# REPORT

TO

## GARDNER WETHERILL AND ASSOCIATES

ON

## GEOTECHNICAL INVESTIGATION

FOR

## PROPOSED ALTERATIONS AND ADDITIONS

AT

## ST EDMUNDS SCHOOL, BURNS ROAD, WAHROONGA

26 September 2008

Ref: 22402LPrpt


**Jeffery and Katauskas Pty Ltd**

CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

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TABLE A: SUMMARY OF LABORATORY SOIL CLASSIFICATION TEST RESULTS

BOREHOLE LOGS 1 TO 4 INCLUSIVE

DYNAMIC CONE PENETRATION TEST RESULTS

FIGURE 1: BOREHOLE LOCATION PLAN

REPORT EXPLANATION NOTES

## 1 INTRODUCTION

This report presents the results of a geotechnical investigation for proposed alterations and additions at St Edmunds School, Burns Road, Wahroonga, NSW. The investigation was commissioned by Mr Ross Gardner of Gardner Wetherill and Associates in an email dated 29 August 2008. The investigation was carried out in accordance with our proposal (Ref: P15944SP) dated 15 August 2008.

While design drawings have not been provided, we understand the proposed alterations and additions comprise a new roof over the existing in-ground swimming pool, a new amenities building to the north of the swimming pool, and a new two-storey classroom building in approximately the same location as the existing technology building (just to the west of Borehole 3) which we understand will be demolished.

The purpose of the investigation was to obtain geotechnical information on the subsurface conditions, and to use this as a basis for our comments and recommendations on site preparation, site classification and footing design.

Jeffery and Katauskas previously completed an investigation in the vicinity of these works, with the results being presented in a report Reference 11438J dated 30 October 1995. We are not certain of the location of the previous investigation, or of changes to the site since that time, and so we consider that the current investigation supersedes the results of the previous investigation. We have however referred to the laboratory test results in Section 3 of this report.

## 2 INVESTIGATION PROCEDURE

The fieldwork for the investigation was carried out on 2 September 2008 and comprised the auger drilling of three boreholes (BH1 to BH3) to depths ranging from

6.0m to 12.0m below existing surface levels using our track mounted JK250 drilling rig. A fourth borehole (BH4) was drilled to 0.45m depth using a hand auger, with a Dynamic Cone Penetration (DCP) test completed to 4.3m depth adjacent to BH4 to assess the apparent compaction of the fill, and the strength of the natural soils; the borehole was hand augered as there was no access for the drilling rig to that location.

Prior to the commencement of drilling, the borehole locations were electro-magnetically scanned for buried services by a specialist sub-contractor.

The borehole locations, as shown on Figure 1, were set out by taped measurements from existing site features and apparent site boundaries shown on the provided survey plan (Dwg No A606-002, dated 25 January 2008 prepared by Whelans Insites Pty Ltd).

A Geotechnical Engineer was present on a full-time basis during the fieldwork, and set out the borehole locations, nominated the in-situ testing and sampling, and prepared the borehole logs. The borehole logs, which include field test results and groundwater observations, are attached, together with a glossary of logging terms and symbols used.

The compaction of the fill and strength of the subsurface soils were assessed from the Standard Penetration Test (SPT) 'N' values, which were augmented by the results of hand penetrometer tests completed on cohesive soil samples recovered from the SPT sampler.

Groundwater observations were made both during and on the completion of the fieldwork. No long term groundwater monitoring has been undertaken.

Selected samples were returned to Soil Test Services Pty Ltd (STS), a NATA registered laboratory, for testing including Moisture Content, Atterberg Limits and Linear Shrinkage. The results of the testing are summarised in the attached Table A.

For further details of the investigation procedures used, and their limitations, reference should be made to the attached Report Explanation Notes.

Testing for possible contamination of the soils and groundwater were beyond the agreed scope of this investigation.

## 3 RESULTS OF THE INVESTIGATION

### 3.1 Site Description

The area around the School appears to be close to the top of a very broad rounded hill. The site is reasonably level and contains a typical school layout with a cluster of one and two storey brick buildings within the southern and south-western portions of the site, and open play areas to the north-east. The school has frontages to Burns Road to the south, Wahroonga Avenue to the west and Braeside Street to the north. There are residential properties to the north-west, south-east and east of the school, which comprise one and two storey brick dwellings.

The existing in-ground swimming pool is located at the southern end of the proposed works, and is contained within a metal framed building with fibreglass roof and glass walls. The pool is surrounded by a brick path. Three sides of the pool are approximately equal to the level of the grass playing field to the north. However, to the east the ground slopes away towards the neighbouring properties. South of the pool is a line of small trees marking the boundary and a residential house set back about 20m.

The proposed amenities building will be to the north of the swimming pool, presumably with a floor level similar to the level of the pool coping. Within this area are several items of playground equipment within a grass covered area, and small existing brick walls.

The buildings to the west of the pool and proposed amenities building area are located in an area which is about 0.8m to 1.0m above the pool level, with a brick retaining wall between the two levels. The proposed new building will be constructed over the location of the northern of these buildings. There are several tall trees to the north of the subject building.

Based on cursory observations from within the subject site, the buildings and concrete footpaths appeared to be in a good condition with no cracks evident.

### 3.2 Subsurface Conditions

The 1:100,000 geological map of Sydney indicates that the site is located near the lithological boundary between the Ashfield Shale and the Hawkesbury Sandstone. The boreholes disclosed a subsurface profile consisting of topsoil and clayey fill over very deep residual silty clays. Bedrock was not encountered in the boreholes. Some of the characteristic features of the strata encountered are described below. For further details of the conditions encountered at each location, reference should be made to the attached borehole logs.

***Topsoil and Fill***

Each of the test locations were within grass covered areas with a thin topsoil layer with root fibres to 0.1m to 0.2m depth. Below the topsoil in Borehole 3 (BH3) and BH4, low and medium plasticity silty clay and clayey silt fill was encountered. The fill extended to a depth of 1.0m in BH3, with the hand augered borehole, BH4, refusing to penetrate the fill, despite several attempts being made to do so.

***Residual Soils***

Residual silty clays were encountered below the topsoil in BH1 and BH2, and below the fill in BH3. These soils extended to the termination depth of the boreholes which ranged from 6m to 12m. The upper portion of the clayey soils was of stiff strength, increasing through very stiff, with soils of hard strength encountered below about 2m depth. The silty clays were of high and medium to high plasticity, with moisture contents in excess of their plastic limits. These clayey soils contained varying proportions of fine to medium grained ironstone gravel. The lower portion of the clayey soils within BH1 was borderline between residual silty clay and extremely weathered fine grained sandstone.

***Groundwater***

All boreholes were 'dry' both during and shortly after the completion of augering, with the exception of BH1 where a groundwater level was measured at a depth of 6.6m approximately 2.5 hours after the completion of drilling. No long term groundwater monitoring was undertaken.

## 3.3 Laboratory Test Results

The Atterberg Limit tests confirmed the natural soils on the site are of high plasticity and correlate with a high potential for shrink/swell reactive movements with changes in moisture content. The moisture content of the clayey soils were in excess of their plastic limit.

The laboratory testing conducted during the previous investigation suggested the soils were of lower plasticity and lower shrink-swell potential, however the current test results correlate well with the field logging assessments.

# 4 COMMENTS AND RECOMMENDATIONS

## 4.1 Excavation and Site Preparation

We expect that the proposed new structures will be founded close to the existing ground levels, and as such, only minimal site preparation will be required. There may be some minor stripping of topsoil, fill and natural clays to achieve the required subgrade level, and detailed excavation for footings, services etc. These excavations will be within the soils and should be readily achieved using conventional earthmoving equipment such as tracked excavators.

## 4.2 Batter Slopes and Retaining Wall Design

We expect that any excavation will be limited to about 0.5m, and such cuts may be made subvertically for the temporary case provided it is understood there may be minor instability of some of these cuts; otherwise the cuts could be temporarily battered at no steeper than 1 Vertical (V) in 1 Horizontal (H).

Any permanent slopes in the soils should be battered at no steeper than 1V in 2H, and these should be protected against erosion such as by a dense vegetative cover.

It is possible that there could be new retaining walls associated with the proposed structures, though we expect that such walls would be of low height, say less than 1m or so. Provided that minor movements of these walls can be tolerated, they may be designed for an active lateral earth pressure coefficient (Ka) of 0.35. An increased lateral earth pressure coefficient of 0.6 should be adopted where such movements are to be reduced. These earth pressure coefficients assume that the backslope to the retaining walls will be near level, and if sloping backfill will be present, these coefficients will either need to be appropriately increased, or the sloping backfill treated as a surcharge on a level backslope. Appropriate surcharge

loads and hydrostatic pressures should be taken into account in the design of the retaining walls.

### 4.3 Site Classification

Where the natural soils are present below a thin topsoil layer such as BH1 and BH2, the laboratory testing indicates that the site classification should be class 'H' in accordance with AS2870. It should be noted that this classification is based upon the soil characteristics only, and the designer should take account of other factors such as the presence of trees, the presence of previous buildings and proposed earthworks for the development etc.

Where there is fill present, such as in BH3 and BH4, the fill does not appear to have been placed in a controlled manner, and so these areas would be considered to be Class 'P' in accordance with AS2870.

### 4.4 Footing Design

Due to the presence of fill in some of the boreholes, resulting in the Class 'P' classification, we recommend the proposed amenities and classroom structures be supported on piled foundations, unless stiffened raft slabs are used which have very deep edge and internal beams so they found with embedments of say at least 0.3m into the natural soils where an allowable bearing pressure of 150kPa may be adopted. The upper surface of the fill should be proof rolled using a five tonne minimum deadweight smooth drum roller to improve the compaction of the near surface soils. Representative footings should be inspected by a geotechnical engineer to confirm the appropriate founding material is being achieved. For the proposed amenities building, if the conditions below the entire building are more similar to BH1 and BH2 rather than BH3, a raft slab may be a more attractive option,

and consideration should be given to further investigation of the exact building footprint to determine whether the entire raft wo9uld found within the residual soils.

Another option would be to remove the existing fill and replace it with engineered fill and then using a stiffened raft footing system for the building, though this would be a very difficult exercise given the confined nature of the site and the proximity to the nearby structures. Further advice would be required should you wish to proceed with this option.

Alternatively, a pier and beam system could be adopted for the proposed structures, and piers founded within the clays of very stiff to hard strength at a depth of at least 2.5m below the existing surface level may be designed for an allowable bearing pressure of 450kPa. Rough clean sockets in the very stiff to hard clayey soils below 2m depth may be designed for an allowable shaft adhesion of 20kPa. The bored piers could comprise conventional bored piles. We do not expect that it would be possible to penetrate the hard clayey soils with steel screw piles.

## 5 GENERAL COMMENTS

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. As an example, geotechnical inspection of representative footings where raft slabs are adopted. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and Jeffery and Katauskas Pty Ltd accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

Occasionally, the subsurface conditions between the completed boreholes may be found to be different (or may be interpreted to be different) from those expected.

Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

The offsite disposal of soil will most likely require classification in accordance with the Department of Environment & Climate Change (NSW) guidelines as Virgin Un-Excavated Natural Material (VENM), General Solid, Restricted Solid or Hazardous waste. We can complete the necessary classification and testing if you wish to commission us. As testing requires about seven days to complete, allowance should be made for such testing in the construction program unless testing is completed prior to construction. If contamination is found to be present then substantial further testing and delays should be expected. We strongly recommend this issue be addressed prior to commencement of excavation on site.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. Copyright in this report is the property of Jeffery and Katauskas Pty Ltd. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees

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

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**SOIL TEST SERVICES**
ABN 43 002 145 173

Ref No:22402SP


## TABLE A
## SUMMARY OF LABORATORY TEST RESULTS

| AS 1289 | TEST METHOD | 2.1.1 | 3.1.2 | 3.2.1 | 3.3.1 | 3.4.1 |
|---|---|---|---|---|---|---|
| BOREHOLE NUMBER | DEPTH m | MOISTURE CONTENT % | LIQUID LIMIT % | PLASTIC LIMIT % | PLASTICITY INDEX % | LINEAR SHRINKAGE % |
| 1 | 0.50-0.95 | 24.4 | | | | |
| 1 | 1.50-1.95 | 31.8 | 54 | 20 | 34 | 13.5 |
| 1 | 3.00-3.45 | 29.6 | | | | |
| 2 | 0.50-0.95 | 27.0 | | | | |
| 2 | 1.50-1.95 | 29.8 | | | | |
| 2 | 3.00-3.45 | 27.0 | | | | |
| 2 | 4.50-4.95 | 27.4 | | | | |
| 3 | 0.50-0.95 | 26.2 | | | | |
| 3 | 1.50-1.95 | 30.6 | 59 | 22 | 37 | 14.5 |
| 3 | 3.00-3.45 | 33.8 | | | | |

**Notes:**
- The test sample for liquid and plastic limit was air-dried & dry-sieved
- The linear shrinkage mould was 125mm
- Refer to appropriate notes for soil descriptions

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**Jeffery and Katauskas Pty Ltd**
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

Borehole No. 1 1/2

# BOREHOLE LOG

**Client:** GARDNER WETHERILL AND ASSOCIATES

**Project:** PROPOSED ALTERATIONS AND ADDITIONS

**Location:** ST EDMUNDS SCHOOL, BURNS ROAD, WAHROONGA, NSW

**Job No.** 22402SP **Method:** SPIRAL AUGER JK250 **R.L. Surface:** N/A

**Date:** 2-9-08 **Datum:**

**Logged/Checked by:** M.P./ PW

| Groundwater Record | SAMPLES ES | SAMPLES U50 | SAMPLES DB | SAMPLES DS | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRY ON COMPLETION | | | | | | 0 | | | FILL/TOPSOIL: Silty clay, low to medium plasticity, dark brown, with root fibres. | MC > PL | | | GRASS COVER |
| | | | | | | | | CL | | MC > PL | St-VSt | - | |
| | | | | | N = 6 2,3,3 | 1 | | | SILTY CLAY: low to medium plasticity, orange brown mottled brown and red brown, with ash and a trace of fine grained ironstone gravel. | | | 180 220 230 | |
| | | | | | | | | CH | SILTY CLAY: high plasticity, orange brown. | | VSt | | RESIDUAL |
| | | | | | N = 9 2,3,6 | 2 | | | | | | 220 220 300 | |
| | | | | | | | | | SILTY CLAY: high plasticity, light grey mottled dark red brown, with ironstone gravel. | | H | | |
| | | | | | N = 38 11,14,24 | 3 | | | | | | > 600 > 600 > 600 | |
| | | | | | | 4 | | | | | | | |
| | | | | | N = 37 7,15,22 | 5 | | | | | | 350 > 600 > 600 | |
| | | | | | | 6 | | | | | | 410 380 490 | |
| ▼ AFTER 2.5 HRS | | | | | | 7 | | | | | | | |

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Borehole No. 1 2/2

# BOREHOLE LOG

**Client:** GARDNER WETHERILL AND ASSOCIATES

**Project:** PROPOSED ALTERATIONS AND ADDITIONS

**Location:** ST EDMUNDS SCHOOL, BURNS ROAD, WAHROONGA, NSW

**Job No.** 22402SP **Method:** SPIRAL AUGER JK250 **R.L. Surface:** N/A

**Date:** 2-9-08 **Datum:**

**Logged/Checked by:** M.P./ PW

| Groundwater Record | SAMPLES ES | SAMPLES U50 | SAMPLES DB | SAMPLES DS | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 8 | | CL-CH | SILTY CLAY: medium to high plasticity, light grey and red brown, with ironstone gravel. | MC≈PL | VSt -H | | NOTE: RAPID AUGER DRILLING TO CHECK FOR PRESENCE OF ROCK WITHOUT SAMPLING OR INSITU TESTING. SOIL DESCRIPTION MAY NOT BE RELIABLE IN THIS ZONE |
| | | | | | | 9 | | | | | | | |
| | | | | | | 10 | | | | | | | |
| | | | | | | 11 | | | POSSIBLY EXTREMELY WEATHERED SANDSTONE. | XW | EL | | |
| | | | | | | 12 | | | END OF BOREHOLE AT 12.0m | | | | |
| | | | | | | 13 | | | | | | | |
| | | | | | | 14 | | | | | | | |

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Borehole No. 2 1/1

# BOREHOLE LOG

**Client:** GARDNER WETHERILL AND ASSOCIATES
**Project:** PROPOSED ALTERATIONS AND ADDITIONS
**Location:** ST EDMUNDS SCHOOL, BURNS ROAD, WAHROONGA, NSW

**Job No.** 22402SP **Method:** SPIRAL AUGER JK250 **R.L. Surface:** N/A
**Date:** 2-9-08 **Datum:**
**Logged/Checked by:** M.P./ PW

| Groundwater Record | SAMPLES ES | SAMPLES U50 | SAMPLES DB | SAMPLES DS | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRY ON COMPLETION & AFTER 2 HRS | | | | | | 0 | | | FILL/TOPSOIL: Silty sand, fine to medium grained, dark brown. | M | | | GRASS COVER |
| | | | | | N = 3 1,1,2 | | | CL | SILTY CLAY: low to medium plasticity, brown and orange brown, with a trace of ash. | MC > PL | St | - 210 | |
| | | | | | | 1 | | CH | SILTY CLAY: high plasticity, orange brown. | MC > PL | VSt | - | |
| | | | | | N = 8 3,3,5 | | | | | | | 300 350 290 | |
| | | | | | | 2 | | CH | GRAVELLY CLAY: high plasticity, red brown and orange brown, with fine to medium grained ironstone gravel. | MC > PL | H | | RESIDUAL |
| | | | | | N = 31 10,13,18 | 3 | | | | | | 560 > 600 > 600 | |
| | | | | | | 4 | | CH | SILTY CLAY: high plasticity, light grey mottled orange brown, with a trace of ironstone gravel. | | | | |
| | | | | | N = 44 11,19,25 | 5 | | | | | | > 600 > 600 > 600 | |
| | | | | | | | | | as above, but red brown and light grey. | | | | |
| | | | | | | 6 | | | END OF BOREHOLE AT 6.0m | | | | |
| | | | | | | 7 | | | | | | | |

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Borehole No. 3 1/1

# BOREHOLE LOG

**Client:** GARDNER WETHERILL AND ASSOCIATES

**Project:** PROPOSED ALTERATIONS AND ADDITIONS

**Location:** ST EDMUNDS SCHOOL, BURNS ROAD, WAHROONGA, NSW

**Job No.** 22402SP **Method:** SPIRAL AUGER JK250 **R.L. Surface:** N/A

**Date:** 2-9-08 **Datum:**

**Logged/Checked by:** M.P./PW

| Groundwater Record | SAMPLES ES | SAMPLES U50 | SAMPLES DB | SAMPLES DS | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRY ON COMPLETION & AFTER 1 HR | | | | | N = 4 2,2,2 | 0 | | | FILL/TOPSOIL: Silty sand, fine to medium grained, dark brown. | M | | | GRASS COVER |
| | | | | | | | | | FILL: Clayey silt, low plasticity, brown mottled orange brown, with a trace of rounded fine grained ironstone gravel. | MC > PL | | | APPEARS POORLY COMPACTED |
| | | | | | N = 13 6,6,7 | 1 | | CH | SILTY CLAY: high plasticity, orange brown. | MC > PL | VSt -H | - 470 350 330 | RESIDUAL |
| | | | | | | 2 | | | SILTY CLAY: high plasticity, light grey and red brown, with fine to medium grained ironstone gravel. | | H | | |
| | | | | | N = 29 8,11,18 | 3 | | | | | | 360 440 >600 | |
| | | | | | N = 34 9,15,19 | 4 | | | as above, but red brown and light grey. | | | >600 >600 >600 | |
| | | | | | | 5 | | | | | | | |
| | | | | | | 6 | | | END OF BOREHOLE AT 6.0m | | | | |
| | | | | | | 7 | | | | | | | |

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# BOREHOLE LOG

**Borehole No.** 4 1/1

**Client:** GARDNER WETHERILL AND ASSOCIATES
**Project:** PROPOSED ALTERATIONS AND ADDITIONS
**Location:** ST EDMUNDS SCHOOL, BURNS ROAD, WAHROONGA, NSW

**Job No.** 22402SP **Method:** HAND AUGER **R.L. Surface:** N/A
**Date:** 2-9-08 **Datum:**
**Logged/Checked by:** M.P./ PW

| Groundwater Record | SAMPLES ES | SAMPLES U50 | SAMPLES DB | SAMPLES DS | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRY ON COMPLETION | | | | | REFER TO DCP TEST RESULTS | 0 | | | FILL/TOPSOIL: Silty sand, fine to medium grained, dark brown. | M | | | APPEARS POORLY COMPACTED |
| | | | | | | | | | FILL: Silty clay, medium to high plasticity, light grey, red brown and brown, with a trace of brick fragments and pipes. | MC > PL | | | HAND AUGER REFUSAL ON OBSTRUCTION IN FILL INFERRED BRICK SEVERAL ATTEMPTS MADE WITH SAME RESULT |
| | | | | | | 1 | | | END OF BOREHOLE AT 0.45m | | | | |
| | | | | | | 2 | | | | | | | |
| | | | | | | 3 | | | | | | | |
| | | | | | | 4 | | | | | | | |
| | | | | | | 5 | | | | | | | |
| | | | | | | 6 | | | | | | | |
| | | | | | | 7 | | | | | | | |

# Jeffery and Katauskas Pty Ltd

CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

# DYNAMIC CONE PENETRATION TEST RESULTS

| | | | |
|---|---|---|---|
| Client: | GARDNER WETHERILL AND ASSOCIATES PTY LTD | | |
| Project: | PROPOSED ALTERATIONS AND ADDITIONS | | |
| Location: | ST EDMUNDS SCHOOL, BURNS ROAD, WAHROONGA, NSW | | |
| Job No. | 22402SP | Hammer Weight & Drop: | 9kg/510mm |
| Date: | 2-9-08 | Rod Diameter: | 16mm |
| Tested By: | M.P. | Point Diameter: | 20mm |

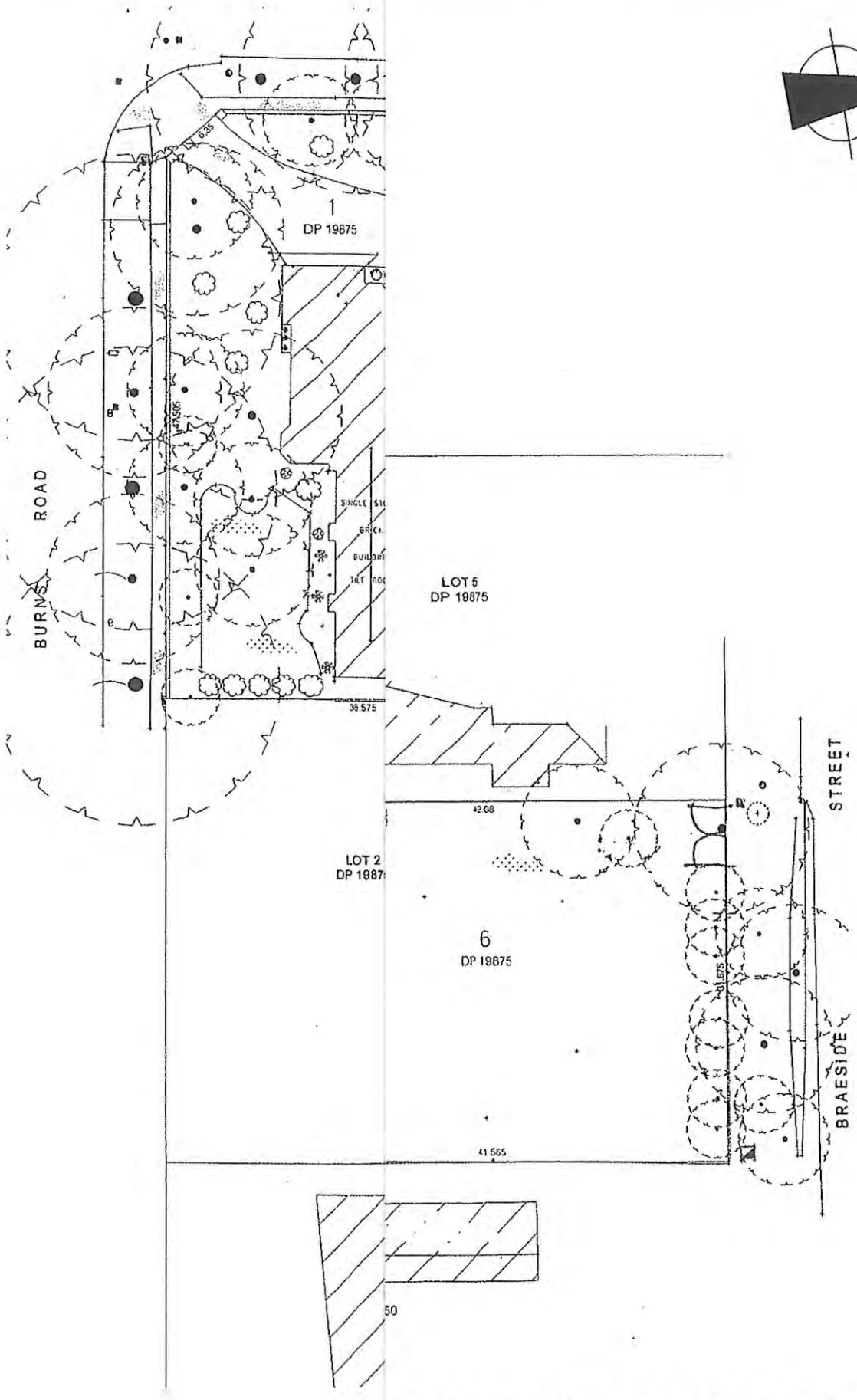
Number of Blows per 100mm Penetration

| Test Location | | | | Test Location | | | |
|---|---|---|---|---|---|---|---|
| Depth (mm) | 4 | | | Depth (mm) | 4 | | |
| 0 - 100 | 2 | | | 3000-3100 | 12 | | |
| 100 - 200 | 1 | | | 3100-3200 | 14 | | |
| 200 - 300 | 2 | | | 3200-3300 | 14 | | |
| 300 - 400 | 3 | | | 3300-3400 | 14 | | |
| 400 - 500 | 3 | | | 3400-3500 | 18 | | |
| 500 - 600 | 1 | | | 3500-3600 | 17 | | |
| 600 - 700 | 1 | | | 3600-3700 | 15 | | |
| 700 - 800 | 2 | | | 3700-3800 | 16 | | |
| 800 - 900 | 1 | | | 3800-3900 | 17 | | |
| 900 - 1000 | 2 | | | 3900-4000 | 17 | | |
| 1000 - 1100 | 2 | | | 4000-4100 | 17 | | |
| 1100 - 1200 | 2 | | | 4100-4200 | 21 | | |
| 1200 - 1300 | 2 | | | 4200-4300 | 21 | | |
| 1300 - 1400 | 2 | | | 4300-4400 | END | | |
| 1400 - 1500 | 5 | | | 4400-4500 | | | |
| 1500 - 1600 | 6 | | | 4500-4600 | | | |
| 1600 - 1700 | 6 | | | 4600-4700 | | | |
| 1700 - 1800 | 7 | | | 4700-4800 | | | |
| 1800 - 1900 | 8 | | | 4800-4900 | | | |
| 1900 - 2000 | 8 | | | 4900-5000 | | | |
| 2000 - 2100 | 7 | | | 5000-5100 | | | |
| 2100 - 2200 | 11 | | | 5100-5200 | | | |
| 2200 - 2300 | 11 | | | 5200-5300 | | | |
| 2300 - 2400 | 8 | | | 5300-5400 | | | |
| 2400 - 2500 | 7 | | | 5400-5500 | | | |
| 2500 - 2600 | 11 | | | 5500-5600 | | | |
| 2600 - 2700 | 11 | | | 5600-5700 | | | |
| 2700 - 2800 | 11 | | | 5700-5800 | | | |
| 2800 - 2900 | 14 | | | 5800-5900 | | | |
| 2900 - 3000 | 14 | | | 5900-6000 | | | |

Remarks: +

2. Usually 8 blows per 20mm is taken as refusal

Ref. Scala6.xls April 99




# ESTIGATION LOCATION PLAN

SCALE (m)

0 25

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Report No. 22402SP Figure No. 1

**Jeffery and Katauskas Pty Ltd**
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS
ABN 17 003 550 801

# REPORT EXPLANATION NOTES

## INTRODUCTION

These notes have been provided to amplify the geotechnical report in regard to classification methods, field procedures and certain matters relating to the Comments and Recommendations section. Not all notes are necessarily relevant to all reports.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

## DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, the SAA Site Investigation Code. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached Unified Soil Classification Table qualified by the grading of other particles present (eg sandy clay) as set out below:

| Soil Classification | Particle Size |
|---|---|
| Clay | less than 0.002mm |
| Silt | 0.002 to 0.06mm |
| Sand | 0.06 to 2mm |
| Gravel | 2 to 60mm |

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Test (SPT) as below:

| Relative Density | SPT 'N' Value (blows/300mm) |
|---|---|
| Very loose | less than 4 |
| Loose | 4 – 10 |
| Medium dense | 10 – 30 |
| Dense | 30 – 50 |
| Very Dense | greater than 50 |

Cohesive soils are classified on the basis of strength (consistency) either by use of hand penetrometer, laboratory testing or engineering examination. The strength terms are defined as follows.

| Classification | Unconfined Compressive Strength kPa |
|---|---|
| Very Soft | less than 25 |
| Soft | 25 – 50 |
| Firm | 50 – 100 |
| Stiff | 100 – 200 |
| Very Stiff | 200 – 400 |
| Hard | Greater than 400 |
| Friable | Strength not attainable – soil crumbles |

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'Shale' is used to describe thinly bedded to laminated siltstone.

## SAMPLING

Sampling is carried out during drilling or from other excavations to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, moisture content, minor constituents and, depending upon the degree of disturbance, some information on strength and structure. Bulk samples are similar but of greater volume required for some test procedures.

Undisturbed samples are taken by pushing a thin-walled sample tube, usually 50mm diameter (known as a U50), into the soil and withdrawing it with a sample of the soil contained in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling used are given on the attached logs.

## INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application. All except test pits, hand auger drilling and portable dynamic cone penetrometers require the use of a mechanical drilling rig which is commonly mounted on a truck chassis.

**Test Pits:** These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures. Care must be taken if construction is to be carried out near test pit locations to either properly recompact the backfill during construction or to design and construct the structure so as not to be adversely affected by poorly compacted backfill at the test pit location.

**Hand Auger Drilling:** A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Premature refusal of the hand augers can occur on a variety of materials such as hard clay, gravel or ironstone, and does not necessarily indicate rock level.

**Continuous Spiral Flight Augers:** The borehole is advanced using 75mm to 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling and insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface by the flights or may be collected after withdrawal of the auger flights, but they can be very disturbed and layers may become mixed. Information from the auger sampling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability due to mixing or softening of samples by groundwater, or uncertainties as to the original depth of the samples. Augering below the groundwater table is of even lesser reliability than augering above the water table.

**Rock Augering:** Use can be made of a Tungsten Carbide (TC) bit for auger drilling into rock to indicate rock quality and continuity by variation in drilling resistance and from examination of recovered rock fragments. This method of investigation is quick and relatively inexpensive but provides only an indication of the likely rock strength and predicted values may be in error by a strength order. Where rock strengths may have a significant impact on construction feasibility or costs, then further investigation by means of cored boreholes may be warranted.

**Wash Boring:** The borehole is usually advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from "feel" and rate of penetration.

**Mud Stabilised Drilling:** Either Wash Boring or Continuous Core Drilling can use drilling mud as a circulating fluid to stabilise the borehole. The term 'mud' encompasses a range of products ranging from bentonite to polymers such as Revert or Biogel. The mud tends to mask the cuttings and reliable identification is only possible from intermittent intact sampling (eg from SPT and U50 samples) or from rock coring, etc.

**Continuous Core Drilling:** A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, an NMLC triple tube core barrel, which gives a core of about 50mm diameter, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as CORE LOSS. The location of losses are determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the top end of the drill run.

**Standard Penetration Tests:** Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test F3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube with a tapered shoe, under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

- In the case where full penetration is obtained with successive blow counts for each 150mm of, say, 4, 6 and 7 blows, as

  N = 13
  4, 6, 7

- In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm, as

  N>30
  15, 30/40mm

The results of the test can be related empirically to the engineering properties of the soil.

Occasionally, the drop hammer is used to drive 50mm diameter thin walled sample tubes (U50) in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

A modification to the SPT test is where the same driving system is used with a solid 60° tipped steel cone of the same diameter as the SPT hollow sampler. The solid cone can be continuously driven for some distance in soft clays or loose sands, or may be used where damage would otherwise occur to the SPT. The results of this Solid Cone Penetration Test (SCPT) are shown as "$N_c$" on the borehole logs, together with the number of blows per 150mm penetration.

**Static Cone Penetrometer Testing and Interpretation:** Cone penetrometer testing (sometimes referred to as a Dutch Cone) described in this report has been carried out using an Electronic Friction Cone Penetrometer (EFCP). The test is described in Australian Standard 1289, Test F5.1.

In the tests, a 35mm diameter rod with a conical tip is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the frictional resistance on a separate 134mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are electrically connected by wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output as incremental digital records every 10mm. The results given in this report have been plotted from the digital data.

The information provided on the charts comprise:

- Cone resistance – the actual end bearing force divided by the cross sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio – the ratio of sleeve friction to cone resistance, expressed as a percentage.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and occasionally very soft clays, rising to 4% to 10% in stiff clays and peats. Soil descriptions based on cone resistance and friction ratios are only inferred and must not be considered as exact.

Correlations between EFCP and SPT values can be developed for both sands and clays but may be site specific.

Interpretation of EFCP values can be made to empirically derive modulus or compressibility values to allow calculation of foundation settlements.

Stratification can be inferred from the cone and friction traces and from experience and information from nearby boreholes etc. Where shown, this information is presented for general guidance, but must be regarded as interpretive. The test method provides a continuous profile of engineering properties but, where precise information on soil classification is required, direct drilling and sampling may be preferable.

**Portable Dynamic Cone Penetrometers:** Portable Dynamic Cone Penetrometer (DCP) tests are carried out by driving a rod into the ground with a sliding hammer and counting the blows for successive 100mm increments of penetration.

Two relatively similar tests are used:

- Cone penetrometer (commonly known as the Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS1289, Test F3.2). The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various Road Authorities.
- Perth sand penetrometer – a 16mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test F3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

## LOGS

The borehole or test pit logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on the frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will enable the most reliable assessment, but is not always practicable or possible to justify on economic grounds. In any case, the boreholes or test pits represent only a very small sample of the total subsurface conditions.

The attached explanatory notes define the terms and symbols used in preparation of the logs.

Interpretation of the information shown on the logs, and its application to design and construction, should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than "straight line" variations between the boreholes or test pits. Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations.

## GROUNDWATER

Where groundwater levels are measured in boreholes, there are several potential problems:

- Although groundwater may be present, in low permeability soils it may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes and may not be the same at the time of construction.
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must be washed out of the hole or 'reverted' chemically if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read after stabilising at intervals ranging from several days to perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from perched water tables or surface water.

## FILL

The presence of fill materials can often be determined only by the inclusion of foreign objects (eg bricks, steel etc) or by distinctly unusual colour, texture or fabric. Identification of the extent of fill materials will also depend on investigation methods and frequency. Where natural soils similar to those at the site are used for fill, it may be difficult with limited testing and sampling to reliably determine the extent of the fill.

The presence of fill materials is usually regarded with caution as the possible variation in density, strength and material type is much greater than with natural soil deposits. Consequently, there is an increased risk of adverse engineering characteristics or behaviour. If the volume and quality of fill is of importance to a project, then frequent test pit excavations are preferable to boreholes.

## LABORATORY TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 *'Methods of Testing Soil for Engineering Purposes'*. Details of the test procedure used are given on the individual report forms.

## ENGINEERING REPORTS

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building) the information and interpretation may not be relevant if the design proposal is changed (eg to a twenty storey building). If this happens, the company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions – the potential for this will be partially dependent on borehole spacing and sampling frequency as well as investigation technique.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of persons or contractors responding to commercial pressures.

If these occur, the company will be pleased to assist with investigation or advice to resolve any problems occurring.

## SITE ANOMALIES

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed that at some later stage, well after the event.

## REPRODUCTION OF INFORMATION FOR CONTRACTUAL PURPOSES

Attention is drawn to the document *'Guidelines for the Provision of Geotechnical Information in Tender Documents'*, published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Copyright in all documents (such as drawings, borehole or test pit logs, reports and specifications) provided by the Company shall remain the property of Jeffery and Katauskas Pty Ltd. Subject to the payment of all fees due, the Client alone shall have a licence to use the documents provided for the sole purpose of completing the project to which they relate. License to use the documents may be revoked without notice if the Client is in breach of any objection to make a payment to us.

## REVIEW OF DESIGN

Where major civil or structural developments are proposed or where only a limited investigation has been completed or where the geotechnical conditions/ constraints are quite complex, it is prudent to have a joint design review which involves a senior geotechnical engineer.

## SITE INSPECTION

The company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related.

Requirements could range from:

i) a site visit to confirm that conditions exposed are no worse than those interpreted, to

ii) a visit to assist the contractor or other site personnel in identifying various soil/rock types such as appropriate footing or pier founding depths, or

iii) full time engineering presence on site.

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# GRAPHIC LOG SYMBOLS FOR SOILS AND ROCKS

## SOIL

FILL

TOPSOIL

CLAY (CL, CH)

SILT (ML, MH)

SAND (SP, SW)

GRAVEL (GP, GW)

SANDY CLAY (CL, CH)

SILTY CLAY (CL, CH)

CLAYEY SAND (SC)

SILTY SAND (SM)

GRAVELLY CLAY (CL, CH)

CLAYEY GRAVEL (GC)

SANDY SILT (ML)

PEAT AND ORGANIC SOILS

## ROCK

CONGLOMERATE

SANDSTONE

SHALE

SILTSTONE, MUDSTONE, CLAYSTONE

LIMESTONE

PHYLLITE, SCHIST

TUFF

GRANITE, GABBRO

DOLERITE, DIORITE

BASALT, ANDESITE

QUARTZITE

## DEFECTS AND INCLUSIONS

CLAY SEAM

SHEARED OR CRUSHED SEAM

BRECCIATED OR SHATTERED SEAM/ZONE

IRONSTONE GRAVEL

ORGANIC MATERIAL

## OTHER MATERIALS

CONCRETE

BITUMINOUS CONCRETE, COAL

COLLUVIUM

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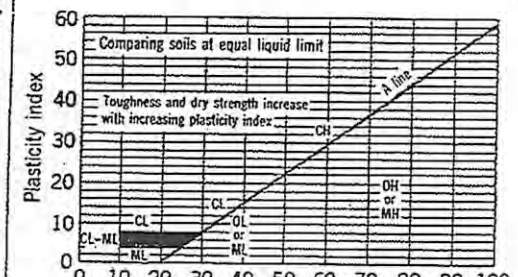
# UNIFIED SOIL CLASSIFICATION TABLE

| Field Identification Procedures (Excluding particles larger than 75 μm and basing fractions on estimated weights) | | | | Group Symbols [3] | Typical Names | Information Required for Describing Soils | Laboratory Classification Criteria |
|---|---|---|---|---|---|---|---|
| Coarse-grained soils: More than half of material is *larger* than 75 μm sieve size[b] (The 75 μm sieve size is about the smallest particle visible to naked eye) | Gravels: More than half of coarse fraction is larger than 4 mm sieve size | Clean gravels (little or no fines) | Wide range in grain size and substantial amounts of all intermediate particle sizes | *GW* | Well graded gravels, gravel-sand mixtures, little or no fines | Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses<br>For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics<br>Example:<br>*Silty sand*, gravelly; about 20% hard, angular gravel particles 12 mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*) | Determine percentages of gravel and sand from grain size curve<br>Depending on percentage of fines (fraction smaller than 75 μm sieve size) coarse grained soils are classified as follows:<br>Less than 5% — *GW, GP, SW, SP*<br>More than 12% — *GM, GC, SM, SC*<br>5% to 12% — *Borderline* cases requiring use of dual symbols<br>Use grain size curve in identifying the fractions as given under field identification |
| | | | Predominantly one size or a range of sizes with some intermediate sizes missing | *GP* | Poorly graded gravels, gravel-sand mixtures, little or no fines | | |
| | | Gravels with fines (appreciable amount of fines) | Nonplastic fines (for identification procedures see *ML* below) | *GM* | Silty gravels, poorly graded gravel-sand-silt mixtures | | |
| | | | Plastic fines (for identification procedures, see *CL* below) | *GC* | Clayey gravels, poorly graded gravel-sand-clay mixtures | | |
| | Sands: More than half of coarse fraction is smaller than 4 mm sieve size | Clean sands (little or no fines) | Wide range in grain sizes and substantial amounts of all intermediate particle sizes | *SW* | Well graded sands, gravelly sands, little or no fines | | $C_U = \frac{D_{60}}{D_{10}}$ Greater than 4<br>$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3<br>Not meeting all gradation requirements for *GW*<br>Atterberg limits below "A" line, or *PI* less than 4 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols<br>Atterberg limits above "A" line, with *PI* greater than 7 |
| | | | Predominantly one size or a range of sizes with some intermediate sizes missing | *SP* | Poorly graded sands, gravelly sands, little or no fines | | $C_U = \frac{D_{60}}{D_{10}}$ Greater than 6<br>$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3<br>Not meeting all gradation requirements for *SW*<br>Atterberg limits below "A" line or *PI* less than 5 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols<br>Atterberg limits below "A" line with *PI* greater than 7 |
| | | Sands with fines (appreciable amount of fines) | Nonplastic fines (for identification procedures, see *ML* below) | *SM* | Silty sands, poorly graded sand-silt mixtures | | |
| | | | Plastic fines (for identification procedures, see *CL* below) | *SC* | Clayey sands, poorly graded sand-clay mixtures | | |
| Fine-grained soils: More than half of material is *smaller* than 75 μm sieve size (The 75 μm sieve size is about the smallest particle visible to naked eye) | Identification Procedures on Fraction Smaller than 380 μm Sieve Size | | | | | | |
| | Silts and clays: liquid limit less than 50 | Dry Strength (crushing characteristics) | Dilatancy (reaction to shaking) | Toughness (consistency near plastic limit) | | | |
| | | None to slight | Quick to slow | None | *ML* | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity | Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses<br>For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions<br>Example:<br>*Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*) |
| | | Medium to high | None to very slow | Medium | *CL* | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | |
| | | Slight to medium | Slow | Slight | *OL* | Organic silts and organic silt-clays of low plasticity | |
| | Silts and clays: liquid limit greater than 50 | Slight to medium | Slow to none | Slight to medium | *MH* | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts | |
| | | High to very high | None | High | *CH* | Inorganic clays of high plasticity, fat clays | |
| | | Medium to high | None to very slow | Slight to medium | *OH* | Organic clays of medium to high plasticity | |
| Highly Organic Soils | | Readily identified by colour, odour, spongy feel and frequently by fibrous texture | | | *Pt* | Peat and other highly organic soils | |




Plasticity chart
for laboratory classification of fine grained soils

NOTE: 1) Soils possessing characteristics of two groups are designated by combinations of group symbols (e.g. GW-GC, well graded gravel-sand mixture with clay fines).

2) Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity.

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## LOG SYMBOLS

| LOG COLUMN | SYMBOL | DEFINITION |
|---|---|---|
| Groundwater Record | ⊣ | Standing water level. Time delay following completion of drilling may be shown. |
| | ⊂ | Extent of borehole collapse shortly after drilling. |
| | ▶ | Groundwater seepage into borehole or excavation noted during drilling or excavation. |
| Samples | ES | Soil sample taken over depth indicated, for environmental analysis. |
| | U50 | Undisturbed 50mm diameter tube sample taken over depth indicated. |
| | DB | Bulk disturbed sample taken over depth indicated. |
| | DS | Small disturbed bag sample taken over depth indicated. |
| | ASB | Soil sample taken over depth indicated, for asbestos screening. |
| | ASS | Soil sample taken over depth indicated, for acid sulfate soil analysis. |
| | SAL | Soil sample taken over depth indicated, for salinity analysis. |
| Field Tests | N = 17<br>4, 7, 10 | Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'R' as noted below. |
| | $N_c$ = 5<br>7<br>3R | Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60 degree solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment. |
| | VNS = 25 | Vane shear reading in kPa of Undrained Shear Strength. |
| | PID = 100 | Photoionisation detector reading in ppm (Soil sample headspace test). |
| Moisture Condition (Cohesive Soils) | MC > PL | Moisture content estimated to be greater than plastic limit. |
| | MC ≈ PL | Moisture content estimated to be approximately equal to plastic limit. |
| | MC < PL | Moisture content estimated to be less than plastic limit. |
| (Cohesionless Soils) | D | DRY - runs freely through fingers. |
| | M | MOIST - does not run freely but no free water visible on soil surface. |
| | W | WET - free water visible on soil surface. |
| Strength (Consistency) Cohesive Soils | VS | VERY SOFT - Unconfined compressive strength less than 25kPa |
| | S | SOFT - Unconfined compressive strength 25-50kPa |
| | F | FIRM - Unconfined compressive strength 50-100kPa |
| | St | STIFF - Unconfined compressive strength 100-200kPa |
| | VSt | VERY STIFF - Unconfined compressive strength 200-400kPa |
| | H | HARD - Unconfined compressive strength greater than 400kPa |
| | ( ) | Bracketed symbol indicates estimated consistency based on tactile examination or other tests. |
| Density Index/ Relative Density (Cohesionless Soils) | | **Density Index ($I_D$) Range (%)** / **SPT 'N' Value Range (Blows/300mm)** |
| | VL | Very Loose: <15 / 0-4 |
| | L | Loose: 15-35 / 4-10 |
| | MD | Medium Dense: 35-65 / 10-30 |
| | D | Dense: 65-85 / 30-50 |
| | VD | Very Dense: >85 / >50 |
| | ( ) | Bracketed symbol indicates estimated density based on ease of drilling or other tests. |
| Hand Penetrometer Readings | 300<br>250 | Numbers indicate individual test results in kPa on representative undisturbed material unless noted otherwise. |
| Remarks | 'V' bit | Hardened steel 'V' shaped bit. |
| | 'TC' bit | Tungsten carbide wing bit. |
| | T 60 | Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers. |

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# LOG SYMBOLS

## ROCK MATERIAL WEATHERING CLASSIFICATION

| TERM | SYMBOL | DEFINITION |
|---|---|---|
| Residual Soil | RS | Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported. |
| Extremely weathered rock | XW | Rock is weathered to such an extent that it has "soil" properties, ie it either disintegrates or can be remoulded, in water. |
| Distinctly weathered rock | DW | Rock strength usually changed by weathering. The rock may be highly discoloured, usually by ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores. |
| Slightly weathered rock | SW | Rock is slightly discoloured but shows little or no change of strength from fresh rock. |
| Fresh rock | FR | Rock shows no sign of decomposition or staining. |

## ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Journal of Rock Mechanics, Mining, Science and Geomechanics. Abstract Volume 22, No 2, 1985.

| TERM | SYMBOL | Is (50) MPa | FIELD GUIDE |
|---|---|---|---|
| Extremely Low: | EL | 0.03 | Easily remoulded by hand to a material with soil properties. |
| Very Low: | VL | 0.1 | May be crumbled in the hand. Sandstone is "sugary" and friable. |
| Low: | L | 0.3 | A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling. |
| Medium Strength: | M | 1 | A piece of core 150mm long x 50mm dia. can be broken by hand with difficulty. Readily scored with knife. |
| High: | H | 3 | A piece of core 150mm long x 50mm dia. core cannot be broken by hand, can be slightly scratched or scored with knife; rock rings under hammer. |
| Very High: | VH | 10 | A piece of core 150mm long x 50mm dia. may be broken with hand-held pick after more than one blow. Cannot be scratched with pen knife; rock rings under hammer. |
| Extremely High: | EH | | A piece of core 150mm long x 50mm dia. is very difficult to break with hand-held hammer. Rings when struck with a hammer. |

## ABBREVIATIONS USED IN DEFECT DESCRIPTION

| ABBREVIATION | DESCRIPTION | NOTES |
|---|---|---|
| Be | Bedding Plane Parting | Defect orientations measured relative to the normal to the long core axis (ie relative to horizontal for vertical holes) |
| CS | Clay Seam | |
| J | Joint | |
| P | Planar | |
| Un | Undulating | |
| S | Smooth | |
| R | Rough | |
| IS | Ironstained | |
| XWS | Extremely Weathered Seam | |
| Cr | Crushed Seam | |
| 60t | Thickness of defect in millimetres | |