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Technical Memorandum

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To	Ros Green
Client	Rio Tinto Copper
CC	Marcelo Llano
Project	J24050
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1.0 Introduction

Rio Tinto Copper (RTC) is developing the Winu Project in Eastern Pilbara, Western Australia (Figure 1-1). The copper and gold deposit, discovered in 2017, will be mined as an open pit below the water table at a planned production rate of approximately 7 Mtpa.

The project includes the development of mine infrastructure including an open pit which will extend below the water table. Mine infrastructure includes waste management infrastructure (rock dump and tailings facility), ore processing facilities, mine dewatering, water management, water supply, roads and support facilities. A conceptual plan of the infrastructure surrounding the pit is shown on Figure 1-2. The final location of key elements will be within the development footprint, which extends to 37,344 ha around the conceptual plan footprint.

The Tailings Storage Facility (TSF) design (location not shown) is at the preliminary stage, with assessments favouring storage in earthfill impoundments, essentially forming an integrated waste storage facility.

Development of the mine and associated infrastructure will disturb the entire overburden sequence and will likely require lowering of the water table locally to allow mining to progress to the target ore zone (RTC 2023).

Red Earth Engineering (REE) have been commissioned to undertake a deskstudy to assess the potential for acid sulfate soils (ASS) to exist within surface soils at the site. The soil profile is defined as the quaternary aeolian sedimentary sequence.

REE have completed a desk study review of the available information pertaining to the site environmental setting to evaluate the potential for ASS to be present in the soils for the project. No site visit or sampling was undertaken as part of this scope.

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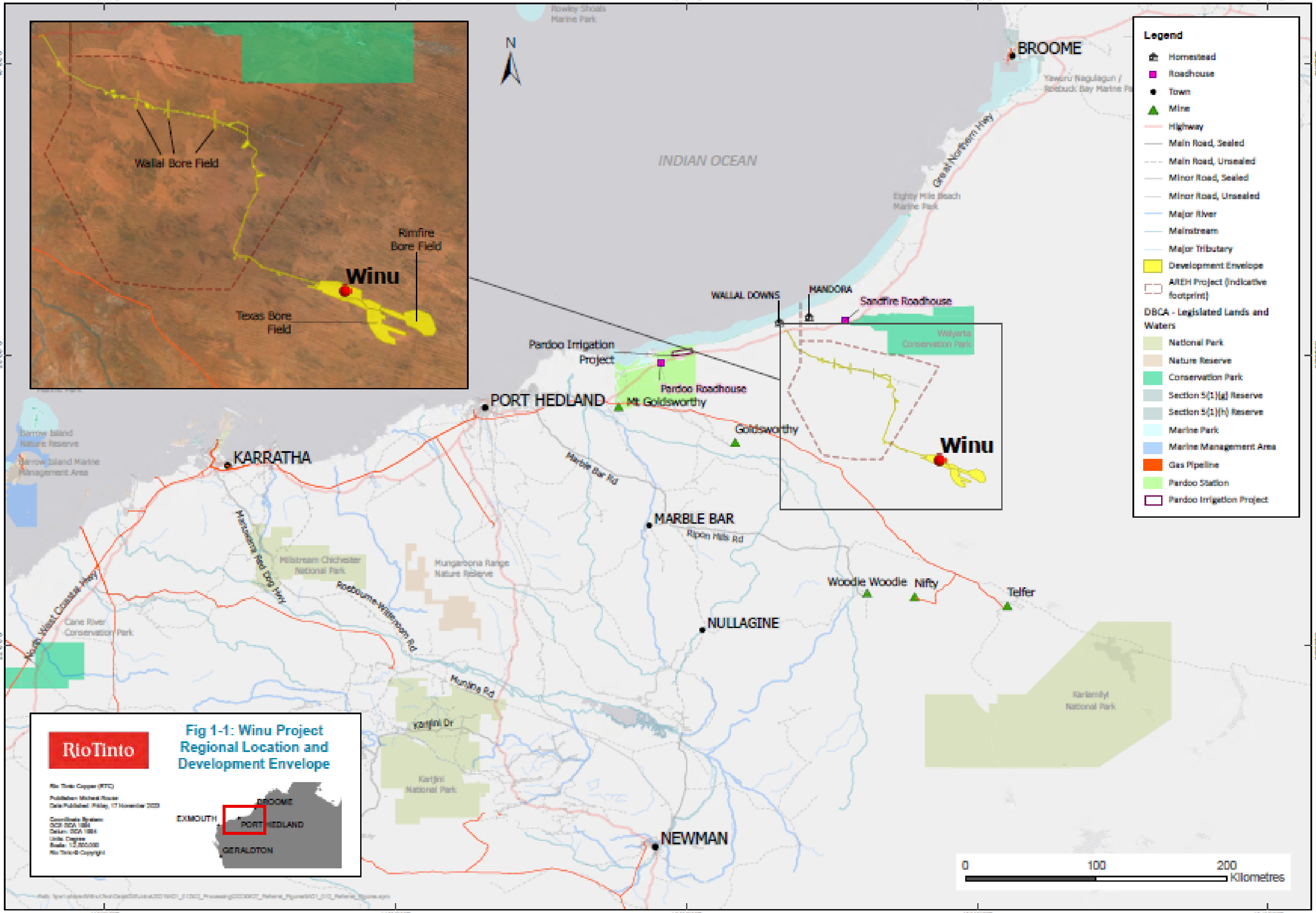

Figure 1-1 Location

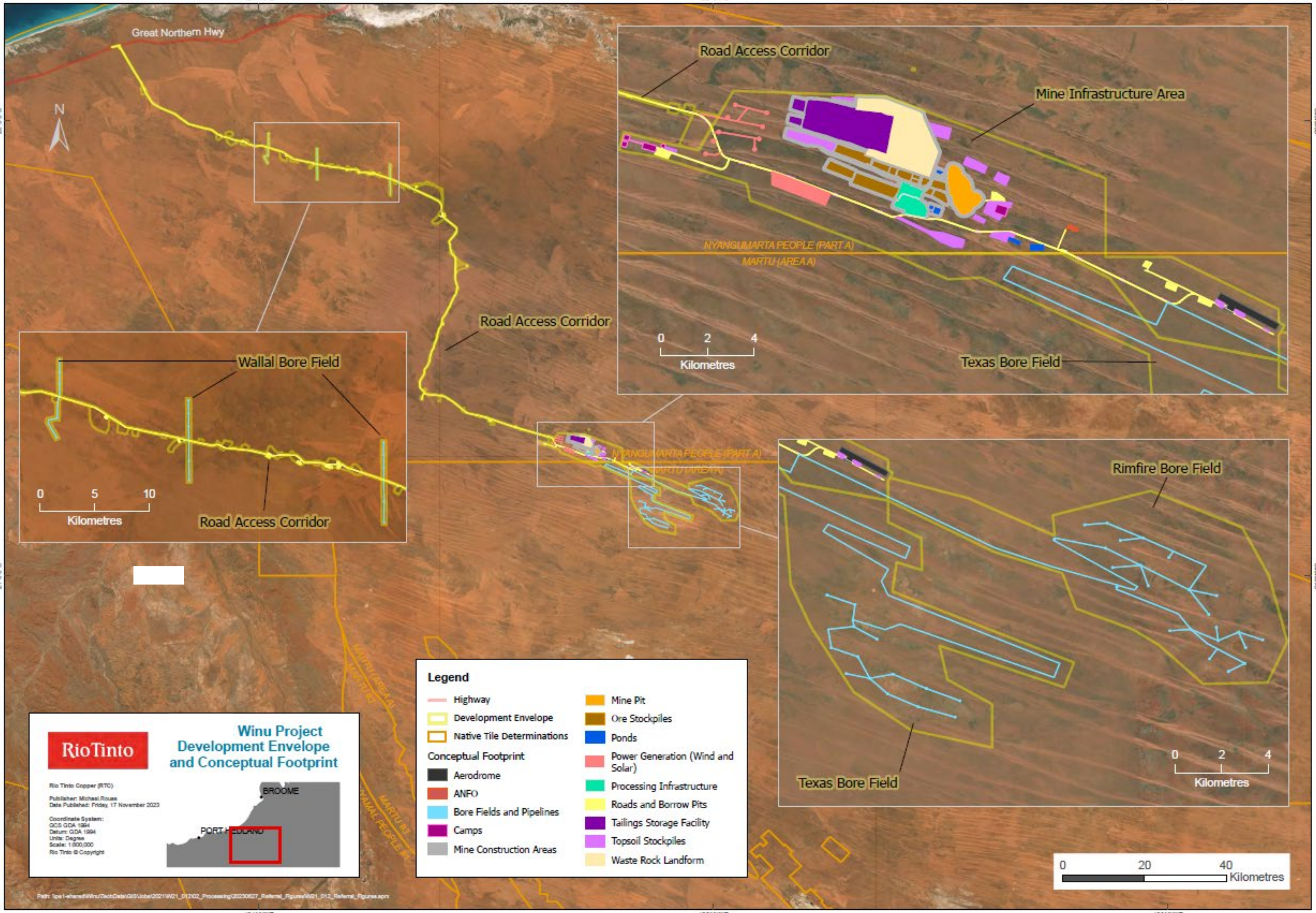

Figure 1-2 Winu project, development envelope and conceptual footprint (RTC 2023)

2.0 Documents reviewed

Rio Tinto provided a number of reports and sections of internal reports for review to assist with the completion of this deskstudy. The documents provided for review are listed in Table 2-1.

Table 2-1: Project-specific documents provided and reviewed

ID	Type	Title
1	PDF	Landloch 2020. Winu Soil Characterisation Report. Prepared for Rio Tinto Copper and Diamonds. Ref 2433.20a
2	PDF	Rio Tinto Copper 2023. Winu Project. Environmental Protection Act 1986 (WA) Section 38 Referral Supporting Document. November 2023.
3	Word doc	Rio Tinto Copper 2021. Winu Final Study Report, Section 05. Geology
4	Word doc	Rio Tinto Copper 2021. Winu Final Study Report, Section 08. Geotechnical
5	Word doc	Rio Tinto Copper 2021. Winu Final Study Report, Section 10. Water Management
6	Word doc	Rio Tinto Copper 2024. Winu Waste Rock Characterisation Report; Upper (Oxide and Overburden) zone. 20th June 2024.
7	PDF	Golder 2022. H3 Hydrogeological Assessment of the Winu Project. Report No. 20136763-062-R-Rev3. Issued March 2022.

In addition to the listed documents the following national databases and guidance documents were used to generate an acid sulfate soil knowledge base for the project:

- Geoscience Australia web portal https://portal.ga.gov.au
- Sullivan, L., Ward, N., Toppler, N. and Lancaster, G. 2018, National Acid Sulfate Soils guidance: National acid sulfate soils sampling and identification methods manual, Department of Agriculture and Water Resources, Canberra ACT. CC BY 4.0.

3.0 Acid sulfate soil formation and occurence

ASS's are soils and or sediments which contain (or have contained) reduced inorganic sulfur (RIS) minerals.

The presence of RIS minerals in soils and or sediments have the capacity to alter the properties of the soil and or sediments should they be disturbed.

Should these soils interact with water (surface water and/or groundwater) alteration of the chemical properties of this contact water may occur. These soils and sediments do not pose a hazard to human health or the environment if the sub-aqueous environment remains anoxic and quiescent (undisturbed).

Soils and sediments containing RIS typically occur in areas of recent sediment deposition such as lakes, tidal flats, estuaries, dunal swales, wetlands, marshes, swamps and sumplands (inclusive of inland areas).

The likelihood of sulfide to persist in these soils and sediments is increased if the soils and sediments are waterlogged (e.g., water table is within 3 m of the site surface).

The geological descriptions of soils and sediments in these areas may include comments on the presence of sulfides, descriptions relating to the marine origin of the sediment, presence of organic matter (i.e. coal) or mineral sand deposits.

Waterlogged areas/shallow groundwater zones may be identified through vegetation mapping where, for example, flora such as mangroves, paperbarks, reeds and swamp oak occur.

The inorganic sulfur is formed by a process known as bacterial sulfate reduction whereby bacterial populations in the soil consume sulfate and generate the sulfide as a byproduct of their biological process. The bacterial population use sulfate which is present in the soils, sediments and water as a source of energy, with the sulfate acting as an electron acceptor for their respiration pathway. Reduced sulfur produced from these biological processes has a strong affinity for bonding with dissolved metals and should there be sufficient aqueous iron present, precipitation of iron sulfide minerals can occur insitu.

The process has occurred on earth for billions of years but is also an active process occurring in sediments today, hence soils and sediments containing RIS can be generated should conducive conditions be present, of which a lack of oxygen is a key requirement for RIS mineral formation.

3.1 Acid sulfate soil classification

When the sulfidic soils (those containing RIS) are formed in anaerobic (chemically reducing) environments, which typically are wet, they hold the potential to oxidise and generate acidity if exposed to atmospheric oxygen, and hence are known as potential acid sulfate soils (PASS). When the soils have begun to oxidise, and have become acidic, these soils are known as actual acid sulfate soils (AASS).

Disturbance of PASS to generate AASS can have detrimental effects on soil structure, water quality, biota and potentially human health. Leachate from water interaction with PASS is typically characterised by low pH values, elevated salinity and elevated dissolved metals concentrations. The impacts may persist for a long period of time. In addition, the release of solutes from disturbed PASS can lead to oxidation of PASS downgradient of the project and outside the project footprint. As a consequence the impacts may have a large aerial extent.

4.0 Climate

From the information reviewed for the site, it is evident that the average rainfall (387 mm estimated long term median rainfall (1970-2018) quoted by Golder (2022)) is lower than the median annual pan evaporation rate (3,559 mm SILO data (1920-2020) quoted by Golder (2022)) by an order of magnitude.

Given these data, any standing water present at the site will evaporate, and therefore it is unlikely that any permanent surface water or permanent waterlogged areas will exist at the project.

5.0 Landuse

Most of the area is defined as unallocated crown land for the use, management and enjoyment of the Nyangumarta and Martu people (RTC 2023). Additional landuse includes pastoral grazing (RTC 2023) and national road infrastructure (Great Northern Highway).

6.0 Geology

6.1 Surface geology and soils

The soils at the project area have been mapped, sampled (to a maximum depth of 1.5 m) and their physical and to some extent chemical composition documented (Landloch 2020). The survey found the soils in the project area to be dry, consisting primarily of two major soil units: deep sands and gradational sands. These soil units fell within the soil class (using both the Australian Soil Classification (ASC) system and the Great Soil Group (GSG) system) Tenosol (deep red sand) and Kandosol (brown earthy sands) soil classes. Both soils were described as wind blown aeolian dune sands, and the gradational sands were found to overlie sandy loam subsoils.

Review of the Australian Soil Resource Information System (ASRIS) dataset available through the Geoscience Australia data portal indicates that these surface soils are classed as having an extremely low probability of hosting ASS. The confidence of this prediction is very low as no sampling has occurred at the site to provide empirical evidence to support the classification provided by ASRIS.

Table 6-1 Summary of soil classifications

Soil Unit	Description	Soil Class (ASC)	Soil Class (GSG)	ASS Class
Deep Sands	Wind blown aeolian sands with no pedological development	Tenosol	Red deep sand	C4 – Extremely low Probability/Very low Confidence
Gradational sands	Wind blown aeolian sands overlying sandy loam subsoils	Kandosol	Brown sandy earth	C4 – Extremely low Probability/Very low Confidence

Figure 6-1 Tenosol from Winu (site no S02, Landloch 2020)

Figure 6-2 Gradational sand at Winu (location S13, Landloch 2020)

Chemical analysis of these soils by Landloch consisted of measurement of the pH (solution composition unknown), electrical conductivity (EC), chloride, total nitrogen, total phosphorus, organic carbon, plant available nutrients (phosphorus, potassium, sulfur, copper, iron, manganese and zinc), exchangeable cations (calcium, magnesium, potassium, sodium and aluminum), effective cation exchange capacity and calculation of exchangeable sodium percentage. Particle size distribution and Emerson class were also measured.

From these data the deep sands were found to be persistenly sandy throughout the profile (to the maximum depth investigated), moderately acidic to circum neutral, non-saline, non-sodic to highly sodic (with low dispersion potential due to low clay content) with low nutrient content and a low capacity to hold nutrients.

The gradational sands were found to be loamy sands, moderately acidic to circum neutral, non-saline, non-sodic to sodic (at depth, with low dispersion potential) with low nutrient content and a low capacity to hold nutrients.

Although sulfur was not discussed in the report nor was it speciated to determine whether any sulfide exists in the soil profile, the shallow soil descriptions (to a depth of 1.5 m below surface) are consistent with an oxidised dry soil profile; conditions which are not conducive to sulfide formation. Given these findings, the ASRIS ASS classification is considered verified, there is a very low probability that ASS will exist in surface soils in the project area.

The surface geology of the project area is describe as consisting of Cenozoic sediments consisting of sands with minor gravel and laterite (Towner and Gibson 1983). Aeolian processes have reworked the sands into parallel sand dunes. Towner and Gibson (1983) describe the sands to consist of clays, silts, gypsum, calcrete and variably laterised materials. This description is consistent with the soil classifications summarised in Table 6-1.

7.0 Hydrogeology

The hydrogeology of the Winu project area was assessed by Golder Associates Pty Ltd (Golder) in 2022. Golder summarised the geology, climate and key hydrogeological attributes of all known hydrostratigraphic units within the regional hydrological catchment. A short summary of their findings focussing on the shallowest hydrostratigraphic unit is presented in this section.

7.1 Hydrostratigraphy

The major aquifer units within the Winu project upper zone are the Cenozoic surface deposits which may host locally perched aquifers and the sediments of the Canning Basin (Permian sandstones and mudstones) which form a major unconfined aquifer known as the Wallal Aquifer (DoW 2012).

The Wallal Aquifer is largely unsaturated; Golder defined this as the Unconfined Permian aquifer. This aquifer is thought to be mostly sandstones bound by the Permian mudstones which act at Winu as the local aquitard.

Depth to groundwater at Winu is typically more than 50 metres below ground level (mbgl). The exceptions being in the perched groundwater areas where shallow groundwater (less than 5 mbgl) have been reported, but perched groundwater has not been reported near the Winu project footprint (Golder 2022).

The shallowest upper zone hydrostratigraphic units (HSU) at Winu as summarised by Golder is the Quaternary (Cenozoic) aeolian sands up to 30 m thick and (largely) unsaturated. A detailed description of the lithology of this HSU is presented in Table 7-1.

Table 7-1 Description of lithologies present in shallowest HSU

Hydrostratigraphic unit (HSU)	Detailed description of lithologies present
Quaternary	Unconsolidated silt to coarse, poorly sorted quartz sand with minor clay, stained red-orange and weakly to moderately lateritised in places. Golder reported that these units were intersected in all hydrogeological bores at Winu with unit thickness to 20 m (increasing in thickness in proximity to dune ridges). The unit will likely becoming partially saturated following rain and is predominantly aeolian-derived, interspersed with alluvial and colluvial deposits. Where finer-grained or clayey units are encountered, local perching of groundwater may occur, but this has not been observed at Winu. In-situ deposited silcrete and ferricrete are logged in some bores and occurs as pavement at ground surface where sands are absent in some lower-lying areas.

The perched groundwater areas in the Quaternary unsaturated HSU correlate to the presence of soaks (i.e. Toramah and Winu Soaks to the west and north of the conceptual footprint respectively) where vegetation such as paperbarks have been mapped (RTC 2023). These soaks and vegetation are not found within the Winu project extent.

Regional groundwater flows in a NNW direction towards the coast. Gradients decrease towards the northwest and are generally expected to mimic surface topography.

8.0 Upper zone geochemical characterisation

Rio Tinto Copper (RTC) completed a geochemical characterisation study (RTC 2024) for the upper zone of the project stratigraphic sequence, including the oxide and overburden materials.

Samples in the geochemical data set included those representative of the Cenozic (upper 30 m of the stratigraphic sequence), this data set is nominated as quaternary aeolian sands. From the sulfur assay data in the block model, this stratigaphic unit was predicted to have a low probability of acid generation (RTC 2024), with median sulfur levels of 0.01%S and a 95th percentile of 0.02 %S (Table 8-1).

Table 8-1 Sulfur statistics for Quaternary aeolian sand in block model at Winu (provided by RTC)

STRAT	Count	Median %S	Percent of total assay data	95th percentile (%S)
Quaternary aeolian sand	5178	0.01	0.001	0.02

The analysis of the composite samples during the geochemical assessment confirmed this hypothesis. Although S was variable in these units, the mineralogy did not include sulfide, no sulfur bearing minerals were identified, the mineral assemblage was dominated by iron oxyhydroxides, kaolinite and muscovite (RTC 2024). Carbonate minerals have a low abundance in the Cenozoic due to the leaching that has occurred in this zone (RTC 2024).

Sulfur speciation was completed on composite samples representative of each stratigraphic unit present at the project in the characterisation program, with sulfide measured via LECO following acid extraction of sulfate minerals[1]. Sulfide sulfur was then used to calculate the maximum potential acid (MPA) likely to be generated.

Modified sobek method was used to determine acid neutralising capacity (ANC). Net acid generation (NAG) tests were completed and the total net acid production potential (NAPP) was calculated.

The classification of the samples was completed in general accordance with the AMIRA classification criteria summarised in Table 8-2.

Table 8-2 AMIRA 2002 geochemical classification criteria

AMIRA (2002)		
Sample Potential	Criteria	Comments
Potentially acid forming (PAF)	NAPP > 0 NAG pH < 4.5	A sample classified as PAF always has a sulfide S content, the acid generating potential of which exceeds the inherent acid neutralising capacity of the material. If NAG is <5 kg H2SO4/t the samples is designated PAF low capacity (PAF_LC).
Non-acid forming (NAF)	NAPP < 0 NAG pH ≥ 4.5	A sample classified as NAF may, or may not, have a significant sulfur content but the availability of ANC within the sample is more than adequate to neutralise all the acid that theoretically could be produced by any contained sulfide minerals. If total S is < 0.1% and ANC is ≤ 5 H2SO4/t the sample is classed as barren.
Uncertain (UC)	NAPP > 0 NAG pH ≥ 4.5	An uncertain classification is used when there is an apparent conflict between the NAPP and NAG results. Uncertain samples are generally given a tentative classification that is shown in brackets e.g. UC (NAF).
	NAPP < 0 NAG pH < 4.5	

[1] The limit of reporting of this analysis is inferred to be 0.01%S given the data is presented to 2 decimal places in the text.

From the sulfur data generated on the composites, the quaternary sands produced a negative mean NAPP (– 0.7 kg H_2SO_4/t). All samples were classified as non-acid forming (NAF) (4 out of 4 samples).

Geochemical analysis confirmed the initial hypothesis that the Cenozoic deposits, Quaternary aeolian sands (generally found in the upper 30 m of the stratigraphic sequence) have a low risk of acid generation.

9.0 Acid Sulfate Soil Risk Assessment

From the information presented in this technical memorandum, ASS are unlikely to exist at Winu in the shallow sediments inclusive of the shallow aquifer units (top 30m of the site stratigraphy). The principal lines of evidence to support this conclusion are:

- The shallow dunal soils (to a depth of 1.5 mbgl) are dry and fully oxidised.
- It is unlikely that any permanent surface water will exist at the project given the net evaporative climate, therefore the shallow stratigraphic sequence will likely be dry for most of the year.
- Groundwater is around 50 mbgl and therefore the shallow stratigraphic sequence (dunal sands and Cenozic sediments, to their maximum depth of around 30 mbgl) will likely be permanently dry/unsaturated and as such will unlikely be ASS.
- Highly localised areas of perched groundwater may exist regionally, which may host ASS but these areas are not found within the Winu project area.

In summary (Table 9-1) the stratigraphy (aeolian sediments inclusive of the dunal soils and Cenozoic sediments) above the water table at the project have **a very low potential of being ASS**.

Table 9-1 Summary of ASS risk for soils and sediments at Winu

Stratigraphic unit	Saturated Y/N	ASS risk
Dunal soils	N	Tenosols and Kandosols on surface (top 1.5 m) of Winu project area have **a very low risk of being ASS.**
Cenozoic	N	Soils and sediment from 1.5 mbgl **have a very low potential for ASS** to be present unless perched water is encountered

10.0 References

These references are those which have not previously been fully cited in Section 2.0:

Alavi 2013. Alavi, S.N. Structure, stratigraphy and petroleum prospectivity of the Waukarlycarly Embayment, Canning Basin, Western Australia. Geological Survey of Western Australia, Record 2013/10.

AMIRA 2002. ARD Test Handbook. Project P387A Prediction and kinetic control of acid mine drainage. May 2002. Prepared by Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd.

SILO. SILO is a climate database from 1889 to present hosted by Queensland Department of Environment, Science and Inovation. Datsets are constructed from observationsal data obtained from the Bureau of Meterology and other sources.

Towner R.R. and Gibson D.L. 1983. Geology of the onshore Canning Basin, Wesern Australia. Bureau of Mineral Resources, Australia, Bulletin 215.

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