Evolution MINING
Mungari

ACN 002 124 745

Mungari Operations
P +61 8 9268 4024
F +61 8 9022 7411
Kundana Road
Kalgoorlie WA 6430

Registered Office
P +61 2 9696 2900
F +61 2 9696 2901
Level 30
175 Liverpool Street
Sydney NSW 2022

www.evolutionmining.com.au

20 June 2022

Department of Mines, Industry Regulation and Safety
Mineral House
100 Plain Street
East Perth WA 6004

To Whom It May Concern

Application for a Native Vegetation Clearing Permit for Golden Hind, Hornet and Pegasus Projects

Evolution Mining (Evolution) is proposing to commence mining of the Golden Hind, Hornet and Pegasus deposits as part of the existing Mungari Gold Operations (MGO).

This letter has been prepared to support an application for a Native Vegetation Clearing Permit (NVCP) in pursuant to Section 51E of the *Environmental Protection Act 1986* (EP Act).

The total disturbance envelope comprises land within mining tenements M15/669, M15/993 and M16/309 and miscellaneous tenement L16/104. This application proposes a total allowable clearing area of **650 ha**.

CONTENTS

FIGURES

TABLES

ANNEXES

Annex I: Proof of Ownership

APPENDICES

Appendix A: Soil Characterisation for Golden Hind (SoilWater 2021)

Appendix B: Soil Characterisation for Hornet (SoilWater 2010)

Appendix C: Soil Characterisation for Pegasus (SoilWater 2020)

Appendix D: Groundwater Assessment (Aquaterra 2003)

Appendix E: Surface Water Assessment for Kundana (RPS 2020)

Appendix F: Surface Water Management Strategy for Hornet (Aquaterra 2003)

Appendix G: Flora, Vegetation and Fauna Survey (Botanica 2020)

1 Background

The Project is located approximately 25 km north of the Township of Coolgardie and 4 km north-west of Evolution’s existing Mungari Processing Plant (MGO) (**Figure 1-1**).

The Golden Hind, Hornet and Pegasus Open Pits are situated in a greenfields area that has not been previously mined. The Projects are located within a 1 km radius of the Rubicon-Hornet-Pegasus (RHP) underground mine. Mining at RHP began in 2002 with the Rubicon Stage 1 Open Pit (Notice of Intent **(NOI) 3825)**. In 2008, underground mining of the Rubicon, Hornet and Pegasus deposits commenced via a portal in the Rubicon pit **(Reg ID. 19883)** and has been actively mined since.

Regional Project Location

0 10
kilometers
GDA 94 / MGA Zone 51

N

Author: S. Tiller
Date: 16/06/2022

LEGEND

🟨	CPS Disturbance Envelope

Evolution MINING
Mungari

Figure 1-1: Regional Project Location

2 Proposed Works

The Hornet Open Pit Mining Proposal **(Reg ID. 29733)** was approved by the Department of Mines, Industry Regulation and Safety (DMIRS) on 30 March 2011.

A Mining Proposal for Golden Hind and Pegasus is currently being drafted and is scheduled for submission to DMIRS in the next 6 months.

As there is potential for this project to expand in the future, Evolution is requesting a total allowable clearing area of **650 ha** on the clearing permit to allow the flexibility to expand the project footprint without the requirement for seeking amendment if changes to design remain within the proposed disturbance envelope.

2.1 Tenements

Clearing will occur on the Mining and Miscellaneous leases listed in **Table 2-1** and shown in **Figure 2-1.**

Table 2-1: Tenement Details Summary

Tenement	Holder 1	Holder 2	Holder 3	Area (ha)
M 15/669	Kundana Gold Pty Limited	-	-	938.60
M 15/993	Gilt-Edged Mining Pty Limited	Rand Mining Limited	Tribune Resources NL	704.95
M 16/309	Gilt-Edged Mining Pty Limited	Rand Exploration NL	Tribune Resources NL	939.20
L 16/104	Kundana Gold Pty Limited	-	-	113.00

Kundana Gold Pty Limited and Gilt-Edged Mining Pty Limited are wholly owned subsidiaries of Evolution Mining Limited. Proof of Evolution’s tenement holdings is provided in **Annex 1** along with letters of consent from holders Rand Exploration NL, Rand Mining Limited and Tribune Resources NL.

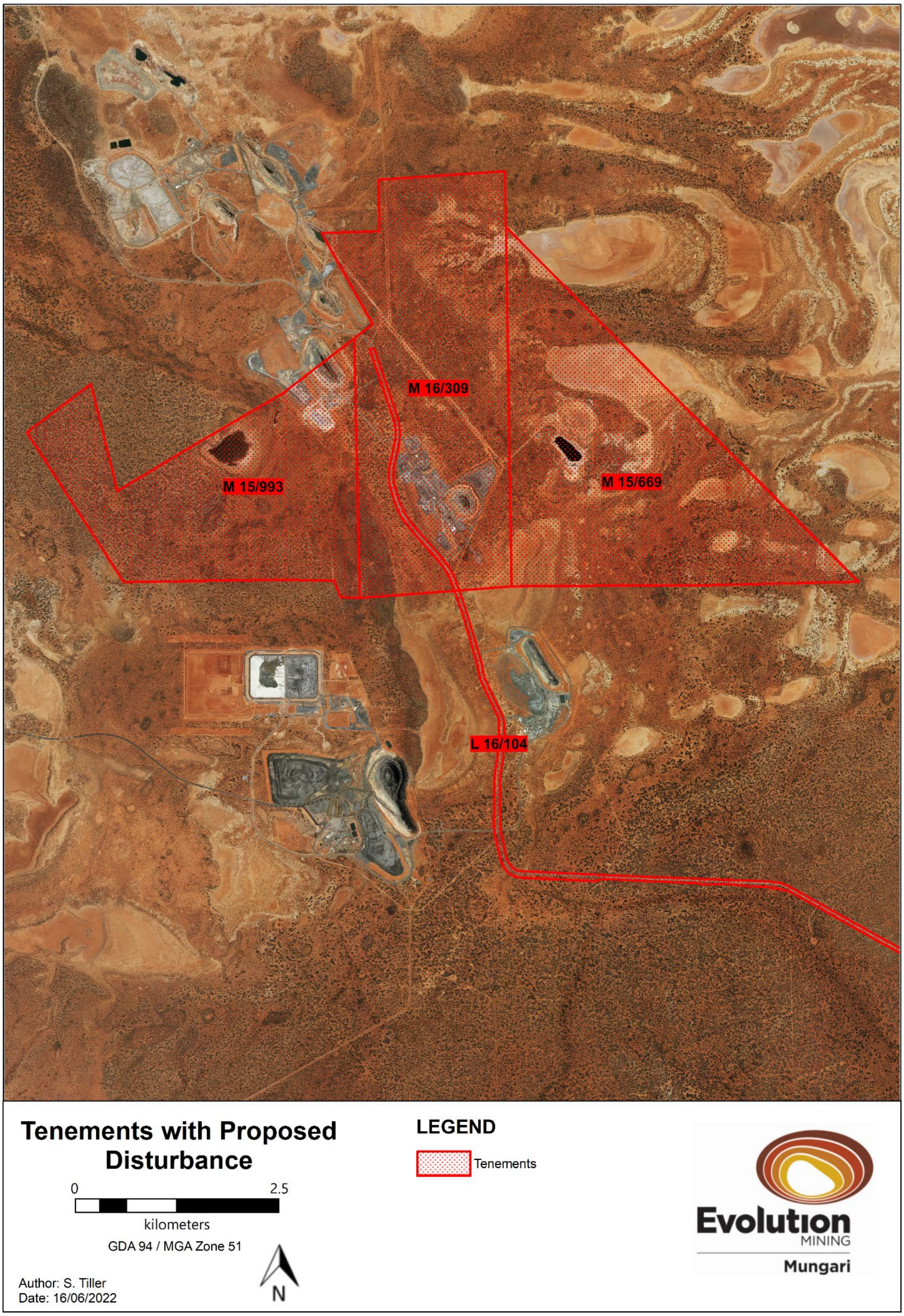


Figure 2-1: Map of Tenements

2.2 Disturbance Envelope

The disturbance envelope encompasses an area of **650 ha** as shown in **Figure 2-2.** To ensure operational flexibility in both design and siting, Evolution proposes to undertake a predetermined area of clearing per tenement while remaining confined to the disturbance envelope. This clearing will facilitate the construction of the following:

- Open Pit Mining Voids;
- Waste Rock Landforms (WRL);
- ROM Pads;
- Saline water dams;
- Haul roads;
- Explosives magazine;
- Laydown area;
- Topsoil stockpiles;
- Pipelines;
- Transport and service infrastructure corridors;
- Abandonment bunding; and
- Miscellaneous buildings / support infrastructure.

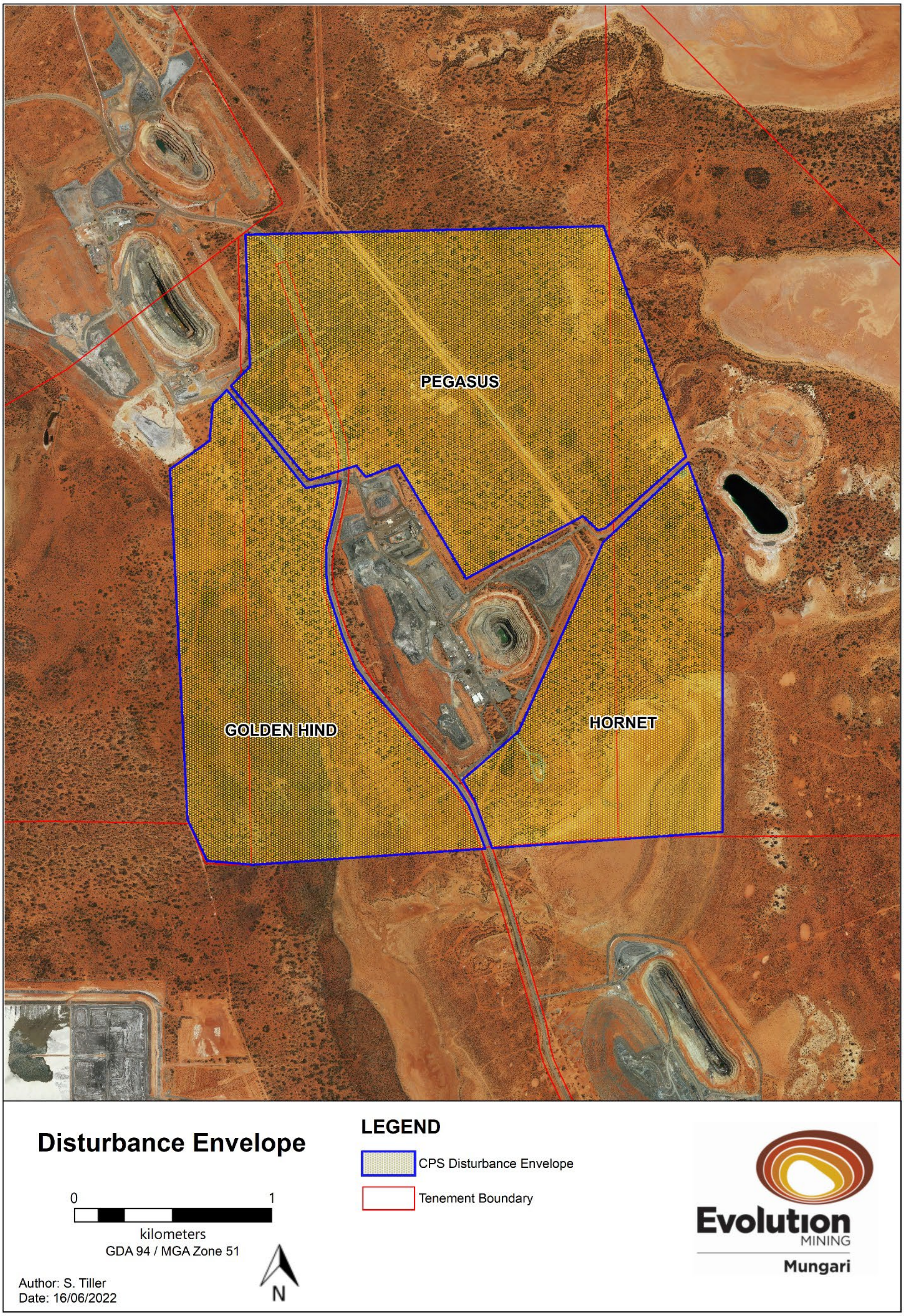


Figure 2-2: Map of Disturbance Envelope

3 Existing Environment

3.1 Landscape

3.1.1 Bioregion

The Project area lies within the Eastern Goldfields (COO3) subregion of the Coolgardie Bioregion, as defined by the Interim Biogeographic Regionalisation of Australia (IBRA). The Eastern Goldfields subregion (5,102,428 ha) lies on the Yilgarn Craton's Eastern Goldfields Terrain, which is described as gently undulating plains with a subdued relief, interrupted in the west with low hills and ridges of Archaean greenstones and in the east by a horst of Proterozoic basic granulite. The underlying geology is of gneisses and granites eroded into a flat plane covered with tertiary soils and with scattered exposures of bedrock. Calcareous earths are the dominant soil group and cover much of the plains and greenstone areas. A series of large playa lakes in the western half are the remnants of an ancient major drainage line (Cowan 2001).

The vegetation consists of Mallees, Acacia thickets and shrub-heaths on sandplains, with diverse *Eucalyptus* woodlands occurring around salt lakes, on ranges, and in valleys. Salt lakes support dwarf shrublands of samphire. Woodlands and *Dodonaea* shrubland occur on basic granulite of the Fraser Range, and the area is rich in endemic Acacias.

In accordance with Beard (1990) the Project area is located in the Coolgardie Botanical District of the Southwestern Interzone Province. The landscape is described as gently undulating with occasional ranges of low hills, with sandplains in the western part and some large playa lakes. Soils are principally brown calcareous earths, which overlays the Proterozoic granite and gneiss of the Fraser Range block and Archaean granite, with infolded volcanics and meta-sediments, of the Yilgarn block. Vegetation is predominately *Eucalyptus* woodlands, with slopes and flats containing

E. longicornis alongside *E. salubris* and *E. salmonophloia*. Woodland understories range from tall sclerophyll shrubland dominated by *Melaleuca pauperiflora* to soft-leaved saltbush shrubland of *Atriplex vesicaria* and *A. nummularia*. Some hill slopes contain mallees of *E. livida* or *E. loxophleba*, while ironstone ridges are covered in thickets of *Acacia quadrimarginea*, *Allocasuarina acutivalvis* and *A. campestris*. Other vegetation assemblages include species-rich scrub-heaths and *Allocasuarina* thickets on sandplains, merging into *Acacia* thickets and Kwongan vegetation to the north.

3.1.2 Landscape Systems

The Project area lies within the Kalgoorlie Province, located in the southern Goldfields between Paynes Find, Menzies, Southern Cross and Balladonia. The landscape consists of undulating plains (with some sandplains, hills and salt lakes) on the granitic rocks and greenstone of the Yilgarn Craton. Soils range from calcareous loamy earths and red loamy earths with some salt lake soils to red deep sands, yellow sandy earths, shallow loams and loamy duplexes. Vegetation communities are predominately Eucalypt woodlands with some acacia-casuarina thickets, mulga shrublands, halophytic shrublands and spinifex grasslands.

The Kalgoorlie Province is further divided into six soil-landscape zones, with the Project area located within the Kambalda Zone (265). This zone is located in the south-eastern Goldfields between Menzies, Norseman and the Fraser Range and contains flat to undulating plains (with hills, ranges and some salt lakes and stony plains) on greenstone and granitic rocks of the Yilgarn Craton. Soils consist of calcareous loamy earths and red loamy earths with salt lakes soils and some red-brown hardpan shallow loams and red sandy duplexes. Vegetation includes red mallee, blackbutt-salmon gum-gimlet woodlands with mulga and halophytic shrublands (and some spinifex grasslands).

The Kambalda Zone is further divided into soil landscape systems, with the Project area located within two soil landscape systems, as shown in **Table 3-1** and **Figure 3-1**, in accordance with soil landscape system mapping data (Government of Western Australia, 2019).

Table 3-1: Soil Landscape Systems

Soil Landscape System	Description
Mx43	Gently undulating valley plains and pediments; some outcrop of basic rock
SV15	Salt lakes and their associated areas

3.1.3 Land Use

The Project is located on the Mungari pastoral lease (N049482) which supports the grazing of cattle and other pastoral activities.

The Project is not within proximity to any conservation parks or reserves. The nearest reserve is the Kurrawang Nature Reserve, located 12 km south-east of the Project area. Rowles Lagoon Nature Reserve and the Clear and Muddy Lake Nature Reserve are located 50 km north-west of the Project.

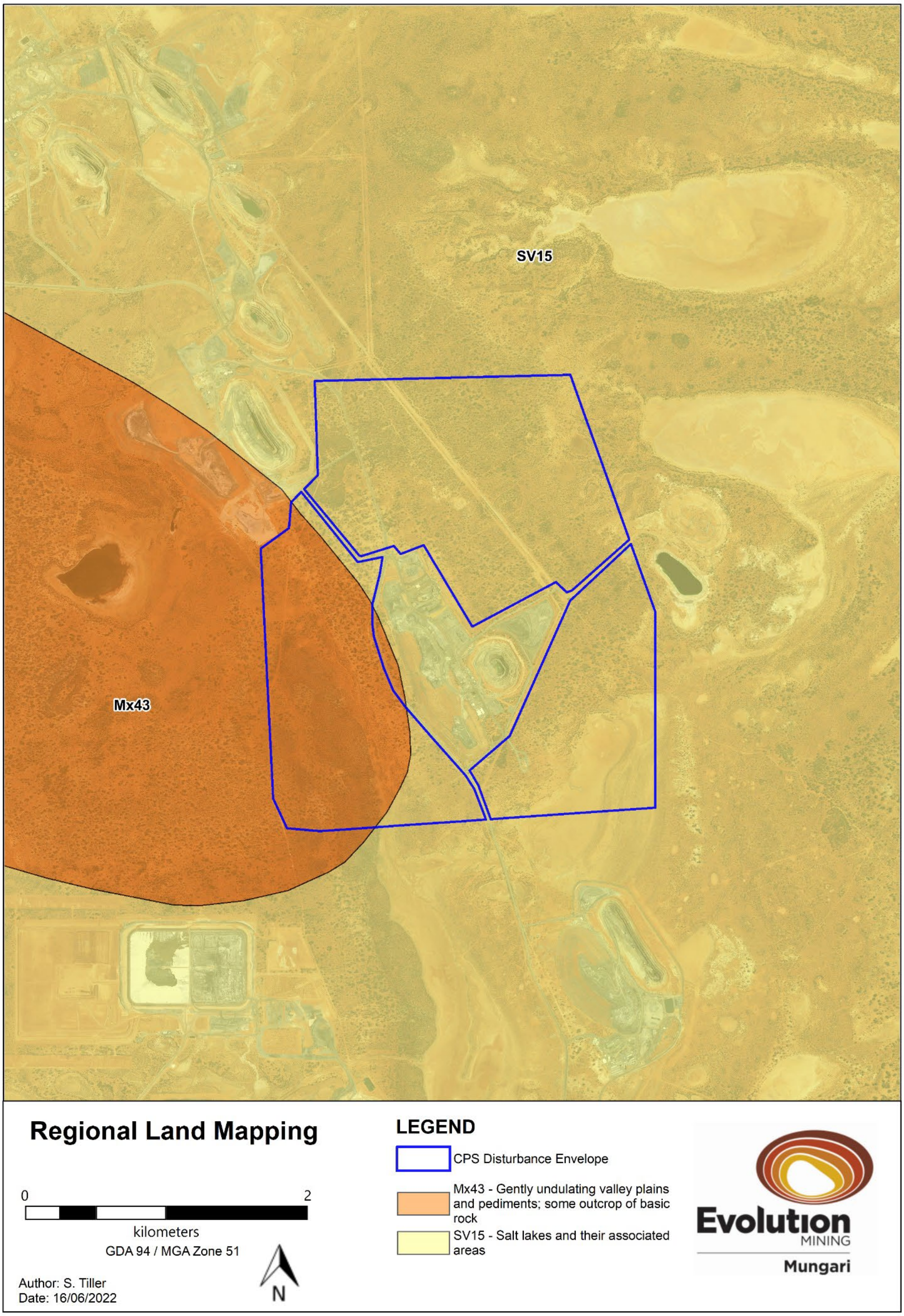


Figure 3-1: Map of Soil Landscape Systems

3.2 Geology

The area is dominated by mafic and ultramafic rocks with minor sedimentary units which have undergone extensive weathering to form deep regolith profiles. The in situ regolith profile has been found to be consists of 15 – 60 m of saprolite and a 10 – 20 m thick transitional or saprock zone. The thickness of the in-situ regolith increases towards zones which have experienced high deformation in the past, such as is found along the Centenary Shale contact. The upper surface of the saprolite has been truncated and subsequently filled with a 4 – 8 m thick transported alluvial cover. The thickness of the transported sediments increases to the south of the deposit, where it reaches a thickness of around 70 m beneath Lake Kopai. A map of the regional geology is provided in **Figure 3-2** (SoilWater 2021; SoilWater 2010).

The Golden Hind deposit is found within a NNW striking Greenstone belt in the Kalgoorlie Terrane of the Eastern Goldfields province of the Yilgarn Craton which is of Achaean age. This shear zone is labelled the K2 shear zone and is part of a 250 km long, NNW striking structural corridor which separates the Ora Banda and Coolgardie Domains Exposure of outcrop locally is extremely sparse with the majority of the area covered by colluvium or laterite formations over the deeply weathered bedrock (SoilWater 2021).

The Hornet deposit is hosted within the Centenary Shale, which occurs at the contact with the Victorious (Catrock) Basalt (western side) and Intermediate Andestic Tuff (Sparoville Formation; eastern side). The contact and subsequent structure of the Centenary Shale is steeply dipping to the west, trending in a north – south direction through the Hornet deposit (SoilWater 2010).

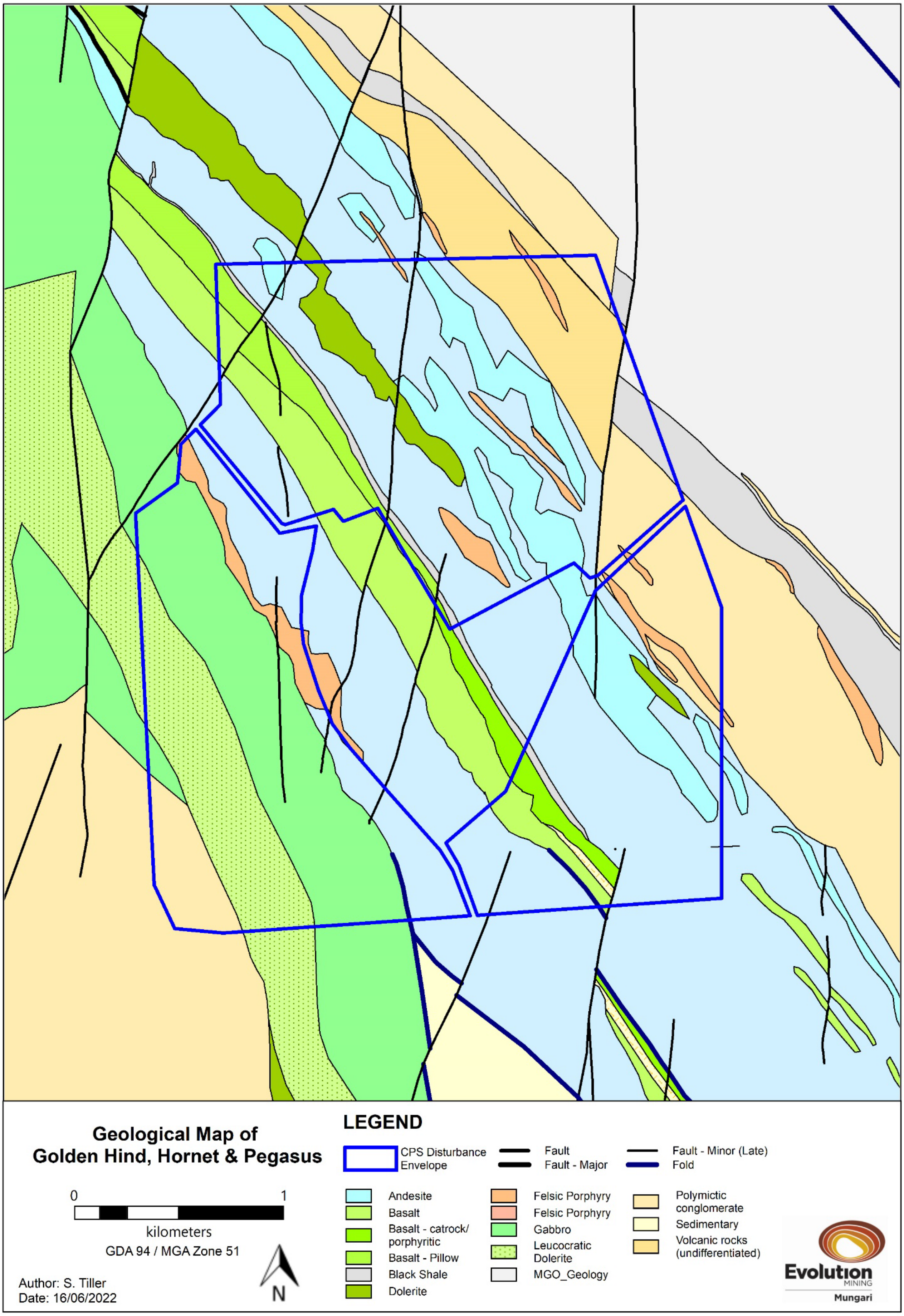


Figure 3-2: Geological Map of the Project

3.3 Soils

Soil characterisation for the Golden Hind area was undertaken by SoilWater in February 2021 (**Appendix A**) for the Hornet area in December 2010 (**Appendix B**) and for the Pegasus area in June 2020 (**Appendix C**).

Soil materials within the Project area were investigated by shallow trench excavation for inspection and sampling. Shallow trenches were excavated to a maximum depth of 1.3 m. A total of 26 sampling sites were investigated; 7 at Golden Hind, 13 at Hornet and 6 at Pegasus as shown in **Figure 3-3.** Samples were collected at 10 cm intervals down the surficial profile to ensure that any pedologic organisation or horizonation was identified and that each of the major soil materials was sampled. Approximately 3kg of soil was collected for each material for detailed laboratory analysis (SoilWater 2010, 2020, 2021).

Based on the morphological characteristics of the soil profiles exposed by trench excavation, five distinct Soil Mapping Units (SMU) were defined across the Golden Hind, Hornet and Pegasus Project areas. These are detailed in **Table 3-2** below and mapped in **Figure 3-3** (SoilWater 2010, 2020, 2021).

Table 3-2: Soil Mapping Units

ID	SMU	Description
1	Calcareous Loamy Earth	This is the dominant soil type in the Golden Hind Project area and is likely to be the only soil type encountered. SMU 1 consists of a 5 – 10 cm thick surface layer of reddish-brown medium - coarse aeolian sand to loamy sandy overlying a reddish brown friable well-structured silty loam. The top 5cm of the sand often forms a crust with defined horizontal structuring.
2	Deep Calcareous Sandy Loam	This is the dominant soil type in the Hornet and Pegasus areas. It consists of a 5 – 15 cm thick surface layer of reddish-brown medium - coarse aeolian sand to loamy sandy overlying a reddish brown friable well-structured sandy loam.
3	Truncated Calcareous Sandy Loam	This soil type is equivalent to SMU 2, although the surface 50 – 100 cm has been previously excavated and removed from site, resulting. In SMU 3 the surface sand, reddish brown sandy loam, evaporite (calcareous) layer has been removed, leaving the underlying brown sandy clay loam exposed at the surface. This material is structurally unstable due to its high sodicity and subsequently it is potentially dispersive.
4	Deep Calcareous Coarse Sand	This SMU represents a minor soil type in the project area. It occurs as a narrow strip fringing the salt lake and it is likely to represent an accumulation of medium to coarse aeolian sand deposited by the prevailing winds across Lake Kopai. This soil type supports the fringing samphire vegetation.
5	Saline Clay	This soil type occurs within Lake Kopai and consists of a surface cover of alluvial brown sandy clay over a well-structured pallid (white) heavy clay. The soils are extremely saline with highly alkaline pH values. They are nutrient deficient with very low mineralised N and Colwell P, but have elevated Colwell K and extractable S in response to mobilisation and subsequent deposition in the lake system.

The Calcareous Loamy Earth (SMU1) and Deep Calcareous Loamy Earth (SMU2) are the optimal soil materials for stripping and rehabilitation in the Project area as they exhibit the best structure and stability. Topsoil will be stripped to a nominal depth of approximately 200mm and stored appropriately for rehabilitation purposes. When stripping topsoil, dust suppression may be undertaken using fresh water. No saline water will be used for dust suppression on topsoil materials. Stockpiles should not exceed 2 m in height to maintain the soils biological component and retention of any nutrient sources (SoilWater 2010, 2020, 2021).

When respreading these soils as part of rehabilitation works, risks associated with erosion must be considered. Placement of sodic and potentially dispersive materials on steep batter slopes can result in significant gullies and erosion. SMU1 and SMU2 are the optimal soils for use on slopes. Fresh competent rock may be mixed with the soil for use on the WRD slopes to limit the potential for dispersion and erosion. Truncated Calcareous Sandy Loam (SMU3) is not recommended for use on slopes; however, can be used for rehabilitation of flat surfaces where required. Disturbance of the Deep Calcareous Coarse Sand (SMU4) and Saline Clay (SMU5) is unlikely to occur during mining. Calculations have confirmed that there is a sufficient amount of topsoil available to rehabilitate the Project area (SoilWater 2010, 2020, 2021).

All topsoils in the Project area are typically nutrient deficient with only a minor accumulation of organic matter; however, native vegetation is adapted to grow in low nutrient status conditions. The WRD will be seeded with provenance species that reflect the surrounding landscape. The surface 30 cm of the soil profile is generally non-saline, with no chemical or physical limitations to plant growth (SoilWater 2010, 2020, 2021).

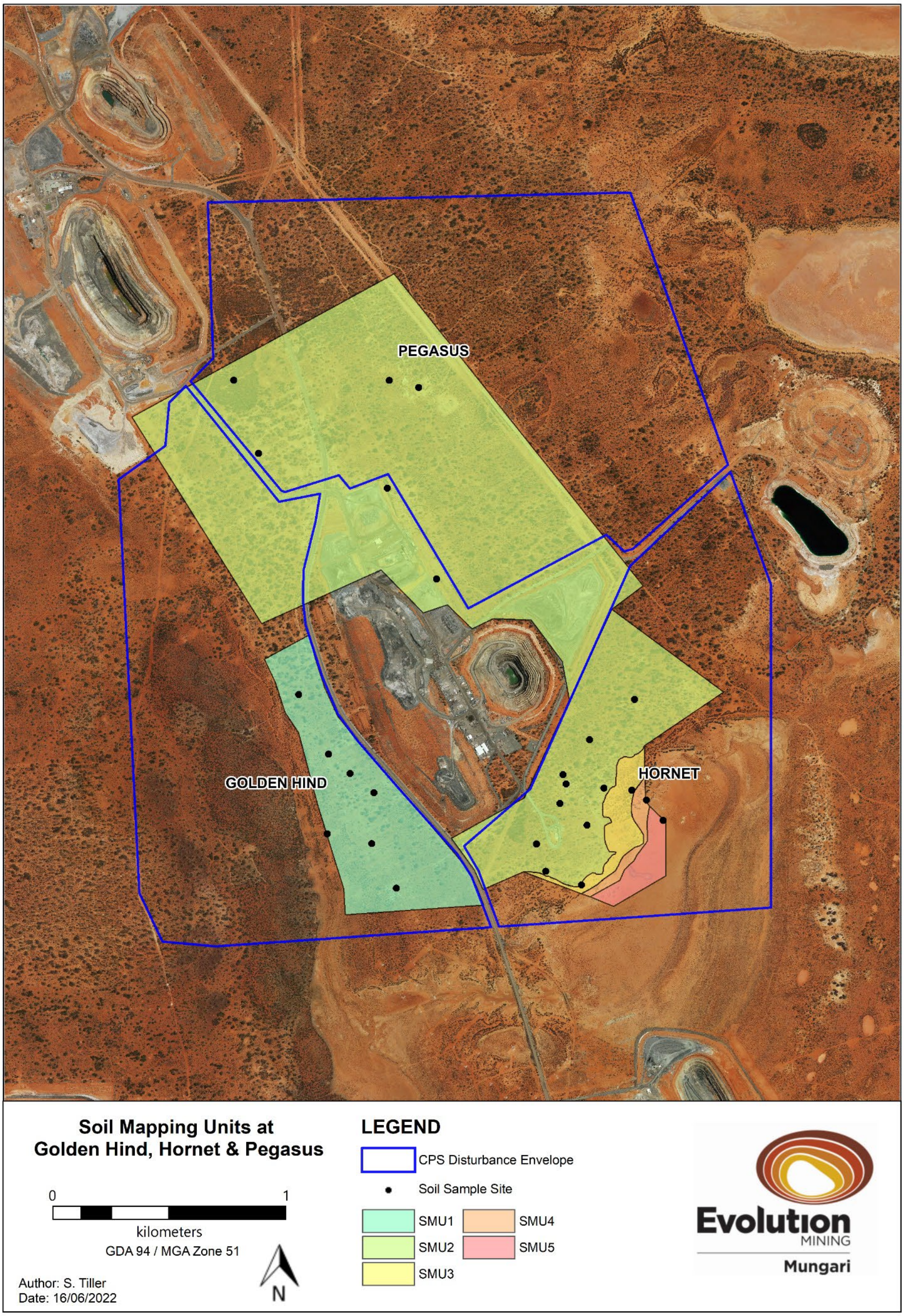


Figure 3-3: Map of Soil Mapping Units (SMUs)

3.4 Hydrology

3.4.1 Groundwater

Numerous hydrogeological studies have been carried out over the Kundana area. A groundwater study by Aquaterra (**Appendix D**) was carried out in 2003 to assess the dewatering requirements for mining, the potential impacts of dewatering, and the nature of the final pit void.

Geologically and structurally, the Project is similar to other mined projects located on the Centenary Structure, including the Rubicon and Raleigh Projects. The basement rock and saprolite/transition zones host a number of aquifers. The shallow saprolites (and overlying alluvium) form unconfined aquifers, while the deeper weathered and fresh rock form semi-unconfined to semi-confined aquifers. The aquifers are generally of low overall permeability, although significant local permeability can be present associated with fractured and or mineralised zones (Aquaterra 2003a).

The Kundana area is located within a major easterly flowing regional surface drainage system. The drainage system which overlies but is much broader than the Tertiary paleochannels, is characterised by numerous ephemeral lakes and salt pans (Aquaterra, 2000).

The regional water table is generally around 5–20m below surface in the Kundana area. The results from drilling indicate that the depth to water in the vicinity of the Project is at the deeper end of this range (ie 10–20m). The lake sediments become partially saturated during flood events but do not constitute a significant aquifer. There is little to no recharge of the water table by infiltration of floodwaters through the Lake sediments (Aquaterra 2003a).

The groundwater in the region is hypersaline, with salinity (TDS) levels up to 150,000 mg/L. The pH is considered slightly acidic to neutral with a 6.4 average and electrical conductivity (EC) levels range from 188,000 to 218,000 µS/cm. All of the groundwater samples collected from Rubicon in 2021 have a similar chemical composition and are dominated by sodium and chloride (AQ2 2022).

Approval to abstract groundwater has been obtained from the Department of Water and Environmental Regulation. Groundwater Well Licence **(GWL) 109476(8)** authorises the taking of water for mining purposes and dust suppression. A works approval for dewatering will be sought from the Department of Water and Environmental Regulation (DWER). Saline (or brackish) dewatering discharge will either be used for dust suppression in the immediate Project area or as an additional source of water for ore processing.

Groundwater extraction associated with dewatering of the Castle Hill mine pits or development of the Kunanalling palaeovalley aquifer is highly unlikely to have adverse impacts on the respective aquifers, the environment (groundwater dependent ecosystems) or other groundwater users. the groundwater is hypersaline and therefore unlikely to be essential for survival of the native vegetation (Rockwater, 2014).

3.4.2 Surface Water

Regional drainage is dominated by a large catchment extending 55 km to the west of Kundana, with a total catchment area of approximately 1,200 km^2. This system feeds a major drainage line running generally from west to east, terminating at the Kopai Lake system to the south. Overtopping from this system discharges to the north of the Project area en route to White Flag Lake (WFL) (Aquaterra 2001).

The general catchment topography comprises of numerous depressions with the occasional major drainage channels. As runoff starts to occur, depressions are filled until over-topping occurs, and water then flows onto the next depression. This process continues until all minor depressions are interconnected (Aquaterra 2001).

A Kundana surface water assessment was carried out in October 2020, attached as **Appendix E**. The main creek draining the large Western Catchment flows to Bullock Hole Dam via diversion bunding located approximately 2 km north-west of the Project area. A rock lined spillway is located at the top of the diversion bund to allow high level flood waters to reduce the retained storage level of the dam and to bypass excess flood flows to Kopai Lake as shown in **Figure 3-4** (RPS 2020).

A surface water management strategy for the Hornet open pit **(Reg ID. 29733)** was prepared in September 2003 (**Appendix F**). The pit will be located partially within Kopai Lake and therefore will be potentially subjected to inundation from floodwaters. All flood protection bunds will need to fully enclose the pit and tie into high ground to prevent the entry of external floodwaters. All other mine infrastructure will be located outside of the lake. Modelling indicated that the pit and flood protection bunding will have a negligible impact on lake flood levels (Aquaterra 2003b).

Surface water studies will be carried out for the Golden Hind and Pegasus Project and management plans will be developed to be included as part of the upcoming Mining Proposal application.

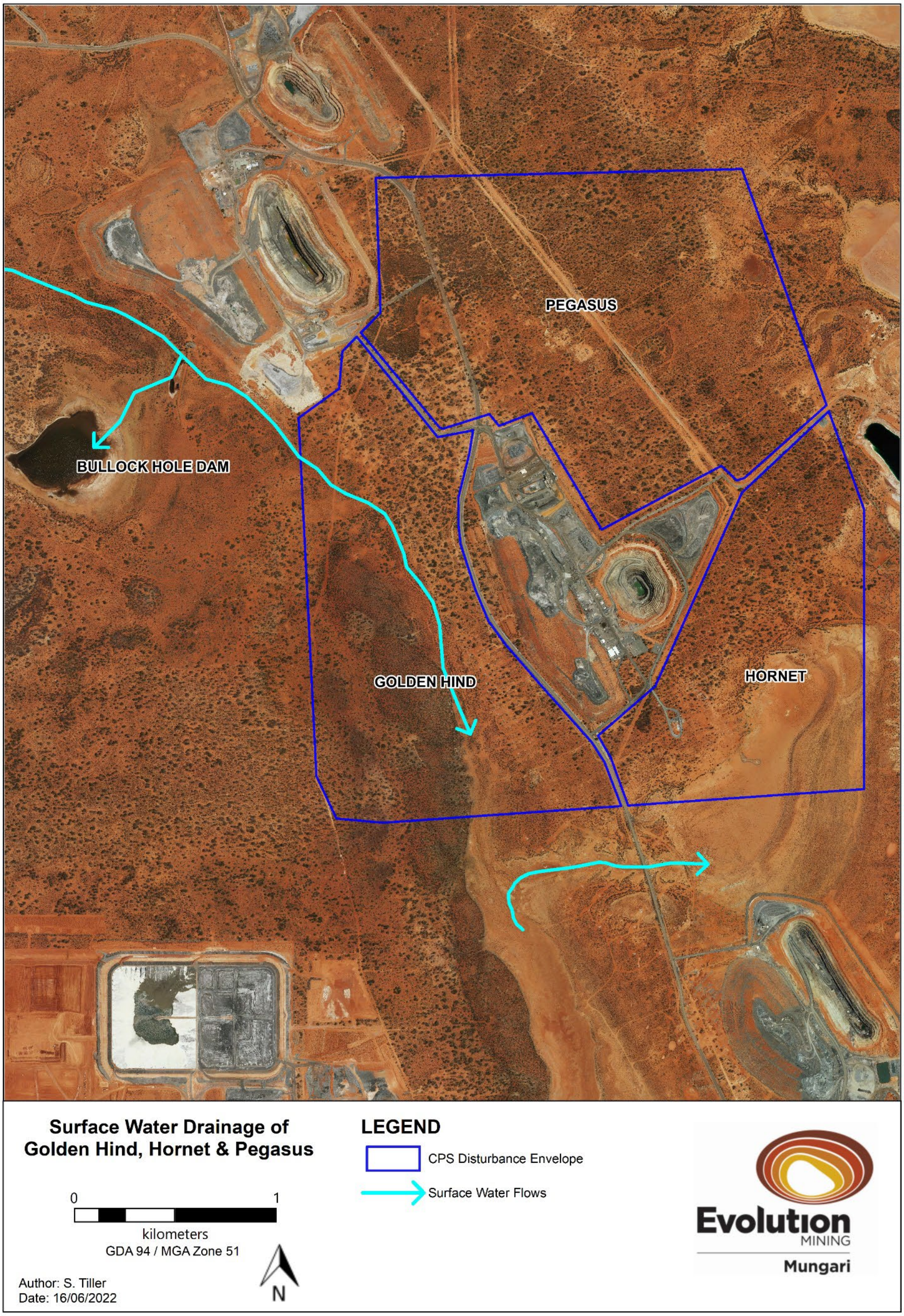


Figure 3-4: Map of Surface Water Drainage

3.5 Flora & Vegetation

A flora and fauna study was carried out by Botanica Consulting in September 2020 over the Golden Hind, Hornet and Pegasus Project area (**Appendix G**). This study is attached as Appendix F. An area of 210 ha was surveyed at Golden Hind, 156 ha at Hornet and 283 ha at Pegasus (Botanica 2020).

3.5.1 Vegetation Associations

The Pre-European vegetation association dataset (DPIRD 2019) indicates that the survey area is located within three vegetation associations. The association descriptions and remaining extent, as specified in the 2018 Statewide Vegetation Statistics (DBCA 2019) is provided in **Table 3-3**. Areas retaining less than 30% of their pre-European vegetation extent generally experience exponentially accelerated species loss, while areas with less than 10% are considered “endangered” (EPA 2000). All vegetation associations retain >90% of their Pre-European extent. Development within the survey area will not significantly reduce the extent of pre-European vegetation of these association (Botanica 2020).

Table 3-3: Pre-European Vegetation Associations

Vegetation Association	Current Extent (ha)	Pre-European Extent Remaining (%)	Extent within survey area (ha %)	Structural Description	Floristic Description
Coolgardie 125	3,146,487	90.3	142 ha (21.9%)	Salt Lake, lagoon, clay pan	-
Coolgardie 468	583,902	98.6	258 ha (39.8%)	Woodland other	Goldfields; gimlet, redwood etc. *E. salubris, E. oleosa.* Riverine; rivergum *E. camaldulensis*
Coolgardie 540	200,158	98.98	249 ha (38.4%)	Saltbush and/or bluebush with scattered low trees	Mulga, other wattle, casuarina *Atriplex* spp. *Maireana* spp. with *Acacia aneura, A. papyrocarpa, Casuarina pauper*

3.5.1 Vegetation Types

A total of seven vegetation communities were identified within the survey area. Vegetation community description and extent are listed in **Table 3-4** and shown in **Figure 3-5**. Vegetation community descriptions and extents were determined from field survey results, aerial imagery interpretation and extrapolation of the communities (Botanica 2020).

The survey found CLP-EW1 to be the most diverse community, with 44 flora species, and CD-CSSSF1 the least with 5 species. CLP-EW1 was the most widespread community in the survey area, occupying 253 ha (39.0%), while RP-CFW1 was the most restricted with 25 ha (3.9%) (Botanica 2020).

Table 3-4: Vegetation Types

Vegetation Type & Extent	Broad Floristic Formation (NVIS III)	Vegetation Description (NVIS V)	Landform	Representative Photo
CLP-EW1 253 ha (39%)	Eucalyptus low open woodland	*Eucalyptus salmonophloia, Eucalyptus salubris and Eucalyptus lesouefii* low woodland over *Eremophila scoparia, Eremophila decipiens* mid shrubland over *Atriplex vesicaria*, *Olearia muelleri* low shrubland.	Clay/loam plain	
CLP-EW2 44 ha (6.8%)	Eucalyptus low closed woodland	*Eucalyptus clelandii* closed woodland over Olearia muelleri low sparse shrubland.	Clay/loam plain	
RP-CFW1 25 ha (3.9%)	Casuarina open forest	*Casuarina pauper* open forest over *Acacia hemiteles* mid open shrubland over *Atriplex nummularia* low open shrubland.	Undulating plains	
CLP-PMNV1 71 ha (10.9%)	Chenopod open shrubland	Open mixed chenopod shrubland	Flats	
CD-CSSSF1 30 ha (4.6%)	Samphire low open shrubland	*Tecticornia indica* subsp. *indica* low open shrubland	Low-lying areas.	
SLP-EW1 158 ha (24.3%)	*Eucalyptus* woodland	*Eucalyptus clelandiurm*woodland over *Eremophila parviflora, Exocarpos aphyllus* open shrubland.	Slight rises	
SLP-MF1 46 ha (7.1%)		*Melaleuca pauperiflora* subsp. *pauperiflora, Melaleuca lateriflora* subsp. *lateriflora* mid shrubland over *Ptilotus obovatus* var. *obovatus*, *Maireana triptera* low open shrubland.	Riparian zone	

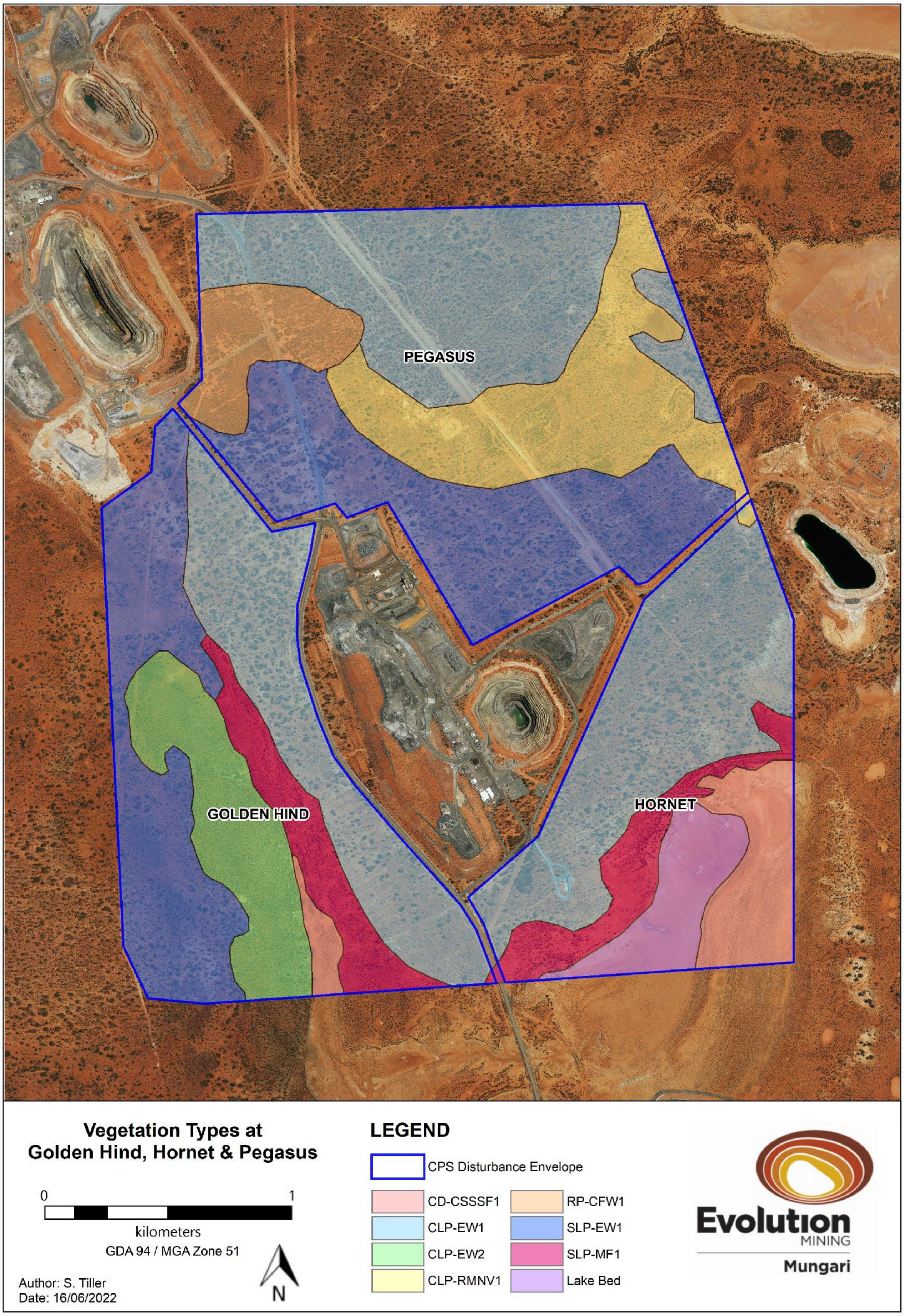


Figure 3-5: Map of Vegetation Types

3.5.2 Vegetation Condition

Based on the vegetation condition rating scale adapted from Keighery (1994) and Trudgen, (1988), native vegetation within the survey area was rated as 'good' (**Table 3-5**). 'Good' condition depicts more obvious signs of damage caused by human activity since European settlement, including impacts to vegetation structure and composition such as low levels of grazing and/or slightly aggressive weeds. Vegetation within the survey area has been subject to mining, exploration and pastoral land use disturbance. Cleared areas associated with road infrastructure and easement were rated as 'completely degraded' (Botanica 2020).

Table 3-5: Vegetation Condition Classifications

Vegetation condition	Area (ha)	% of Study Area	Description
Pristine	0	0	Pristine or nearly so, no obvious signs of damage caused by human activities since European settlement.
Excellent	0	0	Vegetation structure intact, disturbance affecting individual species. Damage to trees caused by fire, the presence of non-aggressive wees and occasional vehicle tracks.
Very Good	0	0	Vegetation structure altered, obvious signs of disturbance. Disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	632	97.4	Vegetation structure significantly altered by obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Degraded	0	0	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds at high density, partial clearing, dieback and grazing.
Completely Degraded	17	2.6	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.

3.5.3 Conservation Significant Vegetation

No significant vegetation (in accordance with the EPA *Environmental Factor Guideline for Flora and Vegetation* (EPA, 2016a)), including representatives of Threatened or Priority Ecological Communities were identified within the survey area (Botanica 2020).

3.5.4 Conservation Significant Flora

No Threatened or Priority flora species (in accordance with the EPA *Environmental Factor Guideline for Flora and Vegetation* (EPA, 2016a)) were recorded within the survey area. The previously recorded Priority 3 species *Notisia intonsa* was not observed. The Botanica (2010) flora survey determined that the vegetation community (*Casuarina* tall shrubland) associated with this record is unsuitable for the presence of this species, and this is likely an incorrectly located record. Areas of *Melaleuca* shrubland in riparian zones, which are more suitable habitat for *Notisia intonsa,* were searched extensively but no individuals of this species were located (Botanica 2020).

3.5.5 Introduced Flora and Weeds

Three species of introduced flora were recorded within the survey area:

- *Atriplex lentiformis* (Big saltbush);
- *Cucumis myriocarpus* (Gooseberry cucumber)*;* and
- *Nicotiana glauca* (Tree tobacco).

None of these species are a Weed of National Significance or a Declared Pest in Western Australia (Botanica 2020).

3.6 Fauna

The main aim of the fauna habitat assessment was to determine the likelihood of fauna species of conservation significance utilising the areas that may be impacted during site development. The habitat information obtained was also used to aid in finalising the overall potential fauna list.

During the field survey, the habitats within the study area were assessed and specific elements identified, if present, to determine the likelihood of listed threatened species utilizing the area and its significance to them. Opportunistic observations of fauna species were made during all field survey work which involved a series of transects across the study area during the day including observations of bird species with binoculars. Secondary evidence of a species presence such as tracks, scats, skeletal remains, foraging evidence or calls were also noted if observed/heard.

3.6.1 Habitats

A total of five broad scale terrestrial fauna habitats were identified, based on vegetation and associated landforms identified during the flora and vegetation assessment, with mixed Eucalyptus woodland being the most extensive (456 ha, 70.3%). The extent of the identified fauna habitats and a summary description of each are provided in **Table 3-6** and mapped in **Figure 3-6**.

Table 3-6: Fauna Habitats

Fauna Habitat Description	Area (ha)	Representative Photo
Open Eucalyptus Woodland	456 ha (70.3%)	
Chenopod Low Open Shrubland	100 ha (15.4%)	
Melaleuca Shrubland	46 ha (7.1%)	
Casuarina Open Forest	25 ha (3.8%)	
Bare Lakes / Playa	22 ha (3.4%)	

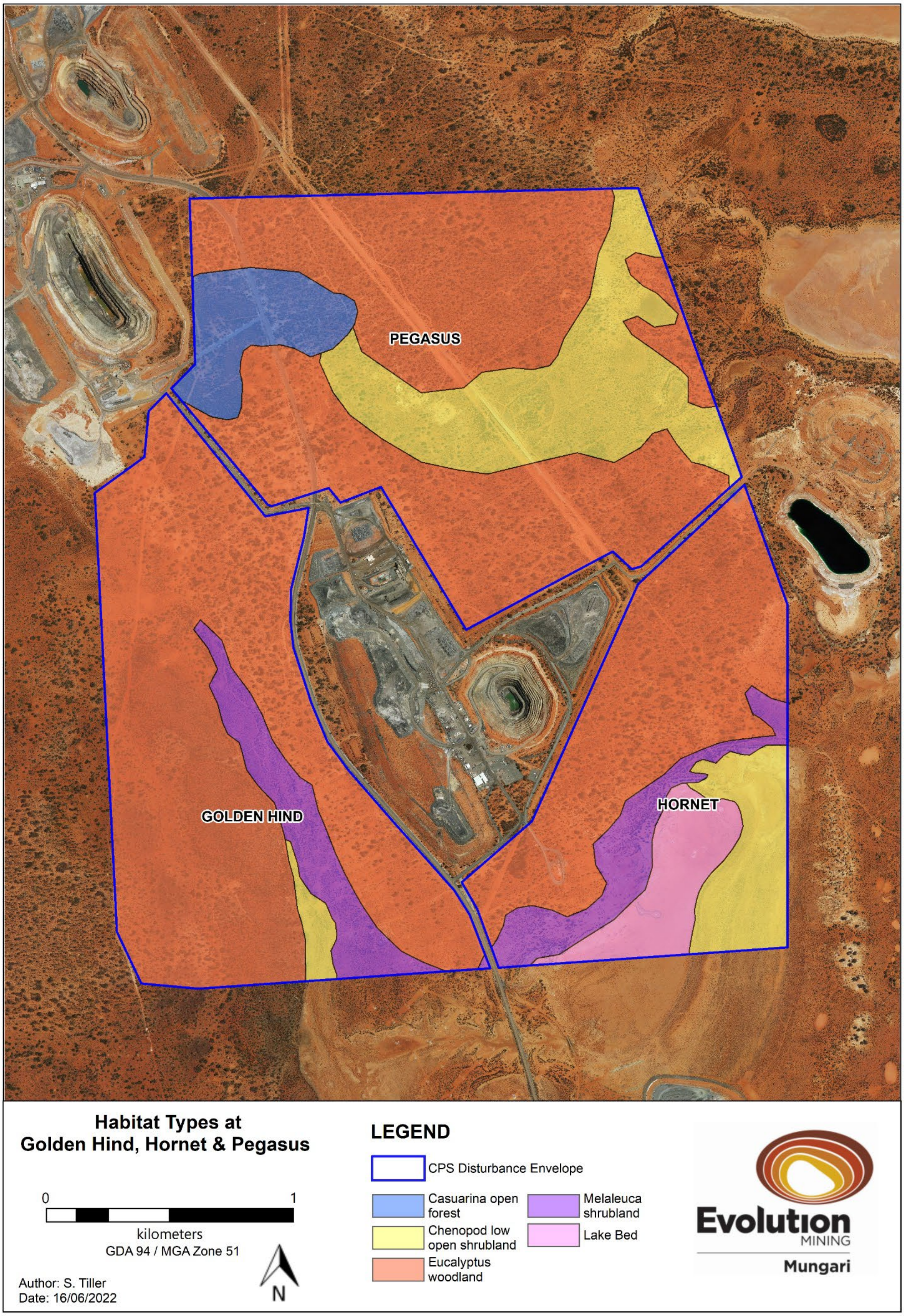


Figure 3-6: Map of Fauna Habitats

3.6.2 Conservation Significant Fauna

No evidence of significant fauna species (in accordance with the EPA *Environmental Factor Guideline for Terrestrial Fauna* (EPA, 2016b)) were observed during the survey, including no evidence of Malleefowl nesting mounds or other activity (Botanica 2020).

The current status of some species on site and/or in the general area is difficult to determine, however, based on the habitats present and, in some cases, direct observations or recent nearby records, the following species of conservation significance can be regarded as possibly utilising the survey area for some purpose at times, these being:

- **Malleefowl *Leipoa ocellata* – Vulnerable (EPBC Act and BC Act)**

  This species is occasionally recorded in the general area with the most recent record from 2016, with the species observed in the Bonnievale survey area, approximately 15 km south-west of the survey area (Terratree, 2016). Habitat appears marginal/or unsuitable for breeding, however occasional transients could potentially occur. No evidence of malleefowl activity (inactive or active mounds, tracks, feathers or bird observations etc.) were observed within the survey area. Significant impact unlikely.

- **Grey Falcon *Falco hypoleucos* – Vulnerable (EPBC Act and BC Act)**

  This species is sparsely recorded throughout inland Australia. Suitable habitat may be present but in unlikely to represent breeding or critical habitat. Significant impact unlikely.

- **Peregrine Falcon *Falco peregrinus* – Other Specially Protected (BC Act)**

  This species is recorded throughout inland Australia. Suitable habitat may be present but in unlikely to represent breeding habitat. Survey area may form part of larger home range but unlikely to breed in area. Significant impact unlikely.

- **Migratory wader (Various Species) – Migratory (EPBC Act and BC Act)**

  Migratory birds may utilize the lake and fringing environments following significant rainfall event; however, the fringing vegetation is of reduced quality, being subjected to multiple disturbances including historic mining and exploration, grazing, tracks and unlikely to support migratory bird populations/ breeding events.

It should be noted that while habitats onsite for one or more of the species listed above are considered possibly suitable, some or all may be marginal in extent/quality and therefore the fauna species considered as possibly occurring may in fact only visit the area for short periods as infrequent vagrants (Botanica 2020).

3.6.3 Short-Range Endemic (SRE) Species

Short range endemic (SRE) fauna are defined as animals that display restricted geographic distributions, nominally less than 10,000 km^2, that may also be disjunct and highly localised (Harvey 2002; Ponder & Colgan 2002). Currently, there is no accepted system to determine the likelihood that a species is an SRE. The WA Museum applies four categories: confirmed, potential, uncertain and not SRE. Confirmed SREs are taxa for which the distribution is known to be less than 10,000 km^2, the taxonomy is well known and the group is well represented in collections and/ or via comprehensive sampling (WA Museum 2013). Potential SREs include those taxa for which there is incomplete knowledge of the geographic distribution of the group and its taxonomy, and the group is not well represented in collections.

SRE species were not surveyed during the Botanica 2020 survey. A study of SRE species was carried out by Spectrum Ecology in 2019 at the Mungari TSF, located 3 km from the Project area with a very similar environment. During the survey, five potential SRE invertebrate fauna taxa were collected from the TSF Area, which is comparable with records made during previous surveys in the region. The SRE species identified are detailed in **Table 3-7** (Spectrum 2019).

Generally, SRE invertebrate species can be difficult to determine due to the uncertainties in determining their distributions. This is often due to the lack of surveys, under-collection of species, lack of taxonomic resolution, and problems in identifying certain life stages. Even when invertebrate species are collected, the majority of them are unknown, undescribed or poorly represented, therefore leaving uncertainties about their status and distribution outside the study areas (Harvey 2002; Harewood, 2014).

Table 3-7: SRE Species near the Project

Order	Family	Taxa	Sampling Type	Abundance	SRE Category
Pseudoscorpiones	Chernetidae	Chernetidae sp.	Leaflitter	1	Potential SRE
Isopoda	Armadilidae	*Buddlundia* 'BIS350'	Foraging, Leaflitter	2	Potential SRE
Geophilida	Chilenophilidae	*Sepedonophilus* 'BGE043'	Foraging	1	Potential SRE
Mollusc	Camaenidae	*Basedowena* cf. *holoserica*	Foraging	1	Potential SRE
		Sinumelon kalgum	Foraging	1	Potential SRE

3.6.4 Subterranean Fauna

Subterranean fauna includes aquatic stygofauna and air-breathing troglofauna. Troglofauna occupy subterranean spaces, such as alluvial interstices, voids and fissures, while stygofauna inhabit water held by such structures. Stygofauna also occur in the alluvium of hyporheic zones (the confluence of groundwater and surface-water habitats) as well as in groundwater-fed springs. Geology and hydrogeology are significant drivers of the distributions of subterranean species and communities. The primary limiting factor on the occurrence of subterranean species will be the apparent unavailability of well-developed underground spaces such as coarse interstices, vughs, fractures and caverns (Eberhard et al. 2005; Hose et al. s 2001).

The RHP and Frog's Leg mines are located less than 1.5 km from the Project and exhibit very similar geological and hydrogeological characteristics. Data from mining shows that the rock in these areas is made up of black flag volcaniclastics, bent tree and victorious basalts and shale / black shale. These are typically characterised by tight formation, very low porosity and permeability which does not support subterranean fauna. This is reflective of other nearby deposits in the Goldfields region as reported by Bennelongia (2019) and Botanica (2013).

There is no highly prospective habitat for subterranean fauna in the study area, therefore the proposed work poses a very low risk to subterranean fauna.

3.7 Heritage

3.7.1 Aboriginal Heritage

3.7.1.1 Native Title Groups

Currently there are two registered Native Title claimants in the region: the Marlinyu Ghoorlie (Tribunal file no. WC2017/007), and the Maduwongga, (Tribunal file no. WC2017/001) under the Native Title Act 1993 (National Native Title Tribunal 2019). Both claims cover the Project Area in its entirety.

Evolution Mining currently has Aboriginal Heritage agreements in place with the Maduwongga people the Marlinyu Ghoorlie people.

Other Native Title claims have been lodged previously; however, were dismissed by the Federal Court of Australia. Notwithstanding their Native Title status, representatives from previous claimant groups assert rights over Aboriginal heritage sites in their former claim areas and have demonstrated relevant cultural knowledge of those areas in the past. Representatives from all the above groups were therefore involved in Aboriginal Heritage surveys.

3.7.1.2 DPLH Aboriginal Heritage Inquiry System

All sites of Aboriginal heritage are protected under Section 5 of the *Aboriginal Heritage Act 1972,* whether previously registered or not. The Department of Planning, Lands and Heritage (DPLH) maintains an online database known as the Aboriginal Heritage Inquiry System (AHIS) which spatially shows and provides information concerning Aboriginal heritage places in WA. No DPLH listed Aboriginal Heritage sites will be disturbed as a result of vegetation clearing or mining operations (DPLH 2022a). Any Aboriginal heritage matters will be considered upon Mining Proposal submission.

3.7.1.3 Evolution Aboriginal Heritage Surveys

A number of surveys have been carried out over the Project area. No Aboriginal heritage sites will be disturbed as a result of the proposed mining activities (O'Connor 2020a & 2020b; O'Reilly 1999; Dobson & O'Reilly 1999). Any Aboriginal heritage matters will be considered upon Mining Proposal submission.

3.7.1 Other Heritage Places

Cultural heritage places in Western Australia can be recorded under many different heritage listings. Some of these listings give statutory protection to heritage places, and others are simply lists with unofficial or semi-official designations, often arising from local, community-based or thematic surveys. Statutory listings are issued by government organisations such as the Heritage Council, the Australian Heritage Council or local governments. DPLH maintains an online database known as inHerit which and provides information concerning heritage places in WA (DPLH 2022b). No inherit listed heritage sites will be disturbed as a result of vegetation clearing or mining operations.

4 Land Clearing Process

Clearing will be undertaken progressively using the following equipment and methodology.

4.1 Equipment

The equipment required to support and undertake clearing at the Project will include:

- Dozer;
- Loader;
- Excavator;
- Water Cart; and
- Service Vehicles.

4.2 Proposed Clearing Methodology

Prior to clearing, the disturbance footprint will be demarcated using high visibility tape or equivalent where suitable to ensure operators undertake clearing within the disturbance envelope. A maximum clearing footprint of **650 ha** is required. Clearing will be undertaken using dozer or loader to remove vegetation, topsoil and overburden. Any salvaged vegetation and topsoil will be stockpiled for rehabilitation purposes. A spotter may be present where required to ensure clearing and disturbance is undertaken within the proposed clearing boundaries.

5 Assessment Against the Ten Clearing Principles

Evolution have undertaken an assessment against each of the ten clearing principles (**Table 5-1**) and engage qualified botanists and zoologists to survey the area of flora, fauna and endemic species where required.

This assessment demonstrates that the proposed total clearing of **650 ha** is not at variance with any of the ten clearing principles and where required, management measures will be established to mitigate any potential unacceptable detrimental environmental harm.

Table 5-1: Assessment Against the Ten Clearing Principles

Clearing Principle	Assessment of Proposed Activities Against Clearing Principles
1. Native vegetation should not be cleared if it comprises a high level of biological diversity.	The Eastern Goldfields subregion is rich and diverse in its flora, however, most species (excluding Priority Flora species) are wide ranging and usually occur in at least one, and often several, adjoining subregions (Cowan, 2001). The Kundana EGS is not considered to comprise a high level of biological diversity as the vegetation is similar to the surrounding regions, hence it is not considered this project is at variance with this principle.
2. Native vegetation should not be cleared if it comprises the whole or a part of, or is necessary for the maintenance of, a significant habitat for fauna indigenous to Western Australia.	Most fauna species occurring in the region tend to be wide ranging, with the exception of Leipoa ocellata (Malleefowl). Malleefowl are known to inhabit the Goldfields region, therefore, Evolution may undertake a targeted Malleefowl survey in areas known to support Malleefowl inhabitance prior to significant clearing occurring in the Kundana EGS to reduce impacts to the species and their breeding habitat. Habitat appears marginal/or unsuitable for breeding, however occasional transients could potentially occur. No evidence of malleefowl activity was observed during the Botanica (2020) survey. Strategies to reduce negative impact to this species include; monitoring active nests, removing inactive nests in high-risk areas (such as those located within the project's footprint or within 50m of an active haul road), reporting all Malleefowl sightings to DBCA, erecting signage warning of Malleefowl in the area and sharing information on Malleefowl to all employees via information posters and toolbox topic talks.
3. Native vegetation should not be cleared if it includes or is necessary for the continued existence of rare flora.	All clearing will be undertaken under an approved Clearing Permit in which a flora and vegetation survey will have been carried out in the proposed clearing areas within the previous five-year period. If any threatened flora was identified in the survey area, a targeted survey will be carried out prior to undertaking clearing to ensure no threatened species remain in the disturbance area. No Threatened or Priority flora species were recorded during the Botanica (2020) survey.
4. Native vegetation should not be cleared if it comprises the whole or a part of or is necessary for the maintenance of a threatened ecological community.	There are no known Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) located within a 30 km radius of the Project area.
5. Native vegetation should not be cleared if it is significant as a remnant of native vegetation in an area that has been extensively cleared	The area applied to be cleared is located within the Coolgardie bioregion (DSEWPaC, 2012). Dwarf shrublands of samphires persist on salt lakes, surrounded by diverse *Eucalyptus* woodlands, which also occur on ranges and in valleys. It is not considered the proposed disturbance area represents a significant portion of remnant vegetation, especially as the entire area to be disturbed lies over an active pastoral lease which supports the grazing of cattle and other pastoral activities.
6. Native vegetation should not be cleared if it is growing in, or in association with, an environment associated with a watercourse or wetland.	Seasonal high rainfall events may result in water flow in drainage channels and the filling of salt-lakes. The water course located to the west of the project will only flow during flood events due to a dam catchment that has been implemented upstream. The Hornet Open Pit will be located partially within Kopai Lake therefore some riparian vegetation will be cleared. The nearest freshwater wetland is Rowles Lagoon, located approximately 25 km to the north west of the project area.
7. Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation.	Potential land degradation as a result of the proposed clearing may be minimised by the implementation of a staged clearing condition. All clearing will be carried out under an approved Clearing Permit and clearing will be conducted with a staged approach, to avoid unnecessary or over-clearing. Areas to be cleared will be pegged out by the Survey Department and overseen by the Environment Department and relevant Open Pit / Underground Supervisors to ensure clearing is appropriately managed as per relevant approvals.
8. Native vegetation should not be cleared if the clearing of the vegetation is likely to have an impact on the environmental values of any adjacent or nearby conservation area.	The nearest reserve is the Kurrawang Nature Reserve, located 12 km south-east of the Project area. Rowles Lagoon Nature Reserve and the Clear and Muddy Lake Nature Reserve are located 50 km north-west of the Project.
9. Native vegetation should not be cleared if the clearing of the vegetation is likely to cause deterioration in the quality of surface or underground water.	The climate of the region is semi-arid, with a low average rainfall of approximately 264 mm per year. Drainage lines in the area are dry for most of the year, only flowing briefly immediately following significant rainfall. Diversion bunding will be implemented to ensure that mine water is not uncontrollably released into the environment during high rainfall flood events. The groundwater of the region is hypersaline which is unsuitable for human or animal consumption and is noted at a depth of greater than 20m below ground level.
10. Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence or intensity of flooding.	The climate of the region is semi-arid, with a low average rainfall of approximately 264 mm per year. Drainage lines in the area are dry for most of the year, only flowing briefly immediately following significant rainfall. The project will not exacerbate or intensify incidences of flooding. Culverts will be installed under haul roads where necessary to ensure surface flows are allowed to follow their natural pathway and surface water management features such as drains, sumps and sediment traps may be included to direct water back to natural surface water flow systems and prevent flooding.

6 Environmental Management

6.1 Environmental Approvals

A Mining Proposal for the Hornet Open Pit was approved in 2011. A Mining Proposal for the Golden Hind and Pegasus areas is currently being drafted for submission to DMIRS. The existing environmental approvals for the Project are listed in **Table 6-1** below.

Table 6-1: Existing Environmental Approvals

Doc ID	Doc Type	Doc Title	Date Approved
Reg. ID 29733	Mining Proposal	Hornet Open Pit – M16/309, M15/669 & L16/28	31 Mar 2011
Reg. ID 66465	Mine Closure Plan	Kundana Operations Mine Closure Plan	28 Apr 2017
GWL 109476(8)	Groundwater License	Kundana Licence to take Water	23 Nov 2016

6.2 Conservation Significant Flora & Vegetation

No Threatened or Priority flora species were recorded within the survey area. (Botanica 2020).

No significant vegetation including representatives of Threatened or Priority Ecological Communities were identified within the survey area (Botanica 2020).

The following management strategies will be implemented for conservation significant flora and vegetation:

- Evolution's Internal Surface Disturbance Permit Application System is utilised on site to assess all upcoming clearing for significant flora or vegetation;
- Evolution maintains a mapping database of all significant flora;
- Clearing and disturbance is limited to approved areas and limits; and
- In the instance where the proposed works unexpectedly intercept any threatened or priority flora / vegetation, Evolution will cease work and seek independent management advice.

6.3 Conservation Significant Fauna

No evidence of significant fauna species was observed during the survey, including no evidence of Malleefowl nesting mounds or other activity (Botanica 2020).

Malleefowl was not recorded in the survey area but have been sighted in surrounding areas. Available information therefore suggests that a breeding population of this species is unlikely to be present in the survey area, though transient non-breeding individuals may occasionally occur (Botanica 2020).

The following management strategies will be implemented for conservation significant fauna:

- Evolution's Internal Surface Disturbance Permit Application System is utilised on site to assess all upcoming clearing for significant fauna or habitats;
- Evolution maintains a mapping database of all significant fauna;
- Clearing and disturbance is limited to approved areas and limits; and
- In the instance where the proposed works unexpectedly intercept any threatened or priority fauna, Evolution will cease work and seek independent management advice.

6.4 Weeds and Introduced Flora

Three species of introduced flora were recorded within the survey area:

- *Atriplex lentiformis* (Big saltbush);
- *Cucumis myriocarpus* (Gooseberry cucumber)*;* and
- *Nicotiana glauca* (Tree tobacco).

None of these species are a Weed of National Significance or a Declared Pest in Western Australia (Botanica 2020).

The following management strategies will be implemented for weeds and introduced flora:

- Evolution's Internal Surface Disturbance Permit Application System is utilised on site to assess all upcoming clearing for significant flora or vegetation;
- Evolution maintains a mapping database of all significant flora;
- Machinery, vehicles and equipment to be cleaned before moving sites;
- Minimise disturbance to soil and native vegetation;
- Practising good weed hygiene;
- Training and awareness of weed management and control; and
- Inspections of disturbed areas and topsoil stockpiles.

6.5 Surface Water

Seasonal high rainfall events may result in water flow in drainage channels and the filling of salt-lakes. A surface water management strategy has been developed for Hornet Open Pit (**Appendix F**) which will be located partially within Kopai Lake. Diversion and flood bunding will be implemented to ensure that flooding does not impact mining activities and mine water is not uncontrollably released into the environment.

The seasonal water course is located to the west of the Golden Hind Project. This water course only flows during high rainfall events due to a dam catchment upstream. A surface water management plan will be formulated to be included in the Golden Hind / Pegasus mining proposal that is currently being drafted.

The following management strategies will be implemented for surface water:

- Clean water should be diverted around the disturbance footprints to the downstream environment to prevent contamination of clean water catchments;
- Flood mitigation measures are required to prevent flood ingress to open pits and mine infrastructure areas, particularly the Hornet Open Pit;
- Drainage around operational areas should be designed to prevent prolonged ponding following rainfall events; and
- Surface water management infrastructure must incorporate measures to avoid excessive scour, erosion and sediment transport.

6.6 Hydrocarbon Spills

Due to the utilisation of heavy machinery and vehicles during the mining activities, there is a potential for minor hydrocarbon spills to occur at the Project. Hydrocarbon storage, handling, disposal, and spillage response will be managed in accordance with Evolution's existing hydrocarbon management procedures.

The following management strategies will be implemented for hydrocarbon spills:

- Hydrocarbon spill kits are closely available and fully stocked;
- Regular inspections and maintenance of machinery;
- All mining personnel are trained to handle the different types of spills and appropriate equipment;
- All mining personnel are aware of the procedure for reporting spills; and
- The bioremediation procedure is understood by all relevant personnel.

6.7 Fugitive Dust

Due to exposure of the ground surface as a result of vegetation clearing and mining activities, there is a potential for fugitive dust to be generated on site. To ensure dust from the project area does not cause a breach of the relevant environmental legislation, Evolution have a number of management strategies and control measures in place.

The following management strategies will be implemented for fugitive dust:

- Common dust suppression measures and management practices used in the WA mining industry are expected to be sufficient to control environmental impacts to acceptable levels.
- Minimising clearing, working to weather conditions and driving on established roads;
- Dust suppression using water carts;
- Ensure water suppression is occurring within pits during open cut operations; and
- Inductions and training of employees and operators on site.

7 References

Australian Government (2019). National Map - Soil Landscape Mapping - Western Australia attributed by WA Soil Group (DPIRD-076). Retrieved from https://nationalmap.gov.au/

Aquaterra Consulting (Aquaterra) (2000), *Hydrogeological Investigation – Raleigh Stage 1 Pit Dewatering and Water Discharge*. Prepared for Kundana Gold. October 2000.

Aquaterra Consulting (Aquaterra) (2001). *Kundana Gold Mine Annual Dewatering Discharge Licence Report.* Licence No. 7323/2.

Aquaterra Consulting (Aquaterra) (2003a), *Assessment of Groundwater Inflows – Hornet Pit.* Prepared for Placer Dome Asia Pacific. July 2003.

Aquaterra Consulting (Aquaterra) (2003b), *Surface Water Management Strategy for Hornet Pit.* Prepared for Placer Dome Asia Pacific. September 2003.

AQ2 (2022), *Kundana Operations and Paradigm Gold Mine GWL104053(8) and GWL109476(8) Groundwater Monitoring Summary.* Prepared for Evolution Mining (Mungari). February 2022.

Botanica Consulting (2010). *Level 1 Rubicon/ Hornet Spring Flora Survey.* Unpublished report prepared for Barrick-Kanowna Belle September 2010.

Botanica Consulting (Botanica) (2013) *Desktop Invertebrate Assessment of the Castle Hill, Red Dam and Kintore Project Areas.* Prepared for Phoenix Gold Limited. April 2013.

Botanica Consulting (Botanica) (2020). *Kundana Reconnaissance Flora/Vegetation Survey and Basic Fauna Survey*. Prepared for Northern Star Resources Ltd, October 2020.

Beard, J.S. (1990), *Plant Life of Western Australia,* Kangaroo Press Pty Ltd, NSW

Bennelongia Environmental Consultants (Bennelongia) (2019) *Mungari Operations: Desktop Assessment of Subterranean Fauna Values at Castle hill, Rayjax and Cutters Ridge.* Prepared for Spectrum Ecology/Evolution Mining. September 2019.

Cowan, M. (2001). *A Biodiversity Audit of Western Australia's 53 Biogeographical Region in 2001; Coolgardie 3 (COO3 –Eastern Goldfields subregion)* pp 156-169, Department of Conservation and Land Management, August 2001.

Department of Biodiversity, Conservation & Attractions (DBCA) (2019). *2018 Statewide Vegetation Statistics (formerly the CAR Reserve Analysis).* Department of Biodiversity, Conservation and Attractions.

Department of Planning, Lands and Heritage (DPLH) (2022a). *Search Aboriginal sites or heritage places (AHIS).* WA Government. Retrieved from: https://www.wa.gov.au/government/document-collections/search-aboriginal-sites-or-heritage-places-ahis. June 2022.

Department of Planning, Lands and Heritage (DPLH) (2022b). *The State Register and Other Heritage Listings – inHerit. WA Government.* Retrieved from: http://inherit.stateheritage.wa.gov.au/public. June 2022.

Department of Primary Industries and Regional Development (DPIRD) (2019). *Pre-European Vegetation (DPIRD_006)* Department of Primary Industries and Regional Development, Western Australia, 24 July 2019

Dobson M., & O'Reilly S & T (1999). *Report on an Ethnographic Survey of the Kundana Project Area.* Prepared for Gilt Edged Mining. March 1999.

Eberhard, S.M., Halse, S.A., and Humphreys, W.F. (2005) *Stygofauna in the Pilbara, north-west Western Australia*: a review. Journal of the Royal Society of Western Australia 88, 167-176.

Environmental Protection Authority (EPA) (2000). Position Statement No. 2 *Environmental Protection of Native Vegetation in Western Australia,* Environmental Protection Authority

Harewood, G. (2014) *Burgundy Project Area. Level 1 Fauna Assessment.* Prepared for Phoenix Gold Ltd.

Harvey, M. S. 2002. *Short-range endemism among the Australian fauna: some examples from nonmarine environments.* Invertebrate Systematics 16: 555–570.

Hose, G, and Pollino, C. (2015) *Stygofauna in Australian Groundwater Systems: Extent of knowledge.* CSIRO, Australia, 71 pp.

Keighery, B. J., (1994). *Bushland Plant Survey: A guide to plant community survey for the community.* Wildflower Society of Western Australia (Inc.), Nedlands.

O'Connor R & E. (2020a). *Aboriginal Heritage Survey of Hornet and Golden Hind Prospects*. Prepared for Northern Star Resources Limited. November 2020.

O'Connor R & E. (2020b). *Addendum to 2012 Report on the Aboriginal Heritage Survey of Pegasus Prospect.* Prepared for Prepared for Northern Star Resources Limited. November 2020.

O'Reilly S & T. (1999) *Report of an Aboriginal Site Survey of the Kundana Project Area, Kalgoorlie, Western Australia.* Prepared for Gilt Edged Mining Pty Ltd. January 1999.

Ponder, W. F. & Colgan, D. J. 2002. *What makes a narrow-range taxon? Insights from Australian freshwater snails.* Invertebrate Systematics 16: 571–582.

Rockwater (2014). Castle Hill Gold Project H2 Level of Hydrogeological Assessment. Prepared for Phoenix Gold Ltd, March 2014.

RPS (2020). *Kundana Surface Water Assessment.* Prepared for Northern Star Resources, October 2020.

SoilWater (2010). *Hornet Deposit Soil Characterisation.* Prepared for Barrick Kanowna, December 2010.

SoilWater (2020). *Pegasus Depsoit Soil Characterisation.* Prepared for Northern Star Resources Pty Ltd, June 2020.

SoilWater (2021). *Golden Hind Deposit Soil Characterisation.* Prepared for Northern Star Resources Limited, February 2021.

Spectrum Ecology (Spectrum) (2019). *Rayjax & Castle Hill Reconnaissance Flora & Level 1 Fauna Survey.* Prepared for Evolution Mining, September 2019.

Western Australian (WA) Museum. 2013. *WAM short-range endemic categories*. Western Australian Museum, Welshpool, WA.

Annex I:

Proof of Ownership

Tenement Summary Reports

ASIC Extracts

Letters of Consent

MINING TENEMENT SUMMARY REPORT

MINING LEASE 15/669

Status: Live

TENEMENT SUMMARY

Area:	938.60000 HA	**Death Reason :**	
Mark Out :	28/06/1993 10:14:00	**Death Date :**	
Received :	29/06/1993 09:06:00	**Commence :**	20/10/1993
Term Granted :	21 Years (Renewed)		

CURRENT HOLDER DETAILS

Name and Address

KUNDANA GOLD PTY LIMITED
MCMAHON MINING TITLE SERVICES PTY LTD, C/- MCMAHON MINING TITLE SERVICES PTY LTD, PO BOX 592, MAYLANDS, WA, 6931, xxxx@mmts.net.au, xxxxxxxxxxx997

DESCRIPTION

Locality: GIDJI LAKES

Datum: DATUM POST IS SITUATED 2185.014 METRES BEARING 86 DEGREES 39 MINUTES 43 SECONDS FORM THE NORTH EAST CORNER OF MINERAL CLAIM 16/316 AND BEING ON THE WESTERN BOUNDARY OF LATE MINING LEASE 26/207

Boundary: THENCE 6266.832 METRES BEARING 135 DEGREES 10 MINUTES 02 SECONDS TO THE SOUTHERN BOUNDARY OF LATE MINING LEASE 26/206 THENCE 1882.762 METRES BEARING 268 DEGREES 46 MINUTES 42 SECONDS TO THE SOUTH WEST CORNER OF LATE MINING LEASE 26/206 THENCE 2541.501 METRES BEARING 269 DEGREES 39 MINUTES 31 SECONDS TO THE SOUTH WEST CORNER OF LATE MINING LEASE 16/85 WHICH IS NOW INACCESSIBLE UNDER KOPAI LAKE AND HAS NOT BEEN MARKED THENCE 4499.514 METRES BEARING 0 DEGREES 04 MINUTES 07 SECONDS ALONG THE WESTERN BOUNDARY OF LATE MINING LEASE 16/85 AND MINING LEASE 26/207 BACK TO DATUM

Area :

Type	Dealing No	Start Date	Area
Surveyed		04/03/2002	938.60000 HA
Granted		20/10/1993	999.28900 HA
Surveyed		01/07/1993	998.90000 HA
Applied For		28/06/1993	999.28900 HA

SHIRE DETAILS

Shire	Shire No	Start	End	Area
COOLGARDIE SHIRE	1960	28/06/1993		938.60000 HA

MINING TENEMENT SUMMARY REPORT

MINING LEASE 15/993

Status: Live

TENEMENT SUMMARY

Area:	704.95000 HA	**Death Reason :**	
Mark Out :	22/08/1996 08:47:00	**Death Date :**	
Received :	22/08/1996 14:23:00	**Commence :**	19/10/2001
Term Granted :	21 Years		

CURRENT HOLDER DETAILS

Name and Address
RAND MINING LIMITED
C/- TENEMENT ADMINISTRATION SERVICES PTY LTD, LEVEL 2, 326 HAY STREET, EAST PERTH, WA, 6004

TRIBUNE RESOURCES NL
C/- TENEMENT ADMINISTRATION SERVICES PTY LTD, LEVEL 2, 326 HAY STREET, EAST PERTH, WA, 6004

GILT-EDGED MINING PTY LIMITED
MCMAHON MINING TITLE SERVICES PTY LTD, C/- MCMAHON MINING TITLE SERVICES PTY LTD, PO BOX 592, MAYLANDS, WA, 6931, xxxx@mmts.net.au, xxxxxxxxxxx997

DESCRIPTION

Locality: Kundana
Datum: Datum situated at AMG co ords N 6598827.222 E328796 zone 51
Boundary: THENCE: 1344 metres bearing 167 degrees 1 minute 1125 metres bearing 59 degrees 54 minutes 1228 metres bearing 60 degrees 40 minutes 1132 metres bearing 53 degrees 18 minutes 3084 metres bearing 180 degrees 2832 metres bearing 270 degrees 997 metres bearing 328 degrees BACK TO DATUM

Area :	Type	Dealing No	Start Date	Area
	Surveyed		20/10/2001	704.95000 HA
	Granted		19/10/2001	746.00000 HA
	Applied For		22/08/1996	746.00000 HA

SHIRE DETAILS

Shire	Shire No	Start	End	Area
COOLGARDIE SHIRE	1960	22/08/1996		704.95000 HA

Government of Western Australia
Department of Mines, Industry Regulation and Safety

eMiTS
MINERAL TITLES ONLINE

MINING TENEMENT SUMMARY REPORT

MINING LEASE 16/309

Status: Live

TENEMENT SUMMARY

Area: 939.20000 HA
Mark Out : 22/08/1996 11:30:00
Received : 22/08/1996 14:23:00
Term Granted : 21 Years
Death Reason :
Death Date :
Commence : 07/09/2001

CURRENT HOLDER DETAILS

Name and Address
RAND EXPLORATION NL
C/- TENEMENT ADMINISTRATION SERVICES PTY LTD, LEVEL 2 326 HAY STREET, EAST PERTH, WA, 6004

TRIBUNE RESOURCES NL
C/- TENEMENT ADMINISTRATION SERVICES PTY LTD, LEVEL 2, 326 HAY STREET, EAST PERTH, WA, 6004

GILT-EDGED MINING PTY LIMITED
MCMAHON MINING TITLE SERVICES PTY LTD, C/- MCMAHON MINING TITLE SERVICES PTY LTD, PO BOX 592, MAYLANDS, WA, 6931, xxxx@mmts.net.au, xxxxxxxxxxx997

DESCRIPTION

Locality: Kundana
Datum: Datum situated 900 metres bearing 49 degrees from SE corner of late surv MC 326s.
Boundary: THENCE: 1600 metres bearing 90 degrees 4850 metres bearing 180 degrees 1900 metres bearing 270 degrees 2940 metres bearing 360 degrees 250 metres bearing 54 degrees (along pt S bdy of late surv MC 316s) 1300 metres bearing 334 degrees (along pt E bdy late surv MC 316s) 700 metres bearing 90 degrees (along S bdy M 16/87) 650 metres bearing 360 degrees (along pt E bdy M 16/87) BACK TO DATUM All boundaries are identical to late M16/117 Section 49 - P16/1526 to P16/1530

Area :

Type	Dealing No	Start Date	Area
Surveyed		04/03/2002	939.20000 HA
Granted		07/09/2001	900.00000 HA
Surveyed		12/02/1999	877.20000 HA
Applied For		22/08/1996	900.00000 HA

SHIRE DETAILS

Shire	Shire No	Start	End	Area
COOLGARDIE SHIRE	1960	22/08/1996		939.20000 HA

Government of Western Australia
Department of Mines, Industry Regulation and Safety

eMiTS
MINERAL TITLES ONLINE

MINING TENEMENT SUMMARY REPORT

MISCELLANEOUS LICENCE 16/104

Status: Live

TENEMENT SUMMARY

Area: 113.00000 HA **Death Reason :**
Mark Out : 13/09/2012 10:30:00 **Death Date :**
Received : 21/09/2012 12:15:00 **Commence :** 28/03/2013
Term Granted : 21 Years

CURRENT HOLDER DETAILS

Name and Address
KUNDANA GOLD PTY LIMITED
MCMAHON MINING TITLE SERVICES PTY LTD, C/- MCMAHON MINING TITLE SERVICES PTY LTD, PO BOX 592, MAYLANDS, WA, 6931, xxxx@mmts.net.au, xxxxxxxxxxx997

DESCRIPTION

Locality: Kundana South
Datum: Datum situated at GDA 94 MGA Z51 332341.70 metres East and 6599409.66 metres North
Boundary: Thence to 332393.68 Metres East and 6599427.63
Metres North 332476.34 Metres East and 6599188.58
Metres North 332527.89 Metres East and 6599036.24
Metres North 332682.42 Metres East and 6598580.58
Metres North 332703.00 Metres East and 6598503.83
Metres North 332713.29 Metres East and 6598395.24
Metres North 332707.53 Metres East and 6598287.32
Metres North 332683.65 Metres East and 6598171.64
Metres North 332636.77 Metres East and 6597971.80
Metres North 332627.92 Metres East and 6597876.05
Metres North 332637.67 Metres East and 6597772.68
Metres North 332669.72 Metres East and 6597653.60
Metres North 332705.24 Metres East and 6597546.56
Metres North 332768.41 Metres East and 6597403.26
Metres North 332843.80 Metres East and 6597293.15
Metres North 332927.33 Metres East and 6597195.47
Metres North 333177.31 Metres East and 6596911.33
Metres North 333258.54 Metres East and 6596814.34
Metres North 333308.21 Metres East and 6596748.82
Metres North 333366.46 Metres East and 6596648.07
Metres North 333406.85 Metres East and 6596544.57
Metres North 333463.28 Metres East and 6596384.11
Metres North 333511.63 Metres East and 6596238.91
Metres North 333551.63 Metres East and 6596112.51
Metres North 333587.87 Metres East and 6595989.64
Metres North 333709.09 Metres East and 6595574.22
Metres North 333721.05 Metres East and 6595516.18
Metres North 333729.30 Metres East and 6595458.62
Metres North 333747.43 Metres East and 6595390.28
Metres North 333780.26 Metres East and 6595315.15

Metres North 333967.78 Metres East and 6594922.25
Metres North 333989.84 Metres East and 6594839.02
Metres North 333993.49 Metres East and 6594716.20
Metres North 333984.52 Metres East and 6594588.32
Metres North 333970.68 Metres East and 6594403.65
Metres North 333960.38 Metres East and 6594323.02
Metres North 333946.90 Metres East and 6594253.40
Metres North 333931.57 Metres East and 6594126.00
Metres North 333934.03 Metres East and 6593890.48
Metres North 333939.24 Metres East and 6593574.32
Metres North 333955.35 Metres East and 6593455.91
Metres North 333993.84 Metres East and 6593289.24
Metres North 334013.35 Metres East and 6593193.30
Metres North 334040.14 Metres East and 6593125.95
Metres North 334097.50 Metres East and 6593057.86
Metres North 334144.91 Metres East and 6593033.23
Metres North 334216.79 Metres East and 6593023.54
Metres North 334471.62 Metres East and 6593012.17
Metres North 335120.62 Metres East and 6592980.86
Metres North 335175.31 Metres East and 6592978.31
Metres North 335476.24 Metres East and 6592964.67
Metres North 336406.02 Metres East and 6592929.10
Metres North 336710.11 Metres East and 6592917.70
Metres North 337004.72 Metres East and 6592907.00
Metres North 337217.77 Metres East and 6592899.47
Metres North 337378.37 Metres East and 6592876.14
Metres North 337494.08 Metres East and 6592823.96
Metres North 337803.33 Metres East and 6592652.01
Metres North 337853.59 Metres East and 6592624.01
Metres North 338160.85 Metres East and 6592451.46
Metres North 338566.04 Metres East and 6592223.61
Metres North 338853.77 Metres East and 6592066.14
Metres North 339128.66 Metres East and 6591913.95
Metres North 339286.85 Metres East and 6591831.18
Metres North 339405.92 Metres East and 6591771.45
Metres North 340008.59 Metres East and 6591476.36
Metres North 340095.29 Metres East and 6591427.56
Metres North 340168.48 Metres East and 6591376.35
Metres North 340310.71 Metres East and 6591263.64
Metres North 340371.28 Metres East and 6591218.27
Metres North 340551.28 Metres East and 6591113.47
Metres North 340716.43 Metres East and 6591021.10
Metres North 340776.33 Metres East and 6590991.82
Metres North 340861.83 Metres East and 6590955.32
Metres North 341178.73 Metres East and 6590819.82
Metres North 341274.30 Metres East and 6590757.45
Metres North 341327.20 Metres East and 6590708.69
Metres North 341418.21 Metres East and 6590628.59
Metres North 341503.78 Metres East and 6590566.14
Metres North 341913.27 Metres East and 6590277.75
Metres North 342130.44 Metres East and 6590118.66
Metres North 342181.69 Metres East and 6590091.47
Metres North 342193.46 Metres East and 6590087.88
Metres North 342245.21 Metres East and 6590081.00
Metres North 342309.92 Metres East and 6590082.21
Metres North 342364.93 Metres East and 6590095.59
Metres North 342407.34 Metres East and 6590114.01
Metres North 342446.69 Metres East and 6590093.96
Metres North 342467.77 Metres East and 6590037.90
Metres North 342462.86 Metres East and 6589997.07
Metres North 342429.31 Metres East and 6589944.72
Metres North 342374.90 Metres East and 6589906.16
Metres North 342188.24 Metres East and 6589782.44
Metres North 342157.04 Metres East and 6589759.14
Metres North 342126.40 Metres East and 6589726.29
Metres North 342111.01 Metres East and 6589676.70

Metres North 342122.94 Metres East and 6589623.83
Metres North 342172.50 Metres East and 6589492.25
Metres North 342212.17 Metres East and 6589429.57
Metres North 342259.62 Metres East and 6589381.90
Metres North 342348.19 Metres East and 6589302.06
Metres North 342460.13 Metres East and 6589156.13
Metres North 342947.49 Metres East and 6588658.68
Metres North 343500.86 Metres East and 6588126.41
Metres North 343473.14 Metres East and 6588097.59
Metres North 342919.34 Metres East and 6588630.27
Metres North 342429.87 Metres East and 6589129.87
Metres North 342318.69 Metres East and 6589274.81
Metres North 342232.04 Metres East and 6589352.92
Metres North 342180.72 Metres East and 6589404.47
Metres North 342136.51 Metres East and 6589474.32
Metres North 342089.68 Metres East and 6589598.65
Metres North 342104.80 Metres East and 6589447.53
Metres North 342121.44 Metres East and 6589284.04
Metres North 342148.53 Metres East and 6589101.99
Metres North 342132.72 Metres East and 6589099.54
Metres North 342105.56 Metres East and 6589282.10
Metres North 342088.88 Metres East and 6589445.92
Metres North 342068.11 Metres East and 6589653.48
Metres North 342073.34 Metres East and 6589718.46
Metres North 342112.72 Metres East and 6589837.75
Metres North 342087.05 Metres East and 6589877.23
Metres North 342107.63 Metres East and 6589948.52
Metres North 342120.35 Metres East and 6590005.95
Metres North 341878.57 Metres East and 6590228.81
Metres North 341468.83 Metres East and 6590517.38
Metres North 341382.10 Metres East and 6590580.66
Metres North 340838.27 Metres East and 6590900.14
Metres North 340751.36 Metres East and 6590937.25
Metres North 340688.59 Metres East and 6590967.93
Metres North 340521.54 Metres East and 6591061.36
Metres North 340341.09 Metres East and 6591166.42
Metres North 340279.66 Metres East and 6591224.46
Metres North 340138.59 Metres East and 6591336.24
Metres North 340068.63 Metres East and 6591385.20
Metres North 339985.32 Metres East and 6591432.09
Metres North 339383.72 Metres East and 6591726.65
Metres North 339264.05 Metres East and 6591786.68
Metres North 339104.96 Metres East and 6591869.92
Metres North 338829.66 Metres East and 6592022.34
Metres North 338541.79 Metres East and 6592179.89
Metres North 338136.35 Metres East and 6592407.88
Metres North 337829.18 Metres East and 6592580.37
Metres North 337779.02 Metres East and 6592608.33
Metres North 337471.61 Metres East and 6592779.24
Metres North 337215.30 Metres East and 6592829.52
Metres North 337002.24 Metres East and 6592837.05
Metres North 336708.24 Metres East and 6592867.74
Metres North 336403.35 Metres East and 6592859.16
Metres North 336367.81 Metres East and 6592874.31
Metres North 335173.04 Metres East and 6592928.37
Metres North 335116.77 Metres East and 6592900.96
Metres North 334467.91 Metres East and 6592932.26
Metres North 334209.65 Metres East and 6592943.79
Metres North 334120.41 Metres East and 6592955.82
Metres North 334046.55 Metres East and 6592994.18
Metres North 333970.60 Metres East and 6593084.33
Metres North 333936.38 Metres East and 6593170.37
Metres North 333915.66 Metres East and 6593272.27
Metres North 333876.59 Metres East and 6593441.49
Metres North 333859.98 Metres East and 6593563.53
Metres North 333864.04 Metres East and 6593889.75

Metres North 333861.53 Metres East and 6594129.83
Metres North 333877.71 Metres East and 6594264.25
Metres North 333891.24 Metres East and 6594334.12
Metres North 333901.01 Metres East and 6594410.70
Metres North 333914.71 Metres East and 6594593.38
Metres North 333923.42 Metres East and 6594717.61
Metres North 333919.88 Metres East and 6594836.95
Metres North 333918.15 Metres East and 6594898.56
Metres North 333730.23 Metres East and 6595292.29
Metres North 333695.36 Metres East and 6595372.11
Metres North 333675.31 Metres East and 6595447.63
Metres North 333666.85 Metres East and 6595506.72
Metres North 333655.67 Metres East and 6595560.94
Metres North 333535.10 Metres East and 6595974.15
Metres North 333499.03 Metres East and 6596096.43
Metres North 333459.32 Metres East and 6596221.93
Metres North 333411.25 Metres East and 6596366.30
Metres North 333355.28 Metres East and 6596525.44
Metres North 333316.75 Metres East and 6596624.17
Metres North 333262.31 Metres East and 6596718.32
Metres North 333215.52 Metres East and 6596780.05
Metres North 333135.57 Metres East and 6596875.50
Metres North 332885.78 Metres East and 6597159.43
Metres North 332800.09 Metres East and 6597259.65
Metres North 332720.15 Metres East and 6597376.40
Metres North 332653.86 Metres East and 6597526.76
Metres North 332617.02 Metres East and 6597637.78
Metres North 332583.35 Metres East and 6597762.88
Metres North 332572.68 Metres East and 6597875.99
Metres North 332582.35 Metres East and 6597980.65
Metres North 332629.93 Metres East and 6598183.48
Metres North 332652.83 Metres East and 6598294.39
Metres North 332658.16 Metres East and 6598394.11
Metres North 332648.68 Metres East and 6598494.04
Metres North 332629.77 Metres East and 6598564.61
Metres North 332475.80 Metres East and 6599018.60
Metres North 332424.30 Metres East and 6599170.78
Metres North 332341.70 Metres East and 6599409.66
Metres North Back to datum

Area :	**Type**	**Dealing No**	**Start Date**	**Area**
	Granted		28/03/2013	113.00000 HA
	Applied For		13/09/2012	113.00000 HA

SHIRE DETAILS

Shire	**Shire No**	**Start**	**End**	**Area**
COOLGARDIE SHIRE	1960	21/09/2012		113.00000 HA

Current Company Extract

Name: GILT-EDGED MINING PTY LIMITED
ACN: 073 565 796

Date/Time: 23 November 2021 AEST 09:55:10 AM

This extract contains information derived from the Australian Securities and Investments Commission's (ASIC) database under section 1274A of the Corporations Act 2001.

Please advise ASIC of any error or omission which you may identify.

Organisation Details		**Document Number**
Current Organisation Details		
Name:	GILT-EDGED MINING PTY LIMITED	029291432
ACN:	073 565 796	
ABN:	29073565796	
Registered in:	Western Australia	
Registration date:	10/04/1996	
Next review date:	01/07/2022	
Name start date:	21/08/2015	
Status:	Registered	
Company type:	Australian Proprietary Company	
Class:	Limited By Shares	
Subclass:	Proprietary Company	
	DISCLOSING ENTITY	

Address Details		**Document Number**
Current		
Registered address:	EVOLUTION MINING LIMITED, Level 24, 175 Liverpool Street, SYDNEY NSW 2000	7EBK51518
Start date:	25/08/2021	
Principal Place Of Business address:	Level 24, 175 Liverpool Street, SYDNEY NSW 2000	7EBK51518
Start date:	18/08/2021	

Officeholders and Other Roles		**Document Number**
Director		
Name:	LAWRENCE CONWAY	7EBK51518
Address:	10 Clermiston Avenue, ROSEVILLE NSW 2069	
Born:	01/10/1969, ROCKHAMPTON, QLD	
Appointment date:	18/08/2021	
Name:	KLEIN JACOB	7EBK51518
Address:	61 Wentworth Road, VAUCLUSE NSW 2030	
Born:	15/08/1965, CAPE TOWN, SOUTH AFRICA	
Appointment date:	18/08/2021	
Secretary		
Name:	EVAN MARK ELSTEIN	7EBK51518
Address:	43 Clyde Street, NORTH BONDI NSW 2026	
Born:	26/07/1965, CAPE TOWN, SOUTH AFRICA	
Appointment date:	18/08/2021	
Ultimate Holding Company		
Name:	EVOLUTION MINING LIMITED	7EBK51518
ACN:	084 669 036	
ABN:	74084669036	

Share Information

Share Structure

Class	Description	Number issued	Total amount paid	Total amount unpaid	Document number
ORD	ORDINARY SHARES	87400010	19967938.86	0.00	07356579K

Members

Note: For each class of shares issued by a proprietary company, ASIC records the details of the top twenty members of the class (based on shareholdings). The details of any other members holding the same number of shares as the twentieth ranked member will also be recorded by ASIC on the database. Where available, historical records show that a member has ceased to be ranked amongst the top twenty members. This may, but does not necessarily mean, that they have ceased to be a member of the company.

Name: TOLEDO HOLDING (AUSCO) PTY LIMITED
ACN: 159 264 598
Address: Level 24, 175 Liverpool Street, SYDNEY NSW 2000

Class	Number held	Beneficially held	Paid	Document number
ORD	87400010	yes	FULLY	7EBK51518

Financial Reports

Balance date	Report due date	AGM due date	Extended AGM due	AGM held date	Outstanding	Document number
30/06/2000	30/09/2000			25/10/2000	no	016767054
30/06/2001	30/09/2001				no	017235166
30/06/2002	30/09/2002			25/10/2002	no	018612067
31/12/2006	31/03/2007				no	7E5782533
31/12/2007	31/03/2008				no	7E5782541
31/12/2008	31/03/2009				no	7E5782548
31/12/2009	31/03/2010				no	7E5782550
31/12/2010	31/03/2011				no	7E5782559
31/12/2011	31/03/2012				no	7E5782563
31/12/2012	31/03/2013				no	7E5782567

Documents

Note: Where no Date Processed is shown, the document in question has not been processed. In these instances care should be taken in using information that may be updated by the document when it is processed. Where the Date Processed is shown but there is a zero under No Pages, the document has been processed but a copy is not yet available.

Date received	Form type	Date processed	Number of pages	Effective date	Document number
04/12/2018	484A1 Change To Company Details Change Officeholder Name Or Address	04/12/2018	2	04/12/2018	7EAG78556
24/05/2019	351 Deed Relating To Class Order	28/05/2019	22	24/05/2019	030556825
19/11/2019	484 Change To Company Details 484E Appointment Or Cessation Of A Company Officeholder 484A1 Change Officeholder Name Or Address	19/11/2019	2	19/11/2019	7EAR44802
11/05/2020	488N Application To Change Review Date Of A Company Or Scheme Synchronise Review Date By Office Holder - No Fee	01/06/2020	6	11/05/2020	030913491
16/02/2021	484E Change To Company Details Appointment Or Cessation Of A Company Officeholder	16/02/2021	2	16/02/2021	7EBE76365
15/06/2021	484E Change To Company Details Appointment Or Cessation Of A Company Officeholder	15/06/2021	3	15/06/2021	7EBI40912
01/07/2021	484E Change To Company Details Appointment Or Cessation Of A Company Officeholder	01/07/2021	2	01/07/2021	7EBJ04090
18/08/2021	484 Change To Company Details 484B Change Of Registered Address 484C Change Of Principal Place Of Business (Address) 484D Change To Ultimate Holding Company 484E Appointment Or Cessation Of A Company Officeholder 484N Changes To (Members) Share Holdings	18/08/2021	5	18/08/2021	7EBK51518
18/08/2021	492 Request For Correction	19/08/2021	2	18/08/2021	7EBK54074
18/08/2021	484E Change To Company Details Appointment Or	18/08/2021	2	18/08/2021	7EBK54083

	Cessation Of A Company Officeholder				
23/08/2021	353 Notice Of Disposal Relating To Class Order	30/08/2021	7	23/08/2021	031382537
09/09/2021	352 Assumption Deed Relating To Class Order	01/10/2021	9	09/09/2021	031427797

*****End of Extract of 4 Pages*****

ASIC
Australian Securities & Investments Commission

Current Company Extract

Name: KUNDANA GOLD PTY LIMITED
ACN: 009 643 252

Date/Time: 20 September 2021 AEST 10:49:33 AM

This extract contains information derived from the Australian Securities and Investments Commission's (ASIC) database under section 1274A of the Corporations Act 2001.

Please advise ASIC of any error or omission which you may identify.

Current Company Extract

KUNDANA GOLD PTY LIMITED
ACN 009 643 252

Organisation Details		Document Number
Current Organisation Details		
Name:	KUNDANA GOLD PTY LIMITED	011368483
ACN:	009 643 252	
ABN:	13009643252	
Registered in:	Northern Territory	
Registration date:	18/05/1988	
Next review date:	01/07/2022	
Name start date:	07/06/1996	
Previous state number:	09581	
Status:	Registered	
Company type:	Australian Proprietary Company	
Class:	Limited By Shares	
Subclass:	Proprietary Company	

Address Details		Document Number
Current		
Registered address:	EVOLUTION MINING LIMITED, Level 24, 175 Liverpool Street, SYDNEY NSW 2000	7EBK51446
Start date:	25/08/2021	
Principal Place Of Business address:	Level 24, 175 Liverpool Street, SYDNEY NSW 2000	7EBK51446
Start date:	18/08/2021	

Officeholders and Other Roles		Document Number
Director		
Name:	LAWRENCE CONWAY	7EBK51446
Address:	10 Clermiston Avenue, ROSEVILLE NSW 2069	
Born:	01/10/1969, ROCKHAMPTON, QLD	
Appointment date:	18/08/2021	
Name:	JACOB KLEIN	7EBK51446
Address:	61 Wentworth Road, VAUCLUSE NSW 2030	
Born:	15/08/1965, CAPE TOWN, SOUTH AFRICA	
Appointment date:	18/08/2021	
Secretary		
Name:	EVAN MARK ELSTEIN	7EBK51446
Address:	43 Clyde Street, NORTH BONDI NSW 2026	
Born:	26/07/1965, CAPE TOWN, SOUTH AFRICA	
Appointment date:	18/08/2021	
Ultimate Holding Company		
Name:	EVOLUTION MINING LIMITED	7EBK51446
ACN:	084 669 036	
ABN:	74084669036	

Share Information

Share Structure

Class	Description	Number issued	Total amount paid	Total amount unpaid	Document number
ORD	ORDINARY SHARES	2	2.00	0.00	0964325A

Members

Note: For each class of shares issued by a proprietary company, ASIC records the details of the top twenty members of the class (based on shareholdings). The details of any other members holding the same number of shares as the twentieth ranked member will also be recorded by ASIC on the database. Where available, historical records show that a member has ceased to be ranked amongst the top twenty members. This may, but does not necessarily mean, that they have ceased to be a member of the company.

Name: TOLEDO HOLDING (AUSCO) PTY LIMITED
ACN: 159 264 598
Address: Level 24, 175 Liverpool Street, SYDNEY NSW 2000

Class	Number held	Beneficially held	Paid	Document number
ORD	2	yes	FULLY	7EBK51446

Financial Reports

Balance date	Report due date	AGM due date	Extended AGM due	AGM held date	Outstanding	Document number
30/06/1998	31/10/1998			26/11/1998	no	014702744
30/06/1999	31/10/1999				no	018164840
30/06/2000	31/10/2000			25/10/2000	no	016767052
30/06/2001	31/10/2001				no	017491230
30/06/2002	31/10/2002			25/10/2002	no	018612068
31/12/2006	30/04/2007				no	7E5815291
31/12/2007	30/04/2008				no	7E5815301
31/12/2008	30/04/2009				no	7E5815314
31/12/2009	30/04/2010				no	7E5815343
31/12/2010	30/04/2011				no	7E5815349
31/12/2011	30/04/2012				no	7E5815359
31/12/2012	30/04/2013				no	7E5815365

Documents

Note: Where no Date Processed is shown, the document in question has not been processed. In these instances care should be taken in using information that may be updated by the document when it is processed. Where the Date Processed is shown but there is a zero under No Pages, the document has been processed but a copy is not yet available.

Date received	Form type	Date processed	Number of pages	Effective date	Document number
04/12/2018	484A1 Change To Company Details Change Officeholder Name Or Address	04/12/2018	2	04/12/2018	7EAG78654
24/05/2019	351 Deed Relating To Class Order	28/05/2019	22	24/05/2019	030556825
10/07/2019	389B Annual Notice By Wholly-Owned Entity Annual Notice By Wholly-Owned Entity - Companies	19/07/2019	3	10/07/2019	030607478
20/11/2019	484 Change To Company Details 484E Appointment Or Cessation Of A Company Officeholder 484A1 Change Officeholder Name Or Address	20/11/2019	2	20/11/2019	7EAR47296
11/05/2020	488N Application To Change Review Date Of A Company Or Scheme Synchronise Review Date By Office Holder - No Fee	01/06/2020	6	11/05/2020	030913496
16/02/2021	484E Change To Company Details Appointment Or Cessation Of A Company Officeholder	16/02/2021	2	16/02/2021	7EBE76380
15/06/2021	484E Change To Company Details Appointment Or Cessation Of A Company Officeholder	15/06/2021	3	15/06/2021	7EBI41001
01/07/2021	484E Change To Company Details Appointment Or Cessation Of A Company Officeholder	01/07/2021	2	01/07/2021	7EBJ04068
18/08/2021	484 Change To Company Details 484B Change Of Registered Address 484C Change Of Principal Place Of Business (Address) 484D Change To Ultimate Holding Company 484E Appointment Or Cessation Of A Company Officeholder 484N Changes To (Members) Share	18/08/2021	5	18/08/2021	7EBK51446

	Holdings				
18/08/2021	492 Request For Correction	19/08/2021	2	18/08/2021	7EBK54043
18/08/2021	484E Change To Company Details Appointment Or Cessation Of A Company Officeholder	18/08/2021	2	18/08/2021	7EBK54048
23/08/2021	353 Notice Of Disposal Relating To Class Order	30/08/2021	7	23/08/2021	031382537

*****End of Extract of 4 Pages*****

RAND
MINING Ltd.

Resource and Environmental Compliance Division
Department of Mines, Industry Regulation and Safety
100 Plain Street
East Perth WA 6004

24 November 2021

Dear Sir/Madam,

RE: EAST KUNDANA JOINT VENTURE LETTER OF CONSENT

The East Kundana Tenements Farm-In and Joint Venture Agreement dated 4 July 1997 is an agreement between Gilt-Edged Mining NL, Tribune Resources Ltd (formerly Tribune Resources NL), Rand Mining Ltd (formerly Rand Mining NL), Lake Grace Exploration Pty Ltd and Rand Exploration NL. Gilt-Edged Mining NL is the nominated operator of the Joint Venture.

I acknowledge that Gilt-Edged Mining NL (ACN: 073 565 796) is part of the Evolution Mining Limited group of companies. On 1st August 2021 Evolution Mining Limited acquired Northern Star Resources Limited's Kundana Mining Operations in Kalgoorlie, Western Australia, which included the acquisition of Gilt-Edged Mining NL.

On behalf of **Rand Mining Ltd**, I consent to any of the Evolution Mining Limited companies submitting any work programs/permits and mining proposals that are required to undertake activities within the tenements within the above Joint Venture (listed in the schedule 1).

Yours faithfully
Rand Mining Ltd

Anthony Billis

Schedule 1: Tenement IDs covered by the letter of consent

Tenement Id	Status	Manager	Project	Grant Date	Reporting Group Number
M15/0993	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M15/1413	LIVE	*EVOM	KUNDANA SOUTH WEST	21/07/2009	C102/2004
M16/0181	LIVE	*EVOM	KUNDANA	10/12/1991	C102/2004
M16/0182	LIVE	*EVOM	KUNDANA	10/12/1991	C102/2004
M16/0213	LIVE	*EVOM	KUNDANA	01/12/1994	C102/2004
M16/0214	LIVE	*EVOM	KUNDANA	06/12/1994	C102/2004
M16/0218	LIVE	*EVOM	MUNGARI	25/01/1995	C102/2004
M16/0308	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M16/0309	LIVE	*EVOM	KUNDANA	07/09/2001	C102/2004
M16/0310	LIVE	*EVOM	KUNDANA	06/09/2012	C102/2004
M16/0325	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M16/0326	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M24/0924	LIVE	*EVOM	KUNDANA EAST	30/08/2012	C102/2004

RAND
EXPLORATION NL

Resource and Environmental Compliance Division
Department of Mines, Industry Regulation and Safety
100 Plain Street
East Perth WA 6004

24 November 2021

Dear Sir/Madam,

RE: EAST KUNDANA JOINT VENTURE LETTER OF CONSENT

The East Kundana Tenements Farm-In and Joint Venture Agreement dated 4 July 1997 is an agreement between Gilt-Edged Mining NL, Tribune Resources Ltd (formerly Tribune Resources NL), Rand Mining Ltd (formerly Rand Mining NL), Lake Grace Exploration Pty Ltd and Rand Exploration NL. Gilt-Edged Mining NL is the nominated operator of the Joint Venture.

I acknowledge that Gilt-Edged Mining NL (ACN: 073 565 796) is part of the Evolution Mining Limited group of companies. On 1st August 2021 Evolution Mining Limited acquired Northern Star Resources Limited's Kundana Mining Operations in Kalgoorlie, Western Australia, which included the acquisition of Gilt-Edged Mining NL.

On behalf of **Rand Exploration NL**, I consent to any of the Evolution Mining Limited companies submitting any work programs/permits and mining proposals that are required to undertake activities within the tenements within the above Joint Venture (listed in the schedule 1).

Yours faithfully
Rand Exploration NL

Anthony Billis

Schedule 1: Tenement IDs covered by the letter of consent

Tenement Id	Status	Manager	Project	Grant Date	Reporting Group Number
M15/0993	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M15/1413	LIVE	*EVOM	KUNDANA SOUTH WEST	21/07/2009	C102/2004
M16/0181	LIVE	*EVOM	KUNDANA	10/12/1991	C102/2004
M16/0182	LIVE	*EVOM	KUNDANA	10/12/1991	C102/2004
M16/0213	LIVE	*EVOM	KUNDANA	01/12/1994	C102/2004
M16/0214	LIVE	*EVOM	KUNDANA	06/12/1994	C102/2004
M16/0218	LIVE	*EVOM	MUNGARI	25/01/1995	C102/2004
M16/0308	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M16/0309	LIVE	*EVOM	KUNDANA	07/09/2001	C102/2004
M16/0310	LIVE	*EVOM	KUNDANA	06/09/2012	C102/2004
M16/0325	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M16/0326	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M24/0924	LIVE	*EVOM	KUNDANA EAST	30/08/2012	C102/2004

Tribune
RESOURCES Ltd.

Resource and Environmental Compliance Division
Department of Mines, Industry Regulation and Safety
100 Plain Street
East Perth WA 6004

24 November 2021

Dear Sir/Madam,

RE: EAST KUNDANA JOINT VENTURE LETTER OF CONSENT

The East Kundana Tenements Farm-In and Joint Venture Agreement dated 4 July 1997 is an agreement between Gilt-Edged Mining NL, Tribune Resources Ltd (formerly Tribune Resources NL), Rand Mining Ltd (formerly Rand Mining NL), Lake Grace Exploration Pty Ltd and Rand Exploration NL. Gilt-Edged Mining NL is the nominated operator of the Joint Venture.

I acknowledge that Gilt-Edged Mining NL (ACN: 073 565 796) is part of the Evolution Mining Limited group of companies. On 1st August 2021 Evolution Mining Limited acquired Northern Star Resources Limited's Kundana Mining Operations in Kalgoorlie, Western Australia, which included the acquisition of Gilt-Edged Mining NL.

On behalf of **Tribune Resources Ltd**, I consent to any of the Evolution Mining Limited companies submitting any work programs/permits and mining proposals that are required to undertake activities within the tenements within the above Joint Venture (listed in the schedule 1).

Yours faithfully
Tribune Resources Ltd

Anthony Billis

Schedule 1: Tenement IDs covered by the letter of consent

Tenement Id	Status	Manager	Project	Grant Date	Reporting Group Number
M15/0993	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M15/1413	LIVE	*EVOM	KUNDANA SOUTH WEST	21/07/2009	C102/2004
M16/0181	LIVE	*EVOM	KUNDANA	10/12/1991	C102/2004
M16/0182	LIVE	*EVOM	KUNDANA	10/12/1991	C102/2004
M16/0213	LIVE	*EVOM	KUNDANA	01/12/1994	C102/2004
M16/0214	LIVE	*EVOM	KUNDANA	06/12/1994	C102/2004
M16/0218	LIVE	*EVOM	MUNGARI	25/01/1995	C102/2004
M16/0308	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M16/0309	LIVE	*EVOM	KUNDANA	07/09/2001	C102/2004
M16/0310	LIVE	*EVOM	KUNDANA	06/09/2012	C102/2004
M16/0325	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M16/0326	LIVE	*EVOM	KUNDANA	19/10/2001	C102/2004
M24/0924	LIVE	*EVOM	KUNDANA EAST	30/08/2012	C102/2004

Appendix A:

Soil Characterisation for Golden Hind

(SoilWater 2021)

SOILWATER CONSULTANTS

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Prepared for:	NORTHERN STAR RESOURCES LIMITED
Date of Issue:	5 February 2021
Project No.:	NST-020-1-1

Distribution:

Electronic Copy – Brendon McGillivray (Environmental & Social Responsibility Advisor)

A Member of the SOILWATER GROUP
SOILWATER CONSULTANTS | SOILWATER ANALYSIS | SOILWATER TECHNOLOGIES
www.soilwatergroup.com
45 Gladstone Street, East Perth, WA 6004 | Tel: +61 8 9228 3060 | Email: swc@soilwatergroup.com

DOCUMENT STATUS RECORD

Project Title:	GOLDEN HIND DEPOSIT SOIL CHARACTERISATION
Project No.:	NST-020-1-1
Client:	NORTHERN STAR RESOURCES LIMITED

Revision History

Revision Code*	Date Revised	Revision Comments	Signatures		
			Originator	Reviewer	Approved
Rev A	28/01/21	Draft issued for internal review	SC	ASP	SC
Rev B	05/02/21	Draft issued for client review	SC		

Revision Code*

A - Report issued for internal review

B - Draft report issued for client review

C - Final report issued to client

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to undertake a soil characterisation study for the Golden Hind gold deposit. This work was conducted in accordance with the Scope of Work presented to Northern Star Resources Limited ('the Client'). SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the soil characterisation study was confined to the immediate area surrounding the Golden Hind gold deposit (geographical extent). No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area. In preparing this study, SWC has relied on relevant published reports and guidelines, and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel. SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client. This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

1 INTRODUCTION

Soil Water Consultants (SWC) were commissioned by Northern Star Resources Limited (NSR) to undertake a soil characterisation study for the proposed Golden Hind gold deposit. The purpose of this assessment was to identify and characterise all surficial soil materials within the disturbance area and suggest management strategies for their handling and utilisation. This information provides baseline data that can be used to assist in the handling of these materials, and in the construction and eventual rehabilitation of the mine site and post-mine landforms.

1.1 OBJECTIVES

The objectives of the soil characterisation work were:

- Define the distribution of soil in the study area.
- Characterise the physical and chemical properties of the soils.
- Identify materials that may be beneficial to the rehabilitation of the waste dumps, and materials that may have an adverse impact on rehabilitation.
- Propose management strategies for the handling, storage and utilisation of these materials to promote successful rehabilitation and closure outcomes.

1.2 SCOPE OF WORKS

The scope of work completed by SWC to meet the above objectives included:

- Field survey and collection of soil samples from the Project Area.
- Undertake field and laboratory analysis to characterise the physical, chemical and hydraulic properties of the surficial materials.
- Utilising data from the laboratory analysis develop and undertake a WEPP computer model to predict erosion rates from a range of possible slope configurations for post-mine landforms.
- Develop soil mapping units (SMU's), prepare descriptions of the surface soil profiles and prepare a soils map for the Project Area.
- Develop management strategies relevant for the identified SMU's and post-mine landform objectives.

2 SITE DESCRIPTION

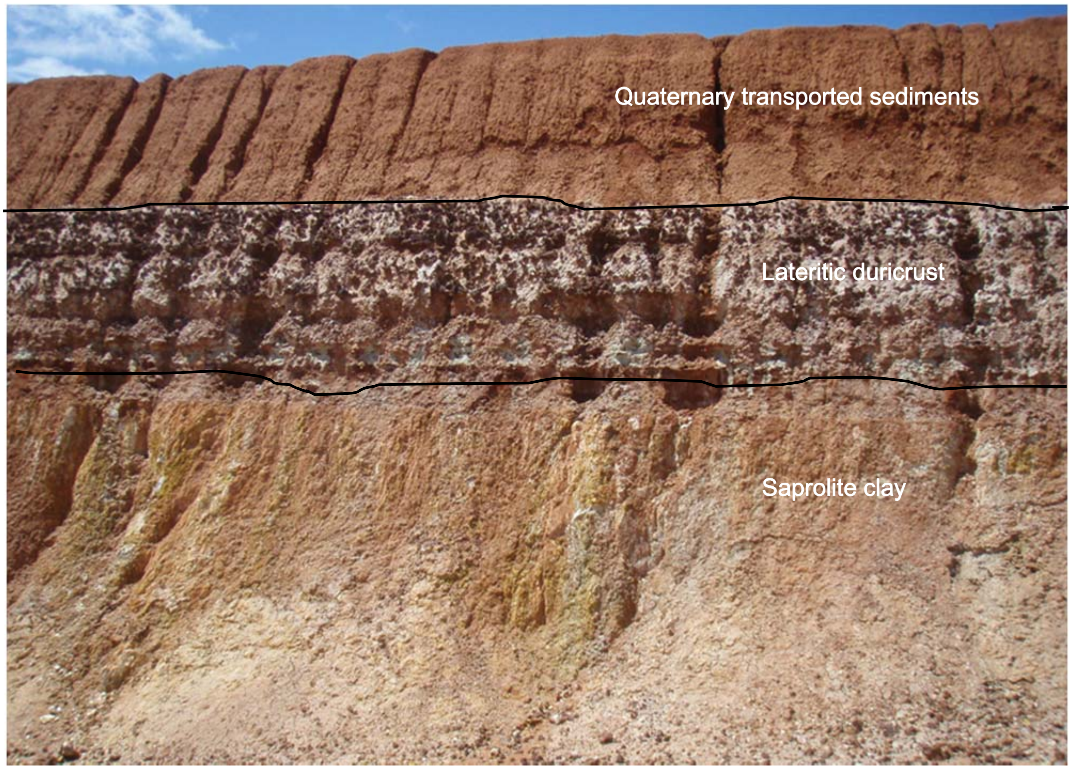
The Golden Hind deposit is located approximately 20 km northwest of Kalgoorlie (Figure 2.1), along the Kundana Haul Road between the existing Rubicon mine-pit and Lake Kopai (Figure 2.2). The disturbance footprint for the estimated Project Area covers approximately 65 ha.

2.1 GEOLOGY & HYDROGEOLOGY

The Golden Hind deposit is found within a NNW striking Greenstone belt in the Kalgoorlie Terrane of the Eastern Goldfields province of the Yilgarn Craton which is of Achaean age. This shear zone is labelled the K2 shear zone and is part of a 250km long, NNW striking structural corridor which separates the Ora Banda and Coolgardie Domains Exposure of outcrop locally is extremely sparse with the majority of the area covered by colluvium or laterite formations over the deeply weathered bedrock.

The area is dominated by mafic and ultramafic rocks with minor sedimentary units which have undergone extensive weathering to form deep regolith profiles. The *in situ* regolith profile has been found to be consists of 15 – 60 m of saprolite and a 10 – 20 m thick transitional or saprock zone. The thickness of the in situ regolith increases towards zones which have experienced high deformation in the past, such as is found along the Centenary Shale contact. The upper surface of the saprolite has been truncated and subsequently filled with a 4 – 8 m thick transported alluvial cover (Plate 2.1). The thickness of the transported sediments increases to the south of the deposit, where it reaches a thickness of around 70 m beneath Lake Kopai (EKJV, 2004).

Plate 2.1: Transported alluvial cover overlying saprolite at the nearby Rubicon mine-pit.

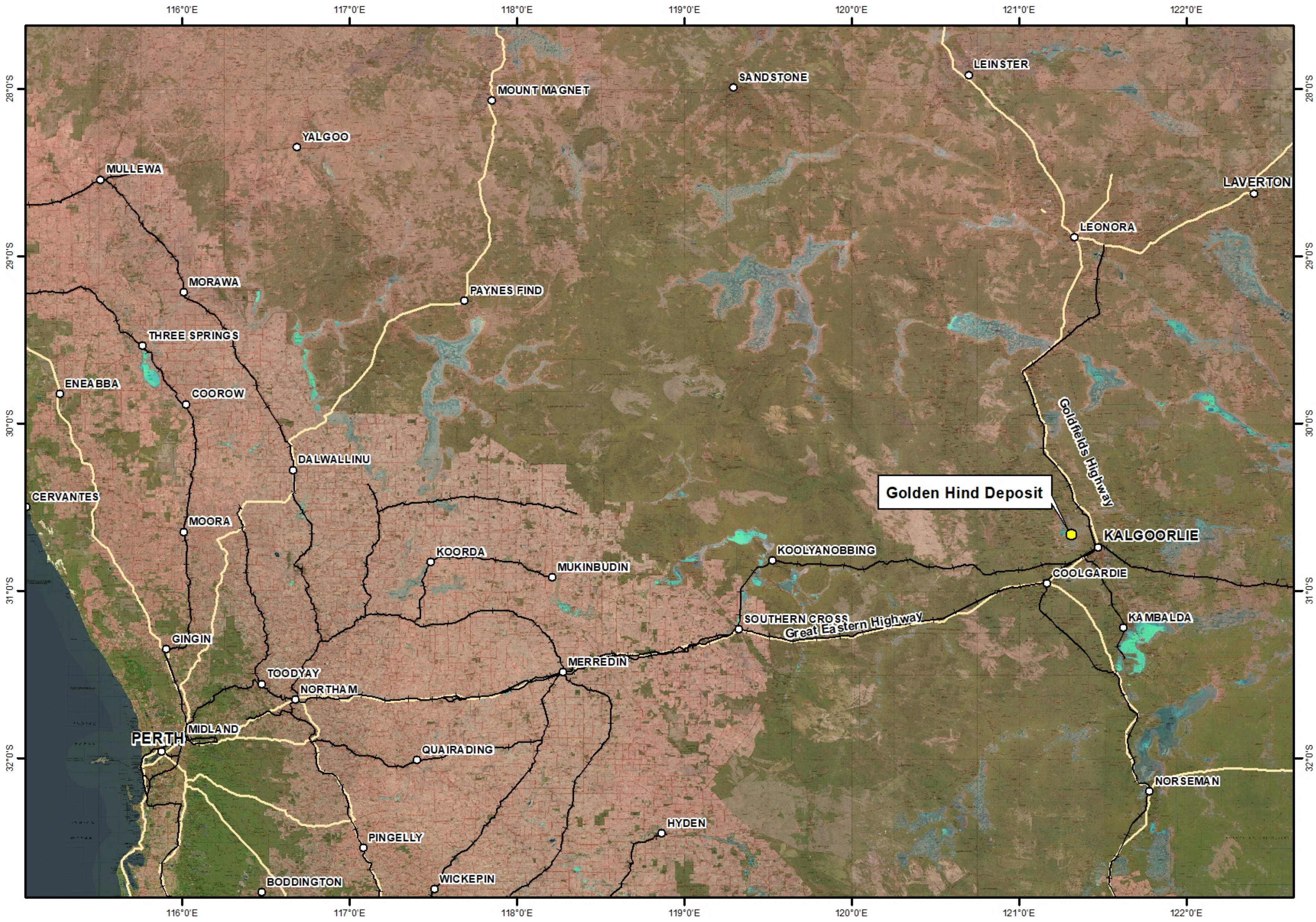


Groundwater in the region is generally associated with the coarser textured transitional zone (exhibiting preserved bedrock fabric), being confined by the overlying more clayey saprolite zone (Aquaterra, 2003). Given the proximity to the Lake Kopai salt lake system it is expected that the groundwater in the vicinity of the Golden Hind deposit is likely to be hyper-saline and subsequently a large section of the oxide materials are likely to be highly saline. Salinity levels of these materials may have an adverse impact on rehabilitation if used in the reconstruction of the growth medium of any post-mine landforms dump (e.g. the outer surfaces of a waste dump).

2.2 REGIONAL SOILS

The soils in the vicinity of the Project Area have been mapped at a regional scale (1:250,000 scale) by the Department of Agriculture, as part of the Southern Goldfields Rangeland Survey. The regional soils distribution is shown in Figure 2.3.

At the regional scale the soils throughout the Project Area are classified as salt lake (saline) soils experiencing wet and waterlogged conditions (265SV15; Figure 2.3). These soils are typically highly saline, with a dominant clayey texture. Surrounding the salt lake system soils are the red loamy earth associated with the gently undulating plains and occasional breakaways characteristic of the Goldfields region (265Mx43 & 266Mx43; Figure 2.3). These loamy soils are typically deep (> 1 m in depth), often calcareous, with a dominant earthy fabric. They are generally well drained and experience oxidising conditions throughout the year. Minor calcareous shallow loams and loamy earths occur in isolated regions, associated with both out- or sub-cropping greenstone and basic igneous bedrocks. These soils are generally shallow (< 1 m) underlain by partially weathered basement rocks.

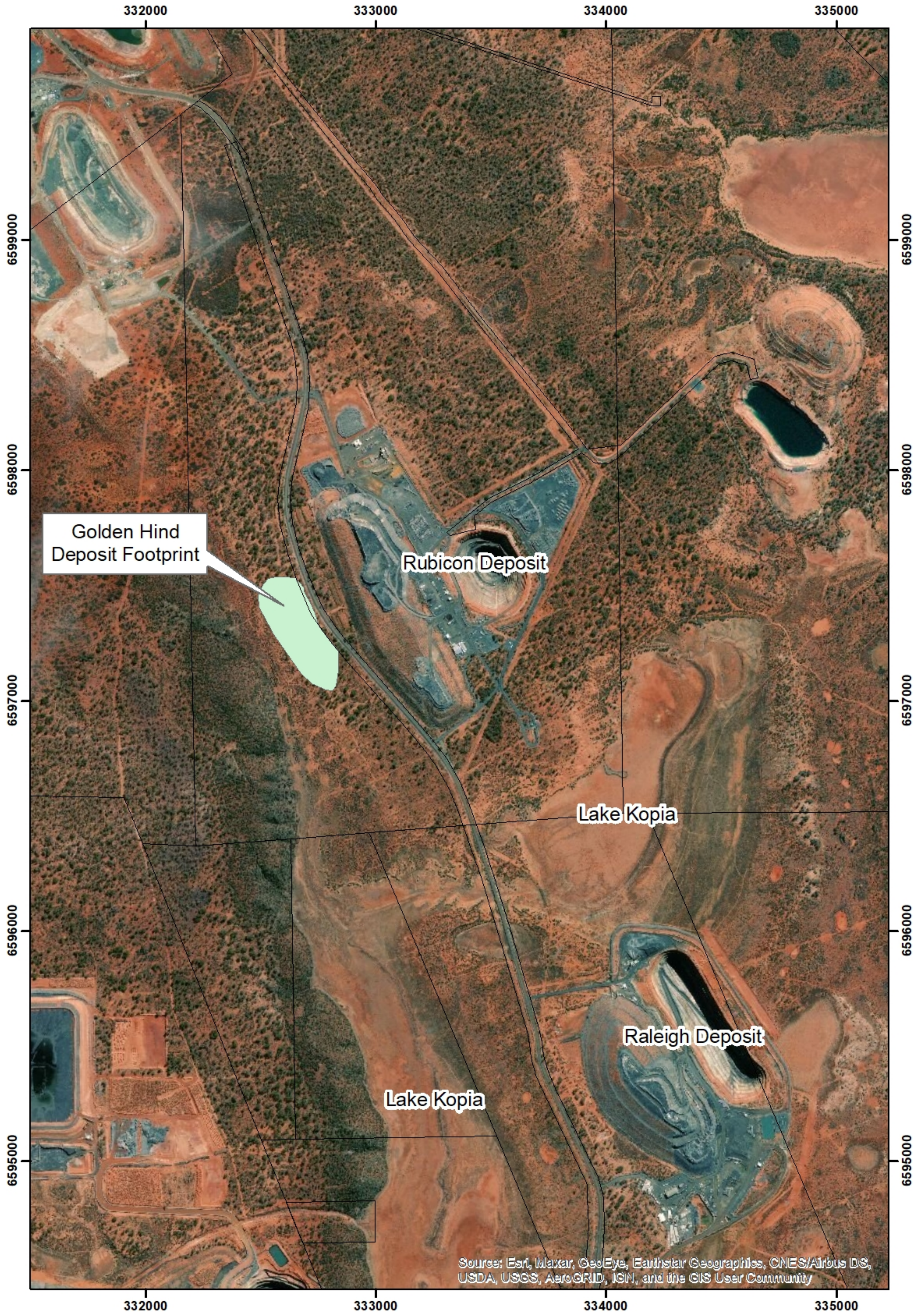


NORTHERN STAR RESOURCES LIMITED

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Figure 2.1: Regional location

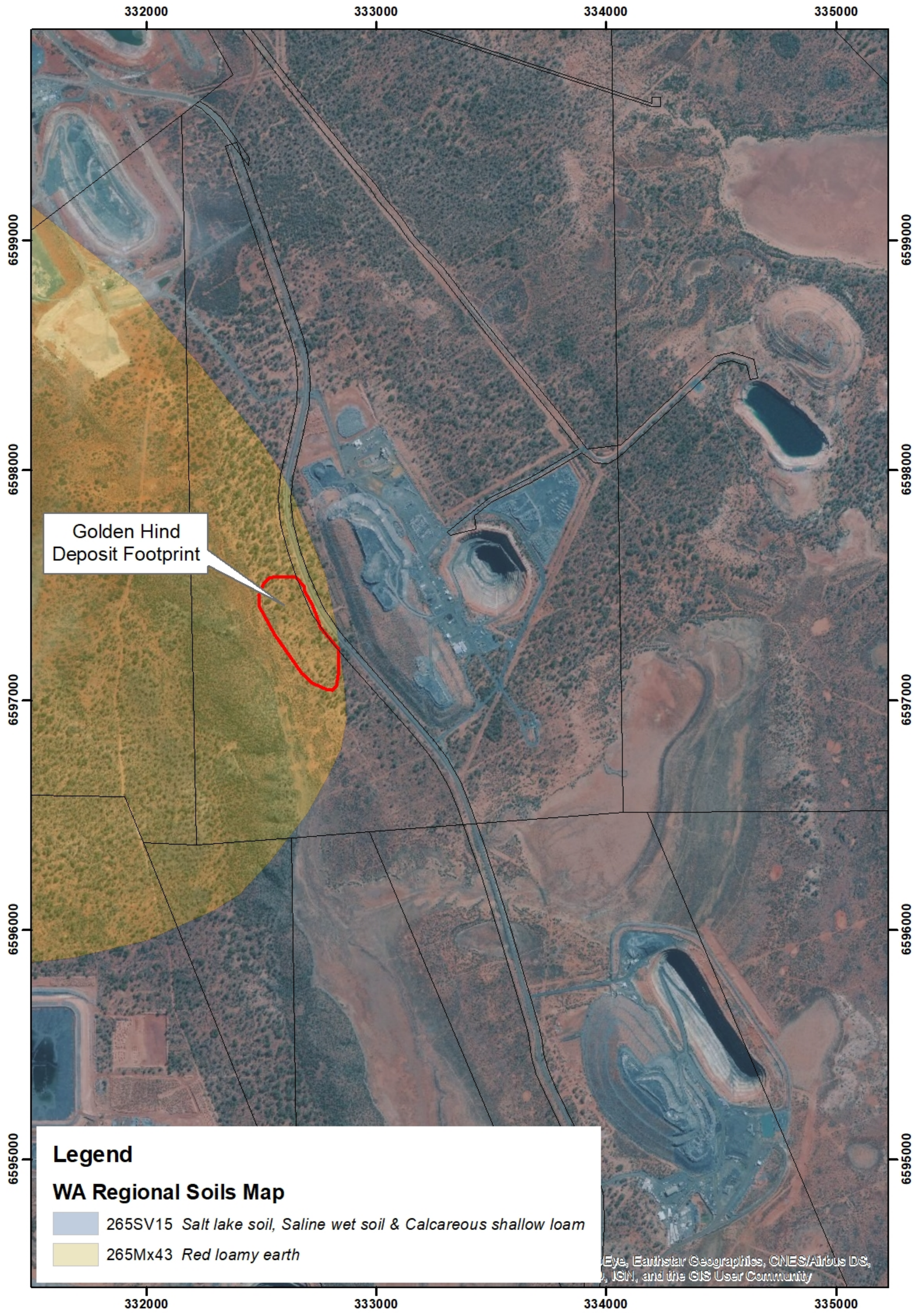
PN: NST-020-1-1 Prepared by: SC Date: 01/27/21 Reviewed by: ASP Date: 02/01/21 Revision: 1



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

NORTHERN STAR RESOURCES LIMITED	Figure 2.2: Local location	soilwater GROUP
GOLDEN HIND DEPOSIT SOIL CHARACTERISATION		

PN: NST-020-1-1 Prepared by: SC Date: 01/27/21 Reviewed by: ASP Date: 02/01/21 Revision: 1



NORTHERN STAR RESOURCES LIMITED	Figure 2.3: Regional soils mapping
GOLDEN HIND DEPOSIT SOIL CHARACTERISATION	

PN: NST-020-1-1 Prepared by: SC Date: 01/27/21 Reviewed by: ASP Date: 02/01/21 Revision: 1

3 STUDY METHODOLOGY

All soil profiles assessed in the field were described in accordance with McDonald and Isbell (2009), whilst the land surface was assessed using the classification scheme outlined in McDonald et al. (2009). Soil profiles were assessed for degree of horizonation, nature of contacts between horizons, presence and abundance of coarse fragments (i.e. gravels) and mottling, and structure, fabric and field texture of soil materials. A semi-quantitative assessment of plant roots (Table 3.1) was also undertaken to assist in identifying any potential adverse soil materials.

Table 3.1: Semi-quantitative assessment of plant roots used in this investigation.

Rating	Number of roots per 0.01 m2 (10 cm × 10 cm)	
	Very fine - fine roots (< 2 mm diameter)	Medium - coarse roots (> 2 mm diameter)
0 No roots	0	0
1 Few roots	1 - 10	1 - 2
2 Common roots	10 - 25	2 - 5
3 Many roots	25 - 200	> 5
4 Abundant roots	> 200	> 5

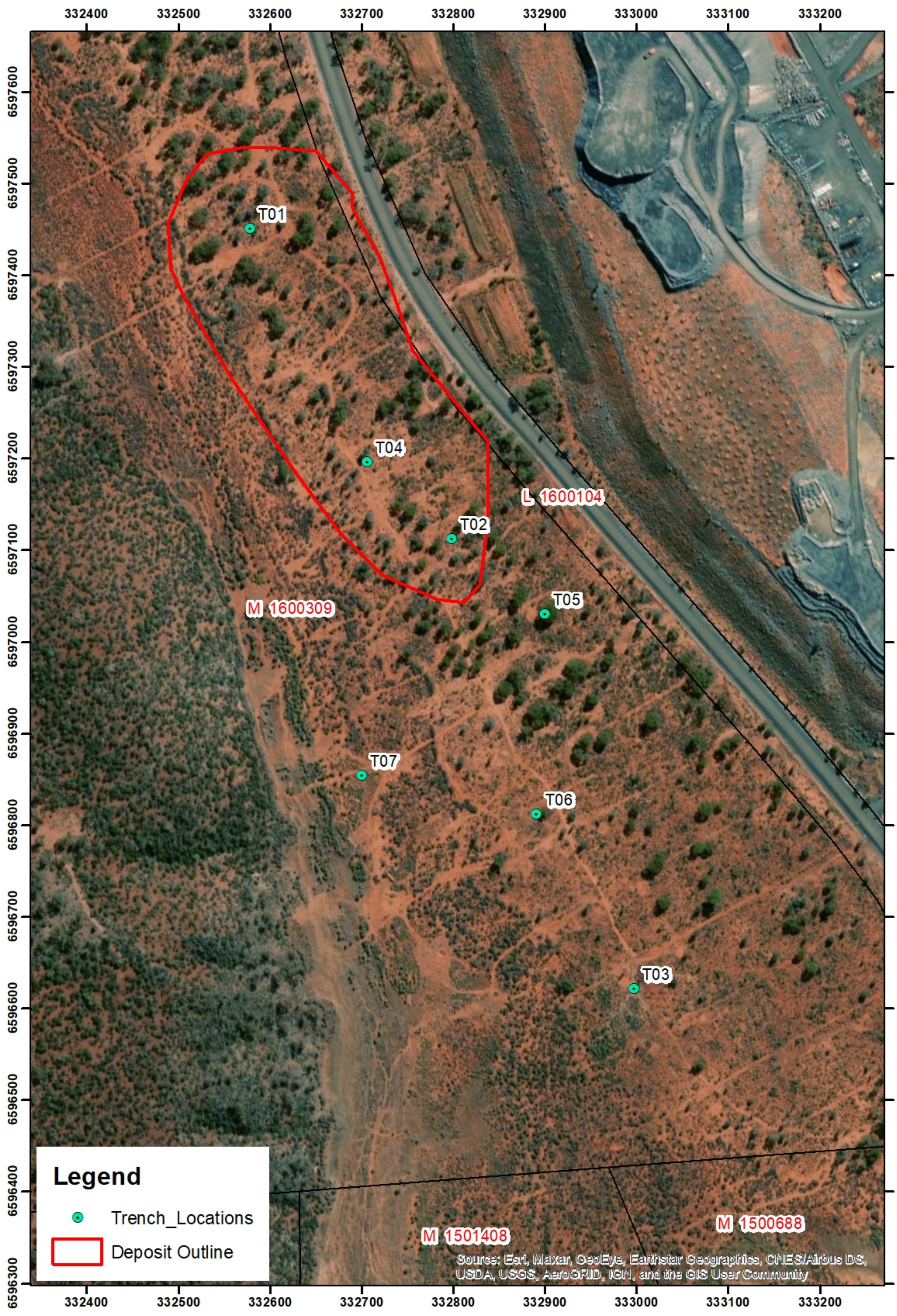
3.1 SOIL SAMPLE COLLECTION

Soil materials within the Project Area were investigated by shallow trench excavation utilising a backhoe. Sampling was undertaken in December, 2020 with the locations of the sampling sites provided in Figure 3.1.

Shallow trenches were excavated to a maximum depth of 1.3 m (Plate 3.1). A total of 7 sampling sites were investigated across the proposed disturbance area (Figure 3.1). Samples were collected at 10 cm intervals down the surficial profile to ensure that any pedologic organisation or horizonation identified was captured and that each of the major soil materials was sampled. Approximately 3 kg of each distinct soil horizon was collected for detailed laboratory analysis (Section 3.3). In addition, large bulk samples compiled from several different trenches were collected to facilitate a laboratory scale erosion study through the use of a rainfall simulator.

Details of the sampling sites assessed are provided in Table 3.2

Trench ID	Coordinates (GDA 94, Zone 51)		Depth (cm)
	Easting	Northing	
T01	332,578	6,597,451	170
T02	332,798	6,597,113	180
T03	332,997	6,596,621	160
T04	332,706	6,597,196	160
T05	332,900	6,597,030	160
T06	332,891	6,596,812	180
T07	332,700	6,596,854	180



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

NORTHERN STAR RESOURCES LIMITED

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Figure 3.1: Soil investigation trench locations

soilwater GROUP

PN: NST-020-1-1 Prepared by: SC Date: 01/27/21 Reviewed by: ASP Date: 02/01/21 Revision: 1

3.2 LABORATORY ANALYSIS

The physical, chemical and hydraulic properties of the soil materials collected in the field were assessed in the laboratory (Plate 3.1). A representative number of samples from each distinctly different soil material present in the Project Area were assessed for the properties listed in Table 3.2

Analysis of the physical and hydraulic properties was undertaken at Soil Water Analysis (SWA) Laboratories, whilst the chemical properties were assessed at CSBP Laboratories.

Table 3.2: Soil physical, chemical and hydraulic properties assessed for this soil characterisation.

Physical properties	Chemical properties	Hydraulic properties
Particle size distribution	pH	Saturated hydraulic conductivity
Gravel content	Electrical conductivity	Water retention characteristics
Particle Density	Nutrients (N, P, K, S)	Gravimetric water content
Bulk Density	Organic Carbon	Erosion properties
	Exchangeable cations	
	Sodicity	

Plate 3.1: Collection of *in situ* soil profile cores in the field.

3.3 EROSION TESTING

Laboratory scale erosion testing was undertaken on a composite bulk sample of the clay loam material found from depths 0.5-1.0m within trenches 03, 04 and 05.

A laboratory-scale rainfall simulator (Plate 3.2) was used to measure the interrill (raindrop impact) erodibility of each material. The rainfall simulator was designed to apply water at an intensity of approximately 80 mm/hr, with a raindrop size and spatial distribution closely resembling natural rainfall. An intensity of 80 mm/hr corresponds to a 1:10, 1:20 and 1:100 year ARI storm event of approximately 10, 15, and 30 min duration, respectively according to the 2016 design rainfall data system (BOM, 2021).

Prior to testing, the material was placed into a 0.75 x 0.75 x 0.20 m container and lightly compacted to approximate the expected field conditions. The base of the container was free draining to avoid saturated conditions and air entrapment within the samples. The material was then pre-treated by sequentially wetting and drying the surface twice to allow natural organisation and settling of the soil particles, and also allow any surface crust development to occur.

The container was set at a slope angle of 15° to simulate the likely batter conditions on post-mine landforms at the Project. The material was then subjected to a simulated rainfall of approximately 80 mm/hr, and 10 samples of the resulting surface runoff were collected over a 4 hour period. Runoff volume and sediment loss in each sample were determined gravimetrically. Measurements from the rainfall simulator were used to calculate soil erodibility parameters required for the WEPP erosion model. The methods used for calculating these parameters are discussed further in Section 3.4.

Plate 3.2: Laboratory rainfall simulator after wetting/drying cycle

3.3.1 RILL EROSION MEASUREMENTS

Laboratory scale testing was completed to measure the rill erodibility (K_r) and critical shear stress (τ_C) of the materials under overland flow conditions. The laboratory testing was designed to expose the materials to a range of overland flow depths to simulate storm events of different sizes, and to measure the resulting sediment content in the surface runoff, generated by rill erosion.

A flume method was used on to test the material for its response to the forces created by longer surface flow (Plate 3.3). Each material was subjected to 8 different overland flow rates at a slope angle of 15°, and the following measurements were made for each:

A timed sample of the resulting surface runoff was collected. Surface flow rate and sediment loss were then determined gravimetrically.

A measurement of surface flow velocity was made using a dye tracer method. The initial breakthrough time of the dye was measured, and the “average” flow velocity was calculated by applying a correction factor ($\alpha = 0.5$) according to Zhang *et al*. (2010).

Measurements of rill width were made at three standardised locations along the rill.

Measurements from the rill erosion test were used to calculate rill erodibility parameters required for the WEPP erosion model. The methods used for calculating these parameters are discussed further in Section 3.4.

Plate 3.3: Laboratory-scale rill erosion test.

3.4 EROSION MODELLING

The Watershed Erosion Prediction Project (WEPP; Flanagan & Livingston, 1995) model was used to predict the long-term (100 year duration) erosion rates from the surface of the proposed waste rock landform at the Hinge deposit. The WEPP model used a series of input files describing the soils, climate, slope geometry, and land management regime for the site. Model input values and assumptions are discussed in the following sections.

3.4.1 SOIL PARAMETERS

The soil parameters required by WEPP were derived from the laboratory testing undertaken at SWA Laboratories. These parameters include the effective hydraulic conductivity (K_{eff}), interrill erodibility (K_i), rill erodibility (K_r), and soil critical shear stress (τ_C), and are summarised in Table 3.3.

Keff was estimated by fitting the Green-Ampt equation (Green & Ampt, 1911) to the measured infiltration rates using Equation 1:

$$F = K_{eff} \left(1 + Ns / F\right) \qquad \text{Equation 1}$$

where: f = infiltration rate (mm/h)

K_{eff} = effective saturated hydraulic conductivity (mm/h)

N_s = effective matric potential at the wetting front (m), and

F = cumulative infiltration (m).

K_i was calculated from the inter-rill erosion rate measured in the rainfall simulator, according to Elliot *et al.* (1989) using Equation 2:

$$D_i = K_i \; I^2 \, S_f \qquad \text{Equation 2}$$

Where: D_i = interrill erosion rate (kg/(m^2 s)

K_i = interrill erodibility (kg s)/m^4

I = rainfall intensity (m/s), and

S_f = dimensionless slope factor ($1.05 - 0.85^{-0.85 \sin(\alpha)}$)

K_r and τ_C were determined from the shear stress (τ) and rill erosion rate (D_c) measurements collected in the laboratory. This was done by a linear regression analysis according to the method described by Foster (1982) and Elliott *et al.*, (1989). The rill erodibility parameters are related to the measured parameters τ and D_c by Equation 3:

$$D_c = K_r \left(\tau - \tau_C\right) \qquad \text{Equation 3}$$

where: D_c = measured erosion rate (kg/m2 s)

K_r = rill erodibility (s/m)

τ = measured shear stress (Pa), and

τ_C = critical shear stress (Pa).

D_c was plotted against τ for each of the flume measurements. The slope of the linear regression line was K_r, and the intercept with the horizontal axis was τ_C.

Table 3.3: Key soil parameters used in the WEPP model.

Material ID	Sand (%)	Clay (%)	OM (%)	CEC [meq/100g]	K_{eff} (mm/hr)	$K_i \times 10^{-5}$ (Kg s / m^4)	$K_r \times 10^3$ (s / m)	τ_C (Pa)
Clay loam	62	19	0.15	21	4.3	3.4	0.012	6.8

3.4.2 CLIMATE DATA

A 100-year synthetic climate file was generated using the CLIGEN stochastic weather generator (Yu, 2003), using 40 years of data from the Kalgoorlie Airport weather station (BOM station #012038). Figure 3.2 a and Figure 3.2 b demonstrate that the CLIGEN file is generally consistent with the 40 years of measured data from which it was generated. Figure 3.2a compares the frequency of 24-hour rainfall totals, indicating that larger 24-hour storms occurred slightly more frequently in the measured data than in the CIGEN file. Figure 3.2b compares average monthly rainfall totals, and shows that the CLIGEN file captures a similar degree of seasonal variability as has been observed at the Kalgoorlie Airport weather station. Figure 3.3 compares the 40 years of measured annual rainfall totals at Kalgoorlie to the 100-year CLIGEN output data, showing a similar degree of variability.

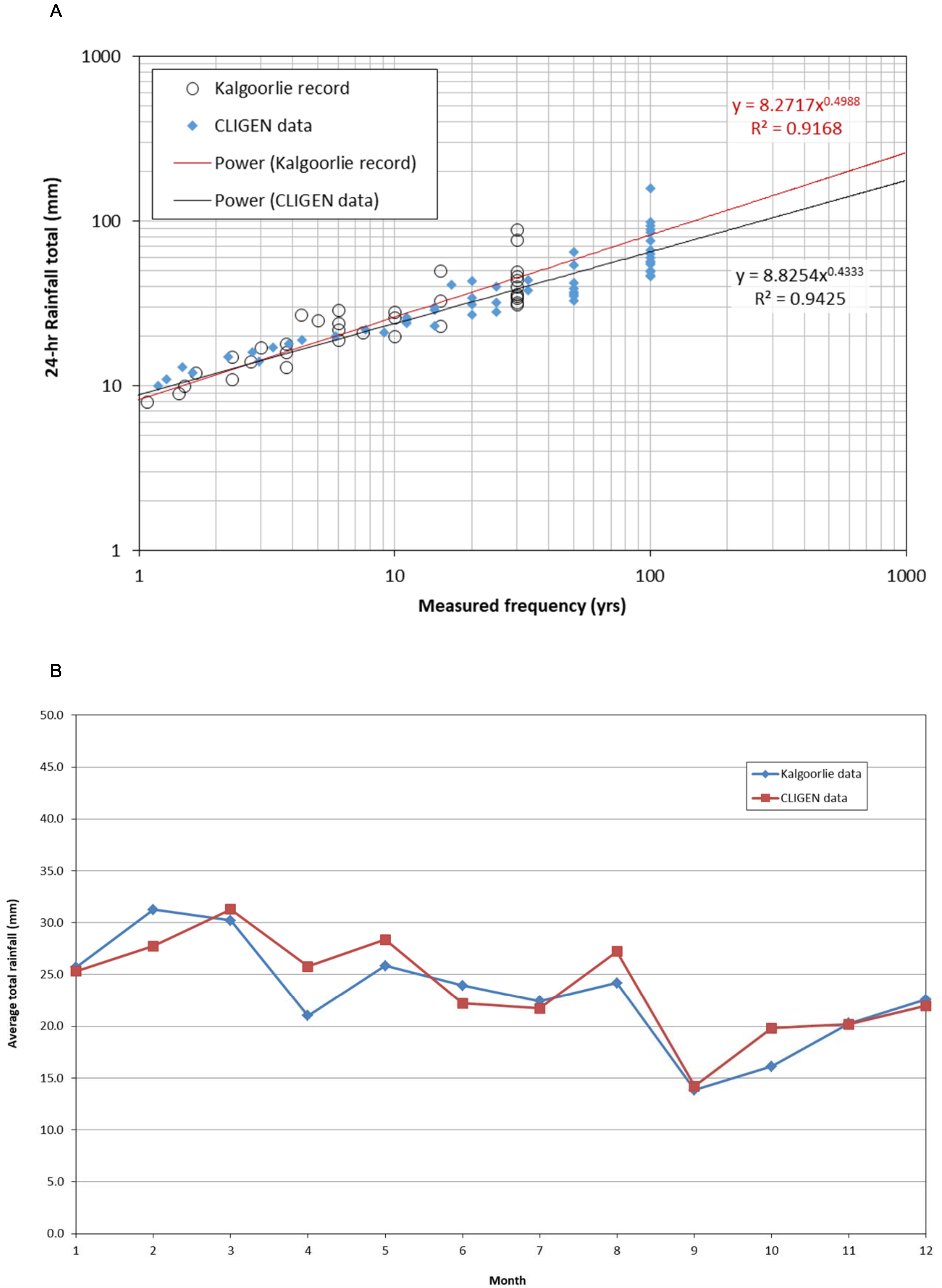
3.4.3 SLOPE PROPERTIES

Batter slopes were modelled assuming slope angles of 15° and 18°, and a lift height of 10 m to simulate conditions on a likely post-mine landform design

3.4.4 MANAGEMENT ASSUMPTIONS

The land management input file used in the WEPP model was designed to describe the expected conditions on a remediated waste rock landform at the Project. The key features of the input management file include:

- A pre-consolidated soil surface. This means that no further settling is simulated within the model, and that the measured infiltration rates and runoff characteristics apply for the duration of the model (i.e., no further changes in these properties with time). This is reasonable because the laboratory measurements (from which the input parameters were derived) were conducted on pre-consolidated soil samples.
- No vegetation. This assumption will result in conservative (i.e. “worst-case”) erosion results, and will apply to the landform during the period prior to re-vegetation establishment. Subsequent vegetation growth will act to enhance the stability of the landform by dissipating rainfall impact energy, producing leaf litter as a ground cover, and stabilising the sub-surface and improving infiltration with root growth. The degree of stabilisation will depend on the types of vegetation used, and their rates of establishment.
- Zero initial surface cover (i.e. no woody debris or plant litter). This means that no additional surface cover was expected to be added to the soil surface to reduce erosion rates. This assumption does not have any impact on the armouring effect of the rock and gravel fraction in the soil, which was already accounted for within the measured soil parameters discussed in Section 3.4.1.
- Rill geometry is adjusted internally in the model based on the input soil parameters and on the size of the erosion events encountered.

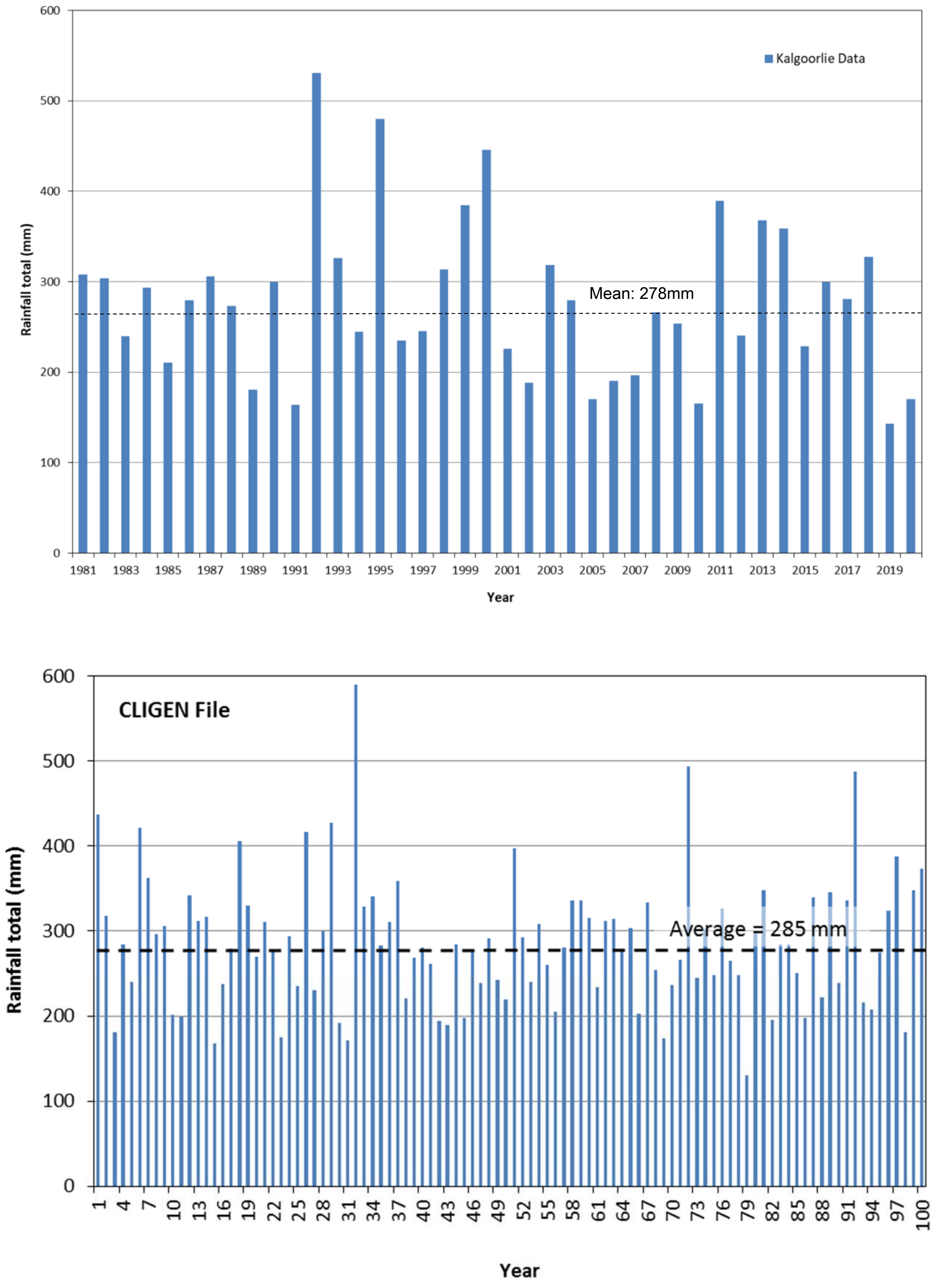


NORTHERN STAR RESOURCES LIMITED

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Figure 3.2: a) 24-hour and b) mean monthly rainfall data.

soilwater GROUP



NORTHERN STAR RESOURCES LIMITED

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Figure 3.3: Comparison of last 40 years annual rainfall data to cligen output

4 SOIL CHARACTERISATION

Based on the morphological characteristics of the soil profiles exposed by trench excavation, two distinct Soil Mapping Units (SMU) were defined: Calcareous loamy earth and Saline clay. The relationship between this SMU definition and the major soil groups of Western Australia (Schoknecht, 2001) and the Australian Soil Classification (Isbell, 1996) are presented in Table 4.1.

Table 4.1: Relationship between SMU and major soil groups of Western Australian and Australian Soil Classification.

SMU (Present study)	Major soil group, WA (Schoknecht, 2001)	Australian Soil Classification (Isbell, 1996)
1. Calcareous loamy earth	Calcareous loamy earth	Calcic Calcarasol
2. Deep Calcareous Silty Sand	Calcareous deep sand	Calcareous Rudosol

This SMU definition is consistent with the regional soil description shown in Section 2.2, which describes a deep, red loamy earth, often calcareous in nature occurring over the majority of the Project Area. Along the western margin of the Project Area a periodic drainage line links up the local salt lake system and flows during large rainfall events. The Calcareous silty sand is located within this drainage line deposited during flood events.

4.1 SMU 1: CALCAREOUS LOAMY EARTH

This is the dominant soil type over the Project Area and is likely to be the only soil type encountered. A characteristic profile for this SMU is shown in Figure 4.1. It consists of a 5 – 10 cm thick surface layer of reddish brown medium - coarse aeolian sand to loamy sandy (87% sand, 2% silt and 9% clay) overlying a reddish brown friable well-structured silty loam. The top 5cm of the sand often forms a crust with defined horizontal structuring (Plate 4.1). The contact between the surface sand and underlying loam is abrupt indicating that the sand has been deposited onto the sandy loam and not formed in situ (i.e. likely to be aeolian sand deposited by prevailing winds across the salt lake).

Plate 4.1: Surface crust and abrupt boundary between surface sand and underlying loam

A defined evaporite layer occurs within the reddish brown sandy loam at typically 40 – 60 cm (Figure 4.2). It is likely that this layer has formed in response to evaporative concentration of soluble salts, most likely to be lime (CaCO3) based on the pH of the soils (i.e. pH around 9; Figure 4.3). The presence of lime nodules in this layer gives the material a mottled appearance (Plate 4.2). The deeper profile consists of a fine silty loam containing abundant calcareous nodules and variable small gravels extending to at least 100 cm depth. The deeper surface profile contained increasing clay content with depth (Table 4.2), with the portion below ~120cm often characterised as a clay loam.

This increase in the fine soil fraction with depth results in a corresponding decrease in hydraulic conductivity of the soils; the permeability of the surface reddish brown sandy loam was measured at approximately 4 m/day, whilst the underlying sandy loam – sandy clay loam soil had a measured permeability of only 0.2 m/day. This significant reduction in hydraulic conductivity with depth is likely to result in perching of infiltrating water in the surface soils, and is the cause of the evaporative accumulation of soluble salts observed.

Plate 4.2: Calcareous nodules formed in the lower profile.

Table 4.2: Particle size distribution (PSD) and soil texture with SMU 1.

Trench	Depth	Texture	% Sand	% Silt	% Clay	% Gravel
T01	0 - 10	Loamy sand	84.1	4.1	11.8	12
	40 - 60	Sandy loam	71.8	9.6	18.7	5
	120 - 140	Silty clay loam	32.9	30.1	37.0	-
T02	0 – 10	Sand	90.1	2.1	7.8	15
	100 - 120	Loam	73.4	11.6	15.0	3
	160 - 180	Clay loam	68.1	10.2	21.7	4

Trench	Depth	Texture	% Sand	% Silt	% Clay	% Gravel
T03	0 - 10	Loamy sand	87.3	4.4	8.3	8
	140 - 160	Silty clay loam	36.6	29.7	33.7	-
T05	30 - 40	Sand	90.1	2.1	7.8	14
	50 - 60	Sandy loam	78.0	5.2	16.8	-
	70 - 80	Sandy clay loam	73.3	5.0	21.7	4
	120 - 140	Sandy clay loam	71.1	5.5	23.4	4
	140 - 160	Clay loam	63.0	8.9	28.1	-
T07	10 - 20	Sand	92.0	5.5	2.5	8
	160 - 180	Silty loam	67.4	31.2	1.4	16

Water retention test results are presented in Table 4.3. Field capacity values (water content at a matric potential of 10 kPa) varied between 18 – 38 % (v,v) and corresponding permanent wilting point values (water content at a matric potential of 1500 kPa) of 3 – 16 % (v,v) were measured. This resulted in average measured plant available water contents (PAW) of 7 – 16 % moisture by volume (70 – 160 mm/m) (Table 4.3). PAW has important implications for the construction and rehabilitation of post-mine landforms, as post-mine soil profiles must be able to support the transpiration requirements of revegetation species, or re-vegetation species must be selected to match the water holding capacity of the reconstructed soil profile.

Soil water content was measured through the profile in all trenches within samples tested for pH and EC. In general, soil water content was very low (near wilting point) at the surface, and increased slightly with greater depth (slightly above wilting point). This is expected to be typical of a period with relatively low rainfall and high evapotranspiration – the profile was generally dry, with plant water uptake drastically reducing the water content throughout the soil profile. The highest soil water content values were recorded at between 80 – 130 cm depth, corresponding with the transition zone between the surface silty loam material and the deeper calcareous materials, and indicating that the deeper materials have significantly slower hydraulic conductivities.

Table 4.3: Water retention test data

Trench	Mean depth	Water retention data (v/v, %)				PAW (%)	
	(cm)	10 kPa	33 kPa	100 kPa	1500 kPa	10kPa - 1500kPa	33kPa - 1500kPa
T02	5	17.7	15.4	9.8	3.1	14.6	12.3
	110	30.5	23.1	23.5	16.2	14.3	6.9
	170	30.7	24.8	16.7	12.3	18.4	12.5
T05	5	18.6	14.7	10.8	3.9	14.7	10.8
	55	30.8	22.5	19.9	6.5	24.3	16.0
	75	31.6	24.2	21.1	14.1	17.5	10.1
	125	28.1	24.9	20.0	10.7	17.4	14.2
	145	38.2	22.4	19.1	12.3	25.9	10.1
Avg. Topsoil		22.2	19.0	12.7	3.5	14.7	11.6
Avg. Sub-soil		31.7	23.7	20.1	12.0	19.6	11.6

The pH and EC (salinity) of the soils within SMU 1 are provided in Figure 4.2. Soils in the surface 30cm of this SMU have typically low to moderate salinity levels, with EC values averaging < 100 mS/m). The salinity of the soil at depths greater than 30cm report elevated salinities, with EC values rising to between 100-300 mS/m. These levels represent moderate to high salinity and have the potential to impact on the germination and early establishment of many plant species which are not tolerant to higher salt levels. It is likely that a proportion of local species would not tolerate these levels at the germination stage and so careful consideration on eventual seed mixes for rehabilitation will be needed. The measured surface profile varied from slightly acidic through to moderately alkaline, with pH values falling in the range of 5.9 – 9.2, with the more alkaline material generally occurring at greater depths.

Samples taken from the base of Trench 07 which were pale silty sand with a coarse texture range showed low pH and coupled with high salinity. This material is interpreted as a layer associated with the nearby drainage line, potentially corresponding to a much wider and heavier floodway in the past. Excavation which approaches the western drainage feature may intersect this sedimentary layer, although its thickness is unknown.

The measured macro-nutrient and organic carbon content of the soils sampled from SMU 1 are provided in Table 4.4. The results show that the topsoils (i.e. 0 – 10 cm soil layer) at all sites investigated in this SMU have low to very low mineralised N (NH4+ – N & NO3- – N < 20 mg/kg) and Colwell P (< 30 mg/kg). Elevated nitrate – nitrogen (NO3- - N) often occurs at depth in some soils, likely due to mobilisation of N from the surface soils. All of the subsoils sampled from SMU 1 had high to very high Colwell K and Extractable S contents. All topsoils in this SMU are poorly developed with only a minor accumulation of organic matter (organic C contents < 1 %). In the field, topsoils are only identified by the presence of abundant surface roots (Plate 4.1), and no clear topsoil organic accumulation occurs throughout the site.

Table 4.4: Nutrients analysis of SMU 1 soils.

Trench	Sample Depth (cm)		Ammonium	Nitrate	Colwell P	Colwell K	Sulphur	OC
	From	To	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(%)
T01	0	10	<1	<1	4	125	1.9	0.18
	30	50	<1	9	<2	194	438	0.15
T03	0	10	<1	16	3	319	169	0.19
	40	60	<1	5	<2	280	859	0.24
T04	0	10	<1	1	4	163	8.0	0.29
	60	80	<1	3	<2	157	303	0.19
T06	0	10	<1	<1	2	111	2.0	0.23
	20	40	<1	1	<2	187	272	0.20
T07	0	10	<1	4	3	145	71	0.17
	20	40	<1	1	<2	237	307	0.17
	160	180	<1	<1	<2	154	333	0.25

Results of the exchangeable cation analysis are presented in Table 4.5. Cation exchange capacity was generally low to moderate (< 20 meq/100g) in all samples. The measured CEC ranged from 1.5- 18.1 meq/100g, and averaged 9 meq/100g, indicating that kaolinite is the dominant clay minerals. Sodic soils (ESP > 15 %) were encountered in Trenches 6, and 7, whereas non-sodic soils (ESP < 6%) were generally restricted to the topsoil within the remainder of the trenches. This response is likely a reflection of the periodic inundation of the salt lake system and the consequent mobilisation of the salts particularly to those areas closest to the western drainage line abutting the ridge line and Lake Kopai to the south.

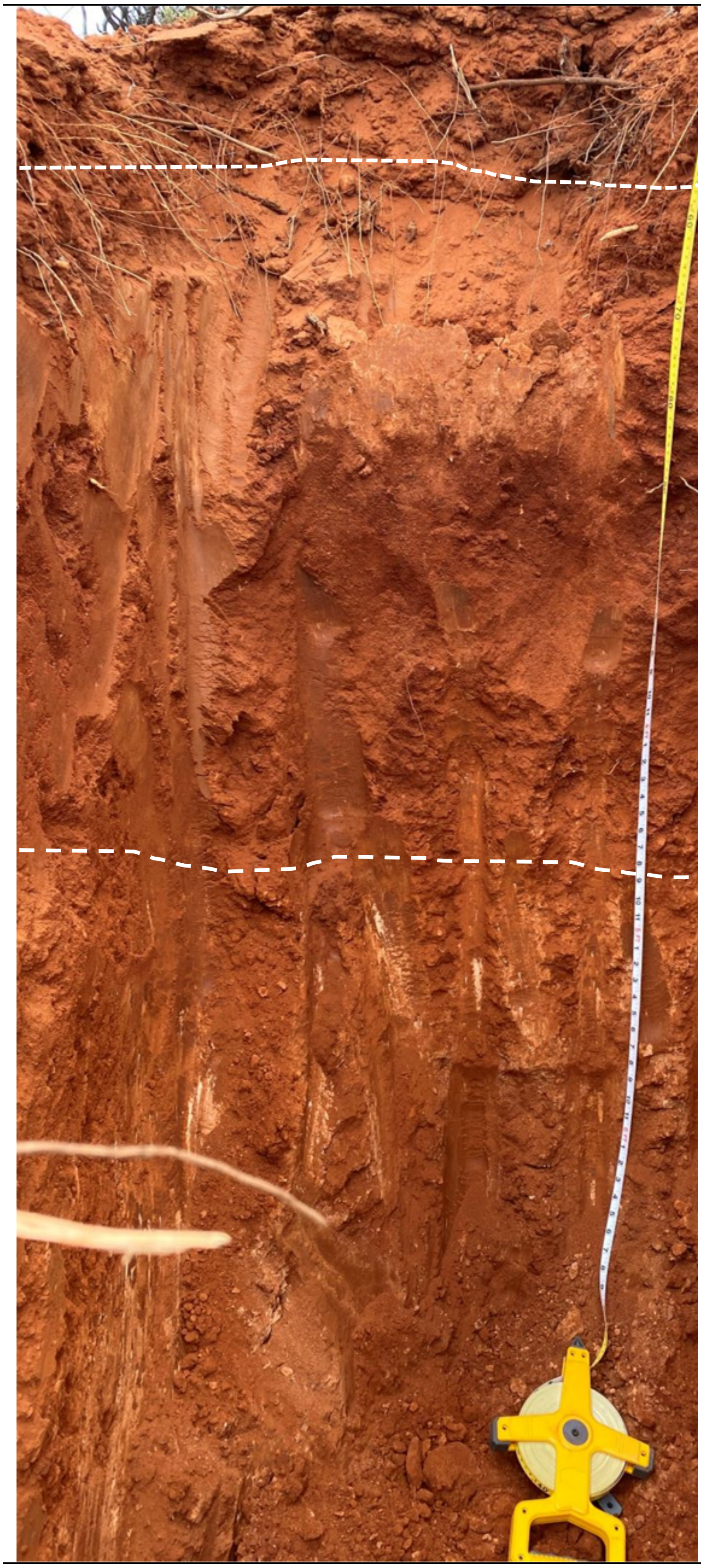
Table 4.5: Exchangeable cation analysis of SMU 1 soils.

Trench	Sample Depth (cm)		Exchangeable cations (meq/100g)					ESP (%)
	From	To	Ca	K	Mg	Na	CEC	
T01	0	10	1.20	0.18	0.91	0.05	2.3	2.1
	30	50	6.44	0.44	4.78	2.00	13.7	14.6
T03	0	10	11.35	0.80	4.52	1.48	18.1	8.2
	40	60	9.68	0.63	6.12	1.63	18.1	9.0
T04	0	10	2.62	0.21	1.35	0.05	4.2	1.2
	60	80	10.83	0.37	5.08	0.77	17.0	4.5
T06	0	10	0.78	0.16	0.76	0.05	1.7	2.9
	20	40	2.99	0.53	5.72	4.74	14.0	33.9
T07	0	10	0.40	0.20	0.50	0.38	1.5	25.7
	20	40	1.26	0.27	2.77	2.24	6.5	34.3
	160	180	0.39	0.11	1.48	0.61	2.6	23.6

Table 4.6: Standard soil chemical criteria (agricultural basis)

Property	Low	Moderate	High
Mineralised N (mg/kg)	< 20	20 – 50	> 50
Colwell P (mg/kg)	< 30	30 – 90	> 90
Colwell K (mg/kg)	< 80	80 – 200	> 200
Extractable S (mg/kg)	< 5	5 – 10	> 10
Organic carbon (%, A1 horizon)	< 1	1 – 2	> 2
Organic carbon (%, B horizon)	< 0.1	0.1 – 0.5	> 0.5
Salinity (mS/m)	< 40	40 – 100	> 100
Sodicity (ESP)	< 6	6 – 15	> 15
CEC (meq/100g)	< 3	3 – 10	> 10

(adapted from Mass & Hoffman, 1977; Strong & Mason, 1999; Moody & Bolland, 1999; Gourley, 1999; Purdie, 2001).



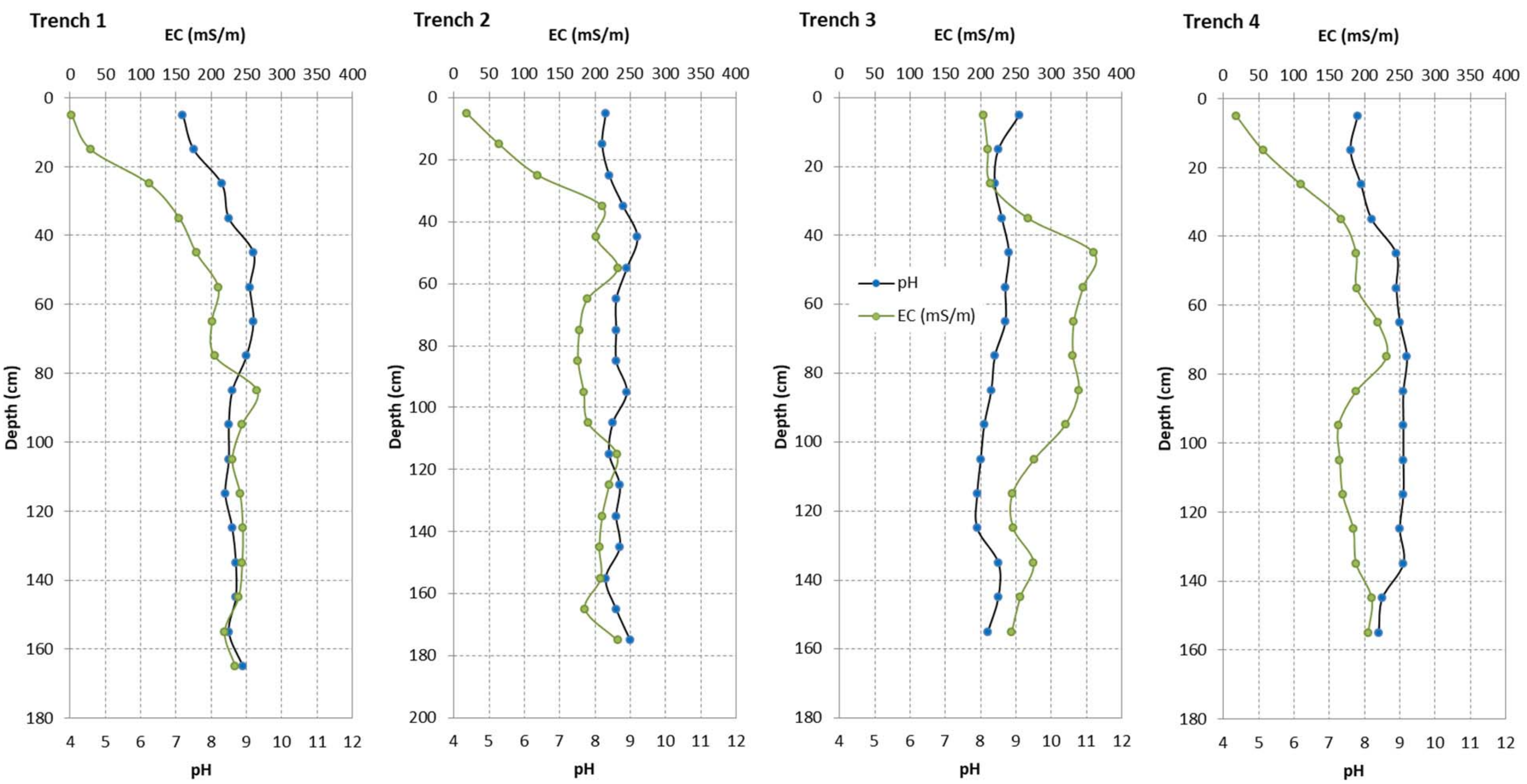
0-20cm	Reddish brown sand to loamy sand. Shows horizontal layered crust formation, abundant lateral roots, generally loose and friable below the top 5cm crust – low gravel content
20-100cm	Reddish brown sandy loam to clay loam. Massive structure and increasing fines content with depth. Shows common small vertical root exploration. Very low gravel content.
>100cm	Gradual transition to calcareous sandy clay loam. Calcareous mottling common with minor sub-rounded 1-2cm gravel throughout. Common fine vertical roots. Clay can be stiff to very stiff.

NORTHERN STAR RESOURCES LIMITED

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Figure 4.1: Characteristic profile in SMU 1

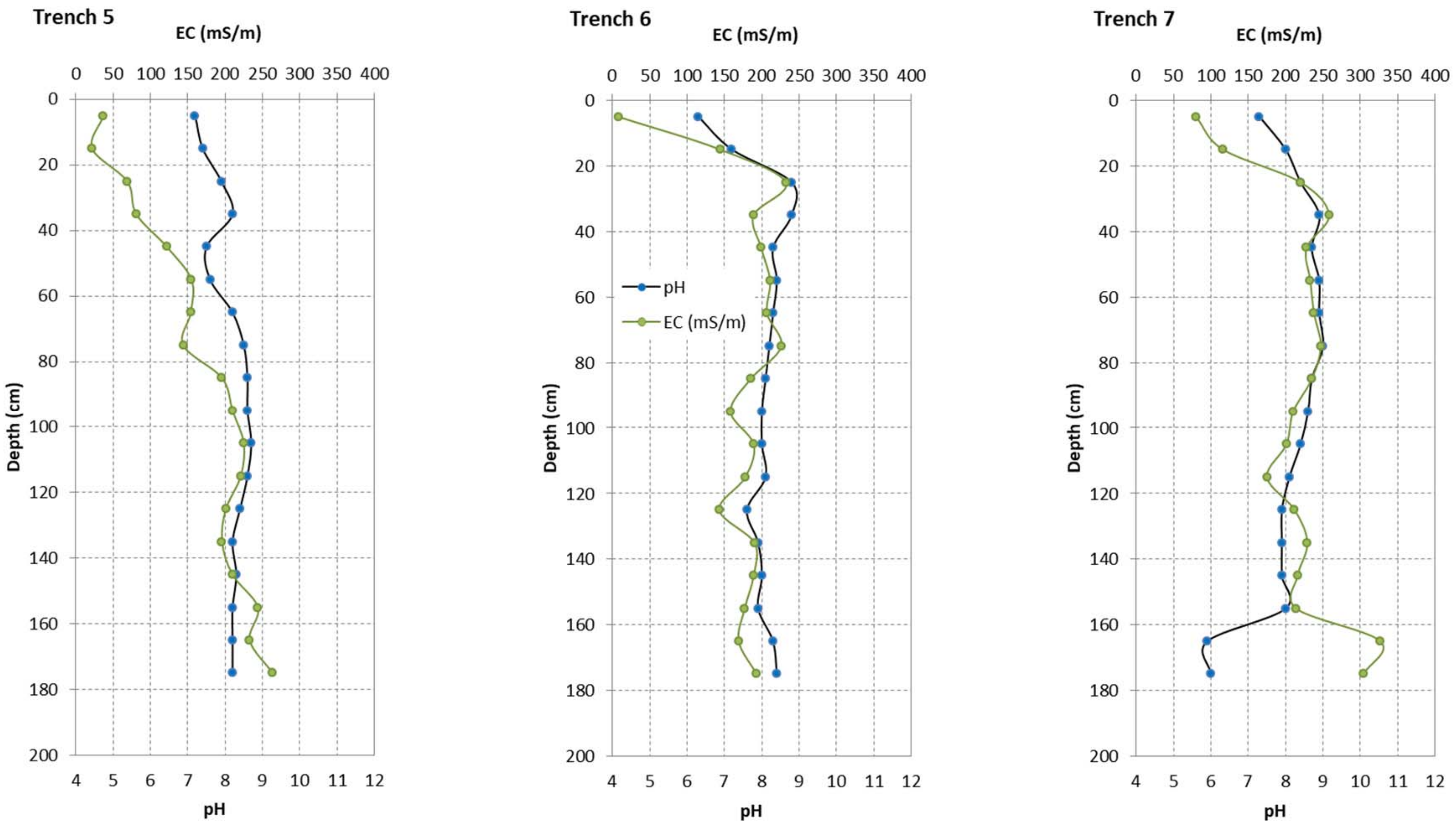
soilwater GROUP



NORTHERN STAR RESOURCES LIMITED

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Figure 4.2: pH and EC depth profiles



NORTHERN STAR RESOURCES LIMITED

GOLDEN HIND DEPOSIT SOIL CHARACTERISATION

Figure 4.3: pH and EC depth profiles continued…

The stability of the soils in SMU 1 is shown in Figure 4.4. The majority of soils sampled from SMU 1 are classified as either Potentially Dispersive or flocculated as a result of variable sodicity levels (Exchangeable sodium Percentage) and variable salinity. The potentially dispersive soils shown in Figure 4.4 are all generally located at depth within the loamy clays, with the high salinity of these soils offsetting the high ESP somewhat, causing some to be classified as stable. It can be seen that generally the topsoil samples displayed low ESP whilst the subsoils generally reported higher ESP. Whilst the deeper loam/clay material ranged from flocculated to dispersive, if placement on a post-mine landform causes their salt loads to decrease due to change in drainage conditions, these material are likely to become more dispersive with time. Based on these results, it can be concluded that the soils within SMU 1 are likely to display variable stability, with the topsoil sands having higher long-term stability than the underlying heavier textured soil materials.

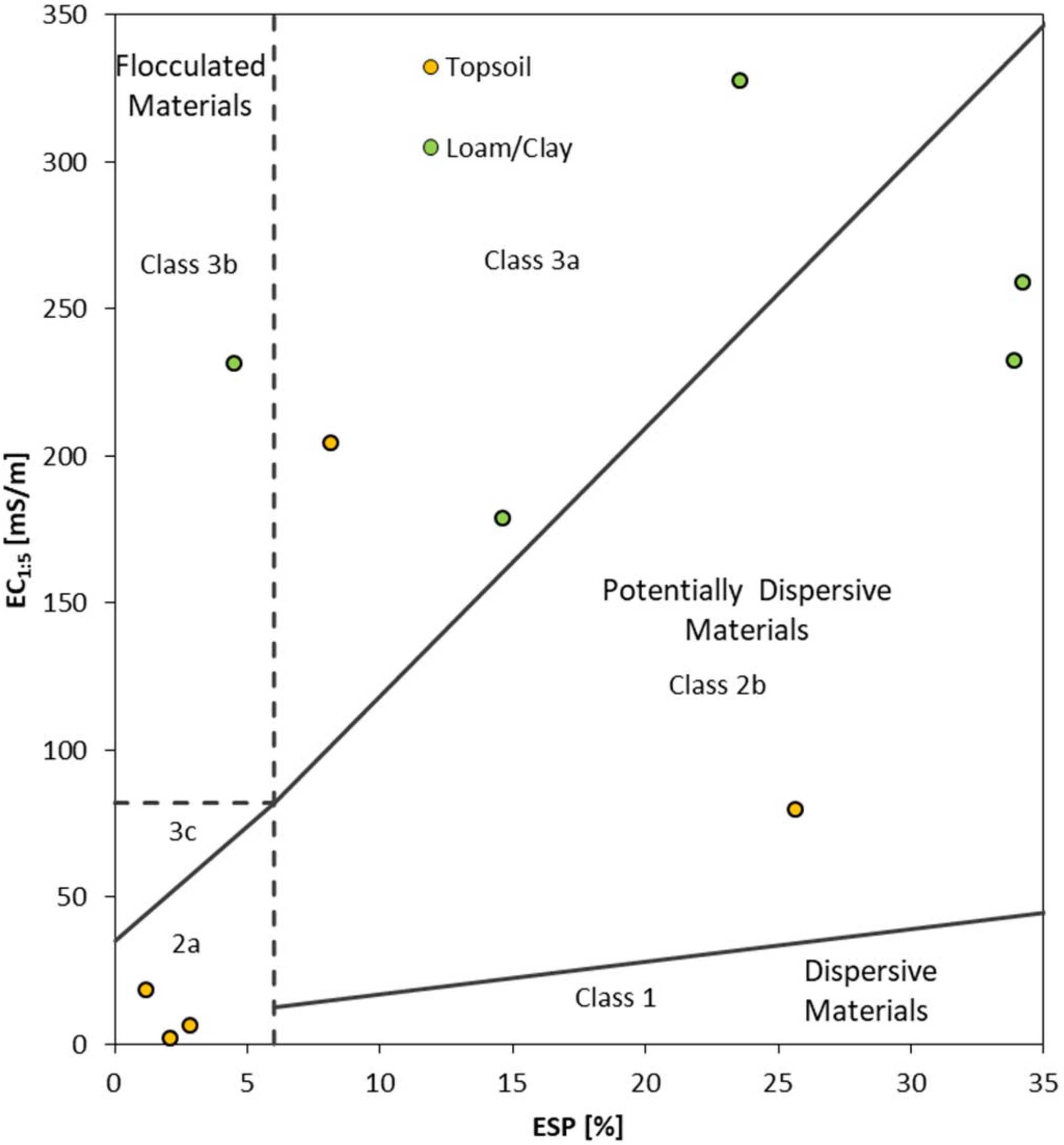


Figure 4.4: Stability plot for all samples

4.2 EROSION MODELLING RESULTS

Table 4.7 summarises the average runoff and sediment yield values predicted by the WEPP erosion model, given the input parameters previously summarised in Section 3.4.

Table 4.7: Summary of WEPP erosion modelling results.

Material ID	Lift height (m)	Slope angle	Average annual runoff (mm/yr)	Average erosion rate (mm/yr)	Average erosion rate (t/ha/yr)
Clay/loam	10	15°	27	1.2	19.5
		18°	26	1.3	20.1

The WEPP model indicated average sediment yields of approximately 20 t/ha/yr (1.2 mm soil loss per year), regardless of slope the slope angle modelled. The laboratory results indicated that the clay/loam subsoil material is highly susceptible to rill erosion, and steeper slope angles generally produced larger erosion rates. The high sediment yields predicted for expected to be a result of the slow infiltration rate, negligible organic matter content, and variable dispersion potential of this material. This subsoil material should not be used on outer batter slopes without the inclusion of a stabilising agent such as fresh competent rock or varying the geometry of the post-mine landform to reduce surface water flow rates. The inclusion of a fresh and competent waste rock component in addition to the clay/loam material would be expected to reduce the erosion rate from this material (particularly during the initial stages of rehabilitation), as would the re-establishment of vegetation.

It should be noted that more than the average amount of sediment (e.g. the average t/ha/yr) will be generated in years with greater than average rainfall, and from extreme individual storm events. Runoff and erosion depend largely on the size and intensity of each rainfall event and the infiltration characteristics of each material – Not all rainfall events generate runoff, and not all runoff events generate erosion. It is reasonable to expect that more than one year’s worth of sediment loss (when considered as an average annual loss) will occasionally occur in a single storm event.

5 SOIL MANAGEMENT

This section outlines management recommendations for the handling and utilisation of the surficial soil materials within the Golden Hind gold deposit Project Area. These recommendations are suggested with the aim of:

- Maintaining optimal soil properties during the mining and rehabilitation process.
- Appropriate handling of soil materials that exhibit adverse physical and chemical properties to ensure no contamination with other ‘good’ or optimal materials.
- Minimising environmental impacts through appropriate handling and placement of soil materials that exhibit adverse properties.

5.1 TOPSOIL MATERIALS

All material in the upper 20 cm of the soil profile over the site should be treated as a homogenous “topsoil: material. This should include all areas disturbed by previous exploration activity. These soils represent the most favourable available material for the re-establishment of plant growth on post-mine landforms due to:

- relatively elevated organic matter and nutrient content
- relative resistance to surface erosion processes, and
- the presence of a pre-existing seed store (i.e. geosporous species) that will be beneficial to the establishment and growth of revegetation species.

It is recommended that the upper 20 cm be stripped from all areas prior to any further disturbance and stockpiled as a resource for later use. To maintain the soils’ biological components and nutrient sources, all topsoil stockpiles should not exceed 2 m in height, and soil should not be stockpiled for longer than 12 months, where practicable. Saline water should not be used for dust suppression on stockpiled topsoil as this will structurally degrade these materials.

5.2 SUBSOIL MATERIALS

All soil materials below 20 cm depth within the pit boundary to the top of the *in situ* saprolite should be separated and saved for later use as an overburden material. This material is erodible, and is not suitable for placement on the surface of the WRL without additional management actions to prevent excessive erosion. Regardless of the erosion potential, the material represents a valuable water store for plant establishment on post-mine landforms and should be saved for this use.

Soil material below 20 cm depth and above the *in situ* saprolite should be considered as overburden materials, as they are:

- able to contribute to a deeper total soil profile – thus enhancing the total soil water holding capacity, and providing more physical space for plant root exploration.
- expected to be less saline and less acidic than the underlying waste rock oxide materials, and
- able to form a barrier between the upper growth medium and the potentially saline and acidic waste material, without inhibiting growth of established revegetation species.

It is therefore recommended that all overburden material be stripped and stockpiled as a resource for later use.

6 REFERENCES

BOM (2021): *Rainfall IFD Data System*, http://www.bom.gov.au/water/designRainfalls/revised-ifd/ Bureau of Meteorology website, last accessed 28 January 2021.

Elliott, W J; Liebenow, A M; Laflen, J M; Kohl, K D (1989): *A compendium of soil erodibility data from WEPP cropland soil field erodibility experiments 1987-88*. NSERL Report 3. The Ohio State University/USDA-Agriculture Research Service, West Lafeyette, Indiana, USA.

Flanagan, D C; Livingston, S J (1995): Water Erosion Prediction Project (WEPP), Version 95.7. User Summary.

Foster, G R (1982): *Modeling the erosion process*. In: Hahn, C.T. (Ed.), Hydrologic Modeling of Small Watersheds, pp. 295–380.

Green, W H; Ampt, G A (1911): *Studies on soil physics, Part I. – The flow of air and water through soil*. Journal of Agricultural Soil Science, 4(1): 1-24.

Isbell, R.F. (1996). *The Australian Soil Classification*. Australian Soil and Land Survey Handbook, Volume 4. CSIRO Publishing, Collingwood, Victoria, Australia.

McDonald, R.C. and Isbell, R.F. (2009). 'Soil Profile'. In: *Australian Soil and Land Survey Field Handbook* (3rd Ed.), National Committee on Soil and Terrain, CSIRO Publishing, Melbourne. pp. 147 – 204.

McDonald, R.C., Isbell, R.F and Speight, J.G. (2009) 'Land Surface'. In: *Australian Soil and Land Survey Field Handbook* (3rd Ed.), National Committee on Soil and Terrain, CSIRO Publishing, Melbourne. pp. 127 – 144.

Schoknecht, N. (2001). *Soil Groups of Western Australia: A guide to the main soils of Western Australia* (Ed. 2). Resource Management Technical Report 193, Department of Agriculture.

Sheridan, G J; So, H B; Loch, R J; Pocknee, C; Walker, C M (2000): *Use of laboratory-scale rill and interill erodibility measurements for the prediction of hillslope-scale erosion on rehabilitated coal mine soils and overburdens*. Australian Journal of Soil Resources, 38:285-297.

Yu, B (2003). *An assessment of uncalibrated CLIGEN in Australia*, Agriculatural and Forest Meterology, 119: 131–148.

Appendix B:

Soil Characterisation for Hornet

(SoilWater 2010)

SOIL WATER CONSULTANTS

HORNET DEPOSIT SOIL CHARACTERISATION

Prepared for:	**BARRICK KANOWNA**
Date of Issue:	21 December 2010
Project No.:	PN0188-1-1-BK-015

A member of the SOIL WATER GROUP

SOIL WATER CONSULTANTS | SOIL WATER ANALYSIS | SOIL WATER TECHNOLOGIES

Soil Water Consultants

ABN 45 096 843 659
Unit 2, 6 Cocos Drive, Bibra Lake, WA 6163 | PO Box 153, Applecross, WA 6153
Tel: +61 8 9434 5836 | Fax: +61 8 9434 5837 | Email: swc@soilwater.biz

DOCUMENT STATUS RECORD

Project Title:	HORNET DEPOSIT SOIL CHARACTERISATION
Project No.:	PN0188-1-1-BK-015
Client:	BARRICK KANOWNA

Revision History

Revision Code*	Date Revised	Revision Comments	Signatures		
			Originator	Reviewer	Approved
B	21/12/10	Draft report issued to client	ASP	SC	ASP

Revision Code*

A - Report issued for internal SWC review	1 - First Revision
B - Draft report issued for client for review	2 - Second Revision
C - Final report issued to	3 - Third Revision

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to undertake a soil characterisation for the proposed Hornet Deposit. This work was conducted in accordance with the Scope of Work presented to Barrick Kanowna ('the Client').

SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the soil characterisation was confined solely to the Hornet Deposit. No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area. In preparing this study, SWC has relied on published soil reports from various soil researchers and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel.

SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client.

This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party

CONTENTS

List of Figures

List of Tables

List of Plates

1. INTRODUCTION

Soil Water Consultants (SWC) were commissioned by Barrick Kanowna (KB) to undertake a soil characterisation for the proposed Hornet deposit. The purpose of this assessment was to identify and characterise all surficial soil materials within the disturbance area and suggest management strategies for their handling and utilisation. This information provides baseline data that can be used to assist in the mining of these materials, and in the construction and rehabilitation of the waste dump. Implementation of the soil management recommendations suggested in this report will ensure that only optimal materials are used in the construction of the outer surface of the waste dump, thus facilitating stability and revegetation, and ultimately closure and bonds return.

1.1 SUBHEADING

The objectives of this soil characterisation were to:

- Define the distribution of soil in the study area.
- Characterise the physical and chemical properties of the soils.
- Identify materials that may be beneficial to the rehabilitation of the waste dumps, and materials that may have an adverse impact on rehabilitation.
- Suggest management strategies for the handling and utilisation of these materials during mining and rehabilitation.

1.2 SCOPE OF WORKS

The Scope of Work completed by SWC included:

- Collect soil samples from the study area using shallow trench excavations.
- Describe the surface soil profiles throughout the study area and prepare a soils map for the area.
- Undertake field and laboratory analysis to characterise the physical and chemical properties of the surficial materials.
- Preparation of this report

2. SITE DESCRIPTION

2.1 LOCATION

The proposed Hornet deposit is located approximately 20 km west of Kalgoorlie (Figure 2.1), along the Kundana Haul Road between the existing Rubicon minepit and Lake Kopai (Figure 2.2). The disturbance footprint for this deposit covers an area of approximately 65 ha.

2.2 SITE LAYOUT

The Hornet deposit will be mined using open pit techniques, with the ore body contained solely within the oxide (regolith) profile. The proposed minepit will cover an area of approximately 6 ha (Figure 2.3) and will extend to a maximum depth 70 m below surface, with termination of mining likely to occur at the oxide/fresh rock contact. Waste oxide material from the deposit will be excavated and stockpiled within a purpose-built waste dump located to the north of the minepit (Figure 2.3), whilst the mined ore will be temporarily stored in an adjacent ROM pad (Figure 2.3), prior to processing at the Kanowna Belle mill.

2.3 GEOLOGY AND HYDROGEOLOGY

The orebody at the Hornet deposit is hosted within the Centenary Shale, which occurs at the contact with the Victorious (Catrock) Basalt (western side) and Intermediate Andestic Tuff (Sparoville Formation; eastern side, Figure 2.4a) (EKJV, 2004). The contact and subsequent structure of the Centenary Shale is steeply dipping to the west, trending in a north – south direction through the Hornet deposit (Figure 2.4b).

The basement rocks within the Hornet deposit have been extensively weathered producing a deep oxide profile, which hosts the remnant gold mineralisation. The *in situ* regolith profile consists of a 15 – 60 m thick saprolite and a 10 – 20 m thick transitional or saprock zone. The thickness of the *in situ* regolith increases towards the centre of the deposit, along the Centenary Shale contact, and to the south along the Mary Fault. The upper surface of the saprolite has been truncated and subsequently filled with a 4 – 8 m thick transported alluvial cover (Plate 2.1). The thickness of the transported sediments increases to the south of the deposit, where it reaches a thickness of around 70 m beneath Lake Kopai (EKJV, 2004).

Plate 2.1: Transported alluvial cover overlying saprolite at the adjacent Rubicon minepit. The upper surficial soil profile at the Hornet deposit is likely to be similar to that observed in the Rubicon minepit given its close proximity.

Groundwater within the Hornet deposit occurs at a depth of 10 – 20 m below the surface, at an elevation of approximately 328 m AHD (Aquaterra, 2003). Groundwater is primarily contained within the coarser textured transitional zone (exhibiting preserved bedrock fabric), being confined by the overlying more clayey saprolite zone (Aquaterra, 2003). Given the proximity to the Lake Kopai salt lake system it is expected that the groundwater in the Hornet deposit is hyper-saline and subsequently all oxide materials below 10 – 20 m (i.e. below the watertable) are likely to be highly saline. Salinity levels of these materials will likely have an adverse impact on rehabilitation if used in the reconstruction of the growth medium of the waste dump (i.e. the outer surfaces of the waste dump).

2.4 REGIONAL SOILS

The soils across the Hornet deposit have been mapped at a regional scale (1:250,000 scale) by the Department of Agriculture, as part of the Southern Goldfields Rangeland Survey. The regional soils distribution is shown in Figure 2.5.

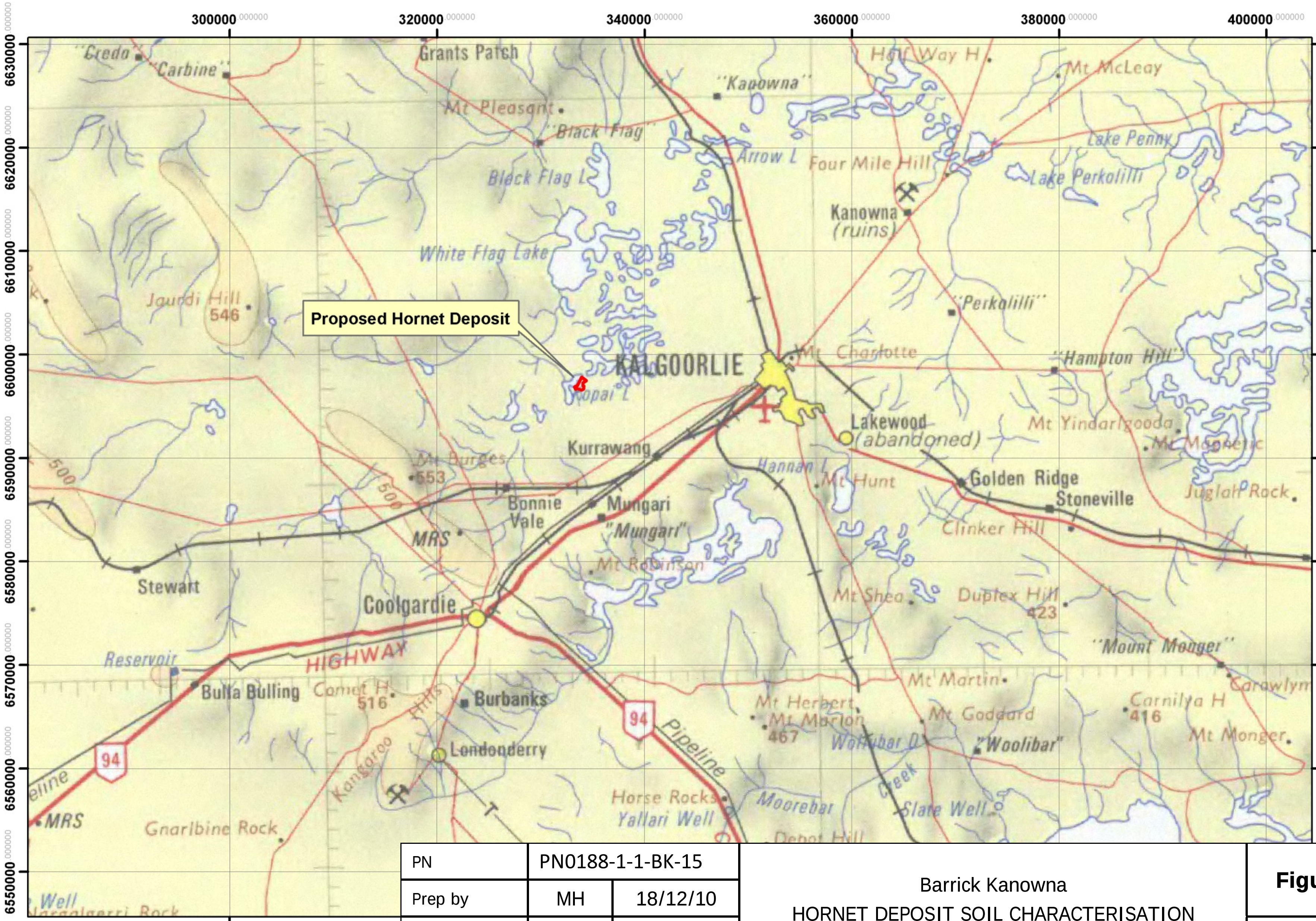
At the regional scale the soils throughout the Hornet deposit are classified as salt lake (saline) soils experiencing wet and waterlogged conditions (265SV15; Figure 2.5). These soils are typically highly to extremely saline, with a dominant clayey texture. Surrounding the salt lake system soils are the red loamy earth associated with the gently undulating plains and pediments, characteristic of the Goldfield region (265Mx43 & 266Mx43; Figure 2.5). These loamy soils are typically deep (> 1 m in depth), often calcareous, with a dominant earthy fabric. They are generally well drained and experience oxidising conditions throughout the year. Minor calcareous shallow loams and loamy earths occur in isolated regions, associated with either out- or sub-cropping greenstone and basic igneous bedrocks. These soils are generally shallow (< 1 m) underlain by fresh or partially weathered basement rocks.

Although at the regional scale the soils throughout the Hornet deposit are classified as salt lake soils, at a local scale the soils are better defined as the red loamy earths as they generally occur at a higher elevation than the salt lake systems (i.e. they are more accurately classified as 265Mx43; Figure 2.5).

2.5 VEGETATION

The vegetation across the Hornet deposit has been mapped by Botanica Consulting (2010). The distribution of the vegetation is shown in Figure 2.6.

The vegetation within the Hornet deposit varies from Mixed *Eucalyptus* and *Eucalyptus clelandii* woodland to Melaleuca thicket and Casuarina tall shrubland to Samphire vegetation within the salt lake (Figure 2.6). The Hornet deposit has been extensively drilled in the past, and these disturbance areas have been rehabilitated to chenopod shrubland. In total 18 families, 30 genera and 57 species of vegetation was reported in the area, and no Declared Rare Flora (DRF), Priority Flora (PF) and Priority or Threatened Ecological Communities occur in the Hornet deposit (Botanica Consulting, 2010). Most of the vegetation in the area, with the exception of those previously rehabilitated, are considered in 'good' health condition.

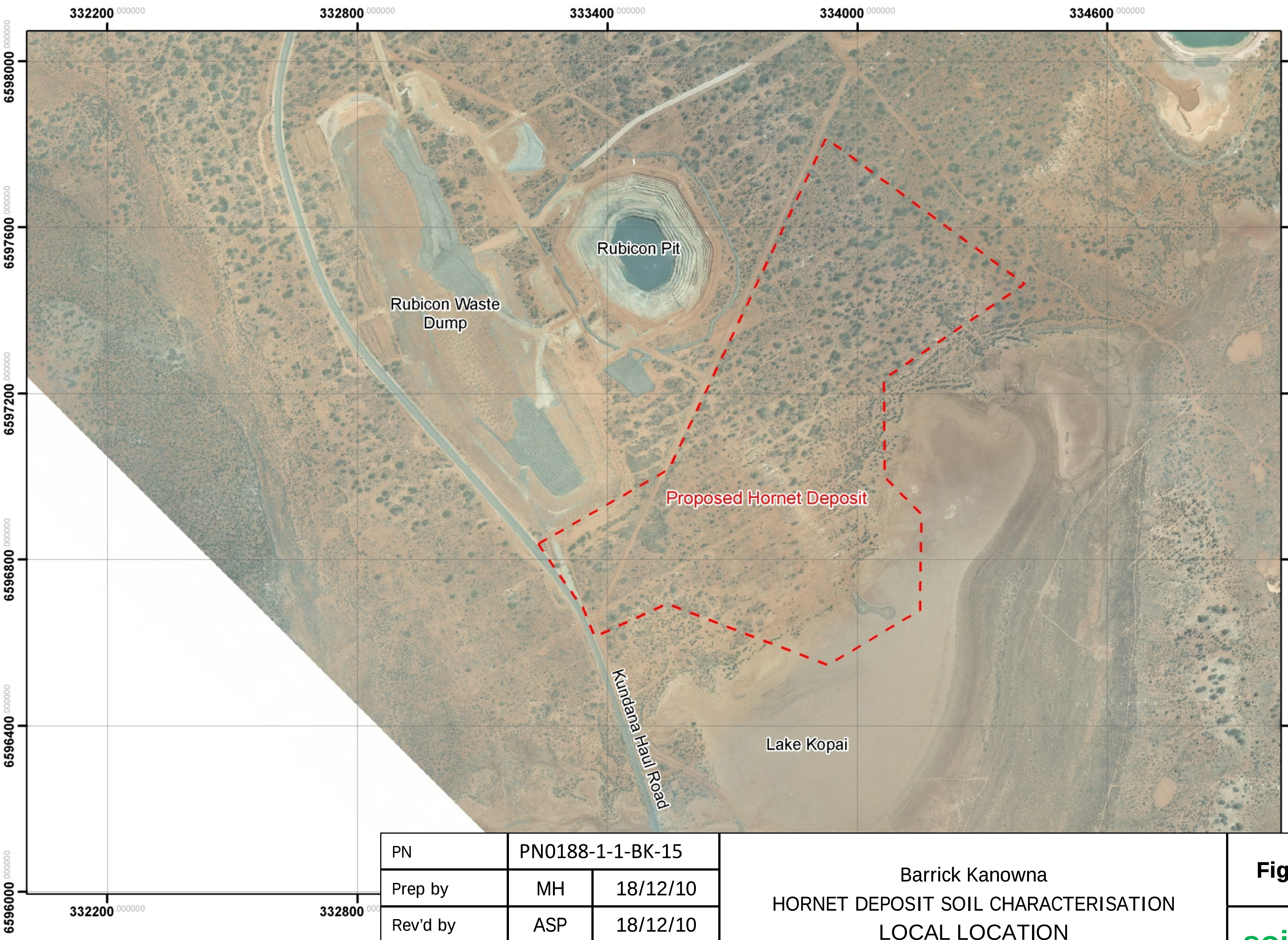


PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

Barrick Kanowna
HORNET DEPOSIT SOIL CHARACTERISATION
REGIONAL LOCATION

Figure 2.1

soilwater

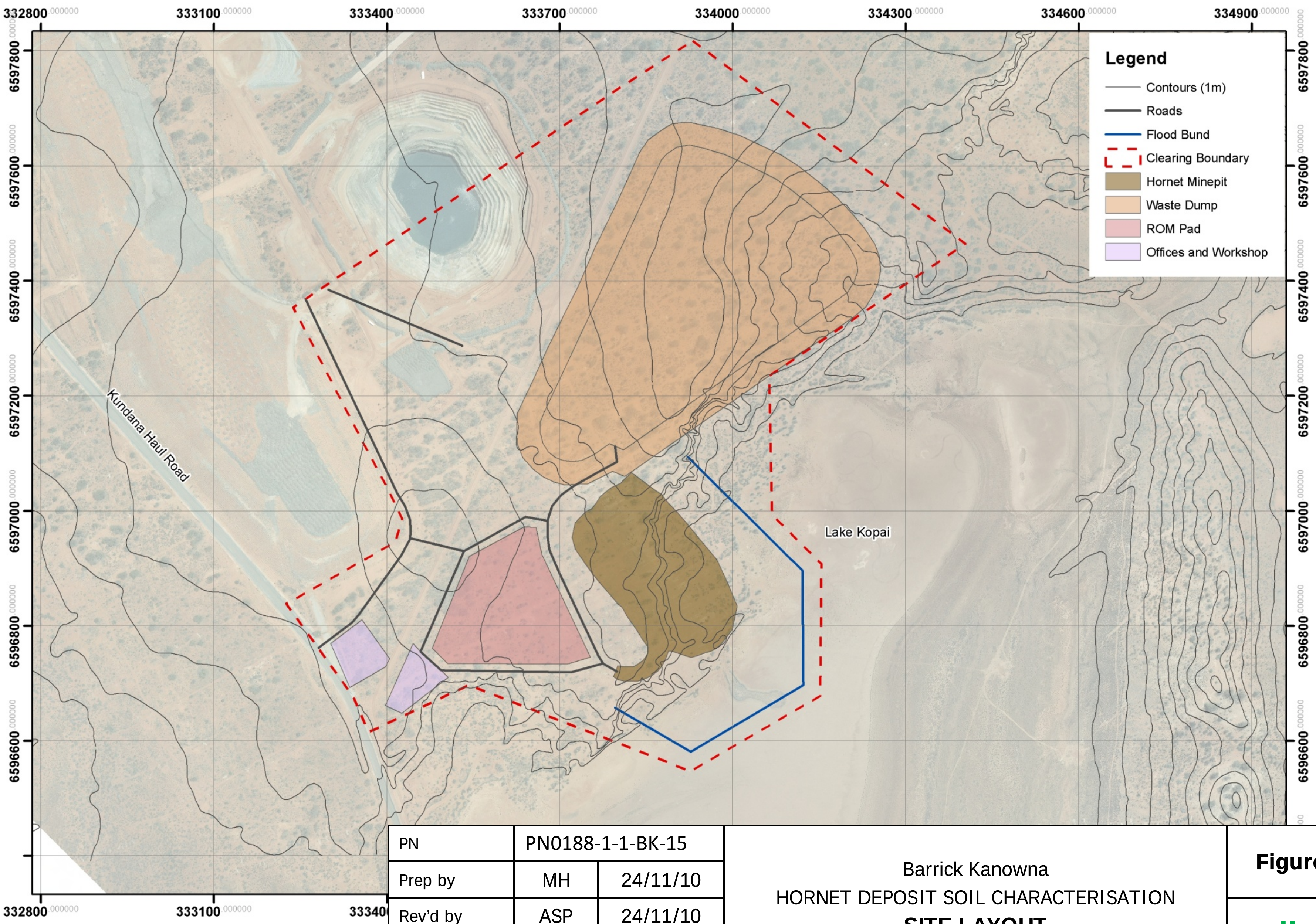


PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

Barrick Kanowna
HORNET DEPOSIT SOIL CHARACTERISATION
LOCAL LOCATION

Figure 2.2

soilwater



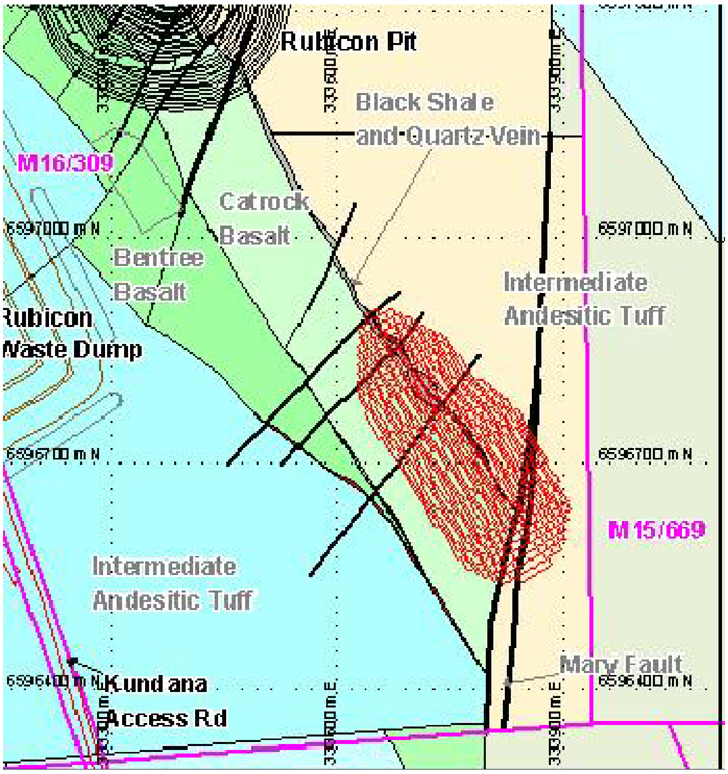
PN	PN0188-1-1-BK-15	
Prep by	MH	24/11/10
Rev'd by	ASP	24/11/10
Revision No.	0	

Barrick Kanowna
HORNET DEPOSIT SOIL CHARACTERISATION
SITE LAYOUT

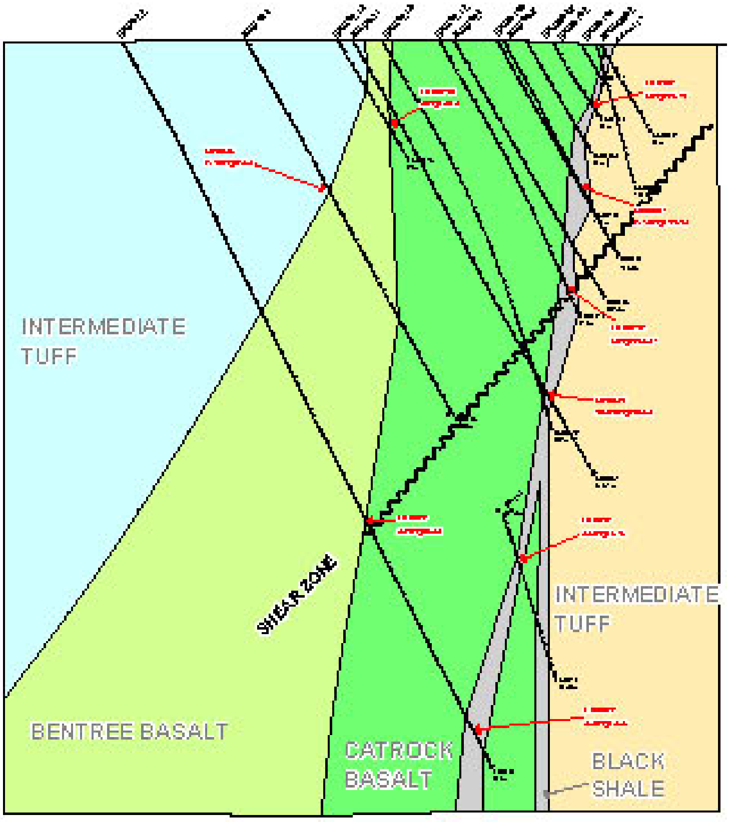
Figure 2.3

soilwater

a) Regional geology – Plan view

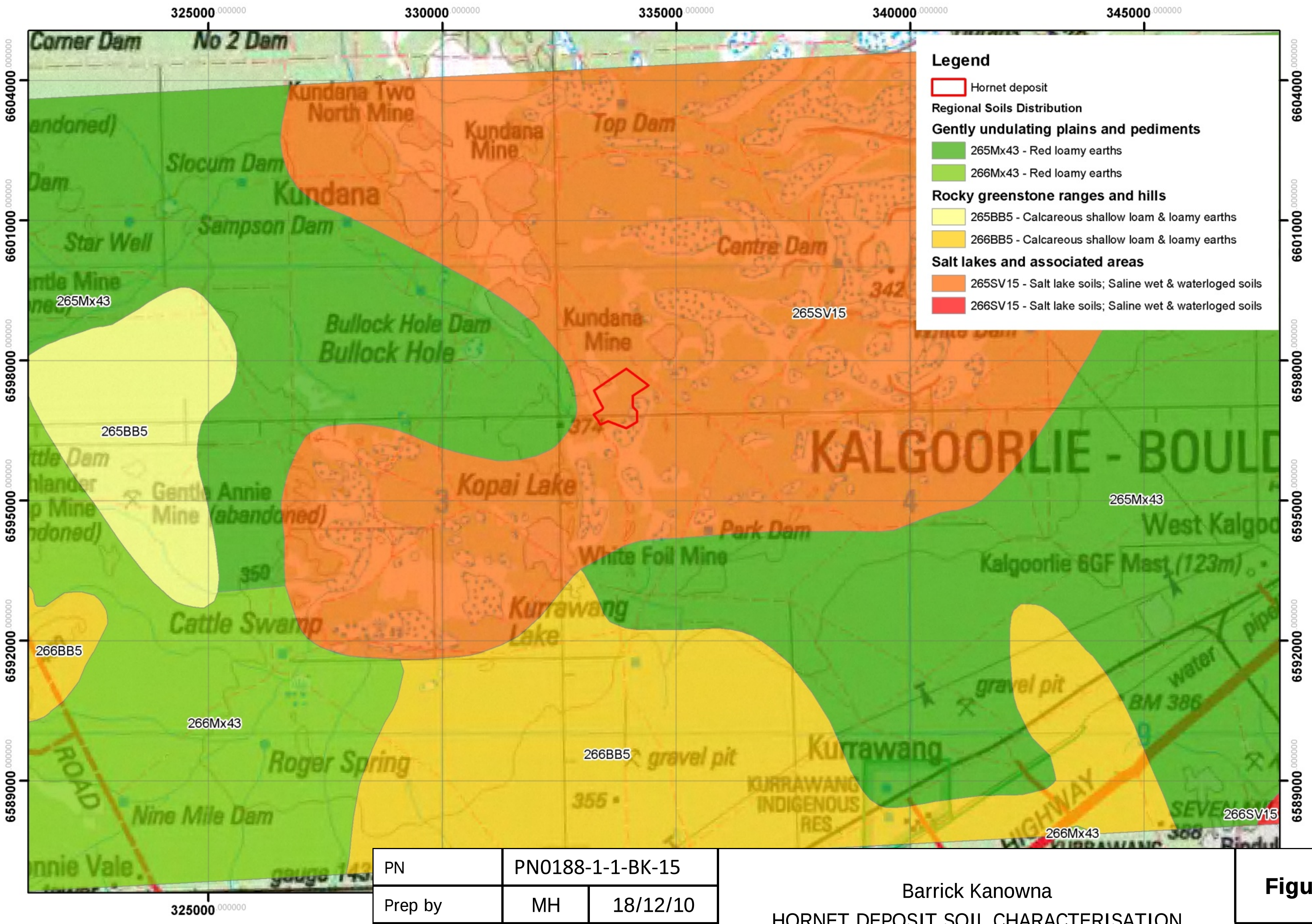


b) Regional geology – Cross section



Soil Water Consultants PTY LTD Perth Offices 08 9434 5836

PN	PN0188-1-1-BK-15		Barrick Kanowna HORNET DEPOSIT SOIL CHARACTERISATION **REGIONAL GEOLOGY**	**Figure 2.4**
Prep. by	ASP	17/12/10		soilwater
Rev'd. by	SC	17/12/10		
Revision No.		0		

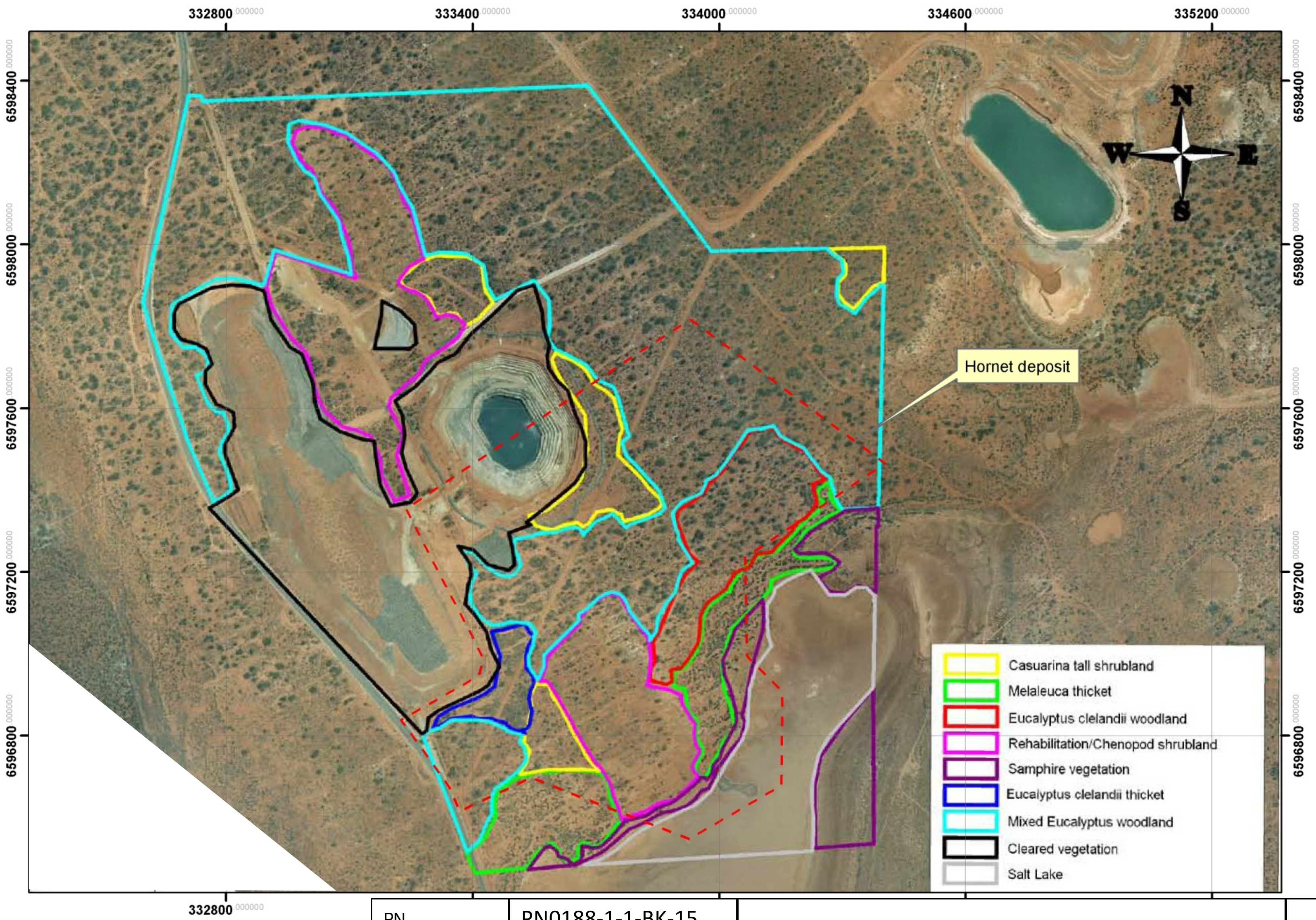


PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

Barrick Kanowna
HORNET DEPOSIT SOIL CHARACTERISATION
REGIONAL SOILS

Figure 2.5

soilwater



PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

Barrick Kanowna
HORNET DEPOSIT SOIL CHARACTERISATION
VEGETATION MAP

Figure 2.6

soilwater

3. STUDY METHODOLOGY

3.1 SOIL PROFILE DESCRIPTION

All soil profiles assessed in the field were described in accordance with the McDonald and Isbell (2009), whilst the landsurface was assessed using the classification scheme outlined in McDonald *et al*. (2009). Soil profiles were assessed for degree of horizonation, nature of contacts between horizons, presence and abundance of coarse fragments (i.e. gravels) and mottling, and structure, fabric and field texture of soil materials. A semi-quantitative assessment of plant roots (Table 3.1) was also undertaken to assist in identifying any potential adverse soil materials.

Table 3.1: Semi-quantitative assessment of plant roots used in this investigation (McDonald and Isbell, 2009).

Rating	Number of roots per 0.01 m^2 (10 cm × 10 cm)	
	Very fine - fine roots (< 2 mm diameter)	Medium - coarse roots (> 2 mm diameter)
0 No roots	0	0
1 Few roots	1 - 10	1 - 2
2 Common roots	10 - 25	2 - 5
3 Many roots	25 - 200	> 5
4 Abundant roots	> 200	> 5

3.2 SOIL SAMPLE COLLECTION

Soil materials within the Hornet deposit were investigated by shallow trench excavation. Sampling was undertaken in August 2010 and the locations of the sampling sites are provided in Figure 3.1.

Shallow trenches were excavated by hand to a maximum depth of 1.3 m (Plate 3.1), and where possible exposed soil profiles along deep erosional gullies were also assessed (Plate 3.2). A total of 13 sampling sites were investigated across the proposed disturbance area (Figure 3.1). Samples were collected at 10 cm intervals down the surficial profile to ensure that any pedologic organisation or horizonation was identified and that each of the major soil materials was sampled. Approximately 3 kg of soil was collected for each material for detailed laboratory analysis (Section 3.3).

Details of the sampling sites assessed are provided in Table 3.2

3.3 LABORATORY ANALYSIS

The physical and chemical properties of the soil materials collected in the field were assessed in the laboratory. The properties listed in Table 3.3 were assessed for a representative number of samples from all soil materials.

Analysis of the physical properties was undertaken at Soil Water Analysis (SWA) Laboratories, whilst the chemical properties were assessed at CSBP Laboratories.

Plate 3.1: Excavation of shallow soil trenches by hand to characterise the surface soils.

Plate 3.2: Assessment of the surface soil profile exposed along a deep erosional gully.

Table 3.2: Details of the locations sampled for the soil characterisation

Trench ID	Coordinates (GDA 94, Zone 50)		Depth (cm)	Trench ID	Coordinates (GDA 94, Zone 50)		Depth (cm)
	Easting	Northing			Easting	Northing	
1	333814	6596891	110	8	334006	6597041	40
2	333724	6597068	50	9	334018	6597431	60
3	333711	6597108	30	10	333698	6596984	110
4	333887	6597050	130	11	333597	6596810	50
5	333790	6596635	130	12	333637	6596693	30
6	334069	6596999	60	13	333825	6597258	30
7	334140	6596912	40				

Table 3.3: Physical and chemical properties examined in the laboratory

Physical properties	Chemical properties
• Bulk density • Particle size distribution • Saturated hydraulic conductivity • Water retention properties • Structural stability	• Nutrients (Mineralised Nitrogen, Colwell Phosphorus and Potassium, and Extractable Sulfur) • Organic carbon • pH • Electrical conductivity (salinity, EC) • Exchangeable cations (Calcium, Magnesium, Sodium and Potassium) • Cation exchange capacity (CEC) • Sodicity (Exchangeable sodium percentage – ESP)

All physical and chemical properties were assessed against standard soil property criteria provided in Appendix A.

3.4 RAINFALL SIMULATOR

In addition to the above characterisation of the physical and chemical properties of the surface soils, the potential erodibility or stability of the surface soils at various slope angles was also assessed using a laboratory-scale (0.75 × 0.75 m plots) rainfall simulator (Plate 3.3). Approximately 150 kg of the surficial soil most likely to be used to construct the outer surface of the waste was collected in large bulk bags and transported to SWA Laboratories in Perth. The soil material was packed to a bulk density similar to that occurring in the field, with the surface exposed to several wetting and drying cycles to allow a crust to develop (similar to that observed in the field).

The slope angles assessed were 10, 12 and 15°, with an applied rainfall intensity of 100 mm/hr (equivalent to a 100 year ARI event for a duration of 10 – 20 mins). Rainfall runoff and sediment generated from the soil surface was collected at regular time intervals and measured gravimetrically to quantify runoff and sediments yields for the various slopes. The effective hydraulic conductivity of the surface soils was estimated by fitting the Green Ampt equation used in WEPP (Equation 1) to the infiltration rates measured on the rainfall simulator plots,

$$f = K_e\left(1 + \frac{N_S}{F}\right) \qquad \text{Eqn. 1}$$

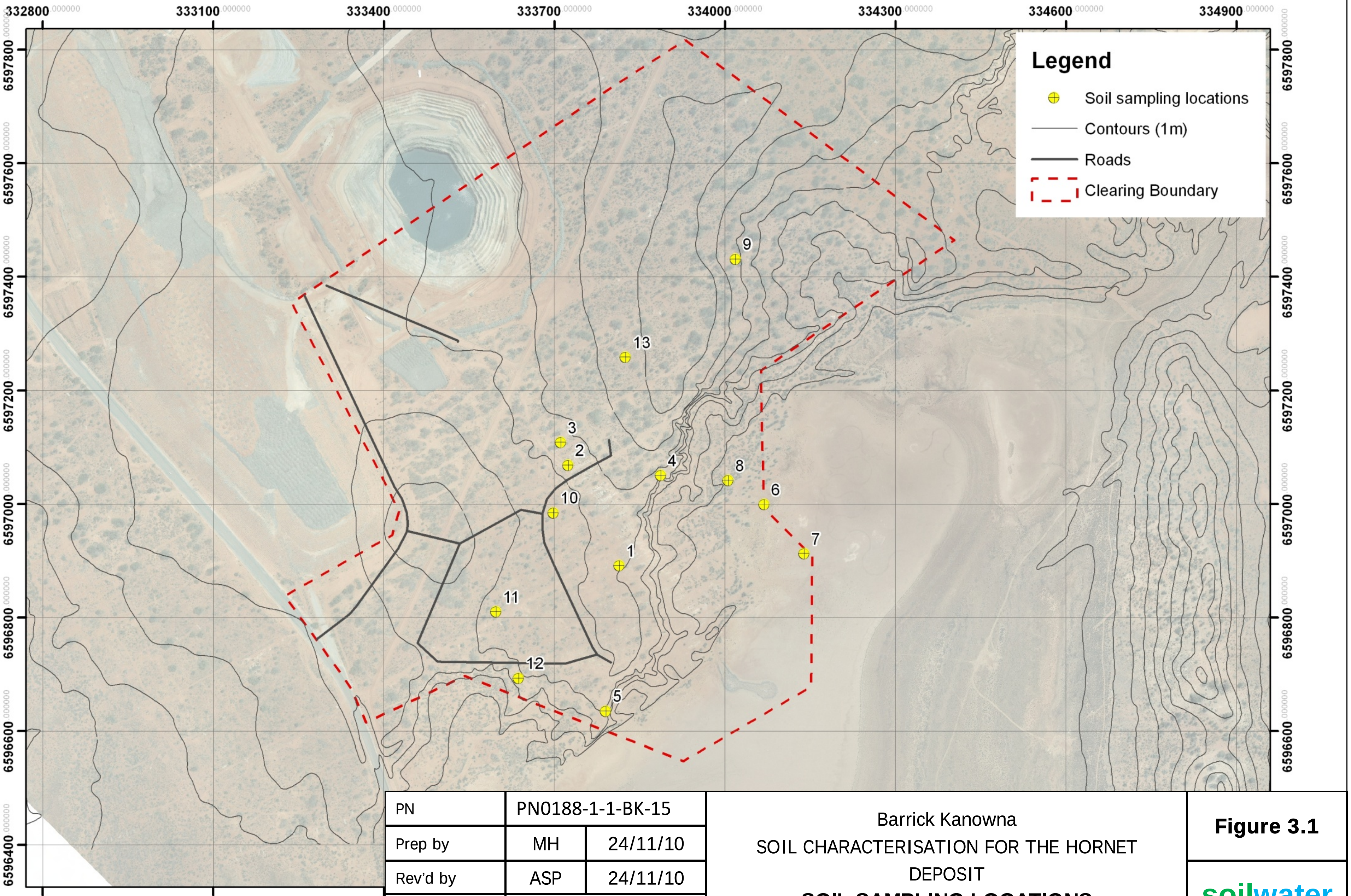
With f = infiltration rate [mm/h], K_e = effective saturated hydraulic conductivity [mm/h], N_s is the effective matric potential at the wetting front [m], and F is the cumulative infiltration [m].

The interrill erodibility of the surface soils were calculated using Equation 2 (Elliot et al., 1989):

$$D_i = K_i \, I^2 \, S_f ,$$ Eqn. 2

where = interrill erosion rate [kg/(m^2*s)], = interrill erodibility [(kg*s)/m^4], I = rainfall intensity [m/s] and = dimensionless slope factor (1.05-0.85 EXP $^{(-0.85\ \sin(alpha))}$).

Plate 3.3: Laboratory-scale rainfall simulator used to assess the stability of the surface soils at various slope angles.



PN	PN0188-1-1-BK-15	
Prep by	MH	24/11/10
Rev'd by	ASP	24/11/10
Revision No.	0	

Barrick Kanowna
SOIL CHARACTERISATION FOR THE HORNET DEPOSIT

SOIL SAMPLING LOCATIONS

Figure 3.1

soilwater

4. SOIL CHARACTERISATION

Based on the evolutionary history of the Hornet deposit and the morphological characteristics of the soil profiles examined in this investigation, the following three distinct Soil Mapping Units (SMU) were defined:

- SMU 1: Deep calcareous sandy loam.
- SMU 2: Truncated calcareous sandy loam.
- SMU 3: Deep calcareous coarse sand.
- SMU 4: Saline clay.

The relationship between these SMU and the major soil groups in Western Australia (Schoknecht, 2001) and the Australian Soil Classification (Isbell, 1996) are presented in Table 4.1.

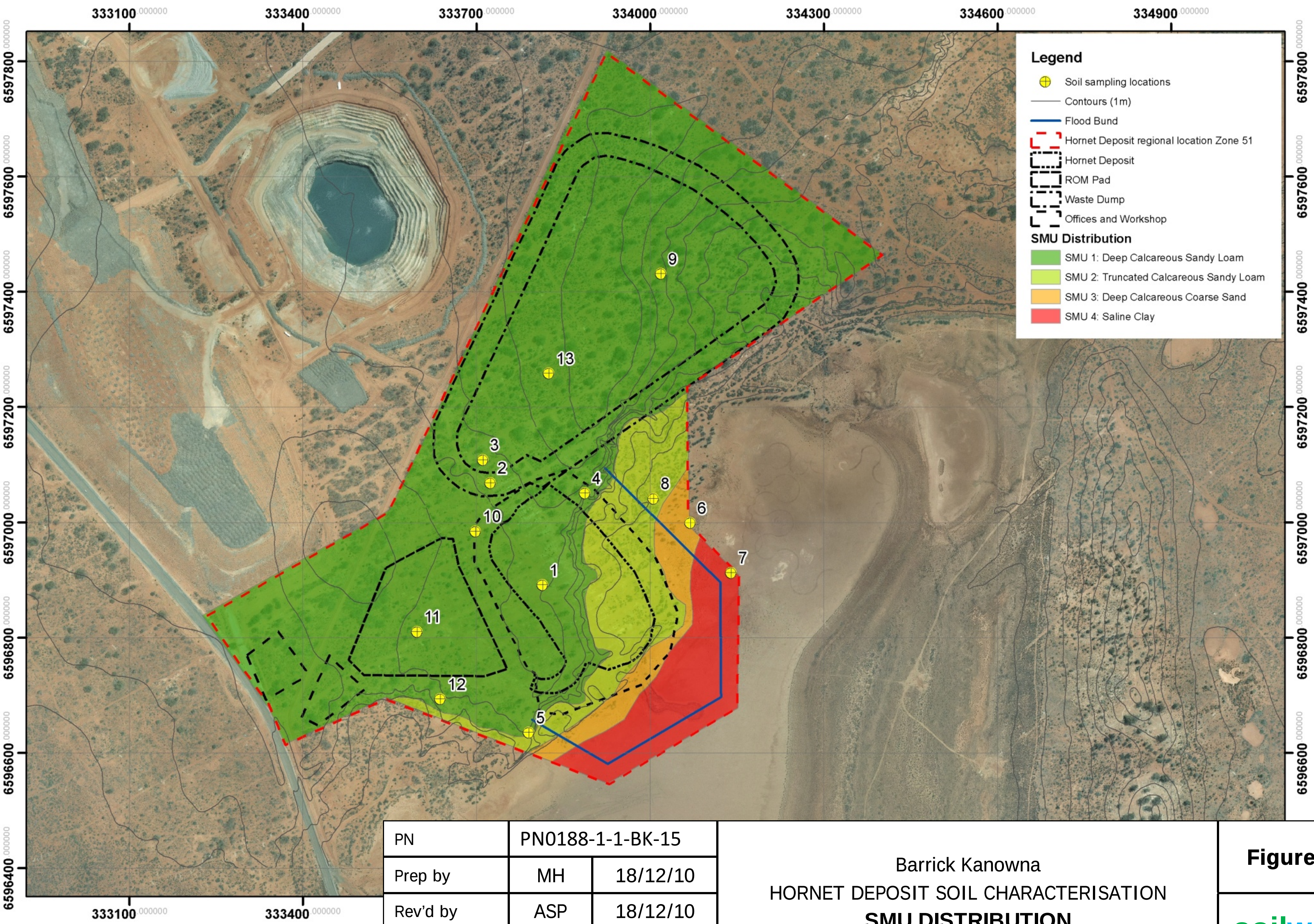
Table 4.1: Relationship between the SMU identified in this study and the major soil groups of Western Australia and the Australian Soil Classification.

SMU (Present study)	Major soil group, WA (Schoknecht, 2001)	Australian Soil Classification (Isbell, 1996)
1. Deep calcareous sandy loam	Calcareous loamy earth	Calcic Calcarosol
2. Truncated calcareous sandy loam	Calcareous loamy earth	Calcic Calcarosol
3. Deep calcareous coarse sand	Calcareous deep sand	Calcareous Rudosol
4.Saline clay	Saline wet soil	Salic Hydrosol

4.1 SOIL DISTRIBUTION

The distribution of the SMU within the Hornet disturbance area is shown in Figure 4.1. The majority of the area (79 %) is underlain by a deep calcareous sandy loam (SMU 1), with the waste dump, ROM pad, offices and workshop areas all occurring on this soil type. A considerable portion of this SMU (around 7 ha), adjacent to Lake Kopai, has been previously disturbed, with the upper portion of the profile being removed resulting in a truncated profile (SMU 2). Along the fringes of the salt lake a relatively thin zone of deep coarse sand occurs, likely representing accumulated aeolian sand (SMU 3), whilst the soils of Lake Kopai are classified as saline clays (SMU 4).

All soils characterised in this investigation have been transported by alluvial and aeolian processes and correspond only to the surface portion of the transported layer shown in Plate 2.1. No assessment of the deeper (potentially Archaean) transported materials or the underlying *in situ* regolith has been made given the limitations of this investigation (i.e. restricted to shallow trenches).



PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

Barrick Kanowna

HORNET DEPOSIT SOIL CHARACTERISATION

SMU DISTRIBUTION

Figure 4.1

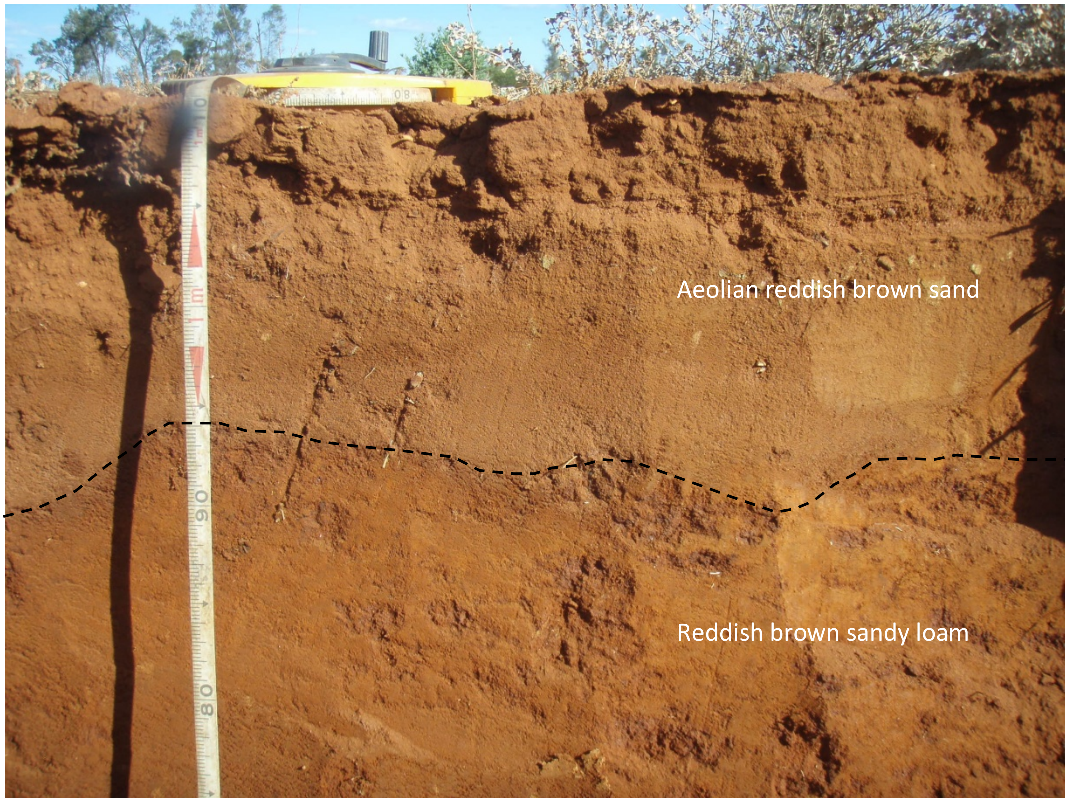
soilwater

4.2 SOIL DESCRIPTION

4.2.1 SMU 1: DEEP CALCAREOUS SANDY LOAM

This is the dominant soil type in the Hornet deposit covering an area of 51.4 ha (79 % of the proposed disturbance area). A characteristic profile for this SMU is shown in Figure 4.2. It consists of a 5 – 15 cm thick surface layer of reddish brown medium - coarse aeolian sand to loamy sandy (84 % sand, 4.1 % silt and 11.8 % clay) overlying a reddish brown friable well structured sandy loam. The contact between the surface sand and underlying sandy loam is abrupt (Plate 4.1) indicating that the sand has been deposited onto the sandy loam and not formed *in situ* (i.e. likely to be aeolian sand deposited by prevailing winds across the salt lake). A defined evaporite layer occurs within the reddish brown sandy loam at typically 40 – 60 cm (Figure 4.2). It is likely that this layer has formed in response to evaporative concentration of soluble salts, most likely to be lime ($CaCO_3$) based on the pH of the soils (i.e. pH around 9; Figure 4.3). The presence of lime nodules in this layer gives the material a mottled appearance (Plate 4.2).

Plate 4.1: Abrupt contact between the surface sand and underlying sandy loam.



Underlying the developing calcrete layer is a brown moderately to well structured sandy loam to sandy clay loam. There is a gradual increase in silt and clay content with depth down the profile (Table 4.2), which has occurred in response to clay elevation and illuviation. This increase in the fine soil fraction with depth results in a corresponding decrease in hydraulic conductivity of the soils; the permeability of the surface reddish brown sandy loam is around 5 – 6 m/day, whilst the underlying sandy loam – sandy clay loam soil has a permeability of only 0.1 – 0.3 m/day. This significant reduction in hydraulic conductivity with depth is likely to result in perching of infiltrating water in the surface soils, and subsequent evaporative accumulation of soluble salts.

Plate 4.2: Mottled appearance of the evaporite layer within the reddish brown sandy loam material.

Table 4.2: Particle size distribution of the < 2 mm soil fraction with depth in SMU 1.

Depth (cm)	% Sand	% Silt	% Clay	Texture
0 - 10	84.1	4.1	11.8	Loamy sand
20 - 30	71.8	9.6	18.7	Sandy loam
40 - 50	76.8	8.3	15.0	Sandy loam
50 - 60	55.9	12.2	32.0	Sandy clay loam
90 - 100	55.9	12.2	32.0	Sandy clay loam

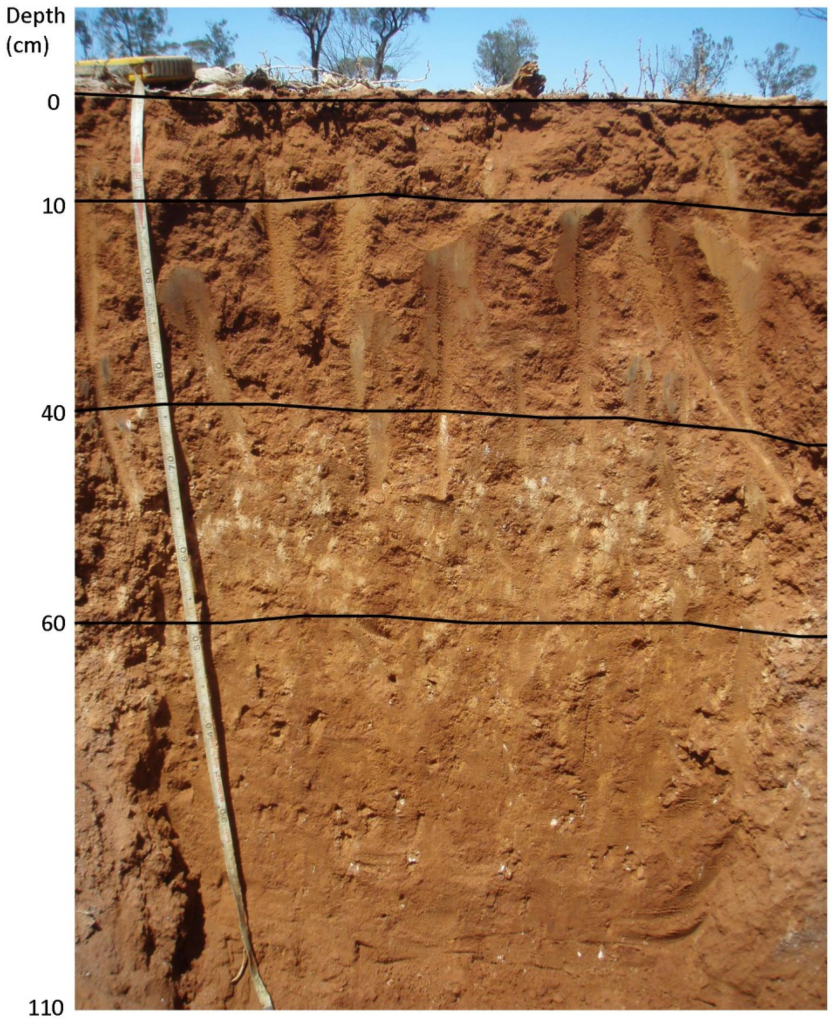
The pH and EC (salinity) of the surface soils within SMU 1 are provided in Figure 4.3. Soils in the surface 30 – 40 cm of this SMU have typically low to moderate salinity levels, with EC values < 100 mS/m). At depths > 40 cm some of the soils have elevated salinities, with EC values rapidly rising to over 300 mS/m. Salinity levels of this magnitude have the potential to significantly impact on the germination and early establishment of most plant species, with the exception of saltbush (Please note that the elevated salinity levels reported in Trench 1 and 10 are not reflective of the wider soils in this SMU, and are due to the ponding of saline groundwater recovered during geological drilling at this site – Trenches 1 and 10 were located on the exposed walls of sumps constructed to store groundwater at this site). The pH of all soils within SMU 1 are moderately to highly alkaline, with pH values varying from 8 – 10; indicating that they are all calcareous.

The stability of the soils in SMU 1 is shown in Figure 4.4a. The majority of soils sampled from SMU 1 are classified as either Potentially Dispersive or Dispersive as a result of their high sodicity (ESP > 6) and relatively low EC. The Flocculated soils shown in Figure 4.4a are all located at depth within Trench 1, with the extremely high salinity of these soils causing them to flocculate; as discussed above, the salinity levels reported for soils in Trench 1 are not representative of the soils throughout SMU 1. Based on these results, it can be concluded that the surface soils in SMU 1 are likely to be (or will develop into) highly dispersive.

The nutrient and organic carbon content of the soils sampled from SMU 1 are provided in Table 4.3. The results show that the topsoils (i.e. 0 – 10 cm soil layer) at all sites investigated in this SMU have low to very low mineralised N (NH_4^+ – N & NO_3^- – N < 20 mg/kg) and Colwell P (< 30 mg/kg). Elevated nitrate – nitrogen (NO_3^- - N) often occurs at depth in some soils, likely due to mobilisation of N from the surface soils. All soils sampled from SMU 1 had high to very high Colwell K and Extractable S contents. All topsoils in this SMU are poorly developed with only a minor accumulation of organic matter (organic C contents < 1 %). In the field, topsoils are only identified by the presence of abundant surface roots (Plate 4.3), and no clear topsoil horizonation occurs throughout the site.

Table 4.3: Chemical properties of selected soils within SMU 1.

Trench ID	Depth from	Depth to	Ammonium Nitrogen	Nitrate Nitrogen	Colwell Phosphorus	Colwell Potassium	Extractable Sulphur	Organic Carbon
			mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	%
1	0	10	1	< 1	3	289	24.9	0.13
1	10	20	1	5	3	435	444	0.14
1	30	40	3	1	2	300	1229	0.13
1	50	60	2	< 1	6	298	767	0.18
1	70	80	2	< 1	2	306	776	0.08
1	100	110	3	< 1	2	335	827	0.18
2	0	10	1	3	2	381	3.73	0.26
2	10	20	1	31	2	442	35.8	0.42
3	0	10	1	4	3	433	8.3	0.44
3	10	20	1	37	3	452	43.6	0.4
3	20	30	1	66	2	302	443	0.08
4	120	130	1	25	< 2	275	268	0.1
9	0	10	1	5	3	293	7.77	1.02
9	20	30	1	40	2	362	12.8	0.52
9	50	60	1	62	< 2	207	44.6	0.24
11	0	10	1	1	9	206	3.48	0.26
11	10	20	1	13	3	137	56.9	0.27



Horizon	Soil material	Description
A	Aeolian sand	Reddish brown aeolian medium—coarse sand, single-grain structure with a loose coherence, abundant root growth through matix, abrupt boundary to
B1	Reddish brown sandy loam	Reddish brown loamy sandy to sandy loam, well structured weak crumb peds, common to many roots growing along structural surfaces and through the soil matrix, gradual boundary to
B2	Mottled gypsic/ calcareous sandy loam	Mottled loamy sandy to sandy loam, poor to moderately structured weak crumb peds, few to common gypsic/calcrete/laterite nodules loosely set in friable matrix, common roots growing along structural surfaces and through the soil matrix, gradual boundary to
B3	Brown sandy loam	Brown loamy sandy to sandy loam, moderately to well structured with weak to firm crumb peds, common to many roots growing along structural surfaces, few gravels.

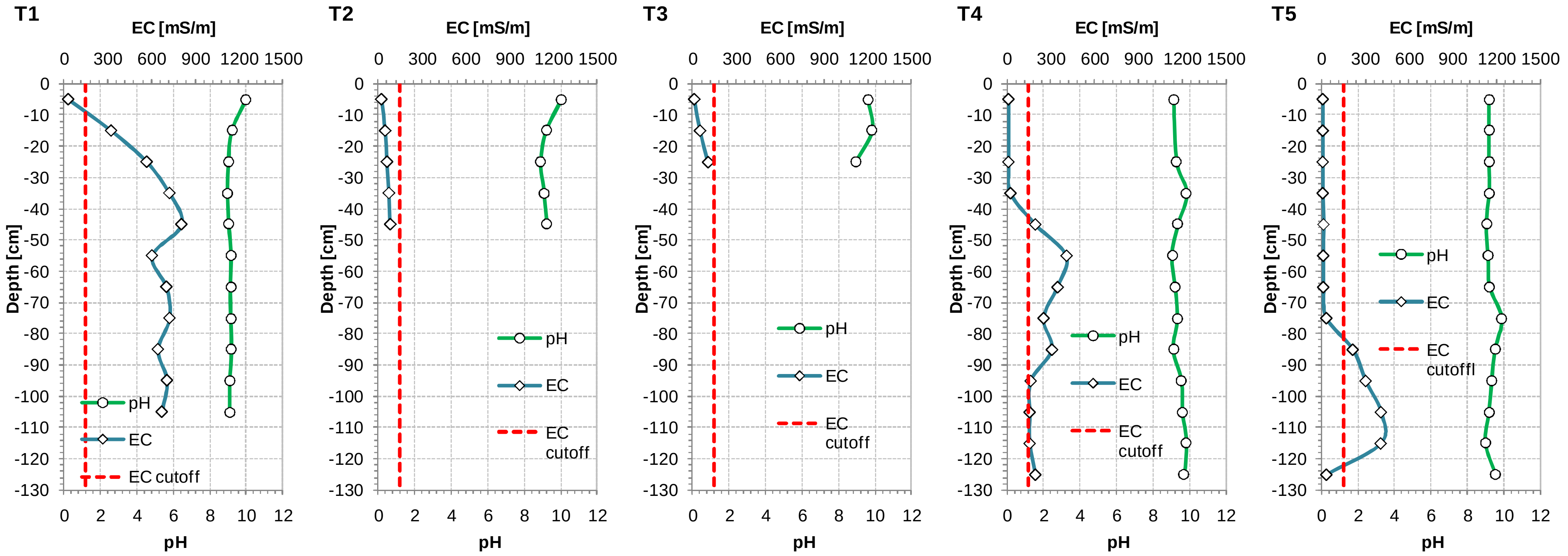
Bottom of Trench

PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

Barrick Kanowna
HORNET DEPOSIT SOIL CHARACTERISATION
CHARACTERISTIC SOIL PROFILE FOR SMU 1

Figure 4.2

soilwater



PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

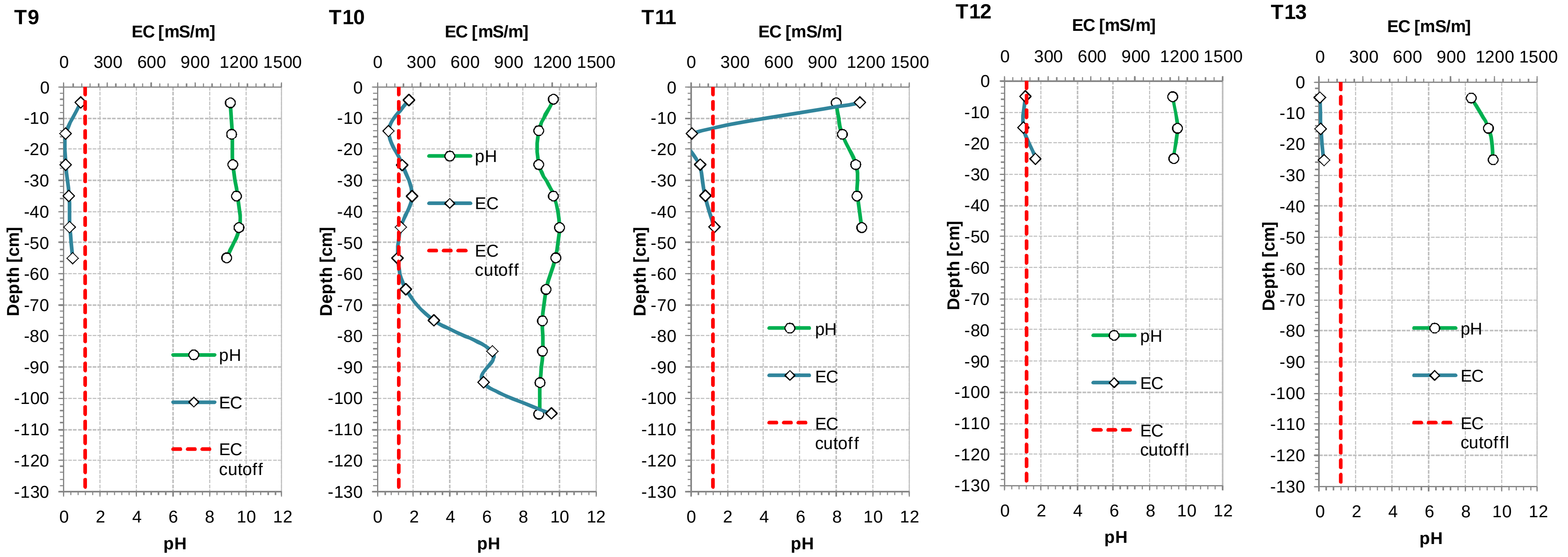
Barrick Kanowna

HORNET DEPOSIT SOIL CHARACTERISATION

pH AND EC PROFILES FOR SOILS IN SMU 1

Figure 4.3

soilwater



PN	PN0188-1-1-BK-15		Barrick Kanowna HORNET DEPOSIT SOIL CHARACTERISATION **pH AND EC PROFILES FOR SOILS IN SMU 1**	**Figure 4.3** ***continued…***
Prep by	MH	18/12/10		**soilwater**
Rev'd by	ASP	18/12/10		
Revision No.	1			

Plate 4.3: Poorly developed topsoil within SMU 1, showing only minor accumulation of organic matter.

4.2.2 SMU 2: TRUNCATED CALCAREOUS SANDY LOAM

This soil type is equivalent to SMU 1, although the surface 50 – 100 cm has been previously excavated and removed from site, resulting in a truncated profile. The removal of the surface soils is clearly evident in Plate 4.4. In SMU 2 the surface sand, reddish brown sandy loam, evaporite (calcareous) layer as been removed leaving the underlying brown sandy clay loam exposed at the surface. This material is structurally unstable due to its high sodicity (ESP > 6; Figure 4.4) and subsequently it is potentially dispersive. The relative high silt and clay content of the exposed subsoils result in it being hardsetting and when dried it exhibits considerable shrinkage cracks, which exacerbates the instability of these materials (Plate 4.5).

The chemical properties of this soil type are provided in Table 4.4. The surface soils are relatively non-saline (EC < 100 mS/m), due to leaching of soluble salts, and they are highly alkaline (pH ~ 9) as a result of the presence of residual carbonates in the profile (Figure 4.5). They are nutrient poor, with low levels of mineralised N ((NH_4^+ – N & NO_3^- – N < 20 mg/kg) and plant available P (Colwell P < 30 mg/kg), and have low levels of organic carbon reflecting the sparse vegetation occurring on this soil type (Plate 4.6). The *Melaleuca* thicket identified by Botanica Consulting (2010) occurs within this soil type, and it is likely that the previous disturbance, and the truncated profile and proximity to the salt lake provide habitat for this vegetation type to dominant.

Plate 4.4: Excavated and removed portion of the surface soil profile in SMU 2.

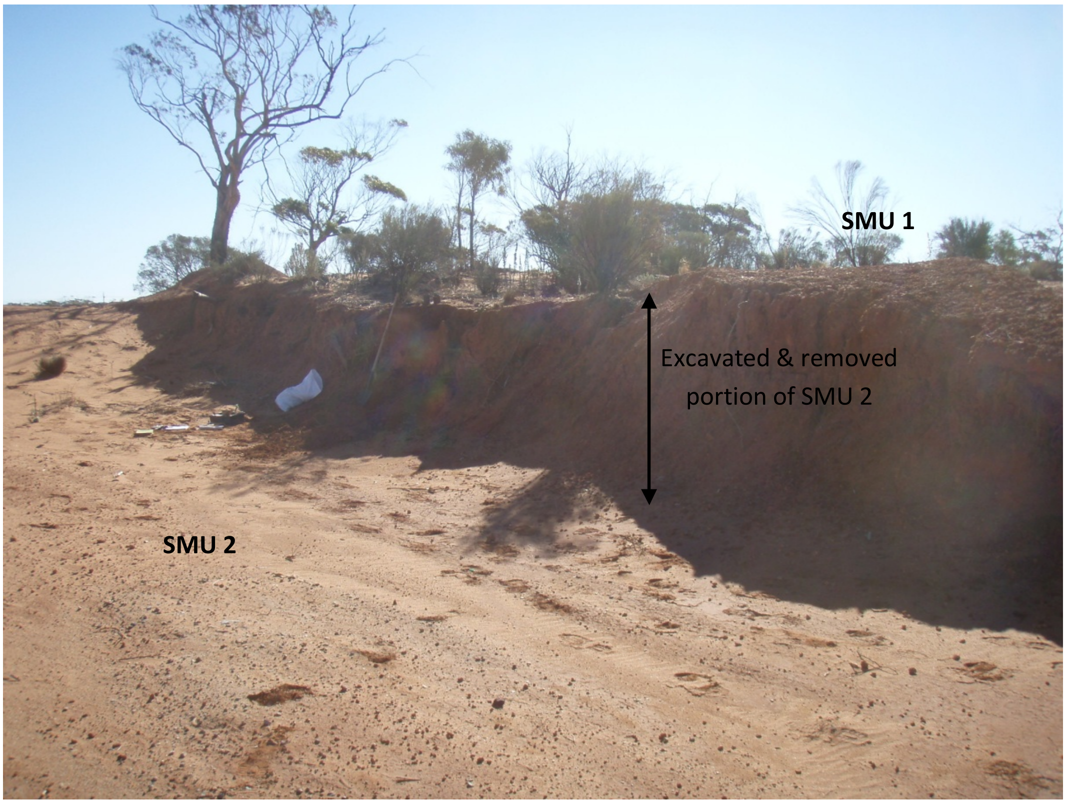


Plate 4.5: Shrinkage cracks and crusting of the surface soils in SMU 2.

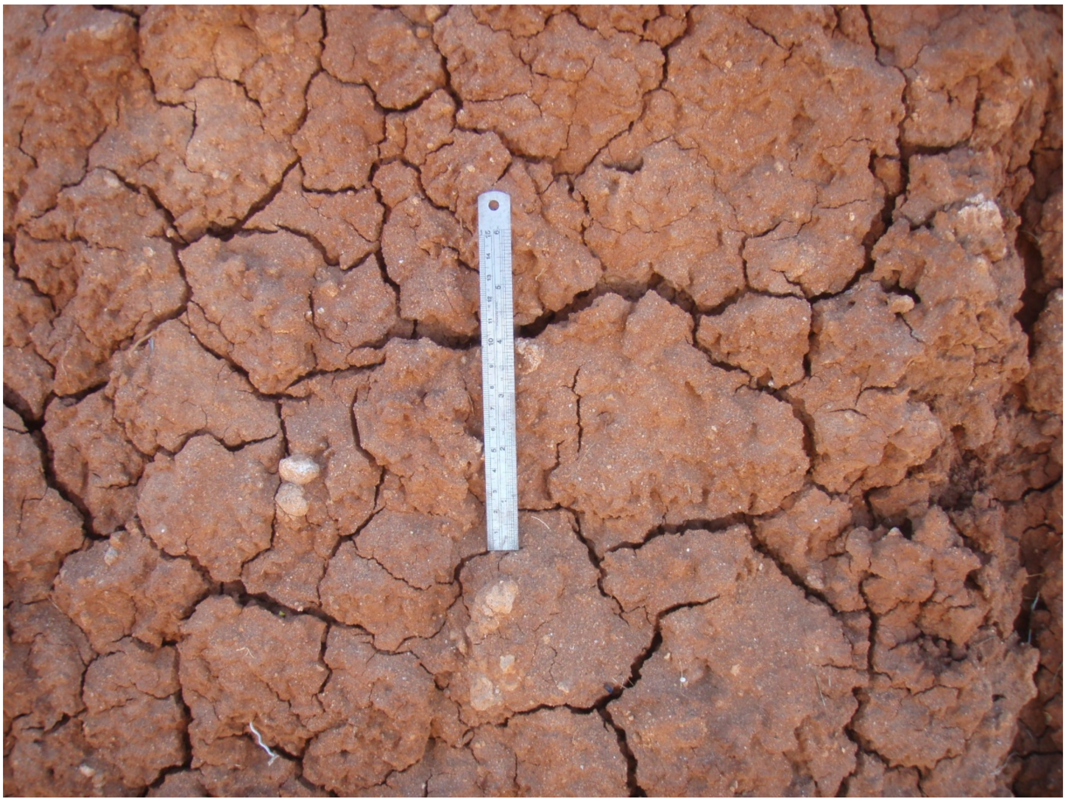
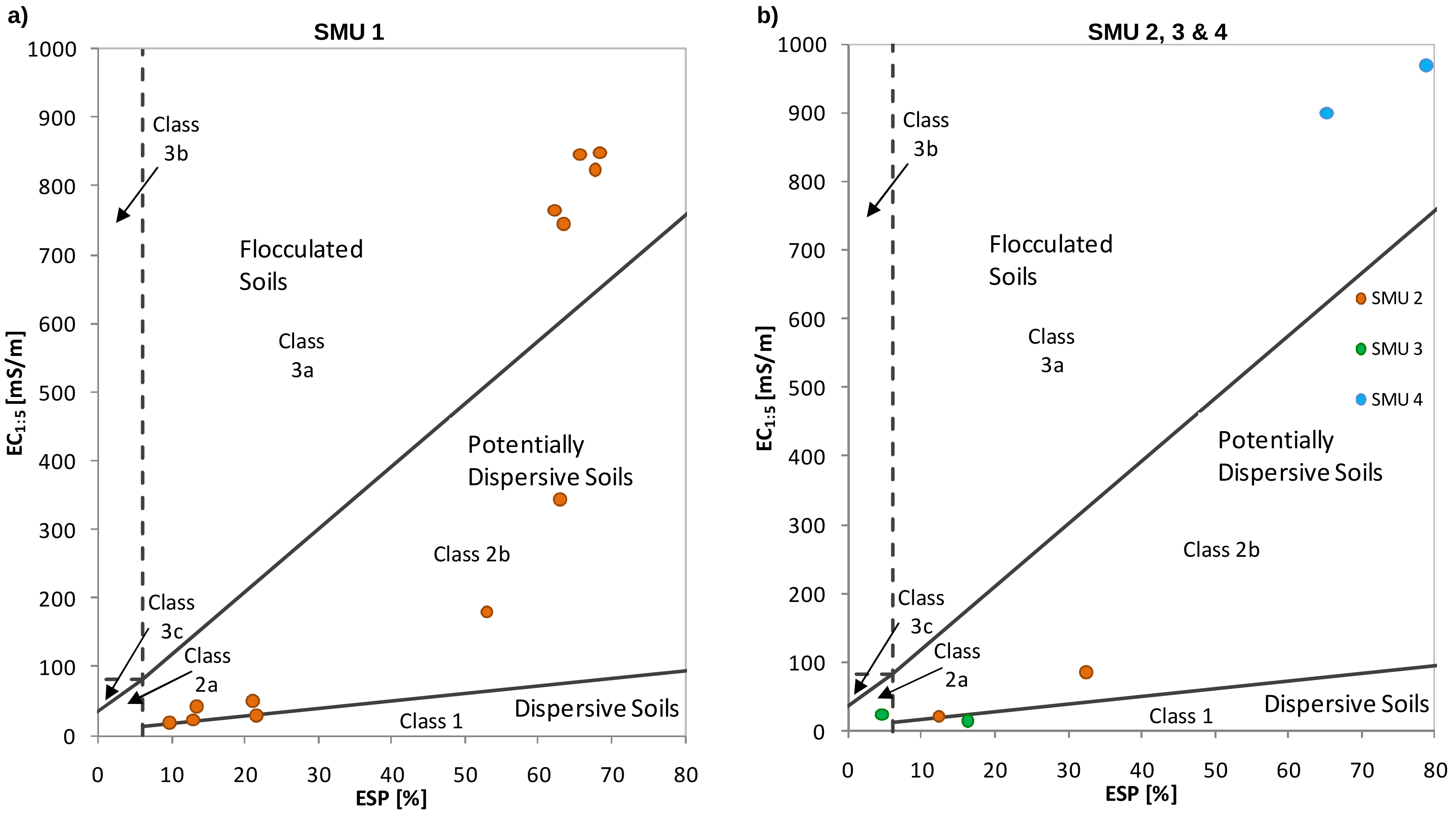


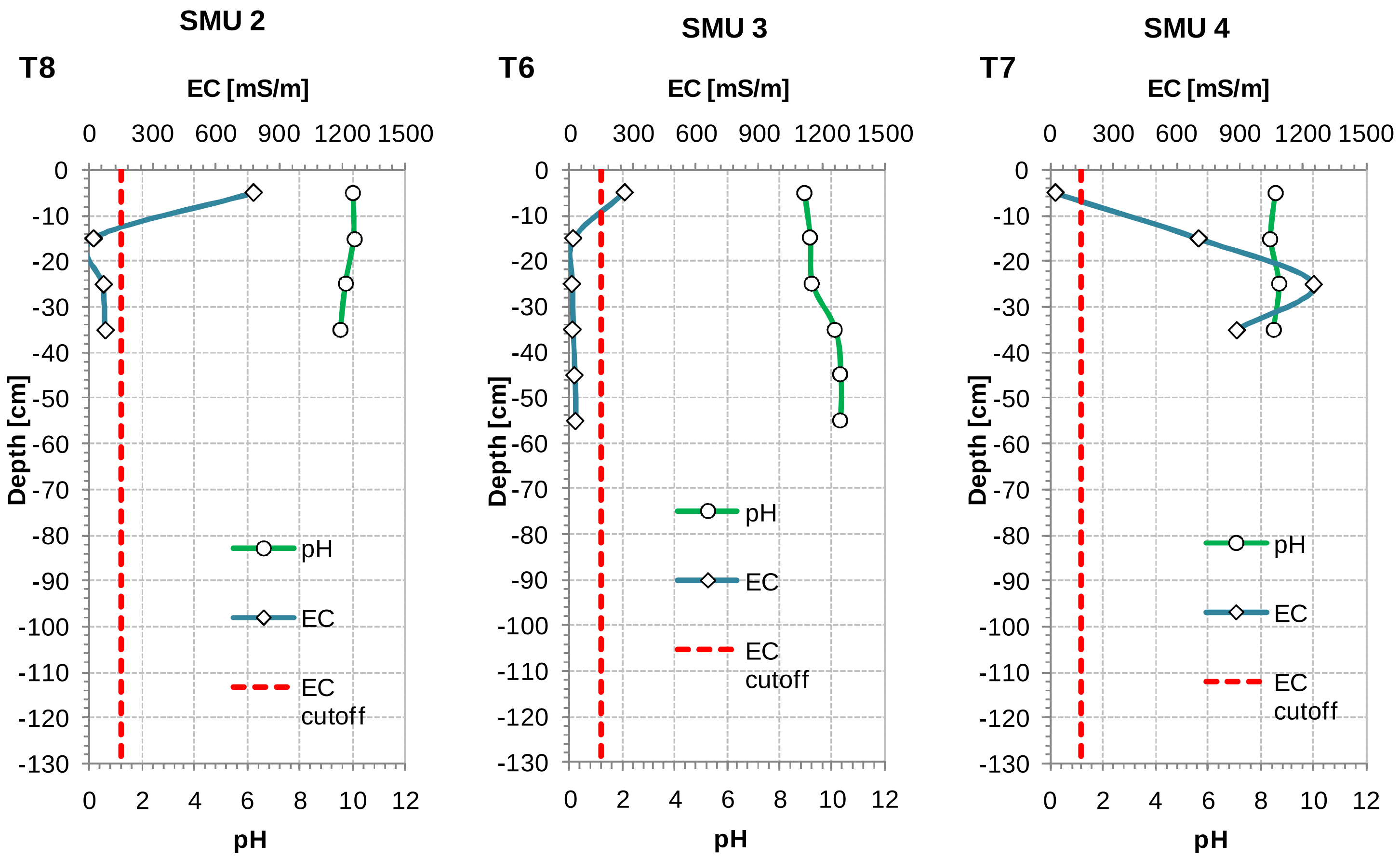
Table 4.4: Chemical properties of the surface soils in SMU 2.

Parameter	Units	Depth (cm)	
		0 - 10	30 - 40
Ammonium Nitrogen (NH_4^+ - N)	mg/kg	1	1
Nitrate Nitrogen (NO_3^- - N)	mg/kg	1	14
Plant available Phosphorus (Colwell P)	mg/kg	2	2
Plant available Potassium (Colwell K)	mg/kg	230	236
Extractable Sulphur	mg/kg	3.04	71.2
Organic Carbon	%	0.3	0.06
Conductivity	mS/m	21	85.2
pH Level ($CaCl_2$)	-	8.2	8.5
pH Level (H_2O)	-	9.1	9
Exchangeable Calcium	meq/100g	9.39	6.81
Exchangeable Magnesium	meq/100g	3.31	4.63
Exchangeable Potassium	meq/100g	0.55	0.56
Exchangeable Sodium	meq/100g	1.87	5.76
Cation Exchange Capacity (CEC)	meq/100g	15.1	17.8
Exchangeable Sodium Percentage (ESP)	%	12.4	32.4

Plate 4.6: Relatively sparse vegetation (*Melaleuca* thicket) occurring in SMU 2.



PN	PN0188-1-1-BK-15		Barrick Kanowna HORNET DEPOSIT SOIL CHARACTERISATION **STABILITY PLOTS FOR ALL SOILS**	**Figure 4.4**
Prep by	MH	18/12/10		
Rev'd by	ASP	18/12/10		soilwater
Revision No.	1			



PN	PN0188-1-1-BK-15	
Prep by	MH	18/12/10
Rev'd by	ASP	18/12/10
Revision No.	1	

Barrick Kanowna
HORNET DEPOSIT SOIL CHARACTERISATION
pH AND EC PROFILES FOR SOILS IN SMU 2, 3 & 4

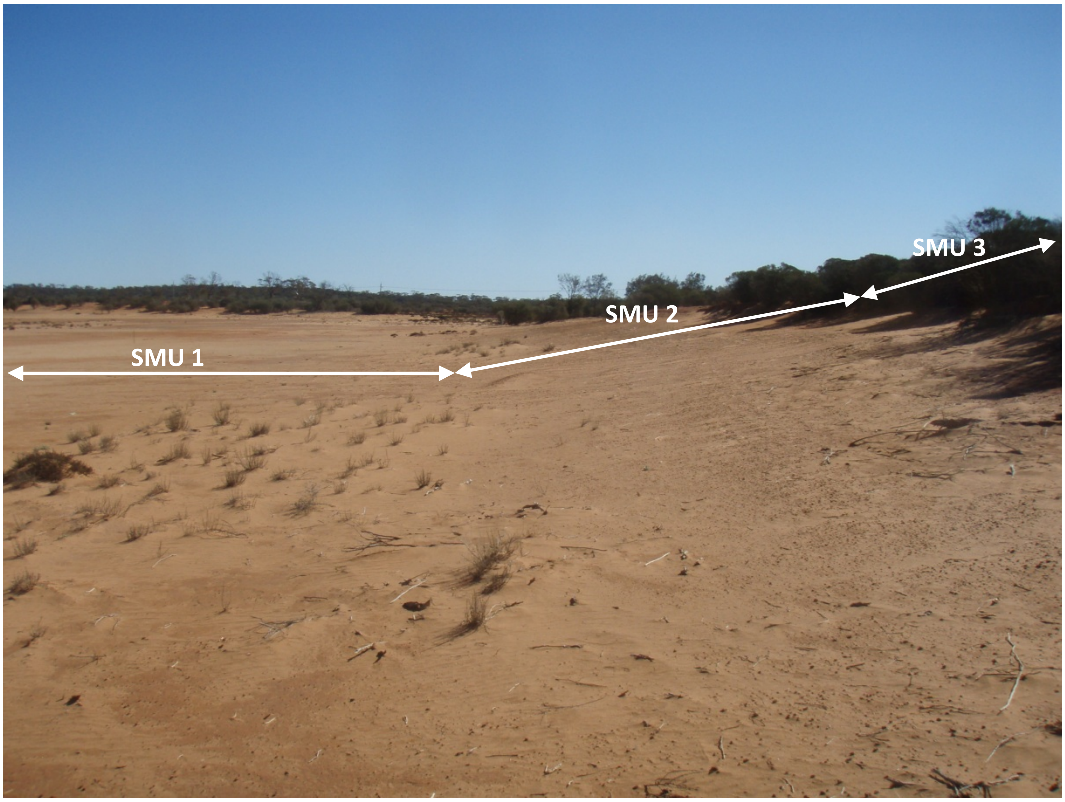
Figure 4.5

soilwater

4.2.3 SMU 3: DEEP CALCAREOUS COARSE SAND

This SMU represents a minor soil type in the project area, occupying an area of only 2.3 ha (Figure 4.1). It occurs as a narrow strip fringing the salt lake and it is likely to represent an accumulation of medium to coarse aeolian sand deposited by the prevailing winds across Lake Kopai (Plate 4.7). A characteristic soil profile for this soil type is shown in Plate 4.8. This soil type supports the fringing samphire vegetation identified by Botanica Consulting (2010; Plate 4.9).

Plate 4.7: Accumulation of aeolian sand on the fringes of Lake Kopai forming SMU 3.



The chemical properties of the soils in SMU 3 are presented in Table 4.5. Given the sandy nature of the soils, they have been leached of the majority of soluble salts resulting in a non-saline soil to a depth of at least 65 cm (EC < 40 mS/m; Figure 4.5). These soils are moderately to strongly alkaline (pH ~ 9; Figure 4.5), characteristic of a salt lake system, and they have low to very low nutrient levels, due to the low nutrient retention properties of sands and the very low organic carbon contents (Table 4.5). At depth the salinity of these soils is likely to significant increase as the hyper-saline groundwater is approached, and it is likely that these soils are inundated periodically with saline water during large storm events and wet seasons.

Mining of the Hornet deposit is not expected to impact on this soil type.

Plate 4.8: Characteristic soil profile in SMU 3.

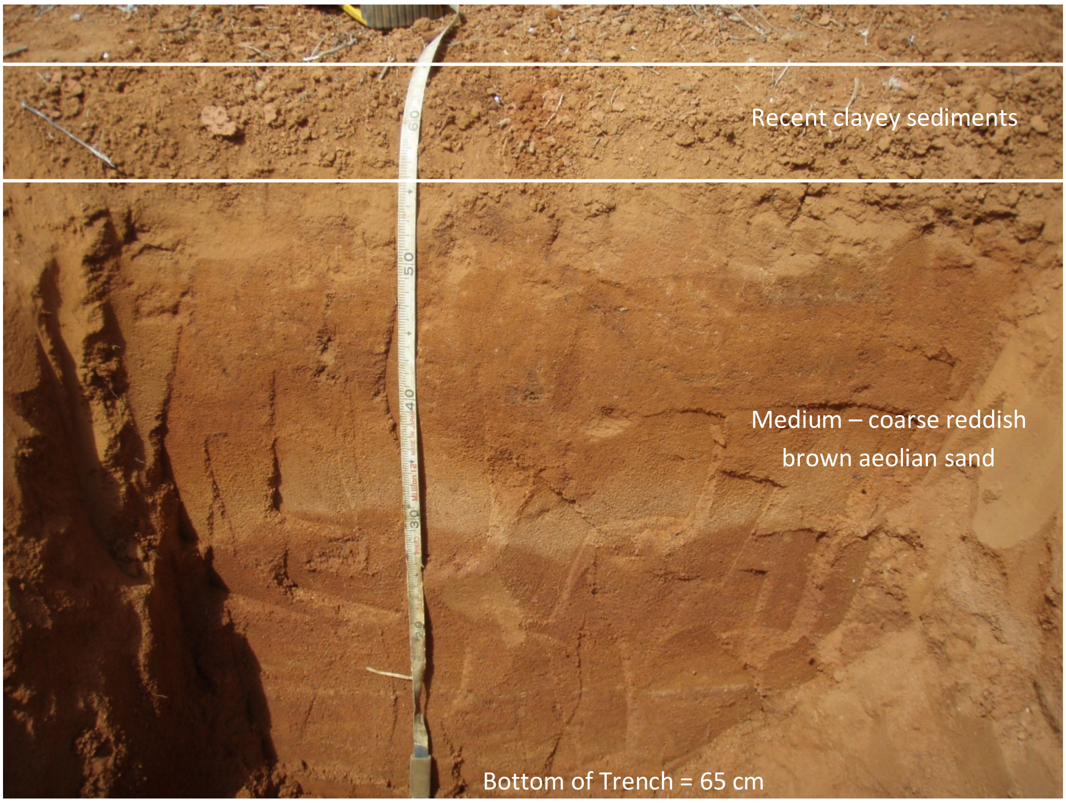


Plate 4.9: Samphire vegetation fringing Lake Kopai within SMU 3.

Table 4.5: Chemical properties of soils within SMU 3.

Parameter	Units	Depth (cm)	
		0 - 10	20 - 30
Ammonium Nitrogen (NH_4^+ - N)	mg/kg	1	1
Nitrate Nitrogen (NO_3^- - N)	mg/kg	8	1
Plant available Phosphorus (Colwell P)	mg/kg	9	4
Plant available Potassium (Colwell K)	mg/kg	561	113
Extractable Sulphur	mg/kg	17.8	4.53
Organic Carbon	%	0.9	0.07
Conductivity	mS/m	24	14.1
pH Level ($CaCl_2$)	-	7.9	8.4
pH Level (H_2O)	-	8.7	9.1
Exchangeable Calcium	meq/100g	17.22	1.8
Exchangeable Magnesium	meq/100g	7.29	1.55
Exchangeable Potassium	meq/100g	1.43	0.24
Exchangeable Sodium	meq/100g	1.25	0.7
Cation Exchange Capacity (CEC)	meq/100g	27.2	4.3
Exchangeable Sodium Percentage (ESP)	%	4.6	16.3

4.2.4 SMU 4: SALINE CLAY

This soil type occurs within Lake Kopai and consists of a surface cover of alluvial brown sandy clay over a well structured pallid (white) heavy clay (Plate 4.10). The soils are extremely saline with highly alkaline pH values (pH ~ 9; Figure 4.5). They are nutrient deficient with very low mineralised N (< 20 mg/kg) and Colwell P (< 30 mg/kg), but have elevated Colwell K (> 200 mg/kg) and extractable S (> 500 mg/kg) in response to mobilisation and subsequent deposition in the lake system. Although the clayey soils are extremely sodic (ESP > 50 %) they are structurally stable due to their very high salinity (Figure 4.4).

No disturbance of these soils is likely to occur during mining of the Hornet deposit.

Plate 4.10: Surficial soil profile within Lake Kopai (SMU 4).

4.3 STABILITY OF THE SURFACE SOILS

4.3.1 FIELD OBSERVATIONS

During the field component of the investigation several erosional features were observed in the native soils, including tunnel (Plate 4.11) and gully erosion (Plate 4.12). The slope of the landsurface in the vicinity of these erosional features is generally low (< 5°) to flat, and the surface soil are typically stabilised by a relatively continuous cryptogram cover (Plate 4.13). In areas where disturbance of the surface soils has removed the cryptogram cover or where it is absent considerable etching of the surface occurs, which ultimately results in the formation of gully erosion (Plate 4.14).

Based on these field observations it is considered that the surface soils within the Hornet deposit are unstable and will likely result in significant erosion if used inappropriately to construct the waste dump or if surface water management over the waste dump is not carefully controlled.

4.3.2 RAINFALL SIMULATOR

The stability and erodibility of the surface soils within the Hornet deposit was quantified in the laboratory using a rainfall simulator (Section 3.4), with additional modelling using WEPP (Watershed Erosion Prediction Project). The stability was tested for large storm events with an applied rainfall intensity of 100 mm/hr, with three waste dump slope angles implemented (10, 12 & 15°).

Plate 4.11: *In situ* tunnel erosion within the native soils of SMU 1.

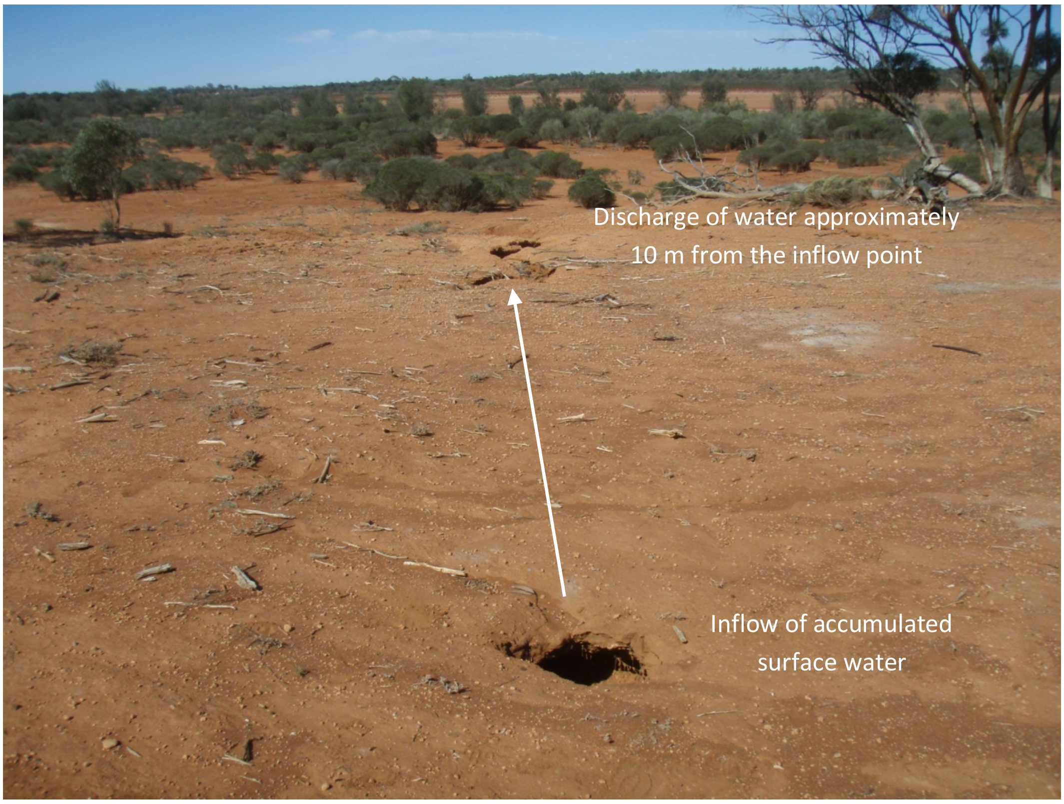


Plate 4.11: Considerable gully erosion at the contact between SMU 1 and 2.

Plate 4.12: Stabilisation of the surface soils by a relatively intact cryptogram cover.

Plate 4.13: Etching and subsequent formation of large gullies through the accumulation of surface water.

The effective hydraulic conductivity (*Keff*) and mean steady state infiltration of the surface soils, for the three slope angles, is provided in Table 4.6 (the permeability values for the Hornet soils are compared to other more stable soils from the Goldfields region). The results show that the *Keff* and infiltration rate for the Hornet soils, for all slope angles tested, are considerably lower than those obtained for either the gravel or stable loamy soil. This indicates that significantly more water is likely to be available for runoff, thus increasing the potential for erosion.

Table 4.6: Effective hydraulic conductivity and mean steady infiltration for the Hornet surface soils.

Soil & slope angle	applied intensity [mm/h]	*Keff* [cm/d]	mean steady infiltration rate [cm/d]
Hornet surface soil (10°)	98	29.6	51.4
Hornet surface soil (12°)	86	51.1	62.4
Hornet surface soil (15°)	96	29.6	54.2
gravel (15°)	119	144.9	170.1
loam (15°)	102	74.9	93.8

The derived interrill erodibility (*Ki*) and average soil loss rate for the Hornet soils for the various slope angles is provided in Table 4.7. The results show that the Hornet surface soils are appreciably more erodible than either the gravel or stable loam, with average soil loss rates from the Hornet soils at the lowest slope angle (10°) being greater than the corresponding rate at the highest slope angle (15°) for the other soils. The modelled average annual runoff and soil loss rates (sediment yield) for the Hornet surface soils are presented in Table 4.8. These results clearly show that the Hornet soils are likely to be highly erodible, even at a low slope angle of 10°, generating considerable sediment mobilisation and subsequent loss (Note: an annual soil loss rate of 5 t/ha is typically used to differentiate between acceptable and unacceptable erosion).

Table 4.7: Interrill erodibility (*Ki*) values and mean soil loss rate at different gradients.

Soil & slope angle	Ki [kg*s/m^4]	avg. Soil loss rate [g/(m^2 *min)]
Hornet surface soil (10°)	1034236	14.4
Hornet surface soil (12°)	2026980	17.8
Hornet surface soil (15°)	1878249	19.7
gravel (15°)	128054	3.0
loam (15°)	664309	10.3

Table 4.8: Average soil annual runoff and soil loss rates for the Hornet surface soils.

Slope	avg. annual runoff [mm]	avg. annual soil loss [t/ha]
10°	14.10	8.41
12°	14.16	10.11
15°	14.21	12.26
20°	14.27	16.22

Plates 4.14 – 4.16 show the response of the Hornet surface soils to the applied rainfall at the various slope angles.

Plate 4.14: Response of the Hornet surface to applied rainfall at a slope angle of 10°.


Considerable accumulation of eroded sediment at the base of the slope

Plate 4.15: Response of the Hornet surface to applied rainfall at a slope angle of 12°.


Considerable etching of surface soil

Plate 4.16: Response of the Hornet surface to applied rainfall at a slope angle of 15°.

5. SOIL MANAGEMENT

- This section outlines management recommendations for the handling and utilisation for the surficial soil materials identified in Section 4. These recommendations are suggested with the aim of:

- Maintaining optimal soil properties during the mining and rehabilitation process.

- Appropriate handling of soil and waste materials that exhibit adverse physical and chemical properties to ensure no contamination with other ‘good’ or optimal materials.

- Minimising environmental impacts that may occur through inappropriate handling and utilisation of soil and waste materials that exhibit adverse properties.

- Preventing the development of adverse properties in these materials during mining and rehabilitation.

- The following management recommendations are suggested for the handling of the various surficial soil materials at the Hornet deposit.

4.1 TOPSOIL MATERIALS (BENEFICIAL MATERIALS FOR USE IN REHABILITATION)

- Topsoils in the Hornet deposit are typically poorly developed with only a minor accumulation of organic matter and are nutrient deficient. Given these properties, and the fact that the waste dump surface will be seeded with provenance species, it is considered that there is no requirement to segregate the surface 10 cm of the profile to capture the stored native seed and prevent dilution of nutrients. The surface 30 cm of the soil profile is generally non-saline, with no chemical or physical limitations to plant growth, and therefore it is recommended that this depth of the surface soil be stripped for use as a topsoil in the rehabilitation of the waste dump.

- Topsoils (0 – 30 cm) from only SMU 1 should be stripped for use in the rehabilitation of the waste dump. No topsoil from SMU 2, 3 or 4 should be stripped.

- Topsoil materials are structurally sensitive and will rapidly turn to dust during excavation and handling. Water (particularly saline water) should not be used for dust suppression as these soils will hardset if exposed to alternating wetting and drying cycles. Soil strengths of hardset topsoils will likely impede the germination and early establishment of revegetation species; and thus strategies to prevent these soils from hardsetting should be adopted.

- All topsoil stockpiles should not exceed 2 m in height to maintain the soils biological component and retention of any nutrient sources, and should not be stockpiled for longer than 12 months.

4.2 SUBSOIL MATERIALS (BENEFICIAL MATERIALS FOR USE IN REHABILITATION)

- Subsoil materials in the Hornet deposit represent the growth medium, and should include all Quaternary transported sediments beneath the topsoil (30 cm depth) and overlying the Achaean transported sediments or *in situ* saprolite. No subsoil materials should be excavated below the watertable as groundwater at this site is likely to be hyper-saline, which will result in soils salinities exceeding the tolerances of most species, including salt bush.

- The Quaternary transported sediments are morphologically dissimilar to the underlying Achaean sediments or *in situ* saprolite, and subsequently they should be easily separable during excavation. Only subsoils from SMU 1 and 2 should be stripped for use in the construction and rehabilitation of the waste dump.

- As with the topsoil materials, subsoils are structurally sensitive and care should be taken to prevent them from hardsetting (i.e. minimise the use of water for dust suppression).

- Subsoil materials do not exhibit physical or chemical properties that will impede the root growth of established (this is clearly observed in the field with roots from the existing vegetation growing throughout this material), and subsequently its capture and use as a growth medium beneath the topsoil will facilitate the sustainable growth and establishment of the revegetation species.

4.3 OVERBURDEN/INTERBURDEN (WASTE) MATERIALS

- All materials below the Quaternary transported sediments, including the Achaean transported sediment and *in situ* saprolite, are considered waste materials.

- Waste materials are likely to exhibit chemical properties that will adversely impact on revegetation growth and establishment. It is therefore critical that these materials are not used to reconstruct the outer surface of the waste dump or be used in the root zone of the revegetation.

- If no separation of Subsoil and Waste materials is likely to occur, then only shallow-rooted revegetation species should be used to rehabilitate the waste dump; this will ensure that the roots of the revegetation will not interact with the underlying (saline) material.

4.4 RECONSTRUCTION AND DESIGN OF THE WASTE DUMP

- As shown in Section 4.3, the surface soils within the Hornet deposit are structurally unstable and are highly erodible. Based on the rainfall simulator results a slope of only 10° is recommended for the waste dump to ensure the outer surface of the waste dump is stable and erosion rates are kept to acceptable levels. Contour ripping will still be required to minimise the catchment areas along the batter slopes, and a 3 m wide backward sloping berm should be constructed between lifts to prevent sediment and runoff from reaching the downslope batter sections. The top of the waste dump should be backward sloping to ensure accumulated water does not overflow onto the batter surfaces.

- A traditional linear batter and berm slope, as opposed to a concave slope, is recommended for this waste dump given the clayey texture and instability of the surface soils.

- If waste rock is available to help stabilise the waste dump surface, then slopes of 12° may be implemented to reduce the footprint size of the waste dump. Any available waste rock should be ripped to a depth of 0.5 m to bring sufficient topsoil materials to the surface, to facilitate revegetation growth, whilst retaining a rocky outer surface.

- Surface flow analysis should be undertaken on all waste dump designs to ensure that surface water is appropriately management. Accumulation of surface water should be discouraged as the surface soils will likely tunnel if surface ponding occurs.

6. REFERENCES

Aquterra (2003). *Assessment of Groundwater Inflows into the Hornet Pit*. Unpublished report submitted to Palcer Dome Asia Pacific.

Botanica Consulting (2010). *Level 1 Rubicon/Hornet Spring Flora Survey*. Unpublished report submitted to Barrick Kanowna.

EKJV (2004). *Hornet Stage 1 Open Pit: Feasibility Study*. East Kundana Joint Venture (EKJV), Placer Dome Asia Pacific.

Isbell, R.F. (1996). *The Australian Soil Classification*. Australian Soil and Land Survey Handbook, Volume 4. CSIRO Publishing, Collingwood, Victoria, Australia.

McDonald, R.C. and Isbell, R.F. (2009). ‘Soil Profile’. In: *Australian Soil and Land Survey Field Handbook* (3rd Ed.), National Committee on Soil and Terrain, CSIRO Publishing, Melbourne. pp. 147 – 204.

McDonald, R.C., Isbell, R.F and Speight, J.G. (2009) ‘Land Surface’. In: *Australian Soil and Land Survey Field Handbook* (3rd Ed.), National Committee on Soil and Terrain, CSIRO Publishing, Melbourne. pp. 127 – 144.

Schoknecht, N. (2001). *Soil Groups of Western Australia: A guide to the main soils of Western Australia* (Ed. 2). Resource Management Technical Report 193, Department of Agriculture.

Appendix C:

Soil Characterisation for Pegasus

(SoilWater 2020)

SOILWATER CONSULTANTS

PEGASUS DEPOSIT SOIL CHARACTERISATION

Prepared for:	**NORTHERN STAR RESOURCES PTY LTD**
Date of Issue:	24 June 2020
Project No.:	PN0243

DOCUMENT STATUS RECORD

Project Title:	Pegasus Deposit Soil Characterisation
Project No.:	PN0243-1-1-BK-018
Client:	Northern Star Resources Pty Ltd

Revision History

Revision Code*	Date Revised	Revision Comments	Signatures		
			Originator	Reviewer	Approved
A	18/07/2012	Internal review of draft report	ASP	JP	ASP
B	20/07/2012	Draft report sent to client	ASP	JP	SC
C	24/06/2020	Updated report send to client	ASP	SC	SC

Revision Code*

A - Report issued for internal SWC review	1 - First Revision
B - Draft report issued for client for review	2 - Second Revision
C - Final report issued to	3 - Third Revision

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to undertake a soils assessment for the proposed Pegasus Deposit to be developed by Northern Star Resources Pty Ltd. This work was conducted in accordance with the Scope of Work presented to Northern Star Resources Pty Ltd (‘the Client’).

SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the soils assessment was confined solely to the proposed Pegasus Deposit Project Area. No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area. In preparing this study, SWC has relied on published soil reports from various soil researchers and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel.

SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client.

This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party

CONTENTS

List of Figures

List of Tables

List of Plates

1 INTRODUCTION

Soil Water Consultants (SWC) were commissioned by Northern Star Resources (NSR) to undertake a soil characterisation for the proposed Pegasus Deposit (‘Project Area’). The purpose of this assessment was to identify and characterise all surficial soil materials within the disturbance area and suggest management strategies for their handling and utilisation. This information provides baseline data that can be used to assist in the mining of these materials, and in the construction and rehabilitation of the waste dump. Implementation of the soil management recommendations suggested in this report will ensure that only optimal materials are used in the construction of the outer surface of the waste dump, thus facilitating stability and revegetation, and ultimately closure and bonds return.

1.1 OBJECTIVES

The objectives of this soil characterisation were to:

- Define the distribution of soil in the Project Area.
- Characterise the physical and chemical properties of the soils.
- Identify materials that may be beneficial to the rehabilitation of the waste dumps, and materials that may have an adverse impact on rehabilitation.
- Identify the optimal batter slope angle and surface cover material composition to create a stable post-mine landform over the long-term.
- Suggest management strategies for the handling and utilisation of these materials during mining and rehabilitation.

1.2 SCOPE OF WORK

The Scope of Work completed by SWC included:

- Collect soil samples from the Project Area using shallow trench excavations.
- Describe the surface soil profiles and prepare a soils map for the Project Area.
- Undertake field and laboratory analysis to characterise the physical and chemical properties of the surficial materials.
- Preparation of this report

2 SITE DESCRIPTION

2.1 LOCATION

The proposed Pegasus deposit is located approximately 24 km west of Kalgoorlie (Figure 2.1), along the Kundana Haul Road immediately to the north east of the existing Rubicon minepit (Figure 2.2). The Project Area covers an area of approximately200 ha.

2.2 SITE LAYOUT

The Pegasus Deposit will be mined using open pit techniques. The proposed minepit will cover an area of approximately 4.3 ha (Figure 2.3) and will extend to an approximate maximum depth 55 m below surface. Waste material from the deposit will be excavated and stockpiled within a purpose-built waste dump located to the west of the minepit (Figure 2.3), whilst the mined ore will be temporarily stored in an adjacent ROM pad (Figure 2.3), prior to processing.

2.3 GEOLOGY AND HYDROGEOLOGY

The Pegasus Deposit is situated within a northwest - southeast striking Greenstone belt in the Eastern Goldfields province of the Yilgarn Craton which is of Achaean age. Exposure of outcrop locally is extremely sparse with the majority of the area covered by colluvium or laterite formations over the deeply weathered bedrock. The Pegasus Deposit mineralisation itself is hosted by a laminated quartz vein which lies parallel to a thin cherty shale bed (Centenary Shale). This structure (given the name K2) marks the boundary between a unit dominantly composed of volcaniclastic sediments, including andesitic tuffs and lavas and minor shale lenses to the east and a foliated porphyritic basalt unit (Victorious Basalt) to the west (Figure 2.4). The Centenary shale is a minor unit which varies in width from 25 m to 0.3 m, being highly carbonaceous (graphitic) and sulfide rich (containing up to 10 % pyrite/pyrrhotite).

The regional geology has been overturned making the youngest unit (volcaniclastic sediments) the foot wall of the K2 structure and the Victorious Basalt the hanging wall. Weathering has been extensive with an oxide profile extending to 60 m depth, with the rock transitioning from saprock to fresh rock at roughly 60 m. A thin layer of transported Quaternary and Archean colluvium exists as a surface layer ranging from 0 to 10 m in thickness (Plate 2.1).

Although regional groundwater levels occur at around 10 – 20 m below the surface, the proximity of the Pegasus Deposit to the operational Rubicon Pit and Decline means that groundwater levels within the Project Area are likely to be well below the oxide profile, are not expected to result in significant inflows during mining of this deposit. Any groundwater that is likely to be encountered is expected to be hypersaline given the proximity of Lake Kopai.

Plate 2.1: Transported alluvial cover overlying saprolite at the adjacent Rubicon mine pit. The upper surficial soil profile at the Pegasus Deposit is likely to be similar to that observed in the Rubicon mine pit given its close proximity.

2.4 REGIONAL SOILS

The soils across the Project Area have been mapped at a regional scale (1:250,000 scale) by the Department of Agriculture, as part of the Southern Goldfields Rangeland Survey. The regional soils distribution is shown in Figure 2.5.

At the regional scale the soils throughout the Project Area are classified as salt lake (saline) soils experiencing wet and waterlogged conditions (265SV15; Figure 2.5). These soils are typically highly to extremely saline, with a dominant clayey texture. Surrounding the salt lake system soils are the red loamy earth associated with the gently undulating plains and pediments, characteristic of the Goldfield region (265Mx43 & 266Mx43; Figure 2.5). These loamy soils are typically deep (> 1 m in depth), often calcareous, with a dominant earthy fabric. They are generally well drained and experience oxidising conditions throughout the year. Minor calcareous shallow loams and loamy earths occur in isolated regions, associated with either out- or sub-cropping greenstone and basic igneous bedrocks. These soils are generally shallow (< 1 m) underlain by fresh or partially weathered basement rocks.

Although at the regional scale the soils throughout the Project Area are classified as salt lake soils, at a local scale the soils are better defined as the reddish brown loamy earths as they generally occur at a higher elevation than the salt lake systems (i.e. they are more accurately classified as 265Mx43; Figure 2.5).

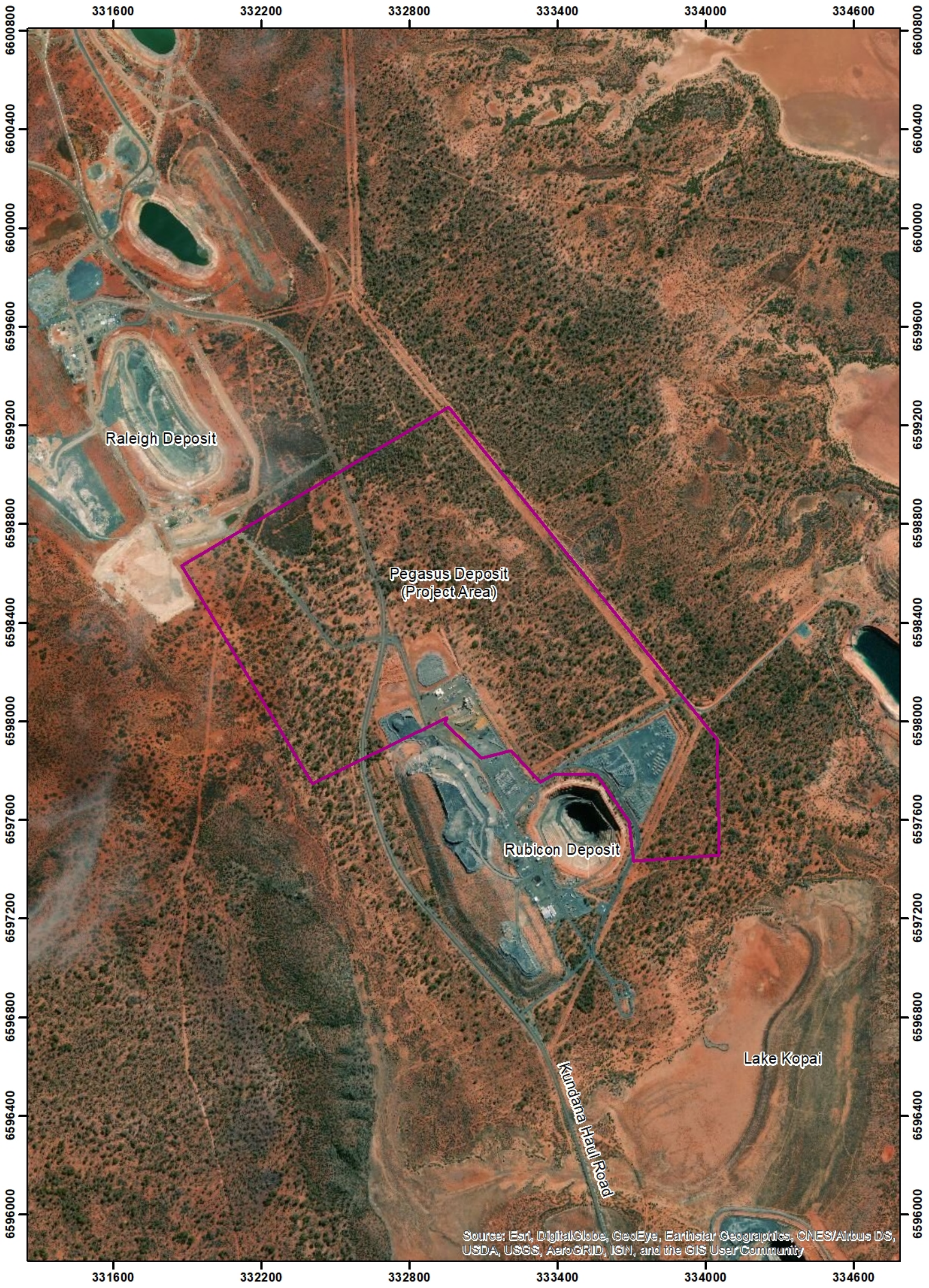
2.5 VEGETATION

The vegetation across the Project Area has been mapped by Botanica Consulting (2012). The distribution of the vegetation is shown in Figure 2.6.

The vegetation over the majority of the area consists of low woodland of mixed *Eucalyptus* sp. over low scrub of *Eremophila scoparia* and *Senna artemisiodes* subsp. *filifolia* (Figure 2.6). Isolated stands of *Casuarina paiper* open low woodland over low scrub of Eremophila scoparia, *Casuarina pauper* thicket over mixed low scrub and E. lesouefii over low scrub of Eremophila caperata and Eremophilia ionantha occur within the Project Area (Figure 2.6).

The Pegasus Deposit has been extensively drilled in the past, and these disturbance areas have been rehabilitated to chenopod shrubland. In total 21 families, 36 genera and 77 species of vegetation was reported in the area, and no Declared Rare Flora (DRF), Priority Flora (PF) and Priority or Threatened Ecological Communities occur in the Project Area (Botanica Consulting, 2012). Most of the vegetation in the area, with the exception of those previously rehabilitated, are considered in ‘very good’ health condition.

PN	PN0243-1-1-BK-018		Northern Star Resources PEGASUS DEPOSIT SOIL CHARACTERISATION **Regional location**	**Figure 2.1** soilwater GROUP
Prep. by	SC	17/06/20		
Rev'd. by	ASP	19/06/20		
Revision No.		1		



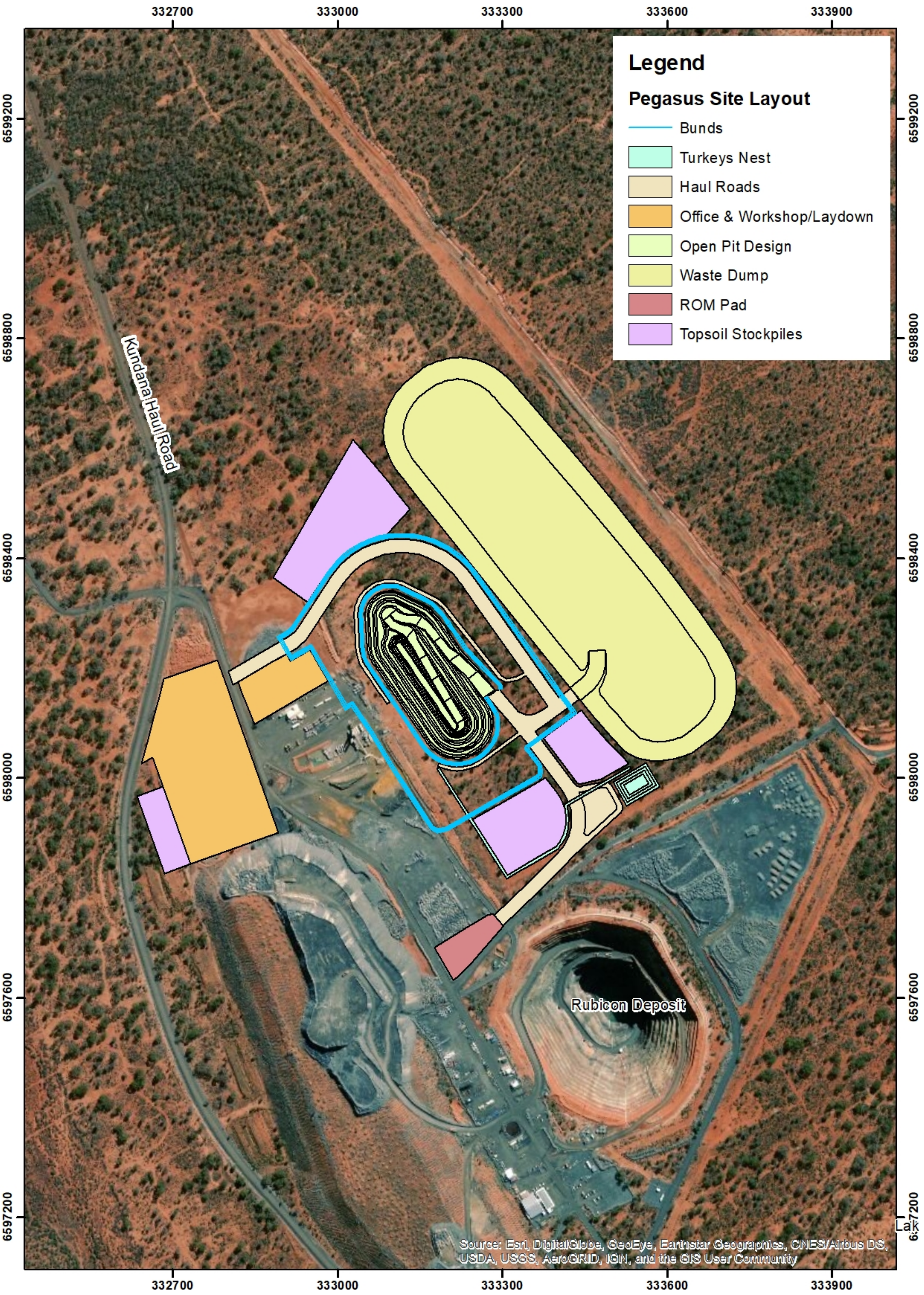
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

PN	PN0243-1-1-BK-018	
Prep. by	SC	17/06/20
Rev'd. by	ASP	19/06/20
Revision No.		1

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACTERISATION
LOCAL LOCATION

Figure 2.2

soilwater GROUP



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

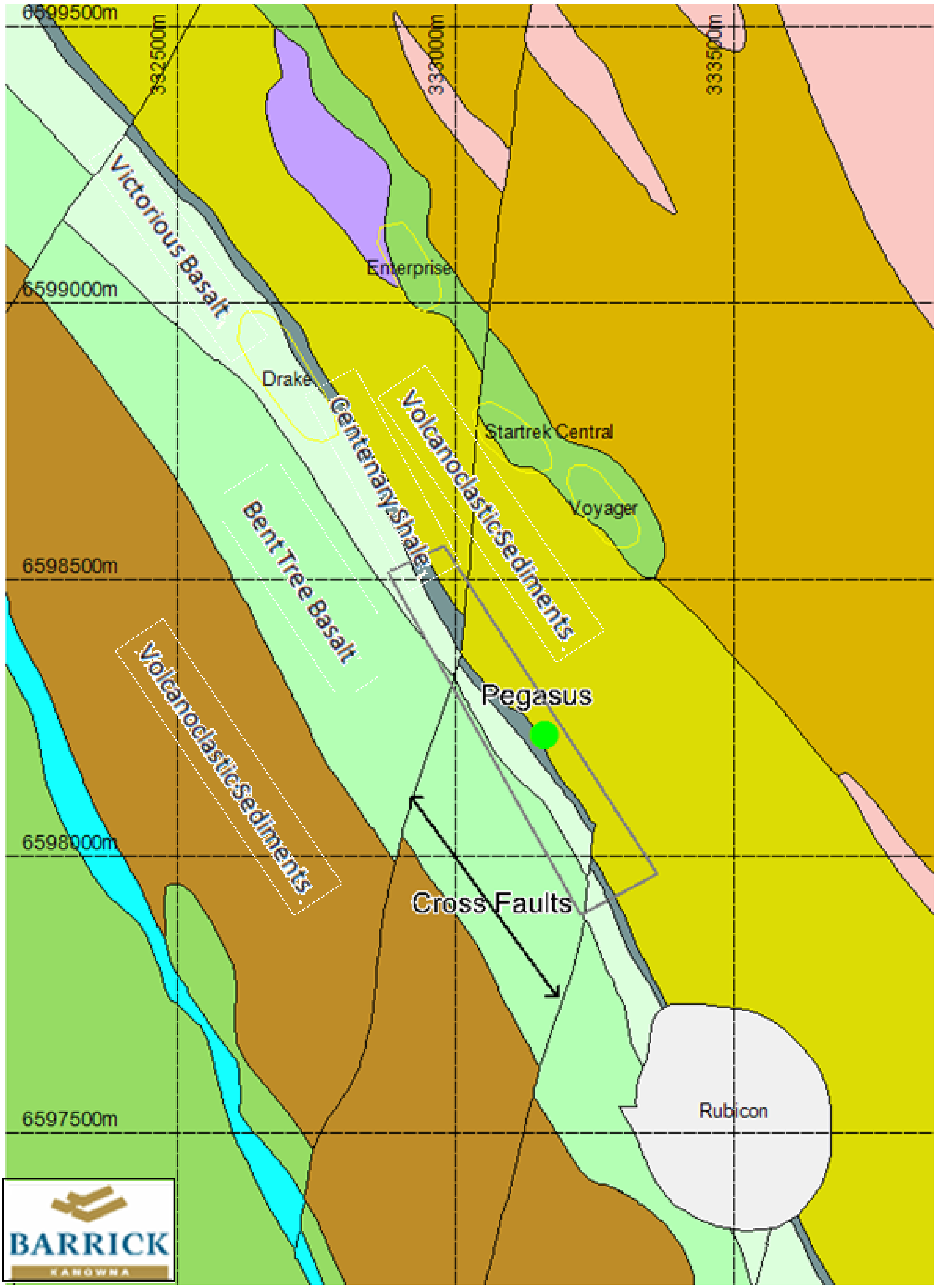
PN	PN0243-1-1-BK-018	
Prep. by	SC	17/06/20
Rev'd. by	ASP	19/06/20
Revision No.		1

Northern Star Resources

PEGASUS DEPOSIT SOIL CHARACTERISATION

SITE LAYOUT

Figure 2.3



PN	PN0243-1-1-BK-018	
Prep. by	SC	17/06/20
Rev'd. by	ASP	19/06/20
Revision No.		1

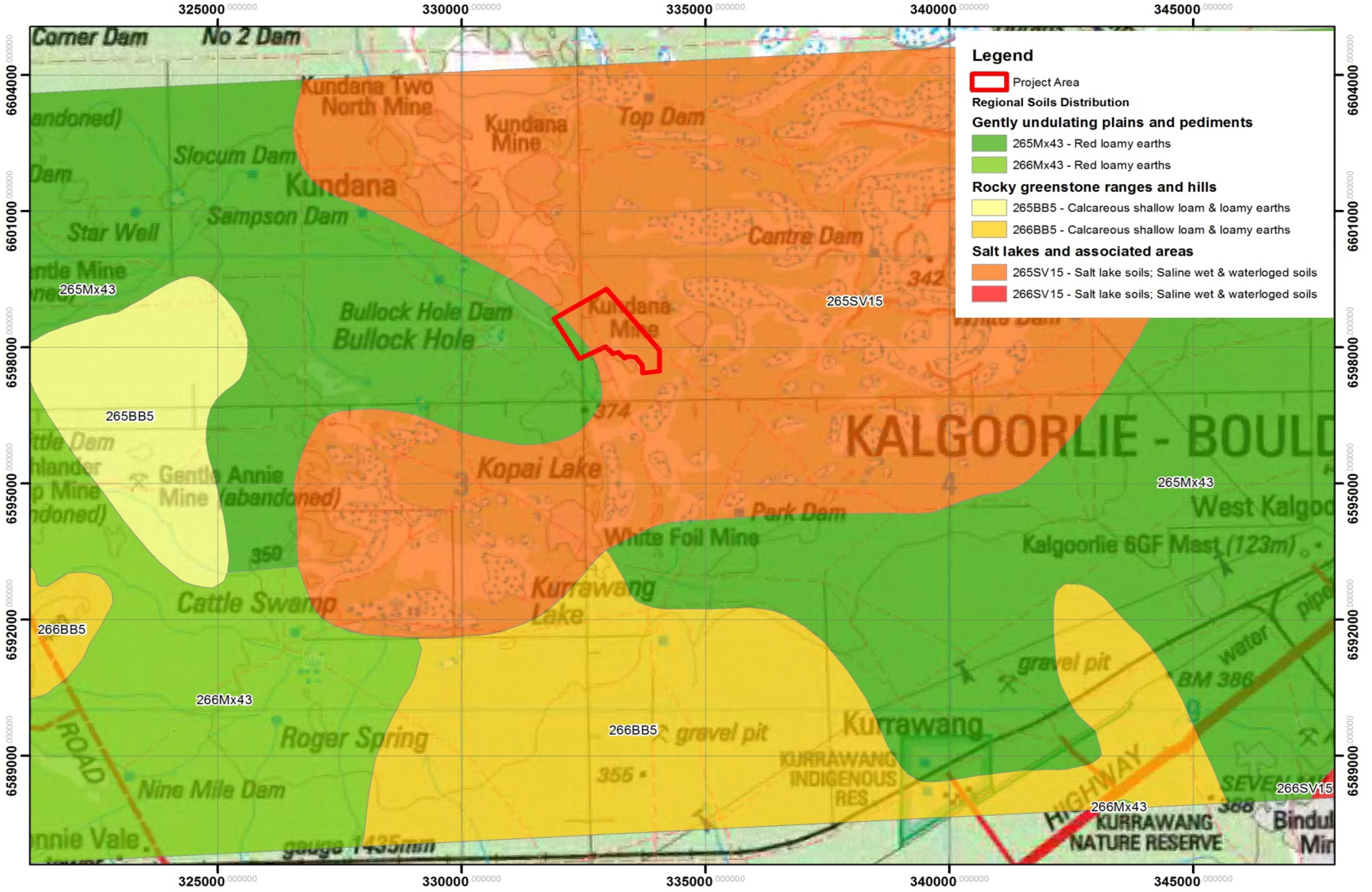
Northern Star Resources

PEGASUS DEPOSIT SOIL CHARACTERISATION

GEOLOGY AT THE PEGASUS DEPOSIT

Figure 2.4

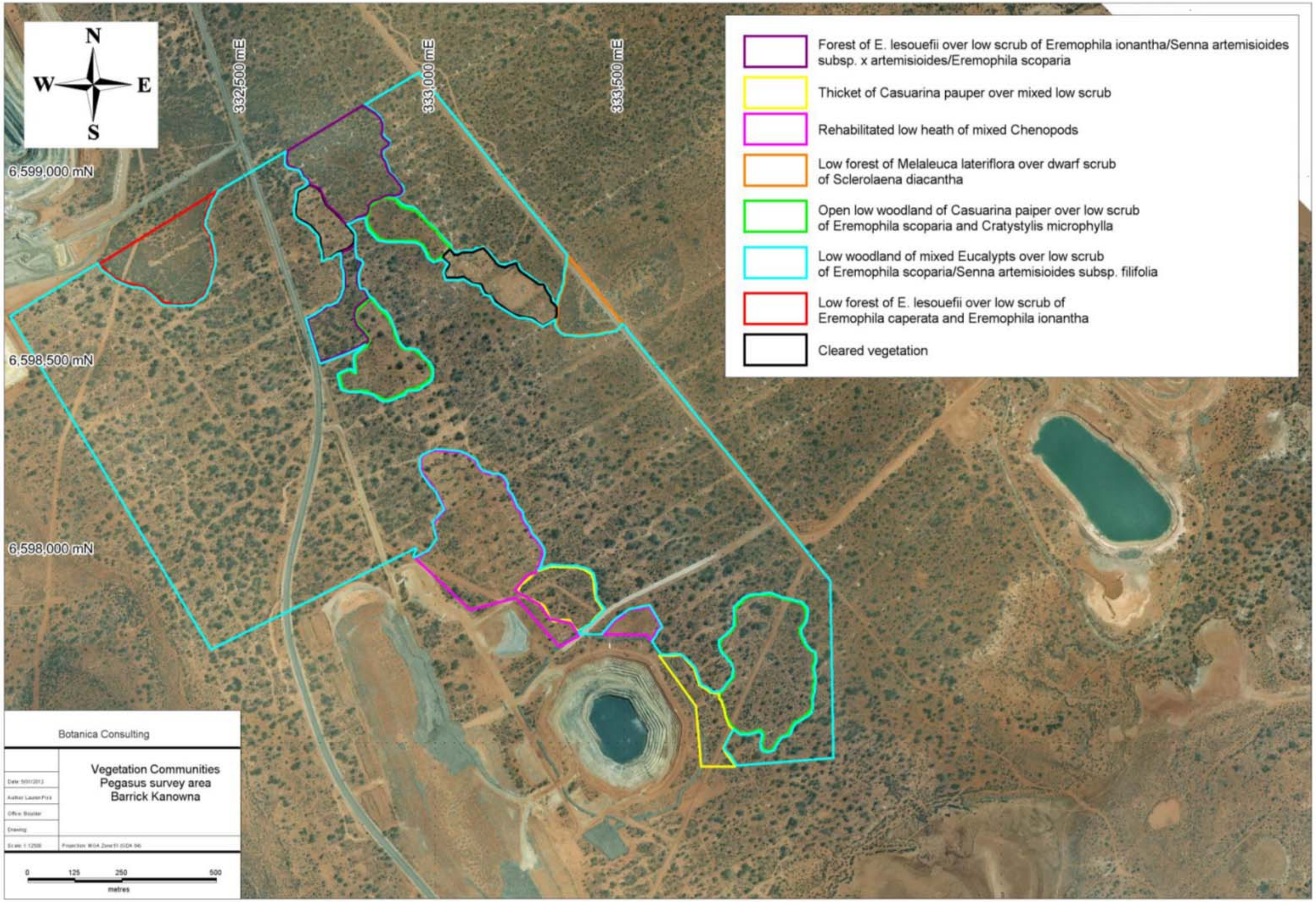
soilwater GROUP



PN	PN0243-1-1-BK-18	
Prep by	SC	19/06/20
Rev'd by	ASP	19/06/20
Revision No.	1	

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACTERISATION
REGIONAL SOILS

Figure 2.5



PN	PN0243-1-1-BK-18		Northern Star Resources PEGASUS DEPOSIT SOIL CHARACTERISATION **VEGETATION MAP AT THE PEGASUS DEPOSIT**	**Figure 2.6**
Prep by	SC	19/06/20		soilwater GROUP
Rev'd by	ASP	19/06/20		
Revision No.	1			

3 STUDY METHODOLOGY

3.1 SOIL PROFILE DESCRIPTION

All soil profiles assessed in the field were described in accordance with the McDonald and Isbell (2009), whilst the land surface was assessed using the classification scheme outlined in McDonald *et al*. (2009). Soil profiles were assessed for degree of horizonation, nature of contacts between horizons, presence and abundance of coarse fragments (i.e. gravels) and mottling, and structure, fabric and field texture of soil materials. A semi-quantitative assessment of plant roots (Table 3.1) was also undertaken to assist in identifying any potential adverse soil materials.

Table 3.1: Semi-quantitative assessment of plant roots used in this investigation (McDonald and Isbell, 2009).

Rating	Number of roots per 0.01 m^2 (10 cm × 10 cm)	
	Very fine - fine roots (< 2 mm diameter)	Medium - coarse roots (> 2 mm diameter)
0 No roots	0	0
1 Few roots	1 - 10	1 - 2
2 Common roots	10 - 25	2 - 5
3 Many roots	25 - 200	> 5
4 Abundant roots	> 200	> 5

3.1.1 SOIL SAMPLE COLLECTION

Soil materials within the Project Area were investigated by shallow trench excavation (Plate 3.1). Sampling was undertaken in April 2012 and the locations of the sampling sites are provided in Figure 3.1.

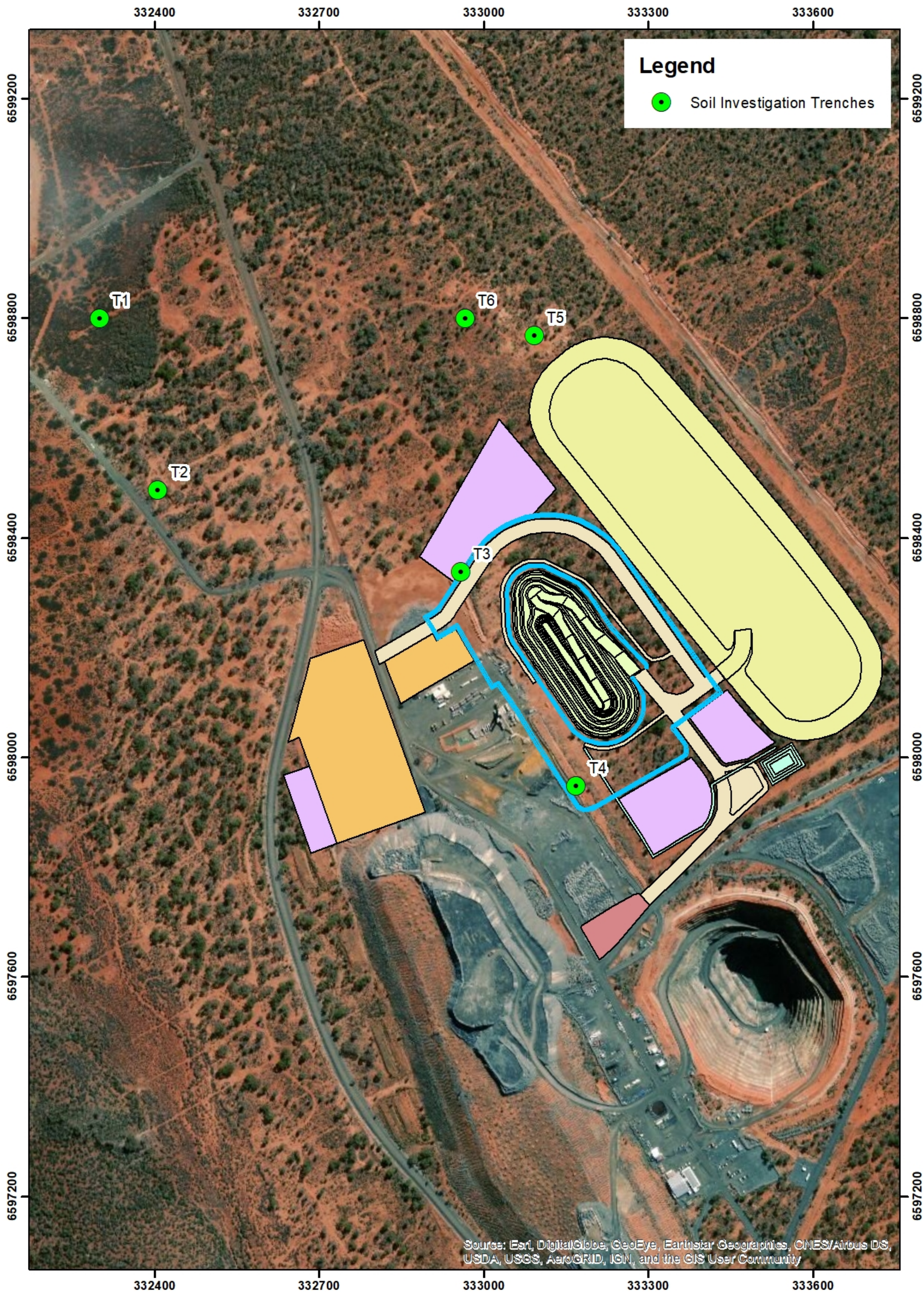
Shallow trenches were excavated by hand to a maximum depth of 1.3 m, and where possible exposed soil profiles from previous drillhole sump excavations were also assessed. A total of 6 sampling sites were investigated across the proposed disturbance area (Figure 3.1). Samples were collected at 10 cm intervals down the surficial profile to ensure that any pedologic organisation or horizonation was identified and that each of the major soil materials was sampled. Approximately 3 kg of soil was collected for each material for detailed laboratory analysis (Section 3.2).

Details of the sampling sites assessed are provided in Table 3.2.

3.2 LABORATORY ANALYSIS

The physical and chemical properties of the soil materials collected in the field were assessed in the laboratory. The properties listed in Table 3.2 were assessed for a representative number of samples from all soil materials.

Analysis of the physical properties was undertaken at Soil Water Analysis (SWA) Laboratories, whilst the chemical properties were assessed at CSBP Laboratories.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

PN	PN0243-1-1-BK-18	
Prep. by	SC	19/06/20
Rev'd. by	AP	19/06/20
Revision No.		1

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACTERISATION
SOIL SAMPLING LOCATIONS

Figure 3.1

Plate 3.1: Excavation of shallow soil trenches by hand to characterise the surface soils.

Table 3.2: Details of the locations sampled for the soil characterisation

Trench ID	Coordinates (GDA 94, Zone 51)		Depth (cm)
	Easting	Northing	
1	332,300	6,598,800	70
2	332,406	6,598,486	70
3	332,958	6,598,337	90
4	333,169	6,597,947	130
5	333,092	6,598,769	80
6	332,966	6,598,799	60

Table 3.3: Physical and chemical properties examined in the laboratory

Physical properties	Chemical properties
• Bulk density	• Nutrients (Mineralised Nitrogen, Colwell Phosphorus and Potassium, and Extractable Sulfur)
• Particle size distribution	
• Saturated hydraulic conductivity	• Organic carbon

• Water retention properties	• pH
• Structural stability	• Electrical conductivity (salinity, EC)
	• Exchangeable cations (Calcium, Magnesium, Sodium and Potassium)
	• Cation exchange capacity (CEC)
	• Sodicity (Exchangeable sodium percentage – ESP)

All physical and chemical properties were assessed against standard soil property criteria provided in Appendix A.

3.3 EROSION TESTING

Laboratory-scale erosion tests were undertaken on the following samples:

- Topsoil: A composite mixture of topsoil samples (0 – 10 cm soil) was prepared.
- Topsoil + rock: The composite Topsoil sample was mixed in an even ratio with competent waste rock to simulate the ripping through of waste rock (see Plate 3.2). A 50 % rock cover was achieved and tested.

Plate 3.2: Mixing of waste rock with Topsoil.

3.3.1 RAINFALL SIMULATOR

A laboratory-scale rainfall simulator (Plate 3.3) was used to measure the interrill (raindrop impact) erodibility of each material. The rainfall simulator was designed to apply water at an intensity of approximately 85 mm/hr, with a raindrop size and spatial distribution closely resembling natural rainfall. An intensity of 85 mm/hr corresponds to a 1:10, 1:20 and 1:100 year ARI storm event of approximately 6, 10, and 20 min duration, respectively, at Kalgoorlie (BOM, 2012).

Prior to testing, each material was placed into a 0.75 x 0.75 x 0.20 m container and compacted to approximate the expected field conditions. The base of the container was free draining to avoid saturated conditions and air entrapment within the samples. Each material was pre-treated by sequentially wetting and drying the surface to allow natural organisation and settling of the soil particles.

The container was set at a slope angle of 15° to simulate the proposed batter conditions at the site. The materials were then subjected to a simulated rainfall of approximately 85 mm/hr, and 8-10 samples of the resulting surface runoff were collected over a 3-4 hour period. Runoff volume and sediment loss in each sample were determined gravimetrically. Measurements from the rainfall simulator were used to calculate soil erodibility parameters required for the WEPP erosion model. The methods used for calculating these parameters are discussed further in Section 2.2.4.

Plate 3.3: Laboratory rainfall simulator.

3.3.2 RILL EROSION MEASUREMENTS

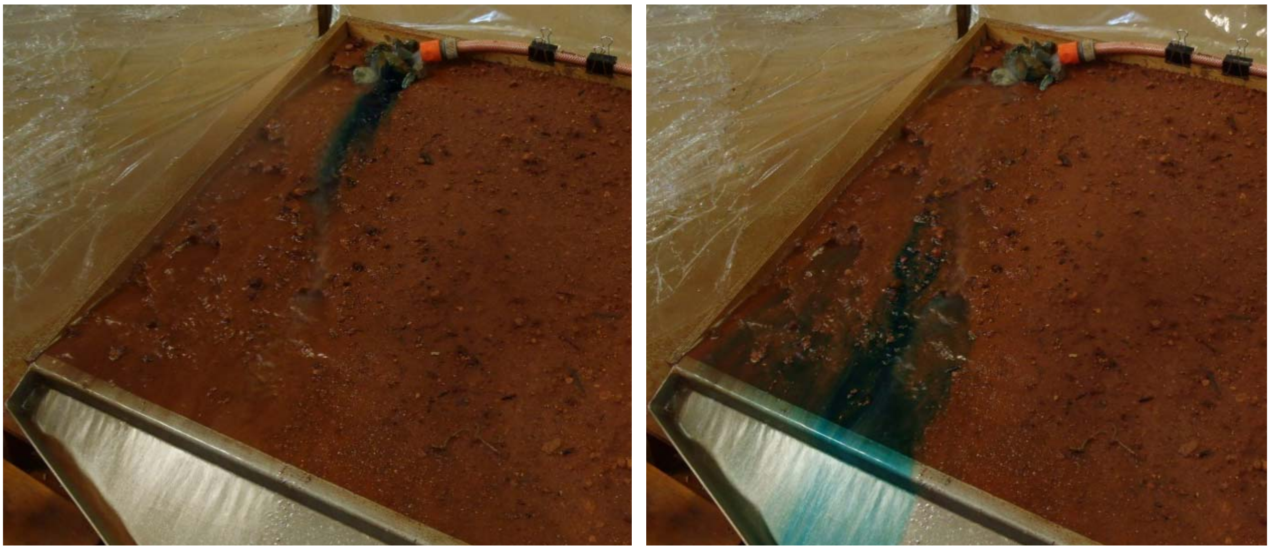
Laboratory scale testing was completed to measure the rill erodibility (K_r) and critical shear stress (τ_C) of the materials under overland flow conditions. The laboratory testing was designed to expose the materials to a range of overland flow depths to simulate storm events of different sizes, and to measure the resulting sediment content in the surface runoff, generated by rill erosion.

Due to lack of adequate sample, a full-scale erosion flume could not be used. Instead, a "mini-flume" method was used on samples previously tested in the rainfall simulator (Plate 3.4). Each material was subjected to 5 different overland flow rates at a slope angle of 15°, and the following measurements were made for each:

- A timed sample of the resulting surface runoff was collected. Surface flow rate and sediment loss were then determined gravimetrically.
- A measurement of average flow velocity was made visually, using a blue dye and stopwatch. The "average" velocity was calculated from the mid-point in time between the initial breakthrough of the dye plume and the time when 90% of the dye plume had exited the rill.
- Measurements of rill width were made at three standardised locations along the rill.

Measurements from the erosion flume were used to calculate rill erodiblity parameters required for the WEPP erosion model. The methods used for calculating these parameters are discussed further in Section 2.2.4.

Plate 3.4: Laboratory-scale "mini-flume" rill erosion test.



3.4 EROSION MODELLING

The Watershed Erosion Prediction Project (WEPP; Flanagan & Livingston, 1995) model was used to predict the long-term (100 year duration) erosion rates from the surface of the proposed waste rock landform at the Pegasus Deposit. The WEPP model used a series of input files describing the climate, soils, slope geometry, and land management regime for the site. Model input values and assumptions are discussed in the following sections.

3.4.1 CLIMATE DATA

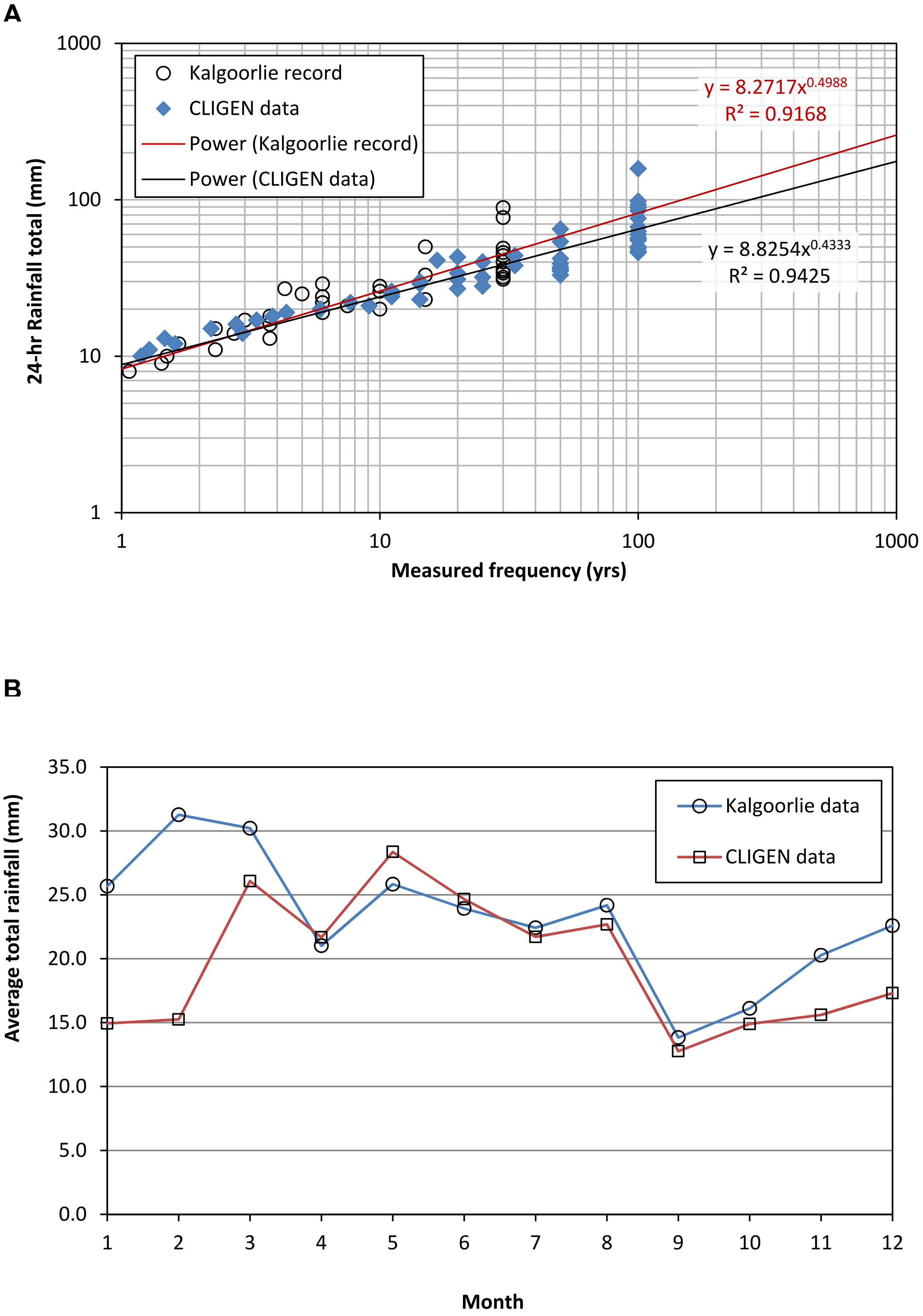
A synthetic climate file was generated using the CLIGEN stochastic weather generator (Yu, 2003), and was used in the WEPP model to simulate 100 years of rainfall, runoff, and erosion. The following climate data was input to CLIGEN to generate this file (BOM station #12038, Kalgoorlie-Boulder):

- 0.5 hourly rainfall data (from Jan 1994 to May 2009)

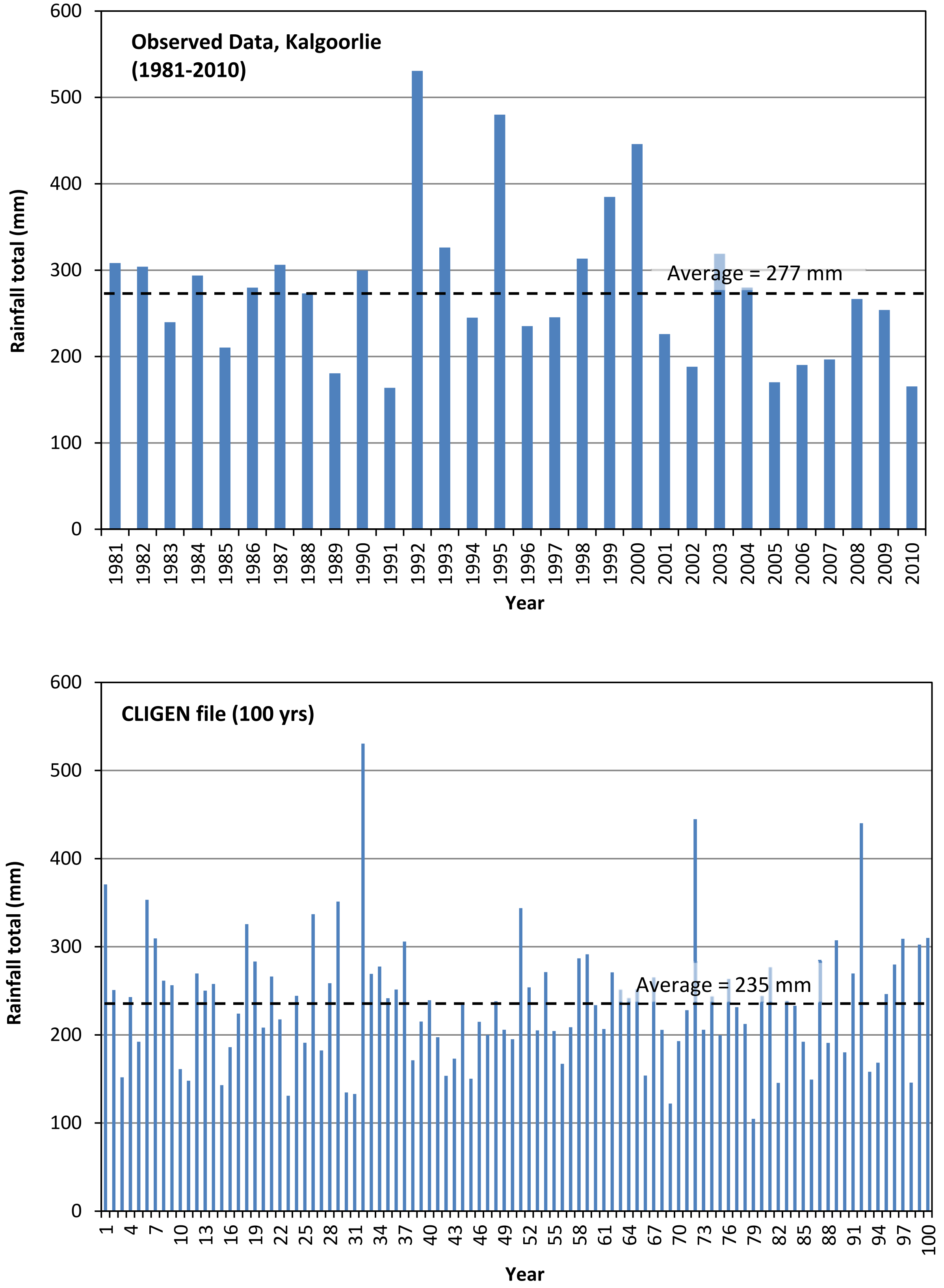
- 30 year data set of daily values for rainfall, maximum and minimum temperatures, and solar radiation

Figures 3.2 and 3.3 demonstrates that the 100 year synthetic CLIGEN file used in this investigation is generally consistent with the 30 years of measured data from which it was generated. Figure 3.2 compares the frequency of 24-hour rainfall totals, indicating that larger 24-hour storms occurred slightly more frequently in the measured data than in the CIGEN file. For example, the observed data shows an average 1:25 year, 24-hour event of approximately 40 mm, while the CLIGEN file includes an average event of approximately 35 mm at the same frequency.

Figure 3.3 compares the monthly and annual rainfall depths (respectively), and shows that the CLIGEN file captures a similar degree of variability in rainfall depths within and between years as was observed over the previous 30 years at Kalgoorlie. The SWC climate file simulates a slightly smaller depth of rainfall, mainly in the November-March period. This is likely to result in underestimation of erosion during these months.



PN	PN0243-1-1-BK-18		Northern Star Resources PEGASUS DEPOSIT SOIL CHARACTERISATION **24 HOUR AND MEAN MONTHLY RAINFALL COMPARISON**	**Figure 3.2**
Prep. by	SC	19/06/20		soilwater GROUP
Rev'd. by	ASP	19/06/20		
Revision No.		1		



PN	PN0243-1-1-BK-18	
Prep. by	SC	12/06/20
Rev'd. by	ASP	19/06/20
Revision No.		1

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACHTERISATION
Annual rainfall comparison

Figure 3.3

3.4.2 SOIL PARAMETERS

The soil parameters required by WEPP were derived from the laboratory testing undertaken at SWA Laboratories. These parameters include the particle size distribution, effective hydraulic conductivity (K_{eff}), interrill erodiblity (K_i), rill erodibility (K_r), and soil critical shear stress (τ_C), and are summarised in Table 3.4.

K_{eff} was estimated by fitting the Green-Ampt equation (Green & Ampt, 1911) to measured infiltration rates using Equation 3.1:

$$f = K_{eff}\left(1 + \frac{N_s}{F}\right) \qquad \text{Eqn. 3.1}$$

where: f = infiltration rate (mm/h)

K_{eff} = effective saturated hydraulic conductivity (mm/h)

N_s = is the effective matric potential at the wetting front (m), and

F = is the cumulative infiltration (m).

K_i was calculated from the inter-rill erosion rate measured in the rainfall simulator, according to Elliot *et al.* (1989) using Equation 3.2:

$$D_i = K_i\, I^2\, S_f \qquad \text{Eqn. 3.2}$$

Where: D_i = interrill erosion rate (kg/(m^2 s)

K_i = interrill erodibility (kg s)/m^4

I = rainfall intensity (m/s), and

S_f = dimensionless slope factor (1.05 - 0.85 $^{-0.85\sin(\alpha)}$)

K_r and τ_C were determined from the shear stress (τ) and rill erosion rate (D_c) measurements collected in the laboratory. This was done by a linear regression analysis according to the method described in the WEPP manual (Elliott *et al.*, 1989). According to Foster (1982), these parameters are related to the measured parameters τ and D_c by Equation 3.3:

$$D_c = K_r(\tau - \tau_C) \qquad \text{Eqn. 3.3}$$

where D_c = measured erosion rate (kg/m^2 s)

K_r = rill erodibility (s/m)

τ = measured shear stress (Pa), and

τ_C = critical shear stress (Pa).

D_c was plotted against τ for each of the flume measurements. The slope of the linear regression line is K_r, and the intercept with the horizontal axis is τ_C (Sheridan *et al.*, 2000).

Table 3.4: Key soil parameters used in the WEPP model.

Material ID	Sand (%)	Clay (%)	OM (%)	CEC [meq/100g]	K_{eff} (mm/hr)	K_i x 10^5 (Kg s / m^4)	K_r (s / m)	τ_C (Pa)
Topsoil A	78	9	0.5*	18*	3	20	0.003	4
Topsoil A + rock	78	9	0.5*	18*	3	7.9	0.002	8.5

* Chemical properties determined from laboratory testing completed by CSBP.

3.4.3 SLOPE PROPERTIES

Batter slopes were modelled assuming a slope angle of 15°. Lift heights of 10 and 20 m (slope lengths of 39 and 78 m, respectively) were modelled to assess the expected erosion from the proposed 10 m lift, as well as the potential impact of increasing lift height beyond the proposed height.

3.4.4 MANAGEMENT ASSUMPTIONS

The land management input file used in the WEPP model was designed to describe the expected land management practices on the remediated waste rock dump at the Pegasus Deposit. The key features of the input management file include:

- Pre-consolidated soil surface. This means that no further settling is simulated within the model, and that the measured infiltration rates and runoff characteristics would apply for the duration of the model (i.e., to further changes in these properties with time).
- No tillage. The “cropping system” value was set to “fallow” within the model to ensure that no further earthworks were simulated. This is in contrast to the model defaults, which consider simulations in an agricultural setting where ploughing or harvesting may occur.
- No vegetation. While some vegetation cover may be expected to develop over the 100 year simulation period, an assumption of zero vegetative cover was used to encourage conservative erosion results (vegetative cover is typically expected to reduce erosion rates).
- No ground cover (i.e., a bare soil surface). As with vegetative cover, any other type of surface cover (e.g., leaf or woody litter) reduces erosion rates within the model. The assumption of zero ground cover was used to encourage conservative erosion results.
- Rill spacing was set internally by the model based on the input soil properties. This resulted in a rill spacing of 1 m. This means that the model will concentrate runoff into rills over a 1 m width of slope in all runoff events, and is considered to be a realistic assumption based on field observations.
- Rill width is adjusted internally in the model based on the input soil erodibility values and the size of the rill erosion events encountered. This resulted in final rill widths of 15-18 cm based on the 1 m rill spacing. This is considered to be a realistic assumption based on field observations.

- The initial surface roughness was set to 2 cm, as random roughness on the rehabilitated soil surface is not expected to be high. Higher roughness values result in less erosion, so this value is considered to be conservative.

4 SOIL CHARACTERISATION

Based on the evolutionary history of the Pegasus Deposit and the morphological characteristics of the soil profiles examined in this investigation, only one Soil Mapping Unit (SMU) occurs across the Project Area and this is classified as a reddish brown sandy loams over calcrete. The relationship between this SMU and the major soil groups in Western Australia (Schoknecht, 2001) and the Australian Soil Classification (Isbell, 1996) are presented in Table 4.1.

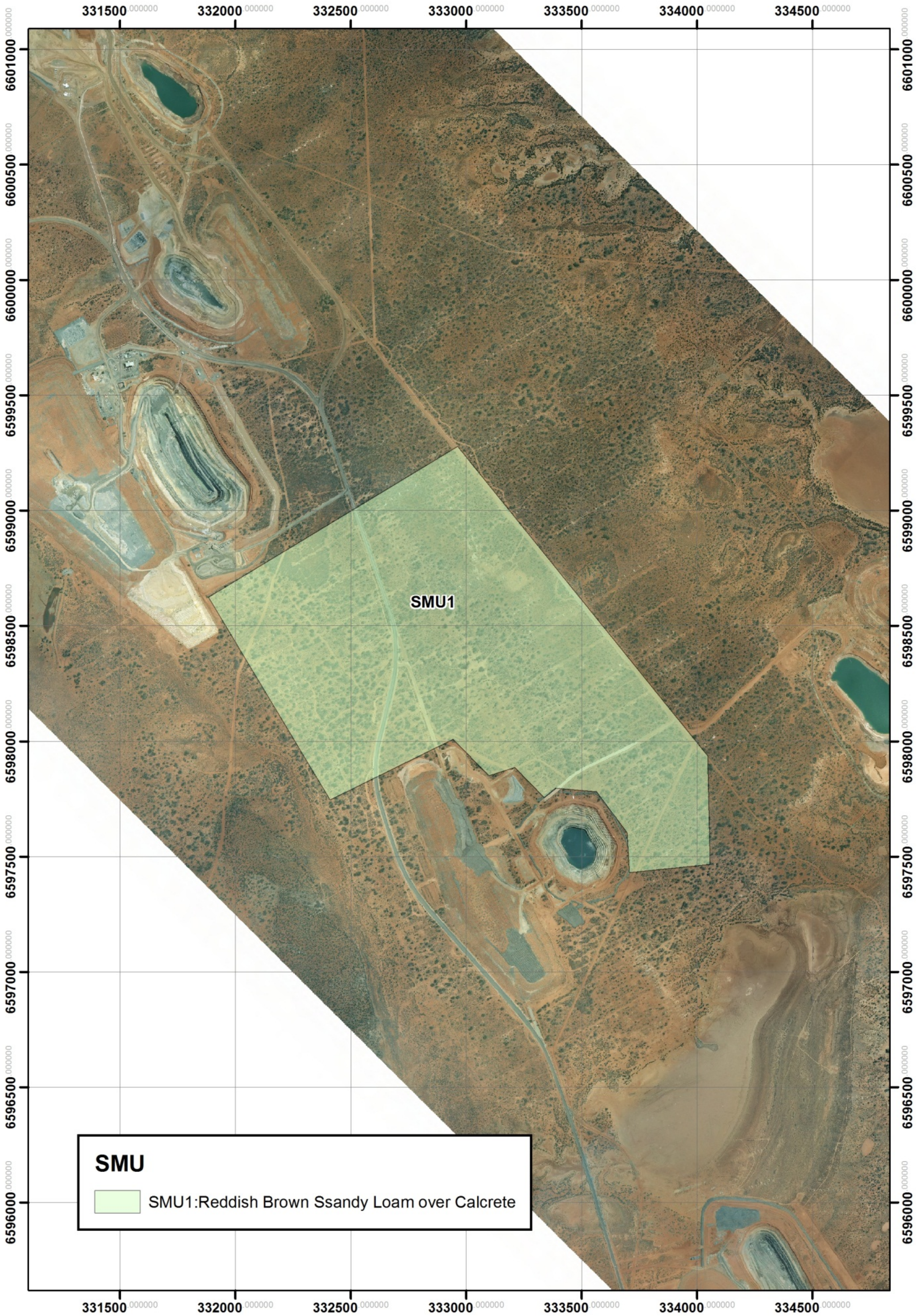
Table 4.1: Relationship between the SMU identified in this study and the major soil groups of Western Australia and the Australian Soil Classification.

SMU (Present study)	Major soil group, WA (Schoknecht, 2001)	Australian Soil Classification (Isbell, 1996)
1. Deep calcareous sandy loam	Calcareous loamy earth	Calcic Calcarosol

4.1 SOIL DISTRIBUTION

The distribution of the soils within the Project Area is shown in Figure 4.1. All soils are homogeneous across the area consisting of a surficial cover of reddish brown sandy loam overlying a calcareous horizon at depth.

All soils characterised in this investigation have been transported by alluvial and aeolian processes and correspond only to the surface portion of the transported layer shown in Plate 2.1. No assessment of the deeper (potentially Achaean) transported materials or the underlying *in situ* regolith has been made given the limitations of this investigation (i.e. restricted to shallow trenches).



PN	PN0243-1-1-BK-018	
Prep. by	SC	17/06/20
Rev'd. by	ASP	19/06/20
Revision No.		1

Northern Star Resources

PEGASUS DEPOSIT SOIL CHARACTERISATION

SOIL DISTRIBUTION THROUGHOUT THE PROJECT AREA

Figure 4.1

soilwater GROUP

4.2 SOIL DESCRIPTION

4.2.1 SMU 1: REDDISH BROWN SANDY LOAM OVER CALCRETE

4.2.1.1 Morphological and Physical Properties

This soil type occurs throughout the Project Area and corresponds to the regionally extensive Red loamy earths (266Mx43; Figure 2.5) that dominate the gently undulating plains and pediments over the entire Goldfields region. Characteristic profiles for this SMU are shown in Figure 4.2.

The reddish brown sandy loam over calcrete can be described as a gradational profile with clay elluviation and subsequent illuviation resulting in a gradual increase in clay content with depth. The surface layers (0 – 10 cm) are characterised as loamy sands, whilst the deeper horizons are considered clay loams (Table 4.2 – 4.5). The clay content in the surface 0 – 20 cm of the profile varies from 6 – 20 %, with an average of 9 and 15 % for the 0 – 10 and 10 – 20 cm soil layers, respectively; corresponding average sand contents vary from 61 – 78 %. At depths greater than 30 cm the clay contents increase to 27 – 29 %, with corresponding silt and sand contents of 16 – 20 % and 51 – 57 %, respectively.

All soils are considered well structured, having predominately crumb peds that are relatively weak in strength (i.e. can be crushed between thumb and forefinger; McDonald and Isbell, 2009). Roots occur throughout the surface 1 m of the profile, and due to their relatively weak strength are able to grow through the soil matrix and are not confined to structural surfaces.

The surface profiles show negligible soil horizonation and morphologically exhibit no pedogenic organisation. Topsoil development throughout the Project Area is very poor, with only minor organic matter accumulation (Plate 4.1); topsoils are only defined in the field by an abundance of fine roots, often with mycorrhizal associations.

Plate 4.1: Poor topsoil development across the Project Area.

At a depth of approximately 40 – 70 cm calcareous mottles begin to occur (Plate 4.2) and from 70 – 130 cm they have fully developed in calcareous gravels loosely set in an unconsolidated calcrete layer (Plate 4.3). This calcareous material represents an evaporite layer that has formed in response to evaporative concentration of soluble salts, most likely to be lime ($CaCO_3$) based on the pH of the soils (i.e. pH around 9; Figure 4.3).

Table 4.2: Particle size distribution of the < 2 mm soil fraction with depth in SMU 1.

Depth (cm)	% Sand	% Silt	% Clay	Texture
0-10	78	13	9	Loamy Sand
10-20	61	24	15	Loam
30-40	57	16	27	Clay loam
50-60	51	20	29	Clay loam
90-100	54	18	28	Clay loam

Table 4.3: Particle size distribution for the topsoil materials (0-10 cm depth).

Trench	% Sand	% Silt	% Clay	Texture
T1	73	17	11	Loamy Sand
T2	74	16	10	Loamy Sand
T3	78	12	10	Loamy Sand
T4	84	9	7	Loamy Sand
T5	69	19	13	Loam
T6	89	6	6	Loamy Sand
Average	78	13	9	Loamy Sand

Table 4.4: Particle size distribution for the topsoil/subsoil materials (10-20 cm depth).

Trench	% Sand	% Silt	% Clay	Texture
T1	64	20	16	Loam
T2	70	18	13	Loam
T3	70	16	14	Loam
T4	34	53	13	Silty loam
T5	70	14	16	Loam
T6	58	22	20	Loam
Average	61	24	15	Loam

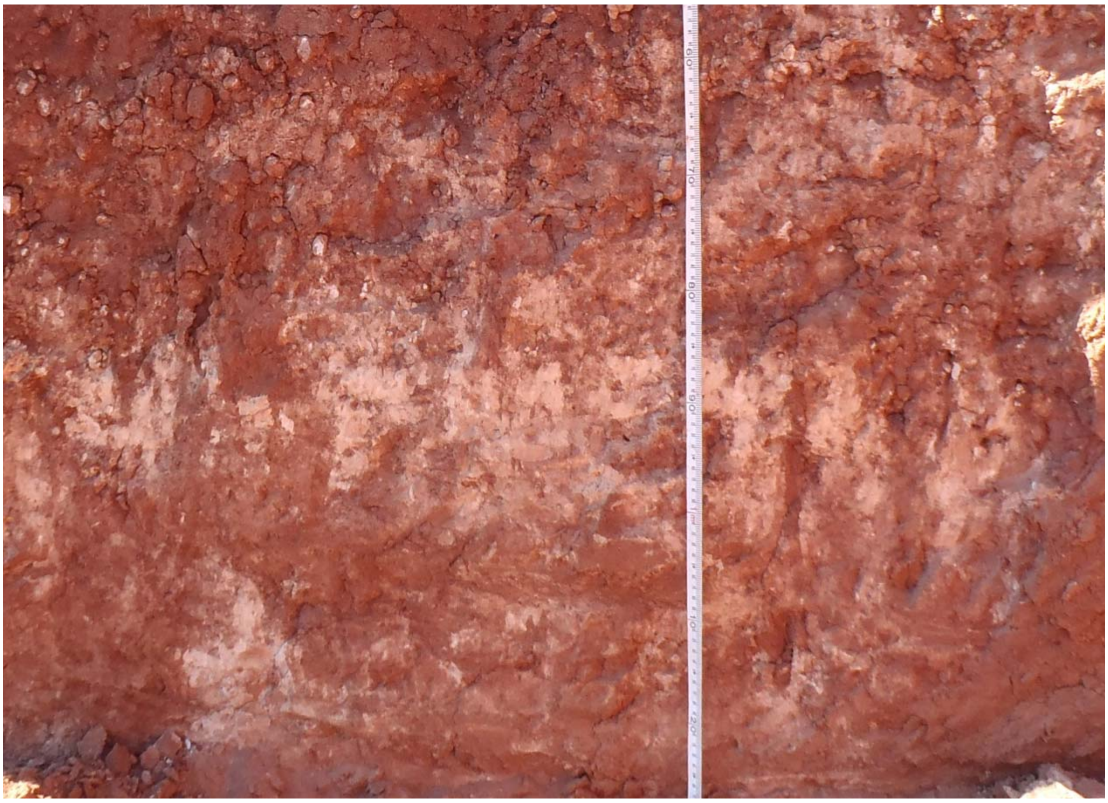
Table 4.5: Particle size distribution for the subsoil materials (30-40 cm depth).

Trench	% Sand	% Silt	% Clay	Texture
T1	54	18	28	Clay loam
T2	-	-	-	(not sampled)
T3	-	-	-	(not sampled)
T4	59	14	27	Clay loam
T5	-	-	-	(not sampled)
T6	58	16	26	Clay loam
Average	57	16	27	Clay loam

Plate 4.2: Calcareous mottling occurring at 40 – 70 cm due to evaporation concentration of soluble salts.

At the time of the field sampling for this study, the moisture content of the surface soils (i.e. 0 – 20 cm) varied from 4 – 11 % (g/g), which is at or below the corresponding wilting point of these soils (Figure 4.3). With depth the moisture content increases, such that by 30 to 50 cm the moisture content is around 12 – 15 % (g/g), whilst at depths > 50 cm the moisture content remains steady at 15 – 20 % (g/g). These moisture contents are ‘available’ to the vegetation falling between field capacity and permanent wilting point for these soils (Figure 4.3). Note: the low moisture contents observed in Trench 4 (T4) are due to exposure on a sump face and do not reflect the actual moisture content of the surrounding soils.

Plate 4.3: Unconsolidated calcrete layer underlying the surface loamy soils.



The water retention data for the surficial soils is presented in Table 4.6. The data shows that these soils have a storage capacity (i.e. field capacity; 10 kPa) of 21.9 – 35.5 % (0.22 – 0.35 m^3/m^3). The corresponding permanent wilting point (1500 kPa) varies from 12.6 – 19.7 % (0.13 – 0.20 m^3/m^3), resulting in a plant available water (PAW) content of between 9.2 – 15.8 % (0.09 – 0.16 m^3/m^3). This PAW content indicates that the surface soils can store between 90 and 160 mm of PAW/m of soil profile. Based on this PAW value the approximate rooting depth of the native vegetation can be determined and is provided in Table 4.7.

Table 4.6: Average water retention data for the surficial soils.

Depth (cm)	Water retention data (v/v, %)					PAW (%)
	0 kPa	10 kPa	33 kPa	100 kPa	1500 kPa	
0 - 10	57.171	21.882	16.999	16.209	12.632	9.250
10 - 20	66.226	25.168	17.329	17.513	13.409	11.758
20 - 30	75.401	31.098	23.594	25.979	18.611	12.487
30 - 40	66.076	26.940	18.344	18.650	15.080	11.860
60 - 70	73.130	32.365	24.420	24.356	16.649	15.716
90 - 100	87.887	35.498	27.067	26.343	19.718	15.780

The predicted rooting depths shown in Table 4.7 has important implications for the construction of the outer surface cover profile of the waste rock landform (WRL) and in the selection of appropriate native species to be used in revegetation and ultimately in the completion criteria used to assess rehabilitation performance. If only 1 m of growth medium is restored on the WRL, with underlying coarse competent waste rock, only groundcovers and small shrubs are likely to be able to be supported by the reconstructed profile, whereas large shrubs and trees will experience significant water deficits throughout the years. If a 2 m growth medium layer is re-established than medium shrubs could be included in the seed mix along with groundcovers and small shrubs. Large shrubs and trees should only be used in water converging/accumulating areas, such as berms and on the top of the WRL.

Table 4.7: Approximate rooting depth of the native vegetation assuming a range of transpiration rates.

Vegetation type	Assumed transpiration rate (mm/year)	Minimum rooting depth (m)	Maximum rooting depth (m)
Ground cover/small (< 30 cm high) shrubs	100	0.6	1.1
Medium shrubs up to 1 m high	200	1.25	2.2
Large shrubs up to 2 – 3 m high	500	3.1	5.6
Trees	1000	6.25	11.1

4.2.1.2 Chemical Properties

The pH and EC (salinity) of the surface soils across the Project Area are provided in Figure 4.4. Soils in the surface 30 cm of the profile typically have low to moderate salinity levels, with EC values < 150 mS/m). At depths > 30 cm salinities generally rise sharply to over 300 mS/m. Salinity levels of this magnitude have the potential to significantly impact on the germination and early establishment of most plant species, with the exception of saltbush (Please note that the elevated salinity levels in the surface soils reported in Trench 5 and 6are not reflective of the wider surface soils, and are due to the ponding of saline groundwater recovered during geological drilling at this site). The pH of all surficial soils in the Project Area are moderately to highly alkaline, with pH values varying from 8 – 10; indicating that they are all calcareous.

The nutrient and organic carbon content of the surface soils sampled from the Project Area are provided in Table 4.8. The results show that all topsoils (i.e. 0 – 10 cm soil layer) are considered nutrient deficient, with low to very low mineralised N (NH_4^+ – N & NO_3^- – N < 20 mg/kg) and Colwell P (< 30 mg/kg) levels. Elevated nitrate – nitrogen (NO_3^- - N) often occurs at depth in some soils, likely due to mobilisation of N from the surface soils. All surface soils have moderate to high Colwell K and Extractable S contents reflecting their parent mineralogy. The majority of topsoils are poorly developed with only a minor accumulation of organic matter (organic C contents < 1 %), whilst the subsoils content low to very low organic carbon contents.

Table 4.8: Chemical properties of the surface soils within the Project Area.

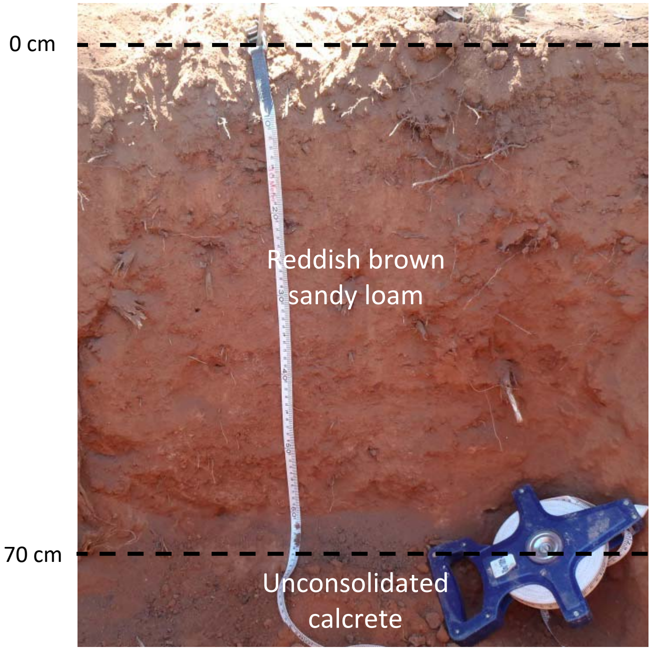
Trench	Depth	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	Potassium Colwell	Sulphur	Organic Carbon
	(cm)	(mg/Kg)	(mg/Kg)	(mg/Kg)	(mg/Kg)	(mg/Kg)	(%)
T1	0-10	< 1	1	7	455	2.2	0.75
	10-20	< 1	2	5	404	12.0	0.45

	30-40	< 1	97	4	372	13.4	0.33
T2	0-10	< 1	1	6	354	2.3	0.97
	10-20	< 1	1	5	365	3.9	0.68
T3	0-10	< 1	3	13	202	2.4	0.61
	10-20	< 1	2	3	218	8.5	0.44
	50-60	< 1	23	< 2	200	123.0	0.24
T4	0-10	1	3	6	274	3.7	0.50
	10-20	< 1	6	< 2	363	30.3	0.18
	30-40	< 1	22	< 2	275	291.2	0.13
	50-60	< 1	16	< 2	281	329.2	0.15
	90-100	< 1	8	< 2	256	276.8	0.10
T5	0-10	< 1	13	6	259	195.6	0.81
	10-20	< 1	9	7	216	43.6	1.04
	0-10	2	2	8	135	3.1	0.31
	10-20	< 1	2	3	232	61.2	0.36
	30-40	< 1	8	< 2	215	204.9	0.13

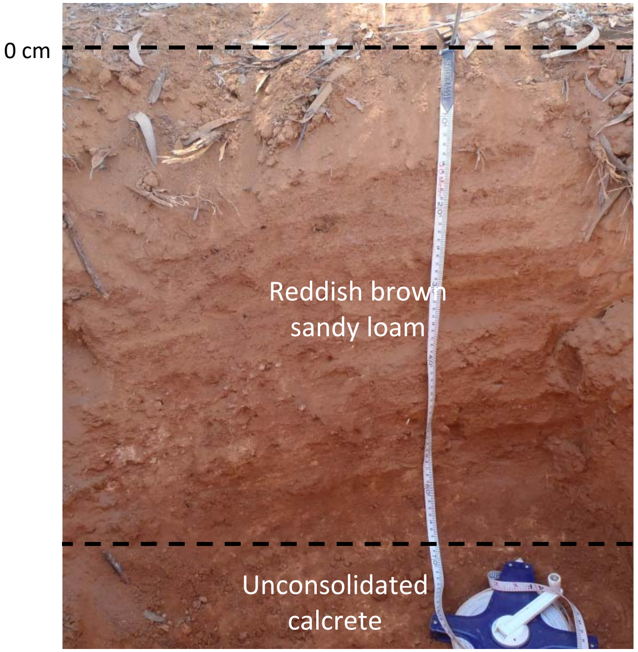
All surface soils are classified as sodic, with ESP values ranging from 8.2 % in the surface 0 -10 cm to 56.3 % at a > 90 cm depth (Table 4.9). Although all soils are considered sodic, their relatively high salinity results in them being structurally stable, with the exception of the topsoils (0 – 10 cm soil layer), which has low salinity levels and are thus potentially dispersive (Figure 4.5). The salinity in soils is generally leach more rapidly than the exchangeable Na, and subsequently any leaching of salts from these soils will result in them becoming dispersive and structurally unstable – this is an important long-term consideration for rehabilitation and closure and requires that waste rock be ripped through the surface soils to assist in stabilising them and prevent excessive erosion and surface runoff.

Table 4.9: Average exchangeable cation and sodicity contents for the surface soils.

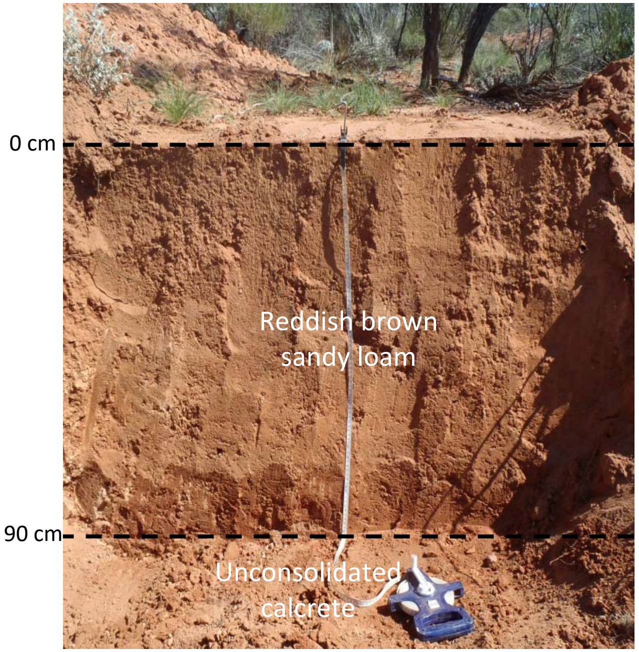
Depth (cm)	Exchangeable cations (meq/100g)				CEC (meq/100g)	ESP (%)
	Ca	Mg	Na	K		
0 - 10	12.32	2.56	0.72	1.18	16.78	8.20%
10 - 20	13.48	4.43	0.79	4.16	22.85	16.81%
30 - 40	10.41	7.17	0.77	12.03	30.38	35.60%
50 - 60	8.79	7.14	0.62	13.86	30.41	44.22%
90 - 100	4.48	7.70	0.66	16.53	29.37	56.30%



Trench 1



Trench 2



Trench 3

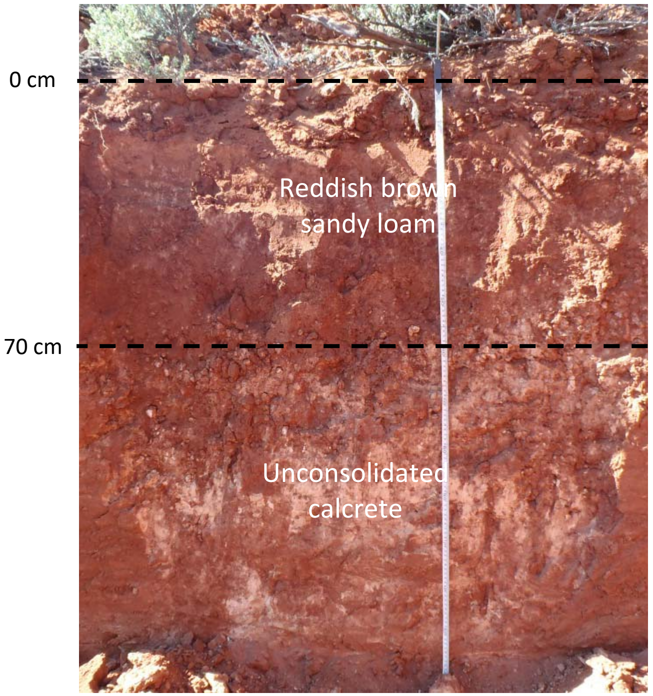
PN	PN0243-1-1-BK-18	
Prep by	SC	18/06/20
Rev'd by	ASP	18/06/20
Revision No.	1	

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACHTERISATION

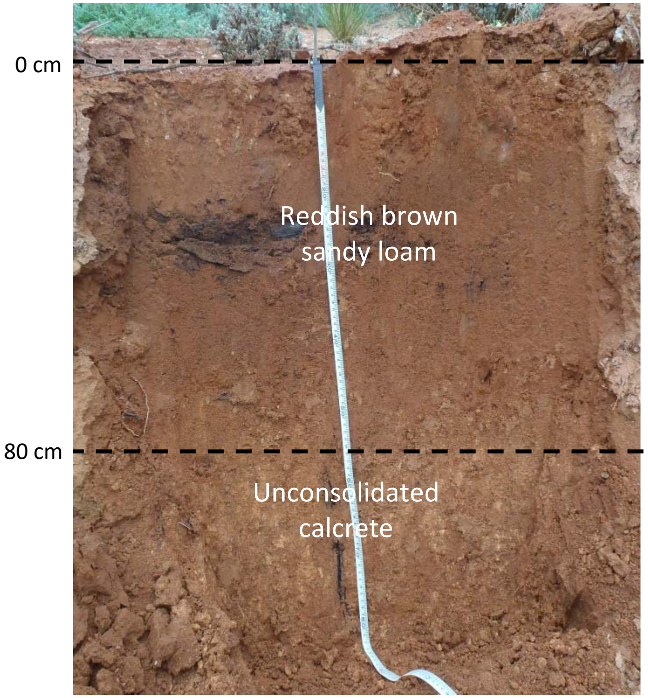
MORPHOLOGICAL PROPERTIES OF THE SOILS IN THE PROJECT AREA

Figure 4.2

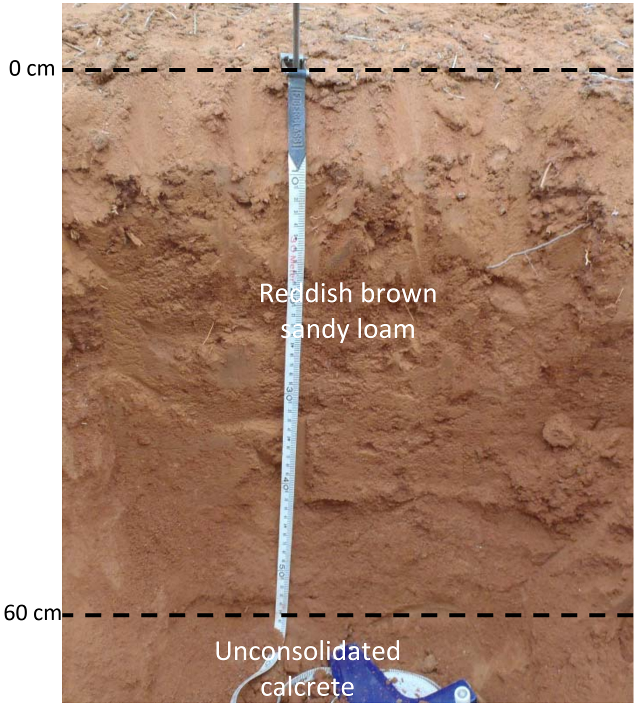
Trench 4



Trench 5



Trench 6



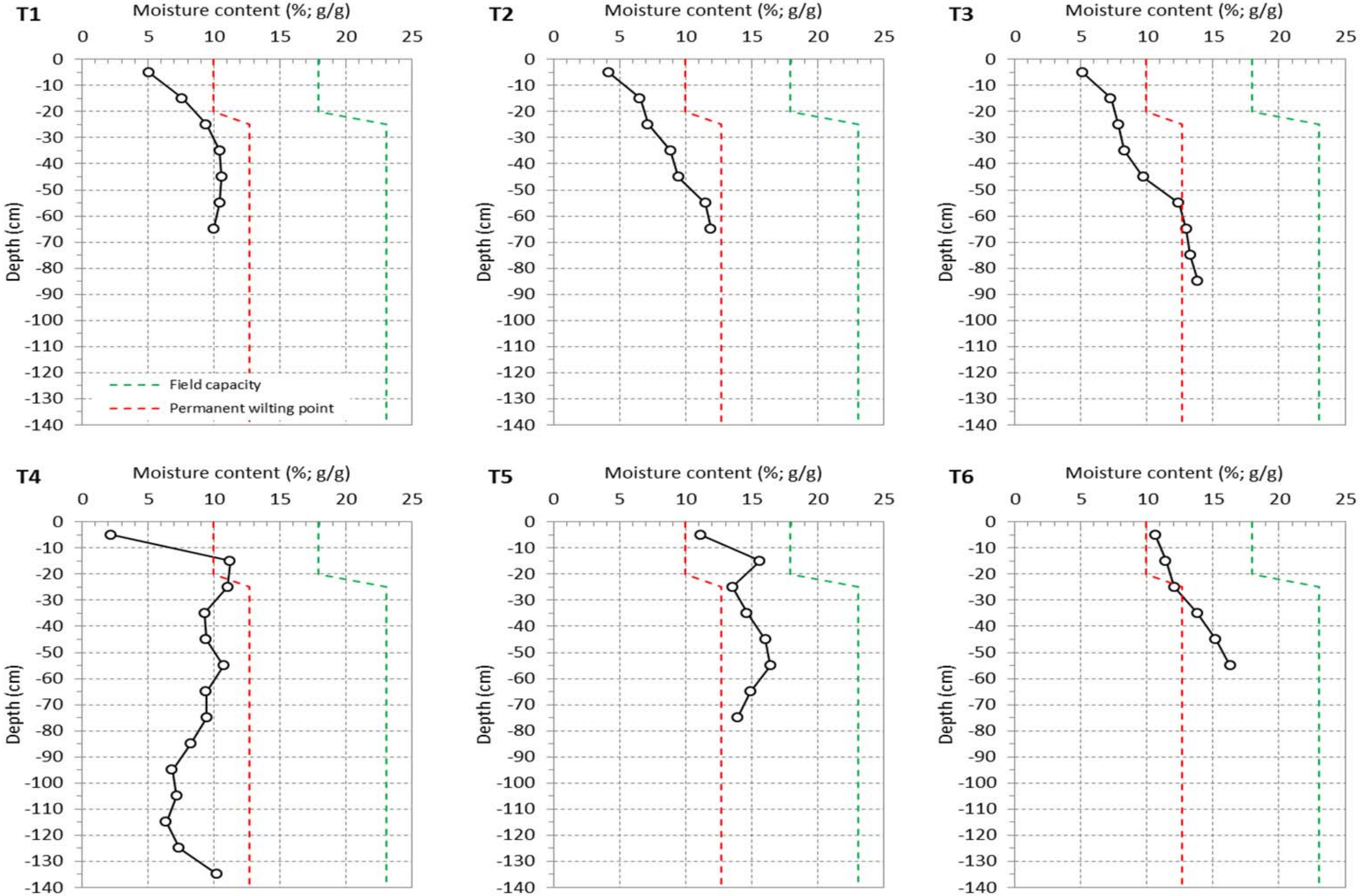
PN	PN0243-1-1-BK-18	
Prep by	SC	18/06/20
Rev'd by	ASP	18/06/20
Revision No.	1	

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACHTERISATION

MORPHOLOGICAL PROPERTIES OF THE SOILS IN THE PROJECT AREA

Figure 4.2
continued…

soilwater GROUP

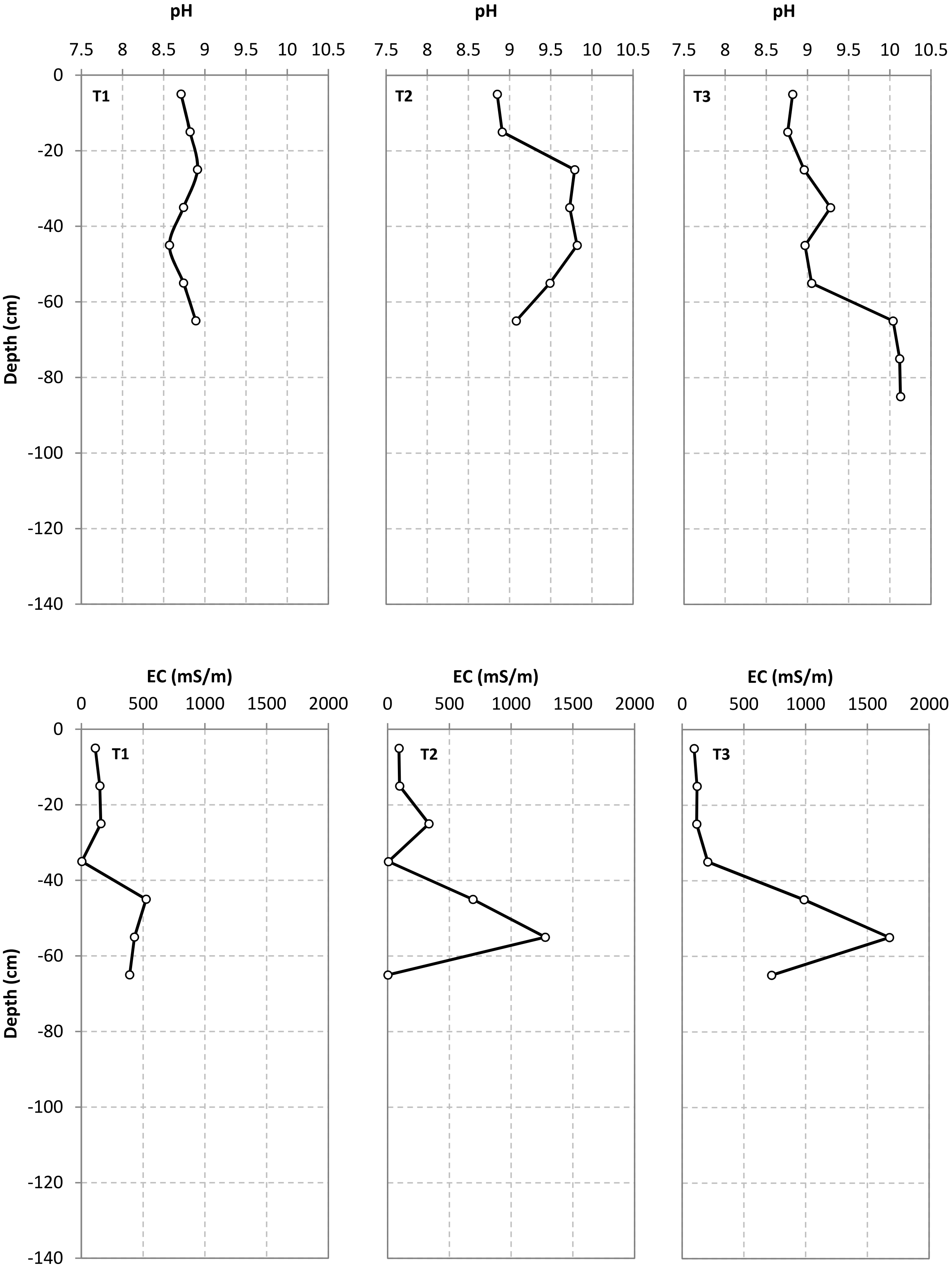


PN	PN0243-1-1-BK-018	
Prep by	ASP	17/06/20
Rev'd by	SC	17/06/20
Revision No.	1	

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACTERISATION
MOISTURE CONTENT PROFILES

Figure 4.3

soilwater GROUP



PN	PN0243-1-1-BK-018	
Prep. by	SC	17/06/20
Rev'd. by	ASP	19/06/20
Revision No.		1

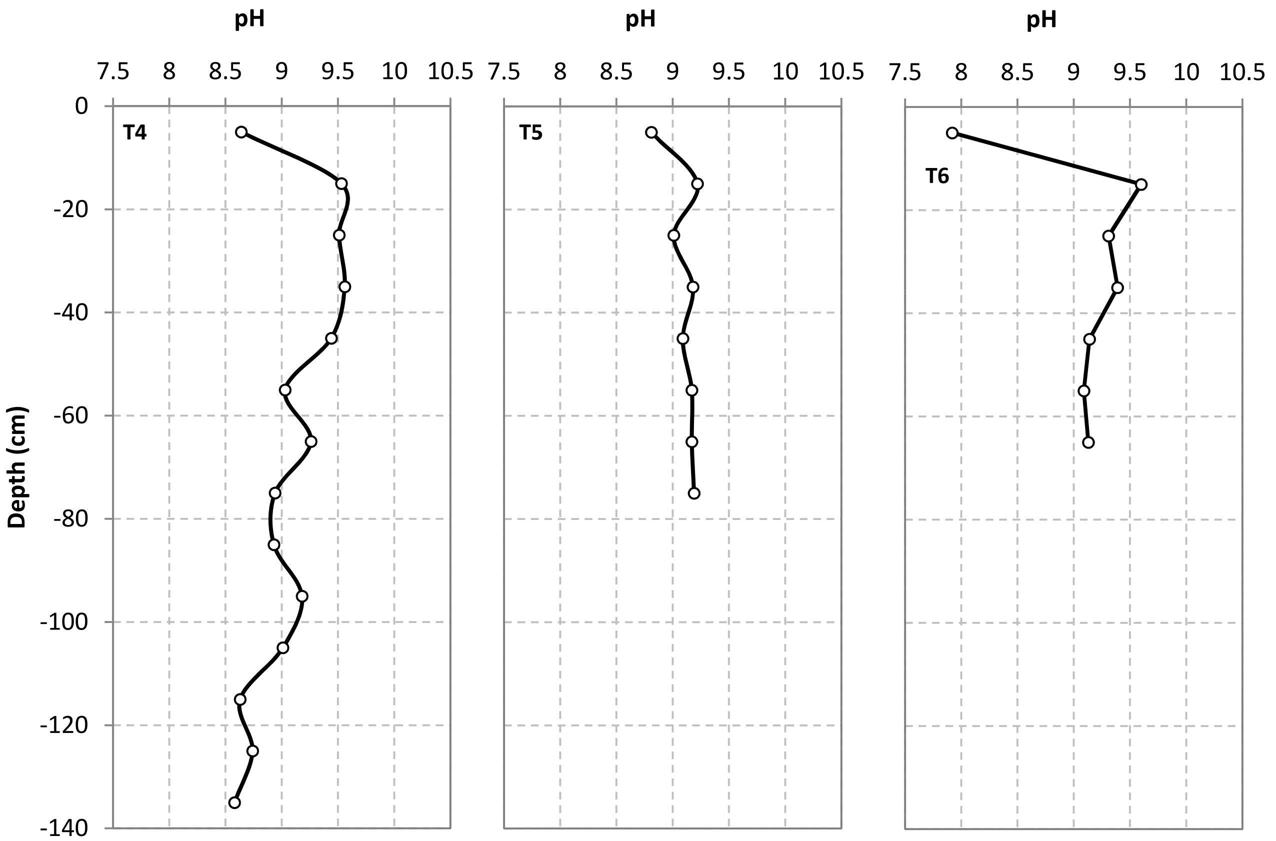
Northern Star Resources

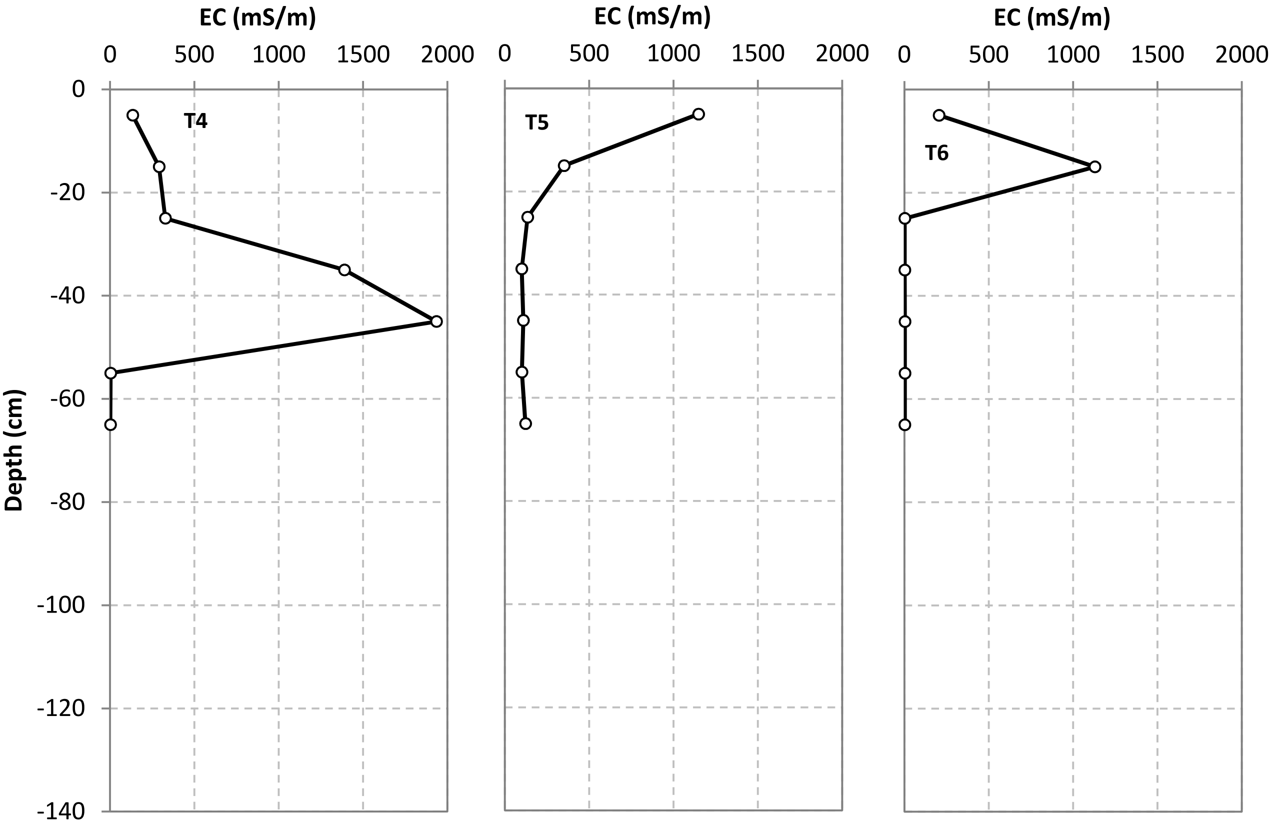
PEGASUS DEPOSIT SOIL CHARACTERISATION

pH and EC Profiles for all Trenches

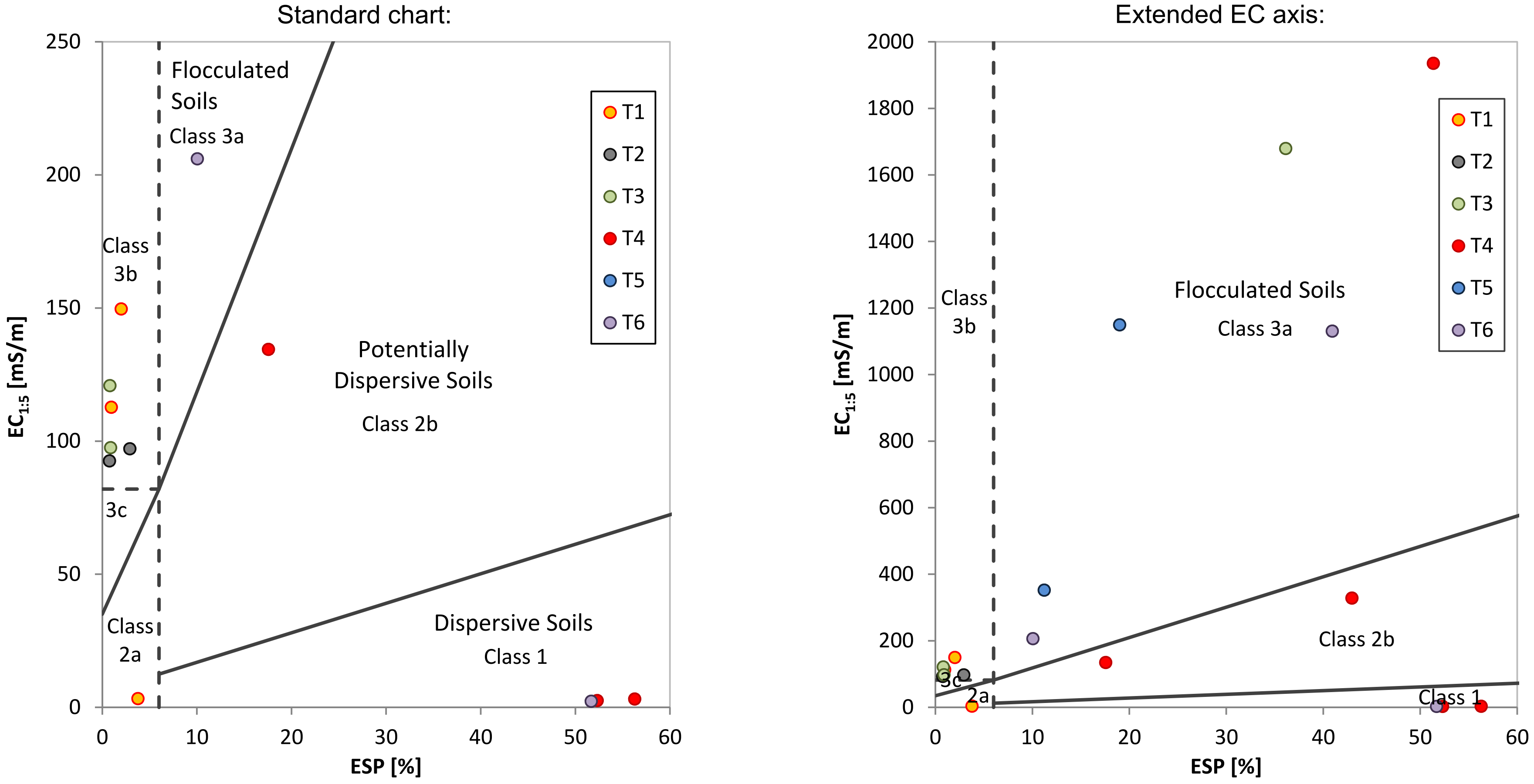
Figure 4.4

soilwater GROUP





PN	PN0243-1-1-BK-018		Northern Star Resources PEGASUS DEPOSIT SOIL CHARACTERISATION **pH and EC Profiles for all Trenches** ***continued…***	**Figure 4.4**
Prep. by	SC	17/06/20		soilwater GROUP
Rev'd. by	ASP	19/06/20		
Revision No.		1		



PN	PN0243-1-1-BK-18	
Prep by	SC	18/06/20
Rev'd by	ASP	18/06/20
Revision No.	1	

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACHTERISATION
STABILITY PLOTS FOR ALL TRENCHES

Figure 4.5

4.3 STABILITY OF THE SURFACE SOILS

4.3.1 FIELD OBSERVATIONS

During the field component of the investigation several erosional features were observed in the native soils, including rill and gully erosion (Plate 4.4). The slope of the landsurface in the vicinity of these erosional features is generally low (< 5°) to flat, and the surface soil are typically stabilised by a relatively continuous cryptogram cover (Plate 4.5). In areas where disturbance of the surface soils has removed the cryptogram cover or where it is absent considerable etching of the surface occurs, which ultimately results in the formation of gully erosion.

Based on these field observations it is considered that the surface soils within the Pegasus Deposit are unstable and will likely result in significant erosion if used inappropriately to construct the waste dump or if surface water management over the waste dump is not carefully controlled.

Plate 4.4: Rilling of the in situ surface soils following disturbance of the cryptogam layer.

4.3.2 EROSION MODELLING

Table 4.10 summarises the modelled runoff and sediment yields for each of the materials that were tested. Before and after photographs of the erosion tests are included in Figures 4.6 and 4.7.

Table 4.10: Summary of erosion modelling results.

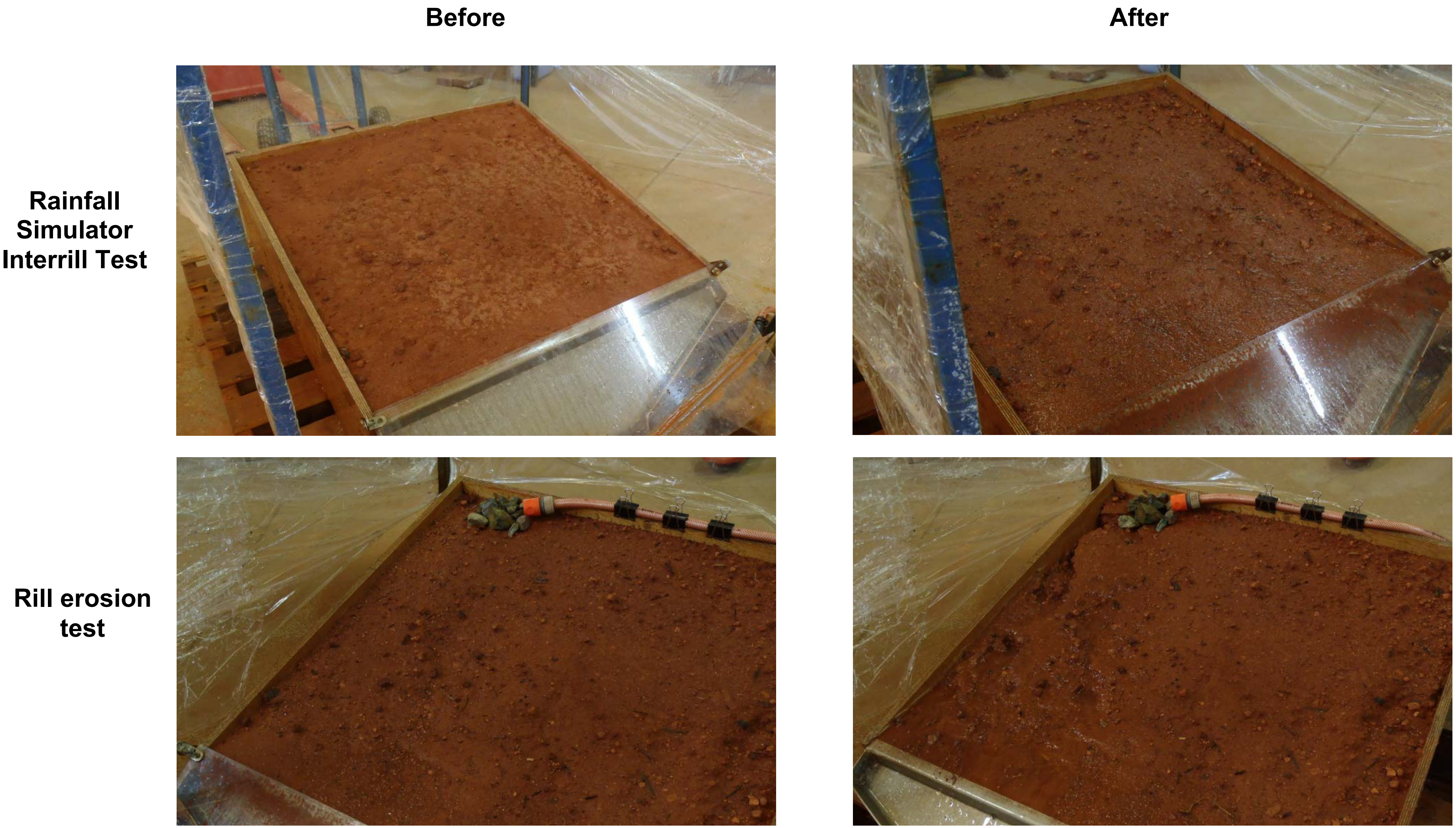
Material ID	Slope angle	Lift height (m)	Average Annual runoff (mm/yr)	Average Erosion Rate (t/ha/yr)	Maximum runoff event (mm)	Maximum erosion event (t/ha)
Topsoil composite	15°	10	35	5.7	118	19.2
	15°	20	34	10.7	118	31.8
Topsoil + rock	15°	10	35	2.6	118	14.8
	15°	20	34	5.8	118	26.7

Plate 4.5: Cryptogam cover stabilising the undisturbed native soils.

The model results for the topsoil composite indicated average sediment yields above the industry standard of 5 t/ha/yr, for both 10 and 20 m lift heights. This suggests that these materials should not be used on any of the batter slopes, particularly at angles ≥ 15°.

The model results for the Topsoil combined withwaste rock, indicated average sediment yields below the industry standard of 5 t/ha/yr, given a 10 m lift height. The sediment yield is predicted to increase to >5 t/ha/yr if the batter lift height is increased to 20 m.

It should also be noted years with greater than average rainfall (or larger storm events) will generate more than the average amount of sediment from these materials. Runoff and erosion depend largely on the size and intensity of each rainfall event and the infiltration characteristics of each material – Not all rainfall events generate runoff, and not all runoff events generate erosion. The WEPP model results indicate that erosion-producing storm events are likely to occur as infrequently as every 2 years, or as frequently as 2-3 times per year. It is reasonable to expect that more than one year's worth of sediment loss (when considered as an average annual loss) could potentially occur in a single storm event. This is demonstrated in Figure 4.8, which shows daily sediment yields predicted by the WEPP model.



PN	PN0243-1-1-BK-18	
Prep by	SC	19/06/20
Rev'd by	ASP	19/06/20
Revision No.	1	

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACTERISATION
EROSION TESTING PHOTOGRAPHS - TOPSOIL

Figure 4.6

soilwater GROUP

Before

After

Rainfall Simulator Interrill Test

Rill erosion test

PN	PN0243-1-1-BK-18	
Prep by	SC	19/06/20
Rev'd by	ASP	19/06/20
Revision No.	1	

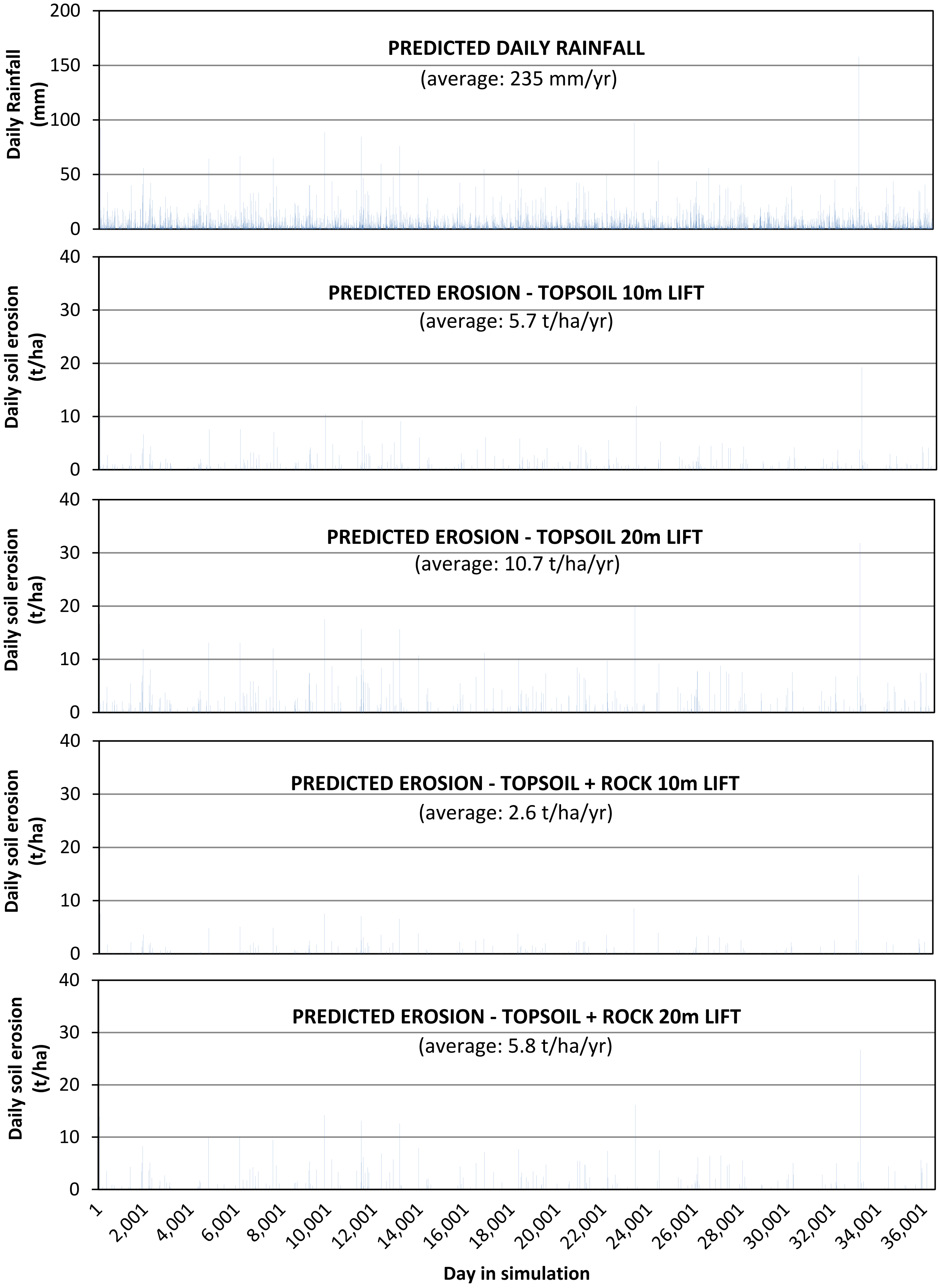
Northern Star Resources

PEGASUS DEPOSIT SOIL CHARACTERISATION

EROSION TESTING PHOTOGRAPHS – TOPSOIL + ROCK

Figure 4.7

soilwater GROUP



PN	PN0243-1-1-BK-18	
Prep. by	SC	12/06/20
Rev'd. by	ASP	19/06/20
Revision No.		1

Northern Star Resources
PEGASUS DEPOSIT SOIL CHARACTERISATION
DAILY SEDIMENT YIELD PREDICTIONS

Figure 4.8

soilwater GROUP

5 SOIL MANAGEMENT

This section outlines management recommendations for the handling and utilisation for the surficial soil materials identified in Section 4. These recommendations are suggested with the aim of:

- Maintaining optimal soil properties during the mining and rehabilitation process.
- Appropriate handling of soil and waste materials that exhibit adverse physical and chemical properties to ensure no contamination with other 'good' or optimal materials.
- Minimising environmental impacts that may occur through inappropriate handling and utilisation of soil and waste materials that exhibit adverse properties.
- Preventing the development of adverse properties in these materials during mining and rehabilitation.

The following management recommendations are suggested for the handling of the various surficial soil materials at the Pegasus Deposit.

5.1 TOPSOIL MATERIALS (BENEFICIAL MATERIALS FOR USE IN REHABILITATION)

- Topsoils in the Pegasus Deposit Project Area are typically poorly developed with only a minor accumulation of organic matter and are nutrient deficient. Given these properties, and the fact that the waste dump surface will be seeded with provenance species, it is considered that there is no requirement to segregate the surface 10 cm of the profile to capture the stored native seed and prevent dilution of nutrients. The surface 20 cm of the soil profile is generally non-saline, with no chemical or physical limitations to plant growth, and therefore it is recommended that this depth of the surface soil be stripped for use as a topsoil in the rehabilitation of the waste dump.
- Topsoils (0 – 20 cm) should be stripped from all areas within the Project Area, where possible.
- Topsoil materials are structurally sensitive and will rapidly turn to dust during excavation and handling. Water (particularly saline water) should not be used for dust suppression as these soils will hardset if exposed to alternating wetting and drying cycles. Soil strengths of hardset topsoils will likely impede the germination and early establishment of revegetation species; and thus strategies to prevent these soils from hardsetting should be adopted.
- All topsoil stockpiles should not exceed 2 m in height to maintain the soils biological component and retention of any nutrient sources, and should not be stockpiled for longer than 12 months, where practicable.

5.2 SUBSOIL MATERIALS (BENEFICIAL MATERIALS FOR USE IN REHABILITATION)

- Subsoil materials in the Pegasus Deposit Project Area represent the growth medium, and should include all Quaternary transported sediments beneath the topsoil (20 cm depth), including the calcrete layer, and overlying the Achaean transported sediments or *in situ* saprolite.
- The Quaternary transported sediments are morphologically dissimilar to the underlying Achaean sediments or *in situ* saprolite, and subsequently they should be easily separable during excavation.

- As with the topsoil materials, subsoils are structurally sensitive and care should be taken to prevent them from hardsetting (i.e. minimise the use of water for dust suppression).
- Subsoil materials do not exhibit physical or chemical properties that will impede the root growth of established (this is clearly observed in the field with roots from the existing vegetation growing throughout this material), and subsequently its capture and use as a growth medium beneath the topsoil will facilitate the sustainable growth and establishment of the revegetation species.

5.3 OVERBURDEN/INTERBURDEN (WASTE) MATERIALS

- All materials below the Quaternary transported sediments, including the Achaean transported sediment and *in situ* saprolite, are considered waste materials.
- Waste materials are likely to exhibit chemical properties that will adversely impact on revegetation growth and establishment. It is therefore critical that these materials are not used to reconstruct the outer surface of the waste dump or be used in the root zone of the revegetation.
- If no separation of Subsoil and Waste materials is likely to occur, then only shallow-rooted revegetation species should be used to rehabilitate the waste dump; this will ensure that the roots of the revegetation will not interact with the underlying (saline) material.

5.4 RECONSTRUCTION AND DESIGN OF THE WASTE DUMP

- As discussed in Section 4.3, the surface soils within the Pegasus Deposit Project Area are structurally unstable and are highly erodible. Waste rock that is ripped through the surface soils is required to stabilise these soils, with a 50 % rock cover required. Based on the rainfall simulator results, a WRL surface with topsoil and 50 % waste rock will be stable (i.e. < 5 t/ha/yr sediment loss) for a maximum slope of 15°; higher batter angles will likely result in unacceptable erosion rates.
- Contour ripping will be required to minimise the catchment areas along the batter slopes, and a 5 - 10 m wide backward sloping berm should be constructed between lifts to prevent sediment and runoff from reaching the downslope batter sections. The top of the waste dump should be backward sloping to ensure accumulated water does not overflow onto the batter surfaces.
- A traditional linear batter and berm slope, as opposed to a concave slope, is recommended for this waste dump given the clayey texture and instability of the surface soils.
- If waste rock is unavailable to help stabilise the waste dump surface, then slopes of only 10° may be implemented as the topsoil material is extremely unstable.
- Surface flow analysis should be undertaken on all waste dump designs to ensure that surface water is appropriately managed. Accumulation of surface water should be discouraged as the surface soils will likely tunnel if surface ponding occurs.

6 REFERENCES

BOM (2012): *Rainfall IFD Data System*, http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml, Bureau of Meteorology website, last accessed 12 May 2012.

Elliott, W J; Liebenow, A M; Laflen, J M; Kohl, K D (1989): *A compendium of soil erodibility data from WEPP cropland soil field erodibility experiments 1987-88*. NSERL Report 3. The Ohio State University/USDA-Agriculture Research Service, West Lafeyette, Indiana, USA.

Flanagan, D C; Livingston, S J (1995): Water Erosion Prediction Project (WEPP), Version 95.7. User Summary.

Foster, G R (1982): *Modeling the erosion process*. In: Hahn, C.T. (Ed.), Hydrologic Modeling of Small Watersheds, pp. 295–380.

Green, W H; Ampt, G A (1911): *Studies on soil physics, Part I. – The flow of air and water through soil*. Journal of Agricultural Soil Science, 4(1): 1-24.

Isbell, R.F. (1996). *The Australian Soil Classification*. Australian Soil and Land Survey Handbook, Volume 4. CSIRO Publishing, Collingwood, Victoria, Australia.

McDonald, R.C. and Isbell, R.F. (2009). 'Soil Profile'. In: *Australian Soil and Land Survey Field Handbook* (3rd Ed.), National Committee on Soil and Terrain, CSIRO Publishing, Melbourne. pp. 147 – 204.

McDonald, R.C., Isbell, R.F and Speight, J.G. (2009) 'Land Surface'. In: *Australian Soil and Land Survey Field Handbook* (3rd Ed.), National Committee on Soil and Terrain, CSIRO Publishing, Melbourne. pp. 127 – 144.

Schoknecht, N. (2001). *Soil Groups of Western Australia: A guide to the main soils of Western Australia* (Ed. 2). Resource Management Technical Report 193, Department of Agriculture.

Sheridan, G J; So, H B; Loch, R J; Pocknee, C; Walker, C M (2000): *Use of laboratory-scale rill and interill erodibility measurements for the prediction of hillslope-scale erosion on rehabilitated coal mine soils and overburdens*. Australian Journal of Soil Resources, 38:285-297.

Yu, B (2003). *An assessment of uncalibrated CLIGEN in Australia*, Agriculatural and Forest Meterology, 119: 131–148.

Appendix D:

Groundwater Assessment

(Aquaterra 2003)

aquaterra

Suite 4, 125 Melville Parade, Como
Western Australia, 6152
Tel: (08) 9368 4044
Fax: (08) 9368 4055

25 July 2003

Gordon Sweby
Placer Dome Asia Pacific
PO Box 622
KALGOORLIE WA 6433

Attention: Gordon Sweby

Dear Gordon,

Re: <u>Assessment of Groundwater Inflows – Hornet Pit</u>

We have just completed the modelling of Hornet pit inflows, and are pleased to present the following report.

1. INTRODUCTION

Aquaterra have been engaged by Placer to conduct a preliminary assessment of inflows to the open pit workings during the Stage 1 and 2 developments of the Hornet deposit. This study follows on from the preliminary water risk assessment and scoping study for Hornet pit (December 2002) and the recent completion of hydrogeological testing during the geotechnical drilling programme.

2. HYDROGEOLOGY

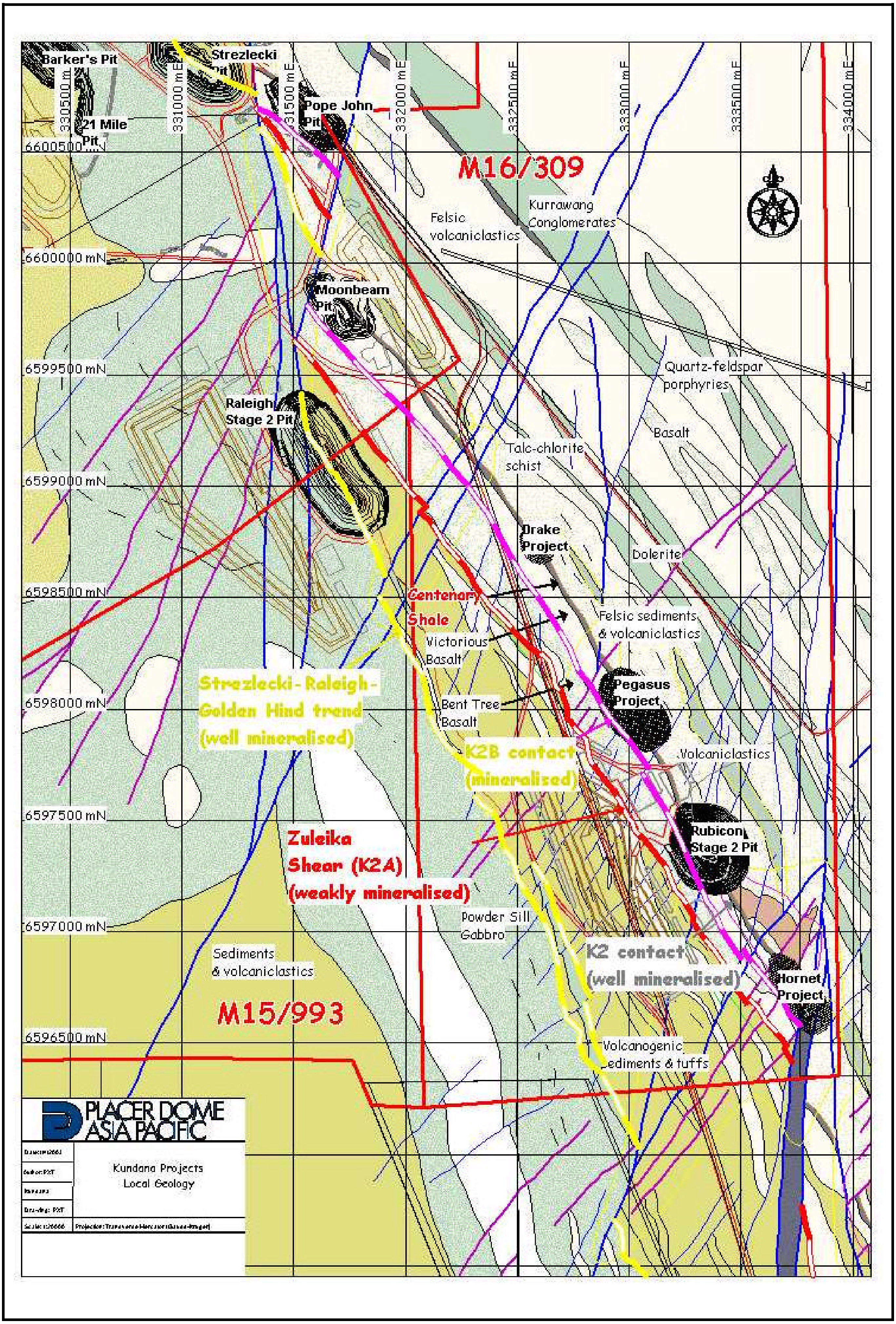
2.1 Background

The Hornet orebody is largely hosted within cherty and carbonaceous shale units at the contact zone between the Victorious Basalt and the Black Flag Beds along the Centenary Structure, a roughly NNW trending structure that hosts numerous orebodies in the region. There is also ore within the Victorious Basalt associated with some cross cutting fault structures. One such feature at Hornet, the Mary Fault, which offsets the Centenary Structure by some 400m, is reported to be a 20m wide shear zone.

The basement rocks and orebody are variably weathered to produce a saprolite (highly weathered to decomposed basement) zone extending to around 40 to 50m below ground surface with a transition zone (to fresh rock) beneath this of generally around 10 to 20m thickness. The south-southeastern end of the proposed pit area extends beneath part of the Kopai Lake system and the weathered basement profile is overlain by several metres of lake sediments (mostly alluvial clays and silts).

Geologically and structurally, the Hornet Pit is similar to other mined pits located on the Centenary Structure, including Moonbeam Pit and Rubicon Pit, but with the added complexity of the Mary Fault.

The basement rock and saprolite/transition zones host a number of aquifers. The shallow saprolites (and overlying alluvium) form unconfined aquifers, while the deeper weathered and fresh rock form semi-unconfined to semi-confined aquifers. The aquifers are generally of low overall permeability, although significant local permeability can be present associated with fractured and or mineralised zones, such as the Mary Fault. Figure 2.1 presents a geological map (subcrop geology) of the Hornet area.



Geological Map
Figure 2.1

The regional water table is generally around 5 to 20m below surface in the Kundana area. The results of recent drilling indicates that the depth to water in the vicinity of Hornet is at the deeper end of this range (ie 10 to 20m). The lake sediments become partially saturated during flood events but do not constitute a significant aquifer. There is little to no recharge of the water table by infiltration of floodwaters through the Lake sediments.

2.2 Conceptual Hydrogeological Model

Based on the above, recent experience at Frogs Leg pit (located south of Lake Kopai) and our general hydrogeological experience in the region, the conceptual hydrogeological model of the Hornet pit area comprises the following key elements (in depth descending order).

- Shallow aquitard - comprising the clays of the saprolite horizon and including overlying recent cover material.
- Shallow aquifer - comprising the transition zone, and confined by the saprolite.
- Deep aquifer - mixed aquifer comprising basement rocks (with slightly enhanced permeability as a result of general fracturing and shearing) and a higher permeability linear aquifer zone associated with the Mary Fault and the main cross-cutting faults. Based on available water quality data, recharge processes are very slow and the principal forms of recharge to the above aquifers will be by throughflow from up gradient areas. Direct rainfall recharge in the Hornet area is minimal.

3. AIRLIFT TEST RESULTS

A hydrogeological testing program was initiated during the geotechnical drilling program to obtain a better understanding of the main aquifers and the Mary Fault. A summary of the airlift tests completed during this program is shown in Table 3.1. Figure 3.1 shows the location of the airlift tests. Bores HGT001 to 006 were angled at 80°, and bores HOPD105 and 112 at 60°.

Table 3.1
Summary of Airlift Test Results

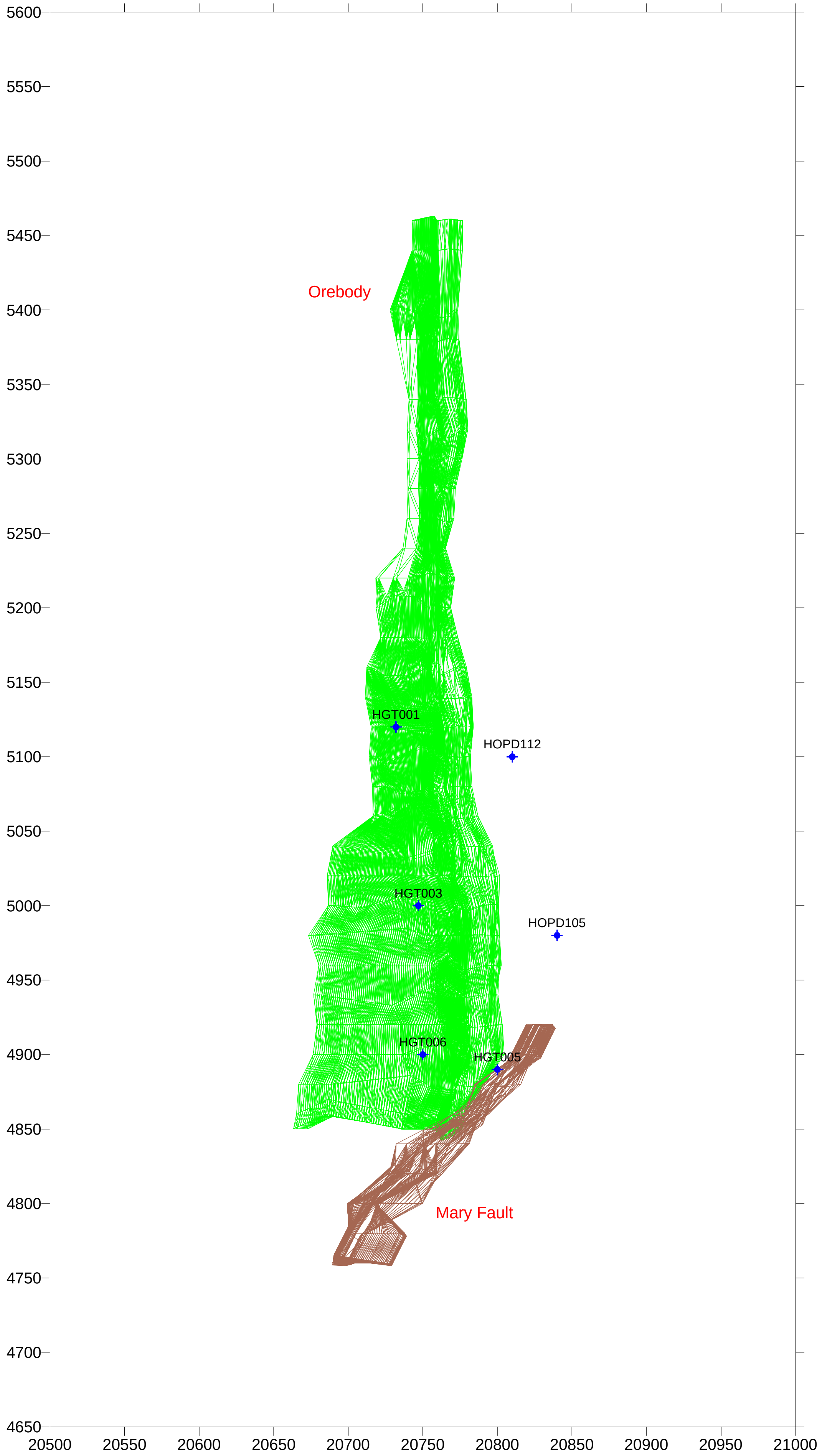
Bore ID	Easting	Northing	Test Section (m)	Water Level (mbtoc)	Yield (L/s)	Derived Transmissivity (m^2/d)
HGT001	20732	5120	TD (35 - 100)	18.6	1.2	0.5 – 3
HGT003	20747	5000	TZ (29.7 - 36.3)	14.1	0.5	0.6
			TD (29.7 - 100)	15.2	0.6	0.1 - 0.6
HGT005	20800	4890	TZ (48 - 75.3)	7.4	2.5	1.5 - 3.5
			TD (48 - 100)	7.8	2.5	1 – 4
HGT006	20750	4900	TZ (25 - 39.5)	12.8	1.5	1.3 - 9.5
			TD (25 - 99.3)	12.2	6	7 – 11
HOPD105	20840	4980	TZ (53 - 87)	7.5	0.5	-
			TD (79.5 - 120)	11.0	0.3	0.1
HOPD112	20810	5100	TZ (41.7 - 57)	10.7	-	-
			TD (41.7 - 120)	15.2	2	1 – 5

Notes:
1. TZ – test carried out over transition zone section; TD – test carried out at total depth of hole.
2. Estimate of permeability has been made for the transition zone only.

The airlift tests data were analysed using standard graphical techniques (Theis Recovery Method and Rising Head Test Method), where the data showed consistent recovery trends. Note that some data could not be analysed. The results of these analyses are also listed in Table 3.1.

The results of the airlift recovery tests indicate a transition zone permeability of up to 0.6 m/d. The majority of inflows while drilling was encountered across the transition zone, with the exception of HGT006 where the main inflow zone was over 80 to 90m across fissures in the basement rock.

Bore HGT005 targeted the Mary Fault to assess the magnitude of flows that could be expected when this structure is intersected during mining. The drill cores inspected by Placer geologists indicated



aquaterra

F:\jobs\415\B2 - Inflows\Report\Figures\Fig 3.1 - Airlift Tests.doc

Location of Airlift Tests

Figure 3.1

that the Mary Fault was intersected across the saprolite zone. The airlift yield during drilling was about 2.5 L/s, with most of the inflow across the transition zone. Greater yields would be expected if the Mary Fault was intersected across the transition zone or the upper basement.

Water quality was fairly consistent in all the bores ranging between 150 and 215 mS/cm (about 100,000 to 140,000 mg/L TDS).

Geological logs for the holes and plots of airlift test data are presented in Appendices A and B.

4. GROUNDWATER MODELLING

4.1 Model Objective and Selection

The objective of the groundwater modelling was to predict inflows to the open pit workings for the proposed Hornet pit (Stage 1 and 2), and assess the potential impact of ex-pit dewatering bores to reduce these inflows.

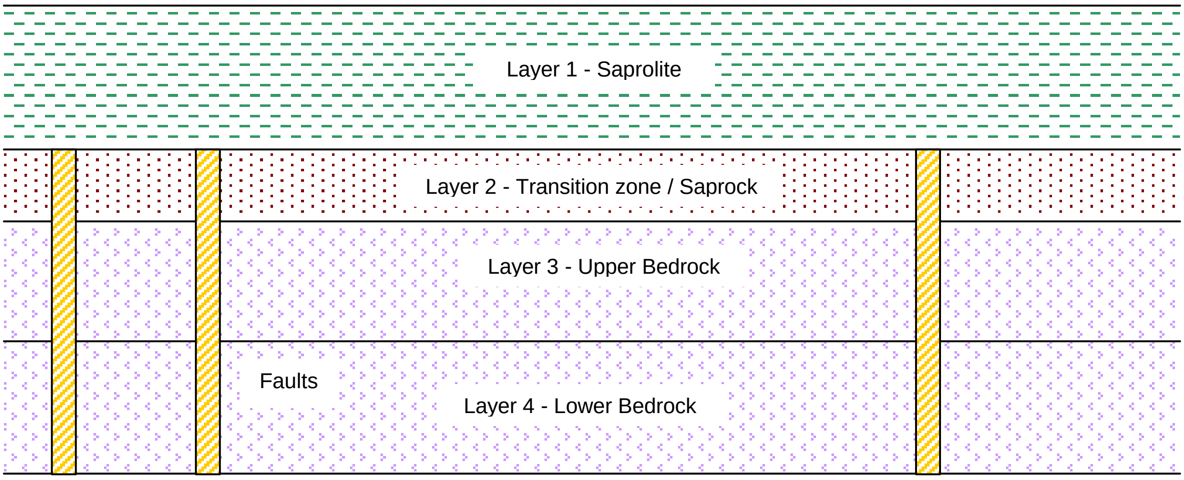
The groundwater flow modelling was undertaken using the numerical finite difference groundwater flow modelling package MODFLOW, operating under the PMWin graphical user interface (Version 7.0.10; Chiang and Kinzelbach, 2002-2003). Modflow is the industry-leading 3D groundwater flow package, developed by the US Geological Survey (McDonald & Harbaugh, 1988).

4.2 Conceptual Numerical Model

The conceptual model was based on that outlined in Section 2. This conceptual model (Figure 4.1) forms the basis of the numerical modelling, and includes the following key units.

- Layer 1: Saprolite.
- Layer 2: Transition zone / Saprock.
- Layer 3: Upper basement rock.
- Layer 4: Lower basement rock.

Figure 4.1
Conceptual Groundwater Model



The thickness of the saprolite and transition zone units was based on geological data supplied by Placer. The thickness of the transition zone is up to 50m around the Mary Fault and the main contact zone. The base of Layer 3 was set at a constant elevation of 230 mAHD (about 110m below ground surface). Contour plans showing the elevation of theses units are presented in Appendix C.

The bedrock has been split into two layers to allow for the impact on dewatering of possible changes in aquifer properties with depth to be assessed. Our experience at Frogs Leg suggested that the majority of inflows to drill holes were over the upper 100m, which is represented by Layers 2 and 3 in the groundwater model. Results from the geotechnical drilling programme at Hornet indicated that the majority of the yield was from the transition zone, with the exception of hole HGT006 where there were significant inflows from fissures between about 80 – 90m below ground.

The main shear zones through the pit area were represented as high permeability features. These zones include the Mary Fault, a series of cross cutting faults and the main Kopai Shear in the Frogs Leg area. The Mary Fault and the main contact zone were specified over the whole length of the model (approximately N-S orientation). All other contact and shear zones were extended a few hundred metres away from the pit. These features were represented as vertical features and are specified in Layers 2, 3 and 4.

4.3 Model Grid and Boundaries

The finite difference grid (Figure 4.1) consists of 217 columns x 295 rows, covering an area of approximately 145 km^2. The cell size has been refined to 10m in the vicinity of the pit, and increases to 100m at the model boundaries. A constant head boundary was assigned to all four boundaries in each layer.

4.4 Pit Design and Schedule

Details of the pit design and schedule for Stage 1 and Stage 2 were provided by Placer. The Stage 1 pit extends to a depth of about 40m below surface, and will be mined over 5 months. The Stage 2 pit design extends to a depth of about 100m below ground at its deepest point, and will be mined over a further 9 months. Figures showing the pit design and schedule are given in Appendix D.

4.5 Aquifer Parameters

The aquifer parameters adopted in the model have been based on the results of airlift tests in the Hornet area our experience at the nearby Frogs Leg area, where extended pumping tests have been completed. There are no calibration data available for Hornet, although a number of sensitivity simulations have been completed to address the uncertainty in key aquifer parameters.

The aquifer parameters adopted for the model are summarised in Table 4.1. The main contact zones, cross cutting faults and the Mary fault were assigned higher aquifer parameters. Figure 4.2 shows the main faults and contacts in the Hornet and Frogs Leg area, as represented in the groundwater model.

Table 4.1
Aquifer Parameters for Hornet Groundwater Model

Layer	Horizontal Conductivity (Kh)	Vertical Conductivity (Kv)	Confined Storage (S)	Specific Yield (Sy)
L1 - Saprolite	0.05	0.005	1 x 10^{-4}	0.01
L2 - Transition zone	0.5 (5)	0.05 (0.5)	1 x 10^{-4} (1 x 10^{-3})	0.01 (0.05)
L3 - Upper basement	0.1 (1)	0.01 (0.1)	1 x 10^{-4} (1 x 10^{-3})	0.01 (0.05)
L4 - Lower basement	0.01 (0.1)	0.001 (0.01)	5 x 10^{-5} (1 x 10^{-4})	0.01 (0.05)

Notes:

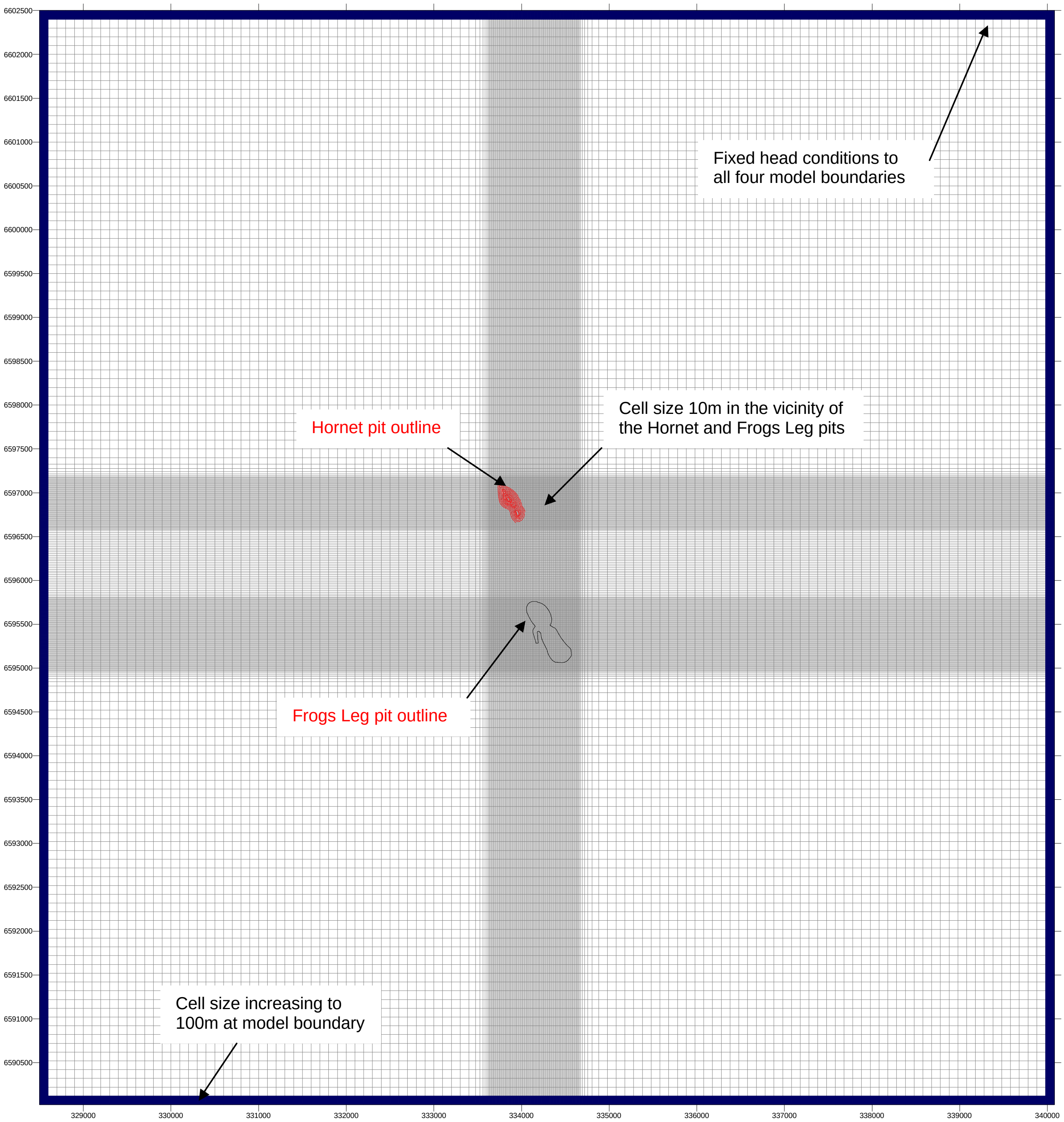
1. Values in brackets represent aquifer parameters adopted for the more permeable fault and contact zones.

5. INFLOW PREDICTION

5.1 Predicted Inflow Rates - Base Case Parameters

The prediction of inflows to the open pit workings for the Stage 1 and Stage 2 developments were made using the pit design and schedule provided by Placer. Figure 5.1 shows the predicted monthly inflow rate and cumulative volume.

Inflows to the open pit workings during Stage 1 are expected to peak at around 4,000 kL/d as mining continues into the transition zone and then declines to around 3,500 kL/d. At the commencement of the Stage 2 pit, mining is mostly “cut back” to the new pit perimeter and predicted inflows continue to decline to less than 3,000 kL/d. Once the pit deepens, predicted inflows increase again to around 4,000 kL/d and remain at, or just below this until the end of mining. The total volume of dewatering discharge is predicted to be about 2.1 GL by the end of mining.



Fixed head conditions to all four model boundaries

Hornet pit outline

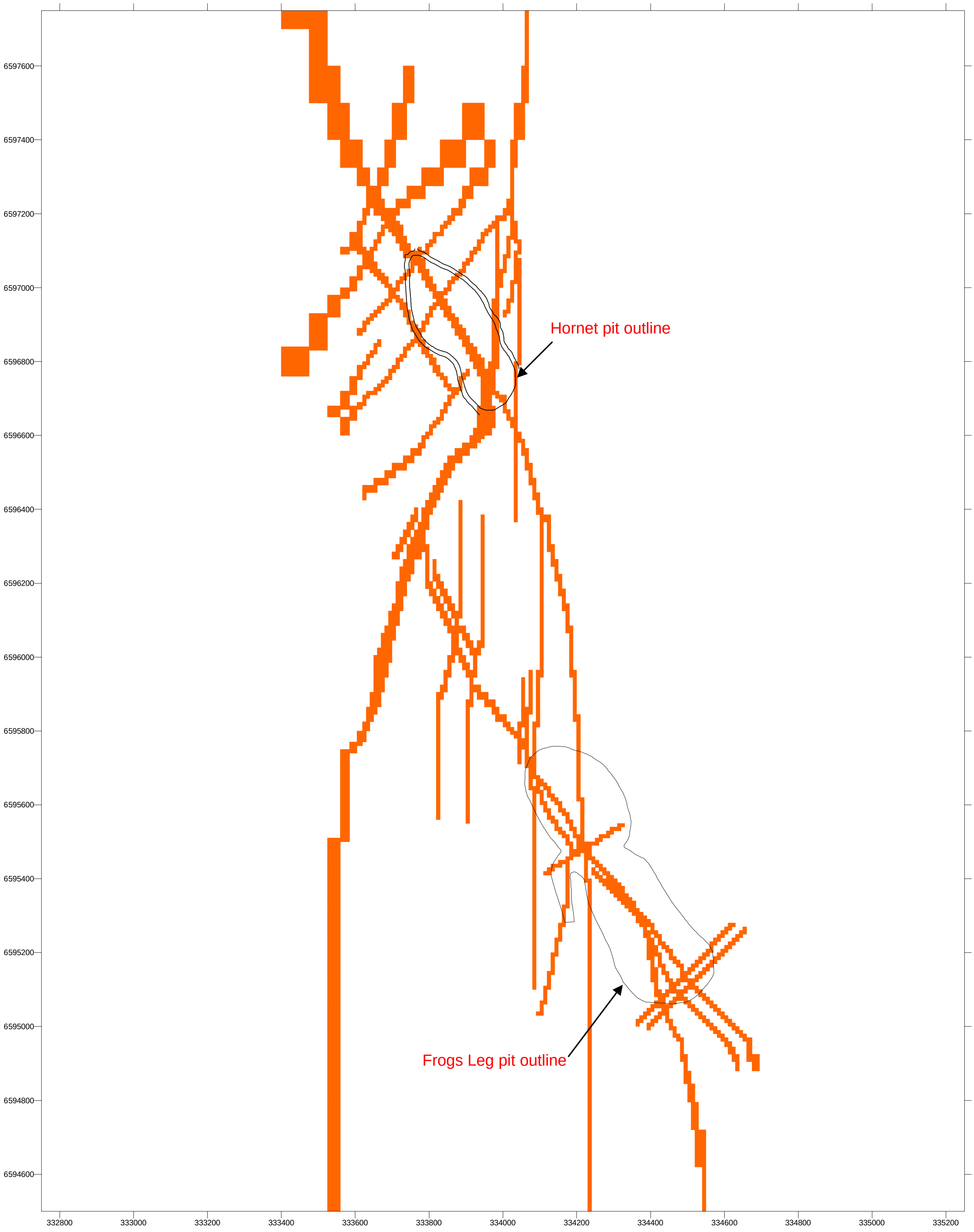
Cell size 10m in the vicinity of the Hornet and Frogs Leg pits

Frogs Leg pit outline

Cell size increasing to 100m at model boundary

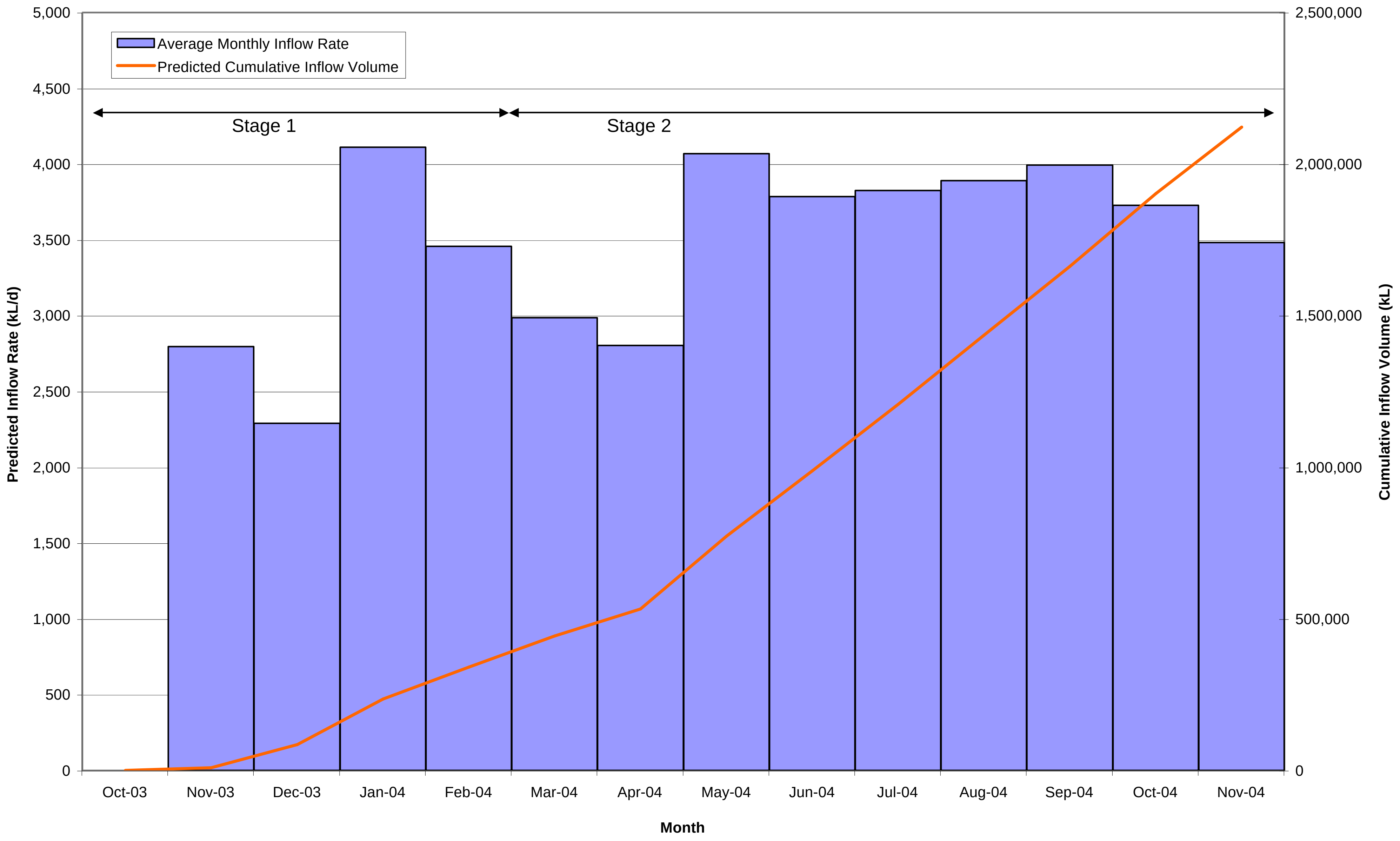
Finite Difference Grid – Hornet Groundwater Model

Figure 4.1



aquaterra
F:\jobs\415\B2 - Inflows\Report\Figures\Fig 4.2 - Faults.doc

Faults and Contact Zones Represented in Model
Figure 4.2



aquaterra

Predicted Inflow Rate and Volume to Open Pit Workings

F:\jobs\415\B2 - Inflows\Data Processing\[Prediction Summary.xls]Pred1 Chart

Figure 5.1

Predicted water level drawdown contours around the base of the open pit workings are shown in Figures 5.2 and 5.3. The impact of in-pit dewatering at Hornet is predicted to extend across to the proposed Frogs Leg pit.

However, it must be remembered that, apart from some site specific data for the transition zone, the aquifer parameters have been adopted based on recent experience at Frogs Leg. As such, there is a degree of uncertainty in predicted inflows for the deeper horizons (ie basement rocks) and in particular for the Mary Fault zone. This uncertainty is addressed in the following section.

5.2 Sensitivity Simulations

A number of sensitivity simulations were carried out to assess the impact of varying key aquifer parameters on the predicted inflow to the open pit workings. A summary of these simulations is presented below:

- Sens1 – two fold increase in the horizontal permeability and specific yield of the Mary Fault.
- Sens2 – increase in the horizontal permeability of the transition zone to 0.75 m/d.
- Sens3 – increase in the horizontal permeability of the upper basement zone to 0.25 m/d.
- Sens4 – decrease in the horizontal permeability of the transition zone to 0.1 m/d.
- Sens3 – decrease in the horizontal permeability of the upper basement zone to 0.01 m/d.

Sensitivity runs 1 to 3 cover similar sensitivities that were applied to recent work at Frogs Leg, where higher permeabilities and storativities appear to be a possibility. Sensitivity runs 4 and 5 cover the potential for the hydrogeology at Hornet to be more similar to that at other Placer pits to the north along the Centenary Structure.

The impact of the above simulations on inflows to the workings is shown in Figure 5.4. The impact of higher aquifer parameters for the Mary Fault does not significantly influence the predicted inflow rates. There is a predicted increase of up to 400 kL/d in the peak inflow rate.

The model is most sensitive to an increase in the hydraulic conductivity of the transition zone and upper basement layers (Sens2 to 5). These simulations show that the peak flow rate can range between 3,200 and 5,200 kL/d. The total volume of predicted inflow to the workings is predicted to be up to ± 30% from the base case volume of 2.1 GL (ie between 1.6 and 2.8 GL).

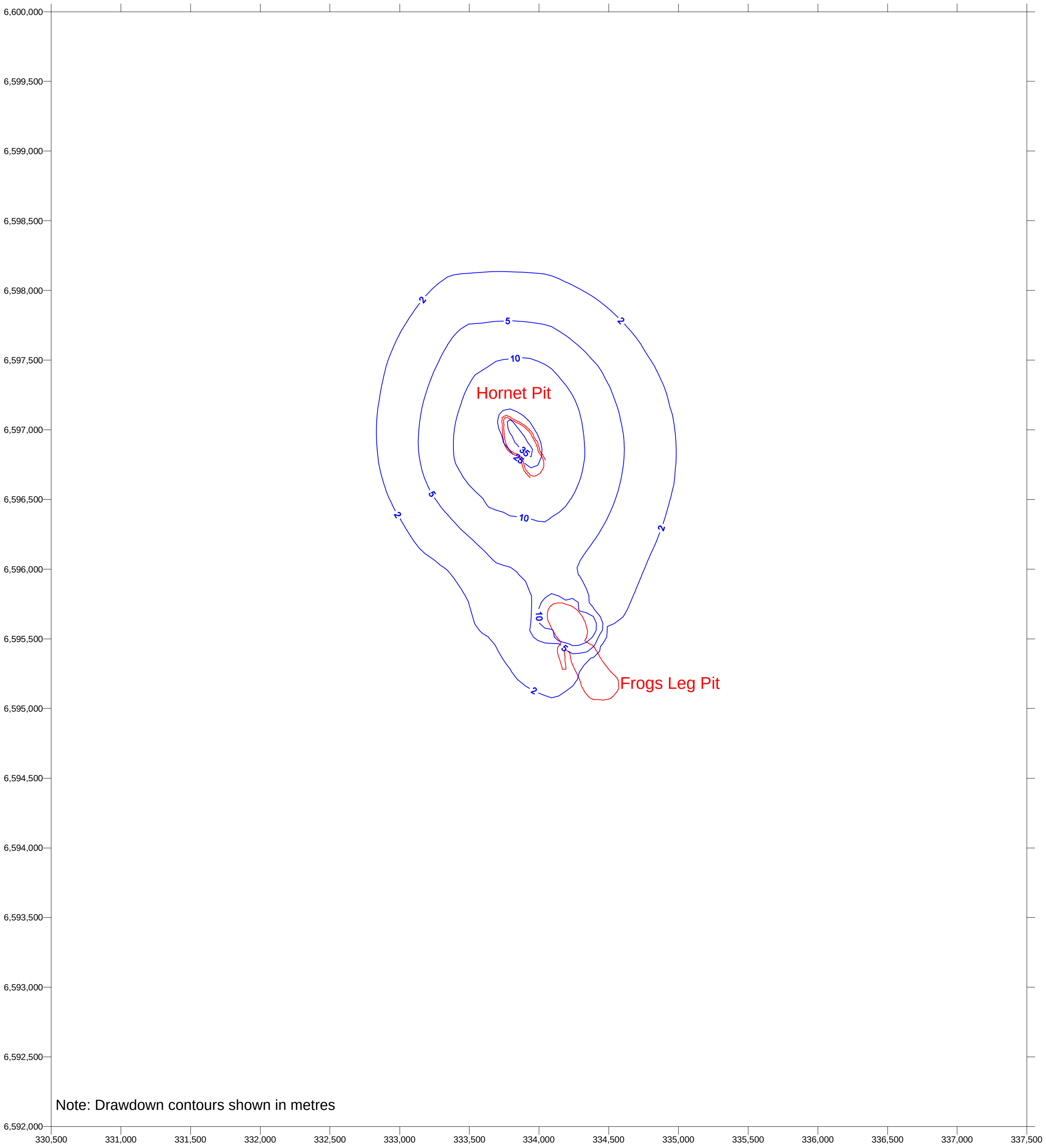
5.3 Impact of Advanced Ex-Pit Dewatering

Advanced dewatering using ex-pit production bores has the potential to significantly reduce inflows to the open pit workings, particularly if a high yielding target in the Mary Fault could be found. The impact of ex-pit dewatering bores on inflows to the open pit workings was assessed for the following two scenarios (using the base case parameters listed in Table 4.1):

- Pred2 - One production bore pumping at 2,000 kL/d located south of the Stage 2 pit crest, intersecting the Mary Fault.
- Pred3 – Pred2 plus another production bore north-west of the Stage 2 pit crest targeting the main contact zone, pumping at 1,000 kL/d.

In both cases, it was assumed that advanced dewatering would commence at the start of Stage 1 pit development. The impact of the above advanced dewatering scenarios on inflows to the open pit workings is shown in Figure 5.5.

There is a significant reduction in inflows due to advanced dewatering of the aquifer by the ex-pit dewatering bores during the Stage 1 pit and early parts of the Stage 2 pit. However, due to the rapid rate of advancement of the pit base towards the end of mining, the reduction in residual pit inflows is not so significant. For one bore operating (at 2,000 kL/d), peak Stage 1 inflows and early Stage 2 inflows are reduced by some 40 to 50%. For two bores operating, the reduction is closer to 60 to 70%. Total dewatering rates (ie bores plus in-pit sumps) are only marginally higher in the early stages of mining but rise significantly towards the end of the Stage 2 pit. The total volume of inflows to the workings can be reduced by up to 35%.

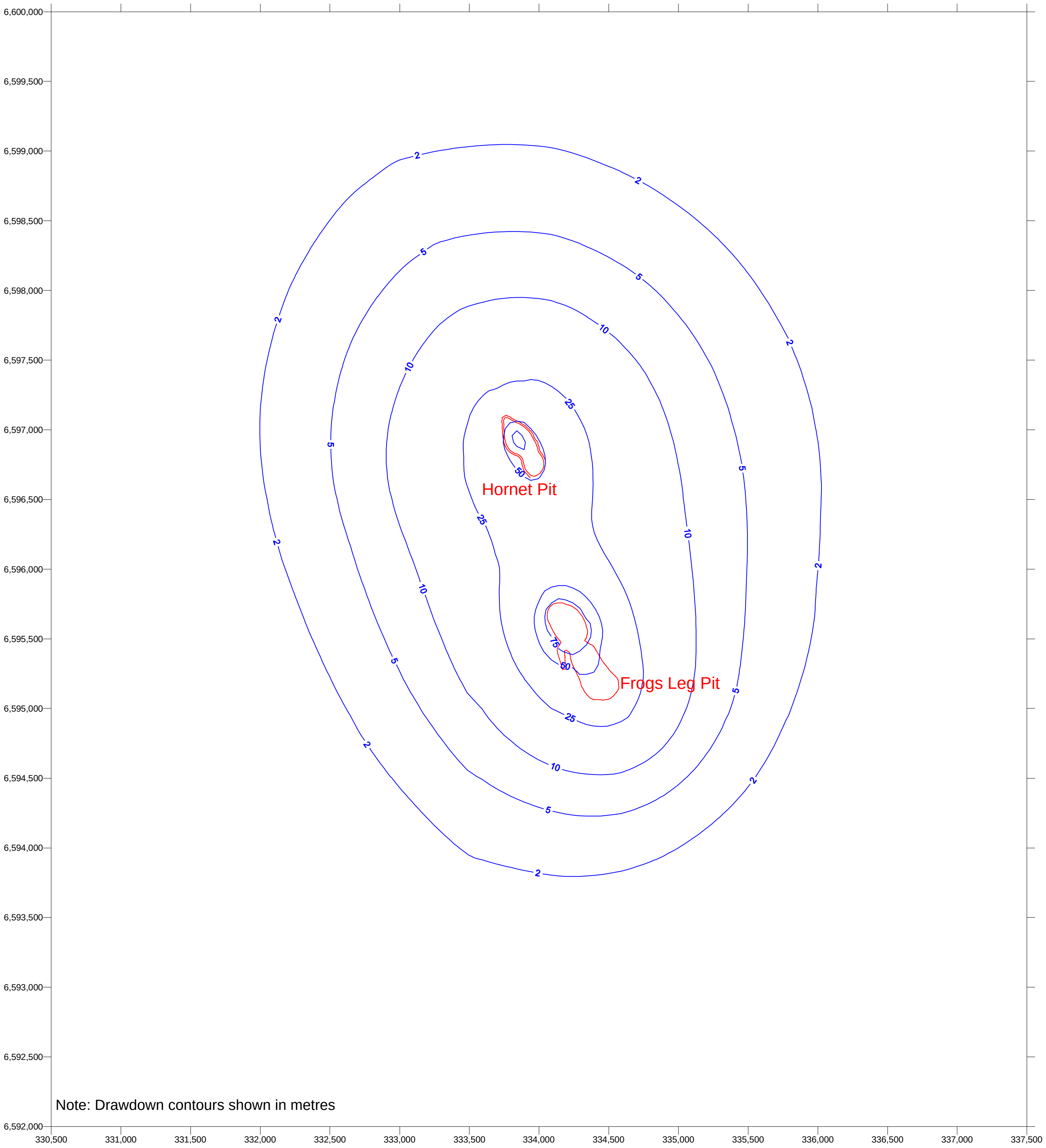


aquaterra

F:\jobs\415\B2 - Inflows\Report\Figures\Fig 5.2 - S1 ddown.doc

Drawdown Contours – February 2004 (End of Stage 1)

Figure 5.2

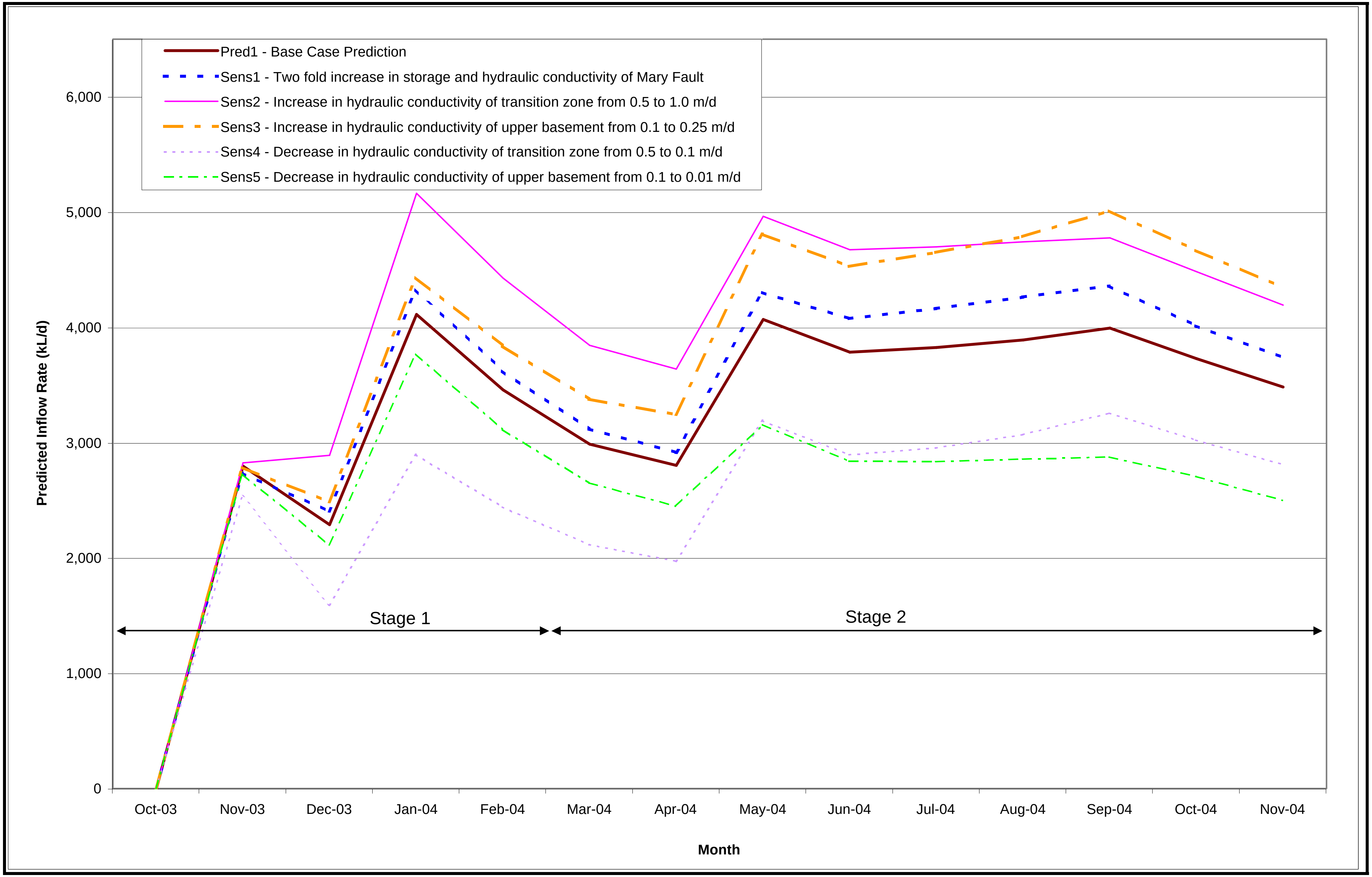


aquaterra

F:\jobs\415\B2 - Inflows\Report\Figures\Fig 5.3 - S2 ddown.doc

Drawdown Contours-November 2004 (End of Stage 2)

Figure 5.3

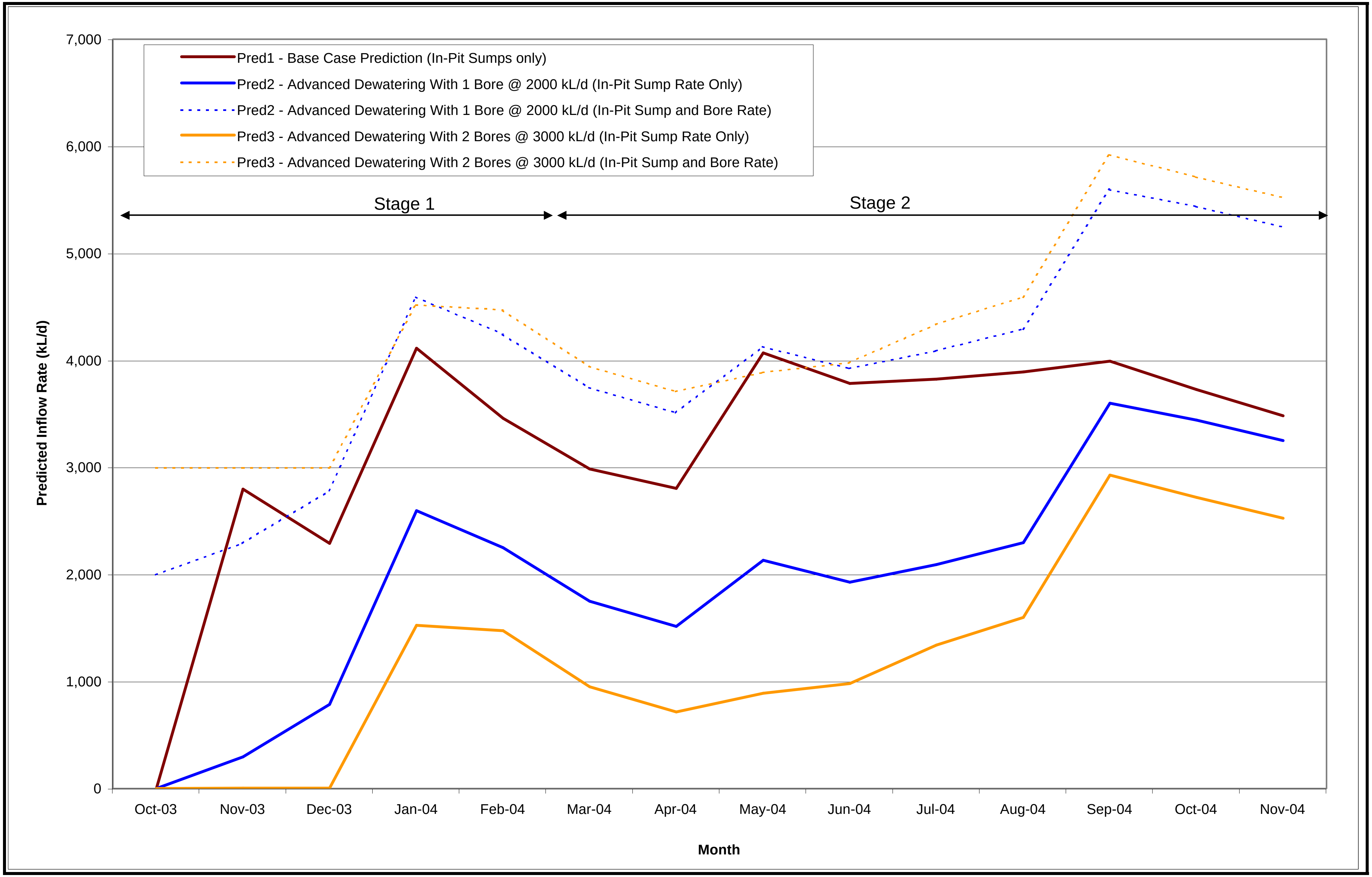


aquaterra

Sensitivity Simulations - Inflow to Open Pit Workings

F:\jobs\415\B2 - Inflows\Data Processing\[Prediction Summary.xls]Sensitivity

Figure 5.4



aquaterra

Impact of Advanced Dewatering on Inflow Rate

F:\jobs\415\B2 - Inflows\Data Processing\[Prediction Summary.xls]Dewater Chart

Figure 5.5

6. SUMMARY AND RECOMMENDATIONS

A simple numerical groundwater model has been used to predict inflows to the open pit workings during Stage 1 and 2 developments of the Hornet deposit. Inflows to the workings is predicted to peak at around 4,000 kL/d during Stage 1 development as mining continues through the transition zone, and at a similar rate during Stage 2 development, as mining continues through the upper basement and intersects the Mary Fault. However, there are no available model calibration data for Hornet and there remains some uncertainty regarding aquifer parameters and the impact of the Mary Fault. The predictions for the Stage 2 development should therefore be considered indicative only.

Sensitivity analysis suggests that inflows could range between ± 35% of the base case prediction (ie peak flows could range between 3,200 and 5,200 kL/d). The results also indicate that inflows are most sensitive to the permeability of the transition zone and upper basement.

The impact of advanced dewatering on inflows to the workings was also assessed. The predictions showed that advanced dewatering using one or two strategically placed bores could reduce pit inflows by as much as 70% (two bore option) during the Stage 1 pit and over most of the Stage 2 pit. Total dewatering over this period is predicted to be marginally higher than if no advanced dewatering was implemented. However, towards the end of the Stage 2 pit, residual pit inflows increase sharply despite bore pumping, and total dewatering also increases up to around 6,000 kL/d. This suggests that advanced dewatering could provide an effective means of controlling inflows during Stage 1 and most of Stage 2, and the bores could be decommissioned towards the end of mining and inflows controlled by in-pit sump pumping alone. However, effective advanced dewatering depends on being able to site/complete production bores with the capacity to sustain the assumed yields.

Please note that the predicted dewatering requirements (up to 2 GL over 12 months) exceeds the current licensed pumping under GWL 109476 (which covers pumping on M16/309 and specifically Rubicon pit, and expires on 31st October 2003). As such and application to extend the licence and to increase the allocation to cover the Hornet pit will need to be submitted to the WRC. This may also require the submission of a formal Hydrogeological Report to support the application. We suggest that WRC is contacted to determine their precise requirements (these have been evolving over the last year and might be more stringent than that applied at Rubicon) prior to preparing the application.

As there is still a high degree of uncertainty surrounding the influence of the Mary Fault on inflows, it is recommended that additional drilling and hydrogeological testing be completed along the Mary Fault. The hydrogeological testing would be the same as that completed during the recent geotechnical drilling programme.

It is also recommended that the model is verified towards the end of Stage 1 mining. At this time, there will be longer term aquifer response data during pit development (and dewatering pumping). This will allow calibration of the model and a more reliable prediction of Stage 2 inflows.

To facilitate monitoring of the impacts of dewatering in the near pit zone (useful for model verification and possibly a requirement of an extended GWL), several of the existing geotechnical holes (drilled recently) should be completed as monitoring bores.

We trust that this report is sufficient for your current requirements. If you have any enquiries regarding this, or any other aspect of the Hornet project, please do not hesitate to call.

Yours sincerely,
Aquaterra

Joe	*Jon*
Joe Ariyaratnam	Jon Hall
Groundwater Modeller	**Principal Hydrogeologist (Director)**

cc: John Lamb

APPENDIX A

GEOLOGICAL LOGS

aquaterra

Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: HGT001

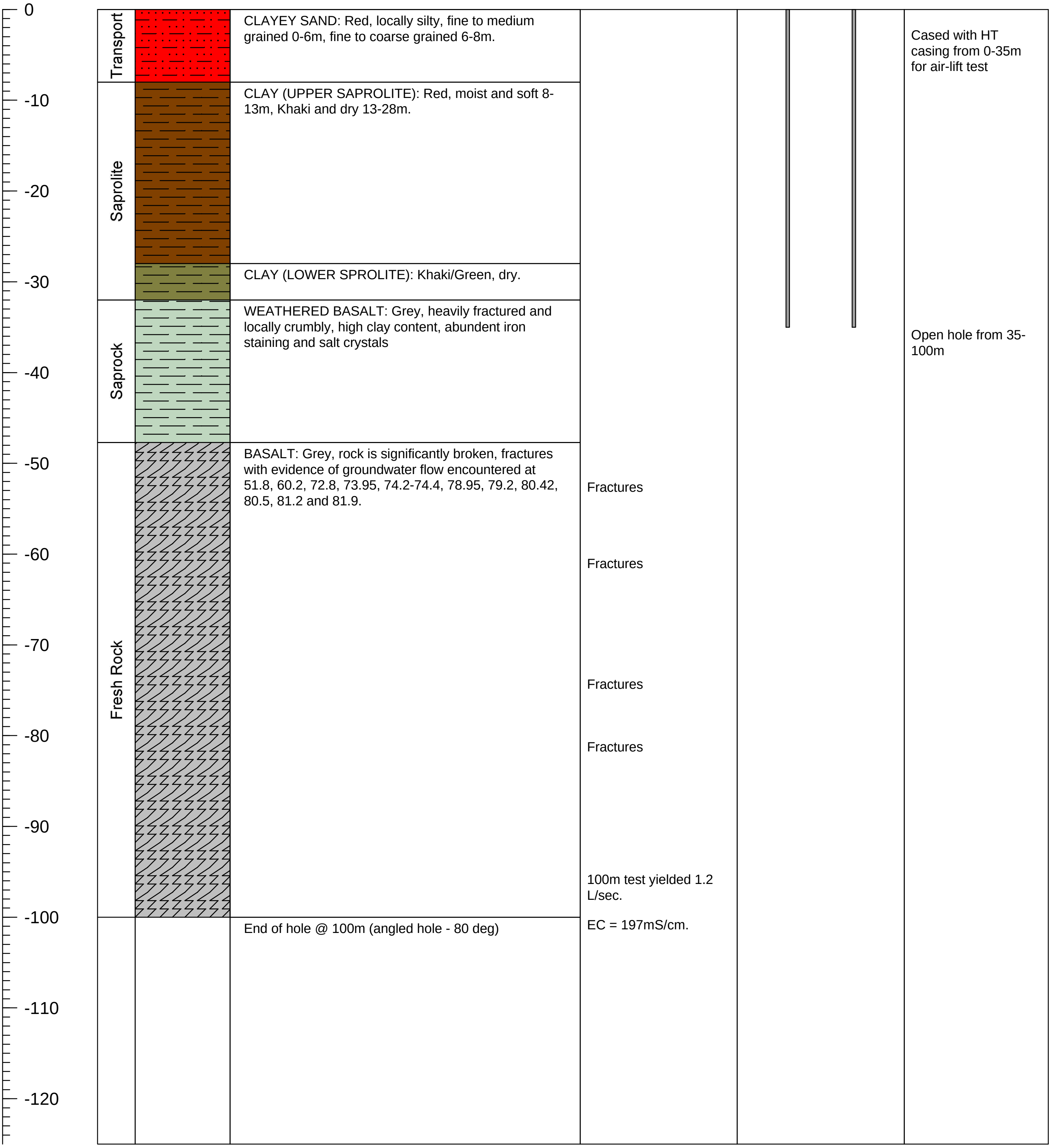
Client: Placer Dome Asia Pacific **Project:** Hornet

Commenced: 17/06/03
Completed: 22/06/03
Drilled: Layne
Logged By: Paul Heaney

Method: RC (0-35); DD (35-100)
Fluid: RC (air); DD (mud)
Bit Record: RC (4.5"); DD (~3.5")

Area: Kundana
East: 20732
North: 5120
Elevation:

Static Water Level: 19.63 mbgl **Date:** 2/07/03



Depth (mbgl)	Geology	Lithological Description	Field Notes	Well Completion Notes
0	Transport	CLAYEY SAND: Red, locally silty, fine to medium grained 0-6m, fine to coarse grained 6-8m.		Cased with HT casing from 0-35m for air-lift test
	Saprolite	CLAY (UPPER SAPROLITE): Red, moist and soft 8-13m, Khaki and dry 13-28m. CLAY (LOWER SPROLITE): Khaki/Green, dry.		
	Saprock	WEATHERED BASALT: Grey, heavily fractured and locally crumbly, high clay content, abundent iron staining and salt crystals		Open hole from 35-100m
	Fresh Rock	BASALT: Grey, rock is significantly broken, fractures with evidence of groundwater flow encountered at 51.8, 60.2, 72.8, 73.95, 74.2-74.4, 78.95, 79.2, 80.42, 80.5, 81.2 and 81.9.	Fractures Fractures Fractures Fractures 100m test yielded 1.2 L/sec. EC = 197mS/cm.	
-100		End of hole @ 100m (angled hole - 80 deg)		

aquaterra

Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: HGT003

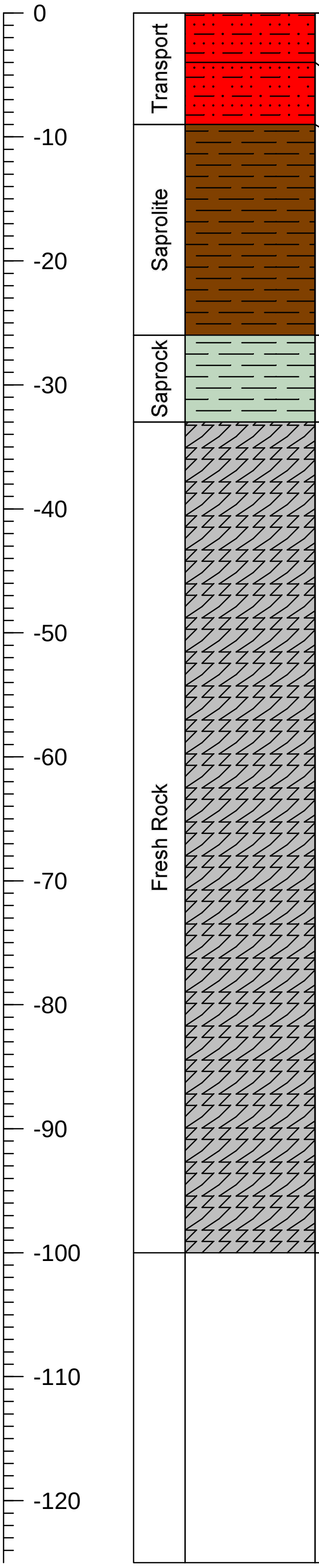
Client: Placer Dome Asia Pacific
Project: Hornet

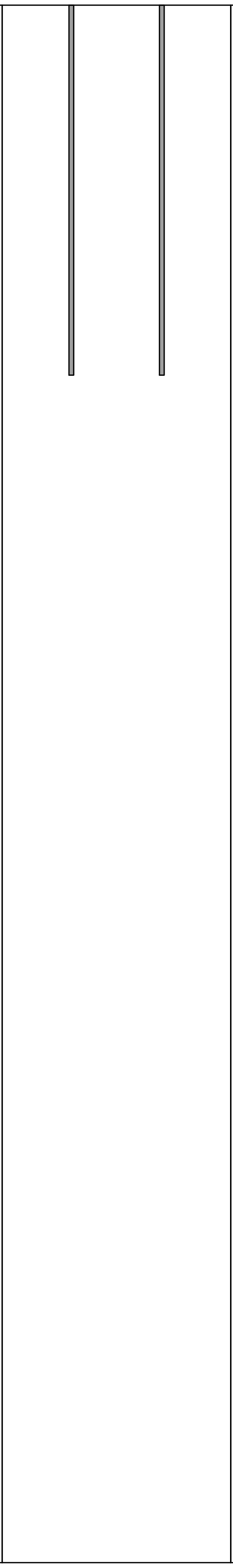
Commenced: 18/06/03
Completed: 24/06/03
Drilled: Layne
Logged By: Paul Heaney

Method: RC (0-30); DD (30-100)
Fluid: RC (air); DD (mud)
Bit Record: RC (4.5"); DD (~3.5")

Area: Kundana
East: 20747
North: 5000
Elevation:

Static Water Level: 14.64 mbgl
Date: 2/07/03





Geology	Lithological Description	Field Notes	Notes
Transport	CLAYEY SAND: Red, locally silty, loose and dry 0-2m, slightly moist 2-4m, gravelly 3-4m. SANDY CLAY: Red/brown, moist and soft, gravelly 4-5m.		Cased with HT casing from 0-29.7m for air-lift test
Saprolite	CLAY (UPPER SAPROLITE): Khaki 9-18m, khaki/green 18-20m, grey/green 20-26m. Dry 9-12m, moist 12-17m, wet from 17m.	Water in hole @ 17m	
Saprock	WEATHERED BASALT: Grey/green, heavily fractured and locally crumbly, high clay content, abundent iron staining and salt crystals		Open hole from 29.7-100m
Fresh Rock	BASALT: Grey with blue hue, distinctive white feldspar crystals (Catrock), abundent quartz and gypsum veins, rock is significantly broken, fractures with evidence of groundwater flow encountered at 33.2, 33.5, 34.8, 38.2, 40.05, 40.7, 42.5, 42.7, 45.2-45.3, 45.5, 46-46.7, 49.7-49.85, 50.3-53.3 (weathered horizon), 54.85, 59.7, 60.1-60.2, 60.35, 63.45, 67.9, 70.4-70.6, 72.8 and 74.6m.	Fractures 36.3m test yielded 0.55 L/sec. Fractures Fractures Weathered horizon 50.3-53.3 Fractures Fractures Fractures 100m test yielded 0.6 L/sec.	
	End of hole @ 100m (angled hole - 80 deg)	EC = 210mS/cm.	

aquaterra

Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: HGT005

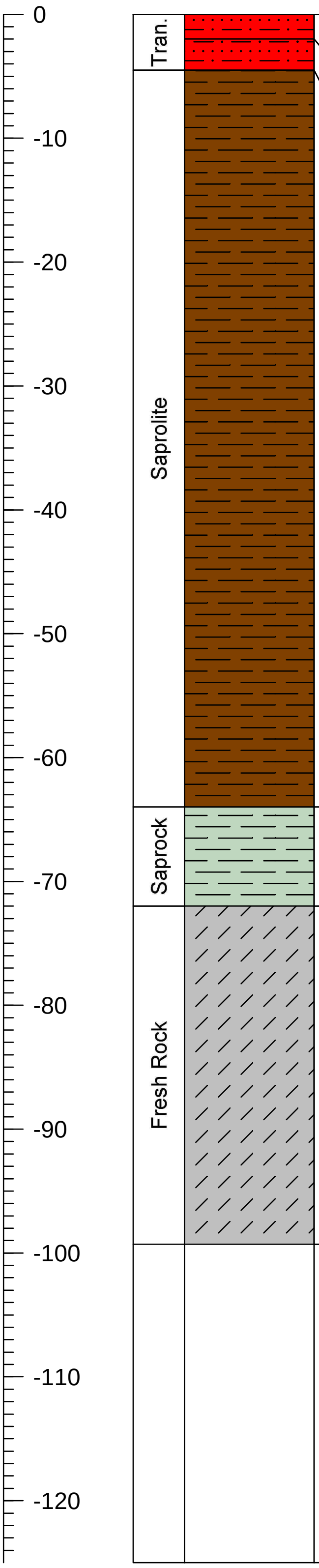
Client: Placer Dome Asia Pacific
Project: Hornet

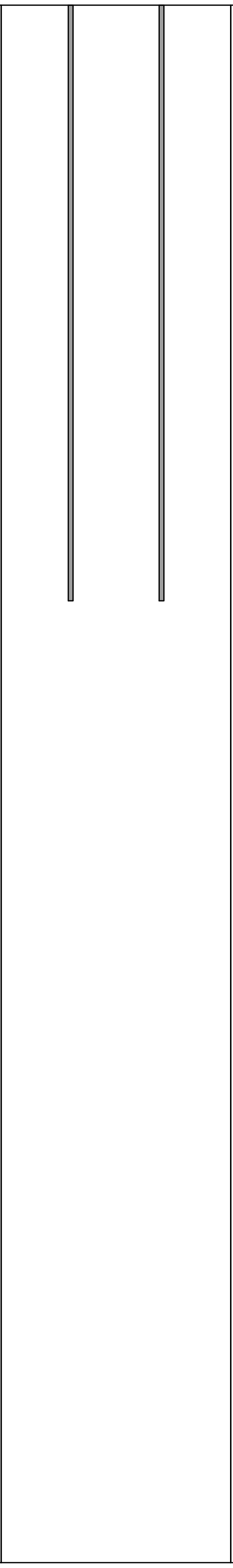
Commenced: 19/06/03
Completed: 30/06/03
Drilled: Layne
Logged By: Paul Heaney

Method: RC (0-48); DD (48-99.3)
Fluid: RC (air); DD (mud)
Bit Record: RC (4.5"); DD (~3.5")

Area: Kundana
East: 20800
North: 4890
Elevation:

Static Water Level: 10.40 mbgl
Date: 2/07/03





Lithological Description	Field Notes	Well Completion Notes
SANDY CLAY: Red/brown, moist and soft.		Cased with HT casing from 0-47.8m for air-lift test
CLAYEY SAND: Red, moist.		
CLAY (UPPER SAPROLITE): Brown 4.5-6m, red/brown 6-24m, khaki 24-30m, light brown/khaki 30-33m, red/brown 33-36m, yellow brown 36-40m, red/brown 40-51.8m, khaki/brown 51.8-59m, grey/green 59-64m. Colour change appears to reflect change in proportion of quartz, oxidised rock and feldspar fragments. Quartz crystals abundent 14-30m, some up to 30mm in length. Clay generally dry, although wet at 30m.	Water in hole @ 30m	Open hole from 47.8-99.3m
WEATHERED ANDESITIC TUFF: Grey/green, heavily fractured and locally crumbly, high clay content, abundent iron staining and salt crystals		
ANDESITIC TUFF: Grey, abundent quartz veins, rock is significantly broken, fractures with evidence of groundwater flow encountered at 81.7-83, 88.45-.55 and 93-93.1m.	75.3m test yielded 2.5 l/sec Fractures 81.7-83 (weathered horizon) Fractures Fractures 99.3m test yielded 2.5 l/sec.	
End of hole @ 99.3m (angled hole - 80 deg)	EC = 210mS/cm.	

aquaterra

Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: HGT006

Client: Placer Dome Asia Pacific
Project: Hornet

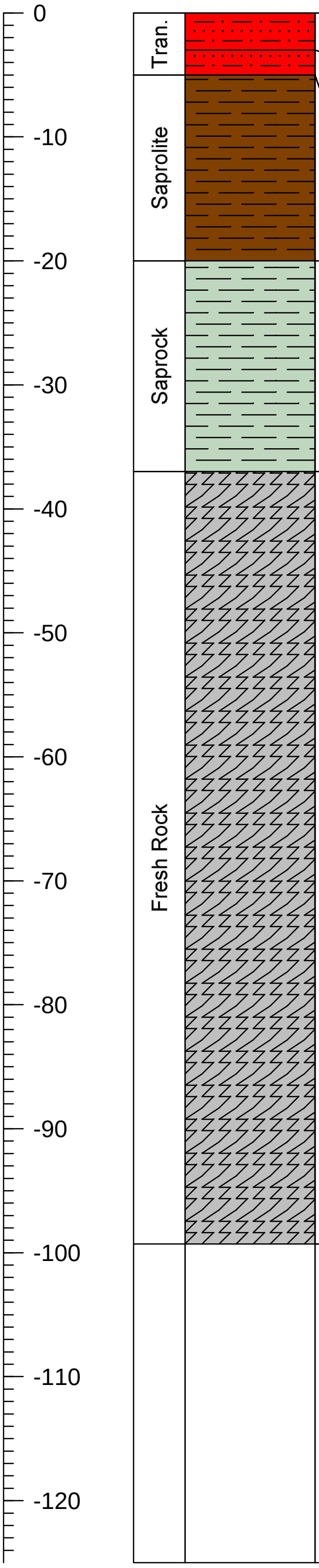
Commenced: 19/06/03
Completed: 2/07/03
Drilled: Layne
Logged By: Paul Heaney

Method: RC (0-24); DD (24-99.3)
Fluid: RC (air); DD (mud)
Bit Record: RC (4.5"); DD (~3.5")

Area: Kundana
East: 20750
North: 4900
Elevation:

Static Water Level: 12.22 mbgl
Date: 2/07/03

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes



Lithological Description

SANDY CLAY: Red/brown, moist and soft.

CLAYEY SAND: Red, moist 3-4m, gravelly and wet 4-5m.

CLAY (UPPER SAPROLITE): Red/brown 8-14m, Khaki 14-17m, Khaki/Grey 17-20m. Dry 8-10m and13-20m, moist 10-13m.

WEATHERED BASALT: Grey, abundent quartz veins, heavily fractured and locally crumbly, high clay content, abundent iron staining and salt crystals

BASALT: Grey, abundent quartz veins and mineralisation, rock is significantly broken, fractures with evidence of groundwater flow encountered at 36.6, 38.35, 57-57.5, 86.5 and 86.9m.

End of hole @ 99.3m (angled hole - 80 deg)

Field Notes

Water in hole @ 12m

Fractures

39.5m test yielded 1.5 l/sec

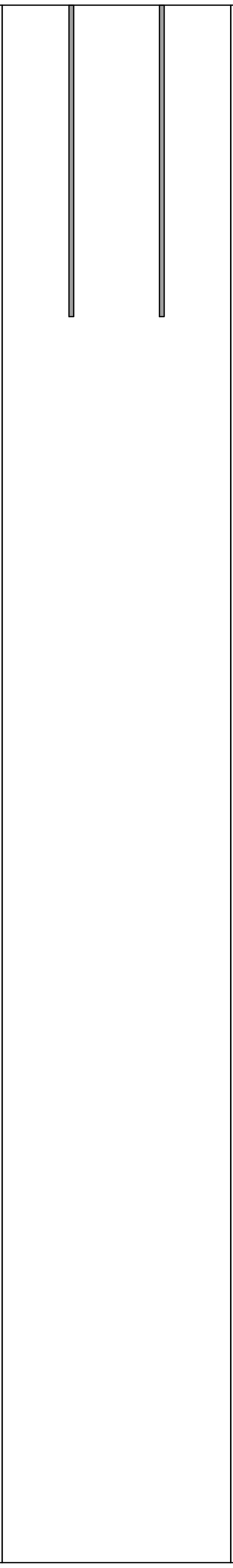
Fractures (100% drilling fluid loss)

Fractures (100% drilling fluid loss)

99.3m test yielded 6 l/sec.

EC = 210mS/cm.

Well Completion



Notes

Cased with HT casing from 0-25m for air-lift test

Open hole from 25-99.3m

aquaterra

Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: HOPD105

Client: Placer Dome Asia Pacific
Project: Hornet

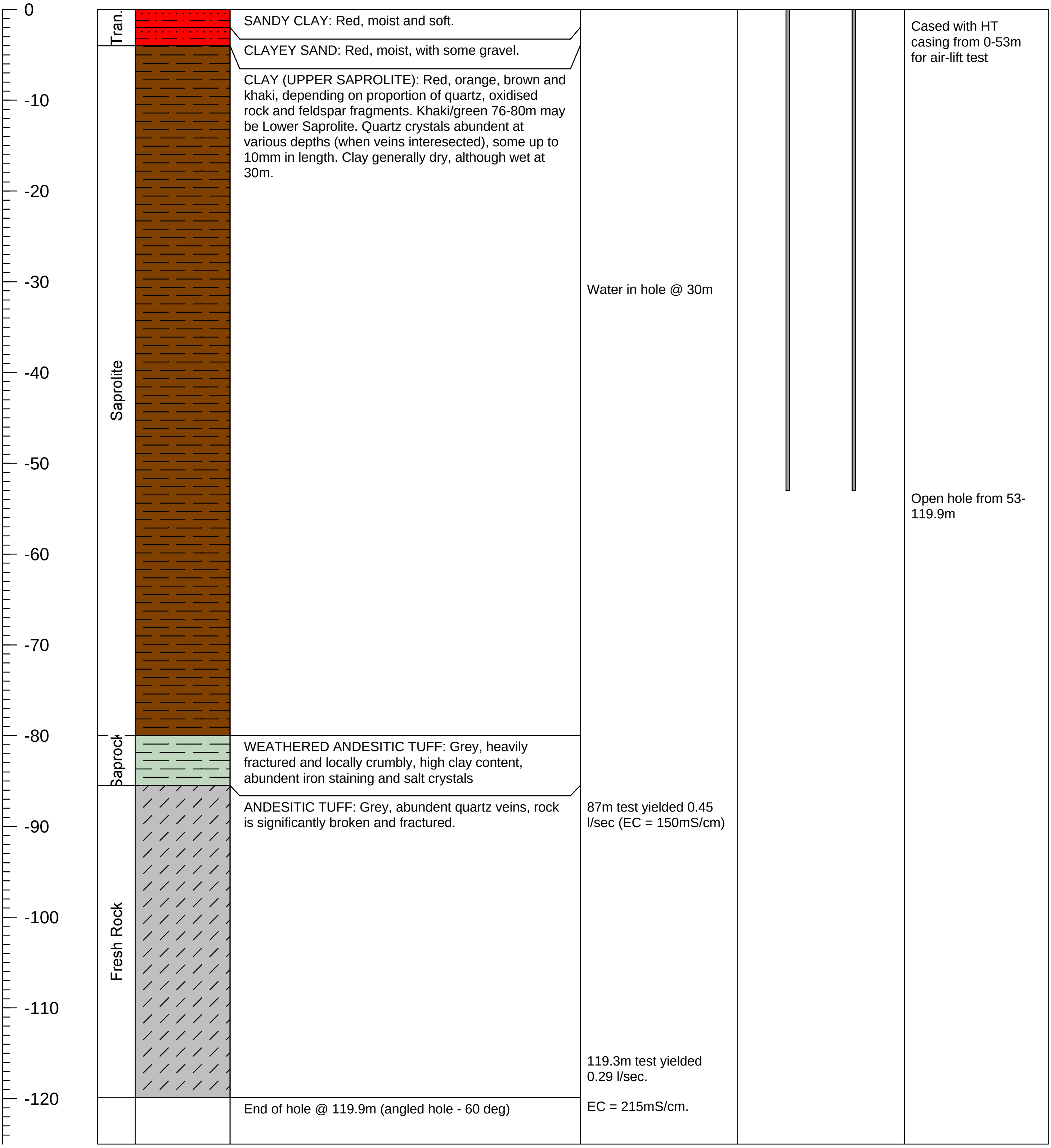
Commenced: 21/06/03
Completed: 26/06/03
Drilled: Layne
Logged By: Paul Heaney

Method: RC (0-53); DD (53-119.9)
Fluid: RC (air); DD (mud)
Bit Record: RC (4.5"); DD (~3.5")

Area: Kundana
East: 20840
North: 4980
Elevation:

Static Water Level: 14.44 mbgl
Date: 2/07/03

Depth (mbgl)	**Geology**	**Graphic Log**	**Lithological Description**	**Field Notes**	**Well Completion**	
					Diagram	**Notes**



SANDY CLAY: Red, moist and soft.

CLAYEY SAND: Red, moist, with some gravel.

CLAY (UPPER SAPROLITE): Red, orange, brown and khaki, depending on proportion of quartz, oxidised rock and feldspar fragments. Khaki/green 76-80m may be Lower Saprolite. Quartz crystals abundent at various depths (when veins interesected), some up to 10mm in length. Clay generally dry, although wet at 30m.

WEATHERED ANDESITIC TUFF: Grey, heavily fractured and locally crumbly, high clay content, abundent iron staining and salt crystals

ANDESITIC TUFF: Grey, abundent quartz veins, rock is significantly broken and fractured.

End of hole @ 119.9m (angled hole - 60 deg)

Water in hole @ 30m

87m test yielded 0.45 l/sec (EC = 150mS/cm)

119.3m test yielded 0.29 l/sec.

EC = 215mS/cm.

Cased with HT casing from 0-53m for air-lift test

Open hole from 53-119.9m

aquaterra

Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

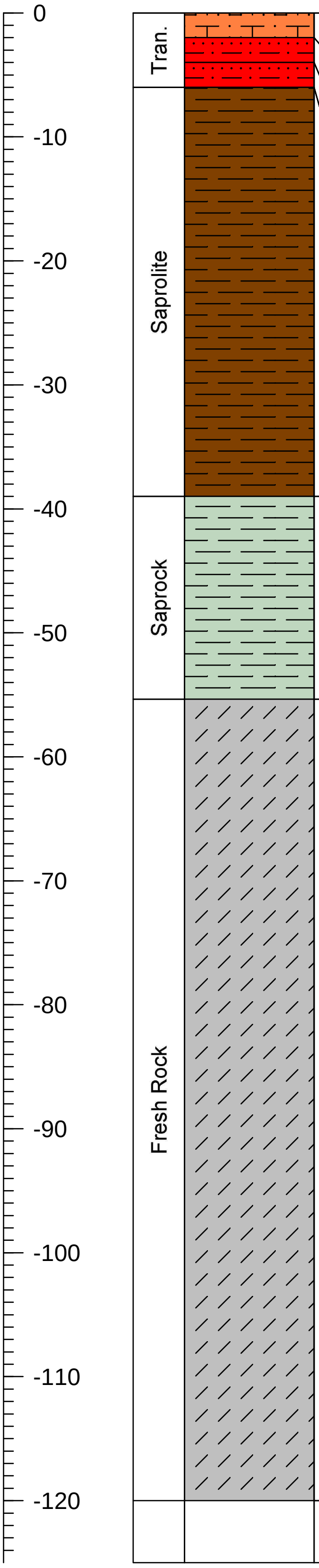
Well No: HOPD112

Client: Placer Dome Asia Pacific
Project: Hornet

Commenced:	23/06/03	**Method:**	RC (0-41); DD (41-120)	**Area:**	Kundana
Completed:	27/06/03	**Fluid:**	RC (air); DD (mud)	**East:**	20810
Drilled:	Layne	**Bit Record:**	RC (4.5"); DD (~3.5")	**North:**	5100
Logged By:	Paul Heaney			**Elevation:**	

Static Water Level: 17.07 mbgl
Date: 2/07/03

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes



SANDY SILTY CLAY: Red brown, dry.

CLAYEY SAND: Red brown, dry and loose.

SANDY CLAY: Red brown moist, soft-firm.

CLAY (UPPER SAPROLITE): Red, orange, brown and khaki, depending on proportion of quartz, oxidised rock and feldspar fragments. Khaki/green 34-39m may be Lower Saprolite. Clay generally dry.

WEATHERED ANDESITIC TUFF: Grey/khaki/brown, heavily fractured and locally crumbly, high clay content, abundent iron staining and salt crystals.

ANDESITIC TUFF: Grey, abundent quartz veins, rock is significantly broken. Fractures with evidence of groundwater flow are abundent between 55.35 and 71.7m, particularly betweeen 62.7-64.3m and 69.4-70.5 where the rock is highly weathered.

End of hole @ 120m (angled hole - 60 deg)

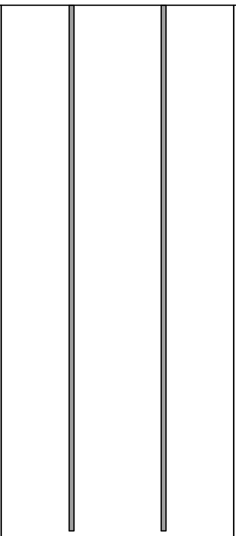
Heavily fractured 55.35-71.7m. 50% drilling fluid loss @ 54-55.5m. 57m test - no water.

Weathered zone 62.7-64.3m.

Weathered zone 69.4-70.5m.

120m test yielded 2 l/sec.

EC = 215mS/cm.

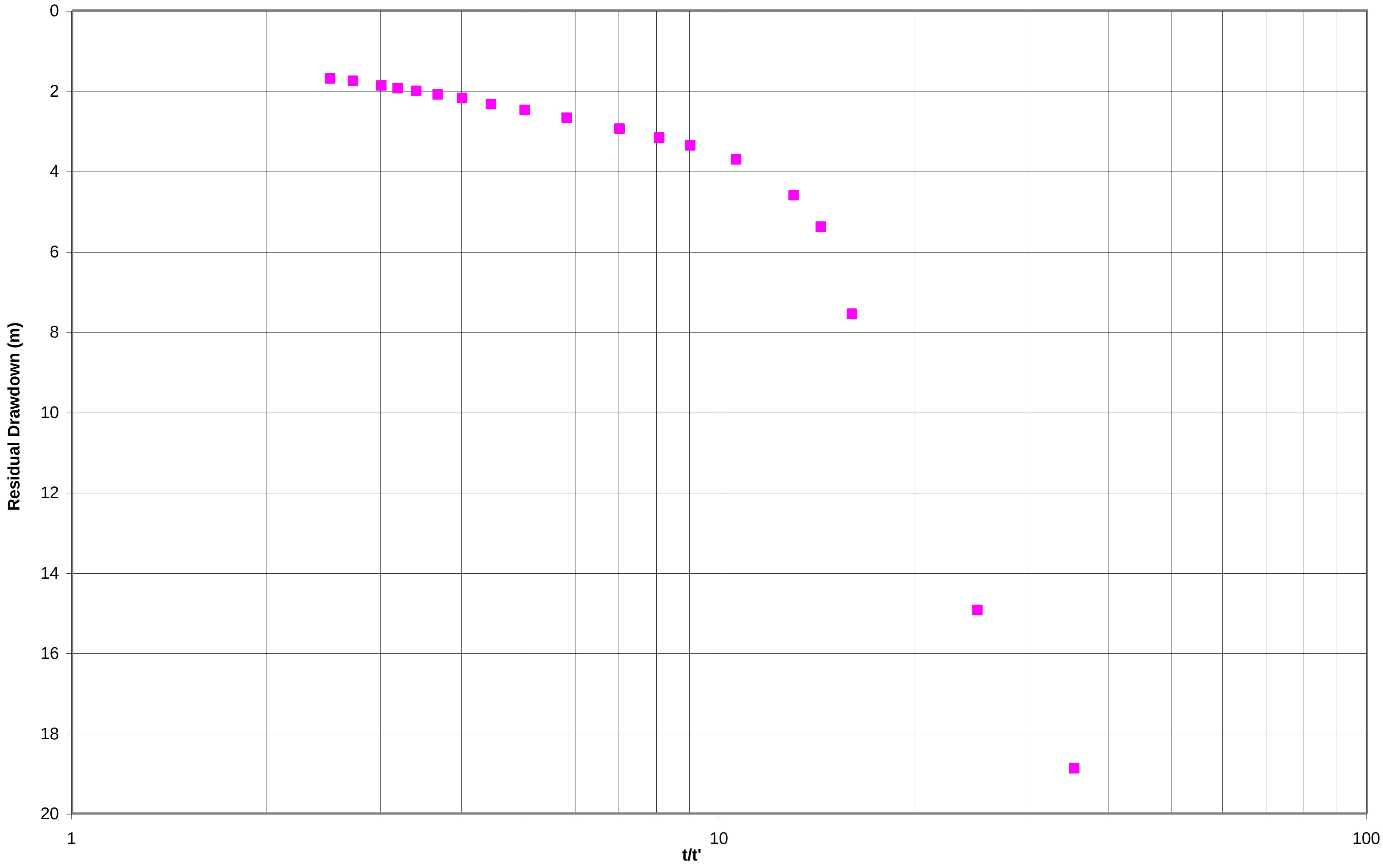


Cased with HT casing from 0-41.7m for air-lift test

Open hole from 41.7-120m

APPENDIX B

AIRLIFT RECOVERY TESTS

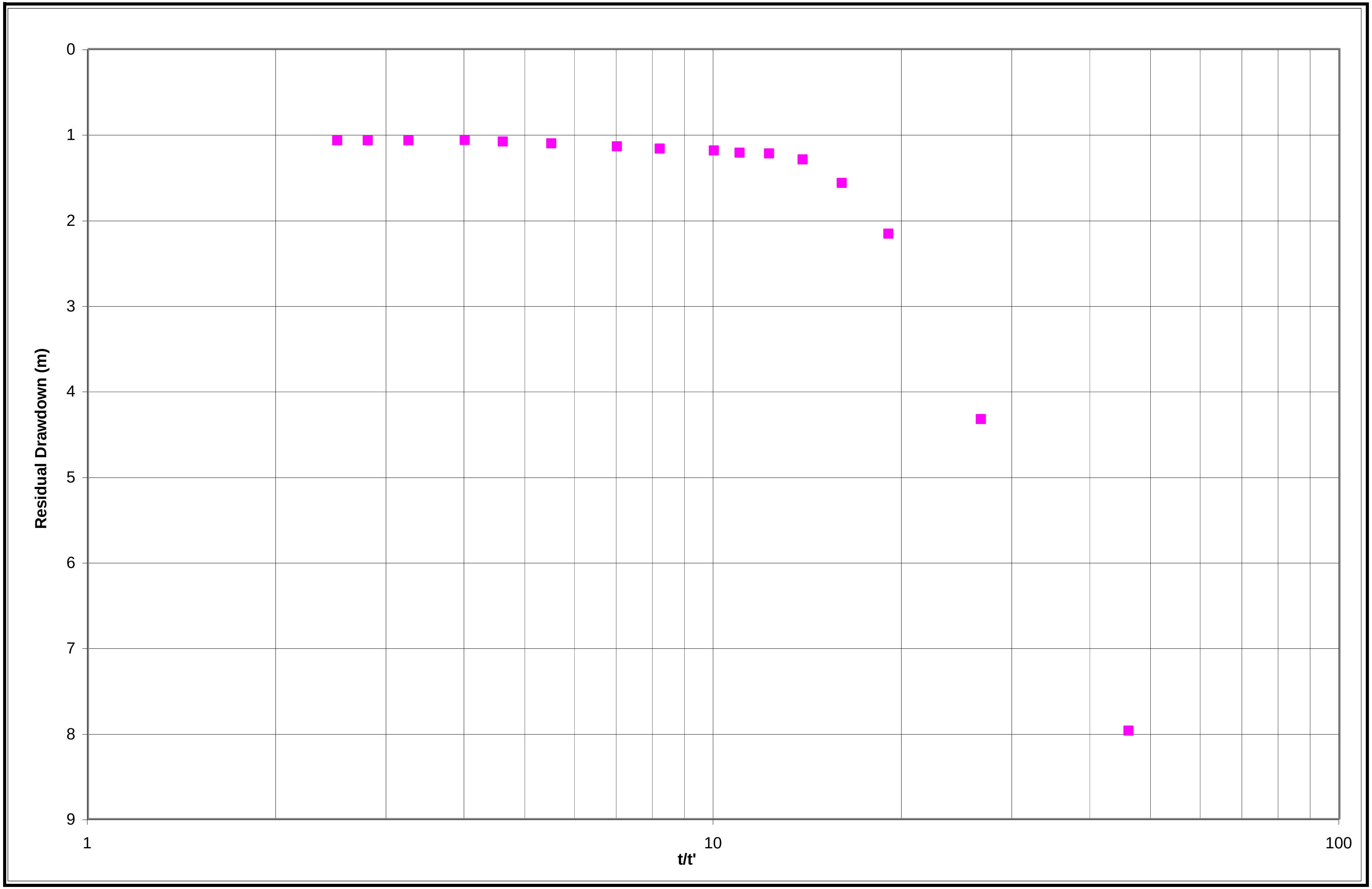


aquaterra

F:\jobs\415\B1 - Drilling\Airlift Tests\[HGT001.xls]Rec Test

Airlift Recovery Test - HGT001

Figure B1

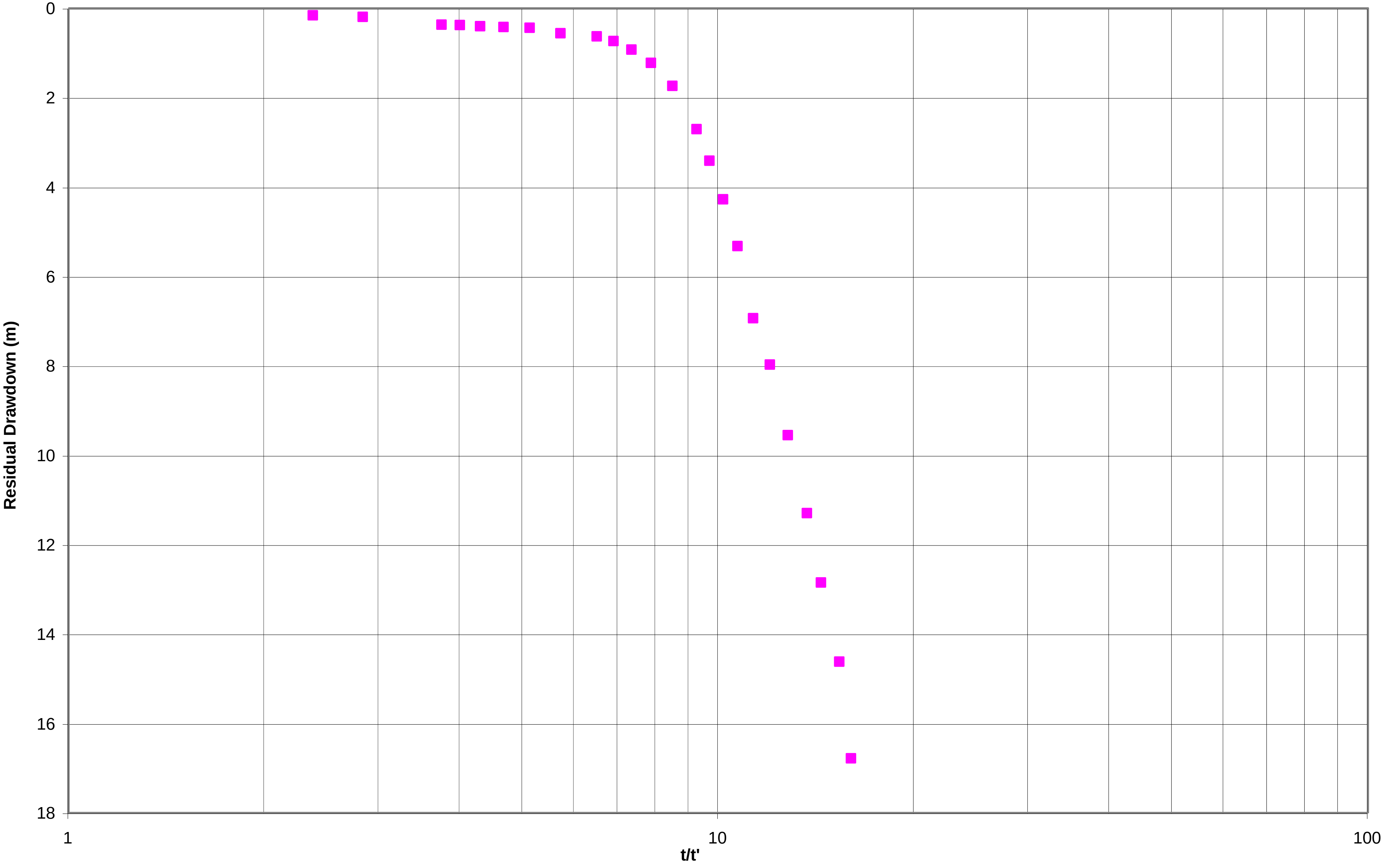


aquaterra

Airlift Recovery Test - HGT003 (Transition Zone)

F:\jobs\415\B1 - Drilling\Airlift Tests\[HGT003a.xls]Rec Test

Figure B2

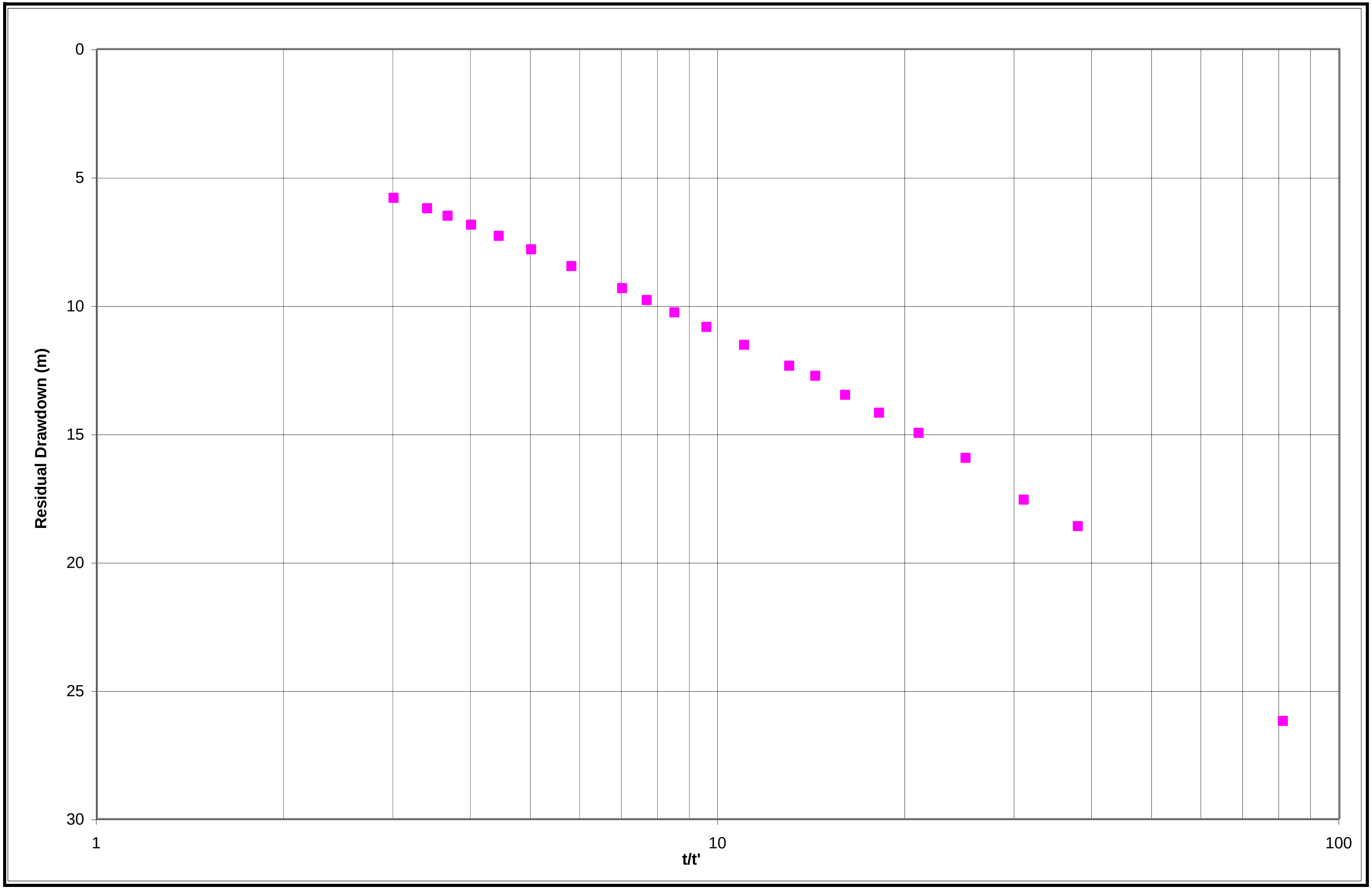


aquaterra

F:\jobs\415\B1 - Drilling\Airlift Tests\[HGT003b.xls]Rec Test

Airlift Recovery Test - HGT003 (Total Depth)

Figure B3

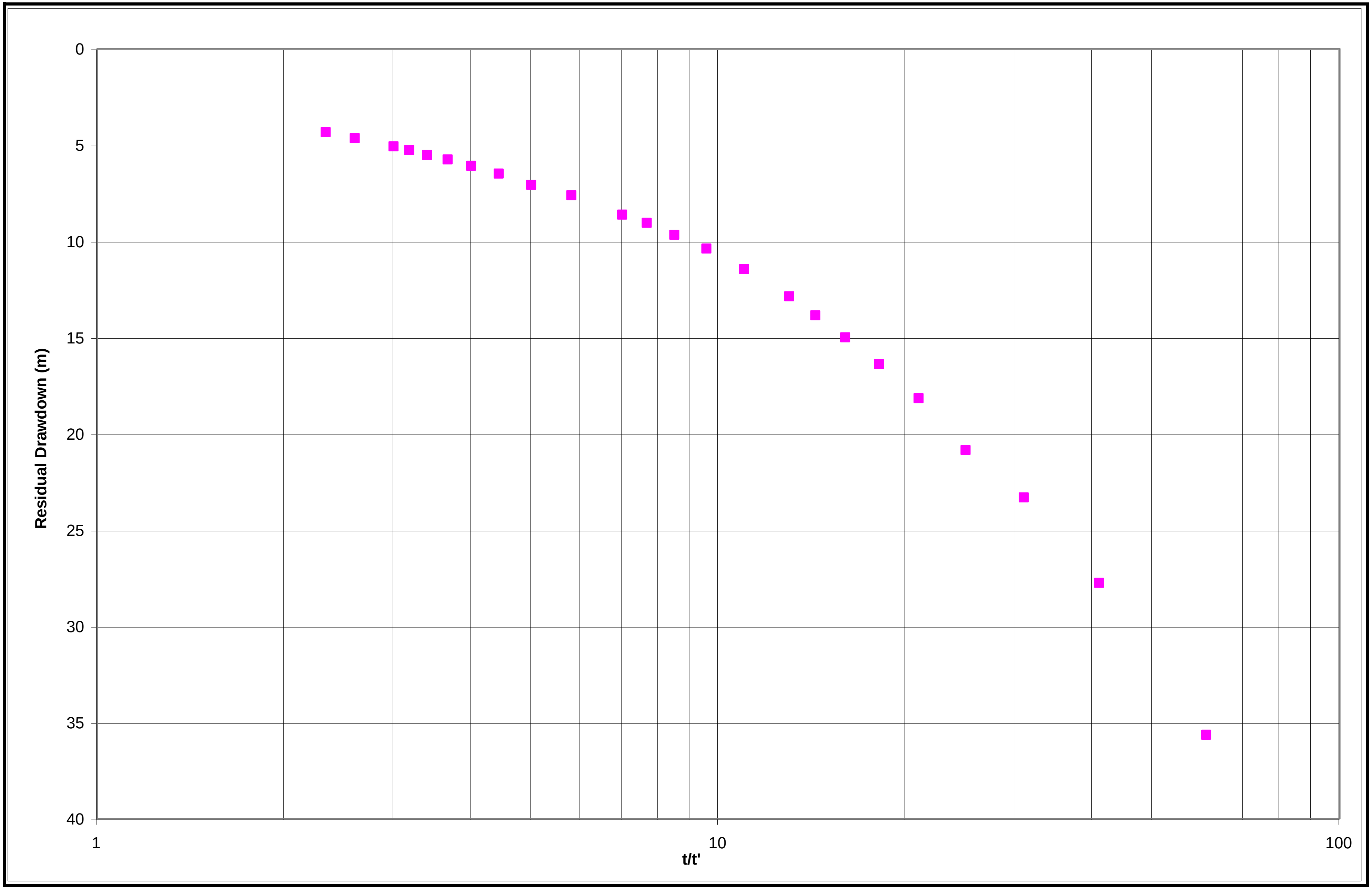


aquaterra

F:\jobs\415\B1 - Drilling\Airlift Tests\[HGT005a.xls]Rec Test

Airlift Recovery Test - HGT005 (Transition Zone)

Figure B4

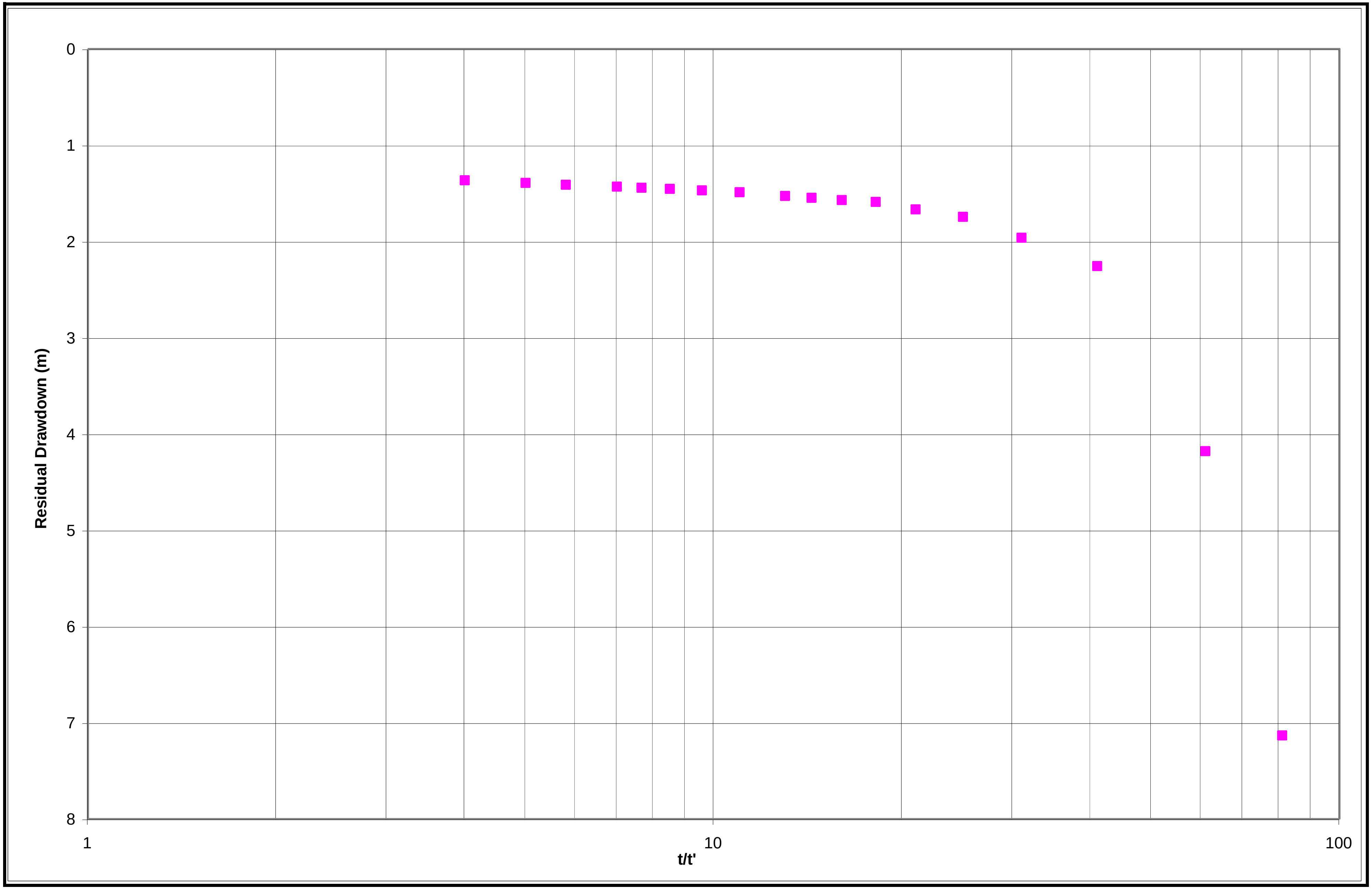


aquaterra

F:\jobs\415\B1 - Drilling\Airlift Tests\[HGT005b.xls]Rec Test

Airlift Recovery Test - HGT005 (Total Depth)

Figure B5

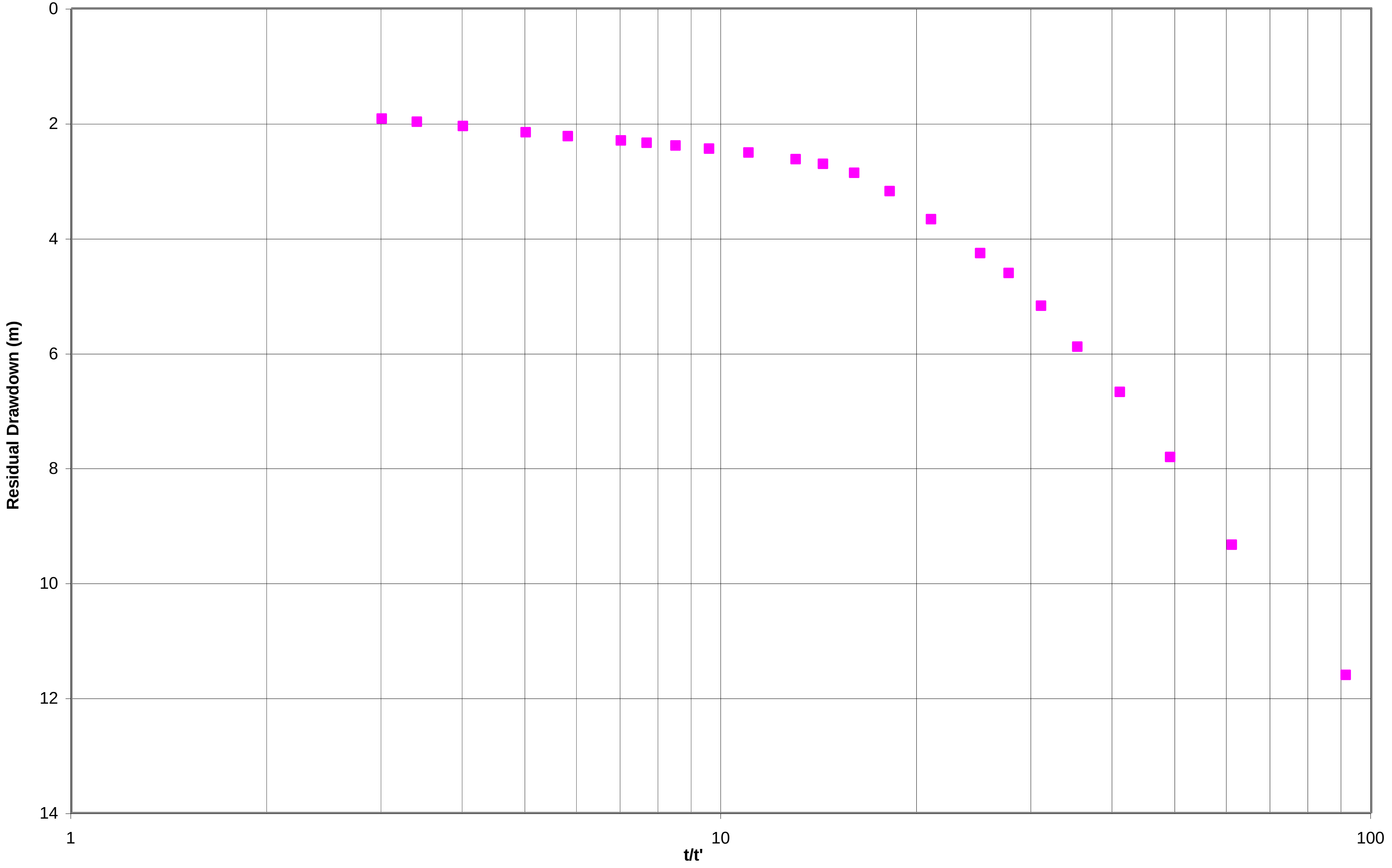


aquaterra

F:\jobs\415\B1 - Drilling\Airlift Tests\[HGT006a.xls]Rec Test

Airlift Recovery Test - HGT006 (Transition Zone)

Figure B6

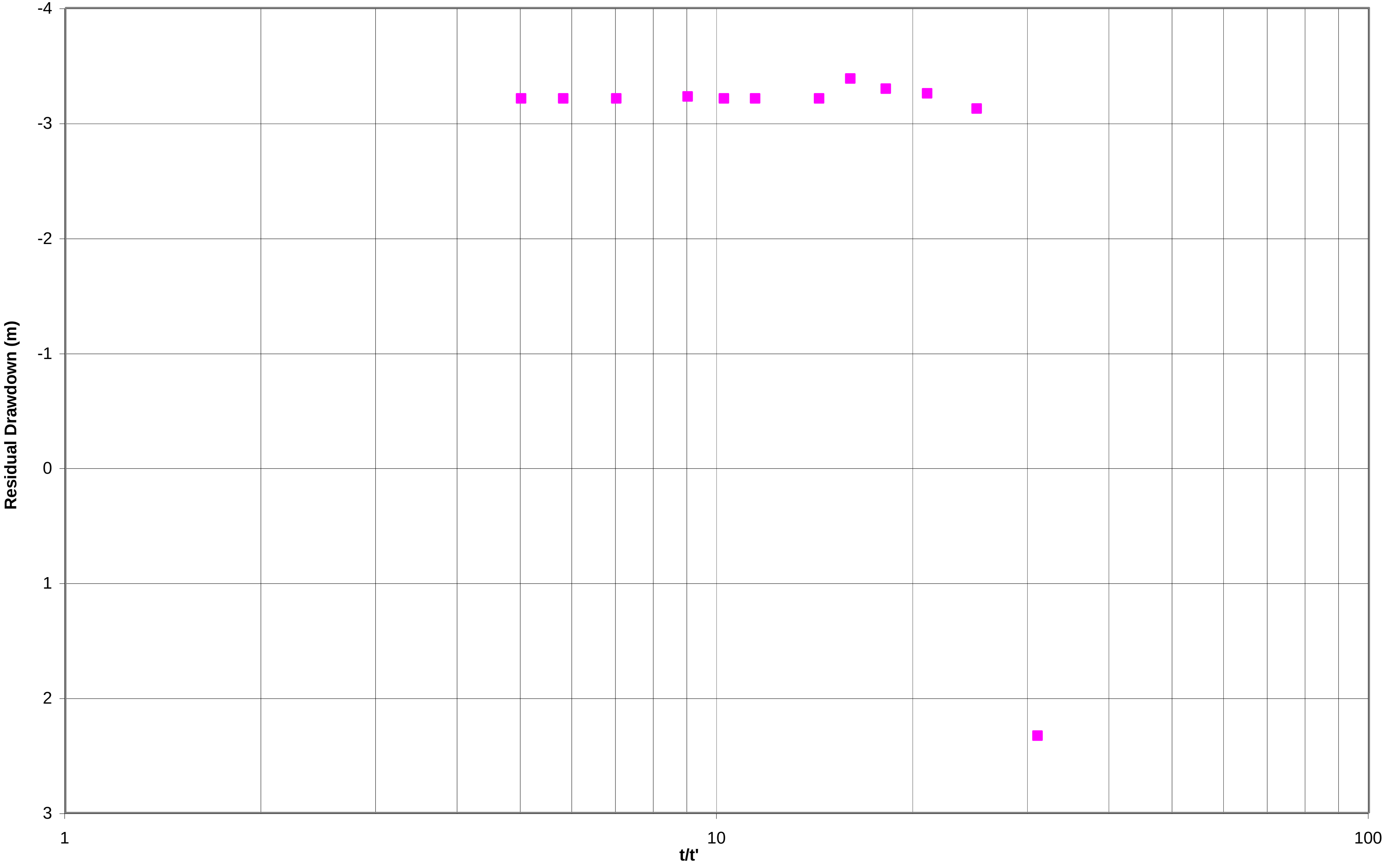


aquaterra

Airlift Recovery Test - HGT006 (Total Depth)

Figure B7

F:\jobs\415\B1 - Drilling\Airlift Tests\[HGT006b.xls]Rec Test

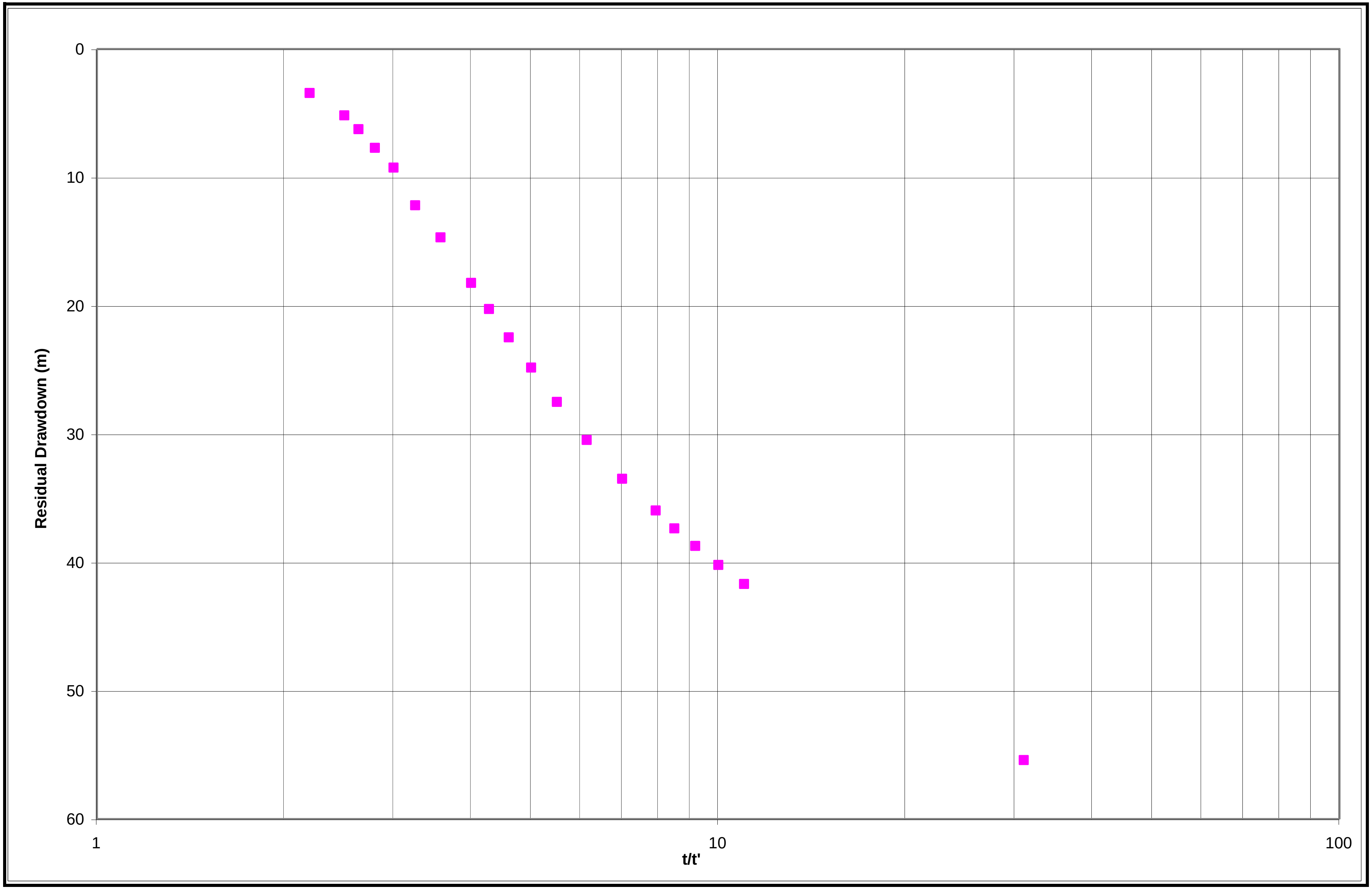


aquaterra

F:\jobs\415\B1 - Drilling\Airlift Tests\[HOPD105a.xls]Rec Test

Airlift Recovery Test - HOPD105 (Transition Zone)

Figure B8

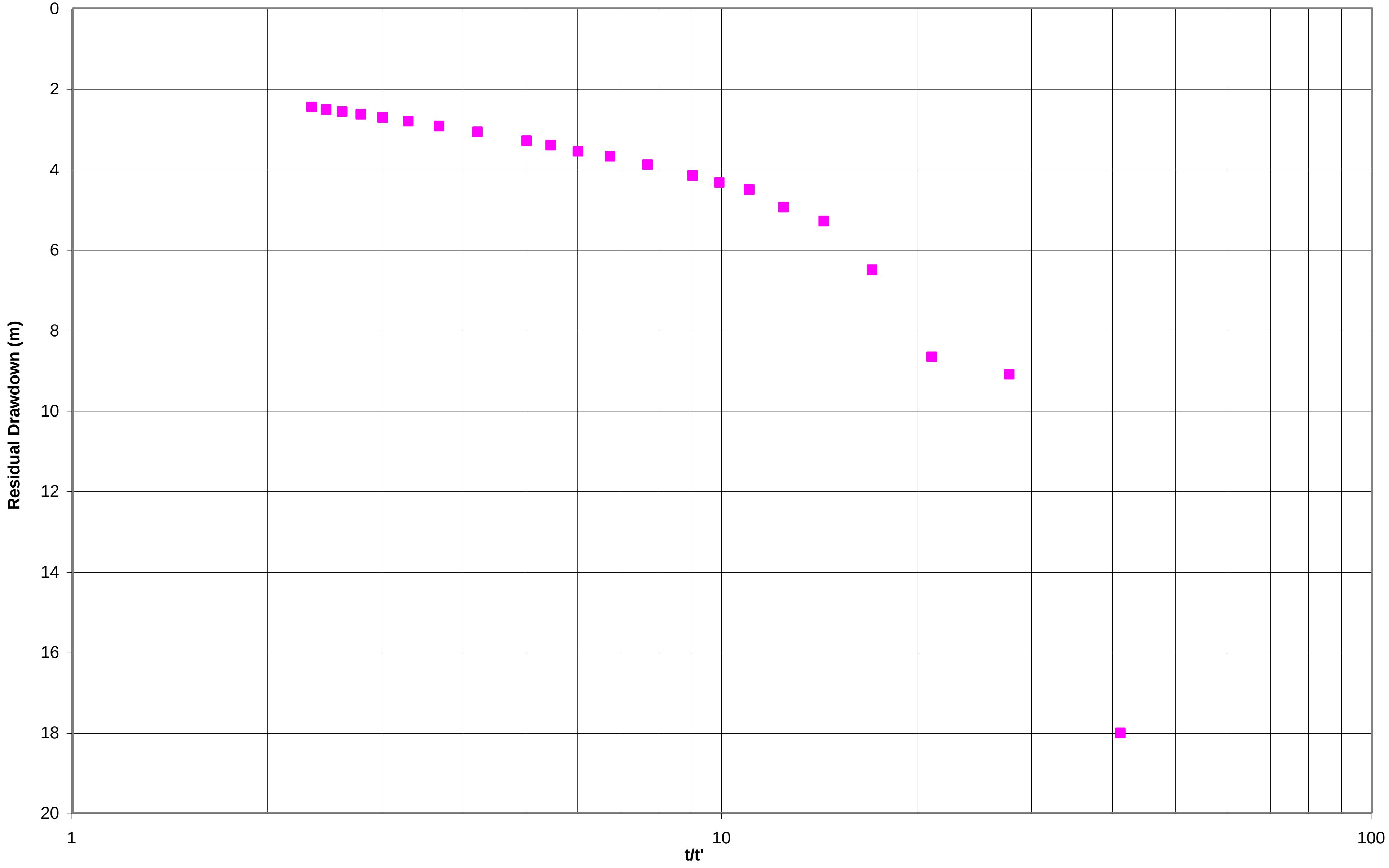


aquaterra

Airlift Recovery Test - HOPD105 (Total Depth)

F:\jobs\415\B1 - Drilling\Airlift Tests\[HOPD105b.xls]Rec Test

Figure B9



aquaterra

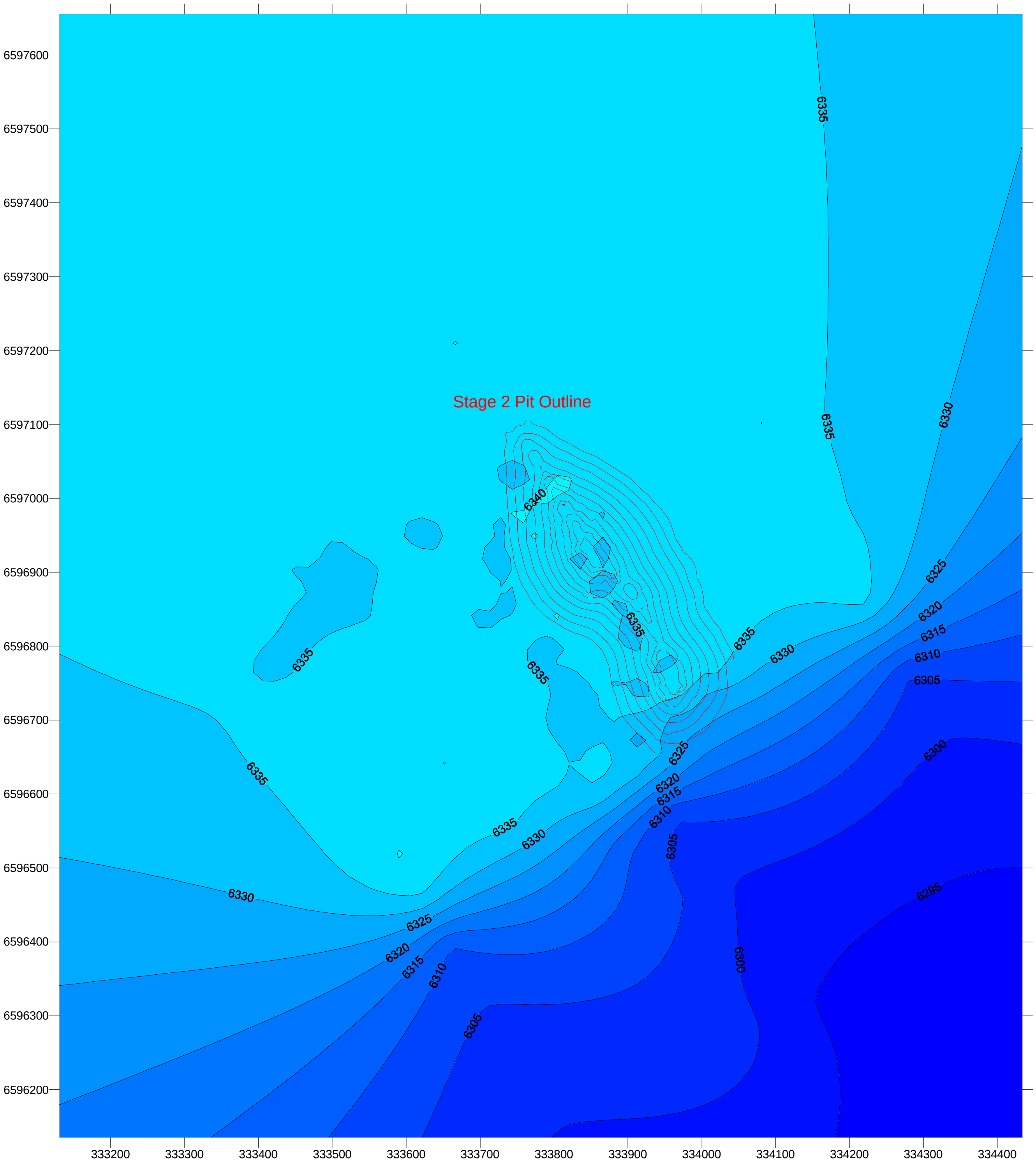
Airlift Recovery Test - HOPD112 (Total Depth)

F:\jobs\415\B1 - Drilling\Airlift Tests\[HOPD112.xls]Rec Test

Figure B10

APPENDIX C

ELEVATION OF GEOLOGICAL UNITS

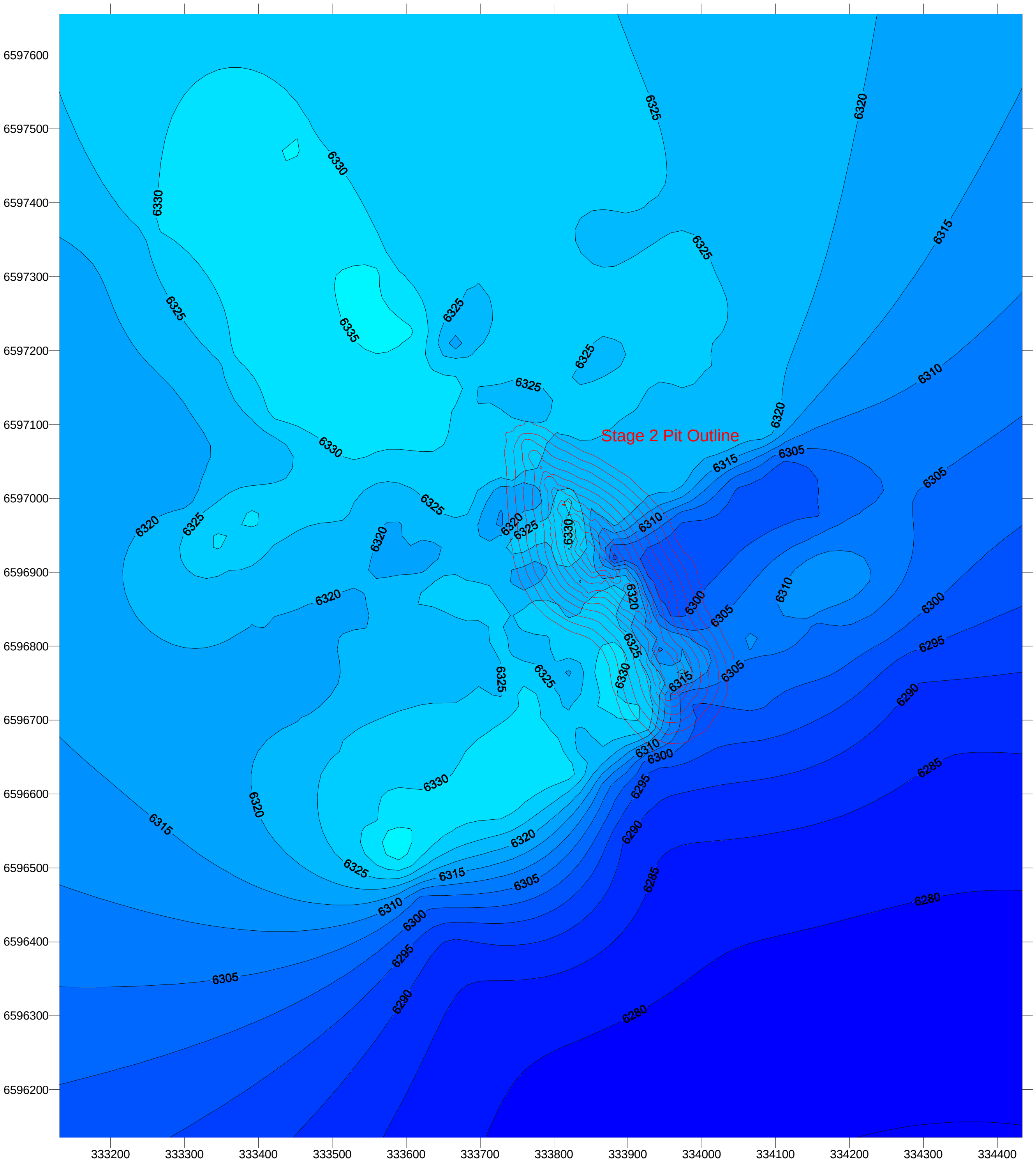


aquaterra

F:\jobs\415\B2 - Inflows\Report\Figures\Fig B1.doc

Base of Transported Sequence

Figure C1

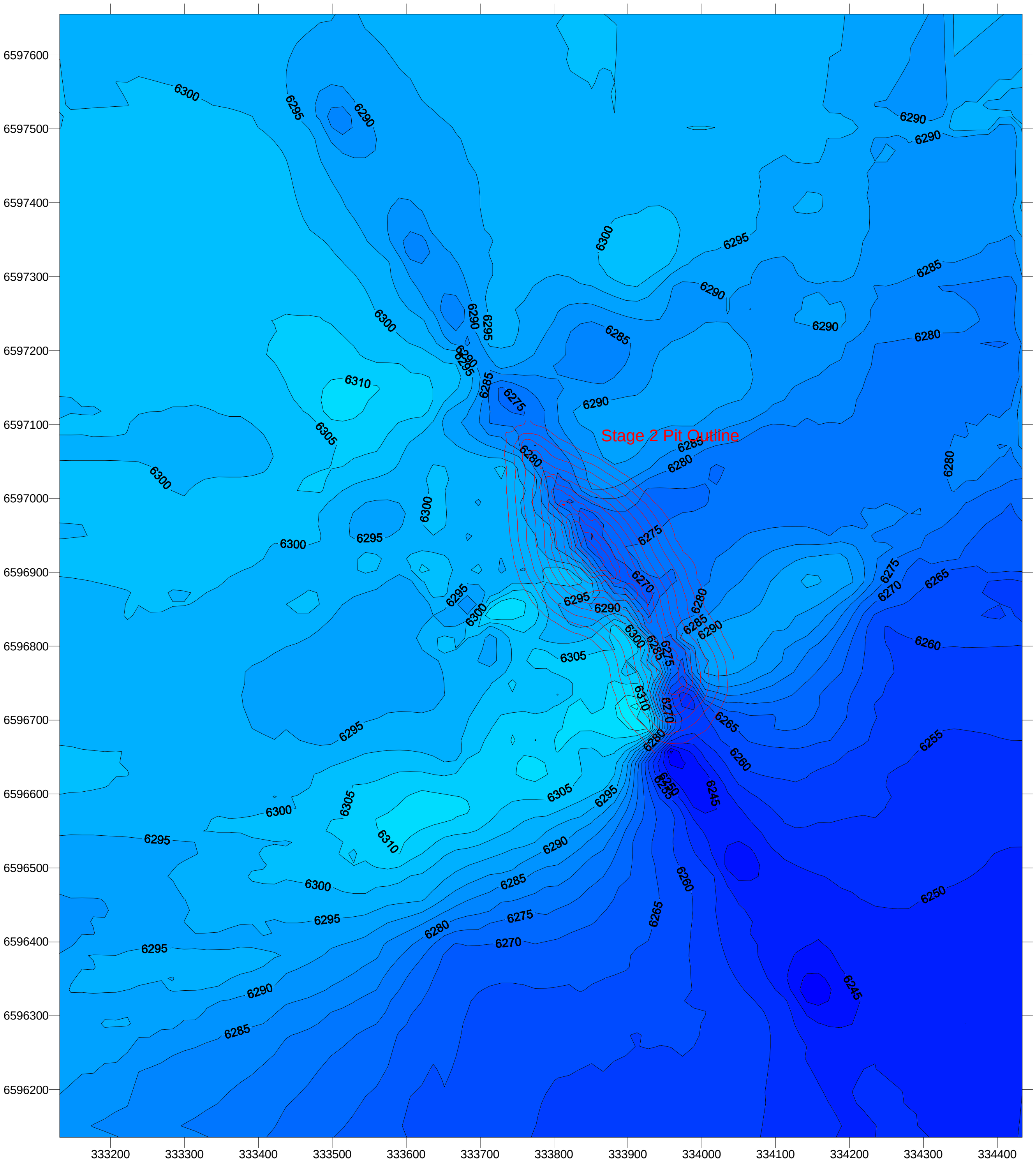


aquaterra

F:\jobs\415\B2 - Inflows\Report\Figures\Fig B2.doc

Top of Transition Zone

Figure C2



aquaterra

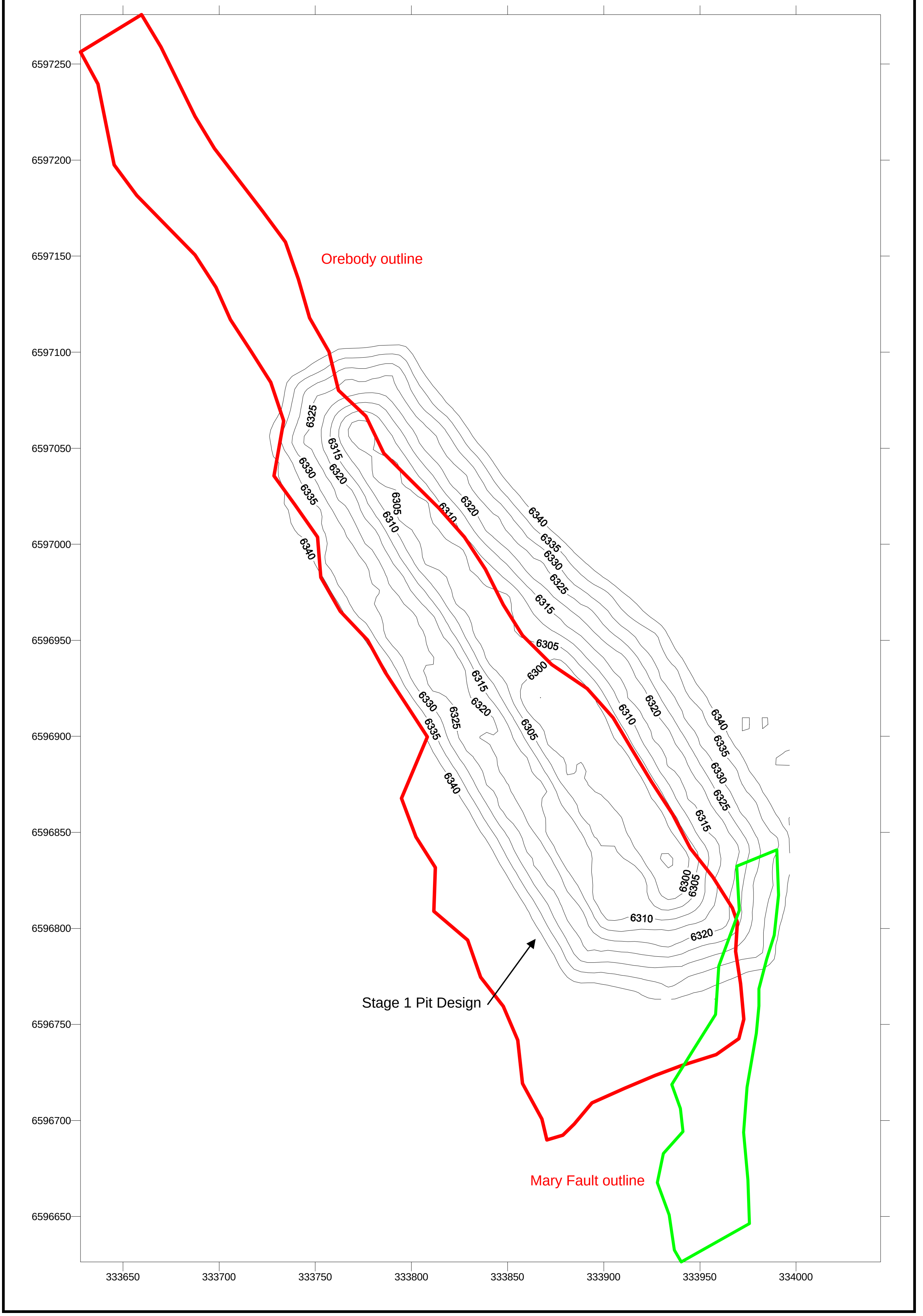
F:\jobs\415\B2 - Inflows\Report\Figures\Fig B3.doc

Base of Transition Zone

Figure C3

APPENDIX D

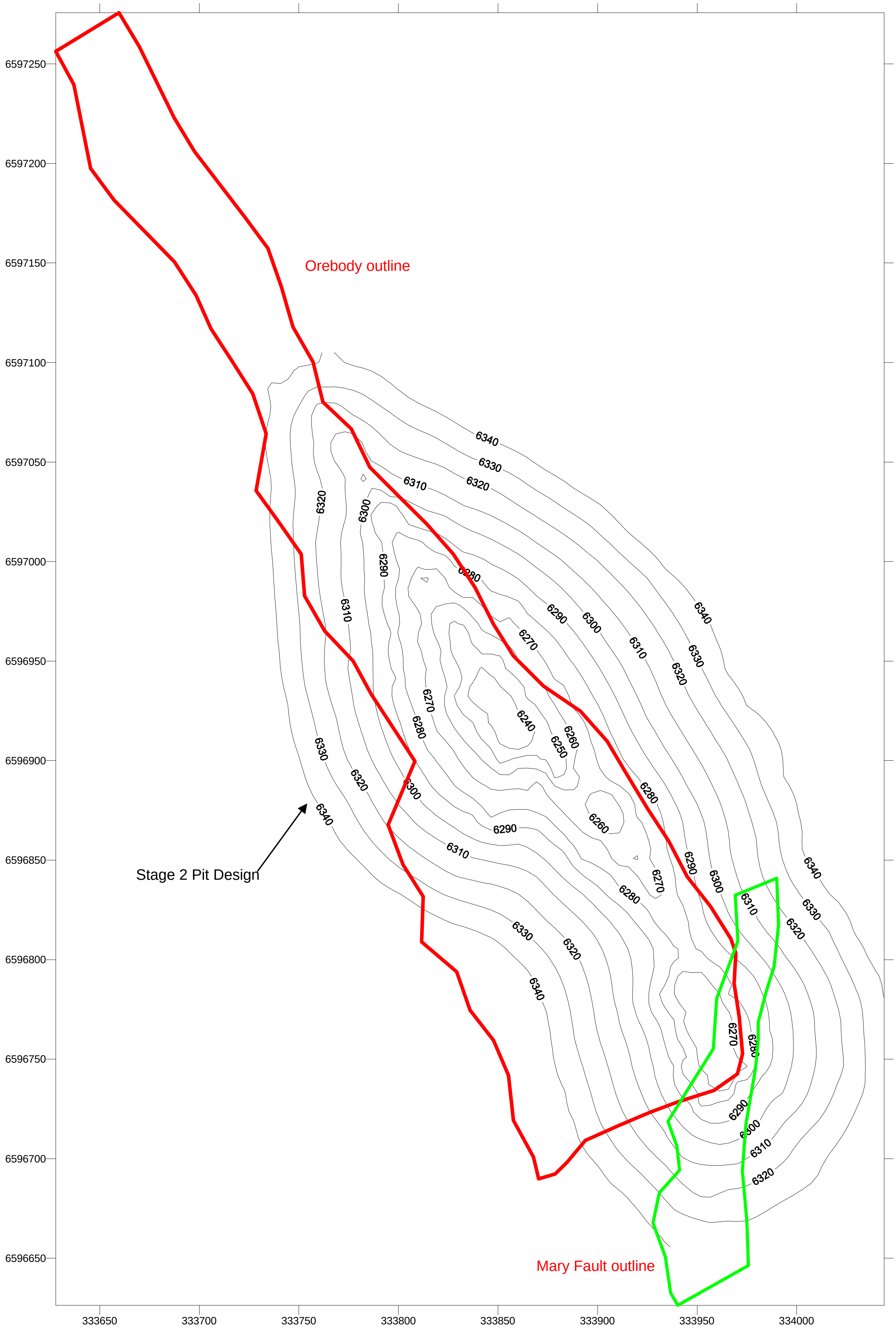
PIT DESIGN AND SCHEDULE



aquaterra

F:\jobs\415\B2 - Inflows\Report\Figures\Fig C1 - Stage 1 design.doc

Stage 1 Pit Design
Figure D1



aquaterra

F:\jobs\415\B2 - Inflows\Report\Figures\Fig C2 - Stage 2 design.doc

Stage 2 Pit Design
Figure D2

Hornet Stage 1 Schedule

		Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04
6344	6340	🟧													
6340	6336		🟧												
6336	6332		🟧												
6332	6328			🟧											
6328	6324			🟧	🟧										
6324	6320				🟧										
6320	6316				🟧										
6316	6312				🟧										
6312	6308				🟧	🟧									
6308	6304					🟧									
6304	6300					🟧									
6300	6296														
6296	6292														
6292	6288														
6288	6284														

Hornet Stage 2 Schedule

		Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04
6344	6340					🟧									
6340	6336					🟧									
6336	6332					🟧	🟧								
6332	6328					🟧	🟧								
6328	6324						🟧	🟧							
6324	6320						🟧	🟧							
6320	6316							🟧	🟧						
6316	6312							🟧	🟧						
6312	6308								🟧	🟧					
6308	6304								🟧	🟧					
6304	6300									🟧	🟧				
6300	6296									🟧	🟧				
6296	6292										🟧	🟧			
6292	6288										🟧	🟧			
6288	6284											🟧	🟧		
6284	6280											🟧	🟧		
6280	6276												🟧		
6276	6272												🟧		
6272	6268												🟧	🟧	
6268	6264												🟧	🟧	
6264	6260													🟧	🟧
6260	6256													🟧	🟧
6256	6252														🟧
6252	6248														🟧
6248	6244														🟧
6244	6240														🟧
6240	6236														🟧
6236	6232														🟧

F:\jobs\415\B2 - Inflows\Report\Figures\[Hornet schedule.xls]Stage 1

Appendix E:

Surface Water Assessment for Kundana

(RPS 2020)

KUNDANA

Surface Water Assessment

EWP19127.001
003c
14 October 20200

rpsgroup.com

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
a	Issued for Client Review	ER	RW	RW	24/06/20
b	Issued for Client Review	ER	RW	RW	02/09/20
c	Final	ER	RW	RW	14/10/20

Approval for issue

Rhod Wright	RW Wright	14 October 2020

Prepared by:

RPS

Ella Robson
Water Resources Engineer

Level 2, 27-31 Troode Street
West Perth WA 6005

T +61 8 9211 1111
E ella.robson@rpsgroup.com.au

Prepared for:

Northern Star Resources

Bryn Jones
Planning Superintendent - EKJV

PO Box 1662
Kalgoorlie WA 6433

T +61 8 9080 6406
E brjones@nsrltd.com

Contents

Figures

1 INTRODUCTION

1.1 Background

NSR's Kalgoorlie Operations are located in the Eastern Goldfields of Western Australia. The Kanowna Belle underground mine is a wholly owned subsidiary of NSR, Kundana (consisting of the Raleigh, Rubicon, Hornet, Pegasus and Millennium underground deposits) is part of the East Kundana Joint Venture (EKJV).

The Kundana site is located 25km north-west of Kalgoorlie-Boulder (Figure A). Mining activities commenced at Kundana in 1988 with the establishment of several open pits, however in recent times, the majority of activity has been underground mining. Ore from the Kundana operations is treated at the Kanowna Belle Processing Plant.

The Kundana Operations comprises three mine areas (Figure C):

- Raleigh mine area (Raleigh open pit and underground operations)
- Rubicon mine area (Rubicon Pit, Rubicon-Hornet-Pegasus underground operations and Kurrawang Pit)
- Kundana mine area (Arctic / North, Barkers, Pope John, South pits, Millennium and Moonbeam u/g)

The Kundana Operations area lies within a major easterly flowing regional surface drainage system. The system is characterised by numerous ephemeral lakes and saltpans; and overlies, but is much broader than, the underlying regional paleo-drainage network.

Significant work has been carried out by Aquaterra and RPS over 20 years. Northern Star would like to update previous surface water assessments.

1.2 Scope of Services

This surface water assessment is a high-level desk-top assessment of potential hydrological impacts on the mine site, and includes:

- Review of existing reports, historical background, and available information (maps, aerial photos)
- Characterisation and description of the existing surface water environments, including climate, catchments, existing drainage conditions and flow directions
- Hydrological analysis - rainfall estimation (intensity frequency and duration) was revised in 2016, based on an expanded rainfall database and more accurate analysis (replaces the ARR87 IFDs)
- Delineation of regional catchments
- Rainfall-runoff modelling (RAFTS), to generate design flood flows impacting the mine site
- Hydraulic analysis – terrain and 2D hydraulic computer flood modelling (HECRAS) to simulate flood levels and flooding regime over the mine site and surrounding salt lakes

2 HYDROLOGY

2.1 Climate

WA has three broad climate divisions - the Kundana and Kalgoorlie areas are located in the central eastern area of WA, with arid / desert climates. The average annual rainfall at Kalgoorlie is about 267mm, but is highly variable with 80-531mm recorded previously. Rainfall is typically 10-20mm per month, slightly higher in winter (May-August).

There is limited evaporation data available, but the annual Class A pan evaporation is about 3500mm.

2.2 Surface Drainage

The topography in the Kundana area is flat to undulating. Surface runoff generally drains towards flat playas or salt lakes, as a dominant and integral feature of the land drainage. The surface hydrology is characterised by large dryland creek systems and salt lakes, erratic extremes of drought and flood with episodic / infrequent rainfall events, high evaporation, low catchment slopes, which result in intermittent sheet run-off from low relief and relatively shallow soil profiles. Floodwater flows slowly down flat gradients and wide floodplains after heavy rain, through low relief. Water is lost to evaporation and seepage, enroute and in the terminal salt lakes.

The lakes are the centres of the extensive internal drainage systems, and retain most runoff from the surrounding catchments, as the final drainage points for present day surface runoff. They are generally dry, or with shallow and separate ponding in low areas, but only contain significant volumes of water after major storms and widespread run-off and flooding. The lakes are now commonly separated from each other, and only overtop one to the other in major events along natural drainage depressions. In exceptional rain events, flood volumes are progressively transferred between the lakes, depending on natural ground elevations and water levels.

Following inundation, the onset of the drying phase is relatively rapid due to high evaporation rates, and surface water may last for a few months.

2.3 Rainfall Data

Intensity-Frequency-Depth (IFD) data is required to characterise storm rainfall intensities and is available from the Bureau of Meteorology (BOM). Information is provided for various AEPs (Average Exceedance Probability), and the equivalent ARI (Average Recurrence Interval), up to the 2,000-year ARI. The 1,000 year rainfalls are ~1.7x the 100 year rainfalls.

Table 1: IFD Data

Duration / ARI (years)	24hr Rainfall (mm)	72hr Rainfall (mm)	96hr Rainfall (mm)
9.5	79	101	105
20	101	130	134
50	131	169	175
100	157	204	211
1,000	256	355	379
10,000	424	551	570
PMP (Point Location)	660	900	1020
PMP (2,000km^2 Catchment)	550	630	710

Closure of mines requires contemplation of rare storms that could occur in time undefined after closure. The 10,000 year rainfalls (2.7x 100 year rainfalls) or the PMP (Probable Maximum Precipitation) are a reasonable indication of the upper limit on rainfall accounting for duration, storm extent and location. The PMPs were also estimated using the BOM GTSMR (Generalised Tropical Storm Method). Typical rainfall data is provided below for various frequencies (ARI) and durations.

2.4 Rainfall–Runoff

The catchment for the areas of interest are shown in Figure B with a total area of around 1,990km². These catchments represent the northern and western catchments entering Kopai Lake, southern and eastern catchments towards White Flag Lake, and the mine area. The flow paths are low-power, but command large catchment areas.

There are no local relevant streamflow gauging data / gauged catchments from which flood estimates may be made directly. Regional flood methods are based on typical average parameters derived from gauged catchments (in an already data-poor region) and are inaccurate in flat terrain and salt lakes which impact directly on flood runoff flows and flood levels. Such methods include the Regional Flood Frequency Estimation (RFFE) technique.

A nonlinear rainfall / runoff program, RAFTS, has been used previously for this area. The impinging catchments are subdivided, and input data derived for each (terrain slopes, roughness, local rainfall data and rainfall losses), with routing links between. The program simulates rainfall with time over a catchment, removing losses to calculate the rainfall excess/ runoff, and then routes this runoff through the model reaches and calculates the resulting flood flows (hydrographs). RAFTS was not used to route flows through the major storages i.e. salt lakes within the catchments. This was carried out in the subsequent HECRAS hydraulic modelling).

2.5 Western Catchment / Bullock Hole Dam

The main creek draining the large Western Catchment flows through Bullock Hole Dam ~2km to the south west of the mine site. During large runoff events, overflows from the creek and dam spill out north and north east through the mine area and towards White Flag Lake, with local flooding in the mine area. Additionally, a smaller catchment to the northwest of the mine area (a tributary of the Western Catchment) can break out through the northern mine site area.

2.6 South West Catchment

Flows from the south west direction run into the western lakes (Kurrawang Lake, Cattle Swamp, and “Western” Lake). These lakes overspill through a constructed diversion cut through dunes on the western side of Lake Kopai. Modelling suggests that for large storm events, flow through the channel can (initially) be westward (out of Kopai Lake) while the western lakes fill, before reversing and flowing east into Kopai Lake.

2.7 White Flag Catchment

White Flag Lake is the major lake in the area, but has a relatively small catchment i.e. it is probably not the termination point of the greater catchments. The lake is surrounded on the south, south east and eastern sides by a myriad of smaller salt lakes, which must first collect local and western flows, before any overspill into White Flag Lake would occur (refer Figure B).

The 100 year modelling suggests that these lakes are not necessarily connected at even the 100 year flood level. If the lakes were already partially full from previous flow events, then overspill in the general direction of White Flag Lake would be more likely to occur.

3 HYDRAULIC MODEL

3.1 General

The HEC-RAS hydraulic computer model was used to undertake 2D hydraulic modelling. In 2D mode, the model performs hydraulic calculations for a network of natural channels and floodplains.

The underlying terrain was compiled from a set of LAZ data, 5m and 8m grid resolution digital elevation models (DEMs), provided by NSR in geotif format. The 5m interval DEM elevations were found to be approximately 3m higher than the 8m DEM elevations along the interface, and the 8m was not used. The 5m interval DEM elevations were found to be up to 1.5m higher than the LAZ data, as a result, most of the 5m data was not used. In some areas the 5m DEM elevation was required, and an attempt was made to manually merge the data, particularly a section to the west of Bullock Hole Dam.

A two-dimensional (2D) flow area (regular variable square grid) was delineated over the resultant topographical surface of about 120km². The area included salt lakes west of Kopai Lake, Kopai Lake and some of the lakes east of Kopai Lake, and the Kundana mine site. These grid cells contain the elevations, land use and other relevant hydraulic data needed for the modelling. A computational mesh spacing of 100m was applied in general, with a mesh spacing of 15m metres applied around the Kundana Mine Site and 5m spacing along break lines for concentrated flow paths, existing bunds, and roadway crests.

A roughness coefficient of 0.06 was uniformly applied to the 2D flow area. The analysis of salt lake terrain largely revolves around storage and volumes in lakes, and the roughness coefficient selected has only minor impact.

Due to sparse historical gauge data, a lack of calibration points, and high localised variability in basin parameters in this arid area, the Australian Rainfall and Runoff (ARR) data hub does not provide (initial and continuing) loss estimates for the region. However, based on work done by Flavell and Belstead (1988) and Dufty (1992) on proportional loss coefficients for the Pilbara, satisfactory and consistent loss rates can be derived. These losses are removed from the precipitation estimates, to account for infiltration, evaporation, and evapotranspiration losses.

The flow hydrographs as estimated by RAFTS, were introduced as time dependent hydrographs at the appropriate locations.

No culverts or bridge structures were included in the hydraulic model. This approach assumes that existing low-flow culverts along any roadways are blocked or ineffective at the (higher) modelled flood stages.

3.2 Hydraulic Model

Preliminary model runs were developed to determine the critical catchment response time. Since the maximum flood levels in this area are mainly affected by surface storage, in general the longer the storm duration, the higher the flood levels. In this regard, it is noted that rainfalls only increase marginally with long durations storms. This initial catchment response assessment suggests a 96 hour (synthetic) storm is the “critical” duration.

The floodplain was hydraulically modelled with the estimated flood flow hydrographs and mining layouts. The model routes the flows through the digital terrain, filling storages / salt lakes and overspilling downstream as required.

The flooding through the main Kundana mine area occurs from overflow of the large northwest catchment (~1,142km²), in large storm events. With Bullock Hole Dam in place, more water is diverted through the mine site and less into Kopai Lake. The 10 and 20 year ARI flood events flow through the northern overflow channel and into Kopai Lake (do not overtop the dam). Larger flood events (i.e. 50 and 100 year ARI) overtop the dam.

During the modelling, it was found that water was flooding into some pits through the pit bunds (which effectively reduces flood levels in the vicinity), which could be (a) due to errors in the terrain data; or (b) the model grid used to represent the model terrain does not accurately pick up narrow bunds (i.e. the bund would appear not to be there); or (c) flood water would in truth overtop the bund into the pit. The pits have been manually blocked out as required, so that water does not enter. The existing pit bund heights and integrity can be checked against the flood levels outside the pits.

3.3 23 January 2014 Event

It is understood that a 20 year rain event occurred on 23 January 2014 as a result of Tropical Cyclone Christine. This was the wettest January on record in the Goldfields. The weather system saw roads closed, power lost, and Great Eastern Highway closed between Coolgardie and Southern Cross.

Kundana measured 111mm, Kalgoorlie 114mm, and Leonora 147mm. The 20 year modelling was carried out with (BOM statistical data) 134mm rainfall (over 96 hours / 4 days). The 111mm recorded at Kundana is more similar to the 10 year 4 day BOM rainfall of 105mm (even though 111mm is a 20 year rainfall for a 1.5 day duration).

The 2014 water level was reported as about 50mm over the causeway (RL340.6m), equivalent to a flood level of RL340.65 - 340.7m. This was the last time Lake Kopai was full. The modelled 10 year flood level in Kopai Lake is RL340.8m i.e. slightly above the 2014 flood level.

There are many factors used in modelling to generate flood levels. In particular:

- Areal Reduction Factor – the 2014 rainfall of 111mm is a point rainfall, measured at one location. The rainfall for the area impacting Kundana needs to be estimated over 1600km². There are standard formulae for the reduction in rainfall intensity over large areas, to factor down the point rainfall (as an estimate of the average rainfall over the whole catchment)
- The 2014 rainfall was obviously widespread, but the average rainfall calculated using the standard areal reduction factor (statistical average for design rainfalls over large areas) is unlikely to have matched the actual 2014 storm patterns
- The rainfall then needs to be translated into a run-off / water volume, by a run-off coefficient. There are natural losses which depend on soil types, vegetation, slopes, etc to produce a run-off volume - there is no accurate way to estimate what this coefficient is. It can be based on experience, published guidelines, other studies, but it is ultimately a best estimate. The selection of the run-off coefficient has direct impact on flood volumes and therefore flood levels
- Where different data sets are combined (as in this model), ground levels do not match at the edges of the different datasets (due to insufficient care by the surveyor, or lack of available survey "control"). Attempts are made to reduce the discrepancies and smooth data at the edges, but mismatches inevitably affect where flood water is directed in the model, and therefore have a direct effect on flood levels

In summary, the 2014 point rainfall as measured at Kundana would have been bigger if it had kept raining, and still been the 20 year event (there must be a duration associated with the event). The 2014 rain event was a 20 year rainfall event, but not necessarily equivalent to a 20 year rainfall event over the whole catchment, or a 20 year flood event. Given uncertainties around the Areal Reduction Factor, run-off coefficient and the data available (2D models are data hungry and require good data), the 2014 flood levels in Lake Kopai generally support the flood modelled levels.

Note that the causeway itself will not impact flood levels at the 10 year level, Lake Kopai would be equally flooded on both sides. At the 5 year event for example, there would be a noticeable difference between the upstream and downstream levels

4 SURFACE WATER MANAGEMENT

4.1 General

The Kundana mine site area has been subjected to disruptive floods and mine surface water management strategies in response, with the aim to generally control flood water in the mine site, ensure the potential for flooding does not prevent development of new mine areas, and enable surface water harvesting in the North / Spice / Artic Pits (from the main Western Catchment).

Topographically, the Kundana area is relatively low lying, and ~5km southwest from White Flag Lake. The catchments impacting the mine site are not necessarily distinct. However, the White Flag Lake catchment appears to be local to the lake.

The Western Catchment is the largest catchment, and the main flow path runs down the western side of the Kundana area - and tends to both break out through the mine site towards White Flag Lake and run into the north end of Kopai Lake. Bullock Hole Dam lies across the creek and was originally installed by a pastoralist to divert and hold water upstream of the dam. The dam is typically 1-2m high, 400m long across the creek.

Initially, flows in excess of the dam storage capacity mainly bypassed the dam and continued into Kopai Lake. Only a portion of the flood flows overspilled through the Kundana area. After breaching in 1992 floods, the dam was repaired and slightly raised, blocking a greater proportion of flow, and diverting it via natural flood overflow routes through the Kundana mine area – protection levees were required to be put in place to protect the mine site. The largest flood flows mostly drain to Kopai Lake.

Picture 1 - View of Bullock Hole Dam from Raleigh Waste Dump

The second largest catchment is the South West Catchment which runs into the western side of Kopai Lake. The natural drainage path previously entered Kopai Lake at the south of the lake, but was blocked off by the Mungari mine, and diverted through the “Northern Drainage Channel”, an excavated channel through the dunes and into the western side of the lake.

Surface runoff in the Kundana area generally drains into the salt lakes around the mine site, with the main flow from the west running into Kopai Lake with some flow overflowing north through the Kundana mine site. Kopai Lake itself overflows to the northeast, across the mine access causeway, and into a string of salt lakes (through which flood flows may or may not eventually find their way into White Flag Lake).

4.2 Previous Findings

Previous surface water assessments were undertaken by Aquaterra and RPS over the last 20 years. Some of the findings included:

- The main flow impacting the Kundana Mine Site is from a large catchment to the northwest of the mine. This catchment follows a relatively defined flow path through to Kopai Lake, before overflowing towards the northeast (south of Kurrawang Pit) into a series of salt lakes before reaching White Flag Lake
- During larger flood events, flood flows tend to overspill to the north and northeast (upstream of Kopai Lake) through the mine site and towards White Flag Lake
- The main access to the mine is via an unsealed causeway across Kopai Lake. Bullock Hole Dam reduced flood levels in Kopai Lake, particularly in smaller flood events, reducing causeway flooding
- Bullock Hole Dam blocks off the flow and directs it through the mine. A rock lined overflow on the northern side of the dam allows some flow through during higher flood events (i.e. greater than 10-year). The Raleigh and Moonbeam Pits are located on higher ground to the east of Bullock Hole Dam, and are protected from flooding by the Raleigh Waste Dump

Picture 2 - Bullock Hole Dam Overflow Channel

- Floodwaters through the main Kundana area (South, Pope John, Barkers North, Barkers, Moonbeam and North / Arctic Pits) from the northwest catchment, enter the south side of the site, along the northern edge of the Raleigh and Moonbeam Pits. The water tends to pond around South Pit and drain via an excavated channel (which is now blocked) to both the North/Arctic Pits and to a natural flow path to White Flag Lake
- The North / Arctic Pits were previously used for surface water harvesting, capturing surface water from the northwest catchment through the excavated channel on the north side of South Pit. This captured water was harvested for the processing plant on site. The processing plant has since been removed, and ore is sent to Kanowna Bell for processing - surface water harvesting is no longer required
- Existing surface water management includes flood bunds around infrastructure (pits, waste dumps, tailings dams etc.), diversion channels and sediment basins to trap dirty water

Picture 3 - North Pit Diversion Entry

4.3 Modelling Findings

The flood modelling results across the site are shown in 18 no Figures:

- 10 year flood levels and depths, with and without Bullock Hole Dam – Figures D-G
- 20 year flood levels and depths, with and without Bullock Hole Dam – Figures H-K
- 50 year flood levels and depths, with and without Bullock Hole Dam – Figures L-O
- 100 year flood levels and depths, with and without Bullock Hole Dam – Figures P-S
- PMF levels and depths, without Bullock Hole Dam – Figures T-U

General surface water management issues include:

- Water ponding around South & Barkers Pits, 100 year flood level RL345.1m (to the west of Barkers Pit)
- Water ponding along the north east side of Pope John Pit, with 100 year flood level RL343.1m
- Water ponding around north & west sides of Moonbeam Pit, 100 year flood level RL345.4m
- The Raleigh and Rubicon Pits are located on higher ground, and protected from the main flow path by waste dumps on the western side of each of the pits
- Downstream of Kopai Lake, water flows along the south side of Kurrawang Pit, running through the external flood bund and pooling to the south of the pit, 100 year flood level RL341.8m
- Bullock Hole Dam blocks flow from the western catchment from entering Kopai Lake. The dam sits at RL345.0m and has an emergency overflow on the northern side at RL343.1m. During larger flood events, flow will pass around the southern side of the dam and finally overtop the dam. The dam and storage to the west of the dam (upstream) stores water backed up from the dam and lowers flood levels in the mine site

4.4 Erosion and Runoff

The landscape can be subject to heavy rainfall, and there is a risk of erosion and sedimentation on disturbed or degraded land which has been subject to vegetation and topsoil removal, mining activities, spoil stockpiling and general construction activities. The environmental objective for "Inland Waters"

(Environmental Protection Authority 2018, "Environmental Factor Guideline: Inland Waters") is to maintain the hydrological regimes and quality of groundwater and surface water due to diffuse source impacts.

Surface water impacts include sediment laden run-off, from waste dumps and stockpiles in particular, but from all disturbed surfaces, as well as disruption to existing surface water flow patterns / possible reduction of surface water runoff volume, spillage of chemicals and hydrocarbons, and pooling of water / invasive vegetation in low-lying areas.

Effective erosion, sedimentation and water quality control minimises adverse water quality and sedimentation impacts on downstream waterways and adjacent environs. Soil and water issues need to be identified, planned, managed, and monitored during the project life.

Surface water management requires engineering surface water controls in each sub-catchment / drainage area to prevent or capture sediment (and other contaminants) from entering natural flow paths. These measures include diversion (and dispersion) mechanisms, and erosion & sedimentation controls.

Potential mitigation measures for the mine area include limiting clearing, diverting water from upstream around the site, minimising disturbance and vehicle movements / use of existing tracks, placing storage areas (chemicals, hydrocarbons, etc) away from, or bunded off from, external surface water flows and flooding, and capturing sediment laden water around the perimeter of infrastructure areas, and either discharging it (slowly allowing settling) or via evaporation or infiltration.

4.5 Flood Impacts

4.5.1 Mine Site Access Causeway

The mine site access causeway runs across Kopai Lake (refer Figure C) and is susceptible to flooding during larger rainfall events. The effect of Bullock Hole Dam on Kopai Lake flood levels has been investigated by modelling the site with and without the dam in place as shown in Table 1 below.

Picture 4 - Causeway across Kopai Lake

Bullock Hole Dam has the effect of lowering flood levels in Kopai Lake levels by ~0.1m.

Table 2: Kopai Lake Flood Levels

Kopai Lake Flood Levels			
AEP / ARI	**Without Bullock Hole Dam**	**With Bullock Hole Dam**	**Difference in Levels**
10% / 9.5y	340.9m	340.8m	0.1m
5% / 20y	341.4m	341.3m	0.1m
2% / 50y	341.8m	341.7m	0.1m
1% / 100y	342.1m	342.0m	0.1m

The elevation of the road causeway across Kopai Lake is about RL340.6m, therefore with Bullock Hole Dam in place, a 10 year flood event or greater will overtop the causeway. If the causeway overtops, an alternative route into the Kundana mine site is possible via a haul road from the north.

4.5.2 Kundana Mine Site

Flood modelling was undertaken of the Kundana Mine for the 10, 20, 50 and 100 year flood events. The flood levels and depths are shown generally, and depths at 4 locations in the mine site (refer Figures D-S), as shown below (and also on a creek crossing of the access road about 2.5km south of the Kopai Lake causeway).

Table 3: Kundana Flood Levels

Flood Levels (With / Without Bullock Hole Dam)			
AEP / ARI	**Between South and Barkers Pit**	**North Raleigh Pit / West Moonbeam Pit**	**East Raleigh**
10% / 9.5y	344.2 / 344.1m	344.5m / 344.5m	0.0 / 0.0m
5% / 20y	344.6 / 344.5m	344.9m / 344.8m	0.0 / 0.0m
2% / 50y	344.9 / 344.8m	345.1m / 345.0m	344.0 / 343.3m
1% / 100y	345.1 / 345.0m	345.4m / 345.3m	344.5 / 344.4m

The flood modelling shows that Bullock Hole Dam increases the flood levels in the main Kundana mine area by between 0.1m for flood events greater than the 10 year. The area to the east of Raleigh Pit is at the edge of the flood extents for the 50 year flood, and has a more noticeable change in flood level of up to 0.7m with / without the dam. The 100-year flood depths across the mine area are shown in Figures Q and S, with a maximum flood depth in the mine area of about 2.7m to the north of Raleigh Pit. As shown in the Figures, the dam stores some of the water blocked off, reducing the water from running through the mine site.

The 100 year maximum velocities in the mine area are less than 1m/s. These velocities are comparatively low, and generally not damaging to (earth) infrastructure. The maximum velocity in the mine area is approximately 2.4m/s in the channel to the north west of South Pit, for the 100 year flood, and rock armour could be considered.

The 100 year velocities downstream of Bullock Hole Dam to the west of the Rubicon waste dump are up to 1.1m/s. The dam overflow has higher velocities ~3.2m/s, however it is noted that some rock armour protection through this channel has been provided. Flow around the southern (opposite) side of the dam has velocities up to 1.9m/s in the 100 year flood. Typically, velocities <2m/s are not usually rock protected against scouring.

5 GUIDELINES POST CLOSURE

5.1 General

Mining is a temporary land use and therefore rehabilitation objectives need to be consistent with the future land use.

Post-mining landforms can contain unconsolidated materials, dispersive, and erodible materials, and steep and long slopes, which give rise to high erosion risks and a reduction in water quality downstream. The objective of the “Statutory Guidelines for Mine Closure Plans”, Department of Mines, Industry Regulation and Safety, 2020) is to ensure an effective planning process is in place through the life of mine, that rehabilitated mines are (physically) safe to humans and animals, (geotechnically) stable, (geochemically) non-polluting / non-contaminating, and capable of sustaining an agreed post-mining land use, and closure is achieved in an environmentally sustainable manner and without unacceptable liability to the State i.e. that surface (and groundwater) hydrological patterns / flows are not adversely affected, and water levels and quality reflect original levels and water chemistry.

Completion criteria are agreed standards to be achieved on particular aspects of mine closure. Progressive assessment against these criteria can demonstrate the relative success of rehabilitation in achieving desired outcomes, and whether the rehabilitation end point has been reached.

5.2 Flood Impacts

The mine infrastructure has minimal impact on surface flood water levels in their operational form or potential closure form. The closure landforms would include altering the operational landforms (e.g. widened footprint with flattened batters), removal of topsoil stockpiles and access roads, as required for the proposed post-mining use. To ensure surface water flows and levels are returned to their original state Bullock Hole Dam should be removed.

The PMF flood modelling results are shown below and in Figure T and U (without Bullock Hole Dam).

Table 4: Kundana PMF Flood Levels

Flood Levels				
AEP / ARI	**Between South and Barkers Pit**	**North Raleigh Pit / West Moonbeam Pit**	**East Raleigh**	**Kopai Lake**
PMF (without Dam)	346.3m	347.0m	345.4m	344.4m

The PMF flood levels without the dam in place increase from the 100 year levels (with dam) by 2.3m in Kopai Lake, and between 0.9 and 1.6m within the main Kundana mine area.

6 SUMMARY

NSR's Kalgoorlie Operations consists of the Kanowna Belle and Kundana operational areas in the Eastern Goldfields of Western Australia. The Kundana operations are located 25km north-west of Kalgoorlie-Boulder.

Mining activities commenced at Kundana in 1988 with the establishment of several open pits, however in recent times, the majority of activity has been underground mining. Ore from the Kundana operations is treated at the Kanowna Belle Processing Plant.

The Kundana Operations comprises three mine areas:

- Raleigh mine area (Raleigh open pit and underground operations)
- Rubicon mine area (Rubicon Pit, Rubicon-Hornet-Pegasus underground operations and Kurrawang Pit)
- Kundana mine area (Arctic / North, Barkers, Pope John, South pits, Millennium and Moonbeam underground operations)

The arid zone comprises large dryland creek systems, with erratic extremes of drought and flood. Water is lost to evaporation and seepage enroute, and in salt lakes.

The topography in the Kundana area is flat to undulating. Surface runoff generally drains into salt lakes around the mine site, which retain most runoff from the surrounding catchments. The lakes only overspill after a particularly high rainfall runoff event and progressively transfer flood volumes between the lakes down natural drainage depressions.

The total (possible) White Flag Lake catchment area is 1,990km^2. The main flow comes from the west and runs south into Kopai Lake, with some flow breaking out through the Kundana mine site. Kopai Lake overflows to the northeast into a series of salt lakes to the east of the mine site.

The Bullock Hole Dam blocks off some flow from the main Western Catchment flows, directing flow through the mine area and reducing flood levels in Kopai Lake. The main site access is via a causeway across Kopai Lake, and the presence of the dam lowers lake flood levels by about 0.1m for the larger floods (greater than 10 year). The dam has greater impact on Kopai Lake flood levels for small floods.

The maximum 100 year flood depth in the main Kundana mine area is about 2.7m, to the north of Raleigh Pit. Velocities in the mine area are low (typically <1m/s) and are non-damaging to (earth) infrastructure.

The mine infrastructure has minimal impact on surface flood water levels in their operational form or closure form. The closure landforms would include altering the operational landforms (e.g. widened footprint with flattened batters), removal of topsoil stockpiles and access roads, as required for the proposed post-mining use. The PMF flood depths are up to 4.3m, generally 1.6m higher than the 100-year flood level.

FIGURES

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

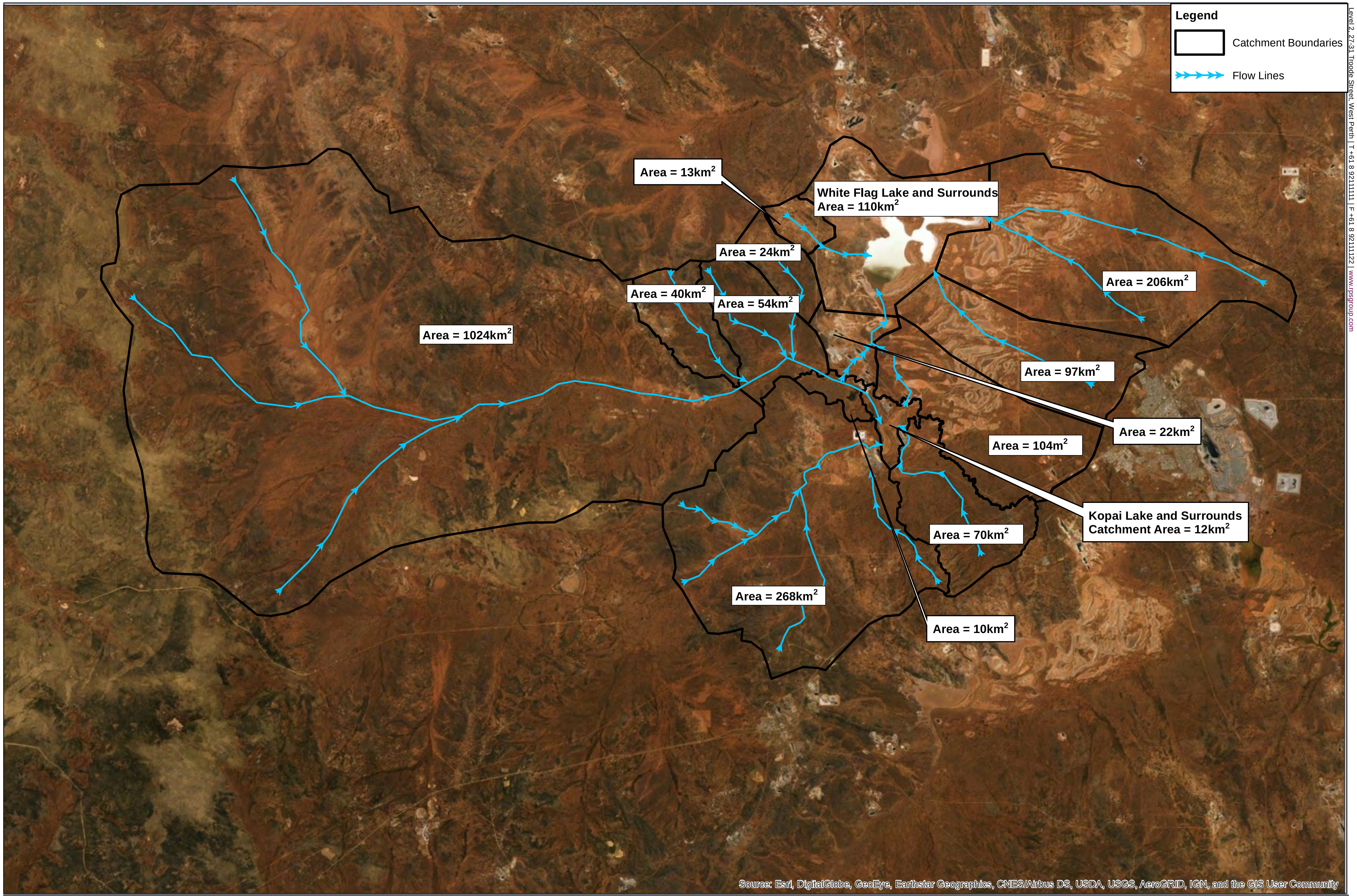
Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 | www.rpsgroup.com

Figure A
Kundana Mine Site
Regional Location Plan

GDA 1994 MGA Zone 50

Job Number:EWP19127.001
Doc Number: 001
Date: 28.05.20
Scale: Map 1:125,000 Overview 1:8,000,000 @ A3
Created by: ER
Source: Orthophoto - Esri, DigitalGlobe, GeoEye, Earthstar, Geographics, CNES/Airbus DS, USDA, USGS, Aerogrid, IGN, IGP and the GIS User Community

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001 - Regional Location Plan.mxd



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure B
White Flag Lake Catchment Areas

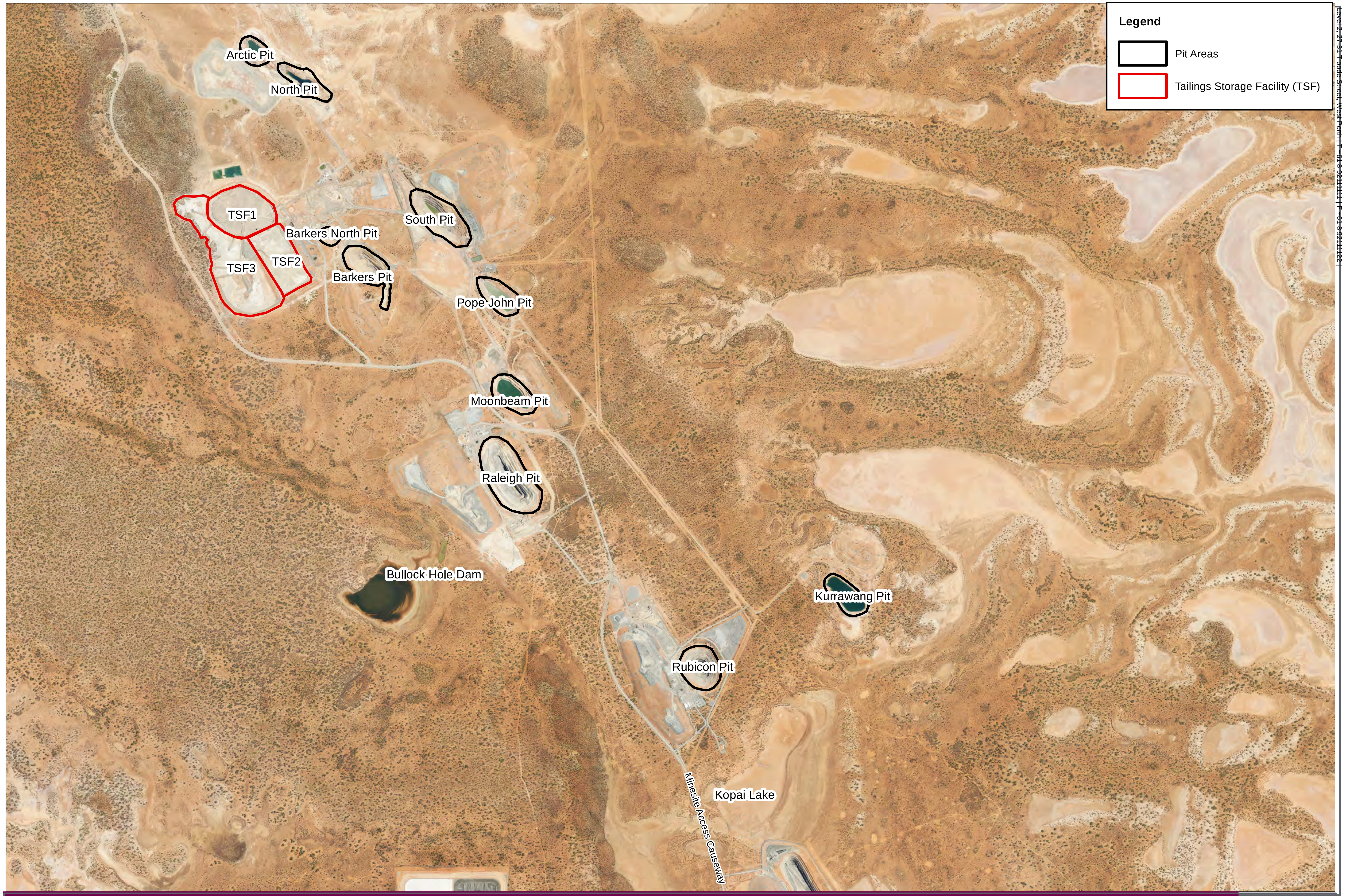
GDA 1994 MGA Zone 51

0 3,750 7,500 15,000 m

Job Number:EWP19127.001
Doc Number: 001
Date: 28.05.20
Scale: Map 1:250,000 Overview 1:250,000 @ A3
Created by: ER
Source: Orthophoto - Esri, DigitalGlobe, GeoEye, Earthstar, Geographics, CNES/Airbus DS, USDA, USGS, Aerogrid, IGN, IGP and the GIS User Community

rps

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 | www.rpsgroup.com



Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122

Figure C
Kundana Mine Site
General Layout

GDA 1994 MGA Zone 51

0 450 900 1,800 m

Job Number:EWP19127.001
Doc Number: 001
Date: 16.06.20
Scale: Map 1:30,000 Overview 1:30,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig C_General Layout.mxd

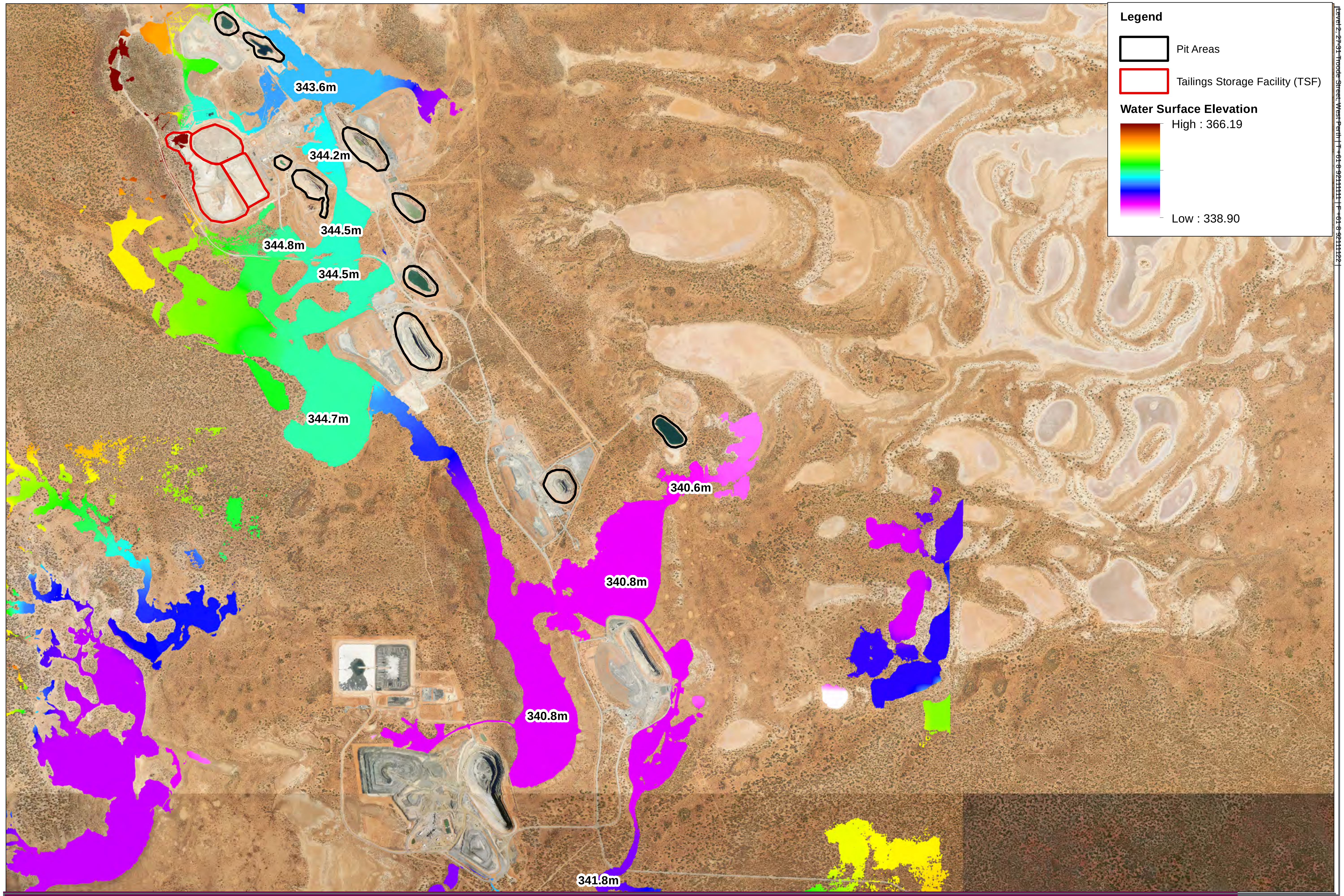


Figure D
Kundana Mine Site
10-Year Flood Levels (With Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

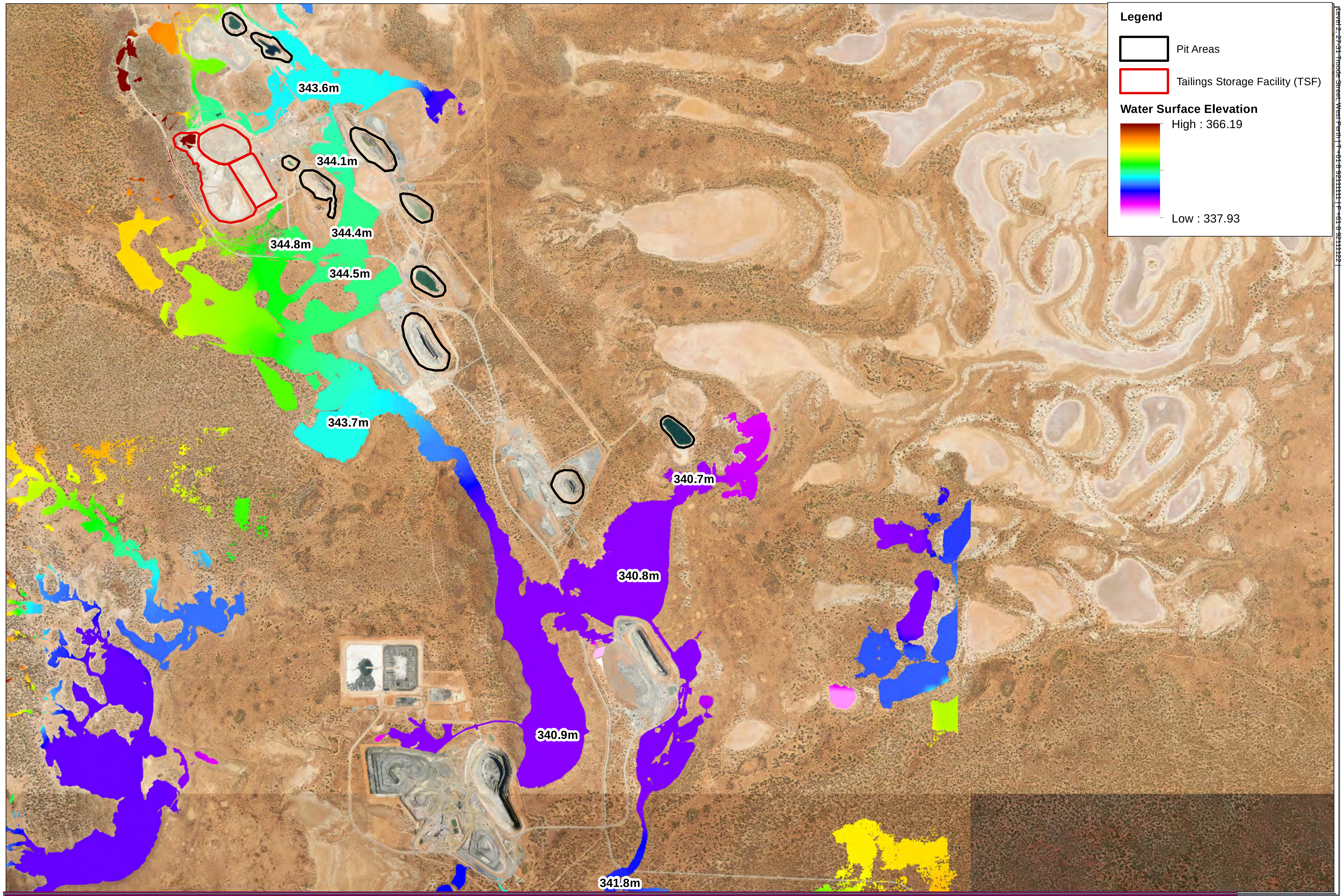
Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig D_10-year Flood Levels With Dam.mxd

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Figure E
Kundana Mine Site
10-Year Flood Depths (With Bullock Hole Dam)

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

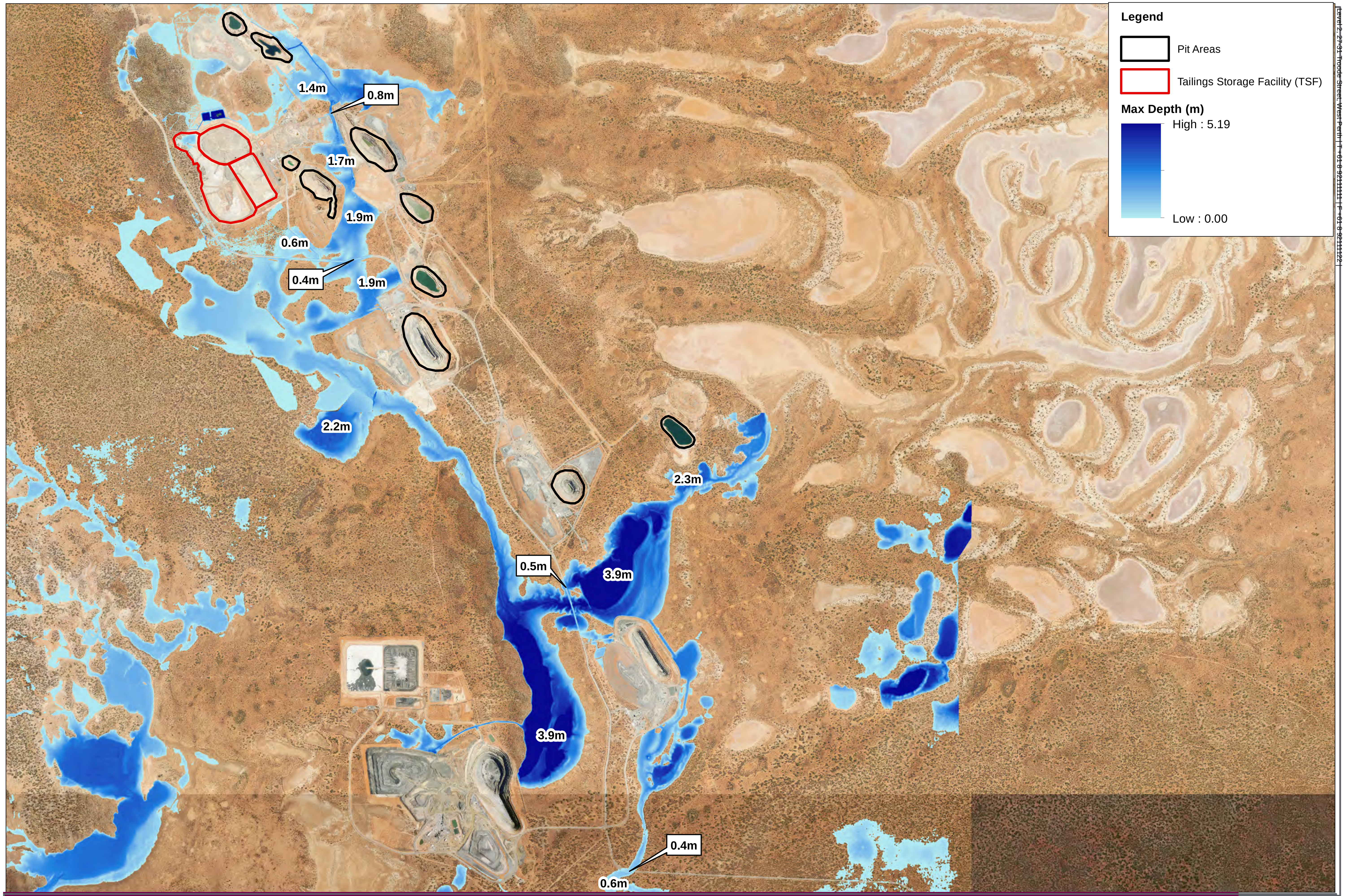


Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Figure F
Kundana Mine Site
10-Year Flood Levels (Without Bullock Hole Dam)

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig F_10-year Flood Levels Without Dam.mxd



Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122

Figure G
Kundana Mine Site
10-Year Flood Depths (Without Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig G_10-year Flood Depths Without Dam.mxd

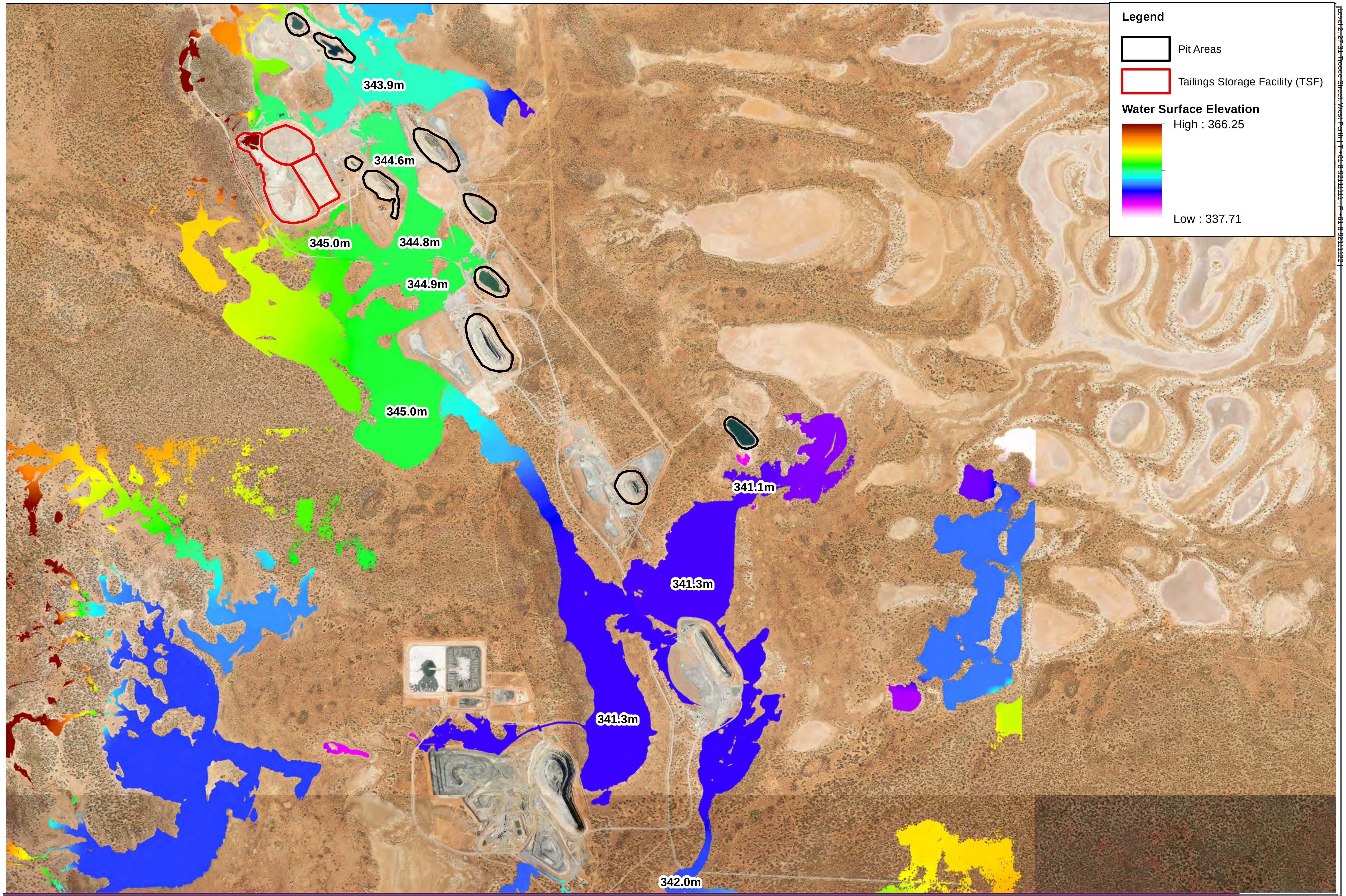


Figure H
Kundana Mine Site
20-Year Flood Levels (With Bullock Hole Dam)

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig H_20-year Flood Levels With Dam.mxd

Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122 |

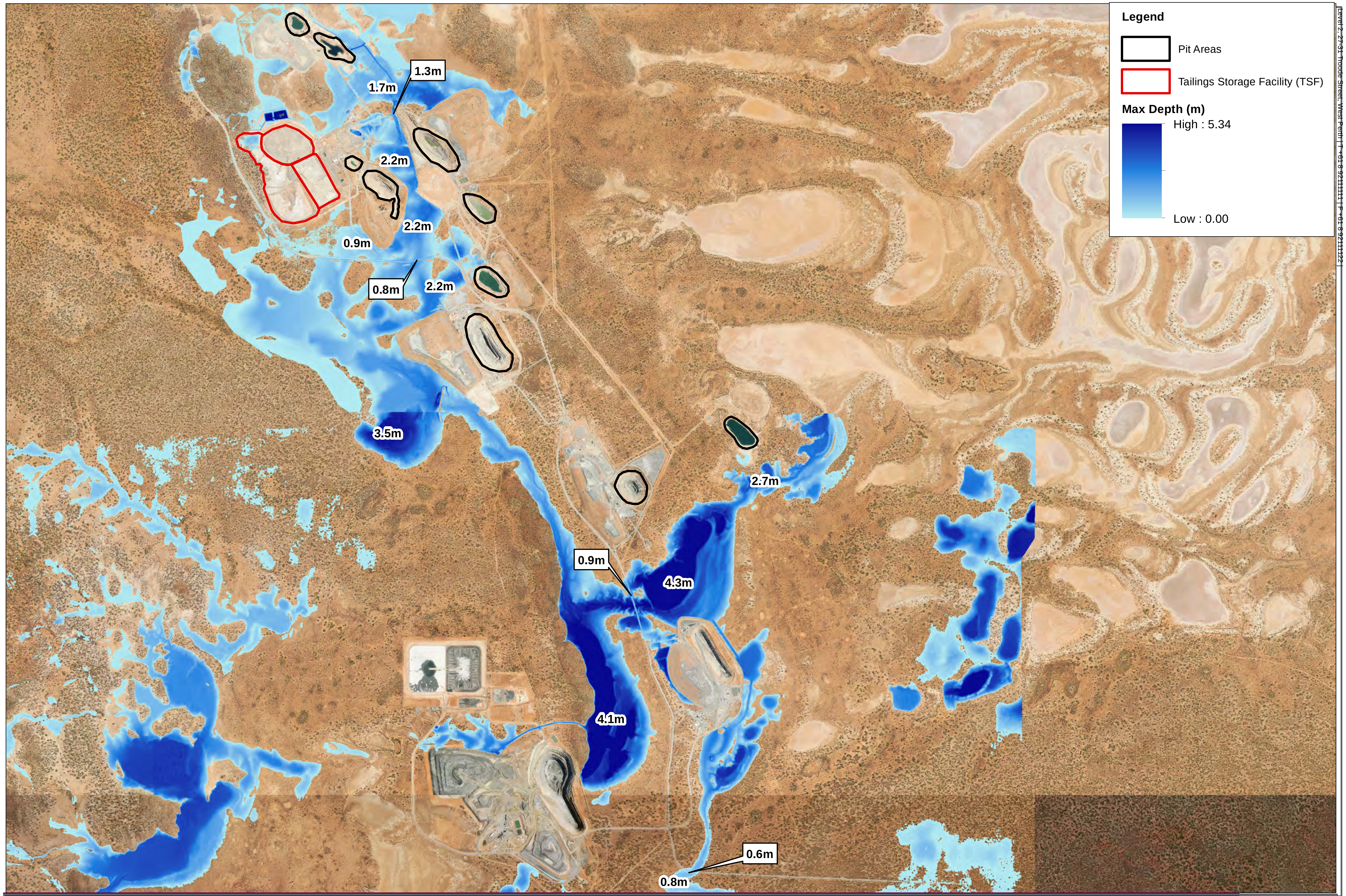


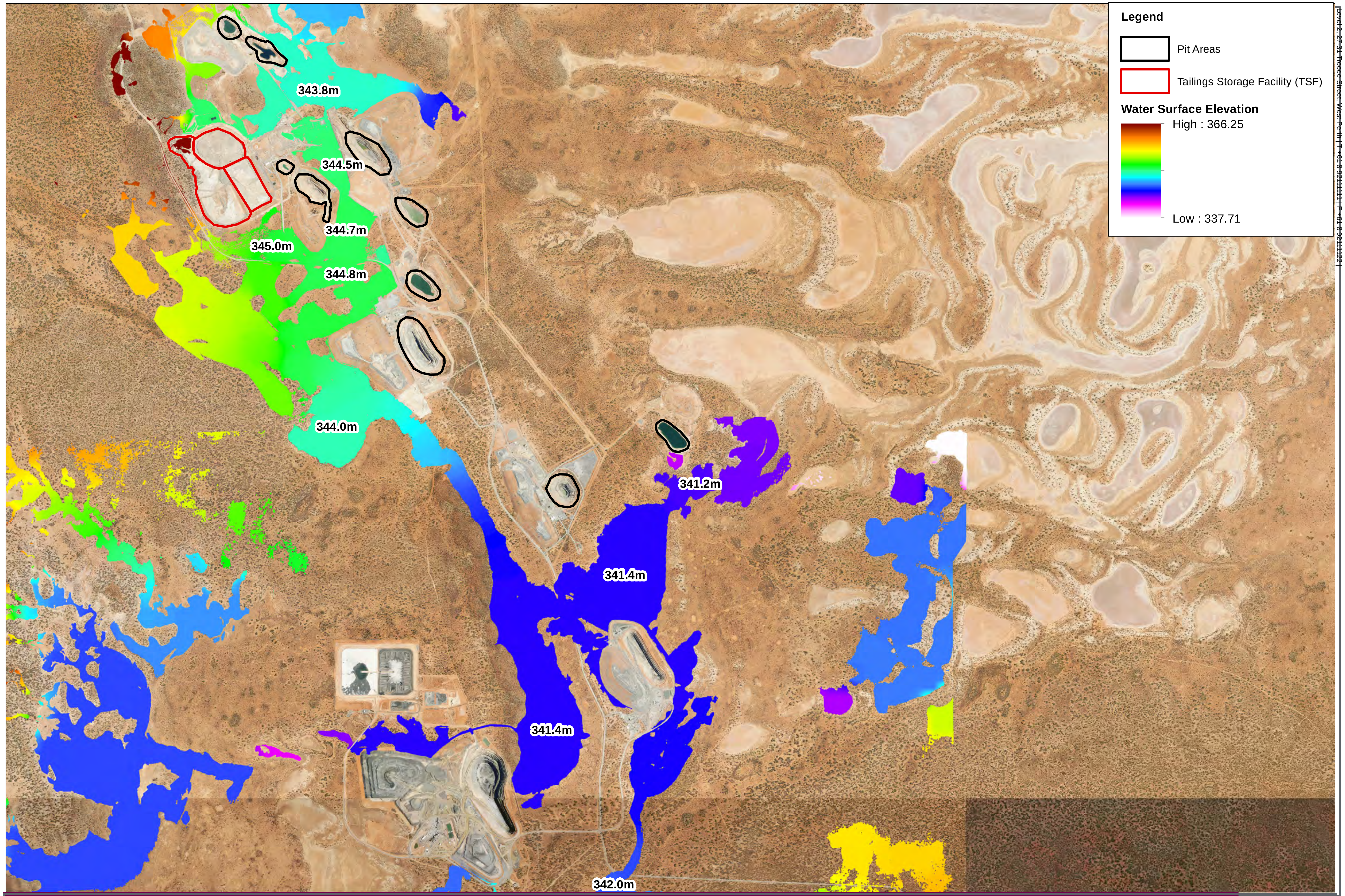
Figure I
Kundana Mine Site
20-Year Flood Depths (With Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig I_20-year Flood Depths With Dam.mxd



Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122 |

Figure J
Kundana Mine Site
20-Year Flood Levels (Without Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 24.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig J_20-year Flood Levels Without Dam.mxd

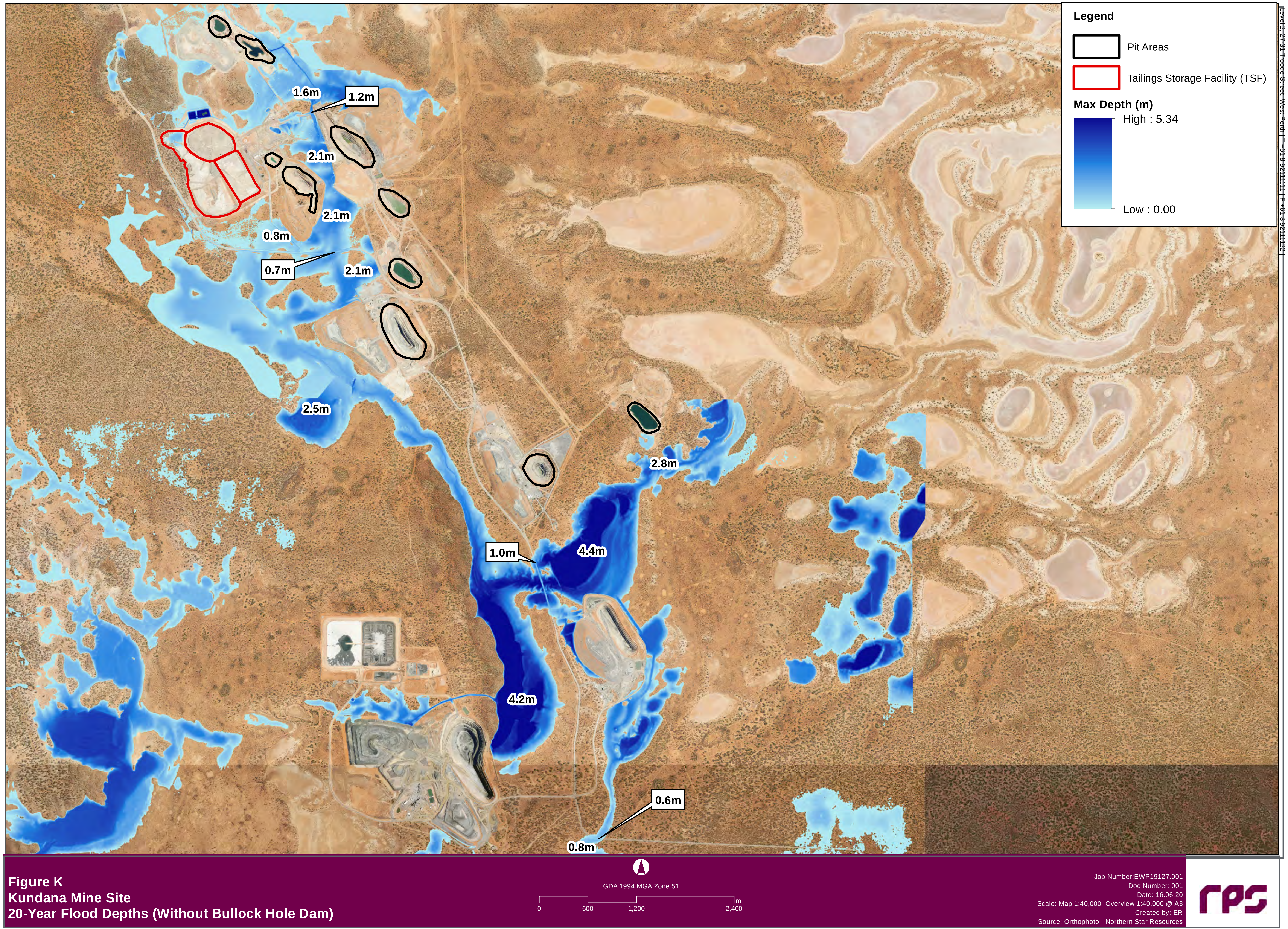
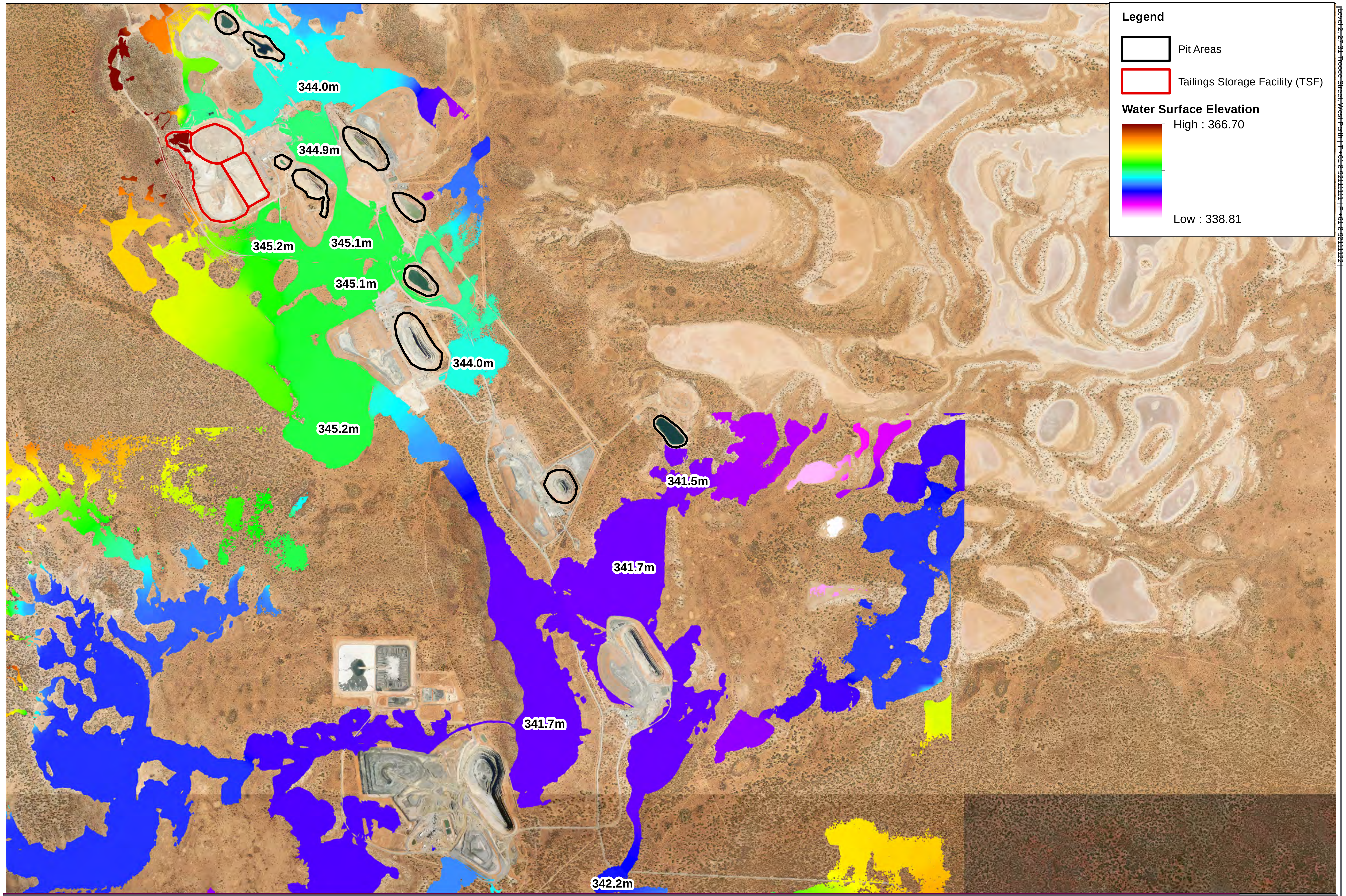


Figure K
Kundana Mine Site
20-Year Flood Depths (Without Bullock Hole Dam)

Job Number:EWP19127.001
Doc Number: 001
Date: 16.06.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig K_20-year Flood Depths Without Dam.mxd



Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Figure L
Kundana Mine Site
50-Year Flood Levels (With Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig L_50-year Flood Levels With Dam.mxd

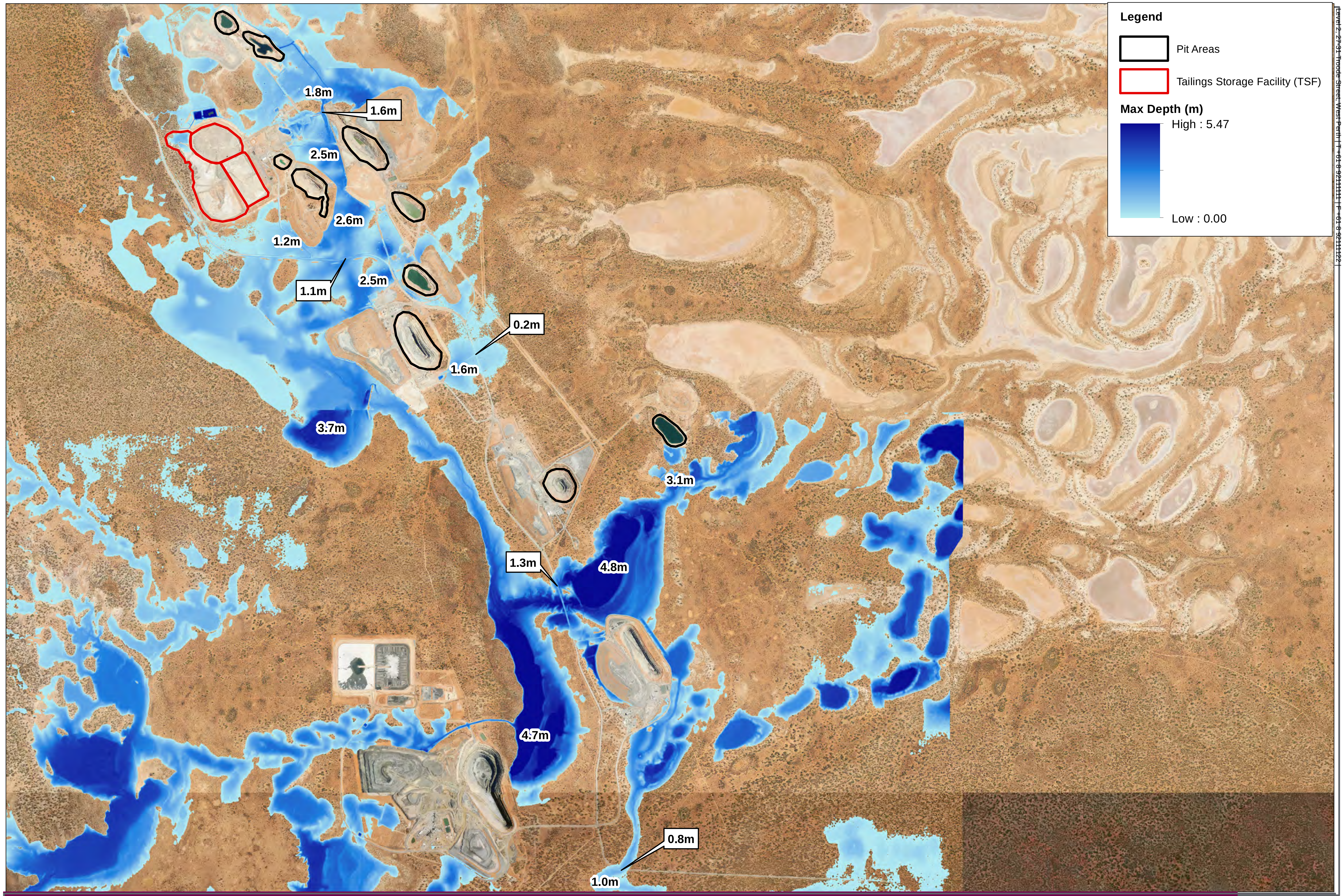


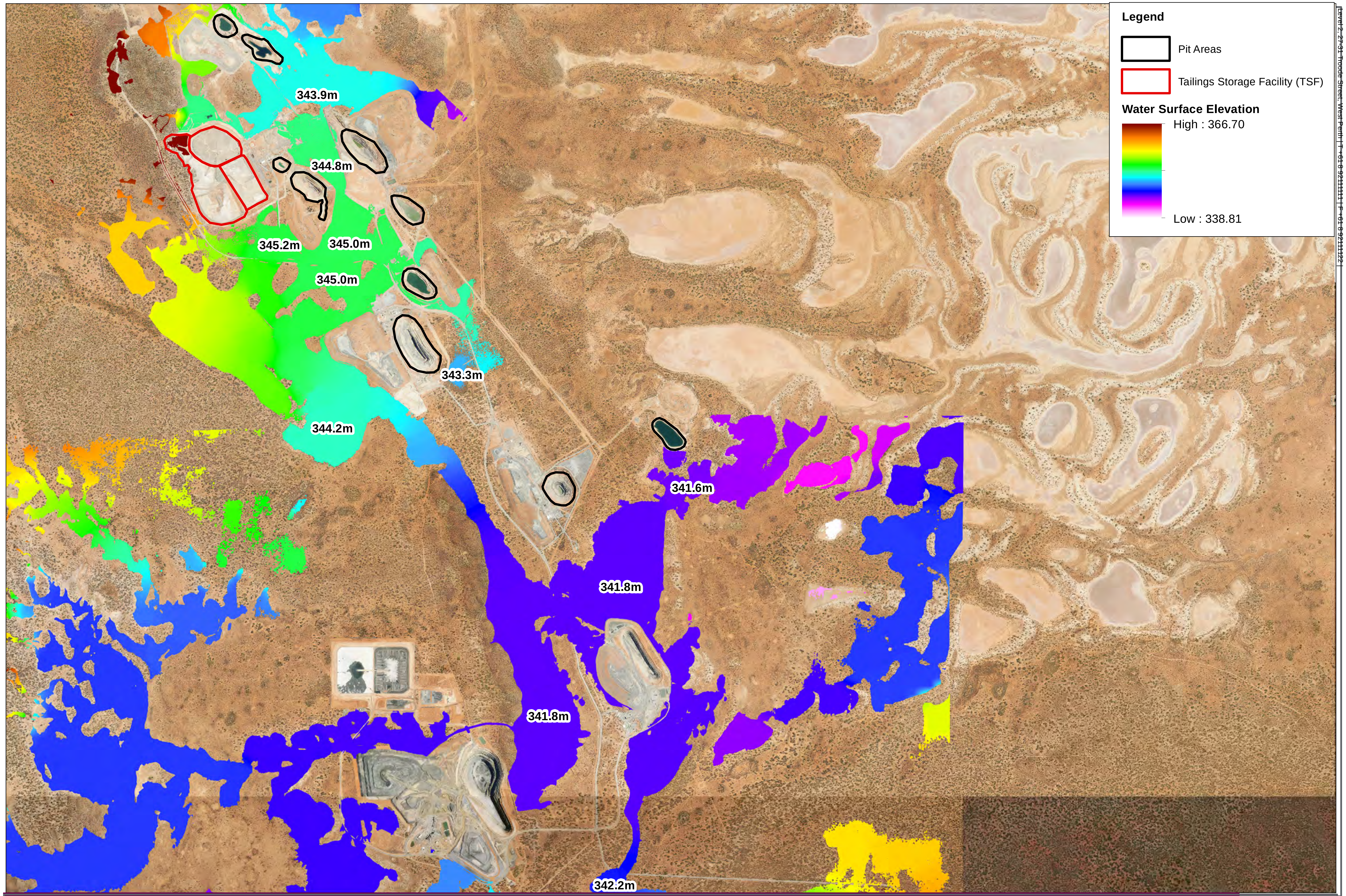
Figure M
Kundana Mine Site
50-Year Flood Depths (With Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |



Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Figure N
Kundana Mine Site
50-Year Flood Levels (Without Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 24.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig N_50-year Flood Levels Without Dam.mxd

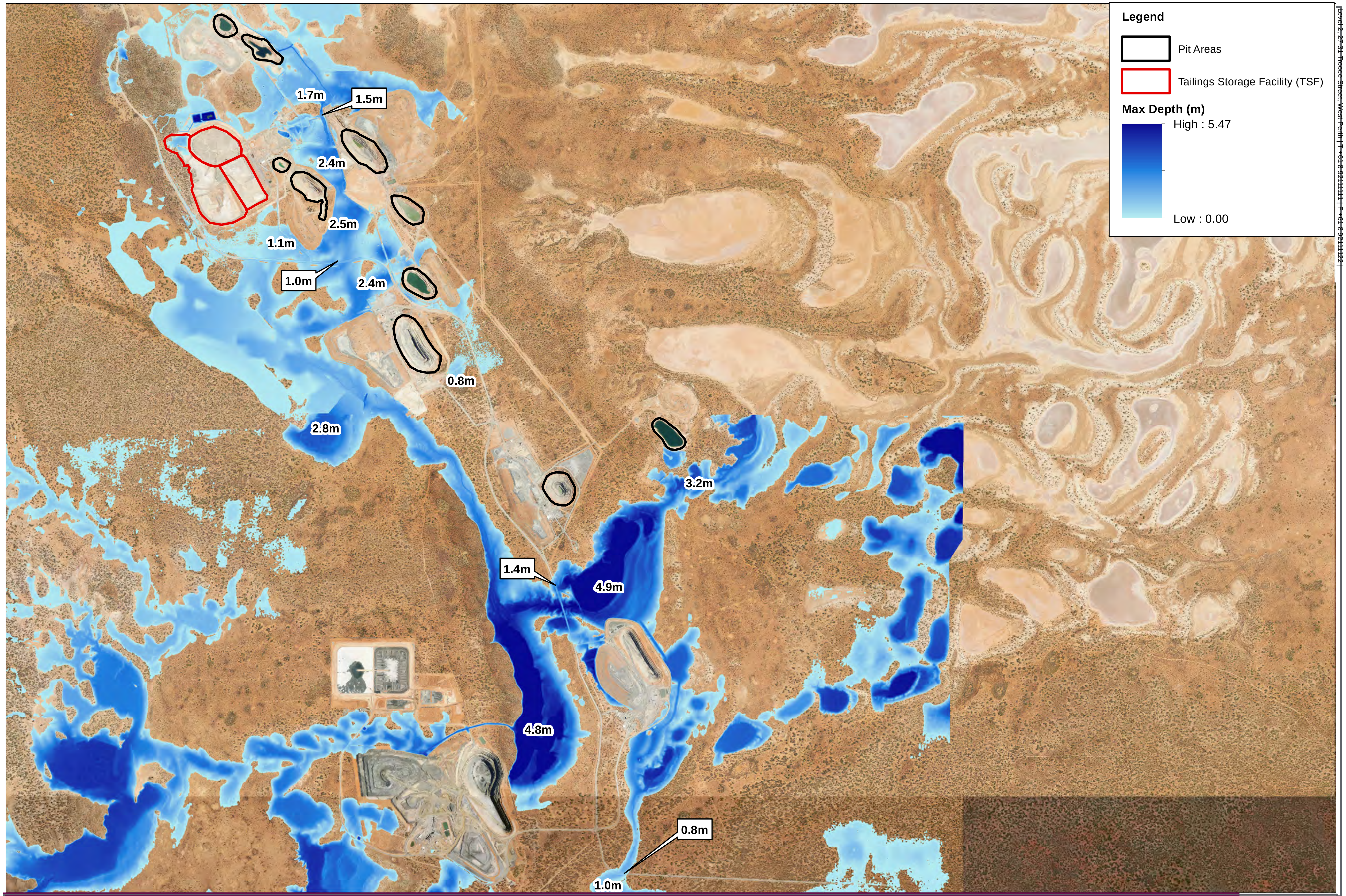


Figure O
Kundana Mine Site
50-Year Flood Depths (Without Bullock Hole Dam)

GDA 1994 MGA Zone 51

Job Number:EWP19127.001
Doc Number: 001
Date: 24.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig O_50-year Flood Depths Without Dam.mxd

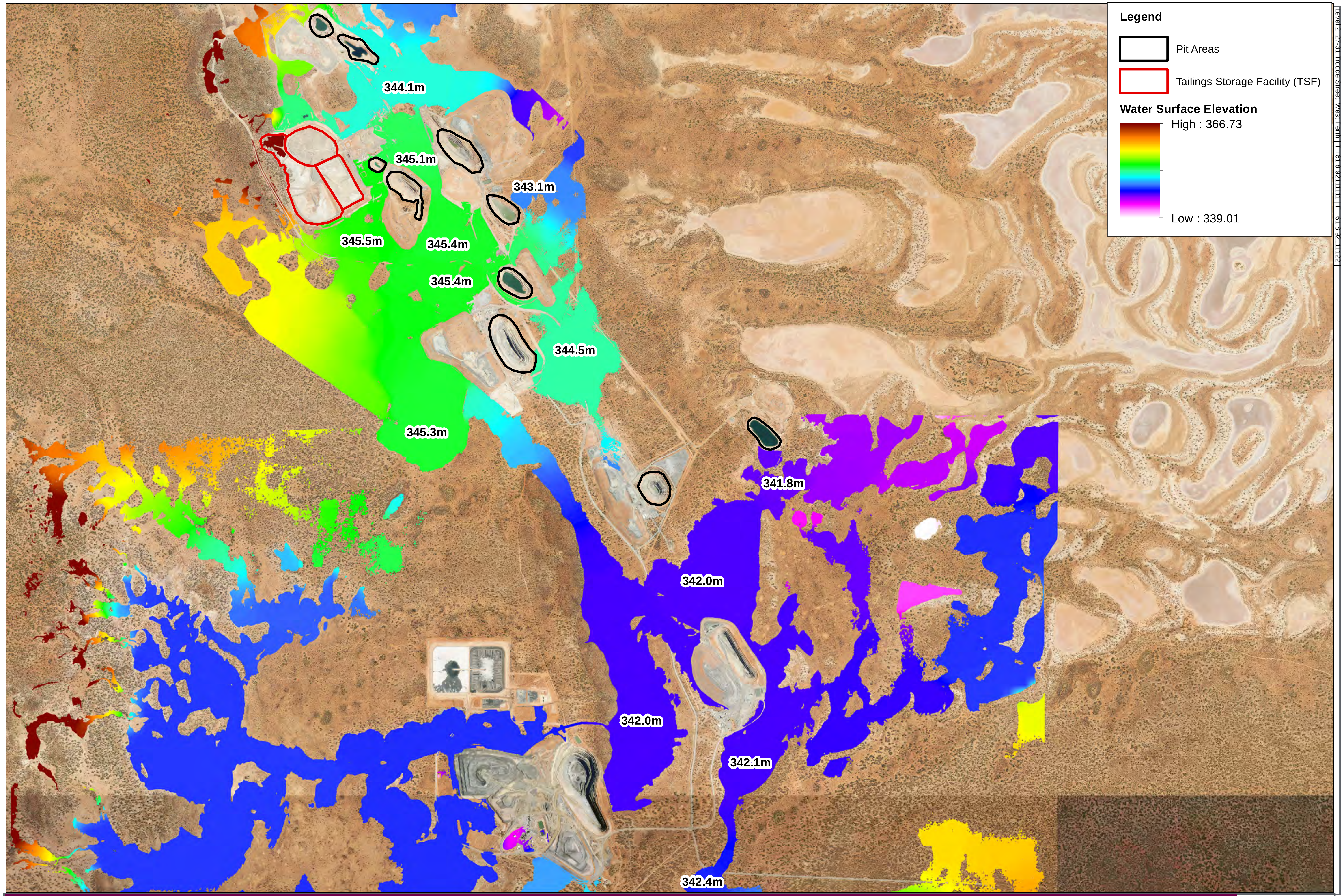
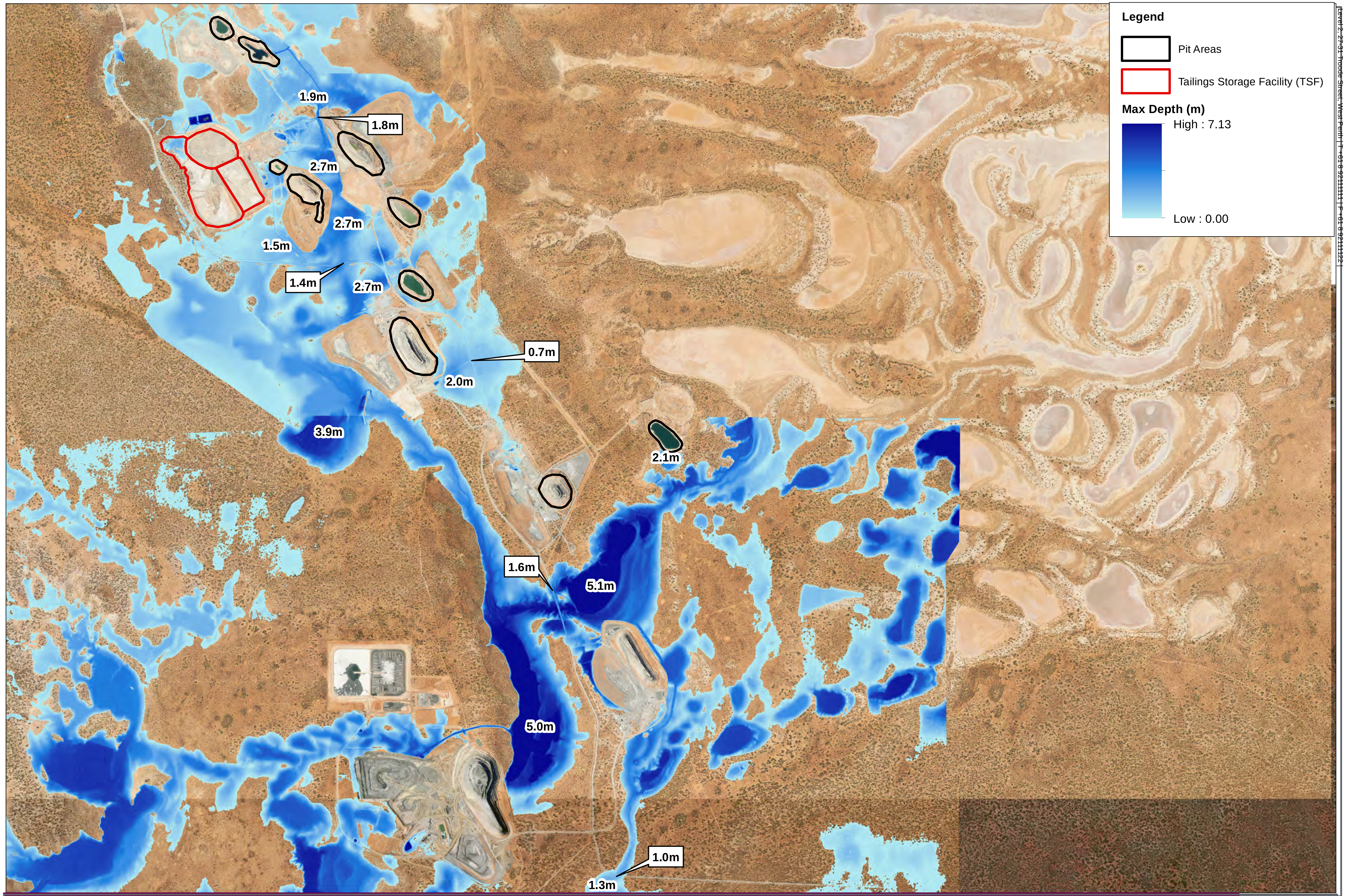


Figure P
Kundana Mine Site
100-Year Flood Levels (With Bullock Hole Dam)

GDA 1994 MGA Zone 51

Job Number:EWP19127.001
Doc Number: 001
Date: 20.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig P_100-year Flood Levels With Dam.mxd

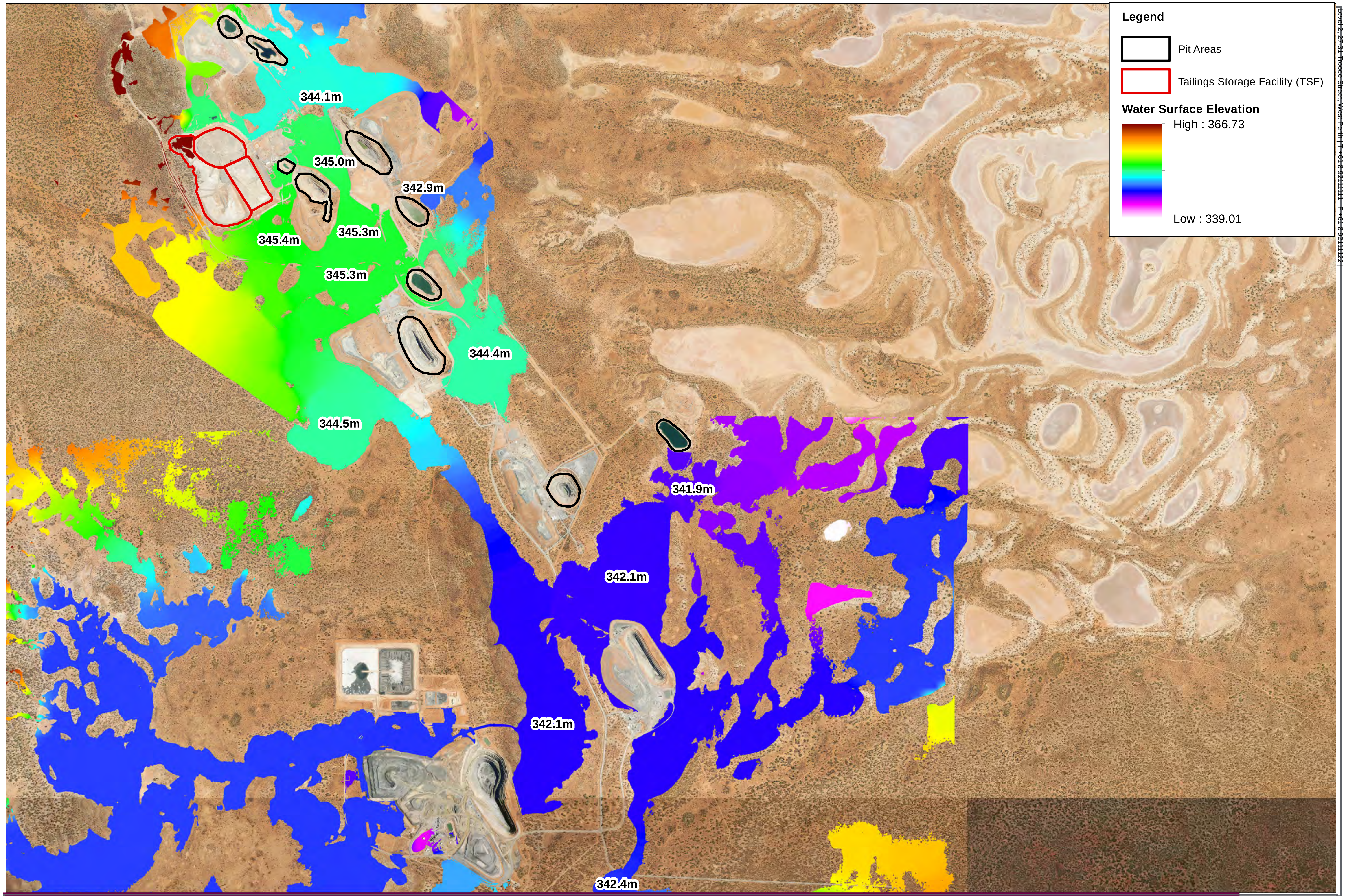


Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Figure K
Kundana Mine Site
100-Year Flood Depths (With Bullock Hole Dam)

Job Number:EWP19127.001
Doc Number: 001
Date: 17.06.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig Q_100-year Flood Depths With Dam.mxd



Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122 |

Figure R
Kundana Mine Site
100-Year Flood Levels (Without Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 24.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig R_100-year Flood Levels Without Dam.mxd

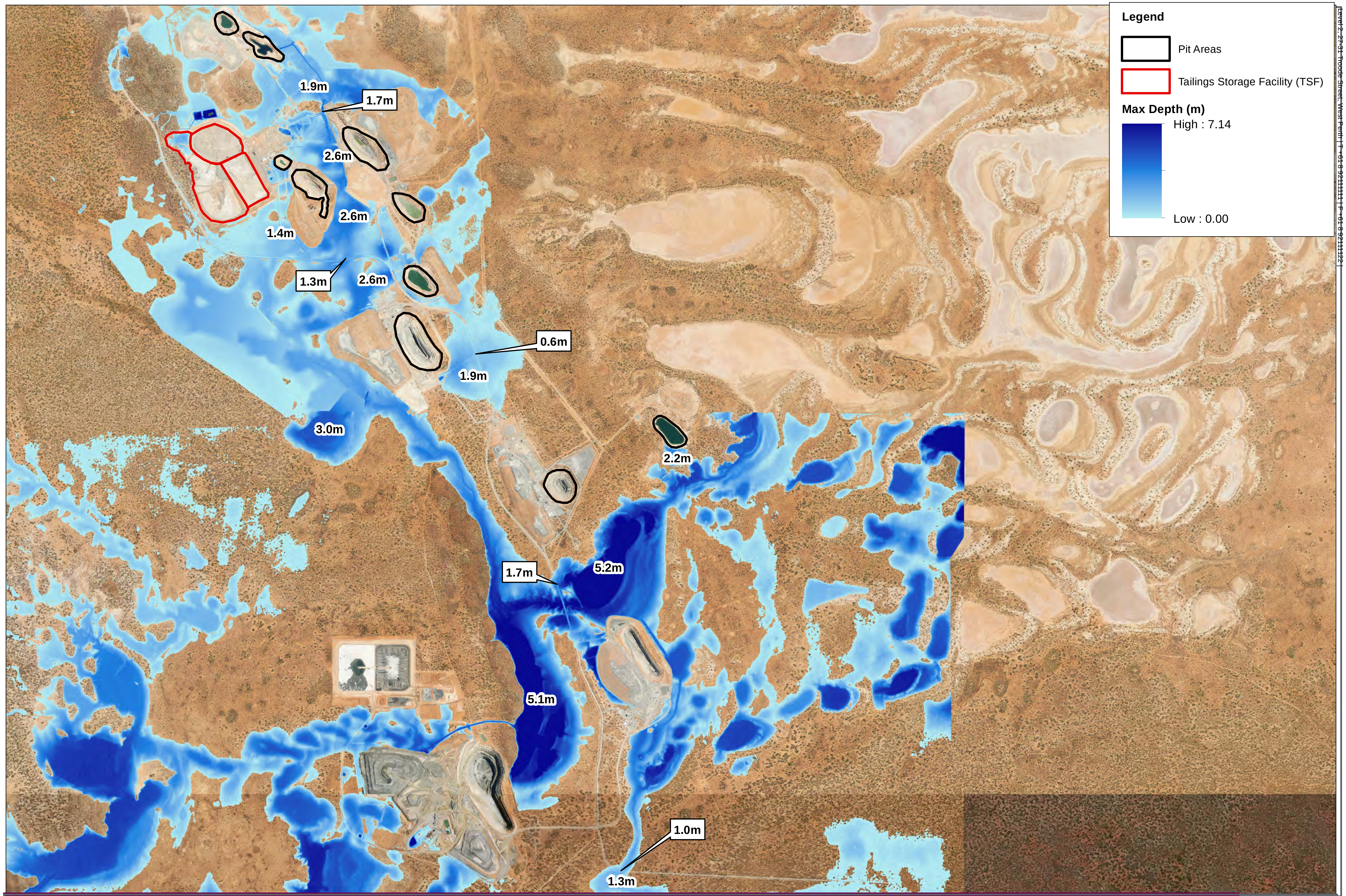


Figure S
Kundana Mine Site
100-Year Flood Depths (Without Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 24.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122 |

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig S_100-year Flood Depths Without Dam.mxd

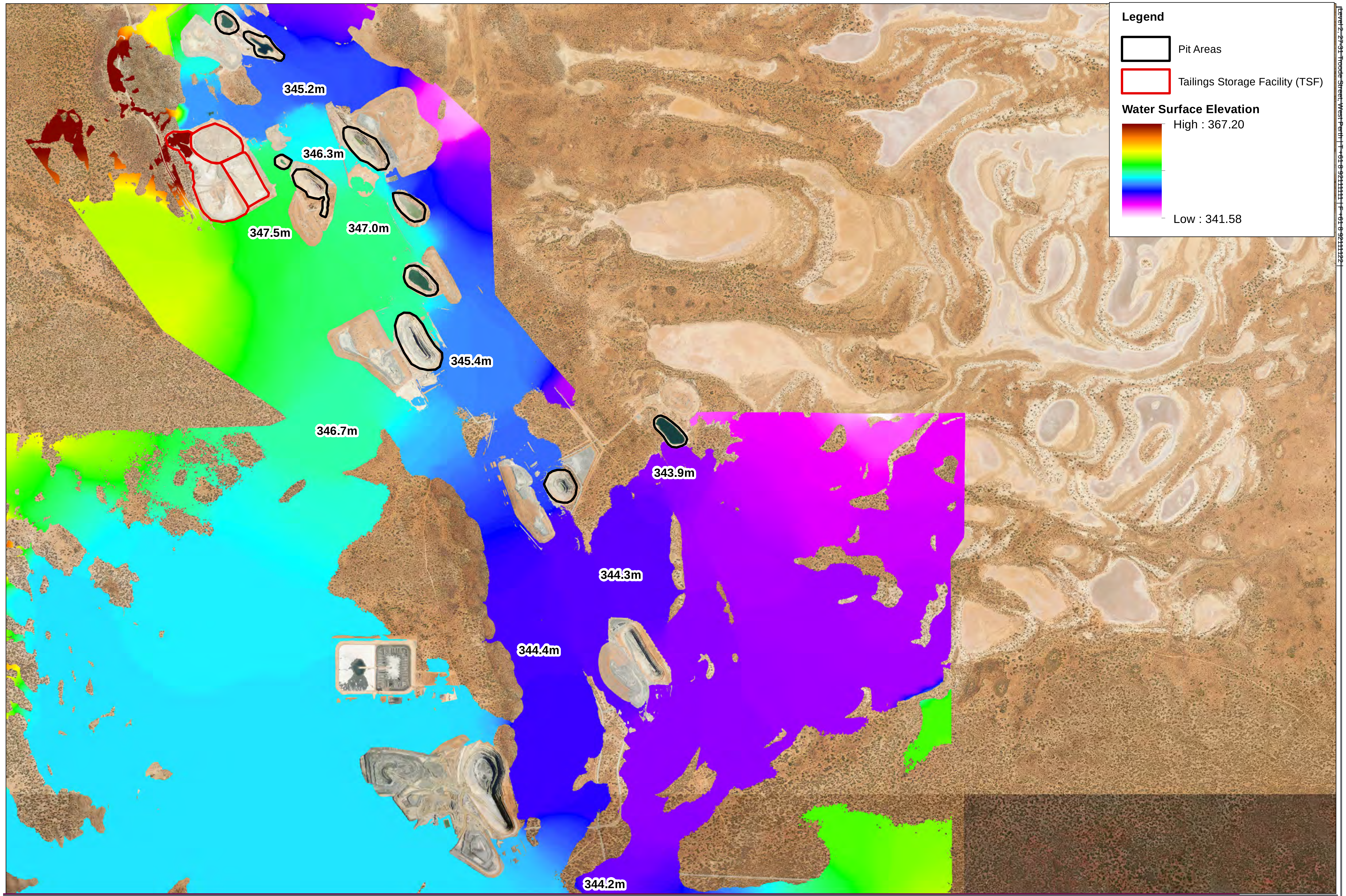


Figure T
Kundana Mine Site
PMF Flood Levels (Without Bullock Hole Dam)

GDA 1994 MGA Zone 51

0 600 1,200 2,400 m

Job Number:EWP19127.001
Doc Number: 001
Date: 26.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig T_PMF Flood Levels Without Dam.mxd

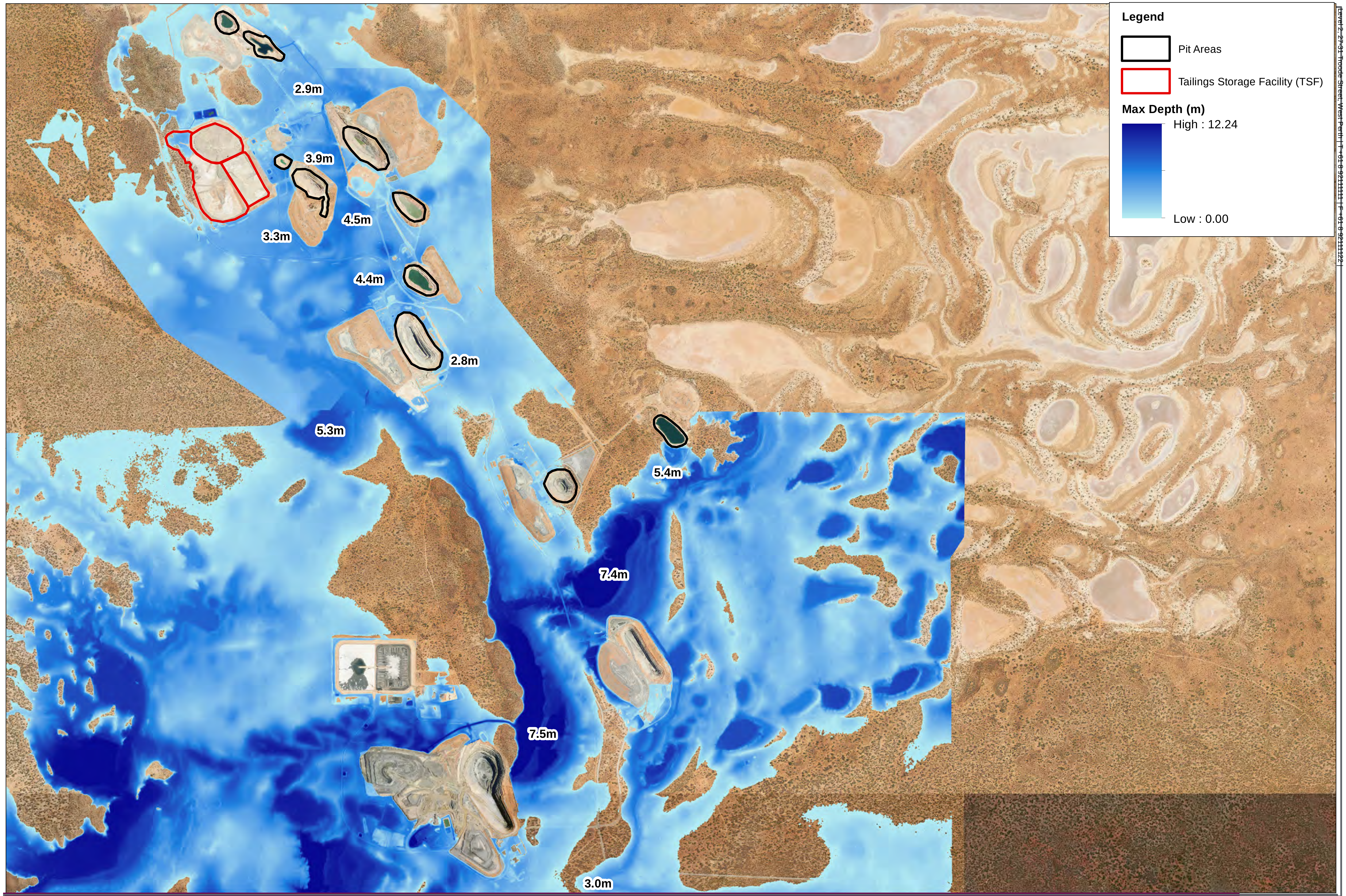


Figure U
Kundana Mine Site
PMF Flood Depths (Without Bullock Hole Dam)

Job Number:EWP19127.001
Doc Number: 001
Date: 26.08.20
Scale: Map 1:40,000 Overview 1:40,000 @ A3
Created by: ER
Source: Orthophoto - Northern Star Resources

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 |

Document Path: F:\Jobs\EWP19127.001 - NSR Kundana SW Assessment\600 - Report\Figures\EWP19127.001_Fig U_PMF Flood Depths Without Dam.mxd

Appendix F:

Surface Water Management Strategy for Hornet

(Aquaterra 2003)

PLACER DOME ASIA PACIFIC

SURFACE WATER MANAGEMENT STRATEGY FOR HORNET PIT

FINAL REPORT

SEPTEMBER 2003

Paul Davies
Senior Civil/Water Resources Engineer

Vince Piper
Principal Civil/Water Resources Engineer

Prepared by:

Aquaterra Consulting Pty Ltd

ABN 49 082 286 708

Suite 4, 125 Melville Parade
Como, Western Australia, 6152

Tel: (08) 9368 4044
Fax: (08) 9368 4055

3rd September 2003

EXECUTIVE SUMMARY

Placer Dome Asia Pacific proposes to develop the Hornet Pit Project on Mining Leases M16/309 and M15/669, located around 20 km west from Kalgoorlie, Western Australia. The proposed mine development, comprising an open cut pit, a waste rock dump and associated infrastructure, will be located in a relatively low lying flood prone area adjacent to Kopai Lake in the White Flag Lake Catchment, as shown in Figure 1.

The White Flag Lake Catchment, including the collection of lakes to the south and east, has a total area of approximately 2,000 km^2 and extends approximately 70 km to the west from Kalgoorlie. Although the catchment topography generally grades to White Flag Lake and the Kopai Lake system, there are numerous areas of depression storage in the catchment that require significant amounts of rainfall to fill before the downstream creeks begin to flow. Flood discharge flow and level data are not recorded in the catchment or in the general area and as such, accurate relationships between rainfall, runoff and flood level cannot be derived. However, some anecdotal flood depth information data is available for Kopai Lake.

The Kopai Lake System is made up of Kopai Lake, Greta Lake and the adjacent downstream lakes as shown on Figure 2. After a significant runoff event, the deepest section of Kopai Lake is reported to hold two to three metres of water making it popular for recreational activities (eg. water skiing, jet skis). The Kundana mine main access road crosses a shallow section of the lake on a causeway and is around two metres high. This causeway has been constructed with a relatively horizontal crest through the lake area with a finished surface level at RL 340.2 m. Kundana mine personnel report that during the March 2000 flood event, flood levels peaked at around 1.0 m depth over the causeway making the March 2000 peak flood level around RL 341.2 m in Greta Lake. Kopai Lake discharges into the downstream channel at around RL 339.3 m and analyses indicate that for the very large flood discharges, the downstream channel flood flow levels will cause backwater to submerge the causeway area. This is likely to have happened during the March 2000 flood event.

Given the lack of definitive flood level (and flood discharge) data for the Kopai Lake area, only an approximate estimate for the 100 year ARI flood level can be made and based on the available data, a design flood level of RL 341.3 m has been estimated.

The pit in the proposed Hornet Pit mine development will be located partially within Kopai Lake as outlined in Figure 3, so will be potentially subjected to inundation from floodwaters. The waste dump also extends into the lake area, so will be subject to partial inundation from floodwaters. It will require protection from water pooling against the toe of the dump, potentially causing instability. All other mine infrastructure will be located outside of the lake.

Hornet Pit Stage One and its associated flood protection bunding, will have only a minor encroachment into the Kopai Lake floodplain, so will have negligible impact on flood levels. However, Stage Two Pit and its associated bunding will have a significant encroachment into the floodplain, but the rise in the estimated 100 year ARI flood level will be negligible. The proposed location of Stage Two Pit and bunding is preliminary, so will likely be revised later.

The average 100 year ARI floodplain velocities in the Kopai Lake floodplain adjacent to Hornet Pit are estimated to be typically less than 0.3 m/s for both Stage One and Stage Two. However, local to the flood protection bunds, flood flow velocities would likely be up to 50 percent higher than those across the general floodplain. Frogs Leg Pit, located to the south of Kopai Lake, is just outside of the main floodplain flow path of the lake, so will have no impact on lake flood levels or flow velocities.

The proposed surface water management plan for the Hornet Pit Project area is outlined in Figure 4. This plan consists of flood protection bunding around the pit development area that provides protection to the pit against the design 100 year ARI flood event including a minimum freeboard allowance of 1.0 m. In addition, the section of the waste dump batter subject to inundation will require rock armouring to protect it from potential instability from water ponding against the toe of the dump.

For both Stage One and Two pit developments, the 100 year ARI design flood level in Kopai Lake adjacent to Hornet Pit has been estimated at RL 341.3 m, so the recommended minimum crest level for the flood protection bunding is RL 342.3 m.

All flood protection bunds will be built to an engineering specification using competent materials and will typically consist of a level top section a minimum of 3 m wide with side batters of 1:3. Bund corners protruding into the lake will be rounded to give a hydraulically smooth profile.

The flood flow velocities adjacent to Hornet Pit are relatively low, so general rock armouring of the bunds to protect them from erosion will not be required. However, bund corners protruding into the lake will require some localised rock armour protection.

TABLE OF CONTENTS

FIGURES

SECTION 1 - INTRODUCTION

Placer Dome Asia Pacific proposes to develop the Hornet Pit Project on Mining Leases M16/309 and M15/669, located around 20 km west from Kalgoorlie, Western Australia. The proposed mine development, comprising an open cut pit, a waste rock dump and associated infrastructure, will be located in a relatively low lying area adjacent to Kopai Lake. Although this proposed development area is known to be periodically inundated by floodwaters, no formal records for streamflow or flood levels have been collected in the local catchments. However, some anecdotal flood level data are available for Kopai Lake.

This report describes the surface hydrology in the project development area, assesses the impact of the proposed project on the surface water systems and defines the surface water management strategy to protect the proposed development area from external flooding.

SECTION 2 - REGIONAL DRAINAGE

The Hornet Pit Project is located adjacent to Kopai Lake in the White Flag Lake Catchment, as shown in Figure 1. The White Flag Lake Catchment, including the collection of lakes to the south and east, has a total area of approximately 2,000 km^2 and extends approximately 70 km to the west from Kalgoorlie. Although the catchment topography generally grades to White Flag Lake and the Kopai Lake system, there are numerous areas of depression storage in the catchment that require significant amounts of rainfall to fill before the downstream creeks begin to flow. Similarly, runoff from the catchment tends to fill one lake before overspilling into the next lake downgradient. Topographic data suggests that excess water collected on White Flag Lake would tend to overspill to Black Flag Lake in the north as well as to the adjacent smaller lakes to the east. However, due to topography, overspill from White Flag Lake would not normally drain to Kopai Lake, or visa versa.

The majority of flow in the White Flag Lake Catchment is from the Western Catchment, with an area in excess of 1200 km^2 (Figure 1). Flood discharge flow and level data are not recorded on the Western Catchment or in the general area and as such, accurate relationships between rainfall, runoff and flood level cannot be derived. However, based on the rainfall data associated with recent flood events, the Western Catchment typically produces a significant flood event following a minimum 100 mm of rainfall spread over a few days. Then, while the catchment is still relatively wet, a second significant flood event could result from a rainfall of less than 100 mm. Over the past ten years, rainfall events of over 100 mm have occurred on five occasions, three of which were over 150 mm. Based on historical data, these last ten years form a period containing above average high rainfall events, which have resulted in several significant flood events. During this period, the more extreme flood events are estimated to represent floods with an Average Recurrence Interval (ARI) of around 20 years.

Historically, runoff from the Western Catchment feeds into the Kopai Lake system with overspill from the main channel flowing northwards through the Kundana area into White Flag Lake. With construction of Bullock Hole Dam (initially for use by the pastoralist) and the Kundana mine infrastructure, all but the most extreme flood flows from the main creek will now be diverted northwards through Kundana. These flows will generally follow the natural flood flow routes within the Kundana mine area into either a disused pit for reuse by the minesite, or to White Flag Lake. During extreme floods, some flows will bypass Bullock Hole Dam and discharge into the Kopai Lake system. Culverts proposed to be constructed through the dam wall will also allow smaller environmental base flows to discharge in to the Kopai Lake system. Upon cessation of mining activities at Kundana, the height of Bullock Hole Dam may be reduced, such that more flow will discharge to the Kopai Lake system.

SECTION 3 - KOPAI LAKE SYSTEM

The Kopai Lake System is made up of Kopai Lake, Greta Lake and the adjacent downstream lakes as shown on Figure 2. The lake system potentially receives rainfall runoff water from the main Western Catchment (the flows that are not diverted by Bullock Hole Dam), from a large catchment to the southwest of the lakes and from its own small local catchment to the south. After a significant runoff event, the deepest section of Kopai Lake is reported to hold two to three metres of water making it popular for recreational activities (eg water skiing, jet skis). Additionally, the Kundana mine main access road crosses the lake on a causeway, making access to the lake relatively easy. The lake on the western side of the access road causeway is referred to by locals as Greta Lake and on the eastern side as Kopai Lake.

The causeway supporting the Kundana mine access road has been located on a shallow portion of the lake and is around two metres high. This causeway has been constructed with a relatively horizontal crest through the lake area with a finished surface level at RL 340.2 m. A nominal sized culvert is reported to have been installed under this causeway. All runoff flowing into Greta Lake must pass this causeway to continue downstream into Kopai Lake and to a string of other lakes further to the east. Flood discharges travelling downstream progressively fill each lake until the flood volume has been absorbed. Insufficient topographical data is available to determine the exact links between all the lakes; however, it is possible that flood waters (if sufficient volume) may eventually drain via a tortuous route all the way to White Flag Lake.

The main discharges to the Kopai Lake system are believed to come from the very large Western Catchment, with only minor discharges from its own small local catchment. The large catchment to the southwest of Greta Lake has had its natural outlet to the lake blocked by the recent White Foil Gold Project development. However, a diversion channel has been constructed to re-establish this flowpath. Anecdotal evidence suggests that floodwaters do not discharge to Greta Lake from the large Southwest Catchment, due to several very large capacity lakes in the catchment (eg Cattle Swamp), which hold all runoff water from the upstream areas. Insufficient topographical data is available to confirm this belief.

Kopai Lake's small local catchment (about 80 km^2) to the south, discharges into the lake during large flow events. Three interconnected lakes in this catchment store smaller flows up to about a 20 year ARI (estimated at 85 m^3/s based on approximate flood volume estimates), with larger flows overtopping into Kopai Lake at about a water level between RL 340.5 to 340.75 m. Hence for the 100 year ARI flood event in Kopai Lake (resulting from discharges in the large Western Catchment), which has an estimated design flood level of RL 341.3 m, water will overspill from Kopai Lake into the lakes in this catchment to the south.

As with most other drainage systems in this region, only anecdotal flood level information is available for the lake system. The White Foil Gold Project, located adjacent to Greta Lake is reported to have flood protection bunds constructed to RL 342.0 m. The design for these bunds is reported to be partly based on a maximum flood level estimate of RL 340.5 m determined for a flood in 1999 (assumed March 1999), following a major cyclonic event (pers. com. Lloyd Townley, June 2003). Also, the Frogs Leg Project located adjacent to Kopai Lake, is proposed to have flood protection bunds constructed to RL 342.5 m. This is 1.0 m above an estimate of the 100 year ARI flood level in Kopai Lake of RL 341.5 m, based on a previous hydrological assessment (Aquaterra, 2003) with limited level data downstream of the lake.

Kundana mine personnel report that during the March 2000 flood event, flood levels peaked at around 1.0 m depth over the lake causeway (pers. com. Jim Nicholson, March 2001). With a causeway crest level of RL 340.2 m, this would make the March 2000 peak flood level around RL 341.2 m in Greta Lake. Rainfall in March 2000 (approx. 130 mm), which caused the large flood event, fell on a catchment still wet from heavy rainfall in January 2000 (approx. 180 mm). Hence it is feasible that the March 2000 flood event was larger than the March 1999 flood event (rainfall approx. 210 mm), based on total rainfall volumes.

Floodwaters discharging over the lake causeway, from Greta Lake to Kopai Lake, would initially flow as weir flow (i.e. free discharge, typically at less than 0.5 m depth over the causeway). As Kopai Lake also filled, the weir would potentially become submerged and flood levels would be controlled by water levels in the downstream channel linking to the next downstream lake. Survey data obtained for the Kopai Lake downstream discharge channel indicates that the lake spill level is around RL 339.3 m (ie approx 0.9 m below the causeway crest level).

A HEC-RAS hydraulic backwater model of this downstream channel and Kopai Lake has been developed, based on survey data to +/- 0.25 m. This modelling indicates that for the very large flood discharges the downstream flood flow levels will submerge the causeway area. With the reported peak flood levels for March 2000 (ie approx. RL 341.2 m), this is likely to have happened.

Given the lack of definitive flood level (and flood discharge) data for the Kopai Lake area, only an approximate estimate for the 100 year ARI flood level can be made. Based on the backwater model mentioned above, the design 100 year ARI flood level estimate in Kopai Lake is RL 341.3 m. This is consistent with the previous assessment of the 100 year ARI flood level estimate in the lake of RL 341.5 m, made for the adjacent Frogs Leg Project, mentioned above. To protect the proposed mine workings, flood bunds should be constructed with a freeboard allowance to reflect the risk involved. For an open pit mine development, a minimum freeboard allowance of 1.0 m is recommended.

SECTION 4 - PROPOSED MINE DEVELOPMENT

The proposed mine development for the Hornet Pit Project comprises an open cut pit, a waste rock dump and other associated infrastructure. The pit will be located partially within Kopai Lake as outlined in Figure 3, so will be potentially subjected to inundation from floodwaters. The waste dump will also extend into the lake area, but will be outside of the major flow path. However, as the waste dump will be subject to partial inundation from floodwaters, it will require protection from water pooling against the toe of the dump, potentially causing instability. All other mine infrastructure will be located outside of the lake.

The open pit and its associated protection bunding will be constructed in two stages as shown in Figure 4. Stage One Pit will be located such that it just extends into Kopai Lake. Its safety/flood protection bunding will be just outside of the proposed footprint of Stage Two Pit. The location of Stage Two Pit and its associated abandonment/flood protection bunding is preliminary, so will likely be revised later. The protection bunding for this second stage of the development extends approximately half way into the lake. All flood protection bunds will need to fully enclose the pit and tie into high ground to prevent the entry of external floodwaters.

SECTION 5 - IMPACT OF THE WORKS

Stage One Hornet Pit and its associated flood protection bunding will have only a minor encroachment into the Kopai Lake floodplain. The HEC-RAS backwater model described above indicated that this pit and flood protection bunding will have a negligible impact on lake flood levels. However, Stage Two Pit and its associated bunding will have a significant encroachment into the floodplain, but the rise in the estimated 100 year ARI flood level will be negligible.

The average 100 year ARI floodplain velocities in the Kopai Lake floodplain adjacent to Hornet Pit are estimated to be typically less than 0.3 m/s for both Stage One and Stage Two. However, local to the flood protection bunds, flood flow velocities would likely be up to 50 percent higher than those across the general floodplain.

Frogs Leg Pit, located to the south of Kopai Lake, is just outside of the main floodplain flow path of the lake, so will have no impact on lake flood levels or flow velocities.

SECTION 6 - SURFACE WATER MANAGEMENT STRATEGY

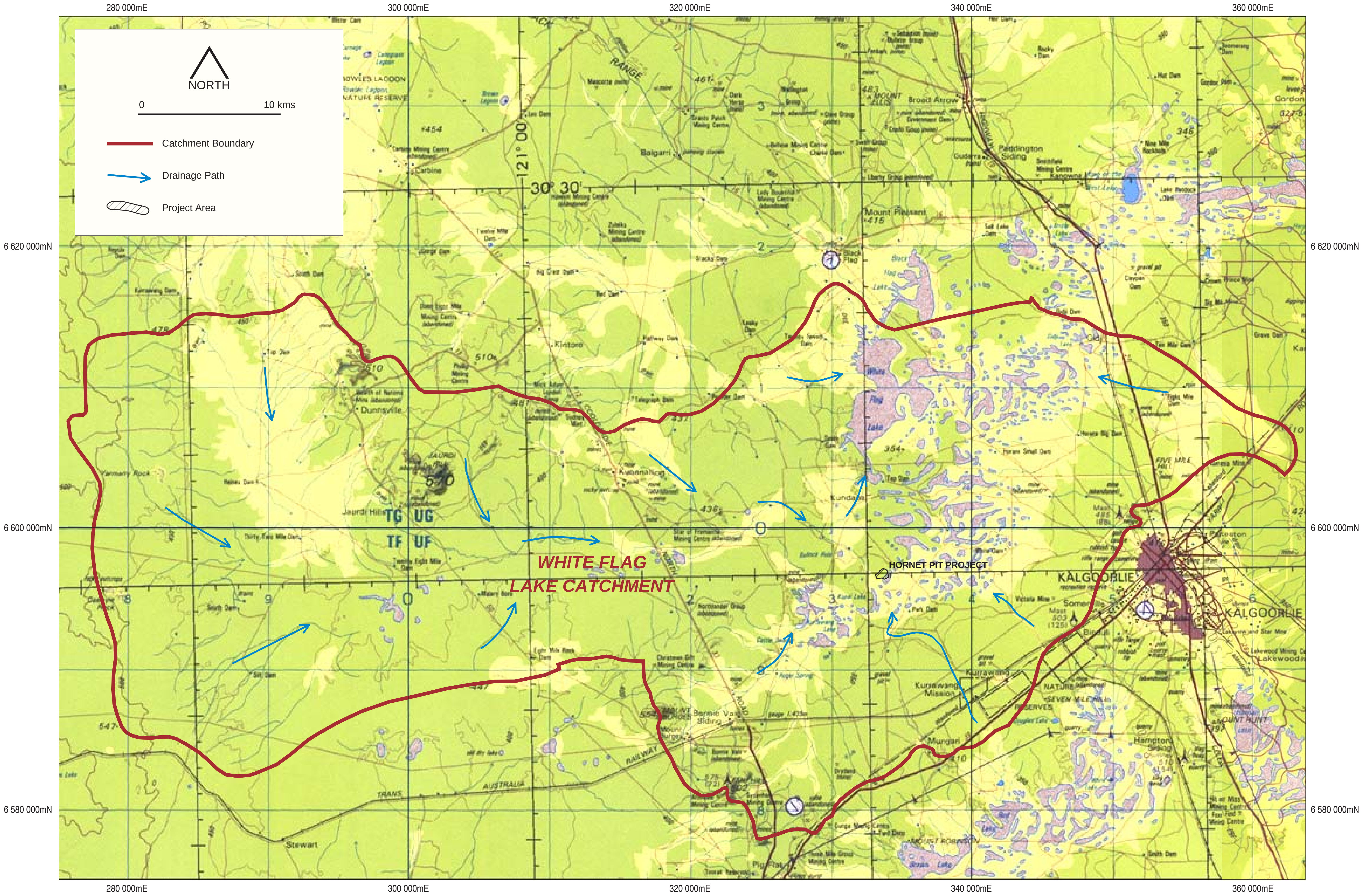
The proposed surface water management plan for the Hornet Pit Project area is outlined in Figure 4. This plan consists of flood protection bunding around the pit development area. This bunding needs to provide protection to the pit against the design 100 year ARI flood event plus have a minimum freeboard allowance of 1.0 m. In addition, the section of the waste dump batter subject to inundation will require rock armouring to protect it from potential instability from water ponding against the toe of the dump.

For both Stage One and Two, the design flood level in Kopai Lake adjacent to Hornet Pit has been estimated at RL 341.3 m, so the recommended minimum crest level for the flood protection bunding for the pit is RL 342.3 m.

Flood protection bunding will typically consist of a level top section a minimum of 3 m wide with side batters of 1:3. All bunds will be built to an engineering specification using competent materials, with bund corners protruding into the lake rounded to give a hydraulically smooth profile.

The flood flow velocities adjacent to Hornet Pit are relatively low, so general rock armouring of the bunds to protect them from erosion will not be required. However, bund corners protruding into the lake will require some localised rock armour protection.

FIGURES

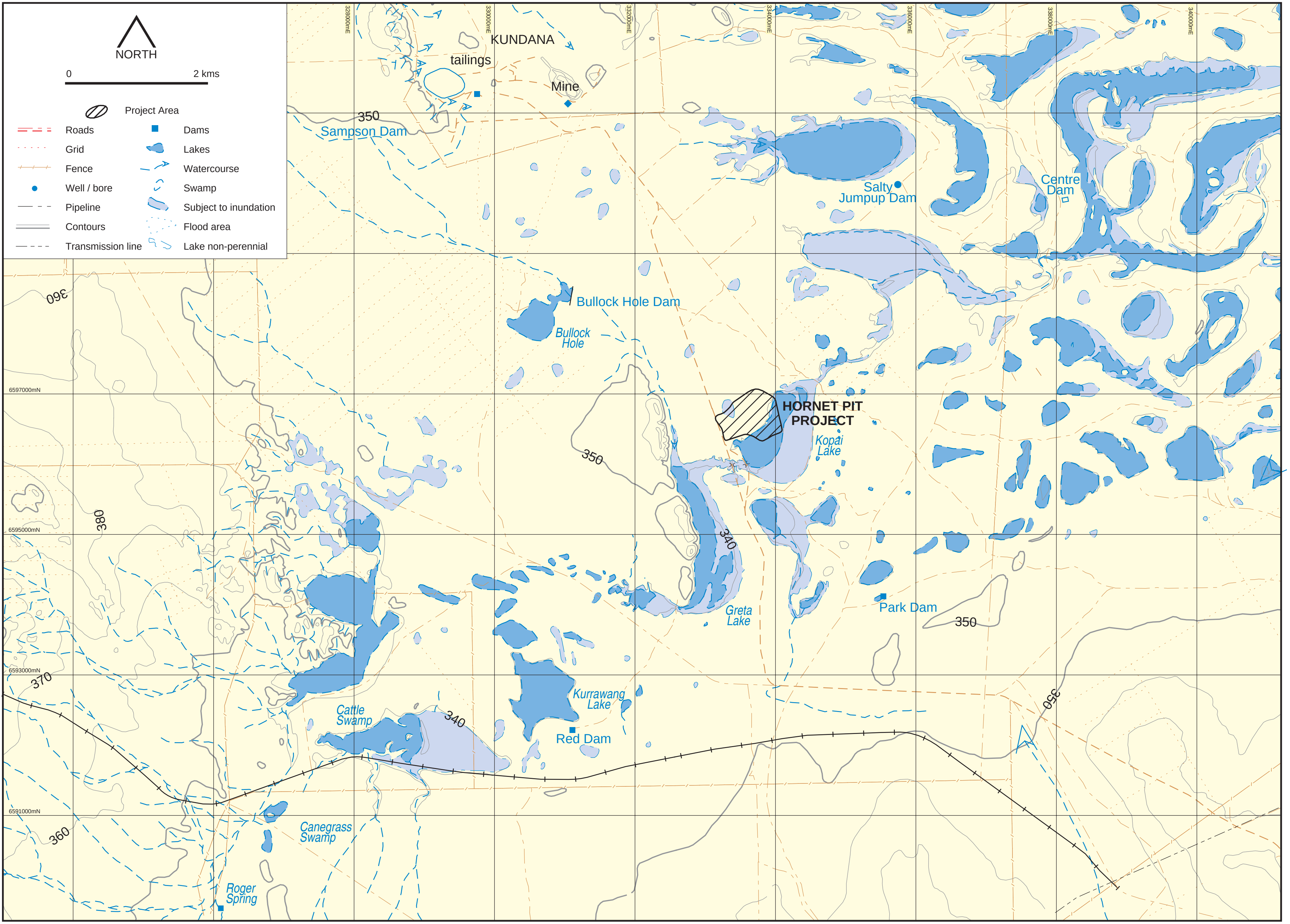


BIBRA DRAFTING SERVICE - \aquaterra\hornet_pit\hornet_pit_fig1aug03.dgn

aquaterra

PLACER DOME ASIA PACIFIC
Hornet Pit Project
Surface Water Management

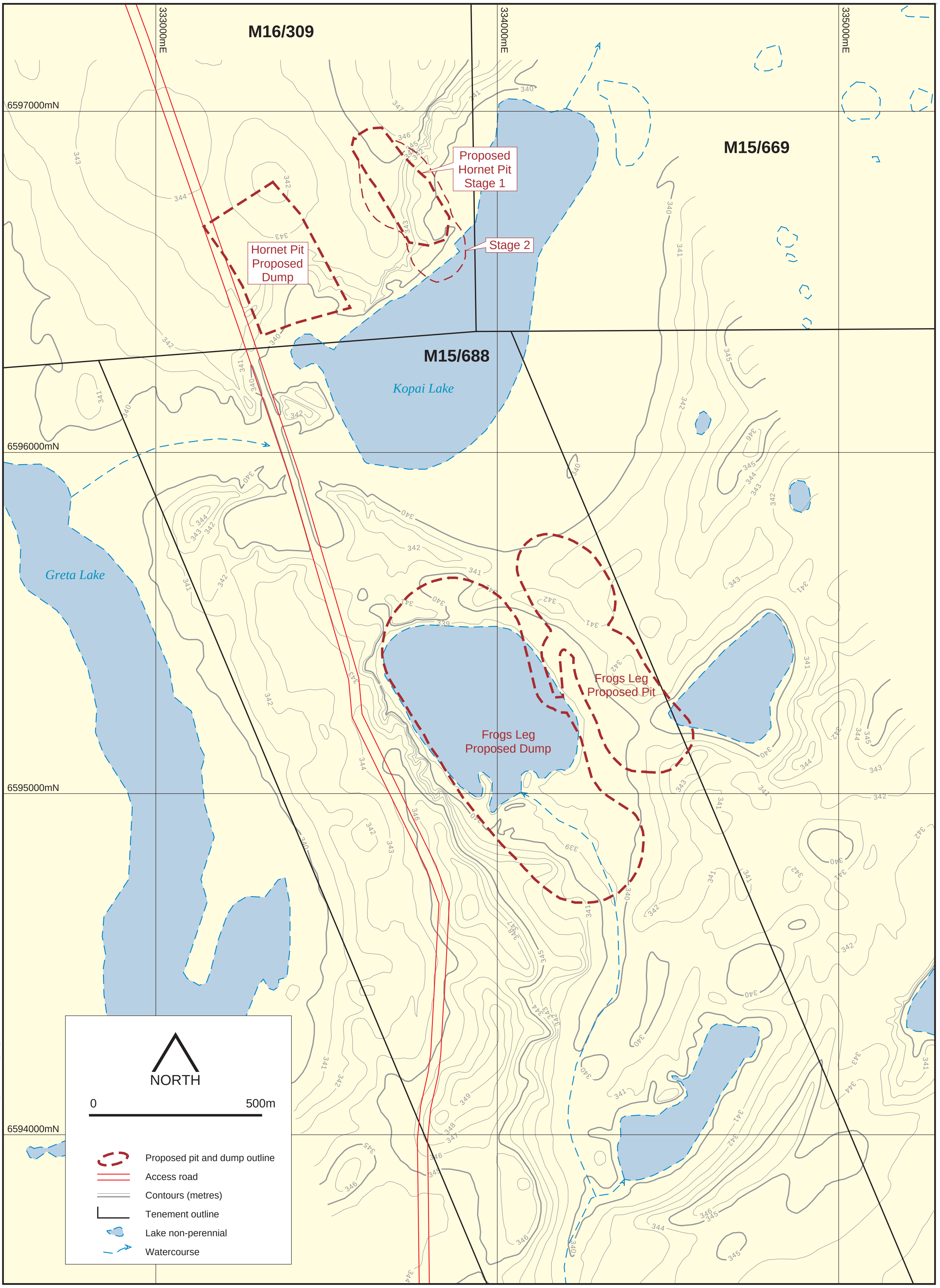
Regional Drainage
Figure 1



BIBRA DRAFTING SERVICE - \aquaterra\hornet_pit\hornet_pit_fig2aug03.dgn

PLACER DOME ASIA PACIFIC
Hornet Pit Project
Surface Water Management

Project Area Drainage
Figure 2



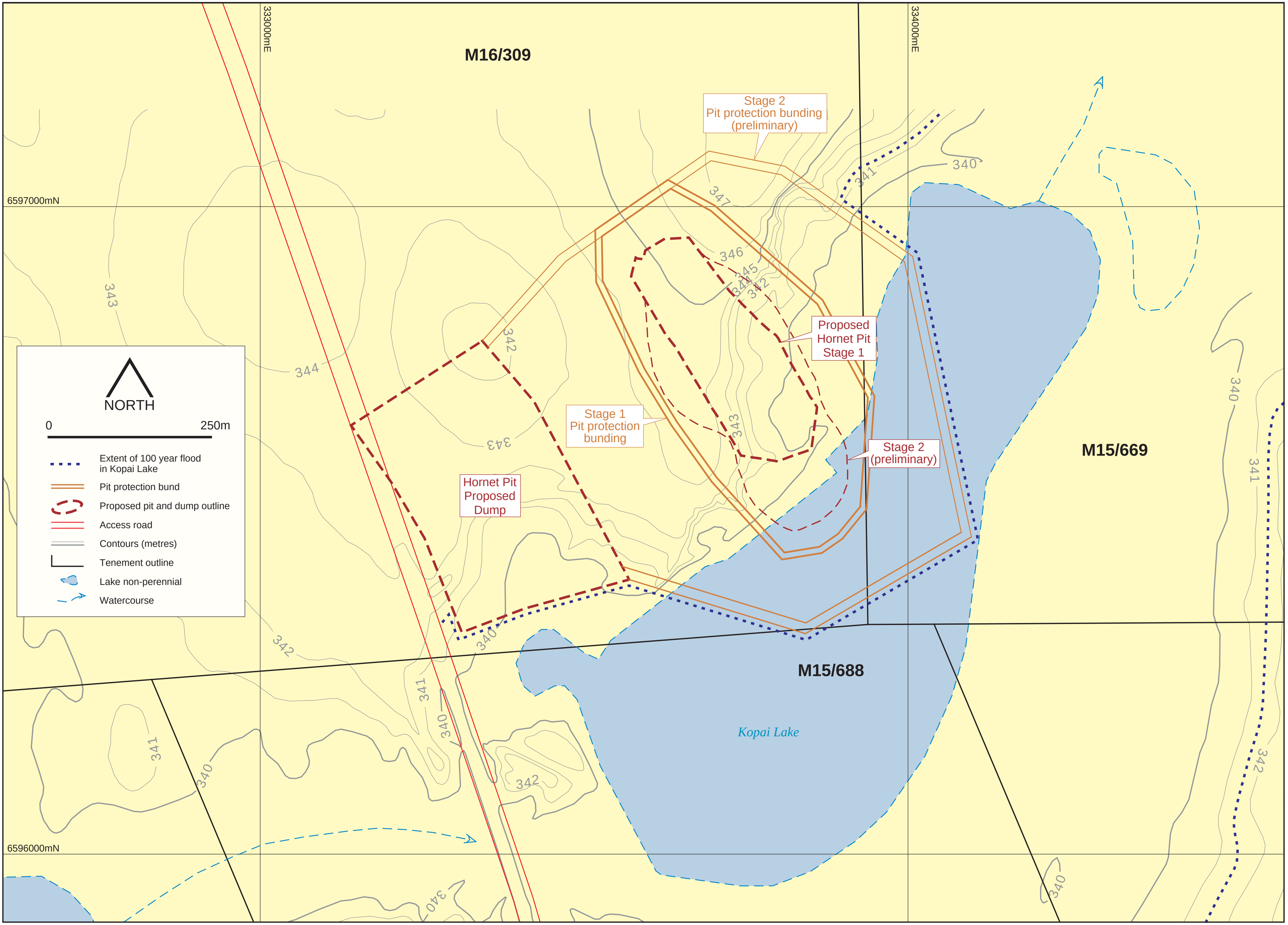
BIBRA DRAFTING SERVICE - \aquaterra\hornet_pit\hornet_pit_fig2aug03.dgn

aquaterra

PLACER DOME ASIA PACIFIC
Hornet Pit Project
Surface Water Management

Proposed Mine Development

Figure 3



BIBRA DRAFTING SERVICE - \aquaterra\hornet_pit\hornet_pit_fig4aug03.dgn

aquaterra

PLACER DOME ASIA PACIFIC
Hornet Pit Project
Surface Water Management

Surface Water Management Plan
Figure 4

Appendix G:

Flora, Vegetation and Fauna Survey

(Botanica 2020)

Kundana
Reconnaissance Flora/ Vegetation Survey and Basic Fauna Survey

Prepared for Northern Star Resources Ltd.

October 2020
Version 1

Prepared by:
Botanica Consulting Pty Ltd
PO Box 2027
Boulder WA 6432

Disclaimer

This document and its contents are to be treated as confidential and are published in accordance with and subject to an agreement between Botanica Consulting (BC) and the client for whom it has been prepared and is restricted to those issues that have been raised by the client in its engagement of BC. Neither this document nor its contents may be referred to or quoted in any manner (report or other document) nor reproduced in part or whole by electronic, mechanical or chemical means, including photocopying, recording or any information storage system, without the express written approval of the client and/or BC.

This document and its contents have been prepared utilising the standard of care and skill ordinarily exercised by Environmental Scientists in the preparation of such documents. All material presented in this document is published in good faith and is believed to be accurate at the time of writing. Any person or organisation who relies on or uses the document and its contents for purposes or reasons other than those agreed by BC and the client without primarily obtaining the prior written consent of BC, does so entirely at their own risk. BC denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be endured as a consequence of relying on this document and its contents for any purpose other than that agreed with the client.

Quality Assurance

An internal quality review process has been implemented to each project task undertaken by BC. Each document and its contents are carefully reviewed by core members of the Consultancy team and signed off at Director Level prior to issue to the client. Draft documents are submitted to the client for comment and acceptance prior to final production.

Document Job Number:	2020/170
Prepared by:	Kelby Jennings Senior Environmental Consultant
Reviewed by:	Andrea Williams Director Botanica Consulting
Approved by:	Jim Williams Director Botanica Consulting

Contents

Tables

Figures

Glossary

Acronym	Description
BAM Act	*Biosecurity and Agriculture Management Act 2007*, WA Government.
BC Act	*Biodiversity Conservation Act 2016*, WA Government.
Botanica	Botanica Consulting Pty Ltd.
BoM	Bureau of Meteorology.
DAFWA	Department of Agriculture and Food (now DPIRD), WA Government.
DAWE	Department of the Agriculture, Water and Environment (formerly known as DotEE), Australian Government.
DBCA	Department of Biodiversity, Conservation and Attractions (formerly DPaW), WA Government.
DEC	Department of Environment and Conservation (now DBCA), WA Government.
DER	Department of Environment Regulation (now DWER), WA Government.
DMIRS	Department of Mines, Industry Regulation and Safety (formerly DMP), WA Government
DotEE	Department of the Environment and Energy (now known as DAWE), Australian Government.
DoW	Department of Water (now DWER), WA Government.
DPaW	Department of Parks and Wildlife (now DBCA), WA Government.
DPIRD	Department of Primary Industries and Regional Development, WA Government
DWER	Department of Water and Environmental Regulation (formerly EPA, DER and DoW), WA Government
EP Act	Environmental Protection Act 1986, WA Government.
EP Regulations	Environmental Protection (Clearing of Native Vegetation) Regulations 2004, WA Government.
EPA	Environmental Protection Authority, WA Government.
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*, Australian Government.
ESA	Environmentally Sensitive Area.
Ha	Hectare (10,000 square meters).
IBRA	Interim Biogeographic Regionalisation for Australia.
IUCN	International Union for the Conservation of Nature and Natural Resources – commonly known as the World Conservation Union.
JAMBA	*Japan Australia Migratory Bird Agreement 1981.*
Km	Kilometer (1,000 meters).
NVIS	National Vegetation Information System.
PEC	Priority Ecological Community.
TEC	Threatened Ecological Community.
WA	Western Australia.
WAHERB	Western Australian Herbarium.
WAM	Western Australian Museum, WA Government.

Executive Summary

Botanica Consulting (Botanica) was commissioned by Northern Star Resources Ltd. (Northern Star) to undertake a reconnaissance flora/ vegetation survey and basic fauna survey within the Hornet (156 ha), Pegasus (283 ha) and Golden Hind (210 ha) project areas, which surround their current mining developments and which will be assessed collectively as the Kundana Project. The three survey areas total 649 ha and are located approximately 20 km west of Kalgoorlie-Boulder, Western Australia. The survey was conducted on the 10th September 2020, with the area traversed on foot and 4WD by Jim Williams (Director/Principal Botanist, Diploma of Horticulture). The survey was conducted to support a Native Vegetation Clearing Permit (NVCP) application and mining proposal with regards to the further development of the Kundana Project.

The survey area lies within the Eastern Goldfields (COO3) subregion of the Coolgardie Bioregion. It is described as gently undulating plains with a subdued relief, interrupted in the west with low hills and ridges of Archaean greenstones and in the east by a horst of Proterozoic basic granulite. The underlying geology is of gneisses and granites eroded into a flat plane covered with tertiary soils and with scattered exposures of bedrock. Calcareous earths are the dominant soil group and cover much of the plains and greenstone areas. A series of large playa lakes in the western half are the remnants of an ancient major drainage line.

The vegetation consists of Mallees, Acacia thickets and shrub-heaths on sandplains, with diverse *Eucalyptus* woodlands occurring around salt lakes, on ranges, and in valleys. Salt lake support dwarf shrublands of samphire. Woodlands and *Dodonaea* shrubland occur on basic graninulites of the Fraser Range, and the area is rich in endemic Acacias. The survey area lies within the Great Western Woodlands, located approximately 30 km from the northern boundary. The Great Western Woodlands is considered by The Wilderness Society of WA to be of global biological and conservation importance as one of the largest and healthiest temperate woodlands on Earth, containing many endemic taxa.

Prior to the field assessment a literature review was undertaken of previous flora and fauna assessments conducted within the local region. Documents reviewed included:

- Botanica Consulting (2010). *Level 1 Rubicon/ Hornet Spring Flora Survey.* Unpublished report prepared for Barrick-Kanowna Belle September 2010.
- Harewood, G (2010). *Terrestrial Fauna Survey (Level 1) of the proposed Rubicon/ Hornet Mine Area.* Unpublished report prepared for Barrick-Kanowna Belle October 2010.
- Terratree Pty. Ltd. (2017). *Bonnievale Flora and Vegetation Assessment.* Unpublished report prepared on behalf of Focus Minerals Ltd. April 2017.

In addition to the literature review, searches of the following databases were undertaken to aid in the compilation of a list of significant flora within the survey area:

- DBCA Threatened/ Priority Flora Database Search (DBCA, 2019a);
- DBCA NatureMap database (DBCA, 2020); and
- EPBC Protected Matters search tool (DAWE, 2020a).

The desktop review identified 829 vascular flora species as occurring within 40 km of the survey area, including 87 introduced (weed) species. The most diverse families were Fabaceae (107 species), Asteraceae (106 species) and Myrtaceae (101 species). Significant genera were *Eucalyptus* (55 species), *Acacia* (54 species) and *Eremophila* (38 species).

The desktop review identified 87 introduced flora (weed) species as potentially occurring in the vicinity of the survey area. Of these, eight are listed as a Declared Pest on the Western Australian Organism List (WAOL) under the *Biosecurity and Agriculture Management* (BAM) *Act 2007.* One species is listed as a Weed of National Significance (WoNS); *Lycium ferocissimum* (African Boxthorn).

The desktop assessment of the government database and previous relevant literature identified 45 significant flora species recorded within a 40 km radius of the survey area. These consist of three Threatened, 16 Priority 1, six Priority 2, 16 Priority 3 and four Priority 4 taxa (Appendix 2). These taxa were assessed for distribution and known habitat to determine their likelihood of occurrence within the survey area. The assessment identified one significant flora species as likely to occur in the survey area; *Notisia intonsa* (P3). Nine taxa were assessed as possibly occurring in the survey area, consisting of six Priority 1, three Priority 3 and one Priority 4.

A total of 326 fauna taxa have been recorded within a 40 km radius of the survey area, consisting of 149 bird, 29 mammal, 73 reptile, six amphibian, one fish and 68 invertebrate taxa. This total includes nine introduced (feral) species.

The desktop assessment identified 14 fauna species of conservation significance as previously being recorded in the general area, consisting of eight Threatened species, two Priority 3 species, one Priority 4 species and two migratory or otherwise protected species. In addition, numerous migratory shorebirds were assessed collectively due to their similar habitat requirements. Habitat and distribution data was used to determine the likelihood of occurrence within the survey area. The assessment identified five significant fauna species as potentially occurring in the survey area, as well as migratory wading birds.

No Threatened or Priority Ecological Communities were identified as likely or possibly occurring within the survey area.

There are no proposed or vested Conservation Reserve located within the survey area.

There are no DBCA managed or interest land located within the survey area.

There are no Environmentally Sensitive Areas located within the survey area.

There are no Nationally Important or RAMSAR wetlands located within the survey area.

The closest significant environmental feature is the Kurrawang Nature Reserve, which is DBCA-managed land located approximately 12 km south-east of the survey area. Disturbances within the survey area are unlikely to impact this area.

The field survey identified 60 flora taxa within the survey area, including three introduced (weed) species. These taxa represented 30 genera across 19 families, with the most diverse genera being *Eucalyptus* (8 species), *Eremophila* (7 species) and *Maireana* (6 species). Three species of introduced flora were recorded within the survey area: *Atriplex lentiformis*, *Cucumis myriocarpus* and *Nicotiana glauca*. None of these species are a Weed of National Significance or a Declared Pest in Western Australia.

No Threatened or Priority flora species were recorded within the survey area. The previously recorded Priority 3 species *Notisia intonsa* was not observed. The Botanica (2010) flora survey determined that the vegetation community associated with this record is unsuitable for the presence of this species, and this is likely an incorrect record. Suitable habitat (lake shore *Melaleuca* vegetation) within the survey area was searched however this taxon was not identified.

A total of seven vegetation communities were identified within the survey area. CLP-EW1 was the most diverse community, with 44 flora species, and CD-CSSSF1 the least with 5 species. CLP-EW1 was the most widespread community in the survey area, occupying 253 ha (39.0%), while RP-CFW1 was the most restricted with 25 ha (3.9%).

No significant vegetation, including representatives of Threatened or Priority Ecological Communities, was identified within the survey area.

A total of five broad scale terrestrial fauna habitats were identified, based on vegetation and associated landforms identified during the flora and vegetation assessment, with mixed *Eucalyptus* woodland being the most extensive (456 ha, 70.3%). No evidence of significant fauna species were observed during the survey, including no evidence of Malleefowl nesting mounds or other activity.

Native vegetation within the survey area was rated as ‘Good’ condition, with obvious signs of damage caused by human activity since European settlement, including impacts to vegetation structure and composition such as low levels of grazing and/or slightly aggressive weeds. Cleared areas associated with road infrastructure and easement were rated as ‘completely degraded’.

Based on the outcomes from the survey undertaken, Botanica assessed the results of the desktop and field survey with regards to the native vegetation clearing principles listed under Schedule 5 of the EP Act. The assessment found that the proposed vegetation clearing activities may be at variance with clearing principles (f) and (i).

1 INTRODUCTION

1.1 Project Description

Botanica Consulting (Botanica) was commissioned by Northern Star Resources Ltd. (Northern Star) to undertake a reconnaissance flora/ vegetation survey and basic fauna survey within the Hornet (156 ha), Pegasus (283 ha) and Golden Hind (210 ha) project areas, which surround their current mining developments and which will be assessed collectively as the Kundana Project (Figure 1-1). The three survey areas total 649 ha and are located approximately 20 km west of Kalgoorlie-Boulder, Western Australia (Figure 1-2). The survey was conducted to support a Native Vegetation Clearing Permit (NVCP) application and mining proposal with regards to the further development of the Kundana Project.

1.2 Objectives

The flora assessment was conducted in accordance with the requirements of a reconnaissance flora survey as defined in *Technical Guidance - Flora and Vegetation Surveys for Environmental Impact Assessment – December 2016* (EPA, 2016a). The objectives of the assessment were to:

- gather background information on flora and vegetation in the target area (literature review, database and map-based searches);
- identify significant flora, vegetation and ecological communities and assess the potential sensitivity to impact;
- conduct a field survey to verify / ground truth the desktop assessment findings;
- undertake floristic community mapping to a scale appropriate for the bioregion and described according to the National Vegetation Information System (NVIS) structure and floristics;
- undertake vegetation condition mapping;
- assess the project area's plant species diversity, density, composition, structure and weed cover, using NVIS classification system for vegetation description;
- assess Matters of National Environmental Significance (MNES) and indicate whether potential impacts on MNES as protected under the EPBC Act are likely to require referral of the project to the Commonwealth DAWE; and
- determine the State legislative context of environmental aspects required for the assessment.

The fauna assessment was conducted in accordance with the requirements for a basic terrestrial fauna survey as defined in *Technical Guidance - Terrestrial Fauna Surveys for Environmental Impact Assessment – June 2020* (EPA, 2020). The objectives of the assessment were to:

- Gather background information on fauna in the survey area (literature review, database and map-based searches);
- Delineate and characterise the faunal assemblages and fauna habitats present in the survey area; and
- Assess the likelihood of significant fauna occurring within the survey area.

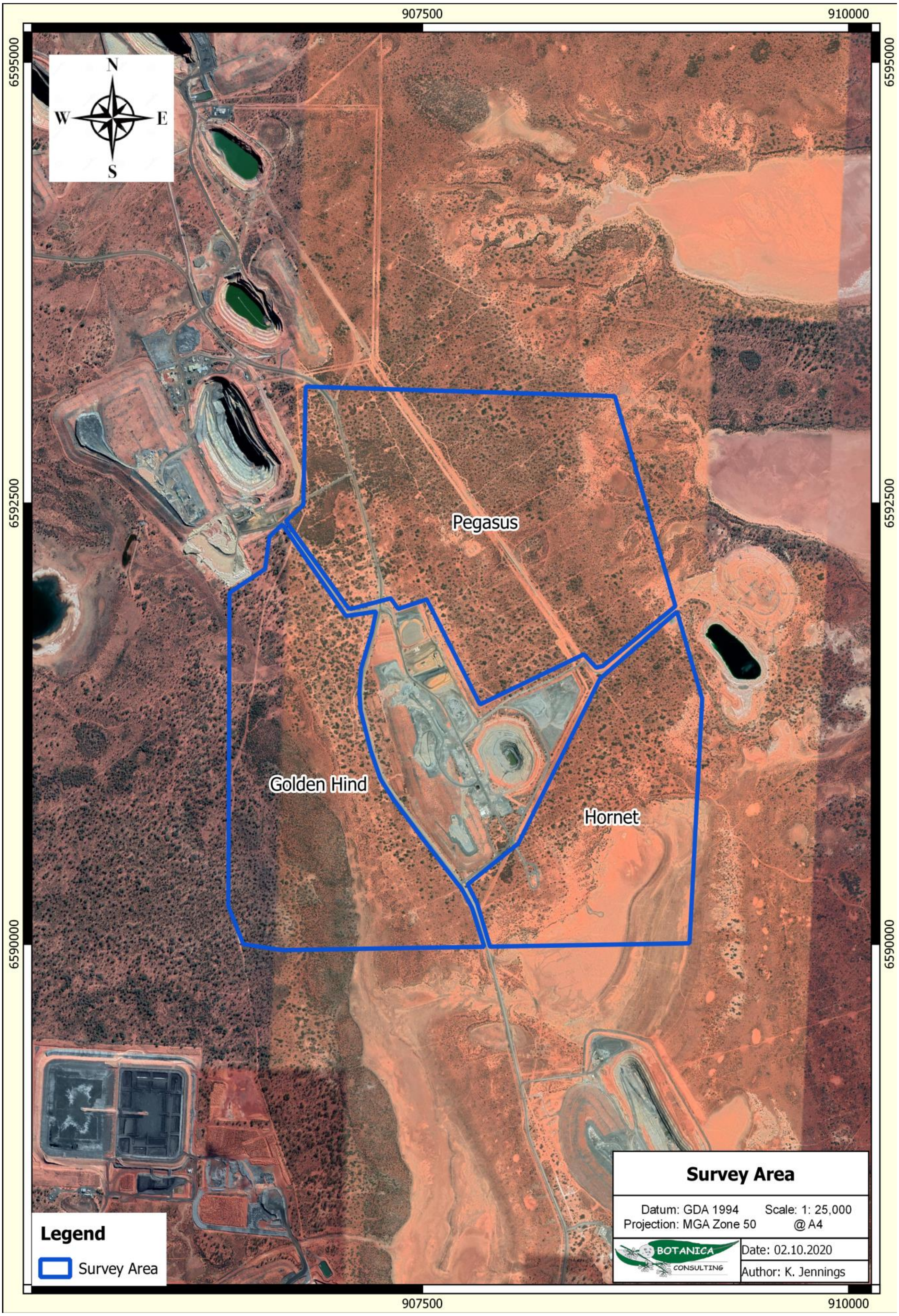


Figure 1-1: Survey Areas

Figure 1-2: Regional map of the survey area

2 BIOPHYSICAL ENVIRONMENT

2.1 Regional Environment

The survey area lies within the Eastern Goldfields (COO3) subregion of the Coolgardie Bioregion, as defined by the Interim Biogeographic Regionalisation of Australia (IBRA).

The Eastern Goldfields subregion (5,102,428 ha) lies on the Yilgarn Craton's Eastern Goldfields Terrain, which is described as gently undulating plains with a subdued relief, interrupted in the west with low hills and ridges of Archaean greenstones and in the east by a horst of Proterozoic basic granulite. The underlying geology is of gneisses and granites eroded into a flat plane covered with tertiary soils and with scattered exposures of bedrock. Calcareous earths are the dominant soil group and cover much of the plains and greenstone areas. A series of large playa lakes in the western half are the remnants of an ancient major drainage line (Cowan 2001).

The vegetation consists of Mallees, Acacia thickets and shrub-heaths on sandplains, with diverse *Eucalyptus* woodlands occurring around salt lakes, on ranges, and in valleys. Salt lakes support dwarf shrublands of samphire. Woodlands and *Dodonaea* shrubland occur on basic granulite of the Fraser Range, and the area is rich in endemic Acacias.

In accordance with Beard (1990) the survey area is located in the Coolgardie Botanical District of the Southwestern Interzone Province. The landscape is described as gently undulating with occasional ranges of low hills, with sandplains in the western part and some large playa lakes. Soils are principally brown calcareous earths, which overlays the Proterozoic granite and gneiss of the Fraser Range block and Archaean granite, with infolded volcanics and meta-sediments, of the Yilgarn block. Vegetation is predominately *Eucalyptus* woodlands, with slopes and flats containing *E*. *longicornis* alongside *E. salubris* and *E*. *salmonophloia*. Woodland understories range from tall sclerophyll shrubland dominated by *Melaleuca pauperiflora* to soft-leaved saltbush shrubland of *Atriplex vesicaria* and *A*. *nummularia*. Some hill slopes contain mallees of *E*. *livida* or *E*. *loxophleba*, while ironstone ridges are covered in thickets of *Acacia quadrimarginea*, *Allocasuarina acutivalvis* and *A*. *campestris*. Other vegetation assemblages include species-rich scrub-heaths and *Allocasuarina* thickets on sandplains, merging into *Acacia* thickets and Kwongan vegetation to the north.

2.2 Land Use

The dominant land uses of the Eastern Goldfields subregion includes Unallocated Crown Land (UCL) and Crown reserves and pastoral grazing, with conservation areas and mining leases also present (Cowan, 2001). The survey area is located within the Mungari Pastoral Lease.

2.3 Soils and Landscape Systems

The survey area lies within the Kalgoorlie Province, located in the southern Goldfields between Paynes Find, Menzies, Southern Cross and Balladonia. The landscape consists of undulating plains (with some sandplains, hills and salt lakes) on the granitic rocks and greenstone of the Yilgarn Craton. Soils range from calcareous loamy earths and red loamy earths with some salt lake soils to red deep sands, yellow sandy earths, shallow loams and loamy duplexes. Vegetation communities are predominately Eucalypt woodlands with some acacia-casuarina thickets, mulga shrublands, halophytic shrublands and spinifex grasslands.

The Kalgoorlie Province is further divided into six soil-landscape zones, with the survey area located within the Kambalda Zone (265). This zone is located in the south-eastern Goldfields between Menzies, Norseman and the Fraser Range and contains flat to undulating plains (with hills, ranges and some salt lakes and stony plains) on greenstone and granitic rocks of the Yilgarn Craton. Soils consist of calcareous loamy earths and red loamy earths with salt lakes soils and some red-brown hardpan shallow loams and red sandy duplexes. Vegetation includes red mallee, blackbutt-salmon gum-gimlet woodlands with mulga and halophytic shrublands (and some spinifex grasslands).

The Kambalda Zone is further divided into soil landscape systems, with the survey area located within two soil landscape systems, as shown in Table 2-1 and Figure 2-1, in accordance with soil landscape system mapping data (Government of Western Australia, 2019).

Table 2-1: Soil Landscape Systems within the survey area

Soil Landscape System	Description	Extent within Survey Area ha (%)
Mx43	Gently undulating valley plains and pediments; some outcrop of basic rock	170 ha (26.2%)
SV15	Salt lakes and their associated areas	479 ha (73.8%)

Figure 2-1: Soil Landscape Systems within the survey area

2.4 Regional Vegetation

In accordance with Tille (2006), the vegetation of the Kambalda Zone is typified by the preponderance of stony plains with acacia shrublands and halophytic shrublands, low hills with eucalypt or acacia woodlands with halophytic undershrubs, stony plains with acacia shrublands and alluvial plains with eucalypt woodlands and halophytic undershrubs rangeland.

More broadly, the vegetation of the Kalgoorlie Province is described by Tille (2006) as woodlands of redwood (*Eucalyptus transcontinentalis*), red mallee (*E. oleosa*), Dundas blackbutt (*E. dundasii*), merrit (*E. flocktoniae*) and salmon gum (*E. salmonophloia*), found on undulating plains over granite. There are also some hummock grasslands with red mallee over spinifex (*Triodia scariosa*) and thickets of *Acacia*, *Casuarina* and *Melaleuca* spp. Plains on greenstone have woodlands of York gum (*E. loxophleba*), salmon gum and gimlet (*E. salubris*). The valley plains have woodlands of salmon gum, red mallee, Goldfields blackbutt (*E. lesouefii*), gimlet, York gum and morrel (*E. longicornis*). These sometimes have an understorey of saltbush (*Atriplex* spp.), pearl bluebush (*Maireana sedifolia*), sago bluebush (*M. pyramidata*) and *Eremophila* spp. There are areas of spinifex grasslands with red mallee, mallees (e.g. *E. youngiana*) and marble gum (*E. gongylocarpa*). Low woodlands of mulga (*Acacia aneura*) and black sheoak (*Casuarina pauper*) over bluebush and saltbush are also present. Apart from the bare salt lake surfaces, saline valley floors have shrublands of samphire (*Tecticornia* spp.) and *Frankenia* spp. in lower areas, shrublands of saltbush and bluebush on red deep sandy duplexes, and woodlands of salmon gum, merrit, red mallee, gimlet and York gum. *Acacia neurophylla*, *A. beauverdiana* and *A. resinimarginea* thickets grow on gently sloping uplands on granite, with thickets of acacia, casuarina and melaleuca. There are also scrub-heaths and York gum-salmon gum-gimlet woodlands on these uplands. The hilly terrain on greenstone supports woodlands of salmon gum, Goldfields blackbutt, coral gum (*E. torquata*), York gum, gimlet, morrel, Dundas blackbutt and black sheoak. Thickets of granite wattle (*Acacia quadrimarginea*) are also present. The stony plains support scattered woodlands of Goldfields blackbutt, gimlet and salmon gum, along with shrublands of saltbush and bluebush. Sandplains in the west have acacia (*A. coolgardiensis, A. ramulosa, A. aneura, A. burkittii* and *A. tetragonophylla*) shrublands, commonly with patchy native pine (*Callitris glaucophylla C. preissii*) and mallees (*E. leptopoda, E. longicornis* and *E. loxophleba*). Native box (*Bursaria occidentalis*), *Melaleuca uncinata* and *Hakea recurva* may also be present. Hard spinifex (*T. basedowii*) grasslands with mulga, marble gum and mallees (e.g. *E. kingsmillii*) are found on sandplains to the east. The sandy-surfaced plains support acacia, casuarina and melaleuca thickets; woodlands of York gum, cypress pine (*Callitris columellaris*), salmon gum, gimlet and mulga; and shrublands of bowgada (*A. ramulosa*).

2.5 Conservation Values

The Eastern Goldfields subregion contains 16 vegetation associations, predominately open *Eucalyptus* woodlands, that have at least 85 per cent of their total extent in the bioregion (Cowan 2001) The subregion is considered a centre of endemism for Eucalypts in the Goldfields Woodlands region, and is also noted for the diversity of *Acacia* spp. and ephemeral flora communities of the tertiary sandplain shrublands and the valley floors of woodland areas.

The subregion contains one wetland of national importance: Rowles Lagoon System, located approximately 40 km east of the survey area. In addition, there are seven wetlands of subregional importance (Cowan, 2001). Other significant assemblages in the region include plant assemblages of the Fraser Range and the Woodline Hills.

No ecosystems are listed as threatened under WA State legislation occur within the subregion, but 18 communities and vegetation associations are thought to be at risk for a variety of reasons. Grazing from livestock, goats and rabbits and impacts from mining are the main threatening processes in the region, with changed fire regimes, erosion and sedimentation also causing significant impacts.

There are 32 flora species of conservation significance, including seven Threatened species, and four fauna species of conservation significance: *Dasyurus geoffroii* (Chuditch), *Leipoa ocellata* (Malleefowl), *Falco peregrinus* (Peregrine Falcon) and *Morelia spilota embricata* (Carpet Python).

2.5.1 Great Western Woodlands

The survey area lies within the Great Western Woodlands, located approximately 30 km from the northern boundary. The Great Western Woodlands is considered by The Wilderness Society of WA to be of global biological and conservation importance as one of the largest and healthiest temperate woodlands on Earth, containing many endemic taxa. The region covers almost 16 million hectares (160,000 square kilometres), from the southern edge of the Western Australian Wheatbelt to the pastoral lands of the Mulga country in the north, the inland deserts to the northeast, and the treeless Nullarbor Plain to the east.

The Great Western Woodlands provides a connection between southwest forests and inland deserts (Gondwana Link) as well as linking the north-west passage to Shark Bay. The majority of the Great Western Woodlands is unallocated crown land (61.1%) with other interests including pastoral leases (20.4%), conservation reserves (15.4%) unallocated crown land, ex pastoral (2%) managed by the Department of Biodiversity, Conservation and Attractions (DBCA) and private land (approximately 1%) (Watson *et. al.,* 2008).

No specific management strategy or formal conservation status applies to the Great Western Woodlands. The Great Western Woodlands currently includes towns, highways, roads, railways, private property, Crown Reserves, agricultural activities and mining tenements.

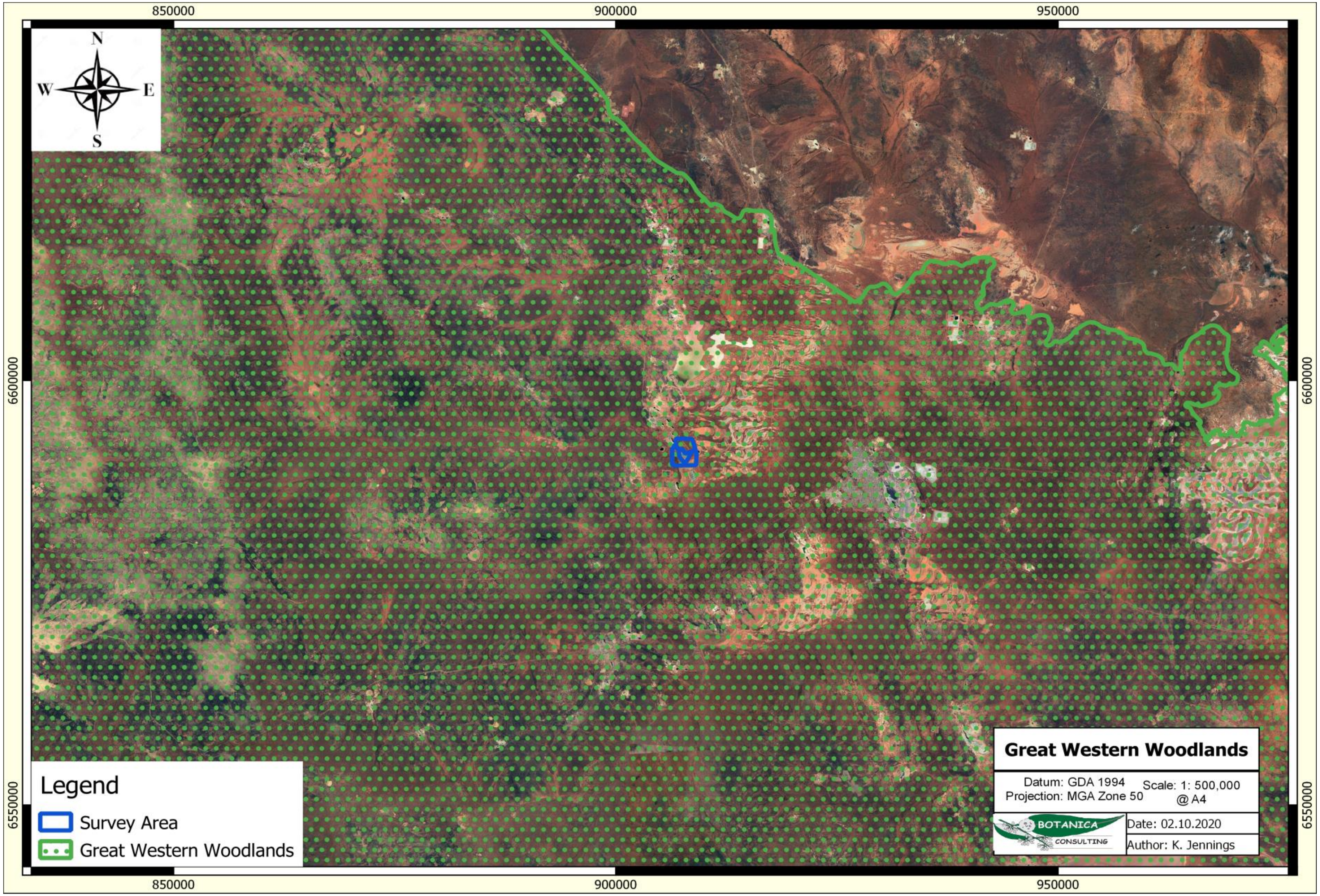
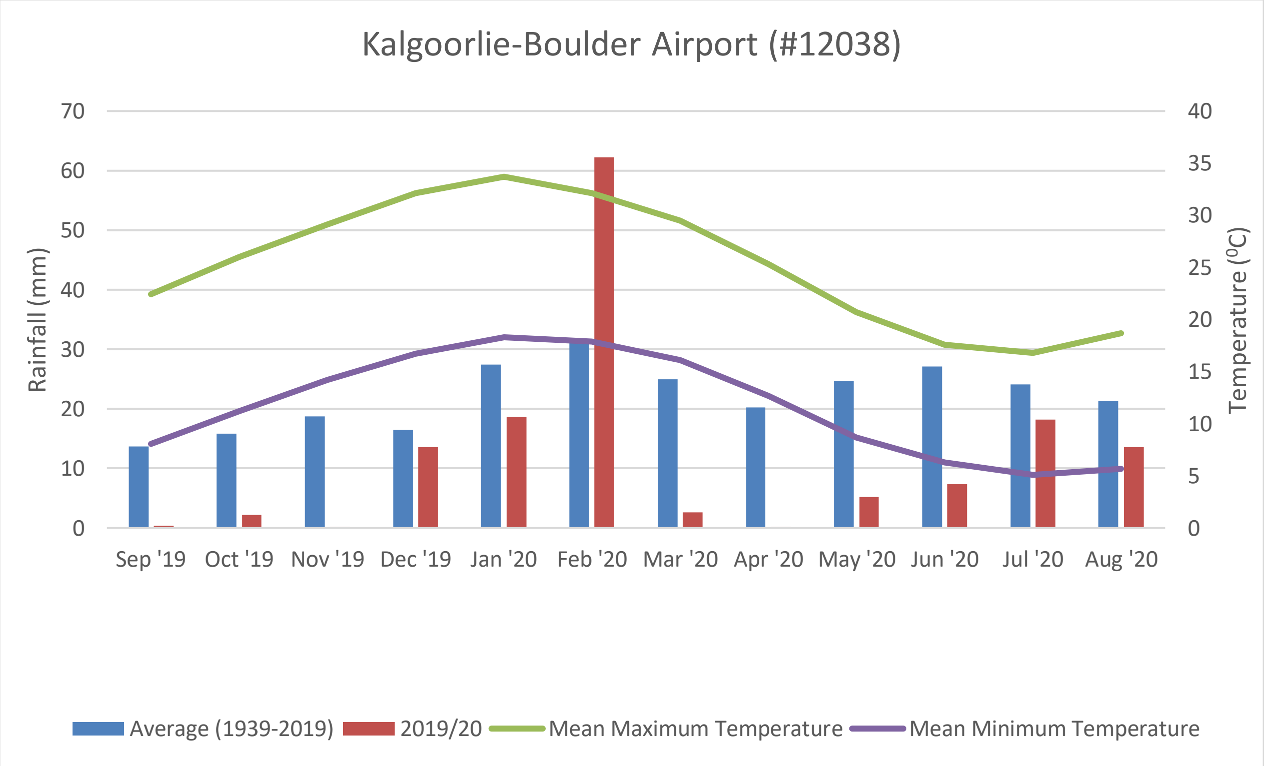


Figure 2-2: Location of survey area within the Great Western Woodlands

2.6 Climate

The climate of the Eastern Goldfields subregion is characterised as arid to semi-arid with 200-300 mm of rainfall, sometimes in summer but usually in winter (Cowan 2001). Rainfall data for the Kalgoorlie airport weather station (#12038) located approximately 15 km south-east of the survey area is shown in Graph 2-1 (BoM, 2020). Mean monthly rainfall ranges from 31.6 mm in February to 13.7 mm in September, with a mean annual rainfall of 266.1 mm. The survey was conducted in September 2020, with the preceding month (August) being characterised by two small rainfall events of 4.8 and 6.8mm. Although climate conditions are not considered optimal for the presence of flowering material and ephemeral species, this is unlikely to be a major survey constraint.



Graph 2-1: Average and recent rainfall and average temperature data of Kalgoorlie-Boulder Airport (BoM, 2020)

2.7 Hydrology

A salt lake (referred to as Kopai Lake) is located within the south-east region of the survey area (Figure 2-3). According to the Geoscience Australia database (2015), no permanent water bodies are located within the survey area (Figure 2-3). There are no perennial drainage lines within the survey area, however one ephemeral drainage line intersects the west region of the survey area.

Groundwater Dependent Ecosystems (GDE) includes biological assemblages of species such as wetlands or woodlands that use groundwater either opportunistically or as their primary water source. For the purposes of this report, a GDE is defined as any vegetation community that derives part of its water budget from groundwater and must be assumed to have some degree of groundwater dependency. In accordance with the BoM *Atlas of Groundwater Dependent Ecosystems* (BoM, 2020b) database, there is one low potential aquatic GDE, associated with the drainage line in the west region of the survey area. There are no potential terrestrial GDE’s in the survey area, although there are several within the broader region (Figure 2-3).

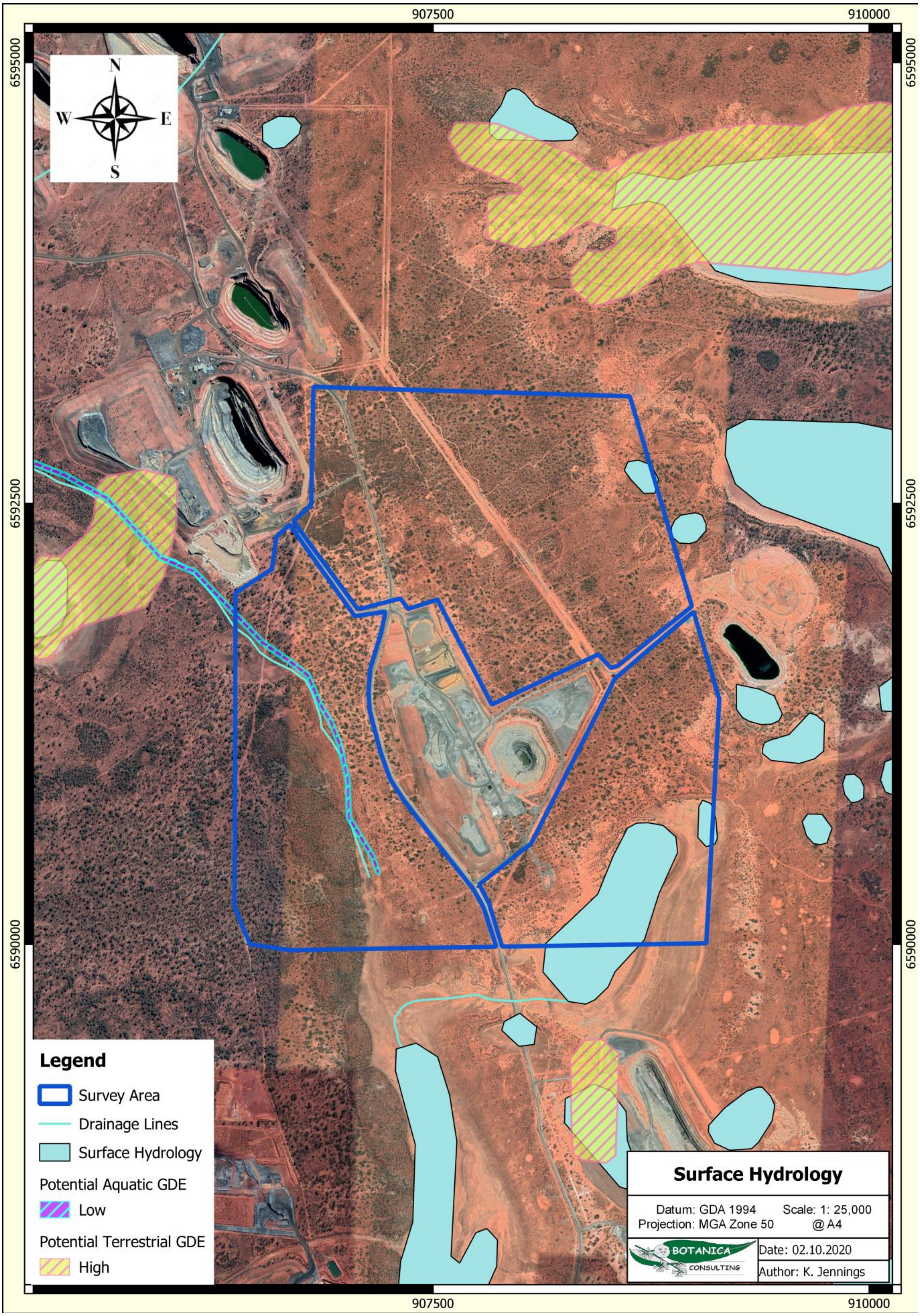


Figure 2-3: Surface Hydrology of the survey area

3 SURVEY METHODOLOGY

3.1 Desktop Assessment

Prior to the field assessment a literature review was undertaken of previous flora and fauna assessments conducted within the local region. Documents reviewed included:

- Botanica Consulting (2010). *Level 1 Rubicon/ Hornet Spring Flora Survey.* Unpublished report prepared for Barrick-Kanowna Belle September 2010.
- Harewood, G (2010). *Terrestrial Fauna Survey (Level 1) of the proposed Rubicon/ Hornet Mine Area.* Unpublished report prepared for Barrick-Kanowna Belle October 2010.
- Terratree Pty. Ltd. (2017). *Bonnievale Flora and Vegetation Assessment.* Unpublished report prepared on behalf of Focus Minerals Ltd. April 2017.

In addition to the literature review, searches of the following databases were undertaken to aid in the compilation of a list of significant flora within the survey area:

- DBCA Threatened/ Priority Flora Database Search (DBCA, 2019a);
- DBCA NatureMap database (DBCA, 2020); and
- EPBC Protected Matters search tool (DAWE, 2020a).

The NatureMap species search and EPBC Protected Matters search were conducted with a 40 km buffer from the survey area.

Significant flora and fauna species identified by the desktop review were assessed with regards to their population extent and distribution and preferred habitat to determine their likelihood of occurrence within the survey area. Identified flora species with no populations within 100 km were not considered in the assessment. The assessment categorised each species as follows:

- Unlikely- Suitable habitat is not expected to occur and/or the survey area is outside the known range of the species.
- Possible- Suitable habitat may be present, and the area is within the known range of the species. This option is also used when there is insufficient information to determine the preferred habitat of a species.
- Likely- Suitable habitat is expected to occur and there are records within 10 km of the survey area.
- Known to Occur- Species has previously been recorded within the survey area.

It should be noted that these lists are based on observations from a broader area than the assessment area (100 km radius) and therefore may include taxa not present. The databases also often include very old records that may be incorrect or in some cases the taxa in question have become locally or regionally extinct. Information from these sources should therefore be taken as indicative only and local knowledge and information also needs to be taken into consideration when determining what actual species may be present within the specific area being investigated.

The conservation significance of flora and fauna taxa was assessed using data from the following sources:

- *Environment Protection and Biodiversity and Conservation* (EPBC) *Act 1999*. Administered by the Australian Government (DAWE);
- *Biodiversity Conservation* (BC) *Act 2016*. Administered by the WA Government (DBCA);

- Red List produced by the Species Survival Commission (SSC) of the World Conservation Union (also known as the IUCN Red List – the acronym derived from its former name of the International Union for Conservation of Nature and Natural Resources). The Red List has no legislative power in Australia but is used as a framework for State and Commonwealth categories and criteria; and
- Priority Flora/ Fauna list. A non-legislative list maintained by DBCA for management purposes (fauna list released January 2019; flora list released December 2018).

The EPBC Act also requires the compilation of a list of migratory species that are recognized under international treaties including the:

- Japan Australia Migratory Bird Agreement 1981 (JAMBA)[1];
- China Australia Migratory Bird Agreement 1998 (CAMBA);
- Republic of Korea-Australia Migratory Bird Agreement 2007 (ROKAMBA); and
- Bonn Convention 1979 (The Convention on the Conservation of Migratory Species of Wild Animals).

Most but not all migratory bird species listed in the annexes to these bilateral agreements are protected in Australia as Matters of National Environmental Significance (MNES) under the EPBC Act. Descriptions of conservation significant species and communities are provided in Appendix 1.

3.2 Field Assessment

Botanica conducted a reconnaissance flora/ vegetation and basic fauna survey over approximately 649 ha. The survey was conducted on the 10th September 2020, with the area traversed on foot and 4WD by Jim Williams (Director/Principal Botanist, Diploma of Horticulture).

3.2.1 Flora Assessment

Prior to the commencement of field work, aerial photography was inspected and obvious differences in the vegetation assemblages were identified. The different vegetation communities identified were then inspected during the field survey to assess their validity. A handheld GPS unit was used to record the coordinates of the boundaries between existing vegetation communities. At each sample point, the following information was recorded:

- GPS location;
- Photograph of vegetation;
- Dominant taxa for each stratum;
- All vascular taxa (including annual taxa);
- Landform classification;
- Vegetation condition rating;
- Collection and documentation of unknown plant specimens; and
- GPS location, photograph and collection of flora of conservation significance if encountered.

Unknown specimens collected during the survey were identified with the aid of samples housed at the Botanica Herbarium and Western Australian Herbarium. Vegetation was classified in accordance with NVIS classifications.

---

[1] Most but not all species listed under JAMBA are also specially protected under Specially Protected Species of the BC Act.

3.2.2 Fauna Assessment

Vegetation and landform units identified during the flora assessment have been used to define broad fauna habitat types across the site. This information has been supplemented with observations made during the fauna assessment.

The main aim of the fauna habitat assessment was to determine the likelihood of fauna species of conservation significance utilizing the areas that may be impacted during site development. The habitat information obtained was also used to aid in finalizing the overall potential fauna list.

As part of the desktop literature review, available information on the habitat requirements of the species of conservation significance listed as possibly occurring in the area was researched. During the field survey, the habitats within the study area were assessed and specific elements identified, if present, to determine the likelihood of listed threatened species utilizing the area and its significance to them.

Opportunistic observations of fauna species were made during all field survey work which involved a series of transects across the study area during the day including observations of bird species with binoculars. Secondary evidence of a species presence such as tracks, scats, skeletal remains, foraging evidence or calls were also noted if observed/heard.

3.2.3 Scientific Licences

Table 3-1: Scientific Licences of Botanica Staff coordinating the flora survey

Licensed staff	Permit Number	Valid Until
Jim Williams	FB62000108 (Licence to flora for scientific purposes)	27/05/2022

3.3 Survey Limitations and Constraints

It is important to note that flora surveys will entail limitations notwithstanding careful planning and design. Potential limitations are listed in Table 3-2.

The conclusions presented in this report are based upon field data and environmental assessments and/or testing carried out over a limited period of time and are therefore merely indicative of the environmental condition of the site at the time of the field assessments. Also, it should be recognised that site conditions can change with time. Information not available at the time of this assessment which may subsequently become available may alter the conclusions presented.

Some species are reported as potentially occurring based on there being suitable habitat (quality and extent) within the survey area or immediately adjacent. The habitat requirements and ecology of many of the species known to occur in the wider area are however often not well understood or documented. It can therefore be difficult to exclude species from the potential list based on a lack of a specific habitats or microhabitats within the survey area. As a consequence of this limitation, the potential species list produced is most likely an overestimation of those species that actually utilise the survey area for some purpose.

In recognition of survey limitations, a precautionary approach has been adopted for this assessment. Any flora and fauna species that would possibly occur within the survey area (or immediately adjacent), as identified through ecological databases, publications, discussions with local experts/residents and the habitat knowledge of the author, has been listed as having the potential to occur.

Table 3-2: Limitations and constraints associated with the survey

Variable	Potential Impact on Survey	Details
Access problems	Not a constraint	The survey was conducted via 4WD and on foot. Numerous tracks were located within the survey area, providing ease of access.
Competency/ Experience	Not a constraint	The BC personnel that conducted the survey were regarded as suitably qualified and experienced. **Coordinating Botanist/ Zoologist:** Jim Williams **Data Interpretation:** Jim Williams, Kelby Jennings, and Greg Harewood.
Timing of survey, weather & season	Minor constraint	The survey was conducted during the EPA recommended timing for the South-West Interzone (i.e. September to November) and during optimal flowering period for Eucalypt Woodland vegetation. Rainfall for the Kalgoorlie-Boulder region has however been below average since February 2020.
Area disturbance	Not a constraint	The area has been disturbed from exploration, cattle grazing and fire; however, vegetation was mostly intact and comprised of native vegetation.
Survey Effort/ Extent	Not a constraint	Survey intensity was appropriate for the size/significance of the area with a reconnaissance survey completed to identify vegetation types/fauna habitats and conservation significant species/communities.
Availability of contextual information at a regional and local scale	Not a constraint	Threatened flora database searches provided by the DBCA were used to identify any potential locations of Threatened/Priority taxa. BoM, DWER, DPIRD, DBCA and DAWE databases were reviewed to obtain appropriate regional desktop information on the biophysical environment of the local region. Previous Flora/ Fauna surveys within the local area have been assessed for pertinent information and environmental context of the regional area.
Completeness	Minor constraint	In the opinion of Botanica, the survey area was covered sufficiently in order to identify vegetation assemblages. Limited annual species were present during the survey and many of the plants were not in flower; However, previous species identification from previous surveys conducted supplemented the current assessment. It is estimated that approximately 90% of the flora within the survey area were able to be fully identified. The vegetation types for this study were based on visual descriptions of locations in the field. The distribution of these vegetation communities/ fauna habitats outside the study area is not known, however vegetation types identified were categorised via comparison to vegetation distributions throughout WA specified in the NVIS Major Vegetation Groups (DotEE, 2017b).

4 RESULTS

4.1 Desktop Assessment

4.1.1 Flora

The desktop review identified 829 vascular flora species as occurring within 40 km of the survey area, including 87 introduced (weed) species. The most diverse families were Fabaceae (107 species), Asteraceae (106 species) and Myrtaceae (101 species). Significant genera were *Eucalyptus* (55 species), *Acacia* (54 species) and *Eremophila* (38 species).

4.1.1.1 Introduced Flora

The desktop review identified 87 introduced flora (weed) species as potentially occurring in the vicinity of the survey area. Of these, eight are listed as a Declared Pest on the Western Australian Organism List (WAOL) under the *Biosecurity and Agriculture Management* (BAM) *Act 2007* (Table 4-1). One species is listed as a Weed of National Significance (WoNS); *Lycium ferocissimum* (African Boxthorn) (Table 4-1).

The full list of potential weed species is contained in Appendix 3.

Table 4-1: Potentially occurring Declared Pests and WoNS

Family	Taxon	Common Name	WAOL Status	Control Category	WONS
Asteraceae	*Xanthium spinosum*	Common Cockleburr, Spiny Cockleburr	Declared Pest - s22(2)	C3 Management, Whole of State	No
Boraginaceae	*Echium plantagineum*	Paterson's Curse	Declared Pest - s22(2)	No Control Category, Whole of State	No
Cactaceae	*Cylindropuntia fulgida* var. *mamillata*	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Cylindropuntia imbricata	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Cylindropuntia kleiniae	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Opuntia elata	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Opuntia ficus-indica	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
Fabaceae	*Alhagi maurorum*	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
Solanaceae	*Lycium ferocissimum*	African Boxthorn	Permitted - s11		Yes

4.1.1.2 Significant Flora

The assessment of the DBCA Priority/ Threatened Flora Database Search (DBCA, 2019a), NatureMap (DBCA, 2020) and Protected Matters searches (DAWE, 2020a) and previous relevant literature identified 45 significant flora species recorded within a 40 km radius of the survey area. These consist of three Threatened, 16 Priority 1, six Priority 2, 16 Priority 3 and four Priority 4 taxa (Appendix 2).

These taxa were assessed for distribution and known habitat to determine their likelihood of occurrence within the survey area. The assessment identified one significant flora species as likely to occur in the survey area; *Notisia intonsa* (P3). A record of this ephemeral species is listed on the government database as occurring in the southern region of the survey area. However, the Botanica (2010) flora survey determined that the vegetation community (*Casuarina* tall shrubland) associated with this record is unsuitable for the presence of this species, and this is likely an incorrect record (Figure 4-2). Nine taxa were assessed as possibly occurring in the survey area, consisting of six Priority 1, three Priority 3 and one Priority 4 (Appendix 2). The locations of the DBCA database records are illustrated spatially in Figure 4-1.

4.1.1.3 Significant Ecological Communities

The Protected Matters search (DAWE, 2020a) did not identify any Threatened Ecological Communities recorded within 40 km of the survey area. Analysis of the Priority Ecological Communities within the Goldfields region (DBCA, 2017) did not identify any significant vegetation assemblages as likely or possibly occurring within the survey area.

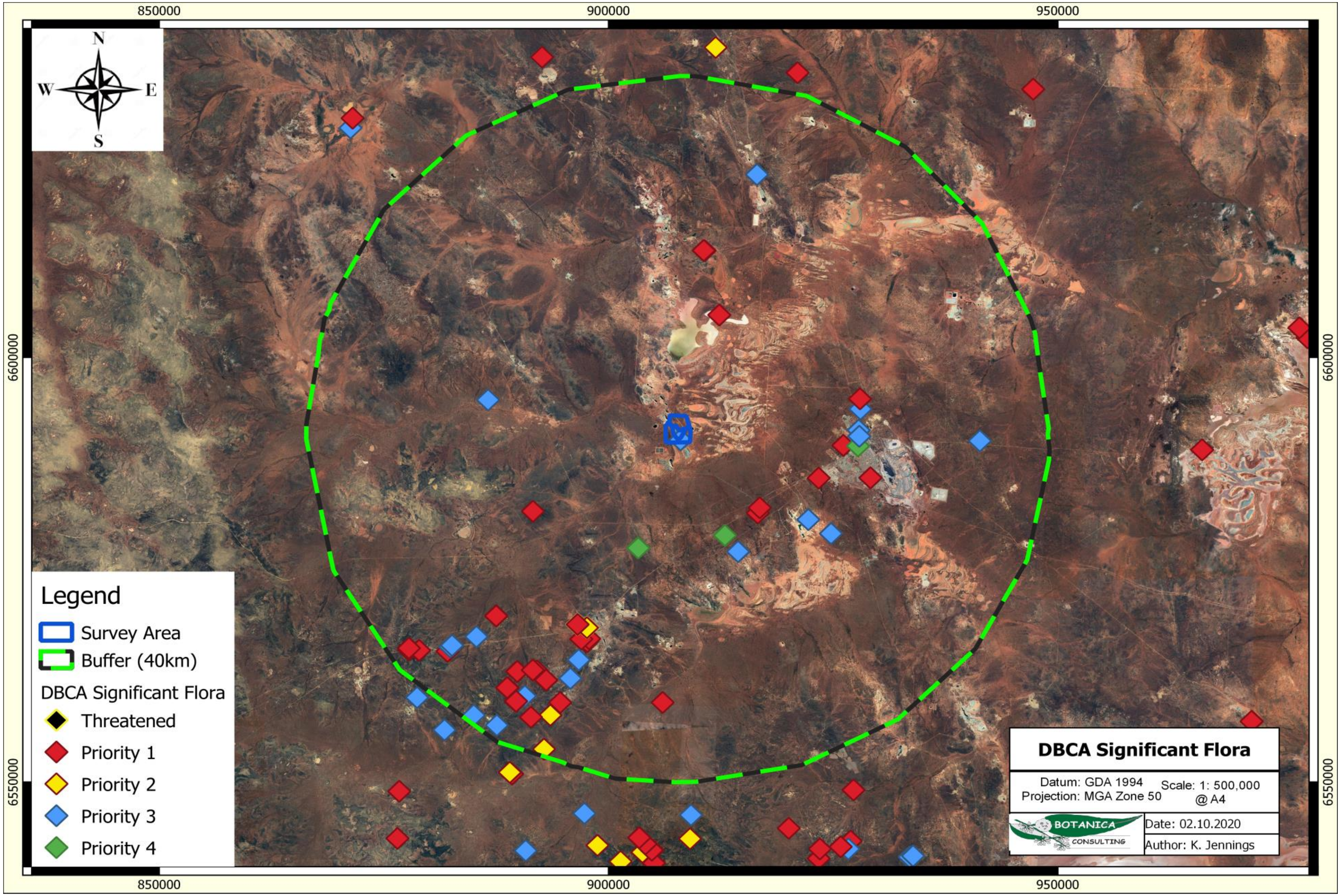


Figure 4-1: DBCA significant flora records

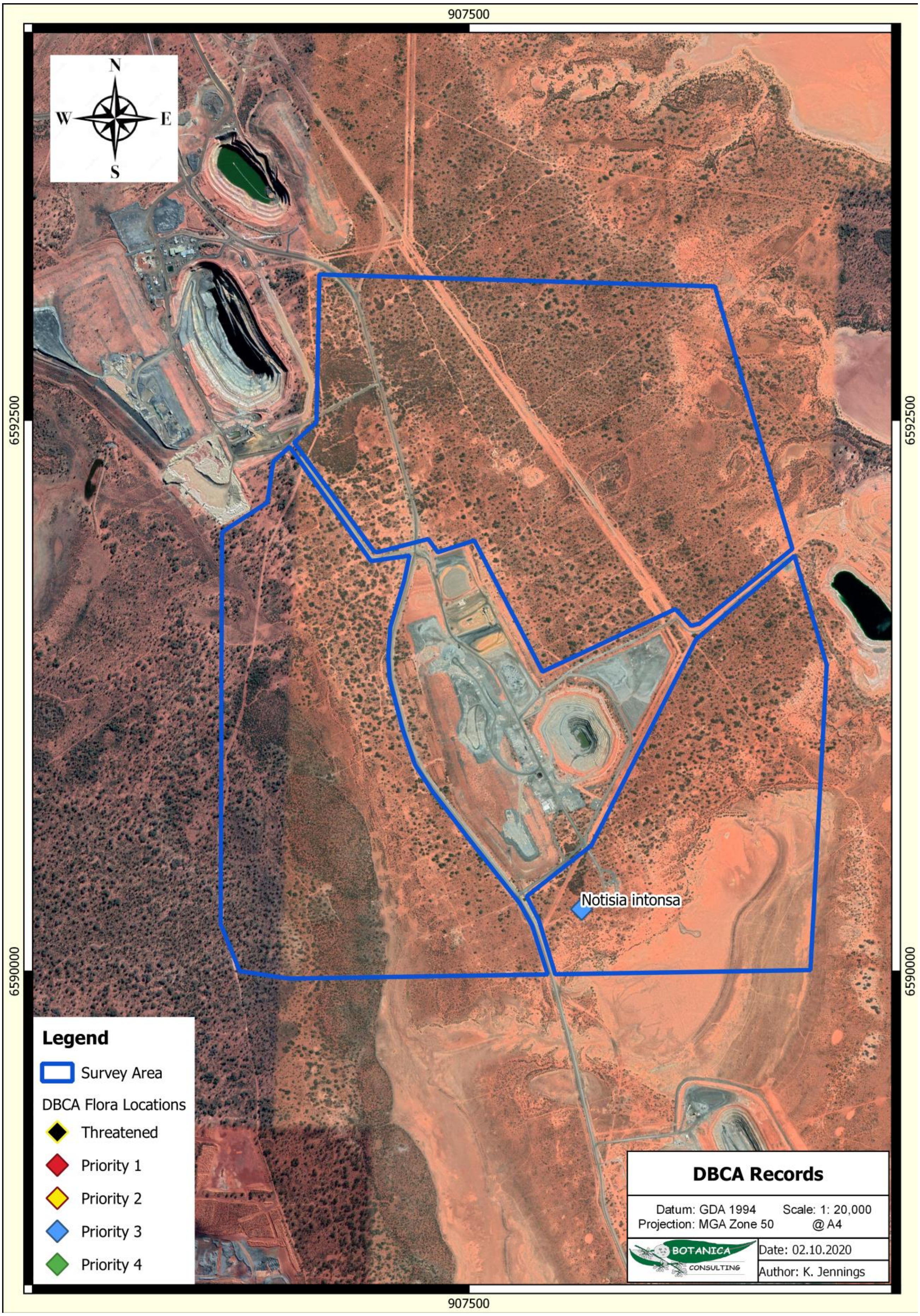


Figure 4-2: DBCA records within the survey area

4.1.2 Vegetation

The Pre-European vegetation association dataset (DPIRD, 2018) indicates that the survey area is located within the three vegetation associations (Figure 4-3). The association descriptions and remaining extent, as specified in the 2018 Statewide Vegetation Statistics (DBCA, 2019) is provided in Table 4-2. Areas retaining less than 30% of their pre-European vegetation extent generally experience exponentially accelerated species loss, while areas with less than 10% are considered "endangered" (EPA, 2000). All vegetation associations retain >90% of their Pre-European extent. Development within the survey area will not significantly reduce the extent of pre-European vegetation of these associations.

Table 4-2: Pre-European Vegetation Associations within the survey area

Vegetation Association	Current Extent (ha)	Pre-European extent remaining (%)	% in DBCA managed lands	Structural Description	Floristic Description	Extent within survey area Ha (%)
Coolgardie 125	3,146,487	90.3	5.4	Salt lake, lagoon, clay pan	-	142 ha (21.9%)
Coolgardie 468	583,902	98.6	4.1	Woodland other	Goldfields; gimlet, redwood etc. *E. salubris*, *E. oleosa*. Riverine; rivergum *E. camaldulensis*.	258 ha (39.8%)
Coolgardie 540	200,158.84	98.98	27.8	Saltbush and/or bluebush with scattered low trees	Mulga, other wattle, casuarina *Atriplex* spp. *Maireana* spp. with *Acacia aneura*, *A. papyrocarpa*, *Casuarina pauper*	249 ha (38.4%)

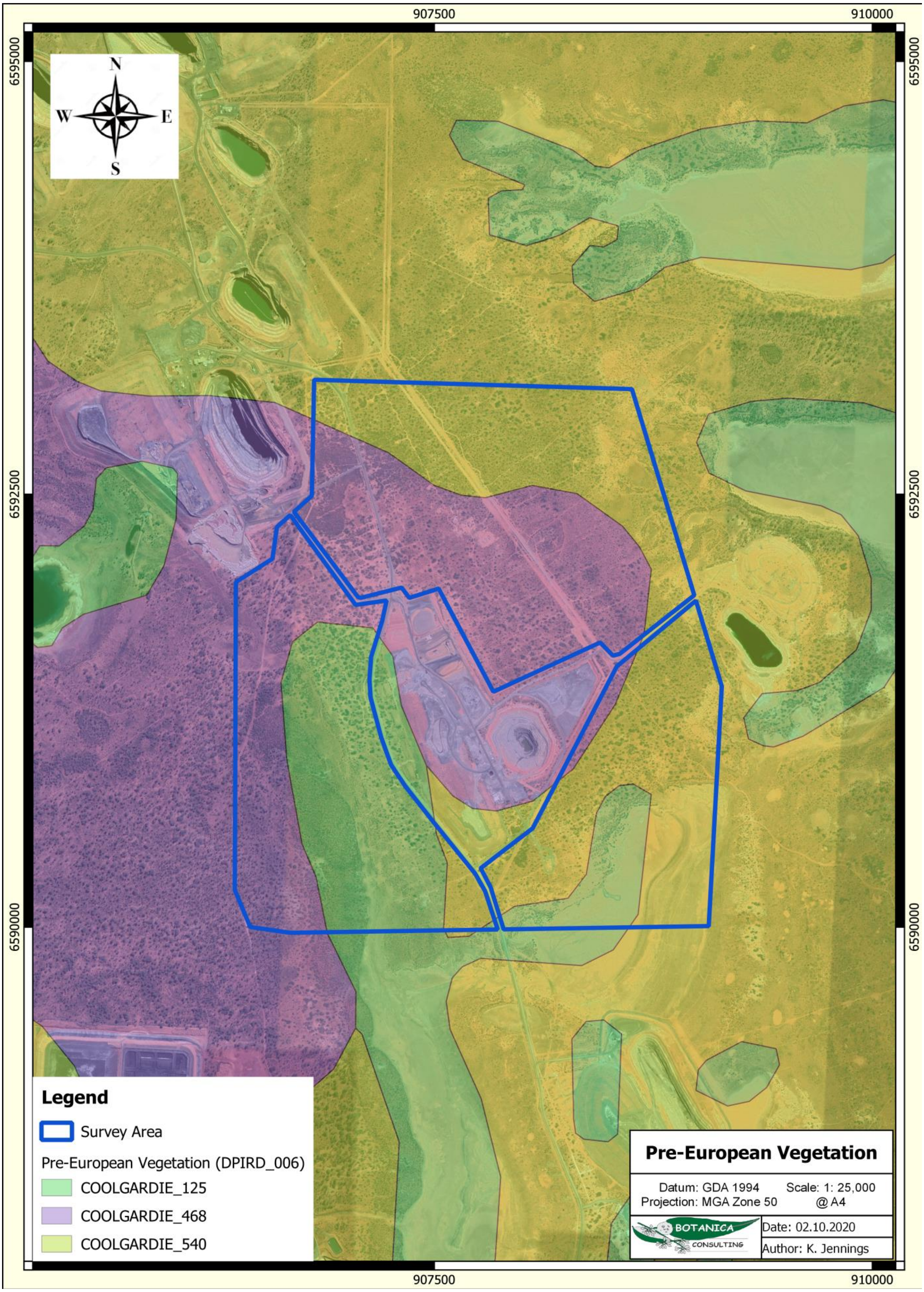


Figure 4-3: Pre-European Vegetation Associations within the survey area

4.1.3 Fauna

According to the results of the NatureMap search (DBCA, 2020), a total of 326 fauna taxa have been recorded within a 40 km radius of the survey area, consisting of 149 bird, 29 mammal, 73 reptile, six amphibian, one fish and 68 invertebrate taxa. This total includes nine introduced (feral) species.

4.1.3.1 Introduced (Feral) Fauna

The NatureMap and EPBC database searches identified 15 feral species as potentially occurring in the survey area (Table 4-3).

Table 4-3: Potentially Occurring Introduced Fauna

Family	Taxa	Common Name
Bovidae	*Bos taurus*	European Cattle
	Capra hircus	Goat
	Ovis aries	Sheep
Canidae	*Canis lupus familiaris*	Domestic Dog
	Vulpus vulpus	Red Fox
Columbidae	*Columba livia*	Domestic Pigeon
	Streptopelia chinensis	Spotted Turtle-Dove
	Streptopelia senegalensis	Laughing Turtle-Dove
Equidae	*Equus asinus*	Donkey, Ass
	Equus caballus	Horse
Felidae	*Felis catus*	Cat
Gekkonidae	*Hemidactylus frenatus*	Asian House Gecko
Leporidae	*Oryctolagus cuniculus*	Rabbit
Motacillidae	*Anthus australis*	Australian Pipit
Muridae	*Mus musculus*	House Mouse

4.1.3.2 Conservation Significant Fauna

The desktop review identified 14 fauna species of conservation significance as previously being recorded in the general area, consisting of eight Threatened species, two Priority 3 species, one Priority 4 species and two migratory or otherwise protected species. In addition, numerous migratory shorebirds were assessed collectively due to their similar habitat requirements. Habitat and distribution data was used to determine the likelihood of occurrence within the survey area. The assessment identified five significant fauna species as potentially occurring in the survey area, as well as migratory wading birds (Table 4-4).

The rankings and criteria used were:

- Would Not Occur: There is no suitable habitat for the species in the survey area and/or there is no documented record of the species in the general area since records have been kept and/or the species is generally accepted as being locally/regionally extinct (supported by a lack of recent records).
    - Locally Extinct: Populations no longer occur within a small part of the species natural range, in this case within 10 or 20km of the survey area. Populations do however persist outside of this area.

    - Regionally Extinct: Populations no longer occur in a large part of the species natural range, in this case within the Goldfields region. Populations do however persist outside of this area.

- Unlikely to Occur: The survey area is outside of the currently documented distribution for the species in question, or no suitable habitat (type, quality and extent) was identified as being present during the field assessment. Individuals of some species may occur occasionally as vagrants/transients especially if suitable habitat is located nearby but the site itself would not support a population or part population of the species.

- Possibly Occurs: Survey area is within the known distribution of the species in question and habitat of at least marginal quality was identified as likely to be present during the field survey and literature review, supported in some cases by recent records being documented in literature from within or near the survey area. In some cases, while a species may be classified as possibly being present at times, habitat may be marginal (e.g. poor quality, fragmented, limited in extent) and therefore the frequency of occurrence and/or population levels may be low.

- Known to Occur: The species in question has been positively identified as being present (for sedentary species) or as using the survey area as habitat for some other purpose (for non-sedentary/mobile species) during field surveys within or near the survey area. This information may have been obtained by direct observation of individuals or by way of secondary evidence (e.g. tracks, foraging debris, scats). In some cases, while a species may be classified as known to occur, habitat may be marginal (e.g. poor quality, fragmented, limited in extent) and therefore the frequency of occurrence and/or population levels may be low.

Table 4-4: Likelihood of Occurrence – Fauna Species of Conservation Significance

Species	Conservation Status			Habitat Description	Assessment	Likelihood
	EPBC Act	BC Act	DBCA Priority			
Arid Bronze Azure Butterfly *Ogyris subterrestris petrina*	CR	CR	-	At the two known extant locations within the Wheatbelt Region, vegetation is mature mixed *Eucalyptus salubris / E. salmonophloia* woodlands on red-brown loam soils, with an open understorey. In addition to gimlet and salmon gum, other smooth-barked eucalyptus at these sites which have basal ant colonies include *E. capilosa* subsp. *wandoo, E. loxophleba* subsp*. lissophloia* and *E. sheathiana*. The habitat at the locally extinct Lake Douglas site located within the Goldfields Region differs from the other sites but is also dominated by mature smooth-barked eucalypt woodland, particularly *E. concinna*. The most critical factor for habitat occupancy by the butterfly is the presence of large colonies of the host ant; *Camponotus sp. nr. terebrans* (DBCA, 2020b).	Unlikely to occur. Only known to be extant at two locations within the Wheatbelt Region and is presumed extinct at another location within the Goldfields Region (Lake Douglas-approximately 17km south-east of the survey area). Suitable habitat for host ant unlikely to be present. Survey area has been subject to previous mining/ exploration and pastoral disturbance and is unlikely to provide floristically diverse habitat. The survey area has been subject to soil disturbance which adversely affects the host ant (DotEE, 2015).	Unlikely
Inland Hairstreak/Desert Blue Butterfly *Jalmenus aridus*	-	-	P4	Acacia shrubland in the eastern goldfields and wheatbelt of WA, favouring young shrubs of the Senna food plant up to 1.5m high and old mature trees of the Acacia food plant up to 4m high, growing in shallow gullies and gentle slopes (Braby, 2016). The larvae feed on the leaves and flowers of *Senna nemophila* and *Acacia tetragonophylla*. The caterpillars are attended by the ant species *Froggattella kirbii*. (ALA, 2020).	Unlikely to occur. Only known from one location near Kalgoorlie (Lake Douglas-approximately 17km south-east of the survey area). Suitable habitat unlikely to be present.	Unlikely
Night Parrot *Pezoporus occidentalis*	EN	CR	-	Most habitat records are of Triodia (Spinifex) grasslands and/or chenopod shrublands in the arid and semi-arid zones, or *Astrebla* spp. (Mitchell grass), shrubby samphire and chenopod associations, scattered trees and shrubs, *Acacia aneura* (Mulga) woodland, treeless areas and bare gibber are associated with sightings of the species. Roosting and nesting sites are consistently reported as within clumps of dense vegetation, primarily old and large Spinifex (*Triodia*) clumps, but sometimes other vegetation types (DAWE, 2020b).	Would not occur. No suitable habitat.	Would Not Occur
Carnaby's Cockatoo *Calyptorhynchus latirostris*	EN	EN		Carnaby's Cockatoo is endemic to, and widespread in, the south-west of Western Australia. It occurs from the wheatbelt, in areas that receive between 300 and 750 mm of rainfall annually, across to wetter regions in the extreme south-west, including the Swan Coastal Plain and the southern coast. Its range extends from Cape Arid in the south-east to Kalbarri in the north, and inland to Hatter Hill, Gibb Rock, Narembeen, Noongar, Wongan Hills, Nugadong, near Perenjori, Wilroy and Nabawa.	Would Not Occur. No documented records in the region.	Would Not Occur
Grey Falcon *Falco hypoleucos*	VU	VU		The Grey Falcon occurs at low densities across inland Australia. The species frequents timbered lowland plains, particularly acacia shrublands that are crossed by tree-lined water courses. The species has been observed hunting in treeless areas and frequents tussock grassland and	Possibly Occurs. Survey area may form part of larger home range.	Possible

Species	Conservation Status			Habitat Description	Assessment	Likelihood
	EPBC Act	BC Act	DBCA Priority			
				open woodland, especially in winter. While breeding Grey Falcons feed almost exclusively on birds. Prey species include doves, pigeons, small parrots and cockatoos and finches, but a variety of other bird prey species has been recorded. Non-avian prey recorded by direct observation include small mammals and lizards.		
Malleefowl *Leipoa ocellata*	VU	VU	-	Scrublands and woodlands dominated by mallee and wattle species (DAWE, 2020b).	Possibly Occurs. Habitat likely marginal and unsuitable for breeding. Occasional transients only.	Possible
Fork-tailed Swift *Apus pacificus*	MI	MI	-	Low to very high airspace over varied habitat from rainforest to semi desert (Birdlife Australia, 2019).	Unlikely to occur. Very occasional transients only.	Unlikely
Migratory Shorebirds (Various species)	IA/MI	IA/MI	P3-P4	Prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. This includes lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and hypersaline salt lakes inland (DAWE, 2020b).	May utilise ephemeral lakes and fringing vegetation within the survey area during flood events; however, the fringing vegetation is of reduced quality, being subjected to multiple disturbances including historic mining and exploration, grazing, tracks and unlikely to support migratory bird populations/ breeding events.	Possible
Peregrine Falcon *Falco peregrinus*	-	OS	-	The Peregrine Falcon is found in most habitats, from rainforests to the arid zone, and at most altitudes, from the coast to alpine areas. It requires abundant prey and secure nest sites, and prefers coastal and inland cliffs or open woodlands near water, and may even be found nesting on high city buildings (Birdlife Australia, 2018).	Possibly Occurs. Survey area may form part of larger home range but unlikely to breed in area.	Possible
Grey Wagtail *Motacilla cinerea*	MI	MI	-	Running water in disused quarries, sandy, rocky streams in escarpments and rainforest, sewerage ponds, ploughed fields and airfields (Morecombe 2004).	Would Not Occur. No suitable habitat.	Would Not Occur
Bilby *Macrotis lagotis*	VU	VU		In Western Australia, it is mainly restricted to the Gibson Desert, Little Sandy Desert, Great Sandy Desert and parts of the Pilbara and Southern Kimberley.	Would Not Occur. No documented records in the region.	Would Not Occur
Numbat *Myrmecobius fasciatus*	EN	EN		Previously widespread in arid and semi-arid Australia, the species is now restricted to two isolated wild populations in south-west Western Australia and a number of translocations to predator proof locations.	Would Not Occur. No documented records in the region.	Would Not Occur
Chuditch, Western Quoll *Dasyurus geoffroii*	VU	VU		Previously occurred throughout arid and semi-arid Australia but is now restricted to south-west Western Australia. (DAWE, 2020b).	Unlikely to Occur. Considered to be locally extinct.	Unlikely
Central Long-eared Bat *Nyctophilus major tor*	-	-	P3	*Nyctophilus major* occurs in the high rainfall southwest region of Western Australia. Habitat is large to very tall eucalypt species, karri *Eucalyptus diversicolor*, jarrah *E. marginata*, tuart *E. gomphocephala*, and marri *Corymbia calophylla*. Other woodland types inhabited by the bat	Unlikely to Occur. Suitable habitat unlikely to be present.	Unlikely

Species	Conservation Status			Habitat Description	Assessment	Likelihood
	EPBC Act	BC Act	DBCA Priority			
				include stands of melaleuca, banksia and sheoak tees of genus *Allocasuarina*, and include a dense understory.		
Fairy shrimp (Carnarvon to Kalgoorlie) *Branchinella denticulata*			P3	Freshwater bodies	Habitat unlikely to be present.	Unlikely

4.1.4 Conservation Areas

There are no proposed or vested Conservation Reserve located within the survey area.

There are no DBCA managed or interest land located within the survey area.

There are no Environmentally Sensitive Areas located within the survey area.

There are no Nationally Important or RAMSAR wetlands located within the survey area.

The closest significant environmental feature is the Kurrawang Nature Reserve, which is DBCA-managed land located approximately 12 km south-east of the survey area. Disturbances within the survey area are unlikely to impact this area. The location of proposed and vested Conservation Reserves and ESA's in relation to the survey area is provided in Figure 4-4.

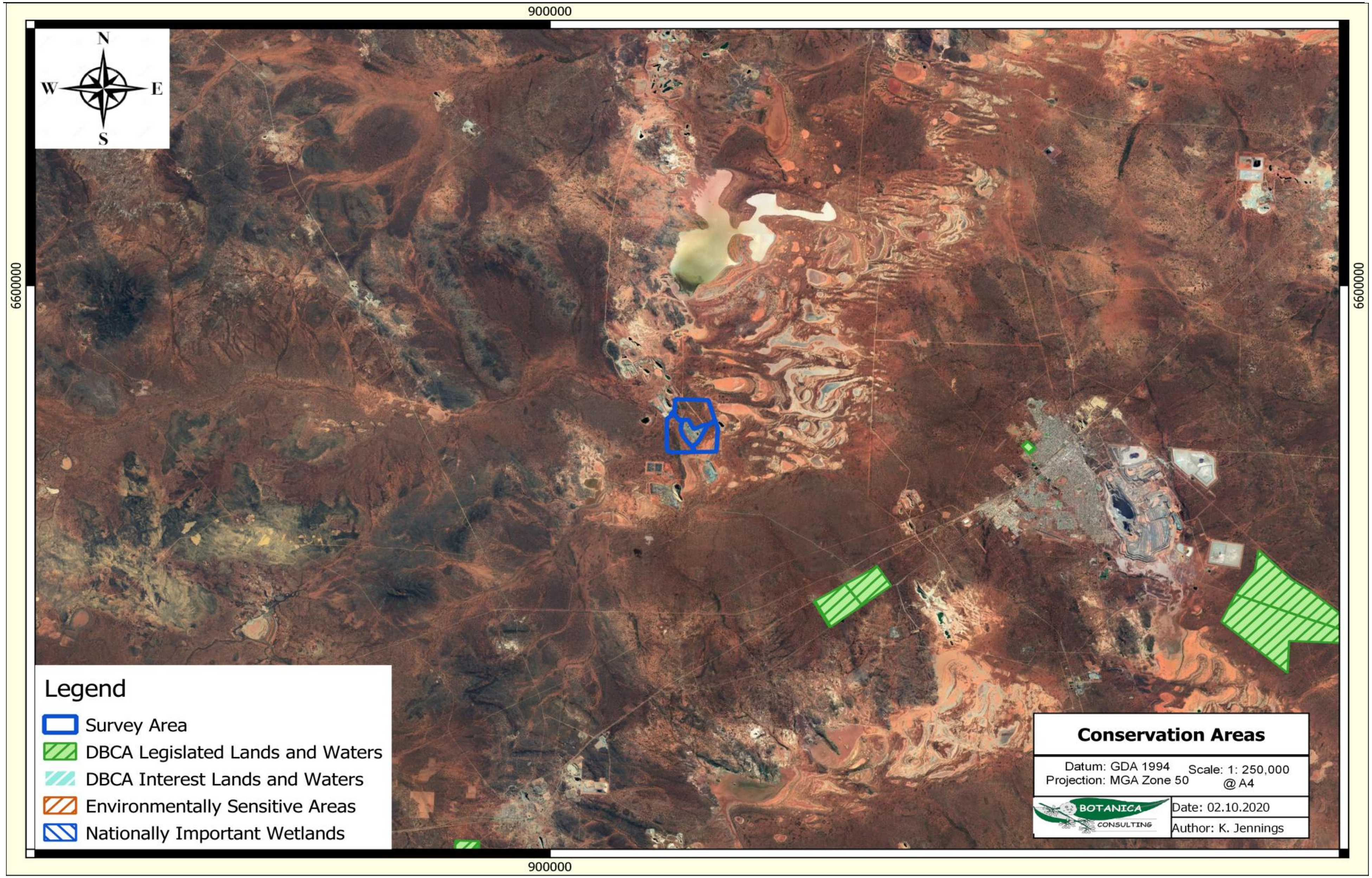


Figure 4-4: Conservation Areas

4.2 Field Assessment

4.2.1 Flora

The field survey identified 60 flora taxa within the survey area, including three introduced (weed) species. These taxa represented 30 genera across 19 families, with the most diverse genera being *Eucalyptus* (8 species), *Eremophila* (7 species) and *Maireana* (6 species).

4.2.1.1 Introduced Flora

Three species of introduced flora were recorded within the survey area: *Atriplex lentiformis*, *Cucumis myriocarpus* and *Nicotiana glauca*. None of these species are a Weed of National Significance or a Declared Pest in Western Australia.

4.2.1.2 Significant Flora

According to the EPA *Environmental Factor Guideline for Flora and Vegetation* (EPA, 2016b) significant flora includes:

- flora being identified as threatened or priority species;
- locally endemic flora or flora associated with a restricted habitat type (e.g. surface water or groundwater dependent ecosystems);
- new species or anomalous features that indicate a potential new species;
- flora representative of the range of a species (particularly, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range);
- unusual species, including restricted subspecies, varieties or naturally occurring hybrids; and
- flora with relictual status, being representative of taxonomic groups that no longer occur widely in the broader landscape.

No Threatened or Priority flora species were recorded within the survey area. The previously recorded Priority 3 species *Notisia intonsa* was not observed. The Botanica (2010) flora survey determined that the vegetation community (*Casuarina* tall shrubland) associated with this record is unsuitable for the presence of this species, and this is likely an incorrectly located record. Areas of *Melaleuca* shrubland in riparian zones, which are more suitable habitat for *Notisia intonsa,* were searched extensively but no individuals of this species were located.

4.2.2 Vegetation Communities

A total of seven vegetation communities were identified within the survey area. Vegetation community description and extent are listed below in Table 4-5 and illustrated spatially in Figure 4-5. Vegetation community descriptions and extents were determined from field survey results, aerial imagery interpretation and extrapolation of the communities. Floristic species composition for each vegetation community is listed in Appendix 5.

The survey found CLP-EW1 to be the most diverse community, with 44 flora species, and CD-CSSSF1 the least with 5 species. CLP-EW1 was the most widespread community in the survey area, occupying 253 ha (39.0%), while RP-CFW1 was the most restricted with 25 ha (3.9%).

Table 4-5: Vegetation Community Descriptions and Extent

Vegetation Community	Broad Floristic Formation (NVIS III)	Vegetation Description (NVIS V)	Landform	Image
CLP-EW1 253 ha (39.0%)	*Eucalyptus* low open woodland	*Eucalyptus salmonophloia, Eucalyptus salubris and Eucalyptus lesouefii* low woodland over *Eremophila scoparia, Eremophila decipiens* mid shrubland over *Atriplex vesicaria*, *Olearia muelleri* low shrubland.	Clay/loam plain	
CLP-EW2 44 ha (6.8%)	*Eucalyptus* low closed woodland	*Eucalyptus clelandii* closed woodland over Olearia muelleri low sparse shrubland.	Clay/loam plain.	

Vegetation Community	Broad Floristic Formation (NVIS III)	Vegetation Description (NVIS V)	Landform	Image
RP-CFW1 25 ha (3.9%)	Casuarina open forest.	*Casuarina pauper* open forest over *Acacia hemiteles* mid open shrubland over *Atriplex nummularia* low open shrubland.	Undulating plains	
CLP-RMNV1 71 ha (10.9%)	Chenopod open shrubland	Open mixed chenopod shrubland	Flats	

Vegetation Community	**Broad Floristic Formation (NVIS III)**	**Vegetation Description (NVIS V)**	**Landform**	**Image**
CD-CSSSF1 30 ha (4.6%)	Samphire low open shrubland	*Tecticornia indica* subsp. *indica* low open shrubland	Low-lying areas.	
SLP-EW1 158 ha (24.3%)	*Eucalyptus* woodland	*Eucalyptus clelandiurm*woodland over *Eremophila parviflora, Exocarpos aphyllus* open shrubland.	Slight rises	

Vegetation Community	Broad Floristic Formation (NVIS III)	Vegetation Description (NVIS V)	Landform	Image
SLP-MF1 46 ha (7.1%)		*Melaleuca pauperiflora* subsp*. pauperiflora, Melaleuca lateriflora* subsp*. lateriflora* mid shrubland over *Ptilotus obovatus* var. *obovatus*, *Maireana triptera* low open shrubland.	Riparian zone	

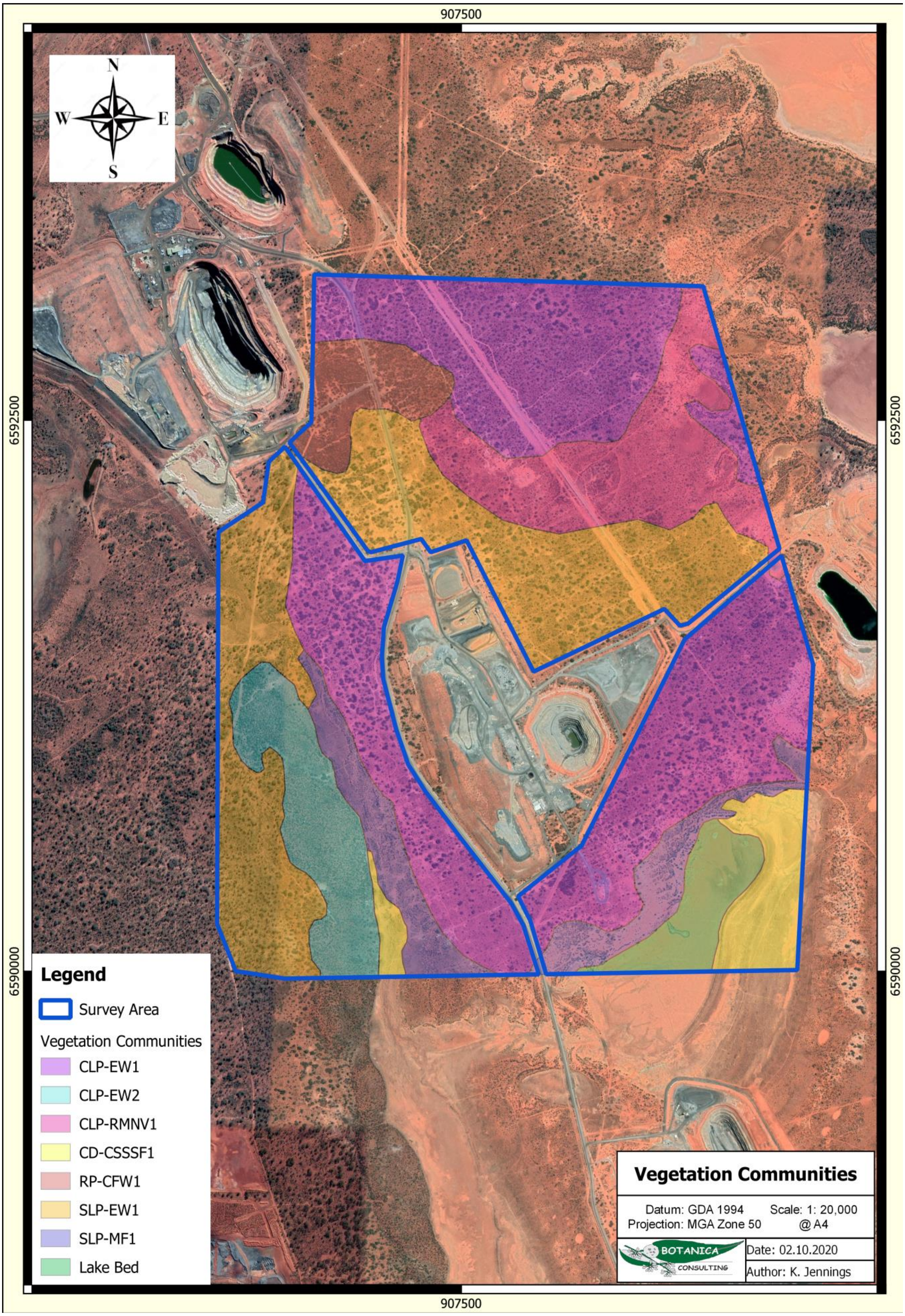


Figure 4-5: Vegetation Communities

4.2.3 Vegetation Condition

Based on the vegetation condition rating scale adapted from Keighery (1994) and Trudgen, (1988), native vegetation within the survey area was rated as 'good' (Table 4-6,

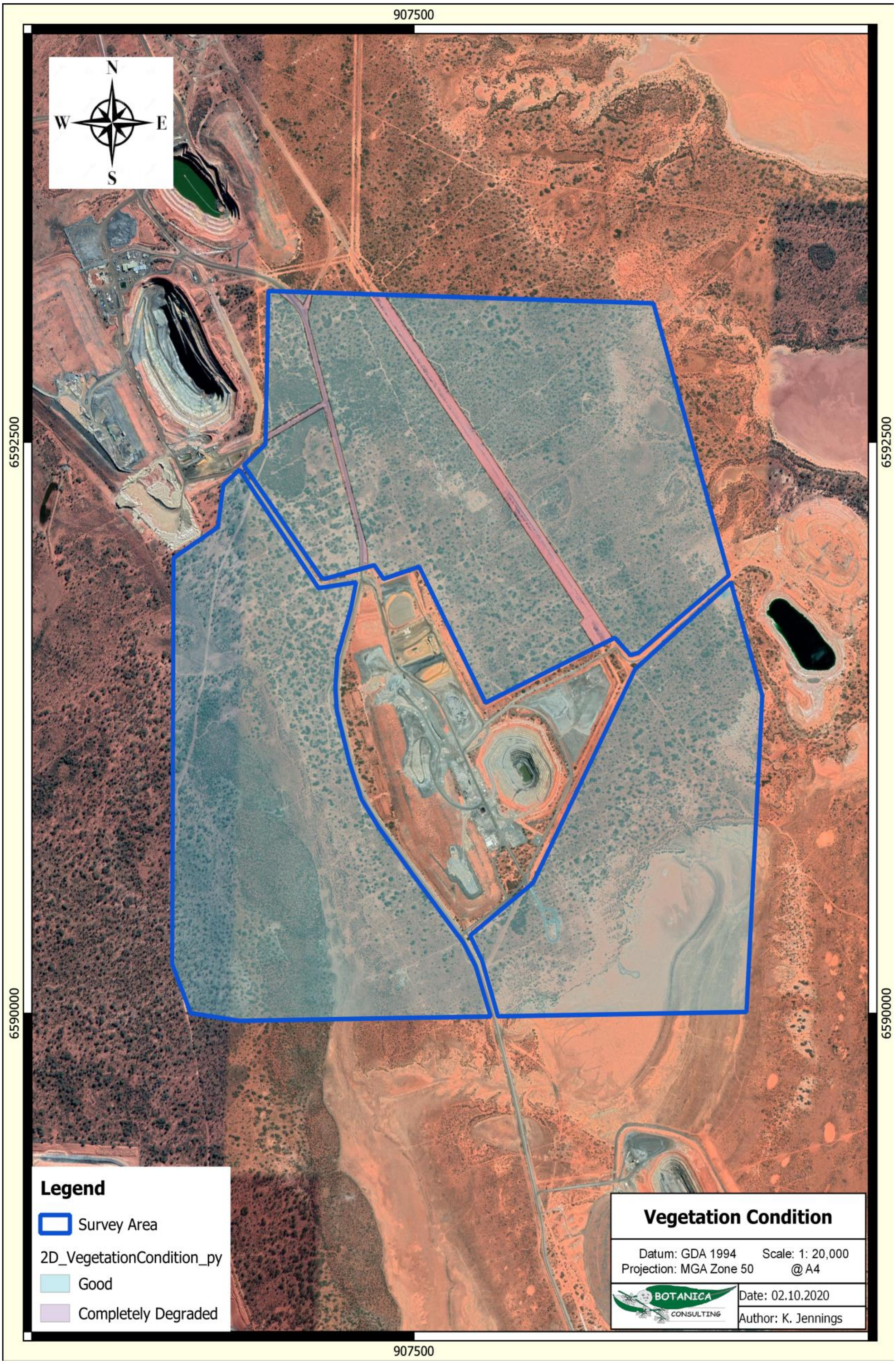

907500
N
W
E
S
6592500
6590000
6592500
6590000
907500
Legend
Survey Area
2D_VegetationCondition_py
Good
Completely Degraded
Vegetation Condition
Datum: GDA 1994
Projection: MGA Zone 50
Scale: 1: 20,000
@ A4
BOTANICA CONSULTING
Date: 02.10.2020
Author: K. Jennings

Figure 4-6). ‘Good’ condition depicts more obvious signs of damage caused by human activity since European settlement, including impacts to vegetation structure and composition such as low levels of grazing and/or slightly aggressive weeds. Vegetation within the survey area has been subject to mining, exploration and pastoral land use disturbance. Cleared areas associated with road infrastructure and easement were rated as ‘completely degraded’.

Table 4-6: Vegetation Condition within the survey area

Condition Rating	Area (ha)	Area (%)
Good	632	97.4
Completely Degraded	17	2.6
Total	**649**	**100.0**

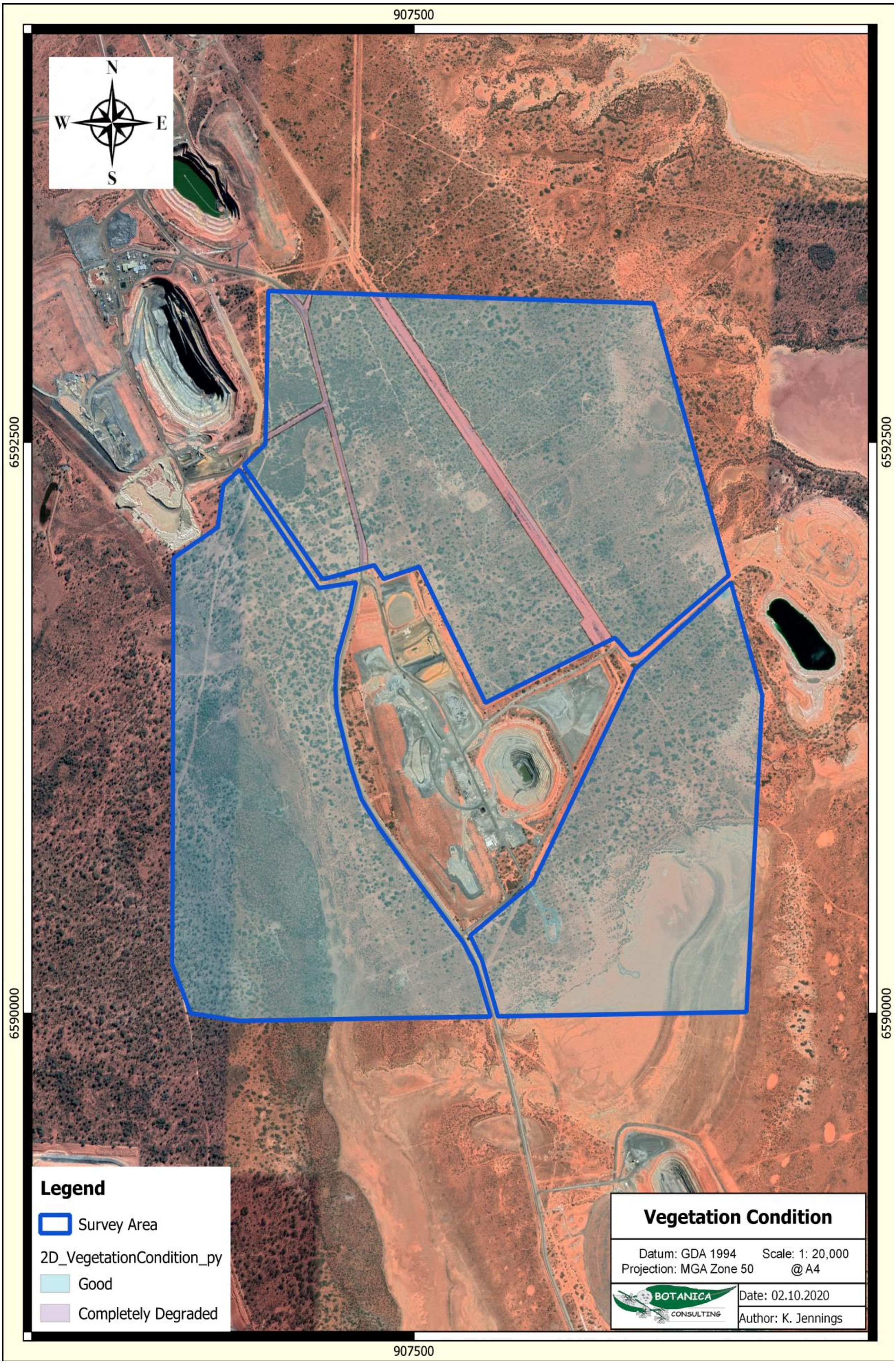


Figure 4-6: Vegetation Condition within the survey area

4.2.4 Significant Vegetation

According to the EPA *Environmental Factor Guideline for Flora and Vegetation* (EPA, 2016b) significant vegetation includes:

- vegetation being identified as threatened or priority ecological communities;
- vegetation with restricted distribution;
- vegetation subject to a high degree of historical impact from threatening processes;
- vegetation which provides a role as a refuge; and
- vegetation providing an important function required to maintain ecological integrity of a significant ecosystem.

No significant vegetation, including representatives of Threatened or Priority Ecological Communities, was identified within the survey area.

4.2.5 Fauna Habitat

A total of five broad scale terrestrial fauna habitats were identified, based on vegetation and associated landforms identified during the flora and vegetation assessment, with mixed *Eucalyptus* woodland being the most extensive (456 ha, 70.3%). The extent of the identified fauna habitats and a summary description of each are provided in Table 4-7. The extent of fauna habitat within the survey area is shown spatially in Figure 4-7.

Table 4-7: Main Terrestrial Fauna Habitats within the survey area

Fauna Habitat Description	Example Image
Open Eucalyptus Woodland Area: 456 ha (70.3%)	
Chenopod Low Open Shrubland Area: 100 ha (15.4%)	
Melaleuca Shrubland Area: 46 ha (7.1%)	

Fauna Habitat Description	Example Image
Casuarina Open Forest Area: 25 ha (3.8%)	
Bare lakes/ playa Area: 22 ha (3.4%)	

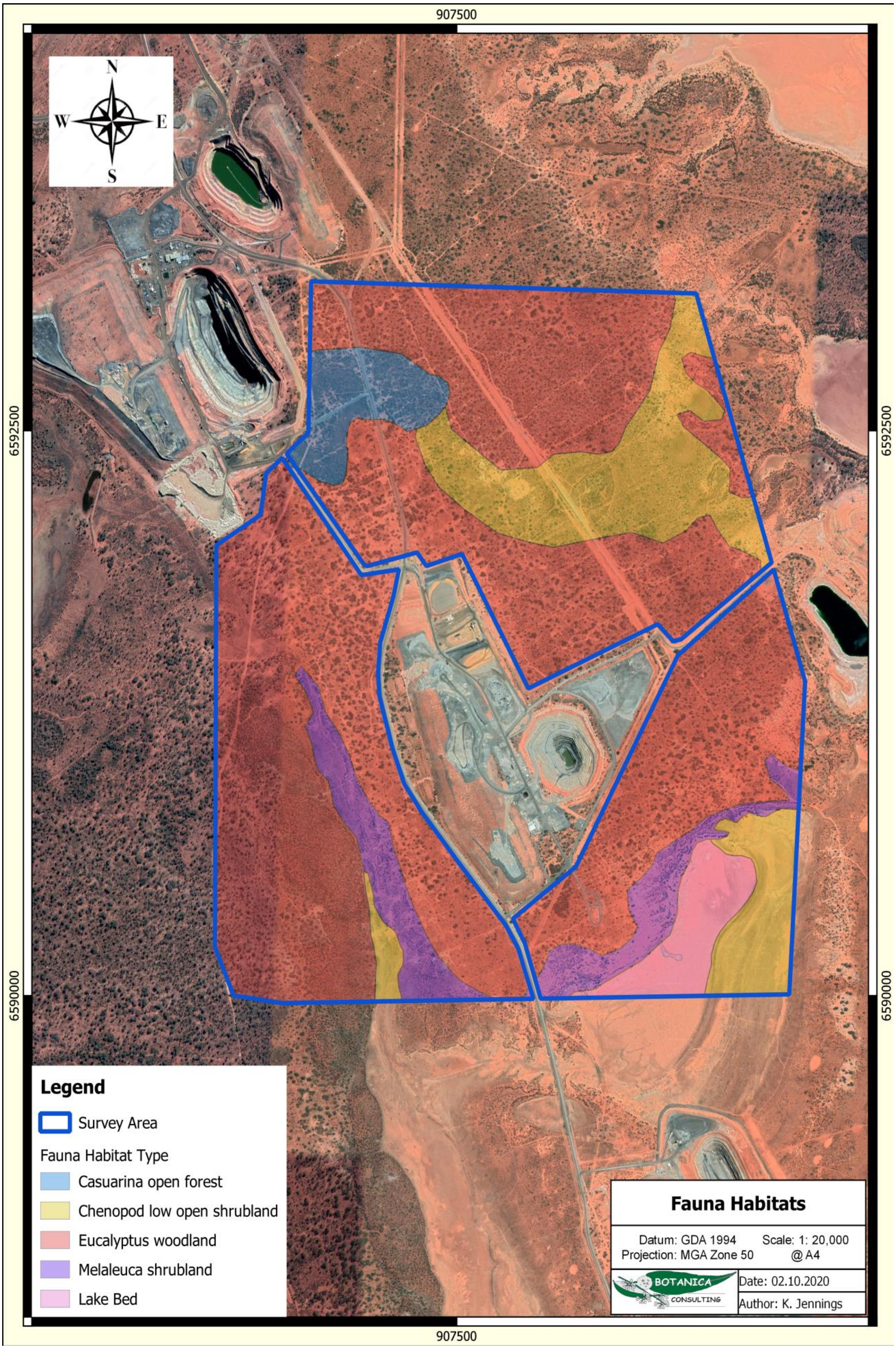


Figure 4-7: Terrestrial Fauna Habitats

4.2.6 Significant Fauna

According to the EPA *Environmental Factor Guideline for Terrestrial Fauna* (EPA, 2016d) significant fauna includes:

- Fauna being identified as a threatened or priority species;
- Fauna species with restricted distribution;
- Fauna subject to a high degree of historical impact from threatening processes; and
- Fauna providing an important function required to maintain the ecological integrity of a significant ecosystem.

No evidence of significant fauna species were observed during the survey, including no evidence of Malleefowl nesting mounds or other activity.

The current status of some species on site and/or in the general area is difficult to determine, however, based on the habitats present and, in some cases, direct observations or recent nearby records, the following species of conservation significance can be regarded as possibly utilising the survey area for some purpose at times, these being:

- **Malleefowl *Leipoa ocellata* - Vulnerable (EPBC Act and BC Act)**
  This species is occasionally recorded in the general area with the most recent record from 2016, with the species observed in the Bonnievale survey area, approximately 15 km south-west of the survey area (Terratree, 2016). Habitat appears marginal/or unsuitable for breeding, however occasional transients could potentially occur. No evidence of malleefowl activity (inactive or active mounds, tracks, feathers or bird observations etc.) were observed within the survey area. Significant impact unlikely.

- **Grey Falcon *Falco hypoleucos* - Vulnerable (EPBC Act and BC Act)**
  This species is sparsely recorded throughout inland Australia. Suitable habitat may be present but in unlikely to represent breeding or critical habitat. Significant impact unlikely.

- **Peregrine Falcon *Falco peregrinus* – Other Specially Protected (BC Act)**
  This species is recorded throughout inland Australia. Suitable habitat may be present but in unlikely to represent breeding habitat. Survey area may form part of larger home range but unlikely to breed in area. Significant impact unlikely.

- **Migratory wader (Various Species) - Migratory (EPBC Act and BC Act)**
  Migratory birds may utilize the lake and fringing environments following significant rainfall event; however, the fringing vegetation is of reduced quality, being subjected to multiple disturbances including historic mining and exploration, grazing, tracks and unlikely to support migratory bird populations/ breeding events.

It should be noted that while habitats onsite for one or more of the species listed above are considered possibly suitable, some or all may be marginal in extent/quality and therefore the fauna species considered as possibly occurring may in fact only visit the area for short periods as infrequent vagrants.

4.3 Matters of National Environmental Significance

4.3.1 *Environment Protection and Biodiversity Conservation Act 1999*

The EPBC Act protects matters of national environmental significance, and is used by the Commonwealth DAWE to list threatened taxa and ecological communities into categories based on the criteria set out in the Act (www.environment.gov.au/epbc/index.html). The Act provides a national environmental assessment and approval system for proposed developments and enforces strict penalties for unauthorised actions that may affect matters of national environmental significance. Matters of national environmental significance as defined by the Commonwealth EPBC Act include:

- Nationally threatened flora species;
- World heritage properties;
- National heritage places;
- Wetlands of international importance (often called 'Ramsar' wetlands after the international treaty under which such wetlands are listed);
- Nationally threatened ecological communities;
- Commonwealth marine area;
- The Great Barrier Reef Marine Park; and
- Nuclear actions (including uranium mining) a water resource, in relation to coal seam gas development and large coal mining development.

No matters of national environmental significance as defined by the Commonwealth EPBC Act were identified within the survey area.

4.4 Matters of State Environmental Significance

4.4.1 Environmental Protection Act WA 1986

The EP Act provides for the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection, enhancement and management of the environment. The Act is administered by The Department of Water and Environment Regulation (DWER), which is the State Government's environmental regulatory agency.

Under Section 51C of the EP Act and the *Environmental Protection (Clearing of Native Vegetation) Regulations (Regulations) WA 2004* any clearing of native vegetation in Western Australia that is not eligible for exemption under Schedule 6 of the *EP Act 1986* or under the Regulations 2004 requires a clearing permit from the DWER or DMIRS. Under Section 51A of the *EP Act 1986* native vegetation includes aquatic and terrestrial vegetation indigenous to Western Australia, and intentionally planted vegetation declared by regulation to be native vegetation, but not vegetation planted in a plantation or planted with commercial intent. Section 51A of the *EP Act 1986* defines clearing as "the killing or destruction of; the removal of; the severing or ringbarking of trunks or stems of; or the doing of substantial damage to some or all of the native vegetation in an area, including the flooding of land, the burning of vegetation, the grazing of stock or an act or activity that results in the above". Exemptions under Schedule 6 of the EP Act and the EP Regulations do not apply in ESAs as declared under Section 51B of the EP Act or TEC listed under State and Commonwealth legislation.

No evidence of the survey area containing any TEC or Threatened flora or fauna was found during the survey period. The survey area is not located within an ESA.

4.4.2 Biodiversity Conservation Act 2016

This Act is used by the Western Australian DBCA for the conservation and protection of biodiversity and biodiversity components in Western Australia and to promote the ecologically sustainable use of biodiversity components in the State. Taxa are classified as 'Threatened" when their populations are geographically restricted or are threatened by local processes (see following sections for Threatened definitions). Under this Act all native flora and fauna are protected throughout the State. Financial penalties are enforced under this Act if threatened species are collected without an appropriate licence.

Under Section 54(1) of the BC Act, habitat is eligible for listing as critical habitat if:

a) it is critical to the survival of a threatened species or a threatened ecological community; and
b) its listing is otherwise in accordance with the ministerial guidelines.

No threatened species or critical habitat listed under the BC Act were recorded within the survey area.

4.5 Native Vegetation Clearing Principles

Based on the outcomes from the survey undertaken, Botanica assessed the results of the desktop and field survey with regards to the native vegetation clearing principles listed under Schedule 5 of the EP Act (Table 4-8). The assessment found that the proposed vegetation clearing activities may be at variance with clearing principles (f) and (i).

Table 4-8: Assessment against native vegetation clearing principles

Letter	Principle	Assessment	Outcome
Native vegetation should not be cleared if it:			
(a)	comprises a high level of biological diversity.	The survey area is located Eastern Goldfields subregion of Western Australia and comprises gently undulating plains interrupted in the west by low hills and ridges of Archaean greenstones and in the east by a horst of Proterozoic basic granulite. The underlying strata are eroded flat and covered with Tertiary sand and gravel soils, scattered exposures of bedrock, and plains of calcareous earths. The region has an arid to semi-arid Warm Mediterranean climate (Cowan, 2001). A total of seven vegetation types were identified within the area. Vegetation identified within the survey area is not considered to be of high biological diversity and is well represented outside of the survey area. The survey area does not occur within any mapped Priority Ecological Communities (PECs), Threatened Ecological Communities (TECs) or associated buffer zones and does not contain any Banded Ironstone Formations. No Threatened Flora taxa listed under the BC Act and EPBC Act are located within the survey area. No Priority Flora taxa were identified within the survey area.	Clearing is unlikely to be at variance to this principle

Letter	Principle	Assessment	Outcome
	Native vegetation should not be cleared if it:		
(b)	comprises the whole or part of, or is necessary for the maintenance of, a significant habitat for fauna indigenous to WA.	No significant fauna were observed within the survey area. Majority of the survey area comprises of broad fauna habitats that are typical of those in the wider region. Migratory birds may utilize the lake and fringing environments following significant rainfall event; however, the fringing vegetation is of reduced quality, being subjected to multiple disturbances including historic mining and exploration, grazing, tracks and unlikely to support migratory bird populations/ breeding events.	Clearing is unlikely to be at variance to this principle
(c)	includes, or is necessary for the continued existence of rare flora.	No Threatened Flora taxa, pursuant to the BC Act and the EPBC Act were identified within the survey area.	Clearing is not at variance to this principle
(d)	comprises the whole or part of or is necessary for the maintenance of a threatened ecological community (TEC).	No TEC listed under the EPBC Act or by the BC Act occur within the survey area.	Clearing is not at variance to this principle
(e)	is significant as a remnant of native vegetation in an area that has been extensively cleared	All pre-European Beard vegetation associations in the survey area retain >90% of their original pre-European vegetation extent.	Clearing is unlikely to be at variance to this principle
(f)	is growing, in, or in association with, an environment associated with a watercourse or wetland	There is an ephemeral salt lake/ playa and ephemeral drainage line within the survey area.	Clearing may be at variance to this principle
(g)	Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation.	The survey area and surrounding region has not been extensively cleared. Clearing within the survey area is not likely to lead to land degradation issues such as salinity, water logging or acidic soils.	Clearing is unlikely to be at variance to this principle
(h)	Native vegetation should not be cleared if the clearing of the vegetation is likely to have an impact on the environmental values of any adjacent or nearby conservation area.	The survey area is not located within a conservation area. The closest conservation reserve is the Kurrawang Nature Reserve, which located approximately 12 km south-east. Given the distance from the survey area, impacts to the environmental values of this conservation reserve are unlikely.	Clearing is unlikely to be at variance to this principle
(i)	Native vegetation should not be cleared if the clearing of the vegetation is likely to cause deterioration in the quality of surface or underground water.	There is an ephemeral salt lake/ playa and ephemeral drainage line within the survey area. Ground disturbance activities will need to be managed to prevent potential impacts.	Clearing may be at variance to this principle
(j)	Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence of flooding	Rainfall in the Eastern Goldfields subregion has an average rainfall of 200-300mm and an evaporation rate of 2400 mm. Rainfall data for Kalgoorlie-Boulder indicates that rainfall is spread throughout the year and rainfall events are unlikely to result in localised flooding. Clearing within the survey area is not likely to increase the incidence or intensity of flooding within the survey area or surrounds.	Clearing is unlikely to be at variance to this principle

5 BIBLIOGRAPHY

Atlas of Living Australia (2020b): *Jalmenus aridus: Inland Hairstreak*, https://bie.ala.org.au/species/urn:lsid:biodiversity.org.au:afd.taxon:5551a54a-2ff6-49c7-9b26-62f2484449b5, viewed 17/09/2020.

Beard, J.S., (1990). *Plant Life of Western Australia*, Kangaroo Press Pty Ltd, NSW.

BoM, (2020a). *Kalgoorlie-Boulder Airport Climate Data*, Bureau of Meteorology. Available: http://www.bom.gov.au/climate

BoM (2020b). Groundwater Dependent Ecosystems Atlas. Bureau of Meteorology, Available: http://www.bom.gov.au/water/groundwater/gde/map.shtml

Botanica Consulting (2010). *Level 1 Rubicon/ Hornet Spring Flora Survey.* Unpublished report prepared for Barrick-Kanowna Belle September 2010.

Cowan, M. (2001). *A Biodiversity Audit of Western Australia's 53 Biogeographical Region in 2001; Coolgardie 3 (COO3 –Eastern Goldfields subregion) pp 156-169,* Department of Conservation and Land Management, August 2001

DAFWA (2014). *Soil Landscape System of Western Australia,* Department of Agriculture and Food Western Australia

DAWE (2020a). *Protected Matters Search Tool, Environment Protection and Biodiversity Conservation Act 1999,* Department of Agriculture, Water and Environment, Australian Government.

DAWE (2020b). *Species Profile and Threats Database,* Department of Agriculture, Water and Environment, Australian Government.

DBCA (2017). *Priority Ecological Communities for Western Australia Version 27*, Species and Community Branch, 30 June 2017.

DBCA (2019). *2018 Statewide Vegetation Statistics (formerly the CAR Reserve Analysis).* Department of Biodiversity, Conservation and Attractions.

DBCA (2019a). Priority/ Threatened Flora Database Search. Obtained from Department of Biodiversity, Conservation and Attractions.

DBCA (2020). *NatureMap Database search*, Department of Biodiversity, Conservation and Attractions.

DBCA (2020b). Guidelines for the survey of arid bronze azure butterfly (ABAB) in Western Australia. Department of Biodiversity, Conservation and Attractions.

DotEE (2012). *Interim Biogeographic Regionalisation for Australia (IBRA),* Version 7, Department of the Environment and Energy.

DotEE (2017). *National Vegetation Information System (NVIS) Major Vegetation Groups, Version 4.2*, Department of the Environment and Energy.

DPIRD (2019). *Pre-European Vegetation (DPIRD_006)* Department of Primary Industries and Regional Development, Western Australia, 24 July 2019

DPIRD (2020). *Declared Organism database search,* Department of Primary Industries and Regional Development, Western Australia.
Available: http://www.biosecurity.wa.gov.au/

EPA, (2000). Position Statement No. 2 *Environmental Protection of Native Vegetation in Western Australia,* Environmental Protection Authority

EPA (2016b). *Environmental Factor Guideline for Flora and Vegetation – December 2016.* Environmental Protection Authority.

EPA (2016a). *Technical Guide - Flora and Vegetation Surveys for Environmental Impact Assessment – December 2016.* Environmental Protection Authority.

EPA (2020). *Technical Guide – Terrestrial Fauna Surveys for Environmental Impact Assessment – June 2020.* Environmental Protection Authority.

Geoscience Australia (2015). *Surface Hydrology GIS*. Australian Government.

Government of Western Australia, (2019): *Soil Landscape Mapping – Systems (DPIRD-064)*, mapping shapefiles obtained from data.wa.gov.au, last updated June 27, 2019

Harewood, G (2010). *Terrestrial Fauna Survey (Level 1) of the proposed Rubicon/ Hornet Mine Area.* Unpublished report prepared for Barrick-Kanowna Belle October 2010.

Keighery, B. J., (1994). *Bushland Plant Survey: A guide to plant community survey for the community.* Wildflower Society of Western Australia (Inc.), Nedlands.

Terratree Pty. Ltd. (2017): *Bonnievale Flora and Vegetation Assessment.* Unpublished report prepared on behalf of Focus Minerals Ltd. April 2017

Tille, P. (2006). *Soil Landscapes of Western Australia's Rangelands and Arid Interior*, Department of Agriculture and Food Western Australia

WAHERB, (2020). *Florabase – Information on the Western Australian Flora,* Department of Biodiversity, Conservation and Attractions.

Available: https://florabase.dpaw.wa.gov.au/

Appendix 1: Conservation Ratings BC Act and EPBC Act

Definitions of Conservation Significant Species

Code	Category
State categories of threatened and priority species	
Threatened Species (T) Listed by order of the Minister as Threatened in the category of critically endangered, endangered or vulnerable under section 19(1), or is a rediscovered species to be regarded as threatened species under section 26(2) of the Biodiversity Conservation Act 2016 (BC Act).	
CR	**Critically Endangered** Threatened species considered to be "facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines". Listed as critically endangered under section 19(1)(a) of the BC Act in accordance with the criteria set out in section 20 and the ministerial guidelines. Published under schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for critically endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for critically endangered flora.
EN	**Endangered** Threatened species considered to be "facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines". Listed as endangered under section 19(1)(b) of the BC Act in accordance with the criteria set out in section 21 and the ministerial guidelines. Published under schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for endangered flora.
VU	**Vulnerable** Threatened species considered to be "facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines". Listed as vulnerable under section 19(1)(c) of the BC Act in accordance with the criteria set out in section 22 and the ministerial guidelines. Published under schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for vulnerable fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for vulnerable flora.
Extinct species Listed by order of the Minister as extinct under section 23(1) of the BC Act as extinct or extinct in the wild.	
EX	**Extinct** Species where "*there is no reasonable doubt that the last member of the species has died*", and listing is otherwise in accordance with the ministerial guidelines (section 24 of the BC Act). Published as presumed extinct under schedule 4 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018* for extinct fauna or the *Wildlife Conservation (Rare Flora) Notice 2018* for extinct flora.
EW	**Extinct in the Wild** Species that *"is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; and it has not been recorded in its known habitat or expected habitat, at appropriate seasons, anywhere in its past range, despite surveys over a time frame appropriate to its life cycle and form*", and listing is otherwise in accordance with the ministerial guidelines (section 25 of the BC Act). Currently there are no threatened fauna or threatened flora species listed as extinct in the wild. If listing of a species as extinct in the wild occurs, then a schedule will be added to the applicable notice.
Specially protected species Listed by order of the Minister as specially protected under section 13(1) of the BC Act. Meeting one or more of the following categories: species of special conservation interest; migratory species; cetaceans; species subject to international agreement; or species otherwise in need of special protection. Species that are listed as threatened species (critically endangered, endangered or vulnerable) or extinct species under the BC Act cannot also be listed as Specially Protected species.	
IA	**International Agreement/ Migratory** Fauna that periodically or occasionally visit Australia or an external Territory or the exclusive economic zone; or the species is subject of an international agreement that relates to the protection of migratory species and that binds the Commonwealth; and listing is otherwise in accordance with the ministerial guidelines (section 15 of the BC Act). Includes birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and fauna subject to the *Convention on the Conservation of Migratory Species of Wild Animals* (Bonn Convention), an environmental treaty under the United Nations Environment Program. Migratory species listed under the BC Act are a subset of the migratory animals, that are known to visit Western Australia, protected under the international agreements or treaties, excluding species that are listed as Threatened species.

Code	Category
	Published as migratory birds protected under an international agreement under schedule 5 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018*.
CD	**Species of special conservation interest** Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened, and listing is otherwise in accordance with the ministerial guidelines (section 14 of the BC Act). Published as conservation dependent fauna under schedule 6 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018*.
OS	**Other specially protected species** Fauna otherwise in need of special protection to ensure their conservation, and listing is otherwise in accordance with the ministerial guidelines (section 18 of the BC Act). Published as other specially protected fauna under schedule 7 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018*.
Priority species Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened fauna or flora. Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring. Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.	
P1	**Priority 1: Poorly-known species** Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.
P2	**Priority 2: Poorly-known species** Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.
P3	**Priority 3: Poorly-known species** Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.
P4	**Priority 4: Rare, Near Threatened and other species in need of monitoring** (a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent. (c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.
Commonwealth categories of threatened species	
EX	**Extinct** Taxa where there is no reasonable doubt that the last member of the species has died.
EW	**Extinct in the Wild** Taxa where it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
CR	**Critically Endangered** Taxa that are facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
EN	**Endangered**

Code	Category
	Taxa which are not critically endangered and is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
VU	**Vulnerable** Taxa which are not critically endangered or endangered and is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.
CD	**Conservation Dependent** Taxa which are the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

Definitions of Conservation Significant Communities

Category Code	Category
State categories of Threatened Ecological Communities (TEC)	
PD	**Presumed Totally Destroyed**
	An ecological community will be listed as Presumed Totally Destroyed if there are no recent records of the community being extant and either of the following applies:
	• records within the last 50 years have not been confirmed despite thorough searches or known likely habitats or;
	• all occurrences recorded within the last 50 years have since been destroyed.
CR	**Critically Endangered**
	An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future, meeting any one of the following criteria:
	The estimated geographic range and distribution has been reduced by at least 90% and is either continuing to decline with total destruction imminent, or is unlikely to be substantially rehabilitated in the immediate future due to modification;
	The current distribution is limited i.e. highly restricted, having very few small or isolated occurrences, or covering a small area;
	The ecological community is highly modified with potential of being rehabilitated in the immediate future.
EN	**Endangered**
	An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. The ecological community must meet any one of the following criteria:
	The estimated geographic range and distribution has been reduced by at least 70% and is either continuing to decline with total destruction imminent in the short-term future, or is unlikely to be substantially rehabilitated in the short-term future due to modification;
	The current distribution is limited i.e. highly restricted, having very few small or isolated occurrences, or covering a small area;
	The ecological community is highly modified with potential of being rehabilitated in the short-term future.
VU	**Vulnerable**
	An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing high risk of total destruction in the medium to long term future. The ecological community must meet any one of the following criteria:
	The ecological community exists largely as modified occurrences that are likely to be able to be substantially restored or rehabilitated;
	The ecological community may already be modified and would be vulnerable to threatening process, and restricted in range or distribution;

Category Code	Category
	The ecological community may be widespread but has potential to move to a higher threat category due to existing or impending threatening processes.
Commonwealth categories of Threatened Ecological Communities (TEC)	
CE	**Critically Endangered** If, at that time, an ecological community is facing an extremely high risk of extinction in the wild in the immediate future (indicative timeframe being the next 10 years).
EN	**Endangered** If, at that time, an ecological community is not critically endangered but is facing a very high risk of extinction in the wild in the near future (indicative timeframe being the next 20 years).
VU	**Vulnerable** If, at that time, an ecological community is not critically endangered or endangered, but is facing a high risk of extinction in the wild in the medium–term future (indicative timeframe being the next 50 years).
Priority Ecological Communities (PEC)	
P1	**Poorly-known ecological communities**
	Ecological communities with apparently few, small occurrences, all or most not actively managed for conservation (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) and for which current threats exist.
P2	**Poorly-known ecological communities**
	Communities that are known from few small occurrences, all or most of which are actively managed for conservation (e.g. within national parks, conservation parks, nature reserves, State forest, un-allocated Crown land, water reserves, etc.) and not under imminent threat of destruction or degradation.
P3	**Poorly known ecological communities**
	Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or:
	Communities known from a few widespread occurrences, which are either large or within significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or;
	Communities made up of large, and/or widespread occurrences, that may or not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing and inappropriate fire regimes.
P4	**Ecological communities that are adequately known, rare but not threatened** or meet criteria for near threatened, or that have been recently removed from the threatened list. These communities require regular monitoring.
P5	**Conservation Dependent ecological communities**
	Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

Appendix 2: Significant Flora Likelihood Assessment

Species	Status			Habitat	Notes	Likelihood
	EPBC Act	BC Act	DBCA			
Conostylis lepidospermoides	EN	EN	-	Grey or yellow-brown sand over laterite.	Habitat unlikely to be present.	Unlikely
Gastrolobium graniticum	EN	EN	-	Sand, sandy loam, granite. Margins of rock outcrops, along drainage lines.	Habitat unlikely to be present.	Unlikely
Thelymitra stellata	EN	EN	-	-	Outside usual species range.	Unlikely
Acacia coatesii			Priority 1	-	Restricted distribution, habitat unlikely to be present.	Unlikely
Acacia sclerophylla var. *teretiuscula*			Priority 1	Clay & loamy soils.	Outside usual species range.	Unlikely
Acacia websteri			Priority 1	Red sand, clay or loam. Low-lying areas, flats.	Habitat possibly present.	Possible
Austrostipa sp. Carlingup Road			Priority 1	-	Scattered records.	Unlikely
Dampiera plumosa			Priority 1	Red sandy soils.	Outside usual species range.	Unlikely
Eremophila xantholaema			Priority 1	-	Restricted distribution, habitat unlikely to be present.	Unlikely
Eucalyptus websteriana subsp. *norsemanica*			Priority 1	Rocky rises.	Habitat unlikely to be present.	Unlikely
Lepidosperma sp. Parker Range			Priority 1	-	Habitat unlikely to be present.	Unlikely
Phebalium appressum			Priority 1	Yellow sandplain.	Habitat likely to be present.	Possible
Ptilotus chortophytus			Priority 1	-	No records in region	Unlikely
Ptilotus procumbens			Priority 1	Red clay.	Habitat possibly present.	Possible
Ptilotus rigidus			Priority 1		Widespread records in region.	Possible
Rhodanthe uniflora	-	-	Priority 1	Brown earth. Open eucalyptus woodland.	Habitat likely to be present.	Possible
Thryptomene sp. Coolgardie	-	-	Priority 1	-	Restricted distribution.	Unlikely
Thryptomene planiflora	-	-	Priority 1	-	Restricted distribution.	Unlikely
Austrostipa sp. Dowerin			Priority 2	-	Scattered records.	Unlikely
Elachanthus pusillus			Priority 2	-	Scattered records.	Unlikely
Eremophila praecox			Priority 2	Red/brown sandy loam. Undulating plains.	Habitat likely to be present.	Possible
Eucalyptus educta			Priority 2	Shallow soils. Granite rocks.	Habitat unlikely to be present.	Unlikely
Goodenia salina			Priority 2	Low gypseous dunes near salt pans.	Scattered records.	Unlikely
Hakea rigida			Priority 2	Sandy soils, yellow sand.	At extreme of known range	Unlikely
Lepidium merrallii			Priority 2	Clay loam.	One record in region.	Unlikely
Allocasuarina eriochlamys subsp. *grossa*			Priority 3	Stony loam, laterite clay. Granite outcrops.	Habitat unlikely to be present.	Unlikely

Species	Status			Habitat	Notes	Likelihood
	EPBC Act	BC Act	DBCA			
Alyxia tetanifolia			Priority 3	Sandy clay, loam, concretionary gravel. Drainage lines, near lakes.	Habitat possibly present. Few records in region.	Unlikely
Angianthus prostratus			Priority 3	Red clay or loamy soils. Saline depressions.	Habitat possibly present.	Possible
Austrostipa blackii			Priority 3	-	Outside usual species range.	Unlikely
Chrysocephalum apiculatum subsp. *norsemanense*			Priority 3	-	Widespread, scattered records.	Unlikely
Cyathostemon verrucosus	-	-	Priority 3	Restricted to Red Hill, Kambalda.	Habitat unlikely to be present.	Unlikely
Diocirea acutifolia	-	-	Priority 3	Clay loam, gravelly loam. Undulating flats.	North of known range.	Unlikely
Diocirea microphylla	-	-	Priority 3	Red-brown clay loam.	North of known range.	Unlikely
Eremophila veronica	-	-	Priority 3	Stony clay, clay loam. Lateritic breakaways.	Habitat unlikely to be present.	Unlikely
Gompholobium cinereum	-	-	Priority 3	Yellow sand, clayey sand, brown loam, sandy gravel, laterite. Well-drained open sites, slopes, plains, roadsides.	Outside usual species range.	Unlikely
Grevillea georgeana	-	-	Priority 3	Stony loam/clay. Ironstone hilltops & slopes.	Outside usual species range.	Unlikely
Isolepis australiensis	-	-	Priority 3	Silty sand, sandy clay. Lake margins, pools.	Outside usual species range.	Unlikely
Lepidium fasciculatum	-	-	Priority 3	-	Scattered records.	Unlikely
Melaleuca coccinea	-	-	Priority 3	Sandy loam over granite. Granite outcrops, sandplain, river valleys.	Habitat unlikely to be present.	Unlikely
Notisia intonsa	-	-	Priority 3	Lake shore, moist red sand.	Annual, previously listed on DBCA database as occurring within the survey area; however, record location appears incorrect (not located in suitable habitat).	Likely
Phlegmatospermum eremaeum	-	-	Priority 3	Stony loam.	Extensive but sparse records in region.	Possible
Eremophila caerulea subsp. *merrallii*			Priority 4	Sand, clay or loam. Undulating plains.	Outside usual species range.	Unlikely
Eucalyptus jutsonii subsp. *jutsonii*			Priority 4	Red to pale orange deep sands. Undulating areas and on dunes.	Habitat may be present.	Possible
Eucalyptus x brachyphylla			Priority 4	Sandy loam. Granite outcrops.	Habitat unlikely to be present.	Unlikely
Frankenia glomerata			Priority 4	White sand.	Outside usual species range.	Unlikely

Appendix 3: Potentially Occurring Introduced (Weed) Flora Species

Family	Taxon	Common Name	WAOL Status	Control Category	WONS
Aizoaceae	*Aizoon pubescens*	-	Permitted - s11		No
	Mesembryanthemum crystallinum	Iceplant	Permitted - s11		No
	Mesembryanthemum nodiflorum	Slender Iceplant	Permitted - s11		No
Amaranthaceae	*Amaranthus viridis*	Green Amaranth	Permitted - s11		No
Anacardiaceae	*Schinus molle* var. *areira*	-	Permitted - s11		No
Apocynaceae	*Asclepias curassavica*	Redhead Cottonbush	Permitted - s11		No
	Orbea variegata	-	Permitted - s11		No
Asparagaceae	*Agave americana*	Century Plant	Permitted - s11		No
Asteraceae	*Arctotheca calendula*	Cape Weed, African Marigold	Permitted - s11		No
	Carduus tenuiflorus	Slender Thistle, Winged Slender Thistle, Sheep Thistle	Permitted - s11		No
	Carthamus lanatus	Saffron Thistle	Permitted - s11		No
	Centaurea melitensis	Maltese Cockspur, Malta Thistle	Permitted - s11		No
	Cichorium intybus	Chicory	Permitted - s11		No
	Conyza bonariensis	Flaxleaf Fleabane	Permitted - s11		No
	Conyza sumatrensis	-	Permitted - s11		No
	Gazania linearis	-	Permitted - s11		No
	Helianthus annuus	Sunflower, Common Sunflower	Permitted - s11		No
	Lactuca serriola forma. *serriola*	-	Permitted - s11		No
	Leontodon rhagadioloides	-	Permitted - s11		No
	Monoculus monstrosus	-	Permitted - s11		No
	Oligocarpus calendulaceus	-	Permitted - s11		No
	Oncosiphon suffruticosus	Calomba Daisy	Permitted - s11		No
	Sonchus oleraceus	Common Sowthistle	Permitted - s11		No
	Symphyotrichum squamatum	Bushy Starwort	Permitted - s11		No
	Xanthium spinosum	Common Cockleburr, Spiny Cockleburr	Declared Pest - s22(2)	C3 Management	
Boraginaceae	*Buglossoides arvensis*	Corn Gromwell	Permitted - s11		
	Echium plantagineum	Paterson's Curse	Declared Pest - s22(2)	No Control Category, Whole of State	No

Family	Taxon	Common Name	WAOL Status	Control Category	WONS
	Heliotropium europaeum	Common Heliotrope	Permitted - s11		No
	Heliotropium supinum	Prostrate Heliotrope	Permitted - s11		No
Brassicaceae	*Alyssum linifolium*	Flax-leaf Alyssum	Permitted - s11		No
	Brassica tournefortii	Mediterranean Turnip	Permitted - s11		No
	Capsella bursa-pastoris	Shepherd's Purse	Permitted - s11		No
	Carrichtera annua	Ward's Weed	Permitted - s11		No
	Sisymbrium erysimoides	Smooth Mustard	Permitted - s11		No
	Sisymbrium irio	London Rocket	Permitted - s11		No
	Sisymbrium orientale	Indian Hedge Mustard	Permitted - s11		No
Cacatuidae	*Cylindropuntia fulgida* var. *mamillata*	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Cylindropuntia imbricata	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Cylindropuntia kleiniae	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Opuntia elata	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Opuntia ficus-indica	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
Caryophyllaceae	*Spergularia diandra*	Lesser Sand Spurry	Permitted - s11		No
Chenopodiaceae	*Chenopodium album*	Fat Hen	Permitted - s11		No
	Chenopodium murale	Nettle-leaf Goosefoot	Permitted - s11		No
Cucurbitaceae	*Cucumis myriocarpus* subsp. *myriocarpus*	-	Permitted - s11		No
Didiereaceae	*Portulacaria afra*	-	Permitted - s11		No
Fabaceae	*Acacia pycnantha*	Golden Wattle	Permitted - s11		No
	Alhagi maurorum	-	Declared Pest - s22(2)	C3 Management, Whole of State	No
	Erythrostemon gilliesii	-	Permitted - s11		No
	Medicago laciniata	Cutleaf Medic	Permitted - s11		No
	Medicago minima	Small Burr Medic	Permitted - s11		No
	Medicago polymorpha	-	Permitted - s11		No
	Vicia monantha subsp. *triflora*	-	Permitted - s11		No
Geraniaceae	*Erodium aureum*	-	Permitted - s11		No
	Erodium botrys	Long Storksbill	Permitted - s11		No
	Erodium cicutarium	Common Storksbill	Permitted - s11		No

Family	Taxon	Common Name	WAOL Status	Control Category	WONS
Lamiaceae	*Salvia reflexa*	Mintweed	Permitted - s11		No
	Salvia verbenaca	Wild Sage	Permitted - s11		No
Malvaceae	*Malva parviflora*	Marshmallow	Permitted - s11		No
Oxalidaceae	*Oxalis bowiei*	Bowie Wood Sorrel	Permitted - s11		No
	Oxalis pes-caprae	Soursob	Permitted - s11		No
Papaveraceae	*Argemone ochroleuca* subsp. *ochroleuca*	-	Permitted - s11		No
Poaceae	*Bromus catharticus*	Prairie Grass	Permitted - s11		No
	Bromus diandrus	Great Brome	Permitted - s11		No
	Cenchrus ciliaris	Buffel Grass	Permitted - s11		No
	Ehrharta villosa	Pyp Grass	Permitted - s11		No
	Hordeum glaucum	Northern Barley Grass	Permitted - s11		No
	Hordeum leporinum	Barley Grass	Permitted - s11		No
	Pentameries airoides subsp. *airoides*	-	Permitted - s11		No
	Phalaris paradoxa	Paradoxa Grass	Permitted - s11		No
	Rostraria pumila	-	Permitted - s11		No
	Schismus arabicus	Araby Grass	Permitted - s11		No
	Schismus barbatus	Kelch Grass	Permitted - s11		No
	Urochloa panicoides	Johnson Grass	Permitted - s11		No
Polygonaceae	*Polygonum aviculare*	Wireweed	Permitted - s11		No
	Rumex vesicarius	Ruby Dock	Permitted - s11		No
Solanaceae	*Datura ferox*	Fierce Thornapple	Permitted - s11		No
	Datura inoxia	Australian Boxthorn	Permitted - s11		No
	Lycium ferocissimum	African Boxthorn	Permitted - s11		Yes
	Nicotiana glauca	Tree Tobacco	Permitted - s11		No
	Solanum nigrum	Black Berry Nightshade	Permitted - s11		No
Urticaceae	*Urtica urens*	Small Nettle	Permitted - s11		No
	Glandularia aristigera	-	Permitted - s11		No
Verbenaceae	*Phyla canescens*	-	Permitted - s11		No
Zygophyllaceae	*Tribulus terrestris*	Caltrop	Permitted - s11		No

Appendix 4: Vegetation Condition Rating

Vegetation Condition Rating	South West and Interzone Botanical Provinces	Eremaean and Northern Botanical Provinces
Pristine	Pristine or nearly so, no obvious signs of disturbance or damage caused by human activities since European settlement.	N/A
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species. Damage to trees caused by fire, the presence of non-aggressive weeds and occasional vehicle tracks.	Pristine or nearly so, no obvious signs of damage caused by human activities since European settlement.
Very Good	Vegetation structure altered, obvious signs of disturbance. Disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.	Some relatively slight signs of damage caused by human activities since European settlement. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds, or occasional vehicle tracks.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.	More obvious signs of damage caused by human activity since European settlement, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or slightly aggressive weeds.
Poor	N/A	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. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds at high density, partial clearing, dieback and grazing.	Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species present including very aggressive species.
Completely Degraded	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 and shrubs.	Areas that are completely or almost completely without native species in the structure of their vegetation; i.e. areas that are cleared or ‘parkland cleared’ with their flora comprising weed or crop species with isolated native trees or shrubs.

Appendix 5: List of species identified within each vegetation type

Family	Taxon	RP-CFW1	CLP-RMNV1	CLP-EW1	CD-CSSSF1	SLP-MF1	SLP-EW1	CLP-EW2
Aizoaceae	*Disphyma crassifolium*				*			
Amaranthaceae	*Ptilotus obovatus*			*		*		*
Apocynaceae	*Alyxia buxifolia*			*				
Asteraceae	*Cratystylis conocephala*			*			*	
Asteraceae	*Cratystylis microcephala*	*		*			*	
Asteraceae	*Olearia dampieri*					*		
Asteraceae	*Olearia muelleri*	*		*		*	*	*
Asteraceae	*Olearia pimelioides*			*				
Boraginaceae	*Halgania andromedifolia*	*		*				
Casuarinaceae	*Casuarina pauper*	*		*				
Chenopodiaceae	*Atriplex lentiformis* (W)					*		
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*	*	*	*				
Chenopodiaceae	*Atriplex stipitata*			*				
Chenopodiaceae	*Atriplex vesicaria*		*	*				
Chenopodiaceae	*Enchylaena tomentosa*			*				
Chenopodiaceae	*Maireana georgei*	*	*	*		*		
Chenopodiaceae	*Maireana pentatropis*		*	*		*		
Chenopodiaceae	*Maireana pyramidata*				*			
Chenopodiaceae	*Maireana sedifolia*			*				
Chenopodiaceae	*Maireana tomentosa*	*	*				*	
Chenopodiaceae	*Maireana triptera*	*	*	*		*		*
Chenopodiaceae	*Rhagodia drummondii*	*	*			*		*
Chenopodiaceae	*Rhagodia eremaea*					*		
Chenopodiaceae	*Sclerolaena diacantha*	*	*	*	*	*		*
Chenopodiaceae	*Sclerolaena eurotioides*			*				
Chenopodiaceae	*Tecticornia indica* subsp. *indica*				*			
Cucurbitaceae	*Cucumis myriocarpus* (W)							*
Fabaceae	*Acacia colletioides*	*		*		*		
Fabaceae	*Acacia hemiteles*	*	*	*			*	*
Fabaceae	*Acacia acuminata*	*		*				
Fabaceae	*Senna artemisioides* subsp. *filifolia*	*	*	*		*		
Goodeniaceae	*Scaevola spinescens*	*		*			*	*
Hemerocallidaceae	*Dianella revoluta*	*						

Family	Taxon	RP-CFW1	CLP-RMNV1	CLP-EW1	CD-CSSSF1	SLP-MF1	SLP-EW1	CLP-EW2
Myrtaceae	*Eucalyptus celastroides*			*				
Myrtaceae	*Eucalyptus clelandiorum*			*			*	*
Myrtaceae	*Eucalyptus gracilis*			*				
Myrtaceae	*Eucalyptus lesouefii*		*	*				
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*			*				
Myrtaceae	*Eucalyptus salmonophloia*			*				
Myrtaceae	*Eucalyptus salubris*			*				
Myrtaceae	*Eucalyptus transcontinentalis*			*				
Myrtaceae	*Melaleuca aff. pauperiflora* subsp. *pauperiflora*					*		
Myrtaceae	*Melaleuca lateriflora* subsp. *lateriflora*					*	*	
Poaceae	*Triodia scariosa*			*			*	
Proteaceae	*Grevillea acuaria*	*		*				
Santalaceae	*Exocarpos aphyllus*	*	*	*		*	*	*
Santalaceae	*Santalum acuminatum*	*		*				
Sapindaceae	*Dodonaea lobulata*	*			*	*		
Sapindaceae	*Dodonaea viscosa* subsp. *angustissima*					*	*	
Scrophulariaceae	*Eremophila caperata*			*				
Scrophulariaceae	*Eremophila clarkei*			*				
Scrophulariaceae	*Eremophila decipiens*	*	*	*		*		*
Scrophulariaceae	*Eremophila ionantha*			*				
Scrophulariaceae	*Eremophila oldfieldii* subsp. *oldfieldii*			*		*		
Scrophulariaceae	*Eremophila parvifolia* subsp. *parvifolia*			*			*	
Scrophulariaceae	*Eremophila scoparia*	*	*	*		*	*	*
Solanaceae	*Lycium australe*			*		*		
Solanaceae	*Nicotiana glauca (W)*		*					
Solanaceae	*Solanum lasiophyllum*			*				
Zygophyllaceae	*Roepera ovata*						*	
Total Species		**22**	**15**	**44**	**5**	**21**	**14**	**12**