Appendix 14.

SLR Consulting Australia (2020e) *Rum Jungle Rehabilitation – Stage 2A Detailed Engineering Design, Growth Medium for WSF Capping.* Memorandum from SLR Consulting Australia to the Department of Primary Industry and Resources, Northern Territory Government, March 2020.

Memorandum

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From:	Cameron Trail	**At:**	SLR Consulting Australia Pty Ltd
Date:	20 March 2020	**Ref:**	680.10421.900010 M06 Growth Ma Capping v1.docx
Subject:	Rum Jungle Rehabilitation - Stage 2A Detailed Engineering Design Growth Medium for WSF Capping		

This memo has been prepared to support the capping design, in particular the erosion modelling, for the WSFs. It is recommended that a detailed Growth Medium Management Plan be developed as part of the Projects Revegetation Management Plan.

1 Growth Material for Waste Storage Facility Capping

A purpose-designed growth material has been designed to cover the new WSFs. The growth material is to provide a long-term, sustainable growing medium for selected native revegetation species. It is also to provide a reduced likelihood of, equal to or better than baseline for the area, sheet, rill, and gully erosion over the proposed life of the WSFs capping. The growth material will need to provide for moderately rapid stormwater infiltration and be moderately permeable to reach field capacity but also have sufficient clay content to provide some structure, water holding capacity, and mineral exchange and nutrient adsorption capacity to support revegetation with, and long-term sustainability of, native shrubs and grasses.

1.1 Historical Soil and Land Resource Information

1.1.1 Land Systems of the Northern Part of the Northern Territory

The *Land Systems of the Northern Part of the Northern Territory* (Lynch, 2010) is an amalgamation of some 16 existing land system surveys covering the northern portion of the Northern Territory. The land system approach provides a broad-scale representation of the main features of the landscape, which are based on detailed information collected at specific field sites.

The Project site and specific areas are located across the land systems described in **Table 1** and shown on **Figure 1**.

These land systems provide an indication of the geology, terrain, soils and vegetation characteristics and associations that may guide design and characterization of the WSFs capping growth material.

1.1.2 Soil and Land Information Soil Profile Descriptions

The Northern Territory Department of Environment and Natural Resources maintains a database of soil profile information from all soil surveys, which is referred to as the Soil and Land Information (SALI) database. Accessing this database provided representative soil profile descriptions within and immediately surrounding the Project site in the dominant land systems described in **Table 1** and shown on **Figure 1** that the Project site is primarily located in. These being Woodcutter (Wdc) and Gully (Gly) land systems.

Table 1 Land Systems of the Project Site

Land System	Geological Zone	Landscape Class	Landscape Class Description	Landform Description	Original Soil Description	Australian Soil Classification	Vegetation Description	Specific Areas
Baker (Bkr)	Pine Creek	Sandstone hills	Low hills, hills and stony plateaus on sandstone, siltstone, quartzite and conglomerate (deeply weathered in places); outcrop with shallow stony soils	Rugged hills and strike ridges with intervening narrow valleys and short lower slopes on folded Burrels Creek greywacke, sandstone and siltstone	Skeletal soils and outcrop with minor sandy red and yellow gradational soils	Leptic Rudosols, shallow Yellow and Brown Kandosols	Mid-high woodland of *C. dichromophloia*, *E. miniata*, *C. bleeseri*, *E. tectifica* and *C. terminalis* over *Sorghum* spp, *Themeda triandra* and *Chrysopogon* spp	Very thin margin of southwestern edge of Borrow Area B Very thin margin of northeastern edge of Borrow Area A
Bend (Bnd)	Pine Creek	Sandstone plains and rises	Plains, rises and plateaus on mostly on sandstone, siltstone, claystone, shale and some limestone; commonly shallow soils with surface stone and rock outcrop	Undulating low strike ridges and rises on folded Burrels Creek greywacke, sandstone and siltstone	Skeletal soils and shallow gravelly loams	Shallow Yellow and Brown Kandosols and Leptic Rudosols	Mid-high woodland of *C. latifolia*, *C. foelscheana*, *E. polysciadia*, *E. tectifica*, *Erythrophleum chlorostachys* over tropical tall grass (*Sorghum* spp, *Heteropogon* spp, *Chrysopogon* spp)	Northwestern portion of Eastern WSF
Gully (Gly)	Pine Creek	Granite plains and rises	Gently undulating to undulating plains with rises and low hills on granite, schist, gneiss (deeply weathered in places); coarse grained sandy, earthy and texture contrast soils	Undulating terrain developed on granite, schist, and gneiss	Red massive earths and mottled yellow duplex soils	Red Kandosols and Yellow Chromosols	Woodland of *C. confertiflora*, *C. foelscheana*, *Erythrophleum chlorostachys*, *Terminalia canescens*, *Petalostigma* spp over perennial grasses (*Heteropogon triticeus*, *Themeda australis*, *Sorghum plumosum*)	Northeastern half of Borrow Area B Far southeastern portion of Eastern WSF
Woodcutter (Wdc)	Pine Creek	Sandstone plains and rises	Plains, rises and plateaus on mostly on sandstone, siltstone, claystone, shale and some limestone; commonly	Very gently [rising] upland surface; probably developed on Tertiary sediments	Deep red massive earths and yellow massive earths	Deep Red and Yellow Kandosols	Mid-high woodland of *Erythrophleum chlorostachys*, *E. miniata*, *C. confertiflora*, *C. papuana*, *Petalostigma*	Majority of Eastern WSF All of Western WSF

			shallow soils with surface stone and rock outcrop	overlying carbonate-rich Lower Proterozoic rocks			spp over perennial grasses (*Heteropogon triticeus*, *Chrysopogon latifolius*, *Imperata cylindricus*)	Most of southwestern half of Borrow Area B Majority of Borrow Area

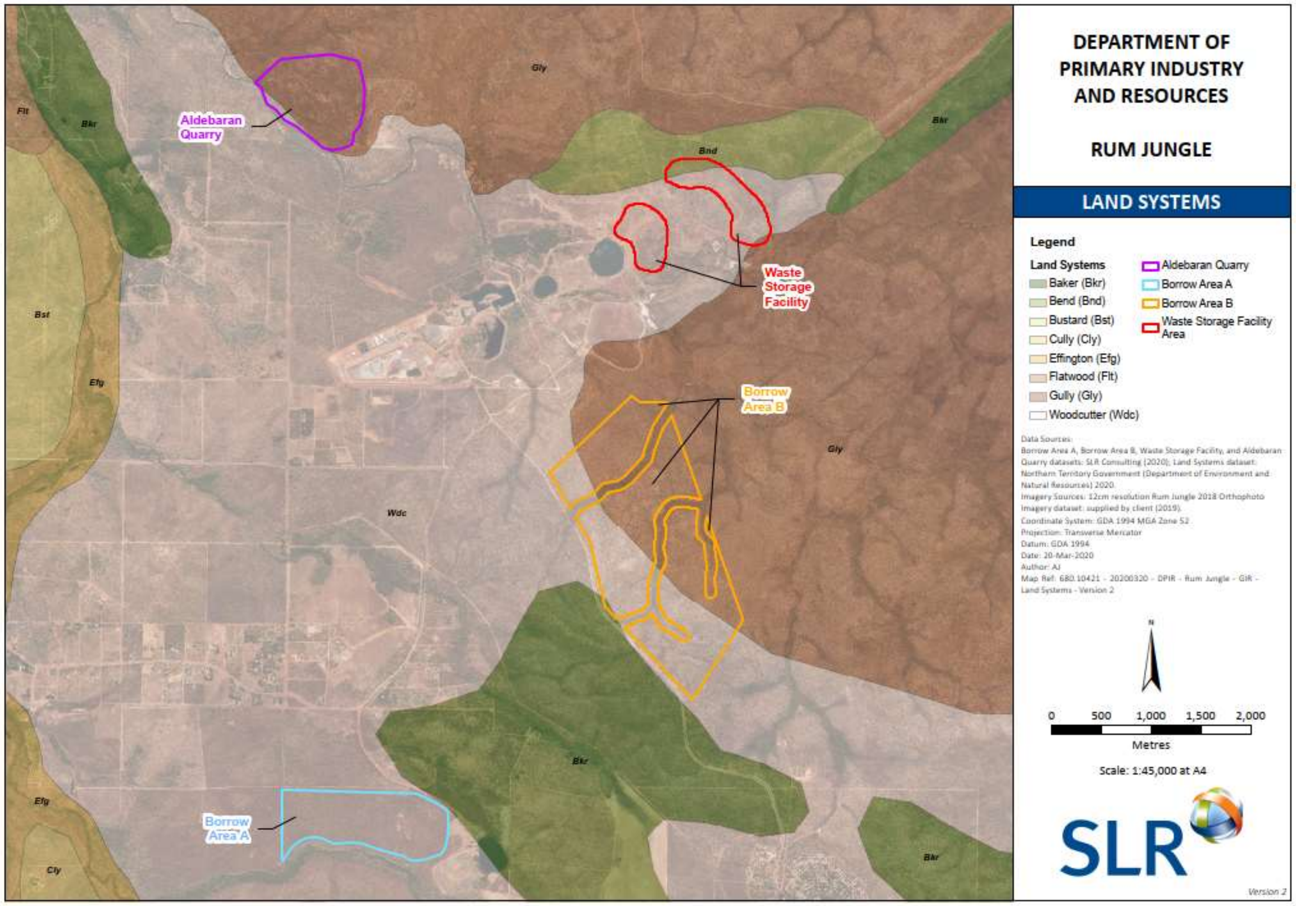

Figure 1 Land Systems of the Project Site

The dominant soils across these land systems appear to be Kandosols that tend to occur on very gently undulating plains, rises and plateaus. The final landforms proposed for the WSFs should be consistent with these landforms and, therefore, these soils should be most suitable to replicate for the growing medium over the capping on the WSFs. Representative profile examples of Kandosols from the surrounding landscape are shown in **Appendix 1** with available historical laboratory data shown in **Appendix 2**.

Aside from being dominant soils in the general landscape, Kandosols are considered a suitable growth medium for the following reasons:

- They tend to be deeply weathered profiles, which are suitable for the tropics
- They have a sandier texture and good humus content in the surface horizon that provide for moderately rapid stormwater infiltration due to lack of surface crusting or hard setting properties
- They have gradually increasing clay contents that provide for good water retention and cation exchange capacity
- They have deep, less consolidated (massive to weak structure) profiles suitable for deep root penetration by grasses and shrubs (but not so deep as to penetrate a clay capping) and are moderately permeable
- They have moderately high humus and organic carbon levels as a result of good vegetation growth that in turn improves surface horizon texture and structure.

Should replication of the Kandosol soil prove problematic, the preference would be to replicate a Dermosol soil, which has a fraction more clay throughout the profile and a structure that is weak to moderate.

1.1 Characteristics of Landforms

Landforms surrounding the Project site are strongly influenced by surface geology, faulting and folding, and climate (typically, a monsoonal wet season from November to March and dry season from May to September). Based on the land systems and SALI database information, landforms surrounding the Project site appear to largely comprise:

- Plateaus with relatively flat (<9 m relief, 0-1% slopes) to gently undulating (<30 m relief, 1-3% slopes) surfaces that abruptly downslope become either short, cliffed (>300%), precipitous (100-200%) and/or very steep (56-100%) slopes, usually rocky, or steep (32-56%) and/or moderately inclined (10-32%) slopes, that grade to gently inclined (3-10%) followed by very gently inclined (1-3%) slopes that level off on flat (0-1%) to very gently undulating (1-3%) plains. Slopes are intersected by shallow and relatively level drainage depressions on the plateaus that become steep gullies, as they drop off the plateaus, that gradually flatten with the concave landform to become streams, creeks and rivers meandering through the landscape.
- Ridges with cliffed (>300%), precipitous (100-200%) and/or very steep (56-100%) slopes, usually rocky, concavely grading to steep (32-56%) and/or moderately inclined (10-32%) slopes, that grade to gently inclined (3-10%) followed by very gently inclined (1-3%) slopes that level off on flat (0-1%) to very gently undulating (1-3%) plains. Slopes are intersected by steep gullies from ridges that gradually flatten with the concave landform to become streams, creeks and rivers meandering through the landscape.

- Gently undulating to rolling low hills (<30 m relief, <10% slopes) with crests that are smoothly convex, flat (0-1% slopes) to very gently inclined (1-3% slopes) convexly grading into gently inclined (3-10%) slopes and terminating on the bank of a drainage feature.

Based on the above, the preferred landform for the new WSFs would be a plateau to low hill with relatively flat (0-1%) grading to gently inclined (1-3%) slopes (convex crest) that relatively rapidly increases to a moderately inclined (10-32%) slope that grades to gently inclined (3-10%) followed by very gently inclined (1-3%) slopes (concave slope) as it grades into natural ground landform conditions.

Drainage off the preferred landform would be sheet flow as much as is practicably possible to minimise concentrated flows creating rills and gullies.

1.2 Characteristics of Kandosols

In accordance with the *Australian Soil Classification* (ASC) (Isbell & NCST, 2016), Kandosols are soils that lack strong texture contrast, have massive or only weakly structured B horizons, and are not calcareous throughout. More specifically, these soils have all of the following characteristics:

- B2 horizons in which the major part is massive or has only weak grade of structure
- A maximum clay content in some part of the B2 horizon which exceeds 15% (i.e. heavy sandy loam, SL+)
- Do not have a tenic B horizon
- Do not have a clear or abrupt textural B horizon
- Are not calcareous throughout the solum, or below the A1 or Ap horizon or a depth of 0.2 m if the A1 horizon is only weakly developed.

Based on the representative profile examples of Kandosols from the surrounding landscape, as shown in **Appendix 1**, and the available historical laboratory data, as shown in **Appendix 2**, the general characteristics of a Kandosol for the growth material should be similar to those detailed in **Table 2**.

Table 2 Generalised Characteristics of Kandosol Soil Profile

Attribute	Description
Slope:	<2% (but can be considerably steeper depending on specific surface texture, depth, vegetative cover and other factors)
Runoff:	Slow to moderate
Permeability:	Moderately to highly permeable
Drainage:	Imperfectly to well-drained
Surface rock:	0%
Horizon:	A1
Depth:	From 0 to 0.1-0.2 m
Texture:	Sandy loam to sandy clay loam (refer to NCST, 2009, pp164-166)
Colour:	Dark brown (may tend reddish or yellowish)
Fabric:	Earthy
Pedality:	Massive
pH:	Range from 4.5 to 5.5
EC:	At least 10 µS/cm
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic

Attribute	Description
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least 20-40 mg/kg
Total Kjeldahl N:	At least 150-250 mg/kg
Total Organic Carbon:	At least 1.5-2.5%
Sulfur:	<10 mg/kg
Horizon:	A2
Depth:	From 0.1-0.2 to 0.2-0.6 m
Texture:	Loam to clay loam, sandy (refer to NCST, 2009, pp164-166)
Colour:	Brown (may tend reddish or yellowish)
Fabric:	Earthy
Pedality:	Massive
pH:	Range from 5.0 to 6.0
EC:	At least 10 µS/cm
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least 20-40 mg/kg
Total Kjeldahl N:	At least 150-250 mg/kg
Total Organic Carbon:	At least 1.5-2.5%
Sulfur:	<10 mg/kg
Horizon:	B21
Depth:	From 0.2-0.6 to 0.4-1.0 m
Texture:	Sandy clay loam to light clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend red or yellow)
Fabric:	Earthy
Pedality:	Massive to weak
pH:	Range from 5.0 to 6.0
EC:	At least 2 µS/cm
Chloride:	<20 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Horizon:	B22
Depth:	From 0.4-1.0 to 0.8-1.6 m
Texture:	Clay loam, sandy to light medium clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend dark red or yellow)
Fabric:	Earthy
Pedality:	Massive to moderate
pH:	Range from 5.0 to 6.0
EC:	At least 5 µS/cm
Chloride:	<50 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1

1.3 Identification of Suitable Materials for the Growth Material

Although a Kandosol replication is proposed for the growth material, the soil profile will be classified as an Anthroposol, in accordance with the ASC (Isbell & NCST, 2016). Anthroposols are described under the ASC as soils that result from human activities that have caused a profound modification, mixing, truncation or burial of the original soil horizons, or the creation of new soil parent materials.

The intent of the design is to utilize naturally occurring layers of material that are inherently suitable for specific horizons of the growth material. Where this is not possible to source in the first instance to the maximum volume required, the deficit may be made up by combining appropriate proportions of other naturally occurring layers of material to meet the desired horizon texture specifications.

Geotechnical field logs within the Borrow Areas A and B were referenced to identify the potentially most suitable layers to form the growth material. Laboratory analytical results for selected samples collected from representative test pits were also referenced to further inform the identification of suitable layers. As the geotechnical field logs were based on the Unified Soil Classification System (USCS) for classifying the proportions of clay, silt, sand and gravel present in each pit layer, interpretation of the data was approximated to the Australian field texture classes described in the *Australian Soil and Land Survey Field Handbook* (NCST, 2009) based on clay, silt and sand fractions only and excluding the gravel fraction. These approximate interpretations were supported by the physical laboratory analytical results for the selected samples that were analysed for most of the following agronomical parameters for each sample:

- pH $_{(1:5\ water)}$ and pH $_{(CaCl2)}$
- Electrical conductivity
- Chloride
- Acid neutralizing capacity
- Cation exchange capacity, exchangeable cations and acidity, calcium: magnesium ratio and exchangeable sodium percentage (ESP)
- Emerson aggregate test
- Particle size distribution
- Bicarbonate extractable potassium
- Sulfur
- Silicon
- Boron
- Extractable metals (Cu, Fe, Mn, Zn)
- Trace metals (arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, vanadium and zinc)
- Mercury
- Hexavalent chromium
- Cyanide
- Nitrogen (ammonia, nitrite, nitrate, total Kjeldahl and total)

- Phosphorus (total and bicarb. extract.)
- Total carbon, total organic carbon and organic matter
- Carbon: nitrogen ratio.

The chemical laboratory analytical results for the selected samples provided for determining whether there were likely to be any highly unsuitable materials to be avoided as specific layers within the growth material. Generally, it appears through this random selection of samples from a range of test pits that the majority of the soil materials with suitable texture classes will not have unsuitable chemical compositions for creating a Kandosol-equivalent soil. The laboratory analytical results are presented in **Appendix 3**.

Although the soil materials will not likely have unsuitable chemical compositions, this does not mean that they will not be deficient in certain nutrients and minerals to support vegetative growth. Ameliorants will be required, applied either during stockpiling and blending of suitable materials for the specific horizons of the Kandosol-equivalent growth medium or following placement of each horizon of the Kandosol-equivalent soil material.

1.4 Suggested Soil Sources to Create Kandosol-Equivalent (Anthroposol) Growth Material

It appears from this desktop review of geotechnical field logs and laboratory analytical results that there should be sufficient volumes of material of suitable quality to replicate the soil profile of a Kandosol to a depth of 2m over the WFSs.

Appendix 4 presents a table of available horizon volumes from the borrow areas against the required volumes for the growth medium capping based for various depths and slope areas (note, slope areas are still under investigation at the time of reporting as part of SLRs erosion assessment).

The results indicate that for the most part, replication can be achieved be by targeting layers that are considered to match the required physical parameters for each horizon of the growth medium; however, there may need to be some mixing of different materials for make up any deficit, particularly for the surface (A1 and A2) horizons. The calculations of potential available volumes of materials is on the basis of assuming the material available within each layer of each geotechnical bore hole is representative for a nominal area around each geotechnical bore hole. As such there is potential for an inherently large error in these calculations; however, given there appears to be substantially more material available than required overall, the potential error should be offset.

Based on the above characteristics of a Kandosol soil, it is suggested that the most appropriate soil materials listed in **Table 3** be used at the depths specified, or adjacent depth, to create the Kandosol-equivalent (Anthroposol) growth material for the WSFs capping. Note the potential sources are not listed in any priority order for each layer, rather they should be further field assessed on site at the time of excavation as to their actual suitability. Advice is provided on how to undertake this in **Section 1.6**.

The suggested sources are indicative for the Kandosol-equivalent growth material depth. These will need to be modified should a Dermosol-equivalent growth material be developed instead. Actual source and depth of placement should be dictated by increasing proportion of clay with depth based on soil texture classification and commensurate increase in plasticity to no more than medium plasticity, preferably low plasticity at 100-200 cm. This means potential sources could be moved one layer up or down where multiple sources in one layer demonstrate slightly higher or lower clay content and plasticity, where appropriate, such that they can provide the gradual increase in soil texture classification throughout the Kandosol-equivalent growth material. Where possible, gravel content is to be limited to the greatest extent practicable, in particular rocky material regarded as cobbles (60-200 mm) or greater and especially in the surface horizons (A1 and A2).

Table 3 Suggested Soil Sources to Create Kandosol Growth Material

Kandosol Growth Material Layers by Depth from Surface (cm)	Potential Soil Sources			Soil Texture Classification	
	Borrow Area	Site	Source Depth (cm)	Approximate USCS	NCST (2009) (Preferred, Excluding Gravel)
0-20 (A1 horizon) and 20-60 (A2 horizon)	A	NTP-05	0-10	Clayey Silty Sand to Silty Clayey Sand, Non-Plastic	Sandy Loam (SL), Sandy Clay Loam (SCL) to Clay Loam, Sandy (CL,S)
		NTP-07	0-20		
		DPIR-TP-01	0-20		
		DPIR-TP-03	0-20		
		DPIR-TP-04	0-20		
		DPIR-TP-06	0-10		
		DPIR-TP-06	350-480		
		GHD TP-01	0-15		
		GHD TP-01_B	0-10		
		GHD TP-02_B	0-10		
		GHD TP-04	0-10		
		GHD TP-05	0-5		
		GHD TP-05_B	0-5		
		GHD TP-06	0-10		
		GHD TP-07	0-10		
		GHD TP-08	0-10		
		GHD TP-09	0-20		
		GHD TP-16	0-15		
		GHD TP-17	0-10		
		GHD TP-18	0-10		
		GHD TP-19	0-10		
		GHD TP-20	0-20		
	B	SLR-TP-05	0-20		
		SLR-TP-06	0-20		
60-120 (B21 horizon)	A	NTP-01	0-20	Clayey Sandy Silt to Sandy Clayey Silt, Very Low to Low Plasticity	Clay Loam, Sandy (CL,S) to Sandy Light Clay (SLC)
		NTP-02	0-20		
		NTP-06	280-310		
		DPIR-TP-01	20-40		
		DPIR-TP-01	200-400		
		DPIR-TP-02	20-60		
		DPIR-TP-04	20-210		
		DPIR-TP-04	420-500		
		DPIR-TP-05	250-450		
		DPIR-TP-06	10-350		
		GHD TP-01	15-95		
		GHD TP-01	95-210		
		GHD TP-01_B	10-220		
		GHD TP-02	120-220		

Kandosol Growth Material Layers by Depth from Surface (cm)	Potential Soil Sources			Soil Texture Classification	
	Borrow Area	Site	Source Depth (cm)	Approximate USCS	NCST (2009) (Preferred, Excluding Gravel)
		GHD TP-02_B	10-200		
		GHD TP-02_B	340-440		
		GHD TP-04	10-230		
		GHD TP-05	5-60		
		GHD TP-05	60-190		
		GHD TP-06	10-210		
		GHD TP-07	10-250		
		GHD TP-08	10-280		
		GHD TP-09	20-260		
		GHD TP-16	15-210		
		GHD TP-17	10-155		
		GHD TP-18	10-170		
		GHD TP-19	10-220		
		GHD TP-20	20-40		
	B	SLR-TP-01	60-430		
		SLR-TP-02	60-200		
		SLR-TP-03	60-330		
		SLR-TP-05	20-160		
		SLR-TP-07	80-290		
120-200 (B22 horizon)	A	NTP-05	10-100	Silty Sandy Clay to Sandy Silty Clay, Low to Medium Plasticity	Sandy Light Clay (SLC) to Sandy Light Medium Clay (SLMC)
		NTP-06	310-400		
		NTP-07	80-100		
		DPIR-TP-01	40-200		
		DPIR-TP-02	60-500		
		DPIR-TP-03	20-310		
		GHD TP-01_B	220-480		
		GHD TP-02_B	200-340		
		GHD TP-06	210-250		
		GHD TP-06_B	140-170		
		GHD TP-15	200-220		
		GHD TP-16	210-250		
		GHD TP-17	155-190		
		GHD TP-18	170-250		
		GHD TP-19	220-280		
		GHD TP-20	40-280		

1.5 Stockpile Establishment

It is suggested that suitably sized stockpile areas be designated for each of the horizon categories. Each stockpile area is to be clearly designated and separated from the other stockpile areas. The preference is for the stockpiles to be established in the following way to prevent cross-contamination of stockpiles where excellent quality materials have been sourced for upper layers and lesser quality materials for lower layers:

- 0-20 cm (SL to SCL texture – A1 horizon) soil material placed at the highest location in the general landscape

- 20-60 cm (SCL to CL, S texture – A2 horizon) soil material placed either downslope of the A1 horizon (0-20 cm) stockpile or adjacent to the A1 horizon stockpile where the A2 horizon stockpile will not impact on the A1 horizon stockpile because both will drain immediately downslope away from each other
- 60-120 cm (CL, S to SLC texture – B21 horizon) soil material placed downslope of the A2 horizon (20-60 cm) stockpile or adjacent to the A2 horizon stockpile where the B21 horizon stockpile will not impact on the A1 or A2 horizon stockpiles because all three will drain immediately downslope away from each other
- 120-200 cm (SLC to SLMC texture – B22 horizon) soil material placed at the lowest location in the general landscape or adjacent to the B21 horizon stockpile where the B22 horizon stockpile will not impact on the A1, A2 or B21 horizon stockpiles because all four will drain immediately downslope away from each other.

1.6 Field Selection of Appropriate Horizon Materials

In the first instance, material with minimal gravel content is to be selected for all horizons, although this is most important for the A1 and A2 horizons and progressively less important for the B21 and then the B22 horizons. In all instances, where there is gravel, it is not to be associated with poorly developed soil material that is more consistent with weathered parent material (i.e. B/C or C horizons) rather than recognisably developed B horizon material.

Prior to each layer of the natural soil profiles being excavated, their pH and electrical conductivity (EC) be tested using a field pH/electrical conductivity kit/meter and soil field texture be confirmed, without the coarse fragments (gravel (>2 mm)), to more effectively grade them in accordance with the *Australian Soil and Land Survey Field Handbook* (NCST, 2009). Reference is to be made to the pH and EC ranges provided in **Table 2** and Recommended Scale (top scale on page 162), figure 16 on page 163 and the field texture grades on page 164-166 of the *Australian Soil and Land Survey Field Handbook* (NCST, 2009), to confirm each layer's suitability in accordance with the soil texture classifications in column 5 of **Table 3**.

For the 0-20 (sandy loam to sandy clay loam texture – A1 horizon) and 20-60 (sandy clay loam to clay loam, sandy texture – A2 horizon) soil materials, preference is to be given to sources at or close to the soil surface. This is to include existing humus, leaf, twig and bark, microbial and seed material to the greatest extent practicable thereby retaining some biologically active organic content in the surface materials. This will likely improve the potential for rapid successful regeneration of vegetation/ pasture and lowering the risk of failure.

Additionally, for the 60-120 (clay loam, sandy to sandy light clay – B21 horizon) and 120-200 (sandy light clay to light medium clay – B22 horizon) soil materials, preference is to be given to sources between the surface and 2 m, where practicable, to minimise the likelihood of unfavourable physical and chemical properties, including gleyed colouring.

The suitably classified and appropriately selected materials can then be excavated and transported to the applicable horizon category stockpile area.

All excavations of materials should be supervised by an appropriately qualified and experienced soil scientist alongside the site geotechnical engineer to ensure greatest possible success with identifying and confirming suitable soil layer materials and ensuring grading and stockpiling are performed as required. All growth material works should be governed by a detailed Planning Construction Soil (Growth Material) Management Plan for the construction and revegetation establishment phases. An overview of growth material management practices is provided in **Section 1.7**.

1.7 Overview of Growth Material Management Practices

1.7.1 Stockpile Management

1.7.1.1 Hydroseeding of Growth Material Stockpiles

Where soil material for any growth material horizon is to be stockpiled for >3 months and/or there is a high likelihood of rain, the stockpile should be hydroseeded with a suitable seed mix (e.g. Japanese millet, annual couch and/or annual and/or perennial native grasses) and watered as needed to ensure vigorous and lush growth. This will form a protective layer of vegetation as soon as possible to prevent any immediate possibility of erosion and loss of this material. Depending on the storage period for the stockpile, the perennial native species will progressively replace the annual species thereby ensuring continued protection of the stockpile surface from erosion. All grasses will also enhance any inherent chemical and biological properties by mulching down and being incorporated into the growth medium by microbes in preparation for final placement. Should the grasses also reach maturity and successfully set seed, they will start to establish a seed bank in preparation for continued protection of the stockpile or establishing a vegetative cover on the WSFs.

1.7.1.2 Weed Control on Growth Material Stockpiles

Weeds have the potential to interfere with successful revegetation of the growth material once placed on the WSF capping material. Where weeds are identified on the stockpiles, they are to be prevented from flowering by appropriate control methods for the weed species identified and to minimise any effects on the hydroseeded grass species. This may mean sufficiently regular inspections and treatment at a rate commensurate with the shortest growth cycle weed species present, ego potentially weekly. Where weeds are not adequately controlled and establish seed banks from successfully flowering and seeding, the stockpiled soil material may have to be scalped to remove the weed seed bank and this material disposed of, potentially wasting a limited resource required for the success of growth material and revegetation establishment on the WSF capping.

1.7.1.3 Inspections and Monitoring of Growth Material Stockpiles

Regular inspections should be made of all the growth material stockpiles to monitor the stockpiles for erosion effects from wind or water, vegetative coverage to ensure it is more than adequate, and weed infestations, and to ensure they are being controlled and prevented from flowering.

Inspections should be immediately following rainfall events, where possible, and at regular intervals sufficient to ensure any erosion is addressed as soon as possible, hydroseeded grass species are establishing and maintaining a high foliage cover, and the fastest growing and maturing weed species are unable to flower and seed between inspections and/or treatments.

1.7.1.4 SL to SCL Texture (0-20 cm) A1 Horizon Soil Material

The A1 horizon (0-20 cm (SL to SCL texture)) soil material is to be stockpiled no greater than 2 m high with batters no steeper than the material's natural dry angle of repose without vegetation. This is to preserve any inherent organic content and, where stored for >3 month, ensure maximum surface area for hydroseeding to generate as much additional organic material for incorporation ahead of final placement whilst providing for the most stable form to minimise erosion potential. Final placement of this material will be on top of the A2 horizon (20-60 cm) Kandosol-equivalent growth material as a topsoil (A1 horizon).

1.7.1.5 SCL to CL, S (20-60 cm) A2 Horizon Soil Material

The 20-60 cm (SCL to CL, S texture) soil material is to be stockpiled no greater than 2 m high with batters no steeper than the material's natural dry angle of repose without vegetation. This is to preserve any inherent organic content and, where stored for >3 month, ensure maximum surface area for hydroseeding to generate as much additional organic material for incorporation ahead of final placement whilst providing for the most stable form to minimise erosion potential. Final placement of this material will be on top of the B21 horizon (60 -120 cm) Kandosol-equivalent growth material as a sub-topsoil (A2 horizon).

1.7.1.6 CL, S to SLC (60-120 cm) B21 Horizon Soil Material

The B21 horizon (60-120 cm (CL, S to SLC texture)) soil material can be stockpiled up to 3 m high with batters no steeper than the material's natural dry angle of repose without vegetation. Final placement of this material will be on top of the B22 horizon (120-200 cm) Kandosol-equivalent growth material as the upper subsoil (B21 horizon).

1.7.1.7 SLC to SLMC (120-200 cm) B22 Horizon Soil Material

The B22 horizon (120-200 cm (SLC to SLMC texture)) soil material can be stockpiled up to 3 m high with batters no steeper than the material's natural dry angle of repose without vegetation. Final placement of this material will be on top of the clay capping as the lower subsoil (B22 horizon).

1.7.2 Growth Material Mixing and Sampling Prior to Placement and Revegetation

Excavation and placement of the respective materials at each stockpile location should ensure maximum mixing without excessive overworking of the soil materials, which would degrade the soil structure, where there is reasonable structure. This is to ensure adequate mixing of the materials for each horizon of the Kandosol-equivalent soil ahead of spreading over the clay capping on the WSFs.

As sufficient volume for each stockpile is being approached or use of the material is impending as capping progresses, a representative number of samples are to be collected, bulked and submitted to a laboratory that is NATA-accredited for undertaking most of the analyses required to understand the physical and chemical properties of the respective horizon material.

For sampling of the topsoil stockpiles, samples are not to be taken directly from the surface as this will give a skewed interpretation of the quality of the topsoil, given it may have a cover crop incorporating organic material into it. The surface material represents a small fraction of the overall stockpile so will largely disappear once mixed, so a sample should be taken >200 mm beneath the surface, preferably quite deep as this will be most representative. Also, should the protective cover crop have been poorly managed and is full of weeds, the surface layer of the topsoil stockpile may have to be scalped and discarded to get rid of the weed seed bank, so samples should not to be collected from the surface.

A sufficient number of samples are to be collected from around each stockpile and then bulked together. Each stockpile should have its own bulked sample to be analysed. The number should be representative of the size of the stockpile, i.e. for small stockpiles only 3-4 samples may be required, however, for large to really large stockpiles, anywhere from 6-10 or more samples will be required and bulked together.

1.7.3 Growth Material Testing and Treatment Prior to Placement and Revegetation

Following sampling, bulking and submission of samples for each growth material horizon stockpile, the bulked samples are to be analysed for the parameters outlined in **Table 4**Error! Reference source not found..

Table 4 Laboratory Testing of Growth Material Layers Following Placement

Parameter	Layers			
	0-20 cm (SL-SCL) (A1 horizon)	20-60 cm (SCL-CL, S) (A2 horizon)	60-120 cm (CL, S-SLC) (B21 horizon)	120-200 cm (SLC-SLMC) (B22 horizon)
pH $_{(1:5\ water)}$ and pH $_{(CaCl2)}$	✓	✓	✓	✓
Electrical conductivity	✓	✓	✓	✓
Chloride	✓	✓	✓	✓
Acid neutralizing capacity	✓	✓	✓	✓
Cation exchange capacity, exchangeable cations and acidity, calcium: magnesium ratio and exchangeable sodium percentage (ESP)	✓	✓	✓	✓
Particle size distribution (by sieve and hydrometer) for the following fractions: clay (<2 µm), silt (0.002 (2 µm)-0.02 mm), fine sand (0.02-0.2 mm), coarse sand (0.2-2 mm) and gravel (>2 mm)	✓	✓	✓	✓
Emerson aggregate test	✓	✓	✓	✓
Bicarbonate extractable potassium	✓	✓		
Sulfur	✓	✓		
Boron	✓	✓		
Extractable metals (Cu, Fe, Mn, Zn)	✓	✓		
Nitrogen (ammonia, nitrite, nitrate, total Kjeldahl and total)	✓	✓		
Phosphorus (total and bicarb. extract.)	✓	✓		
Total carbon, total organic carbon and organic matter	✓	✓		
Carbon: nitrogen ratio	✓	✓		

Following analysis for each layer, the results are to be used to determine whether any specific physical, chemical and/or biological treatments are required to ensure the growth material meets the indicative growth material success criteria (refer to **Section 1.7.4**).

The results of the particle size distribution analysis on the bulked samples are to be categorised according to the recommended scale in NCST (2009), page 162. The scale is to be grouped as follows, disregarding the gravel fraction post analysis (except that the gravel content should not dominate the other fractions), to confirm the texture, in accordance with NCST (2009), figure 16, page 163 and the field texture grades on pages 164-166:

- Clay: <2 µm
- Silt: 0.002 (2 µm)-0.02 mm
- Fine sand: 0.02-0.2 mm
- Coarse sand: 0.2-2 mm.

This will confirm the stockpiled soil material has a suitable texture for the Kandosol-equivalent growth material horizon that the respective stockpile is designated for.

Where the above particle size distribution does not meet the texture specifications for the particular Kandosol-equivalent horizon, additional soil material of the appropriate particle size(s) is to be sourced in sufficient volume to make up the desired texture. On completion of adding and mixing the additional material, the stockpile is to be re-tested for particle size distribution to confirm it meets the texture specification. This process is to be repeated until the texture specification is met for all stockpiles.

Where particular stockpiles of materials do not quite meet the physical, chemical and/or biological specifications (refer to **Section 1.7.4**)Error! Reference source not found., a range of ameliorants may be considered, including, but not limited to:

- Gypsum – to maintain existing pH, increase cation exchange capacity, increase calcium to magnesium ratio, reduce sodicity, improve soil structure
- Lime – to raise pH, increase cation exchange capacity, increase calcium to magnesium ratio, reduce sodicity, improve soil structure
- Humus – to increase organic matter content, improve structure, increase nutrient content, improve water holding capacity
- Fertiliser – to increase nutrient content
- Liquid sulfur – to lower soil pH, increase sulfur availability, increase nitrogen utilisation.

These ameliorants are to be applied to the respective stockpile prior to placement of the growth material onto the growth material area and spread to further mix the combined source materials for that horizon and incorporate the ameliorants.

1.7.4 Establishment Phase Growth Material Monitoring

The growth material should be monitored bi-annually for the revegetation establishment phase. Monitoring should be towards the end of the dry season and at the end of the wet season to compare soil physical and chemical changes that result from annual and seasonal climate variations and on-going revegetation management practices.

Monitoring should include full soil profile (down to the clay capping but not into the clay capping) description and sampling using a hand auger or push tube at all revegetation monitoring sites with laboratory analysis for comparison against growth material design and success criteria, previous growth medium soil profile monitoring results, and revegetation monitoring data.

Indicative growth material design and success criteria are provided in **Table 5**. Where adjustments are made to the growth material design due to availability of materials, e.g. depths of horizons or growth material more in line with a Dermosol texture profile, etc, these design and success criteria will need to be adjusted accordingly.

Table 5 Growth Material Design and Success Criteria

Attribute	Description
Slope:	Consistent with final design gradients
Runoff:	Very slow to moderately rapid (refer to NCST, 2009, pp144-145)
Permeability:	Slowly to moderately permeable (refer to NCST, 2009, pp200-202)
Drainage:	Moderately to well-drained (refer to NCST, 2009, pp202-204)
Surface rock:	<1%
Horizon:	A1
Depth:	From 0 to 0.2 m
Texture:	Sandy loam to sandy clay loam (refer to NCST, 2009, pp164-166)
Colour:	Dark brown (may tend reddish or yellowish) (refer to Munsell colour charts)
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive (refer to NCST, 2009, pp171-180)
pH (1:5 soil:water):	Range from 4.5 to 5.5
EC:	At least 10 µS/cm
Salinity:	Very low to low
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least moderate (>20-40 mg/kg)
Total Kjeldahl N:	At least moderate (>150-250 mg/kg)
Total Organic Carbon:	At least moderate (>1.5-2.5%)
Sulfur:	<10 mg/kg
Horizon:	A2
Depth:	From 0.2 to 0.6 m
Texture:	Sandy clay loam to clay loam, sandy (refer to NCST, 2009, pp164-166)
Colour:	Brown (may tend reddish or yellowish) (refer to Munsell colour charts)
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive (refer to NCST, 2009, pp171-180)
pH:	Range from 5.0 to 6.0
EC:	At least 10 µS/cm
Salinity:	Low to medium
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least moderate (>20-40 mg/kg)
Total Kjeldahl N:	At least moderate (>150-250 mg/kg)
Total Organic Carbon:	At least moderate (>1.5-2.5%)

Attribute	Description
Sulfur:	<10 mg/kg
Horizon:	B21
Depth:	From 0.6 to 1.2 m
Texture:	Clay loam, sandy, to light clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend red or yellow) (refer to Munsell colour charts)
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive to weak (refer to NCST, 2009, pp171-180)
pH:	Range from 5.0 to 6.0
EC:	At least 2 µS/cm
Salinity:	Low to high
Chloride:	<20 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Horizon:	B22
Depth:	From 1.2 to 2.0 m
Texture:	Sandy light clay to sandy light medium clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend dark red or yellow) (refer to Munsell colour charts)
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive to moderate (refer to NCST, 2009, pp171-180)
pH:	Range from 5.0 to 6.0
EC:	At least 5 µS/cm
Salinity:	Low to high
Chloride:	<50 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1

1.7.5 Post-Establishment Phase Growth Material Monitoring

The growth material should continue to be monitored bi-annually biennially for the next 10 years, post-establishment phase, and thereafter biannually every 5 years. Monitoring should be towards the end of the dry season and at the end of the wet season to compare soil physical and chemical changes that result from annual and seasonal climate variations and on-going vegetation management practices.

Monitoring should include full soil profile (down to the clay capping but not into the clay capping) description and sampling using a hand auger or push tube at all revegetation monitoring sites with laboratory analysis for comparison against growth material design and success criteria, previous growth medium soil profile monitoring results, and revegetation monitoring data.

Indicative growth material design and success criteria are provided in **Table 5**. Where adjustments are made to the growth material design due to availability of materials, e.g. depths of horizons or growth material more in line with a Dermosol texture profile, etc, these design and success criteria will need to be adjusted accordingly.

2 Conclusion/Summary

The ideal growth material for the WSF would be a soil profile similar to the Kandosols that naturally occur and are dominant throughout the surrounding landscape. The preferred Kandosol growth medium would consist of the following soil horizons (layers) at these preferred depths, although these may be varied to accommodate the volumes of available materials:

- 0-20 cm (SL to SCL texture – A1 horizon)
- 20-60 cm (SCL to CL,S texture – A2 horizon)
- 60-120 cm (CL,S to SLC texture – B21 horizon)
- 120-200 cm (SLC to SLMC texture – B22 horizon).

The quantity of available soil materials from the available borrow areas appears to not provide sufficient material of the exact textures required for the A1 and A2 horizons of the Kandosol. There appears, however, to be sufficient separate materials to be able to manufacture sufficient volumes of soil materials to create the desired A1 and A2 textures.

The quantity of available soil materials from the available borrow areas appears to provide well and truly sufficient material for the B21 and B22 horizons.

The quality of the soil materials available from the borrow areas appears, in the main, to be suitable for the Kandosol soil profile. There were limited instances of unsuitable materials displaying very strongly acidic, marginally sodic, etc chemical properties; however, should these materials be harvested the dilution factor with the significantly larger volumes of good material would likely nullify their effects and/or they could be treated with small volumes of readily available ameliorants, such as lime and gypsum.

Should it not be practicable to construct the Kandosol growth medium from the available materials, the alternative would be a Dermosol soil. A Dermosol soil has slightly more clay than a Kandosol, particularly in the surface horizons making it more uniformly clay rather than distinctly graduated. The preferred Dermosol growth medium would consist of the following soil horizons (layers) at these preferred depths, although these may be varied to accommodate the volumes of available materials:

- 0-20 cm (SCL to CL, S texture – A1 horizon)
- 20-60 cm (CL,S to SLC texture – A2 to B21 horizon)
- 60-120 cm (SLC to SLMC texture – B21 to B22 horizon)
- 120-200 cm (SLMC to SMC texture – B22 to B23 horizon).

The quantity of available soil materials from the available borrow areas appears likely to provide sufficient material for all horizons of the Dermosol, although some mixing may be required to create additional material sufficient for the upper horizons.

Similar to the Kandosol, the quality of the soil materials available from the borrow areas appears, in the main, to be suitable given the likely dilution factor with the significantly larger volumes of good material nullifying the effects of the poor materials and/or they could be treated with small volumes of readily available ameliorants, such as lime and gypsum.

For either the Kandosol or Dermosol growth material profile, field and laboratory testing at the time of harvesting (during construction) by suitably qualified field and laboratory soil scientists would be sufficient to identify appropriate materials for stockpiling and amelioration ahead of placement on the WSF. A detailed Planning Construction Soil (Growth Material) Management Plan would be advisable to provide detailed instruction to the construction contractor at the time of tendering.

3 References

Lynch, B 2010, "*Land Systems of the Northern Part of the Northern Territory, 1:250,000*", Natural Resources Division, Department of Natural Resources, Environment, the Arts and Sport, Northern Territory.

NCST 2009, "*Australian Soil and Land Survey Field Handbook*", 3rd Ed, CSIRO Publishing, Collingwood, VIC.

Wood, BG 1976, "*A Report on the Land Units on and Surrounding Mr. E. Kerle's Property Near Batchelor*", Department of the Northern Territory, Forestry, Fisheries & Land Conservation Branch, Land Conservation Section, Darwin, NT.

Wood, BG and Day, KJ 1976, "*Report of the Land Units of the Batchelor Township Area*", Department of the Northern Territory, Forestry, Fisheries & Land Conservation Branch, Land Conservation Section, Darwin, NT.

APPENDIX 1

SALI Database Soil Profile Descriptions

Attribute	Description	Description	Description	Description	Description
Location:	E: -1256142.596, N: 8502275.983	E: -1256627.943, N: 8502454.046	E: -1252685.820, N: 8503684.654	E: -1258391.038, N: 8509097.332	E: -1258542.266, N: 8502176.567
Survey:	Gamba Grass Carbon Project, Batchelor, Charles Darwin University	Gamba Grass Carbon Project, Batchelor, Charles Darwin University	Report on the Land Units of the Batchelor Township Area	A Report on the Land Units on and surrounding Mr. E. Kerle's Property near Batchelor	A Report on the Land Units on and surrounding Mr. E. Kerle's Property near Batchelor
Survey Code:	BATCH14	BATCH14	BATCH25	EKERL10	EKERL10
Site No.:	2	1	4	20	26
Date Described:	25-Nov-2014	25-Nov-2014	14-Sep-1976	19-Sep-1976	20-Sep-1976
Date Entered into Database:	04-Dec-2014	04-Dec-2014	07-Jul-2005	06-Jul-2005	08-Jul-2005
Accuracy:	Accuracy estimated to be within a radius of 0-30 metres	Accuracy estimated to be within a radius of 0-30 metres	Accuracy estimated to be within a radius of 30-100 metres	Accuracy estimated to be within a radius of 30-100 metres	Accuracy estimated to be within a radius of 30-100 metres
Landform Element:	Plain	Plain	Plain	Not Described	Not Described
Landform Pattern:	Plain	Plain	Not Described	Not Described	Not Described
Land System:	Woodcutter (Wdc)	Woodcutter (Wdc)	Woodcutter (Wdc)	Woodcutter (Wdc)	Woodcutter (Wdc)
Slope:	0.5%	0.5%	-	-	-
Drainage:	Well drained	Imperfectly drained	Well drained	Well drained	Imperfectly drained
Permeability:	Highly permeable	Moderately permeable	Highly permeable	Moderately permeable	Slowly permeable
Runoff:	Slow	Slow	Very slow	Not Described	Rapid
Surface rock:	0%	0%	0%	0%	
ASC:	Kandosol	Kandosol	Kandosol	Kandosol	Kandosol
Substrate:	Not Described	Not Described	Not Described	Not Described	Quartz
Horizon:	A1	A1	A1	A1	A11
Depth:	0 - 0.12 m	0 - 0.07 m	0 - 0.1 m	0 - 0.1m	0 - 0.1 m
Texture:	Sandy loam	Sandy clay loam	Sandy loam	Sandy loam	Loam
Colour:	Dark reddish brown	Dark brown	Dark brown	Dark reddish brown	Very dark greyish brown
Fabric:	Sandy (grains prominent)	Earthy	Earthy	Earthy	Earthy
Pedality:	Massive	Massive	Massive	Massive	Massive
pH:	4.9	4.5	5.5	6	6
Horizon:	A3	A2	A2	B1	A12
Depth:	0.12 - 0.3 m	0.07 - 0.2 m	0.1 - 0.4 m	0.1 - 0.6 m	0.1 - 0.2 m
Texture:	Sandy loam	Clay loam, sandy	Sandy clay loam	Sandy clay loam	Loam
Colour:	Reddish brown	Brown	Dark yellowish brown	Dark red	Very dark greyish brown
Fabric:	Sandy (grains prominent)	Earthy	Earthy	Earthy	Earthy
Pedality:	Massive	Massive	Massive	Massive	Massive
pH:	5.1	4.9	5.8	6	6
Horizon:	B21	B1	B21	B21	A2
Depth:	0.3 - 0.4 m	0.2 - 0.8 m	0.4 - 0.8 m	0.6 – 1 m	0.2 - 0.4 m
Texture:	Sandy clay loam	Clay loam, sandy	Sandy clay loam	Clay loam	Sandy loam
Colour:	Red	Yellowish red	Strong brown	Dark red	Dark yellowish brown
Fabric:	Sandy (grains prominent)	Earthy	Earthy	Earthy	Earthy
Pedality:	Massive	Massive	Massive	Massive	Massive
pH:	5	5.2	6	5.5	5.8
Horizon:	B22	B21	B22c	B22	B1
Depth:	0.4 - 0.7 m	0.8 - 1.25 m	0.8 - 1.5 m	1 - 1.6 m	0.4 - 0.6 m
Texture:	Sandy clay loam	Light medium clay	Light clay	Clay loam	Sandy clay loam
Colour:	Dark red	Red	Yellowish red	Dark red	Strong brown
Fabric:	Sandy (grains prominent)	Earthy	Earthy	Earthy	Earthy
Pedality:	Massive	Moderate	Massive	Massive	Massive
pH:	5.4	5.1	5.8	5.5	6
Horizon:	B23	B22	-	-	B2
Depth:	0.7 - 0.9 m	1.25 - 1.4 m	-	-	0.6 - 0.9 m
Texture:	Sandy clay loam	Light clay	-	-	Clay loam

Attribute	Description	Description	Description	Description	Description
Colour:	Dark red	Red	-	-	Yellowish red
Fabric:	Sandy (grains prominent)	Earthy	-	-	Earthy
Pedality:	Massive	Moderate	-	-	Massive
pH:	5	5.4	-	-	5.5

APPENDIX 2

Historical Laboratory Data for SALI Database Kandosols Described in Appendix 1

Source: Wood and Day (1976)

Depth	pH	C.E.C.	E.C.	T.S.S.	Total %			Phos. Ext.	Org. N	Org. C	Bicarb.		Exch. Cations m.eq. %				D.T.P.A.		Total	
(cm)	(1:5)	m.eq. %	µmhos cm⁻¹	%	P	K	S	S(ppm)	%		P	K	Ca	Mg	Na	K	Cu	Zn	Cu	Zn
SANDY RED EARTH																				
0- 10	5.8	6.2	15.8	.006	.015	.10	.0072	.2	.058	2.01	-	35	0.9	1.2	.2	.1	6.2	0.5	23	12
10- 35	5.9	5.0	9.6	.004	.015	.10	.0165	.1	.034	0.75	-	10	0.2	1.3	.1	.1	5.0	0.4	33	13
35-150	5.8	5.0	5.1	.002	.018	.10	.0043	.1	-	-	-	-	0.1	2.0	.1	.1	5.0	0.1	27	21
LOAMY RED EARTH																				
0- 15	6.2	8.0	27.8	.015	.02	.27	.023	.22	.07	1.27	1.2	85	1.9	1.8	.15	.22	1.8	.7	+1	27
15- 50	5.8	6.2	9.4	.004	.018	.30	.014	.8	-	-	-	47	0.2	2.1	.15	.15	.35	.5	60	30
50-150	5.6	5.1	5.9	.002	.017	.37	.01	.6	-	-	4.5	30	0.1	2.5	.2	.1	.15	.6	87	30

APPENDIX 3

Laboratory Results on Representative Test Pit Samples

				pH (1:5 water)		pH (CaCl2)		Acid Neutralising Capacity			ExchangeAcidity		Exchangeable Cations (cmol/kg)				Cation Exchange Capacity (cmol/kg)		ESP		Ca/Mg Ratio		Mg/K Ratio	
Area	**Site**	**Depth**	**Texture**	Value	Rating	Value	Rating	H2SO4	CaCO3	Fizz Rating	Exg. Acidity	Exg. Aluminium	Ca	Mg	K	Na	Value	Rating	Value	Rating	Value	Rating	Value	Rating
STP	**5**	0-50	Silty Gravelly Sand	5.0	Very Strongly Acidic	4.4	Very Strongly Acidic	<0.5	<0.1	0	1	0.8	<0.1	0.5	0.1	<0.1	1.8	Very Low	1.9	Non sodic	<0.1	Mg deficient	14.6	-
STP	**7**	0-50	Sand	5.5	Strongly Acidic	4.5	Very Strongly Acidic	2.4	0.2	0	0.6	0.5	<0.1	0.2	<0.1	<0.1	1.0	Very Low	6.7	Marginally Sodic	<0.1	Mg deficient	-	-
WRTP	**2**	0-50	Gravelly Clay	4.8	Very Strongly Acidic	4.3	Very Strongly Acidic	4.8	0.5	0	1.2	1	1.3	2.7	<0.1	<0.1	5.4	Very Low	0.4	Non sodic	0.5	Ca deficient	-	-
WRTP	**15**	10-20	Sandy Gravel	6.2	Slightly Acidic	5.2	Strongly Acidic	3.6	0.4	0	-	-	0.5	2.6	<0.1	<0.1	3.2	Very Low	0.7	Non sodic	0.2	Ca deficient	-	-
WRTP	**12**	40-50	Clayey Gravel	6.0	Moderately Acidic	5.2	Strongly Acidic	1.9	0.2	0	0.5	<0.1	0.8	0.3	<0.1	<0.1	1.7	Very Low	1.2	Non sodic	2.7	Ca low	-	-
WRTP	**14**	40-60	Clayey Sand	6.0	Moderately Acidic	5.4	Strongly Acidic	3.5	0.4	0	<0.1	<0.1	3.0	0.8	<0.1	<0.1	3.8	Very Low	0.6	Non sodic	3.8	Ca low	-	-
STP	**3**	40-60	Gravelly Sand	5.3	Strongly Acidic	4.3	Very Strongly Acidic	2.1	0.2	0	0.7	0.6	<0.1	0.2	<0.1	<0.1	1.1	Very Low	4.8	Non sodic	<0.1	Mg deficient	-	-
STP	**5**	50-60	Clayey Sand	5.5	Strongly Acidic	4.5	Very Strongly Acidic	3.1	0.3	0	0.6	0.5	<0.1	2.2	0.1	<0.1	3.1	Very Low	1.3	Non sodic	<0.1	Mg deficient	5	-
NTP	**1**	60-80	Sandy Clay	6.7	Neutral	6.0	Moderately Acidic	2.6	0.3	0	<0.1	<0.1	2.3	1.0	0.2	<0.1	3.6	Very Low	0.3	Non sodic	2.3	Ca low	4.8	-
STP	**6**	70-90	Gravelly Sand	5.8	Moderately Acidic	5.3	Strongly Acidic	2.2	0.2	0	<0.1	0.1	<0.1	0.8	<0.1	<0.1	1.0	Very Low	3.3	Non sodic	<0.1	Mg deficient	-	-
WRTP	**4**	80-100	Clayey Gravel	6.3	Slightly Acidic	6.0	Moderately Acidic	0.9	<0.1	0	<0.1	0.1	0.6	0.1	<0.1	<0.1	0.8	Very Low	0.1	Non sodic	6.0	Balanced	-	-
STP	**7**	90-100	Clayey Sand	5.4	Strongly Acidic	4.4	Very Strongly Acidic	0.6	<0.1	0	0.9	0.8	<0.1	0.8	<0.1	<0.1	2.0	Very Low	4.3	Non sodic	<0.1	Mg deficient	-	-
NTP	**5**	150-170	Clayey Gravel	6.2	Slightly Acidic	5.9	Moderately Acidic	4.4	0.4	0	-	-	1.2	2.6	<0.1	<0.1	3.8	Very Low	0.5	Non sodic	0.5	Ca deficient	-	-
NTP	**7**	380-400	Silty Sandy Clay	7.4	Mildly Alkaline	6.7	Neutral	7.6	0.8	0	-	-	7.3	30.2	0.2	0.2	37.9	High	0.5	Non sodic	0.2	Ca deficient	171	-
NTP	**1**	530-540	Silty Clay	6.3	Slightly Acidic	5.4	Strongly Acidic	7.6	0.8	0	-	-	7.8	8.6	0.2	<0.1	16.6	Moderate	0.2	Non sodic	0.9	Ca deficient	41.7	-

				EC (1:5, µS/cm)		Chloride (mg/kg)	Sulfur (mg/kg)	Bicarbonate Exactable K (mg/kg)	Silicon (mg/kg)	Boron (mg/kg)	Extractable Metals				Total Metals (mg/kg)														Mercury (mg/kg)	Hexavalent Chromium (mg/kg)	Total Cyanide (mg/kg)
Area	**Site**	**Depth**	**Texture**	Value	Rating	Value	Value	Value	Value	Value	Cu	Fe	Mn	Zn	As	Ba	Be	B	Cd	Cr	Co	Cu	Pb	Mn	Ni	Se	V	Zn	Value	Value	Value
STP	**5**	0-50	Silty Gravelly Sand	5.0	-	<10	<10	137	5	<0.2	<1.00	2.25	<1.00	<1.00	<5	10	<1	<50	<1	<2	<2	<5	5	7	<2	<5	9	<5	<0.1	<0.5	<1
STP	**7**	0-50	Sand	1.0	-	<10	10	<100	10	<0.2	<1.00	5.55	<1.00	<1.00	<5	<10	<1	<50	<1	<2	<2	<5	<5	<5	<2	<5	<5	<5	<0.1	<0.5	<1
WRTP	**2**	0-50	Gravelly Clay	38.0	-	<10	923	102	7	<0.2	22.2	53.3	3.46	<1.00	12	20	<1	<50	<1	32	7	307	62	41	12	<5	64	14	0.1	<0.5	<1
WRTP	**15**	10-20	Sandy Gravel	3.0	-	<10	33	<100	7	<0.2	<1.00	18.9	5.54	<1.00	5	30	1	<50	<1	102	6	<5	9	94	9	<5	121	<5	<0.1	<0.5	<1
WRTP	**12**	40-50	Clayey Gravel	2.0	-	<10	11	<100	8	<0.2	<1.00	7.58	<1.00	<1.00	8	<10	<1	<50	<1	14	<2	<5	<5	52	<2	<5	40	<5	<0.1	<0.5	<1
WRTP	**14**	40-60	Clayey Sand	5.0	-	<10	39	<100	22	<0.2	<1.00	15	18.4	<1.00	<5	40	<1	<50	<1	33	4	8	6	341	5	<5	65	<5	<0.1	<0.5	<1
STP	**3**	40-60	Gravelly Sand	2.0	-	<10	<10	102	10	<0.2	<1.00	4.41	<1.00	<1.00	<5	<10	<1	<50	<1	<2	<2	<5	<5	<5	<2	<5	<5	<5	<0.1	<0.5	<1
STP	**5**	50-60	Clayey Sand	2.0	-	<10	20	<100	6	<0.2	<1.00	9.23	<1.00	<1.00	<5	10	<1	<50	<1	5	<2	<5	<5	<5	<2	<5	8	<5	<0.1	<0.5	<1
NTP	**1**	60-80	Sandy Clay	4.0	-	<10	<10	188	4	<0.2	<1.00	5.14	<1.00	<1.00	9	20	<1	<50	<1	72	8	10	19	290	6	<5	110	<5	<0.1	1.3	<1
STP	**6**	70-90	Gravelly Sand	2.0	-	<10	<10	<100	6	<0.2	<1.00	2.74	<1.00	<1.00	<5	<10	<1	<50	<1	57	<2	<5	<5	11	<2	<5	22	<5	<0.1	<0.5	<1
WRTP	**4**	80-100	Clayey Gravel	5.0	-	<10	19	<100	6	<0.2	30.5	7.63	<1.00	<1.00	<5	<10	<1	<50	<1	11	4	72	<5	16	5	<5	9	<5	<0.1	<0.5	<1
STP	**7**	90-100	Clayey Sand	4.0	-	<10	<10	105	9	<0.2	<1.00	3.84	<1.00	<1.00	<5	10	<1	<50	<1	8	<2	<5	14	<5	<2	<5	31	<5	<0.1	<0.5	<1
NTP	**5**	150-170	Clayey Gravel	3.0	-	<10	<10	<100	6	<0.2	<1.00	8.42	5.92	<1.00	<5	80	1	<50	<1	21	17	<5	8	1440	15	<5	36	<5	<0.1	<0.5	<1
NTP	**7**	380-400	Silty Sandy Clay	36.0	-	20	11	109	25	<0.2	<1.00	5.2	<1.00	<1.00	<5	370	2	<50	<1	24	68	93	9	1900	50	<5	151	<5	<0.1	<0.5	<1
NTP	**1**	530-540	Silty Clay	3.0	-	<10	<10	161	17	<0.2	<1.00	13.6	22.6	<1.00	16	220	4	<50	<1	40	19	59	<5	2230	71	<5	55	17	<0.1	<0.5	<1

				Phosphorus (mg/kg)			Nitrogen (mg/kg)						Total Carbon (%)		TOC (%)		OM (%)		C:N Ratio		Moisture Content (%)
Area	Site	Depth	Texture	Total Phosphorus	Bicarb. Extrac	Rating	Ammonia	Nitrite	Nitrate	Nitrite & Nitrate (Sol.)	Total Kjeldahl Nitrogen	Total Nitrogen	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value
STP	5	0-50	Silty Gravelly Sand	60	<5	Very Low	<20	<0.1	<0.1	<0.1	430	430	0.13	-	<0.5	Very Low	0.8	-	10.8	-	3.3
STP	7	0-50	Sand	36	<5	Very Low	<20	<0.1	<0.1	<0.1	170	170	0.09	-	<0.5	Very Low	<0.5	-	<0.02	-	1.8
WRTP	2	0-50	Gravelly Clay	58	40	Moderate	<20	<0.1	0.5	0.5	90	90	0.36	-	<0.5	Very Low	0.7	-	44.9	-	10.8
WRTP	15	10-20	Sandy Gravel	221	<5	Very Low	<20	<0.1	<0.1	<0.1	300	300	0.83	-	0.6	Very Low	1	-	19.3	-	5.6
WRTP	12	40-50	Clayey Gravel	135	<5	Very Low	<20	<0.1	<0.1	<0.1	180	180	0.13	-	<0.5	Very Low	0.7	-	22.6	-	6.6
WRTP	14	40-60	Clayey Sand	74	<5	Very Low	<20	<0.1	0.1	0.1	390	390	0.35	-	<0.5	Very Low	0.8	-	11.9	-	9.7
STP	3	40-60	Gravelly Sand	55	<5	Very Low	<20	<0.1	<0.1	<0.1	140	140	0.07	-	<0.5	Very Low	<0.5	-	<0.02	-	3.4
STP	5	50-60	Clayey Sand	60	<5	Very Low	<20	<0.1	<0.1	<0.1	130	130	0.03	-	<0.5	Very Low	<0.5	-	<0.02	-	7.4
NTP	1	60-80	Sandy Clay	85	<5	Very Low	<20	<0.1	<0.1	<0.1	190	190	0.07	-	<0.5	Very Low	<0.5	-	<0.02	-	13.1
STP	6	70-90	Gravelly Sand	67	<5	Very Low	<20	<0.1	<0.1	<0.1	90	90	0.06	-	<0.5	Very Low	<0.5	-	<0.02	-	5
WRTP	4	80-100	Clayey Gravel	73	<5	Very Low	<20	<0.1	<0.1	<0.1	50	50	0.07	-	<0.5	Very Low	<0.5	-	<0.02	-	4.2
STP	7	90-100	Clayey Sand	80	<5	Very Low	<20	<0.1	0.2	0.2	130	130	0.03	-	<0.5	Very Low	<0.5	-	<0.02	-	15.9
NTP	5	150-170	Clayey Gravel	180	<5	Very Low	<20	<0.1	<0.1	<0.1	130	130	0.07	-	<0.5	Very Low	<0.5	-	<0.02	-	9.9
NTP	7	380-400	Silty Sandy Clay	25	<5	Very Low	<20	<0.1	<0.1	<0.1	<20	<20	0.19	-	<0.5	Very Low	<0.5	-	-	-	27.8
NTP	1	530-540	Silty Clay	21	<5	Very Low	<20	<0.1	<0.1	<0.1	40	40	0.05	-	<0.5	Very Low	<0.5	-	<0.02	-	24.5

APPENDIX 4

Volumes of Soil Materials Available and Required for the Growth Medium on the WSF

Kandosol Growth Material Layers by Depth from Surface (cm)	Soil Texture Classification		Approximate Preferred Particle Size Distribution Ranges (%)	Soil Structure	Potential Source		Total Volume (m^3)			Range of Depths By Horizon (m)	Volume of Growth Material Required for WSF By Gradient Option														
											1V:2.5H & 1V:3.5H					1V:2.0H & 1V:3.0H					1V:4H & 1V:6.25H				
	Approximate USGS	NCST (2009) (Preferred, Excl Gravel)			Area	Zone	Zone	Area	Horizon		Surface Area (m^2)			Total Volume of Material Required (m^3)	Surplus/ Deficit (m^3)	Surface Area (m^2)			Total Volume of Material Required (m^3)	Surplus/ Deficit (m^3)	Surface Area (m^2)			Total Volume of Material Required (m^3)	Surplus/ Deficit (m^3)
											WSF (East)	WSF (West)	Total of WSFs			WSF (East)	WSF (West)	Total of WSFs			WSF (East)	WSF (West)	Total of WSFs		
0-20 (A1 horizon) and 20-60 (A2 horizon)	Clayey Silty Sand to Silty Clayey Sand, Non-Plastic	Sandy Loam (SL)	Clay: 8-20 Silt: 2-10 Sand: 71-91	Massive	Borrow Area A	1	100,964	152,001	**193,443**	0.4	273,485	245,885	519,370	**207,748**	-14,305	282,958	252,937	535,895	**214,358**	-20,915	277,922	249,230	527,152	**210,861**	-17,418
						2	11,760																		
						3	14,670																		
						4	9,300																		
						5	14,690																		
		Sandy Clay Loam (SCL)	Clay: 18-33 Silt: 2-8 Sand: 65-82			Stripped	618			0.5				**259,685**	-66,242				**267,948**	-74,505				**263,576**	-70,133
					Borrow Area B	2	34,702	41,441																	
						3	6,739																		
					WSF (East)	B	2,437	No Longer Available																	
						F (Nth)	3,924																		
		Clay Loam, Sandy (CL,S)	Clay: 21-35 Silt: 6-15 Sand: 50-70			H,I,K	2,345			0.6				**311,622**	-118,179				**321,537**	-128,094				**316,291**	-122,848
						K	8,076																		
						I,F (Sth)	1,241																		
						I	6,204																		
						J	4,094																		
60-120 (B21 horizon)	Clayey Sandy Silt to Sandy Clayey Silt, Very Low to Low Plasticity	Clay Loam, Sandy (CL,S)	Clay: 21-35 Silt: 6-15 Sand: 50-70	Massive to Weak	Borrow Area A	1	310,533	1,111,886	**3,154,690**	0.6	273,485	245,885	519,370	**311,622**	2,843,068	282,958	252,937	535,895	**321,537**	2,833,153	277,922	249,230	527,152	**316,291**	2,838,398
						2	346,377																		
						3	32,754																		
						4	125,897																		
						5	283,328			0.7				**363,559**	2,791,131				**375,127**	2,779,563				**369,006**	2,785,683
						Stripped	12,997																		
		Sandy Light Clay (SLC)	Clay: 27-40 Silt: 2-20 Sand: 40-71		Borrow Area B	1	1,553,003	2,042,804																	
						2	486,640																		
						3	3,160																		
					WSF (East)	B	3,389	No Longer Available		0.8				**415,496**	2,739,194				**428,716**	2,725,974				**421,722**	2,732,968
						F (Nth)	7,872																		
						F (Sth)	49,639																		
						I,F (Sth)	26,055																		
120-200 (B22 horizon)	Silty Sandy Clay to Sandy Silty Clay, Low to Medium Plasticity	Sandy Light Clay (SLC)	Clay: 27-40 Silt: 2-20 Sand: 40-71	Weak to Moderate	Borrow Area A	1	331,646	802,532	**802,532**	0.8	273,485	245,885	519,370	415,496	387,036	282,958	252,937	535,895	428,716	373,816	277,922	249,230	527,152	421,722	380,810
						2	319,475																		
						3	79,409																		
						4	68,536			0.9				467,433	335,099				482,306	320,226				474,437	328,095
						Stripped	3,465																		
		Sandy Light Medium Clay (SLMC)	Clay: 40-45 Silt: 2-20 Sand: 35-58		WSF (East)	B	13,301	No Longer Available																	
						F (Nth)	47,665																		
						K	12,114			1.0				519,370	283,162				535,895	266,637				527,152	275,380
						F (Sth)	16,209																		
						I,F (Sth)	26,055																		