Dellara

ABN: 26 131 659 339

Orchard Hills Waste and Resource Management Facility

Soils and Land Capability Assessment

Prepared by:

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Soils and Land Capability Assessment

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EXECUTIVE SUMMARY

Soils in the Study Area have been described and two Soil Mapping Units [SMUs] have been identified.

These SMUs are:

- Soil Mapping Unit 1 – Soils Upper Slopes and Crest; and
- Soil Mapping Unit 2 – Soils of the Blaxland Creek Floodplain.

The physical and chemical attributes of the soils of the Study Area have been quantified through a combination of field assessment and laboratory testing which indicates the following.

- Much of the area has been subjected to intensive quarrying and associated activity including stockpiling of soil and building waste with only a limited proportion retaining its original soil profile integrity.
- Because of the limited availability of in-situ soil material for rehabilitation of the final landform, it will be necessary for the Proponent to accumulate suitable topsoil and subsoil resources from materials brought to the site from development sites in the Cumberland Plain and elsewhere.
- The undisturbed soils within the Project Site are generally currently stable but the unprotected stockpiles of subsoil material showed evidence of erosion. It is noted that any sediments from erosion and water containing dissolved and suspended material is collected on site rather than being discharged.
- SMU 1 which covers the majority of the site has a **MODERATE** erodibility rating as determined using the laboratory data obtained from samples from the Project Site in the SOILOSS computer model.
- SMU 2 has a **HIGH** erodibility rating as determined by the SOILOSS model. Because of the location of this SMU on the floodplain of Blaxland Creek it is recommended that this SMU not be further disturbed.
- The topsoil of **SMU 1** showed **slight to moderate** dispersibility.
- The subsoil of **SMU 1** showed **high to very high** dispersibility.
- The topsoils of **SMU 2** showed **slight to moderate** dispersibility.
- The subsoils of **SMU 2** showed **high to very high** dispersibility.
- As a consequence there is a need to rapidly stabilise all topsoil and subsoil stockpiles as soon as possible after stockpile construction.
- The subsoils of both SMUs showed elevated salinity levels that may cause problems for establishing a perennial pasture cover on the subsoil stockpiles. It is suggested that if perennial pasture cover establishment is poor then alternative protective barriers be used to prevent erosion of these stockpiles.

- The soil materials sampled generally had pH values within the acceptable range for plant growth.
- All soils will be subject to structural degradation if worked when too moist.

The pre-disturbance Land Capability [**Classes III and VI**] and Agricultural Land Suitability [**Class 3**] of the Project Site have been determined.

The post-use Land Capability [**Classes III and VI**] and Agricultural Land Suitability [**Class 3**] of the Project Site have been determined.

1 INTRODUCTION AND DESCRIPTION OF PROJECT

1.1 Introduction

This soils assessment was carried out for R.W. Corkery & Co. Pty. Limited on behalf of Dellara Pty Ltd [the Proponent] for the proposed Orchard Hills Waste and Resource Management Facility ("the project"). The Project Site is coincident with the boundary of Lot 40, DP 738126, some 60ha in area, and is located north of Patons Lane at Orchard Hills. The land comprises a former quarry and stockpile area and is surrounded on three sides by agricultural land and on the fourth by the land within the RAAF Orchard Hills Defence Establishment.

Field sampling was undertaken on 4 February 2009.

1.2 Description of the Project Site and the Proposal

The Project Site comprises a generally disturbed area that has been used as a quarry and stockpile site in the past. Prior to disturbance, the site would have been a relatively level area adjacent to a short section of Blaxland Creek.

Native vegetation is absent over the majority of the site with the only occurrence being associated with Blaxland Creek.

The Proponent's objectives for the development and operation of the Orchard Hills Waste and Resource Management Facility are to:

a) provide a facility that would enable waste to be considered as a resource through recycling and re-processing to yield useful and beneficial products;

b) develop a licenced facility able receive and emplace unusable wastes and residual wastes from the on-site recycling and re-processing;

c) recover the remaining high grade light-firing clay/shale resources for the brick industry and other clay/shale products for the construction industry;

d) progressively rehabilitate the entire Project Site in a manner that re-instates the rural agriculturally productive land consistent with the adjoining land to the north and east; and

e) achieve (a) to (d) above in an environmentally and socially responsible manner.

The project would involve a number of components designed to collectively underpin a financially sound facility able to provide an important environmentally friendly waste and resource management service and the ultimate re-instatement of productive rural grazing land in an area zoned for ongoing agricultural production. The principal activities of the project would include the following.

- Erection and operation of the waste recycling and re-processing facility.
- Development and operation of staged waste emplacement cells to contain all residual wastes from the recycling facility, other imported wastes (unable to be reprocessed) and selected construction and demolition wastes recovered from the on-site perimeter bund walls.

- Refurbishment of the former weighbridge and offices together with the construction of a range of on-site infrastructure including truck wheel wash and water management structures.
- Ongoing clay/shale extraction (subject to market demand) to recover light-firing shale for use by the brick industry and other clay/shale materials for off-site construction projects and as optimal cover material for the on-site waste emplacement and final capping.
- Progressive selective removal and management of material from the existing perimeter bund walls including identification, separation and re-processing or disposal of waste materials previously imported to site and incorporated into the bund walls in contravention to the requirements of the *Protection of the Environment Operations Act 1997* and the development consent for the site.

2 LITRATURE REVIEW

2.1 1: 100 000 Scale Soil Landscape Mapping

The Project Site is located within the boundaries of the Penrith 1: 100 000 scale Soil Landscapes map sheet published by the former Soil Conservation Service of NSW [Hazelton, Bannerman and Tille, 1989].

The map shows that the Project Site comprises mainly soils typical of the Blacktown Soil Landscape with a small section associated with Blaxland Creek being described as South Creek Soil Landscape.

The soils of the various soil landscapes within the Penrith sheet boundaries are described by Bannerman and Hazelton [1990]. Descriptions of typical soil profiles within these two soil landscapes are provided in the following sections.

2.1.1 Blacktown Soil Landscape [Bannerman and Hazelton, 1990]

This soil landscape typically occupies gently undulating rises on Wianamatta group shales with gently inclined slopes and broad rounded crests and ridges.

Hazelton and Bannerman [1990] describe typical profiles from the crests, upper and mid-slopes and the lower slope situations.

2.1.1.1 Soils of the Crests [usually <100cm deep; surface condition friable]

Layer 1 [up to 30cm thick or sometimes absent] – friable brownish black loam to clay loam; moderately pedal; pH 7.0**Layer 2 [10-20cm thick] –** hard setting brown clay loam to silty loam; massive to weakly pedal; occurs as an A_2 horizon; pH 5.0

Layer 3 [up to 90cm thick] – brown light to medium clay; mottled; moderately pedal; pH 4.5 to 6.5

2.1.1.2 Soils of the Upper Slopes and Mid-slopes [usually< 200cm deep]

Layer 1 [up to 30cm thick or sometimes absent] – friable brownish black loam to clay loam; moderately pedal; pH 7.0

Layer 2 [10-20cm thick] – hard setting brown clay loam to silty loam; massive to weakly pedal; occurs as an A_2 horizon; pH 5.0

Layer 3 [up to 50cm thick] – brown light to medium clay; mottled; moderately pedal; pH 4.5 to 6.5

Layer 4 - light grey plastic silty clay to heavy clay; mottled; moderately pedal; pH4.0 to 5.5; weathered ironstone concretions and rock fragments common

2.1.1.3 Soils of the Lower Sideslopes [usually> 200cm deep]

Layer 1 [up to 30cm thick] – friable brownish black loam to clay loam; moderately pedal; pH 7.0

Layer 2 [10-30cm thick] – hard setting brown clay loam to silty loam; massive to weakly pedal; occurs as an A_2 horizon; pH 5.0

Layer 3 [40 to 100cm thick] – brown light to medium clay; mottled; moderately pedal; pH 4.5 to 6.5

Layer 4 [usually >100cm thick] - - light grey plastic silty clay to heavy clay; mottled; moderately pedal; pH4.0 to 5.5; weathered ironstone concretions and rock fragments common

2.1.2 Soils of the South Creek Soil Landscape [Bannerman and Hazelton, 1990]

This soil landscape typically occupies floodplains, valley flats and drainage depressions of the channels of the Cumberland Plain, gently undulating rises on Wianamatta group shales with gently inclined slopes and broad rounded crests and ridges.

Hazelton and Bannerman [1990] describe typical profiles from the drainage channels, near the channel, low terraces and high terraces of the landscape.

2.1.2.1 Soils of the Channels [variable depth]

Layers 1 and 2 reoccur down the profile.
Layer 1 [variable depth] – brown sandy clay loam; apedal, single grained; pH 4.5 to 6.5; small gravel may be present

Layer 2 [variable depth] – bright brown light to medium clay; strong structure; sometimes mottled yellow or grey; pH 3.0 to 7.0

2.1.2.2 Soils of the Near Channel Area

Layer 1 [30-50cm thick] – friable and loose brown sandy clay loam; apedal, single grained; pH 4.5 to 6.5; small gravel may be present

Layer 2 [to 15cm thick] - hardsetting dull brown clay loam to fine sandy clay loam; usually massive in structure; pH 5.5 to 7.0

Layer 3 [to 70cm thick] – bright brown light to medium clay; strong structure; sometimes mottled yellow or grey; pH 3.0 to 7.0

2.1.2.3 Soils of the Low Terraces

Layer 1 [2-50cm thick] – friable and loose brown sandy clay loam; apedal, single grained; pH 4.5 to 6.5; small gravel may be present

Layer 2 [to 15cm thick] - hardsetting dull brown clay loam to fine sandy clay loam; usually massive in structure; pH 5.5 to 7.0

Layer 3 [60-85cm thick] – bright brown light to medium to heavy clay; strong structure; not mottled; pH 3.0 to 7.0

2.1.2.4 Soils of the High Terraces

Layer 1 [to 190cm thick] – bright brown medium clay; strong structure; not mottled; pH 3.0 to 7.0

Shale bedrock

3 METHODOLOGY

3.1 Preparations

Prior to field investigations, an airphoto of the Project Site was examined to ascertain the nature of the landforms and disturbance present within the Project Site and to develop a broad appreciation of the landform units that would require sampling.

3.2 Field Procedures

For the soils study, sampling required in the brief involved the complete description of four profiles to a depth of at least 2.5m, or the depth of backhoe refusal if rock was closer to the surface.

The locations of the soil sampling sites within the Project Site are shown in **Figure 1** and are listed in **Table 1.**

REFERENCE
Project Site Boundary
Existing Contour (m AHD)(Interval = 5m)
Spot Height (m AHD)
Internal Road (unsealed)
Soil Test Pit
Soil Mapping Unit Boundary (and reference)

SCALE 1:5 000

50 0 50 100 150 200 250 m

Photo Source: Geo-Spectrum (Australia) - Date of Photo: 4 August 2007

Figure 1
SOIL SAMPLING SITES AND SOIL MAPPING UNITS

Table 1
Soil Pit Locations [AMG Coordinates]

PIT NUMBER	EASTING	NORTHING
1	291276E	6255796N
2	290836E	6255864N
3	291154E	6256677N
4	290859E	6256726N

The soil profiles at each pit location were fully described in the field after a detailed examination of the different layers.

For each test profile [site] described, details of the following soil properties were noted.

- Texture
- Fabric
- Structure
- Consistence
- Boundary sharpness
- Colour [moist and dry]
- Gravel/stone occurrence
- Presence of roots
- Presence of lime
- Presence of manganese
- pH

Soil pH was measured using the Raupach method [Raupach indicator and barium sulphate]. Soil colour [moist and dry] was determined using Munsell soil colour charts [Macbeth, 1992]. The classification of the soils that were described was based on Isbell [1996].

In determining the soil classifications the CD-ROM titled "The Australian Soil Classification - An Interactive Key" [Jacqier et al, 2001] was used.

The information obtained was recorded in a form that is compatible with that required for entry on soil data cards used in the DECCW's SPADE Soil Database.

Samples from all layers in two profiles [Pit Nos. 2 and 4] were forwarded to the Department of Lands' NATA - registered soil testing laboratory at Scone for more detailed analysis to determine the following properties.

- Range of particle size [particle size analysis].
- Dispersion percentage.
- Coherence [Emerson aggregate test].
- Electrical conductivity.

3.3 Soil Stripping Suitability

The stripping suitability of the soils at the sites sampled using the backhoe pits was determined on the basis of the procedure outlined by Elliott and Veness [1981].

From the data gained in this process, recommendations on the depths of topsoil and subsoil stripping were developed.

4 RESULTS

From the information gained from both the detailed soil profile descriptions, two Soil Mapping Units [**SMU**s] were identified.

The identified SMUs are:

- **Soil Mapping Unit 1** –Soils of the Upper Slopes and Crest
- **Soil Mapping Unit 2** –Soils of the Blaxland Creek Floodplain

The soil mapping unit boundaries are shown in **Figure 1**.

It is important to note that not all soil layers described for each of the Soil Mapping Units are present in every profile. Soils are inherently variable in nature and while they may have similar overall characteristics they may vary in layer detail and properties.

Appendix 1 contains detailed information on the layers present in the seven soil pits that were described in detail.

4.1 Soil Mapping Unit Descriptions

Descriptions of the layers found in the profiles of the two SMUs identified within the Project Site are set out below.

In each case, the soil within each unit is described in two ways – a “Plain English” version followed by a technical description.

Definitions of the technical terms used in the descriptions can be found in **Appendix 4** or by consulting McDonald et al [1990] or Houghton and Charman [1986].

4.1.1 Soil Mapping Unit 1 – Soils of the Upper Slopes and Crest

Relevant profiles are numbers 1, 2 and 3

4.1.1.1 “Plain English” Description:

Soil excavated to a maximum of 270cm depth; sometimes encountering bedrock but the lower horizon continued below excavation depth in other profiles

Topsoil - clay loam; light to medium clay; many roots; no lime present; no manganese present; pH 5.5 to 6.0, gravel and stones generally absent; sometimes some small gravel to 5mm, occasional angular gravel to 3cm present; not mottled; not bleached; brown dark yellowish brown dry, dark brown, very dark greyish brown moist; well structured, often hydrophobic.

Sometimes up to two additional relatively coarse textured A horizon layers may be present

Subsoil – up to four subsoil horizons identified; texture generally clayey; many roots in the upper sections but few to absent at depth; recorded pH 4.5 to 5.0; gravel and stones absent or gravel present in varying amounts; usually whole coloured or mottled at depth in colours of white, red, grey, brown and yellow; commonly well structured, usually not hydrophobic.

4.1.1.2 Technical Description [based on test pits]

[a] Australian Soil Classification Names – Brown and Black Kurosols

[b] Field Description:

Crest and upper slope locations; surface condition loose. Firm or hard, sometimes cracked; surface stone absent

Layer 1 [always present] [A1.1 horizon] [recorded 8-24cm thick] - clay loam; light to medium clay; many roots; no lime present; no manganese present; pH 5.5 to 6.0, one reading 8.0; gravel and stones generally absent; sometime some small gravel to 5mm, occasional angular gravel to 3cm present; not mottled; not bleached; brown [10YR5/3, 7.5YR5/3], dark yellowish brown [10YR4/4] dry, dark brown [7.5YR3/2], very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15 mm in size; firm to very strong consistence dry; often hydrophobic; *abrupt to:-*

Layer 2 [sometimes present] [A1.2 horizon] [recorded 13cm thick] - loam fine sandy; many roots; no lime present; no manganese present; pH 6.5; much angular gravel to 5cm; not mottled; not bleached; yellowish brown [10YR5/4] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; slightly hydrophobic; *abrupt to:-*

Layer 3 [sometimes present] [A1.3 horizon] [recorded 16cm thick] - fine sandy loam; many roots; no lime present; no manganese present; pH 6.0; much angular gravel to 5cm; not mottled; not bleached; light yellowish brown [10YR6/4] dry, dark yellowish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

Layer 4 [always present] [B1 horizon[[recorded 17-44cm thick] - light to medium clay, medium clay, medium to heavy clay; roots few to many; no lime present; sometimes much manganese staining present; pH 5.0 to 5.5; gravel and stones absent; not bleached; **often whole coloured** brown [7.5YR5/3], very dark grey [10YR3/1] dry, dark brown [7.5YR3/2], very dark greyish brown [10YR3/2] moist; **sometimes mottled** in colours of red [10R4/6], weak red [10R4/4], yellowish brown [10YR5/6, 10YR5/8] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral or polyhedral / platy, <5-15 mm in size; very strong consistence dry; hydrophobic or not hydrophobic; *clear to:-*

Layer 5 [always present] [B2.1 horizon] [recorded 34-86cm thick] - medium to heavy clay, heavy clay; few roots; no lime present; no manganese present; pH 4.5 to 5.0; gravel and stones absent; not bleached; mottled in colours of light brownish grey [10YR6/2], weak red [10R4/4], red [10R4/6, 2.5YR4/8], white [2.5Y8/1]; grey [7.5YR5/1], light yellowish brown [2.5Y6/3], pale brown [10YR6/3], red [!0R4/6, 10R4/8, 2.5YR4/8] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-20 mm in size strong to very strong consistence dry; ; not or slightly hydrophobic; *gradual to:-*

Layer 6 [always present] [B2.2 horizon] [recorded 83-116cm thick] - heavy clay; medium to heavy clay; few roots or roots absent; no lime present; no manganese present; pH 4.5; decomposing rock, broken rock inclusions or ironstone present; not mottled; not bleached; light greenish grey [gley1 N], strong brown [7.5YR5/6], very pale brown [10YR8/2] with some red [2.5YR4/8] blotches dry, dark yellowish brown [10YR4/6], ght brownish grey [2.5Y6/2], light greenish grey [gley1 7/10Y] moist;
peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size;
very strong consistence dry; not hydrophobic; *profile as excavated ends or gradual to:-*

Layer 7 [sometimes present] [B2.3 horizon] [recorded 45cm thick] - light to medium clay; roots absent; no lime present; no manganese present; pH 4.5; gravel and stones absent; mottled; not bleached; 95% grey [2.5Y6/1], 5% red [10R4/6] dry, 95% grey [2.5Y6/1], 5% red [10R4/6] moist, peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15 mm in size; very strong consistence dry; not hydrophobic.

Layer 8 [sometimes present] [B3 horizon] [recorded 40cm thick] - heavy clay; few roots; no lime present; no manganese present; pH 4.5; gravel and stones absent; not mottled; not bleached; light grey [2.5Y7/1] dry, light grey [2.5Y7/1] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; very strong consistence dry; not hydrophobic.

4.1.2 Soil Mapping Unit 2 – Soils of the Blaxland Creek Floodplain

Relevant profile is number 4

4.1.2.1 "Plain English" Description:

Soil excavated to 250cm depth; surface condition firm; surface stone absent

Topsoil a silty clay to light clay; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; pale brown dry, very dark greyish brown moist; well structured; not hydrophobic

Subsoil [as excavated] comprised of four layers over bedrock or a continuation of the lowest horizon; generally medium or heavy clay textured, roots many near the surface but decreasing with depth; no visible lime present; no manganese present; pH 6.0 to 8.0 at depth; gravel and stones usually absent not bleached; some horizons mottled in colours of grey, brown and yellow; when whole coloured, the colours are brown and yellow; well structured; not hydrophobic.

4.1.2.2 Technical Description [based on test pits]

[a] Australian Soil Classification Name – Yellow Chromosol

[b] Field Description:

Layer 1 – [A1.1 horizon] [recorded 12cm thick] - silty clay to light clay; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; pale brown [10YR6/3] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; strong consistence dry; not hydrophobic; *abrupt to:-*

Layer 2 [A1.2 horizon] [recorded 22cm thick] - silty clay loam; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; light yellowish brown [!0YR6/4] dry, dark yellowish brown [10YR4/4] moist; peds rough- faced, highly pedal [100%], polyhedral, 5-15 mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

Layer 3 [B.1 horizon] [recorded 66cm thick] - light to medium clay; few roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; light yellowish brown [!0YR6/4] dry, dark yellowish brown [10YR4/4] moist; peds rough- faced, highly pedal [100%], polyhedral, 5-15 mm in size; very firm consistence dry; not hydrophobic; *abrupt to:-*

Layer 4 [B2.1 horizon] [recorded 120cm thick] - gritty medium clay; few roots; no lime present; much manganese stains and nodules present; pH 7.0; gravel and stones absent; mottled; not bleached; 95% yellowish brown [10YR5/8], 5% brown [10YR5/3] dry, 95% dark yellowish brown [10YR4/6], 5% brown [10YR5/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; strong consistence dry; not hydrophobic; *abrupt to:-*

Layer 5 [B2.2 horizon] [recorded 30cm thick and continuing with depth] - heavy clay; roots absent; no lime present; no manganese present; pH 8.0; gravel and stones absent; mottled; not bleached; 90% light grey [10YR7/1], 10% yellowish brown [10YR5/8] dry, 90% light grey [10YR7/1], 10% yellowish brown [10YR5/6] moist, peds rough- / smooth-faced, highly pedal [100%], polyhedral / platy, 5-15 mm in size; strong consistence dry; not hydrophobic; *continues below.*

4.2 Soil Laboratory Analyses

Nine samples from two soil profiles were selected for laboratory analysis at the Department of Lands Soil and Water testing Laboratory at Scone.

The tests performed were aimed at assessing the potential erodibility of the soils [Particle Size Analysis [PSA], Dispersion % [D%] and Emerson Aggregate Test [EAT] and Electrical Conductivity [EC].

4.2.1 Physical and Chemical Analyses

Tables 2 and **3** contain the results obtained from laboratory analysis of the samples from the two pits.

Samples from one profile from **SMU 1** [Pit No. 2] and one from **SMU 2** [Pit No.4] were analysed in the laboratory.

Table 2
Physical Laboratory Analysis Data for Selected Soil Profiles
[Whole Soil Particle Size Analysis]

SMU / PIT NO.	LAYER	TEXTURE [fine earth][#]	DEPTH [cm]	PSA % CLAY	PSA % SILT	PSA % FINE SAND	PSA% COARSE SAND	PSA % TOTAL SAND	PSA % GRAVEL
SMU 1 PIT 2	**1**	**clay loam**	**0-24cm**	28	18	33	13	46	8
	2	**clay**	**24-68cm**	44	14	23	10	33	9
	3	**clay / silty clay**	**68-154cm**	61	18	16	4	20	1
	4	**clay**	**154-270cm**	54	20	17	6	23	3
SMU 2 PIT 4	**1**	**loam**	**0-12cm**	13	25	56	6	62	<1
	2	**loamy sand**	**12-34cm**	9	21	63	7	70	0
	3	**clay loam**	**34-100cm**	28	17	51	4	55	<1
	4	**clay loam**	**100-222cm**	22	10	24	26	50	18
	5	**silty clay**	**222-250cm**	43	34	22	1	23	<1

Note: PSA = Particle Size Analysis # texture based on laboratory measurements

Table 2 (Cont'd)
Physical Laboratory Analysis Data for Selected Soil Profiles
[Whole Soil Particle Size Analysis]

SMU / PIT NO.	LAYER	TEXTURE [fine earth]#	DEPTH [cm]	D%	D% level of dispersion	EAT	EAT level of dispersion
SMU 1 PIT 2	**1**	**clay loam**	**0-24cm**	16	slight	3[3]	moderate
	2	**clay**	**24-68cm**	24	slight	3[2]	slight
	3	**clay / silty clay**	**68-154cm**	63	high	2[3]	very high
	4	**clay**	**154-270cm**	76	very high	2[3]	very high
SMU 2 PIT 4	**1**	**loam**	**0-12cm**	19	slight	8/3[1]	negligible to slight
	2	**loamy sand**	**12-34cm**	13	slight	8/3[1]	negligible to slight
	3	**clay loam**	**34-100cm**	12	slight	5	slight
	4	**clay loam**	**100-222cm**	74	very high	2[3]	very high
	5	**silty clay**	**222-250cm**	87	very high	1	very high

Notes: D = Dispersion EAT = Emerson Aggregate Test # texture based on laboratory measurements

Table 3
Chemical Analyses Laboratory Analysis Data for Selected Soil Profiles

SMU / PIT NO.	LAYER	TEXTURE [fine earth]#	DEPTH [cm]	pH *	EC [dS/m]
SMU 1 PIT 2	**1**	**clay loam**	**0-24cm**	5.5	0.03
	2	**Clay**	**24-68cm**	5.5	0.34
	3	**clay / silty clay**	**68-154cm**	4.5	0.91
	4	**Clay**	**154-270cm**	4.5	1.02
SMU 2 PIT 4	**1**	**Loam**	**0-12cm**	6.0	0.03
	2	**loamy sand**	**12-34cm**	6.0	<0.01
	3	**clay loam**	**34-100cm**	6.0	0.04
	4	**clay loam**	**100-222cm**	7.0	0.28
	5	**silty clay**	**222-250cm**	8.0	0.65

Notes: # texture based on laboratory measurements *Raupach field measurement

5 DISCUSSION OF SOIL ANALYSES

5.1 Physical Attributes

The laboratory analysis results contained in **Table 2** are important in assessing the erodibility of the soil units found within the Project Site.

The three tests [Particle Size Analysis, Dispersion %, Emerson Aggregate Test] carried out on samples from each of the horizons within the two selected soil profiles, when considered together, provide a good indication of the soil's likely behaviour in relation to the erosive forces encountered in the field.

5.1.1 Particle Size Analysis

The Particle Size Analysis [PSA] test shows the amounts of gravel, clay, silt, fine sand and coarse sand contained within each sample.

The results shown in **Table 2** are those contained in the laboratory test report.

From this data it is evident that most soil horizons analysed contain variable, but usually small, levels of gravel. With the amount generally associated with distinct separate horizons. Only one horizon [Pit 4, horizon 4] contained significant gravel content.

The texture class of each soil layer is determined by analysis of the material [fine earth fraction] that is less than 2mm in size – i.e. the sample from each tested horizon with the gravel removed. The calculated texture of the fine earth fraction of each of the layers tested in the laboratory is shown in **Table 2**.

It should be noted that the field textures of almost all layers of the four profiles that were examined indicated results that the soils were generally more clayey than was shown in the laboratory analyses.

5.1.2 Dispersion Percentage

The Dispersion Percentage [D%] test indicates the proportion of the soil material less than 0.005 mm in size that will disperse on wetting [i.e. the clay and some of the silt fraction].

Hazelton and Murphy [in press] provide the following guides to the interpretation of D% values [**Table 4**]

Table 4
Interpretation of Dispersion Percentage Values
[after Hazelton and Murphy, in press]

D% Value	Dispersion Rating
< 6	Negligible
6 – 30	Slight
30 – 50	Moderate
50 – 65	High
> 65	Very High

In interpreting the results of the values of dispersion percentage obtained in laboratory testing it is important to consider other related soil attributes such as the Particle Size Analysis [PSA] and Emerson Aggregate Test [EAT] data.

Soil horizons with high clay contents and high Dispersion % values will be more dispersive in practice than those with a high Dispersion % value and a low clay content.

The D% values shown in **Table 2** indicate that:

- the topsoil of **SMU 1** showed **slight** dispersibility;
- the subsoil of **SMU 1** showed **high to very high** dispersibility;
- the topsoil of **SMU 2** showed **slight** dispersibility; and
- the subsoil of **SMU 2** showed **slight to very high** dispersibility.

The subsoils generally contain moderate levels of clay and this fact may make them more dispersive than the analyses indicate.

Given these indications of dispersibility, the erosion potential is undoubtedly high for any areas of exposed subsoil.

Consequently, appropriate measures need to be taken to protect the stockpiles of stripped subsoil during construction and prior to rehabilitation. In fact, given the likely project life, the stockpiles should be rapidly stabilised with a living permanent pasture cover to prevent erosion and dispersion of the eroded sediment.

5.1.3 Emerson Aggregate Test

This test provides a measure of the coherence of soil aggregates when they are immersed in water. Natural peds are used [Houghton and Charman, 1986] and the method used by the Department of Land and Water Conservation to determine the Emerson Class Number is fully described in Craze et al [1993].

Basically, the degree of soil aggregate stability increases from Class 1 through to Class 8. Classes 2 and 3 have a number of subclasses based on the degree of dispersion.

Aggregates in Emerson Classes 1 and 2 are generally regarded as being unstable while those in classes 4 to 8 are considered to be stable.

Hazelton and Murphy [in press] present a summary of the Emerson Aggregate Classes which is reproduced as **Table 5.**

Table 5
Comparison of Aggregate Dispersibility and Emerson Aggregate Classes [after Hazelton and Murphy, in press]

Aggregate Dispersibility	Emerson Aggregate Classes*
Very High	1 and 2[3]
High	2[2]
High to Moderate	2[1]
Moderate	3[4] and 3[3]
Slight	3[2], 3[1] and 5
Negligible / Aggregated	4,6,7,and 8

* **NOTE** – the subclasses of the Emerson Aggregate Test [EAT] Classes are as follows:

[1] slight milkiness immediately adjacent to the aggregate
[2] obvious milkiness, less than 50% of the aggregate affected
[3] obvious milkiness, more than 50% of the aggregate affected
[4] total dispersion, leaving only sand grains [NB – Class 2[4] is equivalent to Class 1]

The EAT data in **Table 2** indicates show that:

- the topsoil of **SMU 1** showed **slight** dispersibility;
- the subsoil of **SMU 1** showed **very high** dispersibility;
- the topsoil of **SMU 2** showed **slight** dispersibility; and
- the subsoil of **SMU 2** showed **slight to very high** dispersibility;

The topsoils of both SMUs show only slight dispersibility as indicated by the EAT but the subsoils in both units are generally highly dispersible. The results of the EAT test parallel those of the D% test.

Consequently, it is essential that any exposed subsoil and subsoil stockpiles are adequately protected from soil erosion at all times.

5.2 Soil Chemical Attributes

Chemical laboratory testing of the samples extended only to an examination of the electrical conductivity. Soil pH was measured in the field using the Raupach method. The results of the laboratory analyses and the field pH measurements are contained in **Table 3.**

5.2.1 Soil pH

In general, the pH [water] range in most soils is between 4.0 and 8.5 although pH values above and below this range are measured at times [Glendinning, 1990].

This range of soil pH levels is generally accepted as being one that is suitable for plant growth.

The pH 6.0 to 6.5 range is usually regarded as the optimum for growth of most plants and there are some more serious impacts on the growth of many species at the lower, or acid, end of the range.

As the pH scale [between 0 and 14] is logarithmic, a soil with a pH of 5.0 is ten times as acid as a soil of pH 6.0 and 100 times as acid as one with a pH of 7.0.

Perusal of the data in the pH column in **Table 3** indicates that all of the topsoils and subsoils tested showed pH levels within the 4.0 to 8.5 range. This was also the case in the other profiles that were not laboratory tested.

Therefore there should not be any problems associated with soil pH in rehabilitation of this site.

5.2.2 Electrical Conductivity

Soil salinity is a measure of the presence of water-soluble salts, mainly of sodium, calcium and magnesium in the soil solution. These salts may be chlorides, sulphates or carbonates and can have a major impact on plant growth if they occur in sufficiently large quantities.

The level of salinity in a soil sample is determined by measuring the electrical conductivity [EC] of a 1:5 soil / water suspension.

As the published salinity tolerance data for crops and pastures is based on the electrical conductivity of a saturated extract of the soil solution, a series of conversion factors, based on the estimated water holding capacity of soil sample, are used to convert the measured EC value to one for the conductivity of the saturated extract [EC_e].

The electrical conductivity of the 1:5 soil / water suspension and that of the saturated extract are measured in units called deciSiemens / metre [dS/m].

The measured level of electrical conductivity of the 1:5 soil / water suspension is multiplied by the appropriate factor in **Table 6** [extracted from Hazelton and Murphy, in press] based on the measured soil texture.

Table 6
Texture Class Multipliers for Calculating EC_e Values

Soil Texture Class	Multiplier Factor
loamy sand, clayey sand, sand	23
sandy loam, fine sandy loam, light sandy clay loam	14
loam, loam fine sandy, silt loam, sandy clay loam	9.5
clay loam, silty clay loam, fine sandy clay loam, sandy clay, silty clay, light clay	8.6
light medium clay	7.5
medium clay	5.8
Heavy clay	5.8

Table 7 shows the calculated EC_e values for the samples analysed in the laboratory and shows the salinity status of the various horizons based on these EC_e values.

Hazelton and Murphy [in press] note that EC_e values below 2.0 indicate non-saline horizons while values between 2 and 4 indicate slight salinity. Values between 4 and 8 indicate moderate salinity while those between 8 and 16 indicate high salinity.

Table 7
Calculated EC_e Values and Salinity Status for Selected Soil Profiles

SMU / PIT NO.	LAYER	TEXTURE [fine earth]#	DEPTH [cm]	EC [dS/m]#	MULTI-PLIER	CALCU LATED EC_e	SOIL SALINITY STATUS
SMU 1 PIT 2	**1**	**clay loam**	**0-24cm**	0.03	8.6	0.26	non-saline
	2	**clay**	**24-68cm**	0.34	7.5	2.6	slightly saline
	3	**clay / silty clay**	**68-154cm**	0.91	8.6	7.8	moderately saline
	4	**clay**	**154-270cm**	1.02	7.5	7.7	moderately saline
SMU 2 PIT 4	**1**	**loam**	**0-12cm**	0.03	9.5	0.29	non-saline
	2	**loamy sand**	**12-34cm**	<0.01	23	<0.23	non-saline
	3	**clay loam**	**34-100cm**	0.04	8.6	0.3	non-saline
	4	**clay loam**	**100-222cm**	0.28	8.6	2.4	slightly saline
	5	**silty clay**	**222-250cm**	0.65	8.6	5.6	moderately saline

The data in **Table 7** indicates that the topsoils of both SMUs are non-saline. However, the subsoils of both SMUs are slightly to moderately saline.

As a consequence, care should be taken to ensure that subsoil stockpiles are minimised in extent at all times and that they are protected by a cover of plant material if such can be established successfully.

Advice should be obtained from the local office of the NSW Department of Primary Industries [Agriculture] with regard to the latest pasture species recommended for saline soils.

If a suitable cover of living vegetation cannot be established then a hay / bitumen cover or a similar protective barrier should be used to prevent erosion of the subsoil stockpiles.

5.2.3 Likelihood of Encountering Acid Sulfate Soils

Acid sulfate soils are basically confined to coastal estuarine floodplain areas in New South Wales.

These soils are extremely acidic soil layers that develop as a consequence of the aeration of soil materials that are rich in iron sulfides, primarily pyrite [FeS].

When drainage or excavation brings these previously waterlogged soil layers into contact with oxygen, the pyrite is oxidised to form sulfuric acid.

If the production of acid exceeds the neutralising capacity of the particular soil such that the pH falls below 4.0, these soils are known as acid sulfate soils.

The soils at the Project Site commonly increase in alkalinity with depth [often to pH 9.5 - 10] and are not waterlogged. There are some profiles that follow this trend down the profile and then revert to an acid pH at the lowest depth sampled.

The soils within the Project Site have pH values within the range suitable for plant growth. As a consequence of this feature and the fact that the Project Site is not located on a coastal estuarine floodplain it is extremely unlikely that any acid sulfate soils will impact in any way on the Project Site during its working life or on the success of subsequent rehabilitation.

5.3 Erosion Potential

The soils within the Project Site are generally unaffected by soil erosion although removal of vegetation cover would result in these currently stable soils being predisposed to erosion.

To minimise any such problems, the access tracks through the Project Site should be limited in number and properly drained and protected where necessary with appropriate soil conservation works.

5.4 SOILOSS Program

An appropriate method of assessing the erosion hazard associated with the soils of the Project Site is to use the SOILOSS computer program devised by Rosewell and Edwards [1988] and updated by Rosewell [1993].

This program computes soil loss values for a given site under various land uses and climatic [rainfall] conditions and so provides an indication of erosion hazard.

SOILOSS is based on the Universal Soil Loss Equation or USLE described by Wischmeier and Smith [1978] and subsequently updated as the Revised Universal Soil Loss Equation or RSLE [Renard et al, 1993].

The USLE is

$$A = R * K * L * S * P * C$$ where;

A is the average annual soil loss [tonnes / hectare]
R is the rainfall erosivity factor, a measure of the erosive power of the rain
K is the soil erodibility factor, a measure of the resistance of the soil to erosion
L is the slope length factor
S is the slope steepness factor
P is the support practice factor, a measure of the effect on erosion of soil conservation measures such as contour cultivation and bank systems
C is the crop and cover management factor

In using SOILOSS, the rainfall erosivity factor is obtained from maps provided with the program manual [Rosewell, 1993].

Soil erodibility is either estimated from details of the soil type and soil surface texture by comparison with a table of soils presented by the program or is derived from a knowledge of soil particle size analysis, organic matter content, surface soil structure and profile permeability.

Slope length and steepness factors are derived from field measurements and / or examination of topographic maps or airphotos.

The support practice factor is estimated by the program from a description of the land management practices in use, details of cultivation direction and information on bank systems if these are present.

To determine the value of the ‘K’ factor for use in the program, a generic or standard method can be utilised from within the program to indicate the likely soil losses from a range of crop rotations and management practices.

In addition, a more detailed approach can be used to determine likely soil loss given the availability of precise detail relating to sowing dates, cultivation practices etc.

Provision is made within the program for estimating soil loss from areas with a range of non-arable uses.

Table 8 provides details of the calculated erodibility values [K] and erodibility ratings for topsoils and subsoils from the two soil profiles in the Project Site that were tested in the laboratory.

The erodibility estimates contained in **Table 8** for all of the SMUs recorded from the Project Site have been calculated using part of the overall SOILOSS program capability and the Particle Size Analysis and other data for the two typical soil profiles from the Project Site that were subjected to laboratory testing.

The only value for which estimates were used in the calculations were those for organic matter %. Generalised organic matter values for soils in the vicinity of the Project Site were obtained from Bannerman and Hazelton [1990]. Organic matter values of 2.0% for the topsoils in both SMUs and 0.4% was used for the subsoil of SMU 1 and 0.8% was used for the subsoil of SMU2 following an examination of data in their report.

The Erodibility classes used were < 0.020 = LOW; 0.020 – 0.040 = MODERATE; > 0.040 = HIGH.

Table 8
Soil Erodibility Values and Ratings for a Selection of Soils

PIT NUMBER	TOPSOIL LAYER [cm]	TOPSOIL 'K' RATING	SUBSOIL LAYER [cm]	SUBSOIL 'K' RATING	AVERAGE 'K' RATING [WHOLE SOIL]	SOIL MAPPING UNIT ERODIBILITY
PIT 2 SMU 1	**0-24**	0.031	**24-68**	0.019	0.025	MODERATE
PIT 4 SMU 2	**0-12**	0.052	**34-100**	0.037	0.045	HIGH

The soils [topsoil and subsoil combined] from SMU1 were allotted a MODERATE erodibility by the SOILOSS model based on their physical characteristics while the soils from SMU2 had a combined rating of HIGH.

These erodibility ratings are of concern if large stockpiles of soil are to be constructed and left for a long period of time.

Consequently, the soils of both SMUs should be managed carefully during the stripping and rehabilitation stages to ensure that soil structure damage is minimal and that they are suitably protected by vegetation or some other medium in the stockpiles and after rehabilitation.

The elevated erodibility ratings are exacerbated for the subsoils of both SMUs when the salinity levels of these subsoils are considered in terms of their possible negative impact on the establishment of protective living vegetative cover.

These two factors make it imperative that stockpiles and rehabilitated areas are at all times properly protected against soil erosion.

6 DESIGN AND OPERATIONAL SAFEGUARDS

6.1 Stripping Suitability of Soil Materials

An approach has been developed by Elliott and Veness [1981] to determine the stripping suitability of soil materials found at a site where stripping of upper soil layers is required. The key used in this method of stripping suitability assessment is contained in **Appendix 2**.

This method has been used in the present study.

The basis for the Elliott and Veness approach is that not all soil material that might be available for topdressing of disturbed sites is suitable for agricultural or pastoral use: some may be poorly structured, too sandy or gravelly or too poorly drained to allow a stabilising vegetative cover to develop.

In their work, Elliott and Veness established that there are a number of critical soil physical attributes that can be used to distinguish between suitable and unsuitable topdressing materials. These are:

[a] soil structure
[b] soil macrostructure
[c] soil coherence
[d] soil texture
[e] the force necessary to disrupt peds

6.2 Stripping Recommendations for Soil Mapping

6.2.4 Layer 1 - Topsoil [0-25cm]

loam fine sandy, clay loam, medium clay, light to medium clay; usually many roots; no lime present; no manganese present; pH 5.5; to 6.5 [one reading 8.0 probably due to spillage of lime or similar material]; gravel and stones absent or some to much angular gravel present; not mottled; not bleached; brown [10YR5/3, 7.5YR5/3], dark yellowish brown [10YR4/4], yellowish brown [10YR5/4] dry; dark brown [7.5YR3/2], very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15 mm in size; usually very strong consistence [sometimes firm] dry; usually hydrophobic.

Suitability Assessment: structure grade 3; coherent dry, mottles absent; macrostructure suitable; force to disrupt peds suitable; texture suitable; layer contains low amounts of gravel; pH levels suitable; salt content suitable.

This material is suitable for topsoiling on the basis of the Elliott and Veness key. It contains valuable organic matter and nutrient reserves and so should be used in rehabilitation. The material should be stripped and stockpiled as topsoil provided suitable stripping and storage methods are used [see **Section 7**].

Recommendation – Strip all of the Layer 1 topsoil to a depth of 25cm from the current surface. This topsoil material can be stored in the same stockpiles as the topsoil material from SMU 2 if there is a need to disturb any areas of SMU 2.

[NOTE: Topsoil stripping should be carried out on all areas that will be disturbed by quarrying and associated infrastructure development. It should not be necessary to further strip subsoil in areas that are only to be used for roads, buildings, hardstand areas etc. However, on areas where the disturbance is deeper, the subsoil should be stripped as indicated for Layers 2 and 3 below.]

6.2.5 Layer 2 - Subsoil [25 – 100cm depth]

fine sandy loam, light to medium clay; medium to heavy clay, heavy clay; few to many roots; no lime present; occasionally much manganese staining present; pH 4.5 to 6.0; gravel and stones usually absent; sometimes much angular gravel to 5cm is present; not bleached; **whole coloured** light yellowish brown [10YR6/4], very dark grey [10YR3/1], very pale brown [10YR8/2] with some red [2.5YR4/8] blotches dry, dark yellowish brown [10YR3/2], light brownish grey [2.5Y6/2], very dark greyish brown [10YR3/2] moist; **OR mottled in colours** of light brownish grey [10YR6/2], red [10R4/6], red [10R4/6, 2.5YR4/8], weak red [10R4/4], white [2.5Y8/1], yellowish brown [10YR5/8] dry; grey [7.5YR5/1], light yellowish brown [2.5Y6/3], pale brown [10YR6/3], red [10R4/6, 10R4/8], yellowish brown [10YR5/6] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral or polyhedral /platy, <5-20 mm in size; very strong consistence dry; not hydrophobic or slightly hydrophobic.

***Suitability Assessment*:** structure grade 3; coherent dry, mottles often present - especially at depth; macrostructure suitable; force to disrupt peds generally suitable; texture suitable; layer sometimes contains gravel; pH levels suitable; salt content is a possible problem.

This material is marginally suitable for use as subsoil on the basis of the Elliott and Veness key. It has limitations resulting from the presence of mottles and elevated salinity levels. Mixing of soil materials from closer to the surface with those from depth may reduce the overall salinity levels in this material. With regard to the presence of mottling – the material is not ideal but should nevertheless be used as it is the only subsoil material available.

It should be stripped and stockpiled as subsoil provided suitable stripping and storage methods are used and adequate protection from erosion is provided. This issue is discussed in **Section 7**.

Recommendation – Strip all of the Layer 2 subsoil to a depth of 75cm below the base of Layer 1 - ie. a total depth from the surface of 100cm. This subsoil material can be stored in the same stockpiles as the subsoil material from SMU 2 if there is a need to disturb any areas of SMU 2.

6.2.6 Layer 3 – [Remainder of Profile]

The material below 100cm depth [the base of Layer 2] can be used as clay for commercial purposes.

6.3 Stripping Recommendations for Soil Mapping Unit 2 [SMU 2]

NOTE: It is recommended that this SMU not be disturbed in any way because of its association with the floodplain of Blaxland Creek. However, the following stripping recommendations are provided for the sake of completeness.

6.3.1 Layer 1 - Topsoil [0-25cm]

silty clay loam, silty clay to light clay; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; light yellowish brown [!0YR6/4], pale brown [10YR6/3] dry; dark yellowish brown [10YR4/4], very dark greyish brown [10YR3/2] moist; peds rough-faced or rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15 mm in size; strong to very strong consistence dry; not hydrophobic.

Suitability Assessment: structure grade 3; coherent dry, mottles absent; macrostructure suitable; force to disrupt peds suitable; texture suitable; layer contains low amounts of gravel [if any]; pH levels suitable; salt content suitable.

This material is suitable for topsoiling on the basis of the Elliott and Veness key. It contains organic matter and nutrient reserves and so should be used in rehabilitation. The material should be stripped and stockpiled as topsoil provided suitable stripping and storage methods are used [see **Section 7**].

> **Recommendation** – Strip all of the Layer 1 topsoil to a depth of 25cm from the current surface. This topsoil material can be stored in the same stockpiles as the topsoil material from SMU 1

[NOTE: Topsoil stripping should be carried out on all areas on which it is currently available and which are proposed for disturbance in any way. On areas where the disturbance is deeper - the subsoil should be stripped as indicated for Layers 2 and 3 below.]

6.3.2 Layer 2 - Subsoil [25-100cm]

silty clay loam, light to medium clay; few to many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; light yellowish brown [!0YR6/4] dry, dark yellowish brown [10YR4/4] moist; peds rough- faced, highly pedal [100%], polyhedral, 5-15 mm in size; very firm to strong consistence dry; not hydrophobic

Suitability Assessment: usually structure grade 3; coherent dry, mottles absent; macrostructure suitable; force to disrupt peds generally suitable; texture suitable; gravel and stones absent; pH levels suitable; salt content is a possible problem.

This material is marginally suitable for use as subsoil on the basis of the Elliott and Veness key. It has limitations resulting from the presence of elevated salinity levels. Mixing of soil materials from closer to the surface with those from depth may reduce the overall salinity levels in this material.

It should be stripped and stockpiled as subsoil provided suitable stripping and storage methods are used and adequate protection from erosion is provided.

Recommendation – Strip [IF NECESSARY] all of the Layer 2 subsoil to a depth of 75cm below the base of Layer 1 - ie. a total depth from the surface of 100cm. This subsoil material can be stored in the same stockpiles as the subsoil material from SMU 1.

6.3.3 Layer 3 [Remainder of the Profile]

The material below 100cm depth [the base of layer 2] can be used as clay for commercial purposes.

7 HANDLING STRIPPED SOILS

Stripping of topsoil materials is proposed for those sections of the Project Site that have not been disturbed by quarrying operations in the past.

In addition, subsoil material will need to be stripped from these areas for later use in rehabilitation.

Because much of the site has already been disturbed there is likely to be a major shortfall in the amount of topsoil that is available on site for rehabilitation.

As a consequence there will be a need to capture and store topsoil delivered from other, sites preferably on the Cumberland Plain, for disposal at the proposed facility. This material should be handled in the same way as topsoil stripped from the site.

It is appropriate to consider, in this report, the techniques for handling the soil materials that are to be stripped, stockpiled and then respread during the rehabilitation phase.

These recommendations are based on an interpretation of the results of soil survey at the Project Site and the associated laboratory analysis data.

As a general rule in soil stripping, stockpiling etc, the weaker [more sandy] the *in situ* structure of the soil being removed, the more care that is required in all phases of handling.

The soil needs to be handled [disturbed] as little as possible to minimise mechanical damage to soil structure that will be detrimental to rapid establishment of ground cover once rehabilitation works commence.

There have been a number of studies in the past relating to the impact of the stripping and stockpiling of soils associated with mining and similar activities.

Working of soils in situations where the soil moisture content is too high can have detrimental impacts on soil structure [Elliott and Veness, 1985; Hunter and Currie, 1956]. There are also unfavourable effects related to mixing of soil materials with different fertility levels, textures and other critical soil properties.

Stockpiling also has its effects although there is evidence that the impacts are, at least to some degree, reversible. Jenkin et al [1987] have noted that these effects seem similar to those of normal agricultural uses on soils.

Dougall [1950] has noted that stockpiling of soil results in some structure breakdown and changes associated with some other physical and chemical properties.

However, despite these negative impacts, Elliott and Veness [1985] conclude that the quality of stockpiled soil can, in fact, improve with time – especially in the outer layers of material.

7.1 Earth Moving Procedures

As mentioned previously, the topsoils and subsoils to be moved within the Project Site generally have a relatively fine structure and so are somewhat resistant to structural damage. In general, the topsoil structure is slightly weaker than that of the subsoils - particularly in the moist state.

As a consequence, improper or excessive handling of the material during the stripping and stockpiling operation has the potential to destroy the soil structure by mechanically breaking down the soil aggregates that are present.

Notwithstanding the comments above, the structure grades of both topsoils and subsoils would allow the stripping operation to be carried out using machines such as open-bowl scrapers and bulldozers. However, the scrapers should place their loads neatly to form a uniform stockpile that requires little further forming prior to establishment of a vegetation cover.

Even so, care should be taken also to ensure that topsoils are not stripped when they are too moist as greater damage will occur at this time.

Similar precautions should be taken with the subsoils.

Driving of machinery on the topsoil and subsoil stockpiles, other than the scrapers during unloading, should be kept to an absolute minimum to maximise soil aggregation and prevent compaction.

Ideally the topsoil stockpiles should be no more than 1 metre high but, if necessary, higher dumps can be used. These should not exceed about 2 metres in height.

The subsoil stockpiles should not exceed 3 metres in height.

7.2 Soil Conservation Measures

Stockpiles should preferably be positioned where runoff water from upslope is minimised, with the best stockpile sites being on a level ridgetop of which such sites exist within the Project Site.

In addition, measures should be taken to minimise loss of soil material from the stockpiles, especially in the period before they are stabilised, eg using geotextile “fences” or lines of hay or straw bales etc.

The stockpile surfaces should be left with a "rough'" but even surface to assist in runoff control and seed retention and germination and be sown with stabilising perennial pasture species as soon as possible after placement. Where stockpile construction is conducted in stages, the stockpiles should be progressively stabilised.

It will be important to stabilise the stockpiles quickly using a suitable pasture cover as recommended by the local staff of the Department of Primary Industries [Agriculture].
As has been previously noted in **Section 5**, the topsoils and subsoils that would require stockpiling are relatively erodible and the subsoils have a level of salinity that may make establishment of a long term living plant cover difficult.

If establishment of a suitable plant cover on the subsoil stockpiles proves to be difficult then alternative stabilising techniques such as application of hay / bitumen mulches etc may have to be used.

8 IMPACT ASSESSMENT

Adherence to the recommended soil stripping, windrowing, handling and storage procedures would result in a minimal impact from a soils and land capability viewpoint on the lands of the Project Site.

9 LAND CAPABILITY AND AGRICULTURAL LAND SUITABILITY

9.1 Land Capability

9.1.1 Overview of the Methodology

Houghton and Charman [1986] in their "Glossary of Terms Used in Soil Conservation" define land capability as follows.

> "The ability of land to accept a type and intensity of use permanently, or for specified periods under specific management, without permanent damage."

They further note that land capability is "…an expression of the effect of biophysical land resources, including climate, on the ability of land to sustain use without damage under various uses such as crop production requiring regular tillage, grazing, woodland or wildlife. Land capability involves consideration of:

- the various land resources;
- the production to be obtained from the land;
- the activities or inputs required to achieve that production;
- the risks of damage to the land, on-site or off-site, resulting from those activities; and
- the inter-relations of the above."

Houghton and Charman note that land capability is taken into account in determining land suitability – another form of land classification relating to use for various purposes.

Land that is used beyond its capability ultimately loses its productive capacity as a consequence of exhaustion of soil nutrient supplies or the development of various forms of land degradation.

The land capability classification system used in New South Wales has been described by Emery [undated] and is a modification of the system devised and used by the former USDA Soil Conservation Service in the United States of America.

Emery's paper [in its Table 1] contains details of the Land Capability legend used on land capability maps prepared by the former Soil Conservation Service of New South Wales [now part of DECC].

This shows the hierarchical classification used in the eight class system based on the management and protection needs of different types of land ranging from land needing no special soil conservation works or practices [Class I] through to land that is unsuitable for agricultural or pastoral production [Class VIII].

Emery's table also shows two other land capability classes – Mining and Urban land use – and also deals with class subscripts used to further subdivide some capability classes. The information presented by Emery is contained in **Appendix 3**.

9.1.2 Land Capability for the Project Site

The 1: 100 000 scale Land Capability mapping program data of the former Soil Conservation Service of NSW that is held by the Department of Environment and Climate Change, Parramatta, shows the Project Site lies mainly within and area mapped as having a **Class III** land capability with the land along Blaxland Creek mapped as **Class VI** land. The map does not differentiate between the quarried sites and stockpile areas and the surrounding agricultural land.

Class III *land is land suitable for regular cultivation on a rotational basis with the land protected by structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage.*

Class VI *land is land suitable for grazing with no cultivation. Soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin and possibly some isolated structural works are required.*

9.1.3 Post-Use Assessment

Following cessation of the activities proposed for this site, rehabilitation should aim to replace a soil profile 100cm deep on the fill material. The recommendations for soils stripping [Section 6] address this issue.

Prior to rehabilitation it is proposed to reshape the site to provide gentle slopes over the disturbed area.

The final landform should be sown to perennial pasture species – ideally a grass / legume mix and kept productive by regular applications of appropriate fertilisers.

If the rehabilitation and soil stripping recommendations outlined in this report are adhered to and additional material is obtained through the proposed recycling activities, the disturbed lands should be able to return to **Class III** land capability status.

As previously discussed, the lands along Blaxland Creek should not be disturbed and if this recommendation is accepted, the land capability of that land would not change.

9.2 Agricultural Land Suitability Classification

9.2.1 NSW Agriculture Pre-Quarrying Assessment

NSW Department of Primary Industries [Agriculture] has prepared a series of maps showing the Agricultural Land Suitability Classification of the land in the Sydney Basin [NSW Agriculture, 1995].

Map **Penrith 9030 -3 – N** in this series shows the land surrounding the Project Site as **Class 3** land. The map does not differentiate between the quarried sites and stockpile areas and the surrounding agricultural land. Similarly the map does not separate the land suitability of the area associated with Blaxland Creek from that of the areas away from the creek.

Class 3 land is '*grazing land that is well suited to pasture improvement. It may be cultivated or cropped in rotation with pasture. The overall level of production is moderate as a result of edaphic [soil related] or environmental constraints. Erosion hazard or soil structural breakdown limit the frequency of ground disturbance, and conservation or drainage works may be required*.'

9.2.2 Post-Use Land Suitability Assessment

If the recommended depth of soil is replaced over the whole of the disturbed area, the post-use agricultural land suitability classification should remain **Class 3** with the proviso that any future occasional cultivation should be limited to work required to establish or renovate perennial pastures rather than crop production.

10 CONCLUSION

Soils in the Project Site have been described and two Soil Mapping Units [SMUs] have been identified.

These SMUs are

- Soil Mapping Unit 1 – Soils Upper Slopes and Crest; and
- Soil Mapping Unit 2 – Soils of the Blaxland Creek Floodplain

SMU 2 is associated with the floodplain of Blaxland Creek and it is recommended that the area occupied by this soil mapping unit not be disturbed any further than it currently is.

The physical and chemical attributes of the soils of the Project Site have been quantified through a combination of field assessment and laboratory testing and indicate the following

- Much of the area has been subjected to intensive quarrying and associated activity including stockpiling of soil and building waste;
- A limited proportion of the Project Site retains its original soil profile integrity.
- Because of this limited availability of in-situ soil material for rehabilitation of the final landform, it will be necessary for the proponent to accumulate suitable topsoil and subsoil resources from materials brought to the site from development sites in the Cumberland Plain and elsewhere.
- The undisturbed soils within the Project Site are generally currently stable but the unprotected stockpiles of subsoil material showed evidence of erosion. It is noted that any sediment from erosion and water continuing dissolved and suspended material is collected on site and not discharging.
- SMU 1 which covers the majority of the site has a MODERATE erodibility rating as determined using the laboratory data obtained from samples from the Project Site in the SOILOSS computer model.
- SMU 2 has a HIGH erodibility rating as determined by the SOILOSS model. Because of the location of this SMU on the floodplain of Blaxland Creek it is recommended that this SMU not be further disturbed.
- The topsoil of **SMU 1** showed **slight to moderate** dispersibility;
- The subsoil of **SMU 1** showed **high to very high** dispersibility;
- The topsoils of **SMU 2** showed **slight to moderate** dispersibility;
- The subsoils of **SMU 2** showed **high to very high** dispersibility.
- As a consequence there is a need to rapidly stabilise all topsoil and subsoil stockpiles with as soon as possible after stockpile construction.
- The subsoils of both SMUs showed elevated salinity levels that may cause problems for establishing a perennial pasture cover on the subsoil stockpiles. It is suggested that if perennial pasture cover establishment is poor then alternative protective barriers be used to prevent erosion of these stockpiles.
- The soil materials sampled generally had pH values within the acceptable range for plant growth.
- All soils will be subject to structural degradation if worked when too moist.
- Detailed soil management recommendations have been provided;
- The pre-disturbance Land Capability [**Classes III and VI**] and Agricultural Land Suitability [**Class 3**] of the Project Site have been determined.
- The post-use Land Capability [**Classes III and VI**] and Agricultural Land Suitability [**Class 3**] of the Project Site have been determined.

11 ADDRESSING DIRECTOR-GENERAL'S REQUIREMENTS

A number of issues relating to soils and land capability have been raised in the Director-General's Requirements.

Table 9 lists the issues and indicates the section of this report where each issue is addressed.

Table 9
Director-General's Requirements

ORGANISATION	ISSUE	SECTION WHERE ADDRESSED
Department of Planning letter dated 20.5.09	Description of the existing [soils] environment	**Sections 2-5, 9**
	Details of proposed erosion and sediment controls [during construction]	**Section 7**
Department of Environment and Climate Change letter of dated 15.4.09	Description of soils and erosion; minimising erosion	**Sections 4, 5, 6, 7, Appendix 1**
	Soil management at the site	**Sections 5, 6, 7**

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Appendix 1 Detailed Soil Profile Descriptions

(No. of pages excluding this page = 3)

Profile 1[SMU 1] - *midslope location; surface condition firm to hard; surface stone absent*

0-8cm - clay loam; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; brown [7.5YR5/3] dry, dark brown [7.5YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; firm consistence dry; hydrophobic; *abrupt to:-*

8-25cm - medium clay; roots common; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; brown [7.5YR5/3] dry, dark brown [7.5YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15 mm in size; very strong consistence dry; hydrophobic; *clear to:-*

25-59cm - heavy clay; few roots; no lime present; no manganese present; pH 5.0; gravel and stones absent; mottled; not bleached; 80% red [10R4/6], 20% red [2.5YR4/8] dry, 80% red [2.5YR4/8], 20% grey [7.5YR5/1] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-20 mm in size; very strong consistence dry; slightly hydrophobic; *gradual to:-*

59-170cm - heavy clay; few roots; no lime present; no manganese present; pH 4.5; decomposing rock common; not mottled; not bleached; very pale brown [10YR8/2] with some red [2.5YR4/8] blotches dry, light brownish grey [2.5Y6/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

170-210cm - heavy clay; few roots; no lime present; no manganese present; pH 4.5; gravel and stones absent; not mottled; not bleached; light grey [2.5Y7/1] dry, light grey [2.5Y7/1] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; very strong consistence dry; not hydrophobic.

Profile 2 [SMU 1] - *ridge crest location; surface condition firm and cracked; surface stone absent*

0-24cm - light to medium clay; many roots; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; dark yellowish brown [10YR4/4] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15 mm in size; very strong consistence dry; hydrophobic; *abrupt to:-*

24-68cm - medium to heavy clay; many roots; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; very dark grey [10YR3/1] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; slightly hydrophobic; *clear to:-*

68-154cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 4.5; gravel and stones absent; mottled; not bleached; 80% light brownish grey [10YR6/2], 20% weak red [10R4/4] dry, 80% pale brown [10YR6/3], 20% red [10R4/8] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

154-270cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 4.5; some reddish broken rock inclusions; not mottled; not bleached; light greenish grey [gley1 8N] dry, light greenish grey [gley1 7/10Y] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; not hydrophobic.

Profile 3 [SMU 1] - *low ridge crest location; surface condition loose to firm; surface stone absent*

0-14cm - clay loam; many roots; no lime present; no manganese present; pH 8.0; some small gravel to 5mm, occasional angular gravel to 3cm; not mottled; not bleached; brown [10YR5/3] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

14-27cm - loam fine sandy; many roots; no lime present; no manganese present; pH 6.5; much angular gravel to 5cm; not mottled; not bleached; yellowish brown [10YR5/4] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; slightly hydrophobic; *abrupt to:-*

27-43cm - fine sandy loam; many roots; no lime present; no manganese present; pH 6.0; much angular gravel to 5cm; not mottled; not bleached; light yellowish brown [10YR6/4] dry, dark yellowish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

43-71cm - light to medium clay; few roots; no lime present; much manganese staining present; pH 5.0; gravel and stones absent; mottled; not bleached; 95% yellowish brown [10YR5/8], 5% weak red [10R4/4] dry, 95% yellowish brown [10YR5/6], 5% red [10R4/6] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral / platy, 5-10 mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

71-122cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 5.0; gravel and stones absent; mottled; not bleached; 95% white [2.5Y8/1], 5% red [10R4/6] dry, 95% light yellowish brown [2.5Y6/3 , 5% red [!0R4/6]] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

122-205cm - medium to heavy clay; roots absent; no lime present; no manganese present; pH 4.5; ironstone layer; not mottled; not bleached; strong brown [7.5YR5/6] dry, dark yellowish brown [10YR4/6]] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

205-250cm - light to medium clay; roots absent; no lime present; no manganese present; pH 4.5; gravel and stones absent; mottled; not bleached; 95% grey [2.5Y6/1], 5% red [10R4/6] dry, 95% grey [2.5Y6/1], 5% red [10R4/6] moist, peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15 mm in size; very strong consistence dry; not hydrophobic.

Profile 4 [SMU 2] - *lower slope location; surface condition firm; surface stone absent*

0-12cm - silty clay to light clay; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; pale brown [10YR6/3] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; strong consistence dry; not hydrophobic; *abrupt to:-*

12-34cm - silty clay loam; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; light yellowish brown [!0YR6/4] dry, dark yellowish brown [10YR4/4] moist; peds rough- faced, highly pedal [100%], polyhedral, 5-15 mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

34-100cm - light to medium clay; few roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; light yellowish brown [!0YR6/4] dry, dark yellowish brown [10YR4/4] moist; peds rough- faced, highly pedal [100%], polyhedral, 5-15 mm in size; very firm consistence dry; not hydrophobic; *abrupt to:-*

100-220cm - gritty medium clay; few roots; no lime present; much manganese stains and nodules present; pH 7.0; gravel and stones absent; mottled; not bleached; 95% yellowish brown [10YR5/8], 5% brown [10YR5/3] dry, 95% dark yellowish brown [10YR4/6], 5% brown [10YR5/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10 mm in size; strong consistence dry; not hydrophobic; *abrupt to:-*

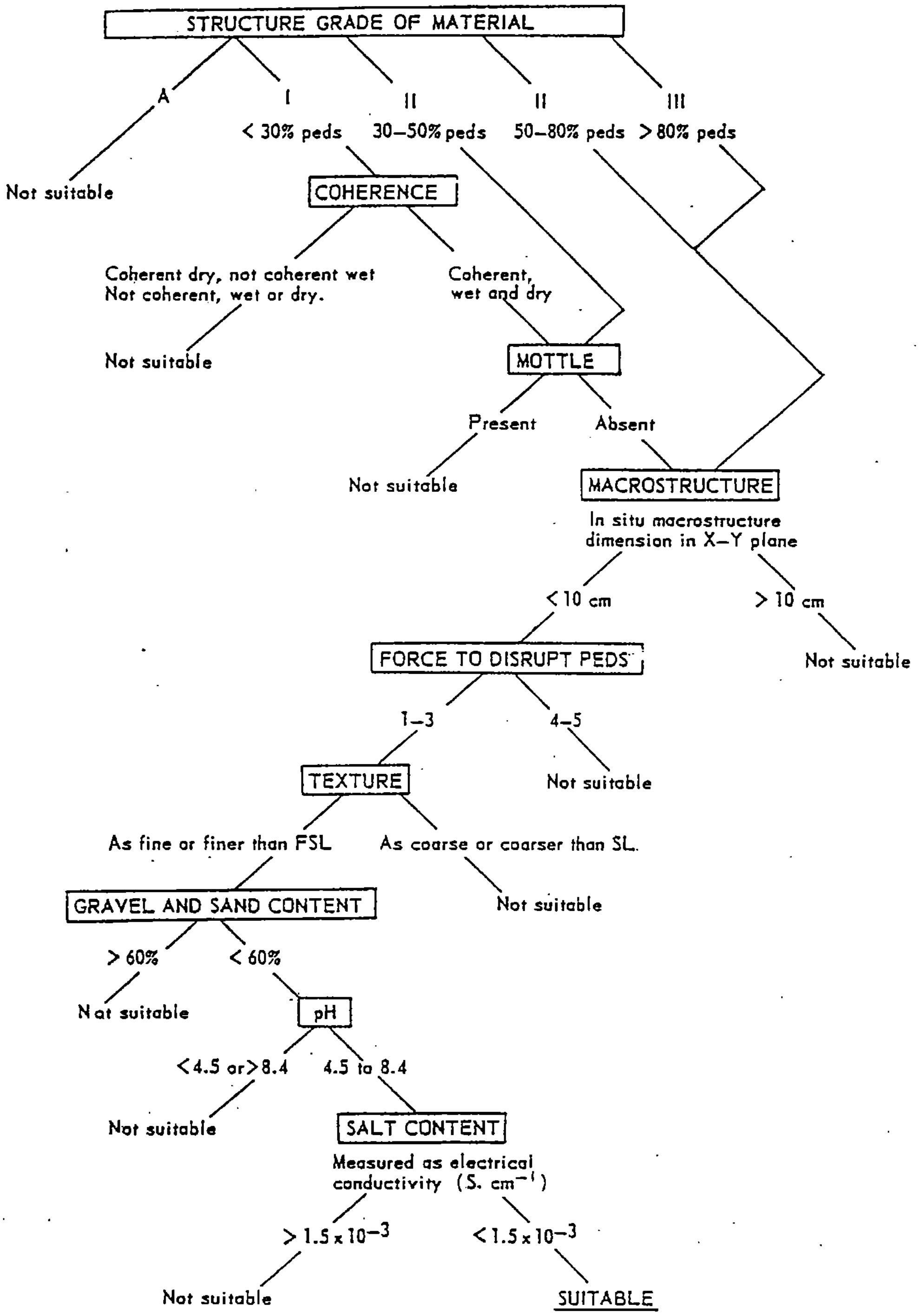
220-250cm - heavy clay; roots absent; no lime present; no manganese present; pH 8.0; gravel and stones absent; mottled; not bleached; 90% light grey [10YR7/1], 10% yellowish brown [10YR5/8] dry, 90% light grey [10YR7/1], 10%yellowish brown [10YR5/6] moist, peds rough- / smooth-faced, highly pedal [100%], polyhedral / platy, 5-15 mm in size; strong consistence dry; not hydrophobic; *continues below.*

Appendix 2 Topsoil Stripping Suitability Key

(No. of pages excluding this page = 1)

[After Elliott and Veness, 1981]

Procedure for the selection of material for use in topdressing of disturbed areas.



Appendix 3 Basis of Land Capability Classification

(No. of pages excluding this page = 1)

[After Emery, Undated]

Table 1 *Land Capability Map Legend*

			LAND CLASSIFICATION AND SOIL CONSERVATION PRACTICES	INTERPRETATIONS AND IMPLICATIONS
SUITABLE FOR REGULAR CULTIVATION		I	No special soil conservation works or practices.	Land suitable for a wide variety of uses. Where soils are fertile, this is land with the highest potential for agriculture, and may be cultivated for vegetable and fruit production, cereal and other grain crops, energy crops, fodder and forage crops, and sugar cane in specific areas. Includes "prime agricultural land".
SUITABLE FOR REGULAR CULTIVATION		II	Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotation.	Usually gently sloping land suitable for a wide variety of agricultural uses. Has a high potential for production of crops on fertile soils similar to Class I, but increasing limitations to production due to site conditions. Includes "prime agricultural land".
SUITABLE FOR REGULAR CULTIVATION		III	Structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage and adequate crop rotation.	Sloping land suitable for cropping on a rotational basis. Generally used for the production of the same type of crops as listed for Class I, although productivity will vary depending upon soil fertility. Individual yields may be the same as for Classes I and II, but increasing restrictions due to the erosion hazard will reduce the total yield over time. Soil erosion problems are often severe. Generally fair to good agricultural land.
SUITABLE FOR GRAZING	Occasional Cultivation	IV	Soil conservation practices such as pasture improvement, stock control, application of fertilizer and minimal cultivation for the establishment or re-establishment of permanent pasture.	Land not suitable for cultivation on a regular basis owing to limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Comprises the better classes of grazing land of the State and can be cultivated for an occasional crop, particularly a fodder crop, or for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms", adequate provision should be made for water supply, effluent disposal and selection of safe building sites and access roads.
SUITABLE FOR GRAZING	Occasional Cultivation	V	Structural soil conservation works such as absorption banks, diversion banks and contour ripping, together with the practices as in Class IV.	Land not suitable for cultivation on a regular basis owing to considerable limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Soil erosion problems are often severe. Production is generally lower than for grazing lands in Class IV. Can be cultivated for an occasional crop, particularly a fodder crop or for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms" adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
SUITABLE FOR GRAZING	No Cultivation	VI	Soil conservation practices including limitation of stock, broadcasting of seed and fertilizer, prevention of fire and destruction of vermin. May include some isolated structural works.	Productivity will vary due to the soil depth and the soil fertility. Comprises the less productive grazing lands. If used for "hobby farms", adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
OTHER		VII	Land best protected by green timber.	Generally comprises areas of steep slopes, shallow soils and/or rock outcrop. Adequate ground protection must be maintained by limiting grazing and minimising damage by fire. Destruction of trees is not generally recommended, but partial clearing for grazing purposes under strict management controls can be practised on small areas of low erosion hazard. Where clearing of these lands has occurred in the past, unstable soil and terrain sites should be returned to timber cover.
OTHER		VIII	Cliffs, lakes or swamps and other lands unsuitable for agricultural and pastoral production.	Land unusable for agricultural or pastoral uses. Recommended uses are those compatible with the preservation of the natural vegetation, namely: water supply catchments, wildlife refuges, national and state parks, and scenic areas.
OTHER		U	Urban areas	
OTHER		M	Mining and quarrying areas.	

CLASS SUBSCRIPTS	SPECIAL USES
c	Terrain developed for a specific crop (capability class range IV to VII) as a result of the combination of particular soil, terrain, climatic and economic conditions. The class includes such crops as grapes, bananas, avocados and pineapples.
d	Terrain developed for intensive agricultural production and associated with flood irrigation. The class includes land developed for cotton and rice production.

Appendix 4 Glossary of Terms

(No. of pages excluding this page = 1)

[Based on Definitions Provided by Houghton and Charman [1986] and Murphy [1993]

Glossary of Terms

[Based on Definitions Provided by Houghton and Charman [1986] and Murphy [1993]

abrupt - describes the thickness of a boundary between two layers in a soil profile where the change between the two layers is complete in a distance of 5 to 20mm.

apedal - describes a soil in which none of the soil material occurs in the form of peds in the moist state. Such a soil is without apparent structure and is typically massive or single-grained.

clear - describes the thickness of a boundary between two layers in a soil profile where the change between the two layers is complete in a distance of 20 to 50mm.

consistence - the degree of resistance to deformation or rupture exhibited by a soil.

diffuse - describes the thickness of a boundary between two layers in a soil profile where the change between the two layers is complete in a distance of >100mm.

fabric - the appearance of a soil when examined with a 10x hand lens with the similarities and differences between samples being based on presence or absence of ped, lustre [or its absence of the ped surfaces and the presence, size and arrangement of voids within the soil sample.

gradual - describes the thickness of a boundary between two layers in a soil profile where the change between the two layers is complete in a distance of 50 to 100mm.

horizon - a layer of soil material within a soil profile with distinct characteristics and properties that are produced by soil forming processes, and that are different from those of the layers above and below.

hydrophobic - describes soils that are water repellent and that resist wetting when dry. Drops of water do not spread spontaneously over their surface and into the pores.

lateritic - describes soil layers comprised of iron-rich material, often concentrated in separate nodules[gravel] or as masses of individual nodules cemented together.

massive - the condition of a soil layer in which the layer appears as a coherent or solid mass that is largely devoid of peds.

ped - an individual natural soil aggregate or unit of structure.

pedal - a term used to describe the proportion of a soil sample composed of individual soil aggregates.

platy - a form of soil structure in which soil particles are arranged around a horizontal plane and bounded by relatively flat horizontal faces with much accommodation to the faces of the surrounding peds.

polyhedral - a form of soil structure where the individual soil aggregates are relatively 'block-like' but have more than six relatively flat, unequal and dissimilar faces.

structure - describes the combination or spatial arrangement of primary soil particles [clay, silt, sand, gravel] into aggregates such as peds or clods and their stability to deformation texture.