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MEMO

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FROM:	Adam Pratt	PROJECT TITLE:	MARDIE SOP PROJECT	
DATE:	29 April 2019	PROJECT & DOCUMENT NO:	BCI-001-1-1	001
SUBJECT:	Summary of Laboratory Results			

1 INTRODUCTION

This memo provides a summary of the laboratory results obtained by Soilwater Water Analysis (SWA) for the samples collected during the recent geotechnical drilling program. The results presented in this memo form the basis for the unsaturated zone modelling undertaken by Soilwater Consultants (SWC). Samples were collected by CMW Geosciences personnel and supplied to SWA. All samples were collected from the surface 0.5 m of the soil profile, within the Disturbance Footprint (DF) of the proposed Evaporation Ponds. As this work was targeting the finer textured soils that will likely form the clay liner for the Evaporation Ponds, no samples were collected from the deeper sediments, including the gravelly sediments that contain the isolated and confined groundwater within the Supratidal Flats.

Two types of samples were collected for analysis:

- Intact U_{50} cores – hydraulically driven into the surface 0.5 m of the mudflats by the drill rig
- Bulk samples – collected by hand digging using a shovel

All samples were sealed to prevent moisture loss and packed for storage and transport.

2 ANALYSIS RESULTS

2.1 PHYSICAL PROPERTIES

Based on the morphological properties (i.e. colour, hand texture, consistence; conducted in accordance with McDonald et al. 1998[1]) the following five soil or material types were identified:

- Clay (C)
- Red Brown Loam (RBL)
- Dark Red Brown Clay Loam (DRBCL)
- Yellow Orange Loam (YOL)
- Clay Loam (CL)

[1] McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1998). *Australian Soil and Land Survey Field Handbook* (2nd Ed.). CSIRO Land and Water, Canberra, Australia.

The analysis results for the five soil types occurring within the proposed footprint of the Evaporation Ponds are provided in Table 3.

2.1.1 Particle Size Distribution

2.1.1.1 Sand Fractionation

A total of 25 soil samples underwent sieve analysis (5 samples per soil type), with the results presented in Table 1 and Figure 1. For all soils tested < 1% was > 2 mm, highlighting the absence of gravel in these materials. For all soils, the sand fraction is generally well graded between 600 - 150 µm, and 38 – 64 % of the particles are < 75 µm; emphasising the fine texture of all soils within the proposed Evaporation Ponds.

Table 1: Sand fractionation results for the five soil types

Soil Type	% Passing (all sieve sizes in mm)								
	Sieve	2	1.18	0.6	0.425	0.3	0.2	0.15	0.075
Clay	Min	99.25	93.64	83.56	40.49	40.07	38.33	34.78	30.10
	Max	99.91	98.53	96.09	94.28	91.26	87.83	82.64	75.60
	Mean	**99.65**	**97.02**	**91.50**	**77.93**	**67.73**	**60.81**	**53.89**	**46.47**
	Median	99.68	97.73	91.89	88.33	70.09	52.22	45.47	34.99
	Std Dev	0.25	1.99	4.86	21.74	20.58	20.45	21.35	20.50
Dark Red Brown Clay Loam	Min	99.92	95.52	93.21	74.95	62.26	44.56	39.13	32.79
	Max	99.76	93.96	70.54	43.83	41.50	39.67	37.15	32.81
	Mean	**99.94**	**98.69**	**97.17**	**88.22**	**75.93**	**63.15**	**49.24**	**42.58**
	Median	99.78	98.97	97.49	95.42	81.44	67.19	64.00	58.07
	Std Dev	99.65	98.26	96.99	96.18	87.66	83.55	41.23	36.11
Clay Loam	Min	99.52	97.77	86.79	72.22	60.87	48.37	43.87	35.80
	Max	99.90	98.88	96.95	87.39	82.25	72.19	57.99	50.63
	Mean	**99.75**	**98.33**	**93.04**	**81.39**	**71.12**	**60.61**	**50.18**	**42.26**
	Median	99.77	98.22	94.56	82.90	70.96	62.69	48.95	42.89
	Std Dev	0.16	0.48	4.00	5.93	7.64	9.01	5.42	5.56
Red Brown Loam	Min	99.61	96.12	88.06	62.47	59.39	53.61	49.83	30.89
	Max	99.85	96.12	84.79	58.07	50.85	45.37	38.27	34.34
	Mean	**99.13**	**96.37**	**90.13**	**85.32**	**77.99**	**74.26**	**70.19**	**63.51**
	Median	99.88	98.00	95.43	93.80	80.32	65.34	61.86	56.43
	Std Dev	99.55	97.02	89.97	75.42	69.26	55.45	52.36	41.23
Yellow Orange Loam	Min	98.65	95.69	81.59	44.23	43.59	42.28	26.95	22.59
	Max	99.90	98.42	96.26	94.29	91.18	88.03	84.64	70.84
	Mean	**99.35**	**96.97**	**88.69**	**70.61**	**59.58**	**54.34**	**45.87**	**38.09**
	Median	99.23	97.25	88.56	71.69	53.69	47.89	39.29	31.17
	Std Dev	0.55	1.10	5.75	20.16	17.74	17.74	21.45	18.15

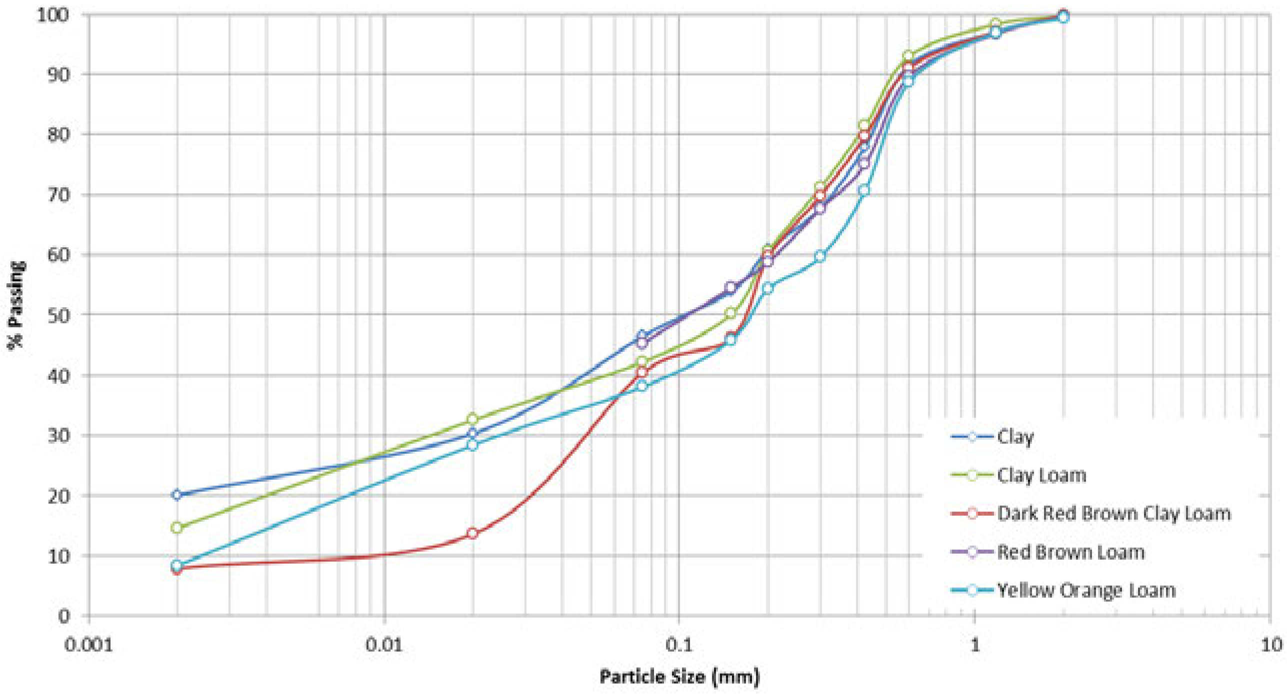


Figure 1: Particle size distribution (PSD) curves for all five soil types

2.1.1.2 Pipette Analysis

A total of 25 soil samples underwent pipette analysis (5 samples per soil type), with the results presented in Table 2 and Figure 1. The results highlight the dominance of the silt + clay fraction for all soil types, with the silt + clay fraction varying from 18 % for the 'coarser-textured' Yellow Orange Loam, to 36 % for the 'finer-textured' Clay.

Table 2: Pipette analysis results

Soil Type	Statistic	% Sand	% Silt	% Clay	Texture
Clay	Min	44.40	5.00	12.00	
	Max	77.50	37.40	28.40	
	Mean	**63.81**	**16.12**	**20.12**	Loam
	Median	68.60	12.80	18.20	Loam
	Std Dev	13.28	12.46	7.04	
Clay Loam	Min	72.80	5.20	11.80	
	Max	78.60	12.40	16.20	
	Mean	**75.62**	**9.66**	**14.64**	Sandy Loam
	Median	75.80	10.70	15.00	Sandy Loam
	Std Dev	2.21	2.91	1.73	
Dark Red Brown Clay Loam	Min	55.00	19.20	2.80	
	Max	78.00	33.40	16.90	
	Mean	**65.26**	**26.84**	**7.90**	Silty Loam
	Median	65.00	27.80	5.40	Silty Loam
	Std Dev	8.43	6.30	6.18	
Red Brown Loam	Min	68.80	5.40	2.40	

	Max	87.40	26.00	16.70	
	Mean	**78.32**	**14.66**	**7.02**	Loamy Sand
	Median	77.20	14.20	5.20	Loamy Sand
	Std Dev	7.29	8.26	5.70	
Yellow Orange Loam	Min	74.60	3.60	2.80	
	Max	88.60	17.00	13.90	
	Mean	**81.92**	**9.66**	**8.42**	Loamy Sand
	Median	82.80	9.80	6.80	Loamy Sand
	Std Dev	5.10	5.11	5.07	

2.1.2 Bulk Density and Field Moisture Content

A total of 35 intact soil (U50) cores were collected in the field and analysed for bulk density and field moisture, with the results presented in Table 3. As expected the bulk density varies with soil texture, such that the Clay soils had the lowest bulk density of 1.13 g/cm^3, and the Yellow Orange Loam soils had the highest bulk density of 1.53 g/cm^3.

When the *in situ* bulk densities are compared with the MBDD values presented in Section 2.1.7, it can be seen that the *in situ* soils are around 72 – 81 % of their corresponding MBDD, with field moisture contents between 7 and 33 % higher than their OMC for compaction; hence all soils will likely need to be dried prior to conditioning and compaction in order to achieve the required MBDD.

When the *in situ* moisture contents are compared with the water retention results presented in Section 2.1.6, it can be seen that the more clayey soils (i.e. Clay and Clay Loam) have matric potentials between 10 and 33 kPa (i.e. close to field capacity), whilst the coarser textured soils (Dark Red Brown Clay Loam, Red Brown Loam and Yellow Orange Loam) are drier and have matric potentials at or below 100 kPa.

Table 3: Bulk density and field moisture content of the as-received samples

Soil Type	Statistic	Bulk Density (g/cm^3)	Field Moisture Content	
			(%; g/g)	(%; v/v)
Clay	Min	0.84	20.52	20.05
	Max	1.48	39.49	45.85
	Mean	**1.13**	**27.42**	**30.85**
	Median	1.14	23.92	30.41
	Std Dev	0.21	7.45	9.47
Clay Loam	Min	0.97	10.87	16.66
	Max	1.53	39.69	45.45
	Mean	**1.20**	**27.57**	**31.54**
	Median	1.20	30.40	31.67
	Std Dev	0.21	10.88	10.47
Dark Red Brown Clay Loam	Min	1.08	5.72	7.48
	Max	1.61	32.45	35.99
	Mean	**1.30**	**19.89**	**24.93**
	Median	1.25	19.42	27.76
	Std Dev	0.21	9.41	9.83

Red Brown Loam	Min	1.14	4.80	7.82
	Max	1.63	37.86	43.30
	Mean	**1.43**	**21.01**	**28.53**
	Median	1.48	19.50	28.42
	Std Dev	0.17	10.28	10.91
Yellow Orange Loam	Min	1.26	8.27	12.77
	Max	1.71	29.77	37.52
	Mean	**1.53**	**17.12**	**25.51**
	Median	1.55	16.23	25.78
	Std Dev	0.15	7.00	7.88

2.1.3 PARTICLE DENSITY

A total of 25 soil samples were analysed for particle density (5 samples per soil type), with the results presented in Table 4. The increase in particle density with soil type, or more specifically quartz or sand content, is clear, with the more clayey soils having particle density values between 2.13 and 2.21 g/cm^3, reflecting the dominance of clay minerals, whilst the coarser-textured loamy soils have particle densities between 2.47 – 2.50 g/cm^3, reflecting the greater abundance of quartz.

Table 4: Particle density results

Soil Type	Particle Density (g/cm3)				
	Min	Max	**Mean**	Median	Std Dev
Clay	2.03	2.28	**2.13**	2.12	0.10
Clay Loam	2.08	2.38	**2.21**	2.16	0.13
Dark Red Brown Clay Loam	1.86	2.46	**2.26**	2.32	0.21
Red Brown Loam	2.09	2.66	**2.47**	2.49	0.23
Yellow Orange Loam	2.30	2.66	**2.50**	2.58	0.16

2.1.4 TOTAL POROSITY

Based on the average bulk density results presented in Table 3 and the average particle density results in Table 4, the total porosity of the five soil types are presented in Table 5. The results show that the more clayey textured soils have total porosity values between 46-47 %, whilst the coarser loamy soils have total porosities between 39 and 42 %.

Table 5: Average total porosity of the five soil types

Soil Type	Bulk Density (g/cm^3)	Particle Density (g/cm^3)	Total Porosity (%)*
Clay	1.13	2.13	47
Clay Loam	1.20	2.21	46
Dark Red Brown Clay Loam	1.30	2.26	42
Red Brown Loam	1.43	2.47	42
Yellow Orange Loam	1.53	2.50	39

*Note: the total porosity values presented in this table vary from the 0 kPa values presented in A total of 25 soil samples were analysed for water retention properties (5 samples per soil type), with the results presented in Table 7 and Figure 2, whilst the derived van Genuchten parameters are provided in Table 8: Derived van Genuchten parameters for the five soil types.

As can be seen in Figure 2, the Soil Water Characteristic Curves (SWCC's) for all soils within the proposed footprint of the Evaporation Ponds are very similar and are characteristic of clayey soils. All soils have very low macro- and meso-porosities (i.e. the difference in moisture content between the 0 kPa and 10 kPa values), and thus the drainable porosity of these materials is between 3 – 9 %. At field capacity (i.e. 10 kPa), the moisture content of the soils will still remain between 32 – 36 % (v/v), and thus any seepage that occurs below the evaporation ponds will quickly saturate the soils.

Table 7 due to average bulk density and particle density values being used.

2.1.5 SATURATED HYDRAULIC CONDUCTIVITY

The saturated hydraulic conductivity of the five soil types occurring in the proposed Evaporation Pond footprint are presented in Table 6. The results show that all soils have inherently low saturated permeabilities varying from 1.3×10^{-3} m/day to 4.8×10^{-2} m/day (or 5.5×10^{-7} m/s to 1.5×10^{-8} m/s).

As can be seen in Figure 3, the hydraulic conductivity of the five soil types decreases significantly as the soils become unsaturated, such that at field capacity (10 kPa) the permeability of the soils drop to 7.2×10^{-4} m/day to 3.5×10^{-2} m/day (or 8.3×10^{-9} m/s to 4.1×10^{-7} m/s), whilst at the moisture contents reported at the time of sampling the unsaturated permeability of the soils has dropped to 1.1×10^{-5} m/day to 3.1×10^{-2} m/day (or 1.2×10^{-10} m/s to 3.6×10^{-7} m/s). It can be seen in Table 6 that the coarser textured clay loam soils, at their current field moisture content, all have permeabilities at or below the DoW Clay Liner guideline of 10^{-9} m/s.

Table 6: Saturated hydraulic conductivity of the five soil types

Soil Type	Saturated Hydraulic Conductivity		Hydraulic Conductivity at Field Capacity		Hydraulic Conductivity at Field Moisture	
	(m/day)	(m/s)	(m/day)	(m/s)	(m/day)	(m/s)
Clay	1.6×10^{-3}	1.8×10^{-8}	1.4×10^{-3}	1.6×10^{-8}	1.3×10^{-3}	1.5×10^{-8}
Clay Loam	4.8×10^{-2}	5.5×10^{-7}	3.5×10^{-2}	4.1×10^{-7}	3.1×10^{-2}	3.6×10^{-7}
Dark Red Brown Clay Loam	5.1×10^{-3}	5.9×10^{-8}	4.4×10^{-3}	5.1×10^{-8}	2.6×10^{-4}	3.0×10^{-9}
Red Brown Loam	1.3×10^{-3}	1.5×10^{-8}	7.2×10^{-4}	8.3×10^{-9}	1.1×10^{-5}	1.2×10^{-10}
Yellow Orange Loam	1.9×10^{-2}	2.2×10^{-7}	5.6×10^{-3}	6.4×10^{-8}	4.1×10^{-5}	4.8×10^{-10}

2.1.6 WATER RETENTION PRPOPERTIES

A total of 25 soil samples were analysed for water retention properties (5 samples per soil type), with the results presented in Table 7 and Figure 2, whilst the derived van Genuchten parameters are provided in Table 8: Derived van Genuchten parameters for the five soil types.

As can be seen in Figure 2, the Soil Water Characteristic Curves (SWCC's) for all soils within the proposed footprint of the Evaporation Ponds are very similar and are characteristic of clayey soils. All soils have very low macro- and meso-porosities (i.e. the difference in moisture content between the 0 kPa and 10 kPa values), and thus the drainable porosity of these materials is between 3 – 9 %. At field capacity (i.e. 10 kPa), the moisture content of the soils will still remain between 32 – 36 % (v/v), and thus any seepage that occurs below the evaporation ponds will quickly saturate the soils.

Table 7: Water retention properties of the five soil types

Soil Type	Statistic	Volumetric Water Content (%; v,v)					PAWC (%)	Drainable Porosity (%)
		0 kPa	10 kPa	33 kPa	100 kPa	1,500 kPa		
Clay	Min	35.3	32.0	23.0	21.0	15.0	4.0	1.8
	Max	41.8	40.0	31.0	31.0	21.0	12.0	3.5
	Mean	**38.6**	**35.6**	**27.2**	**24.8**	**18.8**	**8.4**	**3.0**
	Median	39.5	36.0	27.0	24.0	19.0	9.0	3.3
	Std Dev	3.2	3.6	3.0	4.0	2.3	3.4	0.7
Clay Loam	Min	36.0	33.0	19.0	17.0	8.0	11.0	1.7
	Max	41.7	40.0	33.0	28.0	18.0	15.0	5.0
	Mean	**38.7**	**35.8**	**27.4**	**23.0**	**13.4**	**14.0**	**2.9**
	Median	38.2	35.0	29.0	22.0	14.0	15.0	2.6
	Std Dev	2.2	2.6	5.5	4.9	4.0	1.7	1.3
Dark Red Brown Clay Loam	Min	29.2	26.0	20.0	18.0	10.0	4.0	3.2
	Max	41.0	36.0	29.0	22.0	18.0	13.0	5.0
	Mean	**36.3**	**32.2**	**24.2**	**20.2**	**14.2**	**10.0**	**4.1**
	Median	37.4	34.0	23.0	20.0	16.0	11.0	3.9
	Std Dev	4.4	3.9	3.4	1.8	3.5	3.5	0.9
Red Brown Loam	Min	41.0	29.6	19.9	18.9	12.1	7.8	4.8
	Max	46.1	40.0	32.0	30.0	19.2	13.0	12.1
	Mean	**43.1**	**36.5**	**28.0**	**25.2**	**16.7**	**11.2**	**6.7**
	Median	42.7	37.2	29.9	27.5	18.3	11.5	5.5
	Std Dev	2.0	4.2	4.7	4.6	3.1	2.1	3.1
Yellow Orange Loam	Min	41.0	30.0	22.0	16.0	9.0	12.0	5.4
	Max	46.0	38.0	35.3	30.3	18.0	19.5	14.0
	Mean	**43.5**	**34.2**	**27.7**	**22.3**	**12.4**	**15.4**	**9.2**
	Median	43.9	34.1	24.0	19.3	10.0	15.0	9.0
	Std Dev	1.9	3.3	6.8	6.4	4.2	3.0	3.1

Table 8: Derived van Genuchten parameters for the five soil types

Soil Type	Van Genuchten Parameters			
	θr (m^3/m^3)	θs (m^3/m^3)	α (1/m)	n
Clay	0.180	0.389	0.0086	1.597
Clay Loam	0.090	0.390	0.0074	1.402
Dark Red Brown Clay Loam	0.129	0.364	0.0090	1.568
Red Brown Loam	0.121	0.432	0.0163	1.337
Yellow Orange Loam	0	0.434	0.024	1.212

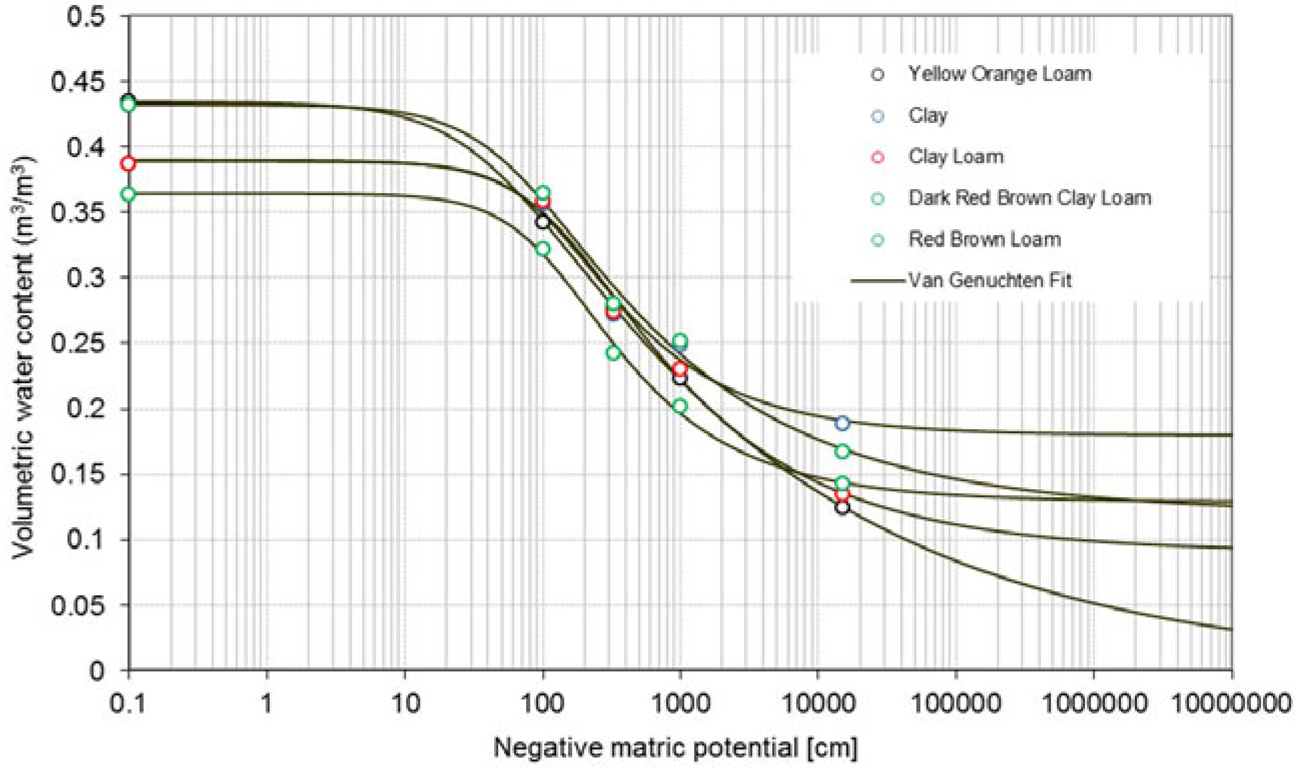
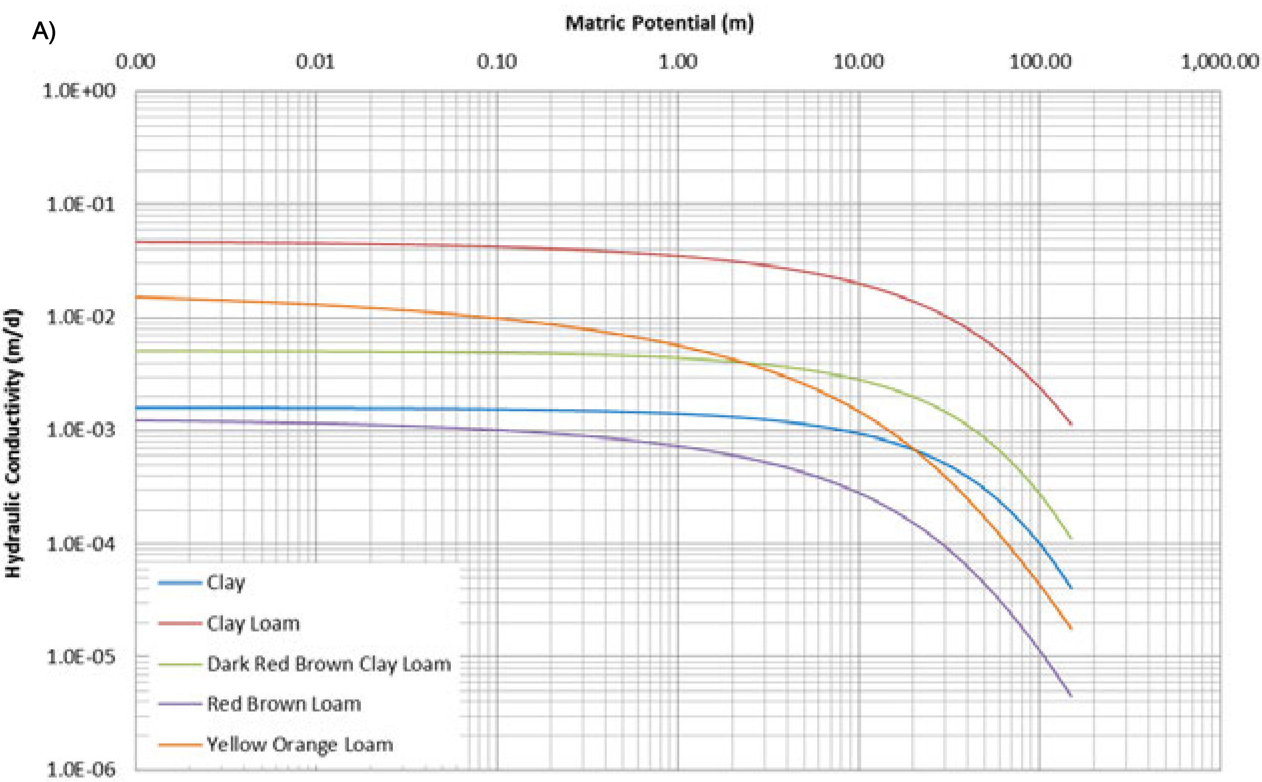


Figure 2: Soil water characteristic curve (SWCC) for the five soil types

A)



B)

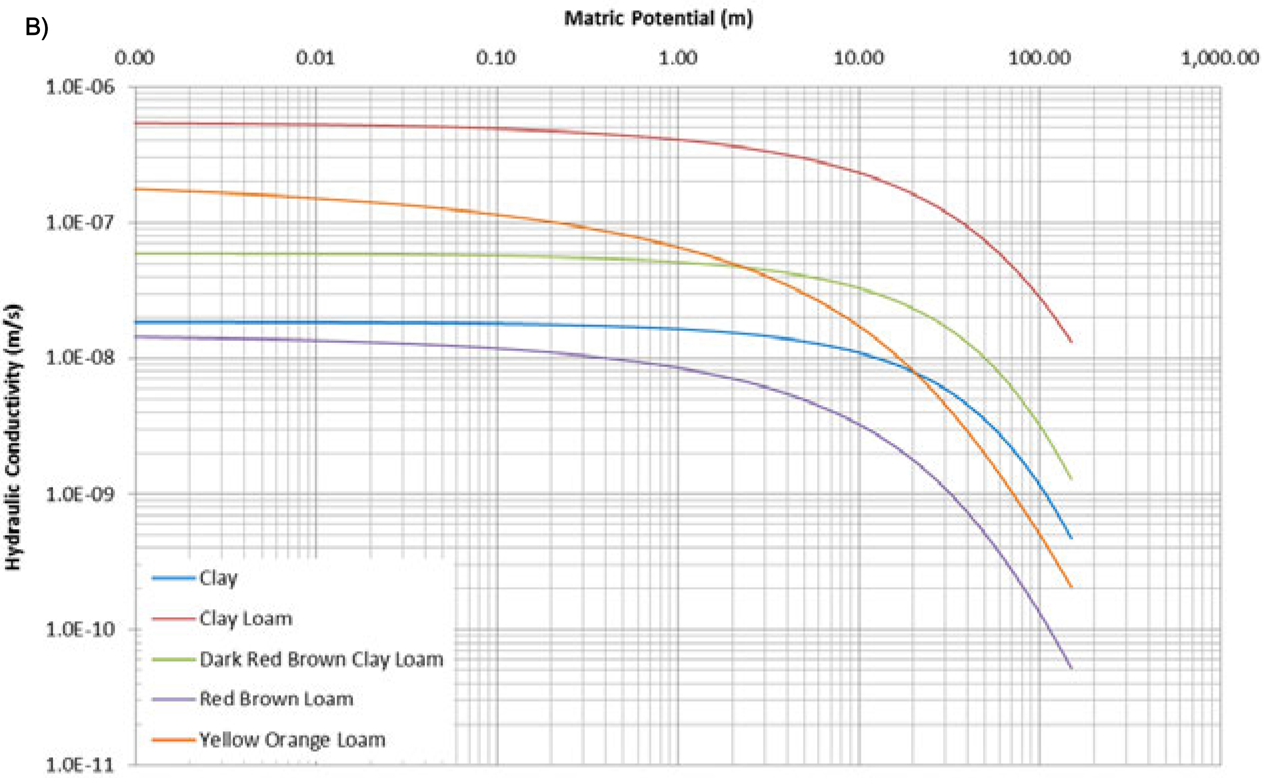


Figure 3: Hydraulic Conductivity Function (HCF) for the five soil types expressed in A) m/d and B) m/s

2.1.7 Maximum Bulk Dry Density (MBDD)

The Maximum Bulk Dry Density (MBDD) of the five soil types was determined using the standard compaction method (Mould A), with the results presented in Table 9 and Figure 4. The results show how the MBDD and OMC changes with texture, with the clayey soils (i.e. Clay and Clay Loam) having a MBDD between 1.57 and 1.61 t/m^3, at an OMC of 20.5 – 20.6 % (g/g), while the coarser textured materials have higher MBDD, between 1.77 – 1.88 t/m3, at a lower OMC (14-18 %; g/g).

Table 9: MBDD results for the five soil types

Soil Material	MBDD (g/cm^3)	OMC (%; g/g)
Clay	1.57	20.6
Clay Loam	1.61	20.5
Dark Red Brown Clay Loam	1.68	18.6
Red Brown Loam	1.77	18.0
Yellow Orange Loam	1.88	13.8

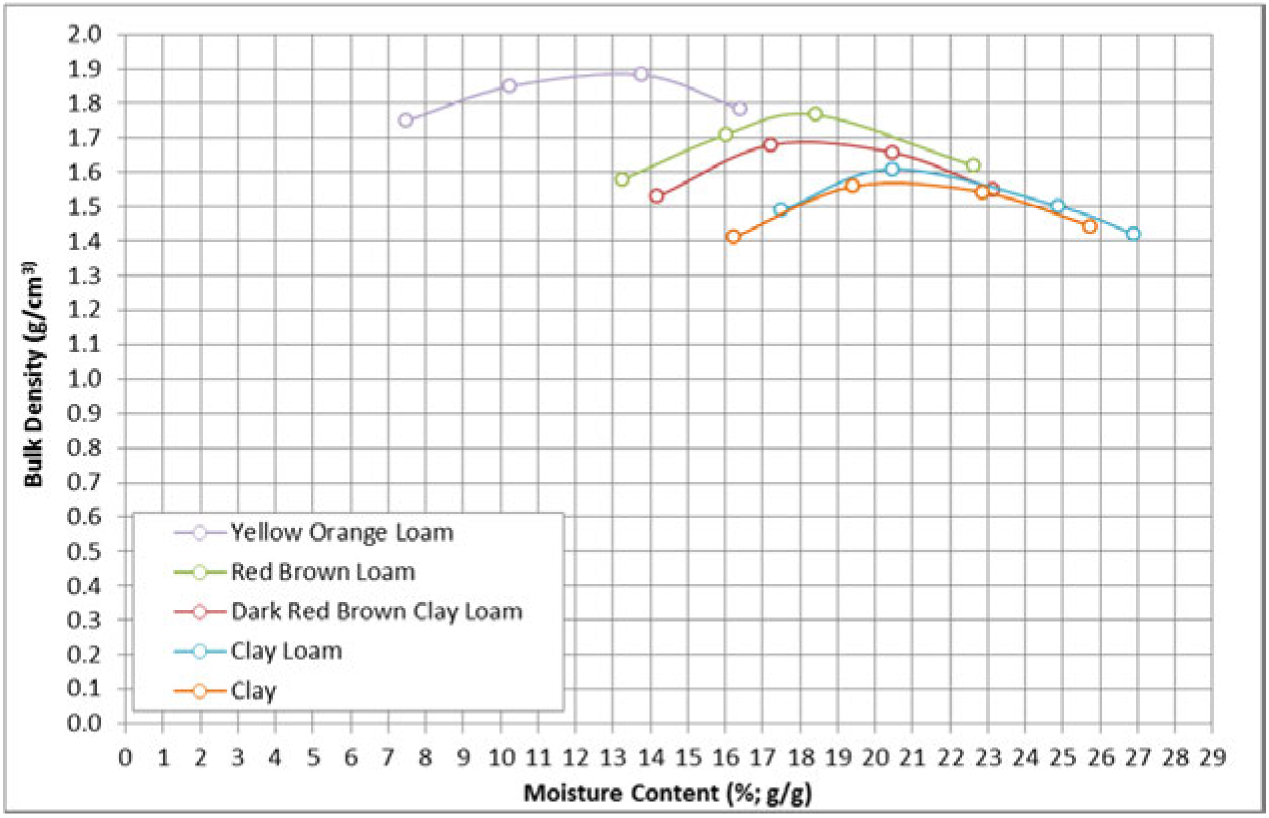


Figure 4: MBDD and OMC for the five soil types

2.1.8 Clay Liner Permeability

The suitability of the five soil types to be used as a clay liner was tested by compacting each material to 95 % MBDD and measuring the permeability under a 1 m pressure head, in accordance with the DoW (2013) Clay Liner Guideline. The saturated permeability results are presented in Table 10. The results show that all soil materials, compacted to 95 % MBDD will meet the DoW Clay Liner Guideline, with permeability values < 10^{-9} m/s.

Table 10: Clay liner permeability of the five soil types

Soil Type	Bulk Density (g/cm^3) (95 % MBDD)	Saturated Hydraulic Conductivity (at 95 % MBDD)	
		(m/day)	(m/s)
Clay	1.49	3.99×10^{-5}	4.62×10^{-10}
Clay Loam	1.53	8.81×10^{-6}	1.02×10^{-10}
Dark Red Brown Clay Loam	1.60	8.50×10^{-5}	9.84×10^{-10}
Red Brown Loam	1.68	1.16×10^{-5}	1.34×10^{-10}
Yellow Orange Loam	1.79	8.64×10^{-5}	1.00×10^{-9}

2.2 CHEMICAL PROPERTIES

A total of 19 soil samples (5 Clay samples, 3 Clay Loam samples, 3 Dark Red Brown Clay Loam, 5 Red Brown Loam samples and 3 Yellow Orange Loam samples) were analysed at CSBP Laboratories for the following chemical properties:

- pH and Electrical Conductivity (EC)
- Major nutrients (mineralised N, colwell P and K, and Extractable S)
- Exchangeable cations (Ca, Mg, Na, K)

The results of the above chemical analysis are presented in Sections 2.2.1 to 2.2.3.

2.2.1 Basic Chemical Properties

The pH and EC of the five soil types is provided in Table 11. All soils are classified as moderately alkaline, reflecting the presence of gypsum, and are highly – extremely saline, with the majority of the soils having EC values > 1,000 mS/m.

Table 11: Basic chemical properties for the five soil types

Soil Type	Statistic	pH (H2O)	pH (CaCl2)	EC (mS/m)
Clay	Min	8.1	7.8	1,600
	Max	8.9	8.6	4,420
	Mean	**8.58**	**8.3**	**2,710**
	Median	8.7	8.4	2,038
	Std Dev	0.30	0.32	1,268
Clay Loam	Min	8.6	8.2	728.7
	Max	8.9	8.7	1,732
	Mean	**8.8**	**8.5**	**1,189**
	Median	8.9	8.6	1,106
	Std Dev	0.17	0.26	507
Dark Red Brown Clay Loam	Min	8.2	7.7	485
	Max	8.7	8.2	596
	Mean	**8.47**	**7.97**	**548**
	Median	8.5	8	562
	Std Dev	0.25	0.25	56.66
Red Brown Loam	Min	8	7.6	53
	Max	8.9	8.1	3,930
	Mean	**8.4**	**7.86**	**1,341**
	Median	8.3	7.9	562
	Std Dev	0.33	0.18	1,569
Yellow Orange Loam	Min	7.9	7.6	645
	Max	8.7	8.3	3,950
	Mean	**8.4**	**8.07**	**1,747**
	Median	8.6	8.3	646
	Std Dev	0.44	0.40	1,908

2.2.2 Nutrients

The major nutrient content of the five soil types is provided in Table 12. All soils are considered to have very low mineralised N and plant available (Colwell) P levels, whilst they all have very high Colwell K and Extractable S levels. All soils also have very low Organic C contents.

Table 12: Major nutrient content of the five soil types

Soil Type	Statistic	NH4-N	NO3-N	Colwell P	Colwell K	Ext. S	Organic C
				mg/kg			%
Clay	Min	<1	<1	19	1,074	1,750	0.54
	Max	17	2	34	2,206	14,100	1.1
	Mean	**5.1**	**0.8**	**24.4**	**1,570**	**7,104**	**0.91**
	Median	3	<1	22	1,402	5,800	0.97
	Std Dev	6.73	0.67	6.19	467	4,656	0.22
Clay Loam	Min	2	<1	14	1,059	1,400	0.37
	Max	2	2	25	1,365	2,350	0.73
	Mean	**2**	**1**	**20.33**	**1,255**	**1,843**	**0.56**
	Median	2	<1	22	1,340	1,780	0.57
	Std Dev	0	0.87	5.69	170	478	0.18
Dark Red Brown Clay Loam	Min	1	<1	13	972	459.3	0.22
	Max	3	<1	15	1,166	725	0.34
	Mean	**2**	**<1**	**14.33**	**1,078**	**622**	**0.29**
	Median	2	<1	15	1,097	680	0.32
	Std Dev	1	0	1.15	98.3	142	0.06
Red Brown Loam	Min	1	<1	6	188	52	0.11
	Max	2	2	19	1,604	2001	0.63
	Mean	**1.2**	**1**	**11.2**	**1,030**	**908**	**0.31**
	Median	1	1	11	1,056	650.2	0.21
	Std Dev	0.45	0.61	4.82	525	744	0.21
Yellow Orange Loam	Min	<1	<1	19	776	241	0.33
	Max	5	27	23	2,200	2,500	0.99
	Mean	**2.5**	**9.83**	**20.33**	**1,260**	**1,200**	**0.66**
	Median	2	2	19	805	858	0.67
	Std Dev	2.29	14.89	2.31	814	1,167	0.33

2.2.3 Exchangeable Cations, CEC and Sodicity

The exchangeable cation, Cation Exchange Capacity (CEC) and Sodicity (ESP) content of the five soil types is provided in Table 13. The exchange complex of all soils is generally dominated by Ca, due to the presence of gypsum, but all classified as highly sodic, with ESP values between 10 and 20 %.

The CEC for all soils is very high, indicating that whilst kaolinite is likely to be the major clay mineral present, there is also likely to be reactive illite and smectite in all soils; hence they will exhibit appreciable shrink-swell properties in response to alternating wet / dry periods.

Table 13: Exchangeable cations, CEC and Sodicity of the five soil types

Soil Type	Statistic	Exchangeable Cations (meq/100g)				CEC	ESP
		Ca	Mg	Na	K	meq/100q	%
Clay	Min	12.88	6.03	3.1	0.64	26.54	3.62
	Max	142.59	8.66	11.15	1.84	156.02	20.54
	Mean	**56.75**	**7.41**	**6.63**	**1.09**	**71.88**	**11.85**
	Median	42.77	7.37	5.65	0.98	52.54	14.06
	Std Dev	51.01	1.02	3.45	0.46	50.71	6.97
Clay Loam	Min	10.58	7.9	2.18	0.61	22.04	9.89
	Max	16.67	11.2	3.42	1.4	28.98	12.85
	Mean	**12.62**	**9.16**	**2.97**	**1.13**	**25.88**	**11.39**
	Median	10.6	8.39	3.31	1.38	26.62	11.42
	Std Dev	3.51	1.78	0.69	0.45	3.53	1.48
Dark Red Brown Clay Loam	Min	1.95	5.05	2.76	1.21	11.59	15.78
	Max	6.63	7.26	3.38	1.4	17.74	29.16
	Mean	**4.71**	**6.41**	**2.98**	**1.32**	**15.42**	**20.42**
	Median	5.56	6.91	2.8	1.34	16.92	16.31
	Std Dev	2.45	1.19	0.35	0.10	3.34	7.58
Red Brown Loam	Min	3.02	1.51	0.13	0.19	4.85	2.68
	Max	10.59	7.22	4.42	1.39	21.96	22.87
	Mean	**8.57**	**5.24**	**2.92**	**1.03**	**17.76**	**14.45**
	Median	10.18	5.83	3.21	1.35	21.24	14.71
	Std Dev	3.19	2.20	1.64	0.53	7.28	7.38
Yellow Orange Loam	Min	4.61	3.51	1.15	0.78	10.05	10.28
	Max	10.65	7.72	9.67	0.95	28.29	34.18
	Mean	**8.40**	**5.78**	**4.28**	**0.84**	**19.3**	**18.63**
	Median	9.95	6.12	2.01	0.78	19.56	11.44
	Std Dev	3.30	2.13	4.69	0.10	9.12	13.48

3 CONCLUSIONS

Given the nature of the deposition events that have created the Supratidal Flats, it is unlikely that the five soil types tested in this report can be separated in the field, and all 'fine textured' soils (i.e. as opposed to the gravel and sand layers that also occur in the Supratidal Flats) should, and can be, homogenised together to form the construction material for the Evaporation Ponds clay liner.

The testing reported in this document confirms that all five soil types meet the DoW Clay Liner permeability rate (i.e. 10^{-9} m/s); however, the likely presence of illite and smectite in the clay mineral fraction, and the high sodicity of the materials is likely to result in them being reactive and potentially unstable if they experience significant fluctuations in soil moisture content. Although this is the case, the stability of the fine-textured sediments can be improved by keeping them 'wet', as will occur for the clay liner, and through the use of the calcarenite to effectively rock-amour the downstream wall of the Evaporation Pond embankment.

Should you have any queries regarding this report, please do not hesitate to contact us.

Yours sincerely,

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