Avonbank Heavy Mineral Sands Project
Dooeen Victoria

Preliminary Soil Assessment

WIM Resource Pty Ltd

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1 Introduction

1.1 Project Overview

WIM Resources (WIM) is proposing to develop the Avonbank Heavy Mineral Sands (HMS) Project between the townships of Dooen and Jung, 15 km due north of the rural Victorian township of Horsham (Figure 1.1). The total project area is 6,545 ha with a proposed mining footprint of approximately 2,500 ha and is covered by granted Retention Licence (RL) 2014. The Avonbank deposit is hosted within the Loxton Parilla Sands formation and forms a sheet like body, with a surface area of approximately 40km^2.

The Avonbank HMS Project hosts a world-class mineral sands deposit that will enable WIM to supply premium quality zircon, rare earths and titanium into overseas markets. The project has an expected life of mine of 30 years. WIM plans to commence mining works by 2021-2022...

The operation will employ a rapid rehabilitation technique, known as a 'moving hole' or 'direct return' method to minimise disturbance to existing land use and return the land to its pre-existing state as soon as practically possible. Top soil and sub soil will be removed and stockpiled adjacent to the pit, separately and sequentially via appropriate earth moving equipment. Overburden will be stripped using conventional earth-moving equipment. A schematic of the proposed mine development is provided in Figure 1.2.

The ore body will be mined an average rate of 10-18 million tpa using conventional earth moving equipment and processed using conventional mineral sands feed preparation modules within or adjacent to the active pit. The slurried ore will be pumped to a centrally located wet concentration plant (WCP) for primary separation to produce a heavy mineral concentrate. The mineral concentrate will be loaded directly from the WCP onto the adjacent rail line facility for export via the Port of Portland and/or Port of Melbourne.

Slimes (gangue fine clay fraction of ore) will be thickened and co-disposed with the gangue sand tailings fraction into the existing mining void, for dewatering and settling. Rehabilitation will include replacement of overburden, replacement of subsoil and topsoil (which have been preserved in protected stockpile areas) and finally revegetation.

1.2 Scope of Work

Tonkin Consulting has undertaken the following tasks in completing the scope of work:

- Review of information provided by WIM Resources, including project overview and geological information reproduced herein;
- Desktop review of readily available internet resources to describe the regional and project scale landform and soil;
- Preliminary assessment of potentially major impacts of mining on soil and landform;
- Summary of potential rehabilitation measures which may be used to mitigate the impact of mining on soils and landform.

This scope of work has been completed by Dr Melissa Salt, Principal Scientist, who is a Certified Professional Soil Scientist. Dr Salt has a Bachelor of Science in Agriculture (Hons) and PhD on *Water Balance and the Influence of Temporal Factors on Final Covers for Landfill Closure*. She is also a certified Lead Auditor in Environmental Management Systems. Dr Salt has 25 years' experience ranging from research and development to field consultation and advice, including preparation and implementation of environmental impact statements and management plans and environmental site assessment.

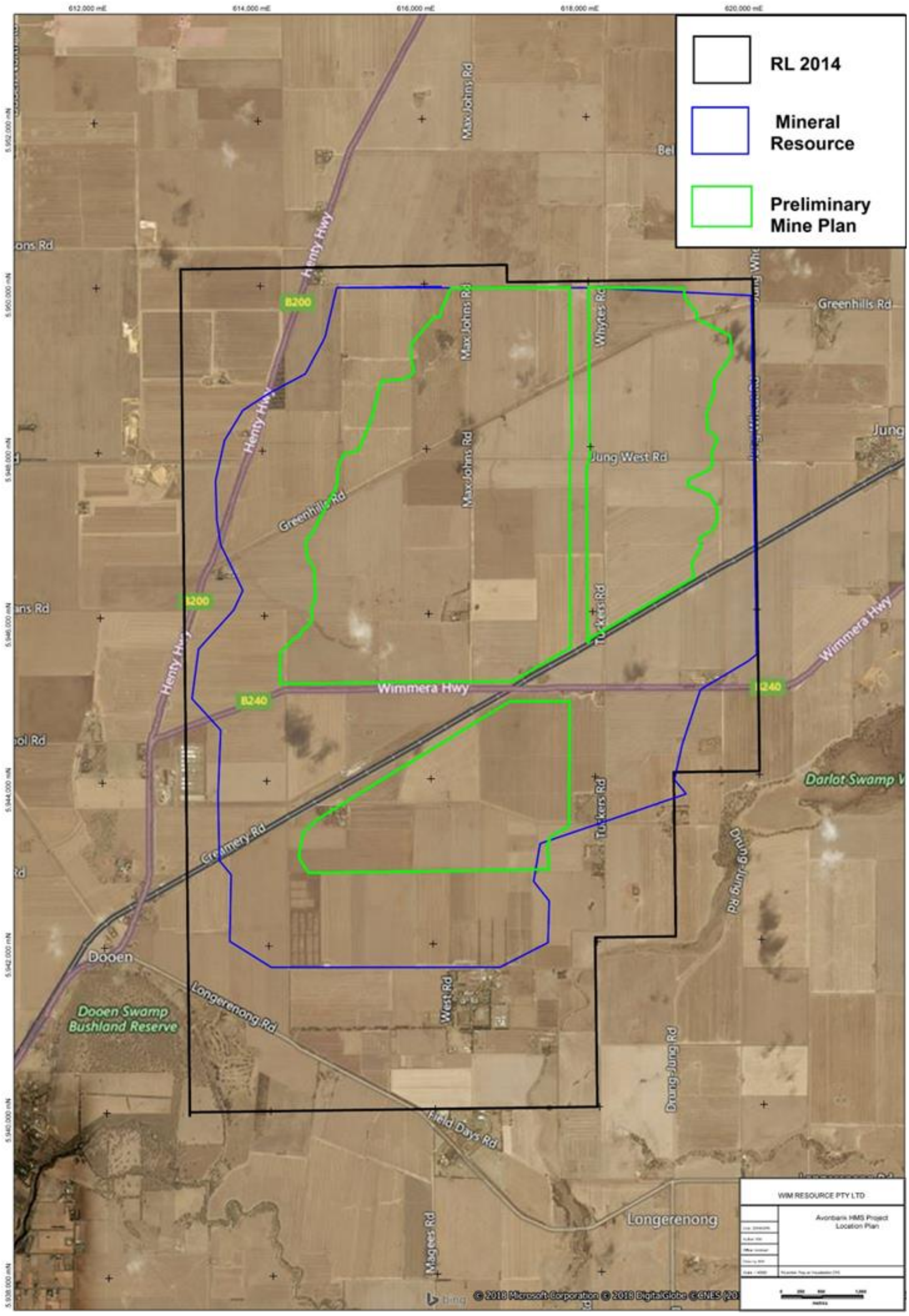

Figure 1.1 Avonbank HMS Project Site Location Plan (Provided by WIM Resources)

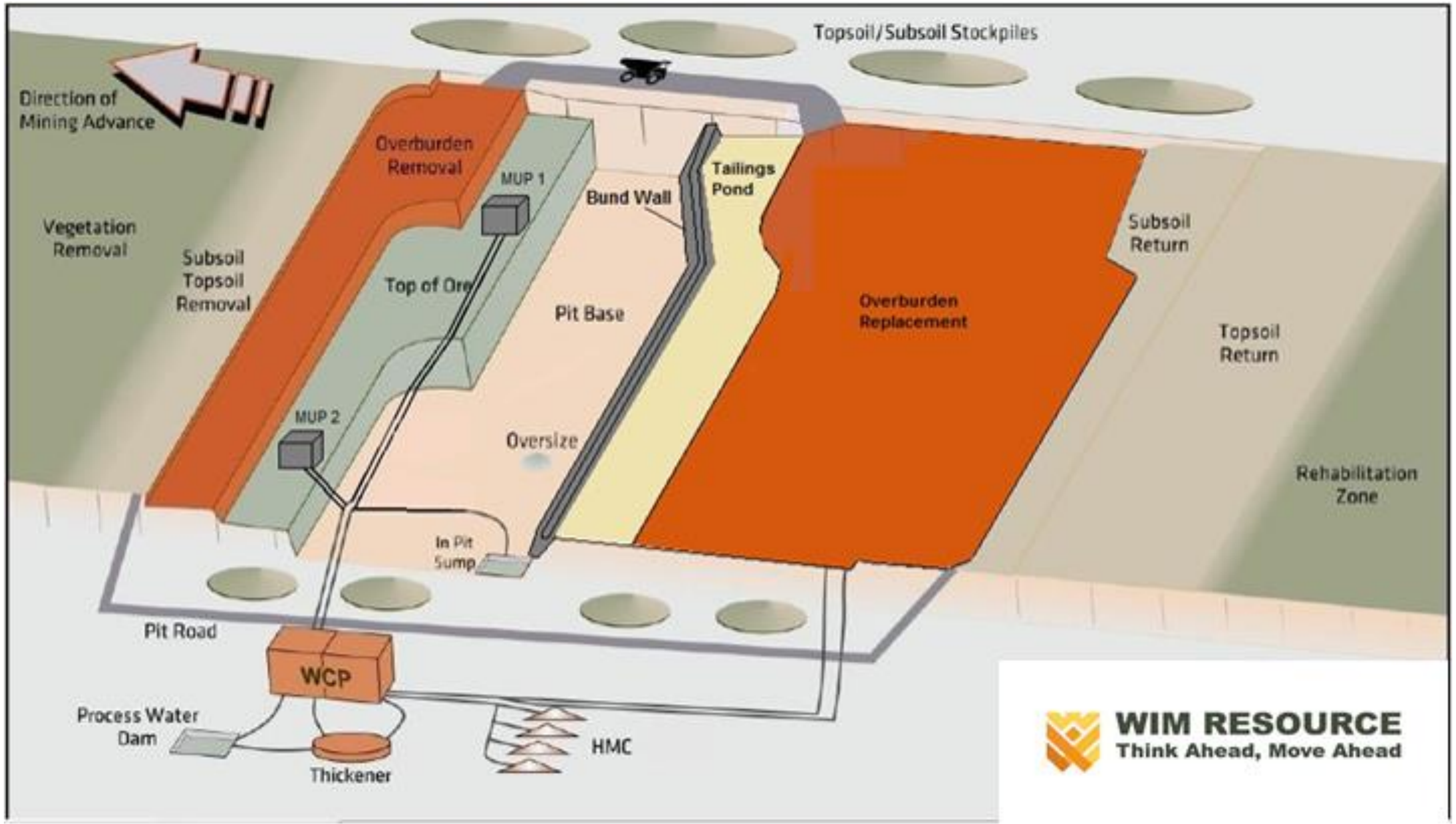

Figure 1.2 Generalised Schematic of Proposed Mine Sequence and Direct-return rehabilitation (provided by WIM Resources)

2 Existing Geographical Conditions

This preliminary assessment of the geology, landform and soil has been undertaken based on readily available published information.

The Avonbank HMS deposit is located within the Wimmera Region of Victoria and in the Horsham Rural City Council local government area.

2.1 Regional and Project-Scale Geology

The project area stratigraphical geology is described below (WIM,2018):

Shepparton Formation

Underlying the top and sub soil units is the Shepparton Formation sedimentary unit (of Pleistocene age) – which is the dominant surface geology in the project area and region. It comprises silts, clays and sandy clays and is typically 6-18 m thick in the region. The lower boundary of the unit may consist of clays cemented by kaolinite, gibbsite or iron. Analysis of drill hole samples completed by WIM indicates the samples are described as sandy clays and silty sandy clays. The Shepparton Formation was deposited in a lacustrine or fluvial environment.

Karoonda Surface

Underlying the Shepparton Formation is the Karoonda unit, marked by an increase of ferruginisation and silicification at the top of the Parilla Sand, typically less than 1-2 m in thickness. This unit is inferred to be an erosional derivative of the Loxton Parilla Sands during the final phase of sea level regression.

Parilla Sand

The Parilla Sands typically comprise Late Miocene to Pliocene aged marine sediments and comprises fine to very fine-grained, well-sorted sands and silts with some coarse sand and gravel material. The Parilla Sand unit is typically 10 to 15 m thick and is present in most of the region. The lithology is described as quartzose sand with fine clays (ranging from yellow, grey, red and brown in colour) and cemented fragments containing iron. The Parilla Sand unit plays host to all heavy mineral sand deposits in the Murray Geological Basin.

Geera Clay

Underlying the Parilla Sands is the Geera Clay (Late Oligocene to Middle Miocene) comprises marine sediments and carbonaceous and calcareous clay indurations that contain marcasite and pyrite. The Geera Clay is typically 30-40 m thick with the top of the layer typically at a depth of around 25-30 m in the project area and immediate region. At a project scale, the depth to Geera increases in a northward trend. The Geera Clay observed during WIM drilling comprised typically Dark Grey to Purple (WIM,2017).

Renmark Group

This Renmark Group is overlain by the Geera Clay, typically comprising semi-consolidated silt, sand, brown coal, carbonaceous clay, sandstone and siltstone. The thickness of this unit has been shown to be at approximately 30 m in the region and 30-60m in the project area. This unit is underlain by Palaeozoic units. Analysis of bore samples showed this unit to typically comprise coarse sand and gravel, quartzose and carbonaceous clays.

2.2 Regional and Project Scale Landform

The Victorian Resources Online website shows the Avonbank HMS project is located with the Wimmera Catchment Management Area. The Wimmera region is typified by flat to gently undulating landscape rising gently from the swamps and lakes in the north (Lake Hindmarsh and

Lake Albacutya) at 75-100 m above mean sea level (MSL), to the south at 150-200 mm above MSL then steeply rising to the mountains in the south-east at over 200 m above MSL. A variety of landform features are present such as rivers, creeks, lakes, lunettes, low ridges and sandstone mountain ranges. The Wimmera region is divided into three main geomorphological units[1]:

- Western Uplands include the Grampians (Gariwerd) Ranges and are located to the south with low hills to the east and south-east past Stawell. The Uplands form a surface water divide directing surface water north away from the coast;
- Northern Riverine Plains extend from Uplands draining to lakes and swamps in the north;
- North Western Dunefield and Plains consist of parabolic and linear siliceous dunes to the west with some sections interspersed with lakes and lunettes in the swales. North of the Wimmera Highway, the clay plains with subdued ridges dominate becoming calcareous dunes further north. The Wimmera River is over 1.5 km south of the site boundary.

The Avonbank HMS Project is located on the clay plains with subdued ridges. The elevation varies from 125-150 m above MSL. The Dooen Swamp is located adjacent to the south-western boundary of the Project site and Darlot Swamp east of the site. An intermittent creek, Two Mile Creek, is located along and within the eastern boundary and flows into Darlot Swamp. A number of channels (Dooen Main, College, Jung West, Dooen East) are noted on topographic maps as located within the site boundary; however, it is understood that these are disused and in some cases no longer present.

2.3 Regional and Project Scale Soil Types

There are four main categories of soil noted by Victoria Resources Online in the Wimmera Region, being:

- Cracking Clays (Vertosols). Grey vertosols are most common and extend throughout the region;
- Texture contrast soil (Sodosols). Red sodosols occur in the older alluvial plains such as the main tributaries to the Lakes and around the Wimmera River associated with the Northern riverine Plains. Brown and Yellow Sodosols occur with other soils in the dune fields in the western portion of the Wimmera;
- Soil lacking strong texture contrast (Calcarosols). Occuring mainly north of Dimboola and Warracknabeal but also west of Kaniva;
- Sandy soil (Tenosols, Rudosolos, Podosols). These soils are mainly associated with the sand dune areas of the west and north-west of the Wimmera region and also around the edge of the Grampians.

A number of soil studies have been undertaken in the Wimmera Region; however most have focussed south of the Wimmera River around the Grampians. The *Soils of the Horsham Map Sheet*[2] was prepared in 1977 and includes the soil within the Avonbank HMS Project. The Soil Landscape Unit at the site is predominantly "Gently Undulating Plains" with small areas of "Flood Plain" along the south eastern boundaries. The main soil types occurring in the gently undulating plains are:

Soil Association H1 – Grey Vertosols.

The most common soil type in the Landscape unit (60%) and mainly occurring north of the Wimmera. Grey cracking clays consist of up to 25 cm of friable, self-mulching brownish grey to

[1] Department of Primary Industries. 2008. *Geomorphological Units Wimmera Catchment Management Region*. Victorian Resources Online Dated May 2008.
[2] Badawy, N.S. 1977. *Soil Associations of the Horsham Map Sheet No 7324*. Soil Survey Report No 57. Dated May 1977.

grey-brown, light to medium clay overlying mottled heavy clay. Cracking calcareous brown clays are also present but are distinguished by their non-friable surface from the Grey Cracking Clays. Red-brown earths may be found on some rises and low ridges. Highly productive agricultural soil used for wheat and may also be used for irrigated pastures.

Soil Association H3 – Sodosols

Approximately 20% landscape unit and occurs mainly south of Wimmera River. Noted as including solonetz (saline, alkaline and sodic throughout A2 present), solodised solonetz (saline, alkaline and sodic B horizon with bleached A2) and solodic (saline, alkaline and sodic subsoil). The greyish brown to brownish grey topsoil (8-45 cm depth) varies from loamy sand to sandy clay loam topsoil. The A2 horizon is massive and variously bleached. Subsoil is mottled yellowish grey and brown to red-brown heavy clay with moderate structure. Non-friable calcareous grey and brown clay soil is also present. Mainly used for sheep grazing (wool and fodder production).

Soil Association H6 - Cracking calcareous brown clays

Approximately 12% landscape unit. Comprises reddish medium to heavy clay topsoil (5-30 cm depth) over red-brown heavy clay with strong structure. Hard when dry, becoming friable when moist and plastic and sticky when wet (12%). Mainly used for wheat production.

The soil landscapes were further described by Robinson et al[3]. Two main Soil/landform Units are mapped as within the boundaries of the Avonbank HMS Project:

- **St Helens gentle plains** – This is the main unit within the Avonbank HMS boundaries. Soil group 34 dominant. Alkaline throughout with non-sodic topsoil and subnatric subsoil. Low risk of sheet/ rill erosion, gully/tunnel erosion and wind erosion. High risk of soil compaction. Used for dryland cropping and grazing
- **Dooen eroded plain** – Soil group 34 dominant with characteristics as described above. Some of the most productive cropping landscapes of the region used for dryland cropping

No soil pits were described in these Soil/landform Units. Based on previous reports Soil Group 34 is described as cracking clay soils comprised of 10 cm of dark grey light to medium clay overlying a calcareous, dark grey heavy clay subsoil to 130 cm. The strongly structure subsoil is noted to grade to a yellower clay at depths continuing below 2 m. This pale subsoil is further noted to have restricted drainage, often strongly acidic and likely to be dispersive.

It is noted that the south-western corner encroaches into the Horsham Lakes and Lunettes unit, associated with the Dooen Swamp. Mining is not proposed to be undertaken within the Swamp so this unit has not been discussed.

An extract from the Soil Landscape Map showing the Soil/Landscape units and the approx. extent of the resource is shown in Figure 2.1.

[3] Robinson, N., Rees, D., Reynard, K., Imhof, M., Boyle, G., Martin, J., Rowan, J., Smith, C., Sheffield, K., and Giles, S. 2005. *A Land Resource Assessment of the Wimmera Region*. Agriculture Victoria. Dated April 2005.

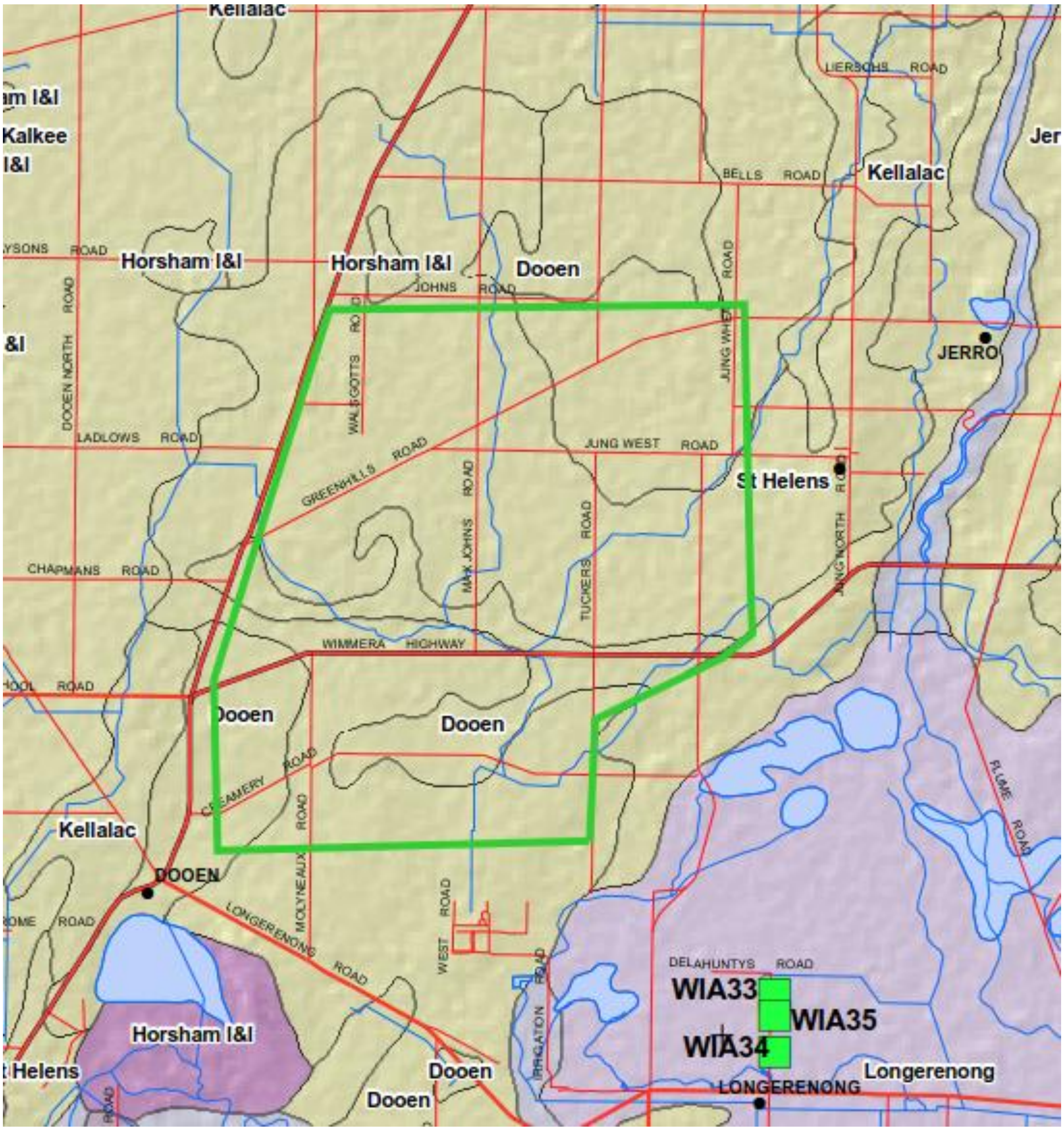

Figure 2.1 ***Soil Landscape Unit Map[3] with approx. extent of resource proposed to be targeted by Avonbank HMS Project denoted by green outline. Geomorphology shown as base with Clay with Subdued Ridges (brown) and Northern Riverine Plains (purple hues) shown.***

3 Preliminary Assessment

3.1 Environmental Values

Environmental values related to geology, soils and landforms in the project area are:

- Soils and landforms (i.e., soil-landform units) that support agriculture;
- Soils and landforms (i.e., soil-landform units) that support ecosystems.

3.1.1 Soils and Landforms – Supporting Agriculture

Agriculture is the predominant land use in the region with approximately 80% of the rural areas of the Horsham Rural City Council area zoned 'Farming Zone'. Agriculture includes dryland cropping (mainly wheat), livestock grazing (mainly sheep for wool) and associated fodder production, with some irrigated pastures. The current dominant land use in the project area is broad acre cropping. Based on Horsham Rural Zones Review, the Avonbank HMS Project is likely to be located in an area with average to high agricultural quality[4].

Soil and landforms that support agriculture are therefore considered of environmental value.

3.1.2 Soil and Landforms – Supporting Ecosystems

The Dooen Swamp is on the south-western corner of the Avonbank HMS Project and soil types that support this ecosystem are noted (see Section 2.3). Though this area is within RL2014, the resource does not extend south of Longerenong Road (Figure 1.1) and hence

Soil and landform that support ecosystems are unlikely to be impacted.

3.1.3 Sensitivity of Environmental Values

The main soil type present at Avonbank HMS Project is grey cracking clay. The material has high agricultural value but is widespread throughout the region, being the most common soil type in the northern Wimmera. The soil is alkaline and not highly erodible and, given it is a self-mulching vertosol, typically has good buffering capacity due to the presence of complex clay minerals. The subsoil is subnatric and known to become plastic and "sticky" when wet suggesting it may be dispersive and difficult to handle when wet.

Based on the general soil information available, the soil is likely to have low to moderate sensitivity to detrimental impacts from mining. Further detailed studies will be required to understand the potential impacts and mitigation measures.

3.2 Issues & Potential Impacts

The potential impacts of the project are physical and chemical alterations to soils and landforms that lead to:

- Reduced capability of land to support agriculture;
- Improved capability of land to support agriculture.

Reduced capability could be due to degradation of soil structure, formation of unfavourable soil chemistry and alterations of landform. Adverse impacts to soil and landform may result in reduced viability of vegetation growth or land use potential.

There are also potential positive impacts on soils and landforms, which could be achieved through rehabilitation measures, such as amelioration of sodic subsoils, reduction in pests and

[4] Horsham Shire Agricultural Quality Map prepared by CPG Australia (2010) and extracted from Coffey Environments. *Draft WIM150 Mineral Sands Project Environment Effects Statement*

diseases due to break from cropping and grazing, increased organic matter from no tillage and increased biodiversity by incorporating natural vegetation to support natural predation of pests by birds in surrounding agricultural areas and reduce wind erosion.

The key project impacts to soils and landform will relate to the excavation of the mine pit and temporary storage of soil prior to and during rehabilitation works. Mining will occur primarily in the soil-landform unit: St Helens Gentle Plain and Dooen Erodible Plain. Mining will occur in a progressive manner, whereby the overburden and upper soil units will be progressively rehabilitated. The proposed mining void will be excavated to a depth of about 27 m - 30m on average. Subject to further studies, a preliminary strip of topsoil & subsoil may include:

- Topsoil to approximately 0.1-0.2 m will be removed first;
- Subsoil separation of the darker heavy clay subsoil, nominally to 1.3 m depth;
- Removal of paler material extending to approx. 3 m. Further studies will be used to determine if this unit is the Shepparton Formation overburden or part of the subsoil.

The different soil horizons will be stockpiled separately before being backfilled in the correct order. There is the potential that, if not managed properly, different layers of the soil profile (i.e. topsoil, subsoils, overburden and tailings) could be mixed resulting in unfavourable soil chemistry and a decline in structure of topsoil following remediation. Exposed soils are also prone to erosion and dispersion. Backfilling may also result in changes to landform (due to swelling).

The primary impacts are the reduced land capability (to support agriculture) due to the degradation of soil structure, formation of unfavourable soil chemistry and changes to landform. There is potential for these changes to occur in both the St Helens and Doon Soil Landform Units as both are pre-dominantly comprised of grey cracking clay.

3.2.1 Degradation of Soil Structure

Soil Erosion

The grey cracking clay identified in the project area has low erodibility to water and wind. Combined with the estimated low rainfall (416 mm/yr on average), relatively flat topography and small area of exposure due to the proposed mining method - degradation due to erosion is likely to be limited and is not considered a likely significant impact of mining activities.

During stockpiling, the risk of degradation increases due to leaching of clay and stabilising salts, such as calcium, deeper into the stockpile. This can occur within months for sand but can take years for clay. Erosion of the stockpile surface can lead to loss of soil materials for rehabilitation. Given the low grades and distance to surface water, erosion is unlikely to result in contamination of surface water at Avondale HMS. Soil erosion will need careful management, particularly for the subsoil stockpiles which are likely to be dispersive.

Sodicity & Dispersion

The topsoil is non-sodic and the subsoil is subnatric (sodicity 6-10%). Poor stripping and stockpiling of the materials could result in the sodic subsoil mixing with the non-sodic topsoil. Upon rehabilitating the site, if the topsoil has not been protected from mixing, this could result in waterlogging and structural decline resulting in reduced agricultural productivity of the rehabilitated site. As with other HMS mining operations – this issue of soil mixing can be managed effectively with careful stockpile management & rehabilitation practices.

Compaction

The soil in the project area is subject to compaction, with the subsoil also noted as being plastic when wet. Excavation and stockpiling of materials can result in over-compaction when material is wet. Given the material is self-mulching, i.e. it can reform structure after wetting and drying cycles, over-compaction is unlikely to be a long-term issue unless combined with other physical or chemical degradation, a discussed above. Management & mitigation measures will be required to manage short-term risks of over-compaction but in the longer term, this is unlikely to be a risk for grey cracking clay soil.

Waterlogging

Waterlogging is noted as an issue in the clay plains area due to the high clay content and low saturated hydraulic conductivity of the soil. Soil structural decline can exacerbate this risk and reduce agricultural productivity and potential for irrigated pasture production. During stockpiling, waterlogging of soil may occur and hamper placement during rehabilitation. Careful stockpile placement and shape will assist in shedding rainfall and limiting waterlogging of the stockpile.

3.2.2 Unfavourable Soil Chemistry

The soil is noted to be alkaline throughout and have a sodic subsoil; however other chemical data are not available. The complex clay minerals in cracking clays typically result in good soil buffering capacity to pH and nutrient changes. Increases in salinity may be caused by spraying with dust suppressants, accidental spillage of leachates or long term stockpiling due to evapo-concentration. Contamination of soil due to accidental spillage of hydrocarbons may also occur if stockpiles are placed near high traffic areas or adjacent to refuelling stations or storage areas. Planning appropriate stockpile locations and ensuring rapid clean-up of spills will limit the potential for unfavourable soil chemistry.

There are opportunities to improve soil chemical imbalances during rehabilitation by the addition of soil ameliorants. This should be determined following detailed soil assessment.

3.2.3 Increase in Weed Seeds in Soil Seed Bank

The soil has a bank of seeds which may remain dormant for a number of years before the right conditions result in germination. If the soil stockpiles are allowed to grow weeds whilst awaiting rehabilitation, the number of weeds seeds in the soil bank will increase. Once the soil is replaced during rehabilitation, excessive weed growth will be expensive and sometimes difficult to control, reducing the land’s value for cropping and pasture production and may also affect wool quality, depending on the which weeds are present. Effective and timely weed control can prevent this possible issue.

There are opportunities to reduce the weed seeds in the topsoil if controlled in a timely manner. A reduction in weeds will reduce competition during rehabilitation and will improve quality of the land following rehabilitation.

3.3 Changes to Landform

3.3.1 Topography

The project will result in changes to local topography. There will be a temporary active mining area, including soil and overburden stockpiles. Changes to surface topography could also result from swelling of backfilled material, ground compaction and areas of construction-related earthworks.

It is expected that changes to landform associated with the project will not affect the capability of the land to support agriculture and ecosystems once rehabilitated. However, there is likely to be an initial increase in surface levels following mining. Consolidation will occur during the first 12 months after rehabilitation, with the final landform surface settling slightly above the pre-mined state. This can be managed via careful soil placement during rehabilitation and post-rehabilitation monitoring.

3.3.2 Surface Drainage

The current topography is gently undulating with the presence of gilgai. This surface generally has low run-on and runoff rates and a tendency for waterlogging due to slow internal drainage.

During mining, localised impacts from the mining area will occur. Following placement of soil during rehabilitation, the surface will be partially restored to similar levels as pre-mining. It is not possible to recreate the gilgai formations typical of cracking soil plains; however, these are likely to reform over time. Given the low rainfall and low local relief of 9-30 m, changes to surface drainage are likely to be short duration and limited impact.

3.4 Summary of Significant impacts and potential mitigation measures

The summary of impacts and potential mitigation measures are shown in Table 3.1.

Table 3.1 Significance of Impacts Potential Mitigation

Hazard	Landform Sensitivity	Potential Significance	Potential Mitigation Measures	Residual Significance
Soil erosion	*In situ* soil is not highly erodible; however the exposed subsoil has higher erodibility due to sodicity	High	Minimise batter slopes on stockpile. Cover or seed susceptible subsoil stockpile Apply gypsum to surface layers	Low
Sodicity	Topsoil non-sodic; subsoil is subnatric	Low or Moderate	Undertake soil survey to identify sodic layer/s and assess dispersion Ensure separation between non-sodic and sodic materials Apply gypsum to sodic materials placed near surface	Low, pending completion of site soil survey
Compaction	Subsoil noted as plastic; however soil is self-mulching	Low	Place materials during dry weather for rehabilitation as possible Do not over-work materials on placement and placement in thick lifts	Low
Waterlogging	Some waterlogging noted due to low internal drainage and local relief Stockpiles may become waterlogged if inappropriately placed	Moderate	Undertaken soil survey to determine extent of natural waterlogging. Soil is naturally prone to waterlogging; however careful placement during rehabilitation will assist in ensuring this does not become more widespread Locate stockpiles away from drainage lines and protect with bunding where required	Moderate as is naturally prone to waterlogging
Changes to Soil Chemistry	Likely to be moderate with no separation of materials but more data required	Moderate	Soil survey and chemical testing required to inform appropriate mitigation. Use soil ameliorants, e.g. gypsum, fertiliser, organics Separate stockpiling of different soil materials Refuelling of machinery away from soil stockpiles and in contained areas or with spill kits and trained staff on hand Refuelling under supervision Servicing off-site or in designated area	Low

Hazard	Landform Sensitivity	Potential Significance	Potential Mitigation Measures	Residual Significance
			Storage of fuels and all chemicals in appropriate receptacles of adequate size, as specified in guidelines	
Weed seeds	Given agricultural setting there is a high potential for weed seeds to invade unprotected or managed stockpiles	High	Train staff in identification of weeds. Inspect stockpiles regularly for weed growth Manage weeds in accordance with best practice guidelines, e.g. spray, chip, etc. Plant sterile ryecorn on stockpiles likely to remain for > 3 months during Autumn to Spring	Low
Topography	Minor changes in elevation and no gilgai following rehabilitation	Low	Match in surface as far as practical but allowing for settlement Gilgai will reform naturally over time in areas where present	Low
Surface drainage	During mining drainage will be greatly affected however duration and exposure minimised as far as practical	Moderate	Rehabilitation of near natural surface will return surface drainage to typical patterns	Low

4 Conclusions

This preliminary assessment suggests that the potential impacts to soil can be managed by careful stockpile placement and management, rehabilitation during suitable conditions and careful use of soil ameliorants if required.

Site specific soil survey and assessment is required to ensure that red sodosols, which may occur locally with grey cracking clays, are not present as these represent a higher erosion risk. Soil chemical data are also required to ensure there are no latent soil chemical conditions which affect this assessment.

4.1 Further Works

This assessment has provided a preliminary understanding of the potential impacts from mining to the soil resource. Based on this assessment a number o measures have been proposed to manage and mitigate these risks and to potentially improve the land quality following rehabilitation. A high level summary of the forward action plant is presented in

Action	Detail	Completion Date
Detailed soil survey of first excavation area	Soil survey by CPSS to describe and map soil materials in accordance with Australian Soil and Land Survey Handbook at adequate precision to understand soil variability. Sample analysis to complement survey and quantify risks	March 2019
Update Soil Assessment	Review and update this based on actual soil materials encountered	June 2019
Prepare an Operations Environmental Management Plan	Include the management and mitigation recommendations from the final soil Assessment into the EMP	Prior to mining commencing
Detailed soil survey of further stages of mining	As per first action	3 months prior to earthworks commencing