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TERRAIN, SOILS & LAND CAPABILITY

ENSHAM CENTRAL PROJECT

TERRAIN, SOILS & LAND CAPABILITY ASSESSMENT

Prepared by:

HANSEN CONSULTING
Level 4
20 Wharf Street
BRISBANE QLD 4000

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For:

ENSHAM RESOURCES PTY LTD
GPO Box 814
BRISBANE QLD 4001

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for
Ensham Resources Pty Ltd

1.0 INTRODUCTION

1.1 THE SURVEY AREA

Hansen Consulting was commissioned by Ensham Resources Pty Ltd to undertake a soils and land capability assessment study to characterise the terrain conditions within and adjacent to Ensham's current mining leases. The purpose of the study is to assist in planning for a proposed mine expansion programme (termed the Ensham Central Project) which will involve both open cut and underground mining operations.

The existing Ensham mine is located approximately 30 km east of the township of Emerald, approximately 5 km to the north of the Capricorn Highway in Central Queensland. The area of interest includes a land area of approximately 5,500 ha, intersected by the Nogoa River and Anabranch which pass diagonally through the central sector of the area. The study area for the soils and land capability assessment is shown on **Figure 1** and includes:

- Areas beyond Ensham's current mining leases; and
- Areas within Ensham's current mining leases that have not previously been subject to a detailed soils and land capability assessment and will be disturbed by the Ensham Central Project.

1.2 SCOPE OF WORK

The objectives of the study were to undertake a terrain analysis, soil survey and land capability and suitability assessments in accordance with the requirements of the Queensland Department Natural Resources and Mines (NRM - 1995), now administered by the Environmental Protection Agency (EPA).

Aspects of the study have included:

- Preliminary terrain mapping based on airphoto interpretation to provide a basis for the field investigation;
- Conducting a soil survey to classify the soil types occurring on the site and to assess their properties in terms of erosion potential, topsoil suitability and topsoil stripping depths;
- Estimating the volume of topsoil resources available at the site for future rehabilitation; and
- Identifying agricultural land classes and conducting agricultural land suitability assessments for both pre-mine and post-mine landforms.

2.0 METHODOLOGY

2.1 TERRAIN CLASSIFICATION AND MAPPING

Terrain units have been identified from airphoto interpretation with reference to geological, topographic and soil information data sources included in **Section 2.2**. A terrain unit comprises a discrete or recurring area of land, which is considered to have a unique combination of physical attributes in terms of bedrock, surface slope and form, and soil/substrate conditions. Accordingly, environmental characteristics determined at one location may be extrapolated to other occurrences of the terrain unit identified through the terrain classification process.

A map showing the occurrence and distribution of the terrain units identified in the study area is shown in **Figure 2**. A key to the identification of terrain units and more detailed descriptions of the terrain units are included in **Appendix A Tables A.1 and A.2.**

2.2 DATA SOURCES

The following data were used for the description and assessment of the physical environment of the study area:

- Queensland Government colour aerial photography – Capella QAPc 6107 Runs 8 and 9, flown 9.04.02; and Comet QAPc 6109 Run1, flown 17.05.04, at an approximate scale of 1:40,000.
- Queensland Topographic 1:100,000 Series Capella, Emerald, Comet and Cooroorah Sheets.
- Australia 1:250,000 Geological Series Queensland, Duaringa and Emerald Sheets.
- Existing soil and land resources reports – Ensham Coal Project Final Impact Assessment Study prepared by Hollingsworth Dames & Moore (1991).
- Ensham EMOS Land and Soils report prepared by Ensham Resources Pty Ltd (2002).
- Land Management Manual Project – Understanding and Managing Soils in the Queensland Central Highlands– Bourne and Tuck (1993).

2.3 FIELD SURVEY

The field investigation was carried out between 18 and 26 October 2004, prior to which time, the general region had experienced extended dry sunny (near drought) conditions with nil or low rainfall.

The purpose of the field investigation was:

- To undertake a reconnaissance survey of the study area to provide ground truth for the preliminary mapping determined from airphoto interpretation.
- To target representative locations for soil type identification and soil sampling, subject to site accessibility and a review of pre-existing soil sampling data (HDM 1991).

A total of 48 sites were investigated within the EIS study area, 42 of which constituted detailed or semi-detailed sites involving soil sampling. An additional 6 sites were inspected where general soil/site conditions only were recorded. The location of sampling sites within the study area is shown in **Figure 1**. Data was also available from an additional 10 sites, within Ensham's current mining lease, but beyond the study area. Sites were selected based on the provisional terrain units identified from the preliminary airphoto interpretation and mapping phase. The frequency of site observations, soil sampling and testing requirements have been carried out generally in accordance with the guidelines recommended by Gunn *et al* (1988) and McDonald *et al* (1990).

Soil profile identification and sampling has been carried out using backhoe pits excavated to depths sufficient to classify and characterise the soil profile. Backhoe pits were excavated to depths between about 1.0 m to 2.5 m, usually terminating in highly weathered rock (HWR) or at backhoe refusal level, whichever was shallower. A total of 206 soil samples (typically 3-5 representative samples from each sampling location) were obtained for soil characterisation, indicative testing, and for soil profile classification purposes. The site inspection/soil sampling locations investigated are shown in **Figure 1**.

2.4 SOIL ANALYSIS

Indicative (in-house) testing was carried out on all (206) soil samples collected. This involved testing of pH (1:5 H_2O), Electrical Conductivity (EC 1:5 H_2O) and Dispersion Class Rating - Emerson (1981). Soil colour, texture and structure were determined for all samples by field methods described by McDonald *et al* (1990).

Laboratory analyses were carried out by CASCO Australia Pty Limited (NATA Approved) laboratory at Toowoomba. The analyses carried out included the following:

- pH (1:5 H2O), Electrical Conductivity (EC), Chloride (Cl);
- Nitrate Nitrogen, available Phosphorus, Organic Carbon (OC) and Sulfur;
- Exchangeable (Major) Cations and CEC; and
- Copper (Cu), Zinc (Zn), Manganese (Mn), Iron (Fe) and Boron (Bo).

The results of the indicative testing are included in **Appendix B, Table B.1**. A summary of the results of the laboratory analyses is included in **Appendix C**.

3.0 DESCRIPTION OF TERRAIN UNITS

3.1 TERRAIN UNITS

5 geological regimes have been identified in the study area, as described in **Section 3.2**. Within these geological regimes, a total of 21 terrain units have been identified based on surface form, steepness of slopes, degree of dissection, drainage condition and soil type or association of soil types. As mapped, terrain units provide the basis for the identification and mapping of soil types and for the assessment of land capability and agricultural suitability within the study area

A description of each terrain unit is provided in **Appendix A, Table A.2**. The occurrence and distribution of terrain units is shown in **Figure 2.**

3.2 GEOLOGY

As mapped from airphoto interpretation, with reference to the GSQ 1:250,000 Emerald and Duaringa map sheets, the occurrence and distribution of the geological regimes within the study area is shown in **Figure 2**. The main geological sequences that occur within the study area include:

- Quaternary Alluvium; River and Floodplain Deposits – clay, silt, sand, gravel.
- Cainozoic Soil Cover including Older Alluvial and Colluvial Deposits – soil, sand, siliceous and ferruginous gravel and reworked laterite.
- Tertiary Emerald Formation – argillaceous sandstone, lateritised sediments, laterite, claystone, siltstone, sandstone and pebbly sandstone.
- Permo-Triassic Rewan Formation – mudstone and interbeds of lithic sandstone.
- Permian Undifferentiated Blackwater Group which includes the Rangal Coal Measures, Burngrove Formation and Fairhill Formation which comprise carbonaceous mudstone, thinly interbedded mudstone and fine sandstone, siliceous siltstone, lithic calcareous and feldspathic sandstone, tuff and coal seams.

3.3 LANDFORM

The Nogoa River and its Anabranch flow through the site in a south-easterly direction and essentially divide the study area into two parts.

The terrain in the northern sector comprises mainly mildly dissected gently to moderately sloping and undulating residual soil plains and dissection slope interfluves developed mainly on the Burngrove Formation sedimentary rocks. Erosion of the Tertiary sediments present in the northern, north-eastern and north-western parts of the study area have given rise to irregular undulating to low hilly lands comprising mesas and eroded plateau remnants. The mesas and dissected plateau remnants are locally bounded by steep irregular and in places, benched escarpment slopes (30-60% or steeper). Local relief is up to 40-50m between the plateau crestal areas and the dissected escarpment footslopes.

The southern part of the site extending south from the Anabranch, comprises part of the extensive floodplain of the Nogoa River system and its major tributaries which flow through the area in a south-easterly direction within a broad alluvial tract approximately 4km wide. The general elevation of the floodplain varies from about 155m AHD in the west, to about 150m AHD in the east and substantial parts of the area are prone to periodic extensive flooding. To the south of the Nogoa floodplain, in the extreme southern sector of the study area the land surface gradually rises to form extensive broadly undulating low (Tertiary) gravelly rises which have a crestal elevation of about 175m AHD. More detailed descriptions of specific landform elements based on surface slope and form are included in **Appendix A, Table A.2**.

3.4 SOILS

3.4.1 Background Information

The soil data generated for the 1991 Ensham Coal Project Impact Assessment Study, included a total of 85 sites investigated by Hollingsworth, Dames & Moore in January 1986 (reported in November 1991). That data has been reviewed and, where appropriate, has been used to supplement the findings from the sites investigated for this current study.

To maintain compatibility with the previous investigations conducted on the site, for soil mapping purposes, the soil types identified in the study area, have been grouped into one of six major soil groups previously identified on the site.

3.4.2 Soil Characterisation

The soils in the study area have been grouped into one of six major soil groups, each of which includes one or more soil type variants as shown in **Table 1**. A total of 15 soil type variants have been identified and in order to fully characterise each soil type, the soils have been classified in terms of four commonly used systems of soil classification namely:

- The Great Soil Group, following Stace *et al*. (1968);
- Principal Profile Form based on Northcote (1971);
- The Australian Engineering Soil Classification (AS 1726-1993); and
- The Australian Soil Classification by Isbell (1996).

The occurrence and distribution of soil types within the study area is shown in **Figure 3.** A brief description of each of the major soil groups recognised is as follows:

Soil Group (1) –Shallow Rocky Soils
These comprise shallow rocky (Skeletal) soils with a sandy or loamy soil matrix that occur on low rocky hills and steep escarpment slopes and eroded plateau remnants mapped as terrain units P7/1-2.2, Ta6/1-3.1and Ta8/1. They are mainly shallow (<0.5m) and they exhibit minimal profile development apart from some slight darkening near the surface due to the influence of organic matter. They mainly

contain gravel and rock cobbles derived from Permo-Triassic sedimentary rocks or siliceous and ferruginous gravels and weathered rock exposed by erosion of the Tertiary weathered zone materials.

Soil Group (2) – Moderately Shallow Gravelly Sands, Loams and Clay Soils
The soils of this group comprise uniform or weakly gradational sands, loamy sands or sandy loams, loams or clayey soils with varying amounts of ferruginous and siliceous gravel or stone included. They are shallow to medium deep and exhibit minimal profile development apart from a slight increase in fines with depth. Three soil variants have been identified in this group, general details of which are given in **Table 1.** As mapped these soils occur on the eroded middle and lower slopes within the Tertiary geological regime in terrain units Ta4/2.3, Ta5/2.2 and on broad low gravelly rises in Ta3/2.2-3.2. Soil fertility and water storage capacity are low in these soils

Soil Group (3) – Gradational Red and Yellow Earth Soils
The soils of this group include sandy, sandy loam or loamy surface soils grading to red, reddish brown or yellowish brown sandy loam to light to medium massive or structured clay subsoils often with appreciable amounts of ferruginous gravel included. Three soil variants have been identified in this group, general details of which are given in **Table 1.** As mapped the soils occur on the elevated dissected and eroded Tertiary plateau remnants in terrain units Ta3/3.2-1, Ta5/3.3 and Ta6/1-3.1 and on undulating plains in terrain unit Ta3/3.2-2.2.

Soil Group (4) – Texture Contrast (Duplex) Soils
These soils are characterized by a clear to abrupt change in texture between the sandy, silty or loamy surface soil and clayey subsoil horizon. They are generally formed by clay illuviation, often under the influence of sodium salts, resulting in the development of a "tough" low permeability massive clay subsoil horizon. The soils have formed on a variety of parent materials derived from the Permo-Triassic sedimentary rocks, in terrain units P3/4.1 and P-T3/4.1-5.1, on gently inclined slopes, dissection slope interfluves, broad low rises and plains in terrain units Cz3/4.3-2.2 and Cz3/5.2-4.2, and on alluvial terraces and drainage flats in terrain unit Qa1/4.2. Three soil variants have been identified in this group, general details of which are given in **Table 1.**

Soil Group (5) – Uniform Fine-textured (Non-cracking) Clay Soils
The soils of this group have uniform profiles or weakly gradational texture profile in which the clay content may increase slightly with depth. The soils occur on a variety of parent materials including the Permo-Triassic rock types where they occur in association with other soil variants of soil groups 4 and 6 on erosional plains in terrain units P-T3/4.1-5.1 and P3/5.1-6.1. They also occur on undulating older alluvial plains (Cz2/5.3) and on very slight rises (Qa2/5.3), on levees and high terraces along the more major stream systems (Qa0/6.2-5.3 and Qa1/6.2-5.3), in a complex association with cracking clays of Soil Group 6. Three soil variants have been identified in this group, general details of which are given in **Table 1.**

Soil Group (6) – Cracking Clay Soils
The main characteristics of these soils are uniform medium to high clay contents and pronounced swelling and shrinkage properties on wetting and drying. Gilgai miro-relief is a feature commonly

associated with these soils in some locations. They occur extensively within the study area on a variety of parent materials including the Permian rock types in terrain units P3/5.1-6.1 and P3/6.2. They also occur as the dominant soil type within the extensive alluvial plains associated with the Nogoa River and its main tributaries. Two soil variants have been mapped within the study area, general details of which are given in **Table 1**.

3.4.3 Soil Physical and Chemical Properties

Descriptions of the soil types found at each of the sampling locations shown in **Figure 1** are included in **Appendix B**. The descriptions also include the results of indicative testing carried out to characterise the soil physical and general chemical properties of each soil type, which together with other more detailed laboratory analyses, have provided the basis for the rating of terrain units in terms of topsoil suitability, as well as an assessment of indicative topsoil stripping depths. The data also provide input for determining the pre-mining agricultural land suitability of terrain units. The methods by which these attributes have been determined are described in in the following sections.

The results of the indicative soil testing are included in **Appendix B.** The results of laboratory testing undertaken are summarised in **Appendix C**. To assist in the interpretation of the results, the limitations imposed by the physical and chemical characteristics of the soils are included in **Appendix D.**

Table 1
Soil Types in the Ensham Central Study Area

Major Soil Group	Soil Type	Soil Description	Soil Classification			
			Group Name [1]	P.P.F.[2]	U.S.C.[3]	A.S.S.[4]
1. Shallow Rocky Soils	1.	Shallow uniform mainly coarse to medium-textured very rocky soils; rock outcrop is common	Skeletal Soils/ Lithosols	Um1.1 Uc1.2	GP, GM, GC	Leptic Rudosols
2. Uniform Gravelly Sands, Loams or Clay Soils	2.1	Thin sandy to sandy loam surface soils underlain by dense siliceous (Si) gravelly sand-sandy gravels.	Lithosols	Uc1 21	SPSM/GP-GM	Colluvic Clastic Rudosols
	2.2	Thin sandy to loamy surface soils grading through gravelly loam-loamy gravel subsoils underlain by dense gravely colluvium and/or HWR	Lithosols	Um5 51. Gn2.11	SC-CL/GM-GC	Regolithic Chernic Tenosols
	2.3	Stony or thin silt to clay loam surface soils with lenses of gravely clay or clayey gravels underlain by strongly acidic clay subsoils or HWR below 0.5-1.0m	Lithosols	Gn4.31 K-Gn2.42	CL-ML/GC	Acidic Brown Clastic-Leptic Rudosols
3. Gradational Red and Yellow Earths	3.1	Sand over clayey sand or sandy loam gradational soils; earthy sands, mainly shallow soils over HWR	Sandy Red/Yellow Earth-Earthy Sand	Gn1.21	SP-SM/SC	Petroferric Red Kandosols-Tenosols
	3.2	Sandy loam to loamy surface soils grading to red, reddish brown or yellowish brown apedal massive sandy clay or light to medium or heavy clay subsoils	Loamy Massive Red or Yellow Earth	Gn2.11 Gn2.12	CL-CH	Acidic Mesotrophic Red Kandosols
	3.3	Silty to loamy surface soils grading to red light to medium structured clay subsoils locally with considerable laterite (Fe) gravel throughout the profile	Red Earth, Lateritic Red Earth	Gn3.11 Gn4.11	CL-ML/GC or GC-CL	Haplic Mesotrophic Red Ferrosols

Major Soil Group	Soil Type	Soil Description	Soil Classification			
			Group Name (1)	**P.P.F.(2)**	**U.S.C.(3)**	**A.S.S.(4)**
4. Texture Contrast (Duplex) Soils	4.1	Shallow to med. deep often stony thin loamy surface duplex soils with dark brown, brown or reddish brown medium to heavy clay subsoils over HWR	Solod, Solodic Soil Solodised Solonetz	Db1.13 Dr2.12	CL-ML/CL-CH	Subnatric Brown Sodosol
	4.2	Mostly deep, thin silty to loamy surface duplex soils with brown or reddish brown neutral to strongly alkaline med. to heavy clay subsoils	Non-calcic Brown Soil, Solodic Soil	Db12 Dd1.13	CL-ML/CL-CH or CH	Eutrophic Mesonatric Brown Sodosols
	4.3	Medium to deep sandy surface duplex soils with a pale or bleached gravely fine sandy to silty A2 horizon and brown, yellowish brown and grey mottled sandy medium to heavy mainly alkaline clay subsoils	Solod, Solodic Soil	Dy3.83 Dy2.11	SM-SC/SM/ CL-CH	Eutrophic Subnatric Yellow Sodosols
5. Uniform (Non-cracking) Clay Soils	5.1	Shallow to med. deep, stony surface, brown, yellowish brown or reddish brown uniform or weakly gradational medium to heavy and heavy clay soils over HW rock	Brown Earth Brown Clay Soil	Uf6.31 Db1.13	CLCL-CH/CH	Sodic Pedaric Brown Dermosols
	5.2	Mainly deep uniform or weakly gradational brown or yellowish brown medium to heavy alkaline clay soils with surface stone and some stony lenses included	Brown Earth Brown Clay Soil	Uf6.31 Gn3.13	GC-CL/CL-CH or CH	Sodic Pedaric Brown Dermosols
	5.3	Deep uniform or weakly gradational brownish black, dark grey-brown or dark brown strongly structured alkaline clay soils of medium to high or high plasticity	Brown or Grey Clays (Incipient Cracking Clays)	Uf6.31 Uf6.32	CL/CL-CH or CL-CH/CH	Sodic Pedaric Brown Dermosol
6. Cracking Clay Soils	6.1	Medium deep dark grey-brown or dark brown strongly structured alkaline heavy clay soils over HW rock	Grey-Brown (Cracking) Clays	Ug5.12	CH/CH	Epipedal Black, Grey or Brown Vertosols
	6.2	Mainly deep dark grey-brown, dark brown or brown, uniform strongly structured heavy alkaline clay soils, locally with gilgai development designated (g).	Dark-coloured and Grey-Brown (Cracking) Clays	Ug5.16 Ug5.25 Ug5.34	CH/CH/CL-CH/CL-ML	Endohypersodic, Epipedal Black, Grey or Brown Vertosols

Notes: (1) Great Soil Group (Stace et.al. 1968); (2) Principal Profile Form (Northcote 1971); (3) Engineering Soil Class (AS 1764-1990);
(4) Australian Soil Classification (Isbell, 1996)

4.0 TOPSOIL RESOURCES

4.1 METHOD OF ASSESSMENT

An appraisal of the depth and quality of useable soil for topsoil use has been undertaken generally in accordance with the procedures adopted by Burgess (2003) for the Windeyers Hill Area and also based on the protocol for topsoil suitability assessment adopted for the initial Ensham Coal Project Final Impact Assessment Study – Hollingsworth Dames & Moore (1991).

Based on the findings of the reconnaissance soil survey, together with the results of the indicative and laboratory testing undertaken, an assessment of topsoil suitability for rehabilitation of lands that may be disturbed by mining operations has been undertaken. Together with field observations of soil surface condition, soil texture and structure, **Table 2** provides the basis for the assessment and criteria used to evaluate the suitability in terms of physical and chemical properties of the soils for use as topsoil. Based on this assessment, indicative topsoil stripping depths of suitable (S) material have been determined. **Table 2** also provides an assessment of materials that are considered to be marginal (M) for use as topsoil material, but would have acceptable properties for the use as subsoil resources, if required.

Table 2
Topsoil Suitability Assessment

Soil Type	Soil Description	Horizon[1]	Soil Physical Factors	Salinity [2]	Sodicity [3]	Soil pH [4]	Dispersion Rating [5]	Overall Rating [6]	Strip Depth (m)
1.	Shallow uniform mainly coarse to medium-textured very rocky soils; rock outcrop is common	A-B	Rocky soils, sandy or loamy matrix	-	-	-	-	U	0
2.1	Thin sandy to loamy sand surface soils underlain by dense siliceous (Si) gravelly sand-sandy gravels.	A	Loamy sand often gravelly, low water storage capacity (WSC)	-	-	-	-	M-U	0.1
		A-C	Sandy coarse gravel, low WSC	-	-	-		U	0
2.2	Thin sandy to loamy surface soils grading through gravelly loam-loamy gravel subsoils underlain by dense gravelly colluvium and/or HWR	A	Sandy loam often gravelly, low WSC	1	-	1	1	S-M	0.1
		B1	Apedal gravelly sandy clay, medium WSC, mod. dispersive	1	-	1	2	M	0.2
		B2-C	Clayey gravel, low WSC	1	-	1	1	U	0
		C	Calcareous claystone	2	-	3b	1	U	0
2.3	Stony or thin silt to clay loam surface soils with lenses of gravelly clay or clayey gravels underlain by strongly acidic clay subsoils or HWR below 0.5-1.0m	A	Gv. loam, weak pedality, mod. WSC	1	-	2a	2	M	0.2
		B	Gravelly clay-clayey gravel, low WSC		-	2a-3a	2	U	0
		B-C	Gv. clay or strongly acidic med.-heavy clay transitional to HW rock	3	-	3a	1	U	0
3.1	Sand over clayey sand or sandy loam gradational soils; earthy sands, mainly shallow soils over HWR	A	Loamy sand apedal massive, low WSC	1	1	1	2	S	0.2
		B1	Loamy sand apedal massive, low WSC	1	1	2a	1	S	0.2
		B2	Gv. sandy loam, massive, low WSC	1	1	2a	1	M	0.2
		B3	Gv. sandy clay-clayey gravel med WSC	1	1	2a	1	M-U	0

Soil Type	Soil Description	Horizon[1]	Soil Physical Factors	Salinity [2]	Sodicity [3]	Soil pH [4]	Dispersion Rating [5]	Overall Rating [6]	Strip Depth (m)
3.2	Sandy loam to loamy surface soils grading to red, reddish brown or yellowish brown apedal massive sandy clay or light, or medium to heavy clay subsoils	A	Loamy sand, loose, low WSC	1	1	1	2	S	0.3
		B1	Loamy Sand-sandy loam massive apedal	1	1	1	2	S	0.3
		B2	Sandy clay, massive, medium WSC	1	1	1	2	S-M	0.3
		B3	Sandy clay, massive, high WSC	1	1	1	1	M	0.5
3.3	Silty to loamy surface soils grading to red light to medium structured clay subsoils locally with considerable laterite (Fe) gravel throughout the profile	A	Silt loam, hard-set, massive, med. WSC	1	1	1	1	S	0.2
		B1	Lateritic gravelly clay, medium WSC	1	1	2a	2	S	0.2
		B2	Gravelly structured clay, medium WSC	1	1	1	1	M	0.5+
4.1	Shallow to med. deep often stony thin loamy surface duplex soils with dark brown, brown or reddish brown medium to heavy clay subsoils over HWR	A	Sandy to silt loam, hard-set or with thin surface crust, low-medium WSC	1-2	1	1	2	S	0.25
		B1	Med.-heavy structured clay, high WSC	2	2	1 & 2b	2	M	0.25
		B2	Med.-heavy structured clay, high WSC	2	2	1 & 2b	2	M	0.3
		B-C	Med.-heavy massive clay/claystone	3	2-3	3b	2	U	0
4.2	Mostly deep, thin silty to loamy surface duplex soils with brown or reddish brown neutral to strongly alkaline med. to heavy clay subsoils	A	Silt loam, hard-set or with thin surface crust, medium WSC	1	1	1	2	S-M	0.25
		B1	Med.-heavy structured clay	1	3	2b	3	U	0
		B2	Med.-heavy structured clay	2	3	3b & 3a	3	U	0
4.3	Medium to deep sandy surface duplex soils with a bleached gravelly fine sandy to silty A2 horizon and brown, yellowish brown and grey sandy medium to heavy acidic or alkaline clay subsoils over HWR or gravel	A1	Loamy sand, massive, low WSC	1	1	1	2	S-M	0.2
		A2	Gravelly bleached silty sand, low WSC	1	1	3b	1	M	0.3
		B	Lateritic gravelly massive sandy clay	1	2	2b	1	M-U	0.4
		B-D	Dense siliceous and quartz gravel	-	-	-	-	U	0

Soil Type	Soil Description	Horizon[1]	Soil Physical Factors	Salinity [2]	Sodicity [3]	Soil pH [4]	Dispersion Rating [5]	Overall Rating [6]	Strip Depth (m)
5.1	Shallow to med. deep, stony surface, brown, yellowish brown or reddish brown uniform or weakly gradational medium to heavy and heavy clay soils over HWR	A	Gravelly clay, thin crust, weak SM below	1-2	1	1, 2a & 2b	2	S	0.2
		B	Heavy clay fine-med. blocky, mod. saline	1-2	2-3	1, 2b & 3b	1-2	M-U	0.3
		B-C	Med.-heavy clay – HWR	1-3	3	3a & 3	1-2	U	0
5.2	Mainly deep uniform or weakly gradational brown or yellowish brown medium to heavy alkaline clay soils with surface stone and some stony lenses included	A	Gv. clay-cl. gravel (± 60mm), 50% fines	1	1	1	2	S	0.2
		B1	Med.-coarse structured heavy clay	2	-	3b	1	M	0.3
		B2	Heavy clay, mod. saline, apedal, massive	2-3	-	3b	1	M-U	0.4
		B3	Heavy clay, mod. saline, apedal, massive	2-3	-	2b	2	M-U	0.5+
5.3	Deep uniform or weakly gradational brownish black, dark grey-brown or dark brown strongly structured alkaline clay soils of medium to high or high plasticity; (incipient cracking clay)	A	Heavy clay, thin crust, weak SM below	1-3	1	1 & 2b	1-2	S-M	0.25
		B1	Heavy structured clay, mod saline	2	2	1 & 3b	1-2	M	0.3
		B2	Med. to heavy mod. saline, massive clay	2	2	3b	1-2	M-U	0.6
		B3	Silty medium clay weak pedal to massive structure	2	2	1, 2a & 2b	1-2	M-U	0.5+
6.1	Medium deep dark grey-brown or dark brown strongly structured alkaline heavy clay soils over HWR	A	Heavy clay, stony, thin weak SM surface	1	1	1-2b	1	S	0.15
		B1	Heavy structured clay	2	2	3b	1	M	0.4
		B2	Heavy clay,weakly pedal to massive	3	2-3	3b	1	U	0
		C	Gravelly clay – HWR	3	2-3	3b	1	U	0
6.2	Mainly deep brownish black, dark grey-brown, dark brown or brown, uniform strongly structured heavy alkaline clay soils, locally with gilgai development designated (g)	A	Heavy clay, strongly structured, thin SM	1	1	1	2	S	0.15
		B1	Heavy clay, strong med. blocky structure	1-2	2	2b & 3b	1-2	S	0.25
		B2	Heavy clay, strong med.-coarse structure	2-3	3	2b & 3b	1	M	0.4
		B2-B3	Heavy clay, massive structure	2-3	2-3	2b & 3b	1	M-U	0.7+
		D	Sandy loam to silty clay, older alluvium	1-2	2	2b & 3b	1-2	M-U	1.5-2.0 (bgl)

Notes accompanying Table 2

Topsoil suitability assessment based on field observations and soil chemical/physical test data given in Appendices B & C.

(1) A – Surficial soil horizon (generally between 0.2-0.3m thick)

B – B horizon (undifferentiated)

B1 – Upper B horizon (usually about 0.3m thick))

B2 – Lower B horizon (typically about 0.3-0.6m thick)

B3 – B2-C/D transition

C-D – Weathered rock or material below the solum

(2) Salinity Rating (E.C. – 1:5 soil/water solution)

Rating 1 – E.C (mS/cm) <0.25 (sand), <0.4 (loam), <0.55 (clay) – Low

Rating 2 – E.C (mS/cm) 0.25-0.47 (sand), 0.4-0.8 (loam), 0.55-1.15 (clay) - Med. To High

Rating 3 – E.C (mS/cm) >0.47 (sand), >0.8 (loam),>1.15 (clay) – High to Very High

(3) Sodicity Rating

Rating 1 – Non Sodic, ESP <6%

Rating 2 – Sodic, ESP 6-14%

Rating 3 – Strongly sodic, ESP >14%

(4) Acidity/Alkalinity Rating (pH 1:5 H_20)

Rating 1 – Slightly to mod. acid to alkaline (pH 6.0-8.0)

Rating 2a – - Mod. to strongly acidic (pH5.0-<6.0); 2b - Mod. to strongly alkaline (pH>8.0-8.5)

Rating 3a – Strongly acidic (pH<5.0); 3b - Strongly alkaline (pH>8.5)

(5) Disperson Rating (Refer to Appendix D)

Rating 1 – Non-dispersive or very slight dispersion (Classes 4 to 8)

Rating 2 – Slightly to mod. Dispersive[Classes 3(1) to 2(1)]

Rating 3 – Strongly dispersive [Classes 1, 2(2), 2(3) to 2(m)]

(6) Overall Suitability rating

U – Unsuitable for use as topsoil replacement

M – Marginal for use as topsoil replacement

S – Satisfactory for use as topsoil replacement.

4.2 RESULTS OF ASSESSMENT

Useable topsoil resources are mainly confined to the surficial (A) horizon materials (and locally in the upper part of the subsurface (B1) horizon), which contain seed-stock, micro-organisms and nutrients necessary for plant growth. Soil microbial activity, organic matter content and other parameters affecting soil fertility, tend to decrease with depth.

In summary, the following general comments below can be made with respect to topsoil suitability and availability.

In terms of acceptable soil properties and extent of occurrence, the most suitable sources of topsoil occur in Soil Groups 5 and 6, more specifically in terrain units having Soil Types 6.2, 5.3, 5.1 and 6.1. The surficial soil layers of these soil types are typically between about 0.15 to 0.25m thick and are the most suitable in terms of soil physical and chemical properties. However the subsoil (B1) horizons which occur at depths of between about 0.2-0.5m below the surface, are usually of lesser quality and in places are unsuitable for use as topsoil due to increasing alkalinity, sodicity and adverse soil structure.

The surficial soil horizons of Soil Types 4.1, 4.2 and 4.3, which are typically between about 0.2-0.3m thick, generally appear to be useable as topsoil replacement, but in places they are somewhat dispersive. The deeper (B1/B2) subsoil horizons tend to become strongly sodic, strongly alkaline and/or saline with depth.

The Red/Yellow Earth Soil Types 3.2 and 3.3, apart from the often sandy or sandy loam texture of the surficial soil horizons, are generally acceptable in terms of physical and chemical properties to depths of 0.4 to 0.6m. Below 0.6m they tend to have some to appreciable fine to medium size ferruginous gravel within or distributed throughout the profile, low nutrient status requiring the addition of a suitable fertilizer, and in places they tend to be moderately strongly acidic. However texturally and structurally, and in terms of other soil chemical and physical soil properties, the deeper soil horizons are considered to be marginal for use as topsoil but acceptable for subsoil use.

Soil Types 1, 2.1, 2.2 and 3.1, apart from recovering the surface soil for its seed stock and organic content, are not considered suitable for use as topsoil due to the predominantly coarse texture, stoniness and low water storage capacity.

4.3 TOPSOIL AVAILABILITY

The land areas likely to be disturbed by the proposed open cut mining operations and construction of the proposed tailings dams and associated infrastructure facilities are shown in **Figure 8.**

Based on the terrain units included within those areas and the topsoil stripping depths assessed for the various soil types included in **Table 2**:

- The average depth of topsoil in the Ensham Central Project open cut mining area is 0.3 m.
- The average depth of topsoil in the Tailings Dam areas is 0.4 m.

4.4 TOPSOIL MATERIAL MANAGEMENT

4.4.1 Planning

Topsoil resource assessments, carried out in advance of mining, will enable detailed volume calculations and preparation of stripping plans prior to clearing. The stripping plans will also include designated respreading areas or stockpile locations.

Variability occurs within the soil types of each of the terrain units. Consequently, monitoring of soil type variability will be undertaken during the ongoing operational phases of the project to ensure that the maximum quantity and quality of useable topsoil resources is recovered.

4.4.2 Stripping

Prior to the commencement of stripping, areas will be cleared of any timber. Earthmoving plant operators will be trained and/or supervised to ensure that stripping operations are conducted in accordance with stripping plans and *in situ* soil conditions. This will ensure that all suitable topsoil material resources are salvaged and that the quality of the stripped topsoil is not reduced through contamination with unsuitable soils.

Care will be taken during stripping, stockpiling, and respreading to ensure that structural degradation of the soil is avoided and that excessive compaction does not occur during stockpiling.

4.4.3 Stockpiling

Where possible, topsoil material will be respread directly from stripped areas onto areas being rehabilitated. Where this is not possible, topsoil will be stored in stockpiles.

Topsoil material stockpiles will be located in areas that are outside the mining disturbance area and away from drainage lines. The side slopes of stockpiles will be reduced to at least 4:1 gradient.

Stockpiles will be formed in low mounds of minimum height (approximately 5 m maximum) and maximum surface area, consistent with the storage area available. Long tem topsoil stockpiles, not used for over six months, will be reshaped to promote pasture growth. Topsoil stockpiles will be clearly sign-posted for easy identification and to avoid any inadvertent losses. Establishment of any declared weeds on the stockpiles will also be monitored and controlled.

4.4.4 Respreading

Mine rehabilitation planning will include topsoil material respreading considerations including:

- Balancing required rehabilitation topsoil quantities against stored stockpile inventories;
- Planning the source of topsoil material to maximise direct respreading from stripping areas and to minimise the length of time that material is stored in stockpiles; and
- Selective placement of more erodible topsoil materials on flatter areas and not on steeper slopes, to minimise erosion.

During the removal of soils from the stockpiles, care will be taken to minimise structural degradation of the soils. The respreading process will result in some mixing of the upper and lower sections of the stockpiles, promoting the spread of seed stock and micro-fauna through the lower sections of the stockpile.

Topsoil material will be respread in even layers at a thickness appropriate for the intended land use of the area to be rehabilitated.

The mine rehabilitation strategy will include the following measures that are designed to minimise the loss of topsoil material respread on rehabilitated areas:

- Contour ripping to encourage rainfall infiltration and minimise runoff;
- Reseeding soon after respreading to establish vegetation cover as early as possible;
- Installation of slope drainage control to limit slope lengths and runoff velocities; and
- Installation of collection drains and sediment dams to collect runoff and remove suspended sediment.

4.5 IMPLICATIONS FOR REHABILITATION STRATEGIES

The soil attributes that need to be considered in the rehabilitation process include soil pH, salinity, sodicity and dispersion characteristics. The indicative and laboratory testing results have been analysed to determine any limitations related to rehabilitation or revegetation. This assessment, which is provided below, will be considered in ongoing rehabilitation and revegetation planning to ensure suitable rehabilitation standards are achieved.

4.5.1 Soil pH

The preferred range for most plants varies between pH 5.6 to 8.4 depending on the plant species. With the exception of Soil Type 2.3 in Terrain Unit Ta4/2.3, which exhibited very strongly acidic surface and subsoil horizons (pH 4.0-5.5), in all other soil samples tested, the pH levels of the surficial (A1) soil horizons in Soil Groups 2 through 6, were mainly within the slightly acidic to moderately alkaline range (pH 6.5-8.3). The pH in the subsoil layers of Soil Types 3.2 and 3.3, were near neutral

to slightly acidic (pH 7.9-6.0). The pH levels in the subsoil horizons in most soils from Soil Groups 4, 5 and 6, were moderately to very strongly alkaline (pH 8.4-9.3).

For materials that have been rated as marginal for use as topsoil due to excessively high or low pH levels, pH correction can be achieved if necessary by the application of lime or sulphur as appropriate.

4.5.2 Salinity

Reference to the results of soil testing in **Appendices B and C,** indicates that a majority of the subsoil samples from soil types from Soil Groups 2, 4, 5 and 6, that were tested for electrical conductivity (EC), have elevated (moderate to high) salinity levels, particularly in the middle to lower B and B-C or B-D horizons. An exception to these conditions occurs in parts of the alluvial plain that have been subject to irrigation for cropping purposes, where the normally elevated subsoil salinity levels were quite low, likely from downwards leaching of salts due to percolating water from the irrigation process. Subsoil salinity was very low in the samples tested from Soil Types 3.2 and 3.3.

In general, soils with high levels of salinity will not be used for rehabilitation purposes and will be incorporated within the general overburden emplacement below the revegetation root zone.

4.5.3 Sodicity

More than half of the samples submitted for laboratory testing, were either sodic or strongly sodic, mainly in the middle to lower B and B-C horizons in Soil Types 4.2, 5.1-5.3, 6.1 and 6.2. In general, the sodic and strongly sodic soils will not be used for topsoil replacement purposes. Those materials will be incorporated in the overburden emplacements so they are not exposed at the surface. Should materials placed at or near the finished surface level of the overburden emplacement be found to be sodic, application of gypsum will be considered, where necessary, to reduce the sodicity levels of those materials prior to the placement of topsoil material.

4.5.4 Dispersion Characteristics

The results of the indicative dispersion testing carried out (**Appendix B, Table B.1**), show that approximately 50% of the samples tested are potentially either slightly to moderately dispersive, mainly in Soil Types 5.1, 5.3 and 6.2, with some strongly dispersive materials associated with Soil Type 4.2. This is consistent with the medium to high levels of sodicity recorded where, in general, the more dispersive materials occur in the subsoil and deeper subsoil layers. Wherever possible, dispersive and certainly strongly dispersive materials will not be recovered for topsoil replacement purposes.

5.0 EROSION AND SEDIMENT CONTROL MEASURES

As discussed in **Section 4.5**, many of the soil types within the study area include soil horizons which exhibit a slight to high potential for dispersion and consequently are likely to be subject to sheet, rill and gully erosion if left exposed and unprotected during mine construction or mining operations. Proposed erosion and sediment control measures for the mine construction and mining operations are discussed in the following sections.

5.1.1 Mine Infrastructure Construction

Erosion and sediment controls, which will be implemented during mine infrastructure construction, are as follows:

- Vegetation clearing will be conducted progressively so that the minimum area necessary for construction is cleared at any time;
- Runoff from higher areas will be directed around construction sites;
- Runoff from bare earthworks areas will be collected in drains and directed through sediment traps and settling ponds to remove suspended sediment prior to discharge from the site;
- Stockpiles of topsoil and any excess cut material will be sown with grass seed and have side slopes reduced to at least a 4:1 gradient;
- Earthworks batters will be constructed to stable slopes and revegetated soon after construction; and
- Earthworks areas will be landscaped and revegetated as soon as possible after construction is completed.

5.1.2 Mining Operations

Erosion and sediment controls, which will be implemented during mining operations, are as follows:

- Vegetation clearing will be conducted progressively so that the minimum area necessary for mining operations is cleared at any time;
- Runoff from higher undisturbed areas will be directed around mining areas;
- Runoff from overburden emplacement areas and bare earthworks areas will be collected in drains and directed through sediment traps and settling ponds to remove suspended sediment prior to discharge from the site;
- Stockpiles of topsoil material will be sown with grass seed and have side slopes reduced to at least a 4:1 gradient;
- The overburden emplacement will be rehabilitated progressively to minimise the total extent of disturbed area on the site at any time;
- Rehabilitated overburden emplacement areas will be deep ripped along the contour to maximise rainfall infiltration and minimise runoff;
- Rehabilitated slopes will have contour drains to minimise slope lengths and runoff velocities;

- Runoff from rehabilitated areas will be collected in contour drains and collection drains and directed to sediment dams and settling ponds to remove suspended sediment prior to draining from the site; and
- A maintenance program will be implemented to ensure the proper functioning of drainage and sediment control structures.

6.0 LAND SUITABILITY

6.1 INTRODUCTION

The assessment of Land Suitability for agriculture requires the evaluation of the potential for the land to sustain a specific land use. Based on the current and recent history of land use in the general vicinity of the project, this relates primarily to the potential for rainfed (dryland) cash or forage cropping, grazing enterprises and some limited areas of irrigated agriculture.

The earlier land resources survey and mapping carried out for the 1991 Ensham Coal Project IAS – HDM (1991), utilised the Rosser (1974) system for the assessment of the broad scale agricultural capability. The Rosser system is now considered to be a tool essentially more suited for broad scale (1:100,00 to >1:250,000) agricultural land evaluation. In accordance with the QDME Technical Guidelines for Environmental Management of Exploration and Mining in Queensland, the agricultural potential of the land in the study area has been assessed based on the Guidelines for Agricultural Land Evaluation in Queensland – DPI (1990). An assessment of the extent of Good Quality Agricultural Land has also been determined in accordance with the State Planning Policy 1/92 and the planning guidelines prepared by the Department of Primary Industries and the Queensland Department of Housing Local Government and Planning (DPI/DH&LGP -1993).

6.2 METHOD OF ASSESSMENT

In accordance with State Planning Policy 1/92: Development and the Conservation of Good Quality Agricultural Land, the terrain within the study area has been rated in terms of Agricultural Land Classes based on the planning guidelines issued by DH&LGP (1993). In summary the guidelines classify land as follows:

6.2.1 Agricultural Land Classes and Good Quality Agricultural Land

Class A	Crop land – land suitable for crops with nil to moderate levels of limitations
Class B	Limited crop land – land that is marginal for crops due to severe limitations and suitable for pastures. Engineering and/or agronomic improvements may be required before this is suitable for cropping.
Class C	Pasture land – land suitable only for improved or native pastures, continuous cultivation precluded; some areas may tolerate short periods of ground disturbance for pasture establishment.
Class D	Non-agricultural land – land not suitable for agricultural uses due to extreme limitations, including steep slopes, shallow rocky soils or poor drainage.

The method of land suitability classification adopted, has been adapted from the guidelines for agricultural land evaluation published by the DPI (1990) with reference to the publication by Shields and Williams (1991) for a land resources survey in the Kilcummin area of Central Queensland.

The system of classification is based on the identification of physical and chemical limiting factors or constraints applied to specific land uses by adopting the following format.

Within the project area the land classified as Class A is regarded as good quality agricultural land (GQAL) with only minor limitations. Land classified as Class B has moderate to severe limitations for cropping due to surface slopes, soil depth and chemical characteristics. Given the local availability of Class A land, the smaller area of Class B land within the project area is not considered to be GQAL.

6.2.2 Land Suitability Classification

Class 1	High quality land with few or very minor limitations for the intended land use.
Class 2	Land with minor limitations for the intended land use.
Class 3	Land with moderate limitations to sustaining the intended land use.
Class 4	Marginal land requiring major inputs to sustain the intended land use.
Class 5	Unsuitable land due to extreme limitations for the intended land use.

For this study, terrain units identified within the study area, have been evaluated for suitability for:

- Rainfed (dryland) cropping;
- Grazing of natural and improved pastures;
- Agricultural land class; and
- Irrigated Agriculture.

The soil/landform criteria used to determine the land suitability class ratings for both dry land and grazing land uses are included in **Appendix E Table E.1**. The levels of limitations adopted, have been adapted from the criteria proposed by Gunn *et al*.(1988), Shields & Williams (1991) and McDonald (1986), for the Emerald Irrigation Area.

6.3 PRE-MINE AGRICULTURAL SUITABILITY

6.3.1 Agricultural Land Class and Good Quality Agricultural Land

The agricultural land class ratings assessed for the terrain units within the study area are included in **Table 3** and **Figure 4.** Analysis of the data indicates:

- Approximately 40% of the study area has been rated Land Class A, which includes terrain units Qa2/6.2 and Qa2/5.3.
- Approximately 4% of the area has been rated Land Class B, which includes terrain units Cz2/5.3, and P3/6.2

- Approximately 48% of the area has been rated Land Class C which includes the drainage flats, stream terraces and floodplains of the tributary drainage systems, mainly terrain unit Qa1/6.2-5.3, the undulating plains, in particular P3/5.1-6.1, P-T3/4.1-5.1 and Ta5/3.3 and Ta5/2.2; and,
- The remaining 8% of the area has been rated Land Class D, which includes the steep escarpment slopes and rocky hilly areas, including terrain units Ta8/1, Ta6/1-3.1 and the land immediately adjacent to and including the major stream systems terrain unit Qa0/6.2-5.3.

6.3.2 Suitability for Rainfed (Dryland) Cropping

The results of the land suitability assessment for rainfed (dryland) cropping, on a terrain unit basis are included in **Table 3** and presented in **Figure 5.**

The main limitations to sustained productivity for rainfed (dryland) cropping enterprises relate to variable climatic conditions, including rainfall and extremes of temperature, flooding frequency in the broad alluvial tracts and adverse soil physical and chemical attributes locally giving rise to the presence of a surface crust and hard set surface soil conditions. Although variable from terrain unit to terrain unit, the major soil limitations also relate to plant available water holding capacity due to the limited thickness of the surface soil and the locally shallow effective plant rooting depth due to the presence of elevated salinity and sodicity and alkalinity levels at relatively shallow depths. Slight to moderate and locally high levels of dispersion in some soil types in the study area, may exacerbate the potential for erosion and present limitations for rainfed (dryland) cropping.

Reference to **Figure 5** and the data included in **Table 3** indicate the following:

- There is no land rated Class 1 for cropping;
- Approximately 35% of the study area has been rated Class 2 lands (Qa2/6.2); these areas represent the most viable opportunities for cash or forage crops and for irrigation within the study area.
- Approximately 32% of the study area has been rated Class 3 lands (Qa2/5.3, Qa1/6.2-5.3, P3/5.1-6.1 and P3/4.1);
- Approximately 25% of the study area has been rated Class 4 lands (Qa5/6.2, Cz3/5.2-4.2, Ta3/3.2-5.2, Ta4/2.3, Ta5/2.2 and P-T3/4.1-5.1);
- Approximately 8% of the land has been rated Class 5, which includes the steep escarpment slopes and rocky hilly areas, (Ta8/1, Ta6/1-3.1 and P7/1-2.2), and the land immediately adjacent to and encompassing the major stream systems (Qa0/6.2-5.3).

6.3.3 Suitability for Grazing

The results of the land suitability assessment for grazing, based on the occurrence of the terrain units identified within the study area, are included in **Table 3**. The distribution of land suitability classes (grazing) is shown in **Figure 6.**

The majority of the land in the study area has been assessed as suitable for grazing with varying levels of land management required to sustain the land use; details are summarised as follows:

- Approximately 35% of the study area has been rated Class 1 lands; these coincide with terrain unit Qa2/6.2;
- Approximately 9% of the study area has been rated Class 2 lands; these include Qa2/5.3, Cz2/5.3 and P3/6.2;
- Approximately 34% of the area has been rated Class 3 lands, the main occurrences of which include Qa1/6.2-5.3, Cz3/5.2-4.2, Ta3/3.2-2.2, P-T3/4.1-5.1 and P3/4.1;
- Approximately 14% of the area has been rated Class 4 lands; these include terrain units Qa5/5.2, Ta4/2.3, and Ta5/2.2;
- Approximately 8% of the land has been rated Class 5, which includes the steep escarpment slopes and rocky hilly areas, (Ta8/1, Ta6/1-3.1 and P7/1-2.2), and the land immediately adjacent to and encompassing the major stream systems Qa0/6.2-5.3). Access to land immediately adjacent to drainage channels, banks and stream levees, in terrain unit Qa0/6.2-5.3, should be restricted from cattle grazing to minimise the potential for stream bank erosion and maintain bank stability.

6.2.4 Suitability for Irrigated Agriculture

A land suitability assessment for irrigated agriculture has been carried out in accordance with the requirements of the Terms of Reference for the project. Based on criteria proposed by McDonald (1986) for the Emerald irrigation area, the results of the land suitability assessment for irrigated agriculture on a terrain unit basis are included in **Table 3.** The suitability of land for irrigated agriculture within the study area is shown in **Figure 7**.

Subject to the availability of suitable quantities and quality of water resources within the general vicinity, a summary of land suitability for irrigated agriculture within the study area is as follows:

- There is no land rated as Class 1 for irrigated agriculture;
- Approximately 35% of the study area has been rated as land suitability Class 2-3, which includes the lands designated as terrain unit (Qa2/6.2). The flooding potential, wetness factors and soil physical and chemical characteristics of the soils in these areas present minor to moderate limitations for the intended land use, however they represent the most viable opportunities for irrigated agriculture;
- A further 7.5% of the study area has been rated as suitability Class 3, which includes terrain units (Qa2/5.3 and Cz2/5.3);
- Approximately 26% of the study area has been rated as suitability Class 3-4. This rating results primarily from the undulating, moderately sloping nature of the lands which include terrain units (Cz3/5.2-4.2, P-T3/4.1-5.1, P3/4.1,P3/6.2 and P3/5.1-6.1);
- Approximately 23.5% of the land has been rated as suitability Class 4, which primarily results from the erosion and flooding potential of the lands comprising the alluvial flats and drainage-

ways in terrain units (Qa1/4.2 and Qa1/6.2-5.3), and the nature and steepness of the surface slopes and the topographic position in the landscape in terrain units, (Ta3/3.1-1, Ta3/3.2-2.2, Ta3/4.3-2.2, Ta4/2.3, Ta5/2.2 and Ta5/3.3).

- Approximately 8% of the study area has been rated as land suitability Class 5, which includes the land within and immediately adjacent to the major drainage lines (Qa0/6.2-5.3) and the rocky hills and escarpment slopes in terrain units (Ta6/1-3.1, P7/1-2.2 and Ta8/1).

Table 3
Agricultural Land Suitability Assessment

Terrain Unit No	Landform	Area (ha)	Ag. Land Class	Land Suitability					
				Dryland Cropping		Grazing		Irrigated Agriculture	
				Land Suitability	Limitations [1]	Land Suitability	Limitations [1]	Land Suitability	Limitations [1]
Qa0/6.2–5.3	River channel, banks, low terraces and levees mostly with cracking and non-cracking clay soils	234	D	5	c5, f5, e5	5	t5, f5, e5	5	f5, e5, t5
Qa1/4.2	Tributary stream flats and terraces with brown or reddish brown alkaline duplex soils.	55	C	4	f4, pc3, sa3	4	f3, p3, e3, n3	4	f4, pb3, pc3,e3, n3
Qa1/6.2–5.3	Tributary stream flats and terraces with deep cracking and non-cracking clay soils.	240	C	3	f4, sa3, so3	3	f3, e3	4	f4, e3, pb3, sa3, so3
Qa2/5.3	Slight rises in the alluvial plain with non-cracking clays with mod. saline, sodic subsoils.	258	A	3	f3, sa3, so3	2	pc3, f2, d3, so3	3	pc3, f2, d3, so3, sa3, w3
Qa2/6.2	Near level alluvial plains with deep dark grey and brown cracking clay soils.	1932	A	2	f3, sa3, so3	1	f2, e2, pc2	2-3	f2-3, e2, sa3, so3
Qa5/6.2	Dissected slopes to drainage mostly with deep dark-coloured cracking clay soils.	177	C	4	f4, t4, c4	4	e3-4, p3	4	e5, t4-5, so3
Cz2/5.3	Gently inclined plains with crusty surface non-cracking clays with mod. saline, sodic subsoils	157	B	3	f2-3, sa3, so3	2	f2, sa2, pc2	3	f2, sa3, pc3, t3, so3
Cz3/5.2–4.2	Gently inclined interfluves with deep uniform clays and thin loamy surface brown duplex soils	182	C	4	t3, r3, pc3	3	pc3, e3	3-4	t3-4, pc3, e3
Ta3/3.2-1	Mesa tops and upper marginal slopes with sandy surface red-yellow earths and shallow rocky soils.	141	C	4	t3, d4, pt3, r3	4	t3, pt3, r4	4	t3, pt3, r4, d3
Ta3/3.2–2.2	Undulating plains and rises with shallow sandy red-yellow earths and gravelly sandy lithosols.	191	C	4	pg4, d3, pd3, t3	3	pg4, pt3, d3	4	pg4, pt3, d3, t4
Ta3/4.3-2.2	Undulating rises with sandy surface duplex soils and shallow	41	C	4	pg4, n3 pt3,	3	pg4, n3, pt3	4	t4, n3, pg4

Terrain Unit No	Landform	Area (ha)	Ag. Land Class	Land Suitability					
				Dryland Cropping		Grazing		Irrigated Agriculture	
				Land Suitability	Limitations [1]	Land Suitability	Limitations [1]	Land Suitability	Limitations[1]
	gravelly loamy lithosols.				e3				
Ta4/2.3	Irregular undulating lands with low jump-ups and gravelly rises	233	C	4	pg4, d3, e3, t4	4	pg4, e4, r34	4	pg4, e4, r3-4
Ta5/2.2	Dissected lower plateau slopes with deep sandy, loamy and clayey gravelly soils	181	C	4	t4, r4	4	pg4, r4	4	pg4, r3-4, t4
Ta5/3.3	Mod. inclined eroded plateau slopes with lateritic gravelly red and yellow earth soils	37	C	4	t4, e3, pc3, n3	3	n3, pc3, e3	4	n3, pc3, e3, pg4, t4, r3-4
Ta6/1–3.1	Low rocky hills and rises with shallow rocky soils and shallow sandy red earths	31	D	5	t5, r4-5, d4	5	n3, e4, r4, t5	5	n3, e4, r4, t5
Ta8/1	Steep escarpment slopes with rock outcrop and shallow rocky soils	159	D	5	t5, r5, d5	5	t5, e5, d5	5	t5, e5, d5, r5
P-T3/4.1–5.1	Undulating plains and rises with med. deep thin loamy brown duplex soils and uniform clay soils.	154	C	4	t3, pc3, pd3, so3, e3	3	pd3, pc3, d3	3-4	pd3, pc3, d3, t4, sa3, so3
P3/5.1–6.1	Undulating plains and rises with shallow to med. deep uniform clays and grey-brown cracking clays	730	C	3	t3, d3	3	pc2, d3, pd3	3-4	pc2, d3, pd3, t4. sa3, so3
P3/4.1	Gently inclined dissection slope interfluves with shallow thin loamy surface red brown duplex soils	270	C	3	t3, d3	3	pc3, e3	3-4	pc3, e3
P3/6.2	Gently undulating, inclined plains with mainly deep grey-brown cracking clay soils.	75	B	3	t3, d2, sa3	2	d2, e2	3-4	d2, e3, so3,sa3, t4
P7/1–2.2	Low rocky hills with shallow rocky soils and rock outcrop.	8	D	5	t5, d5	5	t5, r5, d5	5	t5, r5, d5

Notes: -

(1) An explanation of the limitations is provided in Appendix E, Table E.1

6.4 POST-MINING AGRICULTURAL LAND SUITABILITY

The post-mine land disturbance zones within the study area are shown in **Figure 8.** The areas that will be disturbed as a result of the mining operations include:

1. The Open Cut Footprint, which includes:
   - overburden emplacement areas with re-contoured surface slopes;
   - reinstated floodplain areas, which are restored to the pre-mining topography; and
   - final voids, which are beyond the floodplain boundary.
2. Tailings Dam areas (Tailings Dam 1 and Tailings Dam 2);
3. Underground Mining Subsided Areas. These areas will not be subject to any major earthworks, but will be prone to surface subsidence effects resulting from the underground mining operations. The surface subsidence effects will result in the development of an undulating land surface with slopes up to 2% and local relief of about 1.5-2.0 m between crestal areas and the intervening broadly depressional floors of undulations. Any areas found to be subject to surface water ponding will have appropriate drainage measures incorporated.

Table 4 provides the pre-mine agricultural land suitability of areas to be disturbed by Ensham Central Project mining operations.

Table 4
Analysis of the Impact of Mining on Pre-Mine Agricultural Land Suitability

Agricultural Land Suitability		Open Cut Footprint (ha)		Tailings Dams (ha)		Subsided Areas (ha)	
		Land Suitability		Land Suitability		Land Suitability	
		Pre-Mine	Post-Mine	Pre-Mine	Post-Mine	Pre-Mine	Post-Mine
Ag. Land Classes	**A**	592	0	0	0	1154	0
	B	32	540	53	0	0	1154
	C	294	370	147	0	235	235
	D	89	97	0	200	32	32
Rainfed Cropping Classes	**1**	0	0	0	0	0	0
	2	406	0	0	0	1154	0
	3	408	540	173	0	78	1232
	4	104	370	27	0	157	157
	5	89	97	0	200	32	32
Grazing Land Classes	**1**	406	0	0	0	1154	0
	2	218	540	0	0	0	0
	3	234	0	173	0	78	1232
	4	60	370	27	0	157	157
	5	89	97	0	200	32	32
Irrigated Agriculture Land Classes	**1**	0	0	0	0	0	0
	2-3	406	540	0	0	1154	0
	3	218	0	0	0	0	0
	3-4	168	0	169	0	0	1154
	4	126	0	31	0	235	235
	5	89	467	0	200	32	32
Totals		1007		200		1421	

6.4.1 Impact of Proposed Mining Operations

Open Cut Footprint

The reinstated floodplain area (540 ha) will be rehabilitated to Class B land. The main volume of the EIS describes the reinstatement and rehabilitation techniques to be employed to achieve this land suitability.

The elevated overburden emplacement areas will progressively be re-shaped with surface slopes mostly about 10% with topsoil replaced to promote vegetation regrowth. Rehabilitation of these areas, in the long term, should re-create a land suitability equivalent to Class C land.

Consequently the overall impact of the open cut operations will result in:

- a net loss of approximately 592 ha of Class A lands;
- a net increase of approximately 508 ha of Class B land;
- a net increase of approximately 76 ha of Class C land; and
- a net increase of approximately 8 ha of Class D land.

Tailings Dams

The combined total area of Tailings Dams 1 and 2 is 200 ha, which includes 53 ha of Land Class B and 147 ha of Land Class C.

When decommissioned, the tailings dams, although rehabilitated, will essentially constitute non-agricultural (Class D) lands. Consequently the overall impact of the construction of the tailings dams will result in a reduction of 53 ha of the Class B lands and 147 ha of Class C lands.

Underground Mining Subsided Areas

The underground mining subsided areas includes a land area of approximately 1,421 ha, comprising 1,154 ha of Class A agricultural land, 235 ha of Class C land and 32 ha of Class D land.

The underground mining subsided area, although not likely to be subject to any major surface earthworks, will locally be subject to surface subsidence effects resulting from the underground mining operations. Changes to the surface form and surface slopes in this area as discussed in **Section 6.4** above, is likely to result in a reduction in agricultural land capability from Land Class A to land Class B over much of the area and will restrict any potential for irrigated agriculture.

Accordingly the overall potential impact of surface subsidence effects will be a reduction in agricultural land suitability for 1,154 ha of the Class A land to a Class B level. The impact on the remaining 267 ha of Class C and Class D land will remain unchanged.

A similar analysis of the impact of the mining operations on land suitability for rainfed crops, grazing or irrigated agriculture can be made from reference to the data provided in **Table 4.**

Conclusion

In total, the Ensham Central Project will lead to a loss of 1,746 ha of Class A land, which is considered to be GQAL. Much of this land will be converted to Class B land and the project will lead to a net increase of 1,609 ha of Class B land.

SPP 1/92 provides a framework for the consideration of the GQAL in development assessment. The policy acknowledges that there will be developments that can legitimately alienate GQAL because they represent an overriding benefit to the community.

The project is considered to provide the following overriding community benefits:

- It allows the utilization of the coal resources of the State;
- It will provide substantial employment opportunities and economic benefits;
- It will allow the continuation and expansion of a locally significant industry that provides substantial export income to the State;
- it allows the continued utilization of infrastructure associated with Ensham Mine; and
- There is no alternative location on land of lesser agricultural quality. The project location is dictated by the position of the coal resources.

for
HANSEN CONSULTING

Gavan Renfrey
Consultant Terrain Analyst

Peter Hansen
Principal Environmental Engineer

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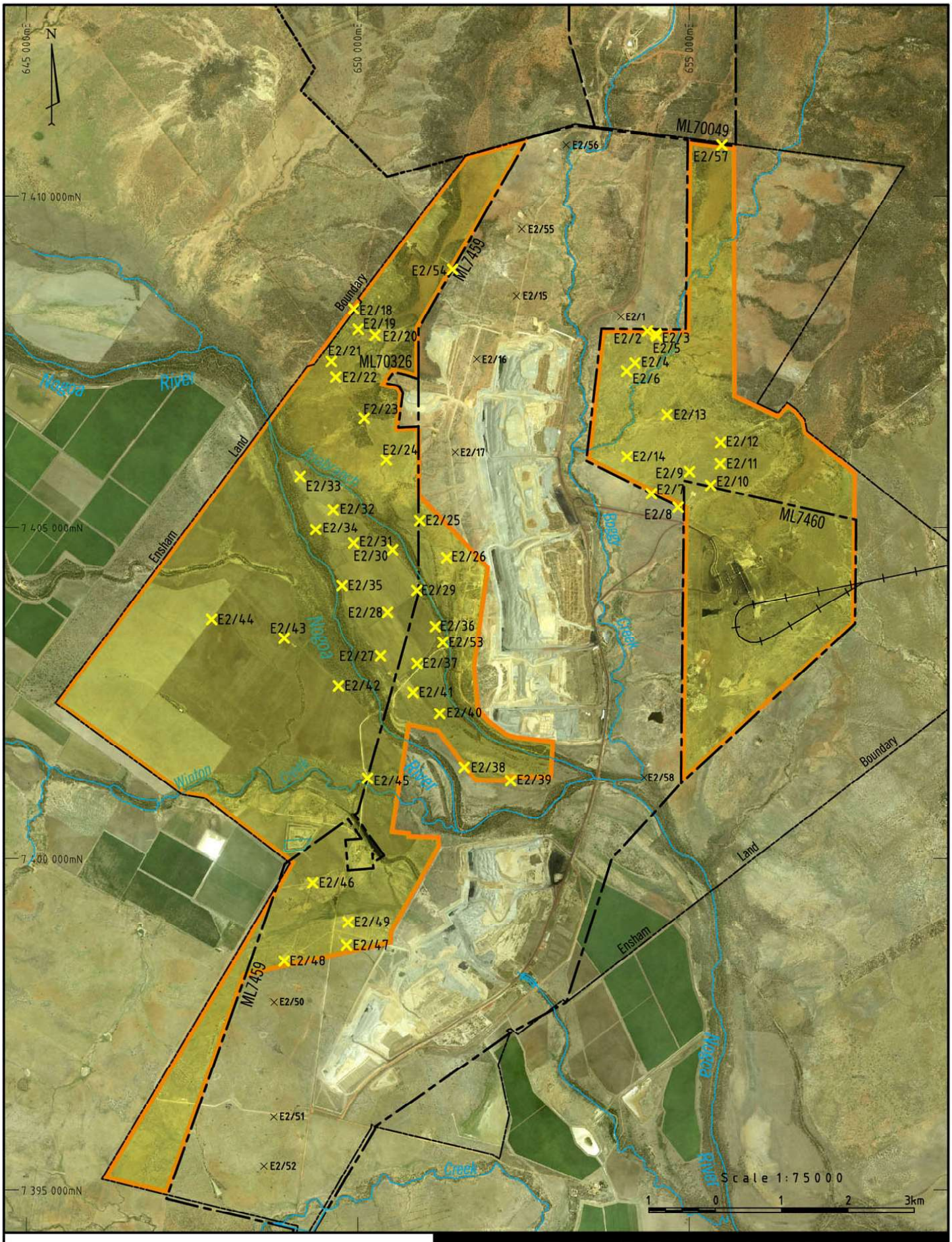
FIGURES



EIS Study Area

E2/54 EIS Site Sampling Location

×E2/54 Site Sampling Location *(Beyond EIS Study Area)*

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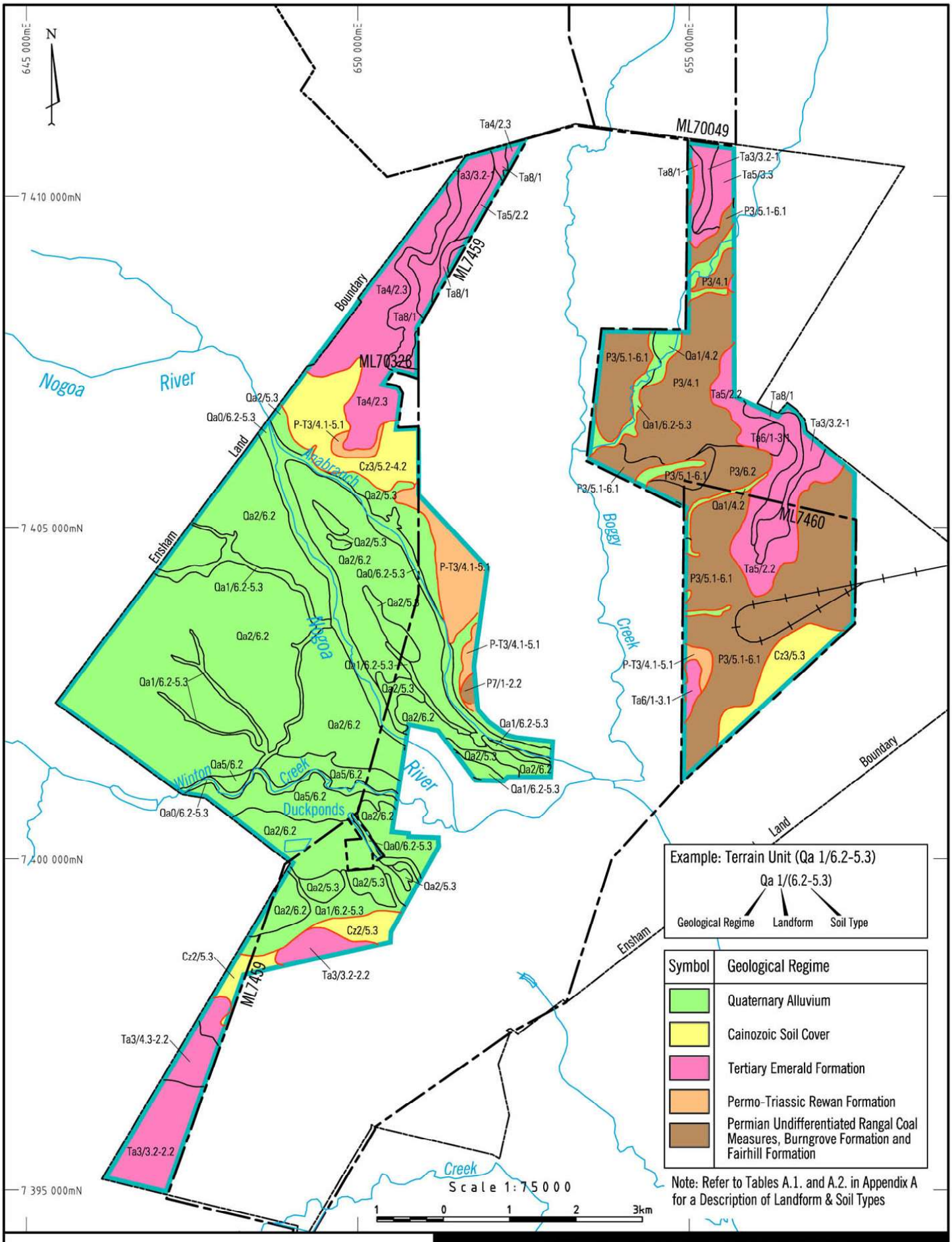
EIS Study Project Area and Site Inspection Locations

Filename: EN EIS 14 – EIS Proj Area & Soil Locn.dwg

Date: 21.10.05

Figure 1



Note: Refer to Tables A.1. and A.2. in Appendix A for a Description of Landform & Soil Types

EIS Study Area

Terrain Unit Boundary

Geological Regime Boundary

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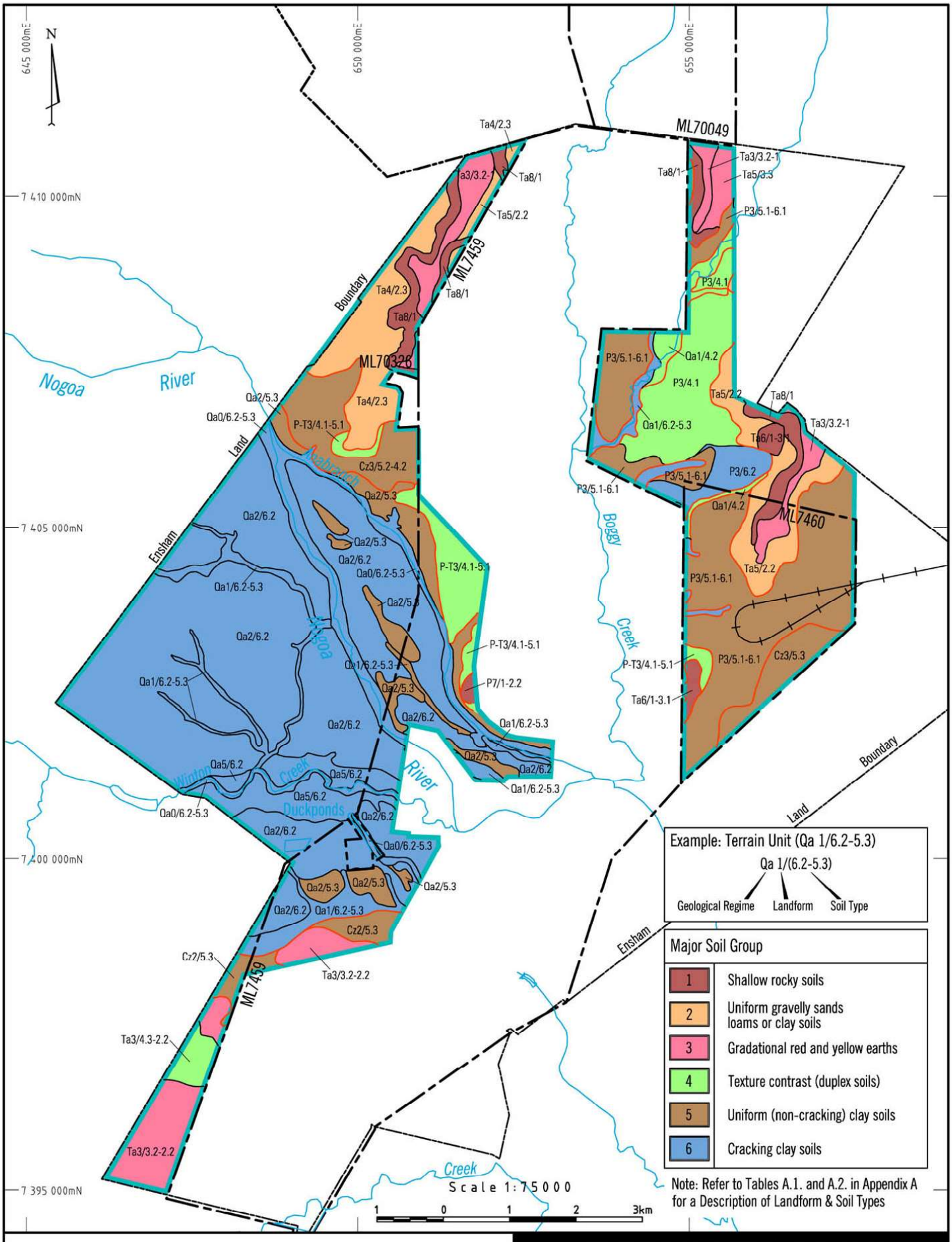
Terrain Units

Filename: EN EIS 14 – EIS Terrain Units.dwg

Date: 21.10.05

Figure 2



ENSHAM CENTRAL PROJECT

Soil Types

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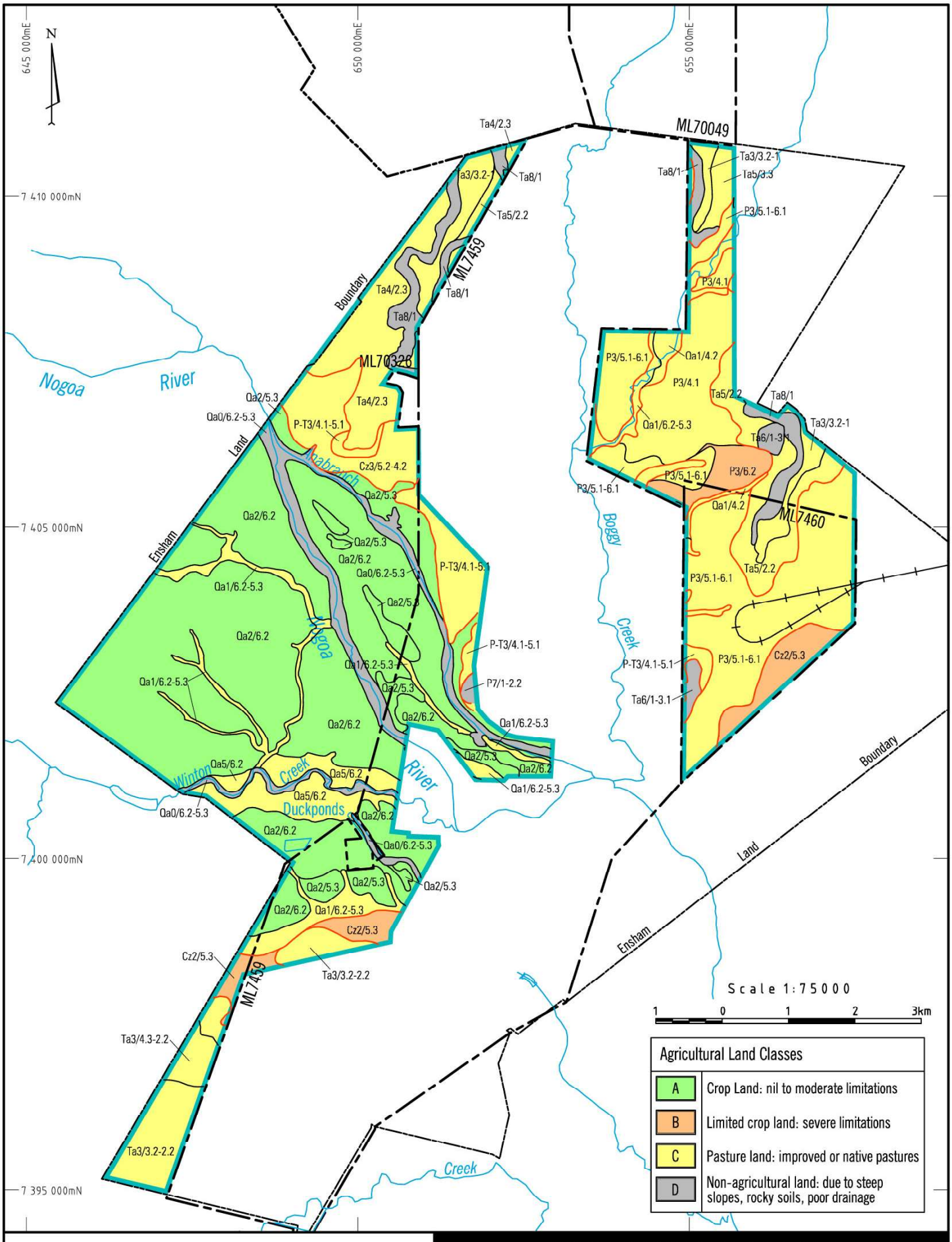

ENSHAM CENTRAL PROJECT

Pre Mining Agricultural Land Classes

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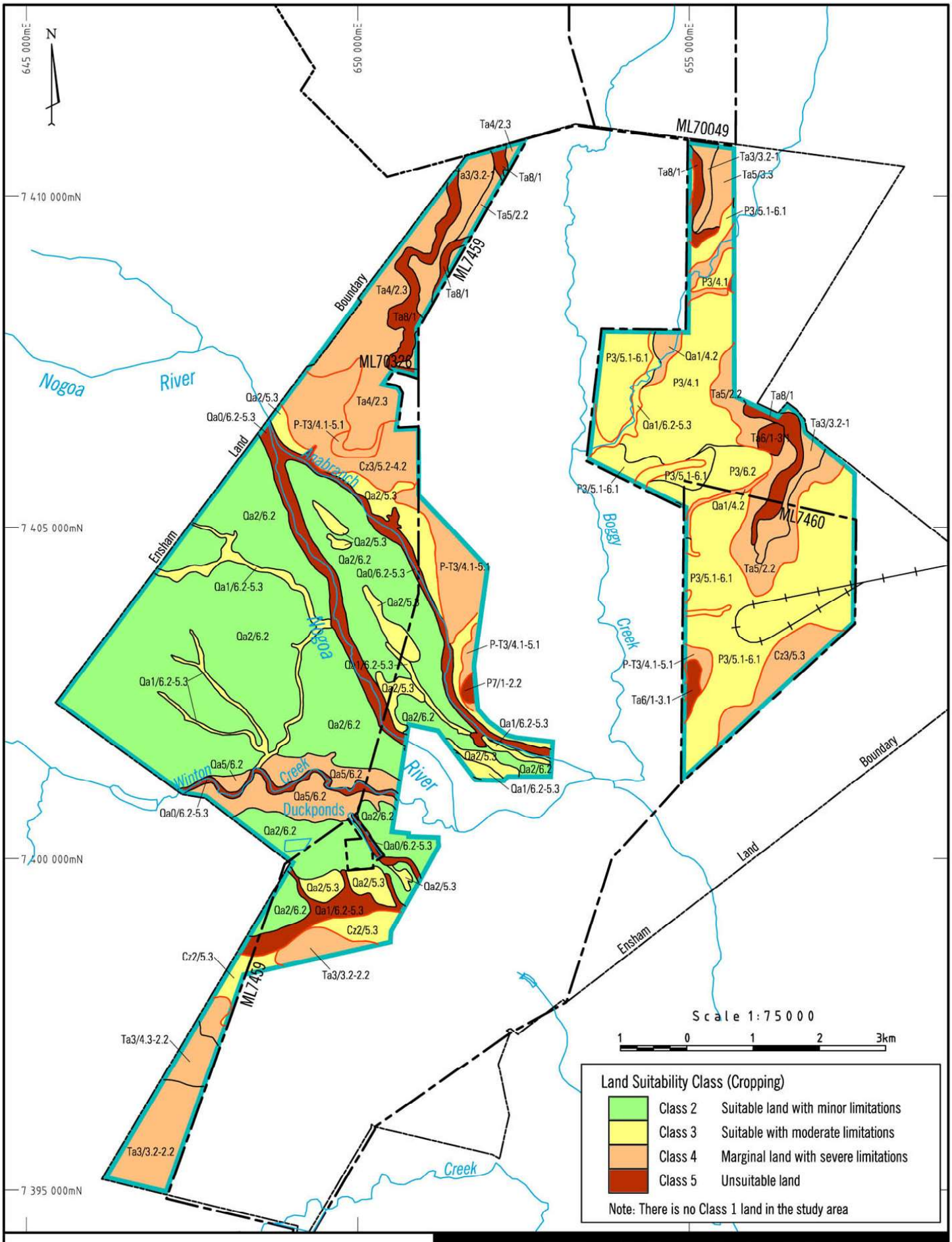
Date: 21.10.05

Figure 4



ENSHAM CENTRAL PROJECT

Pre Mining Land Suitability (Cropping)

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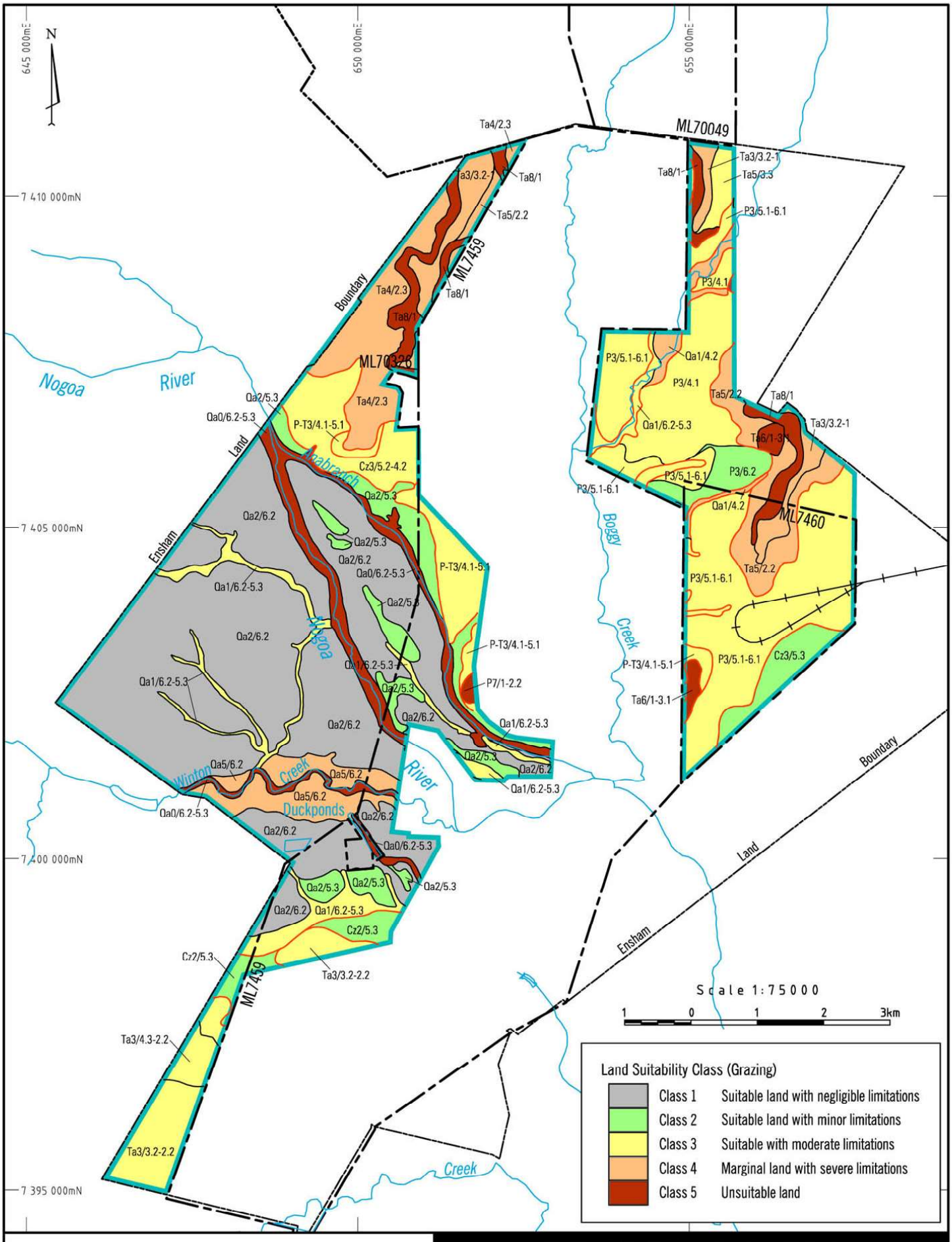

ENSHAM CENTRAL PROJECT

Pre Mining Land Suitability (Grazing)

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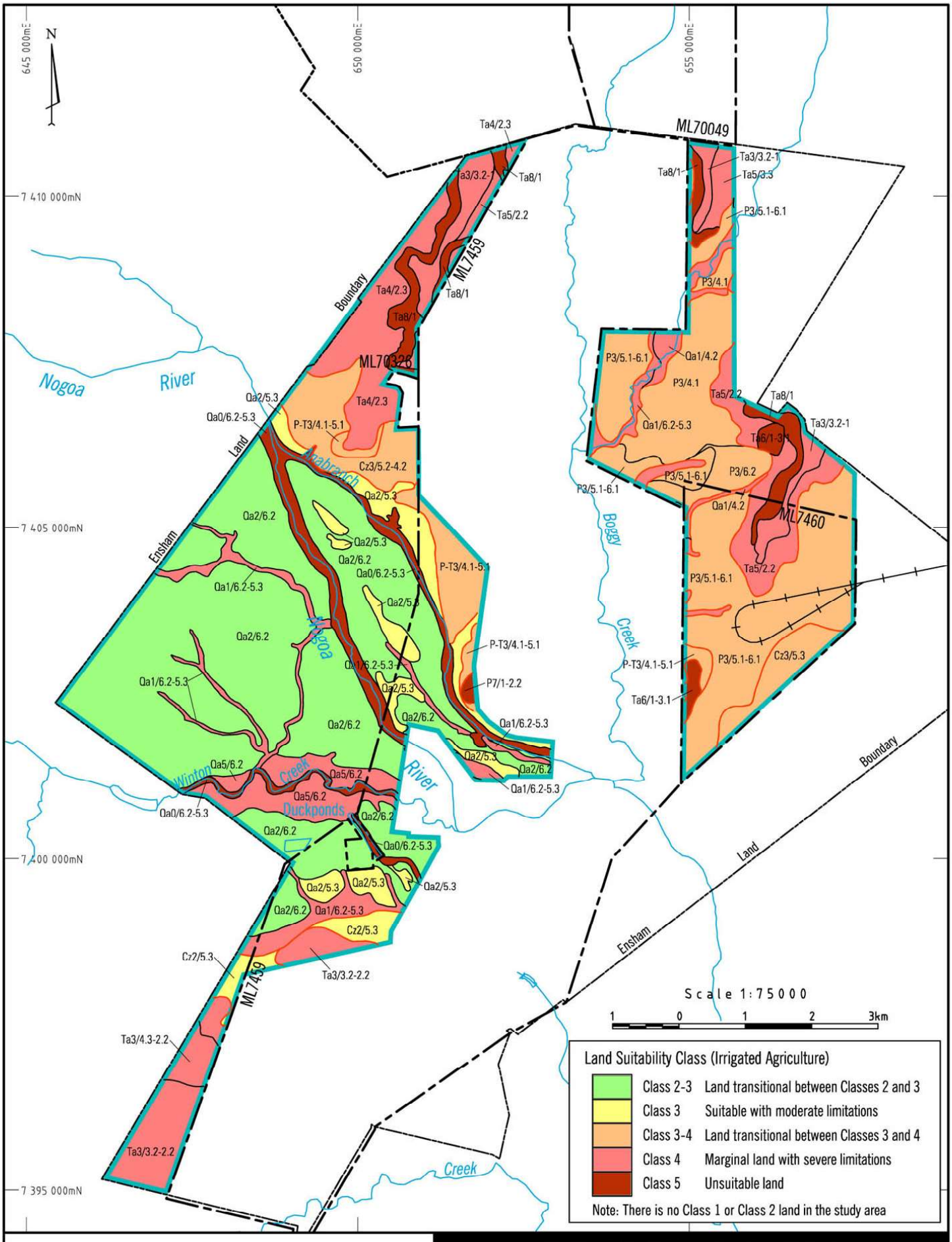
Date: 21.10.05

Figure 6



ENSHAM CENTRAL PROJECT

Pre Mining Land Suitability (Irrigated Agriculture)

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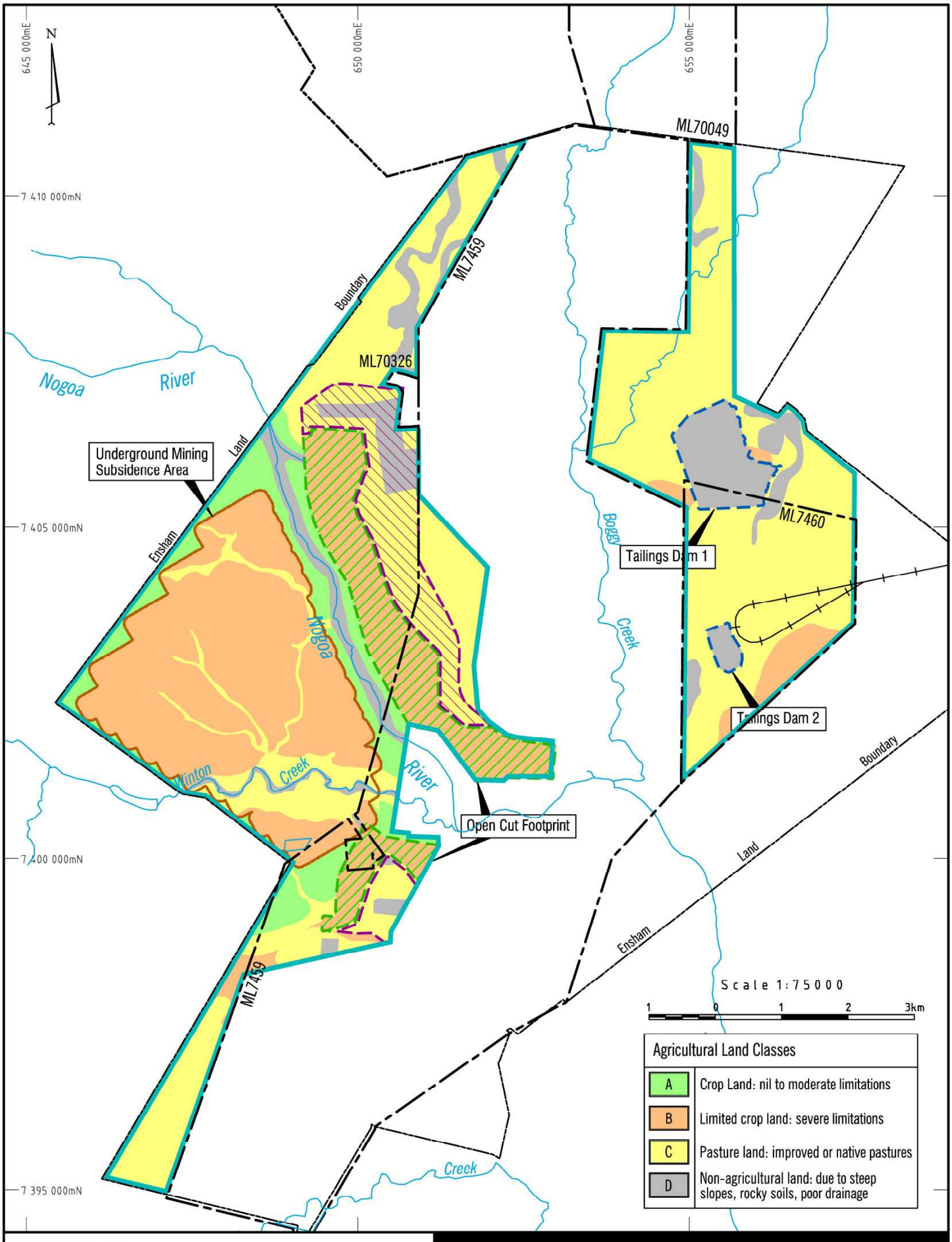


ENSHAM CENTRAL PROJECT

Post Mining Agricultural Land Classes

Filename: EN EIS 14 - EIS Land Capab_Agricultural_Post.dwg | Date: 19.04.06 | Figure 8

APPENDIX A

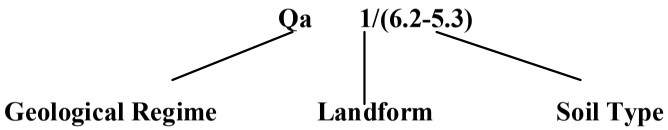
Description of Terrain Units

Appendix A – Table A.1
Key to the Identification of Terrain Units

Geological Regime		Landform		Soils	
Symbol	**Formation / Lithology**	**No.**	**Description – (Surface Form and Slope Range)**	**Group No.**	**Major Soil Group**
Qa	Quaternary Alluvium; River and Floodplain Deposits – clay, silt, sand, gravel	0	Channel floors, low flood terraces and banks of major streams and rivers; overall stream gradient <1%, bank slopes variable 25% to locally sub-vertical	1	Shallow Rocky Soils associated with rock outcrop or exposed rock with skeletal gravely sandy or loamy soils (Uc1, Um1)
Cz	Cainozoic Soil Cover including Older Alluvial and Colluvial Deposits – soil, sand, siliceous and ferruginous gravel and reworked laterite	1	Depressional and shallowly incised drainageways, Intermediate stream terraces, floodplain and drainage flats, frequently floodprone and subject to surface water ponding following wet periods; slopes mostly <1%	2	Gravelly Sand, Loams or Clays, medium to deep uniform or weakly gradational soils dominated by gravel content throughout much of the middle to upper parts of the solum (Uc1, Um5, Gn4).
Ta	Tertiary Emerald Formation – lateritised sediments, laterite, claystone, siltstone, sandstone and pebbly sandstone.	2	Near flat to gently undulating alluvial plain, gently inclined outwash slopes, valley flats and intermediate and higher river terraces and back plains; slopes mostly <2%	3	Gradational Red and Yellow Earth Soils (Gn1-Gn4)
P-T	Permo-Triassic Rewan Formation – mudstone and interbeds of lithic sandstone	3	Undulating plains with broad low rises, gently inclined broadly rounded dissection slope interfluves and near level to gently sloping crestal areas on mesas and eroded plateau remnants; slopes mostly 2-3% locally up to 5%	4	Texture Contrast (Duplex) Soils (Db1, Dr2, Dy3)
P	Permian Undifferentiated Blackwater Group, comprising the Rangal Coal Measures, Burngrove Formation and Fairhill Formation – carbonaceous mudstone, thinly interbedded mudstone and fine sandstone, siliceous siltstone, calcareous and feldspathic sandstone	4	Moderately strongly undulating lands with irregular low rounded rises and moderately inclined dissection slope interfluves and shallowly incised erosion gullies with local low jump-ups adjacent to flatter benched surfaces; slopes variable up to about 12% in the steeper parts	5	Uniform (or weakly gradational) Fine-textured (Non-cracking) Clay Soils (Uf6, Gn3)
		5	Undulating to rolling rises, gently to moderately inclined broadly rounded dissection slope interfluves and footslopes; slopes mostly in the range 6-15%	6	Uniform (Cracking) Clay Soils (Ug5)

Geological Regime		Landform		Soils	
Symbol	**Formation / Lithology**	**No.**	**Description – (Surface Form and Slope Range)**	**Group No.**	**Major Soil Group**
		6	Irregular low hills and rises and low hilly lands, with moderately steep dissection slope interfluves; slopes mostly up to 25%, locally steeper areas occur.		
		7	Hilly lands with steep irregular planar hill slopes mostly within the range 25-35%		
		8	Steep escarpment slopes, 25-50m high, with steep irregular planar and locally benched slopes typically in the range 35-60% to locally sub-vertical		

Example: Terrain Unit (QA1/6.2-5.3)



Notes:

(1) Refer to Text Table 1 for a more detailed description of Soil Group Variants.

(2) The use of dual symbols eg (6.2-5.3) to represent the soil type, serves to indicate that either one, both soil types, or intergrades between the two, may occur within the terrain unit as mapped.

Appendix A – Table A.2
Description of Terrain Units

Terrain Unit No	Landform	Soils	Comments
Geological Regime: (Qa):- Quaternary Alluvium; gravel; sand; silt and clay.			
Qa0/6.2–5.3	Channel floor, flood terraces and banks of major streams and rivers; overall stream gradient <1%; bank slopes variable, 25% to sub-vertical	Gravel, sand, silt and clay in channel floors and low terraces. Dark coloured brownish black, dark grey or dark brown (cracking) clay soils (type 6.2); some dark brown (non-cracking) clays soils (Type 5.3) occur on banks and narrow levees.	Flowing or ponded water in stream floors; some occurrences of bank instability on higher bank slopes due to scour and undercuttings.
Qa1/4.2	Stream terraces, narrow flood plains and drainage flats, mainly on the upper reaches of tributary stream systems, overall slopes <1%	Deep thin silty to loamy surface duplex soils with strongly alkaline to neutral brown or reddish brown medium to heavy clay subsoils (Type 4.2)	Moderate sleet and gully erosion on the approaches to drainage.
Qa1/6.2–5.3	Intermediate and lower stream terraces, floodplains, backplains and broadly depressional to shallowly incised drainage-ways; overall slopes mostly <1%.	Mainly deep dark-coloured, dark grey or dark brown (cracking) clay soils (Type 6.2) forming channel floors and low banks. Some deep uniform brownish black, dark brown or dark reddish brown (non-cracking) clays (Type 5.3)	Prone to regular flash flooding and surface water ponding.
Qa2/5.3	Broad low levees of the present and prior stream systems and slight rises within the alluvial plain (Qa 2/6.2); slopes <2%.	Mostly thin clay loam to clayey surface uniform or weakly gradational clay soils with brownish black or dark brown medium to heavy, mostly strongly alkaline clay subsoils (Type 5.3) some thin loamy surface duplex soils (Type 4.2) occur locally.	Areas of moderately severe sheet erosion on slopes to drainage.
Qa2/6.2	Near flat to very gently undulating or gently inclined alluvial plain and high river terraces; slopes mostly <2%	Deep brownish black, dark grey or dark brown (cracking) clay soils (Type 6.2) with strong alkaline heavy clay subsoils. Some thin weak self-mulching incipient cracking clays (Type 5.3) occur locally	Local occurrences of severe gully erosion on slopes to drainage where runoff becomes concentrated.
Qa5/6.2	Dissected and eroded slopes to drainage mainly along the margins of the high river terraces; slopes up to 12%.	Deep brownish black, dark grey or dark brown heavy uniform (cracking) clays (Type 6.2)	Moderate to locally severe shallow sheet and gully erosion on slopes to drainage, particularly in cleared areas.

Terrain Unit No	Landform	Soils	Comments
Geological Regime: (Cz) – Cainozoic soil cover including older alluvial and colluvial deposits; soil,sand,siliceous graveland reworked laterite			
Cz2/5.3	Gently inclined lower wash slopes on the margins of the broad alluvial plain, planar slopes <2%.	Deep uniform (incipient cracking) clay soils (Type 5.3) with a thin crusty weak self mulching surface and dark brown, medium-heavy alkaline clay subsoils.	Some occurrences of soil type 6.2 may occur in diffuse depressional areas.
Cz3/5.2–4.2	Gently inclined lower wash slopes and lower parts of gently sloping interfluves on the margins of the broad alluvial plain; slopes 2 – 5%	Mixed occurrences of deep dark brown, brown or yellowish brown uniform med to heavy clay soils (Type 5.2) and thin loamy surface duplex soils (Type 4.2) with strongly alkaline medium to heavy clay subsoils.	Moderate severe sheet erosion with and gully erosion on slopes to drainage.
Geological Regime: (Ta) – Tertiary Emerald Formation; laterised sediments; laterite; claystone; siltstbne; sandstone; pebbly sandstone			
Ta3/3.2-1	Near level to gently sloping crestal areas on mesas and eroded plateau remnants; slopes mostly <2% steepening to 5% towards the plateau margins.	Shallow to mod. deep sandy surface red or yellow earth soils (Type 3.2) with loamy sand to sandy loam subsoils on the broader mesa tops; exposed rock and shallow sandy medium to coarse-textured rocky soils (Type 1) mainly along the outer margins of the unit;	Prone to moderately severe sheet erosion towards the outer margins of the unit.
Ta3/3.2-2.2	Undulating plains with broadly rounded slightly higher gravelly rises and plainar gently inclined lower colluvial/wash slopes in the range 2 – 5 %.	Mostly moderately shallow fine sandy to silt loamy surface soils, grading to gravelly fine sandy subsoils underlain by dense clayey (Si, Fe and Co_3) gravels (Soil Type 2.2) on rises; with sandy to loamy surface red yellow earth soil (Type 3.2) on mid to lower slopes.	Sandy surface soils with high infiltration rate; some shallow rill erosion on lower slopes to drainage; potential borrow sources for construction gravels.
Ta3/4.3-2.2-	Undulating crestal areas and broadly rounded rises; slopes 2-5%	Sandy surface duplex soils (Type4.3), with a pale or bleached A2 horizon over mottled yellow, brown and grey sandy alkaline clay subsoils underlain by dense (Si and Fe) gravel, intermingled with mod. shallow gravelly loams to loamy gravels (Type2.2).	Strongly leached low fertility; slightly to moderately dispersive in the surficial soil horizons
Ta4/2.3	Mod. strongly undulating lands with gravel strewn rises and gently to moderate inclined irregular rounded dissection slope interfluves, with low jump-ups adjacent to higher flatter benched surface areas; overall slopes up to 12%, locally steeper	Shallow to medium deep gravelly uniform or weak gradational soils (Type 3.2), locally with bare hardest silty loam surface soils or dense stone/cobble strewn surface with gravelly clay loam to clayey gravel lenses of varying thickness underlain by strongly acidic clay subsoils transitional to HWR between 0.5–1.0m	Low rises with dense gravel /stone strewn surfaces, elsewhere bare soil areas may be prone to surface sheet erosion with local occurrences of moderately severe gully erosion along some drainage lines.

Terrain Unit No	Landform	Soils	Comments
Ta5/2.2	Irregular moderately steep dissected lower escarpment slopes and mod. inclined dissection slope interfluves; slopes up to 12%, locally steeper.	Medium to deep sandy to loamy and locally clayey gravels (up to 50mm)-Type2.2), underlain by flaggy white and ferruginous sandstone.	Dense surface strew of coarse sub-rounded and rounded siliceous gravel; these areas may provide material suitable for construction purposes.
Ta5/3.3	Gently to mod. inclined planar dissection slopes and broadly rounded dissection slope interfluves on eroded plateau remnants; slopes 5-12% locally steeper.	Medium to deep sandy loam to loamy surface red or yellow earth soils (Type 3.3) with ferruginous gravelly sandy clay loam, sandy clay or clayey subsoils of medium to high plasticity	These soils are prone to moderately severe gully erosion where run off becomes concentrated.
Ta6/1–3.1	Low rocky hills and rises and eroded plateau remnants with irregular benched marginal slopes typically about 12%, locally up to 25%.	Rock outcrop and shallow rocky sandy to loamy soils (Type 1) together with shallow weak gradational sandy red earth soils (type 3.1)	Prone to surface sheet erosion; much exposed rock and laterite.
Ta8/1	Escarpment slopes (25 – 50m high) with steep irregular planar locally benched slopes typically 30 – 60%, locally sub-vertical	Shallow rocky soils with a sandy to loamy soil matrix (Type 1); together with exposures of massive laterite or ferruginous sedimentary rocks.	Steep rocky slopes mostly retaining dense vegetation growth; clearing will increase the potential for erosion.
Geolocial Regime: (P-T) - Permo-Triassic Rewan Formation and (P) - Permian Undifferentiated, Rangal Coal Measures, Burngrove Formation and Fairhill Formation, comprising carbonaceous mudstone, thinly interbedded mudstone and fine sandstone, siliceous siltstone, calcareous lithic and feldspathic sandstone.			
P-T3/4.1–5.1	Undulating plain with broad low rises and gently inclined dissection slope interfluves; slopes typically 2 – 3% locally up to 5% on slopes to drainage.	Mixed occurrences of thin loamy surface brown duplex soils (Type 4.1) with alkaline medium to heavy clay subsoils underlain by HWR between 0.5–0.8m, together with medium deep uniform clay soils (Type 5.1) with brown strongly alkaline subsoils over HWR below 0.5 to 0.8m approx.	Local areas have mod. dense surface cover of Si and Fe stone. The immediate subsoil layers have very high alkalinity
P3/5.1–6.1	Gently to moderate strongly undulating plains with occasional low gravel strewn rises and broad shallow (gilgai-like) depressions; slopes mostly <2%, locally up to 5%.	Mainly moderately shallow to deep uniform or weakly gradational clay soils (Type 5.1) with brown, reddish brown or yellowish brown alkaline to strongly alkaline medium to heavy or heavy clay soils underlain by HWR between 0.5 – 0.8m; shallow to moderately deep dark grey brown (cracking) clay soils (Type 6.1) over HWR, occurs in slight depressional areas.	The superficial soil layers in soil type 5.1 tend to be moderately dispersive when reworked. Local areas have mod. dense surface cover of sub-rounded Si and Fe gravel; some occurrences of HWR exposed at the surface.

Terrain Unit No	Landform	Soils	Comments
P3/4.1	Gently inclined broadly rounded dissection slope interfluves and broad low rises; slopes mostly <2%, locally up to 5% on slopes to drainage.	Mainly shallow thin loamy surface duplex soils (Type 4.1) with brown, dark brown or dark reddish brown medium to heavy alkaline clay subsoils over HWR below 0.5m; some uniform brown clay soils (Type 5.1) occur in places.	Surface soils are hard-setting generally with a thin weak surface crust and scattered (Si, Fe) stone cover.
P3/6.2	Gently undulating locally near flat plains and lower parts of gently inclined dissection slope interfluves; slopes mostly <2%, locally to 5% on slopes to drainage lines.	Mainly deep dark-coloured (cracking) clay soils (Type 6.2) with dark grey-brown or dark brown alkaline to strongly alkaline heavy clay subsoils. Some deep uniform brown (non-cracking) clays (Type5.3) with a thin crusty weak SM surface soils on some slightly higher gravel strewn rises.	Moderately severe gully erosion on slopes adjacent to drainage; poor surface trafficability when wet.
P7/1–2.2	Low rocky hills and rises, with steep irregular planar hill slopes in the range 25-35%	Shallow rocky soils with a sandy to sandy loam matrix (Type 1) together with some deeper uniform or weakly gradational gravelly sand to gravelly loam soils (Type 2.2)	Local moderate severe sheet erosion in the deeper soil areas, elsewhere the rocky soil mantle tends to restrict soil erosion.

APPENDIX B

Soil Characterisation and Indicative Testing Results

Appendix B
Site/Soil Characterisation

Soil Type No.	Site ID* / Depth (m)	Soil Horizon	Soil Description	Colour	Soil pH (1:5 H_20)	EC (1:5 H_20) (mS/cm)	Dispersion Class No.	Comments/Soil Classification
4.1	E2/1* 0-0.15	A1	Clay Loam (CL) low (L) to medium (M) plasticity; massive to weak medium prismatic; cohesive, strong dry consistence (sdc); trace sub-angular (s/a) siltstone	10YR4/4 Dark (Dk.) yellow (y) brown	6.76	0.36	3(3)	Terrain unit P3/5.1-6.1, with thin loamy surface brown duplex soils - Db1.13-Uf6.31 (transition) solonetz/solodic soil; hard set surface; local outcrop and some surface stone.
	0.15-0.3	B1	Clay (CL-CH) M-high (H) plasticity; fine-medium blocky to prismatic very strong dry consistence (vsdc)	10YR4/6 Strong (St) y-brown	7.72	0.30	3(4)	
	0.3-0.45	B2	Clay (CL-CH) M-H plasticity; strong medium blocky-prismatic (vsdc); some fine gravel and CO_3 nodules to 5mm	7.5YR4/6 St brown	8.35	0.69	3(2)	
	0.45+	C	Silty Clay (CL) M plasticity; apedal massive crumbly weak, extremely weathered (EW) rock – clayey sandstone/siltstone	2.5Y5/3-4 Light (Lt) olive brown	9.13	1.33	3(4)	
5.1	E2/2 0-0.15	A1	Clay (CL-CH) M-H plasticity; weak to mod. fine blocky to prismatic structure, (sdc) with fibrous roots and a trace fine s/a stone <5mm	10YR4/3 Brown	7.45	0.42	3(4)	Terrain unit P3/5.1-6.1, Uf6.31-Ug5.32 (transitional) soils; thin crusty surface tending to thin self-mulching (SM) beneath.
	0.15-0.3	B1	Clay (CH) H plasticity; strong fine to med. blocky to prismatic (vsdc)	10YR4/4 Dk y-brown	8.33	0.33	6	
	0.3-0.6+	C	Silty Clay (CL) L-M plasticity; fine sandy claystone weak brittle to crumbly – HW rock	2.5Y6/3 Lt y-brown	8.58	0.39		
4.2	E2/3 0-0.25	A1	Silty Clay Loam (CL-ML) L-M plasticity, weak fine to medium prismatic tending to cohesive massive; firm to strong dry consistence (f-sdc)	7.5YR4/6 St brown	7.54	0.24	3(3)	Terrain unit Qa1/4.2, Db1.13 – loamy surface brown duplex soil – solenetz–solodic soil; some fine rounded ® ferruginous (Fe) nodules/stone.
	0.3-0.5	B1	Clay (CL) M plasticity; mod. strong fine to med. blocky – prismatic structure (sdc); some platy WR, some s/a and fine s/r gravel <5mm	7.5YR4/6 St brown	8.14	0.31	3(3)	
	0.6-0.8	B2	Clay (CL-CH) M-H plasticity; moderate fine to M prismatic (vsdc); trace fine s/a stone <5mm	7.5YR4/6 St brown	8.30	0.38	6	

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	0.9-1.1+		Clay (CH) H plasticity, weak fine prismatic tending to massive, some CO_3 nodules + stone fragments <5mm	7.5YR	8.44	0.40	3(1)	
5.1	E2/4 0-0.2	A1	Clay (CH) H plasticity; mod. strong fine to moderate-blocky to prismatic structure (vsdc)	10YR3/3 Dk Brown	8.06	0.54	3(3)	Terrain unit P3/5.1-6.1, Uf 6.12 – Brown Earth profile – numerous fibrous roots.
	0.2-0.5	B	Clay (CH) H plasticity; mod. strong fine prismatic structure (vsdc), some flecks of CO_3	10YR4/3 Brown	8.97	1.03	3(2)	
	0.5-0.75+	C	Clay (CL-CH) M-H plasticity; weak fine blocky to prismatic structure, with heavy pockets of carbonate – HW claystone	10YR5/3 Brown	9.25	1.31	3(2)	
4.2	E2/5 0-0.3	A	Silt Clay loam (CL-ML) L plasticity; apedal massive firm dry consistence (fdc); trace fine (Si), rounded gravel	5YR4/4 Reddish brown	6.40	0.06	3(1)	Terrain unit Qa1/4.2 - Dr 2.12 – Non-calcic Brown Soil, powdery surface when reworked
	0.5-0.7	B1	Clay (CL-CH) M plasticity; fine, medium and coarse blocky-prismatic (vsdc), rough ped faces	2.5YR4/4 Dusty red	7.07	0.22	2(1)	Strongly sub plastic
	0.9-1.1	B2	Clay (CL-CH) M-H plasticity; weak fine-mod, prismatic structure tending to massive, (sdc)	10YR4/4 Dk y brown	7.30	0.38	3(4)	
6.1	E2/6 0-0.15	A	Clay (CH) H plasticity; thIn weak self-mulching (SM) surface together with fine, med. and coarse blocky to prismatic structure (vsdc); some stony inclusions	10YR3/2 Very (V) dk grey-brown	8.00	0.39	7-4	Terrain Unit P3/5.1-6.1 - Ug5.12; Dark Grey-brown (cracking) Clay soil
	0.15-0.5	B	Clay (CH) H plasticity; fine, med. and coarse blocky to prismatic structure (vsdc)	10YR3/2 V dk grey-brown	8.62	0.86	3(1)	
	0.5-0.8+	C	Clayey Gravel – Gravely Clay (GC-CH) with clay fines of H plasticity – HW rock laminated claystone	10YR5/4 y-brown	8.66	1.42	6	
6.2	E2/7 0-01	A1	Clay (CL-CH) M-H plasticity; mod. fine to medium blocky to prismatic structure, thin SM surface, some (Si) stone to 15mm	10YR3/3 Dk brown	7.19	0.43	3(3)	Terrain unitP3/6.2; Ug5.24 - Grey-brown (cracking) Clay soil
	0.2-0.3	B1	Clay (CH) H plasticity; fine to med. blocky to prismatic structure (vsdc); some CO_3 flecks; 10% fine concretions and s/r Fe stone <5mm	10YR4/2 Dk greyish brown	8.29	1.05	4	Moderately saline

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	0.3-0.6	B2	Clay (CH) high plasticity; med. to coarse blocky to prismatic (vhdc); some CO_3 flecks and fine modules	7.5YR4/2 Brown	8.55	1.61	4	High salinity
	1.0-1.25		Clay (CH) H plasticity; apedal massive (vsmc)	7.5YR4/2 Dk brown	6.20	1.91	2(1)	High salinity
5.1	E2/8 0-0.1	A1	Clay (CL-CH) M-H plasticity; weak fine M to coarse prismatic (sdc); tending to friable, thin SM surface, trace of s/r Si stone <10mm	7.5YR2.5/3 V dk brown	7.18	0.33	3(1)	Terrain unit P3/5.1-6.1; Ug transitional Uf profile; Uf6.33 – Ug5.33 Brown (incipient cracking) Clay soil
	0.1-0.3	B1	Clay (CH) H plasticity; mod. strong fine, med. and coarse blocky to prismatic structure (vsdc)	7.5YR2.5/3 V dk. brown	8.63	0.49	7	Strongly alkaline
	0.5-0.7	B2	Clay (CH) H plasticity; mod. fine-med. blocky to prismatic structure, (vsdc); flecks of fine CO_3; trace s/r and s/a (Si) stone	7.5YR2.5/3 V dk. brown	8.96	1.32	7	Strongly alkaline
	0.7-1.1	C	Gravely Silty Clay (GC-CL), L-M plasticity; EW rock – fine sandy siltstone-claystone, weak to moderately strong	10YR5/4 Y-brown	8.98	1.33	3(1)	Strongly alkaline
6.1	E2/9 0-0.15	A1	Clay (CH) high plasticity; moderately strong fine to medium blocky to prismatic structure (vsdc)	10YR3/1 V dk Grey	7.55	0.42	7-3(1)	Terrain unit P3/5.1-6.1, Ug5.12 - Dark Grey-brown (cracking) Clay soil, with humic SM surface soil.
	0.2-0.4	B1	Clay (CH) H plasticity; strong fine-M-blocky prismatic (vsdc); some fine CO_3 nodules	10YR3/2 Dk. G-brown	8.85	0.85	7	
	0.7-0.9	B2	Clay (CH) H plasticity; apedal massive (vsdc); some flecks and fine CO_3 grit and nodules	10YR3/2 Dk G-brown	8.20	2.24	4	
	1.1-1.5+	C	Gravely Clay (GC) – EW sandstone – claystone with clayey fines of medium-high plasticity	10YR5/4 Y-brown	8.25	2.16	6	
6.2	E2/10 0-0.15	A1	Clay (CH) H plasticity; fine nutty to blocky structure, tending to weak thin SM surface, (msdc), some s/a fine gravel	10YR3/7 V dk greyish-brown	7.88	0.34	7	Terrain unit P3/6.2g, with Ug5.34 - Brown (cracking) Clay soils; highly humic, fibrous roots, hummocky microrelief (Debil-debil)
	0.15-0.5-	B1	Clay (CH) H plasticity; strong med. blocky-prismatic structure (vsdc) with flecks of fine CO_3	10YR3/3 Dk brown	8.58	1.13	7	Strongly alkaline
	0.8-1.0	B2	Clay (CH) H plasticity; massive apedal cohesive, (smc) tending to friable when moist	10YR4/3-5/4 Brown and yellow brown	8.10	1.47	6	Highly saline

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	1.3-1.5+	B3-D	Clay (CH) H plasticity apedal massive cohesive (smc), tending to friable when moist	10YR5/4 Y-brown with dark banding	8.07	2.26	6	Extremely saline, varved clay
6.2	E2/11 0-0.15	A1	Clay (CH) H plasticity; fine nutty to blocky and med. Prismatic structure; tending to thin SM surface; some s/r Si stone to 25mm	10YR3/3 Dk brown	7.32	0.37	7	Terrain unit P3/6.2, Ug5.34 - Brown (cracking) Clay soils
	0.3-0.5	B1	Clay (CH) H plasticity; strong med.-coarse blocky to prismatic (vsdc), some CO_3 and (Si) stone s/r < 5mm	7.5YR4/3 Brown	8.59	1.16	7	Strongly alkaline
	0.7-0.9	B2	Clay (CH) H plasticity; weak coarse blocky to prismatic tending to massive structure, some CO_3	7.5YR4/3 Brown	7.96	1.68	6	Highly saline
4.1	E2/12 0-0.2	A	Gv. Light Clay (CL) M plasticity, weak fine blocky to med. prismatic structure (sdc); 10% s/a-s/r Si and Fe stone to 5-30mm	7.5YR3/3 Dk. brown	6.41	0.49	3(2)	Terrain unit P3/4.1, with loamy surface duplex soil – Db1.11; hard set surface
	0.2-0.5	B1	Clay (CH) H plasticity; moderate fine to coarse blocky prismatic (vsdc); with flecks of CO_3 and fine gravel s/a–s/r <5mm	7.5YR3/3 Dk brown	8.22	0.98	7	Moderately saline
	0.5-0.8	B21	Clay (CH) H plasticity; weak coarse blocky-prismatic structure tending to massive with CO_3 flecks	7.5YR4/3 Dk brown	7.45	1.01	6	Moderately saline
	1.0-1.3	B22	Clay (CH) H plasticity, apedal massive structure , (vsdc); fine flecks of CO_3	7.5YR4/4 Brown	5.39	1.16	6	Strongly acidic, moderately saline
4.1	E2/13 0-0.2	A1	Sandy Loam (SC-CL) L plasticity; apedal massive cohesive (msdc); trace fine s/a (Si) gravel	7.5YR4/3 Brown	6.72	0.16	7-3(3)	Terrain unit P3/4.1, Db1.12 - sandy-loamy surface browndDuplex soil
	0.2-0.4	B1	Clay (CL-CH) M-H plasticity; nutty, fine blocky to med. prismatic (vsdc); some a–s/a weathered rock (WR) gravel	7.5YR4/4 Brown	6.87	0.34	7-3(4)	
	0.6-0.8	B-C	Sandy Clay (CL-CH) M plasticity with massive apedal structure, with 25% a – s/a WR fragments	7.5YR4/4	7.80	1.01	3(3)	
	1.0-1.2	C	Gravely Clay (GC-CL) M plasticity - EW rock – massive apedal (sdc) 35% s/a–s/r gravel to 20mm	7.5YR5/4 Brown	7.98	0.85	3(3)	
4.1	E2/14 0-0.3	A	Sandy Loam (CL) L-M plasticity; apedal massive (sdc)	7.5YR3/3 Dk brown	6.48	0.10	7-3(3)	P3/4.1, Db1.13 sandy to loamy surface brown duplex soils

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	0.3-0.6	B1	Clay (CL-CH) M-H plasticity; moderate strong nutty to fine prismatic tending to massive structure	7.5YR4/4 Brown	8.14	0.16	3(3)	Slightly dispersive
	0.6-0.7	B2	Clay (CL-CH) M-H plasticity; some sand, massive apedal (vsdc)	7.5YR4/4 Brown	8.70	0.16	2(1)	Strongly alkaline
5.2	E2/15* 0-0.2	A	Clayey Gravel (GC) with 40% clay fines M plasticity; massive apedal, 60% s/a–s/r (Si) gravel to 50mm	7.5YR4/3 Brown	6.70	0.39	3(4)	Terrain unit Cz3/5.2, Uf6.33 - Prairie-like soil
	0.2-0.5	B1	Clay (CH) H plasticity; strong, fine, med. and coarse blocky to prismatic structure (vsdc)	7.5YR5/4 Brown	8.78	0.80	6	Strongly alkaline, moderately saline
	0.5-0.7	B21	Clay (CH) H plasticity; weak fine to med. prismatic tending to massive (vsdc); some (Fe) stone 5-10mm	7.5YR5/4 Brown	8.65	1.07	3(1)	Strongly alkaline, moderately saline
	1.2-1.3	B22	Clay (CH) H plasticity; massive apedal (vsdc)	7.5YR5/4 Brown	8.25	1.07	3(2)	Moderately saline.
5.2	E2/16* 0-0.15	A1	Clay Loam (CL) M plasticity; weak fine blocky to prismatic structure (sdc); 15% s/a (Si) gravel 5-20mm	10YR4/4 Dk. Y-brown	6.37	0.10	3(4)	Terrain unit Cz3/5.2, Uf 6.31 – Prairie (like) soil
	0.15-0.4	B1	Clay (CL) M plasticity; fine medium and coarse blocky to prismatic, (vsdc); trace quartz gravel <10mm	7.5YR4/4 Brown	7.58	0.39	3(4)	Slightly dispersive
	0.5-0.6	B21	Clay (CH) H plasticity; nutty to weak fine blocky to prismatic tending to massive structure (vsdc)	7.5YR4/6 St brown	7.94	0.75	3(4)	Slightly dispersive
	0.9-1.0	B22	Clay (CL-CH) M-H plasticity; weak nutty to fine blocky to prismatic; tending to massive (sdc)	7.5YR4/4 Brown	8.16	1.32	3(4)	Slightly dispersive
5.1	E2/17* 0-0.2	A	Clay (CL-CH) H plasticity; moderate fine-med. blocky to prismatic structure, (sdc); trace WR fragments	7.5YR4/4	7.95	0.26	7-3(4)	Terrain unit P-T3/4.1-5.1, with Uf 6.31 Prairie (like) soils
	0.15-0.4	B1	Clay (CH) H plasticity; fine to med. blocky-prismatic structure, (vsdc)	7.5YR4/4 Brown	9.05	0.66	5	Very strong alkalinity
	0.4-0.65	B2-C	Clay (CH) H plasticity; weak fine-med. prismatic tending to massive, (vsdc); some EW rock inclusions	7.5YR4/6 St brown	9.36	0.62	5	Very strong alkalinity. Weathered rock, platy (Fe) sandstone below 0.65
4.3	E2/18 0-0.2	A1	Clay Loam (CL) L-M plasticity; weak nutty to fine blocky-prismatic; tending to apedal massive cohesive structure, (fsdc); 10% fine Si & Fe gravel 2-10mm	7.5YR4/3 Brown	5.53	0.08	3(4)	Terrain unit T4/2.3, K-Gn 2.12 - Clayey gravels Lithsols. Surface soils become powdery when reworked

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	0.2-0.5	A-B	Clayey Gravel (GC) 60-70% s/a-s/r (Fe & Si) gravel, 2-100mm; 30% clayey fines (CL-CH) M-H plasticity	7.5YR4/3	5.71	0.42	3(4)	
	0.5-0.7	B	Clayey Gravel (GC) with 70% s/r-r (Fe & Si) gravel; 2-15mm, with clayey fines (CH) of H plasticity	7.5YR5/4 Brown	6.98	1.49	3(3)	Strongly saline clayey fines
	0.7-1.0+	B-D	Clayey Gravel (GC) with 30% clayey fines (CH) of H plasticity and 70% fine r-s/r (Fe) concretions and sandstone rock fragments	2.5Y5/4 Lt. Olive brown	6.99	1.55	3(2)	Strongly saline clayey fines.
2.3	E2/20 0-0.05	A1	Clay Loam (CL) M plasticity with 30% s/r-s/a (Si-Fe) stone to 25mm; apedal massive partly cohesive (sdc)	7.5YR4/4 Brown	4.88	0.18	3(4) – 8	Terrain unit P4/2.3, Gn4.31 Gravelly clay, very strongly acidic clayey fines
	0.05-0.25	B1	Clay (CL-CH) M-H plasticity moderate fine to weak med. blocky-prismatic structure, (fsdc) with 25% fine r-s/a fine gravel up to 25mm	7.5YR4/3 Brown	4.06	0.10	5	Very strongly acidic
	0.25-0.4	B2	Clay (CH) H plasticity; weak fine blocky-prismatic (fsdc); 20% s./r-r(Fe and Si) fine gravel 2-10mm	7.5YR4/6 St brown	3.94	0.09	6	Very strongly acidic; HWR below 0.4m
2.3	E2/21 0-0.1	A1	Clay (CH) H plasticity; fine, med. and coarse blocky-prismatic structure, (vsdc) with fine s/r-r (Fe) gravel and coarse s/a stone to 50mm	7.5YR4/6 St brown	5.40	1.09	6-7	Terrain unit P4/2.1, Uf6.31 Surface strew of coarse gravel
	0.1-0.4	B1	Clay (CH) H plasticity; strong very coarse and medium blocky-prismatic (vsdc)	7.5YR4/6 St brown	6.26	0.79	7-5	
	0.4-0.6	B-C	Clay (CL-CH) M-H plasticity; weak fine prismatic to massivestructure, (mfdc) friable crumbly	10YR5/4 Y brown	4.83	1.17	2(1)	Very strongly acidic
	0.6-0.9	C	Clay (CH) H plasticity; massive apedal (vsdc)	7.5YR5/4-7/4 Variegated	4.70	1.23	2(1)	Very strongly acidic, HW mudstone-claystone.
4.2	E2/22 0-0.25	A1	Loam (CL) L plasticity; massive apedal partly cohesive firm priable; some s/d WR to 20mm	7.5YR3/3 Dk brown	6.90	0.10	8-3(2)	Terrain unit Cz3/5.2-4.2, with Db1.12 loamy duplex soil
	0.2-0.5	B2	Clay (CL-CH) H plasticity; strongmed. Blocky-prismatic, (vsdc); some s/r-s/a (Si) stone <10mm	10YR4/4 Dk y brown	6.56	0.27	3(4)	
	0.5-0.8	B-C	Silty Clay (CL-ML) L plasticity; weak fine to M prismatic tending to massive (cf-sdc); some 5-10% s/r–s/a stone to 20mm	7.5YR5/6 St brown	7.23	1.01	3(4)	

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	1.1-1.2	B-C	Gravely light fine sandy Clay (CL) L –M plasticity with fine-M and coarse blocky prismatic (vsdc); 25% s/r (Fe) – stone and WR fragments 2-10mm	7.5YR5/4 Brown	7.61	1.26	3(4)	
2.3	E2/23 0-0.5	A	Loamy Gravel (GM) with (30%) silt loam fines (CL-ML) of L-M plasticity; gravel is s/r to 100mm	7.5YR3/4 Dk brown	5.93	0.07	3(2)	Terrain unit Ta4/2.3, K-Um1.41 - shallow rocky soils - Lithosols
	0.5-0.9	B-C	Clay (CH) H plasticity; apedal massive, (vsdc)	10YR5/4 Y brown	5.24	0.60	2(3)	Very strongly acidic
	1.0-1.3	C	EW Rock – mudstone – claystone – breaks down to Clay (CL-CH) M-H plasticity	10YR5/8 Y brown	5.04	0.66	1	Very strongly acidic
4.2	E2/24 0-0.25	A	Silty Clay Loam (CL-ML) M plasticity; massive apedal	7.5YR4/4 Brown	6.81	0.06	3(4)	Terrain unit Cz3/5.2-4.2, with Db1.13 thin loamy surface brown duplex soils
	0.25-0.5	B1	Clay (CL-CH) M-H plasticity; strong fine-medium blocky-prismatic (vsdc)	7.5YR4/4 Brown	8.01	0.36	2(2)	Moderately dispersive
	0.5-0.9	B21	Clay (CL-CH) M-H plasticity; weak fine blocky-prismaticstructure, (sdc)	7.5YR5/6 St brown	8.83	0.83	2(2)	Very strongly alkaline, moderately dispersive
	1.2-1.3	B22	Clay (CH) H plasticity; fine to med. prismatic to polyhedral, (vsdc); some fine rounded (Fe) gravel	7.5YR5/4 Brown	9.02	1.03	2(2)	Some manganese staining on ped faces, very strongly alkaline, moderately dispersive
5.3	E2/25 0-0.25	A	Clay (CH) H plasticity; firm friable moist consistence (ffmc)	7.5YR3/3 Dk brown	8.47	0.13	7-5	Terrain unit Qa2/5.3, Uf6.31 – Ug5.343 – Incipient (cracking) Brown Clay, crusty hardset surface. Many fibrous roots
	0.25-0.75	B1	Clay (CH) H plasticity, med. to coarse blocky and prismatic structure, (vsdc)	7.5YR4/3 Brown	8.89	0.32	7-5	Strongly alkaline
	0.75-0.9	B21	Clay (CH) H plasticity; strong M-coarse blocky prismatic (smc)	7.5YR4/3 Brown	8.88	0.74	7-6	Strongly alkaline
	1.4-1.5	B22	Clay (CH) H plasticity; weak med. prismatic structure, (sdc); friable when moist	7.5YR4/3 Brown	8.42	1.65	6	Strongly saline
4.1	E2/26 0-0.2	A	Clay Loam (CL) M plasticity; moderate fine blocky prismatic (sdc) approx. 20% s/a-s/r/r Si (quartz) stone	10YR3/3 Dk brown	7.73	0.20	3(2)	Terrain unit P-T3/4.1-5.1, with Db1.13, thin loamy surface brown duplex soils
	02-0.45	B1	Clay (CL-CH) M-H plasticity; weak to moderate fine and med. blocky-prismatic, (vsdc); some platy WR fragments <10mm and fine gravel 2-3mm	7.5YR4/4 Brown	8.47	0.24	5	Strongly alkaline

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	0.5-0.7	C	EW Rock – platy fine sandy mudstone, with fine sandy to silty loam fines (SC-SM) of low plasticity	7.5YR5/6 St brown	8.86	0.13	5	Strongly alkaline
6.2	E2/27 0-0.1	A1	Clay (CH) H plasticity; strong med. to coarse blocky-prismatic structure, (vsdc)	10YR3/1 V dk grey	7.16	0.47	5	Terrain unit Qa2/6.2, Ug5.15 - Dark Brown (cracking) Clay soil, thin weak SM surface soil
	0.3-0.5	B1	Clay (CH) H plasticity; moderate fine to coarse blocky-prismaticstructure, (sdc)	7.5YR2.5/2 V dk brown	8.73	0.58	5	Strongly alkaline
	0.7-0.9	B2	Clay (CH) H plasticity; apedal massive strong friable moist consistence (sfmc)	7.5YR3/2 Dk brown	8.95	0.49	5	Very strongly alkaline
	1.0-1.25	D	Silty Clay Loam (CL) M plasticity; apedal massive cohesive, (fmc)	7.5YR4/3 Brown	9.14	0.32	5	Very strongly alkaline
	1.5-1.7	D	Fine Sandy Silt Loam (CL-ML) L plasticity; massive apedal weak cohesive tending to friable single grain	10YR4/4 Dk y brown	8.38	0.20	5	Moderately alkaline
	2.3-2.5	D	Fine sandy Silk Loam (ML) low plasticity; weak cohesive tending to massive single-grain	10YR4/4 Dk y brown	8.65	0.32	3(1)	Strongly alkaline
6.2	E2/28 0-0.1	A1	Clay (CH) H plasticity; thin friable moist (SM) surface	7.5YR3/2 Dk brown	8.35	0.38	5	Terrain unit Qa2/6.2, Ug5.34 - Brown (cracking) Clay soil
	0.2-0.3	B1	Clay (CH) H plasticity; moderate blocky-prismatic structure, with shiny ped faces (smc)	7.5YR3/3 Dk brown	8.25	0.18	5	
	0.4-0.6	B21	Clay (CH) H plasticity; weak med.-coarse blocky-prismatic structure, firm to friable moist consistence	7.5YR4/3 Brown	8.71	0.11	5	Strongly alkaline; low salinity in irrigation area
	0.7-0.9	B22	Clay (CL-CH) M-H plasticity; apedal massive structure, cohesive, (sfmc) some r (Fe) gravel 5-10mm	10YR4/4 Dk y brown	9.03	0.12	3(1)	Very strongly alkaline
	1.2-1.3	D	Fine Sandy Clay (CL-CH) M-H plasticity; apedal massive single-grain to weak cohesive	7.5YR4/4 Brown	8.93	0.14	2(2)	Moderate dispersive fines
	1.5-1.6	D	Fine Sandy Silt Loam (SC-ML) L plasticity; apedal massive single-grain, with some weak cohesive lumps, friable to loose moist consistence (fmc)	7.5YR4/6 St brown	8.98	0.08	3(4)	Strongly alkaline, moderately dispersive silt-clay fines
6.2	E2/29 0-0.15	A1	Clay (CH) H plasticity; thin SM to fine-med. blocky prismatic structure (vsdc); some fine s/r gravel	10YR311 V dk grey	8.46	0.64	5	Terrain unit Qa2/6.2, Ug5.17 - Grey (cracking) Clay soil underlain by older alluvium

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	0.4-0.6	B1	Clay (CH) H plasticity; strong med.-coarse blocky-prismatic structure (vsdc); flecks of CO_3	7.5YR3/1 V dk grey	8.43	1.21	6	Moderate strongly alkaline – highly alkaline
	0.8-0.9	B21	Clay (CH) H plasticity; weak fine to med.blocky-prismatic structure, (sdc)	7.5YR3/1 V dk grey	8.53	1.40	6	Strongly alkaline, highly saline
	1.2-1.3	B22	Clay (CH) H plasticity; weak fine blocky-prismatic tending to massive apedal cohesive firm friable moist consistence, some flecks of CO_3	7.5YR3/1 V dk grey	8.45	1.05	6	Strongly alkaline
	1.9-2.0	B2-D	Clay (CL-CH) M-H plasticity; massive apedal cohesive (vsdc)	7.5YR4/4 Brown	7.60	1.46	6	High salinity
6.2	E2/30 0-0.15	A1	Clay (CH) H plasticity; thin self-mulching (SM) and weak M-coarse blocky prismatic trace fine s/r-r CO_3 nodules <2mm	10YR3/2 V dk grey-brown	8.50	0.62	5	Terrain unit Qa2/6.2 with Ug5.15 - Dark Grey-Brown (cracking) clay soils
	0.2-0.4	B1	Clay (CH) M plasticity; strong med.-coarse blocky-prismatic structure, (vsdc)	10YR2/2 V dk brown	8.60	0.73	6	Strongly alkaline
	0.8-1.0	B21	Clay (CH) H plasticity weak fine-med. blocky-prismatic (sdc); some s/r-r CO_3 nodules <5mm	10YR3/2 V dk brown	8.59	1.19	6	Strongly alkaline high salinity
	1.5-1.6	B2-D	Clay (CL-CH) M-H plasticity; massive apedal cohesive (vsdc)	7.5YR3/3 Dk brown	8.13	1.46	6	Highly saline
6.2	E2/31 0-0.15	A1	Clay (CH) H plasticity; thin SM surface and mod.-strong fine to med. blocky-prismatic (vsdc)	10YR3/2 Dk. g-brown	8.28	0.96	5	Terrain unit Qa2/6.2 with Ug5.15 - Dark Grey-Brown (cracking) Clay soil
	0.2-0.4	B1	Clay (CH) H plasticity; mod. strong fine-med. blocky prismatic (vsdc); some s/r-r CO_3 nodules 2-3mm	10YR3/2 Dk brown	8.64	0.95	5	Strongly alkaline, moderate saline
	0.6-0.75	B2-D	Silty Light Clay to Clay Loam (CL) M plasticity; weak fine to med. prismatic structure (f-sdc)	10YR4/4 Dk y-brown	8.53	0.50	5	Strongly alkaline
	1.4-1.5	D	Silty Clay Loam (CL) L-M plasticity; weak fine to med. prismatic tending to massive cohesive (vsdc)	10YR4/4 Dk y-brown	7.93	0.48	3(4)	Moderately dispersive clayey fines. Some weak Mn coatings on structure faces.
6.2	E2/32 0-0.01	A1	Clay (CL-CH) M-H plasticity; weak thin SM surface and weak fine to med. M blocky-prismatic (sdc)	10YR3/2 Dk g-brown	6.83	0.22	7/3(4)	Terrain unit Qa2/6.2, Ug5.16 - Dark Grey (cracking) Clay, highly humic, many fine roots
	0.3-0.5	B1	Clay (CH) H plasticity; strong med.-coarse blocky-prismatic structure (vsdc)	10YR3/1 V dk grey	7.55	0.79	7/3(4)	Some fibrous roots

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	0.8-1.0	B2	Clay (CH) H plasticity; weak med. prismatic tending to apedal massive structure (sdc)	10YR4/2 Dk g-brown	8.85	0.83	6	Strongly alkaline
	1.4-1.5	D	Clay (CL) M plasticity; weak fine-med. prismatic structure, (sdc)	10YR4/3 Brown	8.47	0.41	3(2)	Strongly alkaline
6.2	E2/33 0-0.1	A	Clay (CH) H plasticity; thin IM surface and fine M and coarse blocky prismatic (sdc)	7.5YR3/2 Dk brown	8.31	0.57	5	Terrain unit Qa2/6.2, Ug5.16 - Dark Grey-Brown (cracking) Clay
	0.3-0.4	B1	Clay (CH) L plasticity, fine, med. and coarse blocky-prismatic structure (vsdc)	10YR3/2 Dk g-brown	8.70	0.33	5	Very shiny (slickenside) structure faces
	0.8-0.9	B2	Clay (CH) H plasticity; weak fine-med. prismatic tending to apedal massive cohesive (sdc); friable moist	10YR3/2 Dk g-brown	8.32	1.43	6	
	1.5-1.6	B-D	Silty Clay (CL-CH), M-H plasticity; weak fine prismatic tending to apedal massive (f-smc); friable moist, some soft CO_3 flecks	7.5YR4/2 Brown	8.08	1.52	6	High salinity
	2.1-2.2	D	Silty Clay (CL) M plasticity; apedal massive cohesive (sdc) crumbly	7.5YR4/3 Brown	8.35	0.99	6	
6.2	E2/34 0-0.1	A1	Clay (CH) H plasticity; thin SM surface and weak fine to med. prismatic structure (sdc); crumbly	10YR3/2 Dk g-brown	8.30	0.65	5	Terrain unit Qa2/6.2, Ug5.25 - Grey (cracking) Clay soil
	0.3-0.4	B1	Clay (CH) H plasticity; strong fine to med. blocky-prismatic structure (vsdc)	10YR4/2 Dk g-brown	8.52	0.65	5	Strongly alkaline, shiny smooth ped faces
	0.5-0.7	B21	Clay (CH) H plasticity; weak fine-med. prismatic tending to apedal massive, (vsdc); with a trace of rounded (Fe) gravel <10mm, some CO_3 flecks	10YR3/2 Dk. g-brown	8.70	0.80	5	Strongly alkaline
	0.9-1.0	B22	Clay (CH) H plasticity; moderate fine and med. bocky -prismatic (vsdc); some fine CO_3 nodules 1-2mm	10YR4/2 Dk grey-brown	7.98	1.90	6	High salinity
	1.4-1.5	B-D	Clay (CL) M plasticity; weak friable fine-med. blocky-prismatic tending to massive apedal cohesive (f-sdc);	10YR4/3 Brown	8.25	1.37	6	High salinity
6.2	E2/35 0-0.1	A	Clay (CH) H plasticity; thin SM and weak fine to coarse blocky-prismaticstructure (vsdc)	10YR3/2 Dk g-brown	8.29	0.82	6	Terrain unit Qa2/6.2, Ug5.16 – Dark Grey-Brown (cracking) Clay soil;

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	0.3-0.5	B1	Clay (CH) H plasticity; moderate strong med. blocky-prismatic, (vsdc); trace fine CO_3 nodules 1-3mm	10YR3/2 Dk g-brown	8.83	0.54	5	Strongly alkaline
	0.6-0.7	B21	Clay (CH) L plasticity; weak fine to med. prismatic structure (sdc); some fine CO_3 nodules <3mm	10YR3/2 Dk g-brown	8.88	0.85	5	Strongly alkaline
	0.9-1.0	B22	Clay (CH) H plasticity; weak fine-M prismatic tending to massive apedal cohesive (smc); friable moist some fine CO_3 nodules <2mm	10YR3/2 V dk grey-brown	8.59	1.22	6	Strongly alkaline and saline
	1.2-1.3	B-D	Clay (CL-CH) M-H plasticity; massive apedal to weak fine-med. prismatic; some soft CO_3 nodules 2-5mm	10YR4/2 Dk grey-brown	8.55	1.27	6	Strongly alkaline and saline
6.2	E2/36 0-0.15	A1	Clay (CH) H plasticity; thin weak SM surface, fine, med.& coarse blocky-prismatic (vsdc); some CO_3	10YR3/2 Dk grey-brown	8.56	0.54	5	Terrain unit Qa2/6.2, Ug5.16 – Dark Grey-Brown (cracking) Clay soil; strongly alkaline
	0.3-0.5	B21	Clay (CH) L plasticity; friable moist, mod. fine to med. blocky- prismatic structure (f-smc)	10YR2/1 Black	8.86	0.44	5	Strongly alkaline
	0.8-1.0	B22	Clay (CH) H plasticity; firm to moderate strong moist consistence friable; some CO_3 inclusions <5mm	10YR2/1 V dk grey	8.74	0.67	5	Strongly alkaline
	1.4-1.5	B22	Clay (CH) L plasticity; apedal massive cohesive strong moist consistence; some fine CO_3 flecks	10YR3/1 V dk grey	8.60	0.90	6	Strongly alkaline
6.2	E2/37 0-0.3	A1	Clay (CH) H plasticity; mod. strong fine-med. blocky- prismatic structure (vsdc) thin SM surface soil	10YR3/1 V dk grey	8.17	1.12	5	Terrain unit Qa2/6.2, Ug5.25 - Grey (cracking) Clay soil
	0.4-0.6	B	Clay (CH) H plasticity; mod. strong fine-med. blocky- prismatic (vsdc)	10YR4/2 Dk g-brown	8.75	0.83	5	Strongly alkaline, moderate saline
	0.8-0.9	B-D	Silty Clay (CL) M plasticity; massive apedal cohesive (sdc) brittle	10YR4/3 Brown	8.67	0.50	3(1)	Strongly alkaline, slightly dispersive
6.2	E2/38 0-0.2	A1	Clay (CL-CH) M-H plasticity; mod. fine to med. blocky prismatic structure (vsdc) brittle	10YR3/2 Dk g-brown	7.18	0.35	3(1)	Terrain unit Qa2/6.2, Ug5.15 – Dark Grey-Brown (cracking) Clay soil; thin SM surface
	0.4-0.5	B1	Clay (CH) H plasticity; moderate fine M blocky prismatic (vsdc)	10YR3/2 Dk g-brown	8.48	0.62	5	Moderate salinity
	0.7-0.8	B21	Clay (CH) H plasticity, weak fine-M prismatic (sdc); some fine CO_3 gravel 1-2mm	10YR3/2 Dk g-brown	8.26	1.07	6	Moderate salinity

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	1.1-1.3	B2-D	Silty Clay (CL) M plasticity, weak fine prismatic tending to massive apedal cohesive (f-sdc) brittle	10YR4/4 Dk y-brown	8.29	0.68	6	Moderate salinity
6.2	E2/39 0-0.2	A1	Clay (CH) H plasticity; weak thin SM surface over mod. strong fine-med. blocky-prismatic (vsdc); brittle	10YR3/2 Dk g-brown	8.03	1.39	6	Terrain unit Qa2/6.2, Ug5.15 - Dark Grey-Brown (cracking) Clay; thin crusty SM surface
	0.4-0.6	B1	Clay (CH) H plasticity; mod. strong MED. blocky-prismatic (vsdc); some fine s/r-r gravel, 2-3mm	10YR3/2 Dk g-brown	8.64	0.83	3(1)	Strongly alkaline, moderate saline
	0.9-1.0	B2	Clay (CH) H plasticity; weak fine-med. blocky-prismatic (vsdc); some CO_3 nodules (<2mm	10YR3/2 Dk g-brown	8.52	0.98	5	Strongly alkaline, moderate saline
	1.4-1.6	D2-D	Clay (CL) M plasticity; apedal massive cohesive (sdc)	7.5YR3/3 Dk brown	7.29	1.17	6	Moderate-strongly saline
5.3	E2/41 0-0.15	A1	Silty Clay (CL) M plasticity; weak fine to med. prismatic and platy (sdc); brittle, crumbly	10YR3/2 Dk g-brown	6.75	0.25	3(2)	Terrain unit Qa2/5.3, Uf6.32 – Dark Grey-Brown (incipient cracking) Clay on slight rises
	0.3-0.5	B1	Clay (CH) M-H plasticity; strong med. blocky-prismatic structure (vsdc)	10YR3/2 Dk g-brown	7.56	0.56	3(3)	
	0.7-0.9	B21	Clay (CH) H plasticity; massive apedal cohesive (vsdc); some CO_3 flecks	7.5YR3/3 Dk brown	8.78	0.66	3(1)	Strongly alkaline
	1.1-1.2	B3	Silty Clay (CL) L-M plasticity; massive apedal to weak fine prismatic structure, (f-sdc)	7.5YR4/4 Brown	8.59	0.57	5	Strongly alkaline
	1.4-1.5	D	Silty Clay (CL) L-M plasticity; weak fine-med. prismatic tending to massive apedal cohesive (m-sdc)	7.5YR4/4 Brown	8.35	0.50	3(3)	
6.2	E2/42 0-0.2	A1	Clay (CH) H plasticity; thin SM surface over mod. strong fine to coarse blocky-prismatic (vsdc)	10YR3/2 Dk g-brown	8.28	0.48	2(1)	Terrain unit Qa2/6.2, Ug5.15 - Dark Grey-Brown (cracking) Clay; thin crusty SM surface
	0.4-0.5	B1	Clay (CH) H plasticity; strong M-coarse prismatic (vsdc); some flecks and fine CO_3 nodules (<2mm	10YR3/2 Dk g-brown	8.52	0.79	5	Strongly alkaline, shiny smooth ped faces
	0.8-1.4	B21	Clay (CL-CH) M-H plasticity; massive apedal friable (smc); some fine CO_3 nodules <2mm	10YR3/2 Dk g-brown	8.30	1.15	6	Moderate high salinity
	1.4-1.5	B22	Clay (CH) H plasticity; massive apedal cohesive moist friable (fmc), flecks of CO_3	10YR4/3 Brown	7.70	1.23	3(1)	Moderate high salinity
6.2	E2/43 0-0.15	A1	Clay (CH) H plasticity; thin SM surface and mod. med. to coarse blocky prismatic structure (vsdc)	10YR3/2 Dk g-brown	7.89	0.50	3(1)	Terrain unit Qa2/6.2, Ug5.16 - Dark Grey-Brown (cracking) Clay

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	0.4-0.5	B1	Clay (CH) H plasticity; strong fine to coarse blocky to prismatic (vsdc); few CO_3 flecks	10YR3/2 Dk g-brown	8.40	0.92	3(1)	Moderate alkaline, moderately alkaline
	0.6-0.7	B21	Clay (CH) H plasticity; mod. strong fine-med. blocky-prismatic (vsdc); some fine CO_3 nodules <2mm	10YR4/2 Dk g-brown	8.51	1.02	5/3(1)	Strongly alkaline, moderately saline
	07.-0.8	B22	Clay (CH) H plasticity; massive apedal cohesive (sdc); some CO_3 flecks	10YR4/2 Dk g-brown	8.53	1.17	3(3)	Strongly alkaline, moderately saline
	1.2-1.4	D	Fine Sandy Clay (CL) M plasticity; massive apedal cohesive (fmc)	10YR4/4 Dk y-brown	8.33	0.67	2(1)	Moderately dispersive
6.2	E2/44 0-0.1	A1	Clay (CH) H plasticity; thin SM surface over strong fine to med. blocky-prismatic structure (vsdc)	7.5YR3/2 V dk. grey-brown	7.82	0.67	5	Terrain unit Qa2/6.2, Ug5.15 – Dark Brown (cracking) Clay soil
	0.25-0.4	B1	Clay (CH) H plasticity; strong fine-med. blocky-prismatic structure; some CO_3 flecks	7.5YR3/2 V dk grey brown	8.51	0.49	5	Moderate-strongly alkaline
	0.5-0.7	B21	Clay (CH) H plasticity; weak fine prismatic tending to massive (vsdc); some CO_3 flecks	7.5YR3/3 Dk brown	8.72	0.89	3(1)	Strongly alkaline, moderate saline, slightly dispersive
	0.9-1.0	B22	Clay (CH) H plasticity; weak fine prismatic tending to apedal massive; some CO_3 flecks	7.5YR3/4 Dk brown	8.83	0.81	3(3)	Strongly alkaline, moderately saline, moderately dispersive
	1.3-1.5	B2-D	Clay (CH) H plasticity; massive apedal cohesive (vsdc); some very small CO_3 nodules and flecks	7.5YR4/3 Brown	8.55	0.97	2(1) / 3(4)	Strongly alkaline, moderately saline, moderately dispersive
6.2	D2/45 0-0.15	A1	Clay (CH) H plasticity; thin SM surface together with thin platy surface crust and mod. strong fine blocky-prismatic structure (vsdc), brittle crumbly	7.5YR4/2 Brown	8.08	0.68	3(1)	Terrain unit Qa5/6.2, Ug5.1 - Dark Grey-Brown (cracking) Clay soil. Thin SM surface soil locally with a thin surface crust
	0.3-0.5	B1	Clay (CH) H plasticity; strong fine to M blocky prismatic; some CO_3 flecks (vsdc)	10YR3/2 V dk g-brown	8.19	0.88	7/6	Smooth shiny ped faces
	0.6-0.8	B2	Clay (CH) H plasticity; strong fine to med. blocky-prismatic structure (vsdc); some CO_3 flecks	10YR2/2 V dk brown	8.52	0.50	5	Strongly alkaline
5.3	E2/46 0-0.25	A1	Fine Sandy Clay Loam (CL) M plasticity; weak fine-med. prismatic tending to massive cohesive (sdc); trace s/r quartz stone	10YR4/4 Dk y brown	6.63	0.38	3(4)	Qa2/5.3, Uf6.31 - Alluvial soil

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	0.4-0.6	B1	Fine Sandy Clay (CL) M plasticity; moderate strong fine-med. prismatic structure, (vsdc)	10YR4/4 Dk y brown	8.68	1.15	3(3)	Strongly alkaline
	0.8-1.0	B21	Fine Sandy Clay (CL) M plasticity; massive apedal cohesive (msdc); some soft CO_3 segregation	10YR4/4 Dk y brown	6.08	0.62	2(3)	Moderately dispersive
	1.1-1.2	B22	Clay (CL-CH) M-H plasticity; mod. fine prismatic tending to massive apedal cohesive soil structure (sdc)	10YR4/4 Dk y brown	9.12	0.29	5	Very strongly alkaline, diffusely mottled subsoil
	1.4-1.5	B2-D	Fine Sandy Clay (CL-CH) M-H plasticity; massive apedal cohesive structure (vsdc); trace CO_3	10YR5/8 Y brown	5.45	0.69	2(1)	Moderately strongly acidic
2.2	E2/47 0-0.1	A	Fine Sandy Silt Loam (CL) L plasticity; massive apedal cohesive soil structure (fdc); crumbles easily 15% s/r-r (Si) gravel <5mm	7.5YR4/3 Brown	6.57	0.16	3(3)	Terrain unit Ta3/3.2-2.2, Gn2.42 - gravelly loam
	01-0.3	A-B	Gravely Fine Sandy Clay Loam (CL) M plasticity; massive apedal cohesive soil structure (sdc); 10-15% s/r-r (Si) stone up to 25mm	7.5YR4/3 Brown	7.21	0.14	3(4)	Moderately dispersive
	0.3-0.5	B	Clayey Gravel (GC) with 30% clayey fines of M-H plasticity; gravel is s/r-r mostly siliceous (quartz) up to 20-30mm	7.5YR4/4 Brown	8.15	0.14	3(1)	Slopes below gravel bed
	0.5-0.84	C	Gravelly Clay (CH) H plasticity becoming clayey gravel below 1.2m, highly calcareous massive apedal soil structure (vsdc); HW calcareous claystone with some s/r-s/a (Si) stone <10mm with gravel content increasing with depth.	10YR5/8 Yellow brown diffusely mottled grey-brown	8.66	0.80	6	Strongly alkaline, moderately saline
2.2	E2/48	A-B	Loamy to Clayey Gravel GC)	-	-	-	-	Existing gravel pit on crest of low rise upslope of E2/47
3.2	E2/50* 0-0.15	A	Loamy Sand (SM) non-plastic; massive apedal single-grain with weak cohesive lumps; 10% fine s/r Si stone	10R3/6 Dark red	6.25	0.06	3(3)	Terrain unit Ta3/3.2-2.2, Gn2.11 - gradational massive red earth
	0.2-0.4	B1	Loamy Sand (SM-SC) non-plastic; massive apedal with cohesive lumps (w-msdc); tending to single grain	10R4/6 Red	5.91	0.02	3(1)	

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	0.4-0.6	B2	Sandy Loam (SC-CL) L plasticity with 20% rounded coarse sand to fine (Si+Fe) gravel <10mm	10R4/6 Red	5.58	0.02	5	
	0.6+	D	Gravely Sandy Clay (GC-CL) M plasticity, 30% coarse sand and fine to coarse (Fe and quartz) gravel to 50mm	10R4/6 Red	5.79	0.05	5	
3.2	E2/51* 0-0.3	A	Loamy Sand (SM) non-plastic, massive single-grain, some cohesive lumps (w-msdc)	5YR4/4 Reddish brown	7.21	0.07	3(3)	Terrain unit Ta3/3.2-2.2, Gn2.12 - Sandy surface gradational massive red earth
	0.3-0.6	B1	Loamy Sand-Sandy Loam (SM-SC) just plastic, massive apedal single grain with weak cohesive lumps (wdc); 5% s/a-s/r fine gravel-coarse sand <3mm	5YR4/4 Reddish brown	7.70	0.06	3(4)	Slightly dispersive fines
	0.6-0.9	B21	Fine Sandy Clay (CL) M plasticity; massive apedal single-grain with cohesive lumps (w-msdc); 5% s/a-s/r (Si & Fe) fine gravel – coarse sand	2.5YR3/4 Dusky red	7.93	0.07	3(4)	Slightly dispersive fines
	1.3-1.4	B22	Fine Sandy Clay (CL-CH) M-H plasticity; massive apedal cohesive soil structure (msdc)	10R4/8 Red	7.93	0.15	5	
4.3	E2/52* 0-0.15	A1	Loamy Sand (SM) non-plastic; apedal massive single grain (powdery) with weak to moderate strong cohesive lumps – 2-5% S/r-r (Fe) fine gravel	7.5YR3/2 Dk brown	7.00	0.05	3(3)	Terrain unit Ta4.3-2.2, Dy3.83 - Sandy yellow duplex soil - yellow solodic soil
	0.15-0.35	A21	Silty sand (SM) non-plastic apedal massive single-grain (w-msdc)	10YR7/1(d) Light grey	7.55	0.03	3(3)	Powdery and slightly dispersive when reworked
	0.3-0.5	A22	Gravely Silty Fine Sand (SM) non-plastic with <10% silty fines; massive apedal single-grain, with weak to moderate strong cohesive soil lumps	10YR7/1(d) Lt grey	8.55	0.06	3(2)	Strongly alkaline, powders easily when reworked – slightly dispersive
	0.5-0.7	B	Sandy Clay (CL-CH) M-H plasticity; mottled, massive apedal cohesive (vsdc); <20% r fine (Fe) gravel 2-7mm	10YR6/2-6/8 Brown,grey & yellow	8.35	0.19	3(1)	Slightly dispersive
3.3	E2/57 0-0.2	A	Silt Loam (CL-ML) L-M plasticity; mod. nutty to fine prismatic structure (sdc)	2.5YR3/6 Dark red	6.22	0.06	3(3)	Terrain unit Ta5/3.3, Gn3.22 – gradational structured red earth

Soil Type No.	Site ID* / Depth (m)	Soil Horizon	Soil Description	Colour	Soil pH (1:5 H_20)	EC (1:5 H_20) (mS/cm)	Dispersion Class No.	Comments/Soil Classification
	0.3-0.4	B1	Gravely Clay (GC-CL) M plasticity; mod. strong nutty to fine prismatic structure (sdc); 35-40% r-s/r (Fe) fine (lateritic) gravel	2.5YR3/6 Dark red	5.98	0.17	6	Slightly acidic
	0.4-0.6	B21	Gravelly Clay (CL) M plasticity; mod. strong fine to med. prismatic structure (vsdc) with approx. 40% s/r-s/a (Fe) and weathered rock gravel 3-8mm	10R3/6 Dark red	6.22	0.08	6	Slightly acidic
	0.8-1.0	B22	Gravely Clay (GC-CL) with ≈ 55% clay fines of M plasticity; mod. fine to med. prismatic (sdc) with 45% s/a-s/r (Fe) and weathered rock gravel 3-8mm	2.5YR4/6 Dark red	6.49	0.03	6	Slightly acidic

Note:- Sites designated with a superscript (*) were located outside the study area within the current operating mining lease area - ML 7459.

APPENDIX C

Analytical Soil Testing Results

Appendix C
Laboratory Analytical Data - Summary

Analysis	Lab No.	18893	18894	18895	18896	18897	18898	18899	18900	18901	18902	18903
	Site No.*	E 2 / 4	E 2 / 4	E 2 - 9	E 2 - 9	E 2 - 9	E 2 / 10	E 2 / 10	E 2 / 10	E 2 / 14	E 2 / 14	E 2 / 14
	Depth (m)	0 – 0.2	0.2 – 0.5	0 – 0.15	0.2 – 0.4	0.7 – 0.9	0 – 0.15	0.15 – 0.5	0.8 – 1.0	0 – 0.13	0.3 – 0.6	0.6 – 0.7
	Soil Type	5.1–Uf6.31 (P3/5.1-6.1)		6.1 – Ug5.12 (P3/5.1-6.1)			6.2g – Ug5.34 (P3/6.2)			4.1 – Db1.13 (P3/4.1)		
pH (1:5 H_20)	Unit	7.9	9.1	7.4	8.5	8.0	8.0	8.4	8.0	6.4	7.8	8.2
Nitrate Nitrogen	mg/kg	5	2	16	3	2	6	2	2	18	2	2
Phosphorus	mg/kg	9	2	126	4	1	30	7	<1	22	1	1
Potassium (K)	mg/kg	250	140	920	290	330	480	290	270	130	63	76
Sulphur	mg/kg	14.9	36.7	32.1	47.4	996.0	15.8	142.9	366.8	14.0	13.5	15.1
Calcium (Ca)	mg/kg	3800	4600	7300	7500	7100	7600	6600	3900	1400	1900	1900
Magnesium (Mg)	mg/kg	1100	1600	1200	2100	2500	670	1700	2200	170	630	740
Copper (Cu)	mg/kg	0.8	0.6	1.9	1.5	1.2	1.8	1.5	1.1	1.2	1.3	0.9
Zinc (Zn)	mg/kg	1.0	0.5	1.5	1.1	0.4	0.8	0.6	0.9	0.9	0.9	0.7
Manganese (Mn)	mg/kg	9	5	31	4	2	19	8	13	41	10	8
Iron (Fe)	mg/kg	12	8	17	13	9	18	15	11	32	15	17
Boron (B)	mg/kg3	1.5	3.6	2.5	3.2	6.3	1.6	5.3	8.0	1.0	1.3	2.9
Organic Carbon	%	2.3	1.9	5.7	2.1	1.6	4.1	2.2	1.0	2.7	<0.6	<0.6
EC (1:5 H_20)	dS/m	0.18	0.60	0.16	0.51	2.42	0.16	0.80	1.41	0.05	0.05	0.07
Sodium (Na)	mg/kg	630	1600	100	1400	2900	99	1300	2200	19	220	320
Chloride	mg/kg	95	561	40	436	2516	57	929	1692	19	30	38
CEC - (ECEC)	meq/100g	31.87	43.38	49.16	62.31	69.48	45.53	53.70	48.40	8.97	16.07	17.22
Ex. Sodium	meq/100g	2.75	7.01	0.44	6.19	12.54	0.43	5.44	9.66	0.08	0.97	1.39
Ex. Potassium	meq/100g	0.65	0.37	2.36	0.73	0.86	1.24	0.75	0.69	0.33	0.16	0.19
Ex. Calcium	meq/100g	18.95	22.84	36.4	37.75	35.41	38.25	33.09	19.73	7.16	9.67	9.45
Ex. Magnesium	meq/100g	9.52	13.16	9.96	17.64	20.67	5.61	14.42	18.32	1.40	5.27	6.19
ESP	%	8.6	16.2	0.9	9.9	18.0	0.9	10.1	20.0	0.9	6.0	8.1
Ca/Mg	Ratio	2.0	1.7	3.7	2.1	1.7	6.8	2.3	1.1	5.1	1.8	1.5

Note:- Sites designated with a superscript (*) were located outside the study area within the current operating mining lease area - ML 7459

Analysis	Lab No.	18904	18905	18906	18907	18908	18909	18910	18911	18912	18914	18915	18916	18913
	Site No.	E 2 / 24	E 2 / 24	E 2 - 24	E 2 - 24	E 2 - 27	E 2 / 27	E 2 / 27	E 2 / 27	E 2 / 28	E 2 / 28	E 2 / 28	E 2 / 28	E 2 / 28
	Depth (m)	0 – 0.25	0.25 – 0.5	0.5 – 0.9	1.2 – 1.3	0 – 0.1	0.3 – 0.5	0.7 – 0.9	1.1 – 1.25	0 – 0.1	0.2 – 0.3	0.4 – 0.6	0.7 – 0.9	1.2 – 1.3
	Soil Type	4.2 – Db1.13 (Cz3/5.2-4.2)				6.2 – Ug5.15 (Qa2/6.2)				6.2 - Ug5.34 (Qa2/6.2)				
pH (1:5 H_20)	Unit	6.5	7.7	8.9	8.9	7.0	8.6	8.7	8.7	8.3	8.0	8.3	8.8	8.6
Nitrate Nitrogen	mg/kg	10	9	1	1	72	68	39	6	19	15	8	12	15
Phosphorus	mg/kg	12	<1	1	6	51	9	16	26	44	5	14	25	17
Potassium (K)	mg/kg	79	60	66	97	370	280	280	170	510	210	190	170	120
Sulphur	mg/kg	5.4	18.7	65.6	9.9	47.1	63.3	113.8	101.5	16.8	30.1	30.5	22.5	12.3
Calcium (Ca)	mg/kg	1200	1200	1200	2100	4100	5700	5000	3500	4400	3600	3300	3500	1600
Magnesium (Mg)	mg/kg	220	880	950	1300	1400	2100	1800	1100	1000	1200	1200	990	660
Copper (Cu)	mg/kg	1.1	1.3	1.0	0.9	2.0	1.6	1.3	0.8	1.2	1.0	0.8	0.7	0.4
Zinc (Zn)	mg/kg	1.2	0.3	0.7	0.4	0.8	0.4	0.4	0.9	0.9	0.7	1.3	0.4	0.7
Manganese (Mn)	mg/kg	18	11	5	3	47	9	2	3	4	4	3	2	3
Iron (Fe)	mg/kg	33	17	9	9	23	16	12	7	11	9	6	6	11
Boron (B)	mg/kg3	1.1	2.7	4.4	6.3	1.9	3.6	3.9	1.4	2.1	2.8	2.5	1.5	1.2
Organic Carbon	%	1.9	0.9	<0.6	1.1	4.4	3.3	3.1	1.1	2.5	3.2	0.8	<0.1	0.8
EC (1:5 H_20)	dS/m	0.03	0.22	0.65	0.88	0.18	0.26	0.29	0.28	0.10	0.07	0.09	0.14	0.07
Sodium (Na)	mg/kg	35	550	1100	1700	260	700	710	420	120	160	180	230	190
Chloride	mg/kg	27	286	809	1137	67	47	90	213	33	27	26	23	26
CEC - (ECEC)	meq/100g	8.27	16.08	18.78	29.07	34.36	49.74	43.71	28.69	32.26	29.38	27.57	27.36	14.69
Ex. Sodium	meq/100g	0.15	2.37	4.61	7.18	1.14	3.03	3.07	1.84	0.51	0.69	0.78	1.00	0.81
Ex. Potassium	meq/100g	0.20	0.15	0.17	0.25	0.94	0.71	0.73	0.44	1.30	0.54	0.49	0.44	0.32
Ex. Calcium	meq/100g	6.06	6.20	6.07	10.44	20.28	28.35	24.97	17.63	21.81	18.20	16.42	17.67	8.05
Ex. Magnesium	meq/100g	1.86	7.36	7.93	11.20	12.00	17.65	14.94	8.78	8.64	9.95	9.88	8.25	5.51
ESP	%	1.8	14.7	24.5	24.7	3.3	6.1	7.0	6.4	1.6	2.7	2.8	3.7	5.5
Ca/Mg	Ratio	3.3	0.8	0.8	0.9	1.7	1.6	1.7	2.0	2.5	1.8	1.7	2.1	1.5

Note:- Sites designated with a superscript (*) were located outside the study area within the current operating mining lease area - ML 7459

Analysis	Lab No.	18917	18919	18920	18918	18921	18922	18923	18924	18925	18926	18927	18928
	Site No.*	E 2 / 31	E 2 / 31	E 2 - 31	E 2 / 31	E 2 – 38	E 2 – 38	E 2 / 38	E 2 / 38	E 2 / 41	E 2 / 41	E 2 / 41	E 2 / 41
	Depth (m)	0 – 0.15	0.2-0.4	0.6 – 0.75	1.4 – 1.5	0 – 0.2	0.4 – 0.5	0.7 – 0.8	1.1 – 1.3	0 – 0.15	0.3 – 0.5	0.7 – 0.9	1.4 – 1.5
	Soil Type	6.2 – Ug5.15 (Qa2/6.2)				6.2 – Ug5.15 (Qa2/6.2)				5.3 - Uf6.32 (Qa2/5.3)			
pH (1:5 H_20)	Unit	8.2	8.4	8.3	7.7	7.1	8.3	8.2	8.2	6.5	7.5	8.6	8.2
Nitrate Nitrogen	mg/kg	54	33	3	2	2	2	1	1	13	3	2	1
Phosphorus	mg/kg	15	11	67	23	60	12	26	38	42	6	6	22
Potassium (K)	mg/kg	330	280	160	150	300	260	250	180	330	220	200	150
Sulphur	mg/kg	43.6	52.7	30.7	4.9	15.6	58.9	157.6	94.0	17.4	21.5	21.2	4.0
Calcium (Ca)	mg/kg	5500	6200	2300	1800	4000	5800	4600	3300	2000	3700	4100	2000
Magnesium (Mg)	mg/kg	1600	1800	930	690	1200	1700	1700	1200	830	1800	1600	980
Copper (Cu)	mg/kg	1.7	1.5	0.7	0.6	1.8	1.5	1.2	0.7	1.9	1.6	1.0	0.7
Zinc (Zn)	mg/kg	0.2	0.2	0.4	0.3	0.4	0.4	0.3	0.4	0.7	0.2	0.6	0.4
Manganese (Mn)	mg/kg	15	4	3	4	23	7	4	3	40	11	4	3
Iron (Fe)	mg/kg	13	11	8	8	22	12	10	6	30	11	8	7
Boron (B)	mg/kg3	1.7	2.3	1.8	0.7	1.8	3.1	5.2	2.4	1.4	2.3	3.6	1.1
Organic Carbon	%	1.7	1.2	<0.1	<0.6	2.0	1.4	1.0	<0.6	1.9	1.7	0.6	<0.1
EC (1:5 H_20)	dS/m	0.31	0.51	0.32	0.25	0.08	0.39	0.60	0.42	0.06	0.20	0.39	0.22
Sodium (Na)	mg/kg	560	890	540	430	240	670	810	590	120	550	670	490
Chloride	mg/kg	252	511	402	358	68	375	681	555	34	260	400	311
CEC - (ECEC)	meq/100g	43.91	50.43	21.89	16.88	31.73	46.57	41.29	29.52	18.28	36.74	36.85	20.52
Ex. Sodium	meq/100g	2.43	3.85	2.36	1.88	1.04	2.92	3.51	2.56	0.51	2.40	2.90	2.14
Ex. Potassium	meq/100g	0.86	0.71	0.41	0.38	0.77	0.66	0.64	0.45	0.84	0.56	0.51	0.37
Ex. Calcium	meq/100g	27.44	30.80	11.34	8.83	19.76	28.77	22.92	16.30	10.03	18.56	20.30	9.82
Ex. Magnesium	meq/100g	13.18	14.98	7.78	5.79	10.16	14.22	14.22	10.21	6.90	15.22	13.14	8.19
ESP	%	5.5	7.6	10.8	11.1	3.3	6.3	8.5	8.7	2.8	6.5	7.9	10.4
Ca/Mg	Ratio	2.1	2.1	1.5	1.5	1.9	2.0	1.6	1.6	1.5	1.2	1.5	1.2

Note:- Sites designated with a superscript (*) were located outside the study area within the current operating mining lease area - ML 7459

Analysis	Lab No.	18929	18930	18931	18932	18933	18934	18936	18935	
	Site No.*	E 2 / 44	E 2 / 44	E 2 / 44	E 2 - 44	E 2 – 51*	E 2 – 51*	E 2 / 51*	E 2 / 51*	
	Depth (m)	0 – 0.1	0.25 – 0.4	0.5 – 0.7	1.3 – 1.5	0 - 0.3	0.3 – 0.6	0.6 – 0.9	1.3 – 1.4	
	Soil Type	6.2. – Ug5.15 (Qa2/6.2)				3.2 – Gn2.12 (Ta3/3.2-2.2)				
pH (1:5 H_20)	Unit	8.1	8.4	8.6	8.5	7.4	7.9	7.9	8.0	
Nitrate Nitrogen	mg/kg	54	63	7	3	1	<1	<1	<0.1	
Phosphorus	mg/kg	17	5	9	12	8	<1	<1	2	
Potassium (K)	mg/kg	390	230	210	160	110	53	78	77	
Sulphur	mg/kg	18.9	14.7	24.7	4.5	2.8	2.3	1.0	6.2	
Calcium (Ca)	mg/kg	5300	5200	4100	2700	970	620	880	980	
Magnesium (Mg)	mg/kg	1100	1300	1500	1100	63	56	110	190	
Copper (Cu)	mg/kg	1.4	1.5	1.4	0.9	0.4	0.4	0.4	0.3	
Zinc (Zn)	mg/kg	0.9	0.4	0.3	0.4	0.5	0.2	0.4	0.4	
Manganese (Mn)	mg/kg	14	5	6	3	29	7	3	1	
Iron (Fe)	mg/kg	13	13	13	10	9	9	174	19	
Boron (B)	mg/kg3	1.5	1.4	3.5	1.7	0.7	1.0	1.3	1.4	
Organic Carbon	%	1.3	1.0	0.8	<0.1	1.4	<0.6	<0.6	<0.1	
EC (1:5 H_20)	dS/m	0.13	0.19	0.48	0.44	0.02	0.01	0.02	0.02	
Sodium (Na)	mg/kg	200	470	1300	1100	3	1	1	3	
Chloride	mg/kg	29	78	580	578	24	12	17	24	
CEC - (ECEC)	meq/100g	37.88	39.04	38.84	28.00	5.66	3.71	5.55	6.72	
Ex. Sodium	meq/100g	0.86	2.06	5.57	4.85	0.01	0.00	0.00	0.01	
Ex. Potassium	meq/100g	0.99	0.59	0.55	0.41	0.27	0.14	0.20	0.20	
Ex. Calcium	meq/100g	26.65	25.86	20.57	13.58	4.85	3.10	4.40	4.89	
Ex. Magnesium	meq/100g	9.38	10.53	12.15	9.16	0.53	0.47	0.95	1.62	
ESP	%	2.3	5.3	14.3	17.3	0.2	0.1	0.1	0.15	
Ca/Mg	Ratio	2.8	2.5	1.7	1.5	9.2	6.6	4.6	3.0	

Note:- Sites designated with a superscript (*) were located outside the study area within the current operating mining lease area - ML 7459

APPENDIX D

Background on Soil Chemical Properties

Nitrate Nitrogen (NO_3), Phosphorus (P) and Potassium (K)

Depending on soil moisture availability, levels of NO_3 <5 mg/kg, constitute low to very low levels for NO_3, 10 mg/kg rates as medium and 20 mg/kg or more rates as high. levels of Extractable Phosphorus (P) of <10 mg/kg rates as very low and Exchangeable Potassium (K) of <0.2 meq/100 g of soil are considered to be very low.
With the exception of the soil types in Soil Group 3 which returned very low levels of nitrate nitrogen, (No_3) and Phosphorus (P), most other soil types tested had at least medium (No_3 and P) levels in the surficial soil horizons and generally low to very low levels below depths of about 0.2m. The samples tested from the recently cultivated lands (sites E2/27, E2/28, E2/31 and E2/44)) had medium to high (No_3 and P) levels to depths of between 0.4-0.9m (bgl). With the exception of samples tested from Soil Groups 3 and 4, which exhibited very low levels of Potassium (k), all other samples tested had acceptable (K) levels throughout the profile.

Soil pH (1:5 H_2O)

Soil pH is a measure of the acidity or alkalinity of a soil. It characterises the chemical environment of the soil and provides a guide to likely mineral deficiencies and toxicities for plant growth. According to Bruce and Rayment (1982), the general interpretation for soil pH (1:5 H2O) is as follows:

pH	Soil Acidity/Alkalinity
8.5	Greater is strongly to very strongly alkaline
7.4 to 8.4	Mildly to moderately alkaline
6.6 to 7.3	Neutral
5.6 to 6.5	Moderately to slightly acidic
5.5 to 4.5	Strongly to very strongly acidic
<4.5	Extremely acidic

The preferred range for most plants varies between pH 5.6 to 8.4 depending on the plant species. With the exception of Soil Type 2.3 in Terrain Unit Ta4/2.3, which exhibited very strongly acidic surface and subsoil horizons (pH 5.5-4.0), in all other soil samples tested, the pH levels of the surficial (A1) soil horizons in Soil Groups 2 through 6, were mainly within the slightly acidic to moderately alkaline range (pH 6.5-8.3). The pH in the subsoil layers of Soil Types 3.2 and 3.3, were near neutral to slightly acidic (pH 7.9-6.0). The pH levels in the subsoil horizons in most soils from Soil Groups 4, 5 and 6, were moderately to very strongly alkaline (pH 8.4-9.3).

Salinity – Electrical Conductivity (EC-1:5 H_2O)

Salinity relates to the presence of water soluble salts, mainly sodium, calcium and magnesium, which may be in the form of chlorides, sulfates or carbonates. High levels of salinity can severely affect plant growth and as a consequence increase the soil erosion potential. Salinity levels based on the laboratory determined EC (1:5 H_2O) expressed as mS/cm (dS/m), vary depending on the soil texture and have been rated in Hazelton and Murphy (1992); the approximate ranges are as follows:

Salinity Level	Electrical Conductivity		
	Sand	**Loam**	**Medium to Heavy Clays**
Non saline	<0.10 mS/cm	<0.20 mS/cm	<0.30 mS/cm
Slightly saline	0.10-0.25 mS/cm	0.20-0.40 mS/cm	0.30-0.55 mS/cm
Moderately saline	0.25-0.47 mS/cm	0.40-0.80 mS/cm	0.55-1.15 mS/cm
Highly saline	0.47-0.95 mS/cm	0.80-1.60 mS/cm	1.15-2.30 mS/cm
Extremely saline	>0.95 mS/cm	>1.60 mS/cm	>2.30 mS/cm

Reference to the results of soil testing in **Appendices B and C,** indicates that a majority of the subsoil samples from soil types from Soil Groups 2 and 4-6, that were tested for electrical conductivity (EC) levels, have elevated (moderate to high) salinity levels, particularly in the middle to lower B and B-C or B-D horizons. An exception to these conditions occurs in parts of the alluvial plain that have been subject to irrigation for cropping purposes, where the normally elevated subsoil salinity levels were quite low, possibly due to downwards leaching of salts from percolating water from the irrigation process. Subsoil salinity was very low in the samples tested from Soil Types 3.2 and 3.3.

Chloride (Cl) – (1:5 H_2O)

A rating of chloride levels with respect to potential effects for plant growth (Bruce & Rayment – 1982), is provided below.

Chloride Concentration	Rating
<100 mg/kg (<0.01%)	Very low
100-300 mg/kg (0.01-0.03%)	Low
300-600 mg/kg (0.03-0.06%)	Medium
600-2000 mg/kg (0.06-0.20%)	High
>2000 mg/kg (>0.2%)	Unsustainable for all but very salt tolerant species

Reference to the results of soil testing in **Appendix C,** indicates that the surficial soil horizons above a depth of about 0.3m, in all soil types tested have suitably low levels of chloride for normal plant growth. The subsoil horizons in Soil Types 5.1 and 6.1 and 6.2g, have moderate to high (Cl) levels, below a depth of about 0.3m. Soil Types 4.2, 5.2 and 6.2 all indicated moderate to high (Cl) levels,

below a depth of about 0.4-0.5m (bgl). Soil Types 3.2 and 3.3 exhibited low (Cl) levels, throughout the profile

Exchangeable Cations and Cation Exchange Capacity (CEC)

Cation Exchange Capacity reflects the capacity of the soil to hold and exchange cations. It is a major controlling agent of stability of soil structure and nutrient availability for plant growth. Units are expressed as milli-equivalents per 100 g of soil (meq/100 g). Ratings for CEC range from <6 meq/100 g (very low), 6-12 meq/100 g (low), 12-25 meq/100 g (moderate), 25-40 meq/100 g (high) and >40 meq/100 g (very high).

The five most abundant cations present in soils are calcium (Ca2+), magnesium (Mg2+), potassium, (K+), sodium (Na+) and in strongly acid soils, aluminium (Al3+). The cations, manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn) are usually present in small amounts that do not contribute significantly to the total cation compliment. It is common practice therefore to measure the concentrations of only the four or five most abundant cations. CEC may be measured directly, or the sum of the four major cations (Ca, Mg, Na, K) may be determined to give an approximate value of CEC termed - Effective CEC (ECEC). The individual major cations may then be expressed as a percentage of the CEC or ECEC.

Hazelton and Murphy (1992) rate the levels of the basic cations as follows:

Basic Cation Concentrations (meq/100 g)					
Cation	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Calcium	0-2	2-5	5-10	10-20	>20
Magnesium	0-0.3	0.3-1.0	1-3	3-8	>8
Sodium	0-0.1	0.1-0.3	0.3-0.7	0.7-2.0	>2.0
Potassium	0-0.2	0.2-0.3	0.3-0.7	0.7-2.0	>2.0

With the exception Soil Type 3.2 and probably other soil types in Soil Groups 2 and 3 which are likely to have low or very low ECEC, all other soil types tested had moderate to high or very high levels of ECEC. Similarly with respect to concentrations of basic cations, with the exception of Soil Groups 2 and 3, all other soil types tested had moderate to high, or very high levels of ECEC levels.

Sodicity

Sodicity is the level of exchangeable sodium in the soil and is determined using exchangeable sodium percentage (ESP), which is the amount of exchangeable sodium expressed as a percentage of the effective cation exchanges capacity (ECEC). General ratings for sodicity established by Northcote and Skene (1972) are as follows:

ESP%	Rating
<6	Non-Sodic
6-14	Sodic
>14-25	Strongly Sodic
>25	Very Strongly Sodic

Sodic soils tend to exhibit the following problems:

- Very severe surface crusting;
- Likely dispersion on wetting;
- Very low infiltration and hydraulic conductivity;
- Very hard dense subsoils;
- High susceptibility to severe gully erosion;
- High susceptibility to tunnel erosion.

More than half of the samples submitted for laboratory testing, were either sodic. or strongly sodic, mainly in the middle to lower B and B-C horizons in Soil Types 4.2, 5.1-5.3, 6.1 and 6.2

Ca/Mg Ratio

Values of Exchangeable Calcium to Exchangeable Magnesium (Ca/Mg) ratio of <2 and in particular those approaching 1 or that are <1, are considered to favour clay dispersion and exhibit poor soil structural conditions, generally giving rise to giving rise to hard and tough impermeable sub-soil conditions.

With the exception of the subsoil horizons Soil Type 4.2 from site E2/24, and the deepest subsoil layer of Soil Type 6.2g from site E2/10, which had Ca/Mg ratios of 1.1 or less, most other soil types tested had Ca/Mg ratios mainly in the range 1.5-2.5 or greater.

Dispersion Tests

Soil aggregate stability refers to the stability of soil aggregates when immersed in water in the natural or subsequently remoulded condition. Instability may be indicated by slaking and/or partial or total dispersion of the clay particles forming the soil aggregate.

The Dispersion Class No.-Emerson (1981) provides a measure of soil dispersion potential or structural stability of soils when immersed in distilled/deionised water. The general levels of dispersion assigned to the various classes are explained below.

* Dispersion Class No.	Dispersion Rating
1, 2(3)	Very high
2(2)	High
2(1)	Moderate to High
3(4), 3(3)	Moderate
3(2), 3(1) and 5	Slight
6, 7, 8	Negligible/Aggregated

** Dispersion Sub-classes (Charman, 1978)*
(1) - Slight milkiness adjacent to the aggregates
(2) - Obvious milkiness < 50% of the aggregates affected
(3) - Obvious milkiness, >50% of the aggregate affected
(4) - Total dispersion leaving only sand grains

The results of indicative dispersion testing carried out (**Appendix B**), show that approximately 50% of the samples tested are potentially either slightly to moderately dispersive, mainly in Soil Types 5.1, 5.3 and 6.2, with some strongly dispersive materials associated with Soil Type 4.2. This is consistent with the medium to high levels of sodicity recorded where, in general, the more dispersive materials occur in the subsoil and deeper subsoil layers.

Organic Carbon (OC%) Content

Organic matter is derived from the breakdown of plants and animal matter and is largely responsible for much of the physical and chemical fertility of the soil. Organic matter content is normally only measured in the topsoil horizon and is calculated from the levels of organic carbon (OC%) determined in the soil, multiplied by a factor of 1.72. As reported in Hazelton and Murphy (1992), a ranking for soil organic matter content (OM%), based on (OC%) is as follows:

% Organic Matter	Ranking	Soil Structure
<0.3%	Extremely low	Typical of subsoil levels or severely degraded or eroded surface soils
0.3-1.2%	Low	Indicative of very poor to poor structural condition and structural stability.
1.2-2.9%	Moderate	Indicative of average to good structural condition and structural stability
>2.9%	High or very high	Indicative of good structural condition and high structural stability

Organic Carbon (OC%) levels were low to very low throughout the profile in Soil Type 3.2 and are likely to be similarly low in other soil types in Soil Groups 1, 2 and 3. The surficial soil horizons in all other soil types tested had mostly moderate (OC%) levels, to locally very high levels in sites E2/10 and E2/27. In general (OC%) levels diminish with depth.

APPENDIX E

Basis for the Assessment of Terrain/Soil Attributes

Table E.1
Land Suitability Classes for Agriculture – Limiting Factors

Limitation	Criteria for Degree of Limitation [1]			Suitability Class	Sub-Class Symbol
Topography	Dryland Cropping	Grazing Lands	Irrigated Agriculture		
(Slope classes influencing water management and erosion control)	<1.0%	<1.0 %	0.1 – 0.5%	1	-
	1.0 - 2.0%	1.0 - 2.0%	0.5 – 1.0%	2	t2
	3.0 - 6.0%	3.0 - 6.0%	1.0 – 2.0%	3	t3
	6.0 - 15%	>6.0%	2.0 – 6.0%	4	t4
	>15%	-	>6%	5	t5
Flooding	No flooding			1	f1
(Crop losses due to flooding may occur)	Frequency < 1 in 10 years (occasional)			2	f2
	Frequency 1 in 5 - 10 years (infrequent)			3	f3
	Frequency > 1 in 5 years (frequent)			4	f4
	Subject to erosive flooding			5	f5
Micro-relief	No surface micro-relief			1	-
(Gilgai and gullying, surface levelling required)	Vertical interval of surface micro-relief <250mm			2	g2
	Vertical interval of surface micro-relief 250 – 600mm			3	g3
	Vertical interval of surface micro-relief >600mm			4	g4
Stoniness	No cobble, stone or rock			1	-
(Limitations to cultivation)	Some stone picking may be required for certain crops			2	r2
	Tillage restricted; stone picking required			3	r3
	Tillage difficult; stone/cobble picking necessary			4	r4
	Tillage impractical; not practicable to remove stone			5	r5
Soil Physical Properties	>450mm to subsoil with extremely hard dry consistence			1	-
1. Depth to hard impermeable subsoil – restricted root development and water entry	200 – 450mm to subsoil with extremely hard dry consistence			2	pb2
	100 – 200mm to subsoil with extremely hard dry consistence			3	pb3
	<100mm to subsoil with extremely hard dry consistence			4	pb4
2. Surface crust/hard setting surface condition	No surface crust and surface horizon is not hard setting			1	-
	Hard setting surface with mod. hard dry consistence			2	pc2
	Hard setting surface with hard dry consistence			3	pc3
	Hard setting surface with very hard dry consistence			4	pc4
3. Soil type distribution complexity	Surface textures/soil type changes occur average:				
	150 – 300m apart			3	pd3
	< 150m apart			4	pd4
	Dryland Cropping	- Grazing Lands	- Irrigation		

Limitation	Criteria for Degree of Limitation (1)	Suitability Class	Sub-Class Symbol
4. Soil Texture	Soil types with surficial sand to sandy loam texture to depths of:		
	<450mm	2	pt2
	450-900mm	3	pt3
	>900mm	4	pt4
5. Gravel Beds	Gravel beds >150mm thick, <450mm from the surface	4	pg4
Effective Depth (Depth to rock or hardpan, or other soil layer limiting root development and plant available water capacity)	Deep (>1000mm) - >600mm - >1000mm	1	-
	Mod. Deep (600–1000mm) - 400-600mm - 600-1000mm	2	d2
	Mod. Shallow (450–600mm) - 250-400mm - 450-600mm	3	d3
	Shallow (250–450mm) - 150-250mm - 250-450mm	4	d4
	Very shallow (<250mm) - <150mm - <250mm	5	d5
Salinity/Sodicity	E.C. 1:5 soil/water suspension >1mS/cm at depths of:		
	300 – 900mm	3	Sa3
	<300mm	4	Sa4
	ESP >15% at depths of:		
	300 – 900mm	3	So3
	<300mm	4	So4
Soil Fertility	Based on analyses of major soil nutrients are:		
	- low	2	n2
	- very low	3	n3
Wetness (Trafficability/handling)	Areas remain wet and cannot be used for:		
	limited periods (some levelling required)	3	w3
	long periods – months (special drainage works necessary)	4	w4
	very long periods, permanently water logged (major drainage works necessary).	5	w5
Erosion (Soil susceptibility to water and/or wind erosion)	Soil conservation measures required to control erosion:		
	Low (L) - simple practices (maintenance of surface cover)	2	e2
	Moderate (M) - intensive practices (graded banks)	3	e3
	Moderate to High (M-H) - pasture phase or permanent pasture	4	e4
	High (H) - severe gully erosion (requires reclamation)	5	e5

Notes:

(1) - Land Suitability Class criteria have been adapted from the criteria proposed by Gunn *et al*.(1988), DPI (1990), Schields & Williams (1991) and McDonald (1986), for the Emerald Irrigation Area.

(2) - Where there are two or more (for example) Class 3 Limitations allocated, the overall rating may be down-graded to Suitability Class 4.