GEOTECHNICAL ENGINEER'S REPORT

SITE CLASSIFICATION

NORTHLAKES ESTATE

STAGE 24

for

PARSONS BRINCKERHOFF

at

CAMERON PARK

NEW SOUTH WALES

Ref: 634-10
October 2010

CIVIL ◆ STRUCTURAL ◆ GEOTECHNICAL
ABN 24 057 568 215
SUITE 6, 180 MAIN ROAD SPEERS POINT NSW 2284
P: 02 4958 3308 F: 02 4958 7155 E: mail@csgeng.com.au

Contents

1 Introduction

This report sets out the details of a limited geotechnical assessment for a proposed nineteen (19) lot subdivision in Stage 24 of the Northlakes Estate adjacent to Nithsdle Street, Raleigh Street and Craigvar Way Cameron Park.

The objectives for this assessment were to:

- Identify subsoil conditions and soil types;
- Determine a site classification to AS2870.1996 "Residential Slabs and Footings";
- Provide general structural engineering design parameters for foundations for proposed buildings;
- Earthworks, site preparation, material quality and compaction requirements;
- General advices for retaining wall / battered bank design parameters;

We draw your attention to the Appendices "Important Information about your Geotechnical Engineering Report" and "Limitations of Geotechnical Assessment" and CSIRO BTF18 which should be read in conjunction with the report.

To assist in our assessment, we were supplied with a copy of a site plan of the proposed development prepared by Parsons Brinckerhoff Project No 2118987A. This plan indicates that some local regrading of the sites was undertaken on Lots 2416, 2417, 2418 and 2419. The plan also indicates minor filling along the frontages of Lots 2406-2412 (inclusive) and along the frontage of Lots 2413 and 2414.

For the purposes of this report the frontage to Craigvar Way is assumed to face east.

2 Proposed Development

The proposed development Stage 24 is understood to comprise nineteen (19) residential Lots 2401-2419 (inclusive). Lots 2401-2412 are bounded by Nithsdle Street to the south, Raleigh Street to the North and Craigvar Way to the east. Lots 2413-2419 are located to the north of Raleigh Street with access to the rear lots 2415, 2416 and 2419 provided via Craigvar Way to the east and a concrete driveway off Raleigh Street between Lots 2414 and 2417.

3 Fieldwork

The fieldwork carried out in October 2010 comprised a visual assessment of the site and adjacent properties and the drilling, logging and sampling of ten (10) 100mm diameter machine (4WD utility mounted EVH Scout 1750 drilling rig) augered boreholes (boreholes BH4-BH13 inclusive). Ten (10) Dynamic Cone Penetrometer (DCP) tests were undertaken adjacent to the boreholes (DCP probes P4-P13 inclusive). U50 tube samples were also taken for clay soil shrink/swell testing. A number of U50 tube samples were discarded due to large gravel inclusions in the sample precluding and valid testing. The boreholes were drilled to a maximum depth of 3.0 metres or TC (Tungsten Carbide) bit refusal on confirmed rock at engineer's discretion.

The positions of the boreholes and DCP probes are shown on the site plan 634-10/2. The log sheets and laboratory test reports are attached to this report.

4 Geological Setting

Reference to the 1:100000 Newcastle Coalfield Regional Geology Geological Series Sheet 9231 published by the Department Of Mineral Resources, indicates that the site lies within the Boolaroo Subgroup of the Newcastle Coal Measures. The Boolaroo Subgroup lithology includes sandstone, conglomerate, siltstone, coal and tuff.

5 Site Description

5.1 Surface Conditions

The Stage 24 site is located in a residential subdivision area on the upper western flanks of a broad north to south trending ridgeline. Stage 24 is bounded on the lower south by Nithsdle Street and the upper east by Craigvar Way and is bisected by Raleigh Street that intersects with Craigvar Way to the east. A concrete driveway between Lots 2414 and 2417 provided access to the northern Lots 2415 and 2416.

Some local regrading of the sites was observed on the upper areas of Lots 2416, 2417, 2418 and 2419. Shallow filling was observed along the frontages of Lots 2406-2412 (inclusive) and along the frontage of Lots 2413 and 2414. Discrete mounds of fill associated with recent earthworks were also observed to the lower west areas of the site. The site was vacant and undeveloped and had been recently partly cleared of trees and vegetation to the rear areas of the lots. The front areas supported stands of mature trees to approximately 15m in height and some saplings. Mulch was observed over the majority of the site. Lots between Nithsdle Street and Raleigh Street straddled a broad crest falling to the south west on a shallow convex slope of approximately 5-10^0. Lots to the north of Raleigh Street exhibited a shallow undulating convex fall of approximately 5-10^0 toward a gully line to the lower north and north west.

Existing stormwater drainage is primarily overland sheet flow from the crest areas to the north and west areas of the site.

5.2 Subsurface Conditions

The subsurface conditions, as revealed by and limited to the above fieldwork, may be summarised as shallow and discrete areas of gravelly sandy clay FILL overlying colluvial firm tending stiff high plasticity gravelly silty sandy CLAY (CH) overlying stiff high plasticity silty sandy CLAY (CH) and underlain by weathered SILTSTONE / SANDSTONE at variable depth.

All boreholes were terminated with T.C. (Tungsten Carbide) bit refusal on weathered siltstone / sandstone at depths varying from 0.4m (BH9) to 1.55m (BH10) depth below existing surface levels. DCP probes were terminated at depths varying from 0.4m (P9) to 1.3m (P6 and P10) depth below existing surface level. The log sheets are attached to this report.

For design purposes a nominal 100k Pa may be adopted for unconfined compressive strength (q_u) for the underlying gravelly silty sandy clay at a minimum 0.2m depth into the gravelly silty sandy clay. However, we note that this is an estimate only and the depth to competent bearing material may vary across the site and best confirmed in consultation with the supervising engineer. A nominal 800 k Pa may be adopted for unconfined compressive strength (q_u) for the underlying weathered bedrock.

Groundwater was not encountered in boreholes at the time of the assessment.

6 Discussion and Recommendations

6.1 Area Development

From a Geotechnical Engineer's point of view the site is suitable for the proposed development subject to satisfactory preparation of the site soils and uncontrolled filling as outlined in section 6.4 Earthworks.

Any development must comply with the requirements of the Principle Certifying Authority.

6.2 Site Classification

Based on the fieldwork, laboratory testing, tactile assessment of the clay soils and regional soil data 1, the site lots are classified in accordance with the requirements of AS2870.1996 - "Residential Slabs and Footings" and are set out in the following table.

Lot No	Site Classification	Lot No	Site Classification
2401	M	2411	M
2402	M	2412	M
2403	M	2413	H
2404	M	2414	H
2405	M	2415	M
2406	M	2416	M
2407	M	2417	M
2408	M	2418	M
2409	M	2419	M
2410	M		

Shrink swell Index test results indicate a shrink swell index I_{ss} = 2.5% for borehole BH4 at 0.3m depth. Borehole BH8 had a I_{ss} = 1.8% at 0.7m depth. Shrink swell results for boreholes BH3 and BH6 yielded I_{ss} = 0.5% and 1.1% respectively.

Based on these results and a soil suction of 1.5-1.8 pf, the seasonal movements due to soil moisture change in the clay soils are estimated at y_s = 20-35mm. In accordance with AS2870.1996 the shrink swell result would classify the majority of the sites as Class M (Moderately reactive site).

Borehole BH10 yielded a shrink swell index of I_{ss} = 2.5% at 0.4m depth. Lots 2413 and 2414 have been classified Class H (Highly reactive site) due to differing clay types and a deeper clay profile and higher plasticity clays encountered during the fieldwork.

The site classification generally applies to the existing soil profile at the site and may be amended depending on the extent of cut and fill undertaken at the site to the supervising engineer's inspection and approval. We advise

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1 'Engineering Geology Of The Newcastle-Gosford Region', Ed. S.W.Sloan and M.A. Allman.1995.

that the borehole test results are indicative only for the subject test area. Variations in the depth of soils, depth to rock and some anomalous subsoil conditions may occur at different locations across the site

Any and all proposed controlled filling under the main floor slabs/footings and pavements should be undertaken in accordance with AS3798.1990 "Guidelines on Earthworks for Commercial and Residential Developments", and the recommendations outlined in this report.

The slab / footing design should comply with any requirements of the Mines Subsidence Board.

6.3 Foundations

It is our opinion, based on the findings of the subsoil assessment, that all proposed slab/footings system and retaining wall footings be founded into competent clay or weathered rock strata to the inspection and approval of the supervising engineer. Engineer designed bored concrete piers may be required to support the slab/footings systems through filling and soft upper level clays and down to competent strata.

We recommend that all footings be founded into similar substrata. For example if one section of the building is founded into weathered rock then all footings should be piered / piled to the weathered rock strata. Footings systems adjacent to structures such as retaining walls or services (for example sewer pipes) should be founded (and piered/piled where required) past the engineer designated zone of influence to the structure.

The floor slabs intermediate spans would be constructed on compacted fill where 100 kPa may be adopted for safe bearing capacity. Earthworks construction details for the controlled filling are outlined in the following Section 6.4 Earthworks.

All footings excavations should be inspected and approved by a supervising Geotechnical/Structural engineer prior to steel and concrete placement

6.4 Earthworks

Where excavations or fills are adjacent to boundaries then temporary or permanent support of the excavation or fill is required.

External excavations in excess of 0.5m in depth, should be retained by an Engineered designed retaining wall. Unretained cuts in soil should be battered at no steeper than 3H:1V (Horizontal:Vertical) and must be protected from erosion.

Any existing filling should be either removed or lightly compacted under engineer's supervision prior to the placement of any new fill. Unretained fill should be lightly compacted, should not exceed 0.5m depth, should be battered no steeper than 3H:1V and be protected from erosion. Fill in excess of 0.5m depth should be retained by an Engineer designed retaining wall. Temporary (construction only and retaining wall excavations) excavations in sandy clay may be battered at no steeper than 1.5H:1V.

The general procedures recommended for engineered controlled fill beneath structures and pavements are set out below and defined in AS3798.1990 'Guidelines on Earthworks for Commercial and Residential Developments':

- Subsoil conditions during construction should be checked by the supervising engineer for compliance with this report;
- For the selected areas, remove to stockpile the any unsuitable fill or soft soil to expose subgrade clay. Proof roll the exposed clay subgrade to the supervising engineers approval. A geotextile such as Bidim U24 or similar may be appropriate to assist in providing a working platform and where required should be placed over the exposed subgrade area of the proposed building and extend a minimum 1 metre past the building line. Discrete soft areas may require additional local excavation and replacement of fill.

- Proof roll the subgrade to 95% Standard Compaction (AS1289). Import selected fill and place in compacted layers to raise to design levels. Fill layers to be 150mm deep maximum (loose placement). Imported fill to be select quality bulk fill approved by the supervising engineer;
- Compact the select fill layers with a vibrating roller (or roller deemed appropriate by the supervising engineer) so that a 98% Standard Compaction (AS1289) is achieved in the material to within 0.3m of the finished earthworks design level. 100% Standard Compaction should be achieved in the top 0.3m of earthworks to the supervising Engineers approval.

Where fill consists of clean granular material the following density requirements apply:

65% Density Index (AS1289) when 95% Std compaction is specified.
70% Density Index (AS1289) when 98% Std compaction is specified.
80% Density Index (AS1289) when 100% Std compaction is specified.

We recommend that a Geotechnical Engineer be engaged to inspect and advise on earthworks preparations particularly in the compaction of filling. All fill preparations including placement and compaction of filling should be inspected and approved by the supervising engineer. Site earthworks should be able to be carried out with conventional earthmoving equipment.

All earthworks on the site should be undertaken under a minimum of Level 2 supervision or as approved by the Principle Certifying Authority and in accordance with AS3798.1990. Erosion control measures during construction should be undertaken to the requirements of local Council.

6.5 Retaining Walls

Retaining walls should be engineer designed and the retaining wall footings founded into competent clay or weathered rock strata to the supervising engineer's direction and approval. The following general design parameters may be adopted for retaining wall design in the gravelly silty sandy clay:

- Bulk Density γ = 19 kN/m^3
- Subgrade Modulus k_s =30000 kN/m^3
- Internal Friction ϕ = 26^0

Varying types of retaining wall construction may be utilised subject to consultation with a Geotechnical/Structural Engineer.

6.6 Site Drainage

The effective drainage from the site of surface and subsurface water is important to ensure the stability and long term performance of the footing/slab system and to limit surface soil erosion.

The following measures are recommended:-

- Dish drains installed at the toe of all batters. Subsoil drains installed behind all retaining walls;
- Cut areas sloped to fall away from buildings and water not be allowed to pond around buildings or on pavements. Catch/dish drains formed at the top of all batters;
- The site graded to prevent water from ponding on any compacted fills.
- Surface water and subsoil water collected and disposed of to Council's requirements.

7 General

This report is based on a limited site assessment. Please refer to attached Limitations of Geotechnical Assessment. Any site conditions noted during the development that differ from those described in this report should be referred to the undersigned for assessment.

We recommend that further geotechnical consultation be requested during construction, particularly during the initial excavations on the site. Such work would normally include inspection and verification of foundation materials and advices on excavations and filling.

We are pleased to have been of service in this matter and should you have any queries please do not hesitate to contact the undersigned.

Yours faithfully,

Bruce Fletcher
MIE Aust CPEng 236558

Director
CSG Engineers Pty Ltd

Reviewed:

Stephen H Savage
MIE Aust CPEng 651364

Enclosures:

Important Information about Your Geotechnical Engineering Report
Limitations of Geotechnical Assessment
Design and Site Management Precautions for Construction on Reactive Soils
CSIRO Sheet BTF18

CSG ENGINEERS PTY LTD

CIVIL STRUCTURAL GEOTECHNICAL

ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF

Borehole No: 4

Project: RESIDENTIAL SUBDIVISION

DCP No: 4

Location: NORTHLAKES STAGE 24 CAMERON PARK

Job No: 634-10

Date: OCTOBER 2010

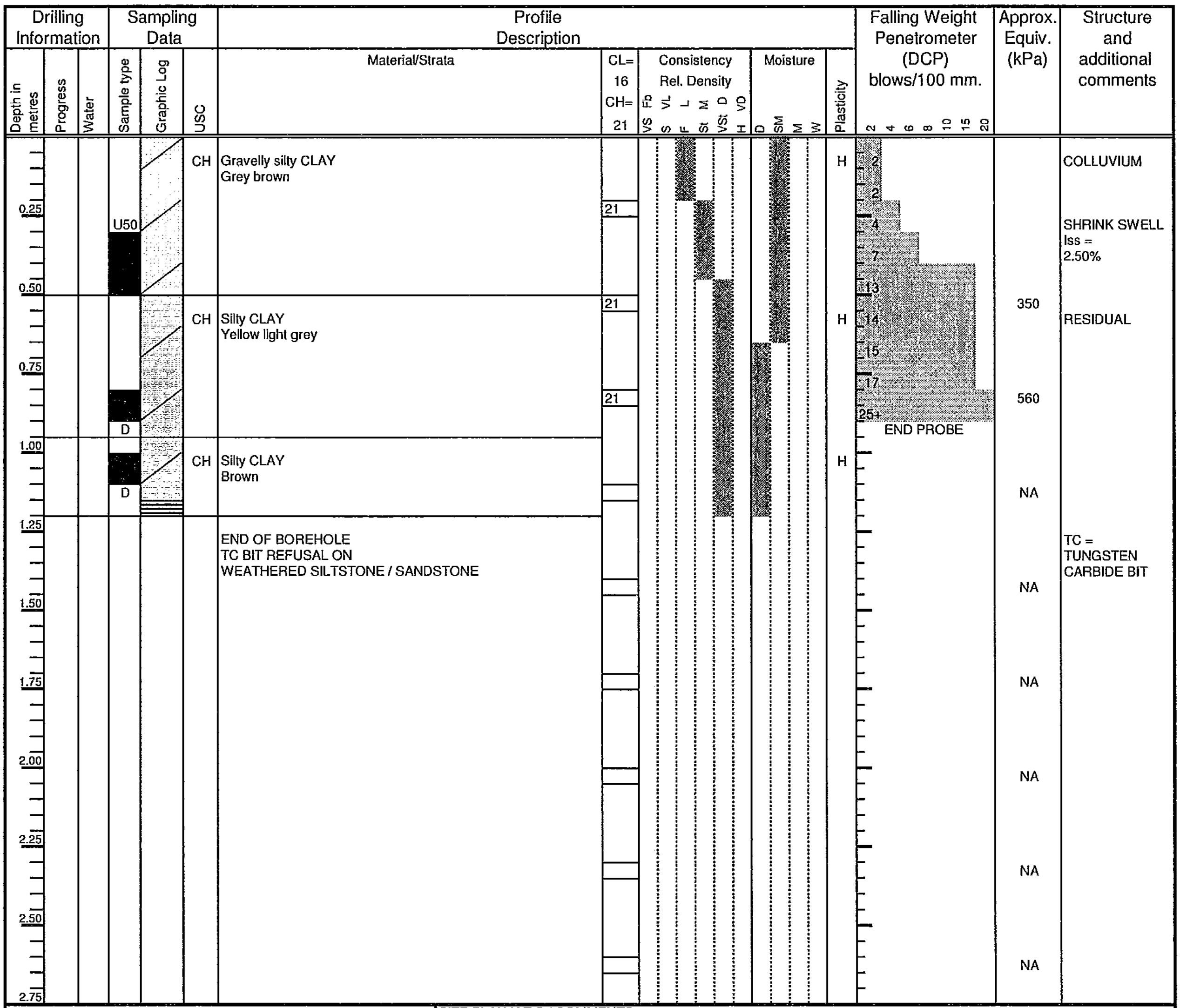
Logged by: MY

Position: SEE SITE PLAN

Equipment: 100mm MACHINE AUGER
16mm DCP PROBE

Surface RL: EXISTING

Groundwater: NIL IN BOREHOLE



Sample type	USC	Material/Strata	CL= 16 CH= 21	Plasticity	DCP blows/100 mm.	Approx. Equiv. (kPa)	Structure and additional comments
U50	CH	Gravelly silty CLAY Grey brown	21	H	2 2 4 7		COLLUVIUM SHRINK SWELL Iss = 2.50%
D	CH	Silty CLAY Yellow light grey	21 21	H	13 14 15 17 25+ END PROBE	350 560	RESIDUAL
D	CH	Silty CLAY Brown		H		NA	
		END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE				NA NA NA NA NA	TC = TUNGSTEN CARBIDE BIT

Key

Water

- seeping
- free standing

Sampling Data

U50 undisturbed sample 50mm diameter
D disturbed sample
NC cone penetrometer
B bulk sample

Plasticity

NP Non Plastic
T Trace
VL Very Low
L Low
M Medium
H High
VH Very High
EH Extra High

Consistency / Relative Density

VS	very soft	Fb	friable
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VD	very dense

Moisture

D dry
SM slightly moist
M moist
W wet

SITE PLAN N.T.S / COMMENTS

CSG ENGINEERS PTY LTD

CIVIL STRUCTURAL GEOTECHNICAL

ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF

Borehole No: 5

Project: RESIDENTIAL SUBDIVISION

DCP No: 5

Location: NORTHLAKES STAGE 24 CAMERON PARK

Job No: 634-10

Date: OCTOBER 2010

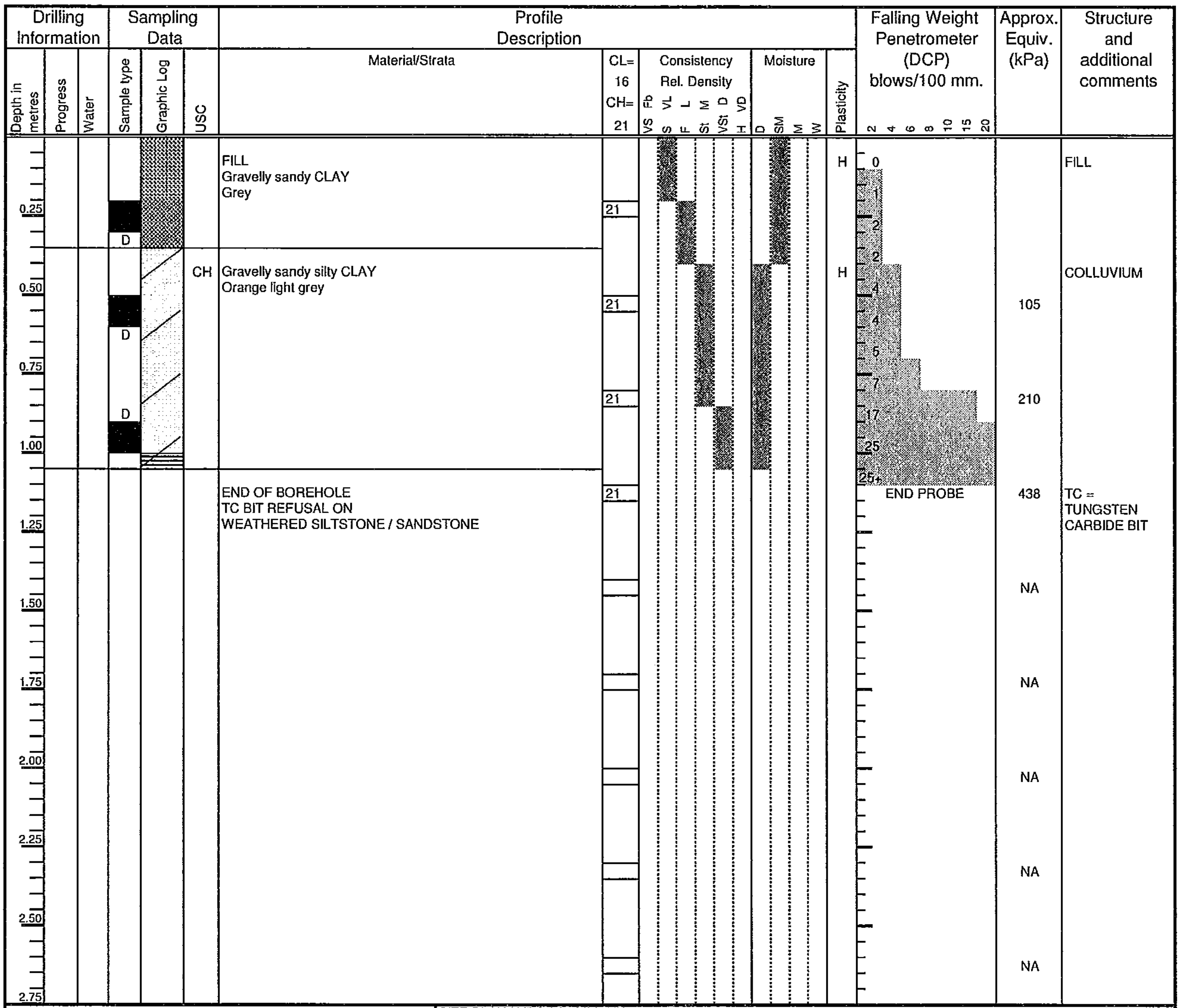
Logged by: MY

Position: SEE SITE PLAN

Equipment: 100mm MACHINE AUGER
16mm DCP PROBE

Surface RL: EXISTING

Groundwater: NIL IN BOREHOLE



Depth in metres	Sample type	USC	Material/Strata	CL= 16 CH= 21	Plasticity	DCP blows/100 mm.	Approx. Equiv. (kPa)	Structure and additional comments
0.00			FILL Gravelly sandy CLAY Grey		H	0		FILL
0.10						1		
0.25	D			21		2		
0.30						2		
0.40		CH	Gravelly sandy silty CLAY Orange light grey		H	4		COLLUVIUM
0.50	D			21		4	105	
0.60						5		
0.75	D			21		7	210	
0.80						17		
1.00						25		
1.10			END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE	21		25+ END PROBE	438	TC = TUNGSTEN CARBIDE BIT
1.50							NA	
1.75							NA	
2.00							NA	
2.25							NA	
2.50							NA	

Key

Water		Sampling Data		Plasticity
═	seeping	U50	undisturbed sample 50mm diameter	NP Non Plastic
▽	free standing	D	disturbed sample	T Trace
		NC	cone penetrometer	VL Very Low
		B	bulk sample	L Low
				M Medium
				H High
				VH Very High
				EH Extra High

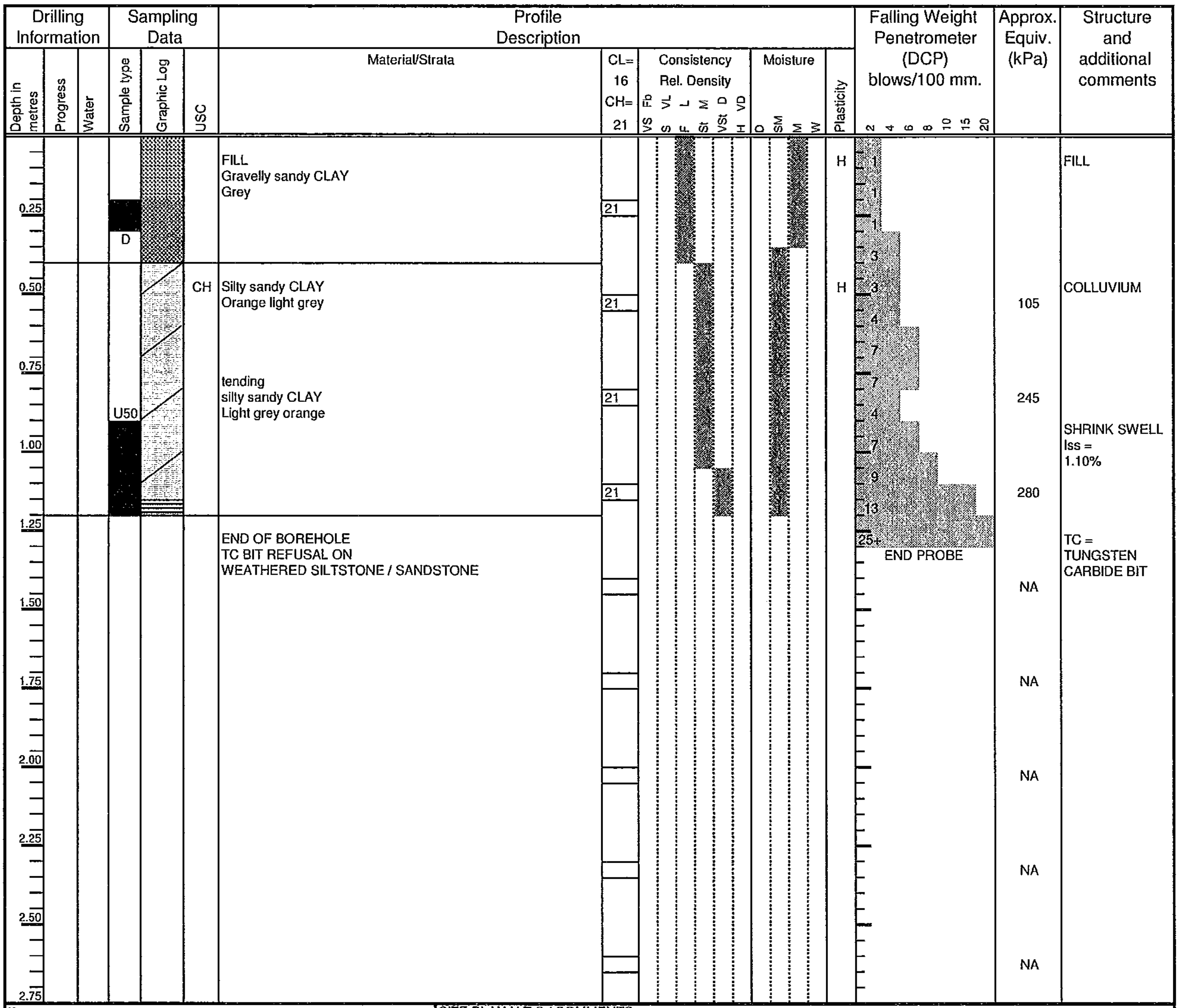
Moisture	Consistency		Relative Density	
D dry	VS	very soft	Fb	friable
SM slightly moist	S	soft	VL	very loose
M moist	F	firm	L	loose
W wet	St	stiff	M	medium dense
	VSt	very stiff	D	dense
	H	hard	VD	very dense

SITE PLAN N.T.S / COMMENTS

CSG ENGINEERS PTY LTD
CIVIL STRUCTURAL GEOTECHNICAL
ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 6
Project: RESIDENTIAL SUBDIVISION
DCP No: 6
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE



Depth in metres	Sample type	USC	Material/Strata	CL= 16 CH= 21	Plasticity	Falling Weight Penetrometer (DCP) blows/100 mm.	Approx. Equiv. (kPa)	Structure and additional comments
0.00–0.40	D		FILL Gravelly sandy CLAY Grey	21	H	1 1 1 3		FILL
0.40–1.25	U50	CH	Silty sandy CLAY Orange light grey tending silty sandy CLAY Light grey orange	21 21 21	H	3 4 7 7 4 7 9 13 25+ END PROBE	105 245 280	COLLUVIUM SHRINK SWELL Iss = 1.10%
1.25			END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE				NA NA NA NA NA	TC = TUNGSTEN CARBIDE BIT

Key

Water
seeping
free standing

Sampling Data
U50 undisturbed sample 50mm diameter
D disturbed sample
NC cone penetrometer
B bulk sample

Plasticity
NP Non Plastic
T Trace
VL Very Low
L Low
M Medium
H High
VH Very High
EH Extra High

Consistency / **Relative Density**

VS	very soft	Fb	friable
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VD	very dense

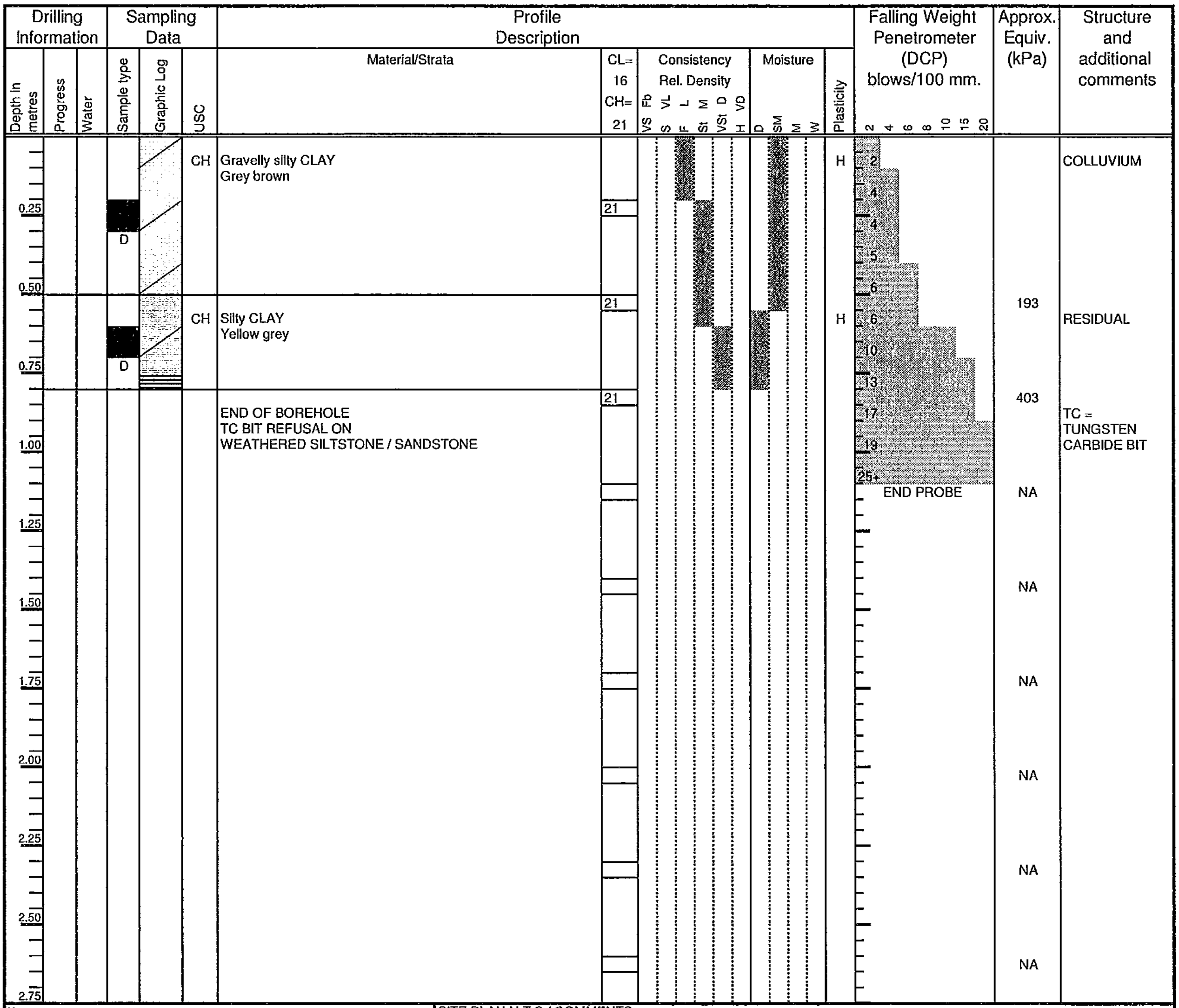
Moisture
D dry
SM slightly moist
M moist
W wet

SITE PLAN N.T.S / COMMENTS

CSG ENGINEERS PTY LTD
CIVIL STRUCTURAL GEOTECHNICAL
ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 7
Project: RESIDENTIAL SUBDIVISION
DCP No: 7
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE



Sample type	USC	Material/Strata	CL= 16 CH= 21	Plasticity	Structure and additional comments
D	CH	Gravelly silty CLAY Grey brown	21	H	COLLUVIUM
D	CH	Silty CLAY Yellow grey	21	H	RESIDUAL
		END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE	21		TC = TUNGSTEN CARBIDE BIT

Falling Weight Penetrometer (DCP) blows/100 mm.	Approx. Equiv. (kPa)
2	
4	
4	
5	
6	
6	193
10	
13	
17	403
19	
25+	
END PROBE	NA
	NA
	NA
	NA
	NA
	NA

Key

Water
seeping
free standing

Sampling Data
U50 undisturbed sample 50mm diameter
D disturbed sample
NC cone penetrometer
B bulk sample

Plasticity
NP Non Plastic
T Trace
VL Very Low
L Low
M Medium
H High
VH Very High
EH Extra High

Consistency
Relative Density

VS	very soft	Fb	friable
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VD	very dense

Moisture
D dry
SM slightly moist
M moist
W wet

SITE PLAN N.T.S / COMMENTS

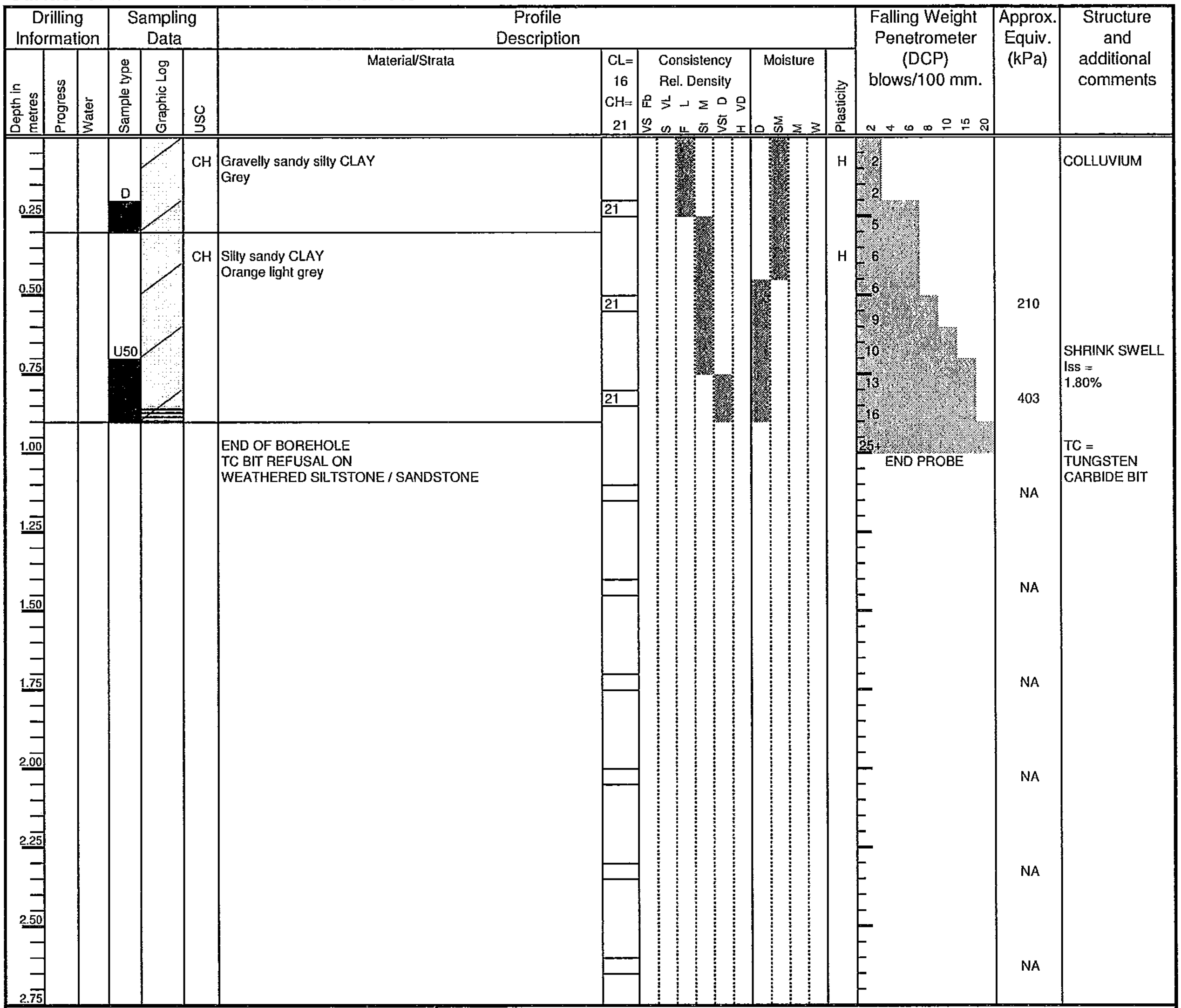
CSG ENGINEERS PTY LTD

CIVIL STRUCTURAL GEOTECHNICAL

ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 8
Project: RESIDENTIAL SUBDIVISION
DCP No: 8
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE



Depth in metres	Progress	Water	Sample type	Graphic Log	USC	Material/Strata	CL= 16 CH= 21	Consistency Rel. Density	Moisture	Plasticity	Falling Weight Penetrometer (DCP) blows/100 mm.	Approx. Equiv. (kPa)	Structure and additional comments
0.25			D		CH	Gravelly sandy silty CLAY Grey	21	F	SM	H	2 2		COLLUVIUM
0.50 0.75			U50		CH	Silty sandy CLAY Orange light grey	21 21	St VSt	SM D	H	5 6 6 9 10 13 16	210 403	SHRINK SWELL Iss = 1.80%
1.00						END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE					25+ END PROBE	NA	TC = TUNGSTEN CARBIDE BIT
1.25 1.50 1.75 2.00 2.25 2.50 2.75												NA NA NA NA NA NA	

Consistency Rel. Density: VS Fb S VL F L St M VSt D H VD

Moisture: D SM M W

DCP scale: 2 4 6 8 10 15 20

Key					
Water	**Sampling Data**			**Plasticity**	SITE PLAN N.T.S / COMMENTS
═ seeping	U50	undisturbed sample 50mm diameter		NP Non Plastic	
▽ free standing	D	disturbed sample		T Trace	
	NC	cone penetrometer		VL Very Low	
	B	bulk sample		L Low	
	Consistency Relative Density			M Medium	
				H High	
				VH Very High	
	VS	very soft	Fb friable	EH Extra High	
Moisture	S	soft	VL very loose		
D dry	F	firm	L loose		
SM slightly moist	St	stiff	M medium dense		
M moist	VSt	very stiff	D dense		
W wet	H	hard	VD very dense		

CSG ENGINEERS PTY LTD
CIVIL STRUCTURAL GEOTECHNICAL
ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 9
Project: RESIDENTIAL SUBDIVISION
DCP No: 9
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE

Drilling Information			Sampling Data			Profile Description					Falling Weight Penetrometer (DCP) blows/100 mm.	Approx. Equiv. (kPa)	Structure and additional comments
Depth in metres	Progress	Water	Sample type	Graphic Log	USC	Material/Strata	CL= 16 CH= 21	Consistency Rel. Density VS Fb S VL F L St M VSt D H VD	Moisture D SM M W	Plasticity	2 4 6 8 10 15 20		
					CH	Gravelly sandy CLAY with some fragmented sandstone Orange grey				H	3 3		COLLUVIUM
0.25			D				21				9 25+ END PROBE		
0.50						END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE						NA	TC = TUNGSTEN CARBIDE BIT
0.75												NA	
1.00												NA	
1.25													
1.50												NA	
1.75												NA	
2.00												NA	
2.25												NA	
2.50												NA	
2.75													

Key

Water
- seeping
- free standing

Moisture
- D dry
- SM slightly moist
- M moist
- W wet

Sampling Data
- U50 undisturbed sample 50mm diameter
- D disturbed sample
- NC cone penetrometer
- B bulk sample

Consistency Relative Density

VS	very soft	Fb	friable
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VD	very dense

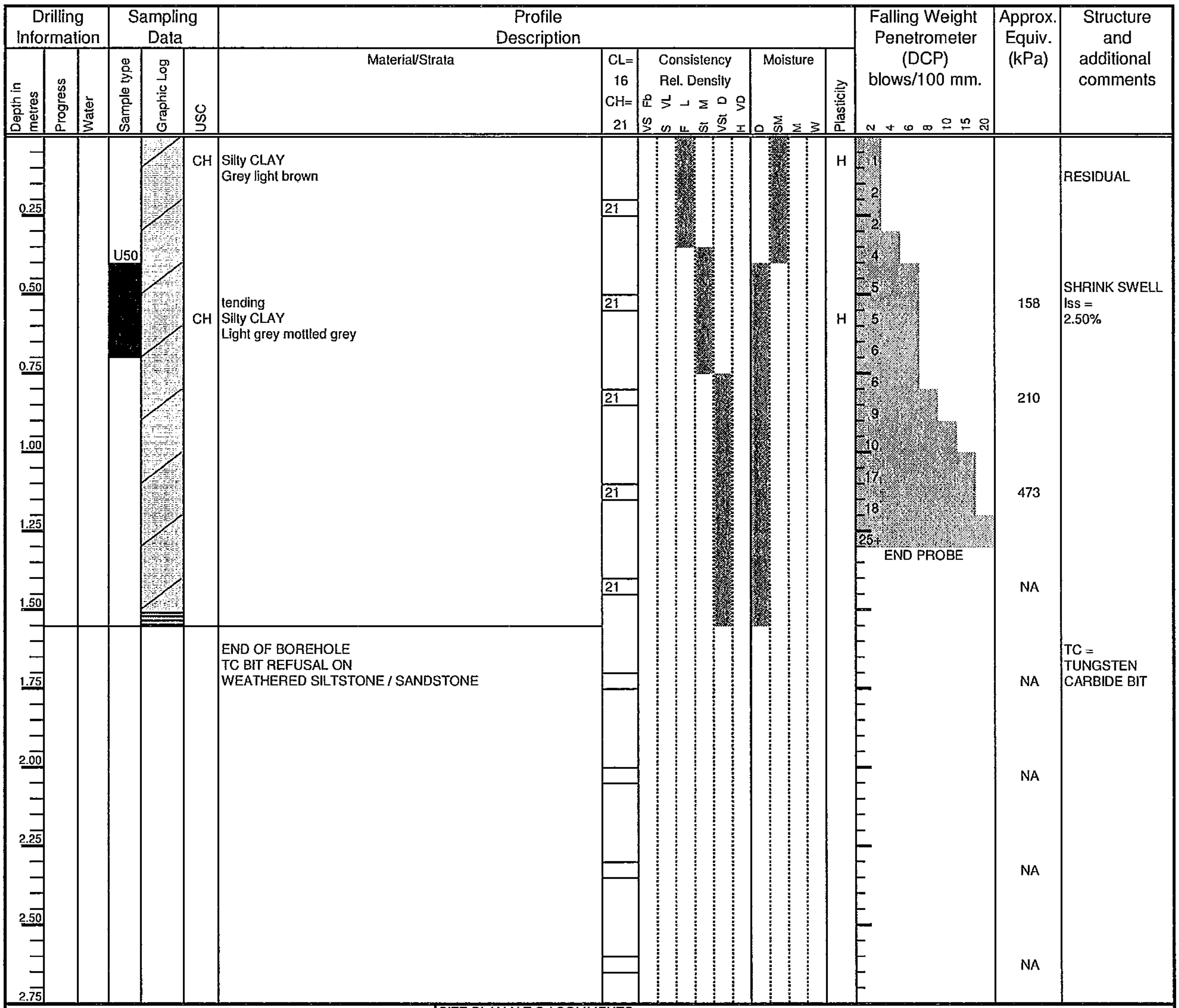
Plasticity
- NP Non Plastic
- T Trace
- VL Very Low
- L Low
- M Medium
- H High
- VH Very High
- EH Extra High

SITE PLAN N.T.S / COMMENTS

CSG ENGINEERS PTY LTD
CIVIL STRUCTURAL GEOTECHNICAL
ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 10
Project: RESIDENTIAL SUBDIVISION
DCP No: 10
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE



Depth in metres	Sample type	USC	Material/Strata	Plasticity	DCP blows/100 mm.	Approx. Equiv. (kPa)	Structure and additional comments
0.00		CH	Silty CLAY Grey light brown	H	1 2 2 4		RESIDUAL
0.40	U50	CH	tending Silty CLAY Light grey mottled grey	H	5 5 6 6 9 10 17 18 25+ END PROBE	158 210 473 NA	SHRINK SWELL Iss = 2.50%
1.60			END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE			NA NA NA NA	TC = TUNGSTEN CARBIDE BIT

Key

SITE PLAN N.T.S / COMMENTS

Water
seeping
free standing

Moisture

D	dry
SM	slightly moist
M	moist
W	wet

Sampling Data

U50	undisturbed sample 50mm diameter
D	disturbed sample
NC	cone penetrometer
B	bulk sample

Consistency
Relative Density

VS	very soft	Fb	friable
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VD	very dense

Plasticity

NP	Non Plastic
T	Trace
VL	Very Low
L	Low
M	Medium
H	High
VH	Very High
EH	Extra High

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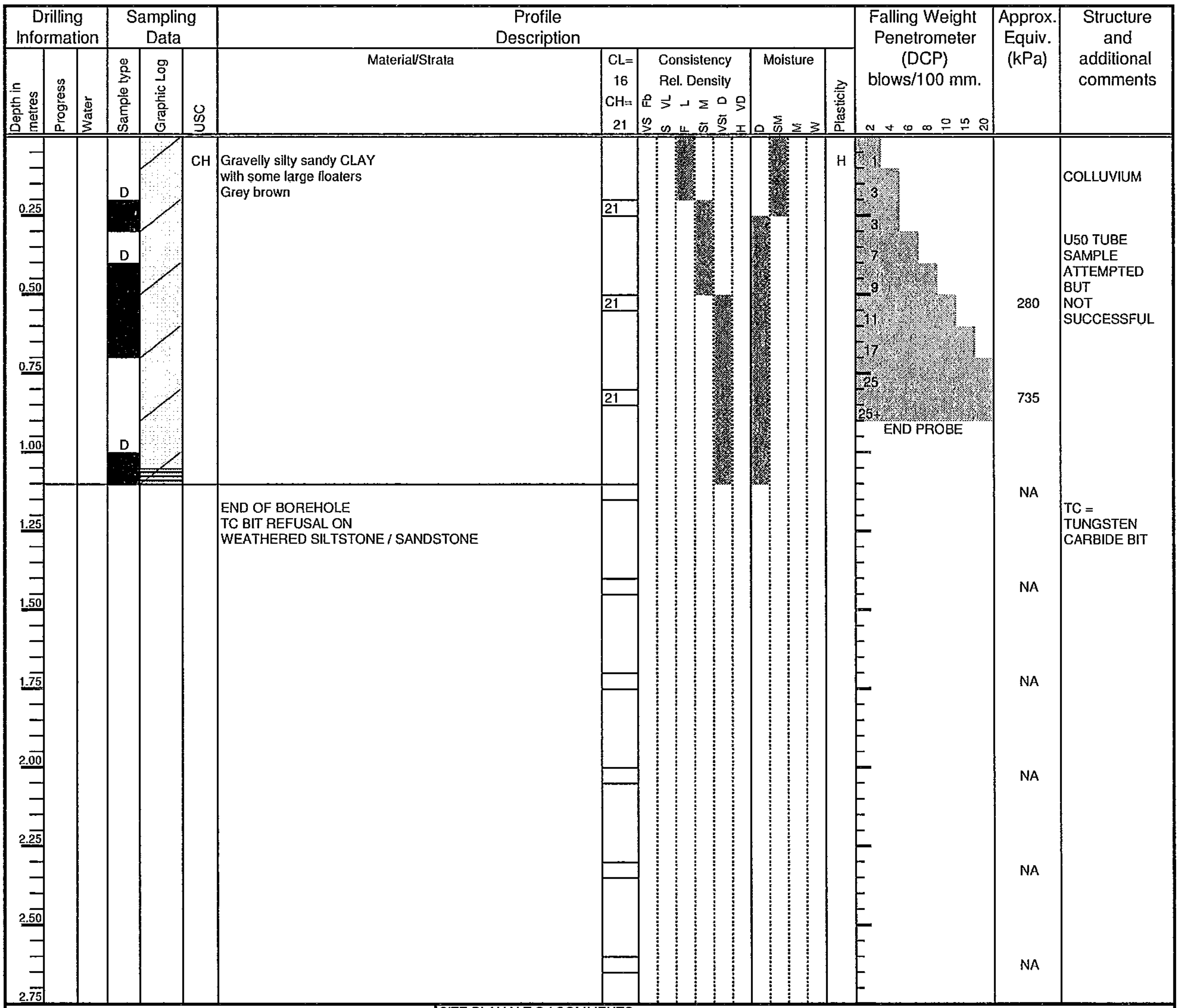
ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 11
Project: RESIDENTIAL SUBDIVISION
DCP No: 11
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE



Depth (m)	Sample type	USC	Material/Strata	CL/CH	Plasticity	DCP blows/100 mm	Approx. Equiv. (kPa)	Structure and additional comments
0.00–1.15	D	CH	Gravelly silty sandy CLAY with some large floaters Grey brown	21 21 21	H	1 3 3 7 9 11 17 25 25+ END PROBE	280 735	COLLUVIUM U50 TUBE SAMPLE ATTEMPTED BUT NOT SUCCESSFUL
1.15			END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE				NA NA NA NA NA NA	TC = TUNGSTEN CARBIDE BIT

Key

Water	
seeping	
free standing	

Sampling Data	
U50	undisturbed sample 50mm diameter
D	disturbed sample
NC	cone penetrometer
B	bulk sample

Consistency		Relative Density	
VS	very soft	Fb	friable
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VD	very dense

Plasticity	
NP	Non Plastic
T	Trace
VL	Very Low
L	Low
M	Medium
H	High
VH	Very High
EH	Extra High

Moisture	
D	dry
SM	slightly moist
M	moist
W	wet

SITE PLAN N.T.S / COMMENTS

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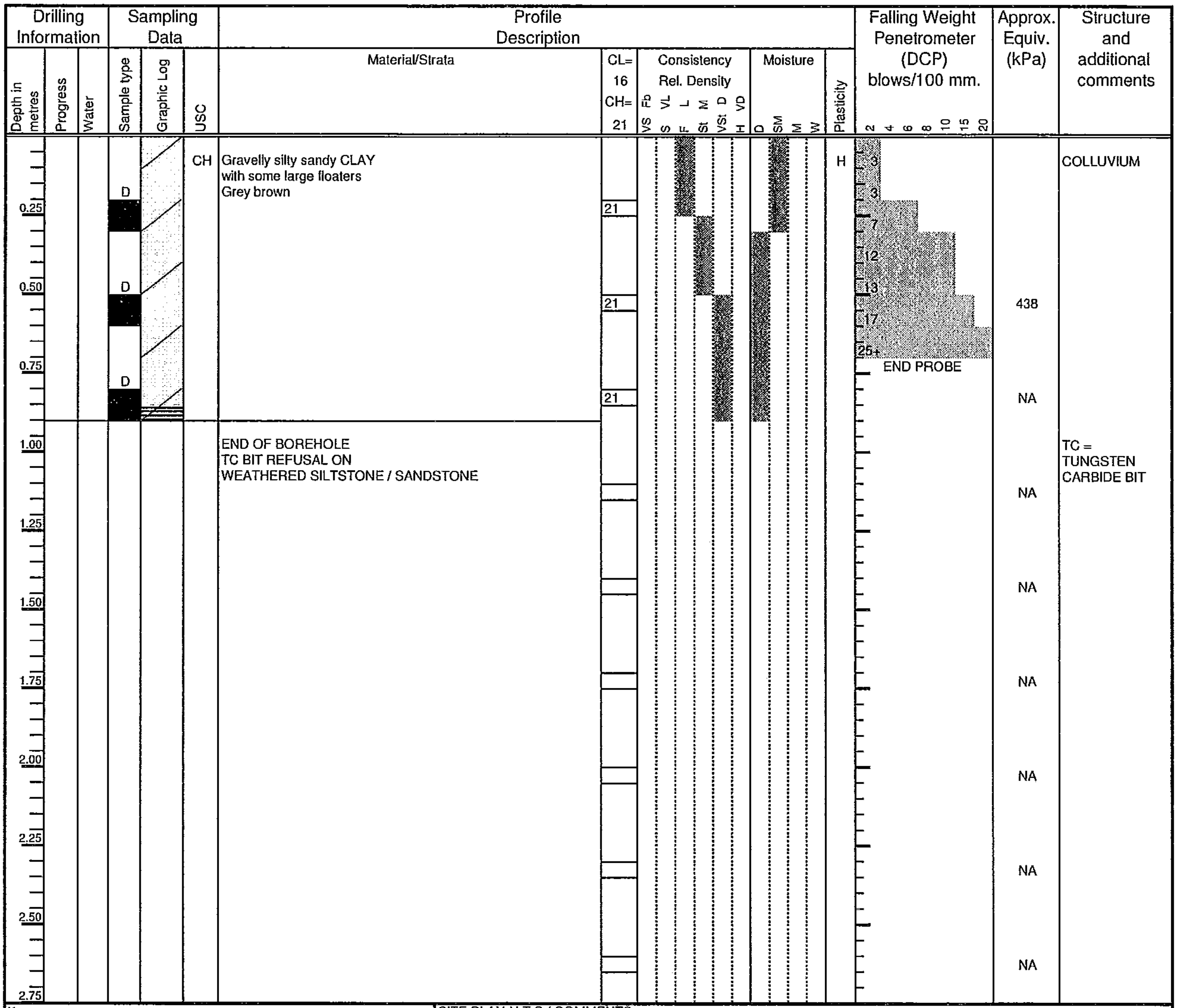
CIVIL STRUCTURAL GEOTECHNICAL

ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 12
Project: RESIDENTIAL SUBDIVISION
DCP No: 12
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE



Depth	USC	Material/Strata	Plasticity	Approx. Equiv. (kPa)	Structure and additional comments
0.00–0.90	CH	Gravelly silty sandy CLAY with some large floaters Grey brown	H	438	COLLUVIUM
0.90		END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE		NA	TC = TUNGSTEN CARBIDE BIT

Approx. Equiv. (kPa) further down: NA, NA, NA, NA, NA, NA

Key

Water
seeping
free standing

Sampling Data
U50 undisturbed sample 50mm diameter
D disturbed sample
NC cone penetrometer
B bulk sample

Plasticity
NP Non Plastic
T Trace
VL Very Low
L Low
M Medium
H High
VH Very High
EH Extra High

Consistency Relative Density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
M medium dense
D dense
VD very dense

Moisture
D dry
SM slightly moist
M moist
W wet

SITE PLAN N.T.S / COMMENTS

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CIVIL STRUCTURAL GEOTECHNICAL
ACN 057 568 215

ENGINEERING LOG

Client: PARSONS BRINCKERHOFF
Borehole No: 13
Project: RESIDENTIAL SUBDIVISION
DCP No: 13
Location: NORTHLAKES STAGE 24 CAMERON PARK
Job No: 634-10
Date: OCTOBER 2010
Logged by: MY
Position: SEE SITE PLAN
Equipment: 100mm MACHINE AUGER
16mm DCP PROBE
Surface RL: EXISTING
Groundwater: NIL IN BOREHOLE

Drilling Information			Sampling Data			Profile Description					Falling Weight Penetrometer (DCP) blows/100 mm.	Approx. Equiv. (kPa)	Structure and additional comments
Depth in metres	Progress	Water	Sample type	Graphic Log	USC	Material/Strata	CL= 16 CH= 21	Consistency Rel. Density VS Fb S VL F L St M VSt D H VD	Moisture D SM M W	Plasticity	2 4 6 8 10 15 20		
0.25						FILL Gravelly sandy CLAY with concrete fragments and rubble grey brown	21			M	2 4 11		FILL
0.50 0.75 1.00			D D		CH	Gravelly silty sandy CLAY Grey orange	21 21			H	3 4 7 6 9 17 18 22	123 263	U50 TUBE SAMPLE ATTEMPTED BUT NOT SUCCESSFUL
1.25						END OF BOREHOLE TC BIT REFUSAL ON WEATHERED SILTSTONE / SANDSTONE	21				25+ END PROBE	700	TC = TUNGSTEN CARBIDE BIT
1.50												NA	
1.75												NA	
2.00												NA	
2.25												NA	
2.50												NA	
2.75													

Key

Water
═ seeping
▽ free standing

Moisture
D dry
SM slightly moist
M moist
W wet

Sampling Data
U50 undisturbed sample 50mm diameter
D disturbed sample
NC cone penetrometer
B bulk sample

Consistency
Relative Density

VS	very soft	Fb	friable
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
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M Medium
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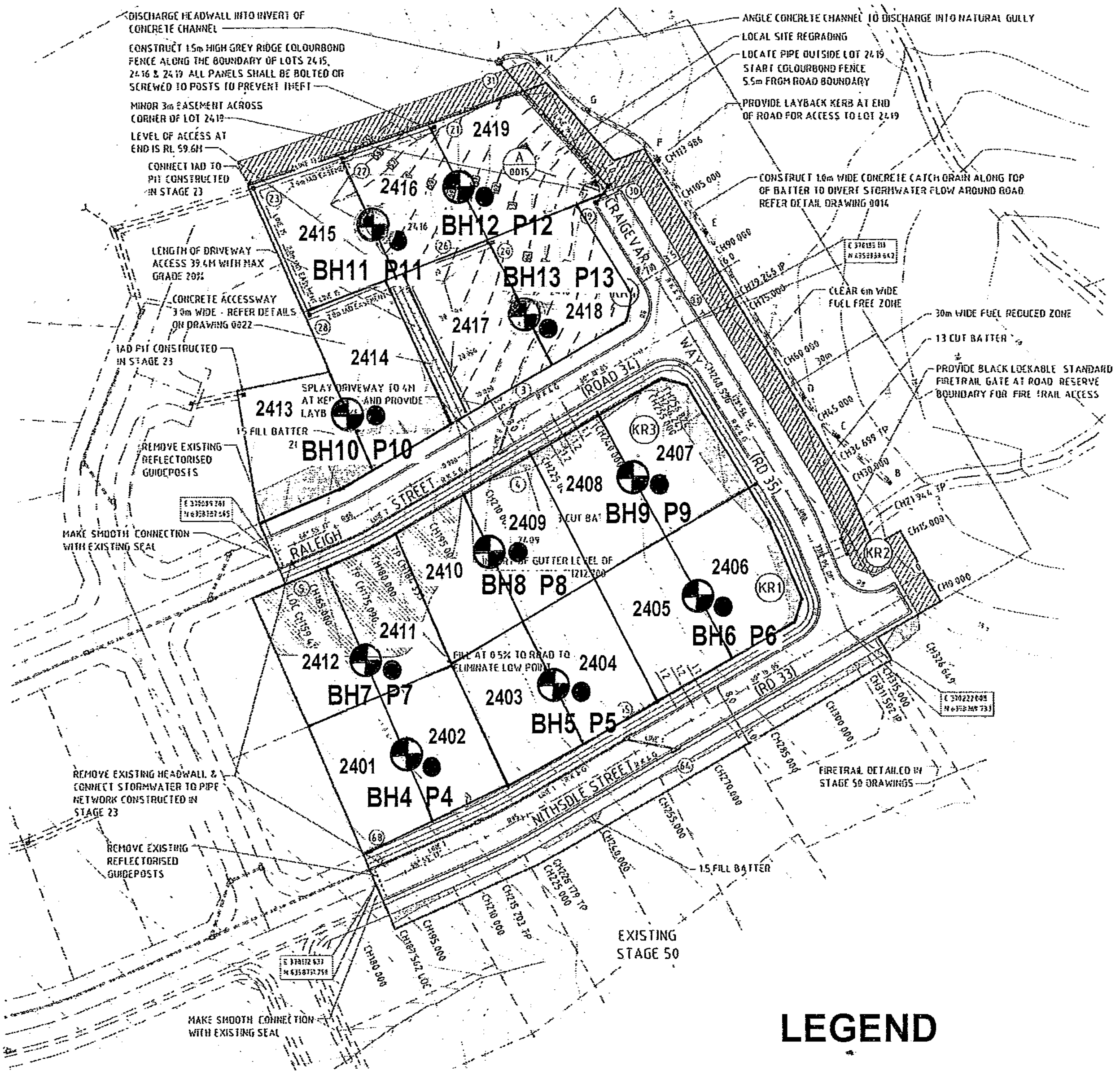
VH Very High
EH Extra High

SITE PLAN N.T.S / COMMENTS



LEGEND

BH1	◐	BOREHOLE MACHINE AUGER SEE LOG SHEET APPROXIMATE LOCATION
P1	●	DCP PENETROMETER PROBE 16MM DIAMETER SEE LOG SHEET APPROXIMATE LOCATION

SITE PLAN

NOT TO SCALE

DIAGRAMMATIC ONLY
SEE SURVEY & ARCHITECTURAL
PLANS FOR SITE SETOUT & DETAILS

CSG ENGINEERS PTY LTD

CIVIL STRUCTURAL GEOTECHNICAL
CONSULTING ENGINEERS

ABN 24 057 568 215 ACN 057 568 215
SUITE 6, 180 MAIN ROAD, SPEERS POINT, N,S,W 2284
Phone : (02) 4958 3308 Fax : (02) 4958 7155 Email : mail@csgeng.com.au

client **PARSONS BRINCKERHOFF**	drawn **BF**	rev.	drg no:
project **STAGE 24 NORTHLAKES**	date **OCT 2010**		**634-10**
	checked BF	approved	SHEET 1 OF 1

A.B.N. 50 103 355 531 A.C.N. 103 355 531

VALLEY/CIVILAB

GEOTECHNICAL TESTING & ENGINEERING SERVICES

Units 10-11, 21 Babilla Close. BERESFIELD NSW 2322 Phone:(02) 49661844 Facsimile:(02) 49661855

Shrink Swell Index Report

Client :	**CSG Engineering**	Report Number:	**P134 - 4**
Address :	**Suite 6, 180 Main Road , Speers Point, NSW, 2284**	Report Date :	**29/10/2010**
Project Name :	**Materials Qualities- Client Supplied**	Order Number :	
Project Number :	**P134**	Test Method :	**AS1289.7.1.1**
Location:			**Page 1 of 2**

Sample Number :	S10-876	S10-877	S10-878	S10-879
Test Number :				
Sampling Method :	Sampled by Client	Sampled by Client	Sampled by Client	Sampled by Client
Sampled By :	Sampled by Client	Sampled by Client	Sampled by Client	Sampled by Client
Date Sampled :	22/10/2010	22/10/2010	22/10/2010	22/10/2010
Date Tested :	22/10/2010	22/10/2010	22/10/2010	22/10/2010
Material Type :	Refer to Client Borelogs	Refer to Client Borelogs	Refer to Client Borelogs	Refer to Client Borelogs
Material Source :	U50 Tube sample	U50 Tube sample	U50 Tube sample	U50 Tube sample
Sample Location :	Client Sampled Job No;634-10 BH-3 -0.3m	Client Sampled Job No;634-10 BH-4 -0.3m	Client Sampled Job No;634-10 BH-6 -0.9m	Client Sampled Job No;634-10 BH-8 -0.7m
Inert Material Estimate (%) :	12	15	14	8
PP before (kPa) :	600	350	600	400
PP after (kPa) :	550	250	550	250
Shrinkage Moisture Content (%) :	15.4	20.1	14	16.8
Shrinkage (%) :	**0.9**	**1.9**	**1.7**	**2**
Swell Moisture Content Before (%) :	15	20.2	14.6	16.3
Swell Moisture Content After (%) :	16.6	30.1	19.6	23.3
Swell (%) :	**0**	**5**	**0.6**	**2.2**
Unit Weight (t/m³) :	2.08	2.01	2.05	2.09
Shrink Swell Index Iss (%) :	**0.5**	**2.5**	**1.1**	**1.8**
Visual Classification :	Refer to clients borelogs	Refer to clients borelogs	Refer to clients borelogs	Refer to clients borelogs
Cracking :	None	Major	Minor	Major
Crumbling :	Minor	Minor	Minor	Minor
Remarks :				

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This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

APPROVED SIGNATORY

Alex Matthew - Manager
NATA Accreditation Number
14975

A.B.N. 50 103 355 531 A.C.N. 103 355 531
VALLEY CIVILAB
GEOTECHNICAL TESTING & ENGINEERING SERVICES
Units 10-11, 21 Babilla Close. BERESFIELD NSW 2322 Phone:(02) 49661844 Facsimile:(02) 49661855

Shrink Swell Index Report

Client :	**CSG Engineering**	Report Number:	**P134 - 4**
Address :	**Suite 6, 180 Main Road , Speers Point, NSW, 2284**	Report Date :	**29/10/2010**
Project Name :	**Materials Qualities- Client Supplied**	Order Number :	
Project Number :	**P134**	Test Method :	**AS1289.7.1.1**
Location:			**Page 2 of 2**

Sample Number :	S10-880			
Test Number :				
Sampling Method :	Sampled by Client			
Sampled By :	Sampled by Client			
Date Sampled :	22/10/2010			
Date Tested :	22/10/2010			
Material Type :	Refer to Client Borelogs			
Material Source :	U50 Tube sample			
Sample Location :	Client Sampled Job No;634-10 BH-10 -0.4m			
Inert Material Estimate (%) :	10			
PP before (kPa) :	600			
PP after (kPa) :	320			
Shrinkage Moisture Content (%) :	17.8			
Shrinkage (%) :	**3.2**			
Swell Moisture Content Before (%) :	16.2			
Swell Moisture Content After (%) :	21.2			
Swell (%) :	**2.5**			
Unit Weight (t/m³) :	2.03			
Shrink Swell Index Iss (%) :	**2.5**			
Visual Classification :	Refer to clients borelogs			
Cracking :	Minor			
Crumbling :	Minor			
Remarks :				

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APPROVED SIGNATORY

Alex Matthew - Manager
NATA Accreditation Number
14975

APPENDICES

CSG ENGINEERS PTY LTD
CIVIL-STRUCTURAL-GEOTECHNICAL
CONSULTING ENGINEERS
ABN 24 057 568 215

IMPORTANT INFORMATION
ABOUT YOUR
GEOTECHNICAL ENGINEERING REPORT

More construction problems are caused by site subsurface conditions than any other factor. As troublesome as subsurface problems can be, their frequency and extent have been lessened considerably in recent years, thanks to the Association of Soil and Foundation Engineers (ASFE).

When ASFE was founded in 1969, subsurface problems were frequently being resolved through lawsuits. In fact, the situation had grown to such alarming proportions that Consulting Geotechnical Engineers had the worst professional liability record of all design professionals. *By 1980, ASFE-Member Consulting Soil and Foundation Engineers had the best professional liability record.* This dramatic turn-about can be attributed directly to client acceptance of problem-solving programs and materials developed by ASFE for its members' application. *This acceptance was gained because clients perceived the ASFE approach to be in their own best interests.* Disputes benefit only those who earn their living from other' disagreements.

The following suggestions and observations are offered to help you reduce the geotechnical-related delays, cost-overruns and other costly headaches that can occur during a construction project.

A GEOTECHNICAL ENGINEERING REPORT IS BASED ON A UNIQUE SET OF PROJECT SPECIFIC FACTORS

A geotechnical engineering report is based on a subsurface exploration plan designed to incorporate a unique set of project specific factors. These typically include: the general nature of the structure involved, its size and configuration; the location of the structure on the site and its orientation; physical concomitants such as access roads, parking lots and underground utilities, and the level of additional risk which the client assumed by virtue of limitations imposed upon the exploratory program. To help avoid costly problems, consult the Geotechnical Engineer to determine how any factors, which change subsequent to the date of his report, may affect his recommendations.

Unless your consulting Geotechnical Engineer indicates otherwise, *your geotechnical engineering report should not be used:*

* when the nature of the proposed structure is changed, for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one;

* when the size or configuration of the proposed structure is altered;

* when the location or orientation of the proposed structure is modified;

* when there is a change of ownership, or

* for application to an adjacent site.

A Geotechnical Engineer cannot accept responsibility for problems which may develop if he is not consulted after factors considered in his report's development have changed.

MOST GEOTECHNICAL "FINDINGS" ARE PROFESSIONAL ESTIMATES

Site exploration identifies actual subsurface conditions only at those points where samples are taken, when they are taken. Data derived through sampling and subsequent laboratory testing are extrapolated by the Geotechnical Engineer who then renders an opinion about overall subsurface conditions, their likely reaction to proposed construction activity, and appropriate foundation design. Even under optimal circumstances actual conditions may differ from those opined to exist, because no Geotechnical Engineer, no matter how qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. For example, the actual interface between materials may be far more gradual or abrupt than the report indicates, and actual conditions in areas not sampled may differ from predictions. *Nothing can be done to prevent the unanticipated, but steps can be taken to help minimize their impact.* For this reason, *most experienced owners retain their Geotechnical Consultant through the construction stage,* to identify variances, conduct additional tests which may be needed, and to recommend solutions to problems encountered on site.

SUBSURFACE CONDITIONS CAN CHANGE

Subsurface conditions may be modified by constantly changing natural forces. Because a geotechnical engineering report is based on conditions which existed at the time of subsurface exploration, *construction decisions should not be based on a geotechnical engineering report whose adequacy may have been affected by time.* Speak with the Geotechnical Consultant to learn if additional tests are advisable before construction starts.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations may also affect subsurface conditions and thus, the continuing adequacy of a geotechnical report. The Geotechnical Engineer should be kept appraised of any such events, and should be consulted to determine if additional tests are necessary.

A GEOTECHNICAL ENGINEERING REPORT IS SUBJECT TO MISINTERPRETATION

Costly problems can occur when other design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to geotechnical issues.

BORING LOGS SHOULD NOT BE SEPARATED FROM THE ENGINEERING REPORT*

Final boring logs are developed by the Geotechnical Engineer based upon his interpretation of field logs (assembled by site personnel) and laboratory evaluation of field samples. Only final boring logs customarily are included in geotechnical engineering reports. *These logs should not under any circumstances be redrawn* for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process. Although photographic reproduction eliminates this problem, it does nothing to minimize the possibility of contractors misinterpreting the logs during bid preparation. When this occurs, delays, disputes and unanticipated costs are the all-too-frequent result.

To minimize the likelihood of boring log misinterpretation, *give contractors ready access to the complete geotechnical report.* Those who do not provide such access, may proceed under the *mistaken* impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes which aggravate them to disproportionate scale.

* Note this clause may not be directly applicable to Australian practice depending upon the nature of latent condition clauses in the contract and other matters. SAA and Institution of Engineers Australia have this and related matters under consideration (June 1986).

READ RESPONSIBILITY CLAUSES CLOSELY

Because geotechnical engineering is based extensively on judgement and opinion, it is far less exact than other design disciplines. This situation had resulted in wholly unwarranted claims being lodged against Geotechnical Consultants. To help prevent this problem, Geotechnical Engineers have developed model clauses for use in written transmittals. These are *not* exculpatory clauses designed to foist the Geotechnical Engineer's liabilities onto someone else. Rather, they are definitive clauses which identify where the Geotechnical Engineer's responsibilities begin and end. Their use helps all parties involved recognise their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your geotechnical engineering report, and you are encouraged to read them closely. Your Geotechnical Engineer will be pleased to give full and frank answers to your questions.

OTHER STEPS YOU CAN TAKE TO REDUCE RISK

Your consulting Geotechnical Engineer will be pleased to discuss other techniques which can be employed to mitigate risk. In addition, the Association of Soil and Foundation Engineers has developed a variety of materials which may be beneficial. Contact ASFE for a complimentary copy of its publications directory.

Published by

ASFE
ASSOCIATION OF SOIL AND FOUNDATION ENGINEERS
8811 Colesville Road, Suite 225
Silver Spring, Maryland 20910
301/565-2733

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CONSULTING ENGINEERS
ABN 24 057 568 215

LIMITATIONS OF GEOTECHNICAL ASSESSMENT

Geotechnical Assessment

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared to meet the specific needs of individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor or even some other consulting civil engineer. This report was prepared expressly for the Client and expressly for the purposes indicated by the Client or his representative. The Client should not use this report for other than its intended purpose without seeking additional geotechnical advice.

Report for Benefit of Client

The report has been prepared for the benefit of the Client and no other party. CSG Engineers Pty Ltd assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of CSG Engineers Pty Ltd or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Scope of Services

This geotechnical site assessment has been prepared in accordance with the scope of services set out in the proposal, or as otherwise agreed, between the Client and CSG Engineers Pty Ltd. In some circumstances the scope of services may have been limited by a range of factors such as time, **budget**, access and/or site disturbance constraints.

Reliance on Data

In preparing the report, CSG Engineers Pty Ltd has relied upon the data which are referred to in the report. Except as otherwise stated in the report, CSG Engineers Pty Ltd has not verified the accuracy or completeness the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are dependent upon the accuracy and completeness of the data. CSG Engineers Pty Ltd will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to CSG Engineers Pty Ltd.

This Geotechnical Report is Based on Project-specific Factors

This geotechnical engineering report is based on a subsurface assessment which was designed for project-specification factors, including the nature of any development, its size and configuration, the location of any development on the site and its orientation, and the location of access roads and parking areas.

Unless further geotechnical advice is obtained this geotechnical engineering report cannot be used when the nature of any proposed development is changed; or when the size, configuration location or orientation of any proposed development is modified. This geotechnical engineering report cannot be applied to an adjacent site.

The Limitations of Site Assessment

In making an assessment of a site from a limited number of boreholes or test pits there is the possibility that variations may occur between test locations. Site exploration identifies specific subsurface conditions only at those points from which samples have been taken. The risk that variations will not be detected can be reduced by increasing the frequency of test locations; however this often does not result in any overall cost savings for the project. The assessment programme undertaken is a professional estimate or scope of work required by the client at the time of engagement to provide a general profile of the subsurface conditions. The data derived from the site assessment programme and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. . Despite assessment the actual conditions at the site might be different from those inferred to exist, since no subsurface exploration programme, no matter how comprehensive, can reveal all subsurface details and anomalies.

The borehole logs should not be regarded as definitive statements of subsurface conditions at a particular location. They are in fact the subjective interpretation of trained personnel and these interpretations are limited by the method of assessment. For example, inspection of an excavation or test pit allows a greater area of the subsurface profile to be inspected than borehole assessment, however, such methods are limited by depth and site disturbance restrictions. In borehole assessment, the actual interface between materials may be more gradual or abrupt than a report indicates.

Subsurface Conditions may Undergo Variations with Time

Subsurface conditions may be modified by changing natural forces or man-made influences. A geotechnical engineering report is based on conditions which existed at the time of subsurface exploration. Natural events such as floods, or groundwater fluctuations, or construction operations at or adjacent to the site, may affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

Avoid Misinterpretation

A geotechnical engineer should be retained to work with other appropriate design professionals explaining relevant geotechnical findings and in reviewing the adequacy of their plans and specifications relative to geotechnical issue

Bore/Profile Logs Should Not Be Separated from the Engineering Report

Final bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports. These logs should not under any circumstances be redrawn for inclusion in architectural or other design drawings. To minimise the likelihood of bore/profile log misinterpretation, contractors should be given access to the complete geotechnical engineering report prepared or authorised for their use. Providing the best available information to contractors helps prevent costly construction problems. For further information on this matter reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by the Institution of Engineers Australia, National Headquarters. Canberra 1987.

Geotechnical Involvement During Construction

During construction, excavation is frequently undertaken which exposes the actual subsurface conditions. For this reason geotechnical consultants should be retained through the construction stage, to identify variations if they are exposed and to conduct additional tests which may be required and to deal quickly with geotechnical problems if they arise.

Other Limitations

CSG Engineers Pty Ltd will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

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CONSULTING ENGINEERS

ABN 24 057 568 215

DESIGN AND SITE MANAGEMENT PRECAUTIONS FOR CONSTRUCTION ON REACTIVE SOILS

GENERAL DESIGN PRECAUTIONS

These procedures generally apply to single storey, brick residential buildings, or as specified in the design/report, founded on reactive clay soils. Such soils are prone to heave/shrink movements due to moisture variations (either by natural or artificial causes). It must be accepted that some minor masonry cracking can occur with these soils, despite the listed precautions and associated foundation design. However, the basic design philosophy is to minimize any cracking and provide a serviceable structure. It is thus a compromise between economy and performance.

The following procedures are considered supplementary to any other foundation recommendations given in the design/report:-

* All surface water runoff must be directed away from the building by appropriate grading, in order to prevent ponding near foundations. Site drainage must form part of the building contract.

* Peripheral impermeable pathways should be provided around the building. This action supplements site drainage and assists in the stabilisation of moisture conditions near foundations.

* All brickwork should be suitably articulated into discrete units to accommodate the expected movements. In particular, brickwork over doors and windows should be avoided.

* Internal and external walls should be arranged along straight lines.

* All house drains and water pipes must be provided with sufficient flexibility to accommodate the expected differential movements (between foundation and uncovered outside area) at the level of service.

* The extension of services through slabs should be avoided, where possible, in order to prevent hidden leaks under the slab area. Most plumbing fixtures can be arranged to exit through outside walls.

* Septic systems must not be located within any influence (preferably downhill) of the house or neighbouring foundations. Alternatively, a pump-out system must be employed.

* Subgrades beneath elevated and well ventilated floors should be covered with an impermeable liner (with protective soil blanket) to minimize excessive desiccation.

In addition, certain other 'site management' precautions must be adhered to during the life of the structure, as given on our standard sheet. These precautions generally relate to the control of abnormal moisture variations due to the effects of drainage and vegetation.

SITE MANAGEMENT PRECAUTIONS

These precautions are considered supplementary to any structural and/or foundation design measures for the subject building, and are intended for distribution to the prospective house Owner.

Reactive clays are prone to heave/shrink movements with changes in soil moisture content, due to natural or artificial means. The basic design philosophy employed for the dwelling, is to provide a foundation/superstructure adequate to accommodate ground movements, due to extreme seasonal moisture changes only. The possibility of other abnormal and/or localised moisture changes (the cause of most housing distress) has been assumed to be controlled by the following 'site management' procedures:-

* In particular, leaking plumbing or blocked drains should be repaired promptly and site grading maintained to prevent ponding near foundations. Garden watering, particularly by fixed systems, should be controlled carefully to avoid gross over watering. On the other hand, proper garden maintenance should produce year round uniform moisture conditions.

* Trees and some shrubs can cause a substantial drying of the soil and associated shrinking of reactive clays. This effect is most likely to result in damage when added to the drying from a drought or a long dry spell. The problem can be minimized by planting trees at substantial distances from the house. The distance depends upon the species and soil conditions, but generally ¾ of the mature tree height is a minimum.

* Problems during drought can be minimized by extensive pruning (thus reducing water demand) and/or providing trees with adequate water. This watering can be achieved by boreholes or trenches dug well into the clay between the tree and the footing. To avoid any settlement problems, the holes or trenches should not be too close to the footing and should be filled with compacted coarse sand. Frequent moderate watering during dry periods should ensure that the tree does not extract excessive moisture from beneath the foundation of the house.

  This action should also be immediately undertaken by the Owner if brickwork cracking due to tree drying is noticed. Most reactive clay failures can be avoided or minimized by controlling the combined drying effects of trees and drought.

The Owner should also appreciate that on reactive clays it is virtually impossible to design an economic foundation system that will totally prevent movement. Some minor aesthetic cracking, while undesirable, will occur in a significant proportion of houses. In addition, some minor problems should be expected with jamming of windows and doors especially during the settling in period or following a major drought and any repairs should be regarded as part of normal house maintenance. Even significant masonry cracking with widths over 5mm usually has no influence on the function of the wall and only presents an aesthetic problem. Just as it is difficult to design an immovable footing system, it is almost impossible to provide remedial measures that will prevent further movements if distress does occur. Consequently, extreme remedial measures should not be undertaken for minor problems.

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

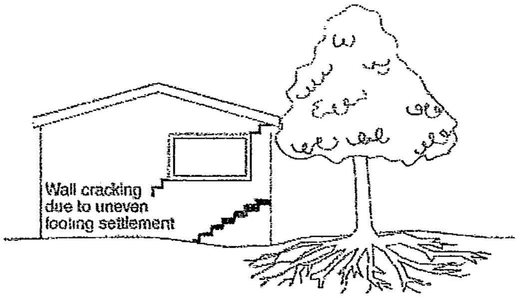
- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.


Trees can cause shrinkage and damage

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem.
It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

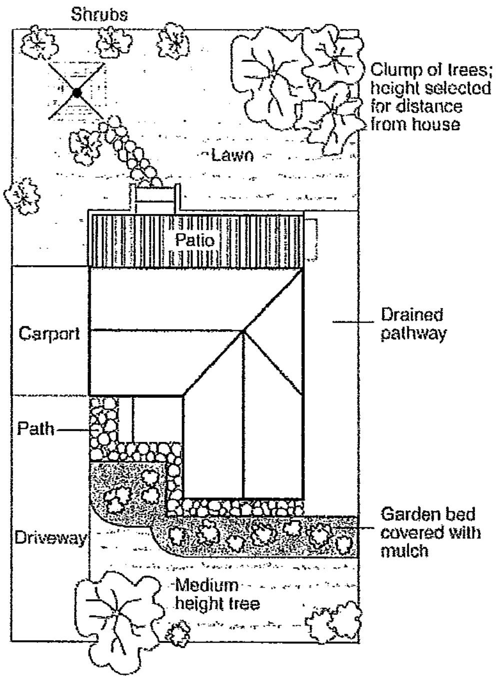
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Garden for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au
Email: publishing.sales@csiro.au