MINE EARTH

The mine closure specialists

IMAGE RESOURCES

ATLAS PROJECT SOIL, OVERBURDEN AND TAILINGS ASSESSMENT

May 2022

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EXECUTIVE SUMMARY

Mine Earth was commissioned by Image Resources to complete a soil, overburden and tailings assessment for the Atlas Project (the Project). The Project is located approximately 18 kilometres (km) east of Cervantes in the Shire of Dandaragan, Western Australia (WA). The study area encompassed a total area of approximately 950 hectares (ha).

The aim of the assessment was to characterise the existing surface soil materials (topsoil and subsoil materials to approximately 1.5m depth) within the study area, to identify available soil resources and potentially problematic soils materials, and to develop associated recommendations for the recovery and stockpiling of soil resources and for their use in rehabilitation and mine closure activities. An assessment of the physical and chemical characteristics of the overburden (i.e. deeper soils below 1.5m, but above the ore zone) and tailings materials to be generated during mining operations, was also conducted.

Surface Soil Characteristics

The physical and chemical characteristics of surface soil materials were assessed from 22 representative locations within the study area, which were sampled to a maximum depth of approximately 1.5 m. Three soil-landform associations were identified within the study area, namely 'Low sandy rises', 'Sandy plains' and 'Drainage lines / flats'.

There was a wide range of physical and chemical surface soil characteristics measured across the study area, however, the characteristics were generally consistent with position within the landscape and soil-landform association.

The characteristics of soils present within the three soil-landform associations are summarised as follows (Table ES1):

- Low sandy rises:
    - Deep, single-grained, structureless sands to depths >1.5m.
    - Consistently non-saline, non-sodic and non-dispersive soils to >1.5m depth, with low nutrient status, low soil strength, 'very rapid' drainage class and low water holding capacity.
    - Topsoils (0-0.2m) characterised as 'moderately' to 'severely' water repellent.
    - Concentrations of all metals tested below the average crustal abundance.
- Sandy plains:
    - Single grained, structureless sandy soils (to variable depths of 0.6 to 1.3m) over weakly structured clayey sand horizon.
    - Consistently non-dispersive sandy soils to variable depths of 0.6 to 1.3m, with low nutrient status, low soil strength, 'very rapid' drainage class and low water holding capacity.
    - Increased salinity at depths of 0.4 to 1.5m at some sampling locations.
    - Topsoils (0-0.2m) characterised as 'Very low' to 'severely' water repellent.
    - Minor elevations of Se above the average crustal abundance at some locations, throughout the soil profiles.
- Drainage line / flats:

- Single grained, structureless sandy soils (to average depth of 0.5m) over massive light clay horizons.
- Consistently non-dispersive sandy soils to approximately 0.5m, with low to moderate nutrient status, low soil strength, very rapid drainage class and low water holding capacity.
- Moderately saline, topsoil and subsoils classified as highly sodic, with minor dispersion of clay fraction upon saturation of some samples, low to moderate nutrient status, moderately slow drainage class and moderate water holding capacity.
- Topsoils (0-0.2m) characterised as 'Very low' to 'Moderately' water repellent.
- Minor elevations of Se above the average crustal abundance within the surface soils (to 0.5m depth) at some locations.
- Clay-rich subsoil horizons exhibited elevated salinity, sodicity and poor structural stability (clay dispersion), 'extremely slow' drainage class and high water holding capacity.
- Elevations of As, Pb and Se above the average crustal abundance within the clay-rich subsoils at some locations.

Overburden and Tailings Characteristics

The characteristics of overburden and tailings materials expected to be generated from mining activities are summarised as follows (Table ES1):

- Overburden characteristics:
  - Variable soil textures, ranging from single grained, structureless sands, to sandy clays with up to 40% clay fraction. Substantial variability within individual profiles and across the study area, but general trend of higher clay fractions in overburden from lower in the landscape.
  - Variable soil pH, with little correlation with landscape position. Variable salinity with trend of higher salinity in overburden materials from lower in the landscape.
  - Generally low organic matter and plant-available nutrient concentrations.
  - Variable sodicity, structural stability, soil strength and hydraulic conductivity, generally correlating to the clay content of the overburden materials. Overburden materials with higher clay contents generally exhibited poor structural stability, high soil strength and low hydraulic conductivity.
  - Minor elevations of As and Zn above the average crustal abundance within some overburden samples.
- Tailings characteristics (clay fines and sand fractions):
  - Tailings clay fines characterised as a 'heavy clay', with neutral pH, 'moderate' salinity classification, low to moderate nutrient concentration, poor structural stability (sodic and dispersive), high soil strength upon drying and an 'extremely slow' drainage characteristics. Minor elevation in As concentration above the average crustal abundance (similar to some subsoil / overburden concentrations).
  - Tailings sand fraction characterised as 'sand', with neutral pH, non-saline, low nutrient concentration, low soil strength and a 'very rapid' drainage classification. Concentrations of all metals below the ACA.

Soil and Mine Waste Management Recommendations

It is recommended that topsoil materials from all disturbance areas are salvaged to a depth of approximately 0.2m and stockpiled as a surface rehabilitation resource. Due to the differences in vegetation (and soil seed store) present lower in the landscape, topsoils from the 'Drainage lines / flats' soil-landform association should be stockpiled separately from the 'Low sandy rise' and 'Sandy plain' topsoils, for surface application in 'low areas' of the reconstructed landscape post mining.

Sandy subsoils from 0.2 to a minimum of 0.5m depth across all soil-landform associations should be salvaged for placement as a subsoil material in reconstructed soil profiles.

Clay-rich subsoils from depths from 0.5m in the 'Drainage lines / flats', and where present in the 'Sandy plain' profiles should not be placed at the surface of reconstructed soils profiles. All clay-rich subsoil / overburden material should be placed below the topsoil and sandy subsoil materials (at depths below 0.5m) in reconstructed soil profiles.

Tailings materials, in particular the tailings clay fines, which have potentially deleterious physical characteristics if placed at the surface, should be returned to the mining void, below the salvaged subsoil and topsoil materials.

The sandy, water repellent nature of the topsoils within the study area indicates that wind erosion and surface water infiltration may be an issue in the early stages of rehabilitation, prior to vegetation establishment. Specific topsoil management and surface rehabilitation recommendations which can optimise the success of rehabilitation activities are as follows:

- Vegetation debris should be collected, stockpiled and returned to the final rehabilitated soil surface.
- Any surface litter present at the surface should be collected and stockpiled with the topsoil.
- Soil stripping should occur as close as possible to the time when the proposed disturbance is scheduled to commence. Direct return of topsoil / subsoil materials to reconstructed soil profiles where possible.
- Application of surface treatments (e.g. scarification, to 'roughen' the soil surface) to promote the infiltration of rainfall into the soil surface.

Further detail pertaining to the management of soil, overburden and tailings materials during operations and at closure for the Project is provided within the Atlas Mineral Sands – Soil and Mine Waste Management Plan (Mine Earth, 2022b).

Table ES1 Summary of physical and chemical characteristics of topsoil, subsoil and overburden (grouped into soil-landform associations) within the study, area and tailings sand / clay fines fractions. The figures / classifications represent average values with broad ratings of good, moderate and poor for each parameter relative to suitability for plant growth and/or utilisation as a surface rehabilitation resource.

Soil-landform association	Depth (cm)	Soil Texture [1.]	Clay content [2.]	Soil pH (H_2O) [3.]	Salinity (dS/m) [3.]	Plant-available nutrients [4.]	Structural stability [5.]	Water repellence [6.]	Soil strength	Drainage class [7.]	Water retention [7.]	Total metals [8.]
Low sandy rises	Topsoils (0 to 0.2m)	Sand	1 – 3%	6.3 – 7.5	0.01 – 0.04	Low	Good	Moderate to Severe	Low	Very rapid	Low	Minor elevation in Se above ACA for some samples
Sandy plains		Sand	1 – 4%	6.0 – 8.1	0.01 – 0.11	Low	Good	Very low to severe	Low	Very rapid	Low	Minor elevation in Se above ACA for some samples
Drainage lines / flats		Sand	3 – 4%	6.0 – 9.4	0.01 – 0.23	Low to moderate	Good	Very low to moderate	Low	Very rapid	Low	Minor elevation in Se above ACA for some samples
Low sandy rises	Subsoils (0.2 to 0.5m)	Sand	1 – 3%	6.5 – 7.3	0.01	Low	Good	Not significant	Low	Very rapid	Low	Minor elevation in Se above ACA for some samples
Sandy plains		Sand	1 – 3%	6.4 – 8.5	0.01 – 0.97	Low	Good	Not significant	Low	Very rapid	Low	Minor elevation in Se above ACA for some samples
Drainage lines / flats		Sand	2 – 4%	6.8 – 9.4	0.01 – 0.04	Low	Good	Not significant	Low	Very rapid	Low	Minor elevation in Se above ACA for some samples
Low sandy rises	Subsoils (0.5 to 1.5m)	Sand	1 – 3%	6.3 – 6.6	0.01	Low	Good	Not significant	Low	Very rapid	Low	Minor elevation in Se above ACA for some samples
Sandy plains		Sand to Clayey sand	2 – 8%	6.4 – 9.3	0.01 – 2.06	Low to moderate	Moderate	Not significant	Low	Very rapid to Moderate	Moderate	Minor elevation in Se above ACA for some samples
Drainage lines / flats		Sand to Light clay	3 – 34%	6.5 -10.0	0.10 – 2.52	Low to moderate	Poor	Not significant	High	Extremely slow	High	Minor elevation in As, Pb and Se above ACA for some samples
Low sandy rises	Overburden (1.5 to 3m)[9.]	Sand to clayey sand	1 – 5%	6.8 – 7.2	<0.01 – 0.02	Low	Good	Not significant	Low	Very rapid	-	Minor elevations of As and Zn above ACA for some samples
Sandy plains		Sand to sandy clay	3 – 30%	4.4 – 9.4	0.05 – 1.13	Low	Moderate	Not significant	Moderate to high	Moderate to Very rapid	-	Minor elevations of As above ACA for some samples
Drainage lines / flats		Clayey sand to sandy clay	30 – 40%	6.6 – 8.5	0.92 – 3.88	Low to moderate	Poor	Not significant	High	Slow to Moderately slow	-	Minor elevations of As above ACA for some samples
Tailings clay fines	-	Heavy clay	>99%	7.8	0.90	Low to moderate	Poor	Not significant	High	Extremely slow	-	Minor elevation of As above ACA
Tailings sand	-	Sand	<1%	6.9	0.037	Low	Good	Not significant	Low	Very rapid	-	All metal concentrations below ACA

1. Range of soil texture classifications of soil sized fraction (<2 mm).
2. Range in % clay of soil sized fraction.
3. Range of soil pH (H_2O) and electrical conductivity values.
4. Overall rating of plant-available soil nutrient (N, P, K and S). Ratings based on measured soil nutrient status of analogue soils and likely native vegetation requirements.
5. Overall structural stability / potential for clay dispersion, based upon ESP, Emerson Aggregate Test and % clay.
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1 INTRODUCTION

1.1 Project background

Image Resources (Image) are proposing to develop the Atlas Project (the Project), located approximately 18 km east of Cervantes in the Shire of Dandaragan. An assessment of the physical and chemical properties of surface soil, overburden and tailings materials is required to support the environmental impact assessment processes required as part of the *Environmental Protection Act 1986* (EP Act) and the *Mining Act 1978* (WA). The aim of the characterisation program was to identify materials with deleterious or beneficial properties so that appropriate soil and overburden management, soil profile reconstruction and surface rehabilitation recommendations can be implemented.

The proposed mining operations will comprise dewatering and excavation to a maximum depth of approximately 16 m (depth variable). The mine pit will be progressively backfilled and rehabilitated. The location of the mine development envelope is provided in Figure 1.

1.2 Objectives

The objective of the assessment was to characterise the existing surface soil (topsoil) and subsoil materials within the study area, to identify available soil resources and potentially problematic soil materials, and to facilitate associated recommendations for the recovery and stockpiling of soil resources and for their use in rehabilitation and mine closure activities. The study area for the baseline soil assessment encompassed a total area of approximately 950 ha.

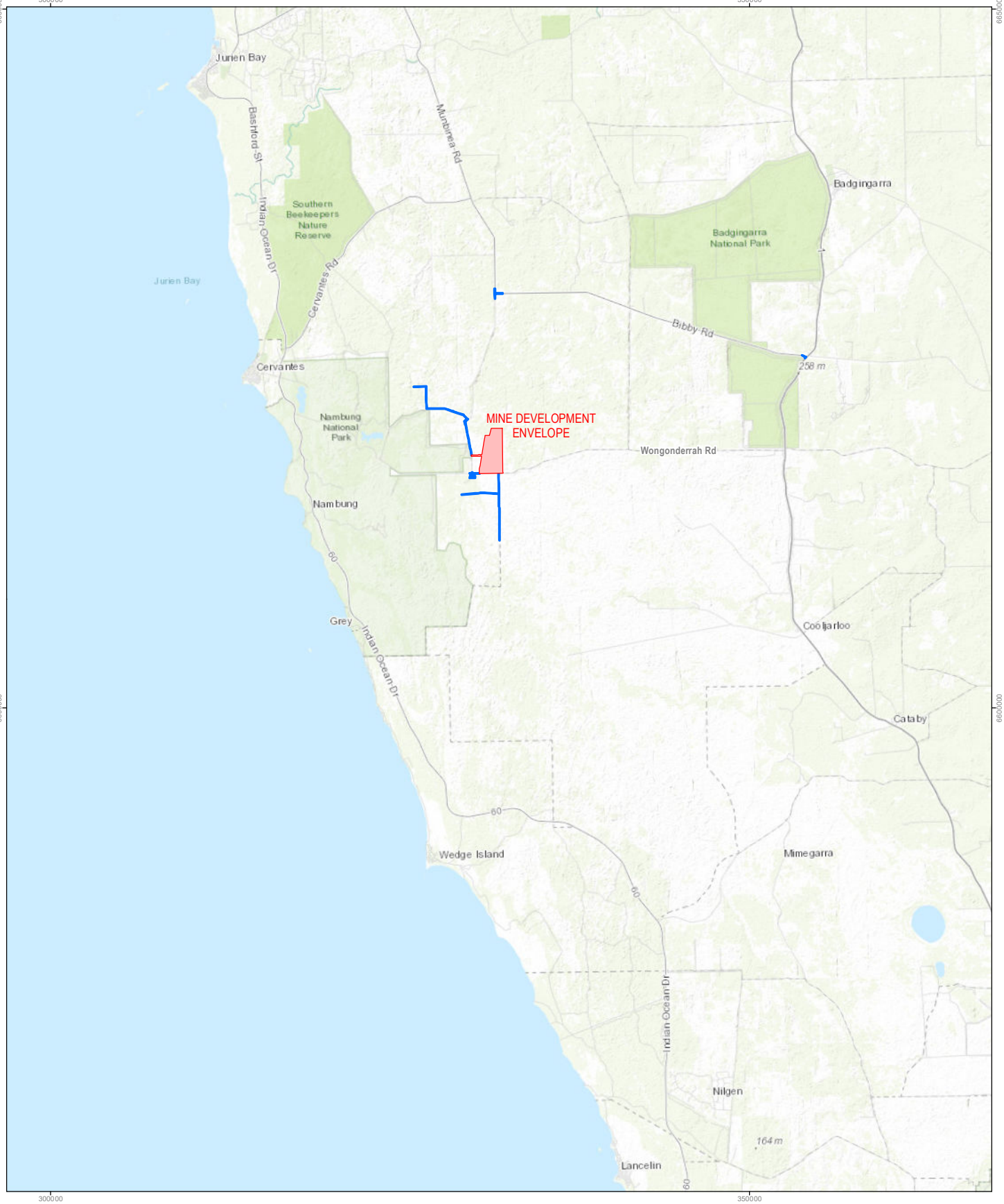
Physical and chemical characterisation of overburden (i.e. deeper soils below subsoil horizons and above the ore zone) and tailings (tailings clay fines and tailings sand fractions) to be returned to the mining void, is also included in this report.

This report includes:

- A review of relevant site information, topography, land system and regional soil information.
- A description of the materials and methods used for sample collection and analysis.
- Surface soil profile descriptions from within the study area.
- A description of topsoil/subsoil, overburden and tailings physical characteristics including surface soil profile morphology, soil texture, soil structure, structural stability, water repellence, soil strength, hydraulic conductivity and water holding capacity.
- A description of topsoil/subsoil, overburden and tailings chemical characteristics including pH, electrical conductivity, organic matter, exchangeable cations, exchangeable sodium percentage, plant-available nutrients and total metal concentrations.
- Mapping of the soil-landform associations within the study area.
- Implications for soil and mine waste management, based upon the characteristics of the materials assessed, and associated recommendations for topsoil stripping, handling and placement as a rehabilitation resource.

An acid-sulphate soil (ASS) assessment for the Project was also conducted. Details of the ASS investigation are provided in the *Atlas Mineral Sands – Acid Sulphate Soil Investigation and Management Plan* (Mine Earth, 2022a).

Further detail pertaining to the management of soil, overburden and tailings materials during operations and at closure for the Project is provided within the *Atlas Mineral Sands – Soil and Mine Waste Management Plan* (Mine Earth, 2022b).



Preston Consulting

CREATED	JOB	DATE	REVISION
ENVIRONMAPS	PC2900270	3/06/2022	0

Image Resources

Figure 1

Regional Location of the Atlas Mineral Sands Project

0 2 4 8
km
Scale: 1:375,000 @ A4

N

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

LOCALITY

Legend

- Mine Development Envelope
- External Infrastructure Development Envelope

Source: Open Street Map

ENVIRONMAPS Environmental Mapping Solutions | t 0406 590 006 | www.environmaps.com.au

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2 DESCRIPTION OF STUDY AREA

A description of the existing environment within the study area is provided in this section under the following headings: climate, geology, land systems and regional soil information.

2.1 Climate

The climate of the study area is temperate Mediterranean, characterised by cool winters and hot summers. The nearest long term weather station is at Jurien Bay, approximately 33km north. Rainfall averages in the order of 540mm per annum and is predominantly received between April and October. Mean daily temperatures range from around 31°C in February to 20°C in July. Jurien Bay is situated on the coast, which has a moderating effect on climate, with temperature ranges at the Atlas project therefore expected to exceed those experienced at Jurien Bay.

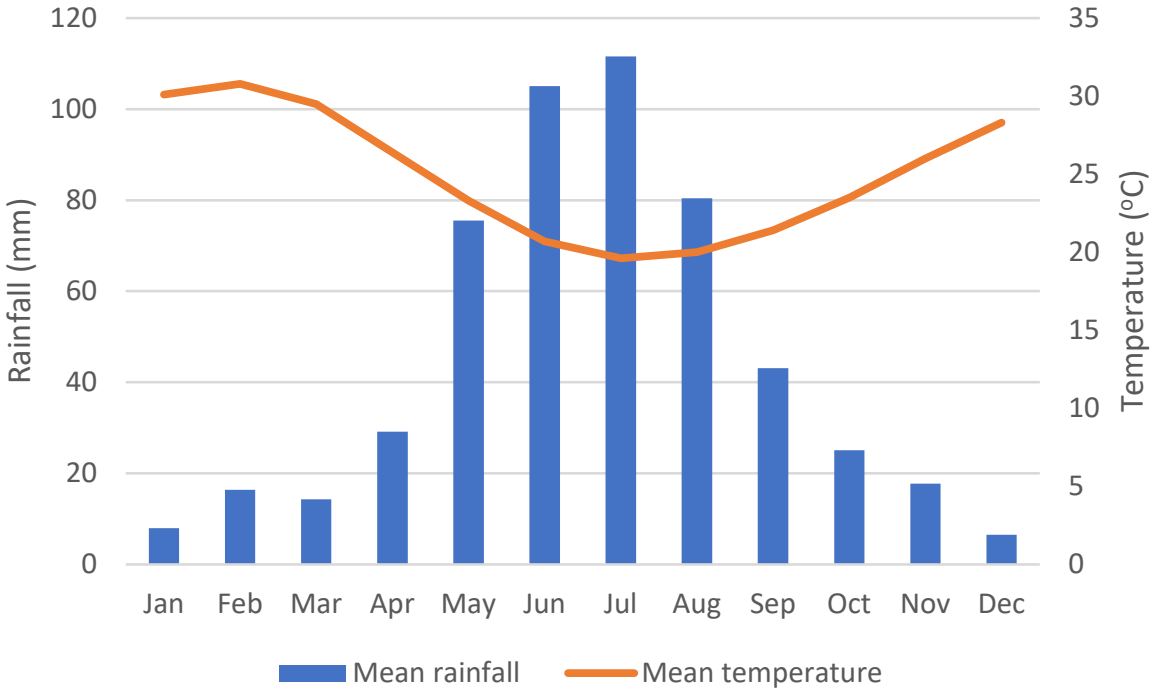


Figure 2 Mean monthly rainfall and mean monthly temperature for the Jurien Bay weather station, 1969 to 2021 (BOM, 2021).

2.2 Geology and stratigraphy

The Project is located within the northern Swan Coastal Plain (SCP), west of the Gingin Scarp on flat-lying to gently west sloping and westerly draining terrain. The Atlas deposit is situated within surficial marine sediments eroded into Cretaceous basal sediments during the Pleistocene marine transgressions. The deposit is formed in generally fine to medium, well sorted sands and clayey sands (Image Resources, 2017).

Mineralisation has been classified as ≥2% heavy mineral (HM) content. This mineralisation often starts at the surface but can be up to 16 m deep. The deposit is oxidised to the base of the mineralisation, predominantly comprised of pale deep Bassendean sands with minor components of yellow deep sand, gravelly sands, sandy duplexes and wet soils (Image Resources, 2017). Where there is a thick clay

base, the underlying grey to black coloured sediments are often less oxidised to reducing. Two zones of iron oxide induration are present in the stratigraphy. The first is located on the contact with the basal Cretaceous sediments (basement) and the second occurs as a layer above the mineralisation, where it is covered by later sands. The formation of iron cementation at two levels in the deposit suggests that water table and redox conditions have varied throughout the sequence. The basement units are predominantly very fine to granular or pebbly, poorly sorted sands and clayey sands. Occasional silt and clay units are also intersected on the edges of the deposit, most likely reflective of facies changes in the underlying Yarragadee Formation and other Jurassic units. (Image Resources, 2017).

2.3 Regional soils and land systems

Regional soil system information indicates that the study area is predominantly comprised of pale deep Bassendean sands with minor components of yellow deep sand, gravelly sands, sandy duplexes and wet soils (Lowry, 1974; Department of Agriculture and Food (DAF), 2012). Five Bassendean 'sub-systems' are present within the study area (Table 1).

Regional DAF (2012) mapping of the area indicates that the soils within the study area may be prone to waterlogging and have a potentially high risk of wind erosion.

Table 1 Bassendean sub-systems present within the study area.

Land system / sub-system	Description
Bassendean 1 Subsystem	Undulating to flat sandplain, with minor low dunes and swampy depressions on unconsolidated sand, aeolian and alluvial in the Coastal plain north of Perth inland from coastal limestone. Pale deep sand dominate; minor areas of yellow deep sand, gravelly sands, sandy duplexes and wet soil. Banksia woodland; heathland or melaleuca scrub in wetter areas.
Bassendean 4 Subsystem	Plain, often poorly drained and with numerous closed depressions on unconsolidated sand, aeolian and alluvial in the Site. Semi-wet soil, grey deep sandy duplex and deep sands, usually pale. Heath of melaleucas with occasional woodland of eucalypts and banksias.
Bassendean 5 Subsystem	Complex pattern of dunes or low sandy rises, poorly drained plains, saline depressions and swamps in the Site. Pale deep sands on rises, semi-wet to wet soils and grey sandy duplexes on flats.
Bassendean 6 Subsystem	Seasonally wet plain and depressions, often saline. Wet or waterlogged soils and grey sandy duplexes; pale deep sands on isolated low rises. Salt tolerant vegetation or salt pans devoid of vegetation.
Bassendean 9 Subsystem	Permanent or semi-permanent swamps. Wet soils.

2.4 Topography

Topography of the study area is subdued and undulating. The land slopes marginally to the west and varies in elevation between 37m AHD and 48m AHD. The undulating topography is due to the movement of sand, low dune formation and dune system blowouts (Shire of Dandaragan, 2011).

2.5 Surface water

The study area is within the catchment of the Nambung River, which feeds into the Nambung National Park. Mount Jetty Creek and Bibby Creeks are ephemeral watercourses that flow to the north of the Project area and form the Nambung River to the west of the Project. Runoff rates are very low and local runoff is mostly retained in seasonal swales and ponds. The high water table gives rise to numerous wetlands and damplands within the study area. These geomorphic wetlands have been mapped but not allocated to a wetland evaluation category (Preston Consulting, 2020).

2.6 Groundwater

The water table across the Project area occurs between 2m and 8m below ground level. The groundwater formations within the Project area include the Superficial Aquifer and the Yarragadee Aquifer, both of which are unconfined (MWES, 2022). Downgradient of the Project areas is the Tamala Limestone, which sits beneath the Nambung National Park. The hydraulic connection between the Superficial aquifer, Yarragadee and Tamala Limestone is considered high (Image Resources, 2017). The Project will require dewatering prior to mining. Groundwater modelling indicates that the predicted drawdown cone extends a maximum of approximately 1.3 km from the edge of the deposit (without mitigation), but will not impact private bores, farm soaks, natural springs or the Nambung National Park (MWES, 2022). Further modelling is currently being undertaken to identify the influence of groundwater drawdown mitigation measures.

2.7 Vegetation and flora

The northern part of the study area has been cleared and is used for cattle grazing. Native vegetation on the southern part of the study area is characterised as Banksia Low Woodland with numerous swampy patches of heath vegetation. Seven broad vegetation groups have been identified within Project area (Morgan, 2022):

(i) Terrestrial vegetation:

- *Banksia* low woodlands on plains and low rises
- *Other terrestrial vegetation*

(ii) Wetland and associated vegetation:

- Heaths fringing the floodplains and in depressions on the sandplain: *Banksia telmatiaea-Regelia ciliata* Heathlands, *Callitris pyramidalis* Tall Shrublands and *Melaleuca seriata* Low Heathlands that grew on the broad gentle slopes surrounding the floodplain and also in small depressions on the sand plain
- Floodplain vegetation that included samphire Low Open Shrublands, *Melaleuca* Shrublands that grew on the fringes of the floodplain and vegetation of sumplands
- Flowline, Dampland and associated vegetation: *Melaleuca* spp. Tall Shrublands on a few dampland flats and associated fringing vegetation and *Melaleuca* spp. Tall Shrublands that grew along flowlines crossing the floodplain

Vegetation has been classified as being in ‘Excellent to Pristine’ condition with a negligible weed burden, with the exception of some of the dampland areas, with condition recorded as ‘Completely Degraded’ (Morgan, 2022).

3 MATERIALS AND METHODS

3.1 Sampling

Soil samples were collected by Mine Earth personnel from 22 sites within the study area in March 2021 (Figure 3). Soil profile descriptions and sampling was facilitated by a backhoe (at 19 sites) or collected by hand in areas where access was restricted (3 sites). Samples were taken from three to five depth intervals at each soil sampling site, depending upon the near-surface soil profile morphology and depth of excavation possible.

Field based observations made during the sampling program included a description of soil surface characteristics, soil profile morphology, vegetation assemblage present and the surface drainage characteristics of each soil sampling site, as per the Australian Soil and Land Survey guidelines (CSIRO, 2009). Soil pits were back-filled immediately after sampling.

Samples of deeper overburden soil materials were sourced from the 2021 Acid sulphate soil sampling and analysis program (Mine Earth, 2022a). The location of overburden samples assessed as part of this investigation are detailed in Figure 4.

Representative samples of tailings fines and tailings sand fractions were supplied by Image Resources.

3.2 Laboratory Analysis

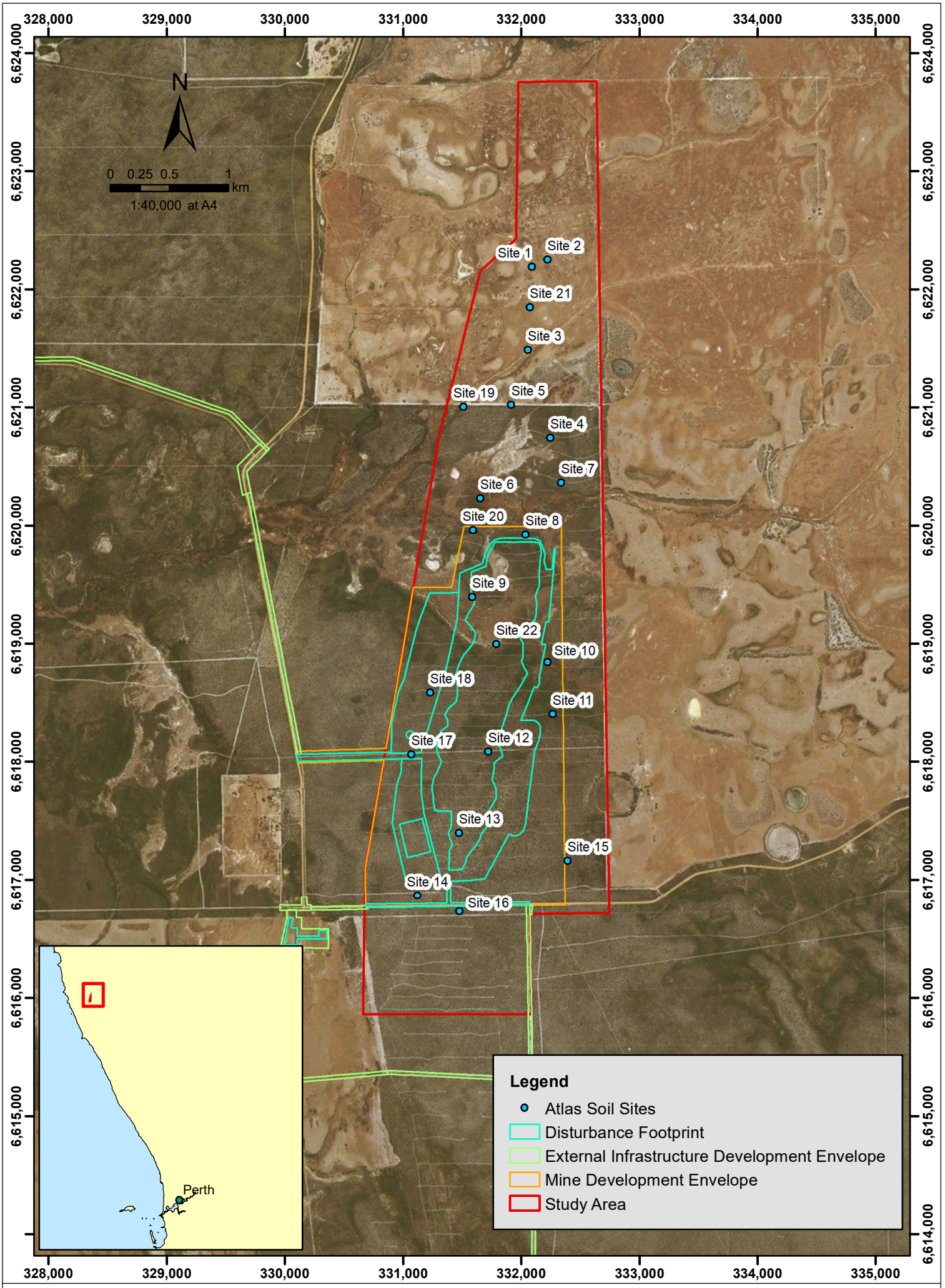
The objective of the laboratory analysis program was to characterise the physical and chemical properties of topsoil, subsoil, overburden and tailings that may influence their management during mining operations and at mine closure. The identification of physical and chemical soil characteristics facilitates delineation of soils into Soil Management Units (SMUs) against which management decisions (soil stripping, stockpiling and use as a rehabilitation resource) can be based. Chemical analyses of baseline conditions also provide an indication of potential impact with respect to saline, sodic or metalliferous properties of the soil materials present.

The soil physical and chemical characteristics assessed provide an indication of the susceptibility of a soil to erosion, the ability to support vegetation growth and baseline values for potentially problematic characteristics. The following physical and chemical analysis were conducted on selected samples of topsoil, subsoil, overburden from the study area, and representative tailings materials supplied by Image Resources:

- Physical soil analyses:
    - Soil texture and particle size distribution (including coarse rock fraction >2mm).
    - Emerson Aggregate Test to indicate soil structural stability and potential for clay dispersion upon saturation.
    - Water retention characteristics (field capacity).
    - Saturated hydraulic conductivity.
    - Soil strength (modified Modulus of Rupture).
    - Soil water repellence.
- Chemical soil analyses:
    - pH and electrical conductivity.
    - Effective cation exchange capacity and exchangeable sodium percentage (ESP).

- Total organic carbon (to indicate organic matter content).
- Plant-available nutrients (N, P K, S).
- Total metal concentrations.

All soil test work procedures were conducted in accordance with standard analytical procedures to assess potential soil physical and chemical characteristics related to the support of plant growth and use as a rehabilitation medium (Rayment, 2011). Descriptions of relevant soil classification categories are detailed in Appendix A. All external laboratory results for the surface soil, overburden and tailings samples are provided in Appendix B.



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Date: 9/06/2022
Author: Julia Heide

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Figure 3

Surface Soil Sampling Locations

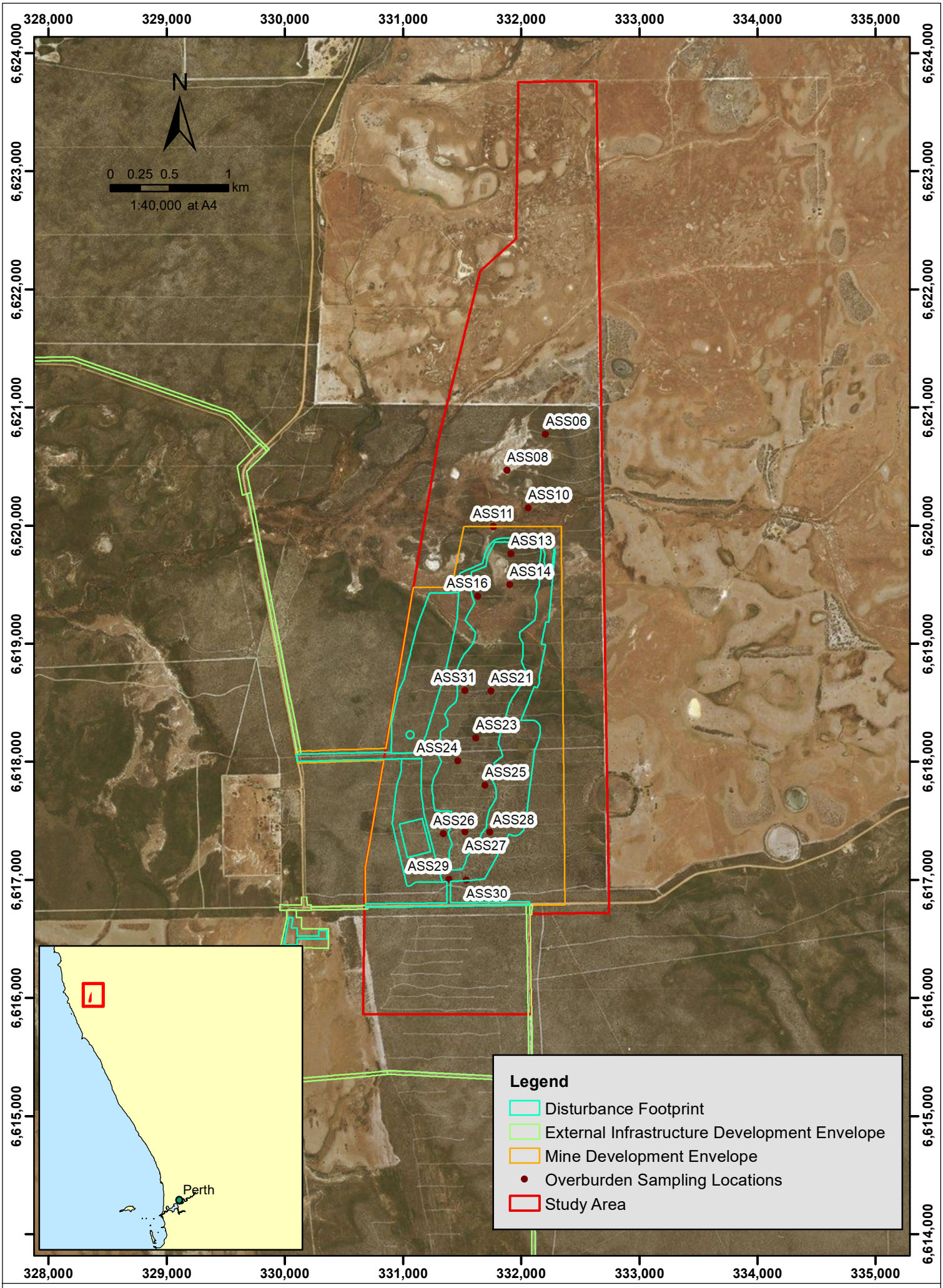

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Figure 4

Overburden Sampling Locations

4 RESULTS AND DISCUSSION – TOPSOIL / SUBSOIL

The findings of the soil survey and laboratory test work program are presented and discussed in the following sections.

4.1 Sample Site and Soil Profile Descriptions

Sampling site and surface soil profile descriptions for the 22 sites within the study area are presented below. The vegetation descriptions and vegetation units at each sampling location are derived from the 2021 Flora and Vegetation Survey for the Atlas Project (Morgan, 2022).

Soil colour classifications are derived from the Munsell Soil Colour Charts.

Site Reference:	Site 01	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	332037
		Northing:	6622183

Plate 1 Surface soil at Site 01

Soil profile description:

0-20 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

20-140 cm (base of excavation): Single-grained, white (2.5Y 8/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth. Soil saturated at approximately 120cm depth.

Soil surface: Single grained, sandy surface with no coarse fragments and approximately 80% vegetation / litter cover.

Vegetation: Pasture species and scattered sedges.

Plate 2 Landscape / vegetation at Site 01

Site Reference:	Site 02	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	332227
		Northing:	6622270

Plate 3 Surface soil at Site 02

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

10-60 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'few'.

60-150 cm: Massive, pale brown (2.5Y 7/4) to yellow (10YR 7/5) sandy clay soil with no coarse fragments and strong consistence. Root growth classed as 'few', decreasing to 'none' at approximately 130cm depth. Orange mottling present. Soil saturation at approximately 130cm depth.

Soil surface: Single grained, sandy surface with no coarse fragments and approximately 60% vegetation / litter cover

Vegetation: Pasture species and scattered sedges

Plate 4 Landscape / vegetation at Site 02

Site Reference:	Site 03	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage line / flats	**Easting:**	332049
		Northing:	6621513

Plate 5 Surface soil at Site 03

Soil profile description:

0-10 cm: Single-grained, light grey (2.5Y 7/2) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

10-50cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many'.

50-80cm: Single-grained to weakly structured, brownish yellow (10YR 6/8) clayey sand with no coarse fragments and weak consistence. Root growth classed as 'few'.

80-140cm: Massive, olive yellow (2.5Y 6/6) sandy clay with no coarse fragments and moderate to firm consistence. Root growth classed as 'none'. Minor orange mottling. Soil saturation at approximately 130cm.

Soil surface: Single grained, sandy surface with no coarse fragments and approximately 75% vegetation / litter cover

Vegetation: Pasture species and scattered sedges

Plate 6 Landscape / vegetation at Site 03

Site Reference:	Site 04	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy Plain	**Easting:**	332246
		Northing:	6620761

Plate 7 Surface soil profile at Site 04

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

10-80 cm: Single-grained, pale brown (2.5Y 8/3) to yellow (2.5Y 8/6) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'few', decreasing to 'none' with increasing depth.

80-140 cm: Single-grained to weakly structured, yellow (2.5Y 7/6) clayey sand with no coarse fragments and moderate consistence. Root growth classed as 'none'. Minor orange mottling. Soil saturation at approximately 130cm.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 70% litter cover

Vegetation: Heaths fringing the flood plain wetlands (Vegetation unit: BtRc).

Plate 8 Landscape / vegetation at Site 04

Site Reference:	Site 05	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy Plain	**Easting:**	331915
		Northing:	6621044

Plate 9 Surface soil profile at Site 05

Soil profile description:

0-20 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

20-100 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

100-130cm: Single-grained to weakly structured, yellow (2.5Y 7/6) clayey sand with no coarse fragments and weak consistence. Root growth classed as 'none'.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 60% litter cover.

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 10 Landscape / vegetation at Site 05

Site Reference:	Site 06	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage lines / flats	**Easting:**	331915
		Northing:	6621044

Plate 11 Surface soil profile at Site 06

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

10-50cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 80% litter cover

Vegetation: Flowline vegetation (Vegetation unit: MyMb)

Plate 12 Landscape / vegetation at Site 06

Site Reference:	Site 07	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy Plain	**Easting:**	332323
		Northing:	6620388

Plate 13 Surface soil profile at Site 07

Soil profile description:

0-20 cm: Single-grained, dark grey (2.5Y 4/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

20-130 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 50% litter cover

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: Bp)

Plate 14 Landscape / vegetation at Site 07

Site Reference:	Site 08	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage lines / flats	**Easting:**	332018
		Northing:	6619949

Plate 15 Surface soil profile at Site 08

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many'.

10-90 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many' to 'few'.

90-150cm: Single-grained to weakly structured, yellow (2.5Y 7/6) clayey sand with no coarse fragments and weak consistence. Root growth classed as 'none'. Soil saturation at approximately 140cm.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 80% litter cover.

Vegetation: Floodplain vegetation (Vegetation unit: Ti).

Plate 16 Landscape / vegetation at Site 08

Site Reference:	Site 09	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage lines / flats	**Easting:**	331575
		Northing:	6619398

Plate 17 Surface soil at Site 09

Soil profile description:

0-10 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

20-50cm: Single-grained, white (2.5Y 8/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'few'.

50-140cm: Weakly structured to massive, grey (2.5Y 6/1), to olive (2.5Y 6/6) sandy clay with no coarse fragments and moderate consistence. Root growth classed as 'few'. Orange mottling at approximately 120cm. Soil saturation at approximately 100cm.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 75% litter cover.

Vegetation: Flowline vegetation (Vegetation unit: MyMb).

Plate 18 Landscape / vegetation at Site 09

Site Reference:	Site 10	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage lines / flats	**Easting:**	332207
		Northing:	6618880

Plate 19 Surface soil profile at Site 10

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

10-50cm: Single-grained, light grey (2.5Y 7/1) to brownish yellow (10YR 6/8) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many'.

50-140 cm: Weakly structured to massive, grey (2.5Y 6/1), to olive yellow (2.5Y 6/6) sandy clay to light clay with no coarse fragments and moderate to strong consistence. Root growth classed as 'few' decreasing to 'none with increasing depth. Minor orange mottling at approximately 120cm. Soil saturation at approximately 130cm.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 50% litter cover

Vegetation: Floodplain vegetation (Vegetation unit: Ti).

Plate 20 Landscape / vegetation at Site 10

Site Reference:	Site 11	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	332267
		Northing:	6618411

Plate 21 Surface soil profile at Site 11

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

10-130 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 80% litter cover

Vegetation: Heaths fringing the flood plain wetlands (Vegetation unit: BtRc)

Plate 22 Landscape / vegetation at Site 11

Site Reference:	Site 12	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	331733
		Northing:	6618084

Plate 23 Surface soil at Site 12

Soil profile description:

0-20 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

20-50cm: Single-grained, white (2.5Y 8/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

100-130cm: Weakly structured, yellow (2.5Y 7/6) clayey sand with no coarse fragments and moderate. Root growth classed as 'few'.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 70% litter cover.

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 24 Landscape / vegetation at Site 12

Site Reference:	Site 13	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Low sandy rise	**Easting:**	331461
		Northing:	6617415

Plate 25 Surface soil at Site 13

Soil profile description:

0-20 cm: dark grey (2.5Y 4/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

20-100 cm: Single-grained, brownish yellow (10YR 6/8) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many', decreasing to 'few' with increased depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 70% litter cover

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 26 Landscape / vegetation at Site 13

Site Reference:	Site 14	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Low sandy rise	**Easting:**	331119
		Northing:	6616902

Plate 27 Surface soil profile at Site 14

Soil profile description:

0-20 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as ‘abundant’.

20-100 cm: Single-grained, white (2.5Y 8/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as ‘many’, decreasing to ‘few’ with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 60% litter cover

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 28 Landscape / vegetation at Site 14

Site Reference:	Site 15	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	332393
		Northing:	6617200

Plate 29 Surface soil at Site 15

Soil profile description:

0-20 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

20-100 cm: Single-grained, white (2.5Y 8/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 70% litter cover

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 30 Landscape / vegetation at Site 15

Site Reference:	Site 16	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	331441
		Northing:	6616610

Plate 31 Surface soil at Site 16

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

10-50cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 50% litter cover

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 32 Landscape / vegetation at Site 16

Site Reference:	Site 17	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Low sandy rise	**Easting:**	331062
		Northing:	6618073

Plate 33 Surface soil profile at Site 17

Soil profile description:

0-20 cm: Single-grained, dark grey (2.5Y 4/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

20-120 cm: Single-grained, white (2.5Y 8/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 60% litter cover

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 34 Landscape / vegetation at Site 17

Site Reference:	Site 18	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	331223
		Northing:	6618593

Plate 35 Surface soil profile at Site 18

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

10-50cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 80% litter cover

Vegetation: Banksia low woodlands on plains and low rises (Vegetation unit: BaBm).

Plate 36 Landscape / vegetation at Site 18

Site Reference:	Site 19	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage lines / flats	**Easting:**	331493
		Northing:	6621031

Plate 37 Surface soil profile at Site 19

Soil profile description:

0-25 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

25-80 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

80-130 cm: Weakly structured to massive, grey (2.5Y 6/1) sandy clay with no coarse fragments and moderate consistence. Root growth classed as 'few' to 'none'. Soil saturation at approximately 110cm.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 50% litter cover

Vegetation: Flowline vegetation (Vegetation unit: MrMvBc)

Plate 38 Landscape / vegetation at Site 19

Site Reference:	Site 20	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage lines / flats	**Easting:**	331621
		Northing:	6619969

Plate 39 Surface soil at Site 20

Soil profile description:

0-10 cm: Single-grained, grey (2.5Y 6/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many'.

10-90 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'many' to 'few'.

90-140cm: Single-grained to weakly structured, yellow (2.5Y 7/6) to olive yellow (2.5Y 6/6) clayey sand with no coarse fragments and weak consistence. Root growth classed as 'none'. Orange mottling at 100cm. Soil saturation at approximately 120cm.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 80% litter cover

Vegetation: Heaths fringing flood plan wetlands (CbPt)

Plate 40 Landscape / vegetation at Site 20

Site Reference:	Site 21	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Sandy plain	**Easting:**	331704
		Northing:	6622022

Plate 41 Surface soil profile at Site 21

Soil profile description:

0-20 cm: Single-grained, light grey (2.5Y 7/2) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'abundant'.

20-70cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many'.

70-140cm: Massive, olive yellow (2.5Y 6/6) sandy clay with no coarse fragments and moderate to firm consistence. Root growth classed as 'none'. Soil saturation at approximately 100cm.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 10% litter cover

Vegetation: Pasture species and scattered sedges

Plate 42 Landscape / vegetation at Site 21

Site Reference:	Site 22	**Datum:**	GDA 1994 MGA Zone 50
Soil Landform Association:	Drainage lines / flats	**Easting:**	331783
		Northing:	6618998

Plate 43 Surface soil profile at Site 22

Soil profile description:

0-10 cm: Single-grained, light grey (2.5Y 7/1) sandy soil with no coarse fragments, weak consistence. Root growth classed as 'abundant'.

10-50 cm: Single-grained, white (2.5Y 8/1) sandy soil with no coarse fragments and weak consistence. Root growth classed as 'many', decreasing to 'few' with increasing depth.

50-100 cm: Weakly structured to massive, grey (2.5Y 6/1), clayey sand with no coarse fragments and moderate consistence. Root growth classed as 'few' to 'none'.

100-140cm: Massive dark grey (2.5Y 4/1) sandy clay with no coarse fragments and firm consistence. Root growth classed as 'none'. Saturated soil present at base of excavation at approximately 130cm depth.

Soil surface: Loose sandy surface with no surface crust evident. No coarse fragments. Approximately 70% litter cover

Vegetation: Wetland vegetation (MbGcVp)

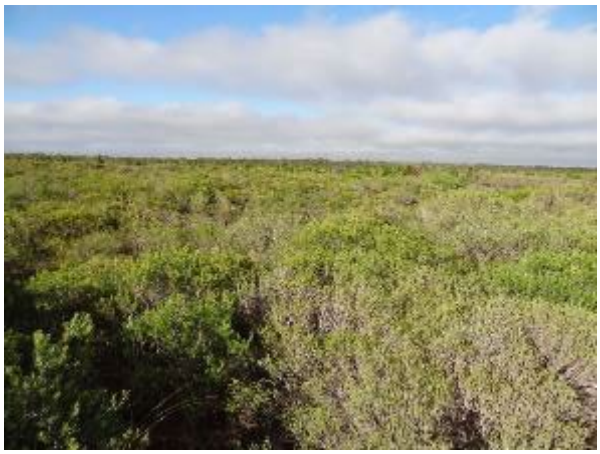

Plate 44 Landscape / vegetation at Site 22

4.2 Soil Physical Characteristics

The physical characteristics of the topsoil and subsoil materials within the study area, as determined by the field investigation and laboratory analysis of collected samples, are discussed in the following sections.

4.2.1 Soil Profile Morphology

The surface soil profiles within the study area exhibited minor variation in terms of morphological characteristics. The soil profiles were grouped into three soil-landform associations, namely 'Low sandy rises', 'Sandy plains', 'and 'Drainage lines / flats'. The landform and soil profiles within these soil associations were typically characterised as follows:

- Low sandy rises:
    - Low undulating hills.
    - Deep, single grained, structureless sandy soils to >1.5m depth.
- Sandy plains:
    - Relatively flat landform surface, with gentle relief.
    - Single grained, structureless sandy soils (to variable depths of 0.6 to 1.3m) over weakly structured clayey sand horizons.
    - Saturated soils present at some sampling locations, at variable depths within the soil profiles.
- Drainage lines / flats:
    - Flat landform surface situated low in the landscape, dissected by shallow drainage channels.
    - Single grained, structureless sandy soils (to variable depths of 0.5 to 0.9m) over weakly structured to massive, clayey sand to light clay horizons with moderate to strong consistence.
    - Saturated soils present at depths ranging from 1.0 to 1.4m.
    - Orange iron mottling often present within clay rich, saturated horizons at depths of 1.2 to 1.4m.

4.2.2 Soil Texture

Soil texture describes the proportions of sand, silt and clay (the particle size distribution) within the <2 mm fraction of a soil. The particle size distribution and resulting textural class of a soil is an important factor influencing most physical and many chemical and biological properties. Soil structure, water holding capacity, hydraulic conductivity, soil strength, fertility, water repellence, erodibility and susceptibility to compaction are some of the factors closely linked to the texture of a soil material.

There were a range of particle size distributions exhibited throughout the study area, with soil textures ranging from 'sand' (<5% clay) to 'medium clay' (30 to 35% clay) (Table 2 and Figure 5). The near surface soils (<0.5m) at all sampling sites were classified as sands, with sandy soil textures extending to the base of sampling at all 'Low sandy rise' locations. Increased clay content at depths below 0.5m were recorded for some 'Sandy plain' soil profiles, with soil textures classified as 'clayey sands' (approximately 5 to 10% clay).

There was a distinct increase in clay content observed within the soil profiles of the 'Drainage line / flats', with sharp textural boundaries observed at depths ranging from 0.5 to 0.8m at those sampling locations. Clay content of the soils below 0.5 to 0.8m within the 'Drainage line / flats' soil profiles ranged from approximately 9 to 33% (Figure 5).

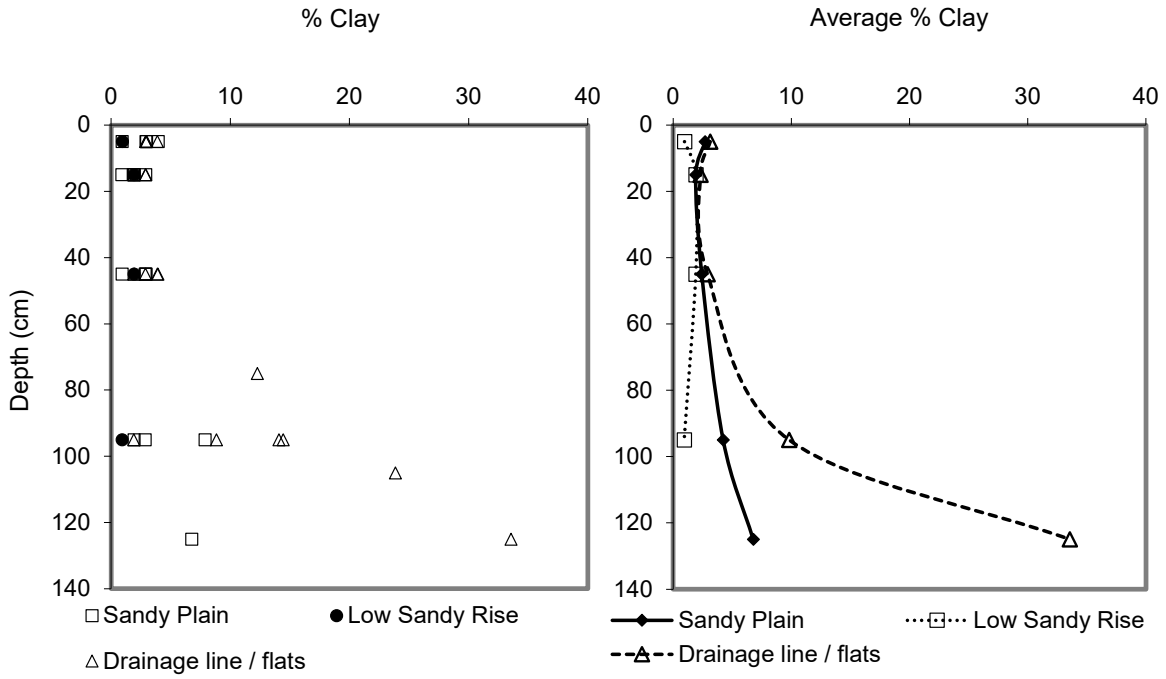

Figure 5 Individual and average % clay of soils with depth for each soil-landform association

4.2.3 Soil Structure

Soil structure describes the arrangement of solid particles and void space in a soil. It is an important factor influencing the ability of soil to support plant growth, store and transmit water and resist erosional processes. A well-structured soil is one with a range of different sized aggregates, with component particles bound together to give a range of pore sizes facilitating root growth and the transfer of air and water.

Soil structure can be influenced by the particle size distribution, chemical composition and organic matter content of a soil. Soil structure is often affected by root growth, vehicle compaction and, with

respect to reconstructed soil profiles, the methods of soil handling and deposition. When a soil material is disturbed, the breakdown of aggregates into primary particles can lead to structural decline (Moore, 1998). This can result in hard-setting and crusting at the soil surface and a 'massive' soil structure at depth, potentially reducing the ability of seeds to germinate, roots to penetrate the soil matrix and water to infiltrate to the root zone.

The structure of the sandy surface soils (to approximately 0.5m depth) across the study area and to the base of sampling in the 'Low sandy rise' sites was classified as 'single-grained', with no aggregation of soil particles upon disturbance. Deep soils (i.e. below approximately 0.5m) within the 'Sandy plain' soil landform association exhibited some weak aggregation, corresponding to an increase in clay content at depth.

The clay rich soils below 0.5 to 0.8m depth within the 'Drainage lines / flats' typically exhibited a 'massive' soil structure with a very firm consistence.

4.2.4 Structural Stability

The structural stability of a soil and its susceptibility to structural decline is complex and depends on the net effect of a number of properties, including the amount and type of clay present, organic matter content, soil chemistry and the nature of disturbance. Soil aggregates that slake and particularly those that disperse, indicate a weak soil structure that is easily degraded. These soils can be potentially problematic when used as a rehabilitation medium, particularly if left exposed at the surface.

The Emerson Aggregate Test identifies the potential slaking and dispersive properties of soil aggregates. The dispersion test identifies the properties of the soil materials under a worst-case scenario, where severe stress is applied to the soil material. Generally, samples allocated into Emerson Classes 1 and 2 are those most likely to exhibit dispersion of the clay sized fraction and therefore be the most problematic.

The Emerson Aggregate test is performed on soils which exhibit aggregation of soil particles. As such, soils with no aggregates (i.e. those soils with a 'single-grained' structure, are not tested). The very low % clay within the majority of the surface soils from the study area indicates that dispersion of the clay fraction will not be an issue for those soils. Aggregated soils, with higher clay contents were identified within the subsoil horizons of the 'Sandy plain' and 'Drainage lines / flats' soil-landform associations.

The majority of the 'clayey' soils from the 'Sandy plain' and 'Drainage lines / flats' soil-landform associations were identified as Emerson Class 3 (slaking, remoulded soil partially dispersed), Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed), or Class 6 (aggregate slakes but does not disperse, no dispersion of remoulded soil, dispersion of a 1:5 soil:water suspension) (Table 2). These results indicate that the soils are not prone to dispersion of the clay fraction in their natural state but may exhibit dispersion following severe disturbance (e.g. earthworks). Care should be taken to minimise the handling of these soils where possible, particularly when wet.

Several clay-rich subsoil samples from 'Drainage lines / flats' sampling classified as Emerson Class 2 (Table 2). These samples exhibited partial dispersion of the clay fraction upon saturation of an undisturbed soil aggregate.

It should be noted that the salinity of some soils, particularly those from within the 'Drainage lines / flats' soil-landform association, may have a flocculating effect on clay particles, masking the potential dispersion in these clay-rich, highly sodic (see Section 4.3.3) soil materials.

Table 2 Emerson Aggregate Test Class and % clay for selected soil samples.

Site #	Depth (cm)	Soil-landform association	Clay fraction (%)	Emerson Test Class
2	40-50	Sandy plain	3%	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)
	90-100	Sandy plain	2%	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)
3	90-100	Drainage lines / flats	14%	Class 2 (aggregate slakes and partially disperses)
4	90-100	Sandy plain	8%	Class 6 (aggregate slakes but does not disperse, no dispersion of remoulded soil, dispersion of a 1:5 soil: water suspension)
	120-130	Sandy plain	7%	Class 6 (aggregate slakes but does not disperse, no dispersion of remoulded soil, dispersion of a 1:5 soil: water suspension)
8	90-100	Drainage lines / flats	2%	Class 2 (aggregate slakes and partially disperses)
9	90-100	Drainage lines / flats	9%	Class 6 (aggregate slakes but does not disperse, no dispersion of remoulded soil, dispersion of a 1:5 soil: water suspension)
10	90-100	Drainage lines / flats	14%	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)
	120-130	Drainage lines / flats	33%	Class 3a (aggregate slakes but not disperse, complete dispersion of remoulded soil)
19	120-130	Drainage lines / flats	20%	Class 2 (aggregate slakes and partially disperses)
20	90-100	Drainage lines / flats	15%	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)
21	40-50	Sandy plain	10%	Class 3a (aggregate slakes but not disperse, complete dispersion of remoulded soil)
22	40-50	Drainage lines / flats	4%	Class 3a (aggregate slakes but not disperse, complete dispersion of remoulded soil)
	70-80	Drainage lines / flats	12 %	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)
	100-110	Drainage lines / flats	24%	Class 2 (aggregate slakes and partially disperses)

4.2.5 Hydraulic conductivity

Hydraulic conductivity (K_{sat}) refers to the saturated permeability of soil, or the ability of water to infiltrate and drain through the soil matrix. The K_{sat} of a soil is dependent on soil characteristics such as texture and structure (Moore, 1998). Freely draining soils with high K_{sat} values will generally be less susceptible to surface runoff and erosion. Slow draining soils with low K_{sat} values, are more likely to experience waterlogging, increased surface runoff and erosion.

Saturated hydraulic conductivity was determined for the <2.0 mm fraction of selected, representative soil samples from the study area. Drainage classes were determined for each sample according to their K_{sat} (Hunt and Gilkes, 1992) (Table 3).

The drainage class of soil samples from the study area ranged between 'extremely slow' and 'very rapid'. As would be expected, the coarser textured (sandy) 'near surface' soils sampled from all soil-landform associations within the study area recorded the highest hydraulic conductivity and are classified as free-draining. The low K_{sat} values recorded for the clay rich subsoil horizons within the 'Drainage lines / flats' soil-landform association indicate a propensity for waterlogging and / or surface run-off and erosion, particularly if placed close to the surface in reconstructed soil profiles.

Table 3 Saturated hydraulic conductivity (K_{sat}), drainage class and soil water holding capacity (field capacity) for selected soil samples.

Site #	Depth (cm)	Soil-landform association	K_{sat} (mm/hr)[1.]	Drainage Class[2.]	Soil-water holding (field capacity) (% vol)[1.]
1	0-10	Sandy plain	548	Very Rapid	20.0
	40-50		463	Very Rapid	20.5
3	0-10	Drainage lines / flats	489	Very Rapid	18.3
	40-50		345	Very Rapid	16.9
	90-100		0.06	Extremely Slow	41.7
4	0-10	Sandy plain	496	Very Rapid	20.2
	40-50		502	Very Rapid	19.3
	90-100		39	Moderate	26.6
5	0-10	Sandy plain	1,612	Very Rapid	18.8
	40-50		1,116	Very Rapid	16.0
	90-100		1,122	Very Rapid	22.0
8	0-10	Sandy plain	469	Very Rapid	22.1
	40-50		541	Very Rapid	20.5
	90-100		326	Very Rapid	18.8
11	0-10	Sandy plain	1,272	Very Rapid	19.7
	40-50		998	Very Rapid	16.6
13	0-10	Low Sandy Rise	1,018	Very Rapid	18.3
	40-50		1,586	Very Rapid	20.5
14	0-10	Low Sandy Rise	1,749	Very Rapid	20.6
	40-50		1,657	Very Rapid	17.0
20	0-10	Drainage lines / flats	809	Very Rapid	20.9
	40-50		1697	Very Rapid	20.0
22	0-10	Drainage lines / flats	287	Very Rapid	20.2
	40-50		665	Very Rapid	18.6
	100-110		0.03	Extremely Slow	43.4

1. Determined for the <2 mm fraction of the soil material.
2. (Hunt and Gilkes, 1992).

4.2.6 Water retention

The water retention properties of the surface soils within the study area are an important factor in determining the amount of water available for plant growth when soil materials are re-deposited and rehabilitated. In relatively low-nutrient environments, such as that of the study area, the amount of water available to plants is often the most limiting factor to vegetation establishment and growth. The water

retention or water holding capacity of a soil is influenced by a number of factors including soil particle size (and pore space) distribution, soil structure and organic matter content (Moore 1998).

The field capacity (or upper storage limit) of a soil material refers to the maximum water holding capacity of a freely drained soil, or the volumetric water content after gravity induced drainage has ceased. The field capacity of the <2 mm fraction of the soils from the study area ranged between 23% and 55% (Table 3). These values are considered 'moderate' to 'high' for the field capacity of a soil (Hazelton and Murphy, 2007). The water retention characteristics of the soils throughout the study area were generally reflective of the soil textures present, with the finer textured (clay rich) subsoils from the 'Drainage lines / flats' soil-landform association typically having a higher field capacity water content than the coarser textured (sandy) soils from the 'surface and near surface horizons across the study area.

4.2.7 Water repellence

Hydrophobicity or water repellence characteristics of a soil describes the inability of water to infiltrate the soil matrix (King 1981). Water repellence is primarily caused by a range of hydrophobic organic residues derived from decomposing plant materials. These organic materials alter the contact angle between water droplets and the soil surface, in turn affecting the ability of water to infiltrate into the soil. The severity of hydrophobicity varies according to vegetation type, time since clearing, land use and soil type, and is commonly associated with sandy textured soils.

There were a wide range of soil water repellency ratings recorded for the surface soils sampled from across the study area, with water repellency ratings ranging from 'Not significant' to 'Severe water repellence' (King 1981). The water repellency of the surface samples at the 0-10cm depth interval was typically greater than that measured for the 10-20cm depth interval, reflective of the higher organic matter contents in the surface soils. There was no apparent correlation between the water repellency of the surface soils (0-20cm) and soil-landform association. All samples assessed from below the 0 to 20cm depth intervals recorded water repellency ratings of 'Not significant'.

Table 4 Water repellency of selected surface soils

Site #	Depth (cm)	Soil-landform association	Water drop penetration time (seconds)[1.]	Water repellency rating[1.]
1	0-10	Sandy plain	1-10	Very low water repellence
	10-20		<1	Not significant
	40-50		<1	Not significant
	90-100		<1	Not significant
2	0-10	Sandy plain	50-260	Moderate water repellence
	10-20		<1	Not significant
3	0-10	Drainage lines / flats	1-10	Very low water repellence
	10-20		1-10	Very low water repellence
	40-50		<1	Not significant
	90-100		<1	Not significant
4	0-10	Sandy plain	>260	Severe water repellence
	10-20		<1	Not significant
5	0-10	Sandy plain	>260	Severe water repellence
	10-20		1-10	Very low water repellence
	40-50		<1	Not significant
	90-100		<1	Not significant

Site #	Depth (cm)	Soil-landform association	Water drop penetration time (seconds)[1]	Water repellency rating[1]
6	0-10	Drainage lines / flats	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
7	0-10	Sandy plain	>260	Severe water repellence
	10-20		1-10	Very low water repellence
	40-50		<1	Not significant
	90-100		<1	Not significant
8	0-10	Drainage lines / flats	1-10	Very low water repellence
	10-20		1-10	Very low water repellence
9	0-10	Drainage lines / flats	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
10	0-10	Drainage lines / flats	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
	40-50		<1	Not significant
	90-100		<1	Not significant
11	0-10	Sandy plain	50-260	Moderate water repellence
	10-20		<1	Not significant
12	0-10	Sandy plain	>260	Severe water repellence
	10-20		>260	Severe water repellence
13	0-10	Low sandy rise	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
	40-50		<1	Not significant
	90-100		<1	Not significant
14	0-10	Low sandy rise	>260	Severe water repellence
	10-20		1-10	Very low water repellence
15	0-10	Sandy plain	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
16	0-10	Sandy plain	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
17	0-10	Low sandy rise	50-260	Moderate water repellence
	10-20		50-260	Moderate water repellence
	40-50		<1	Not significant
	90-100		<1	Not significant
18	0-10	Sandy plain	>260	Severe water repellence
	10-20		1-10	Very low water repellence
19	0-10	Drainage lines / flats	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
20	0-10	Drainage lines / flats	1-10	Very low water repellence
	10-20		1-10	Very low water repellence
	40-50		<1	Not significant
	90-100		<1	Not significant
21	0-10	Sandy plain	50-260	Moderate water repellence
	10-20		1-10	Very low water repellence
	40-50		<1	Not significant

Site #	Depth (cm)	Soil-landform association	Water drop penetration time (seconds)[1.]	Water repellency rating[1.]
	90-100		<1	Not significant
22	0-10	Drainage lines / flats	1-10	Very low water repellence
	10-20		1-10	Very low water repellence

1. (King 1981).

4.2.8 Soil Strength

A modified Modulus of Rupture (MOR) test was conducted on selected samples, representative of the various soil materials from across the study area. This test is a measure of soil strength and identifies the tendency of a soil to hard-set as a direct result of soil slaking and dispersion. An MOR of over 60 kPa has been described as the critical value for distinguishing potentially problematic soils in agricultural scenarios (Cochrane and Aylmore 1997). Restricted root penetration into the soil matrix is a likely consequence of a high modulus of rupture. In reconstructed soil profiles, materials normally deep within the profile that may have a high MOR can often be re-deposited closer to the surface, leading to germination / emergence and root penetration problems.

As this test is conducted on reconstructed soil blocks composed of the < 2 mm soil fraction, it does not take into account the effect of soil structure on soil strength, nor any degree of compaction that may be present in the field. It does, however, provide insight into the potential for soils to hard-set and compact with repeated wetting and drying cycles, and the ability of roots to fracture the soil and penetrate crack faces.

The majority of the sandy surface / near-surface soils sampled from across the study area (i.e. across all soil-landform associations) recorded MOR values of zero, indicating no propensity to hard-set with repeated wetting / drying cycles (Table 5). Ten of the 29 samples test recorded MOR values above zero, however only two samples, both from the clay rich horizons within the 'Drainage lines / flats' soil-landform association recorded MOR values above the 60kPa threshold (Table 5).

Table 5 Modulus of Rupture (soil strength) of selected soils. Values above 60kPa (identified as potentially hard-setting) are highlighted in yellow.

Site #	Depth (cm)	Soil-landform association	Modulus of Rupture (kPa)[1.]
1	0-10	Sandy plain	0
	40-50	Sandy plain	0
	90-100	Sandy plain	0
3	0-10	Drainage lines / flats	0
	40-50	Drainage lines / flats	0
	90-100	Drainage lines / flats	76.5
4	0-10	Sandy plain	0
	40-50	Sandy plain	0
	120-130	Sandy plain	3.9
9	0-10	Drainage lines / flats	0
	40-50	Drainage lines / flats	0.2
	90-100	Drainage lines / flats	2.0
10	0-10	Drainage lines / flats	0

Site #	Depth (cm)	Soil-landform association	Modulus of Rupture (kPa)[1.]
	40-50	Drainage lines / flats	2.9
	90-100	Drainage lines / flats	6.3
	120-130	Drainage lines / flats	65.4
12	0-10	Sandy plain	0
	40-50	Sandy plain	0
	90-100	Sandy plain	0
14	0-10	Low sandy rise	0
	40-50	Low sandy rise	0
	90-100	Low sandy rise	0
17	0-10	Low sandy rise	0
	40-50	Low sandy rise	0
	90-100	Low sandy rise	0
22	0-10	Drainage lines / flats	0
	40-50	Drainage lines / flats	4.8
	70-80	Drainage lines / flats	3.5
	100-110	Drainage lines / flats	11.4

1. Values above the threshold of 60kPa are identified as potentially hard-setting (Cochrane and Aylmore 1997).

4.3 Soil Chemical Characteristics

4.3.1 Soil pH and Electrical Conductivity

Soil pH (H_2O) measures the acidity or alkalinity of the soil in relation to suitability for plant growth. Ratings for soil pH are based on the Land Evaluation Standards for Land Resource Mapping categories (van Gool, 2005).

Soil pH (H_2O) results indicated substantial variation between and within the various soil-landform associations / sample depths within the study area, ranging from pH 5.4 (classified as ‘strongly acidic’) for a sample from 10-20 cm depth at a ‘Drainage line / flats’ site, to pH 10.0 (‘strongly alkaline’) for a sample from 90-100 cm depth within the ‘drainage line/ flats’ soil-landform association (Figure 6). On average, soils from the ‘Drainage line / flats’ were typically the most alkaline, with average soil pH increasing with sample depth. The soil pH of samples from the ‘Low sandy rise’ and ‘Sandy plain’ sites were relatively similar within the top 0.5 m of the soil profiles, and generally classified as ‘slightly acidic’ to ‘neutral’ (Figure 6).

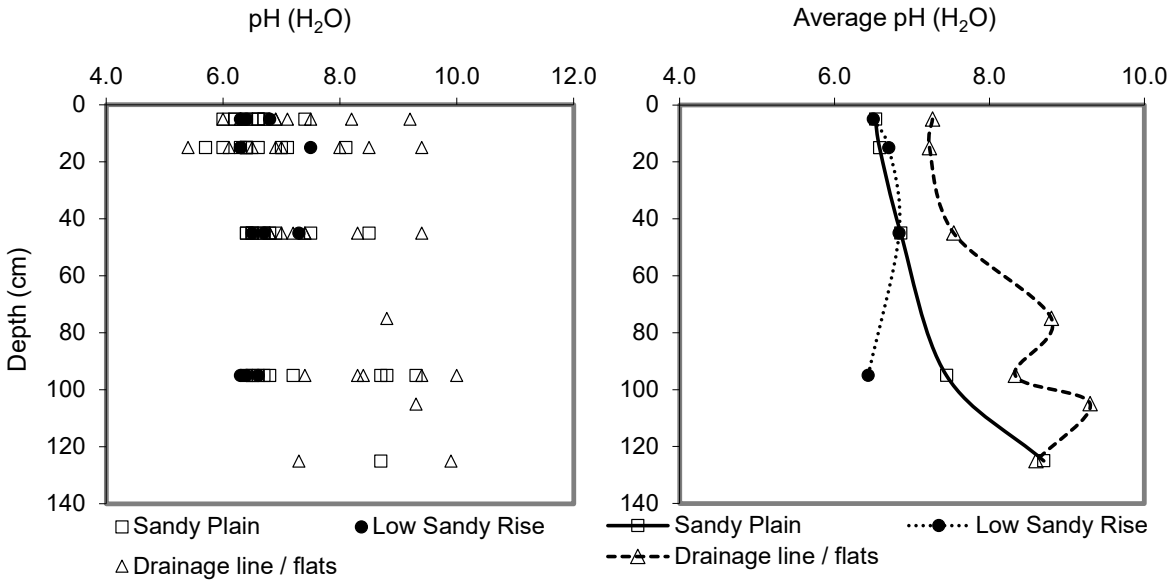

Figure 6 Individual and average pH (H_2O) of soils with depth for each soil-landform association

Electrical conductivity (EC) is a measurement of the soluble salts in soils or water. Soil salinity results from natural processes of landscape evolution, hydrological processes and rainfall (Hunt and Gilkes, 1992). There was a substantial range of EC values recorded for the soils within the study area, with individual values ranging between 0.010 dS/m (non-saline) and 2.526 dS/m (extremely saline) based on the standard USDA and CSIRO electrical conductivity categories (Appendix A). While there was a range of soil salinities measured across the study area, the majority of the soil samples were classed as either 'non-saline' (< 0.010 dS/m) or 'slightly saline' (0.2 to 0.33 dS/m) (Figure 7).

On average, soils from the 'Low sandy rise' soil-landform association recorded the lowest EC values, with EC being uniformly low through the soil profiles (Figure 7). The average EC values of soils with the 'Drainage lines / flats' and 'Sandy plain' soils was low (classed as non to slightly saline) within the upper 0.5 m of the soil profiles, with an increase in salinity with sample depth below approximately 0.5 m, corresponding to soils with increased clay contents and soil saturation at those sample depths (Figure 7).

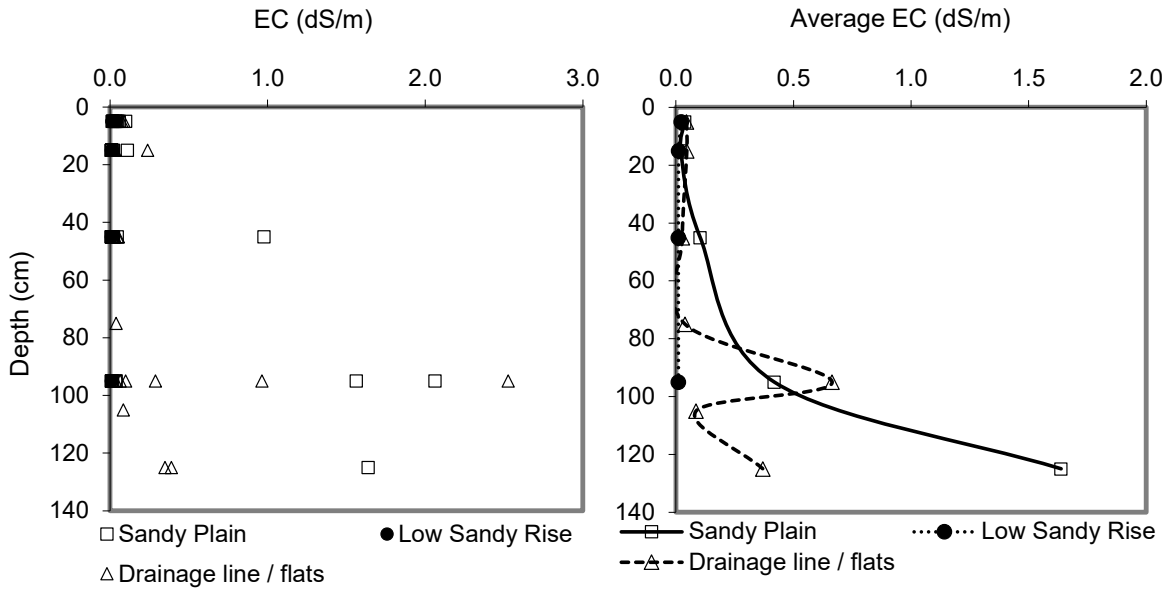

Figure 7 Individual and average electrical conductivity (dS/m) of soils with depth for each soil-landform association

4.3.2 Soil Organic Matter

The organic matter content of soil is an important factor that influences many physical, chemical and biological soil characteristics. The organic matter content is directly derived from plants and animals and its functions include supporting the micro and macro fauna and flora populations in the soil, increasing the water retention capacity, buffering pH and improving soil structure. The organic matter content of the soils within the study area was determined as a measure of the soil organic carbon percentage (SOC%).

The SOC% of the sampled soils was low, as is typical of most sandy soils in the region, ranging between <0.05% and 1.48% (Figure 8). As would be expected, there was generally a sharp decrease in SOC% with depth away from the soil surface.

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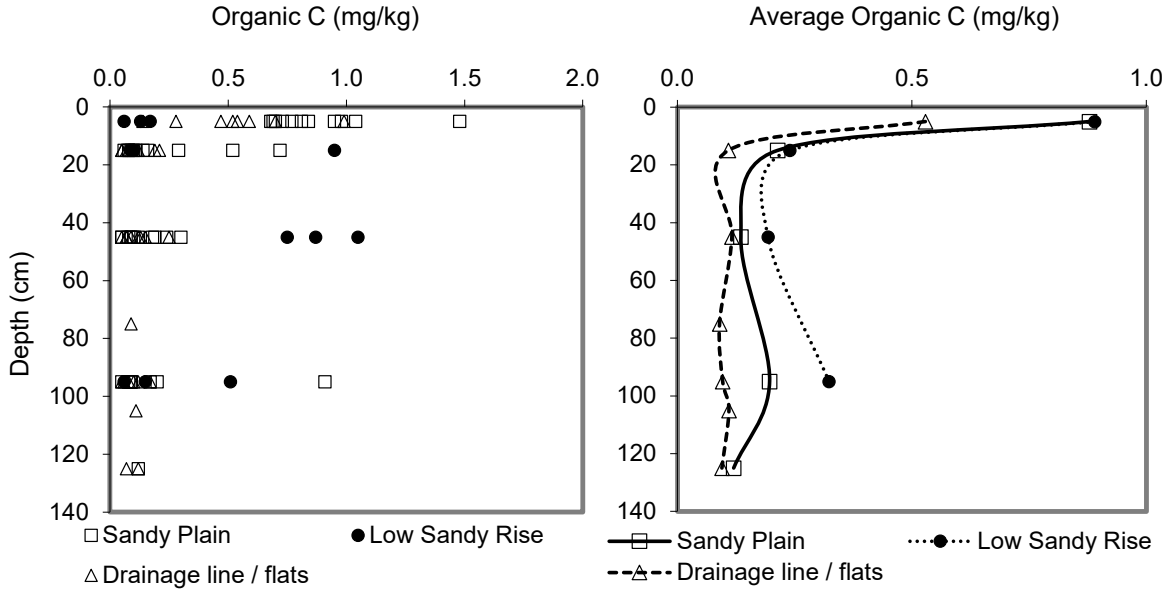


Figure 8 Individual and average organic C concentration (%) of soils with depth for each soil-landform association

4.3.3 Exchangeable Cations and Exchangeable Sodium Percentage

Exchangeable cations, held on clay surfaces and within organic matter, are an important source of soil fertility and can influence the physical properties of soil. Generally, if cations such as Ca^{2+}, Mg^{2+} and K^{+} are dominant on the clay exchange surfaces, the soil will typically display increased physical structure and stability, leading to increased aeration, drainage and root growth (Moore, 1998). If Na cations (Na^{+}) are dominant on exchange surfaces and the exchangeable sodium percentage (ESP) exceeds more than 6% of the total exchangeable cations, then the soil is considered to be 'sodic', which can lead to poor physical properties (i.e. dispersion, hardsetting and erosion in clay-rich soils). ESP values over 15% are classified as 'highly sodic'.

Exchangeable cation concentration, effective cation exchange capacity (eCEC) and exchangeable sodium percentage (ESP) results were highly variable across the various soil-landform associations and with sample depth (Table 6). While a number of soils sampled from each of the soil-landform associations were classed as sodic and highly sodic, the low clay content of the surface and near-surface sandy soil horizons indicates that sodicity is unlikely to influence the structural stability of those soils.

The exchangeable cation and ESP results should be viewed in conjunction with the Emerson Test results, the amount of clay in the soil and the salinity of the material, to identify the likely influence on the physical stability of the soil once the materials are salvaged and utilised as a rehabilitation resource. Sodicity and its influence on clay dispersion, is only likely to have a detrimental influence on the structure of the clay-rich soils situated at depth within the 'Drainage lines / flats' soil-landform association. The Emerson Test identified partial dispersion of the clay fraction in a number of those samples (Section 4.2.4).

Table 6 Exchangeable cations and ESP of selected samples. Shading of ESP values denotes non-sodic, sodic and highly sodic classifications.

Site #	Depth (cm)	Soil-landform association	Exchangeable cations (meq/100g)				eCEC (meq/100g)	ESP (%)	% clay
			Ca	Mg	K	Na			
1	0-10	Sandy Plain	0.57	0.15	0.02	0.05	0.79	6.3	2.9
	10-20		0.14	0.05	0.02	0.05	0.26	19.2	0.9
	40-50		0.12	0.05	0.02	0.05	0.24	20.8	2.9
	90-100		0.12	0.05	0.03	0.05	0.25	20.0	1.9
3	0-10	Drainage line/ flats	0.65	0.20	0.02	0.05	0.92	5.4	3.0
	10-20		0.05	0.05	0.03	0.05	0.18	27.7	1.9
	40-50		0.05	0.05	0.02	0.05	0.17	29.4	2.9
	90-100		0.23	0.42	0.05	0.24	0.94	25.5	14.5
4	0-10	Sandy Plain	4.02	0.31	0.03	0.05	4.41	1.1	4.0
	10-20		0.05	0.05	0.02	0.05	0.17	29.4	1.9
	40-50		0.16	0.05	0.02	0.05	0.28	17.8	2.9
	90-100		8.18	1.08	0.03	0.1	9.39	1.0	7.9
	120-130		1.85	1.15	0.07	0.05	3.12	1.6	6.8
8	0-10	Drainage line/ flats	0.29	0.18	0.03	0.05	0.55	9.0	3.0
	10-20		0.19	0.05	0.01	0.05	0.30	16.6	2.9
	40-50		0.10	0.05	0.02	0.05	0.22	22.7	1.9
	90-100		0.19	0.28	0.04	0.05	0.56	8.9	1.9
9	0-10	Drainage line/ flats	0.63	0.39	0.03	0.05	1.10	4.5	2.9
	10-20		0.12	0.05	0.02	0.05	0.24	20.8	1.9
	40-50		0.05	0.05	0.02	0.05	0.17	29.4	1.9
	90-100		0.80	1.58	0.15	0.24	2.77	8.6	8.8
10	0-10	Drainage line/ flats	0.71	0.32	0.03	0.05	1.11	4.5	2.9
	10-20		0.23	0.12	0.02	0.05	0.42	11.9	1.9
	40-50		0.21	0.12	0.03	0.05	0.41	12.2	3.9
	90-100		6.09	3.42	0.37	1.35	11.23	12.0	14.1
	120-130		1.96	0.76	0.07	0.41	3.20	12.8	33.6
12	0-10	Sandy Plain	0.84	0.19	0.02	0.05	1.10	4.5	3.0
	10-20		0.31	0.05	0.02	0.05	0.43	11.6	1.9
	40-50		0.15	0.05	0.01	0.05	0.26	19.2	0.9
	90-100		0.05	0.05	0.01	0.05	0.16	31.2	2.9
14	0-10	Low Sandy Rise	0.58	0.05	0.01	0.05	0.69	7.2	1.0
	10-20		0.60	0.10	0.02	0.05	0.77	6.4	1.9
	40-50		0.14	0.05	0.02	0.05	0.26	19.2	1.9
	90-100		0.05	0.05	0.02	0.05	0.17	29.4	0.9
18	0-10	Sandy Plain	1.24	0.21	0.02	0.05	1.52	3.2	0.9
	10-20		0.85	0.16	0.01	0.05	1.07	4.6	2.9
	40-50		0.26	0.05	0.02	0.05	0.38	13.1	2.9
21	10-20	Sandy Plain	0.11	0.05	0.01	0.05	0.22	22.7	1.9
22	0-10	Drainage line/ flats	5.51	0.68	0.02	0.05	6.26	0.8	3.9
	10-20		0.57	0.05	0.02	0.05	0.69	7.2	2.9
	40-50		3.03	0.58	0.04	0.05	3.70	1.3	3.9
	70-80		1.44	2.53	0.23	0.05	4.25	1.1	12.3
	100-110		1.65	3.69	0.57	1.07	6.98	15.3	23.9

4.3.4 Soil Nutrients

The most important macro-nutrients for plant growth are nitrogen (N), phosphorus (P), potassium (K), and sulphur (S). These nutrients are largely derived from the soil mineral component and organic matter. Native plant species have several physiological adaptations that enable them to be productive in areas where the supply of macronutrients is limited. There is limited information available which details the specific nutritional requirements for native plant species in WA. Therefore, the use of analogue sites is an effective way to baseline the soil nutritional requirements of native plant species within the study area.

4.3.4.1 Nitrogen

The plant-available nitrogen concentrations of the soils from the study area were variable but generally low and ranged from <1 (below detection limit) to 15 mg/kg nitrate (Figure 9) and from <1 (below detection limit) to 8 mg/kg ammonium (Figure 10). The highest plant-available nitrogen concentrations were recorded for the surface samples within the 'Drainage lines / flats' soil-landform association. As would be expected, there was typically a decrease in plant-available nitrogen concentration with depth through the soil profiles.

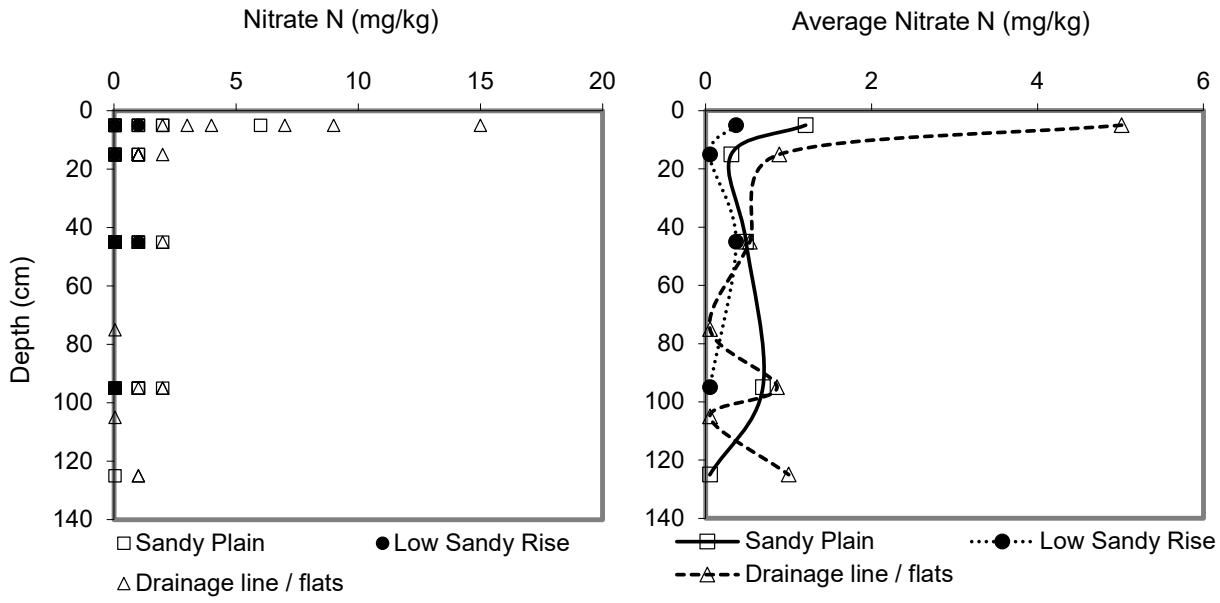


Figure 9 Individual and average Nitrate-N concentration (mg/kg) of soils with depth for each soil-landform association

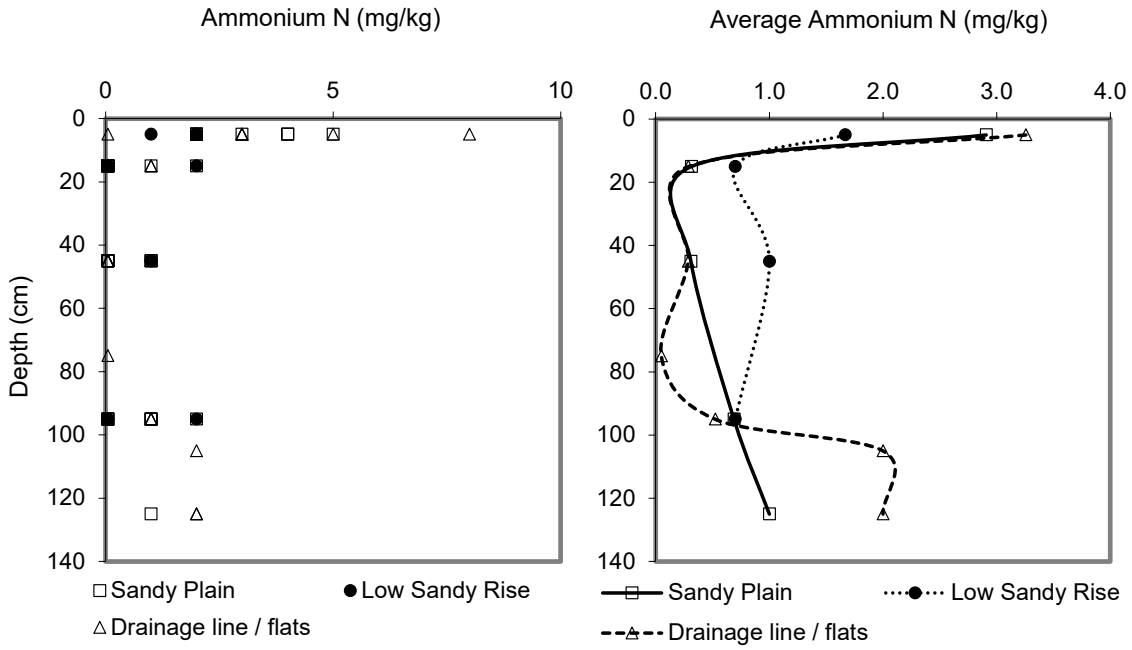


Figure 10 Individual and average Ammonium-N concentration (mg/kg) of soils with depth for each soil-landform association

4.3.4.2 Phosphorus

Phosphorus (P) is essential for the growth of vegetation as it plays a key role in the formulation of energy producing organic compounds. Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production) and maturation (Brady and Weil., 2002).

The plant-available P concentrations of the majority of soils from the study area were classed as low (<10 mg/kg) (Moore, 1998) (Figure 11). This was particularly the case for the soils within the 'Low sandy rise' and 'Sandy plain' soil-landform associations. The highest plant-available P concentrations were recorded for the upper soil profile samples from the 'Drainage lines / flats' soil-landform association.

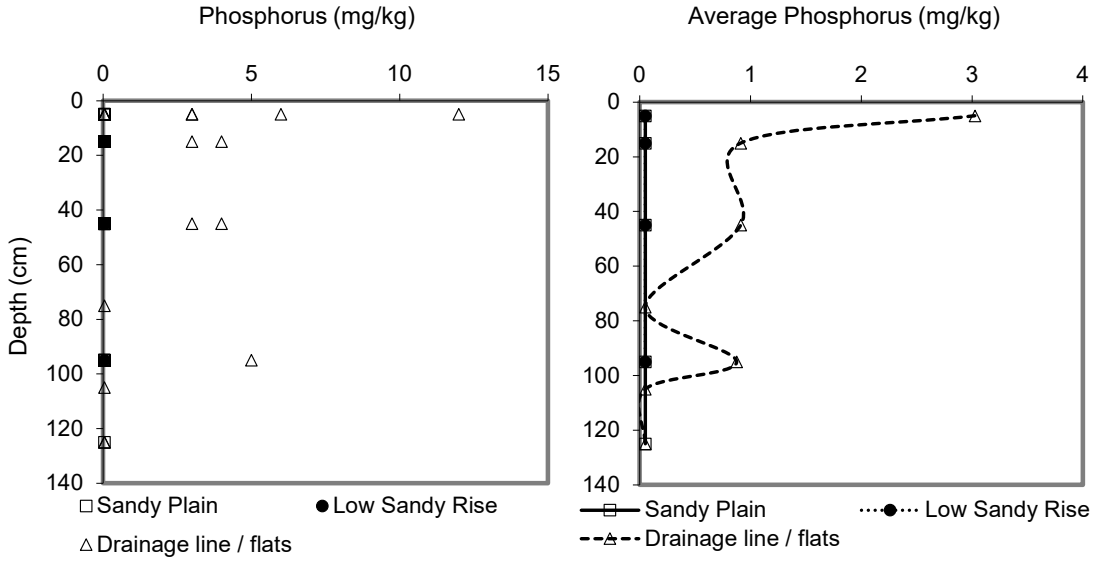


Figure 11 Individual and average plant-available phosphorus concentration (mg/kg) of soils with depth for each soil-landform association

4.3.4.3 Potassium

Potassium (K) plays a critical role in a number of plant physiological processes. Adequate amounts of K have been linked to improved drought tolerance, better resistance to certain fungal diseases and greater tolerance to insect pests (Brady and Weil., 2002).

The plant-available K concentrations of the soils from the study area ranged from low to high (high rating: >200 mg/kg) (Moore, 1998). Soils sampled from the 'Low Sandy Rise' typically reported the lowest plant-available K concentrations, with samples from the 'Drainage lines / flats' and 'Sandy Plains' recording higher concentrations with sample depth, corresponding to an increase in clay content within those soil profiles (Figure 12).

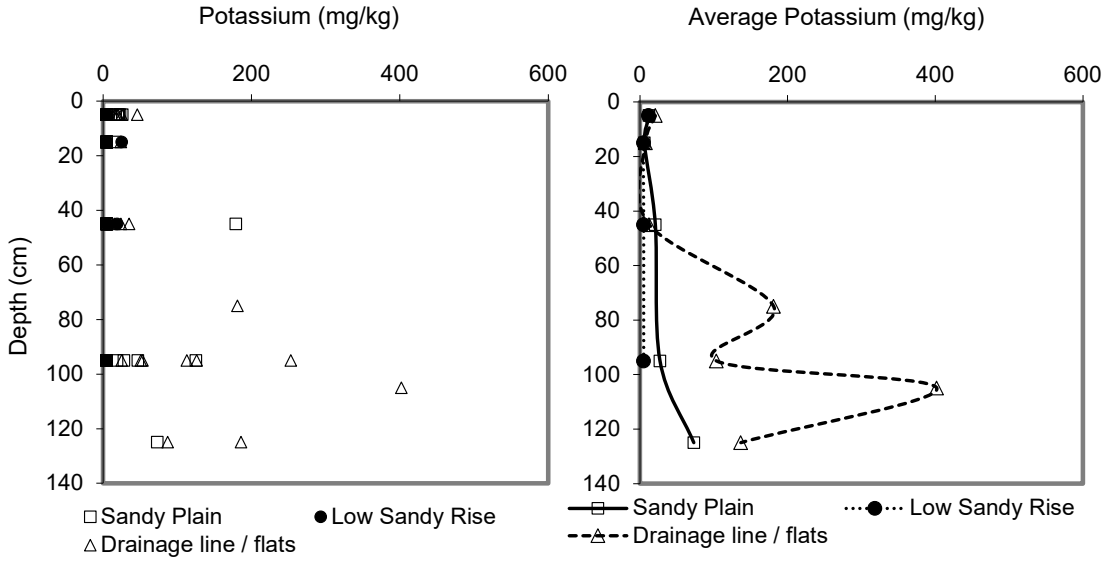


Figure 12 Individual and average plant-available potassium concentration (mg/kg) of soils with depth for each soil-landform association

4.3.4.4 Sulphur

There was a wide range of plant-available sulphur (S) concentrations measured for soils from the study area, with individual values ranging from 0.25 mg/kg (classed as very low) to 204 mg/kg (classed as high) (Moore, 1998). On average, soils from the 'Sandy Plain' and 'Drainage lines / flats' soil-landform association recorded the highest plant-available S values, which increased with depth through the soil profiles (Figure 13).

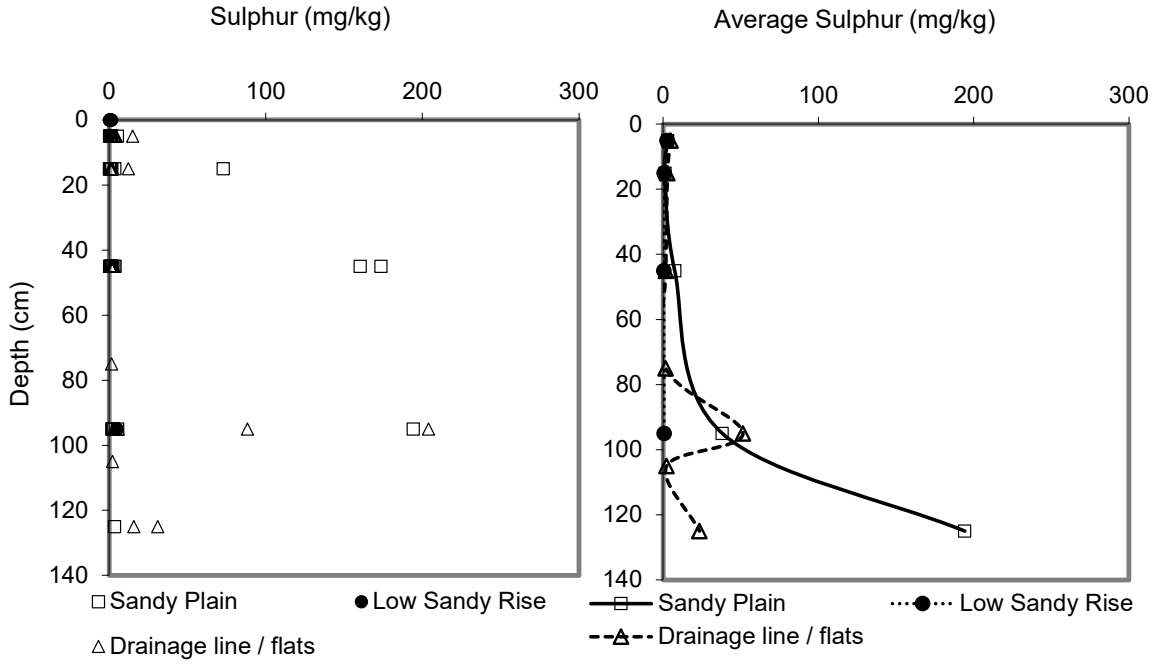


Figure 13 Individual and average plant-available sulphur concentration (mg/kg) of soils with depth for each soil-landform association

4.3.5 Total metal concentrations

The total concentration of selected metals was measured for selected samples that were representative of the soils sampled and associated landscape positions. The results are presented in Table 7. As a point of comparison, the average crustal abundance (ACA) (Reimann and de Caritat, 1998) for each metal is also provided in Table 7.

Of note are the relatively high baseline concentrations (i.e. above the ACA) of Arsenic (As) in three of the deep, clay-rich subsoil samples within the 'Drainage lines / flats' soil-landform association. One of those samples (Site 10, 120-130cm depth) also recorded a concentration of Lead (Pb) above the ACA. The majority of soil samples from all soil-landform associations recorded concentrations of Selenium (Se) slightly above the ACA. There was no apparent correlation between Se concentration and sample depth.

Table 7 Total metal concentrations for selected soil samples. Individual values above the Average Crustal Abundance (Reimann and de Caritat, 1998) are highlighted in yellow.

Site	Sample depth (cm)	Soil-landform association	Total metal concentration (ug/kg)						
			As	Cd	Cr	Co	Pb	Mo	Se
1	0-10	Sandy plain	48	10.9	1,047	46	2,170	102	171
	40-50		126	2.6	394	19	768	24	122
2	0-10	Sandy plain	59	26.6	1,278	99	1,590	74	87
3	0-10	Drainage lines / flats	49	29.6	1,056	84	1,809	48	204
	40-50		228	16.6	1,052	107	1,340	23	160
	90-100		1,138	1.6	20,945	3,649	6,840	125	883
4	0-10	Sandy plain	362	5.2	1,814	108	1,780	146	86
	40-50		123	1.6	1,565	43	1,711	53	151
	120-130		1,590	2.3	13,244	1,425	6,963	99	187
6	0-10	Drainage lines / flats	128	5.2	1,495	103	2,915	65	161
	40-50		66	1.3	861	53	1,653	37	92
8	0-10	Drainage lines / flats	111	4.5	1,673	115	3,050	80	150
	40-50		95	1.4	1,255	70	2,740	53	90
	90-100		759	1.4	2,319	348	1,402	33	126
10	0-10	Drainage lines / flats	271	3.9	1,855	71	1,843	48	200
	40-50		535	2.4	2,780	83	3,660	39	51
	120-130		7,073	2.5	71,230	2,795	19,396	393	186
12	0-10	Sandy plain	153	2.1	520	32	881	52	106
	40-50		105	3.4	363	26	1,019	84	121
13	0-10	Low sandy rise	117	2.8	611	22	638	57	74
	40-50		128	2.5	539	25	821	92	112
14	0-10	Low sandy rise	96	2.9	599	25	437	58	82
	40-50		115	2.8	705	41	557	85	69
15	0-10	Sandy plain	39	3.0	446	24	573	60	60
	40-50		35	8.5	360	25	756	137	116
17	0-10	Low sandy rise	77	7.7	719	34	664	98	95
	40-50		30	2.3	272	16	544	93	76
18	0-10	Sandy plain	54	3.1	550	26	674	66	78
	40-50		36	1.4	413	20	674	88	93
19	0-10	Drainage lines / flats	84	7.8	1,139	138	2,299	99	99
	40-50		155	2.7	712	72	656	38	112
	120-130		1,131	4.6	4,090	745	1,918	71	49
20	0-10	Drainage lines / flats	256	9.6	1,579	380	2,822	62	150
	40-50		308	3.6	730	65	1,397	37	119
	90-100		3,116	3.6	1,446	231	1,346	51	164
21	0-10	Sandy plain	87	18.0	1,994	114	2,801	61	128
	40-50		156	2.5	2,108	136	1,737	23	109
22	0-10	Drainage lines / flats	253	4.0	2,089	144	1,887	43	160
	40-50		445	2.2	3,176	132	2,349	38	192
	100-110		1,727	2.7	18,098	4,762	5,379	79	187
Average crustal abundance[1].			**1,500**	**110**	**100,000**	**20,000**	**14,000**	**1,500**	**50**

1. (Reimann and de Caritat, 1998)

5 RESULTS AND DISCUSSION – OVERBURDEN AND TAILINGS

The physical and chemical characteristics of the overburden and tailings materials, as determined by the laboratory analysis of collected samples, are discussed in the following sections.

5.1 Overburden and tailings physical characteristics

5.1.1 Soil texture

The soil texture of the overburden samples, as logged by Image Resources geologists during the drilling program, ranged from sands to sandy clays (Table 8), corresponding to clay contents of <5% to 40%. There was substantial variation present in the texture of the overburden soils both within and between the soil profiles from the various soil-landform associations, however, in general, the overburden materials from within the 'Low sandy rises', were generally courser in texture than those overburden materials from lower in the landscape.

As would be expected the textures of the tailings clay fines and tailings sand samples were classified as heavy clay (88% clay) and sand (2.8% clay)respectively.

5.1.2 Structural stability

The degree of clay dispersion within the overburden samples was variable, both within and between the soil profiles from the various soil-landform associations, with Emerson test classifications ranging from Class 1 (dry aggregate slakes and completely disperses), to Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed) (Table 8). Although variable, there was a general trend of the clay rich overburden materials from lower in the landscape, i.e., from within the 'Drainage lines / flats' soil-landform association, having a greater propensity for dispersion of the clay fraction than the coarser textured overburden materials from higher in the landscape. The propensity for clay dispersion in these overburden materials is likely to be exacerbated following severe disturbance.

The tailings clay fines material was identified as Emerson Class 1 (dry aggregate slakes and completely disperses) (Table 8). The tailings sand material was identified as Emerson Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed), albeit with a very low clay fraction.

5.1.3 Hydraulic conductivity

The hydraulic conductivity of the overburden samples was variable, reflecting the variable soil textures present across the study area (Table 8). Although variable, there was a general trend of lower hydraulic conductivity for the clay rich overburden materials from lower in the landscape, i.e., from within the 'Drainage lines / flats' soil-landform association, with drainage classifications ranging from 'slow' to 'moderately slow'. Overburden materials from the having a greater propensity for dispersion of the clay fraction than the coarser textured overburden materials from the 'Low sandy rises', which were typified by coarser soil textures recorded 'moderate' to 'very rapid' drainage classifications.

As would be expected, the tailings sand sample exhibited a 'very rapid' drainage classification, and the tailings clay fines, with a heavy clay texture, recorded an 'extremely slow' drainage classification (Table 8).

Table 8 Physical characteristics of overburden and tailings materials

Soil-landform association	Sample ID	Depth	Soil texture	Emerson test class	Water drop penetration time (sec.) [1.] / water repellency rating [2.]	Hydraulic conductivity mm/hr) [1.] / drainage class [3.]	Soil strength (kPa) [1., 4.]
Sandy Plain	ASS06	1-3m	Clayey sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed)	<1 (not significant)	65.3 (Moderately rapid)	167
	ASS06	3-4m	Sandy clay	Class 2 (aggregate slakes and partially disperses)	<1 (not significant)	36.4 (Moderate)	239
	ASS13	2-3m	Clayey sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed)	<1 (not significant)	69.2 (Moderately rapid)	13.3
	ASS21	2-3m	Clayey sand	Class 3b (aggregate slakes but does not disperse, partial dispersion of remoulded soil)	<1 (not significant)	60.4 (Moderately rapid)	26.4
	ASS23	2-3m	Clayey sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed)	<1 (not significant)	101.2 (Moderately rapid)	16.2
	ASS24	2-3m	Clayey sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed)	<1 (not significant)	120.8 (Moderately rapid)	2.8
	ASS30	2-4m	Sand / Clayey sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil:water suspension remains dispersed)	<1 (not significant)	541.7 (Very rapid)	1.7
	ASS31	2-3m	Sandy clay	Class 3b (aggregate slakes but does not disperse, partial dispersion of remoulded soil)	<1 (not significant)	49.9 (Moderate)	329
Drainage Lines / Flats	ASS08	1-3m	Clayey sand / Sandy clay	Class 2 (aggregate slakes and partially disperses)	<1 (not significant)	19.6 (Moderately slow)	290
	ASS10	1-2m	Sandy clay	Class 3b (aggregate slakes but does not disperse, partial dispersion of remoulded soil)	<1 (not significant)	3.26 (Slow)	92
	ASS11	1-3m	Sandy clay	Class 2 (aggregate slakes and partially disperses)	<1 (not significant)	16.1 (Moderately slow)	242

Soil-landform association	Sample ID	Depth	Soil texture	Emerson test class	Water drop penetration time (sec.) [1.] / water repellency rating [2.]	Hydraulic conductivity mm/hr) [1.] / drainage class [3.]	Soil strength (kPa) [1., 4.]
	ASS14	2-3m	Sandy clay	Class 1 (dry aggregate slakes and completely disperses)	<1 (not significant)	9.8 (Moderately slow)	155
Low Sandy Rise	ASS25	1-3m	Sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)	<1 (not significant)	250.6 (Very rapid)	18.1
	ASS26	1-3m	Sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)	<1 (not significant)	593.9 (Very rapid)	1.0
	ASS27	1-3m	Sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)	<1 (not significant)	778.8 (Very rapid)	0.2
	ASS28	2-3m	Sandy clay	Class 3a (aggregate slakes but does not disperse, complete dispersion of remoulded soil)	<1 (not significant)	33.7 (Moderate)	179
	ASS 29	2-3m	Clayey sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)	<1 (not significant)	313.3 (Very rapid)	1.0
Tailings clay fines	-	-	Heavy clay	Class 1 (aggregate slakes and completely disperses)	<1 (not significant)	<0.1 (Extremely slow)	557
Tailings sand	-	-	Sand	Class 5 (aggregate slakes but does not disperse, no dispersion of remoulded soil, soil: water suspension remains dispersed)	<1 (not significant)	1677 (Very rapid)	0.3

1. Determined for the <2 mm fraction of the soil material.
2. (King, 1981)
3. (Hunt and Gilkes, 1992).
4. Values highlighted yellow are above the threshold of 60kPa, identified as potentially hard-setting (Cochrane and Aylmore, 1997).

5.1.4 Water repellence

As would be expected for samples from deep within the soil profile with very low organic matter concentrations, all overburden samples exhibited negligible levels of water repellence (Table 8).

5.1.5 Soil strength

Hard-setting characteristics of the overburden materials were variable, again reflective of the variable soil textures and degree of clay dispersion within the materials. As was the case for the soils from higher in the soil profiles, overburden soils from lower in the landscape with higher clay contents (i.e. within the 'Drainage lines / flats') exhibited high MOR values above the 60kPa threshold to denote potential hard-setting upon disturbance, wetting and drying cycles (Table 8). The coarser textured (i.e. sandy) overburden materials exhibited low MOR values and a low hard-setting potential.

The tailings clay fines sample exhibited the highest MOR values, reflective of its clay rich texture and dispersive nature. As would be expected, the tailings sand sample, which has a negligible clay fraction recorded a very low MOR (Table 8).

5.2 Overburden and tailings chemical characteristics

5.2.1 pH and Electrical Conductivity

The overburden samples recorded a substantial range in pH values, ranging from pH (H_2O) 4.4 (very strongly acid) to pH (H_2O) 9.4 (strongly alkaline) (Table 9). There was no apparent correlation between soil pH of the overburden materials and position within the landscape.

The tailings clay fines sample recorded a pH (H_2O) of 7.8, classified as pH neutral (Table 9). The tailings sand sample was also classified as pH neutral, with a pH (H_2O) of 6.9.

There was a substantial range of EC values recorded for the overburden materials, with individual values ranging between 0.010 dS/m (non-saline) and 3.886 dS/m (extremely saline) (Table 9) based on the standard USDA and CSIRO electrical conductivity categories (Appendix A). Overburden materials from within the 'Drainage lines / flats' soil-landform association typically recorded the highest EC values. Overburden materials from within the 'Low sandy rise' soil-landform association recorded non-saline EC values.

The tailings clay fines sample recorded an EC of 0.9 dS/m, classified as moderately saline (Table 9), while the tailings sand was classified as non-saline with an EC of 0.037 dS/m.

5.2.2 Soil organic matter

Soil organic matter in the overburden samples was very low, ranging from <0.05 to 0.34% (Table 9), as would be expected for soil from deep within the profile.

Table 9 Chemical characteristics of overburden and tailings materials

Soil-landform association	Sample ID	Depth	pH (H_20)	EC (dS/m)	Org C (%)	Plant available nutrients (mg/kg)					Exchangeable cations (meq/100g)				eCEC (meq/100g)	ESP (%)[1.]
						NH_4^+	NO_3^-	P	K	S	Ca	Mg	K	Na		
Sandy Plain	ASS06	2-3m	9.0	1.138	0.08	< 1	< 1	< 2	81	92.7	2.67	3.45	0.30	2.56	8.98	28.51
	ASS06	3-4m	9.4	0.454	<0.05	< 1	< 1	< 2	146	28.2	2.67	3.45	0.30	2.57	8.99	28.59
	ASS13	2-3m	6.7	0.116	0.12	< 1	1	< 2	< 15	4.8	0.21	0.15	0.02	0.43	0.81	53.09
	ASS21	2-3m	6.4	0.050	0.34	1	1	< 2	< 15	15.7	0.86	0.28	0.02	0.17	1.33	12.78
	ASS23	2-3m	5.7	0.105	0.07	1	< 1	< 2	< 15	44.4	0.33	0.20	0.04	0.33	0.90	36.67
	ASS24	2-3m	5.4	0.243	0.05	< 1	< 1	< 2	< 15	137.7	0.47	0.37	0.02	0.41	1.27	32.28
	ASS31	2-3m	4.4	0.617	0.26	3	< 1	2	79	568.1	1.90	2.77	0.16	1.29	6.12	21.08
Drainage Lines / Flats	ASS10	1-2m	8.5	2.686	0.05	< 1	3	< 2	182	184.1	1.64	3.71	0.34	11.83	17.52	67.52
	ASS11	1-3m	8.2	3.886	0.13	< 1	< 1	< 2	314	300.5	2.44	6.85	0.56	19.89	29.74	66.88
	ASS14	2-3m	8.0	0.922	<0.05	< 1	< 1	< 2	145	41.9	1.21	2.85	0.31	6.47	10.84	59.69
	ASS16	2-3m	6.6	3.477	0.10	< 1	< 1	< 2	111	256.3	1.02	3.90	0.18	16.01	21.11	75.84
Low Sandy Rise	ASS25	1-3m	7.2	0.024	0.09	< 1	< 1	< 2	< 15	4.1	0.31	0.14	0.02	0.08	0.55	14.55
	ASS27	2-3m	6.8	< 0.010	<0.05	< 1	< 1	< 2	< 15	0.9	0.10	0.03	0.01	0.01	0.15	6.67
	ASS27	3-4m	7.0	< 0.010	<0.05	< 1	< 1	< 2	< 15	3.3	0.09	0.03	< 0.01	0.01	0.13	7.69
Tailings fines	-	-	7.8	0.900	0.25	4	4	6	362	172.5	10.06	11.32	0.76	5.16	27.30	18.90
Tailings sand	-	-	6.9	0.037	0.06	< 1	< 1	6	< 15	3.6	0.13	< 0.1	0.01	< 0.1 [2.]	0.34	Bld [2.]

1. Shading of ESP values denotes non-sodic, sodic and highly sodic classifications.
2. Exchangeable Na below detection limit

5.2.3 Exchangeable cations and exchangeable sodium percentage

Exchangeable cation concentration and effective cation exchange capacity (eCEC) were variable throughout the overburden samples, with the exchangeable sodium percentage (ESP) results indicating that most all overburden samples were classified as sodic or highly sodic (Table 9).

As discussed in Section 4.3.3 however, the exchangeable cation and ESP results should be viewed in conjunction with the Emerson Test results, the amount of clay in the overburden and the salinity of the material, to identify the likely influence on the physical stability of the overburden upon disturbance. Sodicity and its influence on clay dispersion, is only likely to have a detrimental influence on the structure of the more clay-rich overburden materials, as reflected by the dispersive and hard-setting nature of the more clay-rich overburden samples.

The tailings clay fines sample reported a high eCEC and highly sodic ESP, reflective of its high propensity to disperse upon saturation (Emerson Class 1 – Section 5.1.2). Conversely the eCEC and sodicity of the tailings sand was very low, with exchangeable Na below the limit of detection (Table 9).

5.2.4 Soil nutrients

Soil nutrient concentrations were typically low in the overburden and tailings samples, except for moderate to high concentrations of potassium and sulphate sulphur in some clay-rich overburden samples from within the ‘Drainage lines / flats’ soil-landform association, and the tailings clay fines sample (Table 9).

5.2.5 Total metal concentrations

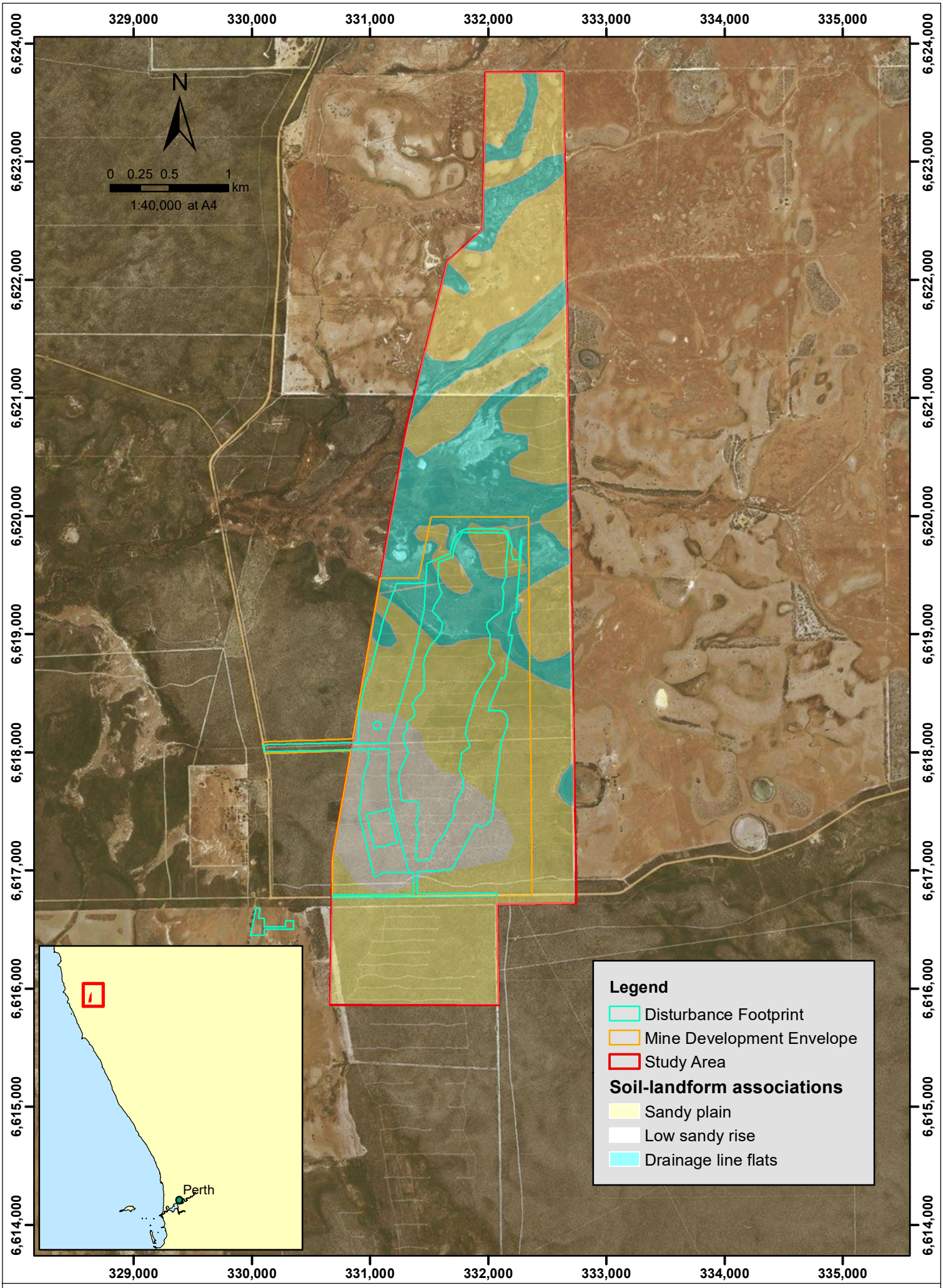
Total metals concentrations for the overburden and tailings samples were generally low and either below the level of detection or the average crustal abundance (Reimann, C. and de Caritat, P, 1998) (Table 10). Exceptions were minor elevations above the average crustal abundance for As and Zn in a small number of overburden samples. The tailings clay fines sample also reported a minor elevation in As (16 mg/kg), above the average crustal abundance (Table 10).

Table 10 Total metal concentrations of overburden and tailings materials. Individual values above the Average Crustal Abundance (Reimann and de Caritat, 1998) are highlighted in yellow.

Soil-landform association	Sample ID	Depth	Total concentration (mg/kg)														
			As	Ba	Be	B	Cd	Cr	Co	Cu	Hg	Pb	Mn	Ni	Se	V	Zn
Sandy Plain	ASS06	1-2m	7	20	<1	<50	<1	8	2	<5	<0.1	<5	5	2	<5	9	<5
	ASS23	2-3m	5	20	<1	<50	<1	19	<2	<5	<0.1	<5	9	<2	<5	36	11
	ASS30	2-3m	<5	<10	<1	<50	<1	<2	<2	<5	<0.1	<5	<5	<2	<5	<5	14
	ASS31	1-2m	<5	<10	<1	<50	<1	<2	<2	<5	<0.1	<5	<5	<2	<5	<5	<5
	ASS31	2-3m	13	20	<1	<50	<1	12	<2	<5	<0.1	6	<5	<2	<5	25	<5
Drainage Lines / Flats	ASS07	2-3m	18	90	<1	<50	<1	15	<2	<5	<0.1	6	74	<2	<5	21	7
	ASS10	1-2m	<5	<10	<1	<50	<1	4	<2	<5	<0.1	<5	246	<2	<5	<5	<5
	ASS14	2-3m	5	20	<1	<50	<1	19	<2	<5	<0.1	<5	9	<2	<5	36	11
Low Sandy Rise	ASS25	1-2m	<5	<10	<1	<50	<1	4	<2	<5	<0.1	<5	14	3	<5	<5	372
	ASS25	2-3m	<5	<10	<1	<50	<1	5	<2	<5	<0.1	<5	14	<2	<5	<5	360
	ASS26	2-3m	<5	<10	<1	<50	<1	<2	<2	<5	<0.1	<5	<5	<2	<5	<5	<5
	ASS27	1-2m	<5	<10	<1	<50	<1	<2	<2	<5	<0.1	<5	<5	<2	<5	<5	<5
	ASS29	2-3m	9	100	<1	<50	<1	10	<2	<5	<0.1	6	9	<2	<5	14	<5
Tailings clay fines	-	-	16	80	<1	<50	<1	51	3	<5	0.2	9	59	5	<5	89	16
Tailings sand	-	-	<5	<10	<1	<50	<1	3	<2	<5	<0.1	<5	<5	3	<5	<5	<5
Average crustal abundance			1.7	500	2.4	10	0.1	100	20	50	0.05	14	950	80	0.05	160	75

6 SOIL LANDFORM ASSOCIATION MAPPING

Three soil-landform associations were identified within the study area namely ‘Low sandy rises’, ‘Sandy plains’ and ‘Drainage line / flats’. Identification of the soil-landform associations was based on field observations of morphological differences between the soil profiles, position within the landscape and analysis of physical and chemical soil characteristics. Approximate boundaries of the soil-landform associations within the study area are detailed in Figure 14.



MINE EARTH

Date: 9/06/2022
Author: Julia Heide

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Soil landform associations

Figure 14

7 CONCLUSIONS AND RECOMMENDATIONS

The aim of the assessment was to characterise the existing surface soil and overburden materials and tailings within the study area, to identify available soil resources and potentially problematic materials, and to develop associated recommendations for the recovery and stockpiling of soil resources and for their potential use in rehabilitation and mine closure activities. The characteristics of the surface soil, overburden and tailings within the study area are summarised below.

7.1 Topsoil/subsoil

Three soil-landform associations were identified within the study area namely 'Low sandy rises', 'Sandy plains' and 'Drainage line / flats'. The major consistent morphological difference in the soil profiles was the depth of sands present over the more clay-rich soil horizons. As would be expected there was a general trend of deeper sand profiles (>1.5m) higher in the landscape (Low sandy rises), with clay-rich subsoils present at relatively shallow depths (from 0.5m) in the soil profiles from lower in the landscape (Drainage lines / flats).

There was a wide range of physical and chemical soil characteristics measured across the study area, however, the characteristics were generally consistent with position within the landscape and soil-landform association.

The characteristics of soils present within the three soil-landform associations are summarised as follows:

- Low sandy rises:
    - Deep, single-grained, structureless sands to depths >1.5m.
    - Consistently non-saline, non-sodic and non-dispersive soils to >1.5m depth, with low nutrient status, low soil strength, 'very rapid' drainage class and low water holding capacity.
    - Topsoils (0-20cm) characterised as 'moderately' to 'severely' water repellent.
    - Concentrations of all metals tested below the average crustal abundance.
- Sandy plains:
    - Single grained, structureless sandy soils (to variable depths of 0.6 to 1.3m) over weakly structured clayey sand horizon.
    - Consistently non-dispersive sandy soils to variable depths of 0.6 to 1.3m, with low nutrient status, low soil strength, 'very rapid' drainage class and low water holding capacity.
    - Increased salinity at depths of 0.4 to 1.5m at some sampling locations.
    - Topsoils (0-0.2m) characterised as 'Very low' to 'severely' water repellent.
    - Minor elevations of Se above the average crustal abundance at some locations, throughout the soil profiles.
- Drainage line / flats:
    - Single grained, structureless sandy soils (to average depth of 0.5m) over massive light clay horizons.
    - Consistently non-dispersive sandy soils to approximately 0.5m, with low to moderate nutrient status, low soil strength, very rapid drainage class and low water holding capacity.

- Moderately saline, topsoil and subsoils classified as highly sodic, with minor dispersion of clay fraction upon saturation of some samples, low to moderate nutrient status, moderately slow drainage class and moderate water holding capacity.
- Topsoils (0-0.2m) characterised as 'Very low' to 'Moderately' water repellent.
- Minor elevations of Se above the average crustal abundance within the surface soils (to 0.5m depth) at some locations.
- Clay-rich subsoil horizons exhibited elevated salinity, sodicity and poor structural stability (clay dispersion), 'extremely slow' drainage class and high water holding capacity.
- Elevations of As, Pb and Se above the average crustal abundance within the clay-rich subsoils at some locations.

In general, the characteristics of the topsoils (0 to 0.2m depth) from all soil-landform associations were relatively consistent. The topsoils will be a valuable resource for rehabilitation of the reconstructed soil profile surface following mining operations.

The characteristics of the sandy subsoil materials to depths of approximately 0.5m within the 'Sandy plain' and 'Drainage lines / flats', and >1.5m in the 'Low sandy rises', were also relatively consistent. These soils (where non-mineralised) are also considered a valuable resource for soil profile reconstruction.

The clay-rich subsoils from approximately 0.5m depth in the 'Drainage lines / flats', and to a lesser degree within the 'Sandy plain' soil-landform associations, exhibited elevated salinity, dispersion of the clay fraction (poor structural stability) and a lower drainage class than the sandy soils from higher in the soil profiles. These soils should not be placed at the surface of reconstructed soil profiles.

7.2 Overburden and tailings

Analysis of the overburden materials indicated that they are highly variable in their physical and chemical characteristics, reflecting the formation of the soil profile under complex cycles of erosion and deposition, particularly lower in the landscape within the study area.

The characteristics of overburden and tailings materials expected to be generated from mining activities are summarised as follows:

- Overburden characteristics:
  - Variable soil textures, ranging from single grained, structureless sands, to sandy clays with up to 40% clay fraction. Substantial variability within individual profiles and across the study area, but general trend of higher clay fractions in overburden from lower in the landscape.
  - Variable soil pH, with little correlation with landscape position. Variable salinity with trend of higher salinity in overburden materials from lower in the landscape.
  - Generally low organic matter and plant-available nutrient concentrations.
  - Variable sodicity, structural stability, soil strength and hydraulic conductivity, generally correlating to the clay content of the overburden materials. Overburden materials with higher clay contents generally exhibited poor structural stability, high soil strength and low hydraulic conductivity.
  - Minor elevations of As and Zn above the average crustal abundance within some overburden samples.

- Tailings characteristics (fines and sand fractions):
    - Tailings clay fines characterised as a 'heavy clay', with neutral pH, 'moderate' salinity classification, low to moderate nutrient concentration, poor structural stability (sodic and dispersive), high soil strength upon drying and an 'extremely slow' drainage characteristics. Minor elevation in As concentration above the average crustal abundance (similar to some subsoil / overburden concentrations).
    - Tailings sand fraction characterised as 'sand', with low soil strength and a 'very rapid' drainage classification. Concentrations of all metals below the ACA.

The physical properties of the clay rich tailings fines indicate potentially problematic characteristics if place at, or close to the surface of reconstructed / rehabilitated soil profiles.

7.3 Soil Management Recommendations

It is recommended that topsoil materials from all disturbance areas are salvaged to a depth of approximately 0.2m and stockpiled as a surface rehabilitation resource. Due to the differences in vegetation (and soil seed store) present at lower positions in the landscape, topsoils from the 'Drainage lines / flats' soil-landform association should be stockpiled separately from the 'Low sandy rise' and 'Sandy plain' topsoils, for surface application in 'low areas' of the reconstructed landscape post mining.

Sandy subsoils from 0.2 to 0.5m depth (minimum) across all soil-landform associations should be salvaged for placement as a subsoil material in reconstructed soil profiles.

Clay-rich subsoils from depths from 0.5m in the 'Drainage lines / flats', and where present in the 'Sandy plain' profiles should not be placed at the surface of reconstructed soils profiles. All clay-rich subsoil / overburden material should be placed below the topsoil and subsoil materials (at depths below 0.5m) in reconstructed soil profiles to ensure that surface soil and drainage characteristics of the reconstructed soil profiles are reinstated as far as practicable.

Tailings materials, in particular the tailings clay fines, which have potentially deleterious physical characteristics if place at the surface, should be returned to the mining void, below the subsoil and topsoil materials.

The sandy, water repellent nature of the topsoils within the study area indicates that wind erosion and surface water infiltration may be an issue in the early stages of rehabilitation, prior to vegetation establishment. Specific topsoil management and surface rehabilitation recommendations which can optimise the success of rehabilitation activities are as follows:

- Vegetation debris should be collected, stockpiled and returned to the rehabilitated soil surface.
- Any surface litter present at the surface should be collected and stockpiled with the topsoil.
- Soil stripping should occur as close as possible to the time when the proposed disturbance is scheduled to commence. Direct return of topsoil / subsoil materials to reconstructed soil profiles where possible.
- Application of surface treatments (e.g. scarification, to 'roughen' the soil surface) to promote the infiltration of rainfall into the soil surface.

Further detail pertaining to the management of soil, overburden and tailings materials during operations and at closure for the Project is provided within the Atlas Mineral Sands – Soil and Mine Waste Management Plan (Mine Earth, 2022b).

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Appendix A

Soil analysis classifications

Emerson Dispersion Test Classes (Moore 1998)

Class	Description
Class 1	Dry aggregate slakes and completely disperses
Class 2	Dry aggregate slakes and partly disperses
Class 3a	Dry aggregate slakes but does not disperse; remoulded soil disperses completely
Class 3b	Dry aggregate slakes but does not disperse; remoulded soil partly disperses
Class 4	Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are present
Class 5	Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains dispersed
Class 6	Dry aggregate slakes but does not disperse; remoulded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains flocculated
Class 7	Dry aggregate does not slake; aggregate swells
Class 8	Dry aggregate does not slake; aggregate does not swell

Soil Electrical conductivity classes (based on standard USDA and CSIRO categories)

EC (1:5) (dS/m)						
Salinity class	**Sand**	**Sandy loam**	**Loam**	**Clay loam**	**Light / medium clay**	**Heavy clay**
Non-saline	<0.13	<0.17	<0.20	<0.22	<0.25	<0.33
Slightly saline	0.13-0.26	0.17-0.33	0.20-0.40	0.22-0.44	0.25-0.50	0.33-0.67
Moderately saline	0.26-0.52	0.33-0.67	0.40-0.80	0.44-0.89	0.50-1.00	0.67-1.33
Very saline	0.52-1.06	0.67-1.33	0.80-1.60	0.89-1.78	1.00-2.00	1.33-2.67
Extremely saline	>1.06	>1.33	>1.60	>1.78	>2.00	>2.67

Soil pH classes (based on standard USDA and CSIRO categories)

	Soil pH rating						
	Very strongly acid (Vsac)	**Strongly acid (Sac)**	**Moderately acid (Mac)**	**Slightly acid (Slac)**	**Neutral (N)**	**Moderately alkaline (Malk)**	**Strongly alkaline (Salk)**
pH_w	< 5.3	5.3 - 5.6	5.6 - 6.0	6.0 - 6.5	6.5 - 8.0	8.0 - 9.0	> 9.0
pH_{Ca}	< 4.2	4.2 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 7.0	7.0 - 8.0	> 8.0

Soil water repellency classifications (King 1981)

Time	Water repellence	Code
< 1 second	Not significant	NS
1 - 10 seconds	Very low water repellence	VL
10 - 50 seconds	Low water repellence	L
50 - 260 seconds	Moderate water repellence	M
>260 seconds	Moderate to severe water repellence	MS

Appendix B

CSBP Laboratory Analysis Certificates

Analysis Results

CSBP Soil and Plant Laboratory

90423
Mine Earth Pty Ltd

	Lab No	SHS21008	SHS21009	SHS21010	SHS21011	SHS21012	SHS21013	SHS21014	SHS21015
	Name	S1	S1	S3	S3	S4	S4	S8	S8
	Code	Site 1	Site 1	Site 3	Site 3	Site 4	Site 4	Site 8	Site 8
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	0-10	40-50	0-10	40-50	0-10	40-50	0-10	40-50
Colour		GR	WH	GR	GRWH	GRBR	GRWH	LTGR	WH
Gravel	%	0	0	0	0	5-10	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	2	< 1	8	1	2	< 1	2	< 1
Nitrate Nitrogen	mg/kg	6	1	15	2	< 1	< 1	3	< 1
Phosphorus Colwell	mg/kg	< 2	< 2	3	3	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	< 15	< 15	16	< 15	26	< 15	20	15
Sulfur	mg/kg	3.8	1.5	4.5	1.4	5.5	0.7	3.7	0.8
Organic Carbon	%	0.69	< 0.05	0.99	< 0.05	0.95	0.05	0.47	0.13
Conductivity	dS/m	0.044	0.023	0.076	0.024	0.100	0.011	0.032	0.011
pH Level (CaCl2)		5.2	6.2	4.7	6.0	6.8	6.2	6.1	6.2
pH Level (H2O)		6.7	6.8	6.0	7.0	7.4	6.7	7.5	6.8
Total Nitrogen	%	0.05	< 0.01	0.08	< 0.01	0.04	< 0.01	0.03	< 0.01
% Clay	%	2.93	2.91	2.99	2.88	3.96	2.93	2.96	1.92
% Course Sand	%	86.55	80.61	82.99	81.14	88.70	82.56	84.61	83.66
% Fine Sand	%	10.52	16.48	14.01	15.00	7.34	14.51	9.42	14.42
% Sand	%	97.07	97.09	97.00	96.14	96.04	97.07	94.03	98.08
% Silt	%	< 0.01	< 0.01	< 0.01	0.98	< 0.01	< 0.01	3.01	< 0.01
Prewash exch. Ca	meq/100g	0.57	0.12	0.65	< 0.10	4.02	0.16	0.29	0.10
Prewash exch. K	meq/100g	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21016	SHS21017	SHS21018	SHS21019	SHS21020	SHS21021	SHS21022	SHS21023
	Name	S10	S10	S12	S12	S14	S14	S18	S18
	Code	Site 10	Site 10	Site 12	Site 12	Site 14	Site 14	Site 18	Site 18
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	0-10	40-50	0-10	40-50	0-10	40-50	0-10	40-50
Colour		GR	BRWH	GR	WH	LTGR	WH	GR	GRWH
Gravel	%	0	0	0	0	0	0	0	0
Texture		1.5	1.5	1.0	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	3	< 1	2	< 1	1	1	2	1
Nitrate Nitrogen	mg/kg	9	1	< 1	< 1	< 1	< 1	1	1
Phosphorus Colwell	mg/kg	3	4	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	16	24	< 15	< 15	< 15	< 15	< 15	< 15
Sulfur	mg/kg	3.4	2.1	2.0	< 0.5	1.0	0.6	1.6	0.8
Organic Carbon	%	0.59	0.25	0.98	0.19	0.75	0.17	0.68	0.24
Conductivity	dS/m	0.033	0.021	0.016	< 0.010	0.013	0.010	0.015	0.010
pH Level (CaCl2)		5.5	6.4	4.8	5.6	5.4	5.3	5.0	5.6
pH Level (H2O)		6.9	7.4	6.7	6.9	6.4	6.5	6.4	6.4
Total Nitrogen	%	0.06	0.01	0.04	< 0.01	0.03	< 0.01	0.03	0.01
% Clay	%	2.94	3.89	2.97	0.94	0.96	1.92	0.94	2.87
% Course Sand	%	89.65	85.72	89.67	93.02	94.07	94.26	93.44	91.49
% Fine Sand	%	7.41	10.39	7.36	6.03	3.96	3.82	3.64	5.64
% Sand	%	97.06	96.11	97.03	99.05	98.03	98.08	97.08	97.13
% Silt	%	< 0.01	< 0.01	< 0.01	< 0.01	1.01	< 0.01	1.98	< 0.01
Prewash exch. Ca	meq/100g	0.71	0.21	0.84	0.15	0.58	0.14	1.24	0.26
Prewash exch. K	meq/100g	0.03	0.03	0.02	0.01	0.01	0.02	0.02	0.02

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21024	SHS21025	SHS21026	SHS21027	SHS21028	SHS21029	SHS21030	SHS21031
	Name	S22	S22	S1	S3	S4	S4	S8	S9
	Code	Site 22	Site 22	Site 1	Site 3	Site 4	Site 4	Site 8	Site 9
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	0-10	40-50	90-100	0-20	0-20	90-100	0-20	0-20
Colour		WH	GRWH	GRWH	GRBR	GRWH	GRWH	WH	GRWH
Gravel	%	5-10	0	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	< 1	< 1	1	< 1	< 1	1	< 1	1
Nitrate Nitrogen	mg/kg	< 1	< 1	< 1	1	< 1	< 1	1	1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	4	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	< 15	35	19	< 15	< 15	47	< 15	24
Sulfur	mg/kg	0.9	1.0	1.7	0.9	< 0.5	173.6	1.9	1.5
Organic Carbon	%	0.14	0.15	0.09	0.12	0.08	0.20	0.08	0.10
Conductivity	dS/m	0.045	0.048	0.039	0.013	< 0.010	1.563	0.029	0.018
pH Level (CaCl2)		7.7	8.2	7.2	4.5	6.6	8.5	6.9	5.8
pH Level (H2O)		9.2	9.4	8.7	5.4	8.1	9.3	8.5	7.0
Total Nitrogen	%	0.01	0.01						
% Clay	%	3.89	3.94	1.92	1.93	1.92	7.88	2.90	1.92
% Course Sand	%	82.44	80.21	86.01	85.48	89.17	73.10	85.74	91.54
% Fine Sand	%	12.69	14.86	11.09	12.59	7.93	17.04	10.38	5.56
% Sand	%	95.13	95.07	97.10	98.07	97.10	90.14	96.12	97.10
% Silt	%	0.98	1.00	0.98	< 0.01	0.98	1.98	0.98	0.98
Prewash exch. Ca	meq/100g	5.51	3.03	0.12	< 0.10	< 0.10	8.18	0.19	0.12
Prewash exch. K	meq/100g	0.02	0.04	0.03	0.03	0.02	0.03	0.01	0.02

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21032	SHS21033	SHS21034	SHS21035	SHS21037	SHS21038	SHS21039	SHS21040
	Name	S9	S10	S10	S12	S12	S14	S14	S18
	Code	Site 9	Site 10	Site 10	Site 12	Site 12	Site 14	Site 14	Site 18
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	90-100	0-20	90-100	0-20	90-100	0-20	90-100	10-20
Colour		BRWH	YWGR	GRBR	GR	WH	GRBK	WH	GR
Gravel	%	0	0	0	0	0	0	0	0
Texture		1.5	1.5	2.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	1	1	1	1	1	2	< 1	< 1
Nitrate Nitrogen	mg/kg	< 1	< 1	< 1	< 1	1	< 1	< 1	1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	113	< 15	253	< 15	< 15	< 15	< 15	< 15
Sulfur	mg/kg	204.0	2.2	2.7	1.2	0.9	1.4	0.6	1.0
Organic Carbon	%	0.08	0.21	0.12	0.29	0.08	0.51	0.09	0.72
Conductivity	dS/m	2.526	0.013	0.289	0.011	0.010	0.017	< 0.010	0.011
pH Level (CaCl2)		7.7	7.1	8.6	5.4	5.6	5.1	5.8	5.2
pH Level (H2O)		8.4	8.0	10.0	7.1	6.4	7.5	6.4	7.0
Total Nitrogen	%								
% Clay	%	8.84	1.91	14.08	1.92	2.87	1.93	0.93	2.91
% Course Sand	%	78.57	90.08	67.26	90.39	91.56	93.82	93.59	94.06
% Fine Sand	%	10.62	7.03	12.62	6.70	5.57	3.26	3.52	3.03
% Sand	%	89.19	97.11	79.88	97.09	97.13	97.08	97.11	97.09
% Silt	%	1.98	0.98	6.05	0.99	< 0.01	0.99	1.96	< 0.01
Prewash exch. Ca	meq/100g	0.80	0.23	6.09	0.31	< 0.10	0.60	< 0.10	0.85
Prewash exch. K	meq/100g	0.15	0.02	0.37	0.02	0.01	0.02	0.02	0.01

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21041	SHS21042	SHS21043	SHS21044	SHS21045	SHS21046	SHS21047	SHS21048
	Name	S22	S22	S9	S9	S3	S4	S8	S10
	Code	Site 22	Site 22	Site 9	Site 9	Site 3	Site 4	Site 8	Site 10
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	10-20	70-80	0-10	40-50	90-100	120-130	90-100	120-130
Colour		WH	GRYW	GR	GRWH	BRWH	BRWH	YWGR	GRWH
Gravel	%	0	0	0	0	0	0	0	0
Texture		1.5	2.5	1.5	1.5	2.5	2.0	1.5	2.0
Ammonium Nitrogen	mg/kg	< 1	< 1	2	< 1	1	1	< 1	2
Nitrate Nitrogen	mg/kg	< 1	< 1	7	< 1	2	< 1	1	1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	< 15	181	25	< 15	126	73	51	186
Sulfur	mg/kg	0.6	1.6	2.4	3.1	5.8	194.2	4.1	15.8
Organic Carbon	%	0.07	0.09	0.54	0.07	0.06	0.12	0.10	0.07
Conductivity	dS/m	0.032	0.039	0.031	0.054	0.100	1.638	0.065	0.350
pH Level (CaCl2)		8.2	7.1	6.2	6.7	7.2	8.1	6.9	7.9
pH Level (H2O)		9.4	8.8	8.2	8.3	9.4	8.7	8.3	9.9
Total Nitrogen	%			0.05	< 0.01				
% Clay	%	2.88	12.28	2.91	1.92	14.45	6.77	1.90	33.56
% Course Sand	%	87.75	63.29	92.00	92.06	77.64	82.83	92.53	57.57
% Fine Sand	%	9.37	20.32	5.08	5.04	5.97	7.47	3.62	7.88
% Sand	%	97.12	83.61	97.08	97.10	83.61	90.30	96.15	65.45
% Silt	%	< 0.01	4.11	< 0.01	0.98	1.93	2.92	1.95	0.99
Prewash exch. Ca	meq/100g	0.57	1.44	0.63	< 0.10	0.23	1.85	0.19	1.96
Prewash exch. K	meq/100g	0.02	0.23	0.03	0.02	0.05	0.07	0.04	0.07

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21049	SHS21050	SHS21051	SHS21052	SHS21053	SHS21054	SHS21055	SHS21056
	Name	S22	S2	S6	S6	S13	S13	S15	S15
	Code	Site 22	Site 2	Site 6	Site 6	Site 13	Site 13	Site 15	Site 15
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	100-110	0-10	0-10	40-50	0-10	40-50	0-10	40-50
Colour		GRBR	LTGR	LTGR	LTGR	DKGR	WH	DKGR	GR
Gravel	%	0	0	0	0	0	0	0	0
Texture		2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	2	4	5	< 1	2	1	2	1
Nitrate Nitrogen	mg/kg	< 1	2	4	1	< 1	< 1	< 1	< 1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	402	17	20	< 15	25	< 15	21	< 15
Sulfur	mg/kg	2.2	1.8	15.0	1.8	5.2	< 0.5	2.4	1.6
Organic Carbon	%	0.11	0.73	0.70	0.12	0.87	0.13	1.48	0.30
Conductivity	dS/m	0.086	0.037	0.089	0.015	0.041	< 0.010	0.017	0.016
pH Level (CaCl2)		7.5	4.9	5.6	5.5	5.5	5.7	4.8	5.1
pH Level (H2O)		9.3	6.6	7.1	7.2	6.8	7.3	6.6	6.7
Total Nitrogen	%		0.06	0.05	< 0.01	0.03	< 0.01	0.04	< 0.01
% Clay	%	23.86							
% Course Sand	%	64.88							
% Fine Sand	%	10.30							
% Sand	%	75.18							
% Silt	%	0.96							
Prewash exch. Ca	meq/100g	1.65							
Prewash exch. K	meq/100g	0.57							

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21057	SHS21058	SHS21059	SHS21060	SHS21061	SHS21062	SHS21063	SHS21064
	Name	S17	S17	S19	S19	S20	S20	S21	S21
	Code	Site 17	Site 17	Site 19	Site 19	Site 20	Site 20	Site 21	Site 21
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	0-10	40-50	0-10	40-50	0-10	40-50	0-10	40-50
Colour		DKGR	GRWH	GR	GRWH	GR	GRWH	DKGR	BRWH
Gravel	%	0	0	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0
Ammonium Nitrogen	mg/kg	2	1	3	< 1	3	1	2	< 1
Nitrate Nitrogen	mg/kg	1	1	< 1	< 1	2	< 1	< 1	< 1
Phosphorus Colwell	mg/kg	< 2	< 2	6	< 2	12	< 2	< 2	< 2
Potassium Colwell	mg/kg	< 15	< 15	18	< 15	46	< 15	20	< 15
Sulfur	mg/kg	1.5	0.5	4.3	2.6	3.9	1.1	3.8	3.7
Organic Carbon	%	1.05	0.28	0.52	0.09	0.28	0.07	0.84	0.08
Conductivity	dS/m	0.013	0.012	0.034	0.032	0.025	0.014	0.059	0.047
pH Level (CaCl2)		4.9	5.5	5.4	5.9	6.0	6.1	4.6	6.3
pH Level (H2O)		6.3	6.7	6.3	6.8	6.9	7.4	6.0	7.5
Total Nitrogen	%	0.03	< 0.01	0.05	< 0.01	0.02	< 0.01	0.06	< 0.01
% Clay	%								
% Course Sand	%								
% Fine Sand	%								
% Sand	%								
% Silt	%								
Prewash exch. Ca	meq/100g								
Prewash exch. K	meq/100g								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21065	SHS21066	SHS21068	SHS21069	SHS21070	SHS21071	SHS21072	SHS21073
	Name	S2	S5	S5	S7	S7	S11	S11	S16
	Code	Site 2	Site 5	Site 5	Site 7	Site 7	Site 11	Site 11	Site 16
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	40-50	0-10	40-50	0-10	40-50	0-10	40-50	0-10
Colour		GR	LTGR	WH	LTGR	WH	LTGR	WH	LTGR
Gravel	%	0	0	0	0	0	0	0	0
Texture		2.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	1	4	< 1	5	< 1	4	< 1	3
Nitrate Nitrogen	mg/kg	2	< 1	< 1	1	1	2	< 1	1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	179	< 15	< 15	< 15	< 15	23	< 15	< 15
Sulfur	mg/kg	72.8	3.4	< 0.5	2.6	< 0.5	2.3	< 0.5	2.1
Organic Carbon	%	0.18	0.81	0.09	0.77	0.09	0.70	0.10	1.04
Conductivity	dS/m	0.977	0.051	< 0.010	0.037	< 0.010	0.023	< 0.010	0.021
pH Level (CaCl2)		7.7	4.8	4.9	4.8	5.6	4.8	5.4	4.7
pH Level (H2O)		8.5	6.6	6.4	6.4	6.5	6.2	6.5	6.2
Total Nitrogen	%	< 0.01	0.03	< 0.01	0.03	< 0.01	0.03	< 0.01	0.03
% Clay	%								
% Course Sand	%								
% Fine Sand	%								
% Sand	%								
% Silt	%								
Prewash exch. Ca	meq/100g								
Prewash exch. K	meq/100g								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21074	SHS21075	SHS21076	SHS21077	SHS21078	SHS21079	SHS21080	SHS21081
	Name	S16	S2	S2	S5	S5	S6	S7	S7
	Code	Site 16	Site 2	Site 2	Site 5	Site 5	Site 6	Site 7	Site 7
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	40-50	10-20	90-100	10-20	90-100	10-20	90-100	10-20
Colour		WH	YWGR	BRWH	WH	WH	GRWH	GRWH	WH
Gravel	%	0	0	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Nitrate Nitrogen	mg/kg	< 1	< 1	2	< 1	< 1	2	1	< 1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	< 15	17	125	< 15	< 15	< 15	< 15	< 15
Sulfur	mg/kg	< 0.5	5.3	160.4	1.2	0.5	1.5	0.7	< 0.5
Organic Carbon	%	0.12	0.09	0.09	0.14	0.09	0.19	0.17	0.10
Conductivity	dS/m	< 0.010	0.110	2.063	< 0.010	0.011	0.012	< 0.010	< 0.010
pH Level (CaCl2)		5.1	5.6	6.7	4.6	5.7	5.2	5.2	5.8
pH Level (H2O)		6.5	6.4	7.2	5.7	6.8	6.1	6.7	6.3
Total Nitrogen	%	< 0.01							
% Clay	%								
% Course Sand	%								
% Fine Sand	%								
% Sand	%								
% Silt	%								
Prewash exch. Ca	meq/100g								
Prewash exch. K	meq/100g								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21082	SHS21083	SHS21084	SHS21085	SHS21086	SHS21087	SHS21088	SHS21089
	Name	S11	S11	S13	S13	S15	S15	S16	S17
	Code	Site 11	Site 11	Site 13	Site 13	Site 15	Site 15	Site 16	Site 17
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	90-100	10-20	90-100	10-20	90-100	10-20	10-20	90-100
Colour		WH	GRWH	GRWH	GRWH	DKGR	WH	GR	DKGR
Gravel	%	0	0	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	< 1	< 1	< 1	< 1	2	< 1	2	2
Nitrate Nitrogen	mg/kg	1	< 1	< 1	< 1	1	< 1	< 1	< 1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
Sulfur	mg/kg	< 0.5	0.8	< 0.5	< 0.5	3.0	0.6	0.5	1.1
Organic Carbon	%	0.09	0.06	0.10	0.06	0.91	0.11	0.52	0.78
Conductivity	dS/m	0.010	< 0.010	< 0.010	< 0.010	0.018	< 0.010	< 0.010	0.013
pH Level (CaCl2)		5.4	5.5	5.6	5.7	4.7	5.7	4.7	4.8
pH Level (H2O)		6.5	6.4	6.6	6.3	6.6	6.4	6.4	6.3
Total Nitrogen	%								
% Clay	%								
% Course Sand	%								
% Fine Sand	%								
% Sand	%								
% Silt	%								
Prewash exch. Ca	meq/100g								
Prewash exch. K	meq/100g								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21090	SHS21091	SHS21092	SHS21093	SHS21094	SHS21095	SHS21096
	Name	S17	S19	S19	S20	S21	S19	S20
	Code	Site 17	Site 19	Site 19	Site 20	Site 21	Site 19	Site 20
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	10-20	90-100	10-20	10-20	90-100	120-130	90-100
Colour		WH	GRBR	GRWH	GRWH	GRWH	GR	YWGR
Gravel	%	0	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	< 1	< 1	< 1	< 1	1	2	< 1
Nitrate Nitrogen	mg/kg	< 1	2	1	1	< 1	1	< 1
Phosphorus Colwell	mg/kg	< 2	5	< 2	3	< 2	< 2	< 2
Potassium Colwell	mg/kg	< 15	25	< 15	< 15	28	87	53
Sulfur	mg/kg	< 0.5	3.6	12.2	1.5	1.9	31.1	88.4
Organic Carbon	%	0.15	0.17	0.05	< 0.05	< 0.05	0.12	< 0.05
Conductivity	dS/m	< 0.010	0.038	0.239	0.018	0.038	0.389	0.965
pH Level (CaCl2)		5.1	5.7	6.0	6.3	6.4	6.8	6.8
pH Level (H2O)		6.3	6.5	6.5	6.9	8.8	7.3	7.4
Total Nitrogen	%							
% Clay	%							
% Course Sand	%							
% Fine Sand	%							
% Sand	%							
% Silt	%							
Prewash exch. Ca	meq/100g							
Prewash exch. K	meq/100g							

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21008	SHS21009	SHS21010	SHS21011	SHS21012	SHS21013	SHS21014	SHS21015
Prewash exch. Mg	meq/100g	0.15	< 0.10	0.20	< 0.10	0.31	< 0.10	0.18	< 0.10
Prewash exch. Na	meq/100g	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Arsenic	ug/kg	48.12	126.36	48.51	228.47	362.14	123.28	111.79	95.84
Cadmium	ug/kg	10.89	2.60	29.59	16.58	5.17	1.55	4.49	1.44
Chromium	ug/kg	1047.41	394.35	1056.17	1051.77	1813.90	1564.84	1673.13	1255.59
Cobalt	ug/kg	46.08	19.20	84.40	106.57	108.27	43.31	115.81	70.32
Lead	ug/kg	2170.04	767.95	1809.13	1339.90	1780.33	1710.53	3050.71	2740.77
Molybdenum	ug/kg	102.4	24.0	48.2	23.6	146.3	53.2	80.1	53.1
Selenium	ug/kg	171.20	122.12	204.33	160.59	86.51	151.49	150.10	90.85

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21016	SHS21017	SHS21018	SHS21019	SHS21020	SHS21021	SHS21022	SHS21023
Prewash exch. Mg	meq/100g	0.32	0.12	0.19	< 0.10	< 0.10	< 0.10	0.21	< 0.10
Prewash exch. Na	meq/100g	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Arsenic	ug/kg	271.84	535.47	153.19	105.25	96.45	115.55	54.34	36.35
Cadmium	ug/kg	3.94	2.41	2.13	3.38	2.86	2.83	3.09	1.42
Chromium	ug/kg	1855.64	2779.99	520.16	363.63	599.68	705.17	550.86	413.05
Cobalt	ug/kg	71.29	83.59	32.46	26.64	25.06	41.14	26.00	20.34
Lead	ug/kg	1842.97	3660.87	881.45	1019.52	437.61	557.18	674.83	674.52
Molybdenum	ug/kg	48.6	39.6	52.8	84.2	58.1	85.5	66.3	88.8
Selenium	ug/kg	200.31	51.40	106.29	121.29	82.48	69.48	78.57	93.70

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21024	SHS21025	SHS21026	SHS21027	SHS21028	SHS21029	SHS21030	SHS21031
Prewash exch. Mg	meq/100g	0.68	0.58	< 0.10	< 0.10	< 0.10	1.08	< 0.10	< 0.10
Prewash exch. Na	meq/100g	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.10	< 0.10	< 0.10
Arsenic	ug/kg	253.93	445.64						
Cadmium	ug/kg	4.00	2.17						
Chromium	ug/kg	2089.35	3176.58						
Cobalt	ug/kg	144.20	132.57						
Lead	ug/kg	1887.50	2349.27						
Molybdenum	ug/kg	43.1	38.0						
Selenium	ug/kg	160.72	192.40						

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21032	SHS21033	SHS21034	SHS21035	SHS21037	SHS21038	SHS21039	SHS21040
Prewash exch. Mg	meq/100g	1.58	0.12	3.42	< 0.10	< 0.10	0.10	< 0.10	0.16
Prewash exch. Na	meq/100g	0.24	< 0.10	1.35	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Arsenic	ug/kg								
Cadmium	ug/kg								
Chromium	ug/kg								
Cobalt	ug/kg								
Lead	ug/kg								
Molybdenum	ug/kg								
Selenium	ug/kg								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21041	SHS21042	SHS21043	SHS21044	SHS21045	SHS21046	SHS21047	SHS21048
Prewash exch. Mg	meq/100g	< 0.10	2.53	0.39	< 0.10	0.42	1.15	0.28	0.76
Prewash exch. Na	meq/100g	< 0.10	< 0.10	< 0.10	< 0.10	0.24	< 0.10	< 0.10	0.41
Arsenic	ug/kg					1138.41	1589.58	759.23	7073.22
Cadmium	ug/kg					1.58	2.32	1.36	2.46
Chromium	ug/kg					20944.54	13243.92	2319.25	71230.84
Cobalt	ug/kg					3648.75	1425.18	348.73	2794.99
Lead	ug/kg					6839.71	6962.78	1402.57	19396.11
Molybdenum	ug/kg					125.6	99.9	33.5	393.6
Selenium	ug/kg					883.49	187.36	126.40	186.94

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21049	SHS21050	SHS21051	SHS21052	SHS21053	SHS21054	SHS21055	SHS21056
Prewash exch. Mg	meq/100g	3.69							
Prewash exch. Na	meq/100g	1.07							
Arsenic	ug/kg	1727.90	59.14	127.66	66.76	117.32	128.82	39.12	35.86
Cadmium	ug/kg	2.66	26.64	5.21	1.30	2.77	2.52	2.98	8.51
Chromium	ug/kg	18098.24	1277.64	1494.82	861.19	611.50	539.93	446.12	360.05
Cobalt	ug/kg	4762.64	98.67	103.46	53.41	22.14	25.07	24.63	25.77
Lead	ug/kg	5379.67	1589.92	2915.36	1653.32	638.84	820.99	573.46	756.93
Molybdenum	ug/kg	79.1	74.4	65.4	37.5	57.1	92.8	60.9	137.0
Selenium	ug/kg	187.01	87.84	161.18	92.06	74.03	112.65	60.29	116.60

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21057	SHS21058	SHS21059	SHS21060	SHS21061	SHS21062	SHS21063	SHS21064
Prewash exch. Mg	meq/100g								
Prewash exch. Na	meq/100g								
Arsenic	ug/kg	77.15	30.63	84.87	155.04	256.49	307.98	87.63	156.06
Cadmium	ug/kg	7.65	2.32	7.81	2.70	9.63	3.62	18.00	2.50
Chromium	ug/kg	719.10	272.46	1139.12	712.67	1579.69	730.31	1994.45	2108.08
Cobalt	ug/kg	34.13	16.69	137.98	72.22	380.15	65.26	114.12	136.04
Lead	ug/kg	664.36	544.04	2298.97	656.55	2821.95	1397.94	2801.00	1736.95
Molybdenum	ug/kg	98.3	93.4	99.0	38.5	62.8	37.0	61.2	23.8
Selenium	ug/kg	95.48	76.69	99.47	112.54	150.71	118.95	128.04	109.76

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21065	SHS21066	SHS21068	SHS21069	SHS21070	SHS21071	SHS21072	SHS21073
Prewash exch. Mg	meq/100g								
Prewash exch. Na	meq/100g								
Arsenic	ug/kg								
Cadmium	ug/kg								
Chromium	ug/kg								
Cobalt	ug/kg								
Lead	ug/kg								
Molybdenum	ug/kg								
Selenium	ug/kg								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21074	SHS21075	SHS21076	SHS21077	SHS21078	SHS21079	SHS21080	SHS21081
Prewash exch. Mg	meq/100g								
Prewash exch. Na	meq/100g								
Arsenic	ug/kg								
Cadmium	ug/kg								
Chromium	ug/kg								
Cobalt	ug/kg								
Lead	ug/kg								
Molybdenum	ug/kg								
Selenium	ug/kg								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21082	SHS21083	SHS21084	SHS21085	SHS21086	SHS21087	SHS21088	SHS21089
Prewash exch. Mg	meq/100g								
Prewash exch. Na	meq/100g								
Arsenic	ug/kg								
Cadmium	ug/kg								
Chromium	ug/kg								
Cobalt	ug/kg								
Lead	ug/kg								
Molybdenum	ug/kg								
Selenium	ug/kg								

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	SHS21090	SHS21091	SHS21092	SHS21093	SHS21094	SHS21095	SHS21096
Prewash exch. Mg	meq/100g							
Prewash exch. Na	meq/100g							
Arsenic	ug/kg						1131.79	3116.47
Cadmium	ug/kg						4.57	3.64
Chromium	ug/kg						4090.47	1446.43
Cobalt	ug/kg						745.74	231.38
Lead	ug/kg						1918.07	1346.32
Molybdenum	ug/kg						71.5	51.1
Selenium	ug/kg						49.76	164.61

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

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Mine Earth Pty Ltd

	Lab No	TSS22061	TSS22062	TSS22063	TSS22064	TSS22065	TSS22066	TSS22068	TSS22069
	Name	ASS01	ASS06	ASS06	ASS10	ASS11	ASS13	ASS14	ASS16
	Code	0-1m	2-3m	4-5m	1-2m	1-2m	1-2m	2-3.2m	3-4m
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Colour		YW	YWGR	BRGR	GR	GRBR	WH	YWGR	YWBR
Gravel	%	0	15-20	5-10	5-10	25-30	0	5-10	0
Texture		2.5	2.0	2.0	2.0	2.5	1.0	2.5	2.5
Ammonium Nitrogen	mg/kg	4	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Nitrate Nitrogen	mg/kg	4	< 1	< 1	3	< 1	1	< 1	< 1
Phosphorus Colwell	mg/kg	6	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Potassium Colwell	mg/kg	362	81	146	182	314	< 15	145	111
Sulfur	mg/kg	172.5	92.7	28.2	184.1	300.5	4.8	41.9	256.3
Organic Carbon	%	0.25	0.08	< 0.05	0.05	0.13	0.12	< 0.05	0.10
Conductivity	dS/m	0.900	1.138	0.454	2.686	3.886	0.116	0.922	3.477
pH Level (CaCl2)		6.9	8.2	8.3	7.9	7.5	5.8	7.0	6.3
pH Level (H2O)		7.8	9.0	9.4	8.5	8.2	6.7	8.0	6.6
Exc. Aluminium	meq/100g	0.060	0.060	0.070	0.090	0.140	0.020	0.070	0.060
Exc. Calcium	meq/100g	10.06	2.67	2.67	1.64	2.44	0.21	1.21	1.02
Exc. Magnesium	meq/100g	11.32	3.45	3.45	3.71	6.85	0.15	2.85	3.90
Exc. Potassium	meq/100g	0.76	0.30	0.30	0.34	0.56	0.02	0.31	0.18
Exc. Sodium	meq/100g	5.16	2.56	2.57	11.83	19.89	0.43	6.47	16.01

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

	Lab No	TSS22070	TSS22071	TSS22072	TSS22073	TSS22074	TSS22075	TSS22076	TSS22077
	Name	ASS21	ASS23	ASS24	ASS25	ASS25	ASS27	ASS27	ASS31
	Code	2-3m	2-3m	2-3m	2-3m	3-4m	2-3m	3-4m	2-3.5m
	Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd	Mine Earth Pty Ltd
	Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Colour		GR	BRGR	BRGR	GR	LTGR	GRWH	WH	GRBR
Gravel	%	5-10	5-10	5-10	0	0	0	0	5-10
Texture		1.0	1.5	1.5	1.0	1.0	1.0	1.0	2.0
Ammonium Nitrogen	mg/kg	1	1	< 1	< 1	< 1	< 1	< 1	3
Nitrate Nitrogen	mg/kg	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Phosphorus Colwell	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	2
Potassium Colwell	mg/kg	< 15	< 15	< 15	< 15	< 15	< 15	< 15	79
Sulfur	mg/kg	15.7	44.4	137.7	4.1	2.0	0.9	3.3	568.1
Organic Carbon	%	0.34	0.07	0.05	0.31	0.09	< 0.05	< 0.05	0.26
Conductivity	dS/m	0.050	0.105	0.243	0.024	0.020	< 0.010	< 0.010	0.617
pH Level (CaCl2)		5.4	4.9	5.0	6.4	6.3	5.9	6.0	4.1
pH Level (H2O)		6.4	5.7	5.4	7.2	7.0	6.8	7.0	4.4
Exc. Aluminium	meq/100g	0.160	0.150	0.130	0.010	0.010	0.020	0.020	0.450
Exc. Calcium	meq/100g	0.86	0.33	0.47	0.31	0.12	0.10	0.09	1.90
Exc. Magnesium	meq/100g	0.28	0.20	0.37	0.14	0.08	0.03	0.03	2.77
Exc. Potassium	meq/100g	0.02	0.04	0.02	0.02	0.01	0.01	< 0.01	0.16
Exc. Sodium	meq/100g	0.17	0.33	0.41	0.08	0.05	0.01	0.01	1.29

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

90423
Mine Earth Pty Ltd

		Lab No	1PS22050	1PS22051
		Name	ATS Tailings Sand	ATS Tailings Slimes
		Code	ATS-2102B	ATS-2102B
		Customer	Mine Earth Pty Ltd	Mine Earth Pty Ltd
		Depth	0-10	0-10
Colour			YWGR	GRYW
Gravel	%		0	0
Texture			1.5	2.0
Ammonium Nitrogen	mg/kg		< 1	4
Nitrate Nitrogen	mg/kg		< 1	6
Phosphorus Colwell	mg/kg		6	3
Potassium Colwell	mg/kg		< 15	361
Sulfur	mg/kg		3.6	145.4
Organic Carbon	%		0.06	0.26
Conductivity	dS/m		0.037	1.017
pH Level (CaCl2)			6.4	7.3
pH Level (H2O)			6.9	7.9
% Clay	%		2.87	88.05
% Course Sand	%		85.25	0.10
% Fine Sand	%		10.91	3.23
% Sand	%		96.16	3.33
% Silt	%		0.97	8.62
Prewash exch. Ca	meq/100g		0.13	7.27
Prewash exch. K	meq/100g		0.01	0.52
Prewash exch. Mg	meq/100g		< 0.10	7.56

CSBP Lab. Extract Value.

Analysis Results

CSBP Soil and Plant Laboratory

		Lab No	1PS22050	1PS22051
Prewash exch. Na	meq/100g		< 0.10	1.52

CSBP Lab. Extract Value.