APPENDIX H

REHABILITATION MATERIALS ASSESSMENT

Snapper Mineral Sands Project
Environmental Assessment

SNAPPER MINERAL SANDS PROJECT
ENVIRONMENTAL ASSESSMENT

REHABILITATION MATERIALS ASSESSMENT

MARCH 2007
Project No. BMX-03-09/2.4
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H1 INTRODUCTION

H1.1 BACKGROUND

The Snapper Mineral Sands Project (the Snapper Mine) involves the construction and operation of a mineral sands mine located approximately 10 kilometres (km) to the south-west of the existing Ginkgo Mineral Sands Mine (the Ginkgo Mine) and approximately 170 km south of the Broken Hill Mineral Separation Plant (MSP) (Figure H-1). The Snapper Mine area comprises the Snapper Mine Mining Lease Application (MLA) area and the electricity transmission line (ETL) and highway access road (HAR) extensions.

The land within the Snapper Mine area shows limited relief and comprises generally flat to undulating sandplains covered by a combination of grasslands, low woodland and shrublands. The mineral deposit is overlain on average by 30 to 35 metres (m) of overburden. The standing water table lies at an average depth of 45 m below the ground level (or at an average Relative Level [RL] of 34 m Australian Height Datum [AHD]).

This report characterises five major *in-situ* overburden units in the Snapper Mine area. These overburden units would be replaced in the rehabilitated landform along with the sand residues and backloaded MSP process waste from mineral separation processes. The overburden would be replaced by a combination of slurrying and conventional load and haul methods. There would be four major stratigraphic components of the rehabilitated landform:

- topsoil/subsoil;
- non-slurried overburden;
- slurried overburden; and
- sand residues and backloaded MSP process waste.

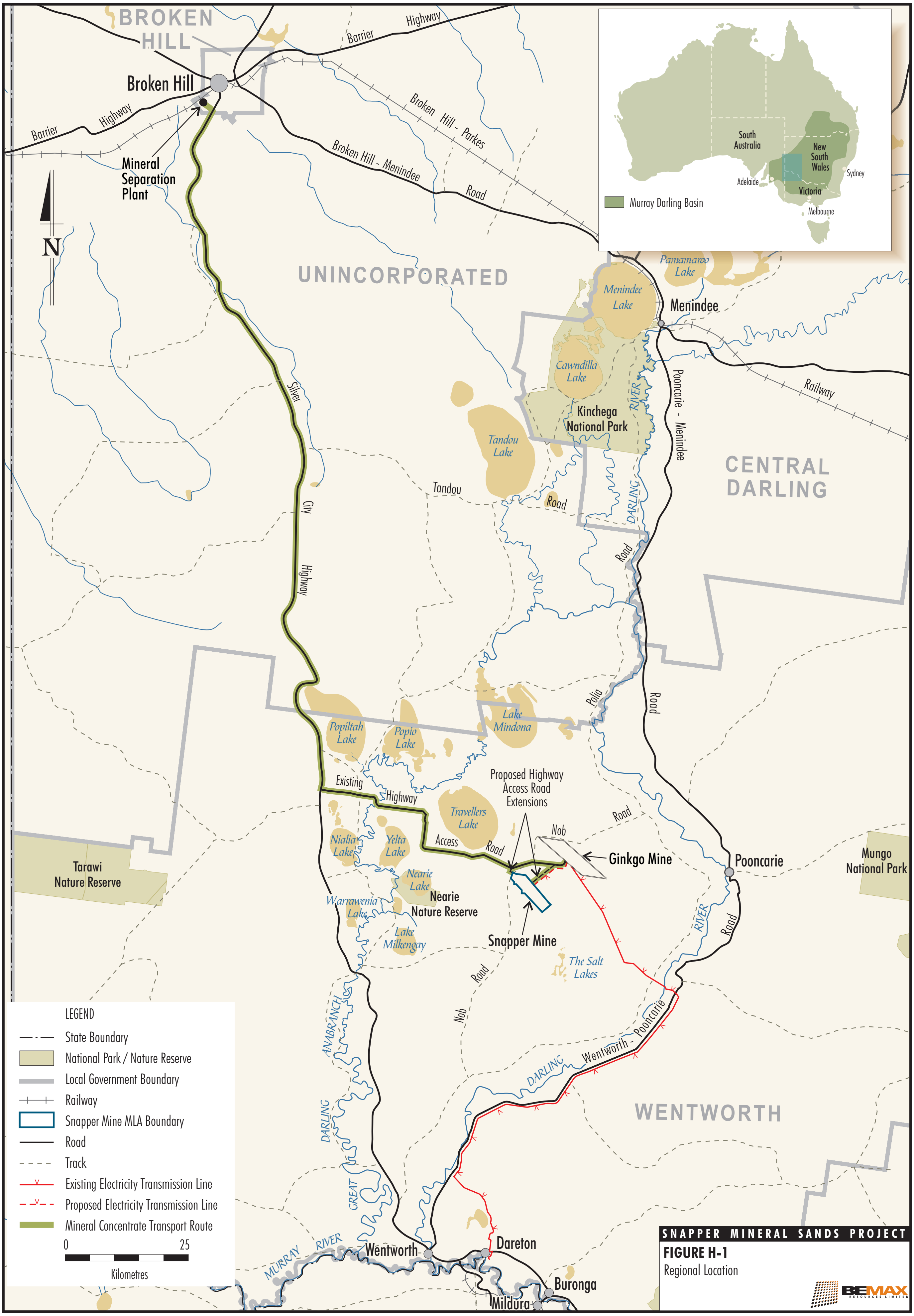
This Rehabilitation Materials Assessment draws on the information contained within the:

- *In-situ* Materials Analysis (Attachment HA).
- Acid Rock Drainage Assessment (Attachment HB).
- Saline Slurried Overburden Risk Assessment (Attachment HC).

H1.2 PURPOSE

This report provides an evaluation of the physical and geochemical characteristics of each of the *in-situ* topsoil, subsoil and overburden units within the Snapper Mine path (the study area), assesses their suitability for rehabilitation, identifies potential impacts to be mitigated by rehabilitation activities, provides the management and mitigation measures for those potential impacts, and provides a summary of recommended rehabilitation management practices. This report (including the Attachments listed above) has been prepared as part of the Environmental Assessment (EA) to address the following Director-General's Requirement (DGR) for the Snapper Mine, issued by the Director-General of the New South Wales (NSW) Department of Planning (DoP) on 17 August 2006:

> ***Rehabilitation and Final Landform –*** *including a justification of the proposed final landform; a detailed description of how the site would be progressively rehabilitated; and the measures which would be put in place for the long term protection and management of the site (and any off-site biodiversity offset areas) following cessation of mining operations.*
>
> *An assessment of the risks to the success of rehabilitation and revegetation of the site associated with the use of saline slurry in the overburden emplacements must also be included.*



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Specifically, the objectives of this report are to:

- describe the major landform units across the study area;
- characterise the surficial soil resources (i.e. the topsoil and subsoil to a depth of approximately 2 m) occurring within the study area to determine their suitability as rehabilitation growth media;
- characterise the overburden materials within the study area to determine their suitability as rehabilitation growth media;
- assess the potential impacts associated with rehabilitation of the study area (including the risks to the success of rehabilitation and revegetation of the site associated with the use of saline slurry in the initial slurried overburden emplacement); and
- provide recommendations related to the handling, storage and replacement of rehabilitation materials of the study area.

H2 SNAPPER MINE OVERVIEW

H2.1 GEOLOGICAL SETTING

The Murray Basin is a large sedimentary basin covering approximately 300,000 square kilometres (km^2) extending across the borders of NSW, Victoria and South Australia. The basin contains mineral sands deposits within the Loxton-Parilla Sands host unit, a sequence of weakly consolidated, near horizontally bedded sands that were deposited during marine transgressions and regressions in the Late Miocene to Late Pliocene period. During deposition of the Loxton-Parilla Sands, the palaeo wind direction is thought to have been from the west, resulting in longshore drift to the south-east (Brown and Stephenson, 1985).

The Ginkgo Mine and Snapper Mine deposits both occur within the Loxton-Parilla Sands host unit. Various sub-units of the Loxton-Parilla Sands are recognised.

The five major *in-situ* overburden units within the study area are (Figure H-2):

- Woorinen Formation.
- Shepparton Formation.
- Upper Loxton-Parilla Sand.
- Mica Sands.
- Lower-Loxton Parilla Sand.

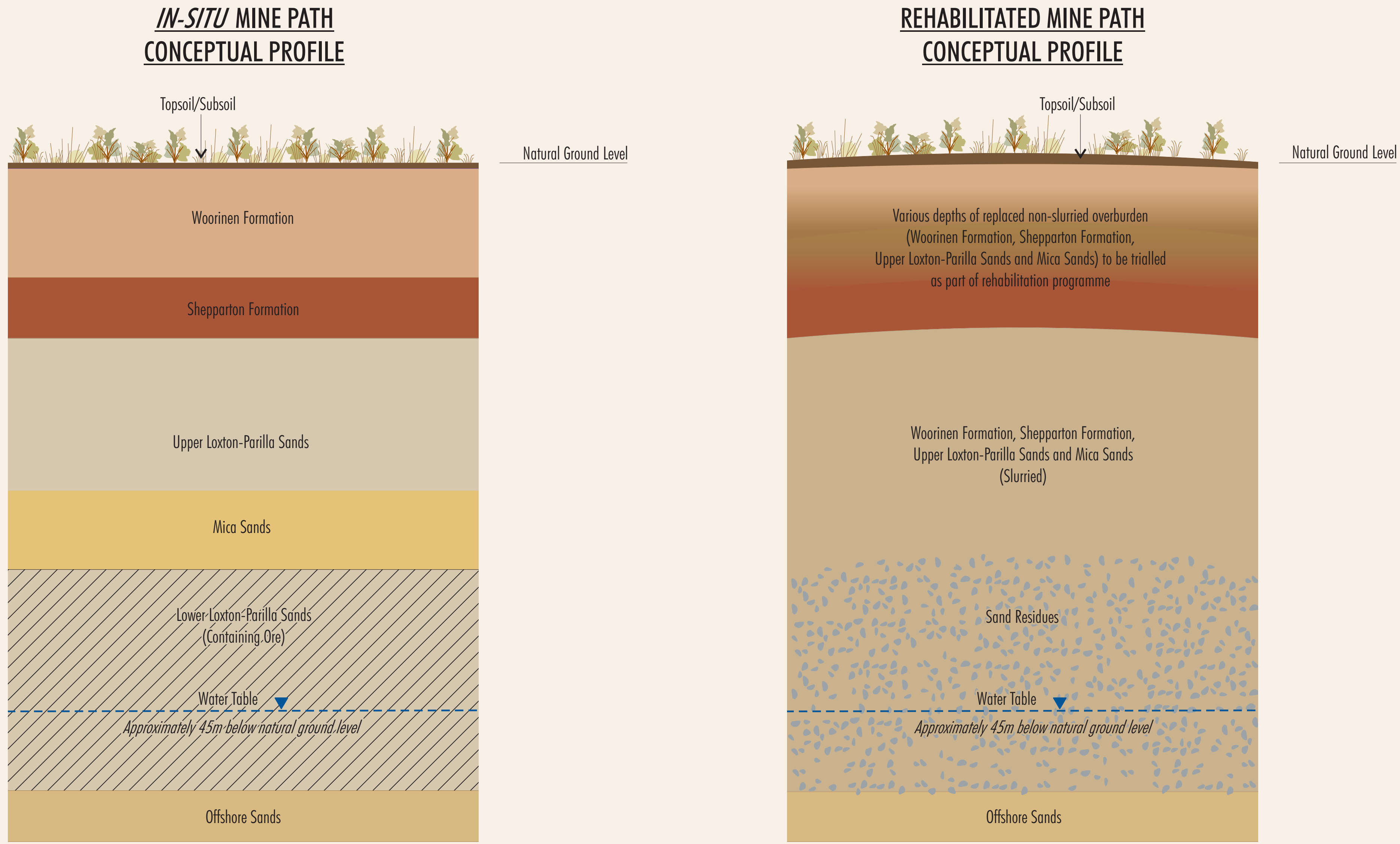
The Snapper deposit is hosted by the Lower Loxton-Parilla Sands unit, which consists of fine to medium grained sands that are generally unconsolidated, well sorted and contain little clay. The Lower Loxton-Parilla Sands are overlain by the Mica Sands unit, which are fine to very fine micaceous sands. The Mica Sands are in turn covered by barren sand representing the Upper Loxton-Parilla Sands. The Shepparton Formation is a sandy clay unit overlying the Upper Loxton-Parilla Sands, which outcrops in places where the uppermost stratigraphic layer, the Woorinen Formation, is absent. The Woorinen Formation consists of very fine to coarse sand and silty sand, sandy clay and minor calcrete. The *in-situ* profile described above is shown conceptually in Figure H-2. The depth of the above overburden types is, on average, 30 to 35 metres (m), increasing at the northern end of the study area where the orebody dips to the north-west.

H2.2 SNAPPER MINE OPERATION

The Snapper Mine would be a similar operation to BEMAX Resources Limited's (BEMAX's) existing Ginkgo Mine. Dredge mining would be the primary method of mining and would involve the same method of mining as the Ginkgo Mine (i.e. conventional mineral sands dredge mining). Secondary mining of ore would occur simultaneous to dredge mining as required, and would be undertaken by conventional mobile equipment (i.e. dozers and/or scrapers) depositing ore in front of the dredge.

Construction of the Snapper Mine would commence approximately between Years 3 to 5 of the Ginkgo Mine life. The mining operation would comprise the following:

- clearance of vegetation and stripping of soils on a campaign basis ahead of the advancing mine operation;
- overburden stripping, slurrying and direct placement;
- predominantly dredge mining of ore by a conventional floating bucket wheel dredge located in the dredge pond;
- adjustment of dredge pond levels to maintain dredge access to the ore;
- supply of water from the borefields;
- disposal of water to the water disposal dam when lowering dredge pond levels;
- secondary mining of ore by conventional mobile equipment (i.e. dozers and/or scrapers), depositing ore in front of the dredge;



Not to Scale

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FIGURE H-2

Conceptual Cross Sections - *In-Situ* and Rehabilitated Mine Path

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- ore concentration in the primary gravity concentration unit to produce heavy mineral concentrate (HMC);
- stockpiling of HMC;
- supply of desalinated water from the reverse osmosis (RO) plant for HMC salt washing;
- HMC separation via the Wet High Intensity Magnetic Separators (WHIMS) circuit either at the Snapper Mine or at the MSP, to produce three types of mineral concentrates (i.e. ilmenite-rich, leucoxene-rich and non-magnetic [rutile-rich and zircon-rich] concentrates);
- stockpiling of mineral concentrates;
- transport of HMC and/or mineral concentrates to the MSP;
- placement of wastes from the primary gravity concentration unit (i.e. sand residues) at the rear of the dredge pond as mining advances;
- treatment of process water to remove fines material (i.e. particles less than 53 microns in diameter);
- transport and placement of backloaded process waste from the MSP;
- replacement of overburden on top of sand residues; and
- staged replacement of soils and progressive rehabilitation.

The combined development of the Snapper and Ginkgo Mines would maintain up to 650,000 tonnes per annum (tpa) feed rate of mineral concentrate to the MSP during the life of the two mines.

The general arrangement of the MLA area at Year 1, Year 14, and post-mining is shown on Figures H-3 to H-5.

The replacement method for overburden at the Snapper Mine would follow the method currently employed at the Ginkgo Mine.

Replacement of the majority of the deeper overburden would be undertaken by feeding the overburden to an overburden slurrying facility in which it would be screened, slurried and then pumped via a slurry pipeline behind the dredge pond and placed on top of the sand residues from the primary gravity concentration unit. Due to the saline nature of the groundwater beneath the Snapper Mine site, the slurried overburden would be saline. Therefore, the slurried overburden material would be covered by an appropriate depth of non-slurried material, to provide a suitable revegetation medium.

Replacement of topsoil, subsoil and non-slurried overburden in the rehabilitated profile would be undertaken using conventional earthmoving equipment. If the slurried overburden has not dried adequately, non-slurried overburden would be pushed out over the slurried material to form a blanket to facilitate direct placement.

For the initial period during start-up, when there is insufficient area behind the dredge pond, overburden slurry would be deposited in the initial slurried overburden emplacement (Figure H-3). During this initial period, non-slurried overburden would be placed in the initial non-slurried overburden emplacements (Figure H-3).

Water would be drawn from the underlying aquifer to slurry the overburden. The water for the system would be sourced from the dredge pond and water draining from the deposited slurry (i.e. return water). Return water would be collected by small dams which would be created on the deposited slurried overburden. Return water would be recycled via a return water pump and pipeline. The remaining component of this water would infiltrate back to the aquifer. For the initial period during start-up, water for the system would be sourced from the borefield. Once a sufficient volume of water has collected in the deposited slurry in the northern initial overburden emplacement, this return water would be recycled via the return water pump and pipeline to augment the water supplied from the borefield.

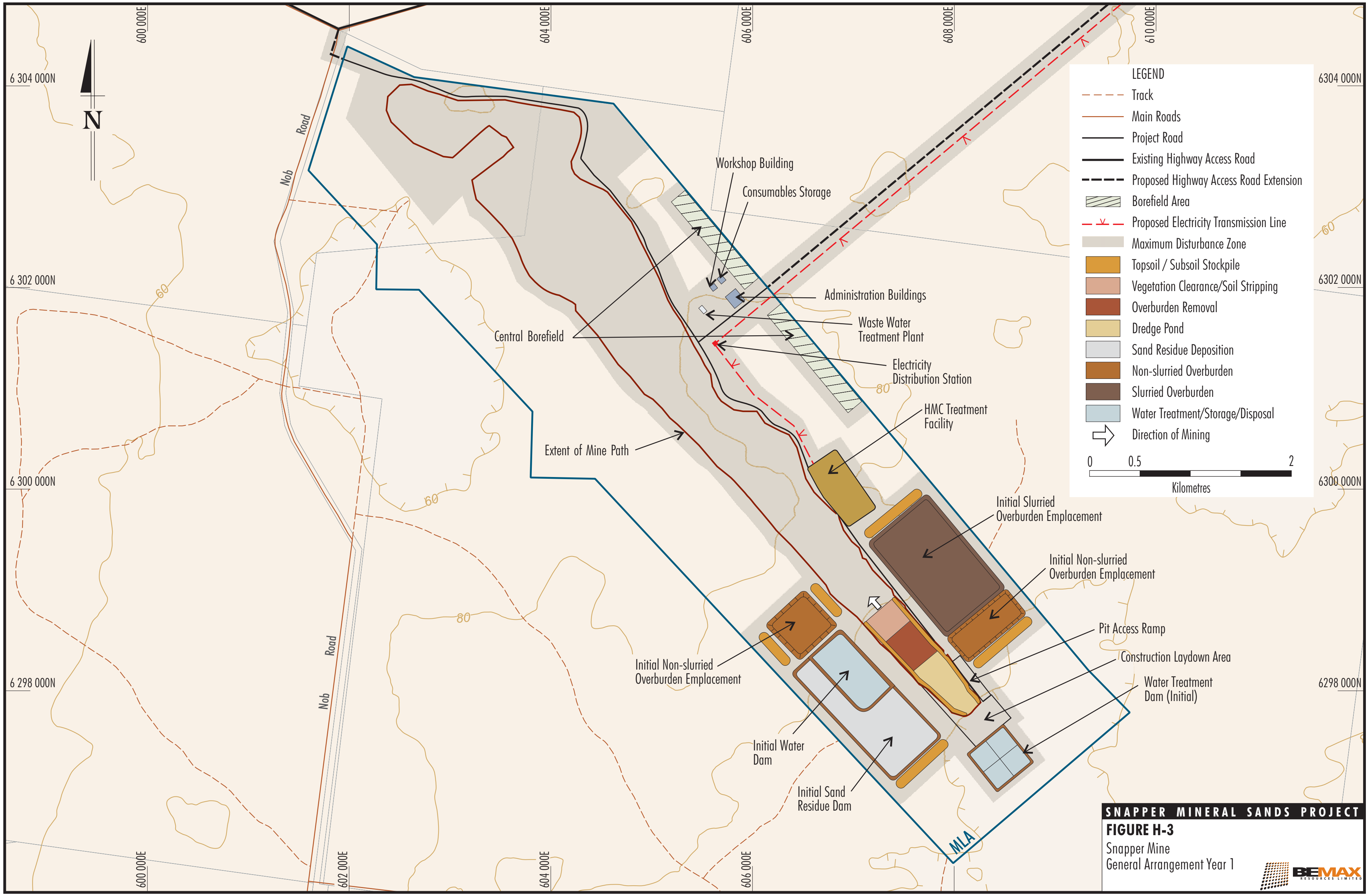

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FIGURE H-3

Snapper Mine General Arrangement Year 1

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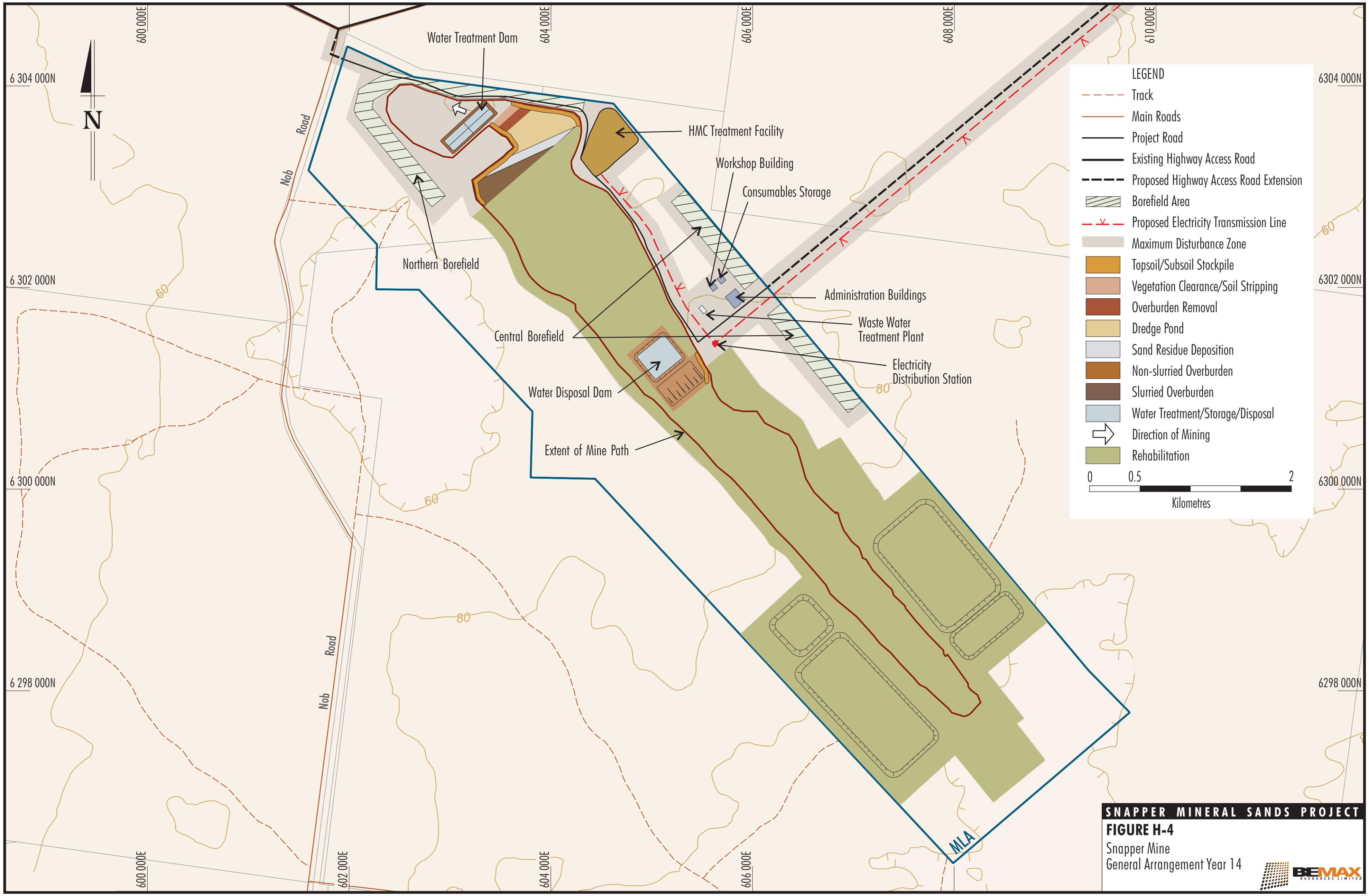

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FIGURE H-4

Snapper Mine
General Arrangement Year 14

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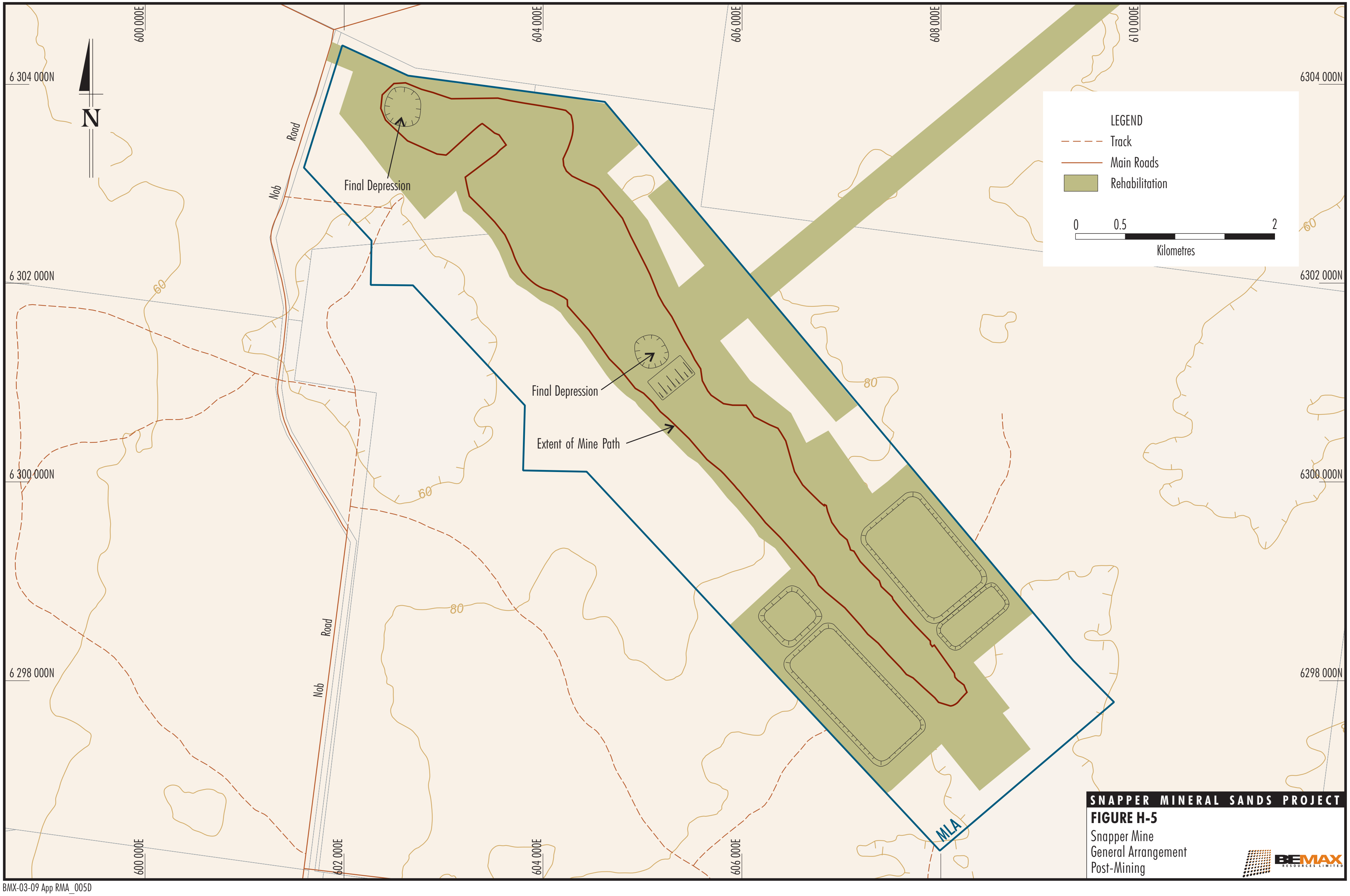
N
600 000E
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6 304 000N
6 302 000N
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6 298 000N
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6300 000N
6298 000N
Nob Road
Final Depression
Final Depression
Extent of Mine Path
MLA
60
80
LEGEND
Track
Main Roads
Rehabilitation
0 0.5 2
Kilometres
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FIGURE H-5
Snapper Mine
General Arrangement
Post-Mining
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H3 *IN-SITU* MATERIALS ANALYSIS

The characteristics relevant to rehabilitation of the overburden types listed in Section H2.1 are described in this section along with those of the topsoil and subsoil types which occur within the study area. Characterisation of the potential rehabilitation materials was undertaken through field surveys, drillhole samples and laboratory analysis, detailed in Attachment HA.

H3.1 METHODOLOGY

The methodology employed for field survey and laboratory analyses is presented in Attachment HA. A summary of the results is provided in this section.

H3.1.1 Field Survey

Forty-four sites (i.e. soil pits) were selected as soil survey locations across the study area. These were distributed as evenly as practicable throughout the study area in all landform elements and vegetation communities. The landform elements sampled included clayey sandplains, low east-west dunes, low-lying flats and run-on depressions. The vegetation communities sampled included:

- Black Box Woodland in run-on depressions;
- Black Oak-Rosewood-Wilga Woodland (also referred to in the region as Belah-Rosewood Woodland) on flat to undulating plains as well as dunes;
- Mallee Shrubland on dunes and in swales;
- Bluebush Shrubland on plains; and
- *Austrostipa* Grassland on plains and in run-on depressions.

Soil pits were excavated to approximately 1.5-2.0 m depth to sample and characterise topsoil and subsoil types (Figure H-6). The soil characteristics were described in the field, in accordance with the *Australian Soil and Land Survey Field Handbook* (McDonald *et al.,* 1990), and included:

- geology and landform;
- depth and type of carbonate layers (detailed below);
- percentage, size and lithology of coarse fragments in each layer;
- depth and texture of each soil layer;
- soil colour, pH, moisture, and pedality[1] (grade & type);
- depth of topsoil and primary root zone (PRZ) depth[2] for the remnant vegetation present; and
- saturated Hydraulic Conductivity or “K” (detailed below).

The five major overburden facies types (Section H2.1) were sampled from four exploration holes.

The presence of calcium carbonate or lime was recorded in accordance with the Wetherby and Oades (1975) Carbonate Layer Classification for Mallee Region soils. The amount of lime present in the soil is important as it affects soil pH, nutrient availability, root growth and drainage.

[1] Relative proportion of peds (individual natural soil aggregates) within the soil.
[2] Depth to which the remnant vegetation root systems extend.

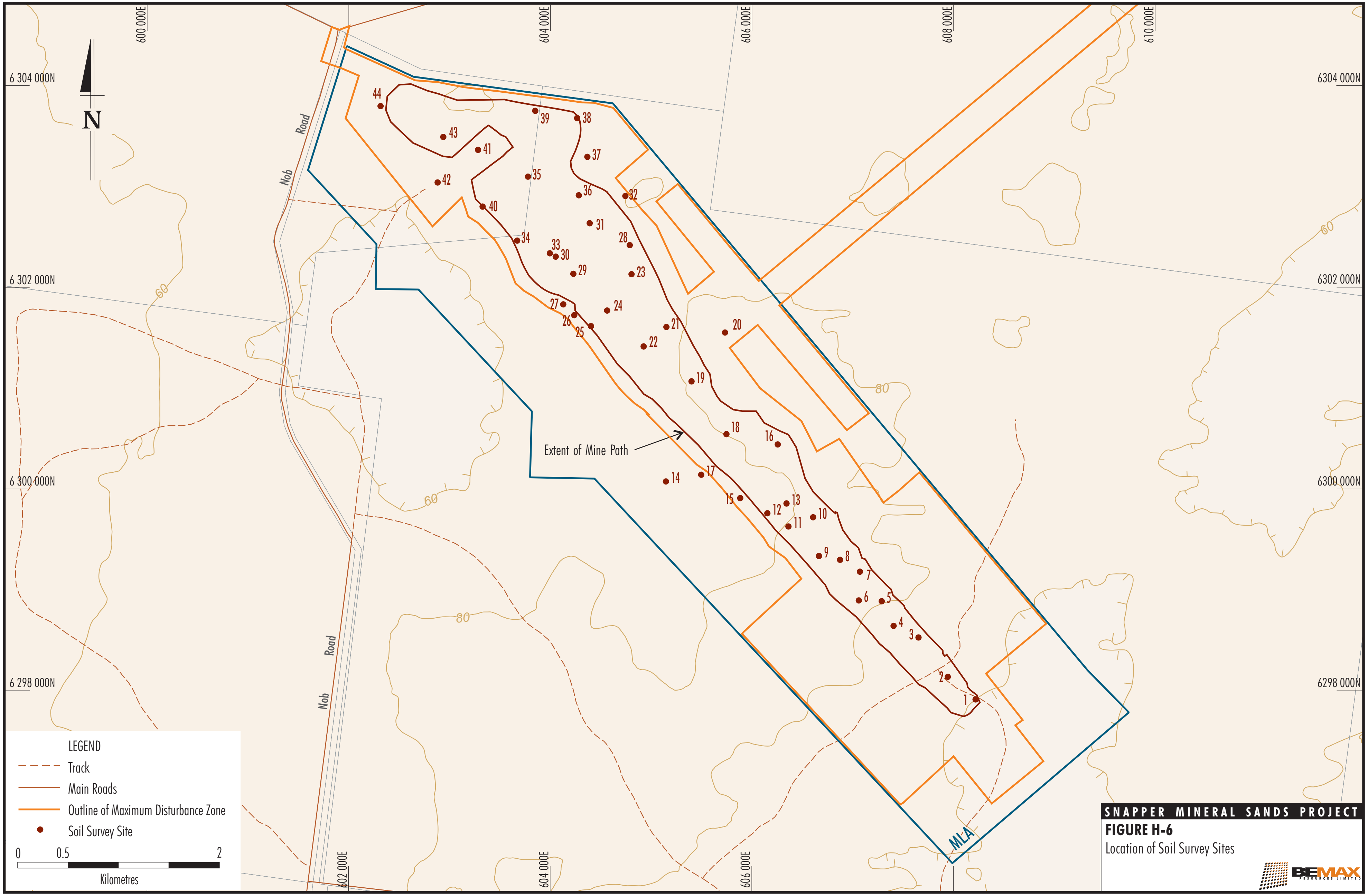

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FIGURE H-6

Location of Soil Survey Sites

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Soil permeability was recorded in accordance with McDonald and Isbell (1990) soil drainage 'K' values, which is based on a relative grade from least permeable to most permeable, according to the scale and descriptions below.

K1 = Very slowly permeable.
K2 = Slowly permeable.
K3 = Moderately permeable.
K4 = Highly permeable.

Permeability characteristics can vary significantly between soil horizons in relation to soil texture and the presence of drainage impeding layers. The K value was assigned based on attributes such as structure, texture, porosity, cracks and shrink-swell properties (McDonald and Isbell, 1990).

H3.1.2 Laboratory Analysis

The suite of analyses undertaken on the soil and overburden samples provided information about parameters which are relevant to rehabilitation requirements. These parameters included:

- Soil conductivity, as soil to water ratio 1:5 and saturation or electrical conductivity of a soil paste extract (ECe) (decisiemens per metre [dS/m]);
- pH (calcium chloride [$CaCl_2$] and water [H_2O]);
- Boron (hot $CaCl_2$);
- Organic carbon (C);
- Soil Dispersion;
- Nitrate (NO_3^-);
- Ammonium (NH_4^+);
- Phosphorous (P);
- Potassium (K), Exchangeable K, and Saturated K;
- Sulphur (S);
- Iron (Fe) and diethylenetriaminepentaacetate (DTPA) Fe;
- DTPA Copper (Cu);
- DTPA Zinc (Zn);
- DTPA Manganese (Mn);
- Exchangeable Magnesium (Mg) and Saturated Mg;
- Exchangeable Sodium (Na) and Saturated Na; and
- Exchangeable Calcium (Ca) and Saturated Ca.

Exchangeable Sodium Percentage (ESP), a universally accepted measure of soil sodicity (Rengasamy and Churchman, 2001), was calculated from the laboratory results.

Laboratory results were compared against criteria developed by Wetherby (2006) for use with Mallee Region soils. These criteria are listed in Attachment HA.

In addition, the overburden samples and one ore sample were analysed for acid forming potential.

H3.2 RESULTS

Topsoil, subsoil and overburden characteristics are described in detail in Attachments HA and HB. A summary of these characteristics is provided in this section.

The physical and geochemical characteristics of the topsoil, subsoil and overburden of the study area are briefly described below. Conductivity, pH, boron and sodicity (expressed as the ESP) are the most variable geochemical parameters in Mallee soils and are the characteristics most likely to affect native plant growth (Ogyris, pers. comm., 14 December 2006). Accordingly, these parameters are described in more detail than other parameters listed in Section H3.1.2. The other parameters are described in detail in Attachment HA.

The acid forming potential of the overburden units (Section H2.1) has been assessed for overburden samples collected during bulk ore sampling in September 2006. All samples are classified as non-acid forming (NAF) (Attachment HB).

H3.2.1 Topsoil and Subsoil

Topsoil and subsoil is characterised within the following six landform units of the study area (Figure H-7), *viz.*:

- dunes;
- dune slopes;
- sandy plains;
- clayey plains;
- swales; and
- run-on depressions.

H3.2.1.1 Dunes

Depth, Geology and Texture

Dunes are estimated to comprise approximately 10% of the study area (Figure H-7) and are typically dominated by Black Oak-Rosewood-Wilga Woodland, occasionally with sparse mallee. Soils of this landform unit are dominated by hypercalcic Calcarosols (Isbell, 2002).

Typical soil horizons of this landform unit include:

- A_1 Topsoil Horizon;
- A_2/Bt Topsoil Horizon;
- Bk Carbonate Layer; and
- Subsoil/Parent Material Layer.

Surface soil textures are typically sandy loam and drainage impeding layers are generally not present within 2 m of the natural surface. Dunes typically have the deepest topsoil (approximately 70 centimetres [cm]) and PRZ (approximately 95 cm), have low free lime contents (approximately 1%) and are generally reddish to reddish-brown in colour with sandy loam field texture. The carbonate layers encountered in dune areas are generally Class IIIAS[3]. The Dunes soil matrix typically has less than 20% calcrete rubble fragments and is generally either sandy loam or light sandy clay loam, although clayey subsoils are also present.

[3] Compact mixture of loamy sand to light sandy clay loam and fine soil carbonate. Contains less than 30% calcrete fragments. Restricts root growth of most cereal and irrigated crops. Medium drainage qualities (Attachment HA).

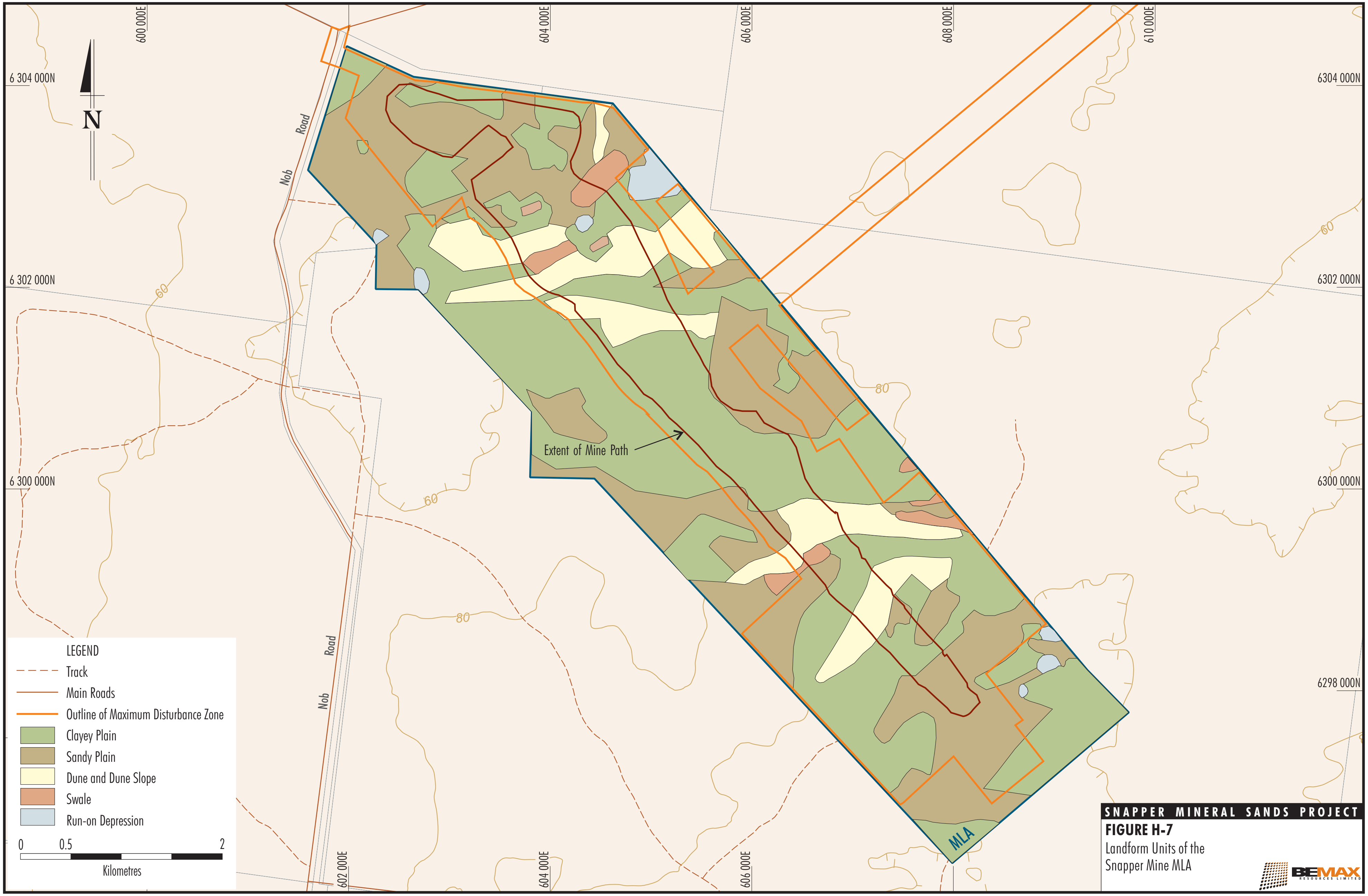

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FIGURE H-7

Landform Units of the Snapper Mine MLA

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Geochemistry

Laboratory results for the Dunes landform unit are summarised by soil layers in Table H-1 for soil conductivity, pH, boron and ESP, and are discussed below.

Table H-1
Laboratory Results* for the Dunes Landform Unit

Parameter	A_1 Topsoil Horizon	A_2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.57	2.04	4.31	7.34
Average pH	8.4	9.1	9.3	9.5
Average Boron Level (milligrams per kilogram [mg/kg], hot $CaCl_2$ Extraction)	0.96	1.23	5.83	12.0
Average ESP	2.67	5.77	19.6	21.86

* Results are expressed as an average value for the 7 Dune sites sampled.

Soil conductivity levels for all topsoil layers within the Dunes landform unit are considered suitable for rehabilitation (Wetherby, 2006). The Bk carbonate layer and subsoil/parent material layer have slightly elevated conductivity levels, but not to a level which is considered limiting to native vegetation growth (Wetherby, 2006). Average soil pH in the Dunes landform unit ranges from weakly alkaline in the upper A_1 topsoil horizon to alkaline in the subsoil/parent material layer. Boron levels in the Dunes landform unit are considered to be non-limiting to native vegetation growth (*ibid.*). Average soil sodicity or ESP is considered to be weakly to moderately sodic in the A_1 topsoil horizon and A_2/Bt topsoil horizon. The Bk carbonate layer and subsoil/parent material layer are considered to be highly sodic (*ibid.*).

H3.2.1.2 Dune Slopes

Depth, Geology and Texture

Dune slopes are estimated to comprise approximately 10% of the study area (Figure H-7), and vegetation of the Dune Slopes is typically Black Oak-Rosewood-Wilga Woodland. Soils of this landform unit are dominantly hypercalcic Calcarosols (Isbell, 2002).

Typical soil horizons of this landform unit include:

- A_1 Topsoil Horizon;
- A_2/Bt Topsoil Horizon;
- Bk Carbonate Layer; and
- Subsoil/Parent Material Layer.

Surface soil textures are variable ranging from clay loam to sandy loam, but are most commonly light sandy clay loam or sandy clay loam. Drainage impeding layers are generally not present within 2 m of the natural surface of this landform unit. Dune Slopes have average topsoil and PRZ depths of approximately 45 cm and 60 cm respectively, have low free lime contents (approximately 1%) and are generally reddish-brown in colour. The carbonate layers encountered in dune areas were universally Class IIIAL[4]. The Dune Slopes soil matrix typically has less than 20% calcrete rubble fragments and is generally either sandy loam or light sandy clay loam, although clayey subsoils are also present.

[4] Compact mixture of sandy clay loam to light clay and fine soil carbonate. Contains less than 30% calcrete fragments. Restricts root growth of most cereal and irrigated crops. Generally poor drainage qualities (Attachment HA).

Geochemistry

Laboratory results for the Dune Slopes landform unit are summarised by soil layers in Table H-2 for soil conductivity, pH, boron and ESP, and are discussed below.

Table H-2
Laboratory Results* for the Dune Slopes Landform Unit

Parameter	A_1 Topsoil Horizon	A_2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.5	1.67	5.07	6.72
Average pH	8.5	9.0	9.1	9.6
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.37	0.85	3.9	9.95
Average ESP	2.09	6.68	11.85	19.24

* Results are expressed as an average value for the 6 Dune Slope sites sampled.

Soil conductivity levels for all topsoil layers within the Dune Slopes landform unit are considered suitable for rehabilitation (Wetherby, 2006). The Bk carbonate layer and subsoil/parent material layer have slightly elevated conductivity levels, but not to a level which is considered limiting to native vegetation (Wetherby, 2006). Average soil pH in the Dune Slopes landform unit ranges from weakly alkaline in the upper A_1 topsoil horizon to strongly alkaline in the subsoil/parent material layer. Boron levels in the Dune Slopes landform unit are considered to be non-limiting to native vegetation growth (*ibid.*). Average soil sodicity or ESP is considered to be weakly to moderately sodic in the A_1 topsoil horizon and A_2/Bt topsoil horizon, moderately to highly sodic in the Bk carbonate layer and highly sodic in the subsoil/parent material layer (*ibid.*).

H3.2.1.3 Sandy Plains

Depth, Geology and Texture

The Sandy Plains landform unit is estimated to comprise approximately 30% of the study area (Figure H-7) and vegetation of the Sandy Plains is typically Black Oak-Rosewood-Wilga Woodland. Soils are dominated by hypercalcic Calcarosols but red Chromosols also occur.

Typical soil horizons of this landform unit include:

- A_1 Topsoil Horizon;
- A_2/Bt Topsoil Horizon;
- Bk Carbonate Layer; and
- Subsoil/Parent Material Layer.

Surface soil textures are generally light sandy clay loam. Drainage impeding layers were present at only two sandy plains sampling locations. Sandy plains have average topsoil and PRZ depths of approximately 45 cm and 65 cm respectively, have low to moderate free lime contents (approximately 1.5%) and are generally reddish-brown in colour. The majority of carbonate layers encountered in Sandy Plain areas are Class IIIAL. The Sandy Plains soil matrix typically has less than 20% calcrete rubble fragments.

Geochemistry

Laboratory results for the Sandy Plains landform unit are summarised by soil layers in Table H-3 for soil conductivity, pH, boron and ESP, and are discussed below.

Table H-3
Laboratory Results* for the Sandy Plains Landform Unit

Parameter	A_1 Topsoil Horizon	A_2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.5	1.84	5.2	7.96
Average pH	8.5	9.0	9.3	9.4
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.15	1.58	7.38	18.74
Average ESP	1.90	7.89	18.86	25.53

* Results are expressed as an average value for the 13 Sandy Plain sites sampled.

Soil conductivity levels for all topsoil layers within the Sandy Plains landform unit are considered suitable for rehabilitation (Wetherby, 2006). Average soil pH in the Sandy Plains landform unit ranges from weakly alkaline in the upper A_1 topsoil horizon to alkaline in the subsoil/parent material layer. Boron levels in the A_1 and A_2/Bt topsoil horizons and Bk carbonate layer are considered to be non-limiting to native vegetation growth (*ibid.*). Boron levels in the subsoil/parent material layer have the potential to limit native vegetation growth (*ibid.*). Average soil sodicity or ESP in the Sandy Plains landform unit is considered to be weakly sodic in the A_1 topsoil horizon, moderately sodic in the A_2/Bt topsoil horizon and highly sodic in the Bk carbonate layer and subsoil/parent material layer (*ibid.*).

H3.2.1.4 Clayey Plains

Depth, Geology and Texture

Clayey Plains are estimated to comprise approximately 40% of the study area (Figure H-7) and associated vegetation communities include Black Oak-Rosewood-Wilga Woodland, Bluebush Shrubland and *Austrostipa* grassland. Soils are dominated by hypercalcic and calcic Calcarosols.

Typical soil horizons of this landform unit include:

- A_1 Topsoil Horizon;
- A_2/Bt Topsoil Horizon;
- Bk Carbonate Layer; and
- Subsoil/Parent Material Layer.

Surface soil textures are typically either clay loam or sandy clay loam. Drainage impeding layers are present on average at approximately 120 cm below the natural surface. Clayey plains have average topsoil and PRZ depths of approximately 30 cm and 60 cm respectively, moderate to high free lime contents (approximately 4%) and are generally reddish-brown to brown in colour. The majority of carbonate layers encountered are Class IIIAL over plain areas. The Clayey Plains soil matrix typically has less than 20% calcrete rubble fragments. Calcic Calcarosols (Isbell, 2002) carbonate layers occur in approximately 30% of the study area, generally in clayey plain areas. These soils have high free lime contents within a clay or light-medium clay matrix and have poor permeability and drainage characteristics.

Geochemistry

Laboratory results for the Clayey Plains landform unit are summarised by soil layers in Table H-4 for soil conductivity, pH, boron and ESP, and are discussed below.

Table HA-4
Laboratory Results[†] for the Clayey Plains Landform Unit

Parameter	A_1 Topsoil Horizon	A_2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.68	*0.96	1.69	7.59
Average pH	8.8	*8.0	9.1	9.4
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.10	*0.74	1.85	30.61
Average ESP	1.62	*8.71	8.5	29.67

† Results are expressed as an average value for the 11 Clayey Plain sites sampled.
* Denotes 1 value only.

Soil conductivity levels for all topsoil layers within the Clayey Plains landform unit are considered suitable for rehabilitation (Wetherby, 2006). Average soil pH in the Clayey Plains landform unit ranges from weakly alkaline in the upper A_1 topsoil horizon to moderately alkaline in the subsoil/parent material layer. Boron levels in the A_1 and A_2/Bt topsoil horizons and Bk carbonate layer in the Clayey Plains landform unit are not considered to be limiting to native vegetation growth (*ibid.*). Elevated boron levels in the subsoil/parent material layer have the potential to limit native vegetation growth (*ibid.*). Average soil sodicity or ESP in the Clayey Plains landform unit is considered to be weakly sodic in the A_1 topsoil horizon, moderately sodic in the A_2/Bt topsoil horizon and Bk carbonate layer and highly sodic in the subsoil/parent material layer (*ibid.*).

H3.2.1.5 Swales

Depth, Geology and Texture

Swales are estimated to comprise approximately 5% of the study area (Figure H-7) and associated vegetation communities include Chenopod Mallee Shrubland, Bluebush Shrubland and *Austrostipa* grassland. Soils are Calcarosols or red Chromosols with surface soil textures of either clay loam or sandy clay loam.

Typical soil horizons of this landform unit include:

- A_1 Topsoil Horizon;
- A_2/Bt Topsoil Horizon;
- Bk Carbonate Layer; and
- Subsoil/Parent Material Layer.

Drainage impeding layers are present at two swale sites at 75 cm and 50 cm respectively. Swales have average topsoil and PRZ depth of approximately 40 cm and 60 cm respectively, have moderate free lime contents (approximately 2.5%) and are generally reddish-brown in colour.

Geochemistry

Laboratory results for the Swales landform unit are summarised by soil layers in Table H-5 for soil conductivity, pH, boron and ESP, and are discussed below.

Table HA-5
Laboratory Results† for the Swales Landform Unit

Parameter	A_1 Topsoil Horizon	A_2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.61	*0.56	2.45	6.67
Average pH	8.6	*8.7	9.3	9.3
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.15	*1.3	2.0	19.9
Average ESP	1.83	*1.15	10.97	27.04

† Results are expressed as an average value for the 4 Swale sites sampled.
* Denotes 1 value only.

Soil conductivity levels for all PRZ layers within the Swales landform unit are considered suitable for rehabilitation (Wetherby, 2006). Average soil pH in the Swales landform unit ranges from weakly alkaline in the A_1 topsoil horizon to moderately alkaline in the subsoil/parent material layer. Boron levels in the A_1 and A_2/Bt topsoil horizons and Bk carbonate layer in the Swales landform unit are considered to be non-limiting to native vegetation growth (*ibid.*). Elevated boron levels in the subsoil/parent material layer have the potential to limit native vegetation growth (*ibid.*). Average soil sodicity or ESP in the Swales landform unit is considered to be weakly sodic in the A_1 topsoil horizon and A_2/Bt topsoil horizon, moderately to highly sodic in the Bk carbonate layer, and highly sodic in the subsoil/parent material layer (*ibid.*).

H3.2.1.6 Run-on Depressions

Depth, Geology and Texture

Run-on depressions have the most variable soils in the Snapper landscape, and make up the least amount of the study area (5%) (Figure H-7). They vary in topsoil depth from 20 cm at a grassland site to 65 cm at a Black Box Woodland site. Vegetation communities present include *Austrostipa* grassland and Black Box Woodland. Soil types are red Chromosols with the occasional yellow Chromosols. The Bk carbonate layer was not present at the Run-on Depressions survey sites.

Typical soil horizons of this landform unit include:

- A_1 Topsoil Horizon;
- A_2/Bt Topsoil Horizon; and
- Subsoil/Parent Material Layer.

Surface soil textures were clay loam and sandy clay. Drainage impeding layers were present at all sites at depths varying from 50-95 cm. Free lime contents are generally low within the topsoil and PRZ, however the moderate angular or sub-angular blocky nature of the Bt topsoil horizon is often restrictive to root growth with root penetration normally only 20-30 cm into this layer. Soil colours are reddish in some run-on areas such as Black Box Woodlands and in other areas overlying gypseous subsoil, the surface colour is greyish-brown.

Geochemistry

Laboratory results for the Run-on Depressions landform unit are summarised by soil layers in Table H-6 for soil conductivity, pH, boron and ESP, and are discussed below.

Table HA-6
Laboratory Results* for the Run-on Depressions Landform Unit

Parameter	A_1 Topsoil Horizon	A_2/Bt Topsoil Horizon	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.59	0.71	5.46
Average pH	8.8	8.7	9.2
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.17	1.03	21.43
Average ESP	1.71	5.32	20.78

* Results are expressed as an average value for the 3 Run-On Depression sites sampled.

Soil conductivity levels for all topsoil layers within the Run-on Depression landform unit are considered suitable for rehabilitation (Wetherby, 2006). Average soil pH in the Run-on Depression landform unit ranges from weakly alkaline in the A_1 topsoil horizon to moderately alkaline in the subsoil/parent material layer. Boron levels in the A_1 and A_2/Bt topsoil horizons in the Run-on Depressions landform unit are not considered to be limiting to native vegetation growth (*ibid.*). Elevated boron levels in the subsoil/parent material layer have the potential to limit native vegetation growth (*ibid.*). Average soil sodicity or ESP in the Run-on Depressions landform unit is considered to be weakly sodic in the A_1 topsoil horizon, weakly to moderately sodic in the A_2/Bt topsoil horizon, and highly sodic in the subsoil/parent material layer (*ibid.*).

H3.2.2 Overburden

H3.2.2.1 Woorinen Formation

Geochemistry

Conductivity values for the four Woorinen Formation overburden samples vary widely, from low to very high. Material with high conductivity has the potential to impact on native vegetation growth and would not be placed within proximity of the PRZ of the rehabilitated profile. pH values for the four Woorinen Formation overburden samples are moderately to strongly alkaline. Boron values for the four Woorinen Formation overburden samples vary widely from moderate to very high. Material with elevated boron levels may potentially impact native vegetation growth if replaced within proximity to plant roots within the newly constructed soil profiles. Overburden material in the Woorinen Formation ranges from sodic to highly sodic.

H3.2.2.2 Shepparton Formation

Geochemistry

Conductivity values for the Shepparton Formation (also referred to as Blanchetown Clay) overburden samples vary widely, from moderate to very high. Material with high conductivity has the potential to impact on native vegetation growth if replaced within the PRZ in the rehabilitated profile. The Shepparton Formation is moderately alkaline and highly sodic. Boron levels in the Shepparton Formation varies widely, from low to very high. Material with elevated boron levels has the potential to impact on native vegetation growth if replaced within the PRZ in the rehabilitated profile.

H3.2.2.3 Upper Loxton-Parilla Sands

Geochemistry

Conductivity values for the five Upper Loxton-Parilla Sand overburden samples also vary widely, from low to very high. The Upper Loxton-Parilla Sands are weakly to moderately alkaline and highly sodic. Boron levels in the Upper Loxton-Parilla Sands are universally low (less than 3.5 mg/kg). This overburden material type is therefore unlikely to be limiting to vegetation growth due to boron levels. The Upper Loxton-Parilla Sand is highly sodic.

H3.2.2.4 Mica Sands

Geochemistry

Conductivity values for the three Mica Sands overburden samples also vary, from low to high, but are generally considered to have moderate conductivity levels. pH levels in the Mica Sands vary widely, from weakly acidic to moderately alkaline. Boron levels are universally very low (less than 1.1 mg/kg), and the Mica Sands are highly sodic.

H3.2.2.5 Lower Loxton-Parilla Sands

Geochemistry

The Lower Loxton-Parilla Sands overburden sample was moderately alkaline, low in boron, highly sodic and had low conductivity.

H4 REHABILITATION MATERIALS ASSESSMENT

H4.1 REHABILITATION MEDIA

Sand residues (including backloaded MSP process waste) would be the bottom stratigraphic unit in the rehabilitated landform profile, overlain by slurried overburden, non-slurried overburden, subsoil and topsoil (Figure H-2).

H4.1.1 Topsoil

Topsoil depths across the study area vary from 20-105 cm according to landform types. The shallowest topsoils occur on clayey plain landforms (average 30 cm depth) and occur over approximately 40-45% of the study area. Dune, dune slope and sandy sand-plain landform units, which together comprise approximately 50% of the study area, have greater topsoil depth generally in the range of 40-70 cm. The topsoils have inherently low nutrient status which has been further depleted by existing land management practices (i.e. grazing) over many years. The topsoils generally have low to moderately high free lime content, are generally non-sodic, have low soil conductivity and pH, and provide a suitable growth medium for the type of remnant vegetation present in Black Oak-Rosewood-Wilga Woodland and Bluebush Shrublands. The topsoils are considered suitable for use as PRZ material during rehabilitation.

An important feature defining the depth of topsoil is a carbonate layer which is a zone of accumulation within the soil profile which is rich in calcium carbonate. This carbonate layer typically restricts root growth within Mallee Region soils and is a significant influence governing the natural distribution of terrestrial plant species and ecological communities within the Murray-Darling Depression Bioregion (Sluiter, 2005). Where present, this horizon is located immediately beneath the topsoil horizon (A_2/Bt horizon discussed above). It is not considered suitable for use as PRZ material during rehabilitation and, along with landform unit type, would be used to guide topsoil stripping operations. In this way the depth of stripped topsoil can be maximized, and any inadvertent harvesting of the carbonate layer can be prevented.

The PRZ seldom includes more than the top 20 cm of the underlying carbonate layer and in some cases it does not include it at all (i.e. *in-situ* vegetation roots are primarily located in the soil horizon above the carbonate layer). Maximising topsoil recovery would allow for an average 50-80 cm of PRZ depth in the rehabilitated landscape (i.e. re-establish the current *in-situ* average PRZ of 50-80 cm).

Attachment HA provides a detailed analysis of topsoils within the study area.

H4.1.2 Subsoil

Subsoil material varies across the study area. Subsoils generally have high soil conductivity, high pH, high sodicity or ESP and high boron levels, which would preclude some of this material from being placed within the PRZ of the rehabilitated land. In addition, these soils have poor permeability characteristics. These soils would be suitable to be placed below the PRZ and above the slurried overburden in the rehabilitated profile.

Other forms of carbonate subsoil have generally low to moderate conductivity levels and low boron levels with moderate to good drainage characteristics, and would be suitable for use within PRZ of the rehabilitated profile. Elevated ESP values for some carbonate layer soils may necessitate the use of low to moderate rates of gypsum application in order to improve soil permeability.

Attachment HA provides a detailed analysis of subsoils within the study area.

H4.1.3 Non-Slurried Overburden

Overburden derived from the geologically younger facies such as Woorinen and Shepparton Formations have varying levels of soil conductivity, pH, boron and sodicity. Materials from these layers with potentially limiting characteristics would not be used within PRZ of the rehabilitated landform.

The older Loxton-Parilla Sands has three major recognised facies – the Upper Loxton-Parilla Sands, Mica Sands and the Lower Loxton-Parilla Sands. These facies have varying sodicity or ESP values (i.e. sodic to highly sodic) and generally high sulphur levels, neutral to slightly alkaline pH, negligible boron levels and moderate conductivity levels. The use of this material, in particular the more clayey facies, should be trialled as a subsoil medium in Rehabilitated Areas. Gypsum may need to be applied at high rates in order to ameliorate calcium and magnesium deficiencies and to mitigate soil sodicity.

Attachment HA provides a detailed analysis of overburden within the study area.

H4.1.4 Slurried Overburden

Due to the saline nature of the groundwater beneath the Snapper Mine site (Appendix A of the EA), the slurried overburden would be saline and generally unsuitable for use as a rehabilitation medium.

H4.1.5 Sand Residues

The sand residues are the waste stream from the primary gravitational (i.e. physical) minerals separation process. The geochemical properties of the sand residues would be essentially the same as the *in-situ* ore. The sand residues would be saline owing to the presence of entrained saline groundwater and would be generally unsuitable for use as a revegetation medium.

Attachment HB presents the acid rock drainage assessment undertaken for ore samples collected during bulk ore sampling in September 2006. All of the samples analysed are classified as NAF.

H4.1.6 Backloaded MSP Process Waste

A *Process Waste Materials Assessment* (BEMAX, 2007) has been prepared to assess the potential environmental impacts and describe management measures associated with the handling, storage and transport of backloaded process waste materials from the MSP and disposal of this waste at the Snapper Mine. Section H4.2.2 provides an overview of the potential impacts and management and mitigation measures associated with the presence of monazite (a radioactive material that naturally occurs in heavy mineral sands deposits) in the process streams.

The backloaded MSP process waste would be disposed of on the sand residue beach and/or with overburden and would be covered under a minimum of 10 m (up to 35 m) of overburden (BEMAX, 2006a). The total tonnage of backloaded MSP process waste disposed of at the Snapper Mine would be up to 210,000 tpa.

H4.2 POTENTIAL IMPACTS, MANAGEMENT AND MITIGATION MEASURES

Potential impacts associated with the operation of the Snapper Mine which would be mitigated by mine rehabilitation include:

- potential impacts on vegetation associated with the placement of saline slurried overburden (Section H4.2.1); and
- potential impacts associated with the storage of backloaded MSP process waste (Section H4.2.2).

H4.2.1 Salinity Effects on Vegetation

An assessment of the risks to the success of rehabilitation and revegetation of the Snapper Mine site associated with the use of saline slurry in the initial slurried overburden emplacement is provided in Attachment HC. The potential impacts on vegetation resulting from the use of saline slurried overburden in the rehabilitated profile identified in the risk assessment include:

- capillary rise increasing salinity levels within the PRZ of the non-slurried material;
- lateral salt movement (seepage) within the slurried overburden along the mine path and in the initial slurried overburden emplacement to rehabilitated/revegetated areas;
- salts contained within the slurried material becoming airborne once the material has dried; and
- failure of clay lining/capping in the initial slurried overburden emplacement.

The mechanisms, and management and mitigation measures that would be put in place to minimise the above potential impacts are described below.

Capillary Rise

Slurried overburden would be saline due to the presence of entrained groundwater. Saline water within the slurried overburden media has the potential to migrate into the non-slurried overburden layers via capillary rise. Subsequently, residual salinity levels due to capillary rise may be expected within the lower section of profile of the non-slurried material (i.e. material placed above the slurried overburden as a rehabilitation medium) during the initial period following replacement. Research has shown that salinity levels throughout the profile of the replaced material would significantly reduce with time due to leaching (i.e. residual salinity levels over the long-term are expected to be negligible) (Brearley, 2006). In order to maximise potential infiltration, potential compaction of the replaced material would be minimised where practicable (e.g. traffic on top of replaced material would be kept to a minimum).

Research conducted on mineral sands projects throughout Western Australia suggests that capillary rise can occur up to 2 m above a saturated zone (i.e. above groundwater or perched aquifer) (Brearley, 2006). The saline slurried overburden at the Snapper Mine would not be a saturated zone as it would be allowed to dry out before placement of an appropriate depth of non-slurried overburden, subsoil and topsoil. Therefore capillary rise is expected to be much less than 2 m.

Management and Mitigation Measures

Due to the saline nature of slurried overburden and the potential for capillary rise, the following rehabilitation concepts would be implemented:

- Slurried overburden material would be covered by at least 3 m of non-slurried material (including topsoil, subsoil and non-slurried overburden) or less should rehabilitation investigations (e.g. laboratory testwork, trials) indicate shallower depths would not increase the risks to revegetation posed by salinity.
- Stockpiled soils would be re-spread on final surfaces.
- Salt tolerant, endemic species would be utilised for revegetation.

Additionally, research has shown that salinity levels throughout the profile of the replaced material would significantly reduce with time due to leaching (i.e. residual salinity levels over the long-term are expected to be negligible) (Brearley, 2006). In order to maximise potential infiltration, potential compaction of the replaced material would be minimised where practicable (e.g. traffic on top of replaced material would be kept to a minimum).

Residual salinity levels within the profile of the non-slurried material would be regularly monitored throughout the rehabilitation period. Trials would be conducted and integrated into this monitoring programme as part of the rehabilitation programme to establish the appropriate depth of cover of non-slurried overburden.

Lateral Salt Movement

Due to the saline nature of the groundwater beneath the Snapper Mine site, the site water, slurried overburden and sand residues would be saline. Initial and final storages of these materials are potential sources for lateral salt movement, including:

- initial water supply dam;
- initial sand residue dam;
- initial slurried overburden emplacement;
- water treatment dams;
- water disposal dam; and
- slurried overburden deposited in the mine path (including areas where fines from the water treatment dams have been disposed).

Management and Mitigation Measures

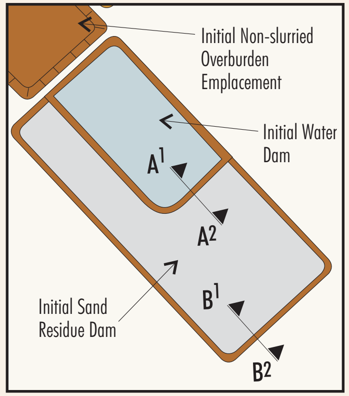
To minimise the potential for seepage from the sources listed above, control measures would be implemented.

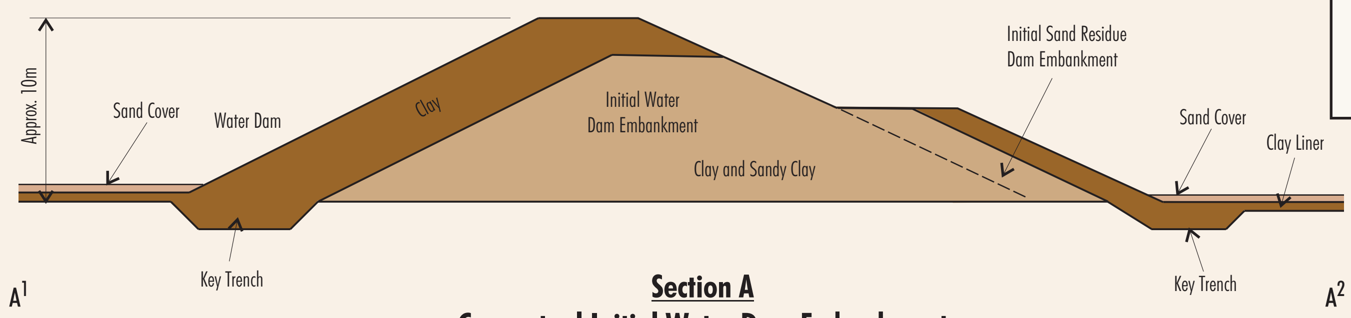
Seepage management design measures would include those set out below:

- A clay liner would be constructed beneath the initial water supply dam, initial sand residue dam, water treatment dams and slurried overburden emplacement (Figures H-8 and H-9). The clay liner would be compacted to provide for low permeability, which would minimise seepage through the base of the dams and emplacement. The clay liner would be covered with clean sand material (track rolled) to prevent cracking or drying out of the liner prior to deposition of slurried overburden.
- Low permeability embankments of the initial water supply dam, initial sand residue dam, water treatment dams, water disposal dam and initial slurried overburden emplacement would be constructed of clay, sandy clay, gravely clay and selected stockpiled material and placed in layers (Figure H-8). The embankments would be compacted with the moisture content at placement to optimise the low permeability outcome.
- A toe drain/trench would be constructed on the downstream face of the embankments of the initial water supply dam, initial sand residue dam, water treatment dams and initial slurried overburden emplacement to collect runoff and/or seepage (Figures H-8 and H-9).
- The water disposal dam would be located on top of sand residues and slurried overburden on the mine path, and is designed so that water reports back to the groundwater table through the permeable floor (Figure H-10). The embankments of the water disposal dam would be lined with clay as described above to minimise lateral movement of water.
- Disposal of fines material from the water treatment dams within the mine path would be in isolated occasional areas (i.e. a continuous fines layer would not be constructed across the mine path within the rehabilitated profile). Seepage which encounters the lower permeability fines would drain from these areas to the higher permeability slurried overburden material and subsequently vertically through the profile.
- Groundwater monitoring bores (i.e. piezometers) would be installed surrounding the overburden emplacements, dams and mine path to monitor for lateral saline seepage to the surrounding PRZ.

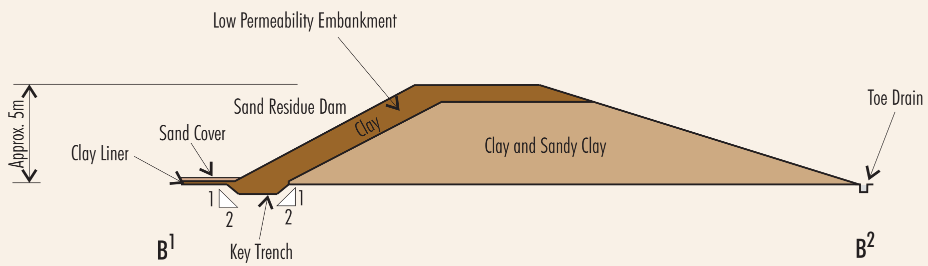
Airborne Salt Movement

Salts contained within the slurried material may become airborne, once that material has dried, and effect vegetation in areas adjacent to the rehabilitated landforms and revegetation areas.





Section A
Conceptual Initial Water Dam Embankment

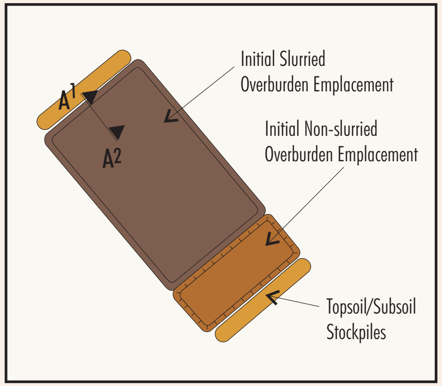


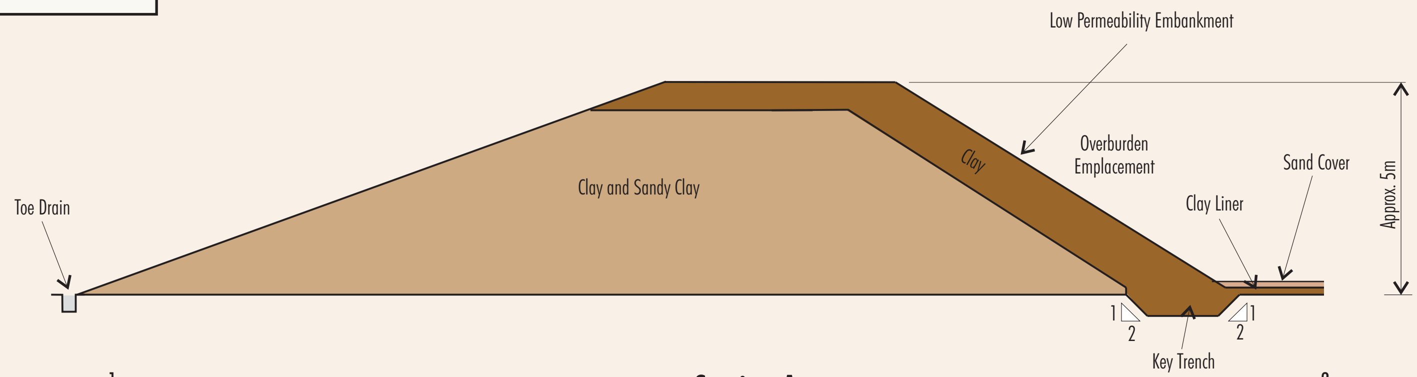
Section B
Conceptual Initial Sand Residue Dam Embankment

Not to Scale

SNAPPER MINERAL SANDS PROJECT

FIGURE H-8
Initial Sand Residue Dam and Initial Water Dam - Conceptual Embankment Detail





Section A

Conceptual Initial Slurried Overburden Emplacement Embankment

Not to Scale

SNAPPER MINERAL SANDS PROJECT

FIGURE H-9

Initial Slurried Overburden Emplacement - Conceptual Embankment Detail

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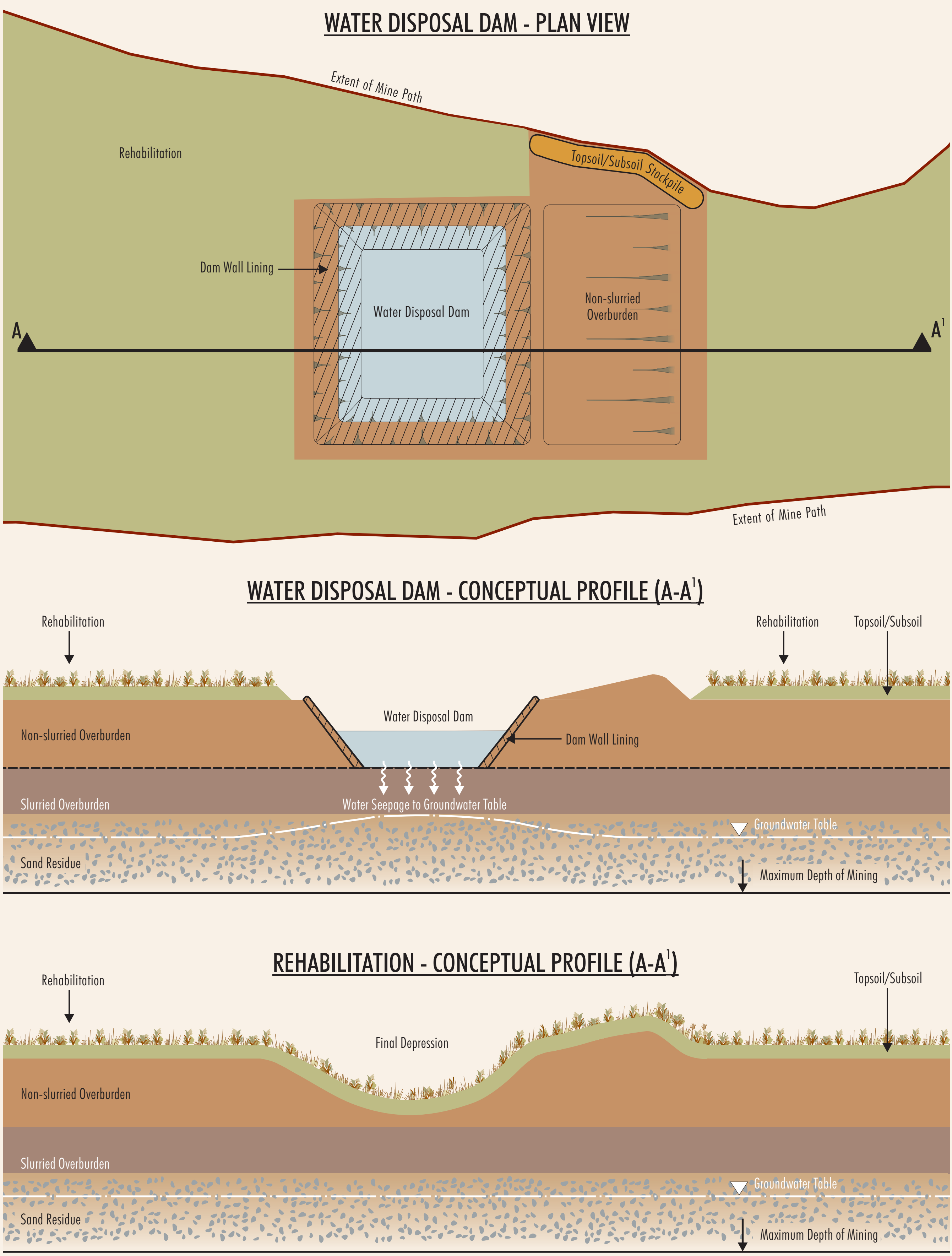

SNAPPER MINERAL SANDS PROJECT

FIGURE H-10

Water Disposal Dam Concept

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Management and Mitigation Measures

Slurried overburden and sand residues would likely have particulate-suppressing properties (i.e. crusting) given the presence of salts within the entrained groundwater, which would reduce particulate (including salt) emissions and therefore reduce potential impacts from airborne salts. Notwithstanding the above, a photographic record of vegetation surrounding the mine path, initial slurried overburden emplacements and initial sand residue dam would be maintained to monitor the potential impacts of airborne salts.

Failure of Clay Lining/Capping

The low permeability clay lining of and embankments of the initial water supply dam, initial sand residue dam, water treatment dams and overburden emplacements is designed to restrict the flow of saline water to the surrounding area. The low permeability capping of the initial water supply dam, initial sand residue dam, water treatment dams and overburden emplacements is designed to direct rainfall off the surface of the dams and emplacements to toe drains to restrict the infiltration of waters through the saline overburden.

Failure of the clay lining/capping may be caused by:

- gaps or breaks in the continuity of the clay lining/capping due to inadequate construction;
- cracks in the clay lining/capping due to drying out; and
- inadequate compaction leading to higher permeability than designed.

Management and Mitigation Measures

The risk of failure of the clay lining/capping would be minimised by:

- survey control during construction; and
- permeability testing during construction and use.

H4.2.2 Contamination from the Disposal of Monazite

All heavy mineral sands orebodies contain traces of the naturally occurring radioactive elements uranium and thorium together with their decay products. The only mineral sands component that is significantly radioactive is monazite. Monazite is a radioactive material containing cerium, lanthanum and neodymium and is a source of the radioactive element thorium (BEMAX, 2006b). In some mineral sands projects, monazite is separated as a product stream; however the Snapper Mine deposit contains a very low level of monazite which is insufficient to warrant its commercial recovery.

The monazite concentrates in the zircon reject stream along with other minerals that have similar specific gravities, magnetic and conductivity properties (BEMAX, 2006b). Typically Australian mineral sands projects encounter monazite contents of less than 15% in the zircon reject stream and this would be an anticipated maximum for the Snapper Mine heavy mineral concentrates (*ibid*.).

The potential impacts due to presence of monazite in the backloaded MSP process waste stream are discussed in the *Process Waste Materials Assessment* (Appendix I of the EA). In summary, potential impacts associated with the presence of monazite in the process streams primarily relate to exposure (via inhalation and/or ingestion) of employees and or members of the public to the radiation source during its handling, storage and disposal. Other potential impacts include land or surface water contamination due to a release of material containing monazite. The heavy nature and solid state of the monazite and its insolubility in water would limit the potential for the dispersal of contamination (Radiation Advice & Solutions, 2006), which would facilitate effective spill response and clean-up.

Management and Mitigation Measures

An investigation into the potential impacts and mitigation measures associated with the production of Monazite is detailed in the *Process Waste Materials Assessment* (Appendix I of the EA). In addition to monitoring, backloaded MSP process waste would be landfilled in a manner that results in the following:

- the average concentration of radioactive material in landfill at the premises would not exceed the average concentration of radioactive material in the original orebody; and
- there would be no detectable change from the original natural background radiation level measured at the ground surface.

As discussed in Section H4.1.6, the backloaded MSP process waste would be disposed of on the sand residue beach and/or with overburden, and would be covered under a minimum of 10 m (up to 35 m) of overburden (BEMAX, 2006a). Similar to the Ginkgo Mine and in addition to the disposal principles above, the radiation level of any material deposited in landfill at Snapper Mine does not exceed 0.7 microGray per hour, measured 1 m vertically above the surface of the landfilled area.

H4.3 REHABILITATION OF DISTURBANCE AREAS

H4.3.1 Materials Handling

The following materials handling procedures would be put in place during rehabilitation of the Snapper Mine:

- Stripping of topsoil to the appropriated depth would be guided by the landform type and depth to the carbonate layer to maximise topsoil recovery.
- Where practicable, topsoil would be direct-placed (i.e. topsoil stockpiling and rehandling should be minimised), in order to:
  - remove the requirement to “double-handle” topsoil;
  - conserve the soil seed store; and
  - reduce the risk of weed invasion.
- Where practicable, the top 5-10 cm of topsoil would be salvaged separately to the rest of the topsoil, to maintain the integrity of the cryptogamic soil crust and seed bank for rehabilitation.
- Where practicable, topsoil would be removed and stockpiled when moist, or in autumn to take advantage of seasonal rainfall.
- Potentially sodic soils, such as some of the Bk carbonate layer and subsoil/parent material, would be stored and managed separately (e.g. with the application of gypsum).
- Mixing of the Bk carbonate layer with topsoil would be largely avoided in topsoil stripping operations with the use of appropriate equipment (e.g. tractors with scoops or front-end loaders with bucket scoops).
- Mixing of the Bk carbonate layer with topsoil would be avoided during storage and rehabilitation procedures across the Snapper Mine path.

H4.3.2 Depth of Cover and Primary Root Zone

As discussed in H2.1, to mitigate the potential effects of capillary rise, a strategy to cover slurried overburden material with at least 3 m of non-slurried material (including topsoil, subsoil and non-slurried overburden) or less should rehabilitation investigations (e.g. laboratory testwork, trials) indicate shallower depths do not increase the risks to revegetation posed by salinity would be implemented.

The study area has topsoil depths varying from 20 to 105 cm. The shallowest topsoils occur on clayey plains which average 30 cm depth and occur over approximately 45% of the study area. Dunes, dune slopes and sandy sand plains which together comprise approximately 50% of the study area (Figure H-7), have greater topsoil depth, normally in the range of 40-70 cm.

The PRZ of the remnant vegetation present, regardless of vegetation community type, seldom extends beyond 20 cm into the underlying carbonate layer of the dominant soil type in Calcarosol soils. In the case of Chromosol soils, characterized by the presence of a zone of illuviation or Bt Horizon beneath the topsoil layer (the Callabonna Clay), plant roots were often found to extend a similar depth into this layer and often not reach the carbonate layer. Topsoil recovery would be maximised, allowing for an average 50-80 cm of PRZ depth in the rehabilitated landscape (i.e. re-establishing the current average PRZ of 50-80 cm).

H4.3.3 Rehabilitation Trials

As a component of the rehabilitation programme a number of trials (including laboratory testwork and field trials) would be undertaken to assess the effectiveness of rehabilitation techniques, including topsoil and subsoil depth and the success of different plant species over the life of the Snapper Mine.

Rehabilitation trials are discussed in Section 5 of the EA and would be detailed in the Mining Operations Plan (MOP). Trials applicable to rehabilitation materials are likely to include:

- evaluation of surface treatments and plant species selection options for rehabilitation of the slurried overburden emplacement;
- investigation of alternative substrates that demonstrate differing soil structure, pH, moisture retention and drainage (e.g. topsoils, subsoils and selected overburden materials such as sandy clay material) for use within the non-slurried overburden, including the suitability and appropriate depth of Loxton-Parilla Sand as a subsoil growth medium with respect to the PRZ in the rehabilitation landscape;
- the use of gypsum to ameliorate sodicity and calcium and magnesium deficiencies; and
- evaluation of the effect of a lack of zinc on the revegetation programme.

H5 REFERENCES

BEMAX (2006a) *Ginkgo Mineral Sands Project and Broken Hill Mineral Separation Plant Landfill Environmental Management Plan.*

BEMAX (2006b) *Broken Hill Mineral Separation Plant Waste Management Plan.*

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ATTACHMENT HA

IN-SITU MATERIALS ANALYSIS

BEMAX RESOURCES LIMITED
SNAPPER MINERAL SANDS PROJECT
IN-SITU MATERIALS ANALYSIS REPORT

December 2006

Ecological Ogyris Research

Report Title: **"BEMAX Resources Limited. Snapper Mineral Sands Project *In-Situ* Materials Analysis Report."**

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Photographs: All photographs used in this report have been supplied courtesy of Ian Sluiter of Ogyris P/L.

Cover Photograph: *In-situ* overburden showing an unconformity where the Blanchetown Clay overlies the Upper Loxton-Parilla Sand at the Ginkgo Mine, east of the Snapper Prospect.

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HA1 INTRODUCTION AND BACKGROUND

HA1.1 Snapper Mine Brief

BEMAX Resources Limited (BEMAX) own and operate the Ginkgo Mineral Sands Project (the Ginkgo Mine) (Mining Lease [ML] 1504) located approximately 40 kilometres (km) west of Pooncarie in far south-west New South Wales (NSW). BEMAX are proposing to develop the Snapper Mineral Sands Project (the Snapper Mine), located approximately 10 km south-west of the Ginkgo Mine (Figure HA-1). The Snapper Mine area comprises the Snapper Mine Mining Lease Application (MLA) area and the electricity transmission line (ETL) and highway access road (HAR) extensions.

BEMAX commissioned Ogyris Pty Ltd to undertake an assessment of the rehabilitation potential of the *in-situ* soil and overburden materials of the Snapper Mine (*In-Situ* Materials Analysis) to be included in the Snapper Mine Environmental Assessment (EA). As part of the *In-Situ* Materials Analysis, a soil survey was conducted over the Snapper Mine path (Figure HA-2) (the study area). In addition to the field soil survey, samples of overburden material collected from exploration drilling conducted within the study area were also examined for physical and chemical properties. The results of the soil and overburden assessments were then used to develop recommendations for the removal, storage, replacement and rehabilitation of soil and overburden.

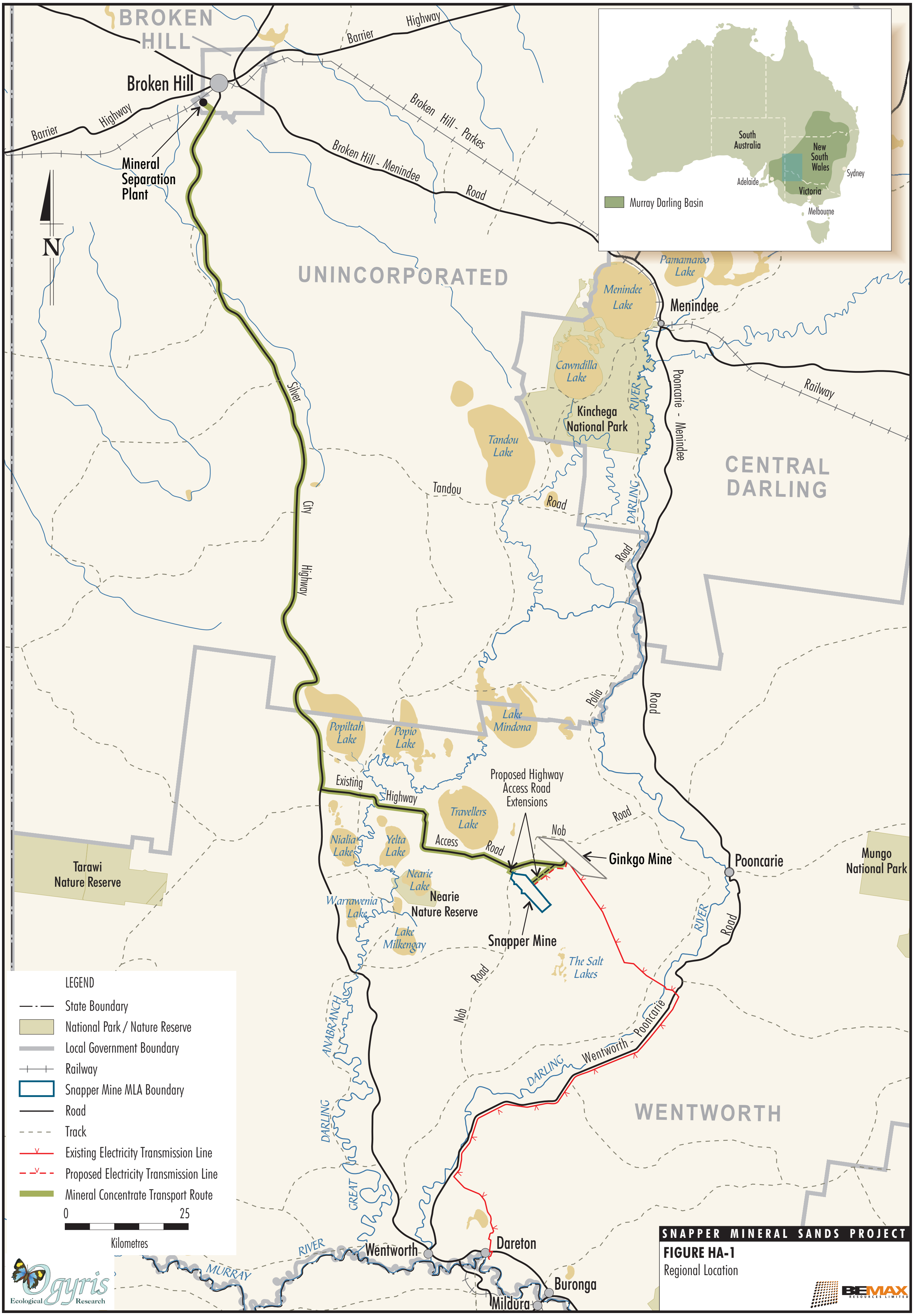
The objective of this report is to:

- describe the major landform units across the study area;
- characterise the surficial soil resources (i.e. the topsoil and subsoil to a depth of approximately 2 metres [m]) occurring within the study area to determine their suitability as rehabilitation growth media; and
- characterise the overburden materials within the study area to determine their suitability as rehabilitation growth media.

HA1.2 Geological Setting of the Murray-Darling Area

The Snapper Mine lies within the Murray Lowlands Province (Jennings and Mabbutt, 1977) or Murray-Darling Depression Bioregion (Environment Australia, 2000), an area dominated by low surface relief above thick Murray Basin sedimentary accumulations. This sedimentary sequence overlies Palaeozoic and Proterozoic basement rocks (Wasson, 1989). The major landform and geological features are dominated by the events of the last 5 million (M) years, a time when Late Miocene-Pliocene high-stand sea levels retreated (Brown and Stephenson, 1985), leaving sheets of quartzitic sands (e.g. Loxton-Parilla Sands) over formerly marine and fluvio-lacustrine sediments of Palaeocene to Miocene age. On the Pliocene strand-plain the retreating of the sea left behind a series of beach ridges (Lawrence, 1966) of generally north-west to south-east trending alignment. These ridges have weathered, mineralised and consolidated over time, and represent the Snapper Mine orebody.

The principal dune type occurring within the study area is the Woorinen Formation of Lawrence (1966), which is typical of the Murray-Darling Depression Bioregion. The Woorinen Formation is characterised by low-linear dunes of generally east-west alignment with moderately high clay and calcareous contents.



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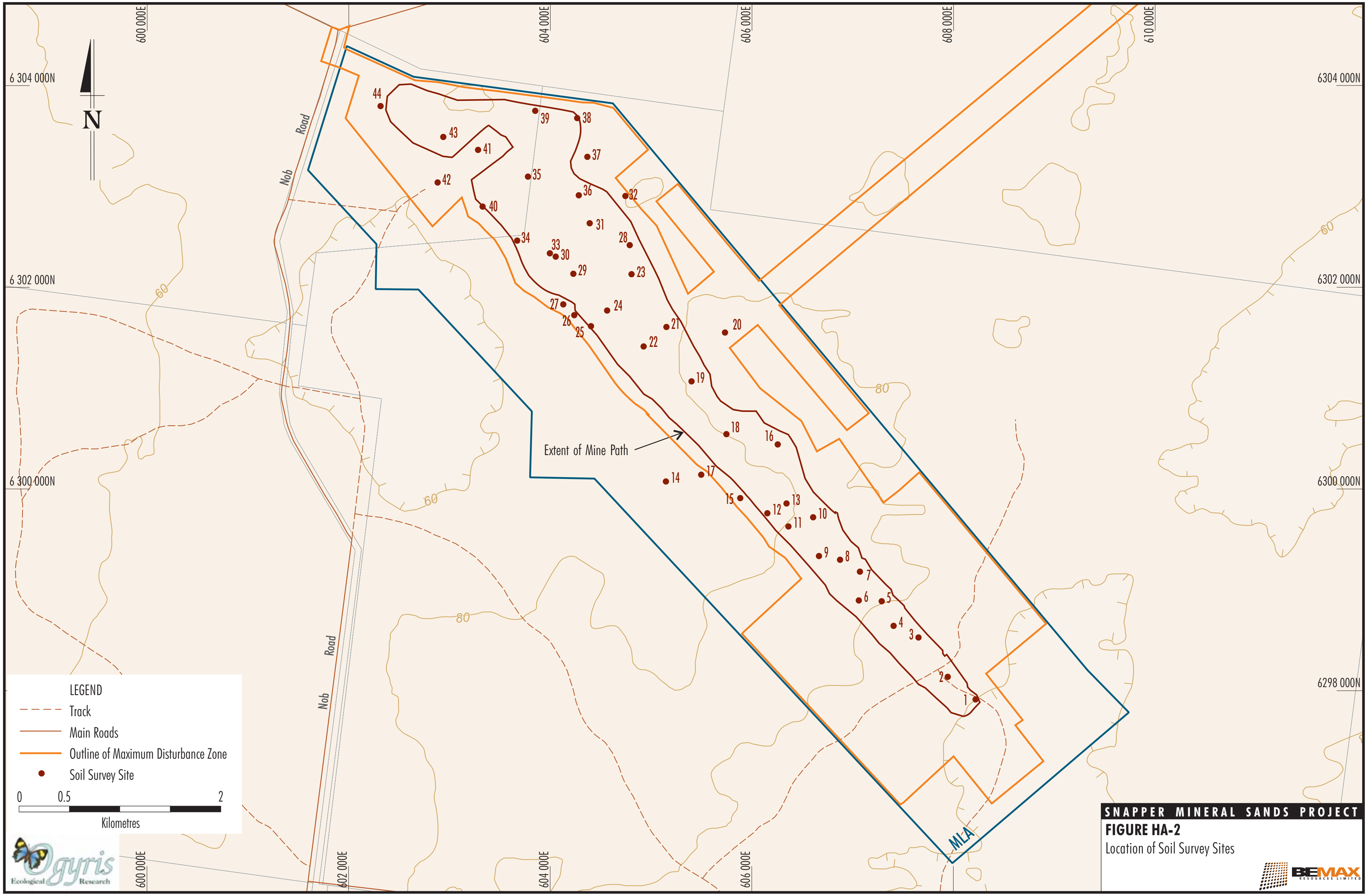

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The surficial geology of the Snapper Mine area is dominated by red-brown earths of the Woorinen Formation (Lawrence, 1966), which in the local area are present primarily as the Trelega Land System, with lesser areas of the Overnewton Land System to the south-east and Hatfield Land System to the north-west (Figure HA-3). Trelega Land System (Walker, 1991) landforms include:

- major areas of loamy and clayey plains; and
- minor areas of low east-west aligned sandy dunes with interdune corridors or swales.

Overnewton and Hatfield Land System (Walker, 1991) landforms include:

- major areas of loamy and sandy plains; and
- minor areas of dunes, sandy rises and occasional depressions and pans.

Both land systems within the study area are dominated by Black Oak-Rosewood-Wilga Woodland (locally referred to as Belah-Rosewood Woodland) and Bluebush Shrubland vegetation.

A feature of Woorinen Formation soils is the presence of a 'B' Horizon zone of accumulation within the soil profile which is rich in calcium carbonate. This carbonate layer typically restricts root growth within Mallee Region soils and is a significant influence governing the natural distribution of terrestrial plant species and ecological communities within the Murray-Darling Depression Bioregion (Sluiter, 2005). Also present at a number of locations across the study area is the Callabonna Clay unit – a pedal structured reddish light clay which is typically present immediately below a shallow layer of Woorinen Formation topsoil or 'A' Horizon.

Underlying the Woorinen Formation is the Blanchetown Clay (also referred to by BEMAX geologists as the Shepparton Formation), described by Firman (1971) and Gill (1973) as a deposit that formed in a marginal marine shallow lake or lacustrine environment. The Blanchetown Clay effectively acts as an impervious layer which, when present close to the surface, has slow permeability and can cause poor drainage. The Blanchetown Clay characterizes the underlying surface geology of a broad part of the study area. Underlying the Blanchetown Clay, and locally confined by it, is a regional groundwater aquifer known as the Loxton-Parilla Sand (Firman, 1966, 1973). The Loxton-Parilla Sand is divided into three major facies[1] in the Snapper Mine area. They include, from youngest to oldest in age:

- Upper Loxton-Parilla Sand – upward fining sequence of re-worked beach/dune sands;
- Loxton-Parilla Sand (Mica Sands) – fine to very fine micaceous lacustrine sands; and
- Lower Loxton-Parilla Sand – fine to medium grained, well sorted beach and dune sands.

Each of these facies was sampled for this study.

Table HA-1 provides a summary of the conceptual stratigraphy of the Snapper Mine area. The stratigraphy has been assembled by BEMAX geologists from drill hole cuttings and core hole sediments from the Snapper Mine area.

[1] Geological term meaning a rock or stratified body distinguished from others by its appearance or composition.

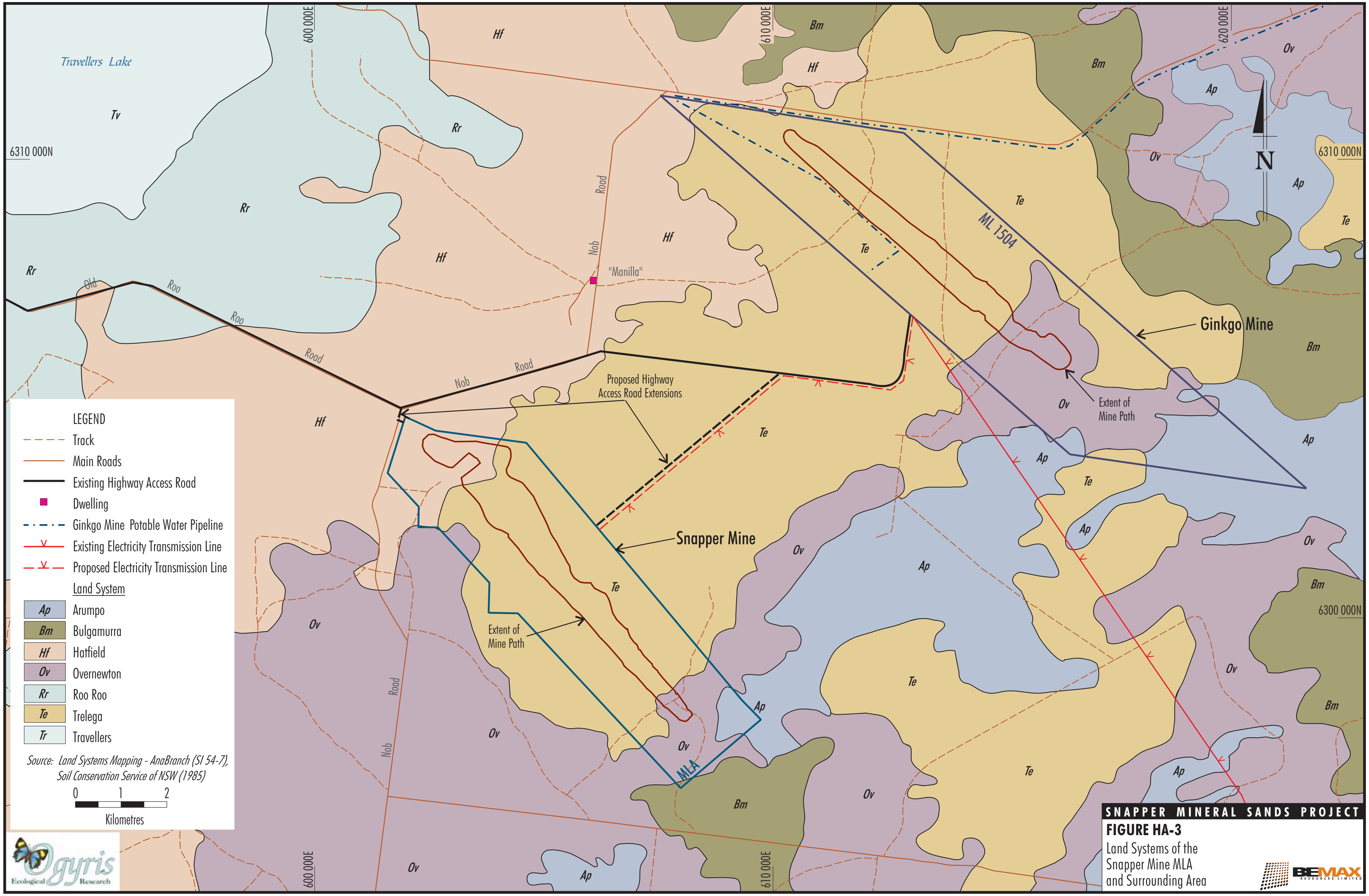

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Table HA-1
Conceptual Stratigraphy of the Snapper Mine Area

Geology[1]	Unit	Lithology	Thickness (m)	Approximate Depth from Surface (m)	Depositional Environment	HM Mineralisation
Qpo	Woorinen Formation	Very fine to coarse sand and silty sand, sandy clay, minor calcrete	0 – 2	0 – 2	Aeolian Dune	Nil
Qph	Blanchetown Clay	Clay and sandy clay with minor sand lenses	3– 20	0– 4	Lake	Nil
Unconformity (Karoonda Surface - Qks)						
Tps	Upper Loxton Parilla Sand	Reworked sand good to moderate sorting Upward fining sequence	10-20	3-20	Possible beach/ dune environment	Mostly barren isolated patches of ~ 1%. Traces of trash HM including tourmaline
	Loxton-Parilla Sand (Mica Sands)	Fine to Very Fine Micaceous Sands	1-15	20-30	Lake	Low grade fine HM
	Grey Clay	Grey Clay	0.1-6	30-40	Lake	Nil
	Lower Loxton-Parilla Sand – Dune	Fine to fine medium, well sorted sand	3-20	30-40	Dune	0 to >10 %
	Lower Loxton-Parilla Sand – Beach	Fine medium to medium, well sorted sand	3-15	30-60	Beach	Generally above 10% HM. High grade core above 50% HM
	Lower Loxton-Parilla Sand – Surf Zone	Coarse to very coarse moderately sorted sand	6-9	60-80	Surf Zone	Low to high grade, fine to medium HM
Possible Unconformity						
Tps	Offshore	Mica rich, fine to very fine sand with minor silt and clay	Approximately 20-30	65-85	Offshore	1 – 4% Fine HM (WIM Type)
Unconformity						
	* Geera Clay	Mica rich green grey clay with minor silt	Unknown	80+	Shallow to marginal marine	Nil

* Only encountered in 2002 water bore.
1 A glossary of geological formations is provided in Appendix HA-A1.
Source for the Table: BEMAX (Chris Buchanan, pers. comm., July 2006).

HA1.3 Quality Assurance

Dr. Ian Sluiter is accredited by the NSW Government to survey soils in the south-west NSW Murray-Darling region area and within the Victorian Murray-Mallee area.

All survey methods follow the Irrigated Crop Management Service (ICMS) industry standard for south-east Australian Mallee Region soils as outlined in the ‘Codes of Practice and Standards’ (September, 1997).

HA2 METHODS

HA2.1 Soil Survey, Timing, Site Selection and Field Sampling

The field survey was conducted between 11 and 14 September 2006. Forty-four sites (i.e. soil pits) were selected as soil survey locations across the study area. The locations of the soil pits are shown on Figure HA-2. The selection of soil survey sites was based on covering all landform elements and vegetation communities across the study area. The landform elements sampled included clayey and sandy plains, low east-west dunes, swales and low-lying flats and run-on depressions. The vegetation communities sampled included:

- Black Box Woodland in run-on depressions;
- Black Oak-Rosewood-Wilga Woodland (also referred to in the region as Belah-Rosewood Woodland) on flat to undulating plains as well as dunes;
- Mallee Shrubland on dunes and in swales;
- Bluebush Shrubland on plains; and
- *Austrostipa* Grassland on plains and in run-on depressions.

Soil pits were excavated to approximately 1.5-2.0 m depth with the aid of an excavator. The soil characteristics were described in the field, in accordance with the "*Australian Soil and Land Survey Field Handbook*" (McDonald *et al.*, 1990), and included:

- geology and landform;
- depth and type of carbonate layers (detailed below);
- percentage, size and lithology of coarse fragments in each layer;
- depth and texture of each soil layer;
- soil colour, pH, moisture, and pedality[2] (grade & type);
- depth of topsoil and primary root zone depth (PRZ)[3] for the remnant vegetation present; and
- saturated Hydraulic Conductivity or "K" (detailed below).

Table HA-2 provides a summary of the site characteristics at all sampling locations. The distribution of landform elements across the Snapper MLA area has been shown on Figure HA-4.

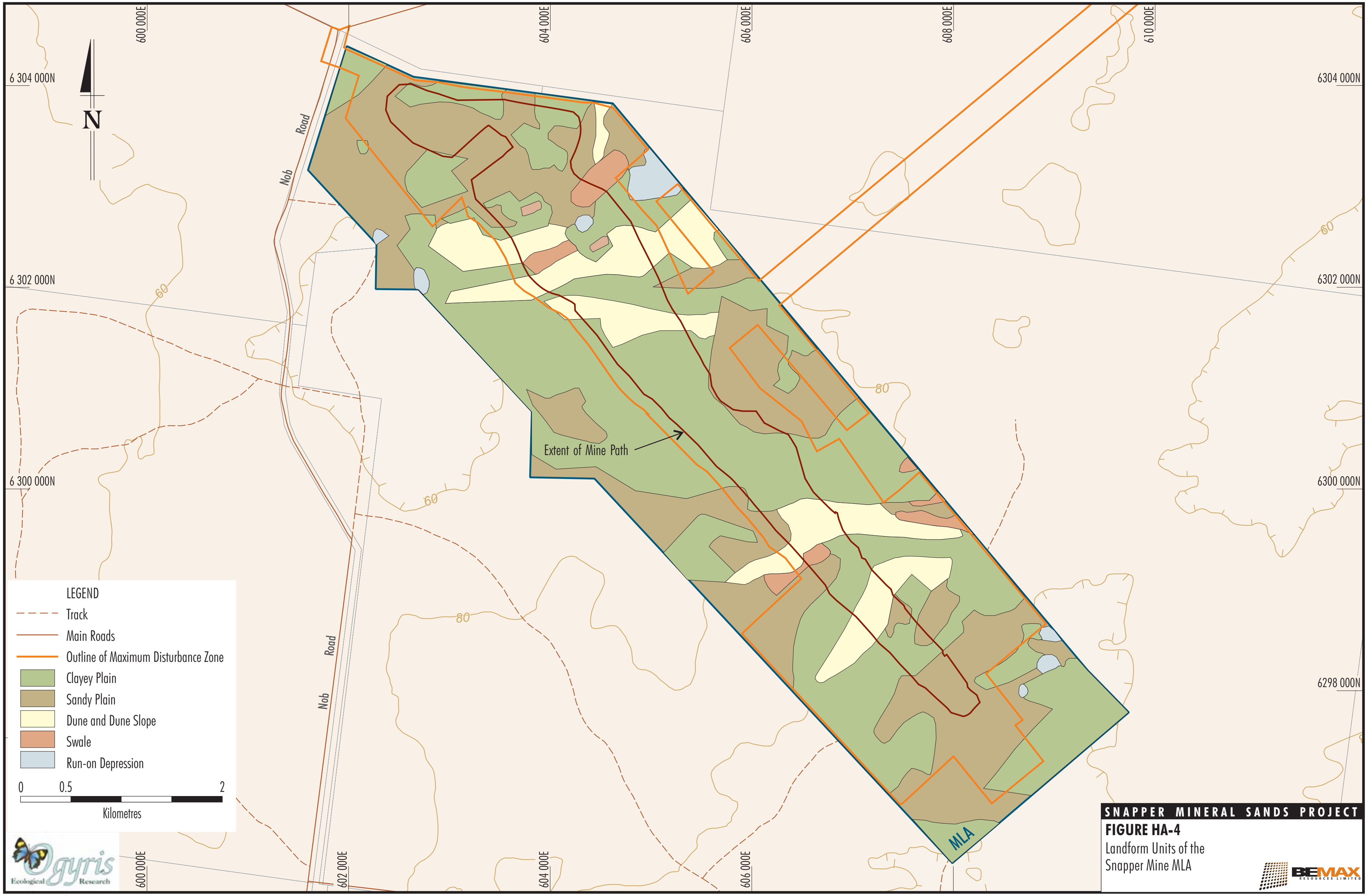
[2] Relative proportion of peds (individual natural soil aggregates) within the soil.
[3] Depth to which the native vegetation root systems extend.

Table HA-2
Summary of Site Characteristics of the 44 Soil Pits Excavated in the Snapper Mine Study Area

Pit No.	Landform Unit	Vegetation Community	Surface Soil Texture	Topsoil Depth (cm)	Observed PRZ Depth (cm)	Depth to Drainage Impeding Layer (cm)
1	Undulating clayey plain	Austrostipa Grassland.	Clay loam	25	75	N/A
2	Undulating clayey plain	Austrostipa Grassland.	Clay loam	25	50	135
3	Slightly elevated clayey plain	Black Oak-Rosewood-Wilga Woodland.	Sandy clay loam	35	60	125
4	Near level clayey plain	Black Oak-Rosewood-Wilga Woodland.	Sandy clay loam	35	55	105
5	Low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	55	70	N/A
6	Near top of an elevated sandy plain	Black Oak-Rosewood-Wilga Woodland.	Sandy loam	70	90	N/A
7	Level sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	30	85	155
8	Level sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	35	70	N/A
9	Clayey swale	Bluebush Shrubland.	Sandy clay loam	30	60	75
10	Near top of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Sandy loam	75	80	N/A
11	South side slope of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Sandy clay loam	35	55	75
12	Level sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	40	65	N/A
13	Undulating sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	35	60	N/A
14	Undulating sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	45	70	N/A
15	Undulating clayey plain	Black Oak-Rosewood-Wilga Woodland.	Sandy clay loam	45	80	N/A
16	Level sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	55	70	N/A
17	Undulating sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	60	75	N/A
18	Undulating clayey plain	Black Oak-Rosewood-Wilga Woodland.	Sandy clay loam	40	80	N/A
19	Level sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	25	50	55
20	Level clayey plain	Bluebush Shrubland.	Clay loam	20	50	145
21	South side slope of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Clay loam	35	50	N/A
22	South side slope of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	55	70	N/A
23	Top of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Sandy loam	85	100	N/A
24	Top of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Sandy loam	75	105	N/A
25	Level sandy plain	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	30	60	N/A
26	Near top of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	35	80	N/A

Table HA-2 (Continued)
Summary of Site Characteristics of the 44 Soil Pits Excavated in the Snapper Mine Study Area

Pit No.	Landform Unit	Vegetation Community	Surface Soil Texture	Topsoil Depth (cm)	Observed PRZ Depth (cm)	Depth to Drainage Impeding Layer (cm)
27	Top of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Sandy loam	105	105	N/A
28	North side upper slope of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	45	85	N/A
29	Top of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Sandy loam	60	110	N/A
30	Narrow clayey swale between two East-West dunes	Mallee Woodland/Shrubland.	Sandy clay loam	30	75	N/A
31	Run-on depression	Austrostipa Grassland.	Clay loam	60	65	80
32	Run-on depression	Black Box Woodland.	Clay loam	65	80	95
33	Narrow clayey swale between two East-West dunes	Mallee Woodland/Shrubland.	Clay loam	50	50	50
34	North side upper slope of a low aligned dune	Black Oak-Rosewood-Wilga Woodland.	Light sandy clay loam	60	55	N/A
35	South side (southerly aspect) of a broad sloping clayey plain	Austrostipa Grassland.	Clay loam	20	55	125
36	Broad clayey swale between two East-West aligned dunes	Austrostipa Grassland.	Sandy clay loam	45	60	N/A
37	South side slope of a low aligned dune	Austrostipa Grassland.	Sandy loam	35	55	N/A
38	Gypseous run-on depression with gilgai	Austrostipa Grassland.	Sandy clay	20	50	50
39	Undulating sandy plain	Austrostipa Grassland.	Light sandy clay loam	45	55	N/A
40	Near top of a broad sloping sandy plain	Black Oak-Rosewood-Wilga Woodland.	Sandy loam	65	65	N/A
41	Undulating clayey plain	Austrostipa Grassland.	Clay loam	30	50	100
42	Undulating sandy plain	Austrostipa Grassland.	Light sandy clay loam	50	60	N/A
43	Near top of a broad sloping clayey plain	Austrostipa Perennial Grassland.	Clay loam	35	55	N/A
44	Undulating clayey plain	Austrostipa Grassland.	Clay loam	30	60	105



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Full soil profile descriptions (SPDs) of each pit are presented diagrammatically on Map HA-1. A glossary of SPD abbreviations is provided in Appendix HA-A1 along with a full list of the SPD attributes for each pit.

Each of the 44 SPDs contains the following information:

- a pit number shown within a circle at the top of a rectangular scale image of each pit profile;
- the depth, geology and soil texture of each soil horizon marked on the left, middle and right of the scale pit image respectively;
- the depth of topsoil coloured in brown on the left hand side of the pit image; and
- the depth of the observed PRZ of the remnant vegetation present coloured in green on the right hand side of the pit image.

All layers (soil horizons) identified were sampled and submitted for subsequent laboratory analysis to CSBP Laboratories in Western Australia.

The Carbonate Layer

The presence of calcium carbonate or lime in Mallee Region soils has been well documented (Butler, 1956; Churchward, 1961; Wetherby and Oades, 1975) with concentrations generally highest in the fine earth fraction (particle size less than 2 millimetres [mm]), characteristic of the Snapper Mine subsoil layers. The amount of lime present in the soil is important as it affects soil pH, nutrient availability, root growth and drainage.

Wetherby and Oades (1975) have developed a 'Carbonate Layer Classification' for Mallee Region soils which rely on characteristics observable in the field, such as form, amount of fine soil carbonate (lime) present, soil texture and the nature of the boundaries with overlying soil layers (Appendix HA-A2). Information pertaining to the carbonate layer type across the study area is shown on Map HA-1.

Hydraulic Conductivity

Soil permeability is controlled by the potential of the soil column to transmit water, or its saturated hydraulic conductivity (McDonald and Isbell, 1990). Soil drainage refers to the rate at which water moves through the soil column and the extent of the water removal from it (McDonald and Isbell, 1990). Soil drainage is expressed as a 'K' value, which is a relative grade from least permeable to most permeable, according to the scale and descriptions below (Map HA-2):

- K1 = Very slowly permeable.
- K2 = Slowly permeable.
- K3 = Moderately permeable.
- K4 = Highly permeable.

Permeability characteristics can vary significantly between soil horizons in relation to soil texture and the presence of drainage impeding layers. The K value is assigned in the field, based on the attributes such as structure, texture, porosity, cracks and shrink-swell properties (McDonald and Isbell, 1990).

The permeability characteristics of each pit are represented diagrammatically on Map HA-A2.

HA2.2 Overburden Sampling

Five major overburden facies types have been identified from the Snapper Mine area. From youngest to oldest, these include:

- Woorinen Formation.
- Blanchetown Clay.
- Upper Loxton-Parilla Sand.
- Loxton-Parilla Sand – termed 'Mica Sands' by BEMAX geologists.
- Lower Loxton-Parilla Sand.

These facies were encountered in varying configurations from four exploration holes drilled by BEMAX during 2006. The drill hole number, geological facies and sampling intervals are listed below.

<u>Drill Hole S35</u>
Woorinen Formation 0-1.5 m
Blanchetown Clay 1.5-3.0 m
Upper Loxton-Parilla Sand 3.0-12.0 m
Loxton-Parilla Sand (Mica Sands) 12.0-18.0 m

<u>Drill Hole S39</u>
Woorinen Formation 0-1.5 m
Upper Loxton-Parilla Sand 1.5-24.0 m
Loxton-Parilla Sand (Mica Sands) 24.0-34.5 m
Lower Loxton-Parilla Sand 34.5-48.0 m

<u>Drill Hole S42</u>
Woorinen Formation 0-3.0 m
Blanchetown Clay 3.0-6.0 m
Upper Loxton-Parilla Sand 6.0-18.0 m
Upper Loxton-Parilla Sand 15.0-18.0 m (drill core)

<u>Drill Hole S45</u>
Woorinen Formation 0-1.5 m
Blanchetown Clay 3.0-4.5 m
Upper Loxton-Parilla Sand 25.5-27.0 m
Loxton-Parilla Sand (Mica Sands) 42.0-43.5 m

In summary, the following overburden samples were submitted for laboratory analysis:

- 4 x Woorinen Formation.
- 3 x Blanchetown Clay.
- 5 x Upper Loxton-Parilla Sand.
- 3 x Loxton-Parilla Sand (Mica Sands).
- 1 x Lower Loxton-Parilla Sand.

HA2.3 Laboratory Analysis

A diverse suite of analyses were undertaken on the soil and overburden samples. These parameters included:

- Soil conductivity, as soil to water ratio 1:5 and saturation or ECe (deciSiemens per metre [dS/m]);
- pH (CaCl2 and H2O);
- Boron (hot CaCl2);
- Organic carbon (C);
- Soil Dispersion;
- Nitrate (NO_3^-);
- Ammonium (NH_4^+);
- Phosphorous (P);
- Potassium (K), Exchangeable K, and Saturated K;
- Sulphur (S);
- Iron (Fe) and diethylenetriaminepentaacetate (DTPA) Fe;
- DTPA Copper (Cu);
- DTPA Zinc (Zn);
- DTPA Manganese (Mn);
- Exchangeable Magnesium (Mg) and Saturated Mg;
- Exchangeable Sodium (Na) and Saturated Na; and
- Exchangeable Calcium (Ca) and Saturated Ca.

Exchangeable Sodium Percentage (ESP), a universally accepted measure of soil sodicity (Rengasamy and Churchman, 2001), was calculated from the laboratory results supplied by CSBP using the following formula (*ibid.*):

$$ESP = (100 \times \text{Exchangeable Na})/(\sum \text{Exchangeable } (Ca + Mg + Na + K)).$$

Sumner (1993) has concluded that there is no generally accepted definition of what constitutes sodic soil. The reason for this is because sodicity is defined by behaviour (i.e. the dispersion and swelling of soil clay) rather than by indices related to the composition of the soil. Emerson Dispersion tests (Emerson, 1991) were also undertaken on all layers from each soil pit to provide an independent assessment of soil sodicity. This test is simple and measures the dispersion of air dry clay particles from soil aggregates in distilled water over time. The test is a very useful screening device to delineate soil sodicity. However, there appears to be no relationship between the empirical results obtained through laboratory analyses and the physical Emerson Dispersion test. For example, no score of greater than 10 was recorded (Appendix HA-A3) and most samples returned values of zero.

HA2.4 Analysis Criteria

Laboratory results have been compared against the following criteria developed by Wetherby (2006) for use with Mallee Region soils:

- **Conductivity**:
  - <2 dS/m – non-saline
  - 2-4 dS/m – slightly saline
  - 4-8 dS/m – moderately saline
  - 8-16 dS/m – saline
  - >16 dS/m – highly saline
- **pH:**
  - 5.8-7 weakly acidic to neutral
  - 7-8 neutral to weakly alkaline
  - 8-9 moderately alkaline
  - 9-9.5 alkaline
  - > 9.5 – Strongly Alkaline
- **Boron:**
  - < 15 milligrams per kilogram (mg/kg) – Non-limiting to vegetation
  - > 15 mg/kg – Potentially limiting to vegetation
- **Sodicity:**
  - 2-7% – Weakly to moderately sodic
  - 7-15% – Moderately to highly sodic
  - > 15% – Highly sodic (Wetherby, 2006)
- **Total Nitrogen:**

Sand	Low – 300 mg/kg	High – 600 mg/kg
Sandy loam	Low – 700 mg/kg	High – 1200 mg/kg
Loam	Low – 900 mg/kg	High – 1400 mg/kg
Clay loam	Low – 1200 mg/kg	High – 1800 mg/kg

- **Phosphorous:**
  - 10-20 mg/kg – low
  - 20-40 mg/kg – adequate
  - > 40 mg/kg – high
- **Potassium:** Low threshold level of 150 mg/kg
- **Sulphur:** 5-10 mg/kg – Normal for pasture and crops
- **Iron:** No threshold levels specified (McFarlane, 2001)
- **Copper:**
  - <0.3 mg/kg – low
  - 0.3-5.0 – adequate for plant growth
  - >5.0 mg/kg – high
- **Zinc:**
  - <0.3 mg/kg – very low
  - 0.3-1.0 mg/kg – low
  - 1.0-5.0 – adequate for plant growth
  - > 5.0 mg/kg - high
- **Manganese:**
  - < 4.0 mg/kg – low
  - 4.0-10.0 – adequate for plant growth
  - > 10.0 mg/kg – high

- **Calcium:** 1,200 mg/kg – adequate for plant growth
- **Magnesium:** 200 mg/kg – adequate for plant growth
- **Organic Carbon:** levels of <1% are normal for Mallee Region soils

Detailed data from the laboratory analysis of topsoil and subsoils is presented in Appendix HA-A3.

HA3 RESULTS AND DISCUSSION

HA3.1 Topsoil and Subsoil Landform Units and Soil Types

Landform units (Figure HA-4) have been used to group similar soil types rather than vegetation community groups, since vegetation communities have been found to occur across several different soil and landform unit types. This is demonstrated by the occurrence of Black Oak-Rosewood-Wilga Woodlands on sandy aligned dunes, sandy plains and clayey plains. Consequently, landform units have been chosen as the primary basis for stratifying like soil types. Table HA-3 summarises the characteristics of the Snapper Mine landform units and information pertaining to the characteristics of the topsoil i.e. average topsoil depth, PRZ depth, soil colour (as per Munsell colour charts [Munsell, 1994]), average free lime content (Free Lime % as outlined by Wetherby and Oades, 1975; Wetherby, 2006), geology and pedality (McDonald and Isbell, 1990).

From Table HA-3 it can be seen that the characteristics of topsoil layers vary widely across the study area. A description of each landform unit within the study area is provided below.

Table HA-3
Characteristics of the Snapper Mine Topsoil Sorted by Landform Unit

Landform Unit	Geology	Average Topsoil Depth (cm)	PRZ Depth (cm)	Average % Free Lime (range)	Soil Colour	Pedality
Dune	Qpo	70	95	1.0	2.5YR4/4 to 2.5YR4/6	Weak, Sub-angular Blocky
Dune Slope	Qpo	45	60	1.0	2.5YR4/4	Weak, Sub-angular Blocky
Sandy Plain	Qpo and Qkcr	45	65	1.5	2.5YR4/4 to 5YR4/4	Weak and Medium, Sub-angular Blocky
Clayey Plain	Qpo and Qkcr	30	60	4	5YR4/4 to 7.5YR4/4	Weak, Sub-angular Blocky
Swale	Qpo and Qkcr	40	60	2.5	5YR4/4	Weak and Medium, Sub-angular Blocky
Run-on Depression	Qpo, Qkcr and Qkcy	20-60	65	0.5	2.5YR4/4 to 10YR5/2	Weak and Medium, Sub-angular to angular Blocky

HA3.1.1 Dunes

Dunes are estimated to comprise approximately 10% of the study area (Figure HA-4) and were sampled at Pits 5, 10, 23, 24, 26, 27 and 29. Plate HA-1 provides an illustration of a Dune site at Pit 27 where a Black Oak-Rosewood-Wilga Woodland containing occasional mallee trees occurs. Soils of this landform unit are dominated by hypercalcic Calcarosols (Isbell, 2002). Surface soil textures are typically sandy loam and drainage impeding layers were generally not present within 2 m of the natural surface. Vegetation of Dunes is typically dominated by Black Oak-Rosewood-Wilga Woodland, occasionally with sparse mallee.

The average topsoil depth and observed PRZ for remnant vegetation are provided in Table HA-3. Dunes typically have the deepest topsoil (approximately 70 centimetres [cm]) and PRZ (approximately 95 cm), with low free lime contents (approximately 1%) and are generally reddish to reddish-brown in colour with sandy loam surface field texture. Plate HA-2 provides an illustration of a dune soil pit excavated at Pit 27 where 105 cm of topsoil overlies a Class IIIAS carbonate layer.

The carbonate layers encountered in dune areas are generally Class IIIAS (Appendix HA-A2). These soils have typically less than 20% calcrete rubble fragments within the soil matrix and are generally either sandy loams or light sandy clay loams, although clayey subsoils are also present.

Laboratory results for the Dune landform unit are summarised by soil layers in Table HA-4 for soil conductivity, pH, boron and ESP, and are discussed below. Table HA-4 provides average results for each soil layer of the four parameters. The full suite of results is provided in Appendix HA-A3.

Table HA-4
Laboratory Results* for the Dunes Landform Unit

Parameter	A1 Topsoil Horizon	A2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.57	2.04	4.31	7.34
Average pH	8.4	9.1	9.3	9.5
Average Boron Level (mg/kg, hot CaCl2 Extraction)	0.96	1.23	5.83	12.0
Average ESP	2.67	5.77	19.6	21.86

* Results are expressed as an average value for the 7 dune sites sampled.

Soil Conductivity

Average soil conductivity is generally low to moderate in the Dunes landform unit, although conductivity levels increase with depth. That is conductivity is lowest in the A1 topsoil horizon [0.57 dS/m], with a marginal increase in the A2/Bt topsoil horizon [2.04 dS/m]. The Bk carbonate layer [4.31 dS/m] and subsoil/parent material layer [7.34 dS/m]) have slightly higher values, but not at levels which are considered limiting to native vegetation.

Soil pH

Average soil pH in the Dunes landform unit ranges from weakly alkaline in the A1 topsoil horizon (8.4) to alkaline (9.5) in the subsoil/parent material layer. pH in the A2/Bt topsoil horizon and Bk carbonate layer are 9.1 and 9.3 respectively, which is considered alkaline.

Soil Boron Levels

Boron levels in the Dunes landform unit are considered to be non-limiting to native vegetation growth. Average boron levels are lowest in the A1 topsoil horizon (0.96 mg/kg), increasing in the A2/Bt topsoil horizon (1.23 mg/kg), Bk carbonate layer (5.83 mg/kg) and subsoil/parent material layer (12.0 mg/kg).

Soil Sodicity

Average soil sodicity or ESP in the Dunes landform unit is considered to be weakly to moderately sodic in the A1 topsoil horizon (2.67%) and A2/Bt topsoil horizon (5.77%). The Bk carbonate layer and subsoil/parent material layer are considered to be highly sodic. Analysis of some A1 topsoil horizon materials of either sandy loam or light sandy clay loam field textures returned values of '9 or 10', indicating low sodicity. The same soils all had sodium saturation or ESP levels of less than 4% indicating a disparity between the results of the two tests. The reasons for the apparent disparity in results between the two tests are unclear. Consequently it is considered conservative to assume that the potential exists for soil profiles within the study area to be sodic, particularly those soils 50 cm below natural surface.

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Dunes landform unit include:

- Total nitrogen and phosphorous for all soil horizons within the Dunes landform unit are considered low to very low for plant growth.
- Potassium levels in the A1 topsoil horizon are above the 'low threshold' for growth (i.e. 150 mg/kg) at all sites with the exception of Pit 23. Potassium levels in the A2/Bt topsoil horizon, Bk carbonate layer and subsoil/parent material layer are generally lower than the A1 topsoil horizon, but are generally above the 'low threshold'.
- Within the PRZ of the remnant vegetation present, sulphur levels generally ranged between 2 and 10 mg/kg (Appendix HA-A3), which are considered normal for plant growth on Australian soils. Sulphur levels generally increased significantly with depth.
- Iron deficiency is considered most likely to occur within the carbonate-rich layers (i.e. the Bk carbonate layer and subsoil/parent material layer).
- Copper levels recorded in the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Zinc levels within the PRZ of the remnant vegetation are variable with half of the sites considered to have adequate zinc levels and the other half very low zinc levels. Trials should be established to ascertain whether a lack of zinc may be limiting within the revegetation programme.
- Manganese levels recorded within the PRZ of the remnant vegetation are low, but are considered adequate for native vegetation growth.
- Calcium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Magnesium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Generally, organic carbon is higher in the topsoil layers than the carbonate layer or subsoil, however all results recorded were less than 1%, which is low but normal for Mallee Region soils.

HA3.1.2 Dune Slopes

Dune slopes are estimated to comprise approximately 10% of the study area and were sampled at Pits 11, 21, 22, 28, 34 and 37. Plate HA-3 provides an illustration of a Black Oak-Rosewood-Wilga Woodland on a Dune Slope at Pit site 34. Soils are dominantly hypercalcic Calcarosols (Isbell, 2002). Surface soil textures are variable, ranging from clay loam to sandy loam, but are most commonly light sandy clay loam or sandy clay loam. Drainage impeding layers were generally not present within 2 m of the natural surface of this landform unit, except at Pit 11 where drainage impeding clay was present 75 cm below natural surface. Vegetation communities associated with Dune Slopes are mostly Black Oak-Rosewood-Wilga Woodland, although one site (Pit 37) was a degraded Bluebush Shrubland site.

The average topsoil depth and observed PRZ for remnant vegetation are provided in Table HA-3. Dune slopes have an average topsoil and PRZ depth of approximately 45 cm and 60 cm respectively, with low free lime contents (approximately 1%) and are generally reddish-brown in colour with highly variable surface field textures ranging from sandy clay loam, through to light sandy clay loam and sandy loam.

The carbonate layers encountered in dune areas were universally Class IIIAL (Appendix HA-A2). These soils have typically less than 20% calcrete rubble fragments within the soil matrix and are generally either sandy loams or light sandy clay loams, although clayey subsoils are also present. Plate HA-4 provides an illustration of a dune slope soil pit excavated (Pit 34) where 60 cm of topsoil overlies a Class IIIAL clay loam carbonate layer.

Laboratory results for the Dune Slope landform unit are summarised by soil layers in Table HA-5 for soil conductivity, pH, boron and ESP, and are discussed below. Table HA-5 provides average results for each soil layer of the four parameters. The full suite of results is provided in Appendix HA-A3.

Table HA-5
Laboratory Results* for the Dune Slopes Landform Unit

Parameter	A1 Topsoil Horizon	A2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.5	1.67	5.07	6.72
Average pH	8.5	9.0	9.1	9.6
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.37	0.85	3.9	9.95
Average ESP	2.09	6.68	11.85	19.24

* Results are expressed as an average value for the 6 dune slope sites sampled.

Soil Conductivity

Average soil conductivity is generally low to moderate in the Dune Slopes landform unit, although conductivity levels increase with depth. That is, conductivity is lowest in the A1 topsoil horizon (0.5 dS/m), with a marginal increase in the A2/Bt topsoil horizon (1.67 dS/m). The Bk carbonate layer (5.07 dS/m) and subsoil/parent material layer (6.72 dS/m) have slightly higher values, but not at levels which are considered limiting to native vegetation.

Soil pH

Average soil pH in the Dune Slopes landform unit ranges from weakly alkaline in the A1 topsoil horizon (8.5) to strongly alkaline (9.6) in the subsoil/parent material layer. pH in the A2/Bt topsoil horizon and Bk carbonate layers in the Dune Slopes are 9.0 and 9.1 respectively.

Soil Boron Levels

Boron levels in the Dune Slopes landform unit are considered to be non-limiting to native vegetation growth. Average boron levels are 1.37 mg/kg in the A1 topsoil horizon, 0.85 mg/kg in the A2/Bt topsoil horizon, increasing to 3.9 mg/kg in the Bk carbonate layer and 9.95 mg/kg in the subsoil/parent material layer.

Soil Sodicity

Average soil sodicity or ESP in the Dune Slopes landform unit is considered to be weakly to moderately sodic in the A1 topsoil horizon (2.09%) and A2/Bt topsoil horizon (6.68%), moderately to highly sodic in the Bk carbonate layer (11.85%) and highly sodic in the subsoil/parent material layer (19.24%). As for the Dunes landform unit, analysis of some A1 topsoil horizon soils of either sandy loam or light sandy clay loam field textures returned values of '9 or 10' indicating low sodicity. The same soils all had sodium saturation or ESP levels of less than 4% indicating a disparity between the results of the two tests. The reasons for the apparent disparity in results between the two tests are unclear. Consequently it is considered conservative to assume that the potential exists for soil profiles within the study area to be sodic, particularly those soils 50 cm below natural surface.

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Dune Slopes landform unit include:

- Total nitrogen and phosphorous for all soil horizons within the Dune Slopes landform unit are considered low to very low for plant growth.
- Potassium levels in the A1 topsoil horizon were all well above the 'low threshold' for growth (i.e. 150 mg/kg). Potassium levels in the A2/Bt topsoil horizon, Bk carbonate layer and subsoil/parent material layer are generally lower than the A1 topsoil horizon, but are generally above the 'low threshold'.
- Within the PRZ of the remnant vegetation present, sulphur levels generally ranged between 2 and 10 mg/kg (Appendix HA-A3), which are considered normal for plant growth on Australian soils. Sulphur increased significantly with depth.
- Iron deficiency is considered most likely to occur within the carbonate-rich layers (i.e. the Bk carbonate layer and subsoil/parent material layer).
- Copper levels recorded in the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Zinc levels within the PRZ of the remnant vegetation are considered very low to low, and trials should be established to ascertain whether a lack of zinc may be limiting within the revegetation programme.
- Manganese levels recorded within the PRZ of the remnant vegetation are low, but are considered adequate for native vegetation growth.

- Calcium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Magnesium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Generally, organic carbon is higher in the topsoil layers than the carbonate layer or subsoil, however all results recorded were less than 1%, which is low but normal for Mallee Region soils.

HA3.1.3 Sandy Plains

The Sandy Plains landform unit is estimated to comprise approximately 30% of the study area and was sampled at Pits 6, 7, 8, 12, 13, 14, 16, 17, 19, 25, 39, 40 and 42. Plate HA-5 provides an illustration of a Black Oak-Rosewood-Wilga Woodland on a Sandy Plain at Pit 17. Soils are dominated by hypercalcic Calcarosols, but red Chromosols also occur at Pits 12, 14 and 16. Surface soil textures, with the exception of two sandy loam sites (Pits 6 and 40), are light sandy clay loam. Drainage impeding layers were present at only two locations (Pits 7 and 19). Vegetation of the Sandy Plains is typically Black Oak-Rosewood-Wilga Woodland, with the exception of Pits 39 and 42 where Bluebush Shrublands with varying amounts of *Austrostipa* grassland occurred.

The average topsoil depth and observed PRZ for remnant vegetation are provided in Table HA-3. Sandy plains have an average topsoil and PRZ depth of approximately 45 cm and 65 cm respectively, with low to moderate free lime contents (approximately 1.5%) and are generally reddish-brown in colour.

The majority of carbonate layers encountered in Sandy Plain areas are Class IIIAL (Appendix HA-A2). These soils have typically less than 20% calcrete rubble fragments within the soil matrix and are generally clay loam to light clay in soil texture. The only exception to this rule occurred at Pit 40 where a Class IIIB calcrete was found with 50% calcrete rubble within the soil matrix. Plate HA-6 provides an illustration of a Sandy Plain soil profile excavated at Pit 17 where 60 cm of light sandy clay loam topsoil overlies Class IIIAL carbonate.

Laboratory results for the Sandy Plain landform unit are summarised by soil layers in Table HA-6 for soil conductivity, pH, boron and ESP, and are discussed below. Table HA-6 provides average results for each soil layer of the four parameters. The full suite of results is provided in Appendix HA-A3.

Table HA-6
Laboratory Results* for the Sandy Plains Landform Unit

Parameter	A1 Topsoil Horizon	A2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.5	1.84	5.2	7.96
Average pH	8.5	9.0	9.3	9.4
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.15	1.58	7.38	18.74
Average ESP	1.90	7.89	18.86	25.53

* Results are expressed as an average value for the 13 sandy plain sites sampled.

Soil Conductivity

Average soil conductivity is generally low to moderate in the Sandy Plains landform unit, although conductivity levels increase with depth. That is, conductivity is lowest in the A1 topsoil horizon (0.5 dS/m), with a marginal increase in the A2/Bt topsoil horizon (1.84 dS/m). The Bk carbonate layer (5.2 dS/m) and subsoil/parent material layer (7.96 dS/m) have moderately high values, with only the occasional site at levels which may possibly be considered to be limiting to native vegetation (e.g. 19 dS/m was recorded at Pit 7).

Soil pH

Average soil pH in the Sandy Plains landform unit ranges from weakly alkaline in the A1 topsoil horizon (8.5) to alkaline (9.4) in the subsoil/parent material layer. pH in the A2/Bt topsoil horizon and Bk carbonate layer in the Sandy Plains are 9.0 and 9.3 respectively.

Soil Boron Levels

Boron levels in the A1 and A2/Bt topsoil horizons and Bk carbonate layer in the Sandy Plains landform unit are considered to be non-limiting to native vegetation growth. Average boron levels are lowest in the A1 topsoil horizon (1.15 mg/kg), increasing in the A2/Bt topsoil horizon (1.58 mg/kg) and Bk carbonate layer (7.38 mg/kg). Boron levels in the subsoil/parent material layer (18.74 mg/kg) have the potential to limit native vegetation growth.

Soil Sodicity

Average soil sodicity or ESP in the Sandy Plains landform unit is considered to be weakly sodic in the A1 topsoil horizon (1.9%); moderately sodic in the A2/Bt topsoil horizon (7.89%); and highly sodic in the Bk carbonate layer (18.86)% and subsoil/parent material layer (25.53%). As for the Dunes and Dune Slopes landform units, analysis of some A1 topsoil horizon soils of either sandy loam or light sandy clay loam field textures returned values of '9 or 10' indicating low sodicity. The same soils all had sodium saturation or ESP levels of less than 4% indicating a disparity between the results of the two tests. The reasons for the apparent disparity in results between the two tests are unclear. Consequently it is considered conservative to assume that the potential exists for soil profiles within the study area to be sodic, particularly those soils 50 cm below natural surface.

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Sandy Plains landform unit include:

- Total nitrogen and phosphorous for all soil horizons within the Sandy Plains landform unit are considered low to very low for plant growth.
- Potassium levels in the A1 topsoil horizon were above the 'low threshold' for growth (i.e. 150 mg/kg). Potassium levels in the A2/Bt topsoil horizon, Bk carbonate layer and subsoil/parent material layer are generally lower than the A1 topsoil horizon, but are generally above the 'low threshold'.
- Within the PRZ of the remnant vegetation present, sulphur levels generally ranged between 2 and 10 mg/kg (Appendix HA-A3), which are considered normal for plant growth on Australian soils. Sulphur increased significantly with depth.

- Iron deficiency is considered most likely to occur within the carbonate-rich layers (i.e. the Bk carbonate layer and subsoil/parent material layer).
- Copper levels recorded in the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Zinc levels within the PRZ of the remnant vegetation are considered very low and trials should be established to ascertain whether a lack of zinc may be limiting within the revegetation programme.
- Manganese levels recorded within the PRZ of the remnant vegetation are low, but are considered adequate for native vegetation growth.
- Calcium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Magnesium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Generally, organic carbon is higher in the topsoil layers than the carbonate layer or subsoil, however all results recorded were less than 1%, which is considered to be low but normal for Mallee Region soils.

HA3.1.4 Clayey Plains

Clayey Plains are estimated to comprise approximately 40% of the study area and were sampled at Pits 1-4, 15, 18, 20, 35, 41, 43 and 44. Plate HA-7 provides an illustration of a Bluebush Shrubland vegetation community type on a Clayey Plain at Pit site 41. Soils are dominated by hypercalcic and calcic Calcarosols, with a single (Pit 15) red Chromosol (Isbell, 2002). Surface soil textures are typically either clay loam or sandy clay loam. Drainage impeding layers were present on average at approximately 120 cm below the natural surface. Associated vegetation communities include Black Oak-Rosewood-Wilga Woodland, Bluebush Shrubland and *Austrostipa* grassland.

The average topsoil depth and observed PRZ for remnant vegetation are provided in Table HA-3. Clayey plains have an average topsoil and PRZ depth of approximately 30 cm and 60 cm respectively, with moderate to high free lime contents (approximately 4%) and are generally reddish-brown to brown in colour with field textures ranging from clay loam to sandy clay loam.

The majority of carbonate layers encountered are Class IIIAL (Appendix HA-A2) over plain areas. These soils have typically less than 20% calcrete rubble fragments within the soil matrix and are generally clay loam to light clay in soil texture. Calcic Calcarosols (Isbell, 2002) carbonate layers were found to occur in approximately 30% of the soil pits (Pits 3, 4, 20, 41 and 44) and were most commonly found, generally speaking, in clayey plain areas. These soils have high free lime contents within a clay or light-medium clay matrix and have poor permeability and drainage characteristics. Plate HA-8 provides an illustration of a soil profile at Pit 41 where 30 cm of topsoil overlies a Class I carbonate layer with poor drainage characteristics at just 100 cm below the natural surface.

Laboratory results for the Clayey Plain landform unit are summarised by soil layers in Table HA-7 for soil conductivity, pH, boron and ESP, and are discussed below. Table HA-7 provides average results for each soil layer of the four parameters. The full suite of results is provided in Appendix HA-A3.

Table HA-7
Laboratory Results† for the Clayey Plains Landform Unit

Parameter	A1 Topsoil Horizon	A2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.68	*0.96	1.69	7.59
Average pH	8.8	*8.0	9.1	9.4
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.10	*0.74	1.85	30.61
Average ESP	1.62	*8.71	8.5	29.67

† Results are expressed as an average value for the 11 clayey plain sites sampled.
* Denotes 1 value only.

Soil Conductivity

Average soil conductivity is low in the PRZ of the Clayey Plains landform unit, but increases within Subsoil/Parent Material layers. That is the A1 topsoil horizon (0.68 dS/m) has the lowest conductivity, followed by the A2/Bt horizon (0.96 dS/m), Bk horizon (1.69 dS/m), and increasing in the subsoil/parent material layer (7.59 dS/m). Soil conductivity levels for all topsoil layers within the Clayey Plains landform unit are considered suitable for rehabilitation.

Soil pH

Average soil pH in the Clayey Plains landform unit ranges from weakly alkaline in the A1 topsoil horizon (8.8) to moderately alkaline (9.4) in the subsoil/parent material layer. pH in the A2/Bt topsoil horizon and Bk carbonate layer in the Clayey Plains are 8.0 and 9.1 respectively.

Soil Boron Levels

Boron levels in the A1 and A2/Bt topsoil horizons and Bk carbonate layer in the Clayey Plains landform unit are considered to be non-limiting to native vegetation growth. Average boron levels are 1.10 mg/kg in the A1 topsoil horizon, 0.74 mg/kg in the A2/Bt topsoil horizon and 1.85 mg/kg in the Bk carbonate layer. Elevated boron levels in the subsoil/parent material layer (30.61 mg/kg) have the potential to limit native vegetation growth.

Soil Sodicity

Average soil sodicity or ESP in the Clayey Plains landform unit is considered to be weakly sodic in the A1 topsoil horizon (1.62%), moderately sodic in the A2/Bt topsoil horizon (8.71%) and Bk carbonate layer (8.5%) and highly sodic in the subsoil/parent material layer (29.67%).

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Clayey Plains landform unit include:

- Total nitrogen and phosphorous for all soil horizons within the Clayey Plains landform unit are considered low to very low.
- Potassium levels in the A1 topsoil horizon were above the 'low threshold' for growth (i.e. 150 mg/kg). Potassium levels in the A2/Bt topsoil horizon, Bk carbonate layer and subsoil/parent material layer are generally lower than the A1 topsoil horizon, but are generally above the 'low threshold'.
- Within the PRZ of the remnant vegetation present, sulphur levels generally ranged between 2 and 10 mg/kg (Appendix HA-A3), which are considered normal for plant growth on Australian soils. Sulphur increased significantly with depth.
- Iron deficiency is considered most likely to occur within the carbonate-rich layers (i.e. the Bk carbonate layer and subsoil/parent material layer), but high free lime contents (approximately 4%) within the topsoil are also a cause for concern. Additions of iron should be considered if lime chlorosis symptoms are observed in the revegetation.
- Copper levels recorded in the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Zinc levels within the PRZ of the remnant vegetation are considered very low, and trials should be established to ascertain whether a lack of zinc may be limiting within the revegetation programme.
- Manganese levels recorded within the PRZ of the remnant vegetation are low, but likely adequate for native vegetation growth.
- Calcium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Magnesium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Generally, organic carbon is higher in the topsoil layers than the carbonate layer or subsoil, however all results recorded were less than 1%. Levels of less than 1% are considered normal for Mallee Region soils.

HA3.1.5 Swales

Swales are estimated to comprise approximately 5% of the study area and were sampled at Pits 9, 30, 33 and 36. Plate HA-9 provides an illustration of Mallee vegetation at Pit site 30. Soils are Calcarosols or red Chromosols with surface soil textures of either clay loam or sandy clay loam. Drainage impeding layers were present at two sites (Pits 9 and 33) at 75 cm and 50 cm respectively. Associated vegetation communities include Mallee Shrubland (Pits 30 and 33), Bluebush Shrubland (Pit 9) and *Austrostipa* grassland (Pit 36).

The average topsoil depth and observed PRZ for remnant vegetation are provided in Table HA-3. Swales have average topsoil and PRZ depth of approximately 40 cm and 60 cm respectively, have moderate free lime contents (approximately 2.5%) and are generally reddish-brown in colour with sandy clay loam field textures. Plate HA-10 provides an illustration of a soil profile from a Swale at Pit site 30, which has 30 cm of topsoil above a Class IIIC carbonate layer. This soil is a lithocalcic Calcarosol (Isbell, 2002).

Laboratory results for the Swale landform unit are summarised by soil layers in Table HA-8 for soil conductivity, pH, boron and ESP, and are discussed below. Table HA-8 provides average results for each soil layer of the four parameters. The full suite of results is provided in Appendix HA-A3.

Table HA-8
Laboratory Results† for the Swales Landform Unit

Parameter	A1 Topsoil Horizon	A2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.61	*0.56	2.45	6.67
Average pH	8.6	*8.7	9.3	9.3
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.15	*1.3	2.0	19.9
Average ESP	1.83	*1.15	10.97	27.04

† Results are expressed as an average value for the 4 swale sites sampled.
* Denotes 1 value only.

Soil Conductivity

Average soil conductivity is generally low to moderate in the Swales landform unit. Conductivity is lowest in the A1 topsoil horizon (0.61 dS/m) and A2/Bt topsoil horizon (0.56 dS/m), increasing slightly in the Bk carbonate layer (2.45 dS/m) with highest values in the subsoil/parent material layer (6.67 dS/m). Soil conductivity levels for all PRZ layers within the Swales landform unit are considered suitable for rehabilitation.

Soil pH

Average soil pH in the Swales landform unit ranges from weakly alkaline in the A1 topsoil horizon (8.6) to moderately alkaline (9.3) in the subsoil/parent material layer. pH in the A2/Bt topsoil horizon and Bk carbonate layer in the Swales are 8.7 and 9.3 respectively.

Soil Boron Levels

Boron levels in the A1 and A2/Bt topsoil horizons and Bk carbonate layer in the Swales landform unit are considered to be non-limiting to native vegetation growth. Average boron levels are lowest in the A1 topsoil horizon (1.15 mg/kg), increasing in the A2/Bt topsoil horizon (1.3 mg/kg), Bk carbonate layer (2.0 mg/kg) with very high levels in subsoil/parent material layer (19.9 mg/kg) layers. Elevated boron levels in the subsoil/parent material layer have the potential to limit native vegetation growth.

Soil Sodicity

Average soil sodicity or ESP in the Swales landform unit is considered to be weakly sodic in the A1 topsoil horizon (1.83%) and A2/Bt topsoil horizon (1.15%), moderately to highly sodic in the Bk carbonate layer (10.97%), and highly sodic in the subsoil/parent material layer (27.04%).

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Swales landform unit include:

- Total nitrogen and phosphorous for all soil horizons within the Swales landform unit are considered low.
- Potassium levels in the A1 topsoil horizon were above the 'low threshold' for growth (i.e. 150 mg/kg). Potassium levels in the A2/Bt topsoil horizon, Bk carbonate layer and subsoil/parent material layer are generally lower than the A1 topsoil horizon, but are generally above the 'low threshold'.
- Within the PRZ of the remnant vegetation present, sulphur levels generally ranged between 2 and 10 mg/kg (Appendix HA-A3), which are considered normal for plant growth on Australian soils. Sulphur increased significantly with depth.
- Iron deficiency is considered most likely to occur within the carbonate-rich layers (i.e. the Bk carbonate layer and subsoil/parent material layer).
- Copper levels recorded in the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Zinc levels within the PRZ of the remnant vegetation are considered very low and trials should be established to ascertain whether a lack of zinc may be limiting within the revegetation programme.
- Manganese levels recorded within the PRZ of the remnant vegetation are low, but are considered adequate for native vegetation growth.
- Calcium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Magnesium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Generally, organic carbon is higher in the topsoil layers than the carbonate layer or subsoil, however all results recorded were less than 1%. Levels of less than 1% are considered normal for Mallee Region soils.

HA3.1.6 Run-on Depressions

Run-on depressions comprise less than 5% of the study area. Soil types are red Chromosols (Pits 31 & 32) with the occasional yellow Chromosols (Pit 38). Surface soil textures were clay loam at Pits 31 and 32 and sandy clay at Pit 38. Drainage impeding layers were present at all sites at depths varying from 50-95 cm. Vegetation communities present include *Austrostipa* grassland at Pits 31 (see Plate HA-11) and 38 and a Black Box Woodland at Pit 32.

The average topsoil depth and observed PRZ for remnant vegetation are provided in Table HA-3. Run-on depressions have the most variable soils in the Snapper landscape, and make up the least amount of the study area. They vary in topsoil depth from 20 cm at a grassland site (Pit 38 [see Plate HA-12]) to 65 cm at a Black Box Woodland site (Pit 32 [see Plate HA-13]). Free lime contents are generally low within the topsoil and PRZ, however the moderate angular or sub-angular blocky nature of the Bt topsoil horizon is often restrictive to root growth with root penetration normally only 20-30 cm into this layer. Soil colours are reddish in some run-on areas such as Black Box Woodlands whilst at Pit 38, which overlies gypseous subsoil, the surface colour was grayish-brown.

To illustrate even further variation, Plate HA-14 shows a soil profile at a grassland site (Pit 31) which has shallow topsoil 25 cm thick overlying a thick Bt horizon zone of accumulation with a Class I carbonate layer at 80 cm below the soil surface.

Laboratory results for the Run-on Depression landform unit are summarised by soil layers in Table HA-9 for soil conductivity, pH, boron and ESP, and are discussed below. Table HA-9 provides average results for each soil layer of the four parameters. The full suite of results is provided in Appendix HA-A3.

Table HA-9
Laboratory Results* for the Run-on Depressions Landform Unit

Parameter	A1 Topsoil Horizon	A2/Bt Topsoil Horizon	Bk Carbonate Layer	Subsoil/Parent Material Layer
Average Saturation Paste Soil Conductivity (dS/m)	0.59	0.71	-	5.46
Average pH	8.8	8.7	-	9.2
Average Boron Level (mg/kg, hot CaCl2 Extraction)	1.17	1.03	-	21.43
Average ESP	1.71	5.32	-	20.78

* Results are expressed as an average value for the 3 run-on depression sites sampled.

Soil Conductivity

Run-on Depression soil conductivity is low (less than 1 dS/m) within topsoil layers and moderate within subsoil layers (average = 5.46 dS/m). Soil conductivity levels for all topsoil layers within the Run-on Depression landform unit are considered suitable for rehabilitation.

Soil pH

Average soil pH in the Run-on Depression landform unit ranges from weakly alkaline in the A1 topsoil horizon (8.8) to moderately alkaline (9.2) in the subsoil/parent material layer. pH in the A2/Bt topsoil horizon in the Run-on Depressions is 8.7.

Soil Boron Levels

Boron levels in the A1 and A2/Bt topsoil horizons in the Run-on Depressions landform unit are considered to be non-limiting to native vegetation growth. Average boron levels are lowest in the A1 topsoil horizon (1.17 mg/kg) and A2/Bt topsoil horizon (1.03 mg/kg). Elevated boron levels in the subsoil/parent material layer (21.43 mg/kg) have the potential to limit native vegetation growth.

Soil Sodicity

Average soil sodicity or ESP in the Run-on Depressions landform unit is considered to be weakly sodic in the A1 topsoil horizon (1.71%), weakly to moderately sodic in the A2/Bt topsoil horizon (5.32%), and highly sodic in the subsoil/parent material layer (20.78%).

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Swales landform unit include:

- Total nitrogen and phosphorous for all soil horizons within the Swales landform unit are considered low.
- Potassium levels in the A1 topsoil horizon were above the ‘low threshold’ for growth (i.e. greater than 150 mg/kg).
- Within the PRZ of the remnant vegetation present, sulphur levels generally ranged between 2 and 10 mg/kg (Appendix HA-A3), which are considered normal for plant growth on Australian soils. Sulphur increased significantly with depth.
- Iron deficiency is considered most likely to occur within the carbonate-rich layers (i.e. the Bk carbonate layer and subsoil/parent material layer).
- Copper levels recorded in the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Zinc levels within the PRZ of the remnant vegetation are considered very low to low, but are considered adequate for native vegetation growth.
- Manganese levels recorded within the PRZ of the remnant vegetation are low, but are considered adequate for native vegetation growth.
- Calcium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Magnesium levels recorded within the PRZ of the remnant vegetation are considered adequate for native vegetation growth.
- Generally, organic carbon is higher in the topsoil layers than the carbonate layer or subsoil, however all results recorded were less than 1%, which is low but normal for Mallee Region soils.

HA3.2 Overburden

The nature of the *in-situ* overburden material is briefly described in Section HA2.2. The following sections present results and discussions relevant to the overburden samples collected during September 2006 from BEMAX drill hole and core samples. Conductivity, pH, boron, sodicity and soil nutrient results are discussed for the following overburden layers:

- Woorinen Formation (Section HA3.2. 1).
- Blanchetown Clay (Section HA3.2. 2).
- Upper Loxton-Parilla Sands (Section HA3.2. 3).
- Loxton-Parilla Sand (Mica Sands) (Section HA3.2. 4).
- Lower Loxton-Parilla Sand (Section HA3.2. 5).

Table HA-10 provides a summary of the characteristics of the *in-situ* overburden examined in this study.

Table HA-10
Summary of Soil Characteristics for Five Overburden Facies Types at the Snapper Mine

Soil Parameter	Woorinen Formation	Blanchetown Clay	Upper Loxton-Parilla Sand	Loxton-Parilla Sand (Mica Sands)	Lower Loxton-Parilla Sand
Conductivity	Low to High	Low to High	Moderate	Moderate	Low
pH	Weakly to moderately alkaline	Moderately alkaline	Weakly alkaline	Neutral to weakly alkaline	Moderately alkaline
Boron	Low to High	Low to High	Low	Low	Low
Sodicity	Non-limiting to Limiting	Limiting	Limiting	Limiting	Limiting
Permeability	Slow/poor	Very slow/very poor	High/good	High/good	High/good
Nutrients					
N & P	Very low	Very low	Very low	Very low	Very low
K	Low to adequate	Adequate	Low to adequate	Low	Low
Fe	Adequate	Adequate	Adequate	Adequate	Adequate
S	Very high	Very high	Very high	Very high	Very high
Zn	Very low to low	Low to adequate	Low to adequate	Low to adequate	Adequate
Mn	Low	Low	Low	Low	Low
Ca & Mg	Adequate	Adequate	Low	Low	Low

Laboratory results are summarised by overburden units for soil conductivity, pH, boron and ESP in Table HA-11 and are discussed below. Table HA-11 provides average results for each soil layer of the four parameters. The full suite of results is provided in Appendix HA-A4.

Table HA-11
Average (and Range) Conductivity (dS/m), pH, Boron (mg/kg) and Sodicity (ESP) for Overburden Facies Types at the Snapper Mine[1]

Parameter[1]	Woorinen Formation	Blanchetown Clay	Upper Loxton-Parilla Sand	Loxton-Parilla Sand (Mica Sands)	Lower Loxton-Parilla Sand
Average Saturation Paste Soil Conductivity (dS/m)	16.90 (3.99-38.90)	16.39 (6.52-24.10)	9.84 (2.30-23.40)	6.82 (3.07-13.81)	*1.10
Average pH	9.2 (8.7-9.5)	8.7 (8.6-8.9)	8.3 (7.8-8.9)	7.9 (6.3-8.7)	*9.1
Average Boron Level (mg/kg, hot CaCl2 Extraction)	10.68 (5.1-17.9)	12.07 (3.5-24.4)	1.6 (0.7-3.5)	0.7 (0.5-1.1)	*0.5
Average ESP	29.66 (14.24-43.28)	42.09 (32.33-48.23)	49.89 (32.01-76.11)	59.02 (54.58-65.77)	*18.78

* Denotes 1 sample only from this facies type.
[1] Values in brackets are the range of values recorded.

HA3.2.1 Woorinen Formation

Conductivity

Conductivity values for the four Woorinen Formation overburden samples vary widely. Conductivity values range from low (3.99 dS/m) to extreme (38.90 dS/m). Values between 8 and 16 dS/m are considered saline, but not necessarily damaging to the remnant vegetation present. Values greater than 16 dS/m may potentially impact on the remnant vegetation present. This material poses a real risk to the rehabilitation programme if replaced within proximity to plant roots within the newly constructed soil profiles.

pH

pH values for the four Woorinen Formation overburden samples are moderately (8.7) to strongly alkaline (9.5).

Boron

Boron values for the four Woorinen Formation overburden samples vary widely from moderate (5.1 mg/kg) to very high (17.9 mg/kg). Values at the higher end potentially pose a risk to native vegetation if replaced within proximity to plant roots within the newly constructed soil profiles.

Sodicity

The ESP values calculated indicate that overburden material in the Woorinen Formation ranges from sodic (14.24%) to highly sodic (43.28%). The significance of sodic overburden material is discussed later in this report.

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Woorinen Formation include:

- Total nitrogen and phosphorous within the Woorinen Formation are considered to be extremely low.
- Potassium levels in the Woorinen Formation are generally above the 'low threshold' for growth (i.e. 150 mg/kg).
- Sulphur levels within the Woorinen Formation are variable but are generally very high (i.e. greater than 150 mg/kg).
- Iron levels are generally highest in the Woorinen Formation when compared to other overburden facies, ranging between 299 and 363 mg/kg.
- Copper levels are generally higher in the Woorinen Formation when compared to other overburden facies, ranging between 0.63 and 1.41 mg/kg.
- Zinc levels in the Woorinen Formation range between 0.25 and 0.54 mg/kg.
- Manganese levels in the Woorinen Formation range between 1.15 and 3.38 mg/kg, and are considered adequate for native vegetation growth.
- Calcium levels recorded are generally highest in the Woorinen Formation, ranging between 1,562 and 2,018 mg/kg, and are considered adequate for native vegetation growth.

- Magnesium levels recorded were generally higher in the Woorinen Formation, ranging between 548 and 979 mg/kg, and are considered adequate for native vegetation growth.
- All results for organic carbon recorded were less than 0.2%, which is considered to be extremely low, but as expected for buried facies.

HA3.2.2 Blanchetown Clay

Conductivity

Conductivity values for the three Blanchetown Clay overburden samples vary widely, from moderate (6.52 dS/m) to very high (24.10 dS/m). This material has the potential to impact on native vegetation growth if replaced within proximity to plant roots in the rehabilitated soil profile.

pH

pH values for the three Blanchetown Clay overburden samples are all moderately alkaline with an average pH of 8.7.

Boron

Boron values for the three Blanchetown Clay overburden samples vary widely. Boron values range from low (3.5 mg/kg) to very high (24.4 mg/kg). This material has the potential to impact on native vegetation growth if replaced within proximity to plant roots in the rehabilitated soil profile.

Sodicity

The ESP values calculated indicate that overburden material in the Blanchetown Clay overburden unit is highly sodic (ranging from 32.33% to 48.23%). However, dispersion tests undertaken indicate that only one sample was sodic (dispersion test value of 13).

As stated in Section HA2.3, the reason for the disparity between ESP and Emerson Dispersion calculations is unclear. As a cautionary principle, it should be assumed that any Blanchetown Clay overburden removed from the Snapper Mine path may be potentially sodic, and as such, gypsum should be used in the rehabilitation programme to improve the permeability of the overburden material.

Soil Nutrients

Results and discussions of laboratory analysis for nutrients within the Blanchetown Clay include:

- Total nitrogen and phosphorous within the Blanchetown Clay are considered to be extremely low.
- Potassium levels in the Blanchetown Clay were above the ‘low threshold’ for growth (i.e. 150 mg/kg).
- Within the Blanchetown Clay sulphur levels were variable but generally very high (i.e. greater than 150 mg/kg).
- Iron levels were generally highest in the Blanchetown Clay, ranging between 289 and 530 mg/kg.

- Copper levels were generally highest of all overburden facies in the Blanchetown Clay, ranging between 0.27 and 1.56 mg/kg.
- Zinc levels in the Blanchetown Clay ranged between 0.42 and 1.52 mg/kg.
- Manganese levels in the Blanchetown Clay ranged between 0.55 and 3.87 mg/kg.
- Calcium levels recorded were generally highest of all overburden facies types in the Blanchetown Clay, ranging between 838 and 1,308 mg/kg.
- Magnesium levels recorded were generally highest of all overburden facies types in the Blanchetown Clay, ranging between 587 and 1,490 mg/kg.
- All results for organic carbon recorded were less than 0.2%, which is considered to be extremely low, but as expected for buried facies.

HA3.2.3 Upper Loxton-Parilla Sand

Conductivity

Conductivity values for the five Upper Loxton-Parilla Sand overburden samples also vary widely. Conductivity values range from low (2.30 dS/m) to very high (24.32 dS/m).

pH

pH values for the five Upper Loxton-Parilla Sand overburden samples are weakly (7.8) to moderately alkaline (8.9).

Boron

Boron values for the five Upper Loxton-Parilla Sand overburden samples are universally low (less than 3.5 mg/kg). This overburden material type is therefore unlikely to be limiting to vegetation growth due to boron levels.

Sodicity

The ESP values calculated indicate that overburden material tested in the Upper Loxton-Parilla Sand is highly sodic (ranging from 32.01% to 76.11%). However, dispersion tests undertaken indicate that only one sample was sodic (dispersion test value of 13) and one sample was moderately sodic (dispersion test value of 9).

As stated in Section HA2.3, the reason for the disparity between ESP and Emerson Dispersion calculations is unclear. As a cautionary principle, it should be assumed that any Upper Loxton-Parilla Sand overburden removed from the Snapper Mine path may be potentially sodic, and as such, gypsum should be used in the rehabilitation programme to improve the permeability of the overburden material.

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Upper Loxton-Parilla Sand include:

- Total nitrogen and phosphorous within the Upper Loxton-Parilla Sand are considered to be extremely low.
- Potassium levels in the Upper Loxton-Parilla Sand were generally below the 'low threshold' for growth (i.e. less than 150 mg/kg).
- Within the Upper Loxton-Parilla Sand sulphur levels were variable but generally very high (i.e. greater than 150 mg/kg).
- Iron levels in the Upper Loxton-Parilla Sand ranged between 177 and 510 mg/kg.
- Copper levels in the Upper Loxton-Parilla Sand ranged between 0.14 and 1.26 mg/kg.
- Zinc levels in the Upper Loxton-Parilla Sand generally ranged between 0.21 and 0.62 mg/kg. There was one possibly anomalous result of 6.54 mg/kg recorded for an Upper Loxton-Parilla Sands sample.
- Manganese levels in the Upper Loxton-Parilla Sand ranged between 0.21 and 3.47 mg/kg.
- Calcium levels recorded in the Upper Loxton-Parilla Sand ranged between 120 and 1,564 mg/kg, and are considered low.
- Magnesium levels recorded in the Upper Loxton-Parilla Sand ranged between 83 and 858 mg/kg, and are considered low.
- All results for organic carbon recorded were less than 0.2%, which is considered to be low, but as expected for buried facies.

HA3.2.4 Loxton-Parilla Sand (Mica Sands)

Conductivity

Conductivity values for the three 'Mica Sands' overburden samples also vary. Conductivity values range from low (3.07 dS/m) to high (13.81 dS/m). This overburden material type would appear to mostly have moderate conductivity levels.

pH

pH values for the three 'Mica Sands' overburden samples vary widely through a range deemed to be weakly acidic (6.3) to moderately (8.7) alkaline.

Boron

Boron values for the three 'Mica Sands' overburden samples are universally very low (less than 1.1 mg/kg).

Sodicity

The ESP values calculated indicate that overburden material tested in the 'Mica Sands' are highly sodic (ranging from 54.58% to 65.77%).

Soil Nutrients

Observations from the results of laboratory analyses for nutrients within the Mica Sands include:

- Total nitrogen and phosphorous within the 'Mica Sands' are considered extremely low.
- Potassium levels in the 'Mica Sands' were generally below the 'low threshold' for plant growth (i.e. 150 mg/kg).
- Within the 'Mica Sands' sulphur levels were variable but generally very high (i.e. greater than 150 mg/kg).
- Iron levels in the 'Mica Sands' ranged between 201 and 334 mg/kg.
- Copper levels in the 'Mica Sands' ranged between 0.1 and 0.36 mg/kg.
- Zinc levels in the 'Mica Sands' ranged between 0.4 and 1.77 mg/kg.
- Manganese levels in the 'Mica Sands' ranged between 0.26 and 0.37 mg/kg.
- Calcium levels recorded in the 'Mica Sands' ranged between 98 and 180 mg/kg.
- Magnesium levels recorded in the 'Mica Sands' ranged between 66 and 116 mg/kg.
- All results for organic carbon recorded were less than 0.2%, which is considered to be low, but as expected for buried facies.

HA3.2.5 Lower Loxton-Parilla Sand

Conductivity

The conductivity value for the single Lower Loxton-Parilla Sands overburden sample is low (1.10 dS/m).

pH

The pH value for the single Lower Loxton-Parilla Sands overburden sample is moderately alkaline (9.1).

Boron

The boron value for the single Lower Loxton-Parilla Sands overburden sample is very low (0.5 mg/kg).

Sodicity

The ESP value calculated indicate that overburden material tested in the Lower Loxton-Parilla Sands is highly sodic (18.78%).

Soil Nutrients

One Lower Loxton-Parilla Sand sample was tested for nutrients, and the results included:

- Total nitrogen and phosphorous within the Lower Loxton-Parilla Sand are considered to be extremely low.
- Potassium in the Lower Loxton-Parilla Sand is extremely low.

- Within the Lower Loxton-Parilla Sand sulphur levels were variable but generally high.
- Iron in the Lower Loxton-Parilla Sand was 215 mg/kg.
- Copper in the Lower Loxton-Parilla Sand was 0.08 mg/kg.
- Zinc in the Lower Loxton-Parilla Sand was 1.55 mg/kg.
- Manganese in the Lower Loxton-Parilla Sand 0.19 mg/kg.
- Calcium recorded in the Lower Loxton-Parilla Sand was 236 mg/kg.
- Magnesium recorded in the Lower Loxton-Parilla Sand was 31.2 mg/kg.
- All results organic carbon recorded were less than 0.2%, which is considered to be low, but as expected for buried facies.

HA4 MANAGEMENT CONSIDERATIONS FOR *IN-SITU* MATERIALS

HA4.1 General Considerations and Recommendations

HA4.1.1 Topsoil

The study area has topsoil depths varying from 20 to 105 cm. The shallowest topsoils occur on clayey plains which average 30 cm depth and occur over approximately 40-45% of the study area. Dunes, dune slopes and sandy sand plains which together comprise approximately 50% of the study area have greater topsoil depth, normally in the range of 40-70 cm. Topsoils have inherently low nutrient status which has been further depleted by the existing land management (grazing) over many years. The topsoils generally have low (sandy) to moderately high (clayey plains) free lime content, but are universally non-sodic and have low soil conductivity and pH that provides a suitable growth medium for the type of remnant vegetation present over the study area (i.e. Black Oak-Rosewood-Wilga Woodland and Bluebush Shrublands).

Stripping of topsoil at the Snapper Mine should be guided by landform unit type and by the depth to the carbonate layer. In this way the depth of topsoil can be maximized, and any inadvertent harvesting of the carbonate layer can be prevented.

The PRZ of the Black Oak-Rosewood-Wilga Woodland (see Plate HA-15), Bluebush Shrublands, *Austrostipa* Grasslands and Mallee Shrubland generally does not extend more than 20 cm into the underlying carbonate layer. Plant roots in chromosol soils where the Bt Horizon is present were often found to extend to a similar depth and often not reach the carbonate layer at all. Maximising topsoil recovery would allow for an average 50-80 cm of PRZ depth in the rehabilitated landscape (i.e. re-establish the current average PRZ of 50-80 cm).

The use of scrapers to strip topsoil is particularly damaging to the surface cryptogamic crust and topsoil structure when used in Mallee environments. The surface cryptogamic crust has a key role as a nutrient source and as a soil binding agent – assets which are effectively lost when scrapers are used to strip topsoil. Moreover the topsoil structure is effectively lost as the removal, storage and replacement process turns the topsoil to a condition similar to ‘bulldust’. The use of scrapers in Mallee Region areas also has several other major disadvantages. These include the (Richard Hale[4], pers. comm., 2006):

- increased loss of topsoil (estimated at up to 30-40% in shallow dry sandy clay loam and clay loam Mallee topsoils such as occur at the Snapper Mine) combined from each stage of disturbance (initial removal, storage and replacement);
- additional cost of bulldozers to push open-bowl scrapers;
- pulverising effect that elevated scrapers have on the topsoil;
- lack of accuracy in defining the topsoil/carbonate layer boundary in landforms where topsoil depth can change quickly;
- potential for scrapers to become bogged on stockpiles effectively turned to bulldust; and
- occupational health and safety and down-time issues associated with the potential for scrapers to tip over on loose unconsolidated bulldust topsoil stockpiles.

[4] Mr Richard Hale, former manager of the Wemen Mineral Sands Mine, formulated through a practical assessment of scraper use in Mallee topsoil stripping operations compared to other alternatives.

This form of topsoil extraction is both unsuited to, and unsustainable within Mallee landscapes containing dominantly loamy to clayey soils such as occur at the Snapper Prospect area.

Alternative methods of topsoil stripping that exist in broad scale sand mining operations include carry graders, tractors with scoops and front-end loaders with scoops. The first involves the use of carry graders, which have been used in Western Australian mining operations. Carry graders cause less disturbance than scrapers and at a comparable cost (Loch, 2006). The second method involves tractors dragging scoops behind them. Front-end loaders with scoops are used at BEMAX's Wemen Mineral Sands Mine and involves the use of large front-end loaders with scoop buckets to remove and replace topsoil over short distances as a load-haul-dump operation, i.e. without the need for haul trucks. Because of the lower wheel impact of the front-end loaders and the maintained structure of the topsoil within the stockpile, bogging and tipping issues on topsoil stockpiles were not encountered (Hale, pers. comm., 2006). Whilst the cost of using front-end loader scoops is known to be more expensive than using scrapers, the advantages of using front-end loaders to maintain a superior soil medium for rehabilitation is considered to provide a better total outcome for the mine overall.

HA4.1.2 Subsoil

Subsoil material from Class I carbonate and the Blanchetown Clay generally has high soil conductivity, high pH, high sodicity or ESP values and high boron levels, which should preclude some of this material from being placed within the PRZ of the rehabilitated land. In addition, these soils have poor permeability characteristics. Other forms of carbonate subsoil such as Class IIIAL and IIIAS have generally low to moderate conductivity levels and low boron levels with moderate to good drainage characteristics, and would be suitable for use within the top 1.5 m of the rehabilitated profile. Elevated ESP values for some carbonate layer soils may necessitate the use of low to moderate rates of gypsum application in order to improve soil permeability.

HA4.1.3 Overburden

Overburden derived from the geologically younger facies such as Woorinen Formation and the Blanchetown Clay have variable (but sometimes high) levels of soil conductivity, pH, boron and sodicity or ESP. Sometimes these facies may be present very close to the soil surface (see Plate HA-17). Materials from these layers with potentially limiting characteristics should not be placed within the PRZ of the rehabilitated landform. This would also include overburden from these facies that have poor permeability characteristics along with elevated levels of soil conductivity, pH, boron and sodicity. The older Loxton-Parilla Sand has three major recognized facies in the Snapper and Ginkgo Mine areas – the Upper Loxton-Parilla Sand, Loxton-Parilla Sand (Mica Sands) and the Lower Loxton-Parilla Sands (see Plate HA-19). These facies have high sodicity or ESP and sulphur levels, neutral to slightly alkaline pH, negligible boron levels and moderate conductivity levels. The use of this material, in particular the more clayey facies, should be trialled as a medium for capping overburden stockpiles and as subsoil medium for Rehabilitation Areas. Gypsum may need to be applied at high rates in order to ameliorate calcium and magnesium deficiencies and to mitigate soil sodicity.

HA4.2 Storage and Replacement of the Topsoil

HA4.2.1 Conservation of the Surface Soil Crust

The importance of the surface soil crust and cryptogamic layer (see Plate HA-18) was reviewed by McLaughlin and Sluiter (1995) who concluded that conservation of this layer and its use in the rehabilitation programme post sand mining in Mallee areas is recommended. The surface 5-10 cm is known to contain the vast majority of the soil seed store and has generally elevated nutrient status when compared to the lower part of the topsoil. Soil surface layers with cryptogam cover also play a major role in erosion resistance, nutrient recycling, and contain many of the fungal spores that are important in the establishment of plant mycorrhizal relationships.

It is recommended to salvage a separate soil cut of the surface 5-10 cm in order to maintain the integrity of the cryptogamic soil crust and seed bank for subsequent rehabilitation.

HA4.2.2 Management of Topsoil Stockpiles

The timing of topsoil removal is considered to be important in determining what plants colonize the stockpiles. At the Ginkgo Mine, it has been observed that those topsoils removed in late summer to autumn which receive adequate autumn rainfall appear to have been colonized with a greater cover of indigenous taxa (see Plate HA-19) compared to those stripped in spring or early summer.

Stockpiles should be sown with quick-growing indigenous taxa (native perennial grasses and chenopods), and to species which can provide a natural nutrient benefit, such as legumes (e.g. *Acacia* spp., *Senna* spp.). The surface of the stockpiles should also be roughened by shallow cross-ripping, and the addition of low inputs of a fertiliser should be trialled.

Weed control, particularly of Ward's Weed in the vicinity of the topsoil stockpiles (see Plate HA-20) and Rehabilitation Areas should be undertaken as a matter of course. This weed has the potential to out-compete the ground flora of remnant vegetation (see Plates HA-21 and HA-22) and Rehabilitation Areas with calcareous soils.

Goat control around stockpiles and from the MLA area should also be undertaken.

HA4.2.3 Direct Topsoil Replacement

Direct topsoil replacement (i.e. haulage of topsoil from the initial removal site directly to its final placement) should be undertaken where practicable. Benefits of direct topsoil replacement include:

- cost benefits of direct topsoil replacement by removing the requirement to "double-handle" the topsoil;
- conservation of the soil seed store in the freshest state possible; and
- lower risk of weed invasion.

HA4.3 Storage and Replacement of Subsoil and Overburden

HA4.3.1 Management of Subsoil and Overburden Stockpiles

Potential erosion and surface runoff of subsoil (from the carbonate layer) and overburden stockpiles should be minimised by (Loch, 2006):

- batter slope reduction to reduce the speed of runoff;
- cross-ripping of slopes to break-up compaction caused in stockpile construction;
- the use of conventional tines instead of winged tines to reduce the risk of erosion;
- placement of tree debris and mulch (subject to availability) over batter slopes;
- capping with an un-compacted layer up to 50 cm thick which is capable of supporting vegetation; and
- goat control within the MLA.

The use of gypsum in the stockpile capping medium to reduce sodicity should also be undertaken.

HA4.3.2 Replacement of Subsoils and Overburden

The Woorinen Formation and Blanchetown Clay are generally sodic, alkaline, have high conductivity levels and poor permeability characteristics. Some Woorinen Formation and Blanchetown Clay facies have elevated boron levels. The use of light clay, medium or heavy clay textures of these overburden facies types within the PRZ of the rehabilitated surface is not recommended. The use of other sandy textures from the Woorinen Formation should be trialled. The Loxton-Parilla Sand has good permeability characteristics. With amelioration of nutrient deficiencies for nitrogen, phosphorous, potassium, zinc and manganese, and additions of gypsum to correct calcium and magnesium deficiencies and aid in reducing soil sodicity, the use of Loxton-Parilla Sand as a medium for subsoil replacement in the rehabilitated soil profile at the Snapper Mine should be trialled.

HA4.4 Fertiliser Usage

Remnant vegetation of the site is adapted to low nutrient status soils, however vegetation growth has been compromised by the grazing of domestic stock, feral goats and rabbits for many years, resulting in further loss of nutrients from the soil. The addition of nitrogen and/or phosphorous to soils in a rehabilitation programme could be considered, however the remnant vegetation present is clearly adapted to low nutrient status soils, and significant nutrient inputs may increase the potential of weed growth (McLaughlin and Sluiter, 1995). The addition of low inputs of a fertiliser (such as Diammonium Phosphate [DAP]) should be trialled for increased growth of short-term vegetation on naturally revegetated areas and seeded areas including topsoil stockpiles. The incidence of weed invasion should also be monitored in association with these trials.

HA4.5 Summary Recommendations

Based on the results of this investigation, it is recommended that:

- Stripping of topsoil to the appropriated depth should be guided by the landform type and depth to the carbonate layer to maximise topsoil recovery.
- Where practicable, topsoil should be direct-placed (i.e. topsoil stockpiling and rehandling should be minimised), in order to:
  - remove the requirement to "double-handle" topsoil;
  - conserve the soil seed store in the freshest state possible; and
  - reduce the risk of weed invasion.
- If feasible, the top 5-10 cm of topsoil should be salvaged separately to the rest of the topsoil, to maintain the integrity of the cryptogamic soil crust and seed bank for rehabilitation.
- Where practicable, topsoil should be removed and stockpiled when moist, or in autumn to take advantage of seasonal rainfall.
- Topsoil stockpiles should be ripped, seeded and/or fertilized to reduce erosion and maintain biological integrity.
- Older heavy, medium and light medium clay facies of Woorinen Formation and Blanchetown Clay origin are not considered to be suitable rehabilitation growth media and as such are not recommended for use within the PRZ of the rehabilitation landscape.
- Rehabilitation trials should be conducted to assess:
  - the suitability and appropriate depth of Loxton-Parilla Sand as a subsoil growth medium with respect to the PRZ in the rehabilitation landscape;
  - the use of gypsum to ameliorate sodicity and calcium and magnesium deficiencies; and
  - whether a lack of zinc may be limiting within the revegetation programme.
- Class I Carbonate layers and Blanchetown Clay have poor drainage characteristics with slow permeability, and should not be utilised within the PRZ of the rehabilitated soil surface.
- Weed and pest control should be undertaken to prevent damage to Regeneration Areas and topsoil stockpiles. This specifically should include control of Ward's Weed and eradication of goats.
- Potentially sodic soils such as some of the Bk carbonate layer and the subsoil/parent material should be stored and managed separately (e.g. with the application of gypsum).
- Mixing of the Bk carbonate layer with topsoil should be avoided during stripping, storage and rehabilitation procedures across the Snapper Mine path.

- Mixing of the carbonate layer with topsoil can be largely avoided in topsoil stripping operations with the use of appropriate equipment (e.g. tractors with scoops or front-end loaders with bucket scoops).

- Gypsum should be used in the rehabilitation programme to improve the permeability of sodic overburden material.

- Overburden materials that are moderately to extremely saline should not be placed within the PRZ of the reformed surface of the Rehabilitation Areas.

- Overburden materials found to be generally high in boron (i.e. greater than 15 mg/kg) should not be placed within the PRZ of the reformed surface of the Rehabilitation Areas.

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PLATES

Plate HA-1: **Dune landform at Site 27 with a Black Oak-Rosewood-Wilga Woodland containing sparse mallee trees.**

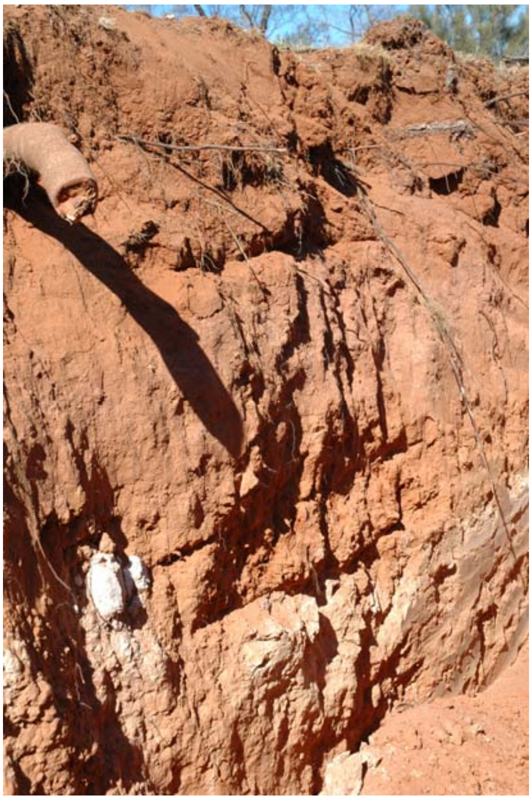


Plate HA-2: **Pit 27 – soil profile of a dune landform. This soil has 105 cm of topsoil (3 layers) with a Class IIIAS (see Appendix HA-A2) carbonate layer.**

Plate HA-3: Dune slope landform with a Black Oak-Rosewood-Wilga Woodland and a sparse Black Bluebush (*Maireana pyramidata*) and herbaceous understorey at Site 34.

Plate HA-4: Pit 34 – soil profile of a dune slope landform. This soil has 60 cm of topsoil overlying a Class IIIAL carbonate layer (see Appendix HA-A2).

Plate HA-5: Sandy plain landform with a Black Oak-Rosewood-Wilga Woodland and a sparse Pearl Bluebush (*Maireana sedifolia*) understorey at Site 17.

Plate HA-6: Pit 17 – soil profile of a sandy plain landform with 60 cm of light sandy clay loam topsoil (2 layers) with an underlying Class IIIAL carbonate layer.

Plate HA-7: **Undulating clayey plain landform with a Bluebush Shrubland at Site 41.**

Plate HA-8: **Pit 41 – soil profile of a clayey plain landform. This soil type is a calcic Calcarosol with shallow (30 cm) clay loam topsoil and Class I carbonate at 100 cm below the surface.**

Plate HA-9: Red swale landform with a Mallee vegetation community at Site 30. This type of landform and vegetation type was uncommon at the Snapper Prospect.

Plate HA-10: Pit 30 – soil profile of a Swale landform. This soil is a lithocalcic Calcarosol and has a Class IIIC carbonate layer (see Appendix HA-2) dominated by calcrete rubble.

Plate HA-11: Run-on depression with minor Gilgai development at Site 31. The vegetation at this site is dominated by Speargrass (*Austrostipa* spp.) and Limestone Copperburr (*Sclerolaena obliquicuspis*), but is badly drought effected.

Plate HA-12: Soil profile of a yellow Chromosol in a run-on depression landform at Pit 38. The subsoil at this site is gypseous clay of Yamba Formation origin.

Plate HA-13: Soil profile of a deep red Chromosol in a run-on depression landform at Pit 32 – a Black Box Woodland site.

Plate HA-14: Pit 31 – soil profile of a run-on depression landform. This soil is a red Chromosol with a shallow clay loam topsoil horizon (25 cm) over a deep Bt horizon with a Class I carbonate at the base of the hole.

Plate HA-15: Soil profile of a shallow clayey plain landform at Pit 20 with topsoil depth of only 20 cm. Here plant roots extended 30 cm into the underlying carbonate layer.

Plate HA-16: Soil profile of a dune landform at Pit 23 with topsoil depth of 85 cm. Here plant roots extended only 15 cm into the underlying carbonate layer.

Plate HA-17: Soil profile of a swale landform at Pit 33 where topsoil depth is just 25 cm and Class I carbonate and Blanchetown Clay are encountered at just 50 cm and 120 cm respectively, below the surface. These soils have poor permeability.

Plate HA-18: Topsoil stockpile at the Ginkgo Mine. Here carbonate layer material has been 'picked up' by the scrapers and mixed with topsoil. When using scrapers in Mallee landscapes, it can sometimes be difficult to discern between rapid lateral changes in topsoil depth.

Plate HA-19: **Topsoil stockpiles at the Ginkgo Mine which has been colonized primarily by indigenous plant taxa including Speargrass (*Austrostipa* spp.), Limestone Copperburr (*Sclerolaena obliquicuspis*) and Cannon Balls (*Dissocarpus paradoxus*).**

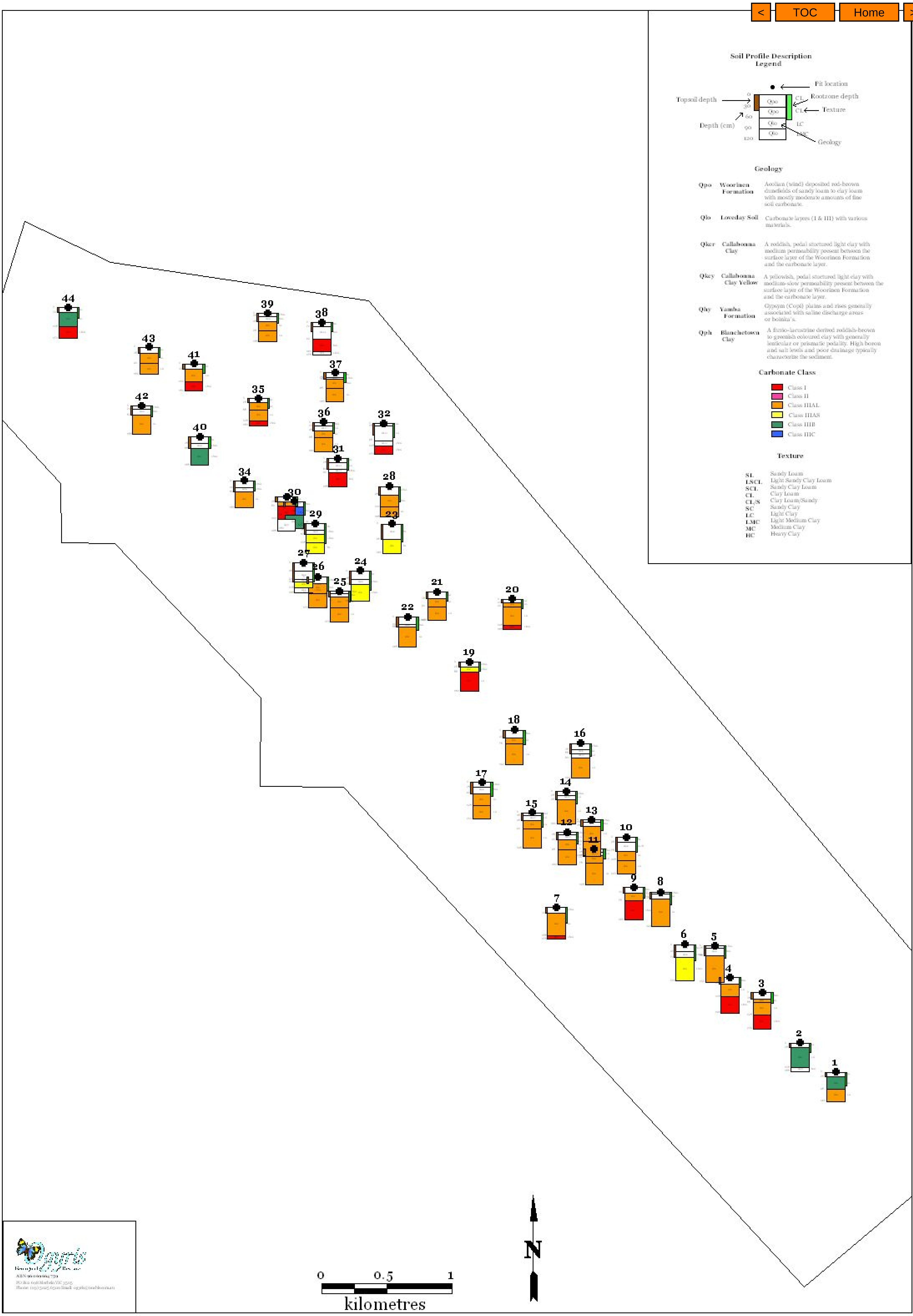
Plate HA-20: **Topsoil stockpile at the Ginkgo Mine. This stockpile has been colonized primarily by weed taxa including Ward's Weed (*Carrichtera annua*), Smooth Mustard (*Sisymbrium erysimoides*) and Mediterranean Turnip (*Brassica tournefortii*).**

Plate HA-21: **Ward's Weed (*Carrichtera annua*) – this species is a significant weed of calcareous soils in semi-arid and arid areas.**

Plate HA-22: **Black Oak-Rosewood-Wilga Woodland in south-west New South Wales rangelands with an understorey totally dominated by Ward's Weed. This plant poses the most serious weed threat to the rehabilitation programme at the existing Ginkgo Mine as well as to the proposed Snapper Mine.**

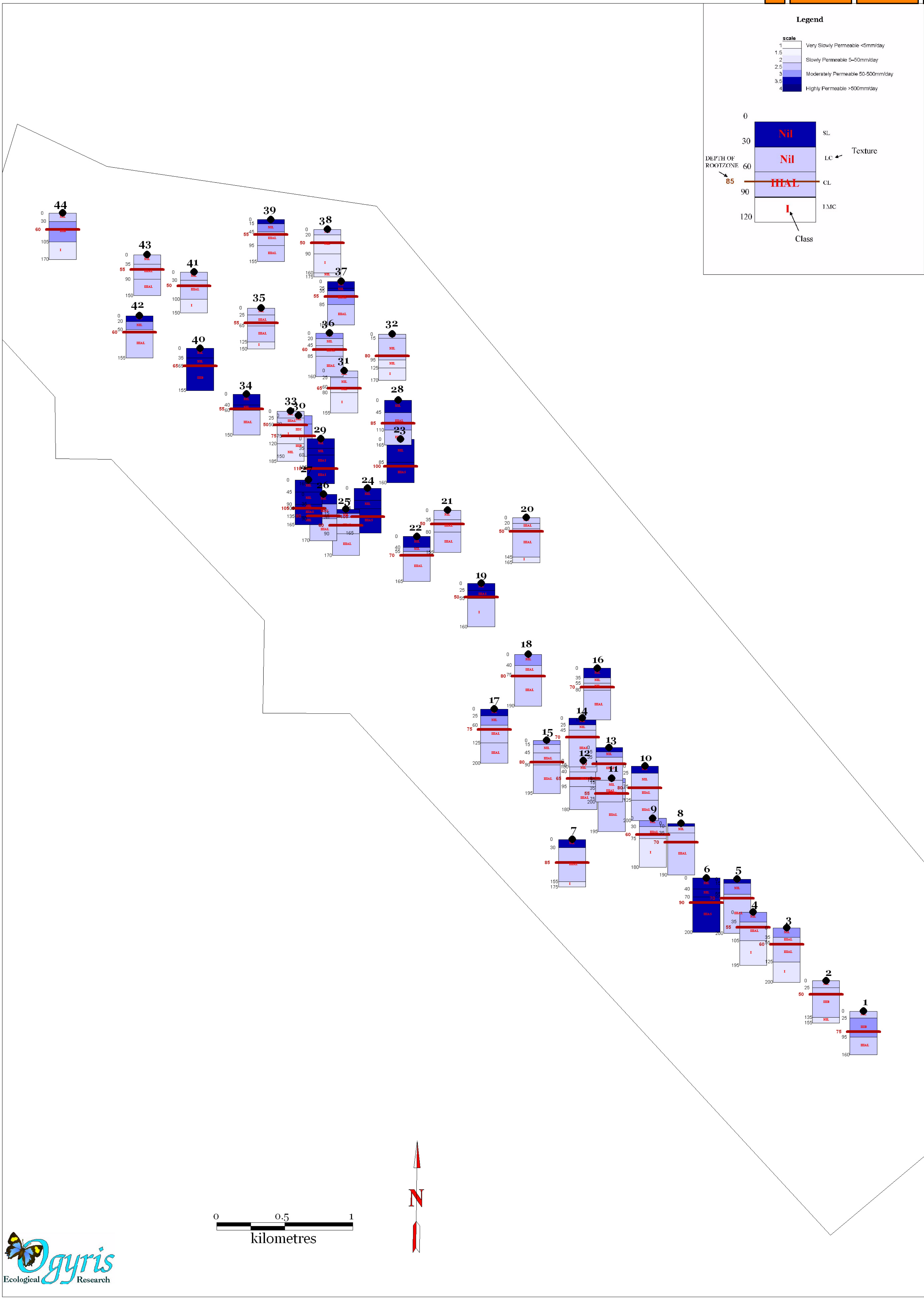
MAP HA-1

SOIL PROFILE DESCRIPTION MAP


Soil Profile Description Legend
Pit location
Topsoil depth
Rootzone depth
Texture
Depth (cm)
Geology
0
30
60
90
120
Qpo
Qlo
CL
LC
Geology
Qpo Woorinen Formation — Aeolian (wind) deposited red-brown dunefields of sandy loam to clay loam with mostly moderate amounts of fine soil carbonate.
Qlo Loveday Soil — Carbonate layers (I & III) with various materials.
Qkcr Callabonna Clay — A reddish, pedal structured light clay with medium permeability present between the surface layer of the Woorinen Formation and the carbonate layer.
Qkcy Callabonna Clay Yellow — A yellowish, pedal structured light clay with medium-slow permeability present between the surface layer of the Woorinen Formation and the carbonate layer.
Qhy Yamba Formation — Gypsym (Copi) plains and rises generally associated with saline discharge areas or boinka's.
Qph Blanchetown Clay — A fluvio-lacustrine derived reddish-brown to greenish coloured clay with generally lenticular or prismatic pedality. High boron and salt levels and poor drainage typically characterize the sediment.
Carbonate Class
Class I
Class II
Class IIIAL
Class IIIAS
Class IIIB
Class IIIC
Texture
SL Sandy Loam
LSCL Light Sandy Clay Loam
SCL Sandy Clay Loam
CL Clay Loam
CL/S Clay Loam/Sandy
SC Sandy Clay
LC Light Clay
LMC Light Medium Clay
MC Medium Clay
HC Heavy Clay
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 34 35 36 37 38 39 40 41 42 43 44
0 0.5 1
kilometres
N

MAP HA-2

PERMEABILITY MAP


Legend
scale
Very Slowly Permeable <5mm/day
Slowly Permeable 5-50mm/day
Moderately Permeable 50-500mm/day
Highly Permeable >500mm/day
Nil
Nil
IIIAL
I
SL
LC
CL
LMC
Texture
DEPTH OF ROOTZONE
85
Class
0
30
60
90
120
0 0.5 1
kilometres
N
Ogyris Ecological Research

APPENDIX HA-A1

SOIL PROFILE DESCRIPTIONS

KEY TO PROFILE DESCRIPTIONS

SOIL TEXTURES PRESENT (In order of increasing clay content)

SL	Sandy Loam
LSCL	Light Sandy Clay Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SC	Sandy Clay
LC	Light Clay
LMC	Light Medium Clay
MC	Medium Clay

CARBONATE CONTENT*

N	Nil	<0.5% fine earth carbonate
S	Slight	0.5 – 1.5% fine earth carbonate
M	Medium	1.5 – 4.0% fine earth carbonate
H	High	4.0 – 8.0% fine earth carbonate
V	Very High	>8% fine earth carbonate

* values from Wetherby (2002)

LITHOLOGY

Kc	Calcium carbonate
Gy	Gypsum

STRUCTURE

	GRADE		TYPE
V	Massive	PL	Platy
W	Weak	PR	Prismatic
M	Moderate	CO	Columnar
S	Strong	AB	Angular Blocky
		SB	Sub-Angular Blocky
		GR	Granular
		N	Unstructured
		Le	Lenticular

GEOLOGY

Qpo	***Woorinen Formation***	Aeolian (wind) deposited red-brown dunes, swales and plains of sandy loam to clay loam with mostly moderate amounts of fine soil carbonate. Carbonate layer usually Class IIIAL, IIIAS, IIIB or IIIC.
Qlo	***Loveday Soil***	The unit at the top of the Woorinen Formation which is usually characterized by a calcrete carbonate layer.
Qcab	***Bakara Calcrete***	Whitish sheet calcrete layer (Class IIB) formed in re-worked Crocker's Loess, and often capping that formation.
Qcl	***Crocker's Loess***	Aeolian calcareous material derived from weathered seashells on the southern margin of Australia or local Tertiary deposits.
Qkcr	***Callabonna Clay***	Reddish to reddish-brown, pedal structured light clay with medium permeability present between the surface layer of the Woorinen Formation and the Loveday Soil carbonate layer.
Qkcy	***Callabonna Clay***	Yellowish to yellowish-brown, pedal structured light clay with medium to slow permeability present between the surface layer of the Woorinen Formation and the Loveday Soil carbonate layer.
Qph	***Shepparton Formation (Blanchetown Clay)***	A fluvio-lacustrine derived reddish-brown to greenish coloured clay with generally lenticular or prismatic pedality. High boron and salt levels and poor drainage typically characterize the sediment.
Qhy	***Yamba Formation***	Gypsum (copi) plains and rises generally associated with current and former saline discharge areas or boinka's.
Tps	***Loxton-Parilla Sand***	Pliocene sands and clayey sands of characteristic whitish or yellow-orange colour which represent the regional groundwater aquifer. Hard ferruginized or silicified layer at the top of the Tps represents the Karoonda Surface (Qks).

SITE	LOWER	HORIZON	TEXTURE	COLOUR	FIELD pH	CARB REACT	CARB CLASS	% CRS FRAG	FRAG LITH	GEOLOGY	PEDALITY GRADE	PEDALITY TYPE
1	25	A	CL	5YR4/4	8.5	H	NIL	0		Qpo	W	SB
	95	Bk	CL	5YR5/6	9	V	IIIB	35	Kc	Qlo	W	SB
	160	Bk	LC	5YR5/8	9	V	IIIAL	5	Kc	Qlo	W	SB
2	25	A	CL	5YR4/4	8.5	H	NIL	0		Qpo	W	SB
	135	Bk	LC	5YR5/6	9	V	IIIB	35	Kc	Qlo	W	SB
	155	C	MC	2.5YR4/8	9.5	S	NIL	0		Qph	W	LE
3	35	A	SCL	5YR4/4	8	M	NIL	0		Qpo	W	SB
	55	Bk	CL	5YR5/6	9	V	IIIAL	10	Kc	Qlo	W	SB
	125	Bk	LC	5YR5/8	9	V	IIIAL	0		Qlo	W	SB
	200	Bk	LMC	2.5YR4/8	9.5	V	I	0		Qlo	W	SB
4	35	A	SCL	5YR3/4	8.5	M	NIL	0		Qpo	W	SB
	105	Bk	LC	5YR5/6	9	V	IIIAL	15	Kc	Qlo	W	SB
	195	Bk	LMC	5YR5/8	9.5	V	I	0		Qlo	W	SB
5	15	A	LSCL	2.5YR3/4	8	N	NIL	0		Qpo	W	SB
	55	A	SCL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	200	Bk	LC	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
6	40	A	SL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	70	A	LSCL	2.5YR4/6	8	N	NIL	0		Qpo	W	SB
	200	Bk	LSCL	5YR5/6	9	V	IIIAS	0		Qlo	W	SB
7	30	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	155	Bk	CL	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	175	Bk	LMC	5YR5/8	9	V	I	0		Qlo	W	SB
8	10	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	35	A	CL	5YR4/6	8	S	NIL	0		Qpo	W	SB
	190	Bk	CL	5YR5/6	9	V	IIIAL	10	Kc	Qlo	W	SB
9	30	A	SCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	75	Bk	LC	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	180	Bk	LMC	5YR5/8	9.5	V	I	0		Qlo	M	SB
10	25	A	SL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	75	A	CL/S	5YR4/6	8.5	S	NIL	0		Qpo	W	SB
	125	Bk	CL	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	200	Bk	LC	5YR5/8	9	V	IIIAL	0		Qlo	W	SB
11	15	A	SCL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	35	Bt	LC	2.5YR4/4	8.5	N	NIL	0		Qkcr	M	SB
	75	Bk	LC	2.5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	195	Bk	CL	5YR5/8	9	V	IIIAL	10	Kc	Qlo	W	SB
12	15	A	LSCL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	40	Bt	LC	2.5YR4/4	8.5	N	NIL	0		Qkcr	M	SB
	95	Bk	CL	2.5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	180	Bk	LC	2.5YR5/8	9	V	IIIAL	5	Kc	Qlo	W	SB
13	15	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	35	A	SCL	5YR4/6	8.5	M	NIL	0		Qpo	W	SB
	120	Bk	LC	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	200	Bk	LC	5YR5/8	9	V	IIIAL	5	Kc	Qlo	W	SB
14	25	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	45	Bt	LC	5YR4/6	8.5	M	NIL	0		Qkcr	M	SB
	180	Bk	LC	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
15	15	A	SCL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	45	Bt	LC	2.5YR4/6	8.5	S	NIL	0		Qkcr	M	AB
	90	Bk	LC	2.5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	195	Bk	LC	5YR5/8	9	V	IIIAL	0		Qlo	W	SB

SITE	LOWER	HORIZON	TEXTURE	COLOUR	FIELD pH	CARB REACT	CARB CLASS	% CRS FRAG	FRAG LITH	GEOLOGY	PEDALITY GRADE	PEDALITY TYPE
16	35	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	55	A	CL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	80	Bt	LC	5YR4/6	8.5	H	NIL	0		Qkcr	M	AB
	190	Bk	LC	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
17	25	A	LSCL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	60	A	SCL	2.5YR4/6	9	H	NIL	0		Qpo	W	SB
	125	Bk	CL	2.5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	200	Bk	LC	2.5YR5/8	9	V	IIIAL	0		Qlo	W	SB
18	40	A	SCL	5YR4/4	8.5	M	NIL	0		Qpo	W	SB
	75	Bk	CL	5YR5/6	9	V	IIIAL	10	Kc	Qlo	W	SB
	190	Bk	LC	5YR5/8	9	V	IIIAL	0		Qlo	W	SB
19	25	A	LSCL	5YR4/4	8	S	NIL	0		Qpo	W	SB
	55	Bk	LSCL	5YR5/6	8.5	V	IIIAS	10	Kc	Qlo	W	SB
	160	Bk	LC	5YR5/8	9	V	I	0		Qlo	W	SB
20	20	A	CL	7.5YR4/4	8.5	H	NIL	0		Qpo	W	SB
	40	Bk	CL	7.5YR4/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	145	Bk	LC	7.5YR5/6	9	V	IIIAL	25	Kc	Qlo	W	SB
	165	Bk	LMC	7.5YR5/8	9.5	V	I	0		Qlo	W	SB
21	35	A	CL	5YR4/4	8.5	M	NIL	0		Qpo	W	SB
	80	Bk	CL	5YR4/6	9	V	IIIAL	25	Kc	Qlo	W	SB
	155	Bk	LC	5YR5/6	9.5	V	IIIAL	5	Kc	Qlo	W	SB
22	40	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	55	A	SCL	5YR4/6	8.5	H	NIL	0		Qpo	W	SB
	165	Bk	CL	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
23	85	A	SL	2.5YR4/4	7.5	N	NIL	0		Qpo	W	SB
	160	Bk	SL	2.5YR5/8	9	V	IIIAS	5	Kc	Qlo	W	SB
24	45	A	SL	2.5YR4/6	7.5	N	NIL	0		Qpo	W	SB
	75	A	LSCL	2.5YR4/6	8.5	H	NIL	0		Qpo	W	SB
	165	Bk	LSCL	2.5YR4/8	9	V	IIIAS	10	Kc	Qlo	W	SB
25	15	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	30	A	SCL	5YR4/4	8.5	M	NIL	0		Qpo	W	SB
	90	Bk	CL	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
	170	Bk	LC	5YR5/8	9	V	IIIAL	5	Kc	Qlo	W	SB
26	35	A	LSCL	2.5YR4/4	8	M	NIL	0		Qpo	W	SB
	90	Bk	SCL	2.5YR4/6	9	V	IIIAL	20	Kc	Qlo	W	SB
	170	Bk	CL	2.5YR5/6	9	V	IIIAL	10	Kc	Qlo	W	SB
27	45	A	SL	2.5YR4/4	7.5	N	NIL	0		Qpo	W	SB
	90	A	SL	2.5YR4/6	8.5	M	NIL	0		Qpo	W	SB
	105	A	LSCL	2.5YR4/6	8	S	NIL	0		Qpo	W	SB
	135	Bk	LSCL	2.5YR5/6	9	V	IIIAS	5	Kc	Qlo	W	SB
	165	C	LSCL	2.5YR5/8	8.5	M	NIL	0		Qpo	W	SB
28	45	A	LSCL	2.5YR4/4	8	S	NIL	0		Qpo	W	SB
	110	Bk	SCL	2.5YR5/6	9	V	IIIAL	20	Kc	Qlo	W	SB
	165	Bk	CL	2.5YR5/8	9	V	IIIAL	5	Kc	Qlo	W	SB
29	35	A	SL	2.5YR4/4	7.5	N	NIL	0		Qpo	W	SB
	60	A	LSCL	2.5YR4/6	8	S	NIL	0		Qpo	W	SB
	105	Bk	LSCL	2.5YR5/6	9	V	IIIAS	0		Qlo	W	SB
	165	Bk	SL	2.5YR4/8	9	V	IIIAS	0		Qlo	W	SB
30	30	A	SCL	2.5YR3/4	8	N	NIL	0		Qpo	W	SB
	75	Bk	SCL	5YR6/8	9	V	IIIC	75	Kc	Qlo	W	SB
	150	Bk	CL	2.5YR5/8	9	V	IIIB	35	Kc	Qlo	W	SB

SITE	LOWER	HORIZON	TEXTURE	COLOUR	FIELD pH	CARB REACT	CARB CLASS	% CRS FRAG	FRAG LITH	GEOLOGY	PEDALITY GRADE	PEDALITY TYPE
31	25	A	CL	5YR4/4	8.5	M	NIL	0		Qpo	W	SB
	60	Bt	LC	2.5YR4/6	9	S	NIL	0		Qkcr	M	SB
	80	Bt	LMC	2.5YR4/6	9.5	H	NIL	0		Qkcr	M	AB
	155	Bk	MC	2.5YR4/8	9.5	V	I	0		Qlo	W	SB
32	15	A	CL	2.5YR3/4	7.5	N	NIL	0		Qpo	W	SB
	95	Bt	LC	10R3/6	8	N	NIL	0		Qkcr	M	SB
	125	Bt	LMC	10R4/6	8	N	NIL	0		Qkcr	M	AB
	170	Bk	LMC	2.5YR5/8	9	V	I	10	Kc	Qlo	W	SB
33	25	A	CL	5YR4/3	8.5	H	NIL	0		Qpo	W	SB
	50	Bk	CL	5YR5/6	9	V	IIIAL	20	Kc	Qlo	W	SB
	120	Bk	LMC	2.5YR5/8	9.5	V	I	0		Qlo	M	SB
	185	C	MC	10R4/8	9	S	NIL	0		Qph	W	LE
34	40	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	60	A	LSCL	5YR4/6	8.5	H	NIL	0		Qpo	W	SB
	150	Bk	CL	5YR5/6	9	V	IIIAL	10	Kc	Qlo	W	SB
35	25	A	CL	5YR4/4	8	H	NIL	0		Qpo	W	SB
	65	Bk	CL	5YR4/6	9	V	IIIAL	10	Kc	Qlo	W	SB
	125	Bk	LC	5YR5/6	9	V	IIIAL	0		Qlo	W	SB
	150	Bk	LMC	5YR5/8	9.5	V	I	0		Qlo	W	SB
36	20	A	SCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	45	Bt	LC	2.5YR4/4	8.5	M	NIL	0		Qkcr	M	SB
	85	Bk	CL	5YR5/6	9	V	IIIAL	20	Kc	Qlo	W	SB
	160	Bk	LC	5YR5/8	9	V	IIIAL	10	Kc	Qlo	W	SB
37	25	A	SL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	35	Bk	LSCL	2.5YR4/4	8	S	NIL	0		Qpo	W	SB
	85	Bk	SCL	5YR5/6	9	V	IIIAL	15	Kc	Qlo	W	SB
	160	Bk	CL	5YR5/8	9	V	IIIAL	5	Kc	Qlo	W	SB
38	20	A	SC	10YR5/2	8.5	N	NIL	0		Qpo	W	SB
	90	Bt	MC	10YR5/3	9	M	NIL	0		Qkcy	M	AB
	160	Bk	MC	10YR5/4	9.5	V	I	0		Qlo	M	AB
	175	C	LMC	10YR6/4	9.5	S	NIL	10	Gy	Qhy	W	SB
39	15	A	LSCL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	45	A	SCL	2.5YR4/6	8	N	NIL	0		Qpo	W	SB
	95	Bk	CL	2.5YR5/6	9	V	IIIAL	0		Qlo	W	SB
	155	Bk	LC	2.5YR5/8	9	V	IIIAL	0		Qlo	W	SB
40	35	A	SL	2.5YR4/4	8	N	NIL	0		Qpo	W	SB
	65	A	LSCL	2.5YR4/6	8.5	H	NIL	0		Qpo	W	SB
	155	Bk	LSCL	2.5YR5/6	9	V	IIIB	50	Kc	Qlo	W	SB
41	30	A	CL	7.5YR4/4	8.5	H	NIL	0		Qpo	W	SB
	100	Bk	LC	7.5YR5/6	9	V	IIIAL	10	Kc	Qlo	W	SB
	150	Bk	LMC	7.5YR5/8	9.5	V	I	0		Qlo	W	SB
42	20	A	LSCL	5YR4/4	8	N	NIL	0		Qpo	W	SB
	50	A	SCL	5YR4/6	8.5	H	NIL	0		Qpo	W	SB
	155	Bk	CL	5YR5/6	9	V	IIIAL	10	Kc	Qlo	W	SB
43	35	A	CL	5YR4/4	8	S	NIL	0		Qpo	W	SB
	90	Bk	CL	5YR4/6	9	V	IIIAL	15	Kc	Qlo	W	SB
	150	Bk	LC	5YR5/6	9	V	IIIAL	5	Kc	Qlo	W	SB
44	30	A	CL	5YR4/4	8.5	H	NIL	0		Qpo	W	SB
	105	Bk	CL	5YR4/6	9	V	IIIB	35	Kc	Qlo	W	SB
	170	Bk	LMC	5YR5/6	9.5	V	I	0		Qlo	W	SB

APPENDIX HA-A2

SUMMARY OF CARBONATE LAYER CLASSES

APPENDIX 2: SUMMARY OF CARBONATE LAYER CLASSES

CLASS	DESCRIPTION	NOTES
I	Fine soil carbonate in clay, few if any calcrete fragments present. Boundary with topsoil often diffuse.	Restricts root growth of most cereal and irrigated crops. Usually indicates very poor drainage.
IIR	Sheet or boulder Ripon age calcrete, very hard and usually banded with pinkish colour. Concretions common in layer just above the calcrete.	Restricts growth in sheet form but roots penetrate the areas around boulders. Drainage is excellent through the boulder form of both IIR and IIB but the sheet calcrete form restricts water movement. Class IIR often indicates clay at depth.
IIB	Sheet or boulder Bakara age calcrete, hard with whitish colour.	
IIIAS	Compact mixture of loamy sand to light sandy clay loam and fine soil carbonate. Contains less than 30% calcrete fragments.	Restricts root growth of most cereal and irrigated crops. Medium drainage qualities.
IIIAL	Compact mixture of sandy clay loam to light clay and fine soil carbonate. Contains less than 30% calcrete fragments.	Restricts root growth of most cereal and irrigated crops. Generally poor drainage qualities.
IIIB	As for IIIAS and IIIAL except that calcrete fragments account for 30 – 60% of the layer.	Root growth is good but water holding capacity is limited by the amount of coarse fragments present. Drainage is good.
IIIC	As for IIIAS and IIIAL except that fragments account for greater than 60% of the layer.	Root growth around the calcrete fragments is good but water holding capacity is limited by the amount of coarse fragments present. Drainage is excellent.
IV	Weak accumulation of fine carbonate in a sand to sandy loam. Carbonate present as a coating on sand grains and is visible as whitening in excavated pits.	Class IV seldom restricts root growth and drainage is excellent.

APPENDIX HA-A3

TOPSOIL AND SUBSOIL LABORATORY RESULTS

CSBP LIMITED ABN: 81 008 668 371

ANALYSIS REPORT

CUSTNO	PADDOCK	SAMPLE_ID	SERIAL_NO	LAB_NUMBER	TEXTURE	GRAVEL	COLOUR	NITRATEN	AMMONIUM	PHOS	POTASSIUM	SULPHUR	ORGCARBON	IRON	CONDUCTY	PH_CACL2
UNITS								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	dS/m	pH
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 25	PIT 1	ZG S06007	1.5		BROR	3	2	7	391	2.8	0.53	429	0.104	7.7
67337	BEMAX SNAPPER PIT 1 TO 8	25 TO 95 A	PIT 1	ZG S06008	3		BROR	28	1	3	135	5.7	0.42	305	0.198	7.9
67337	BEMAX SNAPPER PIT 1 TO 8	25 TO 95 B	PIT 1	ZG S06009	3		BROR	2	2	2	218	112	0.14	354	0.906	8.5
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 25	PIT 2	ZG S06010	3		BROR	2	1	7	486	4.6	0.66	434	0.135	8.1
67337	BEMAX SNAPPER PIT 1 TO 8	25 TO 135	PIT 2	ZG S06011	3		BROR	8	3	4	227	14.3	0.37	363	0.517	8.3
67337	BEMAX SNAPPER PIT 1 TO 8	135 TO 155	PIT 2	ZG S06012	3.5		BROR	7	6	2	220	396	0.13	444	1.564	8.4
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 35	PIT 3	ZG S06013	3		BROR	27	1	14	869	9.3	0.82	483	0.326	8.5
67337	BEMAX SNAPPER PIT 1 TO 8	35 TO 55	PIT 3	ZG S06014	3.5		BROR	6	1	4	128	6.1	0.4	384	0.201	8.1
67337	BEMAX SNAPPER PIT 1 TO 8	55 TO 125	PIT 3	ZG S06015	3.5		BROR	2	2	3	153	40.6	0.29	385	0.527	8.3
67337	BEMAX SNAPPER PIT 1 TO 8	125 TO 200	PIT 3	ZG S06016	3.5		BROR	2	3	2	201	430	0.16	405	1.375	8.4
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 35	PIT 4	ZG S06017	2.5		BROR	2	2	5	508	2.9	0.62	415	0.097	8
67337	BEMAX SNAPPER PIT 1 TO 8	35 TO 105	PIT 4	ZG S06018	3.5		BROR	20	2	3	402	4.9	0.36	379	0.353	8.3
67337	BEMAX SNAPPER PIT 1 TO 8	105 TO 195	PIT 4	ZG S06019	3.5		BROR	7	2	2	150	251	0.18	271	0.935	8.4
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 15	PIT 5	ZG S06020	2		BROR	1	1	17	317	1.9	0.5	403	0.034	7.1
67337	BEMAX SNAPPER PIT 1 TO 8	15 TO 55	PIT 5	ZG S06021	3		BROR	2	1	4	190	33.4	0.46	265	0.644	8.2
67337	BEMAX SNAPPER PIT 1 TO 8	55 TO 200	PIT 5	ZG S06022	3		BROR	2	1	3	145	227	0.31	299	1.209	8.3
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 40	PIT 6	ZG S06023	2.5		BROR	1	2	10	284	1.6	0.39	345	0.081	7.9
67337	BEMAX SNAPPER PIT 1 TO 8	40 TO 70	PIT 6	ZG S06024	2		BROR	2	1	2	174	8	0.29	176	0.167	8.3
67337	BEMAX SNAPPER PIT 1 TO 8	70 TO 200	PIT 6	ZG S06025	3.5		BROR	1	2	2	176	357	0.2	266	0.94	8.3
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 30	PIT 7	ZG S06026	2.5		BROR	1	2	8	261	3.7	0.5	259	0.087	7.8
67337	BEMAX SNAPPER PIT 1 TO 8	30 TO 155	PIT 7	ZG S06027	3.5		BROR	3	1	4	109	61.8	0.39	221	0.442	8.2
67337	BEMAX SNAPPER PIT 1 TO 8	155 TO 175	PIT 7	ZG S06028	3.5		BROR	3	2	4	201	1621	0.19	282	1.793	8.3
67337	BEMAX SNAPPER PIT 1 TO 8	0 TO 10	PIT 8	ZG S06029	2.5		BROR	3	3	16	351	74.2	0.54	309	0.053	7.1
67337	BEMAX SNAPPER PIT 1 TO 8	10 TO 35	PIT 8	ZG S06030	3.5		BROR	2	1	7	213	37.4	0.43	287	0.671	8.1
67337	BEMAX SNAPPER PIT 8 TO 19	35 TO 190	PIT 8	ZG S06032	3.5		BROR	5	2	5	184	212	0.26	345	0.993	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 30	PIT 9	ZG S06033	3		BROR	3	3	5	556	5.7	0.38	293	0.116	7.9
67337	BEMAX SNAPPER PIT 8 TO 19	30 TO 75	PIT 9	ZG S06034	3.5		BROR	13	3	4	245	8.8	0.32	354	0.388	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	75 TO 180	PIT 9	ZG S06035	3.5		BROR	5	2	4	194	371	0.22	391	1.109	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 25	PIT 10	ZG S06036	2		BROR	1	2	12	263	1.5	0.53	329	0.031	6.9
67337	BEMAX SNAPPER PIT 8 TO 19	25 TO 75	PIT 10	ZG S06037	2.5		BROR	2	1	3	129	6.3	0.27	239	0.095	8.2
67337	BEMAX SNAPPER PIT 8 TO 19	75 TO 125	PIT 10	ZG S06038	3.5		BROR	5	2	3	179	91.4	0.26	278	0.584	8.4
67337	BEMAX SNAPPER PIT 8 TO 19	125 TO 200	PIT 10	ZG S06039	3		BROR	1	1	2	140	125	0.13	273	0.567	8.4
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 15	PIT 11	ZG S06040	2		BROR	1	1	13	340	1.6	0.48	325	0.045	7.4
67337	BEMAX SNAPPER PIT 8 TO 19	15 TO 35	PIT 11	ZG S06041	3		BROR	1	2	3	172	3.8	0.36	261	0.113	8
67337	BEMAX SNAPPER PIT 8 TO 19	35 TO 75	PIT 11	ZG S06042	3.5		BROR	10	2	5	127	39	0.32	262	0.583	8.2
67337	BEMAX SNAPPER PIT 8 TO 19	75 TO 195	PIT 11	ZG S06043	2.5		BROR	3	1	4	130	100	0.11	276	0.622	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 15	PIT 12	ZG S06044	2		BROR	1	1	9	284	1.2	0.37	322	0.051	7.3
67337	BEMAX SNAPPER PIT 8 TO 19	15 TO 40	PIT 12	ZG S06045	3		BROR	16	1	3	279	11.6	0.34	273	0.259	8.2
67337	BEMAX SNAPPER PIT 8 TO 19	40 TO 95	PIT 12	ZG S06046	3.5		BROR	3	1	4	166	81.3	0.36	255	0.776	8.2
67337	BEMAX SNAPPER PIT 8 TO 19	95 TO 180	PIT 12	ZG S06047	3		BROR	1	1	3	103	131	0.18	206	0.57	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 15	PIT 13	ZG S06048	2.5		BROR	1	1	10	249	1.4	0.4	272	0.063	7.6
67337	BEMAX SNAPPER PIT 8 TO 19	15 TO 35	PIT 13	ZG S06049	2.5		BROR	1	1	4	153	3.8	0.34	297	0.098	7.4
67337	BEMAX SNAPPER PIT 8 TO 19	35 TO 120	PIT 13	ZG S06050	3		BROR	5	2	3	124	16.6	0.26	290	0.356	7.9
67337	BEMAX SNAPPER PIT 8 TO 19	120 TO 200	PIT 13	ZG S06051	3		BROR	1	3	3	167	190	0.17	263	0.857	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 25	PIT 14	ZG S06052	3		BR	3	2	5	330	2.5	0.5	309	0.09	7.9
67337	BEMAX SNAPPER PIT 8 TO 19	25 TO 45	PIT 14	ZG S06053	3.5		BROR	33	2	2	252	11.4	0.38	330	0.328	8.1
67337	BEMAX SNAPPER PIT 8 TO 19	45 TO 180	PIT 14	ZG S06054	3.5		BROR	8	2	2	219	170	0.32	409	0.881	8.4
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 15	PIT 15	ZG S06055	2.5		BROR	2	53	16	348	2.2	0.64	533	0.05	7
67337	BEMAX SNAPPER PIT 8 TO 19	15 TO 45	PIT 15	ZG S06056	3.5		BRRD	13	2	4	173	7.6	0.32	409	0.108	6.9
67337	BEMAX SNAPPER PIT 8 TO 19	45 TO 90	PIT 15	ZG S06057	3.5		BROR	1	2	4	213	6	0.18	395	0.246	8.2
67337	BEMAX SNAPPER PIT 8 TO 19	90 TO 195	PIT 15	ZG S06058	3		BROR	1	2	3	210	7.5	0.14	366	0.295	8.2
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 35	PIT 16	ZG S06059	2.5		BROR	1	1	5	189	1.8	0.28	345	0.03	7.1
67337	BEMAX SNAPPER PIT 8 TO 19	35 TO 55	PIT 16	ZG S06060	3		BROR	1	3	2	188	3.2	0.25	293	0.174	8.1
67337	BEMAX SNAPPER PIT 8 TO 19	55 TO 80	PIT 16	ZG S06061	3.5		BROR	1	3	2	325	93.5	0.23	364	0.742	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	80 TO 190	PIT 16	ZG S06062	3.5		BROR	1	1	2	240	192	0.24	387	0.918	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 25	PIT 17	ZG S06063	2.5		BROR	1	1	5	304	2	0.52	373	0.14	7.9

67337	BEMAX SNAPPER PIT 8 TO 19	25 TO 60	PIT 17	ZG S06064	2.5		BROR	12	1	3	310	7.2	0.37	369	0.179	8
67337	BEMAX SNAPPER PIT 8 TO 19	60 TO 125	PIT 17	ZG S06065	3.5		LTBR	17	1	2	199	123	0.3	266	0.879	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	125 TO 200	PIT 17	ZG S06066	3.5		BROR	4	1	2	238	187	0.16	267	1.01	8.4
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 40	PIT 18	ZG S06067	3.5		BR	1	1	2	233	3.9	0.41	287	0.153	8
67337	BEMAX SNAPPER PIT 8 TO 19	40 TO 75	PIT 18	ZG S06068	3.5		BR	5	2	3	280	8.9	0.38	325	0.153	8.1
67337	BEMAX SNAPPER PIT 8 TO 19	75 TO 190	PIT 18	ZG S06069	3.5		BROR	1	1	2	265	272	0.22	306	0.995	8.3
67337	BEMAX SNAPPER PIT 8 TO 19	0 TO 25	PIT 19	ZG S06070	3		BROR	1	1	7	240	1.7	0.54	310	0.133	8
67337	BEMAX SNAPPER PIT 8 TO 19	25 TO 55	PIT 19	ZG S06071	3		BROR	1	1	2	102	10	0.4	224	0.232	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	55 TO 160	PIT 19	ZG S06073	3.5		BROR	1	2	3	168	224	0.17	403	0.975	8.2
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 20	PIT 20	ZG S06074	3		BRGR	6	2	8	325	3.6	0.97	329	0.159	8
67337	BEMAX SNAPPER PIT 19 TO 32	20 TO 40	PIT 20	ZG S06075	3		GRBR	1	1	6	133	6.3	0.6	272	0.115	7.9
67337	BEMAX SNAPPER PIT 19 TO 32	40 TO 145	PIT 20	ZG S06076	3.5		BRGR	5	1	4	159	26.1	0.3	284	0.419	8.2
67337	BEMAX SNAPPER PIT 19 TO 32	145 TO 165	PIT 20	ZG S06077	3.5		BROR	2	1	3	336	429	0.22	354	1.615	8.4
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 35	PIT 21	ZG S06078	2.5		BR	2	1	3	520	2.2	0.64	303	0.092	8
67337	BEMAX SNAPPER PIT 19 TO 32	35 TO 80	PIT 21	ZG S06079	3.5		BROR	2	1	2	486	4.8	0.31	372	0.166	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	80 TO 155	PIT 21	ZG S06080	3.5		BROR	3	1	2	288	22.9	0.16	293	0.323	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 40	PIT 22	ZG S06081	2.5		BROR	1	1	5	279	3.6	0.35	289	0.065	7.6
67337	BEMAX SNAPPER PIT 19 TO 32	40 TO 55	PIT 22	ZG S06082	2.5		BROR	5	1	2	126	7.1	0.27	279	0.287	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	55 TO 165	PIT 22	ZG S06083	3.5		BROR	1	1	2	186	135	0.24	308	0.956	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 85	PIT 23	ZG S06084	1.5		BROR	2	1	6	153	2.3	0.28	311	0.126	7.9
67337	BEMAX SNAPPER PIT 19 TO 32	85 TO 160	PIT 23	ZG S06085	3		BROR	6	1	2	139	16.6	0.16	243	0.288	8.5
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 45	PIT 24	ZG S06086	2		BROR	1	1	6	257	3.6	0.56	342	0.107	8.2
67337	BEMAX SNAPPER PIT 19 TO 32	45 TO 75	PIT 24	ZG S06087	1.5		BROR	3	1	2	185	11.4	0.21	265	0.143	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	75 TO 165	PIT 24	ZG S06088	2		BROR	1	1	2	259	81.2	0.09	332	0.516	8.5
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 15	PIT 25	ZG S06089	2.5		BROR	1	2	13	475	2.6	0.67	418	0.083	7.7
67337	BEMAX SNAPPER PIT 19 TO 32	15 TO 30	PIT 25	ZG S06090	3.5		BROR	5	2	4	400	3.2	0.44	458	0.137	8
67337	BEMAX SNAPPER PIT 19 TO 32	30 TO 90	PIT 25	ZG S06091	3.5		BROR	11	4	4	573	16.7	0.3	471	0.512	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	90 TO 170	PIT 25	ZG S06092	3.5		BROR	2	2	2	253	183	0.15	326	0.796	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 35	PIT 26	ZG S06093	1.5		BROR	1	1	3	405	1.4	0.41	438	0.138	8
67337	BEMAX SNAPPER PIT 19 TO 32	35 TO 90	PIT 26	ZG S06094	3		BROR	19	1	2	479	5.3	0.21	383	0.344	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	90 TO 170	PIT 26	ZG S06095	3.5		BROR	3	1	2	534	189	0.2	461	0.942	8.4
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 45	PIT 27	ZG S06096	1.5		BROR	2	1	5	342	1.8	0.29	352	0.102	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	45 TO 90	PIT 27	ZG S06103	1.5		BROR	6	4	2	273	3.7	0.2	219	0.106	7.6
67337	BEMAX SNAPPER PIT 19 TO 32	90 TO 105	PIT 27	ZG S06104	2		BROR	11	1	2	260	9.6	0.06	223	0.16	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	105 TO 135	PIT 27	ZG S06105	3		BROR	11	1	2	261	13.4	0.11	227	0.202	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	135 TO 165	PIT 27	ZG S06106	2		BROR	14	1	2	257	12.3	-0.05	205	0.307	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 45	PIT 28	ZG S06107	2.5		BROR	52	1	8	744	19.6	0.38	397	0.573	8.99
67337	BEMAX SNAPPER PIT 19 TO 32	45 TO 110	PIT 28	ZG S06108	3		BROR	3	1	2	200	149.1	0.26	309	0.943	8.11
67337	BEMAX SNAPPER PIT 19 TO 32	110 TO 165	PIT 28	ZG S06109	3		BROR	2	1	1	201	364.2	0.10	346	0.917	8.13
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 35	PIT 29	ZG S06110	2		BR	1	1	9	301	1.4	0.43	404	0.084	7.8
67337	BEMAX SNAPPER PIT 19 TO 32	35 TO 60	PIT 29	ZG S06111	2.5		BROR	1	1	3	271	3	0.24	373	0.116	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	60 TO 105	PIT 29	ZG S06112	3		BROR	1	1	2	264	6.4	0.13	334	0.296	8.2
67337	BEMAX SNAPPER PIT 19 TO 32	105 TO 165	PIT 29	ZG S06113	2.5		BROR	1	1	2	191	89.3	0.08	209	0.515	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 30	PIT 30	ZG S06114	3.5		BR	1	2	16	402	2.6	0.96	438	0.11	7.7
67337	BEMAX SNAPPER PIT 19 TO 32	30 TO 75	PIT 30	ZG S06115	3.5		BROR	35	1	6	119	8.4	0.41	218	0.302	8
67337	BEMAX SNAPPER PIT 19 TO 32	75 TO 150	PIT 30	ZG S06116	3.5		BROR	33	2	3	208	95.6	0.17	333	0.901	8.3
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 25	PIT 31	ZG S06117	3.5		BR	2	1	3	459	2.1	0.45	647	0.141	8
67337	BEMAX SNAPPER PIT 19 TO 32	25 TO 60	PIT 31	ZG S06118	3.5		BR	31	2	2	233	2.7	0.3	664	0.151	8
67337	BEMAX SNAPPER PIT 19 TO 32	60 TO 80	PIT 31	ZG S06119	3.5		BR	6	2	2	198	3	0.25	561	0.267	8.1
67337	BEMAX SNAPPER PIT 19 TO 32	80 TO 155	PIT 31	ZG S06120	3.5		BROR	7	2	2	214	47.9	0.07	462	0.56	8.5
67337	BEMAX SNAPPER PIT 19 TO 32	0 TO 15	PIT 32	ZG S06121	2.5		BROR	1	1	12	400	1.7	0.45	779	0.093	7.8
67337	BEMAX SNAPPER PIT 32 TO 44	15 TO 95	PIT 32	ZG S06123	3		BROR	2	1	7	288	2.3	0.12	578	0.054	7.1
67337	BEMAX SNAPPER PIT 32 TO 44	95 TO 125	PIT 32	ZG S06124	3.5		BROR	1	2	3	237	2.3	0.1	477	0.149	7.4
67337	BEMAX SNAPPER PIT 32 TO 44	125 TO 170	PIT 32	ZG S06125	3.5		BROR	1	2	2	203	2	0.11	418	0.109	7.7
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 25	PIT 33	ZG S06126	3.5		BR	1	2	7	345	3.2	0.69	446	0.117	7.9
67337	BEMAX SNAPPER PIT 32 TO 44	25 TO 50	PIT 33	ZG S06127	3.5	5	BROR	12	1	5	139	8.6	0.4	385	0.448	8.1
67337	BEMAX SNAPPER PIT 32 TO 44	50 TO 120	PIT 33	ZG S06128	3.5		BROR	6	1	3	302	188	0.14	439	0.647	8.5
67337	BEMAX SNAPPER PIT 32 TO 44	120 TO 185	PIT 33	ZG S06129	3.5		BROR	11	2	2	370	339	0.08	457	1.006	8
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 40	PIT 34	ZG S06130	2		BR	1	1	7	344	2	0.42	355	0.075	7.7
67337	BEMAX SNAPPER PIT 32 TO 44	40 TO 60	PIT 34	ZG S06131	2.5		BROR	2	2	3	146	4.9	0.16	304	0.179	8.3
67337	BEMAX SNAPPER PIT 32 TO 44	60 TO 150	PIT 34	ZG S06132	3		BROR	5	1	3	164	79.5	0.17	284	0.567	8.3
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 25	PIT 35	ZG S06133	2.5		BR	1	1	5	439	2.8	0.48	390	0.095	8.1
67337	BEMAX SNAPPER PIT 32 TO 44	25 TO 65	PIT 35	ZG S06134	3		BROR	3	1	2	147	4.8	0.28	429	0.186	8.2

67337	BEMAX SNAPPER PIT 32 TO 44	65 TO 125	PIT 35	ZG S06135	3.5	BROR	1	1	2	217	151	0.16	363	0.783	8.4
67337	BEMAX SNAPPER PIT 32 TO 44	125 TO 150	PIT 35	ZG S06136	3.5	BROR	1	2	2	330	520	0.07	395	1.425	8.5
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 20	PIT 36	ZG S06137	3.5	BROR	2	4	2	612	2.3	0.45	405	0.142	7.9
67337	BEMAX SNAPPER PIT 32 TO 44	20 TO 45	PIT 36	ZG S06138	3.5	BROR	7	5	2	376	5.6	0.41	584	0.12	8
67337	BEMAX SNAPPER PIT 32 TO 44	45 TO 85	PIT 36	ZG S06139	3.5	GRBR	4	4	4	126	6.1	0.28	430	0.166	8.1
67337	BEMAX SNAPPER PIT 32 TO 44	85 TO 160	PIT 36	ZG S06140	3.5	BRGR	1	4	4	118	2.9	0.1	369	0.197	8.2
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 25	PIT 37	ZG S06141	1.5	BR	3	2	30	434	2.2	0.36	492	0.088	7.9
67337	BEMAX SNAPPER PIT 32 TO 44	25 TO 35	PIT 37	ZG S06142	2	BROR	1	2	8	289	2.1	0.22	436	0.087	8
67337	BEMAX SNAPPER PIT 32 TO 44	35 TO 85	PIT 37	ZG S06143	3.5	BROR	1	2	6	266	2.2	0.14	376	0.124	8.1
67337	BEMAX SNAPPER PIT 32 TO 44	85 TO 160	PIT 37	ZG S06144	2.5	BROR	1	2	4	189	3.4	0.05	414	0.184	8.3
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 20	PIT 38	ZG S06145	3.5	GRBR	2	3	13	458	5.3	0.57	699	0.11	7.9
67337	BEMAX SNAPPER PIT 32 TO 44	20 TO 90	PIT 38	ZG S06146	3.5	GRBR	3	3	3	159	7.2	0.24	687	0.24	8
67337	BEMAX SNAPPER PIT 32 TO 44	90 TO 160	PIT 38	ZG S06147	3.5	BRGR	2	2	16	201	138	0.15	584	1.062	8.5
67337	BEMAX SNAPPER PIT 32 TO 44	160 TO 175	PIT 38	ZG S06148	3.5	GRBR	4	4	14	277	3355	0.12	634	4.098	8
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 15	PIT 39	ZG S06149	2	BR	1	2	56	478	171	0.44	470	0.116	7.8
67337	BEMAX SNAPPER PIT 32 TO 44	15 TO 45	PIT 39	ZG S06150	2.5	BROR	1	2	19	351	2.2	0.26	158	0.112	8
67337	BEMAX SNAPPER PIT 32 TO 44	45 TO 95	PIT 39	ZG S06151	3	BROR	1	3	17	283	6.6	0.16	313	0.124	8.3
67337	BEMAX SNAPPER PIT 32 TO 44	95 TO 155	PIT 39	ZG S06152	3.5	BROR	1	2	6	315	33.1	0.08	421	0.52	8.5
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 35	PIT 40	ZG S06153	1.5	BR	2	2	9	401	9.4	0.45	344	0.102	7.9
67337	BEMAX SNAPPER PIT 32 TO 44	35 TO 65	PIT 40	ZG S06154	1.5	BRRD	1	1	2	146	5	0.23	351	0.088	8.1
67337	BEMAX SNAPPER PIT 32 TO 44	65 TO 155	PIT 40	ZG S06155	3	LTGR	3	2	3	90	5	0.2	237	0.196	8.2
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 30	PIT 41	ZG S06156	3	BR	3	2	13	383	10.7	0.63	407	0.116	7.9
67337	BEMAX SNAPPER PIT 32 TO 44	30 TO 100	PIT 41	ZG S06157	3.5	BROR	10	2	4	138	9.8	0.28	371	0.39	8.2
67337	BEMAX SNAPPER PIT 32 TO 44	100 TO 150	PIT 41	ZG S06158	3.5	BROR	1	2	7	216	309	0.14	454	1.179	8.6
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 20	PIT 42	ZG S06159	2.5	BR	2	1	7	375	2.5	0.45	399	0.076	8
67337	BEMAX SNAPPER PIT 32 TO 44	20 TO 50	PIT 42	ZG S06160	3	BROR	1	2	4	212	4.4	0.25	370	0.111	8
67337	BEMAX SNAPPER PIT 32 TO 44	50 TO 155	PIT 42	ZG S06161	3	BROR	2	2	2	270	2.5	0.15	332	0.216	8.3
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 35	PIT 43	ZG S06162	2	BR	1	2	11	397	3.9	0.4	382	0.096	8.2
67337	BEMAX SNAPPER PIT 32 TO 44	35 TO 90	PIT 43	ZG S06163	2.5	BROR	2	2	5	232	3.8	0.19	339	0.118	8.1
67337	BEMAX SNAPPER PIT 32 TO 44	90 TO 150	PIT 43	ZG S06164	3.5	BROR	1	2	4	162	58.8	0.14	347	0.585	8.3
67337	BEMAX SNAPPER PIT 32 TO 44	0 TO 30	PIT 44	ZG S06165	3	BROR	1	2	7	390	2.6	0.45	369	0.106	8.1
67337	BEMAX SNAPPER PIT 32 TO 44	30 TO 105	PIT 44	ZG S06166	3.5	BROR	2	2	4	157	6	0.29	380	0.108	8
67337	BEMAX SNAPPER PIT 32 TO 44	105 TO 170	PIT 44	ZG S06167	3.5	BROR	1	1	3	172	194	0.11	338	0.783	8.4

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pH	mg/kg	mg/kg	mg/kg	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	Index	%	meq/100g	meq/100g	meq/100g	meq/100g	
PH_H2O	DTPA_CU	DTPA_ZN	DTPA_MN	DTPA_FE	EXC_CA	EXC_MG	EXC_NA	EXC_K	BORON_HOT	DISPERSION	Saturated Moisture Content	Saturated Na	Saturated Mg	Saturated K	Saturated Ca	Saturated Conductivity
8.5	0.68	0.29	3.28	8.38	11.7	1.26	0.16	0.97	0.7	0	24.30	1.49	0.61	0.51	3.22	0.48
8.7	1.2	0.11	1.38	6.92	13.02	3.86	0.61	0.33	1	0	39.67	6.33	2.12	0.07	4.21	1.33
9.6	0.58	0.08	0.6	6.98	5.29	6.34	7.71	0.57	32.2	10	57.78	64.55	4.06	0.23	0.86	6.91
8.9	1.07	0.14	2.87	2.97	13.03	1.65	0.23	1.22	1	0	33.50	1.93	0.65	0.54	3.08	0.55
9.5	1.37	0.14	1.46	7.82	9.63	4.58	3.36	0.56	2.7	0	43.61	33.43	3.67	0.26	2.40	4.16
9	0.63	0.11	0.8	10.18	7.27	10.53	9.94	0.62	38.8	9	58.67	99.33	24.61	0.32	8.14	12.59
9.7	0.46	0.45	4.92	6.21	8.2	2.86	2.55	2.17	2.3	0	31.53	17.72	1.81	1.96	2.53	1.94
9.3	1.33	0.12	2.44	6.96	10.98	2.76	1.28	0.32	0.8	0	34.18	9.90	1.49	0.13	1.37	1.26
9.7	1.11	0.09	1.96	5.81	8.39	5.03	4.56	0.39	8.9	0	41.78	45.13	4.23	0.19	1.74	5.30
9.1	1.09	0.17	1.46	11.82	7.67	8.13	9.09	0.51	40.3	0	56.77	86.58	19.06	0.25	5.79	11.01
8.8	0.73	0.27	3.52	5.82	13.72	2.13	0.23	1.29	1.1	0	31.85	1.95	0.60	0.44	2.61	0.50
9.4	1.92	0.14	1.72	7.26	9.43	5.05	2.95	0.97	3.4	0	47.31	18.69	1.82	0.37	0.84	2.29
9.4	0.84	0.08	1.15	5.25	7.83	5.23	6.59	0.39	29.6	0	51.01	66.67	8.79	0.19	3.60	7.85
7.6	0.61	0.62	5.77	7.68	5.72	2.58	0.12	0.7	1	0	22.95	1.42	1.29	0.36	2.08	0.46
9.1	1.14	0.2	2.86	8.79	8.48	3.32	5.66	0.49	1.2	0	37.93	58.40	3.82	0.22	5.66	6.87
8.9	1.43	0.1	1.62	8.06	10.14	6.45	6.9	0.44	18.3	0	49.22	88.30	20.84	0.25	14.25	12.30
9	0.75	0.32	6.01	5.85	5.73	1.29	0.21	0.71	0.7	1	25.08	2.23	0.61	0.40	1.69	0.46
9.3	0.77	0.08	1.92	3.47	6.52	2.35	1.52	0.41	1.6	0	27.85	12.11	0.69	0.16	1.06	1.41
8.9	1.22	0.04	1.31	6.08	9.23	5.35	5.24	0.46	9.4	0	42.44	72.95	20.50	0.37	17.10	10.27
8.5	0.71	0.29	4.3	5.27	10.39	2	0.13	0.64	1	0	25.09	1.03	1.03	0.24	3.10	0.49
9.1	1.17	0.14	1.94	7.09	10.69	3.93	2.96	0.28	4.4	0	40.57	39.15	7.12	0.16	7.15	5.35
8.6	0.79	0.09	1.1	6.24	8.83	8.53	7.57	0.53	37.1	9	45.47	104.15	47.52	0.55	28.03	19.12
7.9	0.75	0.41	6.03	6.44	6.8	3.23	0.22	0.86	0.9	0	23.37	2.05	1.13	0.33	1.71	0.49
8.8	1.32	0.25	2.57	7.33	12.32	4.01	5	0.59	1.2	0	44.86	48.18	8.11	0.24	12.46	6.89
9	2.39	0.16	1.83	10.05	10.51	8.22	8.11	0.5	30.4	0	57.69	71.77	13.44	0.15	8.02	9.18
8.7	1.3	0.17	3.43	8.37	10.73	4.73	0.73	1.39	1.1	0	40.60	3.66	0.87	0.34	1.50	0.63
9.3	2.33	0.26	2.02	9.35	12.77	7.64	4.56	0.64	4.1	0	55.21	20.95	2.34	0.17	1.70	2.61
9.1	1.76	0.2	1.81	11.01	10.7	8.56	8.98	0.54	40.9	9	59.24	70.93	11.88	0.15	8.79	9.13
7.6	0.9	0.57	5.52	9.04	4.21	1.21	0.2	0.57	1	0	21.57	2.20	1.11	0.69	0.97	0.41
9	1.05	0.15	2.5	5.28	7.11	2.37	0.78	0.31	20.3	0	26.45	5.21	0.70	0.05	1.19	0.69
9.4	1.5	0.28	1.42	6.85	8.92	4.97	4.94	0.47	1.1	0	39.77	47.96	5.78	0.14	4.52	5.79
9.5	0.79	0.07	1.15	5.44	8.54	4.73	4.2	0.36	1	0	34.53	50.13	5.46	0.18	3.85	5.84
8.2	0.57	0.45	4.9	4.92	6.17	1.7	0.28	0.84	6.4	0	22.03	2.30	0.66	0.45	1.07	0.40
8.8	1.04	0.12	3.21	4.36	9.65	2.3	0.6	0.45	39.2	0	27.96	4.62	0.66	0.09	2.02	0.71
8.9	1.38	0.12	1.89	5.75	10.82	3.64	3.04	0.31	0.8	9	37.65	47.15	10.22	0.21	12.58	6.98
9.3	0.74	0.06	0.92	6.42	7.66	3.97	3.44	0.37	2.6	0	29.96	62.32	9.04	0.32	5.26	7.45
7.9	0.58	0.46	4.67	8.29	5.59	1.7	0.1	0.69	19	1	24.09	0.99	1.14	0.40	2.68	0.48
9	1.14	0.16	2.71	5.35	9.42	3.71	2.07	0.73	0.5	0	32.11	23.35	3.27	0.37	4.03	3.26
9.2	1.28	0.14	1.61	7.1	9.97	4.79	4.9	0.47	0.9	9	42.80	60.41	8.19	0.27	6.61	7.57
9.4	0.9	0.09	1.12	4.82	7.96	3.84	3.46	0.3	11.8	0	35.71	48.44	5.65	0.22	3.32	5.76
8.3	0.66	0.29	4.46	6.05	7.41	1.44	0.06	0.66	0.5	10	23.31	0.51	0.75	0.24	2.54	0.35
8.7	1	0.15	2.71	4.1	10.97	1.88	0.21	0.39	2	0	26.86	1.91	0.69	0.08	2.26	0.43
9.2	1.25	0.09	1.49	5.27	9.53	4.7	2.27	0.34	0.7	0	36.63	25.19	4.18	0.20	3.21	3.48
9.5	0.86	0.05	1.18	5.85	6.76	4.9	5.98	0.43	2.1	0	45.47	68.54	7.08	0.36	2.73	7.98
8.6	0.78	0.16	3.29	4.82	8.2	2.07	0.2	0.83	5.9	2	26.09	2.47	0.94	0.41	2.24	0.56
9.1	1.16	0.18	2.07	6.59	10.5	5.02	2.35	0.67	0.8	0	38.11	22.90	4.36	0.43	4.37	3.36
9.5	1.57	0.08	2.06	11.54	9.28	6	7.73	0.68	1.1	0	52.25	64.98	6.78	0.30	3.20	7.56
8	0.95	0.92	8.42	8.83	5.82	2.92	0.57	0.86	8.6	0	23.59	4.61	1.21	0.66	0.83	0.63
8	1.64	0.24	3.97	9.38	11.89	7.76	1.92	0.47	18.6	0	45.64	6.83	0.99	0.10	1.26	0.96
9.4	1.35	0.17	1.61	10.22	10.32	6.2	2.66	0.56	0.7	0	37.39	7.99	0.40	0.11	0.40	0.85
9.5	0.95	0.09	1.06	7.11	8.27	4.95	2.81	0.54	1.5	0	36.00	14.00	1.42	0.17	0.47	1.62
7.8	1.09	0.18	4.89	5.48	5.16	1.8	0.2	0.45	20.4	0	25.01	1.95	0.60	0.12	1.07	0.34
9.2	1.06	0.1	2.68	6.88	7.33	2.88	1.44	0.49	0.8	0	29.28	10.90	1.52	0.11	1.14	1.36
9.3	1.67	0.1	1.75	8.47	8.32	6.21	5.79	0.86	0.7	0	46.62	55.04	7.17	0.41	4.63	6.79
9.4	1.29	0.1	1.47	7.31	8.27	5.27	5.02	0.63	1.1	0	43.13	61.90	8.83	0.43	5.03	7.65
8.8	0.87	0.27	3.48	5.15	10.06	1.41	0.18	0.77	1.2	1	23.47	1.38	0.50	0.28	1.99	0.38

9	1.27	0.19	2.12	5.02	10.47	2.46	0.63	0.72	1.8	0	31.14	8.21	2.08	0.41	4.38	1.61
9.3	1.39	0.13	1.35	5.27	8.49	4.84	4.81	0.52	2	0	41.71	73.18	14.64	0.60	6.95	9.57
9.3	0.92	0.07	1.09	4.21	7.5	5.09	5.4	0.62	3.8	10	37.84	76.83	15.12	0.70	5.86	9.86
8.8	1.3	0.15	2.5	5.26	14.08	3.14	0.19	0.6	7.3	0	33.01	1.26	0.70	0.11	2.75	0.44
9	1.04	0.04	1.41	7.4	12.79	4.36	0.68	0.75	0.5	0	47.89	3.28	0.83	0.13	1.16	0.53
9.3	0.88	-0.01	1.22	7.91	8.44	6.56	6.07	0.72	0.7	1	45.84	65.63	12.35	0.52	5.99	8.44
8.7	0.48	0.28	2.93	3.67	8.92	1.65	0.12	0.6	1.6	0	23.46	0.84	0.79	0.18	2.99	0.47
9.5	1	0.03	1.94	4.72	11.01	3.08	2.11	0.29	9.1	0	36.78	13.68	1.45	0.11	1.04	1.63
9.2	0.95	-0.01	1.29	6.1	8.94	5.74	6	0.47	0.7	0	48.88	68.72	11.34	0.19	5.33	8.49
8.7	0.61	0.3	3.57	4.73	12.7	1.32	0.14	0.87	3.5	9	27.49	1.28	0.62	0.41	4.21	0.57
8.8	1.41	0.19	2.22	5.36	13.6	1.83	0.28	0.37	11.6	0	33.51	2.31	0.62	0.06	2.07	0.45
9.4	1.22	0.03	1.32	5.23	8.46	3.28	2.48	0.4	0.7	1	42.64	30.19	3.07	0.25	1.57	3.73
9.1	0.8	0.03	1.49	6.11	7.43	7.13	8.4	0.9	0.7	0	54.51	91.72	21.73	0.97	7.68	12.19
8.8	0.59	0.22	3.76	4.72	9.26	1.53	0.08	1.34	1.2	1	25.80	0.51	0.66	1.02	2.39	0.41
9.2	1.6	0.04	1.45	5.22	9.39	4.93	0.53	1.23	9.9	0	40.39	2.74	0.87	0.40	0.59	0.45
9.7	0.98	0.18	0.94	5.91	7.17	4.12	3.27	0.73	0.6	0	43.60	15.01	0.51	0.20	0.25	1.60
8.3	0.68	0.16	3.3	4.88	6.66	1.54	0.11	0.67	1.6	1	23.47	1.36	1.05	0.34	3.22	0.61
9	0.84	0.07	1.62	4.89	8.73	2.5	1.5	0.35	2.7	0	30.37	21.65	3.78	0.17	5.60	3.28
9.3	1.23	0.04	1.46	6.38	9.47	6.01	5.43	0.52	5.1	0	46.21	67.41	9.20	0.25	6.23	8.24
8.6	0.43	0.17	2.28	5.41	4.22	1.18	0.24	0.39	0.5	9	25.66	3.37	0.80	0.29	1.91	0.56
9.5	0.46	0.04	0.58	5.94	7.1	4.06	1.77	0.33	0.8	0	28.47	22.42	2.49	0.19	1.64	2.80
8.9	0.41	0.21	3.38	5.26	6.75	1	0.17	0.65	2.4	10	26.80	2.20	0.50	0.49	1.80	0.44
9.3	0.8	0.02	1.43	3.9	6.63	2.06	0.65	0.47	22.1	0	24.97	9.12	0.96	0.26	1.39	1.10
9.5	0.54	0.03	0.9	4.45	6.08	3.41	3.11	0.69	1	1	26.27	58.26	7.69	0.89	3.79	7.05
8.4	0.55	0.48	5.57	7.6	8.13	2.08	0.25	1.21	2	0	23.90	2.55	0.78	0.56	2.06	0.51
8.7	0.89	0.12	2.79	6.6	13.19	4.42	0.25	1.14	13.6	9	35.09	1.92	1.22	0.40	3.17	0.64
9.4	1.69	0.16	1.93	6.92	8.66	6.01	3.51	1.52	0.5	0	43.21	34.43	5.03	1.14	2.05	4.54
9.5	0.74	0.03	1.28	6.28	7.48	4.31	5.2	0.69	0.9	0	44.25	61.81	5.65	0.52	2.36	6.99
8.7	0.64	0.09	3.36	4.73	7.58	1.4	0.18	1.08	3.8	0	24.24	1.69	0.53	0.60	1.78	0.43
9.1	0.82	-0.01	1.21	4.1	10.38	3.54	1.63	1.23	6.6	0	31.93	23.23	4.73	1.38	5.93	3.77
9.4	1.01	0.03	1.39	8.18	7.81	5.35	5.28	1.39	0.5	0	43.70	64.18	9.73	1.76	4.05	7.98
9.1	0.41	0.1	4.09	5.26	4.2	0.91	0.32	0.83	1.1	1	26.82	4.07	2.05	2.00	1.87	0.70
8.8	0.6	0.01	1.44	4.83	6.83	1	0.27	0.69	8.3	0	22.05	5.43	0.87	0.83	3.06	1.00
9.3	0.4	0.03	0.74	4.75	7.01	3.92	1.06	0.67	15.4	0	25.89	9.97	0.72	0.31	0.91	1.21
9.4	0.48	0.01	0.54	5.07	8.01	2.89	1.04	0.6	0.9	0	28.56	12.33	0.66	0.33	0.76	1.40
9.6	0.41	-0.01	0.82	3.55	5.41	3.43	1.83	0.68	1.2	10	26.25	28.04	2.31	0.66	1.47	3.23
10.12	1.02	0.18	5.28	14.35	3.93	0.84	8.43	2.04	1.78		25.60	66.97	1.63	2.38	3.04	6.70
9.15	1.00	0.11	1.76	5.17	9.80	4.39	6.67	0.57	3.66		38.70	90.70	10.44	0.50	11.97	11.30
8.93	0.66	0.04	0.89	3.91	8.35	5.23	5.38	0.56	3.66		28.00	106.27	26.45	1.11	25.22	15.90
8.5	0.32	0.82	3.52	5.93	5.33	1.44	0.1	0.79	1.8	0	22.38	1.16	0.92	0.57	1.96	0.48
9	0.73	0.02	1.41	4.63	9.89	2.17	0.44	0.65	26	0	24.90	3.52	0.43	0.20	1.11	0.46
9.5	0.73	-0.01	0.82	4.65	8.96	3.86	2.7	0.65	0.5	0	30.00	19.43	0.55	0.19	0.57	2.12
9.6	0.68	0.05	0.5	3.59	7.13	2.61	2.74	0.5	0.9	0	25.48	56.98	3.90	0.68	1.47	6.28
8.3	0.56	0.52	6.08	7.74	12.77	2.4	0.09	1.01	0.5	1	29.03	1.05	1.18	0.35	4.65	0.64
9.2	0.9	0.03	1.19	7.05	16.05	4.06	1.47	0.31	0.6	1	41.37	17.17	2.41	0.07	5.26	2.56
9.3	0.73	0.01	1.58	7.41	9.47	6.45	5.77	0.54	5.7	1	42.72	74.96	10.63	0.33	5.55	8.89
9.1	0.96	0.24	3.74	13.79	13.54	3.02	0.26	1.22	1	0	31.63	2.39	0.74	0.31	2.77	0.53
8.8	1.17	0.14	2.51	12.99	17.66	7.27	0.98	0.63	1.1	0	47.30	5.42	1.45	0.06	2.79	0.94
9.3	1.07	0.1	2.2	9.44	14.89	7.68	2.19	0.54	2.2	0	51.74	8.49	0.67	0.04	0.81	0.94
9.8	0.59	0.12	0.77	9.22	9.94	10.51	7.51	0.62	23.8	2	79.15	19.78	0.73	0.04	0.32	2.03
8.6	0.85	0.39	5.1	14.92	6.84	1.73	0.12	1.01	1.1	0	23.27	1.26	1.14	0.89	3.44	0.60
8.2	0.9	0.09	4.49	6.72	9.24	1.31	0.06	0.76	0.6	0	25.99	0.45	0.41	0.23	2.69	0.34
7.9	0.82	0.11	4.07	9.87	14.56	3.49	0.07	0.6	0.3	2	37.44	0.72	2.12	0.16	8.18	1.06
8.6	0.63	0.13	1.11	7.81	19.68	5.31	0.27	0.55	0.5	0	43.99	1.05	0.35	0.04	1.45	0.25
8.7	0.51	0.15	1.89	2.37	15.72	2.2	0.11	0.86	0.7	0	29.77	1.16	0.85	0.31	3.83	0.56
9.5	1.01	0.13	1.27	3.69	12.59	6.29	3.65	0.39	1.3	10	40.75	35.98	2.75	0.12	2.73	4.14
9.6	0.72	0.09	0.45	7.3	8.43	9.69	10.63	0.89	27.6	9	61.21	71.82	5.56	0.42	1.54	8.07
8.8	0.55	0.13	0.34	9.21	3.18	9.49	13.35	0.95	29.9	0	95.15	71.17	5.55	0.52	0.98	7.93
8.5	0.42	0.24	5.21	3.65	5.43	1.57	0.28	0.89	1.5	0	23.68	4.01	0.60	0.61	1.42	0.60
9.4	0.74	0.14	1.34	4.87	9.73	4.08	1.54	0.4	1.1	2	28.99	9.90	0.41	0.06	1.01	1.02
9.6	0.83	0.13	1.27	4.53	8.45	4.64	3.95	0.44	7.9	0	34.87	59.76	5.25	0.30	3.02	6.47
9	0.97	0.24	4.42	5.22	11.32	1.66	0.26	1.2	1.1	0	24.81	2.82	0.56	0.54	2.57	0.59
9	1.62	0.09	2.13	5.67	12.03	5.17	0.93	0.48	1.8	1	45.81	8.88	1.61	0.09	2.36	1.24

9.6	1.49	0.12	1.41	7.1	8.91	6.61	5.27	0.59	17.8	0	47.20	55.11	4.63	0.24	1.38	6.25
9.3	1.02	0.08	0.91	8.77	8.27	8.83	9.46	0.96	51	0	58.15	97.52	17.10	0.51	6.27	11.55
8.7	0.99	0.14	4.72	5.96	13.79	2.58	0.37	1.58	2.3	2	33.43	2.96	0.60	0.50	2.35	0.59
8.7	1.7	0.14	2.81	10.15	18.95	4.87	0.29	1.04	1.3	0	46.75	1.80	1.18	0.19	3.20	0.56
9	0.93	0.09	1.82	8.9	15.86	6.39	0.8	0.36	2	1	44.74	3.56	0.93	0.03	1.41	0.51
9.3	0.61	0.06	1.34	5.38	11.15	7.01	1.83	0.33	4.2	0	35.01	6.76	0.36	0.01	0.39	0.65
8.7	0.59	0.27	4.8	4.54	6.84	1.77	0.2	1.12	0.8	0	24.85	2.52	0.66	0.84	1.77	0.48
8.8	1.19	0.08	2.19	4.9	9.89	2.13	0.11	0.76	0.7	0	26.51	1.02	0.71	0.30	2.32	0.37
8.9	0.91	0.05	1.41	5.09	11.23	4	0.27	0.7	0.7	0	32.59	2.81	1.35	0.31	2.14	0.63
9.6	0.71	0.05	1	4.56	8.63	5.44	1.74	0.46	2.4	9	31.09	12.79	0.62	0.11	0.38	1.39
8.8	1.26	0.27	3.52	18.01	16.42	5.01	0.57	1.27	1.4	0	38.60	3.66	0.76	0.26	2.56	0.65
9.1	1.38	0.17	2.6	18.29	18.32	7.87	3.56	0.54	1.4	9	51.16	8.07	0.25	0.02	0.70	0.84
9.2	1.47	0.21	1.64	14.06	12.51	9.1	11.66	0.61	29.6	0	61.00	79.92	5.09	0.11	4.73	8.42
8.1	1.18	0.18	1.44	20.04	17.27	11.23	16.07	0.82	59.1	10	70.58	141.48	22.73	0.30	29.68	18.32
8.6	0.66	0.64	5.97	6.07	5.8	2.06	0.16	1.24	2.2	0	27.10	1.91	1.28	1.50	2.49	0.62
8.8	1.18	0.19	3.12	5.63	7.56	1.79	0.27	0.9	0.7	0	27.49	2.52	0.49	0.32	1.64	0.42
9.1	0.93	0.07	1.27	5.16	9.25	3.91	0.68	0.73	1	0	30.99	4.95	0.44	0.21	0.86	0.55
9.7	1.14	0.05	1.43	7.44	7.72	6.77	4.83	0.85	24.5	0	46.18	27.57	0.68	0.18	0.27	2.89
8.6	0.42	0.3	4.59	3.91	6.51	1.22	0.19	1.05	1.3	0	23.24	2.04	0.92	1.41	3.11	0.68
8.9	0.79	0.07	1.92	4.44	9.85	1.27	0.08	0.4	0.6	1	25.68	1.00	0.73	0.17	3.01	0.42
9.5	0.78	0.07	0.65	3.66	10.52	4.56	1.24	0.26	1.1	0	34.37	9.24	0.61	0.07	0.77	1.04
8.9	0.96	0.23	4.18	4.63	14.84	2.04	0.23	1.02	0.7	0	28.82	2.25	0.80	0.44	3.39	0.66
9.2	1.64	0.14	2.55	5.88	13.29	5.17	2.66	0.37	1.2	0	40.83	29.67	3.71	0.10	4.36	3.81
9.3	1.02	0.1	1.23	8.12	9.18	10.45	8.91	0.65	44.9	1	59.07	82.74	12.33	0.23	3.55	9.69
8.8	0.52	0.27	3.99	4.73	8.83	1.47	0.16	1.05	1.8	0	23.90	2.16	0.78	0.70	3.35	0.66
8.9	1.11	0.15	2.89	3.73	11.76	1.99	0.26	0.56	0.7	0	29.08	2.44	0.59	0.12	2.05	0.44
9.6	1.02	0.08	1.6	4.88	9.71	4.22	1.78	0.71	1.2	0	27.54	9.35	0.26	0.18	0.35	0.95
9	0.94	0.36	4.28	5.96	9.42	1.26	0.12	1.02	0.8	0	24.77	1.60	0.53	0.37	3.06	0.47
9.1	1.35	0.18	2.08	6.42	11.46	2.38	0.4	0.62	0.7	0	33.21	3.91	0.58	0.13	1.70	0.54
9.5	1.44	0.32	1.83	5.45	9.11	5.46	3.86	0.44	7.4	0	29.12	0.90	0.60	0.69	2.70	0.39
9	0.97	0.35	4.17	4.07	10.67	1.39	0.09	1.03	0.8	0	30.04	54.03	4.71	0.19	3.60	6.10
8.9	1.49	0.16	2.18	4.37	12.21	2.26	0.23	0.41	0.8	0	33.28	2.38	0.81	0.08	1.80	0.45
9.6	0.92	0.18	1.5	4.91	7.92	6.05	5.8	0.49	32.5	0	45.16	65.65	6.16	0.22	0.19	6.80

APPENDIX HA-A4

OVERBURDEN LABORATORY RESULTS

CSBP LIMITED ABN: 81 008 668 371

ANALYSIS REPORT

CUSTNO	PADDOCK	SAMPLE_ID	SERIAL_NO	LAB_NUMBER	TEXTURE	GRAVEL	COLOUR	NITRATEN	AMMONIUM	PHOS	POTASSIUM	SULPHUR	ORGCARBON	IRON	CONDUCTY	PH_CACL2	PH_H2O
UNITS								mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	dS/m	pH	pH
67337	OVERBURDEN SAMPLE	UPPER LOXTON	LINE 535	ZG S06169	1.5		YWGR	1	1	2	38	28.3	-0.05	252	0.155	7.3	8.4
67337	OVERBURDEN SAMPLE	WOORINEN	LINE 535	ZG S06170	3	5-10	BROR	1	1	3	153	138	0.21	363	0.909	8.3	9.1
67337	OVERBURDEN SAMPLE	SHEPPARTON	LINE 535	ZG S06171	3	75-80	BROR	1	2	4	194	181	0.12	420	0.733	7.9	8.6
67337	OVERBURDEN SAMPLE	MICA SAND	LINE 535	ZG S06172	1	10-15	GRWH	1	1	2	44	62.6	-0.05	238	0.294	7.5	8.7
67337	OVERBURDEN SAMPLE	UPPER LOXTON	LINE 539	ZG S06173	3.5		BROR	1	3	2	192	252	0.09	510	1.029	7.9	8.6
67337	OVERBURDEN SAMPLE	WOORINEN	LINE 539	ZG S06174	2		BROR	1	2	2	115	33.5	0.08	345	0.37	8.1	9.3
67337	OVERBURDEN SAMPLE	LOWER LOXTON	LINE 539	ZG S06175	1		LTGR	1	1	2	15	19.4	-0.05	215	0.108	8.2	9.1
67337	OVERBURDEN SAMPLE	MICA SANDS	LINE 539	ZG S06176	1	5	GRWH	1	1	2	43	50.5	-0.05	201	0.217	5.5	6.3
67337	OVERBURDEN SAMPLE	UPPER SAND	LINE 542	ZG S06177	1		GRPK	1	1	2	54	354	0.06	209	2.045	7.4	7.8
67337	OVERBURDEN SAMPLE	WOORINEN	LINE 542	ZG S06178	3.5		BROR	12	1	2	172	1136	0.14	299	2.401	8.4	8.7
67337	OVERBURDEN SAMPLE	SHEPPARTON	LINE 542	ZG S06179	3.5	25-30	BROR	2	1	2	180	451	-0.05	289	1.72	8.4	8.9
67337	OVERBURDEN SAMPLE	DRILL CORE	LINE 542	ZG S06180	2		LTGR	1	4	3	131	136	-0.05	177	0.468	7.2	7.9
67337	OVERBURDEN SAMPLE	UPPER LOXTON	LINE 545	ZG S06181	2	5-10	BROR	1	1	2	35	77.2	-0.05	247	0.533	8.2	8.9
67337	OVERBURDEN SAMPLE	WOORINEN	LINE 545	ZG S06182	2.5	5	BROR	4	1	4	228	239	0.17	305	1.252	8.5	9.5
67337	OVERBURDEN SAMPLE	SHEPPARTON	LINE 545	ZG S06183	3.5		BROR	1	2	8	260	495	0.08	530	2.398	8.3	8.7
67337	OVERBURDEN SAMPLE	MICA SANDS	LINE 545	ZG S06184	1.5		GRYW	1	1	2	20	162	-0.05	334	1.073	8.2	8.6

BEMAX RESOURCES ZGS06169-184

mg/kg	mg/kg	mg/kg	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	Index	%	meq/100g	meq/100g	meq/100g	meq/100g		ppb	ppb	ppb	ppb
DTPA_CU	DTPA_ZN	DTPA_MN	DTPA_FE	EXC_CA	EXC_MG	EXC_NA	EXC_K	BORON_HOT	DISPERSION	Saturated Moisture Content	Saturated Na	Saturated Mg	Saturated K	Saturated Ca	Saturated Conductivity	Arsenic	Copper	Lead	Zinc
0.39	0.21	0.21	8.02	1.29	0.69	0.97	0.08	1.4	1	29.16	20.01	4.95	0.79	0.67	2.30	495	2.082	919.3	72.75
1	0.25	2.87	4.99	10.09	6.82	5.26	0.43	17.9	0	46.20	70.79	11.26	0.34	7.51	9.06	4474	14.64	7161	1054
0.72	0.42	0.55	15.05	5.49	7.97	6.69	0.54	8.3	13	57.72	53.93	6.95	0.50	3.66	6.52	4374	10.2	5908	394.7
0.22	1.77	0.26	20.05	0.59	0.64	1.61	0.11	0.6	1	32.79	32.83	1.77	0.58	0.27	3.57	441.7	1.348	4279	96.45
1.26	6.54	3.47	19.07	7.82	7.15	9.71	0.49	3.5	12	61.97	77.54	6.91	0.38	4.73	8.72	4195	12.89	5684	100.9
0.82	0.43	1.15	3.4	8.48	4.72	2.24	0.29	5.1	0	33.20	34.18	2.92	0.19	2.61	3.99	1168	8.257	2653	77.36
0.08	1.55	0.19	2.53	1.18	0.26	0.34	0.03	0.5	0	27.25	8.11	1.31	0.18	1.30	1.10	773	1.44	2381	72.17
0.36	1.05	0.28	9.94	0.49	0.55	1.45	0.08	0.5	0	36.21	27.92	1.32	0.33	0.13	3.07	653.1	1.766	4015	67.53
0.12	0.5	0.5	6.65	0.6	1.77	8.17	0.11	0.7	0	40.25	189.58	34.40	1.44	13.24	23.40	<0.05	1.287	2818	68.69
0.63	0.4	3.16	5.04	8.17	8.16	12.79	0.43	15.1	0	40.90	263.17	91.36	1.24	45.74	38.90	2709	10.35	4430	82.89
0.27	0.87	2.46	4.7	4.19	4.89	8.87	0.44	3.5	0	35.41	191.94	43.15	1.58	16.93	24.10	4090	4.908	4918	74.54
0.29	0.62	0.4	2.84	1.58	1.16	3.45	0.33	1.3	0	38.17	55.48	5.64	0.49	3.22	6.32	158	3.354	8126	76.07
0.14	0.62	0.65	2.54	1.79	1.07	2.84	0.08	1.1	9	26.16	74.67	7.24	0.30	4.13	8.44	828.8	2.602	1470	66.97
1.41	0.54	3.38	3.77	7.81	4.57	7.89	0.63	4.6	9	37.07	139.36	12.56	0.97	5.38	15.66	2806	15.02	3712	88.23
1.56	1.52	3.87	14.2	6.54	12.42	16.63	0.8	24.4	0	70.76	146.24	29.67	0.41	9.32	18.55	4587	24.51	9037	117.5
0.1	0.4	0.37	2.27	0.9	0.97	3.67	0.04	1.1	1	32.70	112.71	18.52	0.59	6.36	13.81	1322	1.613	3261	68.14

ATTACHMENT HB

ACID ROCK DRAINAGE ASSESSMENT

HB1 INTRODUCTION

This Acid Rock Drainage Assessment assesses the acid-forming characteristics of samples representing ore and overburden that would be produced at the Snapper Mineral Sands Project (the Snapper Mine).

HB2 ACID ROCK DRAINAGE TEST PROGRAMME

HB2.1 SAMPLES ANALYSED

The tested Snapper Mine materials include 16 samples of overburden waste rock (four from the Woorinen formation; three from the Shepparton formation; five from the Upper Loxton-Parilla Sands; three from the Mica Sands [Loxton-Parilla Sands]; and one from the Lower Loxton-Parilla Sands) as well as one sample of ore.

HB2.2 ANALYTICAL PROGRAMME

The following tests were conducted on all ore and overburden samples:

- pH;
- total sulphur;
- sulphate;
- acid neutralising capacity (ANC);
- gross acid producing potential (GAPP);
- net acid producing potential (NAPP);
- net acid generation (NAG); and
- NAG pH.

HB2.3 ARD CLASSIFICATION SCHEME

The following classification system was used for the analytical results from the ore and overburden samples:

- PAF – Potential Acid Forming;
- PAF-lc – Potential Acid Forming – lower capacity;
- NAF – Non-acid Forming;
- NAF(org) – Non-acid forming but contains reactive organic carbon; and
- UC – Uncertain.

HB3 ACID FORMING POTENTIAL

Table HB-1 provides the results of the acid rock drainage test programme. All of the overburden waste rock and ore samples were classified as NAF.

HB4 REFERENCES

mpl Laboratories (2006) *Analytical Report – Job No: 065533.*

Table HB-1
Acid Forming Characteristics of Ore and Overburden Samples

Identification Code	Soil Type	pH	Total Sulphur (%)	Sulphate (%)	ANC kilograms sulphuric acid per tonne (kg H_2SO_4/t)	GAPP (kg H_2SO_4/t)	NAPP (kg H_2SO_4/t)	NAG (kg H_2SO_4/t)	NAG pH	ARD Classification
ZGS06169	Overburden	7.00	0.01	0.003	<0.5	0.3	4	15	7.00	NAF
ZGS06170	Overburden	9.30	0.03	0.018	160	0.5	<1	<1	9.30	NAF
ZGS06171	Overburden	8.20	0.03	0.023	<0.5	<0.3	1	12	8.20	NAF
ZGS06172	Overburden	6.30	0.01	0.006	<0.5	<0.3	4	15	6.30	NAF
ZGS06173	Overburden	8.70	0.04	0.026	17	0.5	<1	<1	8.70	NAF
ZGS06174	Overburden	9.65	0.01	0.005	55	<0.3	<1	<1	9.65	NAF
ZGS06175	Overburden	7.90	0.01	0.003	<0.5	0.3	4	14	7.90	NAF
ZGS06176	Overburden	5.75	0.01	0.005	<0.5	<0.3	3	14	5.75	NAF
ZGS06177	Overburden	7.35	0.04	0.037	<0.5	<0.3	4	11	7.35	NAF
ZGS06178	Overburden	9.10	0.13	0.123	180	<0.3	<1	<1	9.10	NAF
ZGS06179	Overburden	9.20	0.04	0.043	14	<0.3	<1	3	9.20	NAF
ZGS06180	Overburden	7.35	0.01	0.011	<0.5	<0.3	4	9	7.35	NAF
ZGS06181	Overburden	8.85	0.01	0.009	<0.5	<0.3	3	11	8.85	NAF
ZGS06182	Overburden	9.80	0.04	0.025	190	0.4	<1	<1	9.80	NAF
ZGS06183	Overburden	8.80	0.06	0.055	11	<0.3	<1	<1	8.80	NAF
ZGS06184	Overburden	9.30	0.02	0.016	<0.5	<0.3	4	9	9.30	NAF
ZGS06185	Ore	7.05	0.01	0.003	<0.5	<0.3	4	10	7.05	NAF

Source: mpl Laboratories (2006)

ATTACHMENT HC

SALINE SLURRIED OVERBURDEN

RISK ASSESSMENT

HC1 INTRODUCTION

The Saline Slurried Overburden Risk Assessment identified and assessed risks to the success of rehabilitation and revegetation of the Snapper Mineral Sands Project (the Snapper Mine) site associated with the use of saline slurry in the initial slurried overburden emplacement.

HC1.1 SCOPE

A risk workshop was conducted to address the following Director-General's Requirement (DGR) issued by the NSW Department of Planning:

> *An assessment of the risks to the success of rehabilitation and revegetation of the site associated with the use of saline slurry in the overburden emplacements must also be included.*

HC1.2 METHODOLOGY

The methodology employed during the workshop was as follows:

(i) Identify the events or risks associated with the handling and disposal of wastes in accordance with requirements relevant to its classification.

(ii) Examine the maximum reasonable consequence[1] of identified events.

(iii) Qualitatively estimate the likelihood of events.

(iv) Propose risk treatment measures.

(v) Qualitatively assess risks to the environment, members of the public and their property arising from atypical and abnormal events and compare these to applicable qualitative criteria.

(vi) Recommend further risk treatment measures if considered warranted.

(vii) Qualitatively determine the residual risk assuming the implementation of the risk treatment measures.

The workshop team comprised an appropriate array of skills and experience relevant to the workshop subject matter. Details of the team members and their relevant qualifications and experiences are included in Table HC-1.

Table HC-1
Risk Workshop Team

Name	Company and Position	Qualifications and Relevant Experience
Joe Bannister	BEMAX Resources Limited (BEMAX) – Development Manager	BE; Grad. Dip. IT; 15 years experience in project management/mineral sands development/environmental planning.
Paul Humphris	BEMAX – Manager Health Safety and Environment	Grad. Dip. OHS; Assoc. Dip. EM; 25 years experience in health and safety/environmental planning.
Greg Lamb	BEMAX – Environmental Officer	B.Sc.; Seven years experience in mineral sands development/environmental management/environmental planning.
Peter Cribb	Resource Strategies – Principal	B.Ag.Sc. (Land Resource Management); 15 years experience in project management and mine environmental management.
Jason Jones	Resource Strategies – Environmental Project Manager	BEM (Sustainable Development); 2.5 years experience in mine environmental management and natural resource management.
Juleen Blunt	Resource Strategies – Environmental Project Manager	BE (Mining); MEM (Sustainable Development); Six years experience in project management, mine planning and mine environmental management.

[1] Definition of Maximum Reasonable Consequence – The worst-case consequence that could reasonably be expected, given the scenario and based upon the experience of the workshop participants.

HC2 RISK MANAGEMENT PROCESS

The risk workshop was undertaken with regard to the risk management process described in Australian Standard/New Zealand Standard (AS/NZS) 4360:2004 *Risk Management* (AS/NZS 4360). The risk management process includes the following components:

- establish the context;
- identify risks;
- analyse risks;
- evaluate risks; and
- treat risks.

HC2.1 RISK IDENTIFICATION

The identification of risks involved the use of risk analysis "tools" appropriate for identifying environmental impacts. The tools used were:

- Overview Session – established the context and team scope before the issues were brainstormed.
- Brainstorming – used to draw out the main issues using the understanding, relevant experience and knowledge of the team. A key word association process was used based on work by Edward de Bono to generate a wide range of data on losses, controls and general issues related to the subject areas.

HC2.2 RISK CRITERIA

The risk workshop Team considered the following qualitative criteria (summarised from NSW Department of Urban Affairs and Planning [DUAP], 1992):

(a) All 'avoidable' risks should be avoided. This necessitates investigation of alternative locations and technologies where applicable.

(b) The risks from a major hazard should be reduced wherever practicable, irrespective of the value of the cumulative risk level from the whole installation.

(c) The consequences (effects) of the more likely hazardous events should, where practicable, be contained within the boundaries of the installation.

(d) Where there is an existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.

HC3 QUALITATIVE MEASURES OF CONSEQUENCE, LIKELIHOOD AND RISK

To undertake a qualitative risk assessment it is useful to define (in a descriptive sense) the various levels of consequence of a particular event, and the likelihood (or probability) of such an event occurring. Risk assessment criteria were developed in accordance with AS/NZS 4360. AS/NZS 4360 allows the risk assessment team to develop risk criteria during the *Establish the Context* phase.

In accordance with AS/NZS 4360, Tables HC-2, HC-3 and HC-4 were reviewed by the workshop team at the commencement of the workshop as part of establishing the context. The tables were considered to be consistent with the specific objectives and context of the Saline Slurried Overburden Risk Assessment.

Table HC-2
Qualitative Measures of Probability

Event	Likelihood	Description	Probability
A	Almost Certain	Happens often	More than 1 event per month
B	Likely	Could easily happen	More than 1 event per year
C	Possible	Could happen and has occurred elsewhere	1 event per 1 to 10 years
D	Unlikely	Hasn't happened yet but could	1 event per 10 to 100 years
E	Rare	Conceivable, but only in extreme circumstances	Less than 1 event per 100 years

Source: Safe Production Solutions (2006)

Table HC-3
Qualitative Measures of Maximum Reasonable Consequence

	People	Environment	Asset/Production
1	Multiple fatalities	Extreme environmental harm (e.g. widespread catastrophic impact on environmental values of an area)	More than $500k loss or production delay
2	Permanent total disabilities, single fatality	Major environmental harm (e.g. widespread substantial impact on environmental values of an area)	$100 to $500k loss or production delay
3	Major injury or health effects (e.g. major lost workday case/permanent disability)	Serious environmental harm (e.g. widespread and significant impact on environmental values of an area)	$50 to $100k loss or production delay
4	Minor injury or health effects (e.g. restricted work or minor lost workday case)	Material environmental harm (e.g. localised and significant impact on environmental values of an area)	$5 to $50k loss or production delay
5	Slight injury or health effects (e.g. first aid/minor medical treatment level)	Minimal environmental harm (e.g. interference or likely interference to an environmental value)	Less than $5k loss or production delay

Source: Safe Production Solutions (2006)

Combining the probability and consequence, Table HC-4 provides a qualitative risk analysis matrix to assess risk levels.

Table HC-4
Risk Ranking Table

		Probability				
		A	B	C	D	E
Consequence	1	1 (H)	2 (H)	4 (H)	7 (M)	11 (M)
	2	3 (H)	5 (H)	8 (M)	12 (M)	16 (L)
	3	6 (H)	9 (M)	13 (M)	17 (L)	20 (L)
	4	10 (M)	14 (M)	18 (L)	21 (L)	23 (L)
	5	15 (M)	19 (L)	22 (L)	24 (L)	25 (L)

Notes: L – Low, M – Moderate, H – High
Rank numbering: 1 – highest risk; 25 – lowest risk

Legend – Risk levels:

(yellow)	Tolerable
(orange)	ALARP – As low as reasonably practicable
(red)	Intolerable

Source: Safe Production Solutions (2006)

Risk acceptance criteria for the Snapper Mine have been formulated following consideration of the *Hazardous Industry Planning Advisory Paper Number 4* (DUAP, 1992) and AS/NZS 4360 guidelines, *viz.*:

> *Qualitative Risk Acceptance Criteria:*
>
> *The risk posed by an event is at a level where the residual risk levels are considered tolerable, following consideration of the proposed risk mitigation and minimisation measures.*

The hazard identification summary table (Table HC-5) illustrates the systematic application of the above criteria for the Snapper Mine. The level of risk is presented with and without treatment measures, where appropriate, to illustrate the effectiveness of treatment measures.

HC4 RISK MANAGEMENT AND EVALUATION

All the identified potential hazards fall into the "Tolerable" category. With respect to the potential hazards, the issues raised are addressed in the Rehabilitation Materials Assessment.

HC5 REFERENCES

Department of Urban Affairs and Planning (DUAP) (1992) *Hazardous Industry Planning Advisory Paper Number 4*.

Safe Production Solutions (2006) *Newcastle Coal Export Terminal Environmental Risk Assessment*.

Table HC-5
Hazard Identification Summary Table

#	Event	Consequence	Likelihood	Risk	Control*	Consequence	Likelihood	Residual Risk
1	Lateral salt movement (seepage) within the slurried overburden out of path emplacements to rehabilitated/revegetated areas.	4	D	21	Clay floor lining, foundation preparation and construction, cut-off key trench, toe drain and spoon drains. Permeability testing of clay lining during construction.			
2	Lateral salt movement (seepage) within the slurried overburden along the mine path to rehabilitated/revegetated areas.	5	E	25	High permeability of sand residues, preferential vertical drainage to saline groundwater table.			
3	Capillary rise increasing salinity levels within the Primary Root Zone (PRZ) of the non-slurried material.	4	E	23	Implementation of a strategy to cover sufficient depth of non-slurried overburden, investigative rehab trials for establishing appropriate depth of cover, revegetation species selection (PRZ, salt tolerance considerations), geotechnical/capillary rise investigations.			
4	Failure of clay lining.	4	C	18	Adequate permeability testing of clay lining during construction.	5	D	24
5	Salts contained within the slurried material becoming airborne once the material has dried.	4	E	23	Crusting of surface of slurried materials due to salt content minimises potential for dust.			

* Inherent control and/or proposed control measure