ACID SULFATE SOIL INVESTIGATION AND MANAGEMENT PLAN – YALYALUP MINERAL SANDS DEPOSIT, MS1168

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PRAGMATIC SOLUTIONS

AIR | LAND | WATER

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1. INTRODUCTION

1.1. BACKGROUND

Doral Mineral Sands Pty Ltd (Doral) propose to mine the Yalyalup Mineral Sands Deposit, located approximately 11km east southeast of Busselton (Figure 1) on the Swan Coastal Plain (i.e. the Site). The Proposal includes the development of mine pits and associated infrastructure, wet concentration processing plant, solar evaporation ponds, groundwater abstraction and water management infrastructure and process water dam. The Proposal involves the disturbance of ~451.33ha, comprising predominantly cleared pasture (~448.61ha) and degraded native vegetation (~2.72ha) within a Development Envelope of 924.84ha (Figure 2). The Site is also located ~4km southeast of the Wonnerup Mine Site (Cristal Mining Australia), ~2.5km northwest of the Tutunup Mine site (Iluka Resources Ltd) and ~6km northeast of the Yoongarillup Mine Site (Doral) (Figure 1).

The deposit occurs in an area depicted on an Acid Sulfate Soil (ASS) risk map as Class II 'moderate to low risk of ASS occurring within 3m of natural soil surface'. Ore from the deposit will be mined progressively via a series of open-cut pits using dry mining techniques to an expected maximum depth of ~10.5mbgl. Dewatering of groundwater inflows into the mine pits will be required in some areas to enable dry mining to occur.

As mining will involve the disturbance of greater than 100m^3 of soil or sediment from below the natural water table in a Class II ASS risk area and also the lowering of the water table in a Class II risk area, Doral have undertaken a targeted ASS investigation in accordance with the Department of Water and Environmental Regulation (DWER) guideline *Investigation and identification of acid sulfate soils and acidic landscapes* (DER, 2015a) to assist in determining the potential presence and distribution of ASS, and if present provide details of proposed management measures.

This Acid Sulfate Soil Management Plan (ASSMP), has also been prepared to meet Ministerial Statement No. 1168 Condition's 9-1 to 9-6, specifically to achieve the following environmental objective (Condition 9-1):

- *Avoid where possible, otherwise minimise, impacts associated with potential Acid Sulfate Soils to conservation significant flora, fauna and inland waters within the Development Envelope delineated in Figure 2 of Schedule 1 during ground disturbing activities and during all phases of mining activities.*

1.2. CONDITION REQUIREMENTS

The ASSMP has been prepared to satisfy of Ministerial Statement 1168 Condition 9 as provided in Table 1.

TABLE 1: CONDITION REQUIREMENTS

NO	CONDITION	OUTCOME/OBJECTIVE	RELEVANT SECTION
9-1	The proponent shall implement the proposal to achieve the following environmental objective: (1) avoid where possible, otherwise minimise, impacts associated with potential Acid Sulfate Soils to conservation significant flora, fauna and inland waters within the Development Envelope delineated in Figure 2 of Schedule 1.	Avoid where possible or otherwise minimise impacts to conservation significant flora, fauna and inland waters	Section 6 (Soil Management Strategy) Section 7 (Dewatering Management Strategy) Section 8 (Groundwater Management Strategy)

NO	CONDITION	OUTCOME/OBJECTIVE	RELEVANT SECTION
9-2	To achieve the objective of Condition 9-1, prior to groundwater abstraction within the development envelope delineated in Figure 2 of Schedule 1, unless otherwise agreed in writing by the CEO, the proponent shall prepare and submit an Acid Sulfate Soils Management Plan. This Plan shall: (1) when implemented, substantiate and ensure that Condition 9-1 is being met; (2) be prepared on the advice of the Department; (3) specify trigger criteria that will trigger the implementation of management and/or contingency actions to prevent further direct or indirect impacts as a result of potential acid sulfate soils; (4) specify threshold criteria to demonstrate compliance with condition 9-1; (5) specify monitoring methodology to determine if trigger criteria and threshold criteria have been met; (6) specify management and/or contingency actions to be implemented if the trigger criteria required by Condition 9-2(3) and/or the threshold criteria required by Condition 9-2(4) have not been met; and (7) provide a format and timing for the reporting of monitoring results against trigger criteria and threshold criteria to demonstrate that Condition 9-1 has been met over the reporting period in the Compliance Assessment report required by Condition 4-6.	Prepare an Acid Sulfate Soils Management Plan and achieve the objective of Condition 9-1.	This ASSMP has been prepared to address Condition 9-2. (1) Reporting (Section 12) (2) Consultation (Section 11) (3) Soil (Section 6), Dewatering (Section 7.4 and 7.5) Groundwater (Section 8.3 and 8.4). (4) Section 9.2. (5) Soil (Section 6), Dewatering (Section 7.3), Groundwater (Section 8.2) (6) Soil (Section 6), Dewatering (Section 7.4 and 7.5) Groundwater (Section 8.3 and 8.4). (7) Reporting (Section 12)
9-3	The proponent shall implement the most recent version of the Acid Sulfate Soils Management Plan which the CEO has confirmed by notice in writing addresses the requirements of conditions 9-1 and 9-2.	Implement the most recent version of the ASSMP which has been confirmed in writing by the CEO.	Section 10.2 – Adaptive Management
9-4	In the event that monitoring, or investigations indicate an exceedance of threshold criteria specified in the Acid Sulfate Soils Management Plan, the proposal shall: (1) report the exceedance in writing to the CEO within seven (7) days of the exceedance being identified; and	Implement contingency management actions and notify CEO	(1) Threshold Criteria (Section 9.2) (2) Contingency Actions detailed in Section 7.5 for

NO	CONDITION	OUTCOME/OBJECTIVE	RELEVANT SECTION
	(2) implement the contingency actions required by condition 9-2(6) within seven (7) days of the exceedance being reported, as required by condition 9-4(1) and continue implementation of those actions until the CEO has confirmed by notice in writing that it has been demonstrated that the threshold criteria are being met and implementation of threshold contingency actions are no longer required.		Dewatering and Section 8.4 for Groundwater.
9-5	The proponent: (1) may review and revise the Acid Sulfate Soils Management Plan; or (2) shall review and revise the Acid Sulfate Soils Management Plan as and when directed by the CEO.	Review or revise ASSMP as required or when directed to by the CEO.	Section 10.2 – Adaptive Management
9-6	The proponent shall implement the Acid Sulfate Soils Management Plan, or any subsequent revisions as approved by the CEO in condition 9-3, until the CEO has confirmed by notice in writing that the proponent has demonstrated the environmental objective in condition 9-1 has been met.	ASSMP to be implemented until it can be demonstrated that Condition 9-1 has been met.	Section 10.2 – Adaptive Management

1.3. OBJECTIVES

The objective of the ASS investigation and management plan (ASSMP) was to:

- Conduct soil sampling to identify the presence or absence of ASS in areas likely to be disturbed;
- Assess the net acidity (comprising both existing and potential acidity) of soil at locations where mining is likely to result in disturbance of soil and/or lowering of the water table through groundwater drawdown;
- Assess the baseline quality of groundwater (from a network of onsite bores) from the Superficial and Leederville aquifers to determine vulnerability of groundwater to acidification and to enable site specific ASS triggers values to be developed;
- Provide appropriate soil, dewatering and groundwater management and monitoring measures, specify trigger criteria and contingency actions, and provide a format and timing for the reporting of monitoring results against trigger criteria, in order to demonstrate that the environmental objective detailed in MS1168 Condition 9-1 has been achieved.

1.4. SCOPE OF WORK

The scope of works for the ASS investigation was developed based on Doral's resource definition drilling program which comprised 51 exploration drill holes (31 holes in December 2014 and a further 20 in

December 2017) to approximately 2m below the maximum anticipated depth of disturbance. The scope of work included the following:

- Collection and logging of soil samples at 1m intervals from 71 targeted locations to approximately 2m below the proposed maximum depth of excavation;
- Field testing of all soil samples for pH_F and pH_{FOX};
- Laboratory analysis using the Chromium Reducible Sulfur (CRS) method for samples with a pH_{FOX} <3 and/or other selected samples;
- Comparison between CRS suite calculated Net Acidity and LECO Total Sulfur (S_T) analysis of samples (~52 samples from 7 drilling locations) using the Bland Altman method in consultation with DWER, to assist with future method for identification of ASS horizons and calculation of specific liming rates for each mine pits/areas (if varying from the default liming rate);
- Assessment of baseline groundwater quality from a network of new and existing groundwater monitoring wells within both the Superficial and Leederville aquifers;
- Preparation of an ASSMP in accordance with DWER ASS guidance (DER, 2015b) to satisfy MS1168 Condition 9-1 to 9-6.

2. EXISTING ENVIRONMENT

2.1. LOCATION AND LANDUSE

The Proposal involves the disturbance of ~451.33ha, comprising predominantly cleared pasture (~448.61ha) and degraded native vegetation (~2.72ha) within a Development Envelope of 924.84ha. The Site is located within the City of Busselton ~11km east southeast of Busselton, WA, on Mining Tenement M70/1400. The ASS investigation was undertaken in areas south of Princefield Road, North of Yalyalup Road and between the Wonnerup South Road (west end) and Ludlow Hithergreen Road (eastern end) (Figure 2).

The Site is located in the Southern Perth Basin, approximately midway between the current coastline and the base of the Whicher Scarp. The Southern Perth Basin sediments are predominately Permian to Cretaceous aged with a thin cover of Pleistocene and Recent sediments.

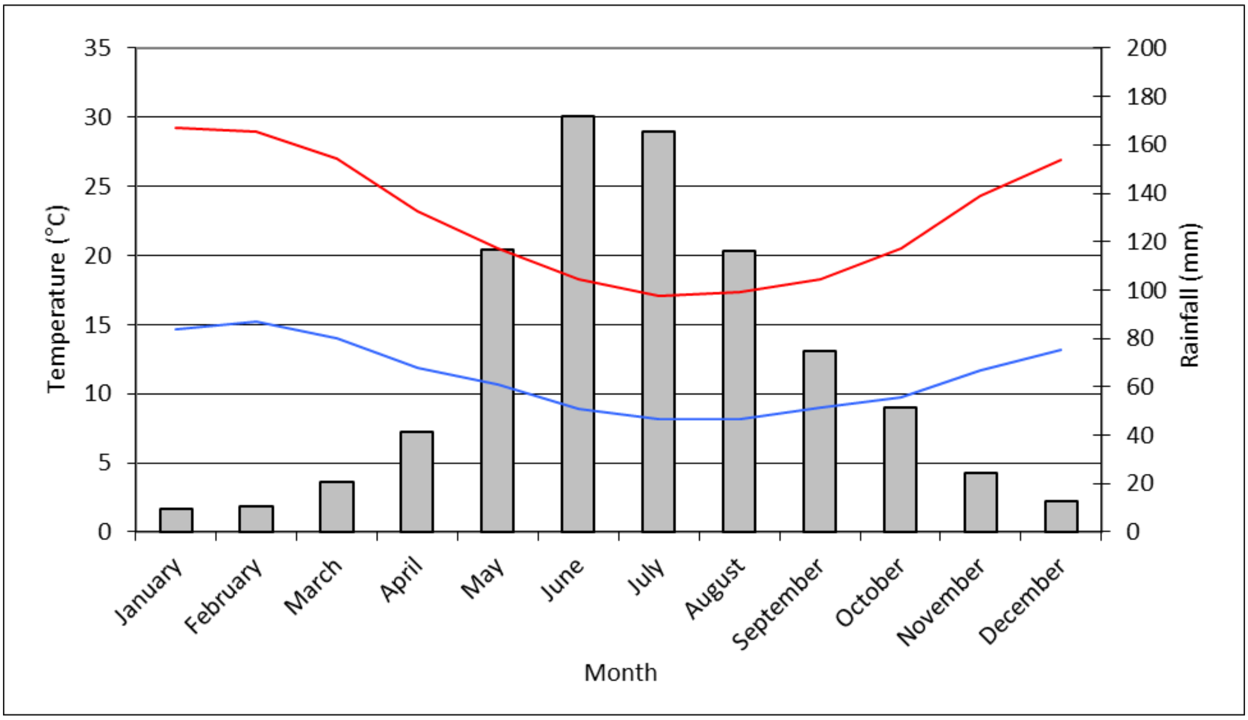
All land comprising the Site is zoned 'agricultural' in accordance with the City of Busselton's Local Planning Scheme (LPS) No. 21. The deposit has been extensively cleared in the past 50-100 years for agricultural purposes. The dominant land use at present is cattle grazing and hay production. Land has also been used for dairy production in recent years with minor irrigation of pasture with untreated effluent water (sourced from dairy within Lot 843). Localised excavation of farm dams has exposed minor areas of the underlying sediments to the atmosphere.

Remnant vegetation within the Site bounds is restricted mainly to road reserves and creek lines, with other scattered clusters of native vegetation occurring in paddocks. Several landholders have planted tree belts that include pine trees and other non-endemic eucalyptus species.

2.2. CLIMATE

The Busselton area experiences a Mediterranean climate with warm to hot dry summers, and mild wet winters. High pressure cells dominate climatic patterns during summer and the passage of cold fronts and associated low pressure cells dominate during winter. Strong sea breezes occur from late November to early March. The annual rainfall generally falls within the 800mm and 1000mm range, peaking in June and July, as shown in Chart 1. In summer the average maximum temperature is 28°C with an average minimum temperature of 12°C. In winter the average maximum temperature is 16°C with an average minimum temperature of 5°C (Bureau of Meteorology, 2017).

CHART 1: ANNUAL AVERAGE CLIMATE DATA



Source: Bureau of Meteorology Busselton Station (Weather Station 009515).

2.3. GEOLOGY

The Site is located within the southern part of the Perth Basin, an elongate north–south rift trough with a series of sub-basins, shelves, troughs and ridges (AQ2, 2020a). The Site is wholly contained within the Bunbury Trough, a sub-basin containing a Permian–Cretaceous succession up to 11 km thick. The sub-basin is wedged between the Vasse Shelf and the Yilgarn Craton, bounded to the east by the Darling Fault and to the west by the Busselton Fault. The Proposal is included on the published 1:50,000 Environmental Geology Series map for Busselton (Belford, 1987) (Figure 3).

A summary of the stratigraphy and hydrogeology within the upper 900m of the Perth Basin at the Proposal is summarised in Table 2.

TABLE 2: SUMMARY OF STRATIGRAPHY AND HYDROGEOLOGY

AGE	FORMATION	STRATIGRAPHY	THICKNESS (m)	LITHOLOGY	HYDROGEOLOGY
Quaternary - late Tertiary	Superficial	Bassendean Sand	0.5-3	Fine to medium sub-rounded quartz sand	Superficial aquifer
		Guildford Formation	2-5	Clay and sandy clay with occasional discontinuous sand lenses	Local aquiclude
		Yoganup Formation	2-5	Leached and ferruginized beach sand conglomerate and clay. Local laterite.	Superficial aquifer
UNCONFORMITY					

AGE	FORMATION	STRATIGRAPHY	THICKNESS (m)	LITHOLOGY	HYDROGEOLOGY
Cretaceous	Leederville	Mowen Member	1-10	Clay and silty clay, with thin interbedded silt, clayey sand and fine grained sand	Regional aquitard; local Leederville aquifer (when significant sand is present)
		Vasse Member	50-100	Fine to medium grained quartz sandstone and interbedded shale.	Leederville aquifer
UNCONFORMITY					
Mid-late Jurassic	Yarragadee	Unit 1	0-50	Medium to coarse grained, weakly consolidated sandstone, minor siltstone and shales	Yarragadee aquifer
		Unit 2	0-250		
		Unit 3	200-500		
		Unit 4	0-100		

AQ2 (2020a) provides the following description of geology for the Proposal.

The upper geology sequence comprises the Quaternary-late Tertiary aged Superficial Formation, which are represented at the Site by the Bassendean Sand towards the top, the Guildford Formation and the Yoganup Formation towards the base. The Bassendean Sand forms a thin bed of fine to medium grained aeolian sand. The Guildford Formation consists predominantly of silty to sandy clay of fluvial origin. The Yoganup Formation comprises leached and ferruginous coarse grained beach sand, with localised concentrations of heavy minerals and some sandy silt and clay layers. The superficial deposits commonly contain ironstone caprock, colloquially known as Coffee Rock, in the zone of water table fluctuation. At the Site, the Coffee Rock is generally 2-3m thick and is exposed at the surface in the eastern side of the Site, near and along the McGibbon Track. The thickness of the Superficial Formation is irregular, reaching a maximum of 12m at the site, but generally 7-8 m thick.

Outside of the Development Envelope closer to the coast, the Bassendean Sand is interfingered by Tamala Limestone (i.e. limestone, calcarenite and sand), which can be up to 15m thick. Tamala Limestone is overlain by Estuarine and swamp deposits at the Vasse-Wonnerup Wetland, consisting of fine sand, silt and clay and by Safety Bay Sand at the coast area. Thin layer of the Guildford Formation underlain Tamala Limestone, with the basal sand of the Guildford Formation being equivalent to the Yoganup Formation.

The Superficial Formation is unconformably underlain by Cretaceous age, riverine and deltaic sediments of the Leederville Formation, comprising discontinuous interbedded weakly consolidated sandstone, clayey sand, silt and shale. Three member units of the Leederville Formation are identified: Vasse Member, Mowen Member, and Quindalup Member, with only Vasse and Mowen Members, present in the Yalyalup area. The lower Vasse Member is highly stratified, containing sand beds interbedded with clay aquitards. Sand beds are generally up to 10m thick with overall unit thickness of 100m at the project site. The upper Mowen Member is dominated by clay and silt with some thin interbedded silty to medium grained sand, with a thickness of up to 10m. The Mowen Member is likely to be very thin or has a greater sand content, especially on the eastern side of the project area.

The Yarragadee Formation (the aquifer being targeted for the mine water supply) underlies the Leederville Formation, comprising predominantly weakly consolidated, medium to very coarse grained quartz sandstone, with minor siltstone and shale beds. Based on lithology and age, this formation has been divided into four sub-units (sequentially, Unit 1 to Unit 4; Baddock et. al., 2005). Unit 1 occurs at the top of the formation and Unit 4 at the base, with all units likely to be present in the project area (a total thickness of approximately 900 m).

The Bunbury Basalt occurs discontinuously between the Yarragadee and Leederville Formations and the top of the basalt is typically highly weathered. The Bunbury Basalt is unlikely to be present at the Site, based on the literature (i.e. DWER drilling information records (DWER, 2019) and the Water Corporation Magnetic data survey (Baddock, et al., 2005)).

2.4. HYDROGEOLOGY

Groundwater is present in the area within a multi-layered aquifer system. Three major aquifers have been identified within the Proposal area (ordered from shallow to deep), namely:

- Superficial;
- Leederville;
- Yarragadee.

A detailed description of the three aquifers and their key properties (from AQ2, 2020a) is provided below.

Superficial Aquifer

The Bassendean Sand, Guildford Formation and Yoganup Formation form an unconfined Superficial aquifer, with a maximum saturated aquifer thickness of ~9m at the Site. The Guildford Formation is present between the Bassendean Sand and Yoganup aquifers and is of low permeability, owing to its more clayey nature. The permeability of the superficial aquifer is variable and depends on sediment type, with saturated sands having higher permeability than clays. At the site, the Yoganup Formation forms the main portion of the aquifer, while the Basendean Sand is generally only saturated in the wet season.

Outside of the proposed mine area, within the modelling study area by AQ2 (2020a) and closer to the coast, the Bassendean Sands are interfingered by Tamala Limestone and Safety Bay Sand, which form a significant aquifer zone along the coastal margin. The basal sand of the Guildford Formation close to the coast also forms local aquifer, which may be equivalent to the Yoganup Formation, that is likely to be absent at this location. The estuarine and swamp deposits at the Vasse-Wonnerup Wetland act as a low permeability aquiclude, owing to its clayey nature.

Recharge

Recharge of groundwater to the Superficial aquifer is mostly from direct infiltration of rainfall, with some recharge occurring by upward leakage from the underlying Leederville aquifer mostly across the seaward section and from down-slope surface drainage from the Whicher Scarp (Hirschberg, 1989). In the climate of South West of WA, most of the rain that falls is lost again through various forms of evapotranspiration. Any precipitation in excess of soil moisture deficit and evapotranspiration will become runoff or infiltrate downward to the water table. The downward flow of water may or may not reach the water table depending on the soil properties in the soil profile. The rate of groundwater recharge is controlled by climate, land use, vegetation type and density, soil hydraulic properties, geology and topography; and is in a range between 5 and 40% of the rainfall, averaging 10%. Much of the Swan Coastal Plain is cleared of native vegetation for pasture, which results in relatively high recharge rates even up to 50% of the rainfall (Baddock, et al., 2005).

Discharge

Groundwater is discharged from the Superficial aquifer to the ocean and the coastal swamps, to surface drainage including rivers, streams and an extensive network of constructed drains. It is also discharged via direct evaporation from swamps and evapotranspiration from vegetation where the water table is shallow. There is also discharge of groundwater downward into the Leederville and Yarragadee aquifers where the hydraulic head gradient is downward, especially where the superficial lithology is sandy (Baddock, et al., 2005). Owing to the very shallow water table, the loss of groundwater to the atmosphere through evapotranspiration is likely to be high (Hirschberg, 1989).

Groundwater Levels and Flow

The water table elevation slopes gently from the Whicher Scarp (i.e. ~40 mAHD) to the coast (i.e. 0 mAHD), closely parallels to the topography in a north-western direction under a low hydraulic gradient (AQ2, 2020a). Groundwater levels, as measured in the Superficial monitoring bores (both Doral's monitoring bores, other private users and DWER monitoring bores), are close to surface, at depths of 0 to 4.7mbtoc (i.e. 15.6 and 34.8 mAHD). Within the Site, low-lying areas are often waterlogged during winter period (i.e. with the water table rising to ground surface). The seasonal water table fluctuation is less than 0.4m close to the coast, approximately 1 to 2m across the central part of the Swan Coastal Plain (including the Proposal area) and up to 2 to 4m close to the Whicher Scarp. Hydrographs for superficial deposits on the Coastal Plain show that variations in water level are usually correlated with variations in rainfall. Peaks in the groundwater hydrographs generally occur 1 to 3 months after peaks in the rainfall and the length of the time lag increases with increasing depth to the water (AQ2, 2020a). The average water table elevation contours in the Superficial aquifer across the Site are shown in Figure 4.

Water Quality

Groundwater at the Site is fresh (<500 mg/L TDS) to brackish (up to 3,000 mg/L TDS) with a general trend of increasing salinity toward the coast from the Whicher Scarp. High salinity groundwater occurs in areas of poorly drained clay soils and swampy areas, exceeding 2,000mg/L in some areas. Elevated groundwater salinity occurs near the coast resulting from coastal saline swamps and groundwater mixing with the sea-water interface (Baddock, et al., 2005). Groundwater chemistry within the Superficial aquifer is normally a sodium-chloride type.

Leederville Aquifer

The Leederville Formation forms a multi-layered confined aquifer system, comprising discontinuous interbedded sequences of sand, clayey sand, silt and shale. It underlies the Superficial deposits across the Proposal area, coming to surface only to the south-east of the Site, where it forms the Whicher Scarp.

At the Site, the Leederville aquifer generally comprises the Vasse Member of the Leederville Formation. The Mowen Member of the Leederville Formation, which overlies the Vasse Member is commonly considered as an aquitard due to its clayey nature. At the eastern portion of the modelled study area by AQ2 (2020a), the Mowen Member is likely to be very thin or has a greater sand content, resulting in the Leederville aquifer directly underlying the Superficial aquifer.

Recharge

The Leederville aquifer is recharged mostly on the Blackwood Plateau by direct recharge where the aquifer is present at surface, with lower rates by downward leakage through the Mowen aquitard. Chloride mass balance calculations suggest that recharge rates are around 7% of rainfall and locally significantly higher, while leakage recharge through the Mowen aquitard may be equivalent to only 1 to 2% of rainfall (Baddock, et al., 2005).

Hirschberg (1989), reports that upward leakage occurs into the Superficial aquifer from the confined aquifers in the vicinity of the Site, although later studies suggest that downward flows have also been occurring since that time, potentially due to ongoing regional abstraction from the Leederville aquifer (Schafer, et al., 2008). Based on the measured groundwater levels for the two aquifers, there is generally a 1m or greater difference in equipotential heads between the Superficial and Leederville aquifers, with lower elevations recorded within the Leederville aquifer. However, water levels recorded in bores screened in the deeper section of the Leederville aquifer show the upward hydraulic heads. The potential for recharge on the coastal plains is restricted by the upward potentiometric head gradients or small downward gradients that exist between the Leederville and Superficial aquifers.

Discharge

Groundwater discharge from the Leederville aquifer into the underlying Yarragadee aquifer occur through the majority of the Site. However, clay layers within the Leederville Formation and shale layers of the upper unit of the Yarragadee Formation are believed to restrict vertical flow (AQ2, 2020a). Groundwater head gradients are upward in the north of the Site, where groundwater is discharged into the overlying Superficial Formation near the coast and offshore.

Groundwater Levels and Flow

Generally, the Leederville Formation receives recharge towards the Whicher Scarp and discharges towards the coast. Groundwater level elevations in the Leederville aquifer reduce from an average of approximately 35mAHD at the foot of the Whicher Scarp (61030067) to approximately 2mAHD close to the coast (61030028). The seasonal water level fluctuations are generally between 2 to 3m. Additionally, a gradual small declining trend associated with ongoing pumping activity in the area is evident since 2003, especially in the bores screened deeper in the Leederville aquifer. The average water table elevation contours in the Leederville aquifer across the modelled area are shown in Figure 5.

Water Quality

Groundwater at the Site is fresh to transitional, with the average salinity of between 300 and 400mg/L TDS. The areas of high salinity groundwater generally correspond to discharge areas of the Leederville aquifer where there is an upward potentiometric head gradient with the overlying Superficial aquifer or affected by downward leakage of higher salinity groundwater from the overlying Superficial aquifer (Baddock, et al., 2005).

Groundwater chemistry within the Leederville aquifer is normally a sodium-chloride type, but the elevated bicarbonate is evident around Busselton area likely associated with the infiltration from the Superficial aquifer containing Tamala Limestone. Locally the aquifer can contain high concentrations of iron (AQ2, 2020a).

Yarragadee Aquifer

The Yarragadee Formation forms a confined Yarragadee aquifer below the Leederville aquifer. There are four sub-units within the Yarragadee Formation with distinct lithological properties. The Yarragadee aquifer is confined by the Leederville Formation. The Bunbury Basalt is discontinuously thin aquitard and it is believed not to be present at the modelled study area (AQ2, 2020a).

Recharge

The Yarragadee aquifer receives recharge by downward leakage from the Leederville Formation (Hirschberg, 1989), especially in the inland areas around the Whicher Scarp where downward heads prevail. As well as downward leakage from the Leederville Aquifer, recharge to the aquifer is likely to occur mostly from the south and south east where the formation outcrops.

Discharge

A major of groundwater discharge from the Yarragadee aquifer is offshore adjacent to Bunbury, where the aquifer subcrops beneath the Superficial aquifer below the sea floor. Groundwater is also discharged to the overlying Superficial and Leederville Formations adjacent to the coast.

Groundwater Levels and Flow

Groundwater flow through the upper part of the Yarragadee aquifer is south to southwest toward the coast. Groundwater level elevations in the Yarragadee aquifer reduce from an average of approximately 25 to 35mAHD at the foot of the Whicher Scarp to approximately 5mAHD close to the coast.

There is generally 4 to 5m of the average seasonal water level fluctuation evident at the study area. The hydrograph for DWER's monitoring bore 61000125 indicates, apart from seasonal fluctuations (peaks in March and lows in September), a gradual small declining trend associated with ongoing pumping activity in the area.

Water Quality

Groundwater at the Site is fresh with the average salinity of groundwater within Yarragadee units 1 to 3, 360 mg/L TDS, while in unit 4 it is 440 mg/L TDS. Groundwater salinity is lowest within the main recharge areas to the aquifer, where the salinity is mostly less than 200 mg/L TDS. Higher groundwater salinity within the Yarragadee aquifer beneath the Swan Coastal Plain in the area of Busselton correspond to elevated groundwater salinity within the overlying Leederville and Superficial aquifers (Baddock, et al., 2005).

Groundwater chemistry within the Yarragadee aquifer is normally a sodium-chloride type, but becomes sodium-bicarbonate type in the deeper portions of the aquifer. An increased proportion of sodium and bicarbonate generally distinguishes older groundwater in the Yarragadee aquifer, possibly as the result of weathering of feldspars (Baddock, et al., 2005). The relative proportions of major ions are similar to those in the Leederville Formation, suggesting a close relationship between the two aquifers at the Site.

Groundwater is present in the area within a multi-layered aquifer system. The superficial deposits contain an unconfined aquifer with saturated thicknesses of generally less than 10m, whereas the Leederville and Yarragadee Formations contain multiple regional-scale confined and semi-confined aquifers.

2.5. SURFACE WATER

Local Rivers

The Site is within the Wonnerup (Busselton Coast) Surface Water Management subarea and the Lower Sabina River sub-catchment. The Site is not within a proclaimed area for surface water management (DoW, 2009).

The Lower Sabina and Abba Rivers are located within ~1km of the Site to the southwest and northeast, respectively, generally flowing in a northwesterly direction. The Lower Sabina River flows from below the Sabina Diversion Weir to the Ramsar listed Vasse-Wonnerup Wetlands. The Lower Sabina, Lower Vasse, Abba and Ludlow rivers drain into the Vasse-Wonnerup Wetlands, before discharging through the Wonnerup Inlet into Geographe Bay.

The Sabina Diversion Weir was constructed to allow overflow during extreme rainfall events from the Upper Sabina to the Lower Sabina, with regular flows through the Sabina Diversion Drain. The weir was over designed and the Upper Sabina catchment (78 km^2) no longer contributes any flow directly to the Lower Sabina river, although some minor sub-drains in the upper catchment may spill in large events (Marillier, 2018). The flow upgradient of the Sabina diversion weir is directed through the Sabina Diversion Drain to the Vasse Diversion Drain system and out to the Geographe Bay, rather than to Vasse-Wonnerup Wetlands.

The Vasse-Wonnerup Wetlands catchment area is 473km^2, excluding the diverted sub-catchments (DWER, 2019) (Figure 6). The Lower Sabina River catchment area of 45.5 km^2 is less than 10% of the Vasse-Wonnerup Wetland Catchment. The Abba River is one of the other major tributaries to the Vasse-Wonnerup Wetland and has a catchment area of 137km^2 which is 29% of the Vasse-Wonnerup Wetlands catchment.

Other regional drainage features outside of the Vasse-Wonnerup Wetlands include the Vasse Diversion Drain, which has a catchment area of 303 km^2 and receives inflows from the diverted Upper Sabina (78 km^2) and Upper Vasse (catchment 180 km^2) rivers (Marillier, 2018).

There are no stream gauges in the Lower Sabina catchment. The closest stream gauges are on the Upper Sabina at the Sabina Diversion (site 610025), and on the Abba River (site 610062). Marillier (2018) analysed gauge information and estimated average annual flows (2001–14) in the major ungauged rivers flowing to the Vasse Estuary Wetland. Marillier (2018) estimated the Lower Sabina discharge as 5.7 GL/year, less than half the Abba River volumes (12.5 GL/yr). In contrast, 4 GL/year is diverted away from Vasse-Wonnerup Wetlands along the Sabina Diversion Drain, and 24 GL/yr is diverted via the Vasse Diversion Drain (Marillier, 2018). The Ludlow River discharges the second highest volumes to the Vasse-Wonnerup Wetlands an annual average of 11.4 GL/yr based on DWER gauging station summary statistics (DWER, 2019).

The Whicher Area Surface Water Management Plan (DoW, 2009) does not list the Sabina or Abba Rivers as connected to the groundwater system. However, the shallow depth of unconfined groundwater at the Site could suggest the possibility of groundwater discharge occurring as baseflow in these rivers. Notwithstanding, hydrographs for both rivers (see AQ2, 2020a) clearly indicate a cessation of the river flow during summer periods, with limited rainfall recharge. Therefore, there is limited or no groundwater connection with the surface water, resulting in minimal or no groundwater contribution to the river's baseflow. The surface water flow regime is therefore likely to be dominated by high-rainfall periods generating surface water runoff, rather than any substantial groundwater flow component.

On-Site Drainage

Several roads and man-made drains installed in the 20th century have modified the natural drainage pattern within the Development Envelope. These include the Princefield Rd drain located across the northern boundary of the Development Envelope and two other first order drainage lines which contribute to a tributary (Woddidup Creek) of the Lower Sabina River (downstream of the Sabina Diversion Weir). The local drains and waterways in the vicinity of the Proposal are shown on Figure 6.

2.6. WETLANDS

Approximately 808ha (~90%) of the Site is mapped as a wetland in the Geomorphic Wetlands of the Swan Coastal Plain dataset (DEC, 2008), all of which has been assessed as being in the 'Multiple Use' management category, which is described as wetlands with few ecological attributes and functions remaining (Figure 7).

The majority of the wetland area within the Site (~624ha or 77%) is mapped as Palusplain (seasonally waterlogged flat), with small areas of Sumpland (seasonally inundated basin, ~30ha or 3%) and floodplain (seasonally inundated flats, ~155ha or 17%). No wetlands of environmental significance are present within the Site bounds.

The Ramsar listed Vasse-Wonnerup wetland is located ~4.6km to the northwest of the Site (Figure 6). The Vasse-Wonnerup Wetlands catchment area is 473 km^2, excluding the diverted sub-catchments (DWER, 2019) (Figure 6). The Lower Sabina River catchment area of 45.5 km^2 is less than 10% of the Vasse-Wonnerup Wetland Catchment. The Abba River is one of the other major tributaries to the Vasse-Wonnerup Wetland and has a catchment area of 137km^2 which is 29% of the Vasse-Wonnerup Wetlands catchment.

The Vasse-Wonnerup system is already highly hydrologically and chemically altered due to extensive clearing, agricultural practices occurring over most of the Geographe catchment, and other commercial and residential developments in the area. Clearing and agricultural practices contribute to altered water regimes and increases in nutrients, sedimentation and pollution (DoW, 2010). The system is highly modified, with diversion of flow from several of the rivers into the ocean that historically flowed into the Vasse and Wonnerup estuaries, which has accounted for a significant decrease in water entering the system. The floodgates were installed in the early 1900s to mitigate flooding of adjoining agricultural land during high river flows in winter and to prevent seawater inundation caused by storm surges. The gates effectively transformed the estuaries in to shallow, winter fresh/ summer saline lagoons, unique in Western Australia (Department of Environment, 2007). DWER estimated a 60% decrease in flow from the Sabina River and a 90% decrease from the Vasse River into the Wonnerup estuary as a result of these diversions (DoW, 2010).

The wetlands are listed as a wetland of International importance under the Ramsar Convention. The high ecological values of the wetlands are coupled with extremely poor water quality in late summer that lead to fish kills and declines in visual amenity. The wetlands are managed for multiple purposes including water bird habitat, flood and storm surge mitigation, visual amenity and the prevention of fish kills.

Department of Environment (2007) reported that the wetlands are subject to poor water quality issues, with the floodgates acting to reduce flushing flows that may otherwise help to ameliorate high nutrient concentrations from catchment runoff, while excessive algal blooms, blooms of potentially toxic cyanobacteria and fish deaths are not uncommon (and) increased salinisation of adjoining pastoral lands and death of colonising native vegetation.

2.7. ACID SULFATE SOIL RISK MAPPING

The Site occurs in an area depicted on DWER's online ASS risk map as Class II 'moderate to low risk of ASS occurring within 3m of natural soil surface' (www2.landgate.wa.gov.au).

3. ACID SULFATE SOIL INVESTIGATION

3.1. SOIL SAMPLING METHODOLOGY

Doral undertook a targeted soil investigation in conjunction with resource definition drilling at the Site in 2014, 2017 and 2019 to assist in determining the presence and distribution of ASS at the Site and also to characterise the various geological/geomorphological units. Drilling was undertaken using an air core drill rig, with soil samples collected and logged by Doral at 1m intervals from 71 locations (Figure 8). The drilling locations were spaced approximately 320m along the strike of the two deeper strandlines and drill holes were located at 80-120m spacing's across the widths of the anticipated deeper ore zones. The depth of drilling at each location was targeted to approximately 1-2m deeper than the anticipated maximum depth of disturbance (10.5mBGL), with a maximum drilling depth of 13mBGL.

Following logging of the soil profile, soil samples were collected for initial screening via field testing (pH_F and pH_{FOX}). Samples were placed in clearly labelled snaplock bags with air excluded and placed in a 12V vehicle freezer whilst on site, allowing the samples to be stored below 4°C. The samples were initially analysed for pH_F at Doral's laboratory during the December 2014 program and in the field during the December 2017 and 2019 programs. All samples were then transported to the Chem Centre Laboratory in Perth for analysis of pH_{FOX} before being placed on cold storage at the laboratory pending decisions about further analytical analysis via the CRS suite method, based on .

3.2. SOIL SAMPLE ANALYSIS

Soil samples were recovered at 1m intervals and field tests were performed on all 717 primary samples (pH_F in the field and pH_{FOX} in the laboratory). The procedure used for field testing is detailed in DER (2015a). Following field testing, 221 of the 717 primary samples (~31%) were selected for laboratory analysis using the Chromium Reducible Sulfur (CRS) suite method. Detailed analysis by CRS suite is used to determine whether soils are likely to generate net acidity, and if so, to quantify this acidity for comparison with action criteria used to determine management requirements. The CRS method is considered very reliable, and is less subject to interference from sulfides in organic matter or sulfate minerals. This method was selected primarily due to the site lithology which was observed to be clayey in nature.

3.3. SOIL ASSESSMENT CRITERIA

The ASS characteristics at the site were compared with guidance criteria provided in DER (2015a).

3.3.1. FIELD TEST CRITERIA

The results of field tests are considered to give an indication of which samples may represent ASS material. The DER recommend that soils which have low pH values (pH_F of $\leq$4, or pH_{FOX} of $\leq$3), or which exhibit a significant change in pH (ΔpH, as pHf – pHfox) may indicate a soil with ASS characteristics (DER, 2015a).

As such field test results were compared with the following criteria to identify potential ASS horizons:

- A pH_F of 4 or less;
- A pH_{FOX} of 3 or less;
- A change in pH value (ΔpH) of at least 3 units.

3.3.2. NET ACIDITY CRITERIA

Net acidity (NA) results were calculated using the equations presented in *Acid Sulfate Soils Laboratory Methods Guidelines* (Ahern *et al.,* 2004). The NA is calculated as the sum of actual acidity and potential acidity, as well as retained acidity (for low pH samples) and is used to characterise the current state and acid producing potential of the soils. Acid neutralising capacity is not included in the net acidity calculations, consistent with DER (2015a) guidance.

Actual acidity is available for release into the environment in the short term and is represented by Titratable Actual Acidity (TAA) values, using the CRS method, while potential acidity is represented by S_{CR} values. The pH_{KCl} of a sample is used to determine the net acidity equation, which varies for samples with alkaline pH (net acidity = potential acidity), near neutral pH (net acidity = actual + potential acidity), and acid pH (net acidity = actual + potential + retained acidity).

The NA results are compared to the DER (2015a) action criterion of 0.03%S (for projects where more than 1,000 tonnes of soil will be disturbed). If results exceed this criterion, it requires the preparation of an ASS Management Plan (ASSMP).

3.4. SOIL RESULTS

The data obtained from soil logs, field testing and CRS analysis is presented in Appendix 1.

3.4.1. FIELD TEST RESULTS

Field test results are summarised as follows:

- Field pH (pH_F) values range between 4.32 and 7.67, with an average of 6.34;
- Field pH peroxide (pH_{FOX}) values range between 1.30 and 7.50, with an average of 3.59;
- The change in pH (ΔpH) ranges between -1.25 and 5.86, with an average of 2.75.

Comparison to the DER (2015a) field test criteria for all 717 primary field tests indicates the following:

- 5 primary samples with a $pH_F \leq 4$ were identified;
- 261 primary samples (~36% of all samples) with a $pH_{FOX} \leq 3$ were identified;
- 297 primary samples (~41%) with ΔpH of three or greater were identified.

A significant fraction of samples would be considered to represent ASS material on the basis of the field test indicator values.

3.4.2. LABORATORY RESULTS

A total of 221 primary samples (~31% of total samples) were analysed via the CRS suite method from samples collected from 25 investigation locations. Samples were selected based on the field test results. The results of the laboratory CRS analyses are summarised as follows:

- 24 samples contained actual acidity (as s-TAA) in excess of the 0.03%S action criterion;
- 95 samples contained potential acidity (as S_{CR}) equal to or greater than the 0.03%S action criterion;
- Using the standard net acidity equation, NA values range from <0.005%S to 2.535%S.

Comparison of the CRS results to the assessment criteria indicates the following:

- 111 of the 221 samples analysed contained NA in excess of the 0.03%S action criteria.

Based on the calculated NA values, using the appropriate NA equation on the basis of the pH_{KCl} results, there are a total of 111 samples (50%) which exceed the 0.03%S NA action criterion, with values ranging from 0.005%S to 2.535%S. The maximum actual acidity (as s-TAA) is 0.083%S, and the maximum potential acidity (as S_{CR}) is 2.5%S. The maximum NA calculated from the CRS results is 2.535%S, with an average NA of 0.137%S and standard deviation of 0.30%S for all samples.

3.5. INTERPRETATION

Field results indicate that Site soils are generally slightly acidic to neutral as a large proportion of pH_F results are within the pH6.0 to pH7.0 range. This indicates that there is generally very little actual acidity present in the soil profile, which is confirmed by the laboratory results, which show very little acidity is present as s-TAA. However, field results also show a high proportion of samples with $pH_{FOX} \leq 3$ and a ΔpH above 3pH units, indicating that there is additional potential acidity yet to be released into the soil profile. This is also confirmed by the laboratory CRS results which show 95 of the 221 samples analysed, contain NA as S_{CR} above the action criterion (0.03%S).

The NA results from the samples that have been analysed can be used as a basis to develop a soil neutralisation rate to counteract acid production potential of disturbed soils as detailed in (DER, 2015b). Where the volume of soil is >1,000m^3 it is appropriate to use the mean plus one standard deviation of the soil investigation NA results to calculate the amount of neutralising material required. Summary statistics from the soil investigation results that will be used to calculate an appropriate default soil treatment rate are:

- Number of samples subjected to CRS and NA calculation = 221
- Mean of calculated NA = 0.127%S
- Standard deviation of calculated NA = 0.299%S
- Mean plus one standard deviation of calculated NA = 0.426%S.

The calculated default soil neutralisation rate is detailed under the Soil Management section that follows (Section 6.6).

4. GROUNDWATER ASSESSMENT

4.1. BASELINE GROUNDWATER MONITORING PROGRAM

Doral recognise the importance of the collection of background or ‘pre-mine’ water quality data given the wider Busselton area has previously been modified by agricultural uses since the 1830s (DoW, 2010) and has the potential to be further impacted by mining. Background groundwater quality data will be used for comparison with data collected pre mining, during mining and post-mining to monitor and identify any impacts.

Doral has installed 12 monitoring bores (YA_MB01S to YA_MB12S) across the Site in order to monitor potential water level and water quality changes during operation of the mine. All bores were drilled to the base of the Superficial Formation (i.e. Yoganup Formation) and screened across all Superficial Formation units. Four other existing private bores form part of the background monitoring program for the Superficial aquifer. Groundwater monitoring has been conducted since 2017 to establish pre-mining baseline conditions and will continue to be monitored during dewatering activities in accordance with the Groundwater Operating Strategy (GWOS) (AQ2, 2021a). Five additional groundwater bores (YA_MB33_GDE to YA_MB37_GDE) have been installed specifically to monitor changes in water levels in proximity to two Groundwater Dependent Ecosystems (GDE’s) along McGibbon Track. These bores will be monitored in accordance with the GDE Management Plan (AQ2, 2020d). Nine existing private bores have also been monitored in order to obtain baseline groundwater monitoring data from the Leederville aquifer.

Details of the Superficial aquifer monitoring bores are presented in Table 3, with Leederville aquifer monitoring bores presented in Table 4.

Locations of Superficial and Leederville monitoring bores selected for the baseline groundwater monitoring program are shown in Figures 9 and 10.

TABLE 3: SUPERFICIAL MONITORING BORE DETAILS

Bore ID	Coordinates (MGA, Zone 50)		Ground Elevation#	Current Cased Total Depth#	Top of Casing (TOC)	TOC Elevation	PVC Casing Diameter	Screened/ Slotted Intervals	Aquifer	Status
	Easting (m)	Northing (m)	(mAHD)	(mbgl)	(mAHD	(mbgl)	(mm)	(mbgl)		
YA_MB01S	357253	6270021	23.46	5.01	24.18	0.72	50	1-7	Superficial	Current
YA_MB02S	356760	6270882	20.23	7.16	21.17	0.94	50	3-9	Superficial	Current
YA_MB03S	356989	6271678	18.76	8.66	19.22	0.46	100	1.8-7.8	Superficial	Current
YA_MB04S	357789	6270637	22.86	7.56	23.57	0.71	50	3-9	Superficial	Current
YA_MB05S	357787	6270960	21.80	7.64	22.28	0.48	100	1.5-7.5	Superficial	Current
YA_MB06S	357960	6271720	20.52	7.43	20.95	0.43	100	1.3-7.3	Superficial	Current
YA_MB07S	358606	6270858	25.04	7.26	25.83	0.79	50	2-8	Superficial	Current
YA_MB08S	358589	6271310	23.24	9.42	23.65	0.41	100	3.3-9.3	Superficial	Current
YA_MB09S	359401	6270501	30.58	7.65	31.2	0.62	50	2-8	Superficial	Current
YA_MB10S	359305	6270896	28.51	4.65	29.26	0.75	50	1-7	Superficial	Current
YA_MB11S	359295	6271545	24.69	8.22	25.14	0.45	100	1.8-7.8	Superficial	Current
YA_MB12S	359159	6271808	22.79	8.51	23.24	0.45	100	2.5-8.5	Superficial/ Leederville	Current (artesian flow)
YA_MB33_GDE	358889	6271018	25.78	4.0	26.43	0.65	50	0.5-4.0	Superficial	Current
YA_MB34_GDE	358725	6271158	24.61	6.4	25.22	0.61	50	0.4-6.4	Superficial	Current

Bore ID	Coordinates (MGA, Zone 50)		Ground Elevation#	Current Cased Total Depth#	Top of Casing (TOC)	TOC Elevation	PVC Casing Diameter	Screened/ Slotted Intervals	Aquifer	Status
	Easting (m)	Northing (m)	(mAHD)	(mbgl)	(mAHD	(mbgl)	(mm)	(mbgl)		
YA_MB35_GDE	358599	6271570	21.98	6.0	22.54	0.56	50	0.5-6.0	Superficial	Current
YA_MB36_GDE	359075	6270792	27.95	5.5	28.56	0.61	50	0.5-5.5	Superficial	Current
YA_MB37_GDE	359475	6271786	24.47	5.0	25.01	0.54	50	0.5-5.0	Superficial	Current
SCPD28A	358612	6271752	21.2	-	-	0.00	50	9m*	Superficial	Existing DWER bore
SCPD29A	359916	6269605	34.8	-	-	0.00	50	9.5m*	Superficial	Existing DWER bore
TS012M	358329	6270015	29.24	-	-	0.48	50	9m*	Superficial	Existing bore
20005166	357402	6269919	23.8	-	-	0.00	50	4.3m*	Superficial	Existing bore

mbgl = metres above ground level

mbgl = metres below ground level

mbtoc = metres below top of casing

Total depth of the bore was measured during May & June 2019 site visits

*Screed depth (meters below TOC), as per GWOS (AQ2, 2021a)

TABLE 4: LEEDERVILLE MONITORING BORE DETAILS

Bore ID	Bore ID (Other Name)	Coordinates (MGA, Zone 50)		Ground Elevation	Screened Depth	Top of Casing (TOC)	Aquifer	Status
		Eastings (m)	Northings (m)	(mAHD)	(mbtoc)	(mabgl)		
20005254	YA_MB21_W	359572	6270576	30	17	0.25	Leederville	Defunct bore, suitable for water levels and quality monitoring
20005356	YA_MB22_L	357207	6270142	23.5	16.5	0.05	Leederville	Defunct bore, suitable for water levels and quality monitoring
20083645	YA_MB23_L	358326	6272028	20.5	42	0.10	Leederville	Current bore, suitable for water levels and quality monitoring
LOT200_BORE	YA_MB25_L	356347	6270064	22.25	70	0.10	Leederville	Current bore, suitable for water quality monitoring (pump in bore)
LOT421_BORE1	YA_MB27_L	357323	6269971	25	48	0.30	Leederville	Current bore, suitable for water quality monitoring (pump in bore)
LOT552_BORE	YA_MB28_W	356220	6269870	23	70	0.00	Leederville	Current bore, suitable for water quality monitoring (pump in bore)
LOT667_WM1	YA_MB29_W	358311	6269190	29	11	0.35	Leederville	Current bore, suitable for water quality monitoring (pump in bore)
LOT668_BORE2	YA_MB31_L	357996	6269745	28	25.3	0.25	Leederville	Current bore, suitable for water levels and quality monitoring
LOT758_BORE	YA_MB32_L	358002	6270118	25.5	30	0.10	Leederville	Current bore, suitable for water quality monitoring (pump in bore)

4.2. ASSESSMENT CRITERIA

Groundwater quality at the Site is compared with guidance criteria provided in (DER, 2015b) to assess whether ASS processes may have taken place at or in the vicinity of the Site. Criteria used for this assessment include the following:

- A sulfate: alkalinity ratio greater than 0.2;
- A pH less than 5;
- Soluble aluminium concentration of greater than 1 mg/L.

In addition, samples are considered in light of indicative guidelines presented in DER (2015b) regarding the buffering capacity of groundwater, based on a review of its alkalinity and pH.

The analytical results were also compared with criteria for Australian Drinking Water Guidelines (ADWG), Non-Potable Use Groundwater (NPUG), Fresh Water Guidelines (FWG) and the Short-Term Irrigation criteria. These criteria are summarised in DWER's document *Assessment and Management of Contaminated Sites* (DER, 2014).

4.3. GROUNDWATER MONITORING RESULTS

4.3.1. GROUNDWATER LEVELS

The results from monthly water level monitoring in the Superficial aquifer as reported in (AQ2, 2020a) indicates the following:

- Pre-mining groundwater levels in the Superficial aquifer across the proposed mining area ranged between 15.6 and 34.8 mAHD (i.e. 0 to 4.7mbtoc);
- Highest water level elevations were recorded in August or September and lowest in May or June;
- Seasonal cycles of water table variations associated with the winter-dominated rainfall recharge to the Superficial aquifer are evident. The seasonal water level variations for these bores were between 1.7 and 2.6 m, averaging of 2 m;
- The site's Superficial groundwater flow direction is towards the north-west under a low hydraulic gradient, closely following the Site topography and consistent with the regional flow direction.

The results from monthly water level monitoring in the Leederville aquifer as reported in (AQ2, 2020a) indicates the following:

- Long-term groundwater elevations (since 2000) recorded in the DWER monitoring bores, 61030085 (BN28I) and 61030088 (BN29I), located nearby to the Site, ranged between 18.2 to 20.3mAHD and 33 to 35.8mAHD, respectively, with the seasonal water level fluctuations of between 2 to 2.5m;
- Bores Lot668_Bore2 and 23073124 recorded water level variation of up to 6m as a response to pumping in these bores;
- Groundwater levels (m below surface) in the Leederville aquifer tend to decrease towards the north-west, which is consistent with the regional groundwater flow direction generally towards the coast.

4.3.2. SUPERFICIAL GROUNDWATER QUALITY

TABLE 5: SUMMARY OF SUPERFICIAL GROUNDWATER QUALITY

Bore	Criteria	pH	Alkalinity	Acidity	SO4	Cl	SO_4: Cl RATIO	SO_4: ALK RATIO	Al (diss)	Fe (diss)	Mn (diss)
Units		pH units	mgCaCO3/L	mgCaCO3/L	mg/L	mg/L			mg/L	mg/L	mg/L
	ASS	<5	NV	40	NV	NV	0.5	0.2	1	NV	NV
	ADWG	**6.5-8.5**	**NV**	**NV**	**500**	**NV**	**NV**	**NV**	**0.003**	**0.3**	**0.5**
	NPUG	*NV*	*NV*	*NV*	*NV*	*NV*	*NV*	*NV*	*0.2*	*0.3*	*5*
	FWG	6.5-8.5	NV	NV	NV	NV	NV	NV	0.055	0.3	1.9
	STI	NV	NV	NV	500	700	NV	NV	20	10	10
YA_MB01S	Min	5.45	39	27	44	238	0.11	1.13	0.009	0.087	0.016
	Max	5.98	62	150	170	673	0.40	2.74	0.23	15	0.34
	Mean	5.81	48.71	65.37	90.51	395.37	0.23	1.86	**0.02**	***1.46***	0.11
YA_MB02S	Min	5.37	13	34	59	400	0.12	4.54	0.006	0.28	0.096
	Max	5.97	66	150	150	581	0.26	2.27	0.92	23	0.61
	Mean	5.73	38.02	93.47	77.41	466.77	0.17	2.04	**0.04**	***10.81***	0.39
YA_MB03S	Min	5.66	38	69	55	425	0.11	1.45	0.012	14	0.59
	Max	6.07	83	150	130	535	0.31	1.57	0.04	27	0.96
	Mean	5.95	57.43	110.64	62.48	503.54	0.12	1.09	**0.03**	***17.03***	**0.7**

Bore	Criteria	pH	Alkalinity	Acidity	SO4	Cl	SO_4: Cl RATIO	SO_4: ALK RATIO	Al (diss)	Fe (diss)	Mn (diss)
Units		pH units	mgCaCO3/L	mgCaCO3/L	mg/L	mg/L			mg/L	mg/L	mg/L
YA_MB4S	Min	5.45	20	45	38	370	0.09	1.90	0.011	0.27	0.16
	Max	5.87	41	120	47	429	0.13	1.15	0.12	11	0.24
	Mean	5.68	32.99	86.49	41.03	407.51	0.10	1.24	**0.02**	***8.47***	0.20
YA_MB5S	Min	5.49	17	28	41	233	0.17	2.41	0.005	0.86	0.019
	Max	6.05	21	52	46	243	0.19	2.19	0.023	1.6	0.06
	Mean	5.71	18.9	42.12	42.41	238.19	0.18	2.24	**0.007**	***1.36***	0.029
YA_MB6S	Min	5.58	66	9	360	1960	0.15	5.45	0.005	0.24	0.1
	Max	6.55	78	43	600	3760	0.18	7.69	0.6	5.2	0.57
	Mean	6.34	70.84	27.08	469.12	2,772.10	0.17	6.62	**0.02**	***0.92***	0.21
YA_MB7S	Min	5.17	10	16	24	55	0.33	2.40	0.005	0.026	0.005
	Max	5.70	13	38	30	83	0.51	2.31	0.17	0.38	0.02
	Mean	5.51	11.42	27.46	27.57	66.00	0.42	2.41	**0.01**	0.11	0.01
YA_MB8S	Min	5.49	15	17	34	100	0.26	2.27	0.005	0.079	0.011
	Max	6.03	20	39	40	138	0.39	2.00	0.014	0.58	0.027
	Mean	5.80	16.72	27.63	36.34	115.78	0.31	2.17	**0.01**	0.245	0.02
YA_MB9S	Min	5.50	30	29	56	130	0.15	1.87	0.005	0.005	0.005
	Max	5.99	60	110	230	1240	0.58	3.83	0.14	2.5	0.059

Bore	Criteria	pH	Alkalinity	Acidity	SO4	Cl	SO_4: Cl RATIO	SO_4: ALK RATIO	Al (diss)	Fe (diss)	Mn (diss)
Units		pH units	mgCaCO3/L	mgCaCO3/L	mg/L	mg/L			mg/L	mg/L	mg/L
	Mean	5.80	41.44	51.86	111.00	402.65	0.28	2.68	**0.02**	0.08	0.01
YA_MB10S	Min	5.60	19	18	96	200	0.23	5.05	0.005	0.28	0.001
	Max	6.06	37	61	150	455	0.65	4.05	0.14	6.8	0.034
	Mean	5.84	28.51	37.8	117.45	366.71	0.32	4.12	**0.02**	***1.56***	0.0061
YA_MB11S	Min	5.75	37	43	110	702	0.11	2.97	0.005	0.094	0.19
	Max	6.10	58	98	180	1120	0.24	3.10	0.023	11	0.78
	Mean	5.94	47.05	64.82	141.41	993.53	0.14	3.01	**0.01**	***3.90***	0.37
YA_MB12S	Min	5.31	24	100	49	469	0.10	2.04	0.012	23	0.89
	Max	6.06	76	170	62	523	0.12	0.82	0.093	32	1
	Mean	5.81	50.77	135.61	52.72	504.11	0.10	1.04	**0.035**	***28.99***	**0.95**
SCPD28A	Min	5.65	48	29	1	502	0.11	0.02	0.006	0.18	0.035
	Max	6.58	110	100	190	1100	0.18	1.73	0.48	2.8	0.66
	Mean	6.01	64.11	60.8	113.1	935.8	0.13	1.76	**0.035**	***1.10***	0.079
SCPD29A	Min	5.16	27	62	18	190	0.09	0.67	0.008	3.9	0.068
	Max	5.67	41	160	30	290	0.13	0.73	0.085	7.4	0.15
	Mean	5.44	34.90	111.86	23.26	220.84	0.11	0.67	**0.020**	***6.31***	0.12
TS012M	Min	5.3	20	65	74	230	0.20	3.70	0.005	0.64	0.015

Bore	Criteria	pH	Alkalinity	Acidity	SO4	Cl	SO_4: Cl RATIO	SO_4: ALK RATIO	Al (diss)	Fe (diss)	Mn (diss)
Units		pH units	mgCaCO3/L	mgCaCO3/L	mg/L	mg/L			mg/L	mg/L	mg/L
	Max	6.05	92	170	240	531	0.57	2.61	0.037	29	0.056
	Mean	5.61	56.37	122.2	132.30	433.82	0.30	2.35	**0.01**	***6.55***	0.038
20005166	Min	6.06	40	4	32	159	0.11	0.80	0.005	0.005	0.001
	Max	7.13	200	59	160	380	0.82	0.80	0.67	0.32	0.66
	Mean	6.46	79.46	22.62	105.42	244.3	0.43	1.33	**0.048**	0.107	0.02

A comparison of the results to the ASS indicator criteria indicates the following for the Superficial aquifer quality:

- Average pH values range from 5.44 to 6.34, with an average of 5.84 and do not exceed the ASS indicator value of pH5.0;
- Average total acidity concentrations range between 22mgCaCO$_3$/L and 135mgCaCO$_3$/L, with an average of 70mgCaCO3/L, exceeding the DWER recommended maximum total acidity concentration of 40mgCaCO$_3$/L at most bore locations (11 of 16 locations);
- Average total alkalinity concentrations range from 11-80mgCaCO$_3$/L, indicating that groundwater has low to moderate alkalinity and is generally adequate to maintain acceptable pH levels at most bore locations;
- The sulfate to alkalinity ratio for all groundwater samples exceeds 0.2;
- Dissolved Al concentrations are below 1mg/L for all samples.

A comparison of the groundwater results to the ADWG criteria indicates the following:

- The average pH of all samples is below the recommended range of 6.5-8.5;
- Average dissolved Al concentrations of all samples exceeded the criterion of 0.003mg/L;
- Average dissolved Fe concentrations exceed the 0.3mg/L criteria at 13 of the 16 bore locations;
- Average dissolved Mn concentrations are generally below the 0.5mg/L criteria (only 2 of 16 locations exceed);
- Average sulfate concentrations are below the assessment criteria of 500mg/L.

A comparison of the groundwater results to the NPUG criteria indicates the following:

- Average of all samples are below the dissolved Al criteria (0.2mg/L);
- Average of all samples are below the dissolved Mn criteria (5mg/L);
- Majority of samples exceed the dissolved Fe criteria (0.3mg/L), with concentrations as high as 28.99mg/L.

A comparison of the groundwater results to the FWG criteria indicates the following:

- The average pH of all samples is below the recommended range of 6.5-8.5;
- All samples are below the dissolved Al criteria of 0.055mg/L;
- Majority of samples exceed the dissolved Fe criteria (0.3mg/L), with concentrations as high as 28.99mg/L.

A comparison of the groundwater results to the Short-Term Irrigation criteria (STI) indicates the following:

- Average pH concentrations are within the acceptable range;
- Four locations have Chloride concentrations above the STI criteria (700mg/L);
- Average concentrations of sulfate, Al, Fe and Mn are all below the STI criteria.

4.3.1. LEEDERVILLE AQUIFER GROUNDWATER QUALITY

TABLE 6: SUMMARY OF LEEDERVILLE GROUNDWATER QUALITY

Bore	Criteria	pH	Alkalinity	Acidity	SO4	Cl	SO_4: Cl RATIO	SO_4: ALK RATIO	Al (diss)	Fe (diss)	Mn (diss)
Units		pH units	mgCaCO3/L	mgCaCO3/L	mg/L	mg/L	nv	nv	mg/L	mg/L	mg/L
	ASS	<5	NV	40	NV	NV	0.5	0.2	1	NV	NV
	ADWG	**6.5-8.5**	**NV**	**NV**	**500**	**NV**	**NV**	**NV**	**0.003**	**0.3**	**0.5**
	NPUG	*NV*	*NV*	*NV*	*NV*	*NV*	*NV*	*NV*	*0.2*	*0.3*	5
	FWG	6.5-8.5	NV	NV	NV	NV	NV	NV	0.055	0.3	1.9
	STI	4.5-9	NV	NV	500	700	NV	NV	20	10	10
YA_MB21_W	Min	5.57	35	89	30	290	0.09	0.86	0.021	19	0.06
	Max	6.04	91	180	43	390	0.13	0.47	0.064	29	0.72
	Mean	**5.80**	76.77	**145.20**	34.53	331.22	0.10	**0.45**	**0.033**	***23.71***	**0.51**
YA_MB22_L	Min	5.09	17	45	58	460	0.13	3.41	0.008	1	0.04
	Max	5.8	56	170	170	525	0.33	3.04	0.110	15	0.6
	Mean	**5.43**	26.18	**94.21**	101.34	487.24	0.21	**3.87**	**0.017**	***4.74***	0.41
YA_MB23_L	Min	5.88	18	66	35	320	0.10	1.94	0.009	30	0.5
	Max	6.32	74	130	46	380	0.14	0.62	0.087	42	0.63
	Mean	**6.14**	50.14	**95.21**	39.13	341.03	0.11	**0.78**	***0.042***	***34.91***	**0.56**
YA_MB25_L	Min	5.91	20	39	5	150	0.03	0.25	0.012	20	0.34

Bore	Criteria	pH	Alkalinity	Acidity	SO4	Cl	SO_4: Cl RATIO	SO_4: ALK RATIO	Al (diss)	Fe (diss)	Mn (diss)
Units		pH units	mgCaCO3/L	mgCaCO3/L	mg/L	mg/L	nv	nv	mg/L	mg/L	mg/L
	Max	6.54	85	150	21	171	0.13	0.25	0.080	45	0.63
	Mean	6.22	53.22	**88.27**	13.10	165.20	0.08	**0.25**	***0.042***	*32.85*	0.49
YA_MB27_L	Min	5.77	46	56	30	310	0.09	0.65	0.016	16	0.49
	Max	6.04	93	150	43	352	0.13	0.46	0.200	27	0.66
	Mean	5.93	64.60	**103.43**	35.19	334.98	0.11	**0.54**	***0.033***	*21.56*	**0.58**
YA_MB28_W	Min	4.91	20	73	12	160	0.07	0.60	0.009	0.07	0.54
	Max	6.45	78	170	19	180	0.11	0.24	0.066	38	0.66
	Mean	5.90	54.21	**118.07**	13.97	171.60	0.08	**0.26**	***0.040***	*19.85*	**0.60**
YA_MB29_W	Min	5.59	19	77	33	300	0.10	1.74	0.029	26	1
	Max	5.95	77	240	46	330	0.15	0.60	0.120	36	1.4
	Mean	5.77	51.58	**166.18**	36.50	314.20	0.12	**0.71**	***0.050***	*31.79*	**1.23**
YA_MB31_L	Min	5.97	43	38	28	260	0.10	0.65	0.007	15	0.08
	Max	6.47	78	110	41	290	0.15	0.53	0.056	24	0.8
	Mean	6.21	63.43	**70.18**	33.18	277.52	0.12	**0.52**	***0.03***	*21.098*	**0.64**
YA_MB32_L	Min	6.00	23	36	15	170	0.08	0.65	0.02	18	0.63
	Max	6.57	74	110	28	297	0.10	0.38	0.051	27	0.85
	Mean	6.18	43.30	**64.68**	22.90	266.02	0.09	**0.53**	***0.03***	*22.18*	**0.74**

A comparison of the results to the ASS indicator criteria indicates the following for the Leederville aquifer quality:

- Average pH values range from 5.43 to 6.22, with an average of 5.93 and do not exceed the ASS indicator value of pH5.0;
- All locations exceed the DWER recommended maximum total acidity concentration of 40mg$CaCO_3$/L, with concentrations ranging from 64-166mg$CaCO_3$/L, with an average 106mg$CaCO_3$/L;
- Total alkalinity concentrations range from 26-76mg$CaCO_3$/L, with an average of 54mg$CaCO_3$/L, indicating that groundwater is generally inadequate to maintain acceptable pH levels in areas vulnerable to acidification;
- The average sulfate to alkalinity ratio for all groundwater bores exceeds 0.2;
- Average dissolved Al concentrations are below 1mg/L for all samples.

A comparison of the groundwater results to the ADWG criteria indicates the following:

- The average pH of all samples is below the recommended range of 6.5-8.5;
- Average dissolved Al concentrations of all samples exceed the 0.003mg/L criteria;
- Average dissolved Fe concentrations at all locations, exceed the 0.3mg/L criteria.

A comparison of the groundwater results to the NPUG criteria indicates the following:

- Average dissolved Fe concentrations at all locations, exceed the 0.3mg/L criteria

A comparison of the groundwater results to the FWG criteria indicates the following:

- The pH of all samples is below the recommended range of 6.5-8.5;
- Average dissolved Al concentrations, are below the FWG criteria of 0.055mg/L;
- All locations exceed the dissolved iron criteria of 0.03mg/L.

A comparison of the groundwater results to the Short-Term Irrigation criteria (STI) indicates the following:

- Average pH concentrations are within the acceptable range.
- Average concentrations of dissolved Fe exceed the STI criteria of 10mg/L, at 8 of 9 locations, with average concentrations of 22mg/L.
- Average concentrations of sulfate, chloride and dissolved Al and Mn at all locations are below the relevant assessment criteria.

Further details on water level and water quality data can be found in (AQ2, 2020a). Doral will continue to assess groundwater quality from both the Superficial and Leederville aquifers in accordance with the GWOS (AQ2, 2021a).

4.4. INTERPRETATION

Groundwater results from groundwater monitoring undertaken by Doral, indicate that Superficial groundwater quality beneath the Site is slightly acidic due to pH levels generally <6.0 (although above the ASS indicator value of pH5.0), elevated total acidity concentrations of up to 135mg$CaCO_3$/L and low to moderate total alkalinity concentrations. Lower values of pH were normally recorded in summer periods and higher values in winter periods. The alkalinity/sulfate ratio indicates that groundwater is being affected by, or has already been affected by, the oxidation of sulfides. Low to moderate alkalinity concentrations coupled with a pH of <6.0 indicates groundwater is generally inadequate to maintain a stable pH in areas vulnerable to acidification. It is also noted that average alkalinity concentrations are approximately half of the total acidity concentrations, indicating that some buffering capacity is present within the system to offset some of the acidity. TDS concentrations indicate water is fresh to marginal.

Groundwater quality within the Superficial aquifer is generally suitable for its current beneficial use as irrigation water and non-potable groundwater uses, however due to the slightly acidic pH and elevated dissolved Al and Fe, it is generally not suitable for drinking water. Elevated dissolved Fe concentrations also exceed the Freshwater criteria.

Groundwater quality in the Leederville Aquifer is also considered to be acidic as evidenced by the high total acidity concentrations (up to 166mg$CaCO_3$/L) and pH generally <6.0. Alkalinity concentrations are in the low to moderate range indicating that groundwater is inadequate to maintain a stable, acceptable pH level. The alkalinity/sulfate ratio also indicates that groundwater is being affected by, or has already been affected by, the oxidation of sulfides. In general, groundwater samples collected from the Leederville monitoring bores during summer and winter periods have a similar chemical composition and are dominated by sodium and chloride.

Groundwater quality within the Leederville aquifer is generally suitable for its current beneficial use as irrigation water and non-potable groundwater uses (provided water is treated to remove elevated Fe), however due to the slightly acidic pH and elevated dissolved Al, Fe and Mn, it is generally not suitable for drinking water. Elevated dissolved Fe concentrations also exceed the Freshwater criteria.

5. MINING AND DEWATERING PROCESS

The mining activities will be scheduled to be undertaken on a campaign basis, with a portion of the ore body being mined and processed in a discrete time period. During each campaign, ore from the targeted area of the deposit will be mined progressively via a series of open-cut pits using dry mining techniques. Once the topsoil and subsoil (where present) are stripped and stockpiled, overburden (if present) will be removed via excavator and truck. Removed overburden will be stockpiled or where possible used in progressive rehabilitation of previously mined areas (i.e. backfilled into mine pits). Exact depths of ore and overburden will vary for each pit, but will not exceed ~10.5mbgl. Ore will be mined in a series of lifts, to a maximum depth of ~10.5mbgl. Additional infill drilling may indicate localised areas where the Yoganup strand ore might exceeds this indicated depth. Pits will be mined on a slight incline from the deepest point and then mined moving up gradient in order to retain pit water within a sump at the deepest point on the pit floor. This form of dewatering is known as 'passive' as no dewatering apparatus (e.g. spears) are used to actively abstract water and groundwater drawdown below the base of the pit (i.e. below 10.5m) is highly unlikely to occur. Only suction pumps (no submersible pumps) are used for dewatering and the suction pumps are set up at a level to maintain a 0.5m saturated pit floor. Mine pit dewater is pumped from the sump to the Drop Out Dam and then to the Process Water Dam for reuse.

Near surface dunal sand ore will be mined from the face using a Front End Loader in a single lift, and fed into the in-pit hopper, and screened and slurried using a mobile in-pit screening unit. The ore sourced from the deeper Yoganup strands will be mined using excavators and trucks to a central ROM pad (then fed into a fixed location feed unit). Alkaline (aglime) material will also be added into the in-pit hopper during the excavation of ore to increase/maintain the pH (pH5.5) and buffering capacity within the wet concentration process. During processing, alkaline material (i.e. aglime) will also be added via the feed-prep hopper at an appropriate rate based on the NA of the material (or at the default rate provided in Table 6). The screened slurry is then pumped to the feed preparation plant where it will move through a trommel and scrubber for removal of material greater than 3mm. Oversize materials (i.e. > 3mm) will be returned to the pit void or used to sheet internal mine site roads.

From the feed preparation plant, the ore will be transported via pumps and pipelines to the wet concentration plant where the process requires all particles >2.4mm to be removed from the ore. Approximately 500,000 to 700,000t of HMC is expected to be produced over the life of the mine. The HMC is stockpiled onsite and the moisture content is then reduced by allowing the stockpile to drain, prior to transportation to the Picton Dry Separation Plant.

Two material streams are produced from the wet concentration plant; sand tails and clay slurry. Sand tails are hydraulically returned as a slurry to the mine pits as rapidly as possible to maximise rebound of groundwater levels. The clay slurry is directed to the thickening circuit, where flocculent agglomerates clay fines, producing clay slurry.

Clay tails are either pumped into solar evaporation ponds (SEPs) to allow settlement and drying or preferably co-disposed with sand tails. Dried clay tails from the SEPs will be removed from the ponds (during the dry months) and placed in-pit with sand tails. Where possible co-disposal of clay fines and sand tails will be undertaken during mining whereby the clay tails are disposed with the sand tails into the pit voids at the same time. This provides a more homogenous distribution of soil particle sizing and improves the hydraulic conductivity and permeability of the returned soil profile. The majority of the water will be decanted from the SEPs and pumped or gravity fed back to the PWD for use as process water.

6. SOIL MANAGEMENT STRATEGY

The Yalyalup deposit is mapped as Bassendean Sands in an area with moderate to low risk of ASS (Class II) occurring within 3m of the natural soil surface. Results derived during the ASS investigation show that site soils proposed for excavation and dewatering contain NA in excess of the DWER's action criterion of 0.03%S. Therefore, soils will require management once excavation and mining activities begin.

The general sequence of mining and processing is as follows:

1. Removal and stockpiling of topsoil and subsoil (where present);
2. Excavation of overburden and/or mineral sands ore as follows:
    a. For strand deposit ore, initial excavation will be to remove overburden (which can be several meters thick):
        i. Overburden that is identified as ASS will then be neutralised and validated within 70 hours of excavation prior to being backfilled into a pre-existing mine void or re-used onsite;
        ii. Alternatively, overburden identified as ASS will be stored on a suitably constructed limestone pad, neutralised and validated within 21 days prior to being backfilled or re-used onsite;
        iii. Excavation and processing of ore commences.
    b. Where ore is present at surface (such as dunal deposit material), processing of excavated material will commence as soon as mining starts.
3. Once ore is excavated, it is immediately processed, starting by being fed into the in-pit hopper. To maintain the process materials at pH5.5, aglime is also added at the in-pit hopper (as necessary to maintain pH5.5). After being loaded into the in-pit hopper, the materials are piped as a wet slurry to the wet concentration plant.
4. At the wet concentration plant the ore slurry is separated into three process streams; HMC, sand tails and clay fines:
    a. The HMC is initially stockpiled onsite prior to transport off-site for further processing at Doral's Picton Dry Plant;
    b. Sand tails rare hydraulically returned as a slurry to the mine voids;
    c. The clay fines are managed either by co-disposal into mine voids with sand tails or directed to SEPs to be consolidated prior to being validated and backfilled to a mine void.

In addition to the general mining and processing sequence, site derived materials may be utilised as 'Construction Material'. These materials may be extracted and used for development of on-site roads, bund walls, infrastructure, or other purposes.

The soil management strategies presented below are intended to minimise the risk of ASS impacts and apply to excavation of any materials extracted from the Site.

6.1. TOPSOIL AND SUBSOIL MANAGEMENT

Topsoil and subsoil (where present) will be stripped to a depth of approximately 100mm and stockpiled, prior to use in progressive rehabilitation. In accordance with DER (2015b), topsoil will not require neutralisation if the pH of surface soils (0-0.3m) is less than pH4.0. Should the pH of this material be less than pH4.0, neutralisation will be undertaken using suitable alkaline material to ensure a revised validation criterion of pH5.0 is achieved.

6.2. OVERBURDEN MANAGEMENT

The strandline deposit ore at Yalyalup is overlain by ~2-5m of overburden. Removal of overburden is therefore necessary prior to being able to access and excavate ore.

Overburden identified as ASS (i.e. NA >0.03%S), referred to as ASS-overburden, will be excavated and immediately stored on a 'guard layer of alkaline material', neutralised and validated within 70 hours, prior to re-use or backfill on-site. This approach is consistent with DWER's short-term stockpiling timeframe.

Where ASS-overburden cannot be neutralised and validated within 70 hours, the materials will be stockpiled on a ''treatment pad'' prior to neutralisation. Neutralisation will then be completed in accordance with DWER's medium-term stockpiling timeframe, that is neutralised and validated within 21 days. Treatment will be undertaken at an appropriate rate based on the NA of the material (or at the default rate provided in Table 6). The treatment pad will be constructed of compacted crushed limestone of not less than 300mm thickness, be graded to ensure good drainage, and all sides will be bunded with limestone or similar alkaline material to a minimum height of approximately 150mm above the surface of the pad to prevent lateral run-off. A leachate collection system will also be present to manage run-off from rainfall events and/or natural drainage of the stockpiled material.

It should be noted that due to the passive dewatering method, overburden excavated from below the natural groundwater level will be maintained in a saturated (anoxic) state, as far as practicable, prior to excavation. This will aid in reducing the potential for oxidation of sulfidic acidity that may be present.

6.3. ORE MANAGEMENT

Ore identified as ASS (i.e. NA >0.03%S), referred to as ASS-ore, will be processed through the wet concentration plant as soon as possible. This material is maintained in a saturated state in the form of a wet slurry throughout excavation and transport for processing, therefore the risk of sulfide oxidation is greatly reduced. In addition, the slurry is maintained at pH5.5 which is necessary to assist with the separation process, and which also reduces the risk of sulfide oxidation. The process slurry pH is maintained in the pit via the addition of alkaline material (i.e. aglime) which is added via an in-pit hopper.

During processing, alkaline material (i.e. aglime) will also be added via the feed-prep hopper at an appropriate rate based on the NA of the material (or at the default rate provided in Table 6).

Any ore material that is not processed immediately upon excavation will be placed on a 'guard layer of alkaline material' and stockpiled for a period of no more than 70 hours (i.e. short-term stockpiling timeframes), prior to being processed. Ore that cannot be processed within 70 hours will be stockpiled on a 'treatment pad' (constructed as per Section 6.2) and will be processed or neutralised and validated within 21 days (i.e. medium-term stockpiling timeframe).

6.4. PROCESSED MATERIALS MANAGEMENT

Processing of ore results in three streams of material; HMC, sand tails and clay fines. The three process streams are dealt with in the following manner:

- HMC is stockpiled and stored on-site until transport to Doral's Picton dry processing plant for further processing;
- Sand tails are hydraulically returned into pit voids (including as co-disposal);
- Clay fines are either hydraulically co-disposed with sand tails into pit voids or directed to SEPs to be consolidated prior to being validated and backfilled to a mine void.

Management of each of the process streams is detailed in the following sections.

6.4.1. HMC

The HMC resulting from processing will be stockpiled and stored on a bunded limestone pad, as described in Section 6.2, until it is transported offsite. Leachate emanating from the stockpiled HMC will be captured and returned to the ore processing circuit, which is maintained at pH5.5.

6.4.2. SAND TAILS

Sand tails resulting from ore processing will be hydraulically returned to mine voids as a single stream and/or co-disposed with clay fines into mine voids. Alkaline material will be added into the feed-prep hopper at an appropriate rate based on the NA of the material (or at the default rate provided in Table 7).

Sand tails will be tested daily for pH_F/pH_{FOX} and Total Sulfur at rates provided in (DWER, 2019) (see Table 8), with 25% of samples being subject to further analysis by CRS suite to ensure excess buffering capacity is present in the outgoing material. Validation criteria is provided in Section 6.7.

6.4.3. CLAY FINES

For clay fines, alkaline material will be added into the feed-prep hopper at an appropriate rate based on the NA of the material (or at the default rate provided in Table 7) prior to being:

- Immediately co-disposed with sand tails by hydraulic return into existing mine voids; or
- Directed to a SEP for consolidation and future use as mine void backfill.

Clay fines will be tested daily at the thickener for pH_F/pH_{FOX} and Total Sulfur at rates provided in (DWER, 2019) (see Table 8), with 25% of samples being subject to further analysis by CRS suite to ensure excess buffering is present in the outgoing material. Validation criteria is provided in Section 6.7.

Clay fines stored in the SEPs will be re-tested prior to final disposal into a mine void for pH_F/pH_{FOX} and Total Sulfur at the rates provided in DWER, 2019) (see Table 8), with 25% of samples being subject to further analysis by CRS suite to ensure excess buffering is present in the outgoing material. The purpose of the pre-disposal testing is to ensure the pH and acid neutralising capacity of material is adequate to mitigate post-disposal risk to the receiving environment. Decant water from the SEP's will be directed back towards the ore processing circuit, which is maintained at pH5.5.

6.5. CONSTRUCTION MATERIAL MANAGEMENT

Overburden and non-processed material identified as ASS (i.e. NA >0.03%S), that will be used for site construction purposes (i.e. roads, pads, bunds etc.) will either be:

- Placed on a guard-layer of alkaline material, neutralised and validated for re-use within 70 hours of excavation; or
- Stockpiled on a treatment pad (as described in Section 6.2), neutralised and validated for re-use within 21 days.

Neutralisation and validation sampling of this material will be undertaken using the rates and criteria provided in Section 6.6.

6.6. DEFAULT NEUTRALISATION RATE (BASED ON SOIL INVESTIGATION)

In accordance with the guidelines for treatment and management of ASS (DER, 2015b) acid-base accounting using results from CRS method (or SPOCAS) can be used to determine the quantity of neutralising material that is required to counteract acidity due to disturbed ASS. For soil volumes >1,000m^3 the mean net acidity plus one standard deviation is used to calculate the amount of neutralising material required. Table 7 presents the uncorrected neutralisation rate calculated using the following equation:

Lime required (kg $CaCO_3$/m^3) = Soil density (t/m^3) x NA (%S x 30.59) x 1.02 x safety factor (1.5) x 100/ENV

The NA adopted for the Project has been calculated using the mean plus one standard deviation of 221 soil investigation samples analysed by CRS suite method.

TABLE 7: DEFAULT LIMING RATE CALCULATION

A: Soil Density (tonne/m^3)	1.65
B: NA (%S)	0.426
C: Conversion Factor (%S to kg lime/tonne soil, including 1.5 x safety factor)	46.80
A*B*C: Uncorrected Liming Rate (kg $CaCO_3$/m^3 soil)	**32.90**

The liming rate presented in Table 7 has been calculated using an assumed bulk density of 1.65 t/m^3 and the average plus one standard deviation of the NA values for soil investigation samples analysed by CRS, it is uncorrected for effective neutralising value (ENV).

Uncorrected liming rates assume that the treatment will be undertaken using pure calcium carbonate which can all be directly utilised to neutralise soil acidity. The most common neutralising agent, aglime, is not 100% calcium carbonate and has particle size variations leading to a reduction in its chemical availability. As such the values presented in Table 7 will need to be corrected for ENV. A lime certificate providing information about the neutralising value and particle size distribution of the neutralising agent will be required. As an indication, the effective neutralising value of commonly available aglime/lime sand may be in the order of 70%, which would yield a theoretical corrected liming rate of approximately 47kg$CaCO_3$/m^3 soil.

6.7. ALTERNATIVE NEUTRALISATION RATE USING TOTAL SULFUR (S_T) ANALYSIS

The default neutralisation rate provided in Table 7 may be varied by Doral on an as needed basis by use of Total Sulfur (S_T) analysis results. Measurement of S_T may be used to estimate the maximum potential environmental risk from acid produced by the oxidation of sulfides (Ahern, McElnea, & Sullivan, 2004). Use of this analysis method is a time and cost-effective way to quantify total sulfur and Doral utilise this form of analysis for grade and process control assessment. Due to the significant amount of S_T data that Doral will have they may choose to determine alternative treatment rates for disturbed ASS using this data.

In order to consider the efficacy of this approach, an assessment of the degree of agreement was undertaken on 52 samples between:

- Method A - %S NA determined from the CRS suite (CRS calculated NA);
- Method B - %S values from S_T analysis using LECO.

Assessment of the degree of agreement was been undertaken by plotting the mean difference of sample results from the two analyses methods, an approach known as the 'Bland Altman Plot Analysis', with reference to a paper titled *Understanding Bland Altman Analysis* (Giavarina, 2015). Detail of this assessment, including the soil samples IDs and corresponding analytical results from each method is provided in Appendix 3. The outcome is that the Bland Altman analysis indicates that:

- On average, the S_T analysis method measures 0.027%S more than CRS-calculated NA (or 28% more %S).

When the Bland Altman Plot data were normalised, it was possible to determine the upper and lower limits of agreement between the methods in accordance with Giavarinia (2015), with the results being:

TABLE 8: LIMITS OF AGREEMENT (%) FOR METHOD A & B USING BOX-COX TRANSFORMED (A-B / MEAN %) DATA.

LIMITS OF AGREEMENT (%)	
Lower	**Upper**
Mean difference – 1.96 *s*	Mean difference + 1.96 *s*
= -19.34627 – (1.96 x 7.878669)	= -19.34627 + (1.96 x 7.878669)
= -34.78846%	= -3.9040788%
Notes: s = standard deviation	

The limits of agreement are both negative (-) which is indicative that the second method (S_T) constantly over-estimates %S compared to the first method (CRS calculated NA) (Giavarina, 2015). As such, it can be stated that:

- Use of S_T data to determine the NA %S (required to calculate ASS neutralising rate) is expected to over-estimate the NA %S determined by CRS calculated NA, and will therefore lead to use of a conservative neutralisation rate.

6.7.1. NUMBER OF SAMPLES REQUIRED TO CALCULATE S_T NEUTRALISATION RATE

The number of sample locations required to be tested by S_T will be in accordance with the ASS guidelines (DER, 2015a) as shown in the table below.

TABLE 9: NUMBER OF SAMPLE LOCATIONS REQUIRED TO CHARACTERISE THE S_T (%S) OF AREAS OF SOIL PROPOSED FOR TREATMENT USING ALTERNATIVE NEUTRALISATION RATE (ADAPTED FROM DER, 2015A).

EXCAVATION PURPOSE	EXCAVATION FOOTPRINT	NUMBER OF SAMPLE LOCATIONS	MINIMUM VERTICAL SAMPLING INTERVAL PER LOCATION
Overburden or Ore	<1ha	4	1m
Overburden or Ore	1–2ha	6	1m
Overburden or Ore	2–3ha	8	1m
Overburden or Ore	3–4ha	10	1m
Overburden or Ore	>4ha	2 per hectare	1m

To use the S_T analysis results to calculate an alternative neutralisation rate for either overburden or ore treatment, soil samples will be collected throughout the entire vertical profile (of either ore or overburden) at the rates detailed above for S_T analysis, with the average and standard deviation of the batch of results used as the adopted NA (%S) in the liming rate calculation detailed in Table 7.

6.8. VALIDATION SAMPLING

Treated material will be subject to validation sampling at a rate consistent with guidance in *Landfill Waste Classification and Waste Definitions 1996 (As amended)* (DWER, 2019), as shown below. Validation samples will be collected so as to represent 'batches' of treatment.

TABLE 10: VALIDATION SAMPLING RATE (DWER, 2019)

VOLUME (m^3)	NUMBER OF FIELD PH SAMPLES	NUMBER OF CRS SAMPLES (25%)
100 to 200	4	1
200 to 500	6	2
500 to 1,000	8	2
1,000 to 2,000	11	3
2,000 to 3,000	15	4
3,000 to 4,000	18	5
4,000 to 5,000	20	5
5,000 to 10,000	24	6
>10,000	24 plus 4 for each additional 10,000m^3	6 plus 1 per each additional 10,000m^3

All samples will be assessed for field pH_F and pH_{FOX}. The accuracy of the field-testing program will be initially 'calibrated' by sending approximately 25% of samples for additional laboratory analysis by either; SPOCAS suite; pH_{KCL} and pH_{OX} undertaken in a laboratory unground sample; or the CRS suite with inclusion of TPA analysis from SPOCAS suite.

Samples meeting the following criteria (DER, 2015b) will be deemed to be effectively neutralised:

1. Visually, the neutralising material must be well-blended with the soil.
2. Samples require a pH_F of between 6.0 and 8.5.
3. Samples require a pH_{FOX} of at least 5, to indicate that there is neutralising capacity greater than the existing plus potential acidity of the soil.
4. Laboratory results need to indicate that excess acid neutralising capacity is present, as evidence that acidity released in the future can be neutralised.

6.9. DOCUMENTATION OF SOIL MANAGEMENT

Documentation of soil management will be maintained as follows:

- Location (i.e. pit number/area), S_T investigation results (using sampling frequency in Table 8) if deviating from the default liming rate, and calculated liming rate using mean plus standard deviation of the S_T data;
- Estimated volume of ASS material (i.e. overburden or ore) requiring neutralisation;
- Source, volume and ENV of neutralising material used;
- Details of validation sampling undertaken for all materials (i.e. overburden, construction materials, sand tails and clay fines);
- Validation sampling results compared to validation criteria;
- Estimated final location of treated materials (i.e. overburden, construction materials, sand tails and clay fines).

A summary of all soil management documentation will be included in Doral's Annual Environmental Report and Compliance Assessment Report (CAR) to demonstrate that Ministerial Condition 9-1 has been met over the reporting period.

7. DEWATERING MANAGEMENT STRATEGY

7.1. DEWATERING PROCESS

Dewatering of mine pits and localised drawdown of the water table will occur in a staged approach, with mine pits being dewatered as per the mining schedule modelled by (AQ2, 2020a). Dewatering to the required depth of excavation will occur passively as groundwater enters the mining excavation. The water will be drained by open channel within the pit to a sump and pumped out using a suction pump set at a level to maintain a 0.5m saturated pit floor. The dewater will then be sent through to a secondary collection sump prior to reaching the Drop Out Dam (DOD) (either directly or via an open drain and then gravity fed) and then to the Process Water Dam (PWD), where it mixes with other water from other mine processes. The use of passive dewatering reduces the extent of groundwater drawdown as far as practical.

The extracted water will be from the Superficial aquifer, which comprises the Bassendean Sand, Guildford Formation and Yoganup Formation, with a maximum saturated aquifer thickness of 9m in the mine pit area. The Guildford Formation is present between the Bassendean Sand and Yoganup Formation and is of low permeability, owing to its more clayey nature. The permeability of the superficial aquifer is variable and depends on sediment type, with saturated sands having higher permeability than clays. The superficial deposits commonly contain ironstone caprock, colloquially known as Coffee Rock, in the zone of water table fluctuation and at the Site, it is generally 2 to 3m thick and is exposed at the surface in parts of the projects (mainly in the western side). At the Site, the Yoganup Formation forms the main portion of the aquifer, while the Bassendean Sand is generally only saturated in the wet season. The Yoganup Formation comprises leached and ferruginous beach coarse grained sand, with localised concentrations of heavy minerals and some sandy silt and clay layers. The thickness of the Superficial Formation is irregular, reaching a maximum of 12m at the Site, but generally being 7-8m thick.

7.2. DEWATERING EXTENT

AQ2 prepared a numerical groundwater flow model (AQ2, 2020a) to assess the dewatering requirements and groundwater drawdown associated with the development of the Yalyalup project.

The modelling study was completed consistent with the *Australian Groundwater Modelling Guidelines* (Barnett, et al., 2012). Key features of the groundwater model are summarised below:

- The Superficial Formation and the underlying Leederville and Yarragadee aquifers;
- Recharge to the aquifer system from rainfall recharge;
- Groundwater inflow from upstream and groundwater outflow to downstream;
- Dewatering of the proposed Yalyalup mine area and dewatering at Cristal's nearby operational mine;
- Water supply pumping from the Superficial, Leederville and Yarragadee aquifers;
- Evapotranspiration from the shallow water table across the modelled catchment and the areas of the Vasse-Wonnerup Ramsar Wetlands System that lie within the model domain, north west of the Proposal.

Groundwater drawdowns (i.e. decrease in water levels) in the Superficial aquifer and the underlying Leederville aquifer due to the open pit dewatering have been predicted by the numerical model. These drawdowns are the difference between the water levels predicted at each selected time interval for the Yalyalup Dewatering Scenario and the corresponding No Yalyalup Development Scenario. The Yalyalup No

Development Scenario contained the same conditions as the Yalyalup Dewatering Scenario, except that proposed dewatering for the Proposal was excluded.

Contours of predicted Superficial aquifer water table drawdown at quarterly intervals, over the mine life, for the Yalyalup Dewatering Scenarios are provided in a series of Figures for both wet and dry climatic scenarios (refer to AQ2, 2020a).

In summary, water level drawdowns in the Superficial aquifer are predicted to be localised in the immediate area of the active mining pits, temporary in duration and relatively small, with a maximum drawdown of 10.5m predicted at the end of mining in Q2 of 2023. The cone of depression of 0.1m generally lies within the proposed mining disturbance areas and only marginally extends past this area (up to 700m for the dry scenario and 600m for the wet scenario).

The following general observations can also be made regarding predicted drawdown:

- As would be expected, maximum drawdown is predicted in the immediate mine area. The total maximum drawdown predicted over the life of the mine varies with mining depth;
- Maximum drawdown is predicted in the immediate mining area and is similar for both climatic cases;
- The extent of predicted drawdown shown (0.1m contour) is generally limited to the mine disturbance areas.
- The maximum distance that drawdown of 0.1m extends outside of the perimeter of the mine disturbance area is 700m to the north, 250m to the south, 300m to the east and 450m to the west, at various times during the mine life for the dry climate scenario.
- For the wet climate scenario, the maximum distance that drawdown of 0.1m extends outside of the perimeter of mine disturbance area is 600m to the north, 200m to the south, 300m to the east and 400m to the west, at various times during the mine life for the wet climate scenario.

Contours of maximum predicted drawdown in the Leederville aquifer from dewatering of the Yalyalup mine (Yalyalup Dewatering Scenario) are also shown for dry and wet climatic conditions in the groundwater model (AQ2, 2020a). The maximum drawdown is predicted in September 2023 and is calculated by subtracting predicted water levels for the Leederville aquifer for the Yalyalup Dewatering Scenario from the No Yalyalup Development Scenario. A similar drawdown profile is predicted for the dry and wet climate scenarios. The extent of predicted drawdown in the Leederville Aquifer shown (0.1 m) is generally limited to the mine disturbance areas. The maximum distance that drawdown of 0.1 m extends outside of the perimeter of the mine disturbance area is 700m to the north, 50m to the south, 300m to the east and 300m to the west for both wet and dry scenarios (i.e. Q3 of 2023).

Additionally, some small drawdowns (up to 0.4m) are predicted in the Leederville aquifer due to dewatering of the overlying Superficial aquifer. The Mowen Member of the Leederville Formation is generally considered as an aquitard, however at the Site the Mowen Member is thin resulting in small indirect upward leakage of water from the Leederville aquifer from below the pit floor. Based on the results of groundwater modelling, the drawdowns in the Leederville aquifer are predicted to be local and likely to extend laterally, but not vertically (owing to clayey layers within the sand).

Long-term post mining effects on water levels are expected to be minimal. The recovery of water levels will commence immediately once mining of each active mine pit is completed, owing to backfilling of mined-out pits. Groundwater inflows to the mined-out pits are driven by water level gradients between the mine voids and the surrounding areas. The pit backfilling acts to recharge groundwater levels rapidly, compared to unassisted rebound by aquifer hydraulic head pressures only. The expedited recharge, thereby reduces the extent of dewatering influence and returns the soil profile to anoxic conditions. Unreacted lime sand that was added to the ore slurry at the in-pit hopper (to ensure the process stream pH is maintained at pH >5.5) also ends up in the sand tails waste stream, assisting to buffer the pH of the groundwater system as rebound occurs. However, it should be noted that during the mining phase, water recovery in mined-out areas may be interfered with by dewatering of subsequent mining areas, thus the rate of water level recovery can be slower. Once all mining areas are completed, dewatering will cease, and water levels will continue to rise until a steady state or equilibrium water level is resumed. The numerical model shows that water levels are predicted to return to pre-mining levels within 18 months of mine closure (i.e. by July 2026).

Therefore, it is unlikely that short-term dewatering at the proposed Site will have any adverse impacts on the water supply potentials of the Superficial and Leederville aquifer systems.

7.3. DEWATERING MONITORING

One sample point will be established to monitor the dewatering effluent quality at a location prior to the water reaching the PWD (i.e. pit dewatering discharge point or sump) and a second sample point will be established at the PWD.

The following monitoring program will be conducted for the pit dewatering sump (pre-treatment) and process water dam (post-treatment).

TABLE 11: DEWATERING QUALITY MONITORING PROGRAM

MONITORING SITE ID	FIELD		LABORATORY	
	FREQUENCY	PARAMETERS	FREQUENCY	PARAMETERS
Pit Dewatering Discharge Point	Daily (7 times per week)	pH, EC, TTA, total alkalinity,	Monthly (lab) (or weekly if triggers exceed in Table 12)	pH, EC, TDS, total acidity, total alkalinity, Cl, SO_4, Al (diss)*, Fe (diss), Mn (diss)
PWD Sampling Site	Daily (7 times per week)	pH, EC, TTA, total alkalinity,	Monthly (lab) (or weekly if triggers exceed in Table 13)	pH, EC, TDS, total acidity, total alkalinity, Cl, SO_4, Al (diss)*, Fe (diss), Mn (diss)
			Quarterly (lab) (or weekly if daily pH_F<4)	pH, EC, TDS, total acidity, total alkalinity, Cl, SO_4, Al (diss)*, Fe (diss), Mn (diss)
			Quarterly (lab)	Total metals (Al, As, Cd, Cr, Co, Cu, Fe, Hg, Ni, Se, Ti, U, Zn, Ra226, Ra228)

*If dissolved Al > 1 mg/L then additional analyses are required for Zn, Cr, Cu, Mg, Ni, Cd, Se, As, Pb and Hg.

7.4. DEWATERING TRIGGER VALUES AND TREATMENT

DER (2015b) guidelines require that dewatering effluent with a pH of less than pH6.0 or total acidity of greater than 40mg$CaCO_3$/L or total alkalinity less than 30mg$CaCO_3$/L, be treated via addition of a neutralising agent prior to reinfiltration (i.e. hydraulic return of sand tails and/or clay fines into mine void).

The following trigger values will apply to the Pit Dewatering Discharge Point.

TABLE 12: PIT DEWATERING DISCHARGE TRIGGER VALUES

PIT DEWATERING WATER PARAMETER	TRIGGER CRITERIA	STATISTICALLY SIGNIFICANT TREND OVER 7 DAYS
pH*	<5.5	Decreasing
TTA	>40 mg$CaCO_3$/L	Increasing
Total alkalinity	<30 mg$CaCO_3$/L	Decreasing
Dissolved Aluminum#	>1 mg/L	Increasing

* Site specific value calculated using the average background pH of Superficial monitoring bores.

If dissolved Al concentration exceeds 1 mg/L for any laboratory sample, then the sample must be analysed further for As, Cd, Cr, Cu, Pb, Hg, Mg, Ni, Se and Zn.

Should any Trigger Criteria provided in Table 12 be triggered, dewatering effluent will be treated via the addition of a suitable neutralising agent until water quality parameters stabilise as detailed in Section 7.5.1.

Should a statically significant trend of either decreasing alkalinity or pH, and/or increasing acidity be observed over a period of 7 days (using Mann-Kendall tests), active groundwater management will be instigated as per Section 7.5.1.

TABLE 13: PWD TRIGGER VALUES

PWD PARAMETER	TRIGGER CRITERIA	STATISTICALLY SIGNIFICANT TREND
pH*	<5.5	Decreasing
TTA	>40 mg$CaCO_3$/L	Increasing
Total alkalinity	<30 mg$CaCO_3$/L	Decreasing
Dissolved Aluminum#	>1 mg/L	Increasing

* values based on average background pH of Superficial monitoring bores.

If dissolved Al concentration exceeds 1 mg/L for any laboratory sample, then the sample must be analysed further for As, Cd, Cr, Cu, Pb, Hg, Mg, Ni, Se and Zn.

Should any Trigger Criteria provided in Table 13 be triggered, dewatering effluent will be treated via the addition of a suitable neutralising agent until water quality parameters stabilise and return to being within suitable range of the Trigger Criteria.

Should a statically significant trend of either decreasing alkalinity or pH, and/or increasing acidity be observed over a period of 7 days (using Mann-Kendall tests), active groundwater management will be instigated as per Section 7.5.

7.5. CONTINGENCY ACTIONS

7.5.1. PIT DEWATERING DISCHARGE POINT (SUMP)

TRIGGER CRITERIA EXCEEDANCE

In the event that water quality monitoring of the dewatering effluent exceeds an ASS Trigger Criteria in Table 12 (as a warning of any oxidation of sulfidic material on site), Doral will undertake the following mitigation measures immediately;

- Undertake neutralisation treatment (liming) of the pit dewater. This is achieved by direct addition of lime to the dewater sumps and/or the more effective method of addition of lime sand to the plant feed. Adding lime to the ore feed acts to effectively neutralize the water circuit through the plant and return neutralising lime sand in the sand tails and neutralized tails return water to the recirculating pit dewatering sumps. Neutralisation will continue until water quality improves above (pH/alkalinity) or below (TTA) the trigger criteria.
- Increase the monitoring listed in Table 11 to weekly laboratory testing of the affected areas.

Following a review of the mine schedule, additional contingencies that may be implemented include:

- Mining activities will be scheduled to be undertaken on a campaign basis, with a portion of the ore body being mined and processed in a discrete time period, to assist in minimising the area of groundwater drawdown at any one time;
- Mitigate the effect of dewatering activities by accelerating backfill of the pit in the affected area to reduce the amount of time PASS horizons are exposed.
- Recharge treated water to the aquifer to increase alkalinity near the dewatering area via recharge basin/trenches.

STATISTICALLY SIGNIFICANT TREND EXCEEDANCE

Should a statically significant trend of either decreasing alkalinity or pH, and/or increasing acidity be observed over a period of 7 days (using Mann-Kendall tests), active groundwater management will be implemented within 48 hours as follows:

- Install recharge basins/trenches in affected areas, and commence recharge with lime-treated water to reduce the acidity and metal concentrations in groundwater;
- Continue to recharge lime treated water for a period of 7 days or until pH, TTA and TAlk have stabilised/improved;
- Monitor groundwater quality for ASS parameters (pH, TTA and TAlk) daily at affected location(s) during recharge activities and for a period of 7 days following cessation of treatment.

7.5.2. PROCESS WATER DAM

TRIGGER CRITERIA EXCEEDANCE

In the event that water quality monitoring of the PWD exceeds an ASS Trigger Criteria in Table 13, the contingency measure will be to treat the process water through the addition of a suitable alkaline material to the ore feed and/or the tails return water sump. Neutralisation will continue until water quality improves above (pH/alkalinity) or below (TTA) the trigger criteria. Whilst the PWD is in exceedance of a Trigger Criteria, no discharge of process water off site will occur.

Doral will increase the monitoring listed in Table 11 to weekly laboratory testing.

STATISTICALLY SIGNIFICANT TREND EXCEEDANCE

Should a statically significant trend of either decreasing alkalinity or pH, and/or increasing acidity be observed over a period of 7 days (using Mann-Kendall tests), active groundwater management will be implemented within 48 hours as follows:

- Install recharge basins/trenches in affected areas, and commence recharge with lime-treated water to reduce the acidity and metal concentrations in groundwater;
- Continue to recharge lime treated water for a period of 7 days or until pH, TTA and TAlk have stabilised/improved;
- Monitor groundwater quality for ASS parameters (pH, TTA and TAlk) daily at affected location(s) during recharge activities and for a period of 7 days following cessation of treatment;

8. GROUNDWATER MANAGEMENT STRATEGY

The disturbance of ASS material can lead to the release of acid and mobilisation of metals, causing contamination of groundwater which may cause offsite impacts to groundwater and groundwater dependent ecosystems. Indirect disturbance via dewatering is a primary concern, as areas of the site contain ASS material below the natural groundwater table, which may be exposed to oxidation via dewatering. Indirect acidification via dewatering may lead to acidic or metal-rich groundwater plumes which may affect onsite or offsite receptors.

In order to identify potential groundwater impacts associated with dewatering, Doral will implement a groundwater monitoring program in accordance with the GWOS (AQ2, 2021a). Results of the monitoring program will be compared to site-specific trigger criteria and/or DWER ASS indicator values (DER, 2015b), with contingency measures to be implemented as required.

Details of the groundwater monitoring program are provided in the following sections.

8.1. GROUNDWATER MONITORING WELLS

Doral has installed 12 monitoring bores (YA_MB01S to YA_MB12S) across the Site in order to monitor potential water level and water quality changes within the Superficial aquifer during operation of the mine. Doral will also utilise four other existing groundwater bores across the Site to monitor groundwater levels and quality. Site specific trigger criteria have been developed for the 16 Superficial groundwater monitoring bores as shown on Figure 9.

Leederville water quality across the Site will also be monitored in accordance with the GWOS (AQ2, 2021a) utilising a network of 9 existing groundwater bores (20005254, 20005356, 20083645, LOT200_BORE, LOT552_BORE, LOT642_BORE1, LOT667_WM1, LOT668_BORE2 and LOT758_BORE). These monitoring bores are shown on Figure 10.

8.2. GROUNDWATER MONITORING PROGRAM

The following monitoring program will be conducted during dewatering operations.

TABLE 14: GROUNDWATER LEVEL MONITORING

<table>
<tr><th>MONITORING PURPOSE</th><th>MONITORING SITE TYPE</th><th>MONITORING SITE ID</th><th>FREQUENCY</th></tr>
<tr><td rowspan="3">Superficial aquifer water level</td><td rowspan="2">Doral monitoring bores</td><td>YA_MB01S to YA_MB12S</td><td>Monthly</td></tr>
<tr><td>GDE monitoring bores (YA_MB33_GDE to YA_MB37_GDE)*</td><td>Monthly (during baseline and pre-dewatering) and
Weekly (during active adjacent dewatering)</td></tr>
<tr><td>Existing other user's bores (local)</td><td>SCPD28A, SCPD29A, TS012M, 20005101, 20005114, 20005115, 20005169, 20005253, 20005165, 20005166</td><td>Monthly</td></tr>
</table>

MONITORING PURPOSE	MONITORING SITE TYPE	MONITORING SITE ID	FREQUENCY
Leederville aquifer water level	Existing other user's bores (local)	20005254, 20005356, 20083645, 23040930, 23073124, LOT229_WM2, LOT668_BORE2	Monthly

*Monitored for levels only in accordance with the GDE Management Plan (AQ2, 2020d).

TABLE 15: GROUNDWATER QUALITY MONITORING PROGRAM

MONITORING PURPOSE	MONITORING SITE ID	FIELD		LABORATORY	
		FREQUENCY	PARAMETERS	FREQUENCY	PARAMETERS
Superficial aquifer	Local bores YA_MB01S to YA_MB12S TS012M, SCPD28A, SCPD29A	Monthly	pH, Eh, EC, TTA, total alkalinity, temp.	Monthly (lab) (or weekly if pH<4)	pH, EC, TDS, total acidity, total alkalinity, Cl, SO_4, Na,
				Quarterly (lab) for first 12 months (Sep, Dec, Mar, Jun)	Dissolved metals Al, Fe, Mn, Zn, Cr, Cu, Mg, Ni, Cd, Se, As, Pb, Hg, Co, U, Ra226 and Ra228
				Quarterly (lab) post 12 months (Sep, Dec, Mar, Jun)	Dissolved metals Al*, Fe, Mn
	Regional 20005166	Quarterly (Sep, Dec, Mar, Jun)	pH, EC, TTA, total alkalinity, temp.	Quarterly (lab) (Sep, Dec, Mar, Jun)	pH, EC, TDS, total acidity, total alkalinity, Cl, SO_4, Na,
				Quarterly (lab) for first 12 months (Sep, Dec, Mar, Jun)	Dissolved metals Al, Fe, Mn, Zn, Cr, Cu, Mg, Ni, Cd, Se, As, Pb, Hg, Co, U, Ra226 and Ra228
				Quarterly (lab) post 12 months (Sep, Dec, Mar, Jun)	Dissolved metals Al*, Fe, Mn

MONITORING PURPOSE	MONITORING SITE ID	FIELD		LABORATORY	
		FREQUENCY	PARAMETERS	FREQUENCY	PARAMETERS
Leederville aquifer	20005254 20005356 20083645, LOT200_BORE LOT552_BORE LOT642_BORE1 LOT667_WM1 LOT668_BORE2 LOT758_BORE	Quarterly (Sep, Dec, Mar, Jun)	pH, EC, TTA, total alkalinity, temp.	NA	

*If dissolved Al > 1 mg/L then additional analyses are required for Zn, Cr, Cu, Mg, Ni, Cd, Se, As, Pb and Hg.

8.3. GROUNDWATER TRIGGER VALUES

Groundwater chemistry site-specific trigger values have been developed for key ASS parameters for each of the 15 Superficial groundwater bores (YA_MB01S to YA_MB12S, TS012M, SCPD28A and SCPD29A), using baseline data and DWER ASS indicator values (DER, 2015b). The bore specific chemical triggers have been determined using background data (refer Section 4) and are based on the mean +/- 2x standard deviations of the background set and are provided in Table 16.

TABLE 16: SUPERFICIAL GROUNDWATER BORE TRIGGER VALUES

Bore ID	Parameter			
	Field pH	Total Alkalinity (mg/L)	Total Acidity (mg/L)	Dissolved Aluminum (mg/L)
DWER Indicator Values	**<5**	**NV**	**NV**	**>1**
YA_MB01S	<5	<33.64	>141.26	>1
YA_MB02S	<5	<20.97	>227.76	>1
YA_MB03S	<5	<52.26	>201.90	>1
YA_MB04S	<5	<23.15	>177.49	>1
YA_MB05S	<5	<21.39	>92.35	>1
YA_MB06S	<5	<59.19	>72.30	>1
YA_MB07S	<5	<9.46	>65.10	>1
YA_MB08S	<5	<15.22	>59.30	>1
YA_MB09S	<5	<31.97	>115.58	>1
YA_MB10S	<5	<25.14	>101.08	>1
YA_MB11S	<5	<47.49	>133.15	>1

Bore ID	Parameter			
	Field pH	Total Alkalinity (mg/L)	Total Acidity (mg/L)	Dissolved Aluminum (mg/L)
YA_MB12S	<5	<50.11	>270.72	>1
SCPD28A	<5	<44.56	>140.24	>1
SCPD29A	<5	<27.85	>251.82	>1
TS012M	<5	<42.00	>271.05	>1
20005166	<5	<11.38	>138.88	>1

NV – DER (2015b) values apply to dewatering effluent

8.4. CONTINGENCY ACTIONS

The trigger values provided are inherently conservative and the initial response to an exceedance by any parameter will be to establish the context of the exceedance and determine whether the result requires re-sampling/analysis, immediate further action, or no response at all. Should an exceedance be confirmed, Doral will commence implementing active groundwater management measures, such as recharging lime treated water into recharge basin/trenches in areas affected by acidification, to reduce acidity and metal concentrations in groundwater.

8.4.1. INITIAL RESPONSE

Initial response to an exceedance of any trigger value will be to implement the following actions immediately of the exceedance being identified:

- Review exceedance in relation to any site wide changes or trends in key ASS risk parameter (pH, total acidity/TTA and total alkalinity);
- Review sample collection, handling and analysis methods and procedures to ensure appropriate methods were used;
- Review groundwater level data, dewatering effluent quality data and current mining operations to consider possible causal factors;
- If necessary, re-sample affected locations immediately to confirm whether or not the groundwater quality parameter(s) exceed the trigger value;
- Increase on-going monitoring frequency of the affected monitoring well or area;
- Notify the CEO within 7 days of the exceedance being identified;
- Implement the contingency actions required by this plan within 7 days of the exceedance being reported and continue the implementation of those actions until the CEO has confirmed in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required.

8.4.2. ACTIVE GROUNDWATER MANAGEMENT MEASURES

Should a groundwater exceedance be confirmed following the initial response actions, Doral will plan to commence active groundwater management to limit the extent to which groundwater acidification may occur. This will include:

- Assess/determine the potential extent of groundwater impacts which requires active treatment;
- Install recharge basins/trenches in affected areas, and commence recharge with lime-treated water to reduce the acidity and metal concentrations in groundwater.

8.5. REPORTING

The monthly groundwater monitoring results will be compared to trigger levels within 7 days of receipt of analytical results. The presence of results that exceed trigger values will be recorded on a monthly groundwater log. If contingency measures are required, the initial response and any active management undertaken will be recorded in the groundwater log within 24 hours.

The groundwater log, field results and laboratory documentation of each year will be reported in the Annual Environmental Report (AER) and Compliance Assessment Report to demonstrate that Ministerial Condition 9-1 has been met over the reporting period.

9. ASSMP PROVISIONS

The key impacts and risks to conservation significant flora and vegetation, fauna and inland waters from exposure of potential acid sulfate soils are when ASS materials are exposed to the atmosphere, the sulfide minerals oxidise and generate sulfidic acidity, resulting in the release of metals, nutrients and acidity into the soil and groundwater system. The release of contaminants such as acid, nutrients, iron, aluminum, arsenic and other heavy metals may adversely affect the natural environment and modify ecosystems such as GDE and wetlands.

9.1. OBJECTIVES

The management, monitoring, trigger criteria and contingency actions provided in this ASSMP have been developed to satisfy Ministerial Condition 9-1:

The proponent shall implement the proposal to achieve the following environmental objective:

> *(1) avoid where possible, otherwise minimise, impacts associated with Potential Acid Sulfate Soils to conservation significant flora, fauna and inland waters within the Development Envelope delineated in Figure 2 of Schedule 1 during ground disturbing activities and during all phases of mining activities.*

9.2. THRESHOLD CRITERIA AND CONTINGENCY ACTIONS

In order to demonstrate compliance with Ministerial Condition 9-1, Doral have developed the following threshold criteria and contingency actions.

TABLE 17: THRESHOLD CRITERIA

ENVIRONMENTAL FACTOR	THRESHOLD CRITERIA	THRESHOLD CONTINGENCY ACTIONS
Inland Waters	Groundwater quality within the Development Envelope becomes unsuitable for its current beneficial uses (i.e. abstraction for non-potable uses and short-term irrigation) or affects offsite down gradient ecological receptors (i.e. Lower Sabina River and Vasse-Wonnerup Ramsar wetland).	• Investigate cause and raise incident report. • Implement the Contingency Actions detailed in Section 7.5 for Dewatering and Section 8.4 for Groundwater. • Report the exceedance in writing to the CEO within 7 days of identifying threshold criteria exceedance. • Supply any affected groundwater user with suitable make-up water. • Conduct contamination groundwater assessment in consultation with DWER to identify the extent and nature of groundwater contamination. • Implement groundwater remediation measures to ensure down gradient ecological receptors are protected and/or groundwater

ENVIRONMENTAL FACTOR	THRESHOLD CRITERIA	THRESHOLD CONTINGENCY ACTIONS
		users. The specific measure will be determined dependent on the specific situation and in consultation with DWER, but may include use of permeable reactive barrier (PRB), use of sub-surface slurry walls, pump and treat with soluble neutralising material. • Implement the contingency actions required by Condition 9-2(6) within 7 days of being reported and continue implementation of those actions until the CEO has confirmed in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required.
Conservation significant flora/vegetation	Decline in vegetation health score of 2 categories (see GDE Management Plan) (AQ2, 2020d) for conservation significant vegetation along McGibbon Track as a result of groundwater acidification (i.e. based on groundwater quality data)	• Investigate cause and raise incident report. • Implement the Contingency Actions detailed in Section 7.5 for Dewatering and Section 8.4 for Groundwater. • Report exceedance in writing to the CEO within 7 days of identifying threshold criteria exceedance. • Apply/increase water supplementation as per the GDE Management Plan (AQ2, 2020d) to provide affected areas with adequate quality water to the root zone. • Conduct contamination groundwater assessment in consultation with DWER to identify the extent and nature of groundwater contamination. • Implement suitable groundwater remediation measures, as required. The specific measure will be determined dependent on the specific situation and in consultation

ENVIRONMENTAL FACTOR	THRESHOLD CRITERIA	THRESHOLD CONTINGENCY ACTIONS
		with DWER, but may include use of permeable reactive barrier (PRB), use of sub-surface slurry walls, pump and treat with soluble neutralising material or continuation of water supplementation to the root zone. • Implement the contingency actions required by Condition 9-2(6) within 7 days of being reported and continue implementation of those actions until the CEO has confirmed in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required.
Conservation significant fauna habitat	Decline in vegetation health score of 2 categories (see GDE Management Plan) (AQ2, 2020d) for conservation significant fauna habitat along McGibbon Track as a result of acidification (i.e. based on groundwater quality data)	• Investigate cause and raise incident report. • Implement the Contingency Actions detailed in Section 7.5 for Dewatering and Section 8.4 for Groundwater. • Report exceedance in writing to the CEO within 7 days of identifying threshold criteria exceedance. • Apply/increase water supplementation as per the GDE Management Plan (AQ2, 2020d) to provide affected areas with adequate water to the root zone. • Conduct contamination groundwater assessment in consultation with DWER to identify the extent and nature of groundwater contamination. • Implement suitable groundwater remediation measures, as required. The specific measure will be determined dependent on the specific situation and in consultation with DWER, but may include use of permeable reactive barrier (PRB),

ENVIRONMENTAL FACTOR	THRESHOLD CRITERIA	THRESHOLD CONTINGENCY ACTIONS
		use of sub-surface slurry walls, pump and treat with soluble neutralising material or continuation of water supplementation to the root zone. • Implement the contingency actions required by Condition 9-2(6) within 7 days of being reported and continue implementation of those actions until the CEO has confirmed in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required.

10. ADAPTIVE MANAGEMENT AND REVIEW OF ASSMP

In accordance with Ministerial Statement 1168 Conditions 9-3 and 9-6, Doral shall implement the most recent version of the Acid Sulfate Soils Management Plan as confirmed by the CEO in writing, and until such time that the CEO has confirmed by notice in writing that the environmental objective detailed in Condition 9-1 has been met.

This ASSMP applies the principles of adaptive management through monitoring, corrective actions and implementing changes. The ASSMP is intended to be dynamic and will be updated to reflect changes in management practices over the life of the Proposal. This will also allow flexibility to respond to new environmental impacts and adopt new technologies/management measures.

10.1. MONITORING TRIGGERS, THRESHOLDS AND CONTINGENCY ACTIONS

Triggers, thresholds and contingency actions for soil, dewatering and groundwater detailed in this ASSMP have been developed and based on industry best guidance detailed in *Treatment and management of soil and water in acid sulfate soil landscapes* (DER, 2015b) and in consultation with DWER.

A summary of the monitoring triggers, threshold and contingency actions are detailed below in Table 18.

TABLE 18: MONITORING TRIGGERS, THRESHOLDS AND CONTINGENCY ACTIONS

MONITORING PARAMETER	TRIGGER	THRESHOLD	CONTINGENCY ACTION
All soils (overburden, sand tails and clay fines)	NA or S_T >0.03%S	Groundwater quality within the Development Envelope becomes unsuitable for its current beneficial uses (i.e. abstraction for non-potable uses and short-term irrigation) or affects offsite down gradient ecological receptors (i.e. Lower Sabina River and Vasse-Wonnerup Ramsar wetland).	• Neutralise soils at an appropriate rate based on the NA of the material or at the default rate provided in Table 7 (Section 6.6). • Report exceedance in writing to the CEO within 7 days of identifying threshold criteria exceedance. Implement the contingency actions required by Condition 9-2(6) within 7 days of being reported and continue implementation of those actions until the CEO has confirmed in writing that it has been demonstrated that the threshold criteria are being met and

MONITORING PARAMETER	TRIGGER	THRESHOLD	CONTINGENCY ACTION
			implementation of the threshold contingency actions are no longer required. •
Dewatering Effluent (Pit and PWD)	pH <5.5 TTA >40 mgCaCO3/L TAlk<30 mgCaCO3/L Diss Al >1 mg/L OR Statistically significant trends over 7 days (using Mann-Kendall) of declining water quality (pH, TTA and/or TAlk).	Groundwater quality within the Development Envelope becomes unsuitable for its current beneficial uses (i.e. abstraction for non-potable uses and short-term irrigation) or affects offsite down gradient ecological receptors (i.e. Lower Sabina River and Vasse-Wonnerup Ramsar wetland).	• Undertake neutralisation treatment (liming) of the pit dewater. • Recharge treated water to the aquifer to increase alkalinity near the dewatering area via recharge basin/trenches. • Report exceedance in writing to the CEO within 7 days of identifying threshold criteria exceedance. Implement the contingency actions required by Condition 9-2(6) within 7 days of being reported and continue implementation of those actions until the CEO has confirmed in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required.
Groundwater quality	Site-specific trigger values provided in Table 16.	Groundwater quality within the Development Envelope becomes unsuitable for its current beneficial uses (i.e. abstraction for non-potable uses and short-term irrigation) or affects offsite down gradient ecological receptors (i.e. Lower Sabina	• Undertake neutralisation treatment (liming) of the pit dewater. • Recharge treated water to the aquifer to increase

MONITORING PARAMETER	TRIGGER	THRESHOLD	CONTINGENCY ACTION
		River and Vasse-Wonnerup Ramsar wetland).	alkalinity near the affected area via recharge basin/trenches • Report exceedance in writing to the CEO within 7 days of identifying threshold criteria exceedance. Implement the contingency actions required by Condition 9-2(6) within 7 days of being reported and continue implementation of those actions until the CEO has confirmed in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required.

10.2. ASSMP REVISIONS

This ASSMP will be reviewed on an annual basis during the life of the Proposal. The ASSMP review will take into account the adaptive management and continual improvement process, new or revised information relevant to inland waters, conservation significant flora/vegetation, conservation significant fauna habitat and/or changes to the Proposal.

Doral will also review and revise the ASSMP as and when directed by the CEO.

11. STAKEHOLDER ENGAGEMENT

Doral has consulted with a number of stakeholders in relation to the management of acid sulfate soils for the Yalyalup Mineral Sands Project. A summary of the consultation is provided in Table 19.

TABLE 19: STAKEHOLDER CONSULTATION

STAKEHOLDER	DATE	ADVICE RECEIVED ON KEY ENVIRONMENTAL ISSUES	RESPONSE TO COMMENTS/ISSUES
DWER - Contaminated Sites Branch	13/11/17	Pre-referral meeting S Appleyard, S Jenkinson to discuss results of acid sulfate soil investigation and proposed treatment, management and monitoring strategies.	Acknowledged.
	02/03/21	Discussion with S Appleyard regarding statistical technique for assessing how comparable two analytical techniques are with each other (CRS v Total S). The purpose of the comparison is to provide Doral with a cost effective alternative for investigating additional areas at the Site and/or refine treatment rates at the site.	Statistical assessment undertaken by ABEC (on behalf of Doral) to compare the two methods using 52 samples analysed by both methods. Results showed that further soil investigation at the Site can use Total S method, as this method slightly over compensates %S.
	22/04/21	Discussion with S Appleyard regarding results of Bland Altman analysis between CRS calculated NA and Total S calculated NA.	Results of statistical analysis to be included in ASSMP to provide alternative investigation method/analysis or to refine neutralisation rates from the default calculated using CRS.
DWER/EPA	27/7/21	Advice by DWER requesting the following be updated/included in the ASSMP: • Increase frequency of field monitoring of pH, TTA and TAlk. • Increase the frequency of monitoring of metals in dewatering effluent. • Trends of decreasing alkalinity or pH, and/or increasing acidity are observed over a period of one week from daily	ASSMP updated to incorporate all recommended amendments

STAKEHOLDER	DATE	ADVICE RECEIVED ON KEY ENVIRONMENTAL ISSUES	RESPONSE TO COMMENTS/ISSUES
		field measurements of these parameters to be included as trigger values for dewatering effluent. If triggered include active management measures such as recharge of lime treated water in affected areas to increase alkalinity near dewatering area. • Rather than monitoring a full suite of metals when Al concentrations exceed 1mg/L, it is recommended that the outlined suite (Zn, Cr, Cu, Ni, Cd, As, Pb and Hg) are monitored on a quarterly basis (in monitoring bores), for at least the first 12 months of mining operations. It is also recommended that Co, U and radium isotopes are included in the metal monitoring suite.	
DAWE	28/7/20	Proponent should discuss the potential area affected by PASS should deeper drawdown occur. Proponent has given insufficient detail on the management of ASS affected waste streams (overburden, HMC, clay fines and sand tails).	Groundwater drawdowns in the Superficial aquifer and underlying Leederville aquifer have been predicted in the Groundwater Model by AQ2. Mining will not extend below 10.5mBGL which has been modelled. An ASSMP has been prepared in accordance with DWER's ASS guidance document (DER, 2015b), which includes proposed treatment and validation strategies for all waste streams.

12. REPORTING

Documentation of soil management will be maintained as follows and reported annually in Doral's AER and CAR:

- Location (i.e. pit number/area), S_T investigation results (using sampling frequency in Table 8) if deviating from the default liming rate, and calculated liming rate using mean plus standard deviation of the S_T data;
- Estimated volume of ASS material (i.e. overburden or ore) requiring neutralisation;
- Source, volume and ENV of neutralising material used;
- Details of validation sampling undertaken for all materials (i.e. overburden, construction materials, sand tails and clay fines);
- Validation sampling results compared to validation criteria;
- Estimated final location of treated materials (i.e. overburden, construction materials, sand tails and clay fines).

Documentation of dewatering and groundwater quality will include the following and be reported annually in Doral's AER and CAR:

- Dewatering monitoring field and laboratory results in comparison to trigger criteria;
- Details of any dewatering treatment undertaken as a result of trigger criteria exceedance;
- Groundwater monitoring field and treatment results in comparison to trigger criteria and threshold criteria;
- Details of any exceedance of groundwater trigger values/threshold criteria and contingency actions undertaken.

In addition to the above reporting requirements, in order to demonstrate compliance with Ministerial Condition 9-1 Doral will undertake a review of groundwater monitoring results in comparison to relevant assessment criteria/threshold criteria to demonstrate that threshold criteria documented in Table 16 have not been exceeded. However, should any threshold criteria be exceeded, the contingency actions undertaken will also be reported (as per requirements in Table 16) and also in Doral's AER and CAR.

13. REFERENCES

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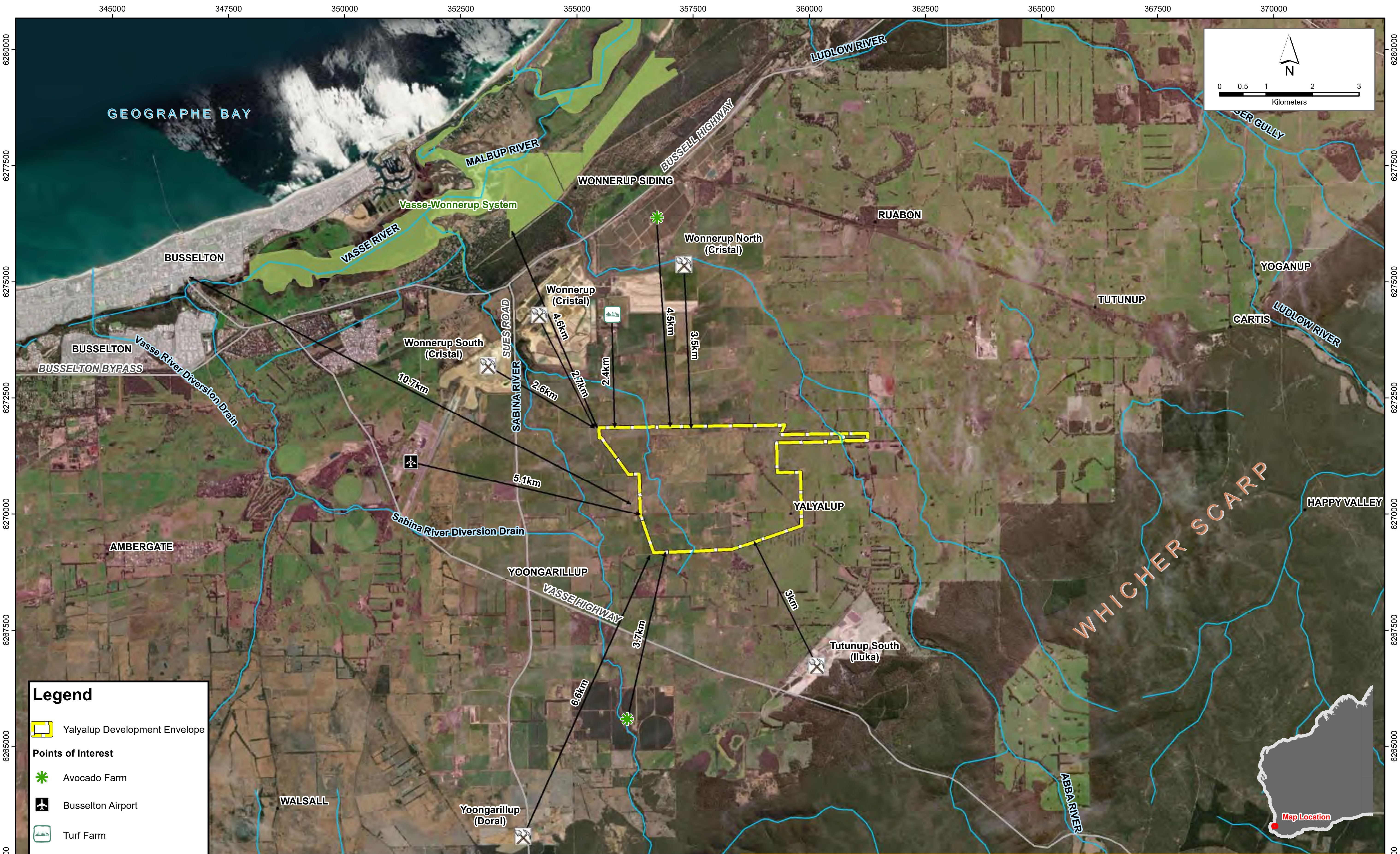
FIGURES

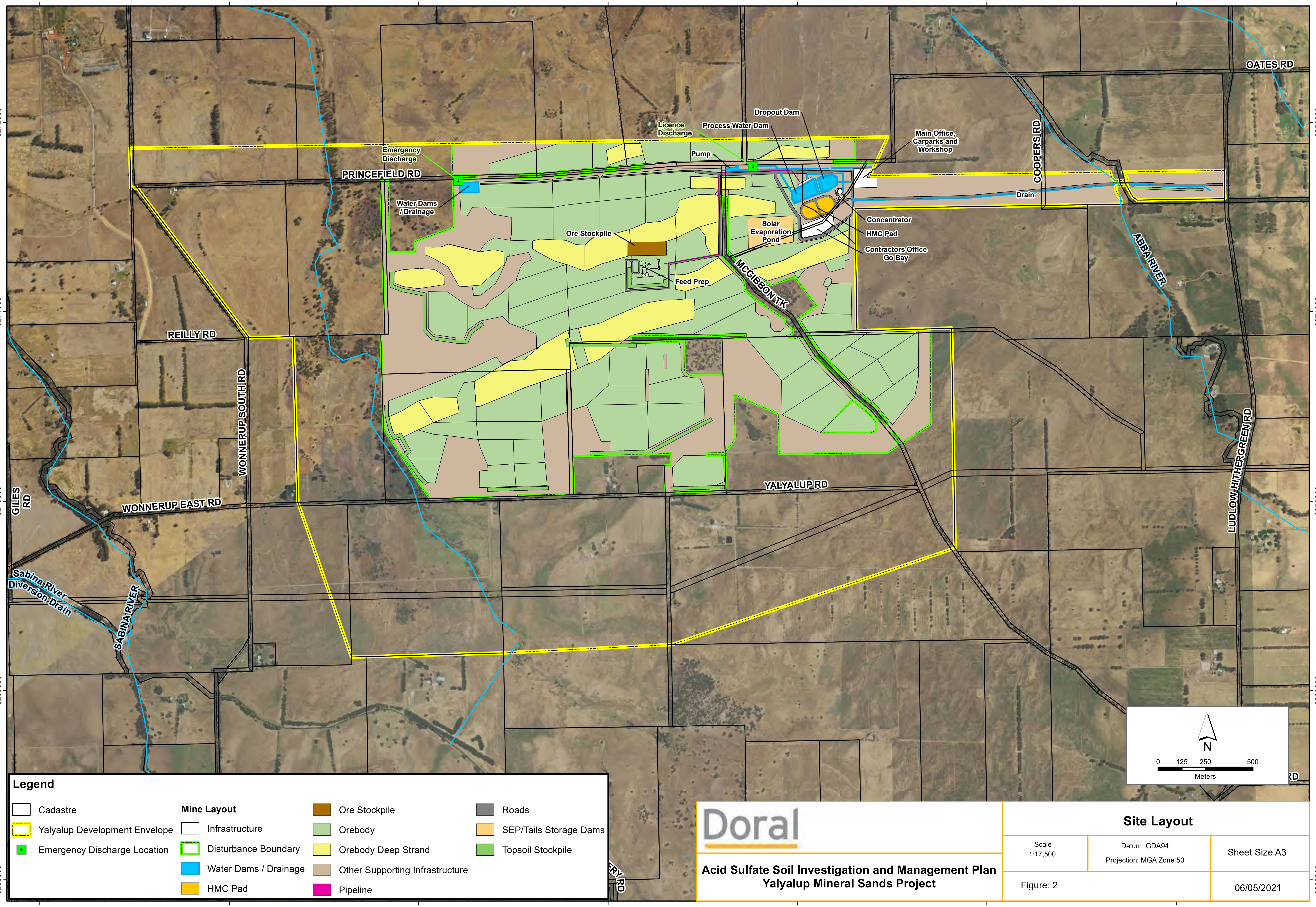


Doral

Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project

Regional Location

Scale 1:75,000	Datum: GDA94 Projection: MGA Zone 50	Sheet Size A3
Figure: 1		06/05/2021


355000
356000
357000
358000
359000
360000
361000
6272000
6271000
6270000
6269000
6268000
OATES RD
Dropout Dam
Licence Discharge
Process Water Dam
Main Office, Carparks and Workshop
Pump
Emergency Discharge
PRINCEFIELD RD
COOPERS RD
Drain
Water Dams / Drainage
Concentrator
HMC Pad
Solar Evaporation Pond
Ore Stockpile
Contractors Office Go Bay
ABBA RIVER
Feed Prep
MCGIBBON TK
REILLY RD
WONNERUP SOUTH RD
YALYALUP RD
LUDLOW HITHERGREEN RD
GILES RD
WONNERUP EAST RD
Sabina River Diversion Drain
SABINA RIVER
N
0 125 250 500
Meters
Legend
Cadastre
Yalyalup Development Envelope
Emergency Discharge Location
Mine Layout
Infrastructure
Disturbance Boundary
Water Dams / Drainage
HMC Pad
Ore Stockpile
Orebody
Orebody Deep Strand
Other Supporting Infrastructure
Pipeline
Roads
SEP/Tails Storage Dams
Topsoil Stockpile
Doral
Site Layout
Scale 1:17,500
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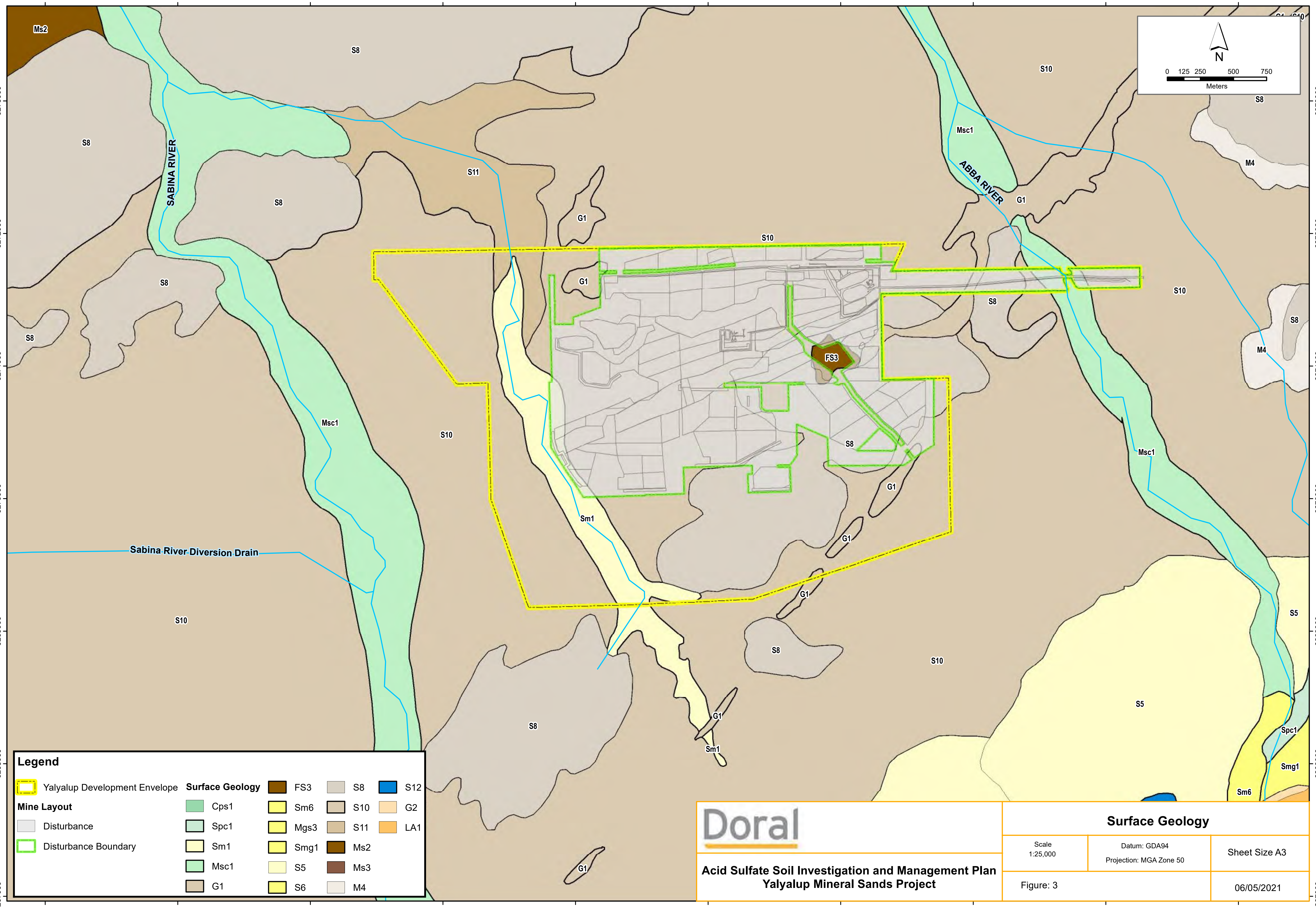
Projection: MGA Zone 50
Sheet Size A3
Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project
Figure: 2
06/05/2021


SABINA RIVER
ABBA RIVER
Sabina River Diversion Drain
Ms2
S8
S10
S11
G1
Msc1
Sm1
FS3
M4
S5
Spc1
Smg1
Sm6
N
0 125 250 500 750
Meters
353000
354000
355000
356000
357000
358000
359000
360000
361000
362000
6273000
6272000
6271000
6270000
6269000
6268000
6267000
Legend
Yalyalup Development Envelope
Mine Layout
Disturbance
Disturbance Boundary
Surface Geology
Cps1
Spc1
Sm1
Msc1
G1
FS3
Sm6
Mgs3
Smg1
S5
S6
S8
S10
S11
Ms2
Ms3
M4
S12
G2
LA1
Doral
Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project
Surface Geology
Scale
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Datum: GDA94
Projection: MGA Zone 50
Sheet Size A3
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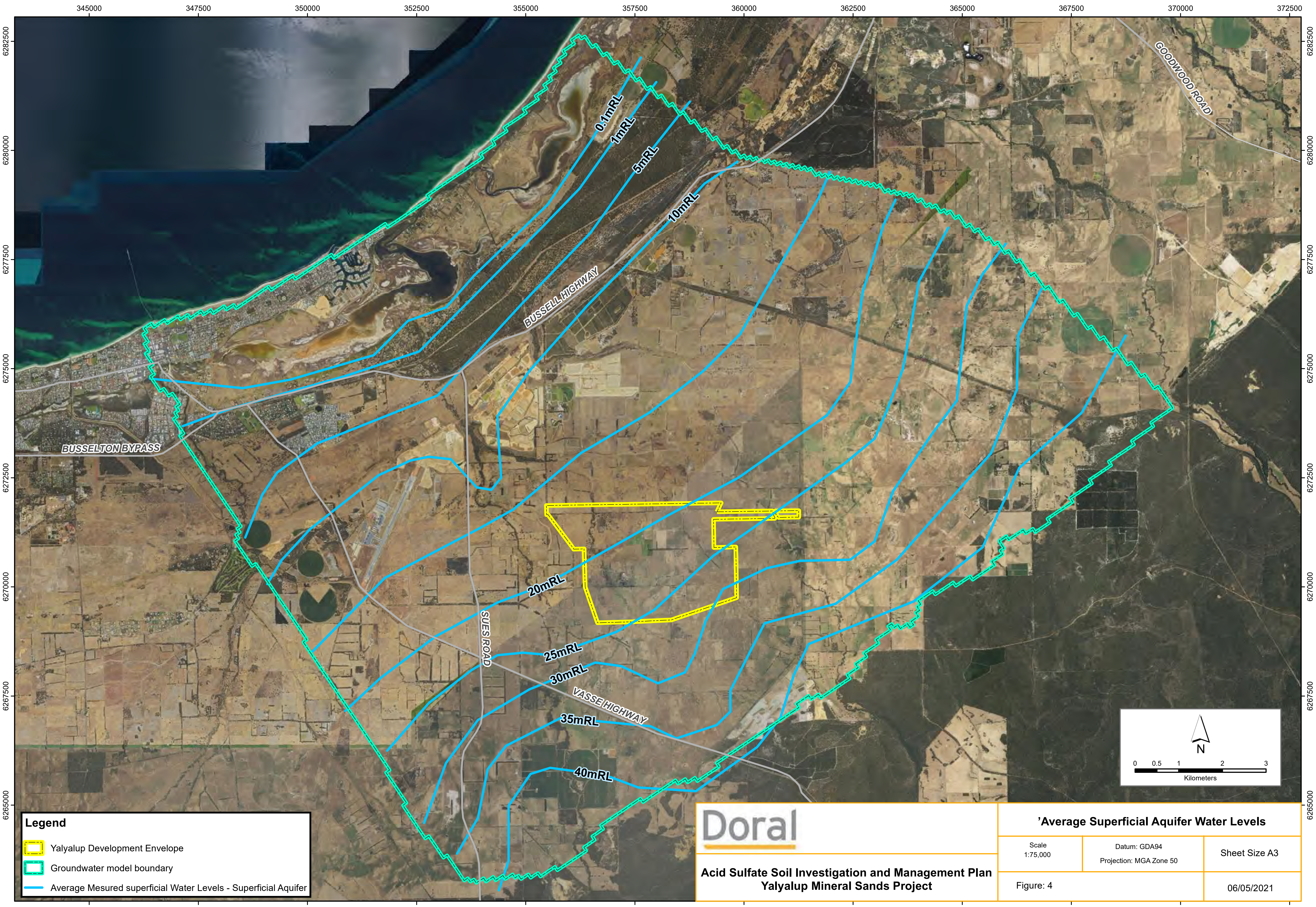
06/05/2021

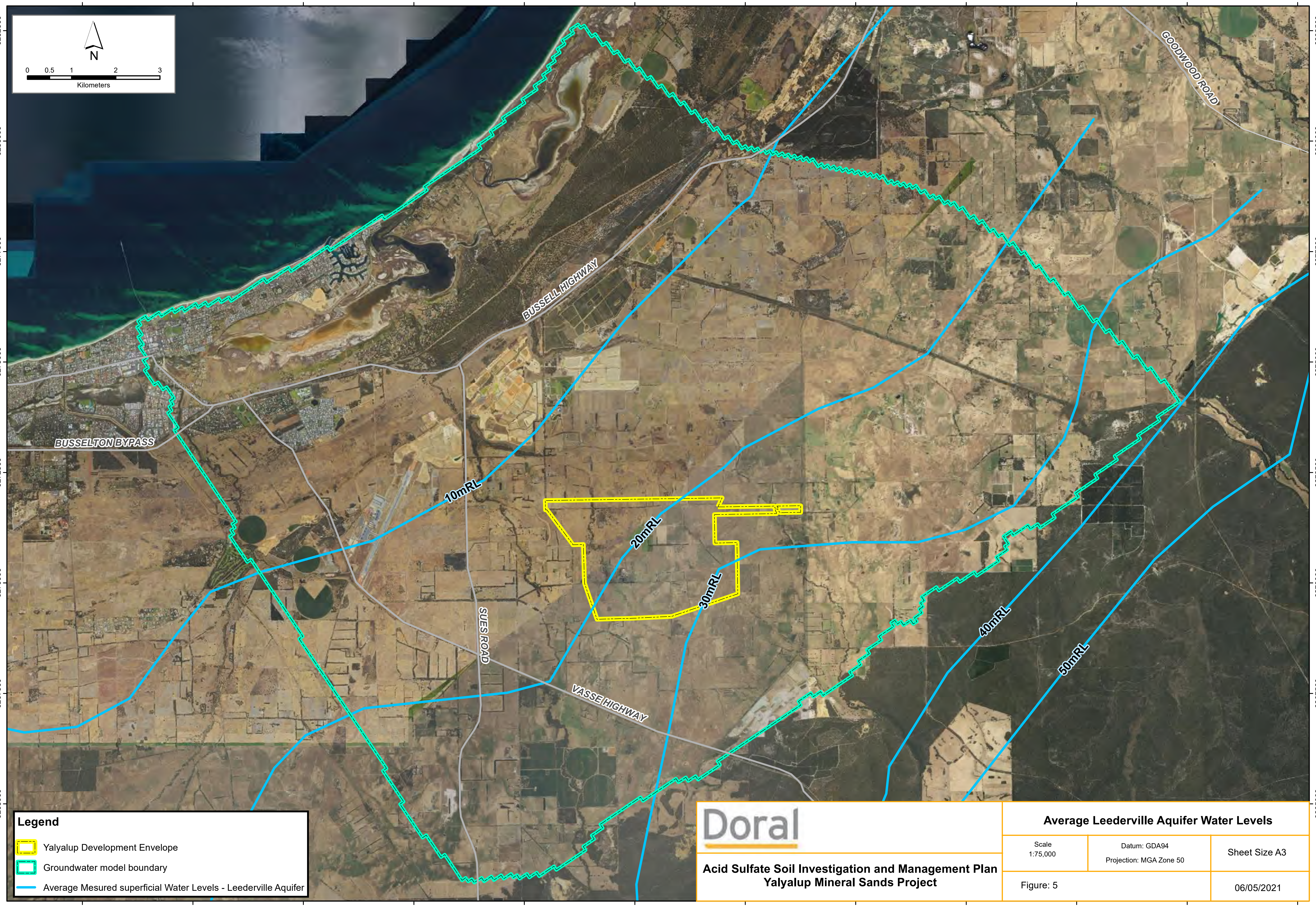


Doral

'Average Superficial Aquifer Water Levels

Scale 1:75,000	Datum: GDA94 Projection: MGA Zone 50	Sheet Size A3
Figure: 4		06/05/2021

Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project



Doral

Average Leederville Aquifer Water Levels

Scale 1:75,000

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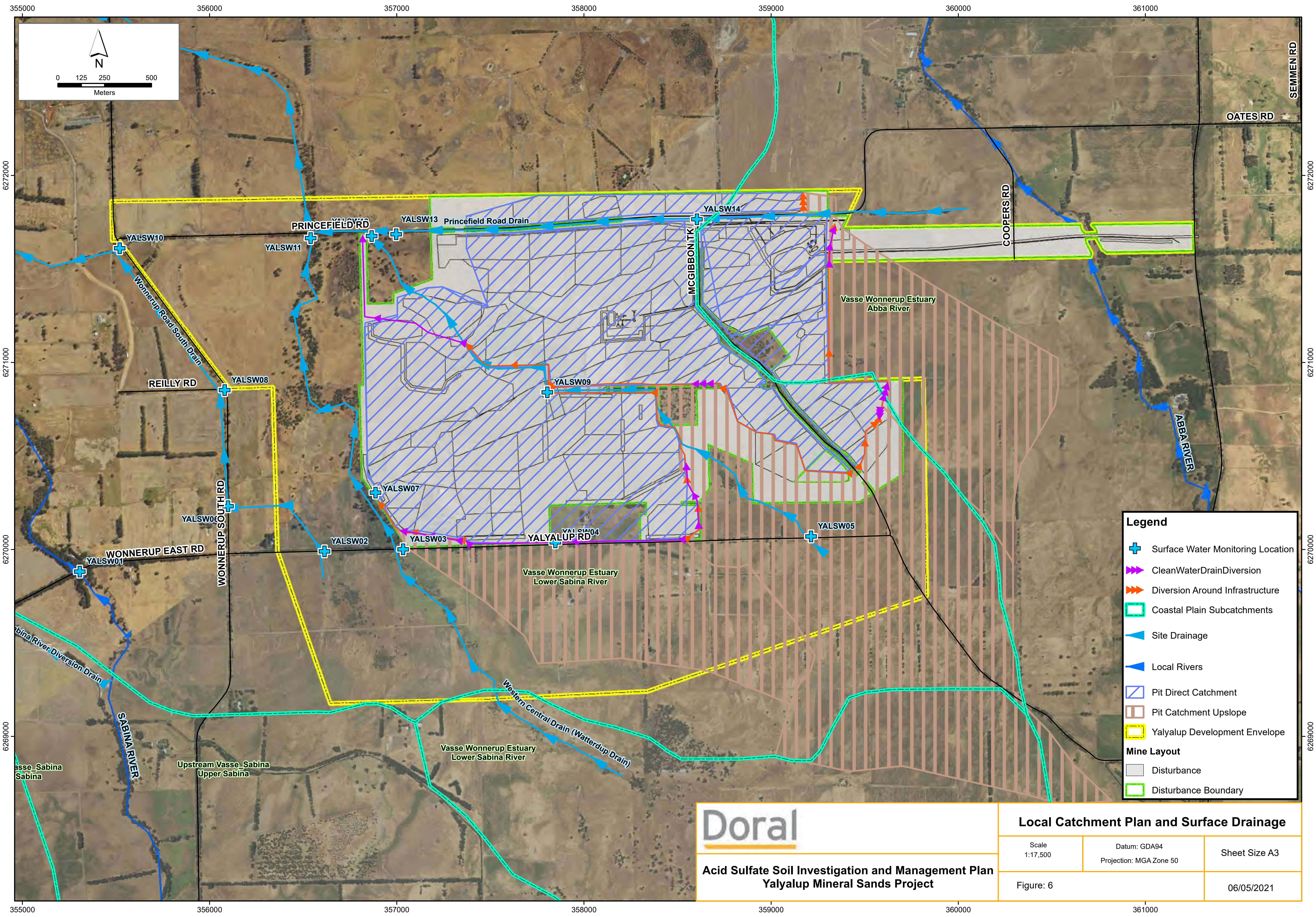
Projection: MGA Zone 50

Sheet Size A3

Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project

Figure: 5

06/05/2021



Doral

Local Catchment Plan and Surface Drainage

Scale 1:17,500

Datum: GDA94

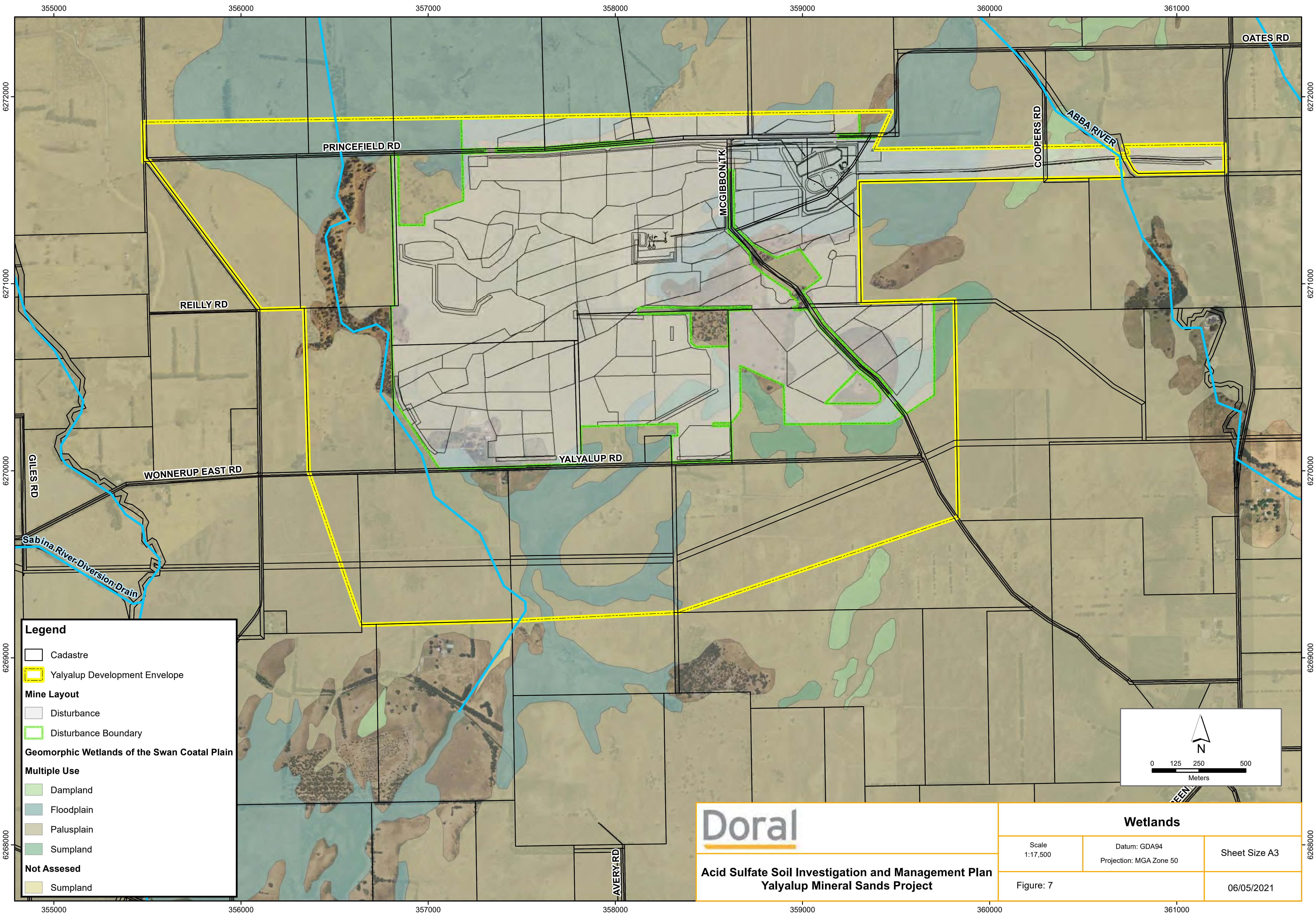
Projection: MGA Zone 50

Sheet Size A3

Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project

Figure: 6

06/05/2021



Doral

Wetlands

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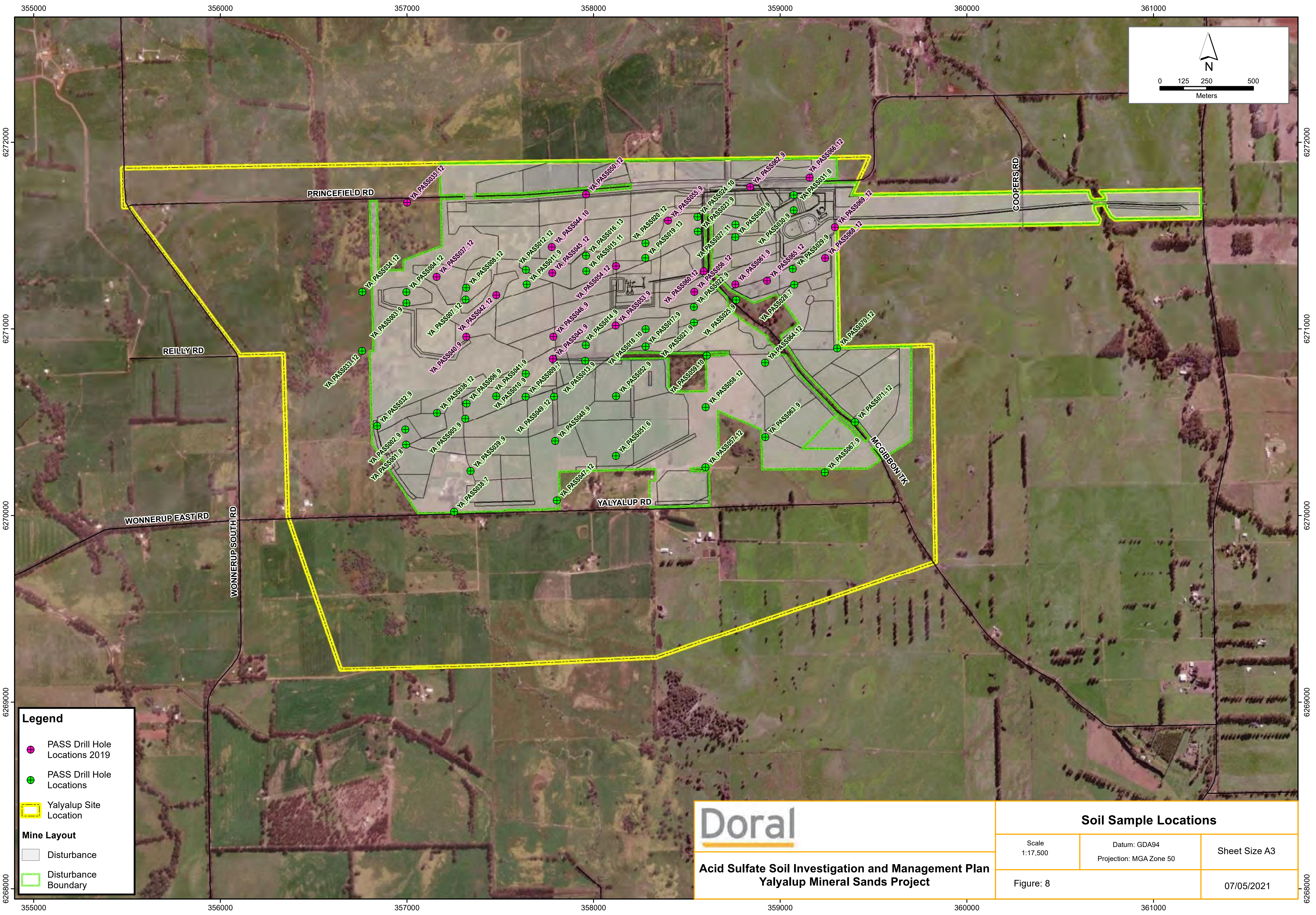
Projection: MGA Zone 50

Sheet Size A3

Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project

Figure: 7

06/05/2021



Doral

Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project

Soil Sample Locations

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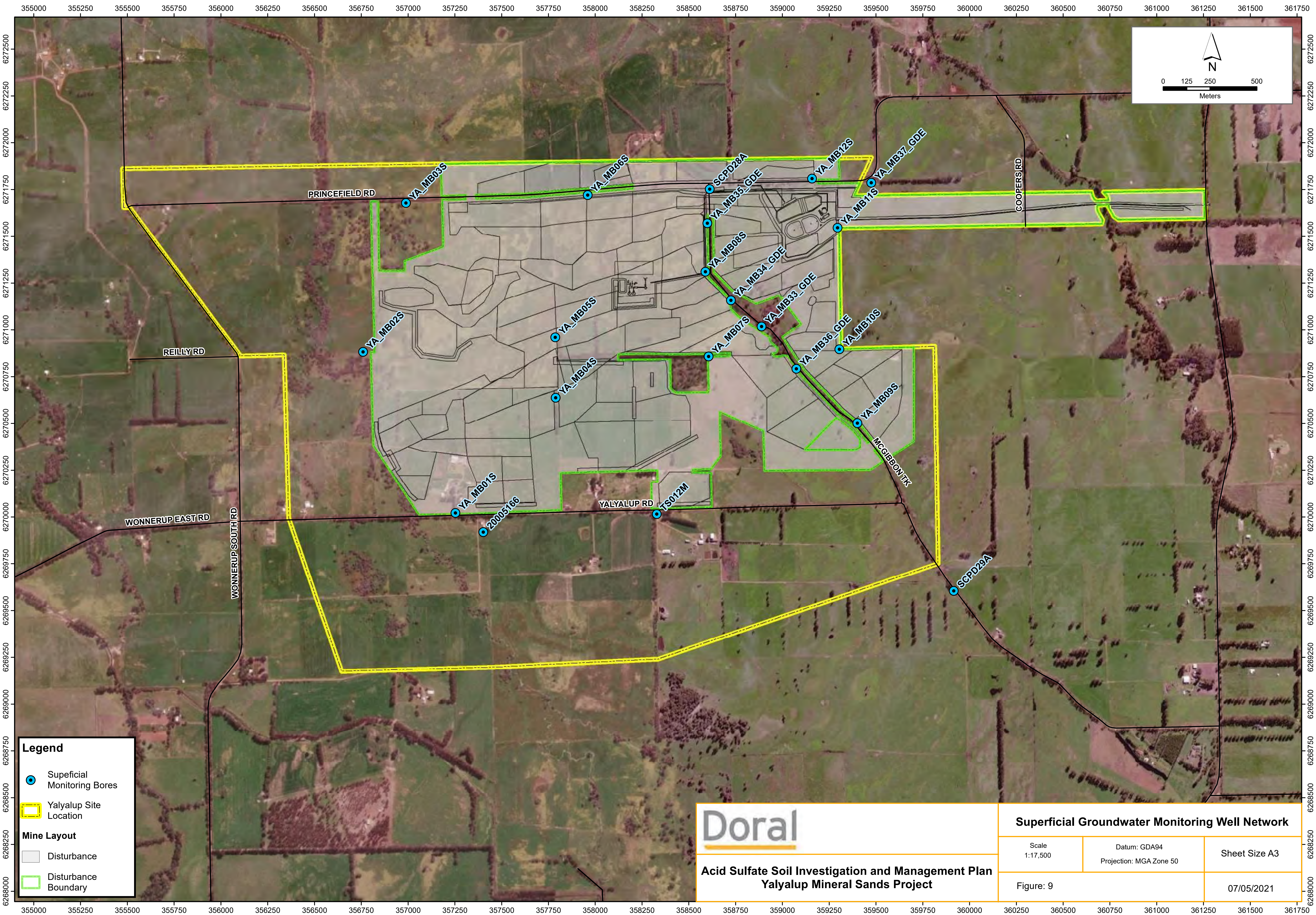
Figure: 8		07/05/2021



PRINCEFIELD RD
REILLY RD
WONNERUP EAST RD
WONNERUP SOUTH RD
YALYALUP RD
COOPERS RD
MCGIBBON TK
YA_MB01S
YA_MB02S
YA_MB03S
YA_MB04S
YA_MB05S
YA_MB06S
YA_MB07S
YA_MB08S
YA_MB09S
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YA_MB35_GDE
YA_MB36_GDE
YA_MB37_GDE
SCPD28A
SCPD29A
TS012M
20005166
N
0 125 250 500
Meters
Legend
Supeficial Monitoring Bores
Yalyalup Site Location
Mine Layout
Disturbance
Disturbance Boundary
Doral
Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project
Superficial Groundwater Monitoring Well Network
Scale 1:17,500
Datum: GDA94
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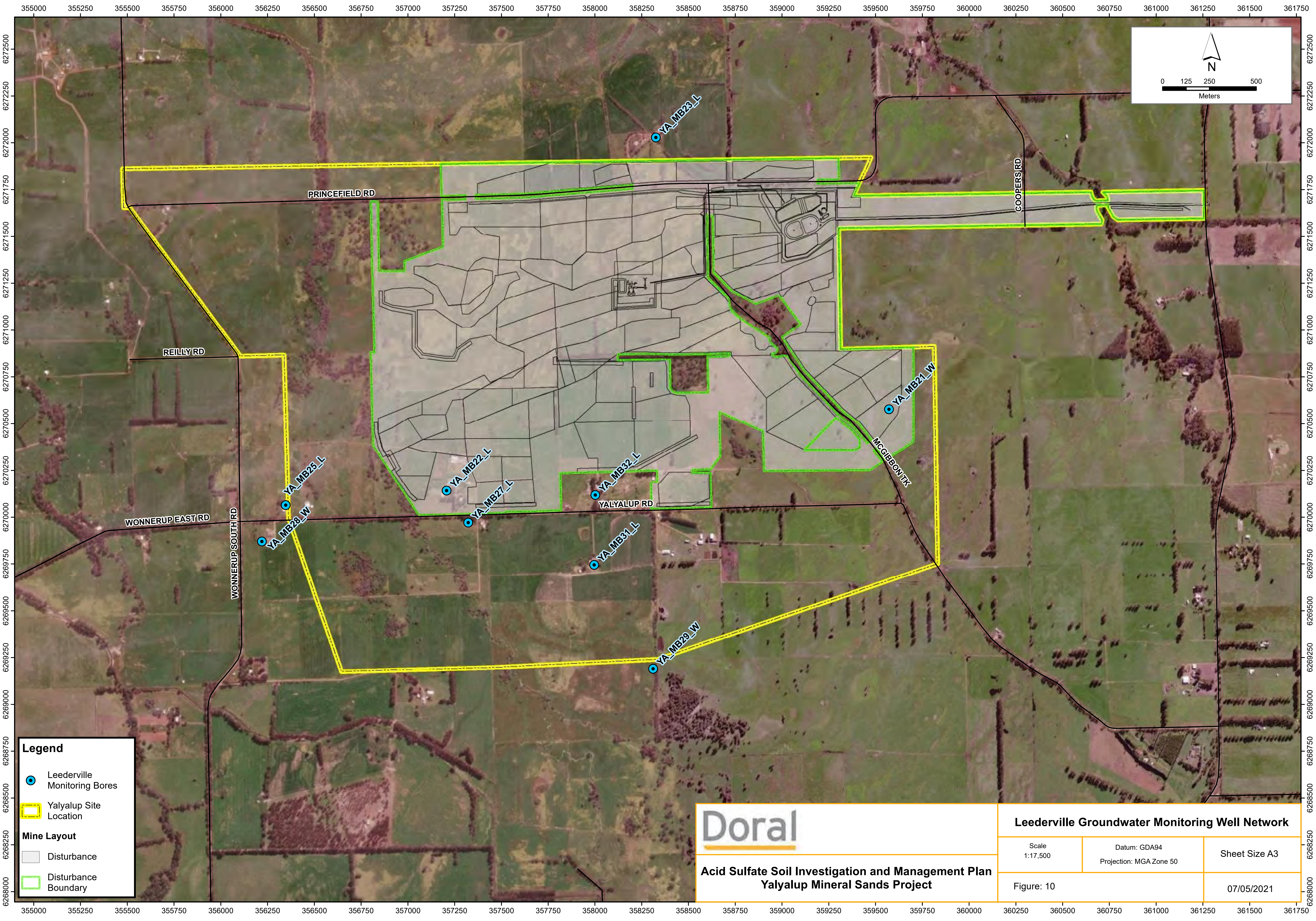
Sheet Size A3
Figure: 9
07/05/2021


YA_MB23_L
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YA_MB31_L
YA_MB29_W
PRINCEFIELD RD
COOPERS RD
REILLY RD
WONNERUP EAST RD
WONNERUP SOUTH RD
YALYALUP RD
MCGIBBON TK
N
0 125 250 500
Meters
Legend
Leederville Monitoring Bores
Yalyalup Site Location
Mine Layout
Disturbance
Disturbance Boundary
Doral
Acid Sulfate Soil Investigation and Management Plan
Yalyalup Mineral Sands Project
Leederville Groundwater Monitoring Well Network
Scale 1:17,500
Datum: GDA94
Projection: MGA Zone 50
Sheet Size A3
Figure: 10
07/05/2021

APPENDIX 1: SOIL RESULTS TABLE

SAMPLE LOCATION	SAMPLE INTERVAL		SOIL DESCRIPTION		LAB ID	FIELD TEST RESULTS				CHROMIUM SUITE						LECO
	depth_ from	depth _ to	COLOUR	LITHOLOGY	samp_id	phF	phFOX	pHf - pH fox	Reaction	pHKCl	sTAA	s-TAA	S_{CR}	NET ACIDITY	NA EQUATION	Total Sulfur
					Units						molesH/t	%S	%S	%S		%S
					LOR	0.01	0.01	0.01	-	0.1	1	0.005	0.01	0.01		0.01
					Criteria	≤4	≤3	≥3		<4	18	0.03	0.03	0.03		0.03
YA_PASS001_8	0	1	GR	SY	D063753	6.64	3.90	2.74	X							
	1	2	GR	SC	D063754	6.56	4.00	2.56	XX							
	2	3	GB	CL	D063755	6.73	5.20	1.53	X							
	3	4	BR	CS	D063756	6.42	5.20	1.22	X							
	4	5	BR	CS	D063757	6.63	4.40	2.23	XXX							
	5	6	BR	CS	D063758	6.76	2.30	4.46	XX	5.40	5	0.008	0.07	0.078	S_{CR} + s-TAA	
	6	7	GB	SC	D063759	6.75	3.70	3.05	X	5.70	5	0.008	0.01	0.010	S_{CR}	
	7	8	GR	CL	D063760	6.58	1.70	4.88	XXX	5.20	5	0.008	0.08	0.088	S_{CR} + s-TAA	
YA_PASS002_9	0	1	GR	SA	D063761	5.30	3.40	1.90	X	5.10	5	0.008	0.01	0.018	S_{CR} + s-TAA	
	1	2	GR	SA	D063762	5.56	3.80	1.76	X	5.00	5	0.008	0.01	0.018	S_{CR} + s-TAA	
	2	3	GB	CL	D063763	6.14	2.80	3.34	XX	5.40	4	0.006	0.01	0.016	S_{CR} + s-TAA	
	3	4	GB	CL	D063764	6.30	3.70	2.60	X	5.40	4	0.006	0.01	0.016	S_{CR} + s-TAA	
	4	5	GR	CS	D063765	7.10	3.80	3.30	X	5.70	4	0.006	0.01	0.010	S_{CR}	
	5	6	GR	SA	D063766	5.63	3.10	2.53	X	6.80	1	0.002	0.01	0.010	S_{CR}	
	6	7	GR	SA	D063767	6.23	3.20	3.03	X	6.10	3	0.005	0.01	0.010	S_{CR}	
	7	8	GR	SA	D063768	6.38	2.30	4.08	XX	6.50	1	0.002	0.01	0.010	S_{CR}	
	8	9	GR	SA	D063769	6.25	2.60	3.65	XX	5.50	3	0.005	0.01	0.010	S_{CR}	
YA_PASS003_9	0	1	OB	CS	D063502	6.39	4.60	1.79	X							
	1	2	OB	CS	D063503	6.53	5.00	1.53	X							
	2	3	GB	SC	D063504	6.44	5.30	1.14	X							
	3	4	GR	SC	D063505	7.00	6.00	1.00	X							
	4	5	GG	CL	D063506	7.22	6.50	0.72	XXXX							
	5	6	GB	CL	D063507	7.10	5.40	1.70	XXXX							
	6	7	GR	SC	D063508	6.59	1.60	4.99	XXXX	4.80	9	0.014	0.96	0.974	S_{CR} + s-TAA	
	7	8	GR	SC	D063509	6.59	1.70	4.89	XXXX	5.50	7	0.011	0.34	0.340	S_{CR}	
	8	9	GR	SC	D063510	6.66	2.00	4.66	XXXX	5.30	7	0.011	0.17	0.181	S_{CR} + s-TAA	
YA_PASS004_12	0	1	OB	CS	D063511	6.61	4.30	2.31	X							
	1	2	OB	SA	D063512	6.68	4.20	2.48	X							
	2	3	OB	SA	D063513	6.59	4.30	2.29	XX							
	3	4	OB	CS	D063514	6.29	4.00	2.29	X							
	4	5	GR	CL	D063515	7.47	6.50	0.97	XXXX							
	5	6	GR	SA	D063516	6.98	3.00	3.98	XX	6.10	4	0.006	0.01	0.010	S_{CR}	
	6	7	GR	SA	D063517	6.47	2.60	3.87	XX	6.20	2	0.003	0.03	0.030	S_{CR}	
	7	8	GR	SA	D063518	6.62	1.90	4.72	XXXX	5.50	5	0.008	0.25	0.250	S_{CR}	
	8	9	GR	SA	D063519	6.56	2.00	4.56	XXXX	6.20	3	0.005	0.1	0.100	S_{CR}	
	9	10	GR	SA	D063520	6.50	2.00	4.50	XXX	5.60	5	0.008	0.05	0.050	S_{CR}	
	10	11	GR	SA	D063521	6.38	2.50	3.88	XXX	6.00	4	0.006	0.06	0.060	S_{CR}	
	11	12	GR	SA	D063522	6.40	2.40	4.00	XXX	5.60	4	0.006	0.03	0.030	S_{CR}	
YA_PASS005_9	0	1	GR	SA	D063770	6.02	3.90	2.12	X							
	1	2	GR	SA	D063771	5.66	3.30	2.36	X							
	2	3	GW	CS	D063772	6.48	4.00	2.48	XX							
	3	4	GB	SC	D063773	6.56	4.80	1.76	X							
	4	5	GW	CS	D063774	6.73	3.90	2.83	X							
	5	6	GB	CS	D063775	6.90	4.30	2.60	X							
	6	7	GB	CS	D063776	7.10	3.60	3.50	X							
	7	8	GR	CS	D063777	7.09	3.00	4.09	X							
	8	9	GW	SA	D063778	6.97	2.30	4.67	XX							
YA_PASS006_9	0	1	GR	SA	D063779	6.30	3.50	2.80	X							
	1	2	GR	SA	D063780	6.50	3.90	2.60	X							
	2	3	GR	SA	D063781	6.52	4.30	2.22	X							
	3	4	OB	IR	D063782	6.98	5.40	1.58	X							
	4	5	GW	CS	D063783	7.23	3.30	3.93	XX							
	5	6	GR	SA	D063784	7.37	5.20	2.17	X							
	6	7	GW	SA	D063785	6.34	4.80	1.54	X							
	7	8	GW	SA	D063786	6.67	4.20	2.47	X							
	8	9	GW	CS	D063787	6.65	2.40	4.25	XXXX							
YA_PASS007_12	0	1	OB	CS	D063523	6.25	3.70	2.55	XX							
	1	2	OB	CS	D063524	6.57	4.30	2.27	XX							
	2	3	OB	CS	D063525	6.34	4.10	2.24	XX							
	3	4	BR	SC	D063526	6.54	4.60	1.94	XX							
	4	5	GR	CL	D063527	6.76	6.20	0.56	XXXX							
	5	6	GG	CL	D063528	7.05	6.90	0.15	XXXX							
	6	7	GR	CS	D063529	7.04	2.70	4.34	XXX							
	7	8	GR	CS	D063530	6.99	1.60	5.39	XXXX							
	8	9	GR	CS	D063531	6.94	1.50	5.44	XXXX							
	9	10	GR	CS	D063532	7.12	1.50	5.62	XXXX							
	10	11	GR	CS	D063533	7.34	2.40	4.94	XXX							
	11	12	GR	CS	D063534	7.21	2.60	4.61	XXXX							
YA_PASS008_12	0	1	OB	SA	D063535	5.42	2.00	3.42	XXX							
	1	2	OB	SA	D063536	5.14	1.90	3.24	XXX							
	2	3	OB	SA	D063537	5.57	2.30	3.27	XXX							
	3	4	OB	SC	D063538	6.25	2.60	3.65	XX							
	4	5	GR	CL	D063539	7.46	7.00	0.46	XXXX							
	5	6	GR	SC	D063540	7.42	2.70	4.72	XXX							
	6	7	GW	SA	D063541	7.18	2.00	5.18	XXX							
	7	8	GW	SA	D063542	7.14	1.50	5.64	XXX							
	8	9	GR	SA	D063543	7.26	1.70	5.56	XXX							
	9	10	GR	SA	D063544	7.08	1.90	5.18	XXXX							
	10	11	GR	SA	D063545	6.23	2.60	3.63	XXXX							
	11	12	GG	SA	D063546	7.12	2.20	4.92	XXXX							
YA_PASS009_7	0	1	GB	CS	D063788	5.88	3.80	2.08	X							
	1	2	GB	CS	D063789	5.82	4.40	1.42	X							
	2	3	OB	IR	D063790	6.21	4.70	1.51	X							
	3	4	GB	CL	D063791	6.40	5.30	1.10	X							
	4	5	GB	SA	D063792	6.41	5.10	1.31	X							
	5	6	GB	SA	D063793	6.50	4.00	2.50	X							
	6	7	GR	SA	D063794	6.38	4.20	2.18	X							
YA_PASS010_9	0	1	GB	CS	D063592	6.09	1.80	4.29	XXXX							
	1	2	GB	CS	D063593	6.41	2.20	4.21	XXXX							
	2	3	GB	SC	D063594	6.51	2.20	4.31	XXX							
	3	4	GB	CS	D063595	6.42	2.10	4.32	XX							
	4	5	GR	SC	D063596	6.75	3.30	3.45	XX							
	5	6	GR	SA	D063597	6.75	3.60	3.15	XX							
	6	7	GR	SA	D063598	6.60	1.70	4.90	XX							
	7	8	GR	SA	D063599	6.66	1.60	5.06	XXXX							
	8	9	GR	SA	D063600	6.76	2.30	4.46	XXXX							
YA_PASS011_9	0	1	GB	SA	D063547	6.80	2.80	4.00	XX							
	1	2	CR	CS	D063548	6.56	3.10	3.46	XX							
	2	3	BR	IR	D063549	6.76	3.90	2.86	XX							
	3	4	GB	CS	D063550	6.72	2.60	4.12	XX							
	4	5	GB	CS	D063551	7.11	4.20	2.91	X							
	5	6	GW	CS	D063552	7.21	5.30	1.91	X							
	6	7	GB	CS	D063553	6.54	2.80	3.74	XXXX							
	7	8	GG	CS	D063554	6.66	2.00	4.66	XXXX							
	8	9	GG	CS	D063555	6.50	2.20	4.30	XXXX							
YA_PASS012_12	0	1	OB	SA	D063556	7.04	2.40	4.64	XX							
	1	2	OB	IR	D063557	6.57	2.40	4.17	XX							
	2	3	BR	IR	D063558	6.56	3.20	3.36	XX							
	3	4	OB	SA	D063559	6.49	2.50	3.99	XX							
	4	5	BR	CS	D063560	6.53	2.70	3.83	XXXX							
	5	6	GB	SC	D063561	7.07	7.30	- 0.23	XXXX							
	6	7	GB	SA	D063562	6.69	4.60	2.09	X							
	7	8	GR	SA	D063563	6.79	1.90	4.89	XXXX							
	8	9	GG	SYS	D063564	6.93	2.40	4.53	XXXX							
	9	10	GG	SYS	D063565	6.63	2.70	3.93	XXXX							
	10	11	GG	SYS	D063566	6.75	2.20	4.55	XXXX							
	11	12	GG	SYS	D063567	6.55	2.30	4.25	XXXX							
YA_PASS013_9	0	1	GR	SA	D063795	5.49	3.40	2.09	X							
	1	2	GR	CS	D063796	6.40	4.20	2.20	X							
	2	3	OB	IR	D063797	6.33	4.80	1.53	XX							
	3	4	OB	CS	D063798	6.38	5.00	1.38	XX							
	4	5	GR	CS	D063799	6.33	4.50	1.83	X							
	5	6	GR	CS	D063800	6.32	4.60	1.72	X							
	6	7	GR	SA	D063801	6.37	4.80	1.57	X							
	7	8	GR	SA	D063802	6.34	4.70	1.64	X							
	8	9	GR	SA	D063803	6.39	4.70	1.69	XX							
	0	1	GB	SA	D063601	6.39	2.90	3.49	XX	5.60	3	0.005	0.04	0.040	S_{CR}	
	1	2	CR	CS	D063602	6.47	2.70	3.77	XX	5.40	3	0.005	0.02	0.025	S_{CR} + s-TAA	
	2	3	CR	CS	D063603	6.64	2.20	4.44	XX	6.10	3	0.005	0.04	0.040	S_{CR}	
	3	4	OB	IR	D063604	6.49	2.90	3.59	XX	6.40	1	0.002	0.09	0.090	S_{CR}	

SAMPLE LOCATION	SAMPLE INTERVAL		SOIL DESCRIPTION		LAB ID	FIELD TEST RESULTS				CHROMIUM SUITE						LECO
	depth_ from	depth _ to	COLOUR	LITHOLOGY	samp_id	phF	phFOX	pHf - pH fox	Reaction	pHKCl	sTAA	s-TAA	S_{CR}	NET ACIDITY	NA EQUATION	Total Sulfur
					Units						molesH/t	%S	%S	%S		%S
					LOR	0.01	0.01	0.01	-	0.1	1	0.005	0.01	0.01		0.01
					Criteria	≤4	≤3	≥3		<4	18	0.03	0.03	0.03		0.03
YA_PASS014_9	4	5	GB	CS	D063605	6.67	3.00	3.67	XX	5.90	3	0.005	0.15	0.150	S_{CR}	
	5	6	GR	CS	D063606	6.86	4.20	2.66	X							
	6	7	GR	CS	D063607	6.77	4.00	2.77	X							
	7	8	GR	CS	D063608	6.76	3.80	2.96	X							
	8	9	GR	CS	D063609	6.70	4.20	2.50	X							
YA_PASS015_11	0	1	GB	SA	D063568	6.47	3.30	3.17	X	5.70	4	0.006	0.01	0.010	S_{CR}	
	1	2	GB	CS	D063569	6.42	2.90	3.52	XX	5.50	5	0.008	0.06	0.060	S_{CR}	
	2	3	GB	CS	D063570	6.52	2.70	3.82	XX	5.80	3	0.005	0.08	0.080	S_{CR}	
	3	4	GB	CL	D063571	6.74	2.40	4.34	XXX	5.90	5	0.008	0.03	0.030	S_{CR}	
	4	5	GW	SC	D063572	6.68	3.80	2.88	X	6.10	3	0.005	0.01	0.010	S_{CR}	
	5	6	GW	CS	D063573	6.75	4.70	2.05	X	6.00	4	0.006	0.01	0.010	S_{CR}	
	6	7	WH	SA	D063574	6.75	3.60	3.15	X	6.30	2	0.003	0.01	0.010	S_{CR}	
	7	8	GR	SA	D063575	6.79	3.20	3.59	XX	6.70	1	0.002	0.02	0.020	S_{CR}	
	8	9	GR	SA	D063576	6.60	2.10	4.50	XX	5.50	3	0.005	0.22	0.220	S_{CR}	
	9	10	GW	SA	D063577	6.67	2.30	4.37	XXXX	5.30	4	0.006	0.31	0.316	S_{CR} + s-TAA	
	10	11	GW	SA	D063578	6.62	1.90	4.72	XXXX	5.80	3	0.005	0.22	0.220	S_{CR}	
YA_PASS016_13	0	1	BR	SA	D063579	6.11	1.90	4.21	XXX	5.70	5	0.008	0.04	0.040	S_{CR}	
	1	2	GR	CS	D063580	6.38	2.10	4.28	XXXX	5.20	4	0.006	0.16	0.166	S_{CR} + s-TAA	
	2	3	GB	CS	D063581	6.47	2.20	4.27	XXX	6.00	3	0.005	0.08	0.080	S_{CR}	
	3	4	GB	CS	D063582	6.56	2.40	4.16	XX	5.90	5	0.008	0.02	0.020	S_{CR}	
	4	5	BR	CS	D063583	6.51	3.50	3.01	XX	5.90	3	0.005	0.02	0.020	S_{CR}	
	5	6	GR	CL	D063584	6.76	6.50	0.26	XX	-	-	-	-	-	-	
	6	7	GR	CL	D063585	6.92	4.50	2.42	XX	-	-	-	-	-	-	
	7	8	GR	CL	D063586	6.99	5.00	1.99	XXX	-	-	-	-	-	-	
	8	9	GR	CL	D063587	6.78	3.60	3.18	XX	5.30	4	0.006	0.05	0.056	S_{CR} + s-TAA	
	9	10	GR	SYS	D063588	6.84	2.30	4.54	XXXX	4.70	5	0.008	0.7	0.708	S_{CR} + s-TAA	
	10	11	GR	SYS	D063589	6.66	2.00	4.66	XXXX	4.10	22	0.035	2.5	2.535	S_{CR} + s-TAA	
	11	12	GR	SYS	D063590	6.63	1.60	5.03	XXXX	4.90	7	0.011	2.2	2.211	S_{CR} + s-TAA	
	12	13	GR	SYS	D063591	6.40	1.70	4.70	XXXX	5.10	4	0.006	1.1	1.106	S_{CR} + s-TAA	
YA_PASS017_9	0	1	CR	CS	D063620	6.59	3.40	3.19	XX							
	1	2	CR	CS	D063621	6.51	3.40	3.11	XX							
	2	3	CR	CS	D063622	6.46	3.00	3.46	XX							
	3	4	GB	SC	D063623	6.45	4.60	1.85	X							
	4	5	GR	CL	D063624	6.23	2.80	3.43	X							
	5	6	BR	CL	D063625	6.18	4.20	1.98	X							
	6	7	GB	CS	D063626	6.40	3.90	2.50	X							
	7	8	CR	CS	D063627	6.47	4.00	2.47	X							
	8	9	CR	CS	D063628	6.52	4.20	2.32	X							
YA_PASS018_10	0	1	GR	CS	D063610	6.55	3.70	2.85	X							
	1	2	GR	CS	D063611	6.82	4.00	2.82	X							
	2	3	GR	CS	D063612	6.53	4.70	1.83	X							
	3	4	OB	IR	D063613	6.70	4.60	2.10	X							
	4	5	GR	CS	D063614	6.62	4.50	2.12	X							
	5	6	GB	SA	D063615	6.64	4.60	2.04	X							
	6	7	GB	SA	D063616	6.56	4.60	1.96	X							
	7	8	GB	SA	D063617	6.57	4.00	2.57	X							
	8	9	GB	SA	D063618	6.65	4.20	2.45	X							
	9	10	GB	SA	D063619	6.62	3.00	3.62	X							
YA_PASS019_13	0	1	GR	CS	D063647	6.23	4.20	2.03	X							
	1	2	CR	CS	D063648	6.39	3.60	2.79	XX							
	2	3	GR	SC	D063649	6.36	4.50	1.86	X							
	3	4	OB	CS	D063650	6.55	2.80	3.75	XXX							
	4	5	OB	IR	D063651	6.49	5.20	1.29	X							
	5	6	OB	SC	D063652	6.59	5.40	1.19	X							
	6	7	GR	CS	D063653	5.83	4.40	1.43	XX							
	7	8	GR	SA	D063654	6.72	4.20	2.52	X							
	8	9	GW	SA	D063655	6.64	4.50	2.14	X							
	9	10	GR	SA	D063656	6.30	5.40	0.90	X							
	10	11	GW	SA	D063657	6.63	5.40	1.23	X							
	11	12	GW	SA	D063658	6.48	4.50	1.98	X							
	12	13	GW	SA	D063659	6.30	4.40	1.90	X							
YA_PASS020_12	0	1	GB	SA	D063660	5.61	3.20	2.41	XX							
	1	2	GB	SA	D063661	6.01	3.50	2.51	XX							
	2	3	GB	SA	D063662	6.35	3.90	2.45	XX							
	3	4	GB	SA	D063663	6.35	3.30	3.05	XX							
	4	5	BR	IR	D063664	6.42	3.90	2.52	X							
	5	6	GR	CL	D063665	6.43	4.80	1.63	XX							
	6	7	GR	SC	D063666	6.63	3.90	2.73	X							
	7	8	GR	SA	D063667	6.54	2.90	3.64	XX							
	8	9	GR	SA	D063668	6.50	3.10	3.40	XX							
	9	10	GR	SA	D063669	6.55	1.50	5.05	XXXX							
	10	11	GR	SC	D063670	6.80	1.90	4.90	XXX							
	11	12	GR	CS	D063671	6.67	1.90	4.77	XXXX							
YA_PASS021_9	0	1	CR	CS	D063629	6.32	3.80	2.52	X							
	1	2	CR	CS	D063630	6.31	4.50	1.81	X							
	2	3	GR	SC	D063631	6.33	4.40	1.93	X							
	3	4	GB	CL	D063632	6.54	3.80	2.74	X							
	4	5	GR	CS	D063633	6.42	4.00	2.42	X							
	5	6	OR	SA	D063634	6.39	4.60	1.79	X							
	6	7	GR	CL	D063635	6.65	4.10	2.55	XX							
	7	8	GR	CL	D063636	6.57	4.60	1.97	XX							
	8	9	GR	CS	D063637	6.44	1.80	4.64	XXX							
YA_PASS022_9	0	1	GR	CS	D063638	6.15	3.80	2.35	X							
	1	2	GR	CS	D063639	5.91	3.50	2.41	XX							
	2	3	GR	SC	D063640	6.27	3.50	2.77	XX							
	3	4	GB	CL	D063641	6.19	3.20	2.99	XX							
	4	5	BR	CL	D063642	6.05	3.60	2.45	XX							
	5	6	GR	CS	D063643	6.25	4.30	1.95	X							
	6	7	OR	CS	D063644	6.24	4.40	1.84	X							
	7	8	GR	CL	D063645	6.56	4.30	2.26	X							
	8	9	GR	CL	D063646	6.10	2.60	3.50	XXX							
YA_PASS023_9	0	1	GB	CS	D063672	6.26	2.30	3.96	XXXX							
	1	2	GR	CS	D063673	6.31	2.70	3.61	XX							
	2	3	GB	SC	D063674	6.53	3.20	3.33	XX							
	3	4	GB	SC	D063675	6.40	3.90	2.50	XX							
	4	5	OB	IR	D063676	6.33	4.20	2.13	X							
	5	6	OB	SA	D063677	6.36	4.90	1.46	X							
	6	7	BK	CL	D063678	6.44	3.00	3.44	XX							
	7	8	GB	SA	D063679	6.40	2.30	4.10	XXXX							
	8	9	GR	SA	D063680	6.64	2.20	4.44	XXXX							
YA_PASS024_10	0	1	GR	SA	D063681	6.24	3.90	2.34	XX							
	1	2	GR	SA	D063682	6.35	4.40	1.95	X							
	2	3	GB	SC	D063683	6.24	2.60	3.64	XX							
	3	4	GB	CL	D063684	6.34	3.70	2.64	XX							
	4	5	GB	SC	D063685	6.78	3.90	2.88	XX							
	5	6	BR	SC	D063686	6.90	5.90	1.00	XX							
	6	7	GR	CS	D063687	6.86	5.00	1.86	XX							
	7	8	GR	CS	D063688	6.70	4.90	1.80	XX							
	8	9	GR	CL	D063689	6.47	2.10	4.37	XXXX							
	9	10	GR	CL	D063690	6.83	1.80	5.03	XXXX							
YA_PASS025_9	0	1	GR	SA	D063711	6.66	4.40	2.26	XX							
	1	2	GR	SA	D063712	6.65	4.80	1.85	XX							
	2	3	GR	CS	D063713	6.54	4.10	2.44	XX							
	3	4	GR	CS	D063714	6.39	3.60	2.79	XX							
	4	5	GB	SC	D063715	6.58	4.20	2.38	XX							
	5	6	RG	SC	D063716	6.02	4.30	1.72	XX							
	6	7	GR	SC	D063717	6.18	4.30	1.88	X							
	7	8	GR	CS	D063718	6.27	4.50	1.77	X							
	8	9	GR	CS	D063719	6.39	4.30	2.09	X							

SAMPLE LOCATION	SAMPLE INTERVAL		SOIL DESCRIPTION		LAB ID	FIELD TEST RESULTS				CHROMIUM SUITE						LECO
	depth_ from	depth _ to	COLOUR	LITHOLOGY	samp_id	phF	phFOX	pHf - pH fox	Reaction	pHKCl	sTAA	s-TAA	S_{CR}	NET ACIDITY	NA EQUATION	Total Sulfur
					Units						molesH/t	%S	%S	%S		%S
					LOR	0.01	0.01	0.01	-	0.1	1	0.005	0.01	0.01		0.01
					Criteria	≤4	≤3	≥3		<4	18	0.03	0.03	0.03		0.03
YA_PASS026_9	0	1	GR	CS	D063702	6.66	1.90	4.76	XXX							
	1	2	GB	SA	D063703	6.75	2.00	4.75	XXX							
	2	3	OB	IR	D063704	6.87	2.10	4.77	XXX							
	3	4	OB	SA	D063705	6.77	2.90	3.87	XX							
	4	5	OB	SA	D063706	6.87	4.00	2.87	XX							
	5	6	GB	CS	D063707	6.88	2.30	4.58	XX							
	6	7	GB	CS	D063708	6.88	3.00	3.88	XX							
	7	8	GB	SC	D063709	6.84	3.50	3.34	XX							
	8	9	GR	CS	D063710	6.81	5.20	1.61	X							
YA_PASS027_11	0	1	GR	SA	D063691	5.78	3.40	2.38	XX							
	1	2	GR	CS	D063692	6.55	4.80	1.75	X							
	2	3	GR	CS	D063693	6.43	2.50	3.93	XX							
	3	4	GR	SC	D063694	6.44	4.00	2.44	XX							
	4	5	GR	SC	D063695	6.62	4.40	2.22	X							
	5	6	GR	CS	D063696	6.63	5.20	1.43	X							
	6	7	GR	CS	D063697	6.58	3.40	3.18	XX							
	7	8	GR	SC	D063698	6.72	4.10	2.62	XX							
	8	9	GR	SA	D063699	6.64	3.90	2.74	X							
	9	10	GR	SA	D063700	6.76	2.30	4.46	XX							
	10	11	GR	CS	D063701	6.85	2.00	4.85	XXXX							
YA_PASS028_7	0	1	OB	IR	D063720	6.06	5.60	0.46	XXXX							
	1	2	OB	IR	D063721	6.30	6.10	0.20	XXXX							
	2	3	OB	IR	D063722	6.09	6.20	- 0.11	XXXX							
	3	4	OB	IR	D063723	6.13	5.90	0.23	XXX							
	4	5	GB	SC	D063724	6.55	4.00	2.55	XX	5.90	3	0.005	0.02	0.020	S_{CR}	
	5	6	BK	CL	D063725	6.37	3.30	3.07	XXX	4.40	10	0.016	0.01	0.026	S_{CR} + s-TAA	
	6	7	GR	CL	D063726	6.67	2.90	3.77	XXXX	4.60	7	0.011	0.09	0.101	S_{CR} + s-TAA	
YA_PASS029_9	0	1	GR	SA	D063727	6.12	3.50	2.62	X	5.30	4	0.006	0.01	0.016	S_{CR} + s-TAA	
	1	2	GR	SA	D063728	6.38	3.50	2.88	X	6.70	1	0.002	0.01	0.010	S_{CR}	
	2	3	OB	IR	D063729	6.38	3.50	2.88	XX	5.80	6	0.010	0.02	0.020	S_{CR}	
	3	4	GB	CS	D063730	6.23	2.00	4.23	XXX	5.90	4	0.006	0.05	0.050	S_{CR}	
	4	5	GR	CS	D063731	6.47	3.60	2.87	XX	6.10	3	0.005	0.02	0.020	S_{CR}	
	5	6	OB	CS	D063732	6.34	1.80	4.54	XXX	5.30	6	0.010	0.09	0.100	S_{CR} + s-TAA	
	6	7	GR	SA	D063733	6.33	1.30	5.03	XXXX	4.60	12	0.019	0.86	0.879	S_{CR} + s-TAA	
	7	8	GB	CL	D063734	6.35	2.20	4.15	XXXX	4.70	7	0.011	0.19	0.201	S_{CR} + s-TAA	
	8	9	GB	CS	D063735	6.64	2.60	4.04	XXX	5.90	4	0.006	0.03	0.030	S_{CR}	
YA_PASS030_9	0	1	GB	SA	D063736	6.29	4.00	2.29	XXXX	6.60	1	0.002	0.03	0.030	S_{CR}	
	1	2	OB	IR	D063737	6.40	4.00	2.40	XXX	6.00	3	0.005	0.03	0.030	S_{CR}	
	2	3	BR	SA	D063738	6.56	6.00	0.56	XXX	-	-	-	-	-	-	
	3	4	BR	SA	D063739	6.49	3.60	2.89	XXX	5.80	4	0.006	0.04	0.040	S_{CR}	
	4	5	OB	SA	D063740	6.55	2.50	4.05	XXX	5.70	3	0.005	0.03	0.030	S_{CR}	
	5	6	GB	SA	D063741	6.47	2.00	4.47	XXXX	4.80	5	0.008	0.22	0.228	S_{CR} + s-TAA	
	6	7	GB	SD	D063742	6.49	2.00	4.49	XXXX	4.50	11	0.018	1.2	1.218	S_{CR} + s-TAA	
	7	8	GR	SD	D063743	6.11	1.50	4.61	XXXX	5.00	5	0.008	0.26	0.268	S_{CR} + s-TAA	
	8	9	GR	SD	D063744	6.12	1.60	4.52	XXXX	5.00	5	0.008	0.29	0.298	S_{CR} + s-TAA	
YA_PASS031_8	0	1	GB	SA	D063745	6.19	2.70	3.49	XXXX	7.00	1	0.002	0.08	0.080	S_{CR}	
	1	2	GB	SA	D063746	6.22	2.10	4.12	XXXX	5.10	4	0.006	0.43	0.436	S_{CR} + s-TAA	
	2	3	GB	CS	D063747	6.21	1.70	4.51	XXXX	5.00	6	0.010	0.44	0.450	S_{CR} + s-TAA	
	3	4	GB	SA	D063748	6.23	1.90	4.33	XXXX	4.80	6	0.010	0.45	0.460	S_{CR} + s-TAA	
	4	5	GB	SA	D063749	6.43	2.60	3.83	XX	5.50	5	0.008	0.05	0.058	S_{CR} + s-TAA	
	5	6	GB	CS	D063750	6.38	1.90	4.48	XXXX	4.90	7	0.011	0.04	0.051	S_{CR} + s-TAA	
	6	7	GB	CS	D063751	6.46	6.20	0.26	XXXX	-	-	-	-	-	-	
	7	8	GR	SA	D063752	6.42	2.70	3.72	XX	5.10	5	0.008	0.02	0.028	S_{CR} + s-TAA	
YA_PASS032_9	0	1	OB	SA		5.12	3.00	2.12	X	5.1	5	0.008	<0.01	0.018	S_{CR} + s-TAA	
	1	2	OB	CS		5.87	4.40	1.47	X	5.6	2	0.003	<0.01	0.010	S_{CR}	
	2	3	OB	IR		6.01	4.50	1.51	XX	5.6	2	0.003	<0.01	0.010	S_{CR}	
	3	4	GB	CS		6.15	3.70	2.45	X	5.4	2	0.003	0.02	0.023	S_{CR} + s-TAA	
	4	5	GR	CS		6.32	2.60	3.72	X	5.7	2	0.003	0.02	0.020	S_{CR}	
	5	6	GR	CS		6.37	2.40	3.97	X	5.6	2	0.003	0.01	0.010	S_{CR}	
	6	7	GR	CS		6.15	2.30	3.85	XX	5	4	0.006	0.02	0.026	S_{CR} + s-TAA	
	7	8	GR	SA		5.95	3.00	2.95	X	5.4	1	0.002	<0.01	0.012	S_{CR} + s-TAA	
	8	9	GR	SA		5.84	3.30	2.54	X	5.4	1	0.002	<0.01	0.012	S_{CR} + s-TAA	
YA_PASS033_12	0	1	GB	CS		5.50	3.30	2.20	X							
	1	2	OB	LA		5.75	4.40	1.35	X							
	2	3	OB	LA		5.77	4.70	1.07	X							
	3	4	GR	SC		5.84	3.80	2.04	X							
	4	5	GR	SC		6.34	2.40	3.94	XX							
	5	6	GR	CS		6.82	2.30	4.52	XXX							
	6	7	GR	CS		6.60	2.60	4.00	X							
	7	8	GR	CS		6.41	2.50	3.91	X							
	8	9	GR	CS		6.49	2.00	4.49	X							
	9	10	GR	CS		6.39	1.60	4.79	X							
	10	11	GR	CL		6.53	1.40	5.13	XXXX							
	11	12	GR	SA		6.49	1.60	4.89	XXXX							
YA_PASS034_12	0	1	OB	LA		5.70	4.30	1.40	X	5.5	3	0.005	<0.01	0.010	S_{CR}	
	1	2	OB	LA		5.91	5.50	0.41	XX	5.7	4	0.006	<0.01	0.010	S_{CR}	
	2	3	OB	SC		6.25	7.50	- 1.25	XXXX	5.5	5	0.008	<0.01	0.010	S_{CR}	
	3	4	OB	SC		6.30	6.80	- 0.50	X	5.7	2	0.003	0.01	0.010	S_{CR}	
	4	5	OB	SC		6.66	6.60	0.06	XXXX	5.6	2	0.003	0.01	0.010	S_{CR}	
	5	6	GB	SC		6.67	4.60	2.07	X	5.3	3	0.005	<0.01	0.015	S_{CR} + s-TAA	
	6	7	GR	CS		6.44	3.40	3.04	X	6.6	<1	0.002	<0.01	0.010	S_{CR}	
	7	8	GR	CL		6.46	3.40	3.06	XX	4.5	19	0.030	0.02	0.050	S_{CR} + s-TAA	
	8	9	GR	CL		6.59	3.30	3.29	X	4.6	17	0.027	0.02	0.047	S_{CR} + s-TAA	
	9	10	GR	CL		6.31	1.50	4.81	XXXX	4.3	30	0.048	0.1	0.148	S_{CR} + s-TAA	
	10	11	GR	SC		6.23	1.50	4.73	XXXX	4.4	26	0.042	0.33	0.372	S_{CR} + s-TAA	
	11	12	GR	SC		6.22	1.60	4.62	XXXX	4.5	19	0.030	0.51	0.540	S_{CR} + s-TAA	
YA_PASS035_12	0	1				6.12	5.10	1.02								0.19
	1	2				5.88	3.80	2.08								0.12
	2	3				5.94	3.00	2.94								0.05
	3	4				6.00	5.30	0.70								0.01
	4	5				6.21	5.00	1.21								0.02
	5	6				6.57	4.80	1.77								0.01
	6	7				6.38	4.60	1.78								0.01
	7	8				6.37	1.80	4.57								0.6
	8	9				6.38	1.40	4.98								0.83
	9	10				6.35	1.70	4.65								0.21
	10	11				5.96	2.00	3.96								0.25
	11	12				6.33	1.90	4.43								
YA_PASS036_12	0	1	GB	SA		4.32	3.90	0.42	X	5	7	0.011	<0.01	0.021	S_{CR} + s-TAA	
	1	2	GB	CS		5.92	3.60	2.32	X	5.4	2	0.003	<0.01	0.013	S_{CR} + s-TAA	
	2	3	GR	CL		5.58	3.90	1.68	X	5.9	1	0.002	<0.01	0.010	S_{CR}	
	3	4	GR	CL		6.82	4.60	2.22	X	5.9	2	0.003	0.01	0.010	S_{CR}	
	4	5	GR	SC		6.92	2.20	4.72	X	5.7	2	0.003	0.03	0.030	S_{CR}	
	5	6	GR	CS		7.30	2.40	4.90	X	6.2	<1	0.002	<0.01	0.010	S_{CR}	
	6	7	GR	CS		7.11	5.30	1.81	X	6.6	<1	0.002	<0.01	0.010	S_{CR}	
	7	8	GR	SC		7.57	1.80	5.77	XXX	4.9	8	0.013	0.1	0.113	S_{CR} + s-TAA	
	8	9	GR	SC		6.55	3.10	3.45	XX	5.1	5	0.008	0.2	0.208	S_{CR} + s-TAA	
	9	10	GR	CL		6.62	1.40	5.22	XXXX	4.3	24	0.038	0.45	0.488	S_{CR} + s-TAA	
	10	11	GR	SA		6.54	1.80	4.74	XXXX	4.4	21	0.034	0.5	0.534	S_{CR} + s-TAA	
	11	12	GR	SA		6.60	2.10	4.50	XXXX	4.9	4	0.006	0.15	0.156	S_{CR} + s-TAA	
YA_PASS037_12	0	1				6.57	4.50	2.07		5.4		0.015	0.005	0.020	S_{CR} + s-TAA	0.06
	1	2				6.50	4.60	1.90		5.5		0.018	0.005	0.005	S_{CR}	0.09
	2	3				6.51	4.80	1.71		5.3		0.016	0.005	0.021	S_{CR} + s-TAA	0.05
	3	4				6.88	6.20	0.68		5.3		0.024	0.005	0.029	S_{CR} + s-TAA	0.06
	4	5				6.42	4.90	1.52		5.9		<0.01	0.005	0.005	S_{CR}	0.01
	5	6				6.70	3.70	3.00		5.7		<0.01	0.005	0.005	S_{CR}	0.04
	6	7				6.57	4.20	2.37		5.8		<0.01	0.005	0.005	S_{CR}	0.01
	7	8				6.41	2.10	4.31		5.9		<0.01	0.013	0.013	S_{CR}	0.06
	8	9				6.62	2.20	4.42		5.9		<0.01	0.019	0.019	S_{CR}	0.09
	9	10				6.73	1.60	5.13		5.4		0.010	0.14	0.150	S_{CR} + s-TAA	0.16
	10	11				6.57	1.90	4.67		5.6		0.010	0.14	0.150	S_{CR} + s-TAA	0.42
	11	12				6.68	2.10	4.58		6.2		0.010	0.37	0.380	S_{CR} + s-TAA	0.69

SAMPLE LOCATION	SAMPLE INTERVAL		SOIL DESCRIPTION		LAB ID	FIELD TEST RESULTS				CHROMIUM SUITE						LECO
	depth_ from	depth _ to	COLOUR	LITHOLOGY	samp_id	phF	phFOX	pHf - pH fox	Reaction	pHKCl	sTAA	s-TAA	S_{CR}	NET ACIDITY	NA EQUATION	Total Sulfur
					Units						molesH/t	%S	%S	%S		%S
					LOR	0.01	0.01	0.01	-	0.1	1	0.005	0.01	0.01		0.01
					Criteria	≤4	≤3	≥3		<4	18	0.03	0.03	0.03		0.03
YA_PASS038_7	0	1	CR	SA		4.93	3.40	1.53	XX							
	1	2	BR	CS		5.36	4.20	1.16	X							
	2	3	GB	CS		5.72	4.10	1.62	X							
	3	4	BR	IR		5.61	4.50	1.11	X							
	4	5	GR	CL		5.46	3.90	1.56	XX							
	5	6	GR	CL		5.58	3.20	2.38	XX							
	6	7	GR	CL		6.08	4.20	1.88	XXXX							
YA_PASS039_9	0	1	CR	CS		5.28	4.30	0.98	X							
	1	2	CR	SC		5.63	4.40	1.23	X							
	2	3	BR	SC		5.58	5.00	0.58	X							
	3	4	OB	IR		5.62	4.80	0.82	X							
	4	5	GB	CS		5.38	4.50	0.88	X							
	5	6	GB	CS		5.44	4.30	1.14	XX							
	6	7	GR	CL		5.40	2.10	3.30	XX							
	7	8	GR	CL		5.62	2.10	3.52	XX							
	8	9	GR	SC		5.87	3.20	2.67	XX							
YAS_PASS040_7	0	1				5.67	3.40	2.27								0.01
	1	2				5.61	4.40	1.21								0.01
	2	3				5.87	5.30	0.57								0.04
	3	4				6.61	5.60	1.01								0.03
	4	5				6.53	3.40	3.13								0.04
	5	6				6.77	2.70	4.07								0.07
	6	7				6.46	2.40	4.06								0.04
YA_PASS041_9	0	1	CR	CS		4.88	4.50	0.38	X	5.7	2	0.003	<0.01	0.010	S_{CR}	
	1	2	GR	CL		5.13	4.20	0.93	X	5.5	3	0.005	<0.01	0.010	S_{CR}	
	2	3	GR	CL		5.56	4.50	1.06	X	5.5	4	0.006	<0.01	0.010	S_{CR}	
	3	4	GR	SC		6.06	2.40	3.66	X	5.5	2	0.003	0.02	0.020	S_{CR}	
	4	5	GR	CL		5.82	2.80	3.02	XX	5.8	2	0.003	0.01	0.010	S_{CR}	
	5	6	GR	SC		6.02	3.20	2.82	X	5.7	2	0.003	0.01	0.010	S_{CR}	
	6	7	GR	SC		5.84	3.30	2.54	X	5.7	2	0.003	0.01	0.010	S_{CR}	
	7	8	GR	CS		5.95	1.40	4.55	XXXX	4.7	17	0.027	0.19	0.217	S_{CR} + s-TAA	
	8	9	GR	CS		5.95	1.30	4.65	XXXX	4.6	13	0.021	0.44	0.461	S_{CR} + s-TAA	
YA_PASS042_12	0	1				6.50	4.50	2.00								0.11
	1	2				6.33	4.70	1.63								0.05
	2	3				6.40	2.30	4.10								0.05
	3	4				6.48	3.80	2.68								0.04
	4	5				6.31	3.30	3.01								0.02
	5	6				6.23	4.20	2.03								0.04
	6	7				6.31	1.90	4.41								0.33
	7	8				6.08	2.40	3.68								0.22
	8	9				6.43	2.30	4.13								0.25
	9	10				6.46	2.70	3.76								0.11
	10	11				6.45	1.90	4.55								0.25
	11	12				6.40	2.20	4.20								0.93
YA_PASS043_9	0	1				6.48	3.60	2.88		6		<0.01	0.009	0.019	S_{CR}	0.05
	1	2				6.66	5.60	1.06		6.1		<0.01	<0.005	0.015	S_{CR}	0.06
	2	3				6.58	5.50	1.08		6		<0.01	<0.005	0.015	S_{CR}	0.03
	3	4				6.50	5.20	1.30		5.8		<0.01	<0.005	0.015	S_{CR}	0.01
	4	5				6.61	5.20	1.41		5.3		0.017	0.005	0.022	S_{CR} + s-TAA	0.01
	5	6				7.03	4.20	2.83		5.3		0.010	0.005	0.015	S_{CR} + s-TAA	0.03
	6	7				7.07	3.40	3.67		5.4		0.017	0.005	0.022	S_{CR} + s-TAA	0.01
	7	8				7.00	1.60	5.40		5.1		0.031	0.069	0.100	S_{CR} + s-TAA	0.1
	8	9				6.99	1.90	5.09		5.1		0.035	0.54	0.575	S_{CR} + s-TAA	0.17
YA_PASS044_10	0	1				5.13	4.60	0.53								0.03
	1	2				5.51	5.40	0.11								0.06
	2	3				6.26	5.40	0.86								0.06
	3	4				6.30	5.00	1.30								0.06
	4	5				6.46	6.80	- 0.34								0.04
	5	6				6.41	7.20	- 0.79								0.03
	6	7				6.55	3.90	2.65								0.08
	7	8				6.06	1.50	4.56								0.27
	8	9				6.44	1.40	5.04								1.19
	9	10				6.57	2.90	3.67								0.27
YA_PASS045_12	0	1				5.51	3.20	2.31		5.9		<0.01	<0.005	0.005	S_{CR}	0.03
	1	2				5.81	4.00	1.81		5.7		0.012	0.005	0.005	S_{CR}	0.06
	2	3				5.80	3.90	1.90		5.7		0.011	<0.005	0.005	S_{CR}	0.09
	3	4				6.20	2.80	3.40		5.3		0.019	0.010	0.029	S_{CR} + s-TAA	0.05
	4	5				6.07	5.00	1.07		5.5		0.016	0.037	0.053	S_{CR} + s-TAA	0.04
	5	6				6.11	4.70	1.41		5.3		0.020	0.005	0.025	S_{CR} + s-TAA	0.04
	6	7				6.18	4.30	1.88		5.8		<0.01	<0.005	0.005	S_{CR}	0.02
	7	8				6.19	1.70	4.49		5.6		0.010	0.052	0.062	S_{CR} + s-TAA	0.1
	8	9				6.22	1.80	4.42		5.4		0.010	0.190	0.200	S_{CR} + s-TAA	0.3
	9	10				6.27	1.60	4.67		5.0		0.034	0.130	0.164	S_{CR} + s-TAA	0.38
	10	11				6.10	1.60	4.50		5.3		0.014	0.070	0.084	S_{CR} + s-TAA	0.2
	11	12				6.25	1.60	4.65		5.1		0.024	0.340	0.364	S_{CR} + s-TAA	0.65
YA_PASS046_9	0	1				6.80	4.00	2.80								0.03
	1	2				7.67	5.60	2.07								0.03
	2	3				7.64	5.40	2.24								0.06
	3	4				7.34	6.10	1.24								0.08
	4	5				7.06	6.20	0.86								0.01
	5	6				7.03	7.20	- 0.17								0.31
	6	7				7.05	3.70	3.35								0.01
	7	8				6.71	4.50	2.21								0.01
	8	9				6.38	2.30	4.08								0.01
YA_PASS047_10	0	1	GR	SA		6.44	4.80	1.64	X							
	1	2	GR	SA		6.63	5.00	1.63	X							
	2	3	CR	CS		6.22	4.60	1.62	X							
	3	4	CR	CS		6.17	4.40	1.77	X							
	4	5	GR	CS		6.04	4.60	1.44	X							
	5	6	GR	CS		6.06	4.30	1.76	X							
	6	7	GR	CS		6.20	3.80	2.40	X							
	7	8	GR	CS		6.00	1.90	4.10	XXX							
	8	9	GR	SA		5.97	1.80	4.17	XXXX							
	9	10	GR	SA		5.84	2.00	3.84	XXX							
YA_PASS048_9	0	1	GB	SA		5.72	4.40	1.32	X							
	1	2	BR	IR		6.53	5.50	1.03	XX							
	2	3	OB	IR		6.50	5.70	0.80	XX							
	3	4	GB	CS		6.47	5.40	1.07	XX							
	4	5	GR	CS		6.45	5.60	0.85	X							
	5	6	GR	CS		6.51	5.10	1.41	X							
	6	7	GR	SA		6.22	3.90	2.32	X							
	7	8	GR	SA		6.09	3.70	2.39	X							
	8	9	GR	SA		6.26	3.70	2.56	X							
YA_PASS049_12	0	1	CR	CS		4.86	4.00	0.86	XX							
	1	2	CR	CS		5.25	4.50	0.75	X							
	2	3	OB	IR		5.66	4.80	0.86	X							
	3	4	GB	CS		5.80	2.10	3.70	XX							
	4	5	GR	CL		5.99	2.70	3.29	XXX							
	5	6	GR	SC		5.89	3.40	2.49	X							
	6	7	GR	CS		5.56	3.70	1.86	X							
	7	8	GR	SA		5.62	4.20	1.42	X							
	8	9	GR	SA		5.52	3.90	1.62	X							
	9	10	GR	SA		5.73	4.10	1.63	X							
	10	11	GR	SA		5.70	1.70	4.00	X							
	11	12	GR	SA		5.89	2.00	3.89	XXX							
YA_PASS050_12	0	1				5.95	4.00	1.95								0.06
	1	2				5.85	4.60	1.25								0.04
	2	3				6.02	5.40	0.62								0.04
	3	4				6.04	5.20	0.84								0.02
	4	5				6.06	5.90	0.16								0.01
	5	6				6.16	5.00	1.16								0.02
	6	7				6.06	5.60	0.46								0.02
	7	8				6.45	2.40	4.05								0.28
	8	9				6.49	1.40	5.09								0.24
	9	10				6.36	1.80	4.56								0.4
	10	11				6.16	1.90	4.26								0.14
	11	12				6.65	2.70	3.95								0.09

SAMPLE LOCATION	SAMPLE INTERVAL		SOIL DESCRIPTION		LAB ID	FIELD TEST RESULTS				CHROMIUM SUITE						LECO
	depth_ from	depth _ to	COLOUR	LITHOLOGY	samp_id	phF	phFOX	pHf - pH fox	Reaction	pHKCl	sTAA	s-TAA	S_{CR}	NET ACIDITY	NA EQUATION	Total Sulfur
					Units						molesH/t	%S	%S	%S		%S
					LOR	0.01	0.01	0.01	-	0.1	1	0.005	0.01	0.01		0.01
					Criteria	≤4	≤3	≥3		<4	18	0.03	0.03	0.03		0.03
YA_PASS051_6	0	1	GR	SA		4.92	2.90	2.02	X	5.5	3	0.005	0.01	0.010	S_{CR}	
	1	2	GR	SA		5.62	2.60	3.02	X	5.7	2	0.003	0.01	0.010	S_{CR}	
	2	3	GR	SA		5.70	2.00	3.70	X	5.5	3	0.005	-	-	-	
	3	4	CR	CS		5.94	3.20	2.74	X	5.5	3	0.005	0.01	0.010	S_{CR}	
	4	5	WH	CL		6.13	4.20	1.93	XX	5.1	4	0.006	0.01	0.016	S_{CR} + s-TAA	
	5	6	GR	CL		6.18	4.20	1.98	XX	4.7	12	0.019	0.01	0.029	S_{CR} + s-TAA	
YA_PASS052_9	0	1	CR	CS		5.24	4.20	1.04	X							
	1	2	CR	CS		6.24	4.60	1.64	X							
	2	3	GB	CS		6.33	4.60	1.73	X							
	3	4	GB	CS		6.24	5.40	0.84	X							
	4	5	GB	CS		6.36	5.20	1.16	X							
	5	6	GR	SA		6.19	4.60	1.59	X							
	6	7	GR	SA		6.25	5.20	1.05	X							
	7	8	CR	SA		6.59	5.40	1.19	X							
	8	9	CR	SA		6.23	5.20	1.03	X							
YA_PASS053_9	0	1				6.06	4.00	2.06								0.04
	1	2				5.93	4.30	1.63								0.03
	2	3				5.98	4.20	1.78								0.05
	3	4				6.07	4.00	2.07								0.07
	4	5				6.30	3.60	2.70								0.03
	5	6				6.31	4.00	2.31								0.04
	6	7				6.03	4.20	1.83								0.04
	7	8				6.05	2.40	3.65								0.04
	8	9				6.35	1.40	4.95								0.51
YA_PASS054_12	0	1				5.26	3.80	1.46								0.02
	1	2				5.65	5.40	0.25								0.03
	2	3				5.95	5.10	0.85								0.02
	3	4				6.09	5.10	0.99								0.03
	4	5				6.16	5.90	0.26								0.02
	5	6				6.12	5.80	0.32								0.02
	6	7				5.93	5.30	0.63								0.01
	7	8				6.04	4.50	1.54								0.02
	8	9				6.17	1.50	4.67								0.26
	9	10				6.00	1.40	4.60								0.56
	10	11				6.16	1.30	4.86								0.31
	11	12				6.17	1.30	4.87								0.8
YA_PASS055_9	0	1				6.09	4.50	1.59		5.6		<0.01	<0.005	0.005	S_{CR}	0.02
	1	2				6.36	6.00	0.36		5.5		0.010	0.055	0.065	S_{CR} + s-TAA	0.02
	2	3				6.41	5.60	0.81		5.4		0.014	0.005	0.019	S_{CR} + s-TAA	0.02
	3	4				6.32	5.70	0.62		5.5		0.014	0.005	0.005	S_{CR}	0.03
	4	5				6.55	5.30	1.25		5.3		0.014	0.005	0.019	S_{CR} + s-TAA	0.02
	5	6				6.34	5.50	0.84		5.7		<0.01	<0.005	0.005	S_{CR}	0.01
	6	7				6.20	5.30	0.90		5.9		<0.01	<0.005	0.005	S_{CR}	0.01
	7	8				6.64	3.30	3.34		5.9		0.017	0.009	0.009	S_{CR}	0.05
	8	9				6.59	1.50	5.09		4.7		0.083	0.42	0.503	S_{CR} + s-TAA	0.67
YA_PASS056_12	0	1				6.13	4.30	1.83		5.5		<0.01	<0.005	0.015	S_{CR}	0.01
	1	2				6.05	4.70	1.35		5.3		0.021	0.005	0.026	S_{CR} + s-TAA	0.01
	2	3				6.34	3.70	2.64		5.1		0.025	0.005	0.030	S_{CR} + s-TAA	0.01
	3	4				6.31	4.50	1.81		5		0.030	0.005	0.035	S_{CR} + s-TAA	0.02
	4	5				6.20	4.20	2.00		5		0.030	0.005	0.035	S_{CR} + s-TAA	0.02
	5	6				5.92	5.00	0.92		5.6		0.022	<0.005	0.005	S_{CR}	0.01
	6	7				6.13	4.70	1.43		5.7		<0.01	<0.005	0.005	S_{CR}	0.01
	7	8				6.41	3.40	3.01		5.1		0.029	0.005	0.034	S_{CR} + s-TAA	0.01
	8	9				6.33	3.80	2.53		5.6		<0.01	<0.005	0.005	S_{CR}	0.01
	9	10				6.99	2.30	4.69		5.4		0.010	0.22	0.230	S_{CR} + s-TAA	0.09
	10	11				7.66	1.80	5.86		4.7		0.070	0.17	0.240	S_{CR} + s-TAA	0.3
	11	12				7.19	1.50	5.69		5.5		0.010	0.078	0.088	S_{CR} + s-TAA	0.28
YA_PASS057_12	0	1	BR	SA		5.77	4.40	1.37	X							
	1	2	CR	CS		6.57	5.60	0.97	X							
	2	3	BR	CS		6.72	5.40	1.32	X							
	3	4	GB	SA		6.63	4.90	1.73	X							
	4	5	RG	CS		6.64	4.70	1.94	X							
	5	6	GR	CL		6.25	5.00	1.25	X							
	6	7	WH	CL		6.37	4.00	2.37	XX							
	7	8	GR	CL		6.66	2.00	4.66	XX							
	8	9	GR	CL		6.70	2.60	4.10	XXXX							
	9	10	GR	CL		6.44	2.20	4.24	XXXX							
	10	11	GR	CL		6.48	3.10	3.38	XXXX							
	11	12	GR	CL		6.52	-	-								
YA_PASS058_12	0	1	GB	SA		5.58	4.60	0.98	X							
	1	2	GB	SC		6.32	4.30	2.02	X							
	2	3	CR	SC		6.24	3.70	2.54	X							
	3	4	CR	SC		6.08	4.10	1.98	X							
	4	5	GB	CL		6.08	3.90	2.18	X							
	5	6	GW	CL		6.02	2.90	3.12	XX							
	6	7	GW	CL		6.19	4.00	2.19	X							
	7	8	GW	SC		5.72	4.10	1.62	X							
	8	9	GW	SC		5.81	4.70	1.11	X							
	9	10	GW	CS		5.52	4.80	0.72	X							
	10	11	GR	CS		5.98	2.80	3.18	X							
	11	12	GR	CS		6.05	2.00	4.05	XXX							
YA_PASS059_9	0	1	GB	SA		6.15	4.20	1.95	XX							
	1	2	GB	CS		6.13	3.50	2.63	XX							
	2	3	GB	CL		6.15	2.00	4.15	XXXX							
	3	4	OB	CL		6.31	4.20	2.11	X							
	4	5	OB	CL		6.46	2.30	4.16	XX							
	5	6	GR	CS		6.35	4.30	2.05	X							
	6	7	GB	SA		6.42	4.40	2.02	X							
	7	8	GB	SA		6.29	2.20	4.09	XX							
	8	9	GR	SA		6.40	3.70	2.70	X							
YA_PASS060_12	0	1				6.10	4.20	1.90								0.01
	1	2				6.40	3.80	2.60								0.01
	2	3				6.33	4.10	2.23								0.01
	3	4				6.17	4.20	1.97								0.02
	4	5				6.07	3.80	2.27								0.01
	5	6				5.94	4.10	1.84								0.01
	6	7				6.07	4.20	1.87								0.01
	7	8				6.15	3.10	3.05								0.01
	8	9				6.43	3.20	3.23								0.01
	9	10				6.42	1.70	4.72								0.95
	10	11				6.55	1.70	4.85								0.16
	11	12				6.63	2.00	4.63								0.14
YA_PASS061_9	0	1				5.00	3.90	1.10								0.01
	1	2				5.48	5.10	0.38								0.01
	2	3				5.65	5.00	0.65								0.01
	3	4				5.66	4.70	0.96								0.01
	4	5				5.93	5.00	0.93								0.01
	5	6				5.95	5.30	0.65								0.01
	6	7				5.95	5.20	0.75								0.01
	7	8				5.97	5.10	0.87								0.01
	8	9				6.04	5.20	0.84								0.01
YA_PASS062_9	0	1				5.99	4.40	1.59								0.01
	1	2				6.47	5.20	1.27								0.01
	2	3				6.39	5.30	1.09								0.01
	3	4				6.33	4.60	1.73								0.01
	4	5				6.37	5.20	1.17								0.01
	5	6				6.30	4.30	2.00								0.01
	6	7				6.28	4.20	2.08								0.01
	7	8				6.26	1.50	4.76								0.27
	8	9				6.80	2.20	4.60								0.22
YA_PASS063_9	0	1	OB	SA		5.19	3.40	1.79	X	5.1	6	0.010	<0.01	0.020	S_{CR} + s-TAA	
	1	2	GB	SC		5.85	4.00	1.85	X	6.2	<1	0.002	<0.01	0.010	S_{CR}	
	2	3	GB	CL		5.78	4.10	1.68	X	5.3	4	0.006	<0.01	0.016	S_{CR} + s-TAA	
	3	4	GR	SC		5.97	2.00	3.97	XXX	5	5	0.008	0.11	0.118	S_{CR} + s-TAA	
	4	5	GR	CL		6.22	2.20	4.02	XX	5.7	1	0.002	0.05	0.050	S_{CR}	
	5	6	GB	CL		6.46	2.50	3.96	XX	5.3	10	0.016	0.03	0.046	S_{CR} + s-TAA	
	6	7	BR	CL		6.55	2.70	3.85	XX	5	15	0.024	0.05	0.074	S_{CR} + s-TAA	
	7	8	GR	CL		6.27	2.80	3.47	XX	5.3	8	0.013	0.24	0.253	S_{CR} + s-TAA	
	8	9	GR	CL		6.27	1.80	4.47	XXXX	5	4	0.006	0.66	0.666	S_{CR} + s-TAA	

SAMPLE LOCATION	SAMPLE INTERVAL		SOIL DESCRIPTION		LAB ID	FIELD TEST RESULTS				CHROMIUM SUITE						LECO
	depth_ from	depth _ to	COLOUR	LITHOLOGY	samp_id	phF	phFOX	pHf - pH fox	Reaction	pHKCl	sTAA	s-TAA	S_{CR}	NET ACIDITY	NA EQUATION	Total Sulfur
					Units						molesH/t	%S	%S	%S		%S
					LOR	0.01	0.01	0.01	-	0.1	1	0.005	0.01	0.01		0.01
					Criteria	≤4	≤3	≥3		<4	18	0.03	0.03	0.03		0.03
YA_PASS064_9	0	1	OB	SA		5.47	3.90	1.57	X							
	1	2	OB	SA		6.27	4.70	1.57	X							
	2	3	OB	IR		6.23	4.50	1.73	X							
	3	4	OB	SA		6.32	2.30	4.02	XX							
	4	5	OB	IR		6.59	2.20	4.39	XX							
	5	6	GR	SC		6.77	3.70	3.07	XX							
	6	7	GR	CL		6.63	2.60	4.03	XX							
	7	8	GR	SY		6.60	2.40	4.20	XXX							
	8	9	GR	SY		6.37	2.10	4.27	XXXX							
YA_PASS065_12	0	1				6.00	3.70	2.30								0.01
	1	2				5.97	4.50	1.47								0.02
	2	3				5.73	4.30	1.43								0.01
	3	4				5.83	4.80	1.03								0.01
	4	5				5.89	4.70	1.19								0.01
	5	6				5.95	4.70	1.25								0.01
	6	7				6.50	2.40	4.10								0.01
	7	8				6.41	2.00	4.41								0.31
	8	9				6.38	2.10	4.28								0.21
	9	10				6.15	3.90	2.25								0.01
	10	11				5.86	4.40	1.46								0.01
	11	12				5.88	3.90	1.98								0.01
YA_PASS066_12	0	1				6.78	5.00	1.78		5.4		0.023	0.01	0.033	S_{CR} + s-TAA	0.06
	1	2				6.55	4.60	1.95		5.2		0.032	0.005	0.037	S_{CR} + s-TAA	0.08
	2	3				6.80	5.40	1.40		5.2		0.033	0.005	0.038	S_{CR} + s-TAA	0.06
	3	4				6.98	6.40	0.58		5.0		0.043	0.005	0.048	S_{CR} + s-TAA	0.04
	4	5				6.80	4.50	2.30		4.9		0.045	0.007	0.052	S_{CR} + s-TAA	0.02
	5	6				6.78	4.80	1.98		4.9		0.051	0.005	0.056	S_{CR} + s-TAA	0.01
	6	7				6.80	4.50	2.30		4.9		0.049	0.005	0.054	S_{CR} + s-TAA	0.01
	7	8				6.83	2.20	4.63		5.4		0.016	0.017	0.033	S_{CR} + s-TAA	0.06
	8	9				6.41	1.90	4.51		5.2		0.036	0.84	0.876	S_{CR} + s-TAA	0.27
	9	10				6.53	1.80	4.73		5.6		<0.01	0.063	0.063	S_{CR} + s-TAA	0.24
	10	11				6.33	2.00	4.33		5.6		<0.01	0.11	0.110	S_{CR} + s-TAA	0.1
	11	12				6.20	1.80	4.40		5.8		<0.01	0.056	0.056	S_{CR} + s-TAA	0.09
YA_PASS067_9	0	1	GB	CS		5.87	3.50	2.37	X							
	1	2	GB	SC		5.58	3.50	2.08	XX							
	2	3	GB	CL		6.11	3.90	2.21	X							
	3	4	GB	CL		5.89	4.00	1.89	XX							
	4	5	YG	CL		5.30	4.50	0.80	XXXX							
	5	6	GR	CL		5.74	1.90	3.84	XXXX							
	6	7	GR	CL		6.03	2.00	4.03	XXXX							
	7	8	GR	CL		6.11	2.20	3.91	XXXX							
	8	9	GR	CL		5.97	2.10	3.87	XXXX							
YA_PASS068_12	0	1				5.65	4.00	1.65		5.5		<0.01	<0.005	0.005	S_{CR}	0.01
	1	2				5.76	5.10	0.66		5.6		<0.01	<0.005	0.005	S_{CR}	0.01
	2	3				6.21	5.40	0.81		5.6		0.011	<0.005	0.005	S_{CR}	0.03
	3	4				6.58	2.90	3.68		5.4		0.013	0.008	0.021	S_{CR} + s-TAA	0.06
	4	5				6.32	4.50	1.82		5.7		<0.01	<0.005	0.005	S_{CR}	0.01
	5	6				6.36	2.10	4.26		5.6		<0.01	0.021	0.021	S_{CR}	0.04
	6	7				6.67	1.80	4.87		5.1		0.027	0.081	0.108	S_{CR} + s-TAA	0.15
	7	8				6.84	2.80	4.04		5.7		<0.01	0.018	0.018	S_{CR}	0.1
	8	9				6.59	3.20	3.39		5.2		0.028	0.024	0.052	S_{CR} + s-TAA	0.04
	9	10				6.58	2.20	4.38		5.0		0.037	0.075	0.112	S_{CR} + s-TAA	0.15
	10	11				6.62	3.10	3.52		5.1		0.032	0.018	0.050	S_{CR} + s-TAA	0.11
	11	12				6.50	2.60	3.90		5.1		0.035	0.033	0.068	S_{CR} + s-TAA	0.12
YA_PASS069_12	0	1				6.23	4.10	2.13								0.01
	1	2				6.13	5.00	1.13								0.03
	2	3				6.04	1.90	4.14								0.42
	3	4				6.18	2.70	3.48								0.05
	4	5				6.20	3.80	2.40								0.01
	5	6				6.23	2.20	4.03								0.02
	6	7				6.21	1.90	4.31								0.23
	7	8				6.62	1.60	5.02								0.22
	8	9				6.42	1.50	4.92								0.16
	9	10				6.38	2.00	4.38								0.24
	10	11				6.68	NA	NA								0.21
	11	12				6.65	NA	NA								0.06
YA_PASS070_12	0	1	OB	CS		5.64	4.20	1.44	X	5.2	3	0.005	0.01	0.015	S_{CR} + s-TAA	
	1	2	CR	CS		6.06	4.30	1.76	X	5.6	1	0.002	<0.01	0.010	S_{CR}	
	2	3	BR	SA		6.06	4.20	1.86	X	5.6	<1	0.002	<0.01	0.010	S_{CR}	
	3	4	GR	CS		5.98	4.20	1.78	X	5.5	1	0.002	<0.01	0.010	S_{CR}	
	4	5	GR	SA		6.23	4.30	1.93	X	5.6	1	0.002	<0.01	0.010	S_{CR}	
	5	6	GR	SA		6.24	4.10	2.14	X	5.6	<1	0.002	<0.01	0.010	S_{CR}	
	6	7	GR	SA		6.55	3.00	3.55	X	5.5	<1	0.002	0.04	0.040	S_{CR}	
	7	8	GR	SA		6.56	1.90	4.66	XXX	5.1	3	0.005	0.17	0.175	S_{CR} + s-TAA	
	8	9	GR	SA		6.35	1.70	4.65	XXXX	4.5	16	0.026	0.44	0.466	S_{CR} + s-TAA	
	9	10	GR	SA		6.25	1.90	4.35	XXXX	4.9	5	0.008	0.28	0.288	S_{CR} + s-TAA	
	10	11	GR	SA		6.32	1.90	4.42	XXXX	4.8	7	0.011	0.15	0.161	S_{CR} + s-TAA	
	11	12	GR	SA		6.24	1.90	4.34	XXXX	4.8	8	0.013	0.22	0.233	S_{CR} + s-TAA	
YA_PASS071_12	0	1	CR	CS		5.84	3.90	1.94	XX							
	1	2	GB	CS		5.94	4.20	1.74	X							
	2	3	GB	CS		6.48	4.60	1.88	XX							
	3	4	GB	CS		6.56	3.50	3.06	XX							
	4	5	GB	SC		6.39	4.40	1.99	XX							
	5	6	GR	CL		6.31	4.20	2.11	X							
	11	12	GR	SC		6.33	1.40	4.93	XXXX							
																* red text = LOR
						pHf	pHfox	Change				s-TAA	Scr	NA		Total S
					max	7.67	7.50	5.86			max	0.083	2.50	2.535		1.19
					min	4.32	1.30	- 1.25			min	0.01	0.01	0.005		0.01
					average	6.34	3.59	2.75			average			0.127		0.11
					Total samples	717	714	714			St Dev			0.30		0.19
					exceed	5	261	297			Ave + St Dev			0.43		0.30
					% exceed		0.37	0.42			Total Samples			221		214
											Exceed			111		128
											% exceed			50.23		59.81

APPENDIX 2: BLAND-ALTMAN ANALYSIS FOR YALYALUP MINERAL SANDS PROJECT DATA

BLAND-ALTMAN ANALYSIS FOR YALYALUP MINERAL SANDS PROJECT (YMS PROJECT) DATA.

ABEC has assessed a batch of drill hole samples for which two methods of sulfur analysis were conducted upon the samples. The purpose of the assessment is to consider the degree of agreement between the methods. The analytical methods are:

- Method A: Net Acidity (%S) calculated by acid-base accounting of Chromium Suite of Analysis (CRS).
    - A method described in the Acid Sulfate Soil Laboratory Methods Guidelines (V2.1) (Ahern, McElnea, & Sullivan, 2004) as appropriate to measure reduced inorganic sulfur compounds in sediments. These compounds that are the constituents of Acid Sulfate Soils (ASS) that are of environmental concern and hence have been measured in soil samples from the YMS Project to assessment and determine management measures for ASS that may be present in soil disturbed during the proposed mining activities.
- Method B: Total Sulfur (S_T) analysis (using the LECO instrument).
    - A low cost, propriety method used routinely by the mineral sands industry for processing and grade control assessment. Measurement of S_T. may be used to estimate the maximum potential environmental risk from acid produced by the oxidation of sulfides (Ahern, McElnea, & Sullivan, 2004).

Method A has been used to conduct an ASS assessment of the YMS Project, in accordance with the WA ASS guidelines [(DER, 2015a) & (DER, 2015b)] and to determine an appropriate 'default treatment rate' for soil excluding topsoil, that is excavated during the project. However, as a significant amount of soil samples will be analysed for T_S during the work, assessment of the degree of agreement between these methods is being undertaken to consider the suitability of use of Method B (S_T) to refine the management of ASS as the Project proceeds. That is, considered the efficacy of the use of T_S to determine 'batch specific' treatment rates as an alternative to use of the default rate.

Bland Altman (BA) analysis of the batch of data has therefore been used to assess the method agreement.

Soil Sample ID and Depth			Method A (A)	Method B (B)	Bland Altman Calculations		
Bore Hole ID	Depth From	Depth To	Net Acidity CRS Suite (%S)	Total Sulfur LECO method (%S)	Mean (A+B)/2 (%S)	(A-B) (%S)	(A-B)/Mean (%)
YA_PASS037_12	7	8	0.013	0.060	0.037	-0.047	-128.767
YA_PASS043_9	1	2	0.015	0.060	0.038	-0.045	-120.000
YA_PASS043_9	2	3	0.015	0.030	0.023	-0.015	-66.667
YA_PASS043_9	5	6	0.015	0.030	0.023	-0.015	-66.667
YA_PASS68_12	7	8	0.018	0.100	0.059	-0.082	-138.983
YA_PASS037_12	8	9	0.019	0.090	0.055	-0.071	-130.275

Soil Sample ID and Depth			Method A (A)	Method B (B)	Bland Altman Calculations		
Bore Hole ID	Depth From	Depth To	Net Acidity CRS Suite (%S)	Total Sulfur LECO method (%S)	Mean (A+B)/2 (%S)	(A-B) (%S)	(A-B)/Mean (%)
YA_PASS043_9	0	1	0.019	0.050	0.035	-0.031	-89.855
YA_PASS55_9	2	3	0.019	0.020	0.020	-0.001	-5.128
YA_PASS55_9	4	5	0.019	0.020	0.020	-0.001	-5.128
YA_PASS037_12	0	1	0.020	0.060	0.040	-0.040	-100.000
YA_PASS68_12	3	4	0.021	0.060	0.041	-0.039	-96.296
YA_PASS037_12	2	3	0.021	0.050	0.036	-0.029	-81.690
YA_PASS68_12	5	6	0.021	0.040	0.031	-0.019	-62.295
YA_PASS043_9	4	5	0.022	0.010	0.016	0.012	75.000
YA_PASS45_12	5	6	0.025	0.040	0.033	-0.015	-46.154
YA_PASS45_12	3	4	0.029	0.050	0.040	-0.021	-53.165
YA_PASS037_12	3	4	0.029	0.060	0.045	-0.031	-69.663
YA_PASS56_12	2	3	0.030	0.010	0.020	0.020	100.000
YA_PASS066_12	0	1	0.033	0.060	0.047	-0.027	-58.065
YA_PASS066_12	7	8	0.033	0.060	0.047	-0.027	-58.065
YA_PASS56_12	3	4	0.035	0.020	0.028	0.015	54.545
YA_PASS56_12	4	5	0.035	0.020	0.028	0.015	54.545
YA_PASS066_12	1	2	0.037	0.080	0.059	-0.043	-73.504
YA_PASS066_12	2	3	0.038	0.060	0.049	-0.022	-44.898
YA_PASS066_12	3	4	0.048	0.040	0.044	0.008	18.182
YA_PASS68_12	10	11	0.050	0.110	0.080	-0.060	-75.000
YA_PASS066_12	4	5	0.052	0.020	0.036	0.032	88.889
YA_PASS68_12	8	9	0.052	0.040	0.046	0.012	26.087
YA_PASS45_12	4	5	0.053	0.040	0.047	0.013	27.957
YA_PASS066_12	6	7	0.054	0.010	0.032	0.044	137.500
YA_PASS066_12	11	12	0.056	0.090	0.073	-0.034	-46.575
YA_PASS45_12	7	8	0.062	0.100	0.081	-0.038	-46.914

Soil Sample ID and Depth			Method A (A)	Method B (B)	Bland Altman Calculations		
Bore Hole ID	Depth From	Depth To	Net Acidity CRS Suite (%S)	Total Sulfur LECO method (%S)	Mean (A+B)/2 (%S)	(A-B) (%S)	(A-B)/Mean (%)
YA_PASS066_12	9	10	0.063	0.240	0.152	-0.177	-116.832
YA_PASS55_9	1	2	0.065	0.020	0.043	0.045	105.882
YA_PASS68_12	11	12	0.068	0.120	0.094	-0.052	-55.319
YA_PASS45_12	10	11	0.084	0.200	0.142	-0.116	-81.690
YA_PASS56_12	11	12	0.088	0.280	0.184	-0.192	-104.348
YA_PASS043_9	7	8	0.100	0.100	0.100	0.000	0.000
YA_PASS68_12	6	7	0.108	0.150	0.129	-0.042	-32.558
YA_PASS066_12	10	11	0.110	0.100	0.105	0.010	9.524
YA_PASS68_12	9	10	0.112	0.150	0.131	-0.038	-29.008
YA_PASS037_12	9	10	0.150	0.160	0.155	-0.010	-6.452
YA_PASS037_12	10	11	0.150	0.420	0.285	-0.270	-94.737
YA_PASS45_12	9	10	0.164	0.380	0.272	-0.216	-79.412
YA_PASS45_12	8	9	0.200	0.300	0.250	-0.100	-40.000
YA_PASS56_12	9	10	0.230	0.090	0.160	0.140	87.500
YA_PASS56_12	10	11	0.240	0.300	0.270	-0.060	-22.222
YA_PASS45_12	11	12	0.364	0.650	0.507	-0.286	-56.410
YA_PASS037_12	11	12	0.380	0.690	0.535	-0.310	-57.944
YA_PASS55_9	8	9	0.503	0.670	0.587	-0.167	-28.474
YA_PASS043_9	8	9	0.575	0.170	0.373	0.405	108.725
YA_PASS066_12	8	9	0.876	0.270	0.573	0.606	105.759

Summary Statistics	Method A (A)	Method B (B)	Bland Altman Calculations		
	Net Acidity CRS Suite (%S)	Total Sulfur LECO method (%S)	Mean (A+B)/2 (%S)	(A-B) (%S)	(A-B)/Mean (%)
Count (N)	52.000	52.000	52.000	52.000	52.000
Mean	0.108	0.136	0.122	-0.027	-28.251
St Dev	0.163	0.165	0.148	0.139	71.353
Mean + St dev	0.271	0.300	0.270	0.111	43.102
Mean - St Dev	-0.054	-0.029	-0.026	-0.166	-99.604

A summary interpretation of this data is that, due to the negative values of the mean of A-B, it can be said that on average Method B measures 0.027%S more than Method A or, 28%. In order to consider the limits of agreements, data normality was considered as shown in the following charts and notes.

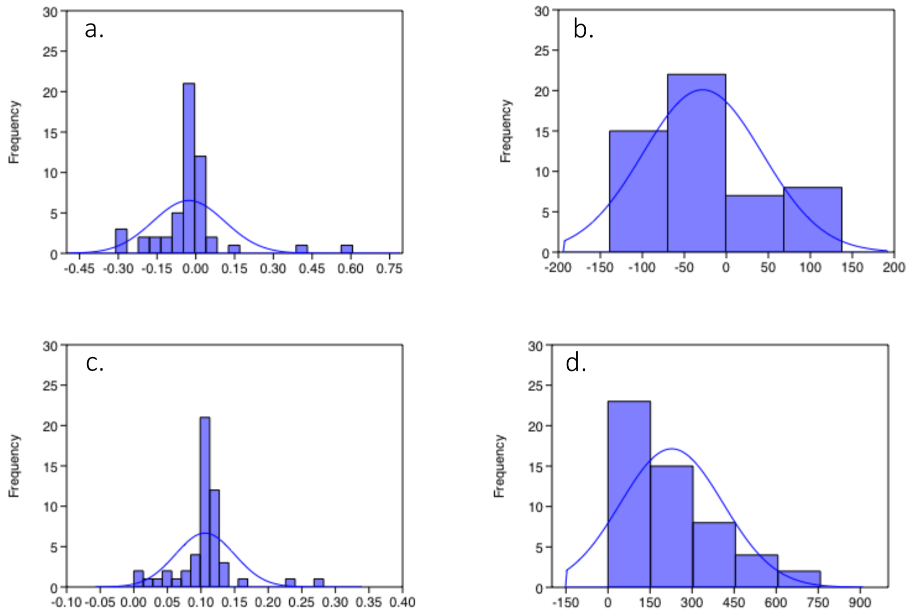

Figure 1. Normality histogram plots of the difference between methods A and B a. A-B data; b. (A-B) / mean %; c. Log ((A-B)+1.31) and d. Log (A-B +1.31)/Mean (%); *n*=52.

Notes:

1. The Shapiro-Wilk test for normal distribution indicate that the data are not normally distributed as the probability values are greater than $p>0.05$ ((A-B) 0.7362, $p= 2.534 \times 10^{-8}$ and for (A-B) / mean %; (0.9313, $p=0.005$)).
2. Skewness test (and visual inspection of the histogram (Fig 1) indicates the data are skewed-right (a. Skewness=2.053; b. Skewness=0.6973; Table 1).
3. Therefore, a Box Cox transformation on the **(A-B) / mean %** data was performed (where constant of 139.983 included, lambda = 20.523 and log likelihood = -216.982).

4. Shapiro-Wilk test on the transformed data confirmed normality (0.97787 p=0.4354; Fig 2 and Table 1).

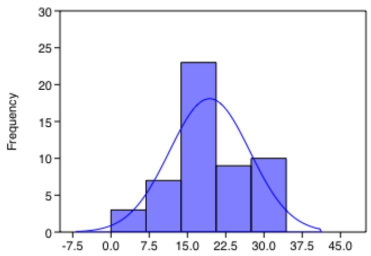

Fig 2. Normality histogram for Box Cox transformed (A-B) / mean % data.

5. The limits of agreement can be defined using the standard deviation s = 7.879 of the transformed data (Table 1) as follows:

Table 1. Summary statistical output of the untransformed data and logarithmic transformed data for method A and B. Note a constant of the minimum value (-1.31) was added prior to the log transformation to handle the negative data points.

Statistics	A-B	(A-B)/Mean (%)	Log ((A-B)+1.31)	Log (A-B +1.31)/Mean (%)	BoxCox (A-B)/Mean (%)
N	52	52	52	52	52
Min	-0.31	-138.9831	0	0	0
Max	0.606	137.5	0.2823955	757.7	34.35826
Sum	-1.412	-1469.063	5.507668	11829.74	1006.11
Mean	-0.02715385	-28.25121	0.1059167	227.495	19.34627
Std. error	0.01921274	9.8949	0.006085164	25.43972	1.092575
Variance	0.01919472	5091.27	0.001925519	33653.31	62.07343
Stand. dev	0.138545	71.35314	0.04388074	183.4484	7.878669
Median	-0.028	-46.74446	0.1078879	228.535	18.58886
25 prcntil	-0.058	-78.30882	0.09760267	75.0725	14.6009
75 prcntil	0.0095	16.01732	0.1204093	310.28	24.92146
Skewness	2.052653	0.6973285	1.041735	0.8858376	-0.066772
Kurtosis	9.615983	-0.3942242	6.147841	0.3470038	-0.235540
Geom. mean	0	0	0	0	0
Coeff. Var	-510.2224	-252.5667	41.42949	80.63843	40.72028
Shapiro-Wilk test	0.7362	0.9313	0.7932	0.9221	0.97787
p	2.534×10^{-8}	0.005	4.14×10^{-7}	0.002241	0.4354

Table 2. Limits of agreement for method A and B using Box-Cox transformed (A-B / mean %) data.

Lower	Upper
Mean difference – 1.96 *s*	Mean difference + 1.96 *s*
= -19.34627 – (1.96 x 7.878669)	= -19.34627 + (1.96 x 7.878669)
= -34.78846	= -3.9040788

Conclusion

Method B (S_T) measures 0.027% more than %S than is determined by Method A (Net acidity derived via CRS).

END

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