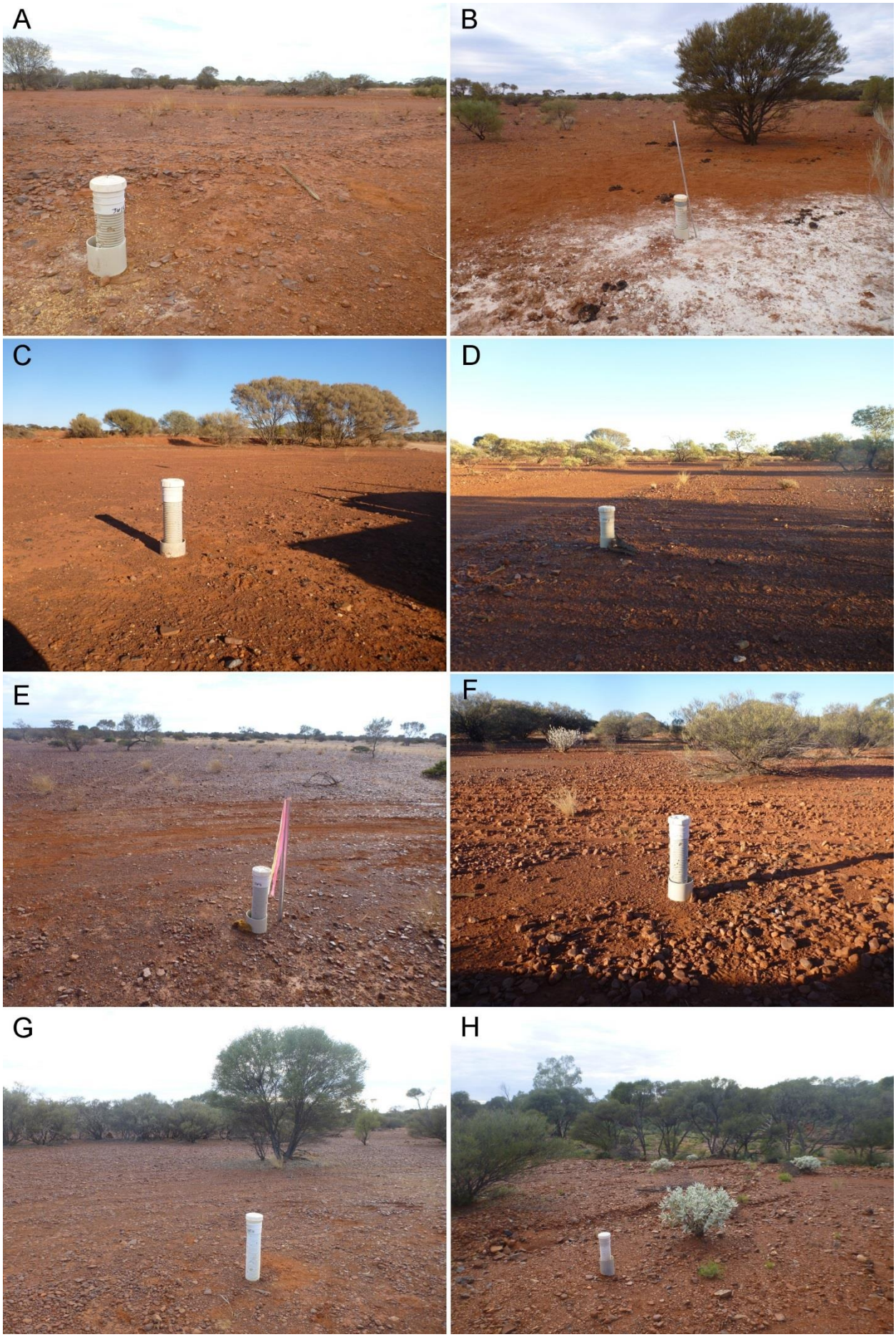

Figure A-2: Representative site photos: A) JHP04; B) JHP05; C) JHP07; D) JHP09; E) JHP13; F) JHP14*; G) JHP15*; H) JHP19. * indicates sites where stygofauna recorded.

Figure A-3: Representative site photos: A) NARC13*; B) STAB06; C) STAB08; D) STAB10*; E) TNG0018R; F) WAM DB02 & WAM WMDB02; G) WAM WMDB01*; H) sampling WAM WMDB01 windmill outlet. * indicates sites where stygofauna recorded.

A.3 Geological Drill Logs.

Table A-3: Geological drill logs available for JHP series sites, of which all were sampled. The source from which the following RC geological drill logs were extracted was from Geopeko, Western Australia, for the Jillawarra Project Ethel River Prospect, undertaken in September 1990 by drilling contractor Robinson Drilling Co (Robinson Drilling Company 1990).

Site Name	From (mbgl)	To (mbgl)	Geological Log
JHP01	0	2	Hard pan brown clay (surficial material).
	2	4	Salmon pink clay.
	4	36	Clean white kaolin with white to very pale green moist clay balls. Chips of fresh quartzite observed from 30 mbgl.
	36	38	Pale purple clay with iron stained quartzite.
	38	76	Pale green clay, damp at 42 m, with fresh medium grained quartzite. Trace of clear vein quartz observed 50 to 76 mbgl. SWL at 44 mbgl.
JHP02	0	2	Surficial material.
	2	20	Yellow clay with fragments of severely oxidised siltstone, becoming fresher.
	20	30	Brown-grey clay with almost fresh siltstone.
	30	70	Monotonous siltstone. SWL at 42 mbgl.
JHP03	0	4	Surficial material.
	4	28	Pale yellow clay with faintly greenish clay balls.
	28	32	Grey clay.
	32	38	Reddish (ferruginous?) clay.
	38	64	Grey-brown clay with partially oxidised siltstone. SWL at 42 mbgl.
	64	70	Fresh grey siltstone with subordinate greenish mudstone.
JHP04	0	2	Surficial material.
	2	34	Yellow clay with oxidised fine grained sediment. SWL at 30 mbgl.
	34	36	Purple clay.
	36	44	Yellow-brown clay, with partially oxidised fine grained sediment.
	44	60	Fresh siltstone and lesser mudstone, the former grey, the latter greenish grey in colour.
JHP05	0	2	Surficial material.
	2	8	Clean white kaolin.
	8	10	Salmon pink clay.
	10	40	White clay with medium grained quartz sand. SWL at 26 mbgl.
JHP06	0	2	Surficial material.
	2	6	Pale cream/ yellow clay.
	6	8	Dark purple-brown clay
	8	10	Pale cream/ yellow clay.
	10	22	Pale cream/ brown clay.
	22	44	Pale olive green/ brown clay with 1/ 2 mm rounded sand grains, sand running into hole. SWL at 32 mbgl.
JHP07	0	8	Red surficial clays.
	8	16	Red-brown clays. SWL at 14 mbgl.
	16	60	Yellow puggy clay, damp, with pale green clay balls.
JHP08	0	4	Brown surficial material.
	4	10	Brown clay.
	10	28	Yellow puggy clay. SWL at 15 mbgl.
JHP09	0	4	Surficial material.
	4	10	Brown clay.
	10	28	Yellow puggy clay. SWL at 19 mbgl.
JHP10	0	8	Pale brown clay.
	8	22	Red-brown clay. SWL at 20 mbgl.
	22	34	Dark (chocolate) brown clay with 3 to 5 mm ferruginous pesoliths
JHP13	0	4	Pale surficial clays with white calcareous chips (calcrete).
	4	28	Brown clay, calcrete absent after 8 mbgl, damp at 14 mbgl. SWL at 20 mbgl.
JHP14*	0	2	Surficial material.
	2	8	Brown clay.
	8	34	Brown oxidised siltstone/ shale with minor ferricrete (washed in?). SWL at 19 mbgl.

Site Name	From (mbgl)	To (mbgl)	Geological Log
JHP15*	0	2	Pale brown surficial clays.
	2	8	Brown clay.
	8	34	Mustard yellow clay, puggy form 18 mbgl. SWL at 25 mbgl.
JHP16	0	4	Surficial material.
	4	20	Partially oxidised sandstone and siltstone, from 10 to 14 mblgl reddish.
	20	44	Fresh medium grained sandstone and subordinate siltstone. SWL at 36 mbgl.

* indicates sites where phreodrilid oligochaete, *Phreodrilus* OES25, was recorded.

Appendix B Desktop Review Taxon Results

Table B-1: Literature review and database search stygofauna taxon results. No troglofauna were found.

Catchment	Site	Latitude	Longitude	Group	Family	Taxon	Reference Source
Ashburton River	Erswell 15, Vernon1	-24.36580	118.55400	Ostracoda	Candonidae	*Deminutiocandona bicauda*	WAM Crustacea (regno. 35624)
Ashburton River	9 Mile Well, Vernon3	-24.27520	118.38200	Ostracoda	Candonidae	*Deminutiocandona neara*	WAM Crustacea (regno. 35628 & 29)
Gascoyne River	un-named bore	-25.17590	118.06140	Bathynellacea	Parabathynellidae	*Billibathynella sp. 1*	Abrams *et al.* 2012
Gascoyne River	Old Production bore	-25.26745	119.16398	Coleoptera	Dytiscidae	*Neobidessoides gutteridgei*	(Watts and Humphreys 2003)
Gascoyne River	MB5	-25.26730	119.16417	Coleoptera	Dytiscidae	*Neobidessoides gutteridgei*	(Watts and Humphreys 2003)
Gascoyne River	MB2	-25.27360	119.17200	Coleoptera	Dytiscidae	*Neobidessoides gutteridgei*	(Watts and Humphreys 2003)
Gascoyne River	MB3	-25.26943	119.17202	Coleoptera	Dytiscidae	*Neobidessoides gutteridgei*	(Watts and Humphreys 2003)
Gascoyne River	Limestone Well	-25.28313	119.17577	Coleoptera	Dytiscidae	*Neobidessoides gutteridgei*	(Watts and Humphreys 2003)
Gascoyne River	MB4	-25.27861	119.18333	Coleoptera	Dytiscidae	*Neobidessoides gutteridgei*	(Watts and Humphreys 2003)
Gascoyne River	Limestone Well	-25.28313	119.17577	Coleoptera	Dytiscidae	*Neobidessoides limestoneensis*	(Watts and Humphreys 2003)
Gascoyne River	Earrie Well	-25.12278	118.09556	Coleoptera	Dytiscidae	*Paroster hamoni*	Watts and Humphreys 2003
Gascoyne River	Earrie Well	-25.12278	118.09556	Coleoptera	Dytiscidae	*Paroster milgunensis*	Watts and Humphreys 2003
Gascoyne River	un-named bore near Gascoyne River	-25.11780	119.15115	Coleoptera	Dytiscidae	*Paroster plutonicensis*	Watts and Humphreys 2003
Gascoyne River	disused production bore	-25.26745	119.16398	Coleoptera	Dytiscidae	*Paroster plutonicensis*	Watts and Humphreys 2003
Gascoyne River	MB2	-25.27360	119.17200	Coleoptera	Dytiscidae	*Paroster plutonicensis*	Watts and Humphreys 2003
Gascoyne River	MB1	-25.29213	119.18107	Coleoptera	Dytiscidae	*Paroster plutonicensis*	Watts and Humphreys 2003
Gascoyne River	MB4	-25.27861	119.18333	Coleoptera	Dytiscidae	*Paroster plutonicensis*	Watts and Humphreys 2003
Gascoyne River	Limestone Well	-25.27861	119.18333	Coleoptera	Dytiscidae	*Paroster plutonicensis*	Watts and Humphreys 2003
Gascoyne River	MB5	-25.27861	119.18333	Coleoptera	Dytiscidae	*Paroster plutonicensis*	Watts and Humphreys 2003
Gascoyne River	Isobel Well	-24.38609	117.01932	Coleoptera	Dytiscidae	*Paroster tetrameres*	Watts and Humphreys 2006
Gascoyne River	Three Rivers Plutonic	-25.28313	119.17573	Isopoda	Scyphacidae	*Haloniscus*	Cooper *et al.* (2008)

Appendix C Groundwater Properties Recorded

Table C-1: Groundwater Properties Data.

Area	Site Name	Elevation (AHD)	SWL (AHD)	SWL (mbgl)	DO (mg/L)	EC (uS/cm)	pH	Redox (mV)	Water Temp. (C)	Stygofauna recorded
Boxcut	EP01	552.0	518.4	33.6	3.0	694.0	6.9	282.6	26.3	
Deposit	AB09	546.0	520.2	25.8	1.1	972.0	7.2	71.5	27.8	
Deposit	AB31	549.0	518.0	31.0	1.0	830.0	7.9	-103.5	29.4	
Deposit	AB31	549.0	518.1	30.9	0.5	791.0	7.9	51.7	28.5	
Deposit	JE61	556.0	519.0	37.0	1.9	275.0	7.0	89.7	28.9	
Deposit	STAB04	556.0	517.9	38.1	3.5	890.0	7.4	-99.2	27.6	
Deposit	STAB04	556.0	-	-	0.7	865.0	7.2	51.7	-	
Northern Reference	TNG0018R	459.0	442.4	16.7	2.4	6037.0	7.0	216.8	29.8	
Northern Reference	WAM WMDB01	447.0	441.2	5.8	3.0	2731.0	7.3	209.3	27.3	Yes
Northern Reference	WAM WMDB02	427	-	-	-	-	-	-	-	
Northern Reference	WAMDB02	427.0	417.8	9.3	0.8	796.0	6.9	211.7	27.9	
Potential Drawdown	AB10	542.0	519.0	23.0	1.3	940.0	7.1	-108.3	29.5	
Potential Drawdown	AB10	542.0	520.6	21.4	0.6	963.0	7.5	216.5	28.4	
Potential Drawdown	ABRC001	548.0	518.3	29.8	0.4	3240.0	-	-	28.6	
Potential Drawdown	JHP16	549.0	518.0	32.0	1.6	740.0	6.9	75.9	28.8	Yes
Potential Drawdown	JHP16	549.0	518.1	31.9	0.7	841.0	6.6	280.8	27.4	
Potential Drawdown	JHP18	551.0	518.5	32.5	1.5	1280.0	7.7	149.5	27.9	
Potential Drawdown	JHP18	551.0	517.8	33.3	2.7	1190.0	7.8	327.9	26.3	
Potential Drawdown	STAB06	539.0	516.8	22.2	0.4	870.0	-	-113.5	29.4	
Reference	Ethel Creek Bore 01	524.0	513.4	10.6	5.3	1124.0	7.2	183.3	27.3	
Reference	GE01	559.0	523.4	35.6	3.1	365.5	6.8	260.9	28.2	
Reference	HY01	563.0	518.5	44.5	1.8	1236.0	7.3	296.2	27.4	
Reference	JHP01	569.0	526.1	42.9	1.4	581.0	6.1	299.8	27.1	
Reference	JHP02	561.0	519.1	41.9	4.0	1390.0	7.9	299.9	27.0	
Reference	JHP03	559.0	516.3	41.7	2.3	1060.0	7.2	292.9	27.5	
Reference	JHP04	544.0	514.3	29.7	2.5	830.0	7.5	287.0	28.0	
Reference	JHP05	538.0	511.8	26.2	3.2	714.0	7.5	284.9	27.5	
Reference	JHP06	536.0	504.3	31.7	1.6	909.0	7.6	283.8	27.4	
Reference	JHP07	526.0	511.7	14.3	0.7	459.0	7.2	60.2	28.8	
Reference	JHP07	526.0	514.0	13.3	0.8	493.2	7.2	286.5	26.9	

Area	Site Name	Elevation (AHD)	SWL (AHD)	SWL (mbgl)	DO (mg/L)	EC (uS/cm)	pH	Redox (mV)	Water Temp. (C)	Stygofauna recorded
Reference	JHP08	529.0	527.5	13.5	1.6	1031.0	7.3	281.3	27.1	
Reference	JHP09	535.0	518.5	16.5	4.1	942.0	7.7	274.4	26.5	
Reference	JHP10	532.0	514.7	17.3	2.6	651.0	7.5	281.9	27.8	
Reference	JHP11	532.0	517.5	14.5	1.0	918.0	6.6	94.6	28.0	
Reference	JHP12	552.0	519.6	32.4	1.7	548.0	6.2	267.2	28.0	
Reference	JHP13	532.0	515.0	17.1	1.6	700.0	7.1	114.8	28.8	
Reference	JHP13	532.0	515.1	16.9	3.6	699.0	7.2	284.9	27.3	
Reference	JHP14	535.0	516.7	18.3	3.0	784.0	6.9	229.4	27.9	Yes
Reference	JHP15	534.0	514.5	21.5	2.2	456.0	6.5	89.2	29.1	Yes
Reference	JHP15	534.0	514.5	21.5	1.1	811.0	6.7	290.3	26.4	Yes
Reference	JHP19	536.0	519.7	16.3	1.3	970.0	6.8	-55.2	28.1	
Reference	JHP19	536.0	520.8	15.2	4.2	692.0	7.0	319.8	25.8	
Reference	NARC04	524.0	-	-	1.3	756.0	6.8	298.6	26.4	
Reference	NARC08	528.0	512.4	15.6	3.3	597.0	7.2	294.9	27.6	
Reference	NARC12	530.0	509.9	17.1	3.7	822.0	7.1	297.2	26.3	
Reference	NARC13	529.0	511.0	17.9	3.1	620.0	7.6	298.8	28.0	Yes
Reference	NARC14	529.0	509.5	19.5	3.1	604.0	7.7	287.8	27.8	
Reference	NARC15	533.0	-	-	1.2	606.0	7.0	241.6	28.0	
Reference	STAB10	540.0	516.4	23.6	3.3	437.8	6.8	283.5	27.0	Yes

Appendix D Subterranean Fauna Survey Results

Table D-1: Stygofauna survey results arranged by taxon.

Group	Family	Taxon	Abundance	Site Name	Distance from Deposit or Portal	Sample Date	Collection Method
Amphipoda	Bogidiellidae	*Bogidiella* OES11	1	WAM WMDB01	30.1 km	31/05/2018	Windmill Pump
Amphipoda	Paramelitidae	Paramelitidae-OES10	7	STAB10	1.5 km	01/06/2018	Net Haul
Bathynellacea	Parabathynellidae	*Brevisomabathynella* OES30	1	STAB10	1.5 km	01/06/2018	Net Haul
Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	1	JHP14	2.5 km	29/05/2018	Net Haul
Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	1	JHP15	1.7 km	01/03/2018	Net Haul
Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	1	JHP15	1.7 km	30/05/2018	Net Haul
Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	2	JHP15	1.7 km	01/03/2018	Net Haul
Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	4	JHP16	1.7 km	01/03/2018	Net Haul
Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	6	NARC13	230 m	29/05/2018	Net Haul

Table D-2: Stygofauna survey results arranged by site.

Site Name	Distance from Deposit or Portal	Sample Date	Collection Method	Group	Family	Taxon	Abundance
JHP14	2.5 km	29/05/2018	Net Haul	Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	1
JHP15	1.7 km	01/03/2018	Net Haul	Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	1
JHP15	1.7 km	30/05/2018	Net Haul	Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	1
JHP15	1.7 km	01/03/2018	Net Haul	Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	2
JHP16	1.7 km	01/03/2018	Net Haul	Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	4
NARC13	230 m	29/05/2018	Net Haul	Oligochaeta	Phreodrilidae	*Phreodrilus* OES25	6
STAB10	1.5 km	01/06/2018	Net Haul	Bathynellacea	Parabathynellidae	*Brevisomabathynella* OES30	1
STAB10	1.5 km	01/06/2018	Net Haul	Amphipoda	Paramelitidae	Paramelitidae-OES10	7
WAM WMDB01	30.1 km	31/05/2018	Windmill Pump	Amphipoda	Bogidiellidae	*Bogidiella* OES11	1

Appendix E Molecular Analysis

Insert PDF here

Report prepared for Stantec, 1 August 2018
by Dr Remko Leijs, South Australian Museum.

Molecular identification of Amphipoda from the ABRA project area in the Gascoyne Region, Western Australia

Summary

• One new species of Bogiellid amphipod was identified.

Extraction	BES	Stantec identification	SAM ident.	site	Extr.date	Coll.Date	Site	PCR	seq
ST2125	LN30439	Paramelitidae OES10?	Bogidiella sp.	WAM WMDB01	23-Jun-18	31/05/2018	Gascoyne region	good	ok
ST2126	LN31031	Paramelitidae OES10		STAB10	23-Jun-18	1/06/2018	Gascoyne region	very weak	failed
ST2127	LN31020	Paramelitidae OES10		STAB10	23-Jun-18	1/06/2018	Gascoyne region	good	contaminated
ST2128	LN31015	Paramelitidae OES10		STAB10	23-Jun-18	1/06/2018	Gascoyne region	no PCR	

Table 1. Overview of the Amphipoda specimens analysed from the ABRA project area in the Gascoyne region. The first column gives the DNA extraction numbers, the last column indicates whether the DNA sequencing was successful. Highlighted specimens did not result in sequences of the Amphipod target DNA.

Methods

Biodiversity assessment of the collected fauna (Table 1) was performed using PCR amplification and sequencing in both directions of a 648 bp fragment of CO1, commonly used for DNA barcoding (Hebert et al. 2003). The sequences were added to large datasets that consists of related taxa from other areas complemented with published data from Genbank and unpublished sequence data at the South Australian Museum and the Western Australian Museum.
Phylogenetic analyses using neighbour joining of uncorrected sequence distances in PAUP* (Swofford 1998) were used to match the received specimens with previously identified analysed specimens. Results of phylogenetic analyses are presented as partial phylogenetic trees showing the target species with some closest related species.

Results

Amphipoda

Unfortunately, only one sample resulted in a good DNA sequence. The remaining three specimens from the STAB10 site, did not result in consistend PCRs, despite several attempts using different PCR primers targetting the same DNA-barcode region. Specimen ST2127

(LN31020) produced a PCR band on the gel, but DNA sequencing revealed that it was contaminant Amoeba DNA.

However, sample ST2125 (LN30439) produced a consistent PCR product and good sequence. A BLAST search confirmed that it was an amphipod sequence and the NJ analyses grouped it within a clade of Bogidiella species (Figure 1).

Its closest sister was ST1505 (Bogidiella sp. B02- HB401, Access Road NEW001, identification done for Bennelongia), pairwise sequence divergence 18%, indicating that specimen ST2125 is a new species, that is distantly related to ST1505.

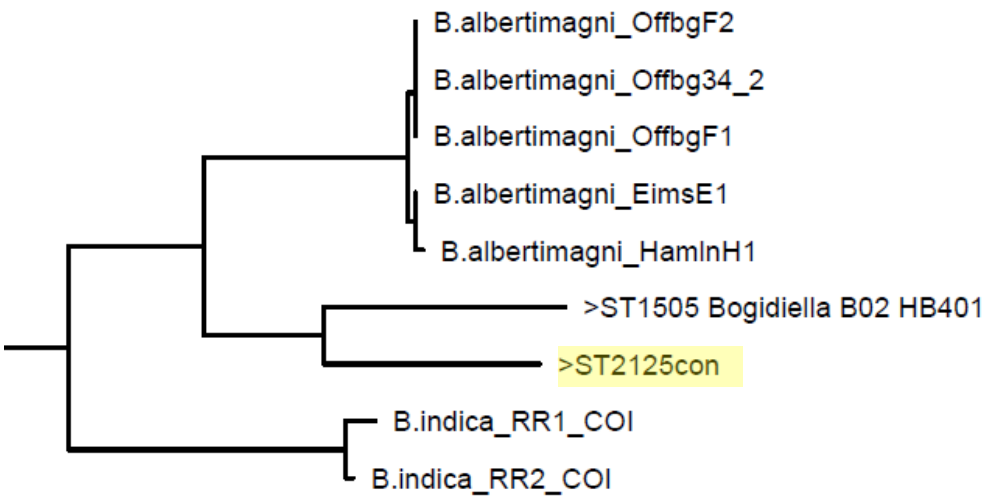

Figure 1. Partial neighbour joining cladogram of Bogidiellidae. Indicated in yellow is the newly sequenced specimen.

Sequences

>ST2125-LN30439
GATATTGGGACACTTTATTTTATTTTAGGTGCATGAGCAAGTATAGTAGGGACAGCATTAAGAA
TTATTATTCGATCAGAACTTAGGTCTCCTGGTAATTTAATtGGAGATGATCAAATTTATAATGT
TATAGTAACAGCCCATGCTTTTATTATAATTTTTTTTATAGTTATACCTATTATAATTGGTGGT
TTTGGTAATTGATTACTTCCTTTAATATTAGGAAGGCCAGATATAGCTTTTCCACGAATAAATA
ACATAAGATTTTGACTTTTAGTCCCATCAATTTCACTATTATTAACTAGAAGGTTAGTAGAAAG
AGGGGTAGGAACAGGATGAACTGTATACCCTCCTTTAGCTAGAGGATTAGCCCATTCAGGAAGT
GCAGTAGATTTTGCTATTTTTTCCCTTCATTTGGCTGGGGCTTCATCTATTTTAGGATCAGCTA
ATTTTATATCTACAGTAATAAATATACGGACTTTAGGGATATCCATAGATAAAGTACCACTTTT
TGTATGATCAGTTTTTATTACAACTATTTTACTTTTATTATCATTACCAGTCTTAGCTGGAGCA
ATCACTATATTATTAACAGATCGTAATATTAATACTTCTTTTTTTGATCCAAGAGGAGGGGGGG
ATCCTATTTTATATCAACACTTATTTTGATTTTT

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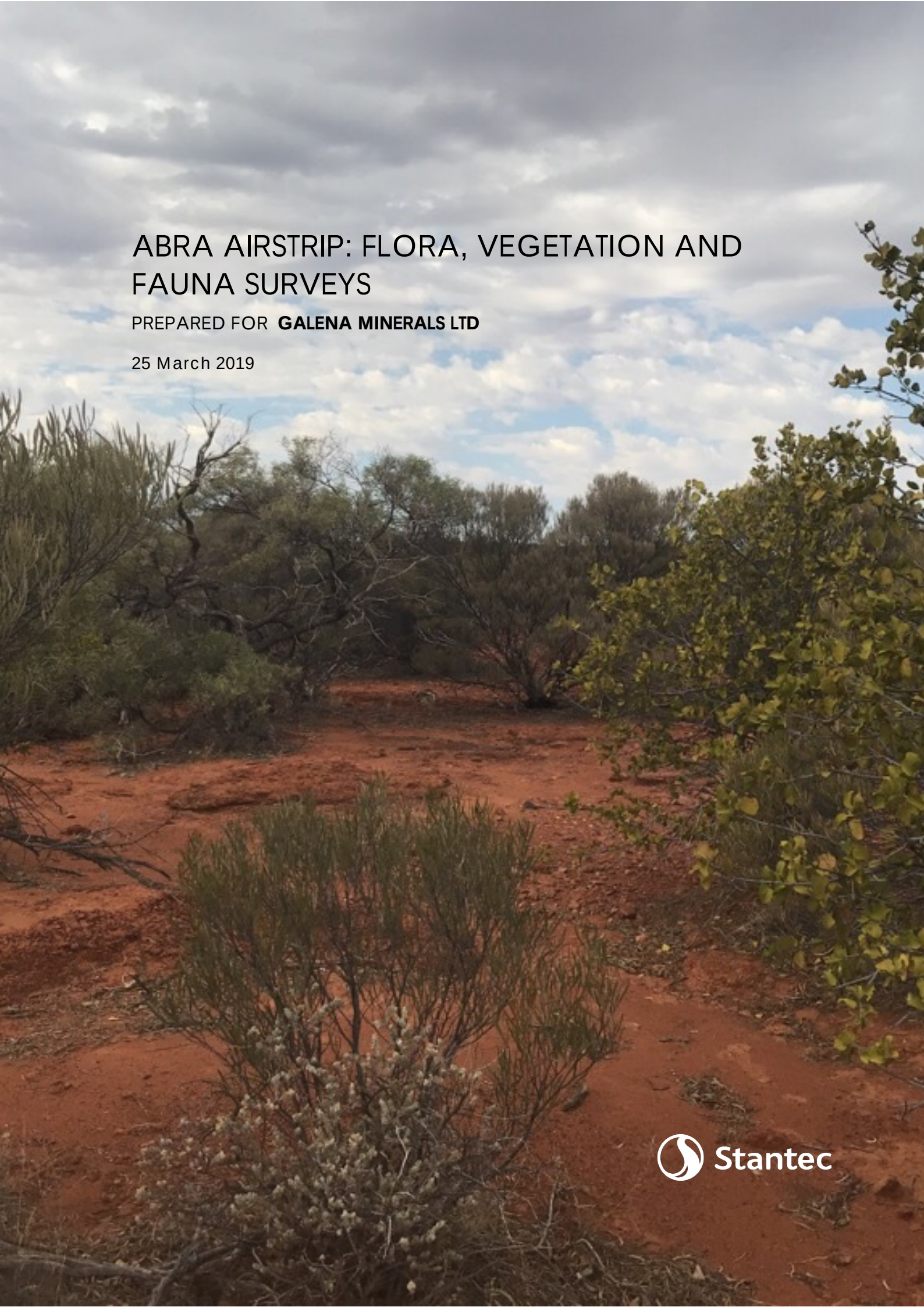

ABRA AIRSTRIP: FLORA, VEGETATION AND FAUNA SURVEYS

PREPARED FOR **GALENA MINERALS LTD**

25 March 2019

Stantec

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REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
v.01	30/01/2019	Draft report for comment	CH & SL	PB	AB	AB
V1.0	25/03/2019	Final report issued to client	CH & SL	PB	AB	AB

Executive Summary

Galena Mining Limited proposes to develop a lead mining operation in the Gascoyne Region of Western Australia, entitled the Abra Base Metals Project. The Project is located approximately 220 kilometres north of Meekatharra and 180 kilometres southwest of Newman. Stantec Australia Pty Ltd has previously completed a Detailed flora and vegetation survey and Level 1 fauna survey of the Project area and has been appointed to undertake a Reconnaissance flora and vegetation survey and Level 1 fauna survey of a proposed air strip (the Study Area), located east of the Project. The Study Area covers 278 hectares and is located on Exploration Lease E52/1455, overlapping partially with the Project.

The desktop assessment identified 22 flora and 26 fauna species of conservation significance with potential to occur in the Study Area. No Threatened or Priority Ecological Communities were identified within the Study Area, and the nearest Priority Ecological Community is the Diorite Land System (Priority 3) located 16 km to the southwest.

The field survey took place between the 2nd and 5th of October 2018 and the Study Area was sampled by way of opportunistic collections, vegetation and fauna mapping and data collected from 16 relevés and two mapping notes. There were 55 vascular flora taxa recorded from the Study Area, representing 19 families and 26 genera, with no introduced flora recorded. The most represented plant families were Fabaceae (legumes), Poaceae (grasses) and Malvaceae (malvas) and the most represented genera were *Acacia* and *Eremophila.* No Threatened or Priority flora taxa were recorded during the field survey and none are considered 'likely' to occur.

Five vegetation types were identified, including two that overlapped with the adjacent Project. None of these vegetation types are analogous to any Threatened or Priority Ecological Communities. Vegetation condition was 'excellent' throughout the Study Area, with disturbances restricted to clearing for tracks and impacts from non-native fauna. No introduced flora species were recorded during the survey. The vegetation types recorded represent what would be expected from similar landforms in the broader Augustus subregion in which the Study Area occurs.

Three broad fauna habitats were identified within the Study Area; open shrubland on sandy plain, open shrubland on stony plain and drainage. All are considered widespread and of limited significance for potential conservation significant vertebrate fauna.

No fauna species of conservation significance were recorded during the current survey. One species of conservation significance, the Peregrine Falcon (S7), was considered 'possible' to occur based on species range and previous records. Although the Study Area does not contain suitable nesting habitat for the species, it may forage over the Study Area from time to time without being dependent on any particular habitat. The remaining species of conservation significance were assessed as 'unlikely' to occur in the Study Area.

Galena Minerals Ltd

Abra Airstrip: Flora, Vegetation and Fauna Surveys

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1. Introduction

1.1 Project Background and Location

Galena Mining Limited (Galena) propose to develop a lead mining operation entitled; the Abra Base Metals Project, located within the Gascoyne Region of Western Australia (WA), 220 kilometres (km) north of Meekatharra and 180 km southwest of Newman (**Figure 1-1**) (the Project). Stantec Australia Pty Ltd (Stantec) previously completed a Detailed flora and vegetation survey and Level 1 fauna survey of the Project area, covering 1,357 hectares (ha)(Stantec 2018). Subsequently, Galena has appointed Stantec to complete a Reconnaissance flora and vegetation survey and Level 1 fauna survey of a proposed air strip (the Study Area), located east of the Project, to inform an application for a Miscellaneous Licence. The Study Area is located on Exploration Lease E52/1455 and covers an area of 278 ha (**Figure 1-2**).

1.2 Report Scope and Objectives

The principal objectives of the Reconnaissance flora and vegetation survey and Level 1 fauna survey were to investigate and define the environmental values of the Study Area and to describe their conservation significance in relation to the Project. To achieve these objectives, the specific scope is detailed below:

- complete a desktop review (database searches and literature review), to develop a list of flora and fauna species and vegetation communities that have been previously recorded within, or in the vicinity of, the Project, including species and communities with the potential to be of conservation significance;
- conduct a Reconnaissance -level field survey to identify, describe and map vegetation types, vegetation condition and fauna habitats within the Study Area;
- conduct targeted searches for flora, vegetation communities and fauna of conservation significance, including species and communities of local and regional significance;
- develop a list of flora and fauna species recorded as occurring within the Project, including introduced flora and fauna species and
- assess the survey findings in a local and regional context by comparing them with available data from other localities within the bioregion.

The objectives and methods adopted for these surveys are aligned with the following relevant regulatory guidelines:

- Environmental Protection Authority (EPA) Environmental Factor Guideline: Flora and Vegetation (EPA 2016d);
- EPA Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016f);
- EPA Environmental Factor Guideline: Terrestrial Fauna (EPA 2016e);
- EPA Technical Guidance – Terrestrial Fauna Surveys (EPA 2016c);
- EPA Factor Guideline: Sampling Methods for Terrestrial Vertebrate Fauna (EPA 2016b);
- Department of Environment Regulation (DER), A guide to the assessment of applications to clear native vegetation (DER 2014); and
- Department of the Environment (DoE), Matters of National Environmental Significance - Significant Impact Guidelines 1.1 EPBC Act (DoE 2013).

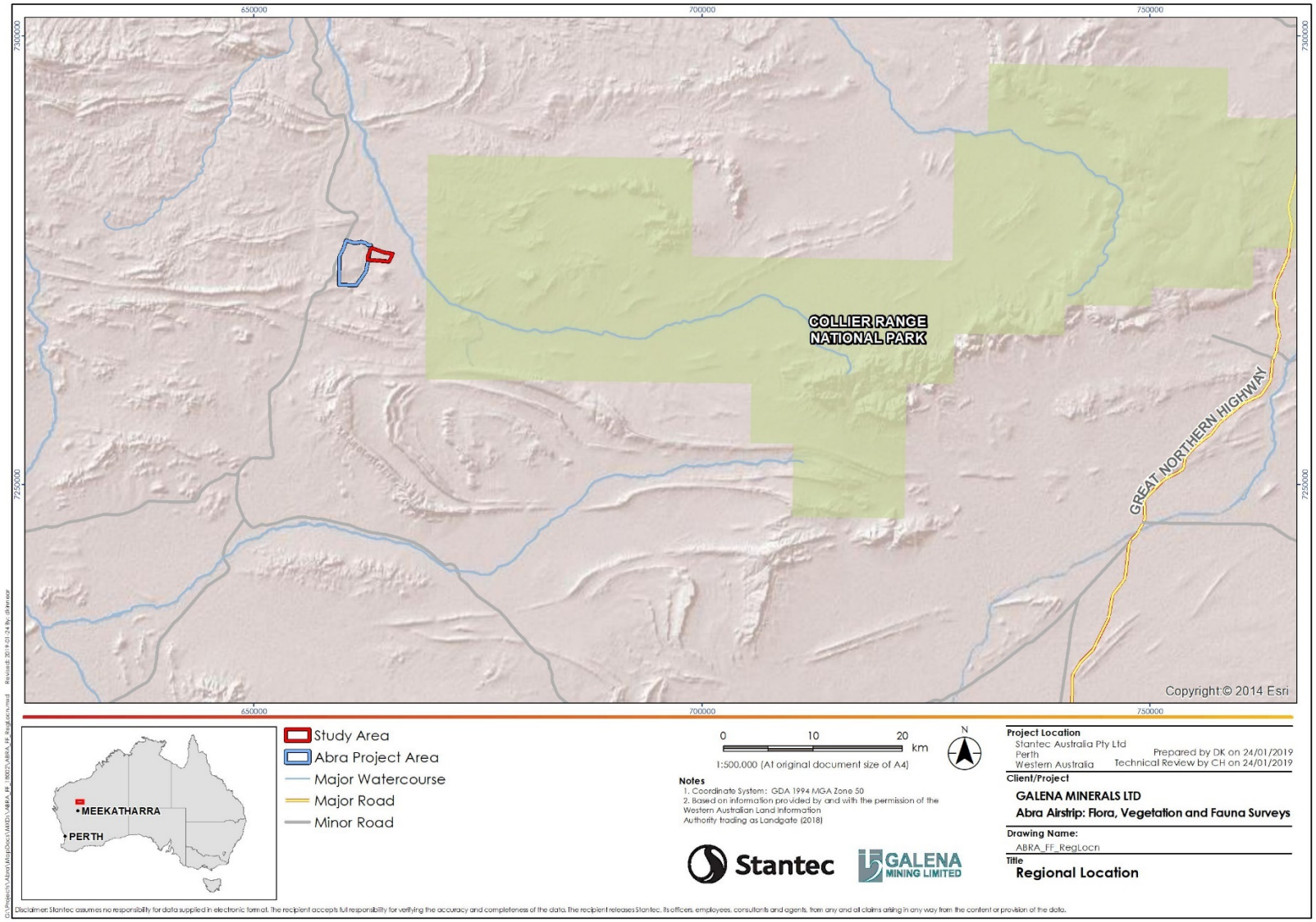

Figure 1-1: Regional locality of the Study Area

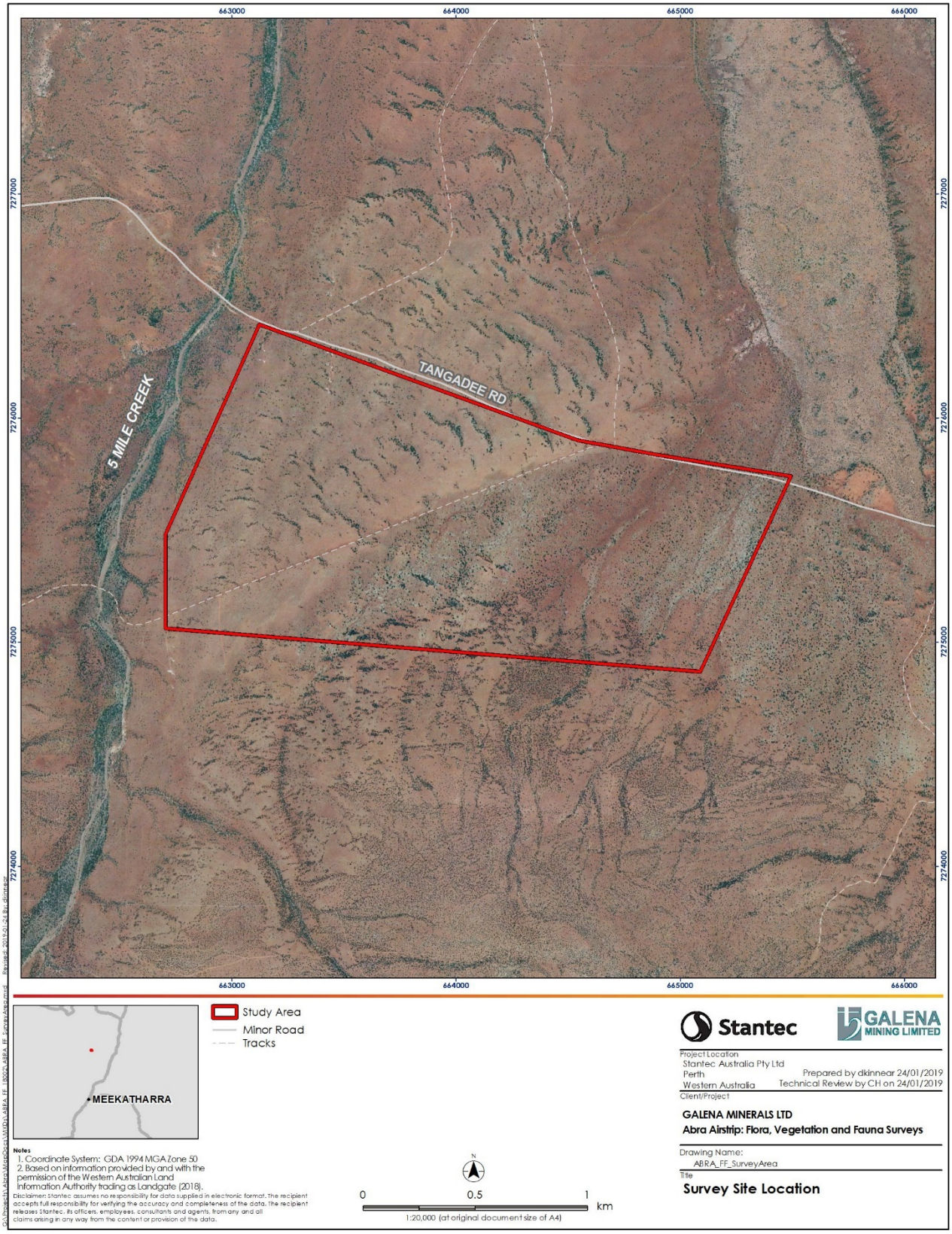

Figure 1-2: The Study Area

2. Existing Environment

2.1 Climate

The Study Area is located 178 km southwest of Newman within the Gascoyne region of Western Australia. The Gascoyne region typically receives low amounts of variable rainfall influenced by northern cyclonic events (GDC 2015).

Long-term rainfall data was collated from Neds Creek (007103) weather station for the period 1947 to 2018, approximately 139 km southeast of the Study Area and long-term temperature records have been collated from Newman Aerodrome (007176) weather station for the period 1966 to 2018 and Meekatharra Airport (007045) for the period 1950 to 2018, approximately 178 km northeast and 219 km south of the Study Area respectively (BoM 2018). The mean annual rainfall recorded at the Neds Creek weather station is 239 mm, with the majority received between January and March each year (**Figure 2-1**). Newman Aero has an annual average maximum temperature of 32.1°C and an annual average minimum temperature of 16.4°C (**Figure 2-1**). Meekatharra Airport has an annual average maximum temperature of 29.0°C and an annual average minimum temperature of 15.9°C (**Figure 2-2**).

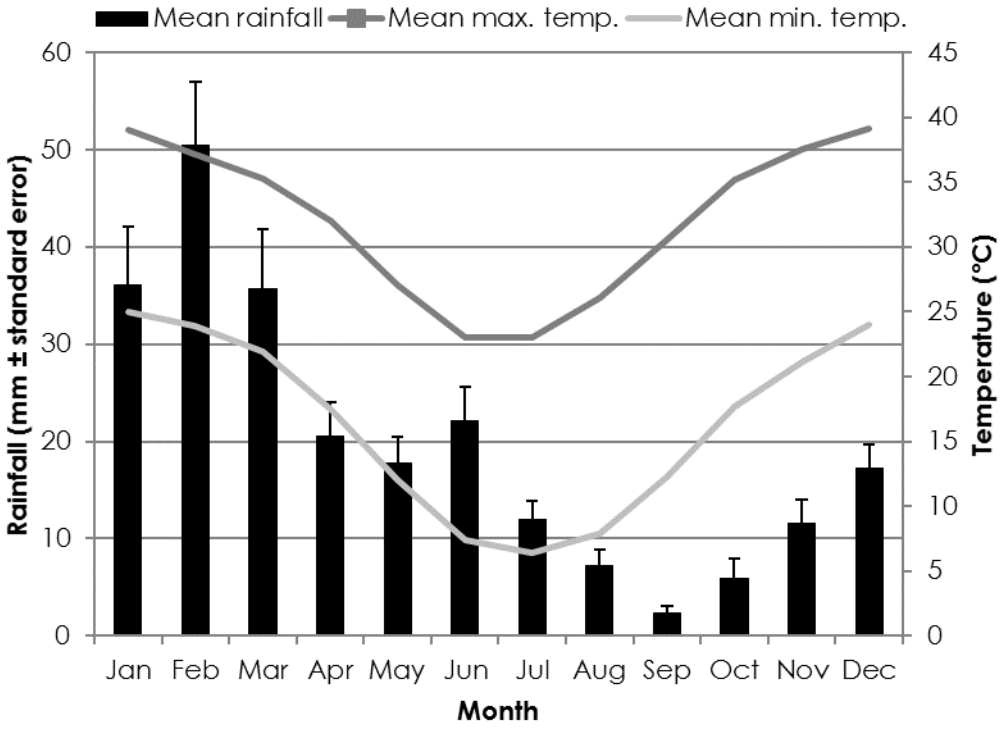

Figure 2-1: Long-term mean rainfall (mm) recorded at Neds Creek station (007103) and long-term maximum and minimum temperatures recorded at Newman Aero station (007176) (BoM 2018)

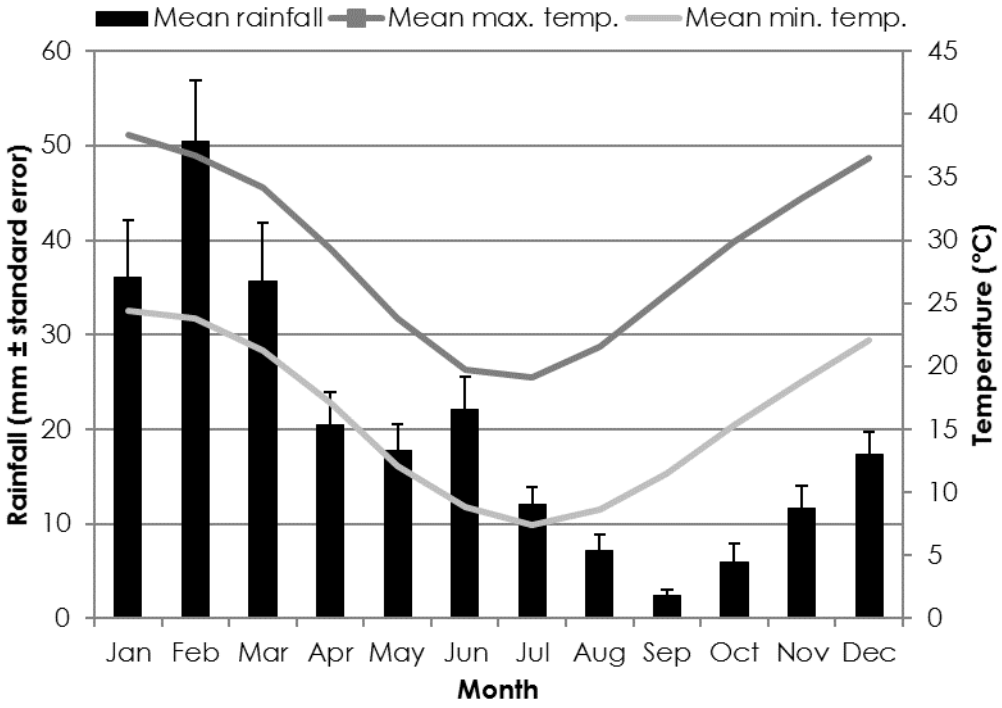

Figure 2-2: Mean rainfall (mm) recorded at Neds Creek station (007103) and long-term maximum and minimum temperatures recorded at Meekatharra Airport station (007045) (BoM 2018).

2.2 Landforms, Geology and Soils

The Study Area is located within the Mesoproterozoic Bangemall Basin and is the youngest of a series of sedimentary basins that unconformably lie over the Capricorn Orogen, a metamorphic terrain that represents amalgamation of the Yilgarn and Pilbara Cratons during the Paleoproterozoic (Payne *et al.* 1988). The Study Area lies within the south-eastern boundary of the Bangemall Geomorphic Province, as described by Payne *et al.* (1988). This province is 18,590 km^2 in size and forms the watershed between the Ashburton and Gascoyne Rivers. It consists predominantly of rugged mountains and hill and ridge country of Bangemall series Middle Proterozoic sedimentary rocks (Payne *et al.,* 1988).

The more weather-resistant rocks of the area, such as sandstone, form massive parallel ridges and ranges, predominantly trending northwest. The lower slopes, restricted valley plains and floors associated with the hills are covered with a dense surface strew of rock fragments of variable lithology. The sediments are frequently intruded by dolerite dykes and sills which are now exposed to form rounded hills and ridges. Soils include red shallow loams (often with hardpans), red loamy earths, stony soils and red deep sands with some red shallow sands (Tille 2006).

2.3 Land Systems

Land systems across the Gascoyne have been mapped by the Natural Resources Assessment Group of the former Department of Agriculture (now Department of Primary Industries and Regional Development, DPIRD) and provide a comprehensive description of biophysical resources within the area (Payne *et al.* 1988). The Study Area falls primarily within the Jamindie and Three Rivers Systems, with a small proportion occurring in the Collier System (**Table 2-1**; **Figure 2-3**).

Table 2-1: Land systems and their extent within the Study Area

Land System	Description	Extent within Study Area	
		Hectare (ha)	Percentage (%)
Jamindie System	Stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understorey.	123.73	44.5
Three Rivers System	Hardpan plains and minor sandy banks supporting sparse mulga shrublands.	146.22	52.6
Collier System	Undulating stony uplands, low hills, ridges, stony plains and drainage floors supporting mulga shrublands and some spinifex.	8.22	3
Total	**-**	**278.17**	**100**

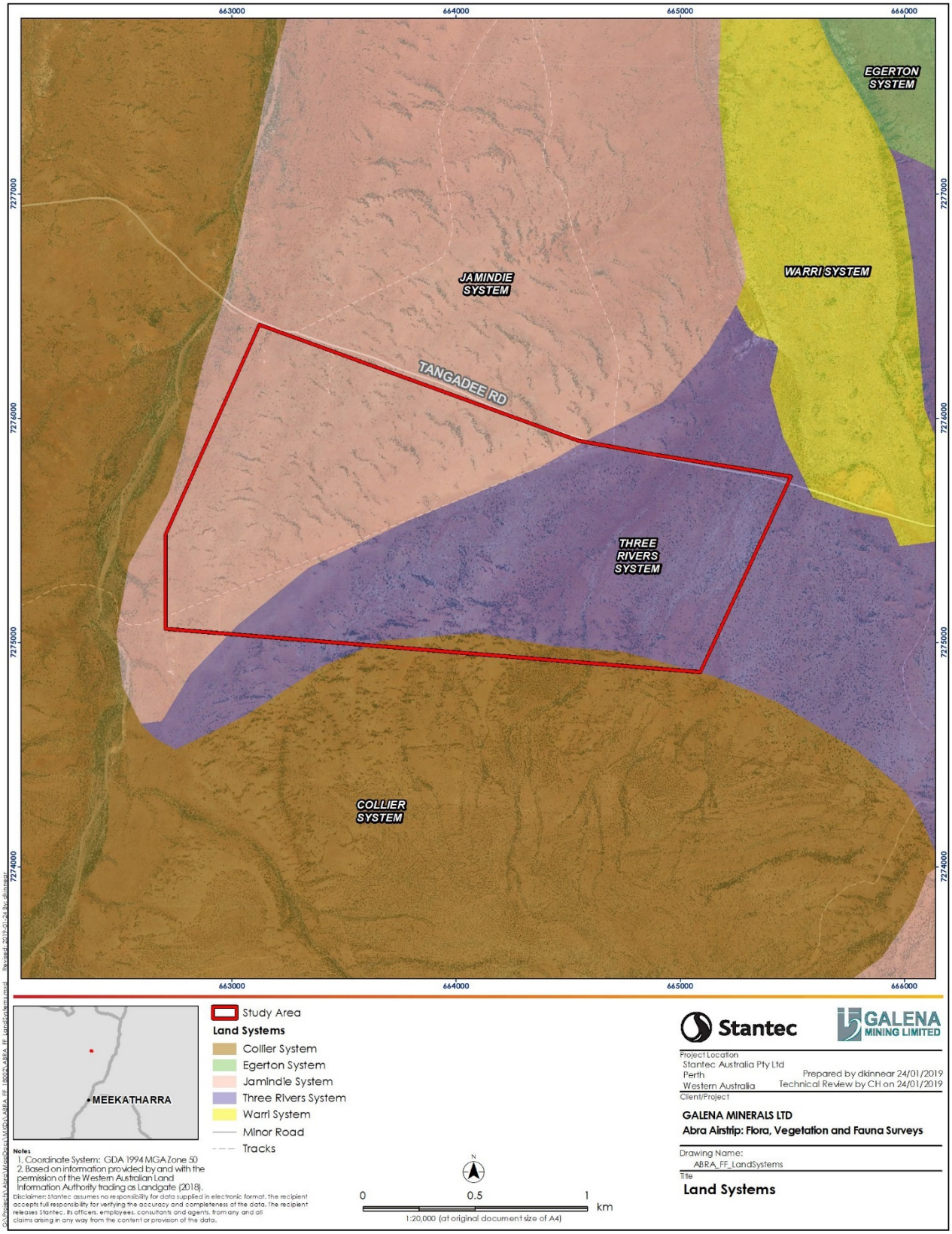

Figure 2-3: Land systems within and surrounding the Study Area

2.4 Surface Water and Hydrology

The main source of drainage within the Augustus subregion is the Gascoyne River system, however drainage is also provided by the Ashburton and Fortescue River headwaters (Desmond *et al.* 2001). The Gascoyne River reaches 760 km, flowing westward to drain into the Indian Ocean.

The Ashburton River and Ethel Creek, located immediately north and east of the survey area respectively, are seasonal watercourses with several permanent pools. A small tributary of the Ethel River, 5 Mile Creek, runs south to north to the west of the Study Area, coinciding with the Abra Project Area.

The drilling at the Project has some generalisations that can be made regarding the slope of the water table and the variable permeability of the lithologies. The relative elevation of the water table is estimated to slope gently from south to north from a range of <5 m to <15 m (Whitford *et al.* 1994). There appears to be some consistent spatial variation in the depth of the water table. It is relatively high in the southwest and appears to drop to the north and northeast. The mean groundwater flow should follow this slope, although on more local scales the anisotropic permeability of the rocks will probably result in a more complex pattern of groundwater movement (Whitford *et al.* 1994).

2.5 Biogeographic Region

The Interim Biogeographic Regionalisation for Australia (IBRA) is a bioregional framework that divides Australia into 89 biogeographic regions and 419 subregions on the basis of climate, geology, landforms, vegetation and fauna (Thackway and Cresswell 1995). It was developed through collaboration between state and territory conservation agencies with coordination by the Commonwealth Department of the Environment, Water, Heritage and the Arts (now the Commonwealth Department of the Environment and Energy, DoEE).

The Study Area is located in the Augustus subregion (GAS3) within the Gascoyne bioregion. The Augustus subregion makes up 10,687,739 ha and is classified as a Desert and Xeric Shrubland ecoregion, characterised by ranges separated by wide flat valleys (Desmond et al. 2001, DoEE 2013). Vegetation mainly consists of Mulga woodland over *Triodia* species on shallow stony loams and rises, and Mulga on shallow earthy loams over hardpan on plains (Hughes and Jones 2010).

2.6 Flora and Vegetation

The Study Area lies within the Ashburton Botanical District, as classified by Beard (1990). This district is almost entirely mulga (*Acacia aneura*) shrublands, sometimes with snakewood (*Acacia xiphophylla*) and other *Acacia* species as scrub on the hills, and as low woodland on the plains. Areas of dwarf scrub of *Eremophila* and *Senna* species also occur (Beard 1990).

2.6.1 Pre-European Vegetation

Vegetation mapping of Western Australia was completed on a broad scale (1:1,000,000 and 1:250,000) by Beard (1975a), who classified vegetation into broad vegetation associations. These vegetation associations were re-assessed by Shepherd *et al.* (2002) to account for clearing in the intensive land use zone, and to divide some larger vegetation units into smaller units. Additionally, Shepherd *et al.* (2002) developed a series of systems to assist in the removal of mosaics; however, some mosaics still occur. The Study Area has been mapped as 'low woodland; mulga (*Acacia aneura*), of the Gascoyne Ranges (Beard 1975a, Shepherd *et al.* 2002) (**Table 2-2**; **Figure 2-4**) (vegetation system associations described by Shepherd *et al.* (2002) correspond with that of Beard (1975a).). The current extent of this vegetation system association suggests that minimal land clearing has occurred across four scales of assessment (State, bioregion, subregion and Local Government Area (LGA) (Shire of Meekatharra) (**Table 2-3**).

Table 2-2: Vegetation system associations and their extent within the Study Area

System	System Code	Extent	Description
Gascoyne Ranges	18.5	278.17	Low woodland; mulga (*Acacia aneura*)

Table 2-3: Vegetation system association extent remaining across four scales (State, Bioregion, Subregion and Local Government Area)

System	Scale	Pre-European Extent	Current Extent	% Remaining	Current extent within IUCN Class I-IV Reserves (ha)	% of current extent protected within IUCN Class I-IV Reserves
Gascoyne Ranges 18	State-wide	1,812,659.31	1,811,127.15	99.92	16,344.03	0.9
	Bioregion	1,794,574.24	1,793,131.87	99.92	16,344.03	0.9
	Sub-region	1,777,829.40	1,776,387.03	99.92	16,344.03	0.9
	LGA	918,276.87	916,753.77	99.83	16,214.53	1.77

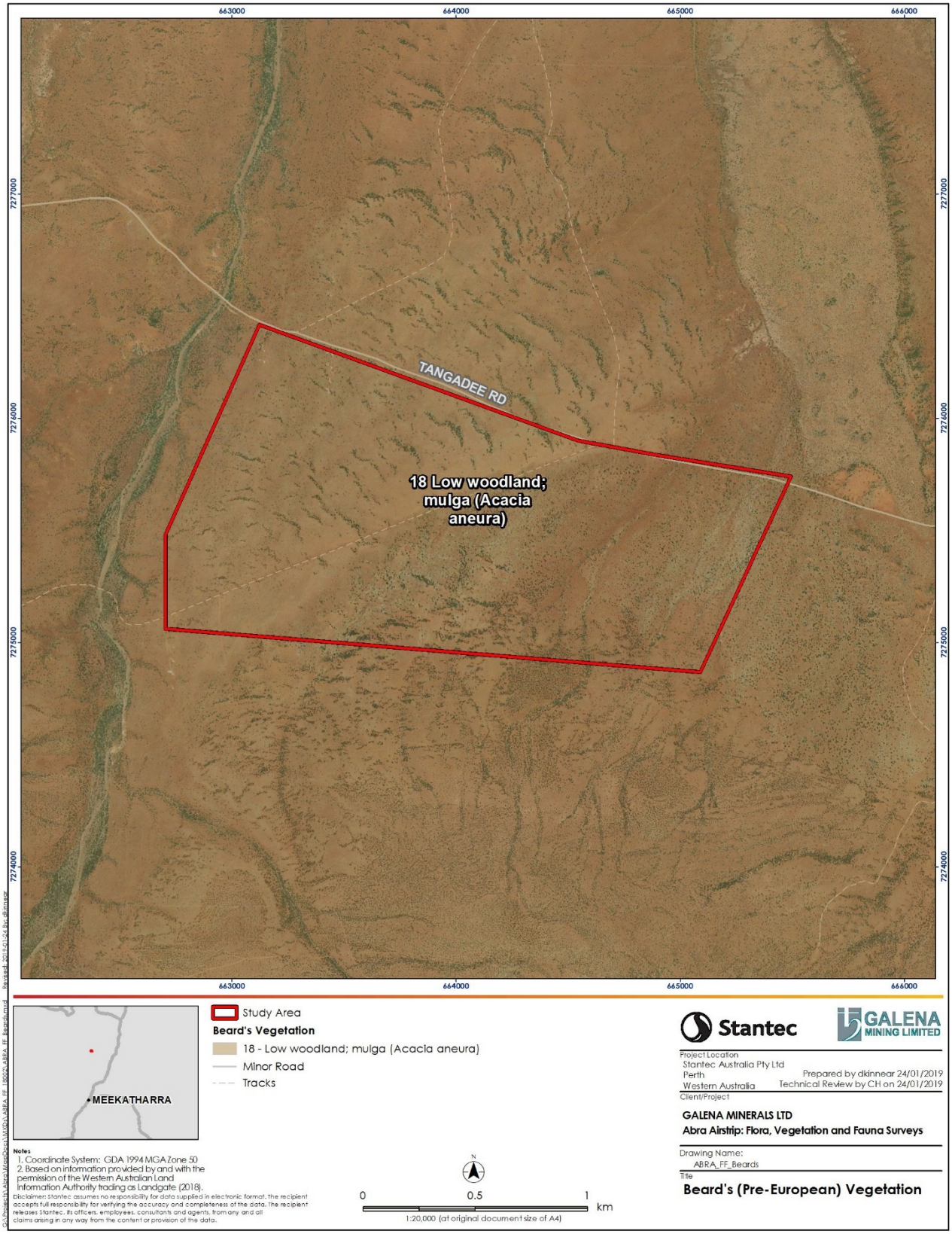

Figure 2-4: Pre-European vegetation associations of the Study Area

2.7 Land Use and Tenure

2.7.1 Land Use

The majority of land within the Gascoyne is used for pastoral purposes, with leases covering 84% of the area (GDC 2015) and only smaller areas serving horticultural or mining purposes (GDC 2015). The Study Area lies within the Mulgul Pastoral Lease with cattle grazing occurring across Galena's leases. The Project was previously known as the Mulgul which was acquired by Galena from Abra Mining Limited.

2.7.2 Conservation Reserves and Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESAs) are declared by the Minister for Environment under Section 51B of the *Environmental Protection Act 1986* (EP Act) to prevent incremental degradation of important environmental values such as declared rare flora, threatened ecological communities (TECs) or significant wetlands.

The Study Area lies approximately 3.8 km west of Collier Range National Park, which is managed by the Department of Biodiversity, Conservation and Attractions (DBCA). The reserve was established due to the potential value of hills and freshwater pools serving as refuge from fire and harsh arid conditions (Desmond *et al.* 2001). Collier Range National Park receives annual baiting for wild dogs and is visited by staff, however there is limited information available regarding the biodiversity of the area (Desmond *et al.* 2001). Significant damage has been recorded from feral donkeys and cattle and there is no current fire regime (Desmond *et al.* 2001).

3. Methodology

3.1 Desktop Assessment

A desktop assessment, comprising a review of database searches and a literature review, was undertaken prior to the field surveys to gather contextual information on the Study Area. The purpose of the desktop assessment was to identify flora, vegetation and terrestrial fauna potentially occurring in the Study Area, in particular species of conservation significance.

3.1.1 Database Searches

Database searches, conducted in January 2018 for the Project (Stantec 2018), were utilised to generate a list of vascular flora, vegetation communities and vertebrate fauna previously recorded within, and in the vicinity of the Study Area.

Eight database searches were conducted from a central coordinate (50J, 660525 m E, 7273300 m S) (**Table 3-1**). Appropriate search buffers were selected based on the technical capabilities of each of the databases and the ecological features of the area.

Conservation significance and conservation rankings used under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and *Biodiversity Conservation Act 2016* (BC Act), as well as by the DBCA, are defined in **Appendix A**.

Table 3-1: Database searches conducted for the desktop assessment

Custodian	Database	Ecological Group	Reference	Buffer (km)
DoEE	Protected Matters Search Tool (PMST)	Matters of National Environmental Significance (MNES) flora and fauna	DoEE (2018a)	100
DBCA	NatureMap	Flora and fauna	(DBCA 2018b)	40
DBCA	Threatened and Priority Ecological Communities	Vegetation communities	(DBCA 2018a)	50
DBCA	Threatened and Priority Flora Database	Flora	(DBCA 2018d)	50
DBCA	Threatened and Priority Species List (TP List)	Flora	(DBCA 2018a)	50
DBCA	Western Australian herbarium Flora	Flora	(DBCA 2018e)	50
DBCA	Threatened and Priority Fauna Database	Fauna	(DBCA 2018a)	100
Birdlife Australia	Birdlife Bird data	Fauna	(Birdlife Australia 2018)	50

3.1.2 Literature Review

Background information on the Study Area and surrounds was compiled to provide broad, contextual knowledge of the vegetation and habitats likely to be encountered in the Study Area. Historic vegetation mapping conducted by Beard (1975b, 1990), Shepherd *et al.* (2002) , soil and landform mapping (Payne *et al.* 1988), IBRA classification system information (Desmond *et al.* 2001) and previous flora and fauna surveys conducted in the area. Previous survey reports were only considered if they were publicly available and undertaken in close proximity to the Study Area. As available relevant and recent literature for the locality was relatively limited, studies that preceded more recent work were reviewed to supplement the literature review.

3.1.3 Likelihood of Occurrence of Flora and Fauna

Prior to undertaking the field survey, the conservation significant species identified from the database searches and literature review were assessed for likelihood of occurrence within the Study Area, based on interpretation of habitat types from aerial imagery and the nearest known location of each species. Each species of conservation significant flora and vertebrate fauna in the Study Area was assessed and ranked for occurrence in the Study Area according to the following definitions:

Confirmed – the presence of the species in the Study Area has been recorded unambiguously during the last ten years (i.e. during recent surveys of the Study Area or from reliable records obtained via database searches);

Very Likely – the Study Area lies within the known distribution of the species and is likely to contain suitable habitat(s), the species generally occurs in suitable habitat and has been recorded nearby within the last 20 years;

Likely – the Study Area lies within the known distribution of the species and the species has been recorded nearby within the last 20 years; however, either:

- the Study Area is likely to contain only a small area of suitable habitat, or habitat that is only marginally suitable; or
- the species is generally rare and patchily distributed in suitable habitat;

Possible – there is an outside chance of occurrence, because:

- the Study Area is just outside the known distribution of the species, but is likely to contain suitable and sufficient habitat (the species may be common, rare, or patchily distributed); or
- the Study Area lies within the known distribution of the species, but the species is very rare and/or patchily distributed; or
- the Study Area lies on the edge of, or within, the known distribution and is likely to contain suitable habitat, but the species has not been recorded in the area for over 20 years;

Unlikely – the Study Area lies outside the known distribution of the species, the Study Area is unlikely to contain suitable habitat, and the species has not been recorded in the area for over 20 years.

Following the field survey, the conservation significant flora species identified from the database searches and literature review were re-assessed to determine the likelihood of occurrence within the Study Area.

3.2 Survey Methodology

3.2.1 Survey Timing

The EPA (EPA 2016f) recommends that flora and vegetation surveys be undertaken following the season of highest rainfall to optimise the likelihood of encountering flowering and fruiting taxa and capturing ephemeral species. The recommended survey timing for the Eremaean botanical province, within which the Study Area lies, is six to eight weeks following the wet season (March to June). The field survey was undertaken between the 2nd and 5th of October 2018, which falls outside of the recommended survey season for the region. Annual rainfall in the 12 months preceding the field survey was 51.2 mm below the average annual rainfall of 187.8 mm (1947 to 2018) (**Figure 3-1**).

It is possible that some of the annual and ephemeral flora taxa that could potentially occur in the Study Area may not have been recorded during the field survey, as they may have senesced or lacked flowering and fruiting parts needed for identification. However, there were no flora of conservation significance that were considered as' likely' to occur, based on the desktop assessment, that could not be identified from vegetative material owing to their perennial life form.

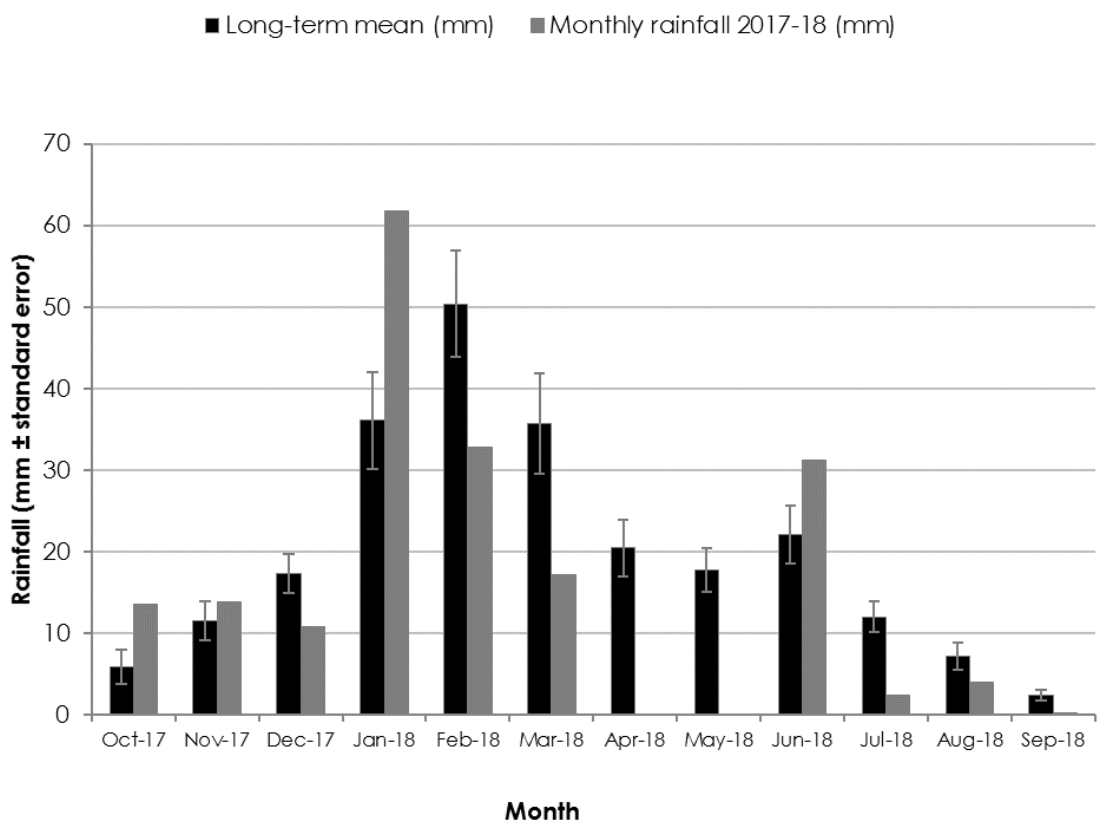

Figure 3-1: Long-term mean monthly rainfall (1947 to 2018) and actual rainfall received at Neds Creek weather station (007103) in the six months preceding the field survey (October)

3.2.2 Survey Team and Licensing

The field survey was led by Alice Bott (senior botanist) with support from Shane Chalwell (senior botanist). Alice is an experienced arid-zone botanist, with extensive experience spanning over nine years conducting vegetation and flora surveys in WA and was the technical lead for the field survey. All plant collections were taken under flora collecting permit SL012377 pursuant to the Biodiversity Conservation Act 2016. In addition, Alice holds a permit to collect Declared Rare Flora (license no. 145A-1718) for herbarium identification purposes.

3.2.3 Flora and Vegetation Assessment

Prior to the field survey, broad vegetation types were mapped on aerial imagery based on vegetation signatures and landscape features. Proposed sampling locations were identified prior to the field survey and according to the estimated number of vegetation types within the Study Area. These habitats were assessed in the field and a reconnaissance-level flora and vegetation survey, consistent with EPA (2016a), was employed to sample the flora and vegetation within the Study Area.

Sixteen relevés (unbounded sampling sites) and two mapping notes were sampled to compile a representative species list and to characterise the vegetation types identified. Where possible, vegetation types were reconciled to the vegetation types previously identified in (Stantec 2018) for the Abra Project. The remainder of the Study Area was traversed on foot and via vehicle to map vegetation types and to sample flora opportunistically**. Table 3-2** presents the information that was recorded at each relevé.

Table 3-2: Summary of data recorded at each relevé

Parameter	Description
Relevé ID	The unique name that was assigned to the site that was sampled
Recorder and Date	The recorder(s) involved in sampling the relevé and date
Coordinates	Measured using a handheld GPS device in GDA94 format
Site photograph	At least one landscape photograph taken of the site
Soil description	A description of the soil colour and types based on the guide in the Australian Soil and Land Survey Field Handbook
Geology type	A description of the outcropping geology (if present) and course fragments
Habitat type	A description of the landform type and aspect
Vegetation Condition	Assessed according to the Trudgen vegetation condition scale (**Appendix B**).
Vascular flora species	A record of each flora species present
Height	The average height of each species in meters
Percent Foliar Cover (PFC)	An estimate of the PFC for each species will be recorded
Reconciled vegetation type	Where applicable, the vegetation will be assigned to a vegetation code from previous surveys undertaken adjacent to the Study Area
Vegetation structure	A description of the vegetation in accordance with the National Vegetation Information System (NVIS), Level 5 – Association (NVISTWG 2017) based on height and foliar cover of strata (**Appendix C**).
Disturbances	A list of any disturbances in the relevé area, if present.
Time since fire	An estimation of the time since the vegetation was last burnt.

3.2.3.1 Targeted Survey

Targeted searches were conducted for conservation significant flora identified from the desktop assessment (**Section 3**). Field personnel familiarised themselves with photographs, reference samples and descriptions of these taxa before the survey and actively searched for them in and around relevés and while traversing the Study Area. Where flora of conservation significance was identified, a record was collected. The following information was collected for each population of conservation significant flora identified in the field:

Table 3-3: Summary of data collected for conservation significant flora species encountered

Parameter	Description
Coordinates	Measured using a handheld GPS device in GDA94 format
Recorder and Date	The recorder(s) involved in sampling the site and date.
ID of individual or pop	The unique name that was assigned to the individual or population that was sampled
Species	Species name
Specimen ID	A unique identifier code will be assigned to any species that cannot be identified in the field.
Abundance	A count of the species in a 50 m x 50 m area or; Estimate of density (PFC) within a mapped polygon (for large populations)
Reproductive characteristics	Whether the species is fruiting, flowering or vegetative.
Photograph	A photograph of the species showing reproductive characteristics (if present) and habitat/form

3.2.3.2 Vegetation Type and Condition Mapping

The broad vegetation type mapping that was completed during the desktop assessment was refined on maps in the field, where necessary, as a result of ground-truthing. Vegetation types were delineated and described from aerial imagery utilising the quadrat and mapping note data. The vegetation types have been described to Level V (Vegetation Association) in the NVIS hierarchical structure (ESCAVI 2003) (**Appendix C**). Vegetation condition was assigned based on the six categories described by (Trudgen 1988) (**Appendix B**).

3.2.4 Terrestrial Fauna Assessment

Broad fauna habitat assessments were undertaken at the flora sampling locations. **Table 3-4** presents the following key habitat parameters that were recorded at each fauna habitat assessment site.

Table 3-4: Summary of data collected at fauna habitat assessment sites

Parameter	Description
Habitat ID	The unique name that was assigned to the site that was sampled
Recorder and Date	The recorder(s) involved in sampling the relevé and date
Coordinates	Measured using a handheld GPS device in GDA94 format
Site photograph	At least one landscape photograph taken of the site
Fauna habitat features	An estimation of the amount of woody debris, leaf litter, peeling bark, burrowing suitability, tree hollows and SRE potential

The Study Area was traversed on foot with searches undertaken for fauna taxa of conservation significance.

4. Results and Discussion

4.1 Desktop Results

The results of the literature review are summarised in **Table 4-1** and **Table 4-2** for flora and fauna respectively. The literature review includes a summary of methods, size of the area surveyed, proximity to the current Study Area and year of the survey, along with key findings that may be relevant to the current study.

Table 4-1: Key findings of flora studies conducted within the vicinity of the Study Area

Reference	Study details	Proximity to Study Area	Vegetation Units	Flora Recorded	Vegetation Condition	Species and communities of conservation significance
Stantec (2018)	Location: the Project Study Type: Detailed flora and vegetation survey Survey date: May 2018 Size of survey area: 1, 357 ha	Immediately west of Study Area	Seven vegetation types comprised of: • *Grevillea berryana* open low woodland over *Acacia ?ramulosa* var. *ramulosa* and *Acacia incurvaneura* tall shrubland to open scrub over *Eremophila forrestii* subsp. *?forrestii* open low shrubland. • *Acacia pruinocarpa* open tall shrubland to open low woodland over *Ptilotus obovatus* open low shrubland. • *Eucalyptus victrix* and *Acacia citrinoviridus* woodland to open tall woodland over *Tephrosia rosea* var. *clementii* low shrubland over *Cymbopogon ambiguus* and *Eulalia aurea* very open tussock grassland. • *Acacia citrinoviridis* open tall shrubland to open low woodland over *Acacia pyrifolia* open shrubland over *Tephrosia rosea* var. *clementii, Corchorus crozophorifolius* and *Senna artemisiodes* subsp. *helmsii* low shrubland. • *Acacia citrinoviridis* and *Corymbia ?ferriticola* open low woodland over *Eriachne benthamii, Eriachne mucronata* and *Themeda triandra* very open tussock grassland. • Vegetation mosaic of mulga groves (*Acacia aneura* complex) and plains • *Grevillea berryana* open low woodland over *Acacia ?ramulosa* hybrid *open* shrubland to tall open shrubland over *Eremophila exilifolia* and *Eremophila jucunda* subsp. *jucunda* low shrubland over *Eriachne mucronata* very open tussock grassland to open tussock grassland.	Taxa: 101 Families: 25 Genera: 58	'Degraded' to 'Excellent'	None
G & G Environmental Pty Ltd (2011)	Location: North-east of Newman – includes a rail corridor Study Type: Level 2 survey Survey date: October 2010 and March 2011 Size of survey area: 79 km (linear)	Approximately 200 km north-east of the Study Area	Forty-one vegetation formations were identified, comprised broadly of: • Hummock Grasslands • Acacia forests and woodlands • Acacia open woodlands • Acacia shrublands • Other shrublands • Eucalypt woodlands • Tussock grasslands • Grasslands.	Taxa: 340 Families: 46 Genera: 147	Very Good to Pristine (96% of vegetation was considered as Excellent to Pristine)	None
Outback Ecology (2006)	Location: Mining tenement M52/766; exploration tenement E52/1455. Study Type: Level 2 survey for M52/766 and level 1 reconnaissance survey for E52/1455. Survey Date: 26-30 June 2006 Survey area size: 1, 000 ha	Immediately west of Study Area	Twenty-one vegetation associations grouped according to the following landforms: major creekline, minor creeklines, stony plain and stony hills/ridgeline.	Taxa: 133 Families: 38 Genera: 81	Excellent to Degraded	None

Reference	Study details	Proximity to Study Area	Vegetation Units	Flora Recorded	Vegetation Condition	Species and communities of conservation significance
Desmond *et al.* (2001)	Location: Augustus subregion Study Type: Government report (overview of priority flora in Augustus subregion) Survey Date: Published 2001	Regional assessment	N/A	N/A	N/A	• *Acacia wilcoxii* (P1); • *Eremophila arguta* (P1); • *Eremophila flaccida* subsp. *attenuata*; • *Eremophila gracillima* (P3); • *Eremophila lanata* (P3); • *Eremophila prolata* (P1); • *Eremophila rigida* (P3); • *Goodenia berringbinensis* (P4); • *Hemigenia pachyphylla* (P1); • *Homalocalyx chapmanii* (P2); • *Pityrodia augustensis* (VU); • *Ptilotus luteolus* (P3); • *Ptilotus lazaridis* (P3); • *Ptilotus trichocephalus* (P4); • *Rhodanthe frenchii* (P2) and • *Stylidium weeliwolli* (P3).
Dames and Moore (1988)	Location: Fortnum Project, 40km northwest of Peak Hill Study Type: Level 1 survey Survey Date: 28-30 September 1988 Size of survey area: 1, 200 ha	80 km south of Study Area	N/A	Taxa: 59	N/A	None

Table 4-2: Key findings of fauna studies conducted within the vicinity of the Study Area

Reference	Study Details	Proximity to Study Area	Fauna Habitats	Fauna Assemblages Recorded	Species of Conservation Significance
Stantec (2018)	Location: the Project Study Type: Level 1 fauna survey Survey date: May 2018 Size of survey area: 1, 357 ha	Immediately west of Study Area	Five fauna habitats were identified: • Banded mulga on plain; • Riparian; • Open shrubland on stony plain; • Drainage; and • Gully.	27 taxa including: • 22 families • 26 genera	None
Phoenix (2017)	Location: Beyondie Potash Project Study Type: Level 2 survey including systematic trapping, motion cameras, bat recording units, and targeted searches Survey Date: 13-23 April 2015 Size of survey area: 19, 588.5 ha	170 km east of Study Area	Ten fauna habitats were identified: • Shrubland and Grassland on Sandplain; • Woodland on Stony Plain; • Salt Lake; • Rocky Hill; • Shrubland and Grassland Mosaic on Sandplain and Dune; • Shrubland and Grassland on Dune; • Freshwater Lake; • Creek and Drainage Line; • Shrubland and Grassland on Calcrete; and Woodland on Dune.	128 taxa including: • 55 families 98 genera	• Brush-tailed Mulgara (P4) • Bilby (Vu, S3) • Northern Marsupial Mole (P4) • *Lerista macropisthopus remota* (P2)
Outback Ecology (2006)	Location: Mining tenement M52/776. Study Type: Level 1 survey. Survey Date: 26-30 June 2006 Survey area size: 1, 000 ha	Immediately west of Study Area	Four fauna habitats were identified: • Hills and Ridges; • Stony Uplands; • Stony Plains and • Drainage lines.	41 taxa including: • 31 families • 37 genera	• Western Pebble-mound Mouse (P4, disused mounds recorded)
Desmond *et al.* (2001)	Location: Augustus subregion Study Type: Government report (overview of priority fauna in Augustus subregion) Survey Date: Published 2001	Overview of Augustus subregion	Habitats associated with priority fauna include: • Low Mulga Woodland; • Open Mulga Woodland; • Sparse, low Mulga Woodland; • Mulga Scrublands; Hummock Grassland (Mulga and *Eucalyptus* over *Triodia*)	6 taxa including: • 6 families • 6 genera	• Crest-tailed Mulgara (Vu, P4) • Bilby (Vu, S3) • Peregrine Falcon (S7) • Princess Parrot (Vu, P4) • Yinnietharra Rock Dragon (Vu, S3)
Dames and Moore (1988)	Location: Fortnum Project, 40km northwest of Peak Hill Study Type: Level 1 survey Survey Date: 28-30 September 1988 Size of survey area: 1, 200 ha	78.9 km south of Study Area	Two fauna habitats were identified: • Low Mulga Woodland on Hills; and • Sparse Mulga Woodland on Plains.	53 taxa including: • 38 families • 47 genera	• Western Pebble-mound Mouse (P4, disused mounds recorded)

4.1.1 Flora

A total of 22 flora taxa of conservation significance were recorded from the desktop assessment (**Appendix D**). One taxon, *Pityrodia augustensis*, is listed as Vulnerable under the BC Act, seven taxa were listed as Priority 1, three were listed as Priority 2, nine were listed as Priority 3 and two were listed as Priority 4. The likelihood of occurrence of these taxa within the Study Area was assessed based on the criteria detailed in **Section 3.1.3.** Two taxa were considered 'likely' to occur (*Eremophila gracillima* [P3]) and *Eremophila humilis* [P31]), four taxa were considered as 'possible' to occur (two P1 taxa and two P3 taxa) and the remaining 16 taxa of conservation significance were considered 'unlikely' to occur within the Study Area.

The threatened species, *Pityrodia augustensis,* was detected via the PMST, which listed the species or species habitat as 'likely to occur within the area' (DoEE 2018a). A review of the recorded specimens of this taxa held by the WA Herb indicates that the closest record of this species is over approximately150 km west of the Study Area (WAH 2018). The species was not recorded during previous surveys within the vicinity of the Study Area, however, was included in the subregion overview, which provides context rather than data specific to the Study Area (**Section 3.1.2**).

The species *Acacia tuberculata, Eremophila appressa, Eremophila coacta, Owenia acidula, Ptilotus actinocladus* T.Hammer & R.W.Davis and *Thysanotus* sp. Desert East of Newman (R.P. Hart 964) were listed on the DBCA TP List, which is searched according to place names rather than coordinates. A review of the recorded specimens held by the WA Herb indicates that all of the above taxa records within the last 20 years do not occur in close proximity to the Study Area; the closest of these occurs greater than 90 km from the Study Area, with some occurring over 200 km from the Study Area (WAH 2018). Further to this, these species have not been recorded during any previous surveys within the vicinity of the Project or Study Area (**section 3.1.2**)

4.1.2 Vegetation

No TECs or PECs were identified from the Threatened and Priority Ecological Community database (DBCA 2018a) or the DoEE PMST (DoEE 2018a) as occurring within the Project or Study Area. One PEC occurs in close proximity to the Study Area, the Diorite Land System (P3), which is located just under 16 km to the southwest (Figure 1-1). The Diorite Land System consists of low bald or sparse *Acacia* shrublands on basaltic domes and low rough hills. Desmond *et al.* (2001) lists 19 ecosystems that are at risk within the Augustus subregion. Several of the ecosystems include invertebrate assemblages of river pools and springs that are restricted and do not occur in the Study Area (Desmond *et al.* 2001). The remaining ecosystems include terrestrial vegetation, however they are restricted to landforms or habitat that do not occur within the Study Area (e.g. plant assemblages of Robinson Range) (Desmond *et al.* 2001).

4.1.3 Fauna

The desktop study identified 219 species of vertebrate fauna which have been recorded and/or have the potential to occur within the Study Area (**Appendix E**). This total comprises 27 native mammal, nine introduced mammal, 112 native bird, 63 native reptile, and eight amphibian species. Many of these species are unlikely to occur in the Study Area because, as is leading practice, these records have been collected from a large area encompassing a wide range of habitats, many of which do not occur within the Study Area. Furthermore, some small, common, ground-dwelling reptile and mammal species tend to be patchily distributed even where appropriate habitats are present, and many species of bird can occur as regular migrants, occasional visitors or vagrants.

Of the 219 species of vertebrate fauna identified during the desktop, 26 species are listed as being of conservation significance, comprising eight mammals, 15 birds and three reptiles (**Table 4-3**).

Table 4-3: Fauna of conservation significance identified during the desktop assessment

Species Name	Common Name	EPBC[1]	WA[1]
Birds			
Anas querquedula	Garganey	Mi	S5
Apus pacificus	Fork-tailed Swift	Mi	S5
Charadrius veredus	Oriental Plover	Mi	S5
Falco peregrinus	Peregrine Falcon		S7
Hirundo rustica	Barn Swallow	Mi	S5
Motacilla cinerea	Grey Wagtail	Mi	S5
Motacilla flava	Yellow Wagtail	Mi	S5
Pezoporus occidentalis	Night Parrot	En	S1
Polytelis alexandrae	Princess Parrot	Vu	P4
Calidris acuminata	Sharp-tailed Sandpiper	Mi	S5
Calidris ferruginea	Curlew Sandpiper	Cr; Mi	S3; S5
Calidris melanotos	Pectoral Sandpiper	Mi	S5
Calidris ruficollis	Red-necked Stint	Mi	S5
Tringa hypoleucos	Common Sandpiper	Mi	S5
Tringa nebularia	Common Greenshank	Mi	S5
Mammals			
Dasycercus blythi	Brush-tailed Mulgara		P4
Dasycercus cristicauda	Crest-tailed Mulgara	Vu	P4
Dasyurus hallucatus	Northern Quoll	En	S2
Macroderma gigas	Ghost Bat	Vu	S3
Pseudomys chapmani	Western Pebble-mound Mouse		P4
Notoryctes caurinus	Northern Marsupial Mole		P4
Rhinonicteris aurantius Pilbara form'	Pilbara Leaf-nosed Bat	Vu	S3
Macrotis lagotis	Bilby	Vu	S3
Reptiles			
Ctenophorus yinnietharra	Yinnietharra Rock Dragon	Vu	S3

Species Name	Common Name	EPBC[1]	WA[1]
Liasis olivaceus barroni	Pilbara Olive Python	Vu	S3
Lerista macropisthopus remota			P2

1= Conservation codes and descriptions are detailed within **Appendix A**.

4.2 Field Survey Results

4.2.1 Flora Composition

A total of 55 flora taxa (including subspecies, varieties and forms) were recorded from the Study Area, representing 19 families and 26 genera (**Appendix F**). Of these, five could not be identified confidently beyond family level and two could not be identified confidently to genus level, due to insufficient material for identification. The most represented families were Fabaceae (legumes), Poaceae (grasses) and Malvaceae (malvas) and the most represented genera were *Acacia* (wattles) with ten individuals, *Eremophila* (poverty bush) with eight individuals and *Dodonaea, Eriachne, Senna* and *Ptilotus* with three individuals (**Table 4-4**). Three of the *Acacia* species recorded within the Study Area belong to the Western Australian Mulga Flora Group (*Acacia aneura* F.Muell. ex Benth. and its close relatives) (Maslin and Reid 2012).

Table 4-4: Families and genera most represented in the Study Area

Family	Total taxa
Fabaceae	13
Poaceae	10
Malvaceae	8
Genus	**Total taxa**
Acacia	10
Eremophila	8
Dodonaea, Eriachne, Senna and *Ptilotus*	3

4.2.2 Flora of Conservation Significance

Despite extensive sampling and targeted searching, no state or Commonwealth listed Threated flora or DBCA listed Priority flora were recorded within the Study Area.

4.2.2.1 Post-survey Likelihood of Occurrence of Conservation Significant Flora

Following the field survey, with a greater understanding of the habitat types that occur within the Study Area, all Threatened and Priority flora species recorded from the desktop assessment are considered as 'unlikely' to occur. Species that were considered as 'likely' or 'possible' to occur in the desktop assessment have a perennial lifeform and it is unlikely that, if present, they would have gone unnoticed at the time of the survey. In addition, none of these species would be restricted to the Study Area as indicated by the vouchered records listed by the WAH (WAH 2018).

4.2.2.2 Flora of Other Significance

The EPA advises that flora species, subspecies, varieties, hybrids and ecotypes may be considered significant for reasons other than listing as a Threatened or Priority Flora taxa, and may include the following:

- a keystone role in a particular habitat for Threatened taxa, or supporting large populations representing a significant proportion of the local regional population of a species;
- relic status;
- anomalous features that indicate a potential new discovery;
- being representative of the range of a species (particularly at the extremes of range, recently discovered range extensions, or isolated outliers of the main range);
- the presence of restricted subspecies, varieties, or naturally occurring hybrids;
- local endemism/a restricted distribution; and/or
- being poorly reserved.

Based on these parameters, none of the native vascular flora taxa recorded from the Study Area during the field survey are of 'other' significance. The native vascular flora taxa recorded from the Study Area are all represented in the local and regional area and no unique taxa were recorded.

4.2.2.1 Introduced Flora

Introduced flora species were compared to the Western Australian Organisms List (WAOL) (Department of Agriculture and Food WA (DAFWA)) to determine if any have been listed as declared pest and the Weeds of National Significance (WoNS) list. No introduced flora taxa were recorded from the Study Area.

4.2.3 Vegetation

A total of five vegetation types were identified in the Study Area (**Table 4-5**; **Figure 4-1**). In general, the vegetation of the Study Area consisted of mixed *Acacia* open shrublands over a mid-layer of predominantly *Eremophila* spp. over a very open tussock grass layer on stony to sandy plains. The most extensive vegetation type was a mosaic of two vegetation types also recorded in the Abra Project Area: GbArrAiEf/GbArrExEjjEm and occupied just under 50% of the Study Area.

Minor branches of the Five Mile Creek, a small tributary of the Ethel River, occurs in the north-western border of the Study Area, representing the AcAcPlSspScHs vegetation type also recorded in the Abra Project Area. The AiAcEspp occurs in ephemeral drainage that runs through the eastern section of the Study Area.

4.2.3.1 Vegetation Condition

With the exception of a previously cleared access track (3%), vegetation condition of the Study Area was assessed as 'excellent' (**Figure 4-2**). Minor disturbances were identified in the form of feral scats, trampling and grazing, however, vegetation structure remained intact and no weed species were recorded.

Table 4-5: Summary of Vegetation Types recorded in the Survey Area

Vegetation type code	Vegetation Type Description	Relevés & Mapping Notes	Extent		Representative Photograph
			Hectares	Proportion of Survey Area (%)	
AcAcPlSspScHs	*Acacia citrinoviridis* (*Grevillea berryana*) low woodland over *Acacia citrinoviridis* and *Psydrax latifolia (Acacia aneura* and *Acacia ?ramulosa* var. *ramulosa)* tall shrubland over *Sida* ?sp. spiciform panicles (E. Leyland 14/08/90), *Senna cuthbertsonii* and *Hibiscus sturtii* var. *forrestii* open shrubland to shrubland Associated species: *Acacia incurvaneura, Acacia kempeana, Aristida contorta, Cheilanthes sieberi, Eremophila forrestii* subsp. *?forrestii, Eriachne benthamii, Eriachne pulchella subsp. pulchella, Fimbristylis dichotoma, Hibiscus coatesii,* and *Solanum lasiophyllum.*	AAr02 AAr03 AAr04	1.53	0.6	
AiAcEspp	*Acacia incurvaneura* and *Acacia citrinoviridis* tall open shrubland over *Eremophila* spp. open shrubland. Associated species: *Acacia ramulosa* var. ramulosa, *Acacia rhodophloia, Acacia tetragonophylla, Eragrostis eriopoda, Grevillea berryana, Psydrax latifolia*, *Ptilotus schwartzii* and *Senna* sp. Meekatharra (E. Bailey 1-26).	AAr12 AAr13 AAr14 AAmn02	7.35	2.6	

Vegetation type code	Vegetation Type Description	Relevés & Mapping Notes	Extent		Representative Photograph
			Hectares	Proportion of Survey Area (%)	
GbArrAiEf/GbArrExEjjEm	Mosaic of: **A-** *Grevillea berryana* open low woodland over *Acacia ?ramulosa* var. *ramulosa* and *Acacia incurvaneura* tall shrubland to open scrub over *Eremophila forrestii* subsp. *?forrestii* open low shrubland and; **B-** *Grevillea berryana* open low woodland over *Acacia ?ramulosa* hybrid *open* shrubland to tall open shrubland over *Eremophila exilifolia* and *Eremophila jucunda* subsp. *jucunda* low shrubland over *Eriachne mucronata* very open tussock grassland to open tussock grassland. Associated species: *Acacia citrinoviridis, Acacia kempeana, Acacia ramulosa var. linophylla, Acacia rhodophloia, Aristida contorta, , Eriachne pulchella* subsp. *pulchella* and *Ptilotus schwartzii*	AAr01 AAr05 AAr06	131.44	47.3	
AiArrEfEe	*Acacia incurvaneura* and *Acacia ramulosa* var. *ramulosa* tall open shrubland over *Eremophila forrestii* open shrubland over *Eragrostis eriopoda* very open tussock grassland. Associated species: *Acacia citrinoviridis, Acacia kempeana, Acacia pruinocarpa, Acacia pteraneura, Acacia ramulosa* var. *linophylla, Acacia rhodophloia, Aristida contorta, Eremophila ?granitica, Eremophila citrina, Eremophila fraseri, Eremophila spectabilis, Eriachne mucronata, Eriachne pulchella* subsp. *pulchella, Grevillea berryana, Marsdenia australis, Psydrax latifolia, Ptilotus obovatus, Ptilotus schwartzii, Senna* sp. Meekatharra (E. Bailey 1-26), *Sida* sp. Golden calyces and *Solanum lasiophyllum*.	AAr07 AAr08 AAr09 AAr15	74.94	26.9	

Vegetation type code	Vegetation Type Description	Relevés & Mapping Notes	Extent		Representative Photograph
			Hectares	Proportion of Survey Area (%)	
ArlApEsppEe	*Acacia ramulosa* var. *linophylla* and *Acacia pteraneura* tall shrubland over *Eremophila* spp. low shrubland over *Eragrostis eriopoda* open tussock grassland. Associated species: *Acacia incurvaneura, Acacia ramulosa* var. *ramulosa, Acacia rhodophloia, Aristida contorta, Grevillea berryana, Senna artemisioides subsp. helmsii, Senna* sp. Meekatharra (E. Bailey 1-26) and *Triodia basedowii.*	AAr10 AAr11 AAr16	62.91	22.6	
			278.17	**100**	

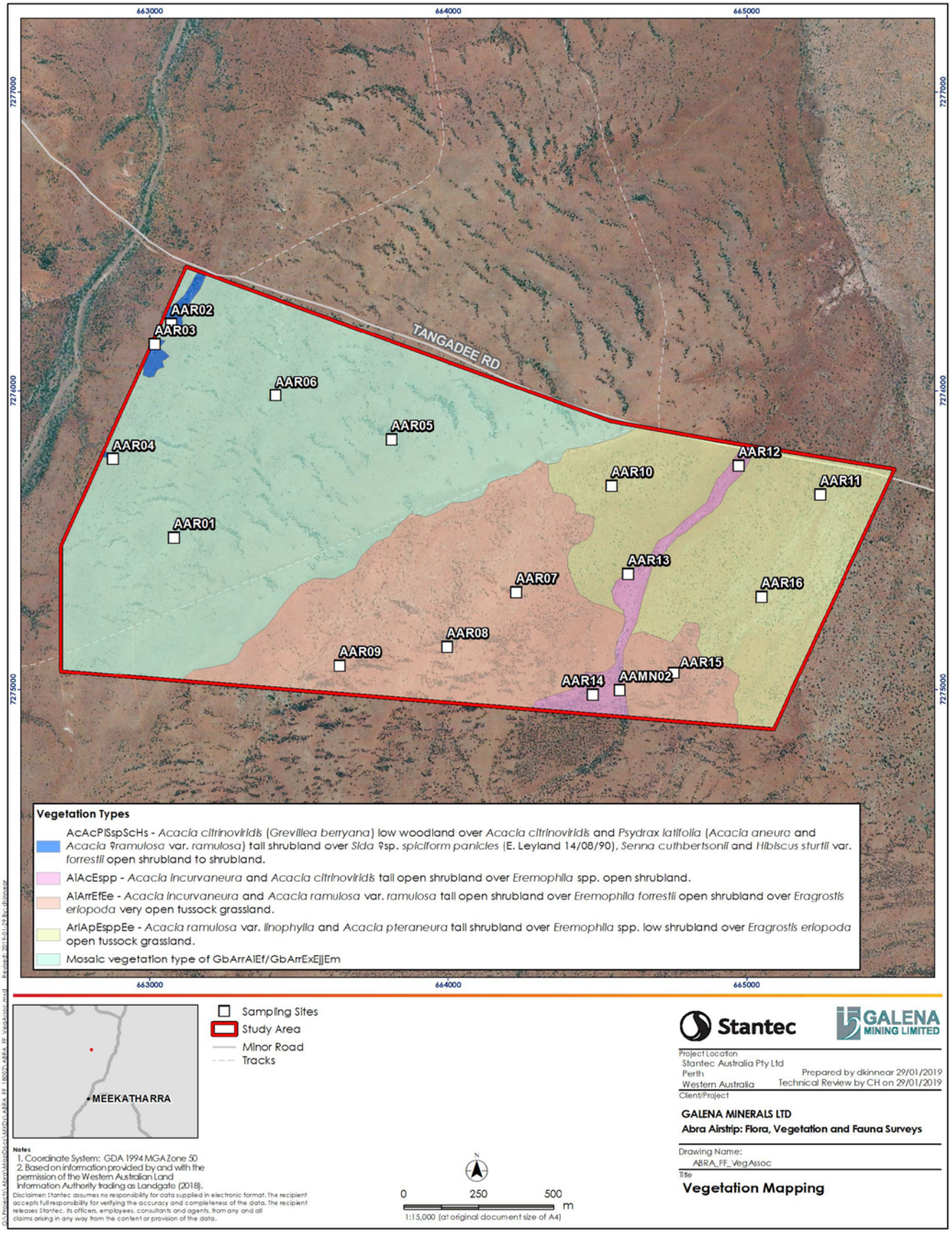

Figure 4-1: Vegetation types identified in the Study Area

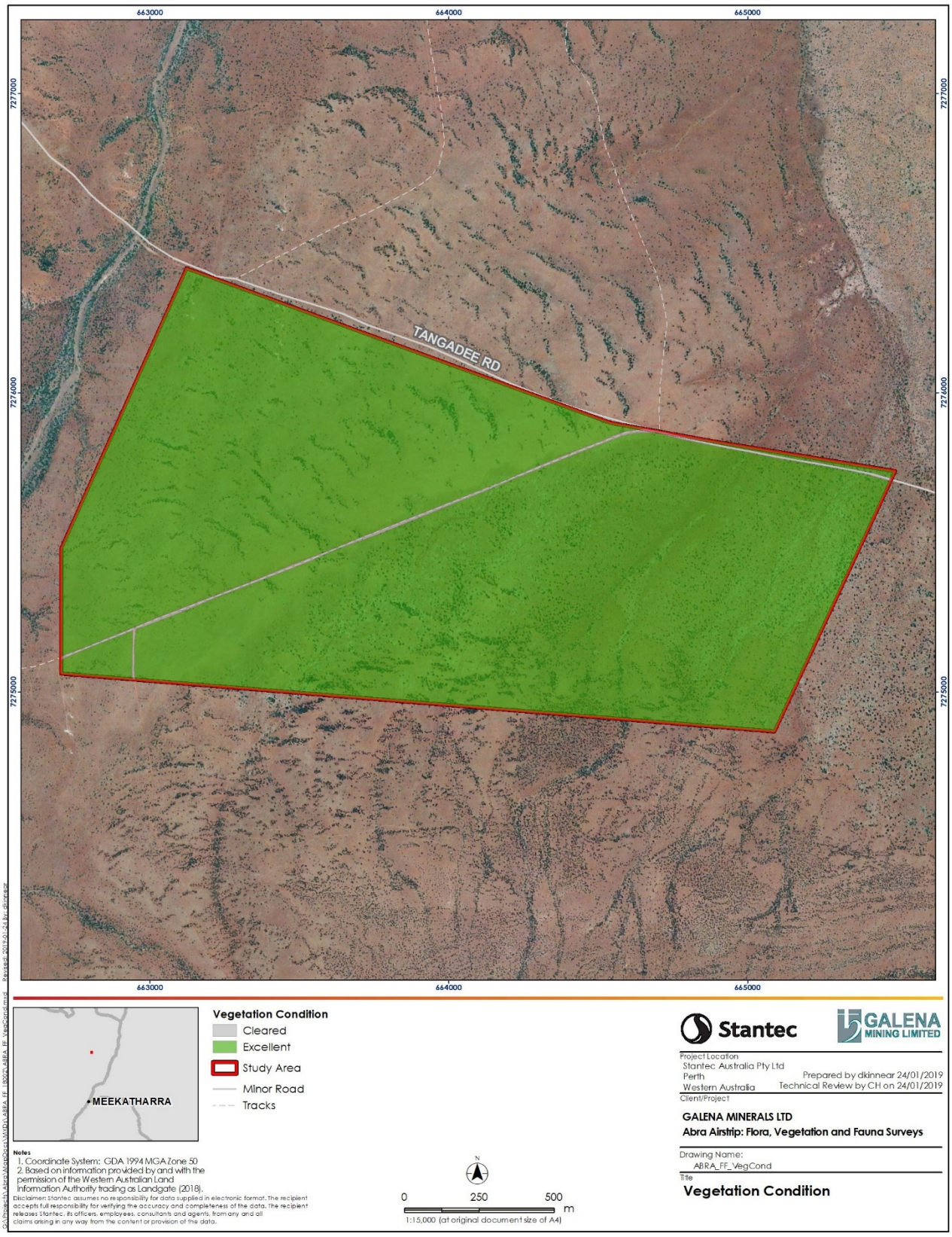

Figure 4-2: Vegetation condition of the Study Area

4.2.4 Terrestrial Fauna

4.2.4.1 Fauna Habitat

Three broad fauna habitats were identified and delineated from fauna habitat assessments conducted across the Study Area (**Table 4-6**). These comprised;

- Drainage;
- Open shrubland on sandy plain; and
- Open shrubland on stony plain.

These habitats differed primarily in the composition of their vegetation and substrate, particularly presence of rocky fragments, alcoves and the likelihood of seasonal water inundation. Most habitats contained rocky substrates. The habitat types in the Study Area were assessed on their extents and levels of significance according to the following criteria:

- Distribution: those habitats widespread and common within the surrounding regions were categorised as widespread; otherwise they were categorised as being of limited extent. All fauna habitats were considered widespread.
- Significance: those habitats considered important to species of conservation significance or distinct fauna assemblages are deemed significant; otherwise they were categorised as being of limited significance. No habitats were classified as significant.

Table 4-6: Broad fauna habitats identified within the Study Area

Habitat Type	Proportion of Study Area		Associated Vegetation Types	Condition	Value to Fauna	Reference Photograph
	Ha	%				
Drainage • Widespread • Limited Significance	8.8	3.2	AiAcEspp AcAcPlSspScHs	Excellent	Drainage areas tended to have increased vegetation cover compared to other habitat types and were prone to flooding. This comprised of an upper *Acacia* sp. storey over *Dodonaea* sp., *Eremophila* sp. and tussock grasses. The increased vegetation cover provided woody debris, and on the rare occasion peeling bark. Some drainage areas comprised sandy substrates (left), while others comprised clay loams with rocky fragments and minor gullies (right). Drainage areas were affected by cattle trampling and grazing. Drainage areas would provide suitable habitat for a range of mammals, reptiles and birds owing to increased shelter availability (vegetation cover, woody debris). This is particularly prevalent in minor gully drainages, where erosion and rocky substrates provided crevices and alcoves. The upper storey may provide nesting and/ or roosting for bird species, and when inundated drainage habitats may support wetland birds and amphibians.	 
Open shrubland on sandy plain • Widespread • Limited Significance	62.91	22.6	ArlApEsppEe	Excellent	Comprised *Acacia* sp. shrubland over *Eremophila* sp. and open tussock grasses on sandy clay loam plains. These areas contained woody debris, termite mounds and occasionally peeling bark, and were affected by feral trampling and grazing. Tall vegetation within sandy shrublands may provide nesting and/ or roosting for bird species, and areas with woody debris would provide shelter for reptiles and mammals.	 

Habitat Type	Proportion of Study Area		Associated Vegetation Types	Condition	Value to Fauna	Reference Photograph
	Ha	%				
Open shrubland on stony plain • Widespread • Limited Significance	206.38	74.2	GbArrAiEf/GbArrExEjjEmAiArrEfEe	Excellent	Varied from open stony plains with a sparse cover of low shrubs and tussock grasses (left) to areas comprising *Acacia* sp. and *Grevillea berryana* over Eremophila *sp., Ptilotus* sp. and tussock grasses (right). Vegetation occurred over stony substrates, and this habitat contained woody debris, minimal peeling bark and termite mounds. Areas were disturbed by cattle trampling and grazing. Areas with sparse vegetation are unlikely to serve as significant habitat for fauna owing to the lack of shelter. However, areas with tall vegetation may provide nesting and/ or roosting for bird species, and areas with woody debris would provide shelter for reptiles and mammals.	

4.2.4.2 Fauna of Conservation Significance

Of the 219 species of vertebrate fauna identified during the desktop study, 26 species are listed as being of conservation significance, comprising eight mammals, 15 birds and three reptiles (**Table 4-3**). Of the 26-vertebrate species in the desktop study:

- Ten are listed as Threatened under the EPBC Act and/or BC Act;
- Six are recognised by DBCA as Priority fauna. DBCA recognises several species that are not listed under the BC Act or the EPBC Act but for which there is some conservation concern, and has produced a supplementary list of Priority fauna;
- One species is listed as recognised by state (BC Act) to be in need of special protection; and
- Twelve species are listed as Migratory under the EPBC Act and/or Schedule 5 under the BC Act.

Some of the species referred to above, listed as Threatened, Migratory and/or Priority fauna, may be included in multiple groups. The likelihood for species of conservation significance occurring in the Study Area was assessed and ranked (**Table 4-3**).

The rankings were assigned following definitions described in the desktop study methodology (**Section 3.1.3**) and conservation significance codes were determined using DBCA and EPBC Act guidelines (**Appendix A**). Of the conservation significant fauna, one species was considered 'possible' to occur; the Peregrine Falcon (S7), the remaining were assessed as 'unlikely' to occur.

Table 4-7: Conservation significant fauna identified during desktop assessment and likelihood of occurrence within the Study Area

Common name (*Scientific name*)	Conservation status		Broad habitat type	**Likelihood of occurrence** Reason for likelihood
	EPBC	WA		
Mammals				
Brush-tailed Mulgara (*Dasycercus blythi*)		P4	Known to inhabit spinifex grasslands (van Dyck and Strahan 2008).	**Unlikely** The Study Area occurs within the species range, however there are no nearby records of the species since 1993 (DBCA 2018b, van Dyck and Strahan 2008) The species was trapped in an area ~170km east of the Study Area, and numerous signs of activity were noted in suitable sandplain habitat (Phoenix 2017). However, the Study Area lacks spinifex sandplains, and therefore the species is considered unlikely to occur.
Crest-tailed Mulgara (*Dasycercus cristicauda*)	Vu	P4	Known to inhabit open sand dunes with limited canegrass cover and near salt lakes with Nitre Bush (van Dyck and Strahan 2008).	**Unlikely** Although two species of Mulgara are known to occur in Australia, it is now recognised that only the Brush-tailed Mulgara (*Dasycercus blythi*) (Priority 4 DBCA) occurs within Western Australia (DoEE 2018, (DoEE 2018b, van Dyck and Strahan 2008). The Crest-tailed Mulgara (*Dasycercus cristicauda*) (Vulnerable EPBC Act) is restricted in its distribution to the eastern portion of the Northern Territory, South Australia and potentially Queensland (DoEE 2018b, van Dyck and Strahan 2008).
Northern Quoll (*Dasyurus hallucatus*)	En	S2	Favour rocky habitats, also found in eucalyptus woodlands and forests and near settlements (van Dyck and Strahan 2008).	**Unlikely** While the species or species habitat was listed as 'likely to occur' (DoEE 2018a), the Study Area occurs well outside of the species current range and the species has not been recorded nearby (van Dyck and Strahan 2008).
Bilby (*Macrotis lagotis*)	Vu	S3	Patchily distributed in the northern arid to semi-arid regions (van Dyck and Strahan 2008).	**Unlikely** The Study Area lies outside of the species current range, and the species has not been recorded nearby since 1970 (DBCA 2018b, van Dyck and Strahan 2008). As such, the species is considered unlikely to occur.
Northern Marsupial Mole (*Notoryctes caurinus*)		P4	Sand dune deserts, particularly the Great and Little Sandy Deserts (van Dyck and Strahan 2008).	**Unlikely** The Study Area occurs well outside of the species current range, and the species has not been recorded nearby (van Dyck and Strahan 2008). The species was recorded ~170km east of the Study Area within suitable dune habitat, however as the Study Area does not contain dunes the species is considered unlikely to occur (Phoenix 2017).

Common name (*Scientific name*)	Conservation status		Broad habitat type	**Likelihood of occurrence** Reason for likelihood
	EPBC	WA		
Western Pebble-mound Mouse (*Pseudomys chapmanii*)		P4	Gentle rocky spinifex slopes (van Dyck and Strahan 2008).	**Unlikely** The Study Area lies outside of the species current range, which is largely restricted to the central and southern Pilbara, Little Sandy Desert and an isolated population in the Gascoyne recorded in 1997 (van Dyck and Strahan 2008). The closest sighting of the species occurred in 1995 55km east of the Study Area (Strahan 2004). Only inactive mounds were recorded within the adjacent area in 2006 (Outback Ecology 2006). Furthermore, no mounds were detected during the 2018 Stantec survey of the same area (Stantec 2018). As such, the species is considered unlikely to occur.
Pilbara Leaf-nosed Bat (*Rhinonicteris aurantius* Pilbara form')	Vu	S3	Inhabit humid roosts, which occur in rocky gorges or abandoned mine shafts (van Dyck and Strahan 2008).	**Unlikely** The Study Area lies outside the species current range, which is restricted to the Pilbara, and lacks suitable gorge habitat (van Dyck and Strahan 2008). The closest record of the species lies 56km to the northwest and was recorded in 1999 (DBCA 2018c). As such, the species is considered unlikely to occur.
Ghost Bat (*Macroderma gigas*)	Vu	S3	Inhabits a wide range of habitats, from arid areas of the Pilbara to northern rainforests (van Dyck and Strahan 2008).	**Unlikely** The species or species habitat was listed as 'likely to occur' (DoEE 2018a). However the Study Area lies outside of the species range, which occurs within the Pilbara and Kimberley in WA (van Dyck and Strahan 2008). The species has not been recorded nearby, and is considered unlikely to occur.
Birds				
Garganey (*Anas querquedula*)	Mi	S5	Sewage ponds and well vegetated freshwater wetlands (Pizzey and Knight 2007).	**Unlikely** The species has not been recorded nearby since 1980, and the Study Area does not contain suitable habitat (DBCA 2018c, Pizzey and Knight 2007). The species is uncommon within Australia, migrating to Northern tropical areas in summer and remaining vagrant elsewhere (Pizzey and Knight 2007).
Fork-tailed Swift (*Apus pacificus*)	Mi	S5	The species has an aerial habitat mainly over open areas ranging from coasts to semi-deserts, and may also occur over forests and urban areas (Pizzey and Knight 2007).	**Unlikely** The species or species habitat was listed as 'likely to occur', and the Study Area lies within the known species range (Pizzey and Knight 2007). However the species has not been recorded in the area.

Common name (*Scientific name*)	Conservation status		Broad habitat type	**Likelihood of occurrence** Reason for likelihood
	EPBC	WA		
Oriental Plover (*Charadrius veredus*)	Mi	S5	Large open areas including plains, muddy and sandy wastes near swamps and mudflats, ploughed land, claypans and open turf e.g. airfields (Pizzey and Knight 2007).	**Unlikely** The species or species habitat was listed as 'may occur', however the Study Area does not contain suitable habitat (DoEE 2018a, Pizzey and Knight 2007). The species has not been recorded nearby, and the Study Area lies outside of the species range (Pizzey and Knight 2007).
Peregrine Falcon (*Falco peregrinus*)		S7	The species occurs along cliffs, gorges, wooded rivers, wetlands, plains and open woodlands, as well as in association with pylons and buildings (Pizzey and Knight 2007). Nests on cliffs, in crevices, large tree hollows, in nests of other large birds or on building ledges (Pizzey and Knight 2007).	**Possible** The Study Area occurs within the species range and the species has been recorded between 90 and 95km from the Study Area, most recently in 2012 (DBCA 2017, Pizzey and Knight 2007). However three of the four records occur along the Great Northern Highway, where the species is likely to rest on pylons (DBCA 2017, Pizzey and Knight 2007). While the Study Area does not contain trees large enough to serve as suitable nesting habitat, the species may still forage over the area from time to time. As such the species is considered as 'possible' to occur but would not be dependent on any of the habitats in the Study Area.
Barn Swallow (*Hirundo rustica*)	Mi	S5	Open areas, particularly near water, such as agricultural land, also in urban areas and rail yards (Pizzey and Knight 2007).	**Unlikely** Species or species habitat was listed as may occur, however the Study Area occurs outside of the species range, does not contain suitable habitat and the species has not been recorded nearby (DoEE 2018a, Pizzey and Knight 2007).
Yellow Wagtail (*Motacilla flava*) and Grey Wagtail (*Motacilla cinerea*)	Mi	S5	Both species inhabit sewage ponds and lawn fields, however the Grey Wagtail also occurs along streams in escarpments, rainforests and unused quarries while the Yellow Wagtail occurs in swamp edges, short grass, bare ground and saltmarshes (Pizzey and Knight 2007).	**Unlikely** The species or species habitat was listed as 'may occur', however the species are summer vagrants that inhabit areas well outside the Study Area (closest range occurs along the northern coast) (Pizzey and Knight 2007). The species have not been recorded nearby and are considered unlikely to occur.
Night Parrot (*Pezoporus occidentalis*)	En	S1	Known to inhabit treeless or sparsely wooded long unburnt spinifex hummock plains often interspersed with chenopods (Pyke and Ehrlich 2014).	**Unlikely** The Study Area does not contain suitable habitat and the species is rare and has not been recorded nearby since 1912 (DBCA 2017, Strahan 2004). As such, the species is considered unlikely to occur.

Common name (*Scientific name*)	Conservation status		Broad habitat type	**Likelihood of occurrence** Reason for likelihood
	EPBC	WA		
Princess Parrot (*Polytelis alexandrae*)	Vu	P4	Areas with spinifex or near succulents around salt lakes, usually far from freshwater (Pizzey and Knight 2007).	**Unlikely** The Study Area occurs within the species irregular range, does not contain suitable habitat and the species has not been recorded nearby since 1919 (DBCA 2017, Pizzey and Knight 2007). As such, the species is considered unlikely to occur.
Sandpipers, stints and greenshanks from the family *Scolopacidae*.	Mi	S5	Habitats associated with water including wetland and lake margins, floodwaters, mudflats, saltmarshes and salt fields, swamps, intertidal flats and estuaries (Pizzey and Knight 2007).	**Unlikely** Six species were listed within this family. However, these species favour shallow aquatic habitats not present within the Study Area, and the species have not been recorded recently nearby (DBCA 2017, Pizzey and Knight 2007). Due to this, they are considered unlikely to occur.
Reptiles				
Yinnietharra Rock Dragon (*Ctenophorus yinnietharra*)	Vu	S3	Low weathered granite outcrops; basks on low rocks and shrubs (Wilson and Swan 2013).	**Unlikely** The species is limited to granite outcrops near Yinnietharra Station (outside of the Study Area), and has not been recorded nearby (Wilson and Swan 2013).
Unpatterned robust slider (subsp.) *Lerista macropisthopus remota*		P2	Acacia shrublands and woodlands in semi-arid and arid areas (Wilson and Swan 2013).	**Unlikely** The Study Area may contain suitable habitat, however the subspecies is restricted to a small range to the east of the Study Area (Wilson and Swan 2013). The species has also not been recorded nearby, and is therefore considered unlikely to occur.
Pilbara Olive Python (*Liasis olivaceus barroni*)	Vu	S3	Gorges and escarpments, often associated with water (Wilson and Swan 2013).	**Unlikely** The subspecies is restricted to the Pilbara, the Study Area contains unsuitable habitat and the subspecies has not been recorded nearby (Wilson and Swan 2013).

4.3 Survey Limitations and Constraints

There are a number of possible limitations and constraints that can impinge on the adequacy of vegetation, flora and fauna survey (DPaW 2016a, EPA 2016). These are summarised in **Table 4-8**, with respect to the survey of the Study Area.

Table 4-8: Potential limitations and constraints of the field survey

Factor	Constraint	Comments
Competency and experience of consultants	No	The field personnel, Alice Bott and Shane Chalwell have appropriate qualifications and experience to undertake the relevant components of the flora, vegetation and fauna survey. The specimen identifications were undertaken by Alice Bott and Crystal Heydenrych, who have extensive experience in WA.
Scope	No	The scope was well-defined and the flora, vegetation, fauna and their habitats were surveyed using standardised and well-established techniques. The desktop study was undertaken prior to the surveys to inform surveyors of the potential occurrence of factors of environmental significance.
Proportion of species identified	No	Given the relatively small extent of the Study Area (217 ha) and the uniformity of the landscapes within the Study Area, the flora taxa inventory is comparable to counts obtained during previous surveys of a similar scope in the vicinity of the Study Area (**Section 4.1**). Survey sampling, timing, and intensity was considered adequate for the identification of most perennial species. Of the flora taxa recorded from the Study Area, five could not be identified confidently beyond family level and two could not be identified confidently to genus level. None of taxa that could not be identified resembled any of the potential flora of conservation concern that occur in the area. All vertebrate fauna encountered were identified and habitats were assessed for their importance to vertebrate fauna and fauna of conservation significance.
Information sources (e.g. historic or recent)	Partial	There is a paucity of information in the immediate vicinity of the Study Area, aside from the surveys undertaken by Outback Ecology in 2006 and Stantec in 2018 of the Abra Project Area. The literature review considered surveys that had been undertaken within a wide radius of the Study Area to account for this. Information was additionally supplemented by from database searches, which considered large search areas i.e. 40 to100 km. Regional contextual information was also obtained from historic vegetation mapping conducted by Beard (1975b, 1990), Shepherd *et al.* (2002) , soil and landform mapping (Payne *et al.* 1988), IBRA classification system information (Desmond *et al.* 2001) and previous flora and fauna surveys conducted in the wider region.
Completeness and intensity	No	A total of 16 relevés and fauna habitat assessments and two mapping notes were sampled across the Study Area. This was sufficient to adequately sample all broad vegetation types, fauna habitats and flora within the Study Area.

Factor	Constraint	Comments
Timing / weather / season / cycle	No	The survey took place outside of the recommended season for flora and vegetation surveys within the Gscoyne bioregion EPA (2016a) and seasonal conditions were sub-optimal, with below average rainfall received in the 12 months preceding the survey. Most flora taxa, however, could be identified from vegetative material and this was not regarded as a significant limitation.
Disturbances	No	Vegetation condition is presented within **Section 4.2.3.1** and shows that the Study Area was in 'excellent' condition. Minimal disturbance had been noted as a result of clearing for access tracks and impacts from feral fauna, however, none of these disturbances limited the outcomes of this report.
Resources	No	Resources were adequate to carry out the survey and the survey participants were competent in identification of species present. WAH herbarium specimens, taxonomic guides, DBCA database searches and the FloraBase database were all used to prepare for the survey and used for the confirmation of any flora or fauna species where identification was uncertain.
Remoteness / access problems	No	All survey sites were easily accessible by vehicle and on foot.

5. Summary

The field survey was undertaken outside of the recommended timeframe for the bioregion, following below average rainfall preceding the field survey. Despite dry seasonal conditions, the Study Area was adequately surveyed through a combination of relevés, mapping notes and fauna habitat assessments to compile a representative species list of the Study Area and to characterise the vegetation types and habitat types present.

It is possible that some of the annual and ephemeral flora taxa that occur in the Study Area may not have been recorded during the field survey, however, it is unlikely that any Threatened of Priority flora species would have gone unnoticed. Three Priority flora species were assessed as 'possible' to occur within the Study Area, based on the post-survey assessment of likelihood of occurrence; all three of these species are perennial and are easily recognisable.

Five vegetation types were mapped within the Study Area, including two vegetation types that were reconciled to previous mapping undertaken for the adjacent Abra Project. The vegetation types recorded represent what would be expected from similar landforms in the broader Augustus subregion and none are analogous to any Commonwealth or State listed TECs or PECs. Due to minimal disturbance of vegetation present, the vegetation condition was 'excellent' throughout the Study Area.

Three broad fauna habitats were identified within the Study Area; open shrubland on sandy plain, open shrubland on stony plain and drainage. All were considered widespread and of limited significance for potential conservation significant vertebrate fauna.

No species of conservation significance were recorded during the current survey. One species of conservation significance was considered 'possible' to occur based on species range and previous records; the Peregrine Falcon (S7). The Study Area does not contain suitable nesting habitat for the species, however it may forage over the Study Area from time to time without being dependent on any particular habitat. The remaining species of conservation significance were assessed as 'unlikely' to occur in the Study Area.

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Appendices

Appendix A Codes and Terms Used to Describe Species of Conservation Significance

Flora and fauna may be accorded legislative protection by being listed under the Environment Protection and Biodiversity Conservation Act 1999 (Cwlth) (EPBC Act) and/or the Biodiversity Conservation Act 2016 (WA) (BC Act), or by being listed on the WA Department of Environment and Conservation's Priority Species List. This Appendix presents a summary of the different rankings and listings used to describe conservation status. Some categories, such as 'extinct', 'extinct in the wild' and 'conservation dependent' (EPBC Act) are not presented here, as the table includes only the information needed to fully understand the codes presented in the preceding report. Refer to the relevant legislation for a full description of all codes in use, as well as their associated criteria.

Definitions of codes and terms used to describe flora and fauna of conservation significance.

Categories used under the EPBC Act		
Status	Code	Description
Critically Endangered	**Cr**	Taxa that is considered to be facing an extremely high risk of extinction in the wild in the immediate future
Endangered	**En**	Taxa that is considered to be facing a very high risk of extinction in the wild in the near future
Vulnerable	**Vu**	Taxa that is considered to be facing a high risk of extinction in the wild in the medium-term future
Migratory	**Mi**	Species that migrate to, over and within Australia and its external territories

Schedules used under the BC Act			Description
Status	Code	Schedule	
Critically Endangered	**Cr**	**S1**	Taxa that is rare or likely to become extinct, as critically endangered taxa
Endangered	**En**	**S2**	Taxa that is rare or likely to become extinct, as endangered taxa
Vulnerable	**Vu**	**S3**	Taxa that is rare or likely to become extinct, as vulnerable taxa
Presumed Extinct	**Ex**	**S4**	Taxa that is presumed to be extinct
Migratory	**Mi**	**S5**	Birds that are subject to international agreements relating to the protection of migratory birds
Conservation Dependent	**CD**	**S6**	Taxa that are of special conservation need being species dependent on ongoing conservation intervention
Special Protection	**SP**	**S7**	Taxa that is in need of special protection

Appendix B Vegetation Condition Scale: Eremaean Province

Code	Description
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
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	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

Appendix C Vegetation Structure Scale

NVIS Vegetation Structural Classifications							
Cover Characteristics							
Foliage cover *	70-100	30-70	10-30	<10	≈0	0-5	unknown
Crown cover **	>80	50-80	20-50	0.25-20	<0.25	0-5	unknown
% Crown cover ***	>80	50-80	20-50	0.25-20	<0.25	0-5	unknown
Cover code	d	c	i	r	bi	bc	unknown

Growth Form	Height ranges (m)	Structural Formation Classes						
tree, palm	>30 Tall	closed forest	open forest	woodland	open woodland	isolated trees	isolated clumps of trees	trees
	10-30 Mid							
	<10 Low							
tree mallee	10-30 Tall	closed mallee forest	open mallee forest	mallee woodland	open mallee woodland	isolated mallee trees	isolated clumps of mallee trees	mallee trees
	<10 Mid							
	<3 Low							
shrub, cycad, grass-tree, fern	>2 Tall	closed shrubland	shrubland	open shrubland	sparse shrubland	isolated shrubs	isolated clumps of shrubs	shrubs
	1-2 Mid							
	<1 Low							
mallee shrub	10-30 Tall							mallee shrubs

Growth Form	Height ranges (m)	Structural Formation Classes						
	<10 Mid <3 Low	closed mallee shrubland	mallee shrubland	open mallee shrubland	sparse mallee shrubland	isolated mallee shrubs	isolated clumps of mallee shrubs	

Growth Form	Height ranges (m)	Structural Formation Classes						
heath shrub	>2 Tall	closed heathland	heathland	open heathland	sparse heathland	isolated heath shrubs	isolated clumps of heath shrubs	heath shrubs
	1-2 Mid							
	<1 Low							
chenopod shrub	>2 Tall	closed chenopod shrubland	chenopod shrubland	open chenopod shrubland	sparse chenopod shrubland	isolated chenopod shrubs	isolated clumps of chenopod shrubs	chenopod shrubs
	1-2 Mid							
	<1 Low							
samphire shrub	>0.5 Mid	closed samphire shrubland	samphire shrubland	open samphire shrubland	sparse samphire shrubland	isolated samphire shrubs	isolated clumps of samphire shrubs	samphire shrubs
	<0.5 Low							
hummock grass	>2 Tall	closed hummock grassland	hummock grassland	open hummock grassland	sparse hummock grassland	isolated hummock grasses	isolated clumps of hummock grasses	hummock grasses
	<2 Low							
tussock grass	>0.5 Mid	closed tussock grassland	tussock grassland	open tussock grassland	sparse tussock grassland	isolated tussock grasses	isolated clumps of tussock grasses	tussock grasses
	<0.5 Low							
other grass	>0.5 Mid	closed grassland	grassland	open grassland	sparse grassland	isolated grasses	isolated clumps of grasses	other grasses
	<0.5 Low							
sedge	>0.5 Mid	closed sedgeland	sedgeland	open sedgeland	sparse sedgeland	isolated sedges	isolated clumps of sedges	sedges
	<0.5 Low							
rush	>0.5 Mid	closed rushland	rushland	open rushland	sparse rushland	isolated rushes	isolated clumps of rushes	rushes
	<0.5 Low							

Growth Form	Height ranges (m)	Structural Formation Classes						
forb	>0.5 Mid <0.5 Low	closed forbland	forbland	open forbland	sparse forbland	isolated forbs	isolated clumps of forbs	forbs
fern	>2 Tall 1-2 Mid <1 Low	closed fernland	fernland	open fernland	sparse fernland	isolated ferns	isolated clumpsof ferns	ferns
bryophyte	<0.5	closed bryophyte land	bryophyte land	open bryophyte land	sparse bryophyte land	isolated bryophytes	isolated clumps of bryophytes	bryophytes
lichen	<0.5	closed lichenland	lichenland	open lichenland	sparse lichenland	isolated lichens	isolated clumps of lichens	lichens
vine	>30 Tall 10-30 Mid <10 Low	closed vineland	vineland	open vineland	sparse vineland	isolated vines	isolated clumps of vines	vines
aquatic	<1 Tall 0-0.5 Low	closed aquatic bed	aquatic bed	open aquatic bed	sparse aquatics	isolated aquatics	isolated clumps of aquatics	aquatics
seagrass	<1 Tall	closed seagrass bed	Seagrass bed	open seagrass bed	sparse seagrass bed	isolated seagrasses	isolated clumps of seagrasses	seagrasses

Appendix D Likelihood of Occurrence of Conservation Significant Flora in the Study Area

Species	Conservation Code			Habitat	Life Form	Nearest known locality (km)	Pre-survey likelihood of occurrence	Post-survey likelihood of occurrence	Source
	EPBC Act	BC Act	DBCA						
Pityrodia augustensis	VU	VU	VU	Amongst rocks on slopes or in drainage lines.	Perennial	112	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies outside of the known distribution for this species.	Desmond *et al.* (2001)
Acacia wilcoxii			1	Granitic soils. Along creeks & adjacent stony plains & granite outcrops.	Perennial	44	**Unlikely**: No granite outcrops are known to occur in the study area.	**Unlikely**: The Study Area does not contain suitable habitat for this species.	TPFL, TP List; WAHerb
Eremophila appressa			1	Ironstone gravel. Ridge slopes.	Perennial	116	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies outside of the known distribution for this species and does not contain suitable habitat.	TP List
Eremophila arguta			1	The edge of floodplains, in dry creek beds and on road verges.	Perennial	98	**Possible**: The Study Area lies outside of the known distribution but may contain suitable habitat	**Unlikely**: The Study Area lies outside of the known distribution for this species and does not contain suitable habitat.	Desmond *et al.* (2001)
Eremophila humilis			1	Stony clay, loam. Rocky ridges.	Perennial	1.6	**Likely:** The Study Area contains suitable habitat for this species and known records are located within proximity.	**Unlikely**: The Study Area does not contain suitable habitat for this species. If present, this species could have been identified from vegetative material, however, despite extensive searches, it was not recorded.	TP List; WAHerb
Eremophila prolata			1	Red stony clay. Flats & rises.	Perennial	82	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies outside of the known distribution for this species.	Desmond *et al.* (2001)
Hemigenia pachyphylla			1	Watercourses, minor creeks, red sandy soils with rocks.	Perennial	270	**Unlikely**: The Study Area lies well outside of the known distribution for this species.	**Unlikely**: The Study Area lies well outside of the known distribution for this species.	Desmond *et al.* (2001)
Ptilotus actinocladus T.Hammer & R.W.Davis			1	Bare areas, flat, seasonally inundated areas.	Annual	130	**Possible**: There is limited information available regarding the distribution and habitat requirements for this species.	**Unlikely**: The Study Area does not contain suitable habitat for this species. If present, this species could have been identified from vegetative material, however, despite extensive searches, it was not recorded.	TP List
Acacia tuberculata			2	Granite outcrops	Perennial	530	**Unlikely**: The Study Area lies outside of the known distribution range for this species and there are no granite outcrops known to occur in the Study Area.	**Unlikely**: The Study Area is located well outside of the known distribution range of this species and does not contain granite outcrops.	TP List
Rhodanthe frenchii			2	Stony hills, rocky river banks & outcrops.	Annual	285	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies well outside of the known distribution for this species.	Desmond *et al.* (2001)
Thysanotus sp. Desert East of Newman (R.P. Hart 964)			2	Red-brown loamy sand or red sand, sometimes silty. Sand plain, pisolitic buckshot plain.	Perennial	445	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies well outside of the known distribution for this species.	TP List
Eremophila coacta			3	Laterite, shale soils. Ironstone hills, creeklines.	Perennial	155	**Possible**: The Study Area lies outside of the known distribution for this species but may contain suitable habitat.	**Unlikely**: The Study Area lies outside of the known distribution for this species and does not contain suitable habitat.	TP List
Eremophila flaccida subsp. attenuata			3	Stony clay over quartzite. Hillslopes, ridges.	Perennial	270	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies well outside of the known distribution for this species and does not contain suitable habitat.	TP List
Eremophila gracillima			3	Stony flats	Perennial	3	**Likely**: The Study Area contains suitable habitat for this species and known records are located within proximity.	**Unlikely**: If present, this species could have been identified from vegetative material, however, despite extensive searches, it was not recorded.	Desmond *et al.* (2001)
Eremophila lanata			3	Stony red clayey sand.	Perennial	117	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies outside of the known distribution for this species.	TPFL, TP List; WAHerb

Species	Conservation Code			Habitat	Life Form	Nearest known locality (km)	Pre-survey likelihood of occurrence	Post-survey likelihood of occurrence	Source
	EPBC Act	BC Act	DBCA						
Eremophila rigida			3	Red sand alluvium. Hardpan plains, stony clay depressions.	Perennial	29	**Possible**: The Study Area lies just outside of the known distribution of this species but may contain suitable habitat	**Unlikely**: The Study Area does not contain suitable habitat for this species. If present, this species could have been identified from vegetative material, however, despite extensive searches, it was not recorded.	Desmond *et al.* (2001)
Owenia acidula			3	Clay plains.	Perennial	371	**Unlikely**: The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies well outside of the known distribution for this species and does not contain suitable habitat.	TPFL; TP List; WAHerb
Ptilotus lazaridis			3	Clay loam. Floodplains.	Perennial	230	**Unlikely**: The Study Area does not contain suitable habitat for this species.	**Unlikely**: The Study Area lies well outside of the known distribution for this species and does not contain suitable habitat.	TP List
Ptilotus luteolus			3	Rocky slopes, screes and ridges.	Perennial	132	**Unlikely:** The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies outside of the known distribution for this species and does not contain suitable habitat.	Desmond *et al.* (2001)
Stylidium weeliwolli			3	Gritty sand soil, sandy clay. Edge of watercourses.	Annual	180	**Unlikely:** The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies outside of the known distribution for this species.	Desmond *et al.* (2001)
Ptilotus trichocephalus			4	Sandy soils. Colluvial plains.	Perennial	51	**Unlikely:** The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area does not contain suitable habitat for this species. If present, this species could have been identified from vegetative material, however, despite extensive searches, it was not recorded.	WAHerb
Goodenia berringbinensis			4	Red sandy loam. Along watercourses.	Annual	135	**Unlikely:** The Study Area lies outside of the known distribution for this species.	**Unlikely**: The Study Area lies outside of the known distribution for this species.	Desmond *et al.* (2001)

Appendix E Vertebrate Fauna Identified in the Desktop Assessment

Legend:

Desktop Searches:

A	Galena Minerals Ltd: Abra Flora, Fauna and Vegetation Survey (Stantec 2018)
B	Birdata: Custom Atlas Bird List (Birdlife Australia 2017)
C	Threatened and Priority Fauna Database (DBCA 2017)
D	NatureMap Database (DBCA 2018b)
E	Protected Matters Search Tool (DoEE 2018a)

Literature Review

F	Gascoyne 3 (GAS3 - Augustus subregion) (Desmond *et al.* 2001)
G	Flora and Fauna Survey: Fortnum Project for Homestake Australia Limited (Dames and Moore 1988)
H	Desktop Vertebrate Fauna Assessment and Reconnaissance Survey of the Mulgul Project (Outback Ecology 2006)
I	Terrestrial fauna survey for the Beyondie Potash Project, Prepared for Kalium Lakes Ltd, Draft Report (Phoenix 2017)

Family	Species Name	Common Name	EPBC	WA	A	B	C	D	E	F	G	H	I
Amphibians													
Hylidae	*Cyclorana maini*	Sheep Frog			x								x
	Cyclorana platycephala	Western Water-holding Frog						x					x
	Litoria rubella	Little Red Tree Frog			x			x					x
Limnodynastidae	*Neobatrachus aquilonius*	Northern Burrowing Frog											x
	Neobatrachus sudellae	Desert Trilling Frog											x
	Neobatrachus sutor	Shoemaker Frog											x
	Notaden nichollsi	Desert Spadefoot											x
Myobatrachidae	*Uperoleia micromeles*	Tanami Toadlet											x
Birds													
Acanthizidae	*Acanthiza apicalis*	Inland Thornbill			x	x		x				x	
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill				x		x					
	Acanthiza iredalei iredalei									x			
	Acanthiza robustirostris	Slaty-backed Thornbill				x		x					x
	Acanthiza uropygialis	Chestnut-rumped Thornbill				x		x			x		x
	Aphelocephala leucopsis	Southern Whiteface				x		x					
	Gerygone fusca	Western Gerygone			x			x					x
	Pyrrholaemus brunneus	Redthroat				x		x					x
	Smicrornis brevirostris	Weebill				x		x			x	x	x
Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk				x		x					
	Accipiter fasciatus	Brown Goshawk											x
	Aquila audax	Wedge-tailed Eagle				x		x			x		x
	Elanus caeruleus	Black-shouldered Kite											x
	Haliastur sphenurus	Whistling Kite				x		x					x
	Hamirostra isura	Square-tailed Kite									x		
	Hamirostra melanosternon	Black-breasted Buzzard				x		x					x
	Hieraaetus morphnoides	Little Eagle											x
Alaudidae	*Mirafra javanica*	Horsfield's Bushlark											x
Alcedinidae	*Todiramphus sanctus*	Sacred Kingfisher									x		
Anatidae	*Anas gracilis*	Grey Teal											x
	Anas querquedula	Garganey	Mi	S5			x						
	Anas superciliosa	Pacific Black Duck									x		
	Cygnus atratus	Black Swan											x
Apodidae	*Apus pacificus*	Fork-tailed Swift	Mi	S5					x				
Ardeidae	*Ardea modesta*	Eastern Great Egret					x		x				
	Ardea novaehollandiae	White-faced Heron									x		
	Ardea pacifica	White-necked Heron				x		x					x
Artamidae	*Artamus cinereus*	Black-faced Woodswallow			x	x		x				x	x
	Artamus minor	Little Woodswallow				x		x					
	Artamus personatus	Masked Woodswallow											x
Cacatuidae	*Cacatua roseicapilla*	Galah				x		x				x	x
	Cacatua sanguinea	Little Corella											x
	Nymphicus hollandicus	Cockatiel				x		x					
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike				x		x					x

Family	Species Name	Common Name	EPBC	WA	A	B	C	D	E	F	G	H	I
	Coracina novaehollandiae subpallida							x					
	Lalage tricolor	White-winged Triller				x						x	
Caprimulgidae	*Eurostopodus argus*	Spotted Nightjar			x	x		x					
Charadriidae	*Charadrius melanops*	Black-fronted Dotterel						x					
	Charadrius veredus	Oriental Plover	Mi	S5					x				
	Vanellus tricolor	Banded Lapwing											x
Columbidae	*Geopelia cuneata*	Diamond Dove						x			x	x	
	Geopelia striata	Peaceful Dove				x		x					
	Ocyphaps lophotes	Crested Pigeon			x	x		x			x	x	x
	Phaps chalcoptera	Common Bronzewing			x	x		x					
Corvidae	*Corvus bennetti*	Little Crow									x	x	
	Corvus orru	Torresian Crow			x						x		
Cracticidae	*Cracticus nigrogularis*	Pied Butcherbird			x	x		x				x	x
	Cracticus tibicen	Australian Magpie			x	x		x			x		
	Cracticus torquatus	Grey Butcherbird				x		x			x		
Cuculidae	*Cacomantis pallidus*	Pallid Cuckoo									x		
	Chrysococcyx basalis	Horsfield's Bronze Cuckoo									x		
Dromaiidae	*Dromaius novaehollandiae*	Emu				x		x			x		x
Estrildidae	*Taeniopygia guttata*	Zebra Finch			x	x		x			x	x	x
Falconidae	*Falco berigora*	Brown Falcon				x		x				x	
	Falco cenchroides	Australian Kestrel			x	x		x			x	x	x
	Falco peregrinus	Peregrine Falcon		S7			x			x			
Hirundinidae	*Hirundo rustica*	Barn Swallow	Mi	S5					x				
	Petrochelidon nigricans	Tree Martin				x		x					
Locustellidae	*Megalurus cruralis*	Brown Songlark				x							
	Megalurus mathewsi	Rufous Songlark											x
Maluridae	*Malurus lamberti*	Variegated Fairy-wren											x
	Malurus leucopterus	White-winged Fairy-wren											x
	Malurus splendens	Splendid Fairy-wren				x		x				x	
Meliphagidae	*Acanthagenys rufogularis*	Spiny-cheeked Honeyeater				x		x			x	x	x
	Certhionyx variegatus	Pied Honeyeater				x		x				x	x
	Epthianura tricolor	Crimson Chat				x		x					
	Gavicalis virescens	Singing Honeyeater			x	x		x					x
	Lacustroica whitei	Grey Honeyeater						x					
	Lichmera indistincta	Brown Honeyeater									x		
	Manorina flavigula	Yellow-throated Miner				x		x					x
	Melithreptus gularis	Black-chinned Honeyeater											x
	Ptilotula keartlandi	Grey-headed Honeyeater											x
	Ptilotula penicillatus	White-plumed Honeyeater				x							x
	Purnella albifrons	White-fronted Honeyeater				x		x			x		x
	Sugomel niger	Black Honeyeater				x							x
Meropidae	*Merops ornatus*	Rainbow Bee-eater					x		x		x		x
Monarchidae	*Grallina cyanoleuca*	Magpie-lark				x		x			x	x	x
Motacillidae	*Anthus australis*	Australian Pipit				x					x	x	x

Family	Species Name	Common Name	EPBC	WA	A	B	C	D	E	F	G	H	I
	Motacilla cinerea	Grey Wagtail	Mi	S5					x				
	Motacilla flava	Yellow Wagtail	Mi	S5					x				
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella										x	
Oreoicidae	*Oreoica gutturalis*	Crested Bellbird			x	x		x			x	x	x
Otididae	*Ardeotis australis*	Australian Bustard						x			x		x
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush			x	x		x				x	
	Pachycephala rufiventris	Rufous Whistler				x		x			x	x	x
Petroicidae	*Melanodryas cucullata*	Hooded Robin			x	x		x					x
	Microeca fascinans	Jacky Winter											x
	Petroica goodenovii	Red-capped Robin				x		x				x	
Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little Black Cormorant				x		x					
Phasianidae	*Coturnix pectoralis*	Stubble Quail				x		x					
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler				x		x			x	x	
	Pomatostomus temporalis	Grey-crowned Babbler				x		x					x
Psittacidae	*Melopsittacus undulatus*	Budgerigar				x		x				x	x
	Neophema bourkii	Bourke's Parrot									x		
	Pezoporus occidentalis	Night Parrot	En	S1			x	x	x				
	Platycercus varius	Mulga Parrot			x	x					x	x	
	Platycercus zonarius	Australian Ringneck			x	x		x			x	x	
	Polytelis alexandrae	Princess Parrot	Vu	P4			x		x	x			
Psophodidae	*Cinclosoma clarum*	Western Chestnut Quail-thrush						x				x	
	Cinclosoma marginatum	Western Quail-thrush						x					
	Cinclosoma castaneothorax	Chestnut-breasted Quail-thrush			x	x							
Ptilonorhynchidae	*Ptilonorhynchus maculatus guttatus*	Western Bowerbird										x	
Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail			x	x		x			x	x	x
Scolopacidae	*Calidris acuminata*	Sharp-tailed Sandpiper	Mi	S5					x				
	Calidris ferruginea	Curlew Sandpiper	Cr; Mi	S3; S5					x				
	Calidris melanotos	Pectoral Sandpiper	Mi	S5					x				
	Calidris ruficollis	Red-necked Stint	Mi	S5			x						
	Tringa hypoleucos	Common Sandpiper	Mi	S5					x				
	Tringa nebularia	Common Greenshank	Mi	S5			x						
Strigidae	*Ninox boobook boobook*	Southern Boobook									x		
Turnicidae	*Turnix velox*	Little Button-quail											x
Mammals													
Bovidae	*Bos taurus*	*European Cattle			x							x	x
Camelidae	*Camelus dromedarius*	*Camel							x		x		x
Canidae	*Canis familiaris*	*Dog			x			x	x				
	Vulpes vulpes	*Red Fox						x	x			x	x
Dasyuridae	*Dasycercus blythi*	Brush-tailed Mulgara		P4				x					x
	Dasycercus cristicauda	Crest-tailed Mulgara	Vu	P4						x			
	Dasykaluta rosamondae	Little Red Kaluta											x
	Dasyurus hallucatus	Northern Quoll	En	S2					x				
	Ningaui ridei	Wongai Ningaui											x
	Sminthopsis crassicaudata	Fat-tailed Dunnart											x

Family	Species Name	Common Name	EPBC	WA	A	B	C	D	E	F	G	H	I
	Sminthopsis macroura	Stripe-faced Dunnart											x
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat											x
Equidae	*Equus asinus*	*Donkey							x			x	x
	Equus caballus	*Horse							x				
Felidae	*Felis catus*	*Cat			x				x		x	x	x
Leporidae	*Oryctolagus cuniculus*	*Rabbit							x		x	x	x
Macropodidae	*Osphranter robustus erubescens*											x	
	Osphranter rufus	Red Kangaroo			x						x	x	x
Megadermatidae	*Macroderma gigas*	Ghost Bat	Vu	S3					x				
Molossidae	*Austronomus australis*	White-striped Freetail-bat									x		x
	Chaerephon jobensis	Greater Northern Freetail-bat											x
	Ozimops lumsdenae	Northern Free-tailed Bat											x
Muridae	*Mus musculus*	*House Mouse									x		x
	Notomys alexis	Spinifex Hopping-mouse											x
	Pseudomys chapmani	Western Pebble-mound Mouse		P4			x	x				x	
	Pseudomys desertor	Desert Mouse											x
	Pseudomys hermannsburgensis	Sandy Inland Mouse											x
	Zyzomys argurus	Common Rock-rat										x	
Notoryctidae	*Notoryctes caurinus*	Northern Marsupial Mole		P4									x
Rhinonycteridae	*Rhinonicteris aurantius Pilbara form'*	Pilbara Leaf-nosed Bat	Vu	S3			x		x				
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna									x		x
Thylacomyidae	*Macrotis lagotis*	Bilby	Vu	S3			x	x		x			x
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat						x			x		x
	Nyctophilus geoffroyi	Lesser Long-eared Bat											x
	Scotorepens greyii	Little Broad-nosed Bat											x
	Vespadelus finlaysoni	Finlayson's Cave Bat											x
Reptiles													
Agamidae	*Ctenophorus caudicinctus caudicinctus*						x						
	Ctenophorus caudicinctus mensarum				x		x						
	Ctenophorus isolepis gularis												x
	Ctenophorus nuchalis	Central Netted Dragon										x	x
	Ctenophorus reticulatus	Western Netted Dragon						x					
	Ctenophorus scutulatus											x	x
	Ctenophorus yinnietharra	Yinnietharra Rock Dragon	Vu	S3						x			
	Diporiphora paraconvergens	Grey-striped Western Desert Dragon											x
	Diporiphora valens	Southern Pilbara Tree Dragon											x
	Gowidon longirostris	Long-nosed Dragon						x					x
	Moloch horridus	Thorny Devil									x		
	Pogona minor minor	Western Bearded Dragon											x
Carphodactylidae	*Nephrurus laevissimus*												x
	Nephrurus levis												x
Cheluidae	*Chelodina steindachneri*	Flat-shelled Turtle						x					
Diplodactylidae	*Diplodactylus conspicillatus*	Variable Fat-tailed Gecko											x

Family	Species Name	Common Name	EPBC	WA	A	B	C	D	E	F	G	H	I
	Diplodactylus laevis	Desert Fat-tailed Gecko											x
	Lucasium stenodactylum										x		x
	Rhynchoedura ornata	Western Beaked Gecko											x
	Strophurus ciliaris aberrans												x
	Strophurus elderi							x					x
Elapidae	*Pseudechis australis*	Mulga Snake									x		x
	Pseudonaja mengdeni	Western Brown Snake											x
	Simoselaps anomalus	Desert Banded Snake											x
	Simoselaps bertholdi	Jan's Banded Snake									x		
	Suta fasciata	Rosen's Snake						x					
Gekkonidae	*Gehyra punctata*							x					
	Gehyra variegata				x						x		x
	Heteronotia binoei	Bynoe's Gecko						x					x
Pygopodidae	*Delma nasuta*							x					
	Lialis burtonis							x					x
Pythonidae	*Aspidites melanocephalus*	Black-headed Python									x		
	Liasis olivaceus barroni	Pilbara Olive Python	Vu	S3					x				
Scincidae	*Ctenotus brooksi*												x
	Ctenotus calurus												x
	Ctenotus grandis grandis												x
	Ctenotus hanloni												x
	Ctenotus inornatus												x
	Ctenotus leae												x
	Ctenotus leonhardii												x
	Ctenotus pantherinus ocellifer										x		x
	Ctenotus quattuordecimlineatus												x
	Ctenotus schomburgkii										x		x
	Cyclodomorphus melanops	Slender Blue-tongue						x					
	Cyclodomorphus melanops melanops												x
	Egernia depressa	Southern Pygmy Spiny-tailed Skink											x
	Eremiascincus musivus	Mosaic Desert Skink											x
	Eremiascincus pallidus	Western Narrow-banded Skink											x
	Eremiascincus richardsonii	Broad-banded Sand Swimmer											x
	Lerista bipes												x
	Lerista ips												x
	Lerista macropisthopus remota			P2									x
	Lerista muelleri										x		
	Lerista neander							x					
	Lerista timida							x					
	Morethia ruficauda exquisita							x					
	Tiliqua multifasciata	Central Blue-tongue											x
Typhlopidae	*Anilios endoterus*												x
Varanidae	*Varanus eremius*	Pygmy Desert Monitor											x
	Varanus giganteus	Perentie									x		

Family	Species Name	Common Name	EPBC	WA	A	B	C	D	E	F	G	H	I
	Varanus gouldii	Sand Monitor									x	x	
	Varanus panoptes	Yellow-spotted Monitor											x
	Varanus tristis tristis	Racehorse Monitor									x		

Appendix F Inventory of Vascular Flora Recorded

Family	Species
Amaranthaceae	*Ptilotus aervoides*
	Ptilotus obovatus
	Ptilotus schwartzii
Apocynaceae	*Marsdenia australis*
Caryophyllaceae	*Polycarpaea corymbosa*
Chenopodiaceae	*Rhagodia eremaea*
Cyperaceae	*Fimbristylis dichotoma*
Euphorbiaceae	*Euphorbia boopthona/ tannensis*
Fabaceae	*Acacia ?macraneura*
	Acacia citrinoviridis
	Acacia incurvaneura
	Acacia kempeana
	Acacia pruinocarpa
	Acacia pteraneura
	Acacia ramulosa var. *linophylla*
	Acacia ramulosa var. *ramulosa*
	Acacia rhodophloia
	Acacia tetragonophylla
	Senna artemisioides subsp. *helmsii*
	Senna cuthbertsonii
	Senna sp. Meekatharra (E. Bailey 1-26)
Goodeniaceae	*Goodenia ? tenuiloba*
Malvaceae	*Hibiscus burtonii*
	Hibiscus coatesii
	Sida sp. Golden calyces
	Sida sp.
Myrtaceae	Myrtaceae sp.
	Calytrix desolata
Nyctaginaceae	*Boerhavia coccinea*
Poaceae	*Aristida contorta*
	Cymbopogon ambiguus
	Enneapogon robustissimus
	Eragrostis eriopoda
	Eriachne benthamii
	Eriachne mucronata
	Eriachne pulchella subsp. *pulchella*
	Poaceae sp.
	Triodia basedowii
Proteaceae	*Grevillea berryana*
Pteridaceae	*Cheilanthes sieberi*
Rubiaceae	*Psydrax latifolia*
	Psydrax suaveolens
Santalaceae	*Santalum spicatum*
Sapindaceae	*Dodonaea pachyneura*
	Dodonaea petiolaris

	Dodonaea sp.
	Eremophila ?granitica
	Eremophila citrina
	Eremophila exilifolia
	Eremophila forrestii subsp. ? forestii
	Eremophila fraseri subsp. *fraseri*
	Eremophila jucunda subsp. *jucunda*
	Eremophila margarethae
Scrophulariaceae	*Eremophila spectabilis*
Solanaceae	*Solanum lasiophyllum*

Appendix G Floristic Data - Flora Sampling Sites

Abra Airstrip – AAr01

Site Details:

Described by: AB

Date: 2/10/2018

Type: Relevé

MGA Zone: 50J 663084mE 7275507mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Tracks, Grazing

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia incurvaneura, Grevillea berryana* and *Acacia ramulosa* var. *ramulosa* open tall shrubland, *over Senna* sp. Meekatharra open shrubland, over *Solanum lasiophyllum, Ptilotus schwartzii*, *Eremophila fraseri* subsp. *fraseri* open low shrubland.

Veg Condition: Excellent

Fire Age: 5 to 15 years

Weeds: None

Fire Notes: N/A

Table A: Species list

Species	Height	Cover
Acacia incurvaneura	4	1
Acacia kempeana	1.5	0.5
Acacia ramulosa var. *ramulosa*	2	4
Acacia rhodophloia	2	1
Aristida contorta	0.2	0.1
Eremophila ?granitica	0.25	0.1
Eremophila fraseri subsp. *fraseri*	0.8	0.5
Eremophila margarethae	2	0.5
Eriachne mucronata	0.3	0.5
Eriachne pulchella subsp. *pulchella*	0.1	0.5
Grevillea berryana	3.5	1
Ptilotus schwartzii	0.4	0.5
Senna sp. Meekatharra (E. Bailey 1-26)	1.6	0.5
Solanum lasiophyllum	0.7	0.5

Abra Airstrip – AAr02

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 663073mE 7276224mN

Environmental Variables:

Landform: Minor gully

Slope: Level (0-3°)

Soils:

Soil Texture:	Clay loam
Soil Colour:	Reddish brown
Rock Type:	Laterite

Impacts:

Waterlogging:	No - Prone to Flooding
Disturbance:	N/A
Introduced species:	N/A

FLORA AND VEGETATION DATA

Description: *Acacia rhodophloia* tall open shrubland *over Eremophila citrina* and *Senna* sp. Meekatharra open shrubland over *Eriachne benthamii*, *Eriachne mucronata* and *Aristida contorta* very open tussock grassland.

Veg Condition:	Excellent	Fire Age:	5 to 15 years
Weeds:	None	Fire Notes:	N/A

Table B: Species list

Species	Height	Cover
Acacia rhodophloia	4	8
Psydrax latifolia	2.1	1
Eriachne mucronata	0.4	1
Eriachne pulchella subsp. *pulchella*	0.15	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	1.8	0.1
Fimbristylis dichotoma	0.05	0.1
Hibiscus coatesii	0.4	0.1
Eremophila citrina	2.2	1
Rhagodia eremaea	0.4	0.1
Cheilanthes sieberi	0.15	0
Dodonaea sp.	2.1	1
Aristida contorta	0.2	0.1
Eriachne benthamii	0.4	0.1
Grevillea berryana	3	1
Boerhavia coccinea	0.45	0.1
Solanum lasiophyllum	0.4	0.1
Hibiscus burtonii	0.5	0.1
Sida sp. Golden calyces	0.4	0.1

Species	Height	Cover
Enneapogon robustissimus	0.45	0.1
Eremophila ?granitica	1.2	0.1
Polycarpaea corymbosa	0.1	0.1
Eremophila ?granitica	0.35	0.1

Abra Airstrip – AAr03

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 663018mE 7276155mN

Environmental Variables:

Landform: Minor gully

Slope: Level (0-3°)

Soils:

Soil Texture:	Clay loam
Soil Colour:	Reddish brown
Rock Type:	Laterite

Impacts:

Waterlogging:	No - Prone to Flooding
Disturbance:	Grazing
Introduced species:	Cattle

FLORA AND VEGETATION DATA

Description: *Acacia citrinoviridus, Acacia rhodophloia* open tall shrubland over *Dodonaea* sp., *Eremophila citrina, Eremophila ?granitica* open shrubland over *Eriachne benthamii,* Poaceae sp., *Enneapogon robustissimus* very open tussock grassland.

Veg Condition:	Excellent	Fire Age:	3 to 5 years
Weeds:	None	Fire Notes:	N/A

Table C: Species list

Species	Height	Cover
Acacia citrinoviridis	3.5	4
Acacia incurvaneura	2.4	1
Acacia rhodophloia	3	3
Acacia tetragonophylla	2.2	0.1
Aristida contorta	0.2	0.1
Cheilanthes sieberi	0.2	0.1
Cymbopogon ambiguus	0.7	0.1
Dodonaea sp.	1.6	0.1
Enneapogon robustissimus	0.4	0.5
Eragrostis ?eriopoda	0.5	1
Eremophila ?granitica	1.2	0.1
Eremophila ?granitica	0.3	0.1
Eremophila citrina	1.8	0.1
Eremophila fraseri subsp. *fraseri*	1.2	0.5
Eremophila jucunda subsp. *jucunda*	0.5	0.1
Eremophila spectabilis	3	0.1
Eriachne benthamii	0.5	1
Eriachne pulchella subsp. *pulchella*	0.15	0.1
Fimbristylis dichotoma	0.2	0.1
Hibiscus coatesii	0.2	0.1

Species	Height	Cover
Psydrax latifolia	1.8	0.1
Santalum spicatum	2.2	0.1
Solanum lasiophyllum	0.45	0.1

Abra Airstrip – AAr04

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 662879mE 7275770mN

Environmental Variables:

Landform: Minor gully

Slope: Level (0-3°)

Soils:

Soil Texture:	Clay loam
Soil Colour:	Reddish brown
Rock Type:	Laterite

Impacts:

Waterlogging:	No - Prone to Flooding
Disturbance:	N/A
Introduced species:	N/A

FLORA AND VEGETATION DATA

Description: *Acacia citrinoviridus, Acacia incurvaneura* tall open shrubland over *Acacia rhodophloia*, *Dodonaea* sp., *Dodonaea pachyneura* open shrubland over *Eriachne mucronata*, *Eriachne benthamii* very open tussock grassland.

Veg Condition:	Excellent	Fire Age:	3 to 5 years
Weeds:	None	Fire Notes:	N/A

Table D: Species list

Species	Height	Cover
Acacia citrinoviridis	6	3
Acacia incurvaneura	4	1.5
Acacia incurvaneura	2.4	0.1
Acacia rhodophloia	2	0.5
Acacia tetragonophylla	0.9	0.1
Aristida contorta	0.2	0.1
Dodonaea pachyneura	1.2	0.5
Dodonaea sp.	1.6	1
Eremophila ?granitica	1.2	0.1
Eremophila fraseri subsp. *fraseri*	0.8	0.1
Eriachne benthamii	0.5	0.5
Eriachne mucronata	0.3	0.5
Eriachne pulchella subsp. *pulchella*	0.5	0.1
Grevillea berryana	0.1	0.1
Hibiscus coatesii	0.9	0.1
Psydrax latifolia	2.2	0.1
Psydrax suaveolens	0.4	0.1
Ptilotus obovatus	0.6	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	1.1	0.1

Abra Airstrip – AAr05

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 663812mE 7275836mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Tracks, Feral scats

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia incurvaneura* and *Acacia kempeana* tall open shrubland over *Acacia rhodophloia* and *Psydrax suaveolens* open shrubland over *Ptilotus schwartzii* and *Ptilotus obovatus* scattered low shrubs

Veg Condition: Excellent

Fire Age: 3 to 5 years

Weeds: None

Fire Notes: N/A

Table E: Species list

Species	Height	Cover
Acacia citrinoviridis	4	0.5
Acacia incurvaneura	2.2	0.1
Acacia incurvaneura	4	1
Acacia kempeana	3.5	2
Acacia kempeana	5	1
Acacia ramulosa var. *ramulosa*	1.53	0.5
Acacia rhodophloia	1.8	0.5
Aristida contorta	0.08	0.1
Eremophila ?granitica	0.25	0.1
Eremophila fraseri subsp. *fraseri*	0.8	0.1
Eremophila spectabilis	0.8	0.1
Eriachne pulchella subsp. *pulchella*	0.08	0.1
Euphorbia boopthona/ tannensis	0.2	0.1
Goodenia ? tenuiloba	0.08	0.1
Grevillea berryana	5	1
Myrtaceae sp.	0.9	0.1
Poaceae sp.	0.8	0.1
Polycarpaea corymbosa	0.05	0.1
Psydrax latifolia	2.2	0.5
Psydrax suaveolens	1.5	0.1
Ptilotus obovatus	1.1	0.1

Species	Height	Cover
Ptilotus schwartzii	0.25	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	1.9	0.1
Sida sp. Golden calyces	0.25	0.1
Solanum lasiophyllum	0.4	0.1

Abra Airstrip – AAr06

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 663423mE 7275984mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Feral scats, Grazing, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia pruinocarpa, Acacia incurvaneura* and *Grevillea berryana* (*Psydrax latifolia*) tall open shrubland over *Eremophila spectabilis* and *Senna* sp. Meekatharra open shrubland over *Eremophila ?granitica* and *Ptilotus schwartzii* scattered low shrubs with scattered Poaceae sp. tussock grasses.

Veg Condition: Excellent

Weeds: None

Fire Age: 3 to 5 years

Fire Notes: N/A

Table F: Species list

Species	Height	Cover
Acacia citrinoviridis	2.8	0.1
Acacia incurvaneura	4	3
Acacia pruinocarpa	4	1
Acacia ramulosa var. *linophylla*	0.8	0.1
Acacia ramulosa var. *ramulosa*	2.5	0.5
Acacia rhodophloia	1.1	0.1
Aristida contorta	0.15	0.1
Eragrostis eriopoda	0.5	0.1
Eremophila ?granitica	0.3	0.1
Eremophila citrina	1.1	0.1
Eremophila fraseri subsp. *fraseri*	0.9	0.1
Eremophila spectabilis	1.1	0.1
Eriachne mucronata	0.25	0.1
Eriachne pulchella subsp. *pulchella*	0.1	0.1
Grevillea berryana	3	1
Poaceae sp.	0.5	0.1
Psydrax latifolia	2.2	1
Psydrax suaveolens	0.8	0.1
Ptilotus schwartzii	0.25	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	1.6	0.1

Species	Height	Cover
Solanum lasiophyllum	0.4	0.1

Abra Airstrip – AAr07

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 664228mE 7275325mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Sandy clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Grazing, Feral trampling, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia pteraneura, Acacia incurvaneura* and *Acacia ramulosa* var. *ramulosa* tall open shrubland over *Senna artemisioides* subsp. *helmsii, Eremophila forrestii* and *Ptilotus obovatus* open shrubland over Poaceae sp. and *Eragrostis eriopoda* scattered tussock grasses.

Veg Condition: Excellent

Fire Age: 3 to 5 years

Weeds: None

Fire Notes: N/A

Table G: Species list

Species	Height	Cover
Acacia citrinoviridis	4	0.5
Acacia incurvaneura	4	2
Acacia kempeana	1.8	0.5
Acacia pteraneura	5	4
Acacia ramulosa var. *linophylla*	1.6	1
Acacia rhodophloia	5	1
Aristida contorta	0.15	0.1
Cheilanthes sieberi	0.1	0.1
Eragrostis eriopoda	0.5	1
Eremophila ?granitica	0.9	0.1
Eremophila citrina	1.4	0.1
Eremophila forrestii	0.9	1.5
Eremophila fraseri subsp. *fraseri*	1.1	0.1
Eremophila spectabilis	0.6	1
Grevillea berryana	4	1
Hibiscus coatesii	0.4	0.1
Marsdenia australis	0	0.1
Psydrax latifolia	0.4	0.1
Ptilotus obovatus	0.9	0.1
Senna artemisioides subsp. *helmsii*	1.4	0.1

Species	Height	Cover
Senna sp. Meekatharra (E. Bailey 1-26)	1.2	1
Sida sp. Golden calyces	0.25	0.1
Solanum lasiophyllum	0.4	0.1
Ptilotus obovatus	0.9	0.1

Abra Airstrip – AAr08

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 663996mE 7275142mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Sandy clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Grazing, Feral trampling, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia incurvaneura, Acacia kempeana* and *Acacia ramulosa* var. *linophylla* and *Psydrax latifolia* tall open shrubland over *Eremophila forrestii* open shrubland over Poaceae sp. and *Eragrostis eriopoda* open tussock grassland.

Veg Condition: Excellent

Fire Age: 3 to 5 years

Weeds: None

Fire Notes: N/A

Table H: Species list

Species	Height	Cover
Acacia citrinoviridis	8	0.5
Acacia incurvaneura	5	6.5
Acacia kempeana	7	2
Acacia pruinocarpa	0.4	0.1
Acacia ramulosa var. *linophylla*	1.5	1.5
Dodonaea petiolaris	1.7	0.1
Eragrostis eriopoda	0.5	1
Eremophila forrestii	1.2	0.5
Eremophila spectabilis	0.4	0.1
Eriachne pulchella subsp. *pulchella*	0.15	0.1
Grevillea berryana	6	0.5
Marsdenia australis	0	0.1
Poaceae sp.	0.5	1
Psydrax latifolia	4	0.5
Ptilotus obovatus	0.8	0.1
Ptilotus schwartzii	0.4	0.1
Senna cuthbertsonii	1.6	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	0.5	0.5
Sida sp. Golden calyces	0.2	0.1
Solanum lasiophyllum	0.5	0.1

Abra Airstrip – AAr09

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 663639mE 7275079mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Sandy clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Grazing, Feral trampling, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia pteraneura, Acacia kempeana* and *Acacia ramulosa* var. *linophylla* (*Grevillea berryana* and *Psydrax latifolia*) over *Eremophila forrestii* open shrubland over Poaceae sp. (*Eragrostis eriopoda*) very open tussock grassland

Veg Condition: Excellent

Fire Age: 3 to 5 years

Weeds: None

Fire Notes: N/A

Table I: Species list

Species	Height	Cover
Acacia kempeana	4	3
Acacia pruinocarpa	5	0.5
Acacia pteraneura	5	3
Acacia ramulosa var. *linophylla*	2.1	1
Acacia ramulosa var. *ramulosa*	4	0.5
Acacia rhodophloia	2.6	0.1
Aristida contorta	0.2	0.1
Eragrostis eriopoda	0.4	0.5
Eremophila forrestii	1.2	1.5
Eriachne mucronata	0.25	0.1
Eriachne pulchella subsp. *pulchella*	0.1	0.1
Grevillea berryana	3.5	0.5
Poaceae sp.	0.5	1
Psydrax latifolia	3	1
Ptilotus obovatus	0.5	0.5
Ptilotus schwartzii	0.3	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	1.2	0.1
Solanum lasiophyllum	0.4	0.1

Abra Airstrip – AAr10

Site Details:

Described by: AB

Date: 3/10/2018

Type: Relevé

MGA Zone: 50J 664548mE 7275681mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Sandy clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Feral trampling, Feral scats, Grazing, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia ramulosa* var. *linophylla*, *Acacia incurvaneura* and *Acacia pteraneura* tall shrubland over *Eremophila forrestii* and *Eremophila spectabilis* shrubland over Poaceae sp. and *Eragrostis eriopoda* very scattered tussock grasses.

Veg Condition: Excellent

Weeds: None

Fire Age: 3 to 5 years

Fire Notes: N/A

Table J: Species list

Species	Height	Cover
Acacia ?macraneura	1.7	0.1
Acacia incurvaneura	5	2
Acacia kempeana	2.5	0.1
Acacia pteraneura	4	2
Acacia ramulosa var. *linophylla*	2.5	12
Acacia ramulosa var. *ramulosa*	1.1	0.1
Acacia rhodophloia	2.2	0.5
Eragrostis eriopoda	0.5	0.5
Eremophila forrestii	1.2	7
Eremophila spectabilis	1.2	5
Grevillea berryana	3	0.1
Poaceae sp.	0.5	1
Psydrax latifolia	0.25	0.1
Ptilotus obovatus	1.1	0.1
Senna artemisioides subsp. *helmsii*	1.6	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	2.1	0.5

Abra Airstrip – AAr11

Site Details:

Described by: AB

Date: 4/10/2018

Type: Relevé

MGA Zone: 50J 665247mE 7275652mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Sandy clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Never

Disturbance: Feral trampling, Feral scats

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia ramulosa* var. *linophylla, Acacia pteraneura* (*Grevillea berryana*) tall shrubland over *Eremophila forrestii* shrubland over *Eremophila spectabilis* low shrubs with scattered Poaceae sp. and *Eragrostis eriopoda* tussock grasses

Veg Condition: Excellent

Weeds: None

Fire Age: 3 to 5 years

Fire Notes: N/A

Table K: Species list

Species	Height	Cover
Acacia incurvaneura	4	0.5
Acacia pteraneura	4	4
Acacia ramulosa var. *linophylla*	2.4	4
Acacia rhodophloia	2	0.1
Aristida contorta	0.15	0.1
Eragrostis eriopoda	0.4	0.5
Eremophila forrestii	1.6	15
Eremophila fraseri subsp. *fraseri*	1.6	0.1
Eremophila spectabilis	0.6	1
Eriachne pulchella subsp. *pulchella*	0.1	0.1
Grevillea berryana	3	0.5
Poaceae sp.	0.4	1
Psydrax suaveolens	3	0.1
Senna artemisioides subsp. *helmsii*	1.1	0.5
Senna sp. Meekatharra (E. Bailey 1-26)	2.2	0.1
Triodia basedowii	0.4	0.1

Abra Airstrip – AAr12

Site Details:

Described by: AB

Date: 4/10/2018

Type: Relevé

MGA Zone: 50J 664973mE 7275749mN

Environmental Variables:

Landform: Minor flowline, not incised

Slope: Level (0-3°)

Soils:

Soil Texture: Sand

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Prone to Flooding

Disturbance: Feral trampling, Grazing, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia incurvaneura, Acacia citrinoviridis* and *Acacia rhodophloia* tall open shrubland over *Calytrix desolata* scattered shrubs over *Eremophila citrina* scattered low shrubs and very scattered tussock grasses.

Veg Condition: Excellent

Weeds: None

Fire Age: 3 to 5 years

Fire Notes: N/A

Table L: Species list

Species	Height	Cover
Acacia citrinoviridis	5	1.5
Acacia incurvaneura	3.5	3
Acacia kempeana	1.1	0.1
Acacia ramulosa var. *ramulosa*	1.3	0.1
Acacia rhodophloia	3.5	1
Aristida contorta	0.15	0.1
Calytrix desolata	1.3	0.5
Eragrostis eriopoda	0.35	0.1
Eremophila citrina	0.7	1.5
Eremophila exilifolia	0.6	0.1
Eriachne pulchella subsp. *pulchella*	0.08	0.1
Poaceae sp.	0.4	0.1
Psydrax latifolia	2.2	0.1
Ptilotus schwartzii	0.25	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	1.2	0.1

Abra Airstrip – AAr13

Site Details:

Described by: AB

Date: 4/10/2018

Type: Relevé

MGA Zone: 50J 664604mE 7275385mN

Environmental Variables:

Landform: Minor flowline, not incised

Slope: Level (0-3°)

Soils:

Soil Texture:	Sand
Soil Colour:	Reddish brown
Rock Type:	N/A

Impacts:

Waterlogging:	No - Prone to Flooding
Disturbance:	Feral scats, Feral trampling, Grazing
Introduced species:	Cattle

FLORA AND VEGETATION DATA

Description: *Acacia citrinoviridis, Acacia incurvaneura* and *Psydrax latifolia* tall open shrubland over *Eremophila citrina* and *Eremophila spectabilis* open shrubland over very scattered tussock grasses.

Veg Condition:	Excellent	Fire Age:	3 to 5 years
Weeds:	None	Fire Notes:	N/A

Table M: Species list

Species	Height	Cover
Acacia citrinoviridis	5	4
Acacia incurvaneura	4	4
Acacia rhodophloia	3.5	1
Acacia tetragonophylla	0.4	0.1
Eragrostis eriopoda	0.4	0.1
Eremophila ?granitica	1.1	0.1
Eremophila citrina	0.5	0.5
Eremophila spectabilis	1.1	0.5
Eriachne mucronata	0.2	0.1
Euphorbia boopthona/ tannensis	0.3	0.1
Grevillea berryana	1.5	0.1
Hibiscus coatesii	0.4	0.1
Poaceae sp.	0.5	0.1
Psydrax latifolia	2.5	1.5
Sida sp.	0.9	0.1

Abra Airstrip – AAr14

Site Details:

Described by: AB

Date: 4/10/2018

Type: Relevé

MGA Zone: 50J 664484mE 7274981mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Prone to Flooding

Disturbance: Grazing, Feral scats, Feral trampling, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia ramulosa* var. *ramulosa, Grevillea berryana* (*Acacia citrinoviridis*) tall shrubland over *Eremophila citrina, Solanum lasiophyllum* and *Senna* sp. Meekatharra open shrubland.

Veg Condition: Excellent

Fire Age: 3 to 5 years

Weeds: None

Fire Notes: N/A

Table N: Species list

Species	Height	Cover
Acacia citrinoviridis	7	0.5
Acacia incurvaneura	2.2	0.1
Acacia ramulosa var. *ramulosa*	2.4	12
Acacia tetragonophylla	3	0.1
Eremophila citrina	1.8	1
Eremophila jucunda subsp. *jucunda*	0.4	0.1
Grevillea berryana	2.1	0.1
Psydrax latifolia	3.2	1
Ptilotus schwartzii	0.25	0.1
Senna artemisioides subsp. *helmsii*	1.1	0.1
Senna sp. Meekatharra (E. Bailey 1-26)	1.4	0.5
Sida sp. Golden calyces	0.25	0.1
Solanum lasiophyllum	1.1	1

Abra Airstrip – AAr15

Site Details:

Described by: AB

Date: 4/10/2018

Type: Relevé

MGA Zone: 50J 664756mE 7275054mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture: Clay loam

Soil Colour: Reddish brown

Rock Type: N/A

Impacts:

Waterlogging: No - Prone to Flooding

Disturbance: Grazing, Feral scats, Feral trampling, Tracks

Introduced species: Cattle

FLORA AND VEGETATION DATA

Description: *Acacia ramulosa* var. *ramulosa, Acacia incurvaneura* and *Grevillea berryana* tall shrubland over *Eremophila citrina* and *Eremophila spectabilis* low shrubland over very scattered tussock grasses.

Veg Condition: Excellent

Fire Age: 3 to 5 years

Weeds: -

Fire Notes: N/A

Table O: Species list

Species	Height	Cover
Acacia incurvaneura	2.5	1
Acacia pruinocarpa	4.5	0.1
Acacia ramulosa var. *linophylla*	1.8	1
Acacia ramulosa var. *ramulosa*	2.8	15
Acacia rhodophloia	3	0.5
Eragrostis eriopoda	0.25	0.1
Eremophila citrina	0.8	1
Eremophila forrestii	1.2	0.1
Eremophila spectabilis	0.8	1
Eriachne mucronata	0.2	0.1
Grevillea berryana	5	1
Ptilotus schwartzii	0.25	0.1
Sida sp. Golden calyces	0.25	0.1
Solanum lasiophyllum	1.1	0.1
Triodia basedowii	0.25	0.1

Abra Airstrip – AAr16

Site Details:

Described by: AB

Date: 4/10/2018

Type: Relevé

MGA Zone: 50J 665050mE 7275309mN

Environmental Variables:

Landform: Plain

Slope: Level (0-3°)

Soils:

Soil Texture:	Sandy clay loam
Soil Colour:	Reddish brown
Rock Type:	N/A

Impacts:

Waterlogging:	No - Prone to Flooding
Disturbance:	Grazing, Feral scats, Feral trampling
Introduced species:	Cattle

FLORA AND VEGETATION DATA

Description: *Acacia ramulosa* var. *ramulosa, Grevillea berryana* and *Acacia rhodophloia* tall open shrubland over *Eremophila spectabilis, Eremophila forrestii* and *Senna artemisioides* subsp. *helmsii* low shrubland over *Eriachne eriopoda* open tussock grassland.

Veg Condition:	Excellent	Fire Age:	3 to 5 years
Weeds:	None	Fire Notes:	N/A

Table P: Species list

Species	Height	Cover
Acacia incurvaneura	4	1
Acacia ramulosa var. *linophylla*	2.1	1
Acacia ramulosa var. *ramulosa*	1.2	0.1
Acacia rhodophloia	4	2
Aristida contorta	0.15	0.1
Eragrostis eriopoda	0.4	2.5
Eremophila forrestii	1.1	5
Eremophila spectabilis	1.2	7
Grevillea berryana	4	1
Senna artemisioides subsp. *helmsii*	1.8	1
Senna sp. Meekatharra (E. Bailey 1-26)	1.8	0.1
Triodia basedowii	0.25	0.1

Abra Airstrip – AAmn02

Site Details:

Described by: AB

Date: 4/10/2018

Type: Mapping note

MGA Zone: 50J 664576mE 7274997mN

Environmental Variables:

Landform: Minor flowline

Slope: Level (0-3°)

FLORA AND VEGETATION DATA

Description: *Acacia incurvaneura*, *Acacia citrinoviridis* and *Acacia rhodophloia tall* open shrubland over *Calytrix desolata* scattered shrubs over *Eremophila citrina* scattered low shrubs and very scattered tussock grasses

Veg Condition:	Excellent	Fire Age:	3 to 5 years
Weeds:	None	Fire Notes:	N/A

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