Appendix H

Derivation of Design Parameters

Contents

This appendix outlines the assumptions made in the allocation of design parameters discussed in text within the main report. These parameters have been derived from the results of field investigations and laboratory testing.

Materials encountered during the investigation were generally comprised of fine to medium sand underlain by alluvial gravel deposits. Between these deposits are layers of silt, clay and peat.

Materials within this report have been separated by both material type, based on the interpretation completed by Site Investigations Ltd, and lateral distribution.

Materials have been separated into the following groups:

- SILT/CLAY/PEAT,
- silty SAND,
- fine to medium SAND, and
- gravely SAND/sandy GRAVEL.

The peak internal angle of friction (ϕ'_{peak}) for these materials was derived directly from empirical relationships between cone tip resistance (q_c) from CPT tests. Indirect correlations were made by conversion to equivalent SPT values, comparison of laboratory gradings and Atterberg Limits. Results of these methods were compared.

The suggested design values are given in Table H2-1. These values have been taken from the CIRIA and plasticity index methods.

Bulk densities (dry and saturated) were derived from Carter & Bentley (1991) and were compared with other published values.

Permeability (k) values for the fine to medium sand deposits are based on the D_{60}/D_{10} results from the grading test (CIRIA C515). Other permeability values were derived from Carter & Bentley (1991) based on the likely particle size distribution.

Young's Modulus (E_{25}), representing 25% of failure stress, was calculated from cone tip resistance (q_c) for these materials (Meigh, 1987). General equations of E_{25} with depth are shown in Table H2-1. These are guidelines only and should not be used for detailed design of structures.

The active (Ka) and passive (Kp) earth pressures were derived from CIRIA C580. The values given represent the horizontal component of the coefficient of earth pressure. In the evaluation of these parameters a vertical face was assumed with the slope behind the face horizontal (β=0) and that δ/ϕ=0.67.

Table H2-1 – Suggested Design Parameters

Area	Deposit	Thickness	Depth Below Ground Level (m)	Material Type	c	ϕ'_{peak}	ϕ_{peak}	Bulk Density (kg/m^3) – Est.	Dry Density (kg/m^3) – Est.	Permeability k (m/s) – Est.	Young's Modulus (E_{25}) (MN/m^2) – from CPT	Ka/Kp – Est.
Alluvial Plain	Alluvial Overbank Deposits (sya)	1.5 – >10	0 – 12	Fine to medium SAND	0	-	36°	1900	1700	1.5×10^{-4} – 5.0×10^{-5}	E_{25} = 18	0.4/6.5
				Silty SAND	0	-	32°	1700	1400	1.0×10^{-5} – 1.0×10^{-6}	E_{25} = 8	0.4/5.6
				SILT	0	30°	-	1700	1400	1.0×10^{-8} – 1.0×10^{-7}	E_{25} = 2	0.4/5.2
	Coastal Swamp and Lagoonal Deposits (cp)	0.5 – 1.0	2.2 – 2.8	CLAY	0	28°	-	1800	1300		E_{25} = 1	NA
	Fluvial Channel Deposits (syg)	Not determined	3.5 – 13.0	Sandy GRAVEL	0	-	38°	2000	1800	1.0×10^{-3} – 1.0×10^{-5}	E_{25} = 40	NA
High Dunes	Dune and Beach Sand Deposits (cp)	Various	0 – 7.5	Fine to medium SAND	0	-	36°	1800	1600	1.5×10^{-4} – 5.0×10^{-5}	E_{25} = 5z	0.4/6.5
				Silty SAND	0	-	32°	1700	1500	1.0×10^{-5} – 1.0×10^{-6}	E_{25} = 6	0.4/5.6
	Coastal Swamp and Lagoonal Deposits (cp)	0.5 – 1.5	1.5 – 4.4	SILT	0	30°	-	1700	1400	1.0×10^{-8} – 1.0×10^{-7}	E_{25} = 2	0.4/5.2
				CLAY	0	28°	-	1800	1300		E_{25} = 1	NA
	Fluvial Channel Deposits (syg)	Not determined	>3.5	Sandy GRAVEL	0	-	40°	2000	1800	1.0×10^{-3} – 1.0×10^{-5}	E_{25} = 1	NA
Low Dunes	Dune and Beach Sand Deposits (cp)	Various	0 – >10	Fine to medium SAND	0	-	36°	1800	1600	1.5×10^{-4} – 5.0×10^{-5}	E_{25} = 4z	0.4/6.5
				Silty SAND	0	-	32°	1700	1500	1.0×10^{-5} – 1.0×10^{-6}	E_{25} = 2.5z	0.4/5.6
	Coastal Swamp and Lagoonal Deposits (cp)	0.5 - >2.0	0.7 – 4.5	SILT	0	30°	-	1700	1400	1.0×10^{-8} – 1.0×10^{-7}	E_{25} = 0.5z	0.4/5.2
				CLAY	0	28°	-	1800	1300		E_{25} = 1	NA
	Fluvial Channel Deposits (syg)	Not determined	>3.0	Gravely SAND	0	-	38°	1900	1700	1.0×10^{-3} – 1.0×10^{-5}	E_{25} = 36	NA
				Sandy GRAVEL	0	-	40°	2000	1800		E_{25} = 4z	NA

The following section documents the four methods used in the interpretation of peak phi values (ϕ') for the materials encountered at the proposed Pegasus Town site.

The first two methods presented derive ϕ' both directly and indirectly from CPT data gathered during the current investigations. Both of these methods use known correlations between material density and depth. The latter of the first two methods, the indirect correlation, converts CPT q_c values to SPT N values.

The correlations used in these two methods are specifically for non-cohesive, granular materials and therefore ϕ' values for fine grained and cohesive materials are indicative only.

The third and fourth methods both use indirect methods of interpretation. The first of these two methods, CIRIA Method, is designed specifically for use with sands and gravel and is based on a combination of visual description, laboratory gradings and *in situ* material density. The last method used is specifically for cohesive materials, using correlation with plasticity index from laboratory testing.

The following sections present each of the methods and were appropriate presents data derived in the analysis.

A summary of these analyses is presented in Table H3-1.

H3.1 Direct Correlation

H3.1.1 q_c vs. Vertical Effective Stress

Method Description

The first method uses the well known and accepted direct relationship between cone resistance (q_c) and vertical effective stress (kN/m2). This relationship is based on uncemented, normally consolidated quartz sand, as is found over the majority of the proposed site.

The initial correlation was proposed by Dorgunoglu and Mitchell (1975) and was later reviewed by Robertson and Campanella (1983) with correlations made to a number of chamber tests. Results of these investigations indicated that the Dorgunoglu and Mitchell theory gave a reasonable lower bound of ϕ' for sands of the type tested.

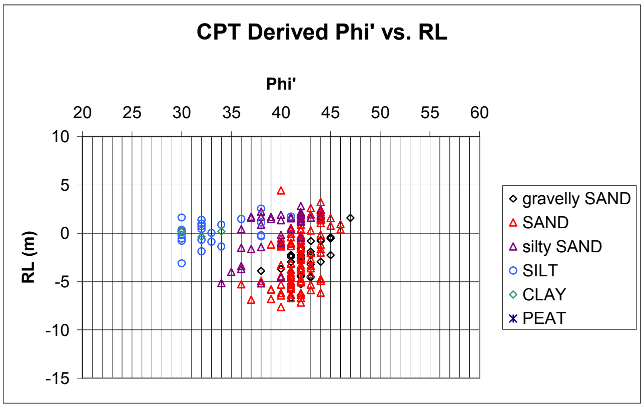
Each CPT plot was independently assessed with material subdivisions based on those interpreted by Site Investigations Ltd using the Robertson and Campanella relationship between q_c and f_R.

Plots have firstly been subdivided into the three main areas of the site (Low and High Dunes and Mapleham) and secondly based on the individual material types within each of these areas.

It must be remembered that these correlations are for sands. Therefore, ϕ' values for silts and clays are only representative of there *in situ* strength relative to sand.

Angle of Internal Friction

Low Dunes Area



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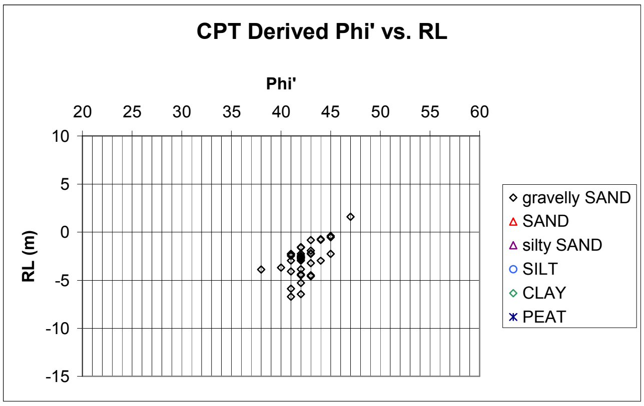
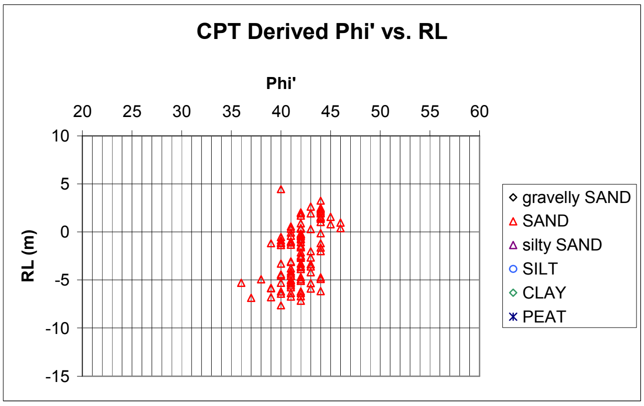
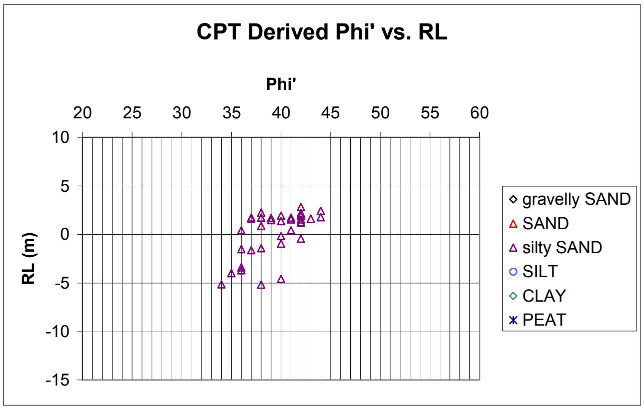


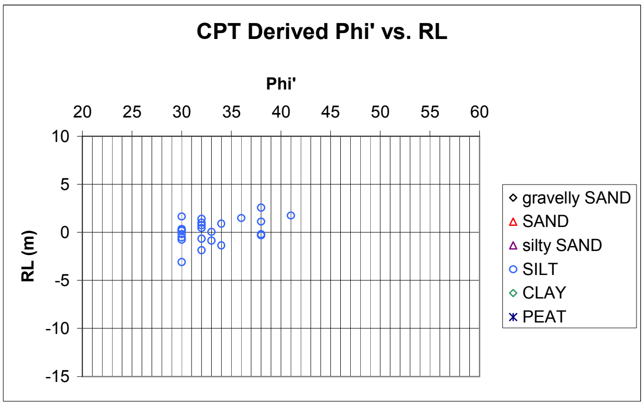
Gravelly SAND/sandy GRAVEL



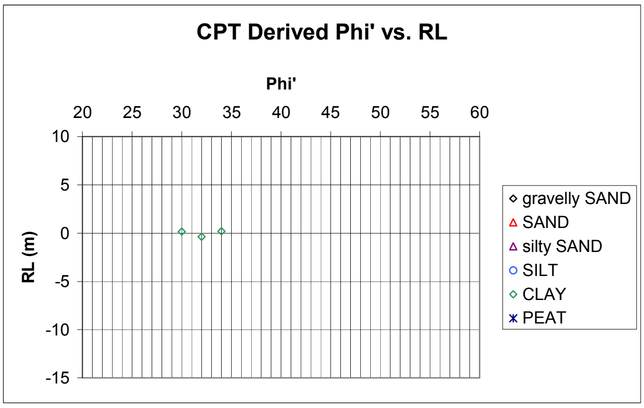
Fine to medium SAND



Silty SAND



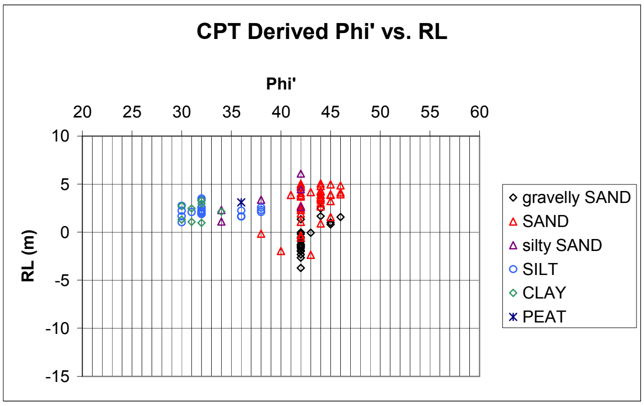
SILT



CLAY

Angle of Internal Friction

High Dunes Area



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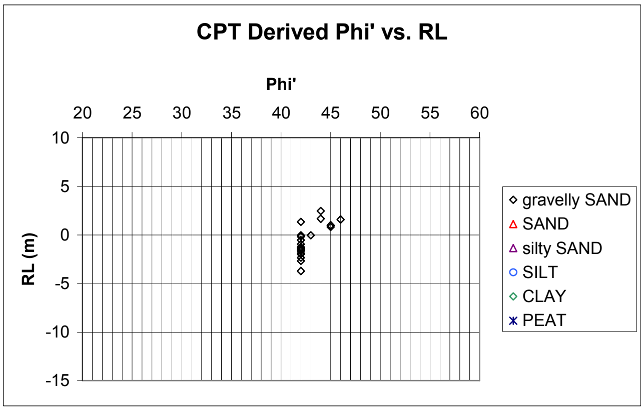
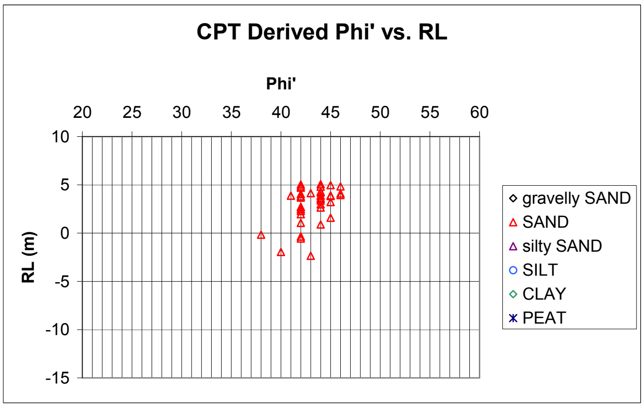
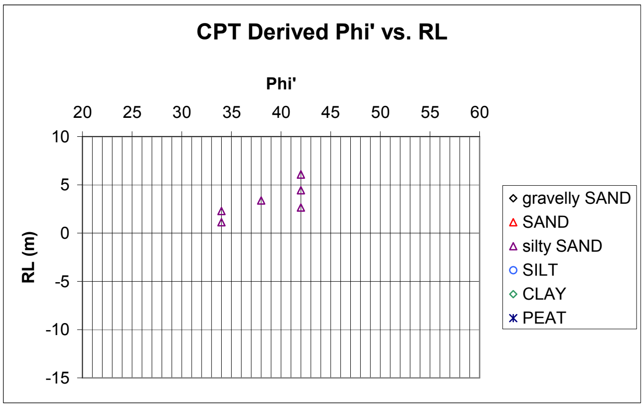


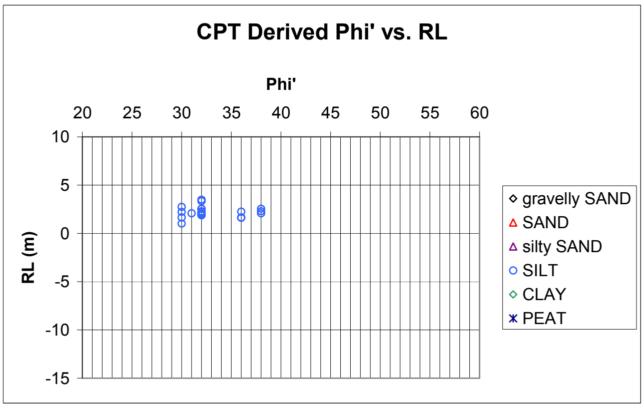
Gravelly SAND/sandy GRAVEL



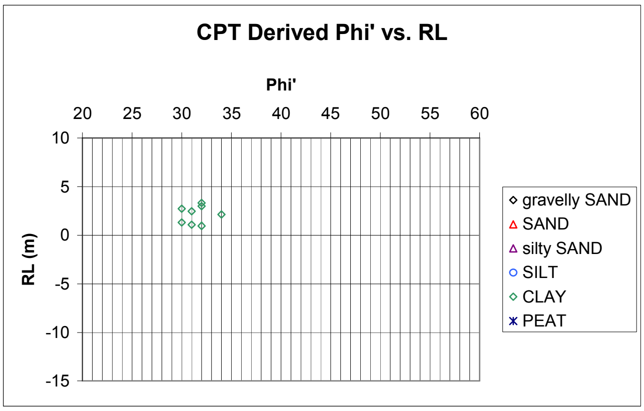
Fine to medium SAND



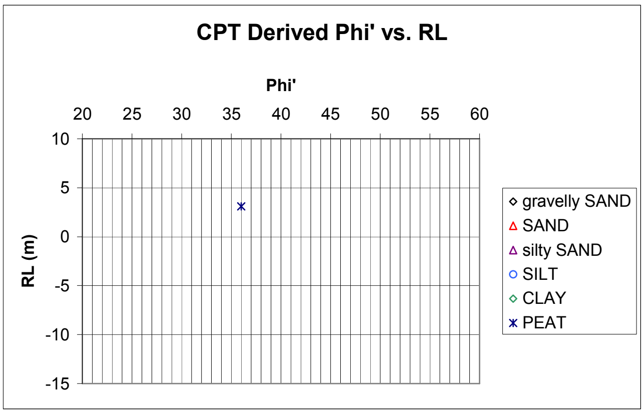
Silty SAND



SILT

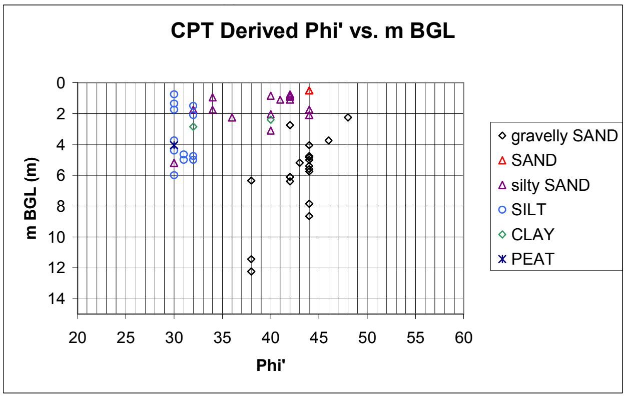


CLAY



PEAT

Alluvial Plain Area



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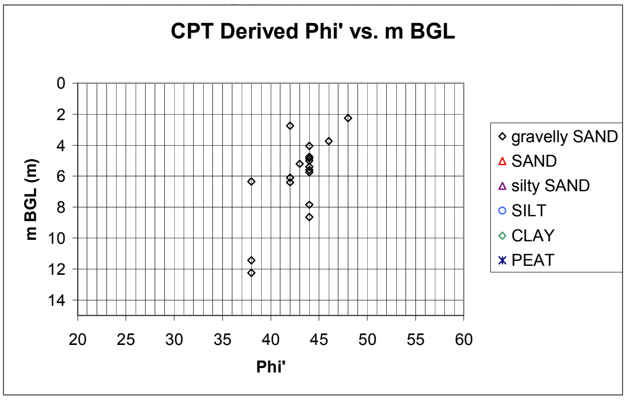
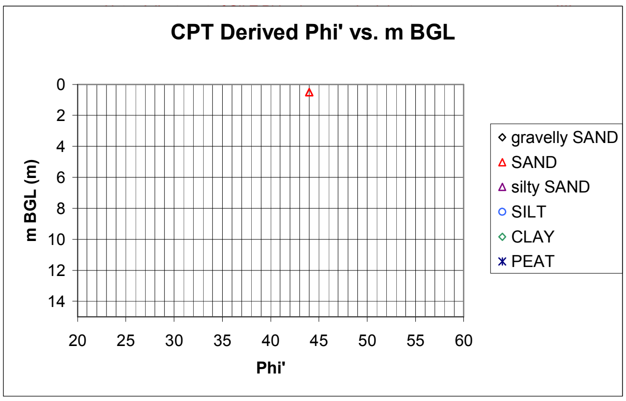
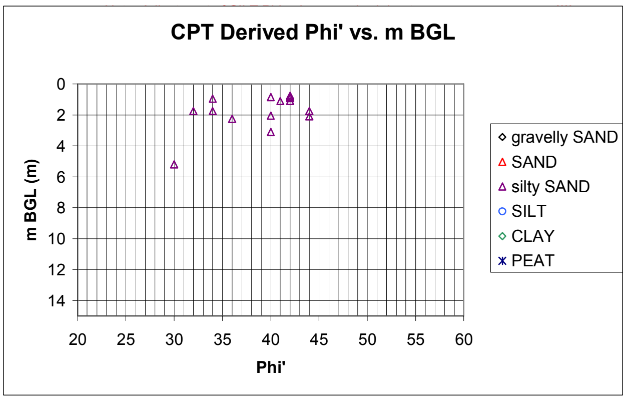


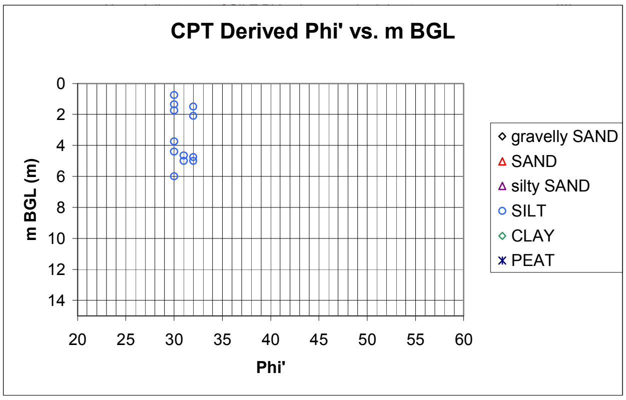
Gravelly SAND/sandy GRAVEL



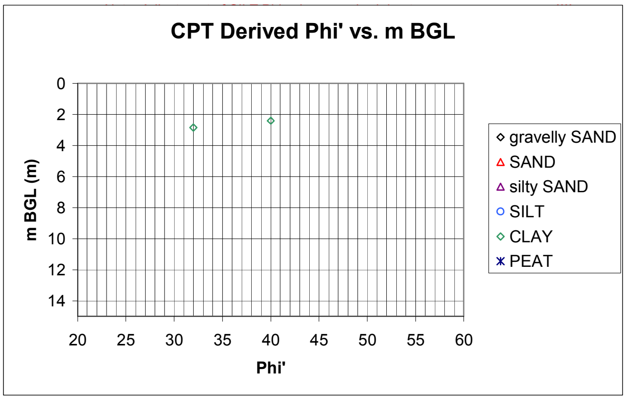
Fine to medium SAND



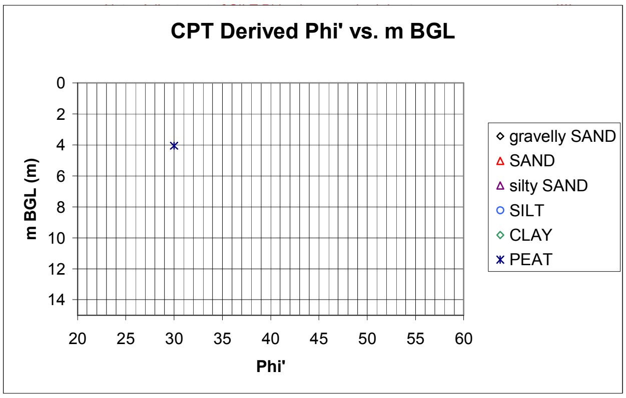
Silty SAND



SILT



CLAY



PEAT

H3.2 Indirect Correlation

H3.2.1 SPT N vs. Depth

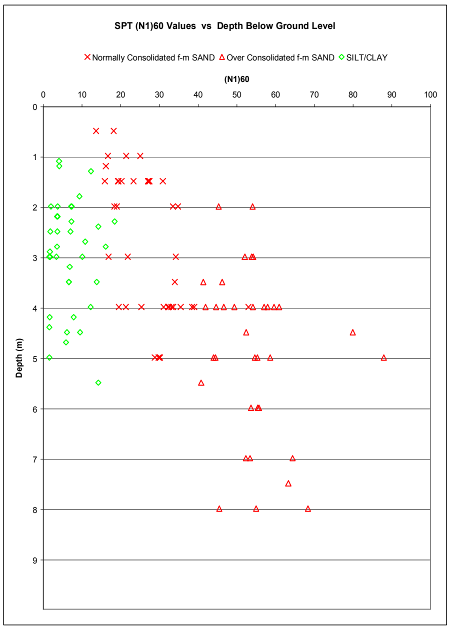
The second method of analysis converted CPT q_c to SPT n-value. A convertion factor of $2.5q_c$ was used in this conversion. Analysis of the CPT plots was undertaken independent to the direct correlation method used above.

Materials were subdivided into two general groups; sand and silt/clay deposits. No analyses of gravel deposits were undertaken using this method.

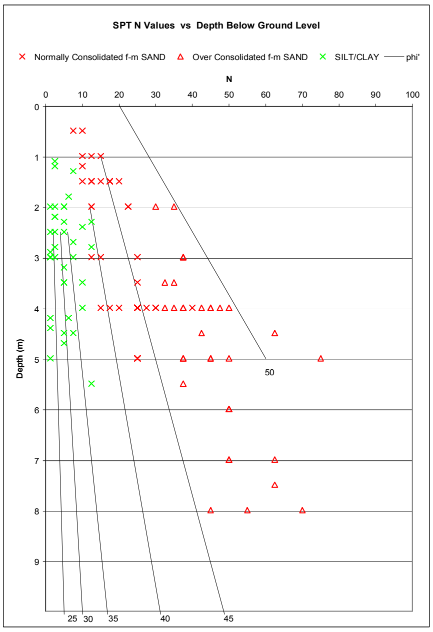
Numerous tests within sand deposits in the low dunes area indicated that deeper deposits were over-consolidated. This is likely to represent the removal of dune deposits of similar height to those seen in the high dunes area.

These over-consolidated materials were separated from the normally consolidated sands to identify any trends in the data; indicated by a triangular symbol.

Low Dunes Area

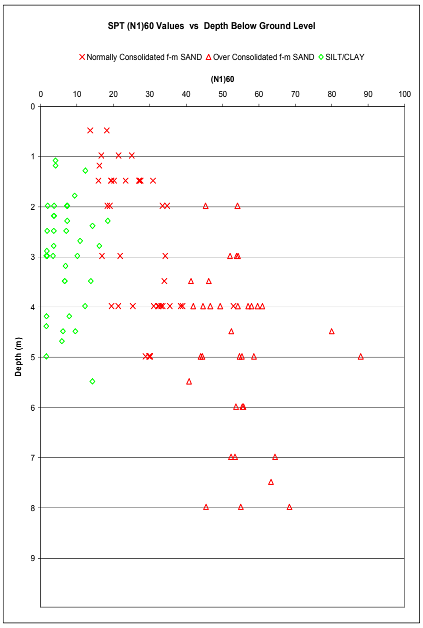


$(N_1)_{60}$ vs. Depth BGL

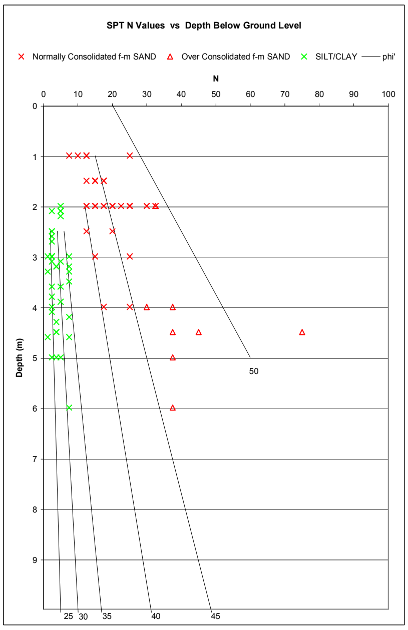


N vs. Depth BGL

High Dunes Area

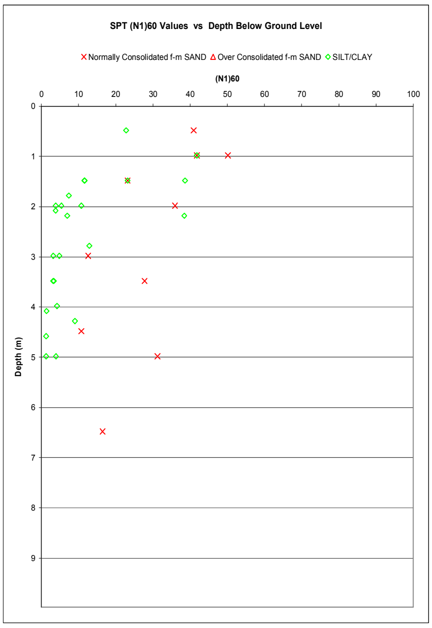


$(N_1)_{60}$ vs. Depth BGL

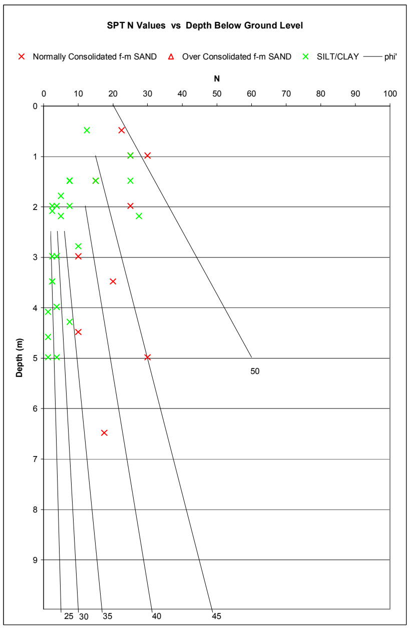


N vs. Depth BGL

Alluvial Plain Area



$(N_1)_{60}$ vs. Depth BGL



N vs. Depth BGL

H3.2.2 CIRIA Method (C580)

Method 3 uses a method of indirect interpretation of the ϕ' of siliceous sands and gravels.

Three material properties are used in this assessment; angularity, uniformity coefficient and SPT N_1.

$\phi'_{peak} = 30 + A + B + C$

	(Degrees)
A – Angularity	
Rounded	0
Sub-angular	2
Angular	4
B – Grading of soil	
Uniformly graded ($D_{60}/D_{10} < 2$)	0
Moderately graded ($2 \le D_{60}/D_{10} \le 6$)	2
Well graded ($D_{60}/D_{10} > 6$)	4
C – SPT N_1	
$N_1 \le 10$	0
$N_1 = 20$	2
$N_1 = 40$	6
$N_1 = 60$	9

These properties have been assessed from field descriptions of materials, material gradings and conversion of CPT q_c to SPT n-value corrected for overburden pressure.

H3.2.3 Plasticity Index (PI)

The previous three methods of deriving phi are specifically for use with sands and gravels. All of these methods become inaccurate as the phi value approaches 30°.

The fourth method uses in this analysis is a relationship between angle of internal friction and plasticity index for remolded clays established by Gibson (1953).

Based on the four Atterberg Limit tests completed in fine grained materials (silts and clays) ϕ' was derived for these materials. Plasticity Index (PI) of these samples ranged from 0 to 10 with an average of 6. This represents ϕ' between 27° and 31°.

Plotting PI against the liquid limit (LL) suggests that the LL of these materials does not vary greatly and that the variations are due to the amount of clay within the deposit.

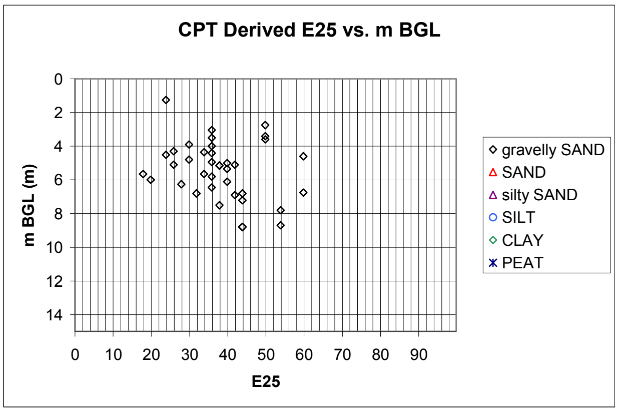
From these results it has been determined that clays (PI 7 – 10%) have a ϕ' of 28° and silts (PI 0 – 5%) have a higher value around 30°.

Table H3-1 – Result of Assessment

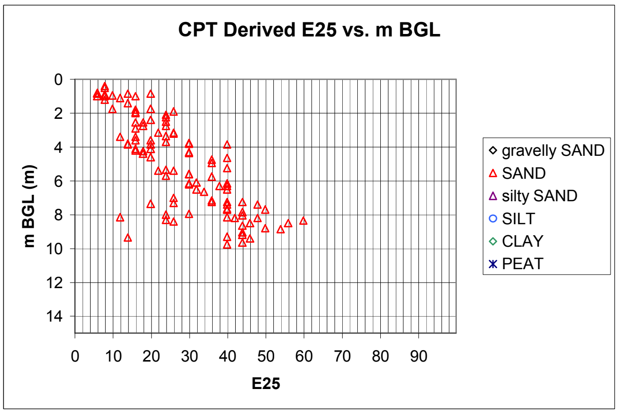
Area	Material Type	Level	q_c vs Vertical Effective Stress		SPT N vs. Depth		CIRIA Method	Plasticity Index
			Range	Average	Range	Average	Range	Average
Low Dunes	Gravelly SAND (sandy GRAVEL)	Various	38° – 47° (9°)	42°	-	-	38° (40°)	-
	SAND	Various	36° – 46° (10°)	42°	38° to 46° (8°) 46° to 53° (7°)	43° NC 47° OC	34° to 36°	-
	Silty SAND	Various	34° – 44° (10°)	39°			-	-
	SILT	Various	30° – 41° (11°)	32°	<25° to 40° (>15°)	30°	-	30°
	CLAY	-0.3 to 0.2 RL	30° – 34° (4°)	32°			-	28°
High Dunes	Sandy GRAVEL	Various	42° – 46° (4°)	42°	-	-	40°	-
	SAND	Various	38° – 46° (8°)	42°	40° to 46° (6°) 46° to 53° (7°)	44° NC 46° OC	34° to 36°	-
	Silty SAND	Various	34° – 42° (8°)	38°			-	-
	SILT	1.5 to 3.5 RL	30° – 38° (8°)	32°	<25° to 35° (>10°)	27°	-	30°
	CLAY	1.0 to 3.0 RL	30° – 34° (4°)	31°			-	28°
	PEAT	-	36° (-)	36°	-	-	-	-
Alluvial Plain	Sandy GRAVEL	Various	38° – 48° (10°)	44°	-	-	40°	-
	SAND	-	44° (-)	44°	35° to 50° (15°)	40°	34° to 36°	-
	Silty SAND	1.0 to 3.5 BGL	30° to 44° (14°)	40°			-	-
	SILT	Various	30° to 34° (4°)	31°	<25° to 48° (>23°)	27°	-	30°
	CLAY	Various	32° to 40° (8°)	35°			-	28°

Grey – values outside limits of interpretation method.
Yellow – Preferred ϕ′ values.

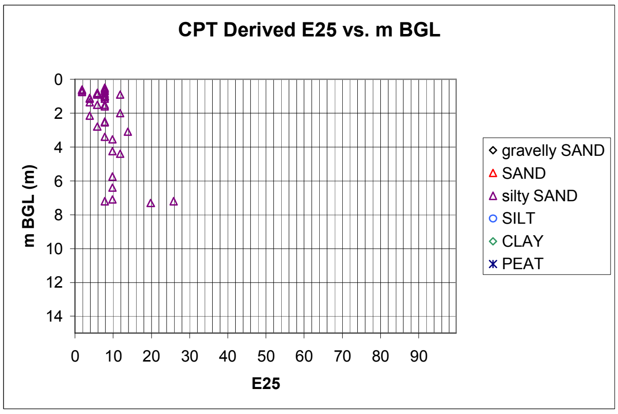
H4.1.1 Low Dunes



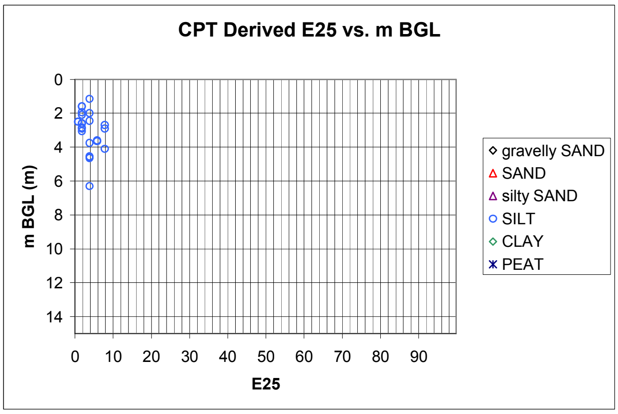
Gravelly SAND/sandy GRAVEL



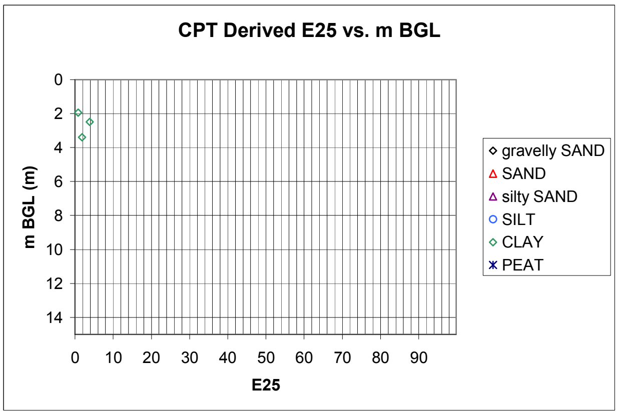
Fine to medium SAND



Silty SAND

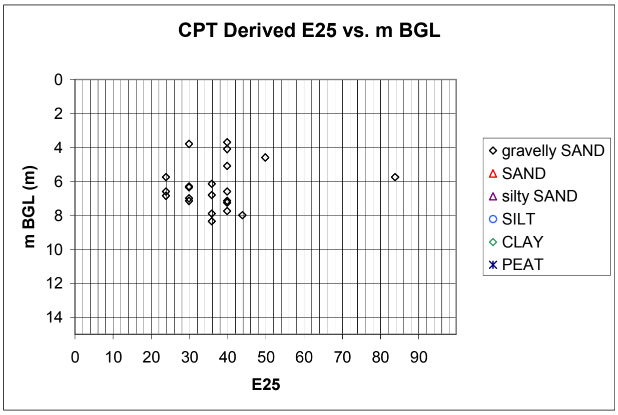


SILT

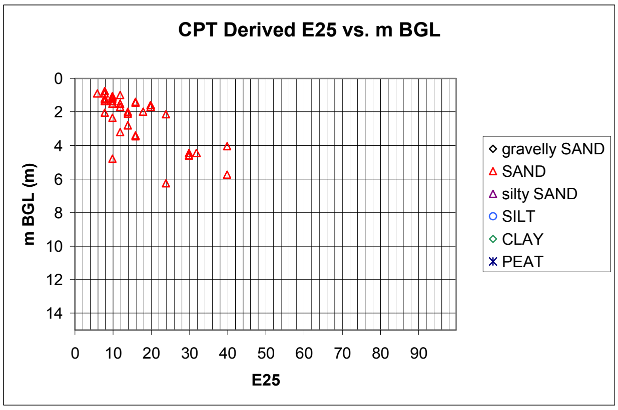


CLAY

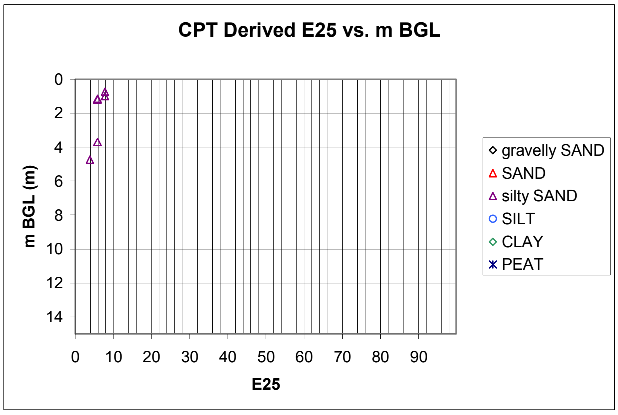
H4.1.2 High Dunes



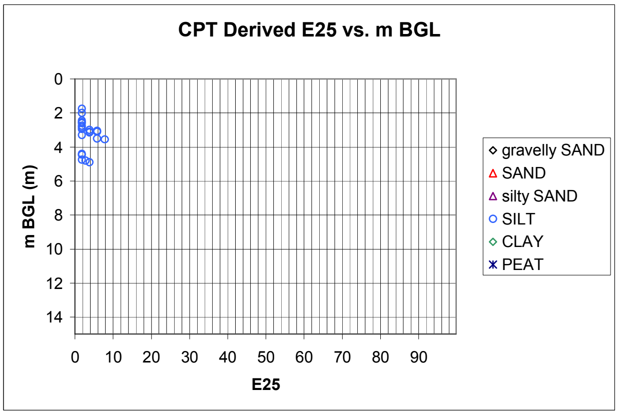
Gravelly SAND/sandy GRAVEL



Fine to medium SAND



Silty SAND



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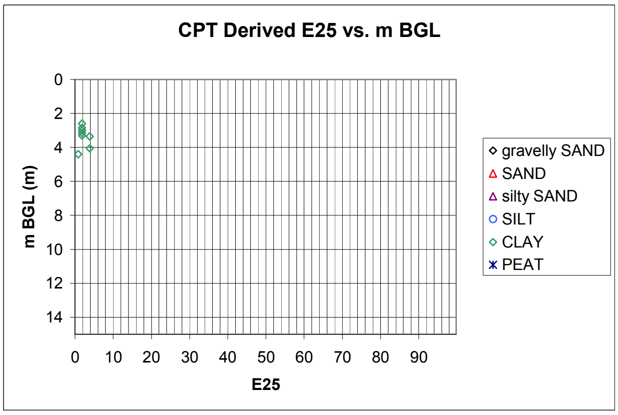

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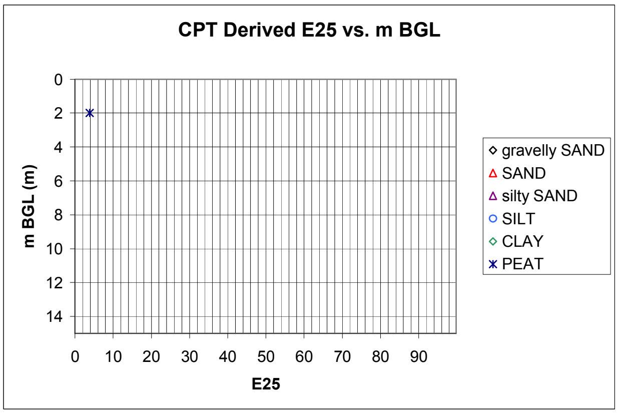
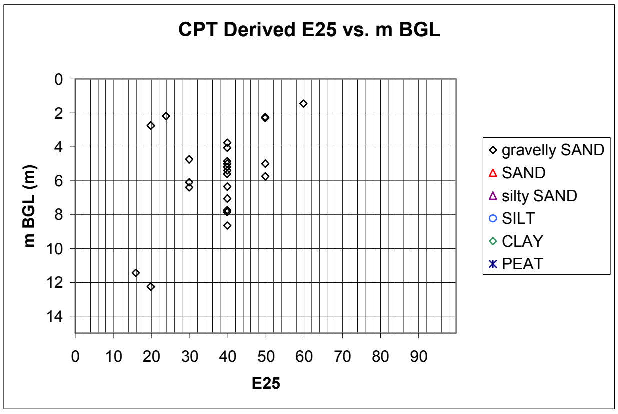
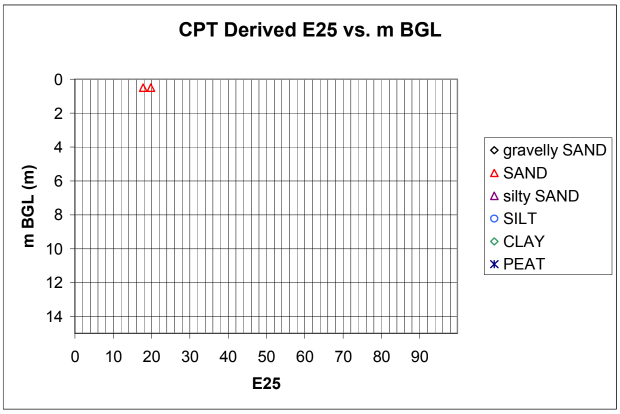


PEAT

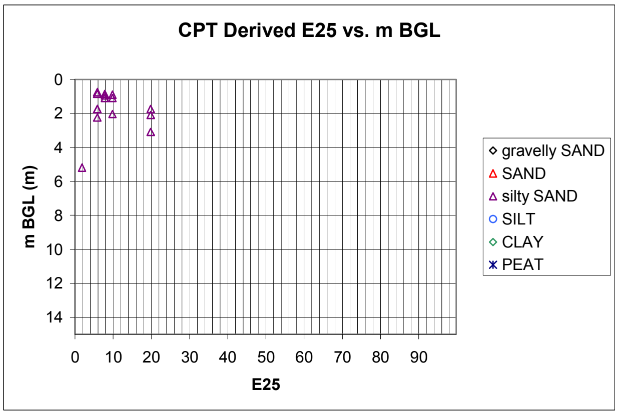
H4.1.3 Alluvial Plain



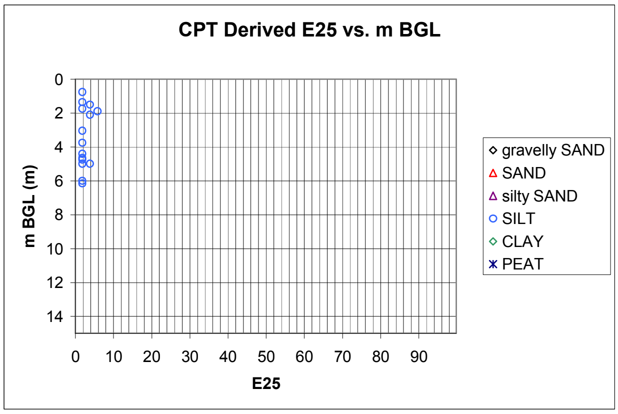
Gravelly SAND/sandy GRAVEL



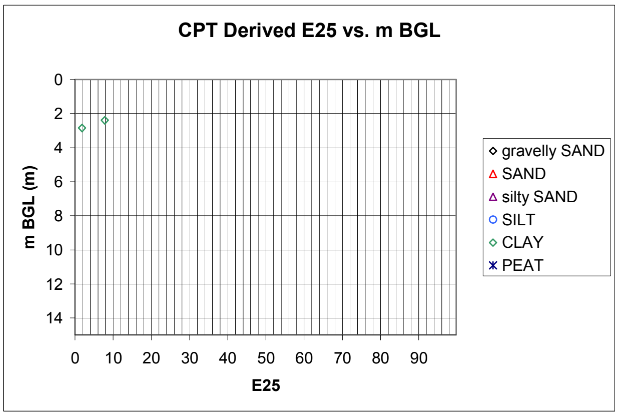
Fine to medium SAND



Silty SAND



SILT



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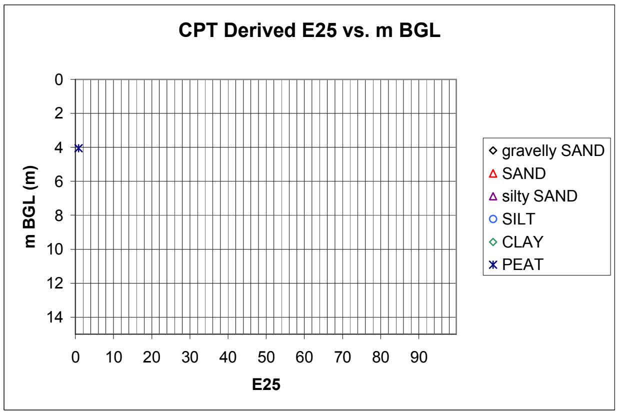

PEAT

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