Douglas Partners

Geotechnics / Environment / Groundwater

Report on
Preliminary Geotechnical Investigation

Proposed Correctional Centre Upgrade
55 The Links Road, South Nowra

Prepared for
Guymer Bailey Architects

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Integrated Practical Solutions

Douglas Partners

Geotechnics | Environment | Groundwater

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The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

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Author	Arthur Castrissios	17.6.2016
Reviewer	R. Hart for K. Schultz	17.6.2016

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Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
1/1 Luso Drive
Unanderra NSW 2526
PO Box 486
Unanderra NSW 2526
Phone (02) 4271 1836
Fax (02) 4271 1897

Table of Contents

Report on Preliminary Geotechnical Investigation
Proposed Correctional Centre Upgrade
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1. Introduction

This report presents the results of a preliminary geotechnical investigation undertaken for the proposed upgrade to the South Coast Correctional Centre at 55 The Links Road, South Nowra. The investigation was commissioned by Guymer Bailey Architects and undertaken in accordance with Douglas Partners proposal WOL160077.P.003 dated 17 February 2016.

It is understood that the proposed Stage 2 development comprises the installation of modular accommodation within the existing correctional centre footprint or the construction of additions to the south of the correctional centre. It is further understood that consideration is also being given to an expansion to the north of the existing development (exact location yet to be determined).

The investigation comprised a review of existing geotechnical information and the drilling of twelve boreholes with in-situ testing and sampling followed by laboratory testing of selected samples, engineering analysis, liaison and reporting. Details of the field work undertaken and the results obtained are given in the report, together with comments relating to design and construction practice. The results of preliminary contamination and salinity testing of the site soils are also discussed within the report.

A site layout was provided by the client who also nominated the test locations for the investigation.

2. Background

Previous geotechnical investigations have previously been undertaken by Douglas Partners (DP) and Cottier and Associates (CA) on the site. The relevant reports are:

- CA Project 21941G(4): mab "South Coast Correctional Centre, Princes Highway, South Nowra" dated 7 May 2007;
- DP Project 48600.06 "Damaged Pavements" (memo) dated 14 December 2010.

The relevant test pit and borehole logs from the previous investigations are included in Appendix B with the approximate locations of the previous field tests shown on Drawing 1.

3. Site Description and Regional Geology

The South Coast Correctional Centre, which includes Lots 102 & 103 in DP 755952, Lot 30 in 1169494, Lot 2 in DP 1112040 and Lot 7041 in DP 1121435, is an irregular-shaped area of approximately 145 ha with maximum north-south and east-west dimensions of 1,250 m and 1,190 m respectively. It is bounded to the north by The Links Road and existing commercial development, to the east by the Princes Highway and existing commercial development and to the south end east by undeveloped Crown reserve and rural land.

Surface levels fall generally in the north-easterly direction at grades of 1 in 30 to 1 in 40, with an overall difference in levels estimated to be about 15 m from the highest part of the site to the lowest. The estimated difference in level across the developed area is about 8 m.

At the time of the investigation, the site was an active correctional centre comprising a series of detention blocks, administration buildings, internal lightly grassed areas and car park areas. The remainder of the site (i.e. outside the fenced area) was mainly undeveloped and moderately timbered. A previous quarry is located in the eastern section of the overall site. Various features observed during the investigation are shown on the colour photoplates in Appendix B.

Reference to the 1:250 000 New South Wales Statewide geodatabase indicates that the site is underlain by sandstone, siltstone, shale, claystone and conglomerate belonging to the Shoalhaven Group of Permian age. The results of the investigation were consistent with the geological mapping with shale encountered in ten of the twelve boreholes drilled for the current investigation.

4. Field Work

4.1 Methods

The current field work comprised the drilling of twelve boreholes (Bores 101 – 112) to depths in the range 0.5 m to 3.0 m with a Kubota KX018-4 mini-excavator fitted with a 150 mm diameter power auger. The boreholes were logged on site by a geotechnical engineer who collected disturbed and "undisturbed" samples (in 50 mm diameter thin-walled tubes) at regular depth intervals to assist in strata identification and for laboratory testing. Dynamic cone penetrometer tests (DCP, AS1289 6.3.2) were undertaken adjacent to eight of the twelve boreholes to assess the penetration resistance of the upper 0.3 – 1.2 m of the subsurface profile.

The locations of the boreholes are shown on Drawing 1 (Appendix B). The surface levels (to Australian Height Datum, AHD) were determined by contour interpolation from web-based mapping. The coordinates to (Map Grid Australia, MGA) were determined using a hand-held GPS receiver. As such, the levels and coordinates are approximate only.

During borehole drilling, environmental samples were collected from near the surface (ie topsoil) and successive at 0.5 m intervals into natural clay at six of the twelve geotechnical borehole locations for possible laboratory testing.

4.2 Results

Details of the conditions encountered in the boreholes are given on the borehole logs in Appendix B. These should be read in conjunction with the accompanying notes defining classification methods and descriptive terms.

Relatively uniform conditions were encountered underlying the site, with the succession of strata broadly summarised as follows:

TOPSOIL:	to 0.1 m depth in Bore 106 only;
FILLING:	apparently well compacted, gravelly clay to depths of 0.1 – 1.0 m in Bores 101, 102, 105, 107, 109 – 112, and to the termination depths of 1.0 m in Bore 103 and 3.0 m in Bore 108;
CLAY:	stiff to very stiff clay and gravelly clay to depths of 0.5 – 3.0 m in Bores 101, 102, 104 – 107 and 109 – 112;
SHALE:	initially variably extremely low to low strength becoming low to medium strength at refusal of the auger at depths of 0.5 – 3.0 m in Bores 101, 102, 104 – 107 and Bores 109 – 112.

No free groundwater was observed in the boreholes during auguring for the short time that they were left open. It is noted that the boreholes were immediately backfilled following drilling, sampling and logging which precluded long term monitoring of groundwater levels.

5. Laboratory Testing

5.1 Geotechnical

Selected samples from the boreholes were tested in the laboratory for measurement of field moisture content, Atterberg limits, linear shrinkage, pH, electrical conductivity, salinity and chloride/sulphate concentrations. The detailed laboratory test report sheets are given in Appendix C and the results summarised in Tables 1 & 2 (following page).

The results indicate that the clays tested are of low to intermediate plasticity and would be expected to be susceptible to shrinkage and swelling movements with changes in soil moisture content.

The results also indicate that the site soils are typically "highly sodic" (ie ESP greater than 15%). The sample from Bore 105 / 0.5 m is "non-sodic".

Furthermore, the soils are generally classified as "non-saline" (i.e. ECe < 2 dS/m). The sample from Bore 108/2.0 m is "slightly saline" (i.e. ECe between 2 dS/m and 4 dS/m). The results also indicate that the soils tested can be classified as "mildly aggressive" to concrete and "non-aggressive" to steel with reference to AS 2159 – 2009 (Ref 2). Further discussion on the implications of the salinity and sodicity testing is given in Section 7.3.

Table 1: Results of Laboratory Testing (Mechanical)

Bore	Depth (m)	W_F (%)	W_P (%)	W_L (%)	PI (%)	LS (%)	I_{SS} (%/ΔpF)	Material
102	0.5 - 0.9	18.6	-	-	-	-	1.4	Clay
108	0.5	11.3	21	46	25	11.0	-	Filling
110	0.5 - 0.9	18.9	20	34	14	14.0	-	Filling/Clay
112	0.5 - 0.9	20.2	-	-	-	-	1.0	Silty Clay

Where:
W_F = Field moisture content
W_P = Plastic limit
W_L = Liquid limit
PI = Plasticity Index
LS = Linear Shrinkage
I_{ss} = Shrink Swell Index

Table 2: Results of Laboratory Testing (salinity / aggressivity)

Bore	Depth	pH (%)	EC(1) (μS/cm)	Factor	ECe(2) (dS/m)	ESP (%)	Cl (mg/kg)	SO_4^{2} (mg/kg)	Material
102	1.0	5.1	230	7	1.6	28	210	170	Clay
105	0.5	5.5	190	8	1.5	3	78	320	Filling
108	2.0	5.0	340	8	2.7	36	430	100	Filling
109	0.5	4.9	210	8	17	20	230	100	Filling

Note: (1) 1 dS/m = 1000 μS/cm
(2) ECe = EC x Factor

pH = Measure of hydrogen ion concentration
Factor = Soil texture factor (Ref 1)
ESP = Exchangeable sodium percentage
$SO_4^{2-=}$ = Sulfate concentration
EC = Electrical Conductivity
ECe = Electrical Conductivity of a saturated extract
Cl^- = Chloride concentration

5.2 Contamination

Selected samples were despatched to Envirolab Services Pty Ltd for testing for a suite of common contaminants to provide preliminary comment on potential restraints to the proposed development from the contamination perspective.

All of the laboratory results for the contamination analysis were either less than the laboratory's practical quantitation limits (PQL) or the relevant adopted SAC. The laboratory results are summarised in Table D1 in Appendix D. The laboratory certificate of analysis, sample receipt advice and chain-of-custody documentation are also included in Appendix D.

Preliminary comment regarding the results of the contamination analysis is provided in Section 7.4.

6. Proposed Development

It is understood that the proposed Stage 2 development comprises the installation of accommodation modules within the existing correctional centre footprint and/or the construction of additions to the south of the correctional centre. Upgrade works are also being considered to the north of the centre (ie in the vicinity of the existing car parks).

Whilst the exact location and nature of the proposed structures was not determined at the time of this report, it is anticipated that minimal earthworks will be required to achieve design levels and structural loads will be commensurate with conventional residential construction.

7. Comments

7.1 General

The following comments are based on a review of available information, the results of the subsurface investigation and laboratory testing and preliminary information provided by the client. Given the preliminary nature of the overall planning and design of the proposed works, further investigations may need to be undertaken at the appropriate time as the planning and design of the individual buildings proceeds. Accordingly, this report and the comments given within must be considered as being preliminary only.

7.2 Site Classification

The presence of filling to depths in excess of 0.4 m (in part) necessitates a P classification in accordance with AS 2870 – 2011 Residential Slabs and Footings (Ref 3). The main requirement for a Class P site is for design to be undertaken by a suitably qualified engineer using engineering principles that take into account the subsurface conditions and the recommendations of this report.

Notwithstanding the P classification, given the apparent well compacted nature of the filling observed at the borehole locations, it is considered that provided additional DCP testing is undertaken at the proposed structure locations following footing excavation, the profiles are considered commensurate with Class M (moderately reactive) conditions.

It is noted however, that site classification is independent of proposed construction and serves only to classify the site in terms of soil reactivity. Furthermore, the foundation details given in AS 2870 – 2011 *Residential Slabs and Footings* (Ref 3) are appropriate for residential buildings and its applicability to this site will need to be determined by the design engineer undertaken by suitably qualified engineers using engineering principles which take into account subsurface conditions determined by geotechnical investigation.

7.3 Salinity Considerations

The results of the investigation have indicated generally non-saline conditions, with one result indicating slightly saline conditions. In this regard, it is considered that potential effects of salinity are minimal. For information, general techniques for addressing salinity are given in the "*Building in a Saline Environment*" document, a copy of which is included in Appendix E. The results of the laboratory testing have also indicated that the soils underlying the site are "highly sodic". Sodic soils have a high susceptibility to dispersion (ie erosion) and can be managed by adopting conventional sediment and erosion control measures.

7.4 Contamination

Four selected soil samples from the topsoil, fill or natural soils, collected from the geotechnical investigation, were analysed at a NATA accredited laboratory for a range of common contaminants. The purpose of the contamination analysis was to identify preliminary potential contamination constraints of the proposed development. It is noted that the contamination analysis does not comprise a contaminated land assessment under the NSW State Environmental Planning Policy No. 55 – Remediation of Land (SEPP 55) or NSW EPA guidelines and, as such, comment cannot be made on the overall contamination status of the site.

The Site Assessment Criteria (SAC) applied to the contamination analysis were adopted for a generic residential land use scenario from the investigation and screening levels of Schedule B1, *National Environment Protection (Assessment of Site Contamination) Measure* 1999, as amended 2013 (NEPC, 2013). NEPC (2013) is endorsed by the NSW EPA under the CLM Act 1997. Petroleum-based health screening levels for direct contact have been adopted from the *Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) Technical Report no.10 Health screening levels for petroleum hydrocarbons in soil and groundwater* (2011) as referenced by NEPC (2013).

Ecological Investigation Levels (EIL) were derived using the *Interactive (Excel) Calculation Spreadsheet* (Standing Council on Environment and Water (SCEW) website (http://www.scew.gov.au/node/941)) based on an average cation exchange capacity (CEC) value of 10.4 cmol/kg, an average pH of 5.1, an assumed clay content of 10% and an "Aged" (>2 years) potential source of contamination in a low traffic volume area in NSW. The CEC and pH data was obtained as part of the salinity testing.

All of the laboratory results for the contamination analysis were either less than the laboratory's practical quantitation limits (PQL) or the relevant adopted SAC. The laboratory results are summarised in Table D1, Appendix D.

Based on the contamination analysis undertaken, limitations on the proposed development with respect to contamination and waste classification of any excess materials requiring removal from site, are expected to be minor.

7.5 Footings

All footing systems should be designed and constructed in accordance with engineering principles which take into account subsurface profiles and proposed loads.

The selection of bearing stratum will be dependent on the type of structures, the proposed loads and the resultant settlements. Project-specific geotechnical investigation with subsurface profiling should be undertaken at the appropriate time as planning proceeds in order to determine appropriate foundation systems for the various structures.

As a guide, typical bearing pressures on various strata are as follows:

- Allowable base bearing on stiff clay or compacted filling 150 kPa
  (for column loads up to 300 kN and live loads of 100 kN/m)
- Allowable base bearing on very low to low strength rock 700 kPa
- Allowable base bearing on low to medium strength rock 1,500 kPa

The feasibility of using a high level footing system will depend on structural loads and resultant settlements. As a guide, working loads on high level footings should be limited to 300 kN and 100 kN/m, which would result in settlements of up to 10 – 15 mm for 1.4 m wide square footings. Differential settlements could approach 5 – 10 mm as a result of variable depth of soil (filling and natural clay) overlying rock.

In the event that high level footings are considered to be appropriate, consideration will need to be given to in structural detailing to accommodate the presence of reactive clays. The provisions of AS 2870 (Ref 3) for Class M sites should form a basis of protecting the foundation system from shrink-swell movement of the soil profile. Furthermore, detailed inspections and dynamic cone penetrometer testing must be undertaken to confirm the appropriateness of the founding stratum for the adopted design pressure.

Where footing systems are proposed adjacent to services or located near retaining walls, local deepening of the footings or alternatively, the inclusion of piers will most likely be required. Founding levels are to be within the underlying very stiff clays/weathered rock below the zone of influence of the service trench and any retaining walls, with the zone of influence defined as an imaginary line extending from the base of the trench to the ground surface inclined at 45° (i.e. 1 horizontal:1 vertical).

If the estimated settlements are beyond tolerable limits or if higher loads are proposed, footings founded on rock would be required. Rock was encountered within Bores 101, 102, 104 – 107 and Bores 109 – 112 at depths of 0.5 – 3.0 m. Pad and strip footings could be utilised where rock is within, say, 1.2 of the prepared surface and bored piers elsewhere. The main advantage of a footings-to-rock system would be that settlements (both total and differential) would be negligible. As a guide, a 500 mm diameter pier founded on medium strength rock could support a working load of 290 kN.

All footing systems should be designed and constructed in accordance with sound engineering principles, with care exercised to ensure that footing trenches/piers are inspected for design compliance prior to the placement of steel and the pouring of concrete. Footings should also be inspected by a suitably qualified geotechnical engineer together with additional dynamic cone penetrometer testing prior to the placement of steel and of concrete to confirm the appropriateness of the bearing stratum for the adopted design pressures.

7.6 Site Maintenance and Drainage

The developed site should be maintained in accordance with the CSIRO publication "Guide to Home Owners on Foundation Maintenance and Footing Performance", a copy of which is attached. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits.

Surface drainage should be installed and maintained at the site. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system.

8. References

1. Site Investigation for Urban Salinity, DLWC (2002)
2. Australian Standard AS 2159 – 2009 Piling – Design and Installation
3. Australian Standard AS 2870 – 2011 *Residential Slabs and Footings.*

9. Limitations

Douglas Partners (DP) has prepared this report for the South Coast Correctional Centre at South Nowra in accordance with DP's proposal WOL160077.P.003 dated 17 February 2016 and acceptance received from Guymer Bailey Architects dated 20 April 2016. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Guymer Bailey Architects for this project only and for the purposes as described in the report. It should not be used for other projects or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attachments and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report

About this Report

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Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

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

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole 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. They may not be the same at the time of construction as are indicated in the report; and
- 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 first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or 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 a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP 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 and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

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, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report 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. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Sampling

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

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil 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.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud 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 the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils 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 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm 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 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

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

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This 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.

Soil Descriptions

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Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 -5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

Rock Descriptions

Douglas Partners

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $Is_{(50)}$ MPa	Approx Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200
Extremely high	EH	>10	>200

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable
Moderately weathered	MW	Staining and discolouration of rock substance has taken place
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock
Fresh stained	Fs	Rock substance unaffected by weathering but staining visible along defects
Fresh	Fr	No signs of decomposition or staining

Degree of Fracturing

The following classification applies to the spacing of natural fractures in diamond drill cores. It includes bedding plane partings, joints and other defects, but excludes drilling breaks.

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and loner sections
Unbroken	Core lengths mostly > 1000 mm

Rock Descriptions

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq 100 \text{ mm long}}{\text{total drilled length of section being assessed}}$$

where 'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling or handling (i.e. drilling breaks) then the broken pieces are fitted back together and are not included in the calculation of RQD.

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	< 6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	> 2 m

Symbols & Abbreviations

Douglas Partners

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

 Asphalt

 Road base

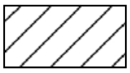
 Concrete

 Filling

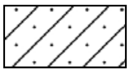
Soils

 Topsoil

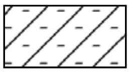
 Peat

 Clay

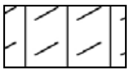
 Silty clay

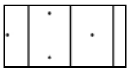
 Sandy clay

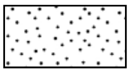
 Gravelly clay

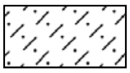
 Shaly clay

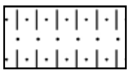
 Silt

 Clayey silt

 Sandy silt

 Sand

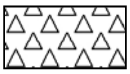
 Clayey sand

 Silty sand

 Gravel

 Sandy gravel

 Cobbles, boulders

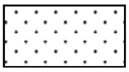
 Talus

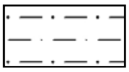
Sedimentary Rocks

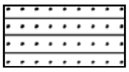
 Boulder conglomerate

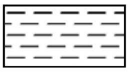
 Conglomerate

 Conglomeratic sandstone

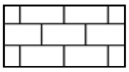
 Sandstone

 Siltstone

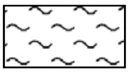
 Laminite

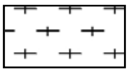
 Mudstone, claystone, shale

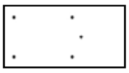
 Coal

 Limestone

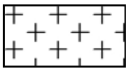
Metamorphic Rocks

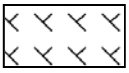
 Slate, phyllite, schist

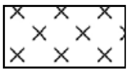
 Gneiss

 Quartzite

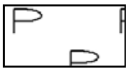
Igneous Rocks

 Granite

 Dolerite, basalt, andesite

 Dacite, epidote

 Tuff, breccia

 Porphyry

Appendix B

Previous Cottier Borehole Logs (Bores BH05 – BH20)
Previous DP Test Pit Logs (Pits 1 – 4)
Current Borehole Logs (Bores 101 – 112)
Site Photographs
Drawing 1

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EX no:	**BH 05/CBR5**
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	**started:**	26.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	**finished:**	26.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	**logged:**	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	**checked:**	MAB
equipment:	IHI 45j EXCAVATOR	**RL surface:**	
dimensions:	0.6m X 2.0m	**datum:**	

excavation information / **material information**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material (soil type: plasticity or particle characteristics, colour, secondary and minor components.)	moisture condition	consistency/ density index	hand penetro-meter kPa (100 200 300 400)	structure and additional observations
EX	N	NE					ML	Clayey SILT, low plasticity, grey/brown, roots	> >Wp	S-F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, mottled light grey and light brown	>Wp	VSt		RESIDUAL
			Bs		0.5							
					1.4		CL	Silty CLAY, medium plasticity, orange-brown with grey and red-brown mottle, some ironstone gravel	> = Wp	VSt-H		
					2.2			SHALE, fine grained, grey/brown, HW, L strength, highly fractured	--	--		BEDROCK - assessed Class 4 Shale
					2.4			BH 05/CBR5 terminated at 2.4m				

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EX no:	BH 06
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	26.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	26.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.6m X 2.0m	datum:	

excavation information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa 100 200 300 400	structure and additional observations
EX	N	NE					ML	Clayey SILT, low plasticity, brown, roots	>>Wp	S-F		TOPSOIL
					0.2		CL	Silty CLAY, medium plasticity, brown with some orange-brown mottle		VSt		RESIDUAL
					0.5							
			D		0.6			Clayey SHALE, fine grained, grey, XW, EL strength	--	--		BEDROCK - assessed Class 5 Shale
					0.7			SHALE, fine grained, grey to dark grey, XW/HW, EL/VL strength, highly fractured				BEDROCK - assessed Class 5/4 Shale
					0.9			SHALE, fine grained, grey to dark grey, HW, L strength, highly fractured				BEDROCK - assessed Class 4 Shale
					1.0							
					1.1			BH 06 terminated at 1.1m				Practical refusal
					1.5							
					2.0							
					2.5							
					3.0							
					3.5							
					4.0							

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EX no:	**BH 07**
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	**started:**	26.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	**finished:**	26.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	**logged:**	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	**checked:**	MAB
equipment:	IHI 45j EXCAVATOR	**RL surface:**	
dimensions:	0.6m X 2.0m	**datum:**	

excavation information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetrometer kPa (100 200 300 400)	structure and additional observations
EX	N	NE			0.0		ML	Clayey SILT, low plasticity, brown, roots	>>Wp	S-F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, mottled brown and light grey/grey		VSt		RESIDUAL
					0.7			SHALE, fine grained, grey with brown banding, XW/HW, EL/VL strength, highly fractured, bands of Shaley CLAY	--	--		BEDROCK - assessed Class 5/4 Shale
					1			SHALE, fine grained, grey to dark grey, HW, VL to L strength, highly fractured				BEDROCK - assessed Class 4 Shale
					1.2			BH 07 terminated at 1.2m				Practical refusal

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

Refer to Information Sheets for Terms and Symbols

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EX no:	**BH 08/CBR6**
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	**started:**	26.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	**finished:**	26.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	**logged:**	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	**checked:**	MAB
equipment:	IHI 45j EXCAVATOR	**RL surface:**	
dimensions:	0.6m X 2.0m	**datum:**	

excavation information | **material information**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetrometer kPa (100 200 300 400)	structure and additional observations
EX	N	NE					ML	Clayey SILT, low plasticity, brown/grey, roots	>>Wp	F		TOPSOIL
					0.2		CL-CH	Silty CLAY, medium to high plasticity, mottled red-brown and grey		VSt		RESIDUAL
			Bs, D		0.5							
					0.8			SHALE, fine grained, grey, XW/HW, EL/VL strength, highly fractured	--	--		BEDROCK - assessed Class 5/4 Shale
					1			SHALE, fine grained, grey, HW, VL/L strength, highly fractured				BEDROCK - assessed Class 4 Shale
					1.2			BH 08/CBR6 terminated at 1.2m				very slow penetration

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

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EX no:	**BH 09/CBR7**
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	**started:**	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	**finished:**	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	**logged:**	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	**checked:**	MAB
equipment:	IHI 45j EXCAVATOR	**RL surface:**	
dimensions:	0.3m X 2.0m	**datum:**	

excavation information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa 100 200 300 400	structure and additional observations
EX	N	NE			0		CL	Sandy Silty CLAY, medium plasticity, grey, roots	>>Wp	F		TOPSOIL
					0.2		CL-CH	Silty CLAY, medium to high plasticity, mottled red-brown, brown and grey		VSt		RESIDUAL
			Bs, D		0.5							
					1.4			SHALE, fine grained, light grey with orange-brown banding, XW/HW, EL/VL strength	--	--		BEDROCK - assessed Class 5 Shale
					1.8			SHALE, fine grained, grey, MW, L strength, highly fractured				BEDROCK - assessed Class 4 Shale
					2			BH 09/CBR7 terminated at 2m				

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

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EX no:	**BH 10**
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	**started:**	26.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	**finished:**	26.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	**logged:**	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	**checked:**	MAB
equipment:	IHI 45j EXCAVATOR	**RL surface:**	
dimensions:	0.6m X 2.0m	**datum:**	

excavation information / **material information**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetrometer kPa (100 200 300 400)	structure and additional observations
EX	N	NE			0		CL	Silty CLAY, medium plasticity, grey/brown, roots	>=Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, red-brown	>Wp	VSt		RESIDUAL
					0.5		CL-CH	Silty CLAY, medium to high plasticity, grading brown	>=Wp	VSt-H		
					0.7			SHALE, fine grained, grey to dark grey, HW, VL/L strength, highly fractured	--	--		BEDROCK - assessed Class 5/4 Shale
					1			SHALE, fine grained, grey to dark grey, HW/MW, L strength, highly fractured, some EL strength bands				BEDROCK - assessed Class 4 Shale
					2			BH 10 terminated at 2m				

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

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EX no:	BH 11
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	26.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	26.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.6m X 2.0m	datum:	

excavation information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa 100 200 300 400	structure and additional observations
EX	N	NE			0.0		ML	Clayey SILT, low plasticity, grey/brown, roots	>>Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, red-brown	>Wp	VSt-H		RESIDUAL
					0.5		CL	Silty CLAY, medium plasticity, mottled light grey, brown and orange-brown	=Wp	H		
					1.5			SHALE, fine grained, light grey, XW/HW, EL/VL strength, highly fractured	--	--		BEDROCK - assessed Class 5/4 Shale
					1.7			BH 11 terminated at 1.7m				very slow penetration

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

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Nowra Office: (02) 4423 4666
Moss Vale Office: (02) 4869 5666

EX no:	BH 12/CBR8
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.3m X 2.0m	datum:	

excavation information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa (100 200 300 400)	structure and additional observations
EX	N	NE					ML	Clayey SILT, low plasticity, grey, roots	>>Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, mottled red-brown, brown and grey		VSt		RESIDUAL
			Bs, D		0.5							
					0.8			SHALE, fine grained, grey with some orange-brown banding, HW, VL/L strength	--	--		BEDROCK - assessed Class 5/4 Shale
					1.0							BEDROCK - assessed Class 4 Shale
					1.5							
					1.8			BH 12/CBR8 terminated at 1.8m				
					2.0							
					2.5							
					3.0							
					3.5							
					4.0							

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EX no:	BH 13/CBR9
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.3m X 2.0m	datum:	

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetrometer kPa (100 200 300 400)	structure and additional observations
EX	N	NE					CL	Sandy Silty CLAY, medium plasticity, grey, roots	>>Wp	F		TOPSOIL
					0.2		CL-CH	Silty CLAY, medium to high plasticity, mottled red-brown, brown and grey		VSt		RESIDUAL
			Bs		0.5							
					0.9		CL	Silty CLAY, medium plasticity, light grey to white with orange-brown mottle, some fine to medium ironstone gravel	>=Wp	H		
					1.3			SHALE, fine grained, light grey with orange-brown banding, XW/HW, EL/VL strength	--	--		BEDROCK - assessed Class 5 Shale
					1.6			SHALE, fine grained, grey, MW, L strength				BEDROCK - assessed Class 4 Shale
					1.8			BH 13/CBR9 terminated at 1.8m				Practical reufsal

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

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Nowra Office: (02) 4423 4666
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EX no:	BH 14
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	**started:**	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	**finished:**	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	**logged:**	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	**checked:**	MAB
equipment:	IHI 45j EXCAVATOR	**RL surface:**	
dimensions:	0.3m X 2.0m	**datum:**	

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa	structure and additional observations
EX	N	NE					CL	Silty CLAY, medium plasticity, brown, roots	>>Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, mottled light brown, light grey and orange-brown	>Wp	VSt		RESIDUAL
					0.6			Shaley CLAY, medium plasticity, brown with grey banding		H		
					0.8			SHALE, fine grained, grey/brown, XW/HW, EL/VL strength, highly fractured	--	--		BEDROCK - assessed Class 5 Shale
					1.4			SHALE, fine grained, grey/brown, HW, L strength, highly fractured				BEDROCK - assessed Class 4 Shale
					1.8			SHALE, fine grained, grey/brown, MW, L-M strength, highly fractured				
					2.3			BH 14 terminated at 2.3m				

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

COTTIER & ASSOCIATES
CONSULTING STRUCTURAL & GEOTECHNICAL ENGINEERS
Nowra Office: (02) 4423 4666
Moss Vale Office: (02) 4869 5666

EX no:	BH 15
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.3m X 2.0m	datum:	

excavation information | **material information**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa (100 200 300 400)	structure and additional observations
EX	N	NE					CL	Silty CLAY, medium plasticity, brown, roots	>=Wp	St		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, mottled brown and grey, grading to Gravelly CLAY at about 0.5m	>Wp	VSt-H		RESIDUAL
			D		0.5							
					0.6			SHALE, fine grained, grey and brown, XW/HW, EL/VL strength, highly fractured	--	--		BEDROCK - assessed Class 5 Shale
					1			SHALE, fine grained, grey, HW, L strength, highly fractured				BEDROCK - assessed Class 4 Shale
					2.5			BH 15 terminated at 2.5m				

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

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Nowra Office: (02) 4423 4666
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EX no:	BH 16/CBR10
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.3m X 2.0m	datum:	

excavation information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa 100 200 300 400	structure and additional observations
EX	N	NE					ML	Clayey SILT, low plasticity, grey, roots	>>Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, red-brown with brown and grey mottle		St-VSt		RESIDUAL
			Bs		0.5							
					0.9			Shaley CLAY, medium plasticity, light grey with brown mottle, XW/HW Shale bands	>=Wp	H		
					1.0							
					1.4			SHALE, fine grained, light grey, XW/HW, EL/VL strength, bands of L strength	--	--		BEDROCK - assessed Class 4 Shale
					1.5							
					2.0							
					2.5							
					2.7			BH 16/CBR10 terminated at 2.7m				
					3.0							
					3.5							
					4.0							

Refer to Information Sheets for Terms and Symbols

COTTIER & ASSOCIATES
CONSULTING STRUCTURAL & GEOTECHNICAL ENGINEERS
Nowra Office: (02) 4423 4666
Moss Vale Office: (02) 4869 5666

EX no:	BH 17/CBR11
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.3m X 2.0m	datum:	

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material (soil type: plasticity or particle characteristics, colour, secondary and minor components)	moisture condition	consistency/ density index	hand penetrometer kPa	structure and additional observations
EX	N	NE					ML	Clayey SILT, medium plasticity, dark grey, roots	>>Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, mottled orange-brown, brown and light grey/white		VSt		RESIDUAL
			Bs, D									
					0.8		CL	Silty CLAY, medium plasticity, mottled light grey/white and orange-brown	>=Wp			
					1.2			SHALE, fine grained, grey, HW/MW, VL/L strength, highly fractured	--	--		BEDROCK - assessed Class 4 Shale
					1.8			BH 17/CBR11 terminated at 1.8m				very slow progress

Refer to Information Sheets for Terms and Symbols

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Nowra Office: (02) 4423 4666
Moss Vale Office: (02) 4869 5666

EX no:	**BH 18/CBR12**
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	**started:**	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	**finished:**	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	**logged:**	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	**checked:**	MAB
equipment:	IHI 45j EXCAVATOR	**RL surface:**	
dimensions:	0.3m X 2.0m	**datum:**	

excavation information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetrometer kPa 100 200 300 400	**structure and additional observations**
EX	N						ML	Clayey SILT, medium plasticity, dark grey, roots	>Wp	F-St		TOPSOIL
					0.2		CL-CH	Silty CLAY, medium to high plasticity, mottled orange-brown, brown and light grey/white		VSt		RESIDUAL
			Bs		0.4			SHALE, fine grained, dark grey, HW, EL/VL strength, highly fractured, remoulds to Clayey GRAVEL, fine grained	--	--		BEDROCK - assessed Class 5 Shale
		slow seepage 0.7-1.3m			0.7			SHALE, fine grained, dark grey, MW, L strength, highly fractured				BEDROCK - assessed Class 4 Shale
					1.5			BH 18/CBR12 terminated at 1.5m				very slow progress

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

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CONSULTING STRUCTURAL & GEOTECHNICAL ENGINEERS
Nowra Office: (02) 4423 4666
Moss Vale Office: (02) 4869 5666

EX no:	BH 19/CBR17
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.3m X 2.0m	datum:	

excavation information / **material information**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetrometer kPa (100 200 300 400)	structure and additional observations
EX	N	NE					ML	Clayey SILT, low plasticity, dark grey, roots	>>Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, orange-brown with brown mottle	>Wp	VSt		RESIDUAL
			Bs		0.4		CL	Gravelly CLAY, medium plasticity, light grey with brown mottle, fine to medium shale gravel	>=Wp	H		
					0.7			SHALE, fine grained, grey, XW/HW, EL/VL strength	--	--		BEDROCK - assessed Class 5 Shale
					0.8			SHALE, fine grained, dark grey, MW, L/M strength, highly fractured				BEDROCK - assessed Class 3/4 Shale
					1			BH 19/CBR17 terminated at 1m				Practical refusal

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

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Nowra Office: (02) 4423 4666
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EX no:	BH 20/CBR18
sheet:	1 of 1
job no.:	21941G

client:	PERUMAL PEDAVOLI PTY LTD	started:	27.3.2007
principal:	NSW DEPT OF CORRECTIVE SERVICES & NSW DEPT OF COMMERCE	finished:	27.3.2007
project:	SOUTH COAST CORRECTIONAL CENTRE	logged:	MAB
location:	PRINCES HIGHWAY, SOUTH NOWRA	checked:	MAB
equipment:	IHI 45j EXCAVATOR	RL surface:	
dimensions:	0.3m X 2.0m	datum:	

excavation information / **material information**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material (soil type: plasticity or particle characteristics, colour, secondary and minor components.)	moisture condition	consistency/ density index	hand penetrometer kPa (100 200 300 400)	structure and additional observations
EX	N	NE					ML	Clayey SILT, low plasticity, dark grey, roots	>>Wp	F		TOPSOIL
					0.15		CL-CH	Silty CLAY, medium to high plasticity, orange-brown with brown mottle	>Wp	VSt		RESIDUAL
			Bs		0.5							
			D									
					0.6		CL	Gravelly CLAY, medium plasticity, light grey with brown mottle, fine to medium shale gravel	>=Wp	H		
					0.9			SHALE, fine grained, dark grey, MW, L/M strength, highly fractured	--	--		BEDROCK - assessed Class 3/4 Shale
					1.0							
					1.5			BH 20/CBR18 terminated at 1.5m				Practical refusal
					2.0							
					2.5							
					3.0							
					3.5							
					4.0							

TEST PIT LOG

CLIENT: Select Civil Pty Ltd
PROJECT: Damaged Pavements
LOCATION: Nowra Correctional Centre
Oxford Road, South Nowra

SURFACE LEVEL: 43.0 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

PIT No: 1
PROJECT No: 48600.05
DATE: 24/11/2010
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm) 5 10 15 20
43	0.05	BITUMINOUS CONCRETE - black, bituminous concrete, 70 - 80% aggregate. Aggregate is fine to medium gravel (blue metal), <5% voids (WEARING COURSE)		D	0.0 – 0.05				
	0.27	FILLING - grey, slightly sandy, fine to medium gravel (blue metal) with some clay, humid to damp (BASE)		B	0.05 – 0.25				
	0.3	FILLING - brown and grey, slightly clayey, fine to medium gravel (blue metal, sandstone), humid to damp		D	0.25 – 0.27				
	0.66	FILLING - grey, fine to coarse gravel (blue metal) with some sand, humid (SUB-BASE)		B	0.3 – 0.5				
	0.95	CLAY - light brown grey mottled light to mid orange brown, slightly gravelly (fine to medium siltstone) clay with some silt, damp (RESIDUAL) - becoming humid to damp below 0.7m		B	0.7 – 0.9				
42	1 / 1.05	SILTSTONE - low strength, moderately to slightly weathered, orange brown to light grey siltstone		B	0.95 – 1.05				
		Pit discontinued at 1.05m (limit of investigation)							

Test Pit Photo 1

RIG: Hitachi 294 with 300mm / 1200mm bucket
LOGGED: RJH
SURVEY DATUM: MGA94
WATER OBSERVATIONS: No free groundwater observed
REMARKS: Damp for top 50mm of residual clay

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Select Civil Pty Ltd
PROJECT: Damaged Pavements
LOCATION: Nowra Correctional Centre
Oxford Road, South Nowra

SURFACE LEVEL: 44.3 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

PIT No: 2
PROJECT No: 48600.05
DATE: 24/11/2010
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm) 5 10 15 20
	0.025	BITUMINOUS CONCRETE - black, bituminous concrete, 60 - 80% aggregate. Aggregate is fine to medium gravel (blue metal), >3% voids (WEARING COURSE)	B	0.1				
44	0.175	FILLING - grey, fine to medium gravel (blue metal) with some sand, silt and trace clay, humid to damp (BASE)	B	0.3				
	0.4	FILLING - grey, slightly sandy, fine to coarse gravel (blue metal), humid to damp (SUB-BASE)	D	0.4				
	0.5	CLAY - red brown clay with some silt and trace rootlets, damp (RESIDUAL)	B	0.5				
	0.6	SILTSTONE - low to medium strength, moderately to slightly weathered, orange brown to grey siltstone		0.6				
		Pit discontinued at 0.6m (limit of investigation)						

Test Pit Photo 2

RIG: Hitachi 294 with 300mm / 1200mm bucket
LOGGED: RJH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Select Civil Pty Ltd
PROJECT: Damaged Pavements
LOCATION: Nowra Correctional Centre, Oxford Road, South Nowra

SURFACE LEVEL: 44.8 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

PIT No: 3
PROJECT No: 48600.05
DATE: 24/11/2010
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm) 5 10 15 20
	0.03	BITUMINOUS CONCRETE - black, bituminous concrete, 60 - 80% aggregate. Aggregate is fine to medium gravel (blue metal), <3% voids (WEARING COURSE)		B	0.05 0.15				
	0.15	FILLING - grey, slightly sandy, fine to medium gravel (blue metal) with some clay and silt, humid to damp (BASE)		B	0.2 0.3				
	0.35	FILLING - grey, fine to coarse gravel (blue metal) with some sand and silt, humid to damp (SUB-BASE)		B	0.35		pp = 310 - 320kPa		
	0.55	CLAY - stiff, red brown mottled light grey, fissured, slightly silty clay with trace rootlets, damp (RESIDUAL)		B	0.55				
	0.75	SILTSTONE - low to medium strength, highly to slightly weathered, red brown to grey siltstone Pit discontinued at 0.75m (limit of investigation)			0.75				

Test Pit Photo 3

RIG: Hitachi 294 with 300mm / 1200mm bucket
LOGGED: RJH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Select Civil Pty Ltd
PROJECT: Damaged Pavements
LOCATION: Nowra Correctional Centre
Oxford Road, South Nowra

SURFACE LEVEL: 45.5 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

PIT No: 4
PROJECT No: 48600.05
DATE: 24/11/2010
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm) 5 10 15 20
	0.025	BITUMINOUS CONCRETE - black, bituminous concrete, 60 - 80% aggregate. Aggregate is fine to medium gravel (blue metal) (WEARING COURSE)		B	0.05 – 0.15				
	0.175	FILLING - grey, slightly sandy, fine to medium gravel (blue metal) with some silt and clay, damp (BASE) - wet in 1/8 pit between 0.05 - 0.10m		B	0.2 – 0.35				
45	0.4	FILLING - grey, slightly sandy, fine to coarse gravel (blue metal) with some silt, humid to damp (SUB-BASE)		B	0.5 – 0.7		pp = 260 - 340kPa		
		CLAY - stiff, orange brown, slightly silty clay with some fine to coarse gravel (siltstone), humid to damp (RESIDUAL)							
	0.75	SILTSTONE - low to medium strength, moderately to slightly weathered, orange brown to grey siltstone		B	0.75 – 0.85				
	0.85	Pit discontinued at 0.85m (limit of investigation)							

Test Pit Photo 4

RIG: Hitachi 294 with 300mm / 1200mm bucket
LOGGED: RJH
SURVEY DATUM: MGA94
WATER OBSERVATIONS: No free groundwater observed
REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

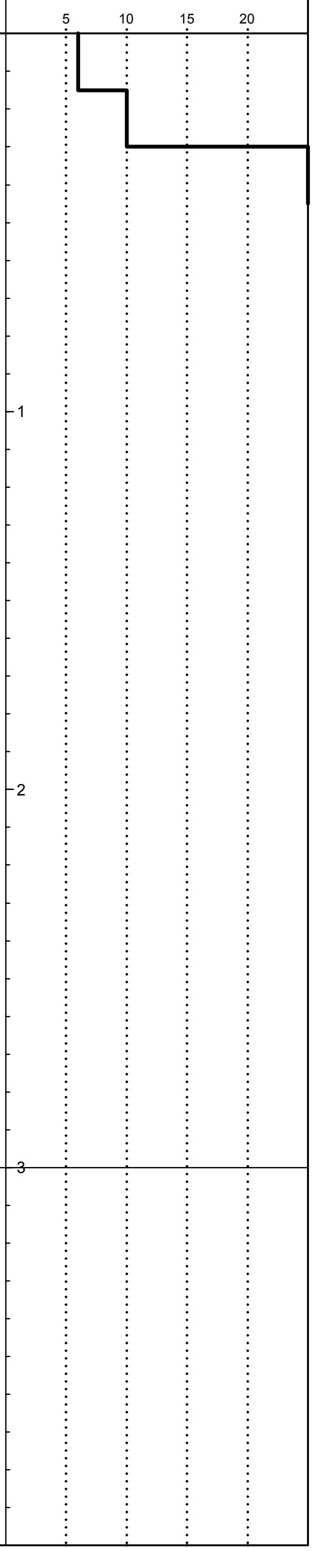
CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 54.8 AHD
EASTING: 280380
NORTHING: 6133107

PIT No: 101
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		FILLING - grey brown, slightly silty, gravelly clay, humid		D	0.1		BD2	
				D, E	0.5			
54	0.9	CLAY - brown grey, slightly silty clay						
	1.2	SILTY CLAY - grey, silty clay, damp		D, E	1.5			
53								
52		- pink mottled below 2.5m						
	3.0	Pit discontinued at 3.0m (Refusal on low to medium strength shale)						
51								

Dynamic Penetrometer Test (blows per 150mm)



RIG: Kubota KX018-4
LOGGED: CMcD
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

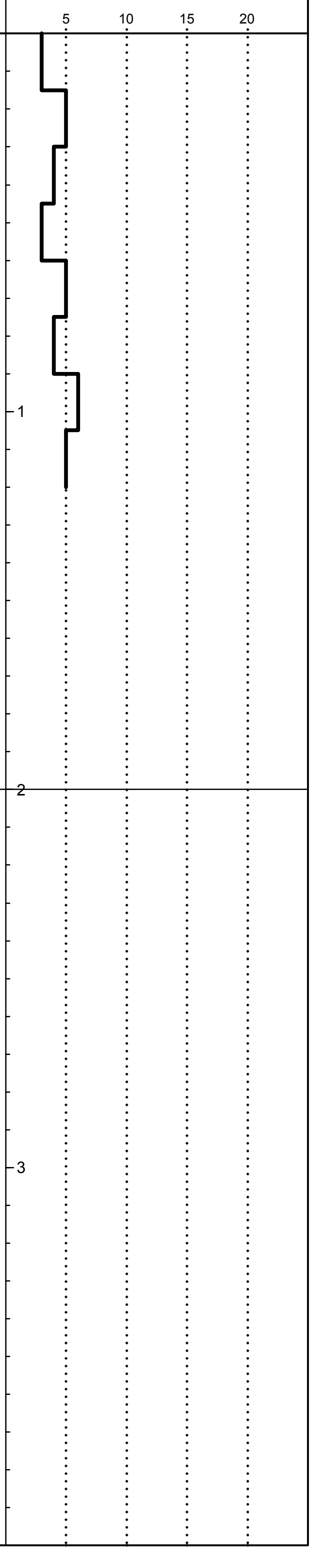
CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 53.6 AHD
EASTING: 280462
NORTHING: 6133136

PIT No: 102
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		FILLING - brown grey, slightly silty, slightly gravelly, clay, damp					
53	0.5	CLAY - stiff to very stiff, red brown mottled grey, slightly silty, clay, damp	D	0.5		pp = 300-350	
			U				
				0.9			
	1		D	1.0		pp = 200-230	
	1.1	SILTY CLAY - stiff to very stiff, grey, slightly sandy, silty clay, damp					
52	1.5	SHALE - extremely low to very low strength, highly weathered, grey, shale	D	1.5		pp = 150-240	
	2 2.0	Pit discontinued at 2.0m (Refusal on low to medium strength shale)	D	2.0			
51							
	3						
50							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Kubota KX018-4
LOGGED: CMcD
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 55.5 AHD
EASTING: 280461
NORTHING: 6133068

PIT No: 103
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
		FILLING - brown grey, slightly silty, gravelly clay, humid							
55				D	0.5		pp = 390-400		
		- slow progess at 0.8m							
	1 1.0	Pit discontinued at 1.0m (Refusal in gravelly filling)		D	1.0				1
54									
	2								2
53									
	3								3
52									

RIG: Kubota KX018-4
LOGGED: CMcD
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

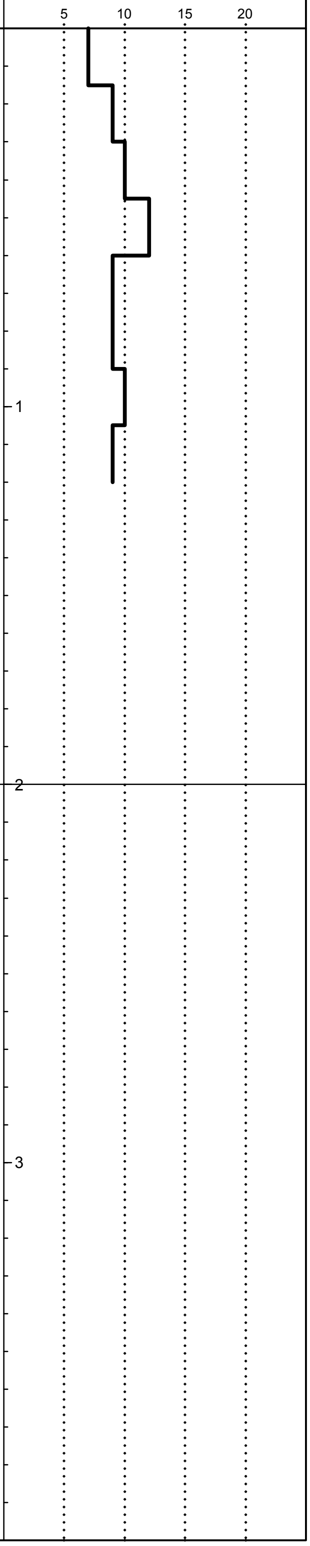
CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 53.8 AHD
EASTING: 280699
NORTHING: 6133047

PIT No: 104
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		SILTY CLAY - very stiff, friable, silty clay with some sand, humid		E	0.1			
				D E	0.5			
				U	0.9			
53	1	- gravelly below 1.0m		D	1.0			
	1.2	SHALE - extremely low to very low strength, highly weathered, light grey, shale						
				D	1.5			
		- very low to low strength below 1.6m						
52	2							
	2.0	Pit discontinued at 2.0m (Refusal on low to medium strength shale)						
51	3							
50								

Dynamic Penetrometer Test (blows per 150mm)



RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
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TEST PIT LOG

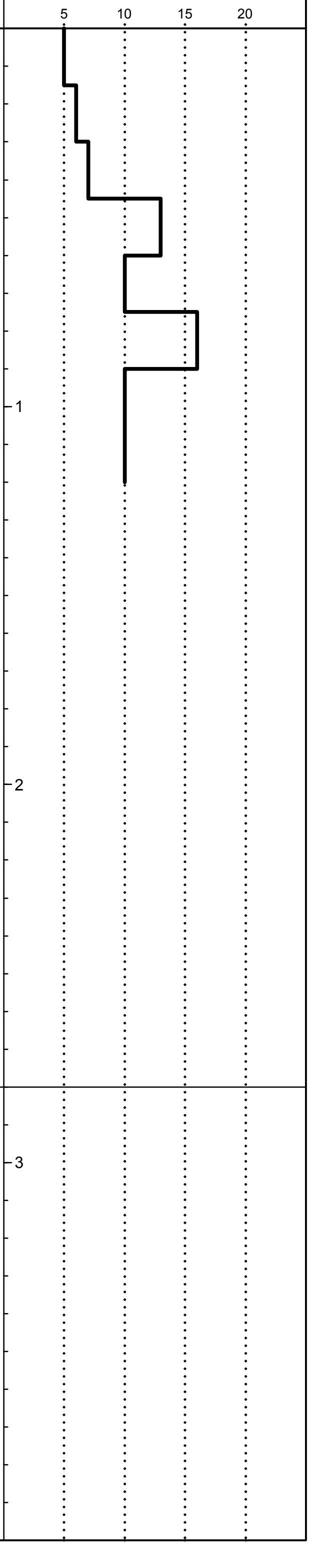
CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 57.3 AHD
EASTING: 280353
NORTHING: 6132889

PIT No: 105
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		FILLING - brown grey, fine to medium clayey silty gravel, humid						
				D	0.5			
	1.0	SILTY CLAY - very stiff to hard, orange brown mottled grey, silty clay, damp		D	1.0		pp = 190-220	
				D	1.5		pp = 190-250	
				D	2.0			
				D	2.5			
	2.8	Pit discontinued at 2.8m (Refusal on low strength shale)						

Dynamic Penetrometer Test (blows per 150mm)



RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 59.1 AHD
EASTING: 280437
NORTHING: 6132874

PIT No: 106
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm)
	0.05	TOPSOIL - brown grey, slightly silty gravelly clay, humid							
59		GRAVELLY SILTY CLAY - orange brown, gravelly silty clay, humid		E	0.1				
		- slow progress at 0.5m		D E	0.5				
	0.7	Pit discontinued at 0.7m (Refusal on low strength shale)							
58	1								
57	2								
56	3								

RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 60.8 AHD
EASTING: 280489
NORTHING: 6132863

PIT No: 107
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm)
	0.1	FILLING - dark grey, slightly silty, fine to medium clayey gravel (sandstone), humid							
	0.5	GRAVELLY SILTY CLAY - orange brown, gravelly silty clay, humid - slow progress below 0.4m		D	0.5				
60		Pit discontinued at 0.5m (Refusal on low strength shale)							
	1								1
59									
	2								2
58									
	3								3
57									

Dynamic Penetrometer Test scale: 5, 10, 15, 20

RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 58.7 AHD
EASTING: 280680
NORTHING: 6132812

PIT No: 108
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm)
		FILLING - slightly clayey, brown grey, slightly silty, fine to medium sandy gravel (sandstone), humid		D E	0.1				
				D E	0.5				
58									
	1	- clayey below 1.0m		D	1.0				
				D E	1.5				
57									
	2			E	2.0				
				D E	2.5				
56									
		- slow progress at 2.8m							
	3 / 3.0	Pit discontinued at 3.0m (Limit of investigation)							
55									

RIG: Kubota KX018-4
LOGGED: CMcD
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 62.4 AHD
EASTING: 280474
NORTHING: 6132640

PIT No: 109
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm) 5 10 15 20
		FILLING - brown grey, slightly silty, gravelly clay, humid							
62				D	0.5		pp = 220		
	0.8	SILTY CLAY - stiff, light brown grey mottled dark grey, silty clay, damp to moist							
	1			D	1.0		pp = 150-180		1
61				D	1.5		pp = 130-140		
	2	- slightly gravelly below 2.0m		D	2.0		pp = 120		2
	2.2	SHALE - extremely low to low strength, highly weathered, grey shale with some silty clay bands							
60				D	2.5				
	2.6	Pit discontinued at 2.6m (Refusal on low to medium strength shale)							
	3								3
59									

RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 62.1 AHD
EASTING: 280382
NORTHING: 6132631

PIT No: 110
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
62		FILLING - brown grey, slightly silty, gravelly clay, humid		E	0.1				
				D	0.5		pp = 150-180		
				E			pp = 400		
				U	0.9				
	0.8	SILTY CLAY - stiff to very stiff, brown grey mottled grey, silty clay, moist							
61	1			D	1.0		pp = 150-220		
				D	1.5				
				E					
60	2 2.0	Pit discontinued at 2.0m (Refusal on low to medium strength shale)		D	2.0				
59	3								

RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 62.2 AHD
EASTING: 280480
NORTHING: 6132616

PIT No: 111
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
		FILLING - brown grey, slightly silty, gravelly clay, humid		D	0.5		pp = 160-200		
	0.8	SILTY CLAY - brown mottled grey, silty clay, damp		D	1.0		pp = 120-150		
				D	1.5				
	1.8	SHALE - extremely low to very low strength, highly weathered, grey, shale		D	2.0				
	2.1	Pit discontinued at 2.1m (Refusal on low to medium strength shale)							

RL scale: 62, 61, 60, 59. Depth scale: 1, 2, 3. Dynamic Penetrometer scale: 5, 10, 15, 20.

RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Guymer Bailey Architects
PROJECT: Proposed Correctional Centre Upgrade
LOCATION: 55 The Links Road, South Nowra

SURFACE LEVEL: 58.4 AHD
EASTING: 280609
NORTHING: 6132576

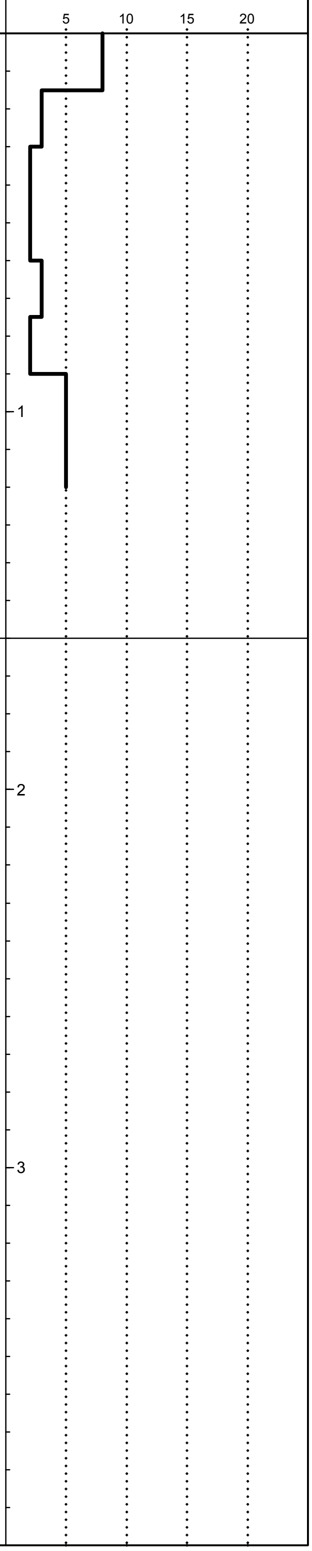
PIT No: 112
PROJECT No: 48600.06
DATE: 27/5/2016
SHEET 1 OF 1

Depth (m)	Description of Strata
0.0–0.2	FILLING - grey brown, slightly silty, slightly sandy, gravelly clay
0.2–1.3	SILTY CLAY - firm to stiff, light brown grey, silty clay with some gravel (ironstone), damp - moist to wet below 1.0m
1.3–1.6	SHALE - extremely low to very low strength, highly weathered grey, shale with some silty clay bands
1.6	Pit discontinued at 1.6m (Refusal on low to medium strength shale)

Sampling & In Situ Testing

Type	Depth	Sample	Results & Comments
E	0.1		
D	0.5		pp = 160-200
E	0.5		pp = 110-130
U	0.5–0.9		
D	1.0		pp = 180-230
D	1.5		

Dynamic Penetrometer Test (blows per 150mm)



RIG: Kubota KX018-4 **LOGGED:** CMcD **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Photo1 – Drilling of Bore 102

Photo 2 – Rear of correctional centre

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	48600.06
	Proposed Correctional Centre Upgrade	PLATE No:	1
	55 The Links Road, South Nowra	REV:	0
	CLIENT: Guymer Bailey Architects	DATE:	17 Jun 2016

Photo 3 – Location of Bore 108, inside the facility

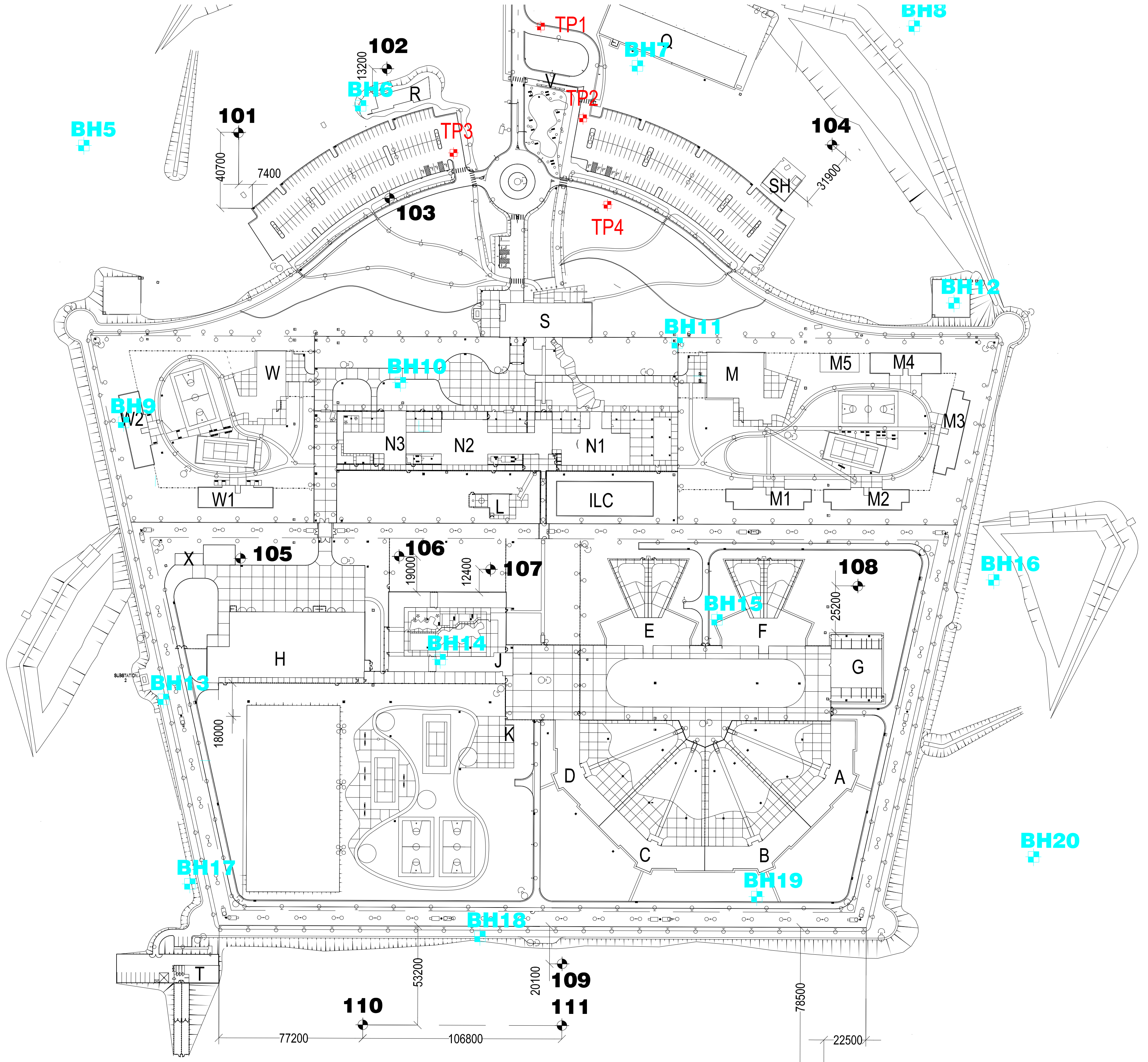
Photo 4 – Location of Bores 106 and 107

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	48600.06
	Proposed Correctional Centre Upgrade	PLATE No:	2
	55 The Links Road, South Nowra	REV:	0
	CLIENT: Guymer Bailey Architects	DATE:	17 Jun 2016

Photo 5 – Gravelly silty clay and sandstone in Bore 107

Photo 6 – Spoil generated by Bore 107

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	48600.06
	Proposed Correctional Centre Upgrade	PLATE No:	3
	55 The Links Road, South Nowra	REV:	0
	CLIENT: Guymer Bailey Architects	DATE:	17 Jun 2016



0 20 40 60 80 100 150 200 250m

1:2500 @ A3

Locality Plan

NOTE: Base drawing provided by Guymer Bailey Architects, dated 04/05/2016

LEGEND

- Previous Test Pit (Project 48600.05, dated 13/12/2010)
- Previous Test Pit (Cottier Project 21941G, 2007)
- Current Borehole Location

Douglas Partners
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CLIENT: Guymer Bailey Architects		TITLE: **Test Locations**	PROJECT No: 48600.06
OFFICE: Wollongong	DRAWN BY: CMcD	**Proposed Correctional Centre Upgrade**	DRAWING No: 1
SCALE: 1: 2500@ A3	DATE: 2.06.2016	**55 The Links Road, South Nowra**	REVISION: -

N
MGA

Appendix C

Results of Laboratory Tests

Douglas Partners
Geotechnics / Environment / Groundwater

Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
Unit 1, 1 Luso Drive
PO Box 486
Unanderra NSW 2526
Phone (02) 4271 1836
Fax (02) 4271 1897

Result of Shrink-Swell Index Determination

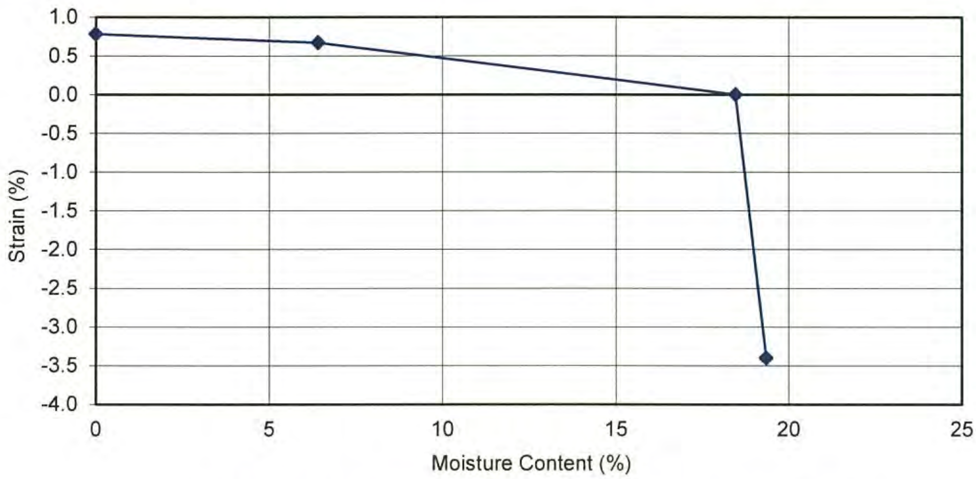
Client :	Guymer Bailey Architects	**Project No. :**	48600.06
		Report No. :	UL16-080
Project :	Proposed Correctional Centre Upgrade	**Report Date :**	07-06-16
		Date Sampled :	25-05-16
Location :	55 The Links Road, South Nowra	**Date of Test:**	01-06-16
Test Location :	Bore 102		
Depth / Layer :	0.5 - 0.9m	**Page:**	1 of 1

CORE SHRINKAGE TEST

Shrinkage - air dried	0.7 %
Shrinkage - oven dried	0.8 %
Significant inert inclusions	5.0 %
Extent of cracking	SC
Extent of soil crumbling	2.0 %
Moisture content of core	18.5 %

SWELL TEST

Pocket penetrometer reading at initial moisture content	300 kPa
Pocket penetrometer reading at final moisture content	260 kPa
Initial Moisture Content	18.6 %
Final Moisture Content	19.3 %
Swell under 25kPa	3.4 %



SHRINK-SWELL INDEX Iss 1.4% per Δ pF

Description: Brown clay.

Test Method(s): AS 1289.7.1.1, AS 1289.2.1.1

Sampling Method(s): Sampled by Wollongong Engineering Department

Extent of Cracking:
UC - Uncracked
SC - Slightly cracked
MC - Moderately cracked
HC - Highly cracked
FR - Fractured

Remarks: -

Note that NATA accreditation does not cover the performance of pocket penetrometer readings

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 828
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Accredited for compliance with ISO/IEC 17025

Tested:	JM
Checked:	SER

Simon Richards
Senior Technician

Douglas Partners
Geotechnics / Environment / Groundwater

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Unanderra NSW 2526
Phone (02) 4271 1836
Fax (02) 4271 1897

Result of Shrink-Swell Index Determination

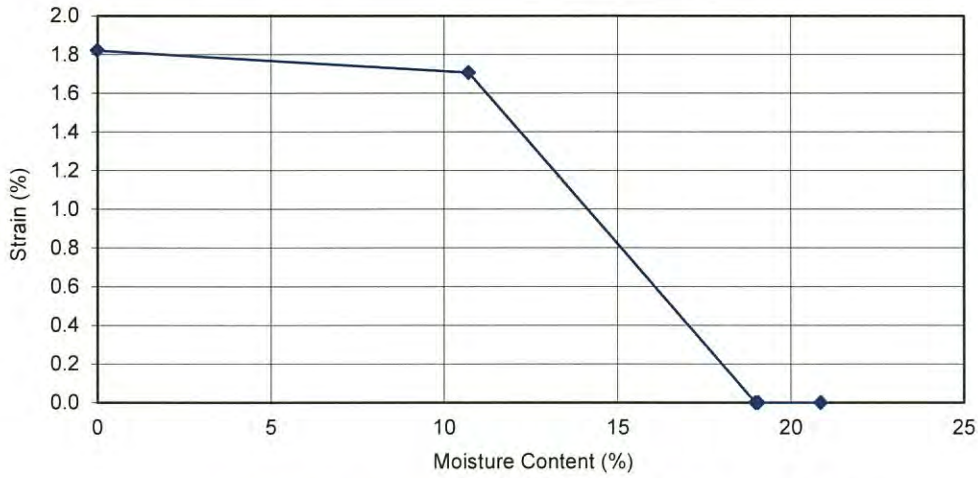
Client :	Guymer Bailey Architects	**Project No. :**	48600.06
		Report No. :	UL16-080A
Project :	Proposed Correctional Centre Upgrade	**Report Date :**	07-06-16
		Date Sampled :	25-05-16
Location :	55 The Links Road, South Nowra	**Date of Test:**	01-06-16
Test Location :	Bore 112		
Depth / Layer :	0.5 - 0.9m	**Page:**	1 of 1

CORE SHRINKAGE TEST

Shrinkage - air dried	1.7 %
Shrinkage - oven dried	1.8 %
Significant inert inclusions	3.0 %
Extent of cracking	SC
Extent of soil crumbling	1.0 %
Moisture content of core	19.1 %

SWELL TEST

Pocket penetrometer reading at initial moisture content	340 kPa
Pocket penetrometer reading at final moisture content	330 kPa
Initial Moisture Content	20.2 %
Final Moisture Content	20.9 %
Swell under 25kPa	0.0 %



SHRINK-SWELL INDEX Iss 1.0% per Δ pF

Description:	Brown silty clay.
Test Method(s):	AS 1289.7.1.1, AS 1289.2.1.1
Sampling Method(s):	Sampled by Wollongong Engineering Department
Extent of Cracking:	**UC** - Uncracked, **SC** - Slightly cracked, **MC** - Moderately cracked, **HC** - Highly cracked, **FR** - Fractured
Remarks:	-

Note that NATA accreditation does not cover the performance of pocket penetrometer readings

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NATA Accredited Laboratory Number: 828
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Accredited for compliance with ISO/IEC 17025

Tested:	JM
Checked:	SER

Simon Richards
Senior Technician

Douglas Partners
Geotechnics / Environment / Groundwater

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Fax (02) 4271 1897

Results of Moisture Content, Plasticity and Linear Shrinkage Tests

Client:	**Guymer Bailey Architects**	**Project No:**	48600.06
		Report No:	UL16-080B
Project:	Proposed Correctional Centre Upgrade	**Report Date:**	7/06/2016
		Date Sampled:	25/05/2016
		Date of Test:	3/06/2016
Location:	55 The Links Road, South Nowral	**Page:**	1 of 1

Test Location	Depth (m)	Description	Code	W_F %	W_L %	W_P %	PI %	*LS %
Bore 108	0.5	Brown gravelly silty clay	2,3,5	11.3	46	21	25	11.0
Bore 110	0.5 - 0.9	Brown silty clay	2,3,5	18.9	34	20	14	6.5

Legend:
- W_F Field Moisture Content
- W_L Liquid limit
- W_P Plastic limit
- PI Plasticity index
- LS Linear shrinkage from liquid limit condition (Mould length125mm)

Test Methods:
- Moisture Content: AS 1289 2.1.1
- Liquid Limit: AS 1289 3.1.2
- Plastic Limit: AS 1289 3.2.1
- Plasticity Index: AS 1289 3.3.1
- Linear Shrinkage: AS 1289 3.4.1

Code:

Sample history for plasticity tests
1. Air dried
2. Low temperature (<50°C) oven dried
3. Oven (105°C) dried
4. Unknown

Method of preparation for plasticity tests

5. Dry sieved
6. Wet sieved
7. Natural

*Specify if sample crumbled CR or curled CU

Sampling Methods: Sampled by Wollongong Engineering Department

Remarks: -

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 828

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025

Tested: JM
Checked: SER

Simon Richards
Senior Technician

Appendix D

Table D1: Contamination Laboratory Summary Table
Laboratory Certificate of Analysis, Sample Receipt Advice and
Chain of Custody Documentation

Douglas Partners
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Table D1: Contamination Laboratory Summary Table (All results in mg/kg unless otherwise stated)

Sample ID	Heavy Metals								TRH/BTEX								PAHs				Phenols	PCB	OCP								OPP	Asbestos
	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	F1	F2	F3	F4	Benzene	Toluene	Ethyl benzene	Total Xylene	Total PAH	B(a)P TEQ	B(a)P	Napthalene			Aldrin + Dieldrin	Chlordane	DDT + DDD + DDE	Endosulfan	Endrin	Heptachlor	HCB	Methoxychlor	Chlorpyrifos	
PQL	<4	<0.4	<1	<1	<1	<0.1	<1	<1	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	NAD
101/0.1	6	<0.4	12	20	8	<0.1	5	21	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	NAD
108/0.1	6	<0.4	12	16	10	<0.1	4	18	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	NAD
110/0.1	7	<0.4	14	17	7	<0.1	2	10	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	NAD
112/0.5	8	<0.4	16	25	10	<0.1	6	34	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	NAD
Summary Statistics																																
Min	6	<0.4	12	16	7	<0.1	2	10	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	-
Max	8	<0.4	16	25	10	<0.1	6	34	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	-
Median	7	<0.4	13	19	9	<0.1	5	20	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	-
Arithmatic Mean	6.8	<0.4	13.5	19.5	8.8	<0.1	4.3	20.8	<25	<50	<100	<100	<0.2	<0.5	<1	<3	<1.55	<0.5	<0.05	<0.1	<5	<0.7	<0.2	<0.2	<0.3	<0.1	<0.1	<0.2	<0.1	<0.1	<0.2	-
Site Assessment Criteria																																
HIL-A	100	20	-	6000	300	40	400	7400	-	-	-	-	-	-	-	-	300	-	3	-	100*	1	6	50	240	270	10	6	10	300	160	NAD
HSL-A Direct Contact	-	-	-	-	-	-	-	-	4400	3300	4500	6300	100	14000	4500	12000	-	-	-	1400	-	-	-	-	-	-	-	-	-	-	-	-
HSL-A Vapour Intrusio	-	-	-	-	-	-	-	-	45	110	-	-	0.5	160	55	40	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Management Limits	-	-	-	-	-	-	-	-	700	1000	2500	10000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EIL	100	-	410	110	###	-	180	280	-	-	-	-	-	-	-	-	-	-	-	170	-	-	-	-	180	-	-	-	-	-	-	-
ESL	-	-	-	-	-	-	-	-	180	120	1300	5600	65	105	125	45	-	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

BOLD	Exceedance of EIL/ESL
-	Not tested/not available
PQL	Practical quantification limit
NAD	No asbestos detected
HIL	NEPC, *National Environment Protection (Assessment of Site Contamination) Measure 1999* (Amended 2013), Schedule B1, Table 1A (1) Health investigation levels for soil contaminants, Residential A.
HSL	NEPC, *National Environment Protection (Assessment of Site Contamination) Measure 1999* (Amended 2013), Schedule B1, Table 1A (3) Soil health screening levels for vapour intrusion, for low-high density residential, clay at depth of 0 to <1m.
Management Limits	NEPC, *National Environment Protection (Assessment of Site Contamination) Measure 1999* (Amended 2013), Schedule B1, Table 1B (7) Management Limits for TPH fractions F1-F4 in soil, residential, parkland and public open space.
EIL	EILs calculated using ABC and ACL based on an average CEC value of 10.4 cmol/kg, an average pH of 5.1, an assumed clay content of 10% and an "Aged" (>2 years) source of contamination in a low traffic volume area in NSW.
ESL	NEPC, *National Environment Protection (Assessment of Site Contamination) Measure 1999* (Amended 2013), Schedule B1, Table 1B (6) ESLs for TPH fractions F1 - F4, BTEX and benzo(a)pyrene in soil - urban residential and public open space (fine soil)
F1	Calculated as being TRH C_6-C_{10} minus BTEX
F2	Calculated as being TRH >C_{10}-C_{16} minus Napthalene
F3	TRH >C16-C34
F4	TRH >C34-C40

12 Ashley Street, Chatswood, NSW 2067
tel: +61 2 9910 6200

email: sydney@envirolab.com.au
envirolab.com.au

Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS 147648

Client:
Douglas Partners Unanderra
Unit 1, 1 Luso Drive
Unanderra
NSW 2526

Attention: Arthur Castrissios

Sample log in details:

Your Reference:	**48600.06, 55 The Links Rd Sth Nowra**
No. of samples:	4 soils
Date samples received / completed instructions received	31/05/16 / 31/05/16

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	7/06/16 / 6/06/16
Date of Preliminary Report:	Not Issued

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Accredited for compliance with ISO/IEC 17025. **Tests not covered by NATA are denoted with *.**

Results Approved By:

Jacinta Hurst
Laboratory Manager

ACCREDITED FOR TECHNICAL COMPETENCE

ESP/CEC					
Our Reference:	UNITS	147648-1	147648-2	147648-3	147648-4
Your Reference	-------------	102	105	108	109
Depth	------------	1.0	0.5	2.0	0.5
Date Sampled		27/05/2016	26/05/2016	26/05/2016	27/05/2016
Type of sample		soil	soil	soil	soil
Date prepared	-	02/06/2016	02/06/2016	02/06/2016	02/06/2016
Date analysed	-	02/06/2016	02/06/2016	02/06/2016	02/06/2016
Exchangeable Ca	meq/100g	0.2	12	0.2	0.7
Exchangeable K	meq/100g	0.2	0.3	0.3	0.3
Exchangeable Mg	meq/100g	4.4	4.4	6.0	5.4
Exchangeable Na	meq/100g	1.9	0.58	3.6	1.6
Cation Exchange Capacity	meq/100g	6.5	17	10	8.0
ESP	%	28	3	36	20

Misc Inorg - Soil					
Our Reference:	UNITS	147648-1	147648-2	147648-3	147648-4
Your Reference	------------- -	102	105	108	109
Depth	------------	1.0	0.5	2.0	0.5
Date Sampled		27/05/2016	26/05/2016	26/05/2016	27/05/2016
Type of sample		soil	soil	soil	soil
Date prepared	-	01/06/2016	01/06/2016	01/06/2016	01/06/2016
Date analysed	-	01/06/2016	01/06/2016	01/06/2016	01/06/2016
pH 1:5 soil:water	pH Units	5.1	5.5	5.0	4.9
Chloride, Cl 1:5 soil:water	mg/kg	210	78	430	230
Sulphate, SO4 1:5 soil:water	mg/kg	170	320	100	100

Texture and Salinity					
Our Reference:	UNITS	147648-1	147648-2	147648-3	147648-4
Your Reference	-------------	102	105	108	109
Depth	------------	1.0	0.5	2.0	0.5
Date Sampled		27/05/2016	26/05/2016	26/05/2016	27/05/2016
Type of sample		soil	soil	soil	soil
Date prepared	-	01/06/2016	01/06/2016	01/06/2016	01/06/2016
Date analysed	-	01/06/2016	01/06/2016	01/06/2016	01/06/2016
Electrical Conductivity 1:5 soil:water	µS/cm	230	190	340	210
Texture Value	-	7.0	8.0	8.0	8.0
TEXTURE	-	Medium Clay	Light Medium Clay	Light Medium Clay	Light Medium Clay
ECe	dS/m	2	2	3	2
Class	-	NON SALINE	NON SALINE	SLIGHTLY SALINE	NON SALINE

Moisture					
Our Reference:	UNITS	147648-1	147648-2	147648-3	147648-4
Your Reference	-------------	102	105	108	109
Depth	------------	1.0	0.5	2.0	0.5
Date Sampled		27/05/2016	26/05/2016	26/05/2016	27/05/2016
Type of sample		soil	soil	soil	soil
Date prepared	-	2/06/2016	2/06/2016	2/06/2016	2/06/2016
Date analysed	-	2/06/2016	2/06/2016	2/06/2016	2/06/2016
Moisture	%	24	9.1	13	12

Method ID	Methodology Summary
Metals-009	Determination of exchangeable cations and cation exchange capacity in soils using 1M Ammonium Chloride exchange and ICP-AES analytical finish.
Inorg-001	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Alternatively determined by colourimetry/turbidity using Discrete Analyer.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25oC in accordance with APHA latest edition 2510 and Rayment & Lyons.
Inorg-008	Moisture content determined by heating at 105+/-5 deg C for a minimum of 12 hours.

QUALITY CONTROL ESP/CEC	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			02/06/2016	147648-1	02/06/2016 || 02/06/2016	LCS-1	02/06/2016
Date analysed	-			02/06/2016	147648-1	02/06/2016 || 02/06/2016	LCS-1	02/06/2016
Exchangeable Ca	meq/100g	0.1	Metals-009	<0.1	147648-1	0.2 || 0.1 || RPD: 67	LCS-1	115%
Exchangeable K	meq/100g	0.1	Metals-009	<0.1	147648-1	0.2 || 0.2 || RPD: 0	LCS-1	107%
Exchangeable Mg	meq/100g	0.1	Metals-009	<0.1	147648-1	4.4 || 4.7 || RPD: 7	LCS-1	111%
Exchangeable Na	meq/100g	0.1	Metals-009	<0.1	147648-1	1.9 || 1.9 || RPD: 0	LCS-1	114%
ESP	%	1	Metals-009	<1	147648-1	28 || 27 || RPD: 4	[NR]	[NR]

QUALITY CONTROL Misc Inorg - Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			01/06/2016	147648-1	01/06/2016 || 01/06/2016	LCS-	01/06/2016
Date analysed	-			01/06/2016	147648-1	01/06/2016 || 01/06/2016	LCS-	01/06/2016
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	147648-1	5.1 || 5.1 || RPD: 0	LCS-	101%
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	147648-1	210 || 170 || RPD: 21	LCS-	102%
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	147648-1	170 || 130 || RPD: 27	LCS-	113%

QUALITY CONTROL Texture and Salinity	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			01/06/2016	147648-1	01/06/2016 || 01/06/2016	LCS-1	01/06/2016
Date analysed	-			01/06/2016	147648-1	01/06/2016 || 01/06/2016	LCS-1	01/06/2016
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	147648-1	230 || 230 || RPD: 0	LCS-1	96%
Texture Value	-		Inorg-002	[NT]	147648-1	7.0 || 7.0 || RPD: 0	[NR]	[NR]
Class	-			[NT]	147648-1	NON SALINE || NON SALINE	[NR]	[NR]

QUALITY CONTROL Misc Inorg - Soil	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Date prepared	-	[NT]	[NT]	147648-2	01/06/2016
Date analysed	-	[NT]	[NT]	147648-2	01/06/2016
pH 1:5 soil:water	pH Units	[NT]	[NT]	[NR]	[NR]
Chloride, Cl 1:5 soil:water	mg/kg	[NT]	[NT]	147648-2	86%
Sulphate, SO4 1:5 soil:water	mg/kg	[NT]	[NT]	147648-2	105%

Report Comments:

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NR: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.
Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.
Spikes for Physical and Aggregate Tests are not applicable.
For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

12 Ashley Street, Chatswood, NSW 2067
tel: +61 2 9910 6200

email: sydney@envirolab.com.au
envirolab.com.au

Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS 147563

Client:
Douglas Partners Unanderra
Unit 1, 1 Luso Drive
Unanderra
NSW 2526

Attention: Arthur Castrissios

Sample log in details:

Your Reference:	**48600.06, 55 The Links Rd Sth Nowra**		
No. of samples:	4 soils		
Date samples received / completed instructions received	30/05/16	/	30/05/16

This report replaces the one dated 06/06/2016 (R00) due to amendment of sample type.

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	6/06/16	/	15/06/16
Date of Preliminary Report:	Not Issued		

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Results Approved By:

Jacinta Hurst
Laboratory Manager

vTRH(C6-C10)/BTEXN in Soil					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date extracted	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Date analysed	-	01/06/2016	01/06/2016	01/06/2016	01/06/2016
TRH C_6 - C_9	mg/kg	<25	<25	<25	<25
TRH C_6 - C_{10}	mg/kg	<25	<25	<25	<25
vTPH C_6 - C_{10} less BTEX (F1)	mg/kg	<25	<25	<25	<25
Benzene	mg/kg	<0.2	<0.2	<0.2	<0.2
Toluene	mg/kg	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	mg/kg	<1	<1	<1	<1
m+p-xylene	mg/kg	<2	<2	<2	<2
o-Xylene	mg/kg	<1	<1	<1	<1
naphthalene	mg/kg	<1	<1	<1	<1
Surrogate aaa-Trifluorotoluene	%	108	99	99	109

svTRH (C10-C40) in Soil					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date extracted	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Date analysed	-	01/06/2016	01/06/2016	01/06/2016	01/06/2016
TRHC $_{10}$ - C $_{14}$	mg/kg	<50	<50	<50	<50
TRHC $_{15}$ - C $_{28}$	mg/kg	<100	<100	<100	<100
TRHC $_{29}$ - C $_{36}$	mg/kg	<100	<100	<100	<100
TRH>C $_{10}$-C $_{16}$	mg/kg	<50	<50	<50	<50
TRH>C $_{10}$ - C $_{16}$ less Naphthalene (F2)	mg/kg	<50	<50	<50	<50
TRH>C $_{16}$-C $_{34}$	mg/kg	<100	<100	<100	<100
TRH>C $_{34}$-C $_{40}$	mg/kg	<100	<100	<100	<100
Surrogate o-Terphenyl	%	73	90	90	87

PAHs in Soil					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date extracted	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Date analysed	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Naphthalene	mg/kg	<0.1	<0.1	<0.1	<0.1
Acenaphthylene	mg/kg	<0.1	<0.1	<0.1	<0.1
Acenaphthene	mg/kg	<0.1	<0.1	<0.1	<0.1
Fluorene	mg/kg	<0.1	<0.1	<0.1	<0.1
Phenanthrene	mg/kg	<0.1	<0.1	<0.1	<0.1
Anthracene	mg/kg	<0.1	<0.1	<0.1	<0.1
Fluoranthene	mg/kg	<0.1	<0.1	<0.1	<0.1
Pyrene	mg/kg	<0.1	<0.1	<0.1	<0.1
Benzo(a)anthracene	mg/kg	<0.1	<0.1	<0.1	<0.1
Chrysene	mg/kg	<0.1	<0.1	<0.1	<0.1
Benzo(b,j+k)fluoranthene	mg/kg	<0.2	<0.2	<0.2	<0.2
Benzo(a)pyrene	mg/kg	<0.05	<0.05	<0.05	<0.05
Indeno(1,2,3-c,d)pyrene	mg/kg	<0.1	<0.1	<0.1	<0.1
Dibenzo(a,h)anthracene	mg/kg	<0.1	<0.1	<0.1	<0.1
Benzo(g,h,i)perylene	mg/kg	<0.1	<0.1	<0.1	<0.1
Benzo(a)pyrene TEQ calc (zero)	mg/kg	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ calc(half)	mg/kg	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ calc(PQL)	mg/kg	<0.5	<0.5	<0.5	<0.5
Total Positive PAHs	mg/kg	NIL (+)VE	NIL (+)VE	NIL (+)VE	NIL (+)VE
Surrogate p-Terphenyl-d14	%	96	89	93	82

Organochlorine Pesticides in soil					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date extracted	-	31/05/2030	31/05/2031	31/05/2032	31/05/2033
Date analysed	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
HCB	mg/kg	<0.1	<0.1	<0.1	<0.1
alpha-BHC	mg/kg	<0.1	<0.1	<0.1	<0.1
gamma-BHC	mg/kg	<0.1	<0.1	<0.1	<0.1
beta-BHC	mg/kg	<0.1	<0.1	<0.1	<0.1
Heptachlor	mg/kg	<0.1	<0.1	<0.1	<0.1
delta-BHC	mg/kg	<0.1	<0.1	<0.1	<0.1
Aldrin	mg/kg	<0.1	<0.1	<0.1	<0.1
Heptachlor Epoxide	mg/kg	<0.1	<0.1	<0.1	<0.1
gamma-Chlordane	mg/kg	<0.1	<0.1	<0.1	<0.1
alpha-chlordane	mg/kg	<0.1	<0.1	<0.1	<0.1
Endosulfan I	mg/kg	<0.1	<0.1	<0.1	<0.1
pp-DDE	mg/kg	<0.1	<0.1	<0.1	<0.1
Dieldrin	mg/kg	<0.1	<0.1	<0.1	<0.1
Endrin	mg/kg	<0.1	<0.1	<0.1	<0.1
pp-DDD	mg/kg	<0.1	<0.1	<0.1	<0.1
Endosulfan II	mg/kg	<0.1	<0.1	<0.1	<0.1
pp-DDT	mg/kg	<0.1	<0.1	<0.1	<0.1
Endrin Aldehyde	mg/kg	<0.1	<0.1	<0.1	<0.1
Endosulfan Sulphate	mg/kg	<0.1	<0.1	<0.1	<0.1
Methoxychlor	mg/kg	<0.1	<0.1	<0.1	<0.1
Surrogate TCMX	%	90	87	89	86

Organophosphorus Pesticides					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	------------- -	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date extracted	-	31/05/2030	31/05/2031	31/05/2032	31/05/2033
Date analysed	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Azinphos-methyl (Guthion)	mg/kg	<0.1	<0.1	<0.1	<0.1
Bromophos-ethyl	mg/kg	<0.1	<0.1	<0.1	<0.1
Chlorpyriphos	mg/kg	<0.1	<0.1	<0.1	<0.1
Chlorpyriphos-methyl	mg/kg	<0.1	<0.1	<0.1	<0.1
Diazinon	mg/kg	<0.1	<0.1	<0.1	<0.1
Dichlorvos	mg/kg	<0.1	<0.1	<0.1	<0.1
Dimethoate	mg/kg	<0.1	<0.1	<0.1	<0.1
Ethion	mg/kg	<0.1	<0.1	<0.1	<0.1
Fenitrothion	mg/kg	<0.1	<0.1	<0.1	<0.1
Malathion	mg/kg	<0.1	<0.1	<0.1	<0.1
Parathion	mg/kg	<0.1	<0.1	<0.1	<0.1
Ronnel	mg/kg	<0.1	<0.1	<0.1	<0.1
Surrogate TCMX	%	90	87	89	86

PCBs in Soil					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date extracted	-	31/05/2030	31/05/2031	31/05/2032	31/05/2033
Date analysed	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Aroclor 1016	mg/kg	<0.1	<0.1	<0.1	<0.1
Aroclor 1221	mg/kg	<0.1	<0.1	<0.1	<0.1
Aroclor 1232	mg/kg	<0.1	<0.1	<0.1	<0.1
Aroclor 1242	mg/kg	<0.1	<0.1	<0.1	<0.1
Aroclor 1248	mg/kg	<0.1	<0.1	<0.1	<0.1
Aroclor 1254	mg/kg	<0.1	<0.1	<0.1	<0.1
Aroclor 1260	mg/kg	<0.1	<0.1	<0.1	<0.1
Surrogate TCLMX	%	90	87	89	86

Acid Extractable metals in soil					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date prepared	-	30/05/2016	30/05/2016	30/05/2016	30/05/2016
Date analysed	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Arsenic	mg/kg	6	6	7	8
Cadmium	mg/kg	<0.4	<0.4	<0.4	<0.4
Chromium	mg/kg	12	12	14	16
Copper	mg/kg	20	16	17	25
Lead	mg/kg	8	10	7	10
Mercury	mg/kg	<0.1	<0.1	<0.1	<0.1
Nickel	mg/kg	5	4	2	6
Zinc	mg/kg	21	18	10	34

Misc Soil - Inorg					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date prepared	-	30/05/2016	30/05/2016	30/05/2016	30/05/2016
Date analysed	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Total Phenolics (as Phenol)	mg/kg	<5	<5	<5	<5

Moisture					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date prepared	-	30/05/2016	30/05/2016	30/05/2016	30/05/2016
Date analysed	-	31/05/2016	31/05/2016	31/05/2016	31/05/2016
Moisture	%	11	8.9	19	20

Asbestos ID - soils					
Our Reference:	UNITS	147563-1	147563-2	147563-3	147563-4
Your Reference	-------------	101	108	110	112
Depth	------------	0.1	0.1	0.1	0.5
Date Sampled		26/05/2016	27/05/2016	27/05/2016	27/05/2016
Type of sample		Soil	Soil	Soil	Soil
Date analysed	-	3/06/2016	3/06/2016	3/06/2016	3/06/2016
Sample mass tested	g	Approx 25g	Approx 15g	Approx 15g	Approx 25g
Sample Description	-	Brown coarse-grained soil & rocks	Brown coarse-grained soil & rocks	Brown coarse-grained soil & rocks	Brown coarse-grained soil & rocks
Asbestos ID in soil	-	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected
Trace Analysis	-	No asbestos detected	No asbestos detected	No asbestos detected	No asbestos detected

Method ID	Methodology Summary
Org-016	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS. F1 = (C6-C10)-BTEX as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater.
Org-014	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS.
Org-003	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-FID. F2 = (>C10-C16)-Naphthalene as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater (HSLs Tables 1A (3, 4)). Note Naphthalene is determined from the VOC analysis.
Org-012	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-MS. Benzo(a)pyrene TEQ as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater - 2013. For soil results:- 1. 'TEQ PQL' values are assuming all contributing PAHs reported as <PQL are actually at the PQL. This is the most conservative approach and can give false positive TEQs given that PAHs that contribute to the TEQ calculation may not be present. 2. 'TEQ zero' values are assuming all contributing PAHs reported as <PQL are zero. This is the least conservative approach and is more susceptible to false negative TEQs when PAHs that contribute to the TEQ calculation are present but below PQL. 3. 'TEQ half PQL' values are assuming all contributing PAHs reported as <PQL are half the stipulated PQL. Hence a mid-point between the most and least conservative approaches above. Note, the Total +ve PAHs PQL is reflective of the lowest individual PQL and is therefore" Total +ve PAHs" is simply a sum of the positive individual PAHs.
Org-005	Soil samples are extracted with dichloromethane/acetone and waters with dichloromethane and analysed by GC with dual ECD's.
Org-008	Soil samples are extracted with dichloromethane/acetone and waters with dichloromethane and analysed by GC with dual ECD's.
Org-006	Soil samples are extracted with dichloromethane/acetone and waters with dichloromethane and analysed by GC-ECD.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Inorg-031	Total Phenolics by segmented flow analyser (in line distillation with colourimetric finish). Solids are extracted in a caustic media prior to analysis.
Inorg-008	Moisture content determined by heating at 105+/-5 deg C for a minimum of 12 hours.
ASB-001	Asbestos ID - Qualitative identification of asbestos in bulk samples using Polarised Light Microscopy and Dispersion Staining Techniques including Synthetic Mineral Fibre and Organic Fibre as per Australian Standard 4964-2004.

QUALITY CONTROL vTRH(C6-C10)/BTEXN in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
Date analysed	-			01/06/2016	[NT]	[NT]	LCS-2	01/06/2016
TRHC_6 - C_9	mg/kg	25	Org-016	<25	[NT]	[NT]	LCS-2	72%
TRHC_6 - C_{10}	mg/kg	25	Org-016	<25	[NT]	[NT]	LCS-2	72%
Benzene	mg/kg	0.2	Org-016	<0.2	[NT]	[NT]	LCS-2	72%
Toluene	mg/kg	0.5	Org-016	<0.5	[NT]	[NT]	LCS-2	74%
Ethylbenzene	mg/kg	1	Org-016	<1	[NT]	[NT]	LCS-2	70%
m+p-xylene	mg/kg	2	Org-016	<2	[NT]	[NT]	LCS-2	73%
o-Xylene	mg/kg	1	Org-016	<1	[NT]	[NT]	LCS-2	71%
naphthalene	mg/kg	1	Org-014	<1	[NT]	[NT]	[NR]	[NR]
Surrogate aaa-Trifluorotoluene	%		Org-016	111	[NT]	[NT]	LCS-2	102%

QUALITY CONTROL svTRH (C10-C40) in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
Date analysed	-			01/06/2016	[NT]	[NT]	LCS-2	01/06/2016
TRHC_{10} - C_{14}	mg/kg	50	Org-003	<50	[NT]	[NT]	LCS-2	108%
TRHC_{15} - C_{28}	mg/kg	100	Org-003	<100	[NT]	[NT]	LCS-2	89%
TRHC_{29} - C_{36}	mg/kg	100	Org-003	<100	[NT]	[NT]	LCS-2	108%
TRH>C_{10}-C_{16}	mg/kg	50	Org-003	<50	[NT]	[NT]	LCS-2	108%
TRH>C_{16}-C_{34}	mg/kg	100	Org-003	<100	[NT]	[NT]	LCS-2	89%
TRH>C_{34}-C_{40}	mg/kg	100	Org-003	<100	[NT]	[NT]	LCS-2	108%
Surrogate o-Terphenyl	%		Org-003	76	[NT]	[NT]	LCS-2	83%

QUALITY CONTROL PAHs in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
Date analysed	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
Naphthalene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	LCS-2	107%
Acenaphthylene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	[NR]	[NR]
Acenaphthene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	[NR]	[NR]
Fluorene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	LCS-2	103%
Phenanthrene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	LCS-2	112%
Anthracene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	[NR]	[NR]
Fluoranthene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	LCS-2	109%
Pyrene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	LCS-2	102%
Benzo(a)anthracene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	[NR]	[NR]
Chrysene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	LCS-2	88%
Benzo(b,j+k) fluoranthene	mg/kg	0.2	Org-012	<0.2	[NT]	[NT]	[NR]	[NR]

QUALITY CONTROL PAHs in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Benzo(a)pyrene	mg/kg	0.05	Org-012	<0.05	[NT]	[NT]	LCS-2	108%
Indeno(1,2,3-c,d)pyrene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	[NR]	[NR]
Dibenzo(a,h)anthracene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	[NR]	[NR]
Benzo(g,h,i)perylene	mg/kg	0.1	Org-012	<0.1	[NT]	[NT]	[NR]	[NR]
Surrogate p-Terphenyl-d14	%		Org-012	98	[NT]	[NT]	LCS-2	116%

QUALITY CONTROL Organochlorine Pesticides in soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			31/05/2030	[NT]	[NT]	LCS-2	31/05/2030
Date analysed	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
HCB	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
alpha-BHC	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	98%
gamma-BHC	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
beta-BHC	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	118%
Heptachlor	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	92%
delta-BHC	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
Aldrin	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	94%
Heptachlor Epoxide	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	89%
gamma-Chlordane	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
alpha-chlordane	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
Endosulfan I	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
pp-DDE	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	80%
Dieldrin	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	96%
Endrin	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	97%
pp-DDD	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	100%
Endosulfan II	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
pp-DDT	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
Endrin Aldehyde	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
Endosulfan Sulphate	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	LCS-2	88%
Methoxychlor	mg/kg	0.1	Org-005	<0.1	[NT]	[NT]	[NR]	[NR]
Surrogate TCMX	%		Org-005	90	[NT]	[NT]	LCS-2	89%

QUALITY CONTROL Organophosphorus Pesticides	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			31/05/2030	[NT]	[NT]	LCS-2	31/05/2030
Date analysed	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
Azinphos-methyl (Guthion)	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	[NR]	[NR]
Bromophos-ethyl	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	[NR]	[NR]
Chlorpyriphos	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	LCS-2	88%
Chlorpyriphos-methyl	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	[NR]	[NR]
Diazinon	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	[NR]	[NR]
Dichlorvos	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	LCS-2	86%
Dimethoate	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	[NR]	[NR]
Ethion	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	LCS-2	93%
Fenitrothion	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	LCS-2	97%
Malathion	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	LCS-2	77%
Parathion	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	LCS-2	100%
Ronnel	mg/kg	0.1	Org-008	<0.1	[NT]	[NT]	LCS-2	113%
Surrogate TCMX	%		Org-008	90	[NT]	[NT]	LCS-2	87%

QUALITY CONTROL PCBs in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			31/05/2030	[NT]	[NT]	LCS-2	31/05/2030
Date analysed	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
Aroclor 1016	mg/kg	0.1	Org-006	<0.1	[NT]	[NT]	[NR]	[NR]
Aroclor 1221	mg/kg	0.1	Org-006	<0.1	[NT]	[NT]	[NR]	[NR]
Aroclor 1232	mg/kg	0.1	Org-006	<0.1	[NT]	[NT]	[NR]	[NR]
Aroclor 1242	mg/kg	0.1	Org-006	<0.1	[NT]	[NT]	[NR]	[NR]
Aroclor 1248	mg/kg	0.1	Org-006	<0.1	[NT]	[NT]	[NR]	[NR]
Aroclor 1254	mg/kg	0.1	Org-006	<0.1	[NT]	[NT]	LCS-2	116%
Aroclor 1260	mg/kg	0.1	Org-006	<0.1	[NT]	[NT]	[NR]	[NR]
Surrogate TCLMX	%		Org-006	90	[NT]	[NT]	LCS-2	87%

QUALITY CONTROL Acid Extractable metals in soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			30/05/2016	[NT]	[NT]	LCS-2	30/05/2016
Date analysed	-			31/05/2016	[NT]	[NT]	LCS-2	31/05/2016
Arsenic	mg/kg	4	Metals-020	<4	[NT]	[NT]	LCS-2	102%
Cadmium	mg/kg	0.4	Metals-020	<0.4	[NT]	[NT]	LCS-2	99%
Chromium	mg/kg	1	Metals-020	<1	[NT]	[NT]	LCS-2	102%
Copper	mg/kg	1	Metals-020	<1	[NT]	[NT]	LCS-2	101%
Lead	mg/kg	1	Metals-020	<1	[NT]	[NT]	LCS-2	100%
Mercury	mg/kg	0.1	Metals-021	<0.1	[NT]	[NT]	LCS-2	104%
Nickel	mg/kg	1	Metals-020	<1	[NT]	[NT]	LCS-2	96%
Zinc	mg/kg	1	Metals-020	<1	[NT]	[NT]	LCS-2	98%

QUALITY CONTROL Misc Soil - Inorg	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			31/05/2016	[NT]	[NT]	LCS-1	31/05/2016
Date analysed	-			31/05/2016	[NT]	[NT]	LCS-1	31/05/2016
Total Phenolics (as Phenol)	mg/kg	5	Inorg-031	<5	[NT]	[NT]	LCS-1	101%

Report Comments:

Asbestos ID was analysed by Approved Identifier:	Paul Ching
Asbestos ID was authorised by Approved Signatory:	Paul Ching

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NR: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.
Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.
Spikes for Physical and Aggregate Tests are not applicable.
For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
enquiries@envirolabservices.com.au
www.envirolabservices.com.au

SAMPLE RECEIPT ADVICE

Client Details	
Client	Douglas Partners Unanderra
Attention	Arthur Castrissios

Sample Login Details	
Your Reference	48600.06, 55 The Links Rd Sth Nowra
Envirolab Reference	**147563**
Date Sample Received	30/05/2016
Date Instructions Received	30/05/2016
Date Results Expected to be Reported	**06/06/2016**

Sample Condition	
Samples received in appropriate condition for analysis	YES
No. of Samples Provided	4 soils
Turnaround Time Requested	Standard
Temperature on receipt (°C)	6.8
Cooling Method	Ice
Sampling Date Provided	YES

Comments
Samples will be held for 1 month for water samples and 2 months for soil samples from date of receipt of samples

Please direct any queries to:

Aileen Hie	Jacinta Hurst
Phone: 02 9910 6200	Phone: 02 9910 6200
Fax: 02 9910 6201	Fax: 02 9910 6201
Email: ahie@envirolabservices.com.au	Email: jhurst@envirolabservices.com.au

Sample and Testing Details on following page

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ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
enquiries@envirolabservices.com.au
www.envirolabservices.com.au

Sample Id	*vTRH(C6-C10)/BTEXN in Soil*	*svTRH (C10-C40) in Soil*	*PAHs in Soil*	*Organochlorine Pesticides in soil*	*Organophosphorus Pesticides*	*PCBs in Soil*	*Acid Extractable metals in soil*	*Total Phenolics (as Phenol)*	*Asbestos ID - soils*
101-0.1	✓	✓	✓	✓	✓	✓	✓	✓	✓
108-0.1	✓	✓	✓	✓	✓	✓	✓	✓	✓
110-0.1	✓	✓	✓	✓	✓	✓	✓	✓	✓
112-0.5	✓	✓	✓	✓	✓	✓	✓	✓	✓

Douglas Partners
Geotechnics / Environment / Groundwater

CHAIN OF CUSTODY

Project Name: Correctional Centre Upgrade, 55 The Links Rd, South Nowra NSW		**To:** Envirolab Services
Project No: 48600.06	**Sampler:** CMcD	12 Ashley St Chatswood 2067
Project Mgr: Arthur Castrissios	**Mob. Phone:** 0419 469 438	**Attn:** Tania Notaras
Email: Arthur.Castrissios@douglaspartners.com.au	Chris.mcdonald@douglaspartners.com.au	**Phone:** (02) 9910 6200 **Fax**: (02) 9910 6201
Date Required: Standard		**Email**: tnotaras@envirolabservices.com.au

Sample ID	Lab ID	Sampling Date	Sample Type S - soil W – water	Container type G – glass P - plastic	Analytes: EC	pH	Chlorides	Sulphates	Texture	CEC	ESP			Notes/preservation
102 / 1.0	1	27.05.16	S	G	X	X	X	X	X	X	X			
105 / 0.5	2	26.05.16	S	G	X	X	X	X	X	X	X			
108 / 2.0	3	26.05.16	S	G	X	X	X	X	X	X	X			
109 / 0.5	4	27.05.16	S	G	X	X	X	X	X	X	X			

ENVIROLAB
Envirolab Services
12 Ashley St
Chatswood NSW 2067
Ph: (02) 9910 6200
Job No: 147648
Date Received: 31.05.2016.
Time Received: 14 00
Received by: CB
Temp: Cool/Ambient
Cooling: Ice/Icepack
Security: Intact/Broken/None

Lab Report No:		
Send Results to: D Metcalf / A Castrissios	**Address:** PO Box 486, Unanderra NSW 2526	**Phone:** (02) 4271 1836 **Fax:** (02) 4271 1897
Relinquished by: David Metcalf		**Transported to laboratory by: Clippers**
Signed:	**Date & Time: 31.05.2016** 10AM	**Received By:**

147563

Douglas Partners
Geotechnics / Environment / Groundwater

CHAIN OF CUSTODY

Project Name: Correctional Centre Upgrades, 55 The Links Rd, South Nowra NSW
Project No: 48600.06
Project Mgr: Arthur Castrissios
Email: Arthur.Castrissios@douglaspartners.com.au
Date Required: Standard

Sampler: CMcD
Mob. Phone: 0419 469 438
Chris.mcdonald@douglaspartners.com.au

To: Envirolab Services
12 Ashley St Chatswood 2067
Attn: Tania Notaras
Phone: (02) 9910 6200
Fax: (02) 9910 6201
Email: tnotaras@envirolabservices.com.au

Sample ID	Lab ID	Sampling Date	Sample Type (S - soil, W – water)	Container type (G – glass, P - plastic)	Analytes: Combo 8A									Notes/preservation
101 / 0.1	1	26.05.16	S	G &P	X									
108 / 0.1	2	27.05.16	S	G & P	X									
110 / 0.1	3	27.05.16	S	G & P	X									
112 / 0.5	4	27.05.16	S	G & P	X									

Lab Report No:
Send Results to: Douglas Partners Pty Ltd **Address:** PO Box 486, Unanderra NSW 2526 **Phone:** (02) 4271 1836 **Fax:** (02) 4271 1897
Relinquished by: CMcD **Transported to laboratory by:** Clippers
Signed: **Date & Time:** 30.05.2016 10am cx **Received By:** AH

31/5/2016 9am
↳ Updated COC

Form COC

Appendix E

Building a Saline Environment
CSIRO Foundation Publication

BUILDING in a SALINE ENVIRONMENT

LOCAL GOVERNMENT
SALINITY INITIATIVE

Contents

Department of
Infrastructure, Planning and Natural Resources

First published 2003
Department of Infrastructure, Planning and Natural Resources
22-33 Bridge Street
Sydney NSW 2000

Building in a Saline Environment
ISBN: 0 7347 5375 6
Designed and printed by ClickMedia, Penrith
Photographs: various sources

Introduction

Salts are a natural part of the Australian landscape. Concentrated salt and different types of salt, once dissolved and mobilised in water, can have an impact on the durability of some building material. This booklet looks at:

1. how salts get into building material
2. the effect salt and water can have on some building materials.

Through the explanation of the processes, ideas are given on how to build structures that are less susceptible to salt damage. Other booklets of the Local Government Salinity Initiative kit, 'Broad Scale Resources For Urban Salinity Assessment' and 'Site Investigations For Urban Salinity', can be used to determine if salty groundwater or salty soil are likely to be affecting a building. 'Indicators Of Urban Salinity', gives a guide to the range of symptoms salt and water damage can create in an urban environment. 'Roads and Salinity' looks at how to construct a road so that it resists the effects of salinity and does not adversely impact on salt and water processes.

Verandah post showing signs of salt and water damage

Render showing signs that excess salt and water are present
Photo: NSW Agriculture

Bricks showing signs of salt and water damage
Photo: NSW Agriculture

Paintwork blistering due to the accumulation of salt
Photo: DIPNR

Sandstone showing signs of salt and water damage
Photo: NSW Agriculture

Sources of Water and Salt

Salts dissolve in water. They can therefore move with water, into and around buildings. This occurs via either 'external' or 'internal' sources of water.

External sources:

- Rising damp, where ground moisture is drawn into the building material by capillary action

Building with wet 'tide' mark - Photo: NSW Agriculture

- Falling damp, where leaking gutters, downpipes, roofs etc allow water to run down into the building

Courthouse showing symptoms of falling damp from a blocked gutter - Photo: NSW Agriculture

Internal sources:

- Condensation, where water vapour in the air can condense on cooler wall surfaces. Examples can include hot moist air from clothes driers, cooking, showers, unventilated combustion heaters, people breathing.

It is important to carefully investigate the source or sources of the water in order to determine the most effective course of action. Massari and Massari (1993) quote an example where a building built in a swamp showed signs of moisture damage on the walls fronting the courtyard. Investigations showed the foundations of the building were such that the moisture from the swampy ground was not affecting the building. The cause of the problem was the downpipes in the courtyard discharging roof water onto the paving of the courtyard which in turn sloped towards the building.

Rusted down pipe allowing rainwater to mobilise salts in the soil. - Photo: DIPNR

Building products may be made with various materials such as sand, aggregates and water that can contain salt. Alternatively the finished product may be stored in a location which allows the addition of salt carried by wind, rain or from the ground to enter the finished product.

Once the product is used in a building, sources of moisture, wind or rain can add further salt. Various coatings or treatments may also add to the type and quantity of salts present. For example magnesite was commonly used on the floors of apartment blocks during the 1960s and 70s to provide a fast level finish to the floor and for sound proofing. It has since been found that salts can leach out of the product, aiding corrosion of the reinforcing within the concrete.

It is important to understand the source or sources of the salt in order to determine the most effective course of action, if action is needed. In some cases salt may appear as efflorescence on the surface of bricks as salts from the manufacturing process come to the surface. This may be a visual effect but does not cause structural damage to the building. In other cases the impact of salt may be less visible but more significant.

Bricks efflorescing - Photo: NSW Agriculture

Bricks exhibiting signs of salt and water damage
Photo: DIPNR

Infiltration Rates

The three main factors driving the rate of water entering a building are:

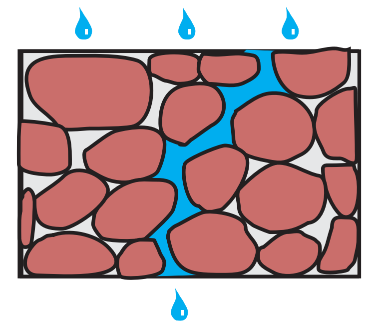
1. Amount of available water. This is influenced by the depth to the ground-water table, leaking water, sewer and stormwater systems, the over watering of gardens and the timing, distribution and intensity of rainfall.
2. Rate of evaporation. This is affected by such things as ventilation, temperature, relative humidity and the amount of building surface exposed.
3. Permeability of the building material. This depends on pore size, distribution and continuity of the pores within a building material.

Porosity vs. Permeability

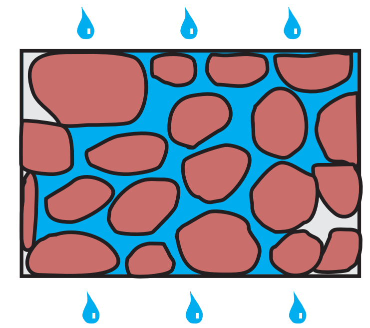
A material may be porous but not permeable. That is, a material may have lots of pore spaces and therefore can hold a lot of water but at the same time not allow water to pass through it. If pores:

- are isolated or closed,
- have a lining that can react with fluid to discourage movement, or
- are too small to be filled as the air they contain cannot escape,

then the material will have a low permeability.

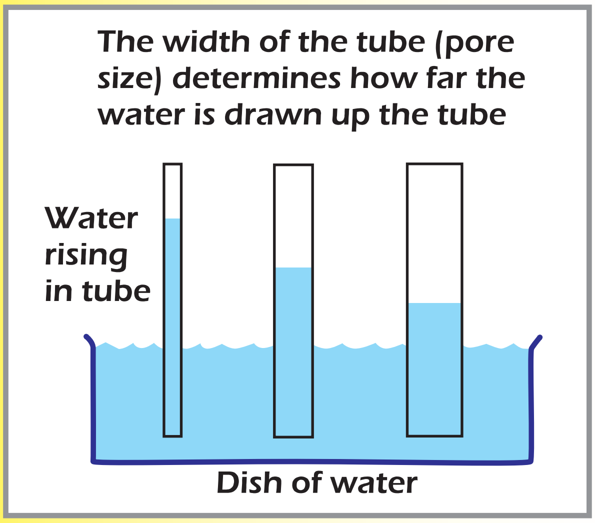


High porosity but low permeability

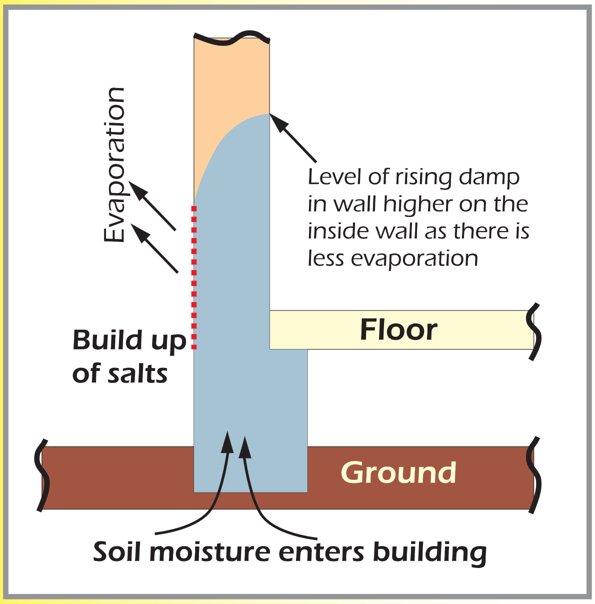


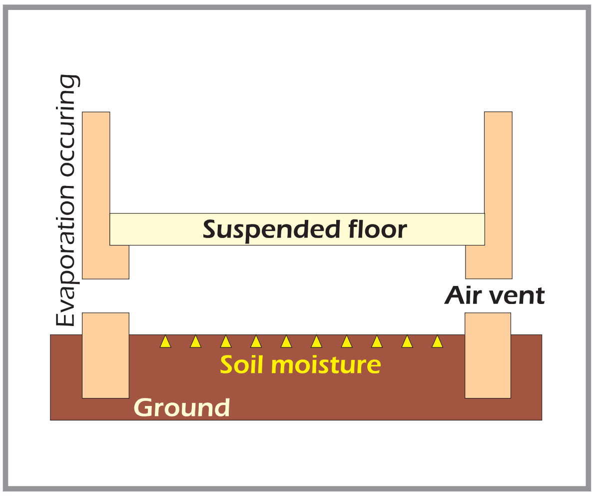
High porosity and high permeability

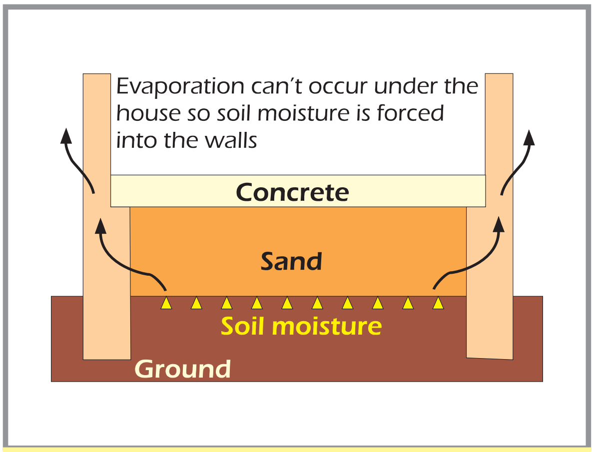
Pore size varies between materials but also within a material. In theory, a pore size of 0.001 mm can support a 1m high column of water. If salts are present in the water then the surface tension of the water is increased and there is increased 'pull' up the pore tube. This is partially offset by the increased weight of the water column due to the salts dissolved in the water. Pore diameters in mortar and brickwork are in the range of 0.1 um (0.0001 mm) to 10 um (0.01 mm). Fine cracks in concrete and other products can also act as capillary tubes. Therefore there is the potential for water to move a long way up a brick wall if the wall is exposed to a source of water.



Moisture moves through material towards the surface where evaporation is occurring. The tide mark or height of the water on the wall is the point where the rate of evaporation equals the amount of water getting into, and moving through, the wall. Construction that maintains low permeability, allows increased ventilation and decreased contact between building materials, so sources of water are less likely to cause large areas of salt and water damage.







Source: Department of Environment and Natural Resources (1995), Rising Damp and Salt Attack, State Heritage Branch and City of Adelaide

A non permeable render has decreased evaporation
Photo: NSW Agriculture

The Reactions of Salts with Building Materials

Once water and salt are absorbed by building materials, chemical and physical damage can result. The extent of chemical attack will depend on the concentrations and particular types of salts present as well as the composition of the building material.

Physical attack on the other hand requires a wetting and drying process. Salts form crystals as the moisture in which they are dissolved evaporates. A large crystal will exert physical pressure on the building material surrounding it. The next wet cycle allows the crystal to dissolve, move and later grow as more salts are supplied in the incoming water.

Different salts form different sized crystals, and even the same salt forms different sized crystals, under different conditions. These crystals can expand with heat. The effect on the building material will depend on the location of the crystal within the building material, as well as the physical properties and cohesive strength of the building material.

In a brick veneer building for example, evaporation is most likely to be highest on the outside wall of the northern side of the building. Higher levels of evaporation lead to a greater concentration of salt and more damage, provided there is a supply of salt and water. The outer surface, or fire skin, of the brick may be removed grain by grain by the force the salt crystals exert. This grain by grain removal increases the surface area of the brick, increases evaporation potential and also exposes the weaker interior of the brick. This process is called fretting.

Brick work showing the effects of fretting
Photo: NSW Agriculture

Brick work showing the effects of fretting and the accumulation of brick 'grains' at the base of the wall
Photo: DIPNR

Concrete

Concrete is a mixture of coarse and fine aggregate, cement and possibly additives such as fly ash, slag or chemical admixtures which enhance properties of the concrete for specific purposes. Although the aggregates are chemically reactive themselves, for example they can add alkalies and chlorides to the pore solution, it is the chemical properties of the cement that are more important.

Cement hardens through the chemical reaction of "hydration", where water reacts chemically with the cement to form new compounds. The hydrated cement paste forms ribbon-like crystals that interlock and bind the sand and gravel to form concrete. The more interlocking and growth of crystals, the stronger and denser the concrete. Maintaining moisture in concrete during the curing period is essential in maintaining the process of hydration. However too much water in the mix or too little cement can result in weak concrete since the crystals can't mesh and interlock well due to the distance between particles. The concrete will also be more porous due to all the pore spaces created once the excess water finally evaporates.

Concrete being mixed on site - Photo:DIPNR

What is Cement?

Cement is often referred to as Portland Cement. This was the name given by the inventor Joseph Aspdin because the hardened product looks like limestone quarried from the Isle of Portland, England.

Cement is made from

- calcium carbonates in limestone, shale and coral
- alumina in clay, shale and bauxite
- silica in sand
- iron oxide

These ingredients are finely ground together and cooked at high temperatures (approx. 1500^{0}C) in rotary kilns until they chemically react to form new chemical compounds, collectively known as clinker. The clinker is then cooled, mixed with a small amount of gypsum and finely ground. The components of clinker are:

- Tricalcium silicate
- Dicalcium silicate
- Tricalcium aluminate
- Tetracalcium aluminoferrite

The proportion of these four components in the clinker determine the properties of the cement such as whether it sets quickly or slowly, gains strength early or late, releases a little or lot of heat as it sets. These differing properties are suitable for different building structures and conditions.

Generally, chemicals in their dry state don't attack concrete. However, once mobilised in water, various chemical and physical interactions can occur.

Acids dissolve the alkaline components of concrete (eg calcium hydroxide) to form soluble salts. These can be leached from concrete, increasing its porosity and decreasing its strength. Concrete containing blast furnace slag or fly ash has less calcium hydroxide than other cements and is therefore less susceptible to acid attack. In the case of acids containing sulphates, other processes occur as well.

Sulphates react with the hydrated calcium aluminate component of cement. The products of these reactions have a larger volume than the original ingredients and exert a physical stress on the concrete. The rate of sulphate attack is affected by such factors as the solubility of the different sulphates. For example calcium, magnesium and sodium sulphates have different solubilities. The process is exacerbated if magnesium and /or ammonium are present as they attack the silicates and calcium hydroxide components, not just the calcium aluminates.

Sulphate resistant cement is often called marine or ocean cement and contains only small amounts of calcium aluminates. Note gypsum (calcium sulphate) is often applied to saline soils to improve the soil properties for landscaping and soil erosion purposes. The level of gypsum applied should be taken into account when designing concrete structures.

Kerb and guttering affected by sulphates
Photo: DIPNR

Chlorides do not react chemically with concrete. However, wetting and drying cycles, changes in humidity and temperature, can result in the formation of salt crystals that exert a physical stress on concrete.

Carbonates can decrease the alkalinity of the cement paste from around pH 12 to pH 9.5. This decreases the resistance of the reinforcing metal within some concrete structures to corrosion.

Corrosion of reinforcement in concrete occurs in 2 phases, namely initiation and propagation. The initiation phase occurs when the alkalinity of the concrete is reduced by carbonation or ionization. Carbonates may come from sources such as groundwater or carbon dioxide in the air. Ionization occurs where there is a higher concentration of reactive ions such as chlorides. Chlorides may come from groundwater, the atmosphere, acid etching, admixtures, or the water, aggregate and sand used to make the concrete. Once initiated, the propagation phase of the corrosion continues at a rate dependent on the amount of available oxygen, moisture, reactive ions and remaining alkalinity.

Reinforcing steel exposed and corroding
Photo: DIPNR

It is therefore important to know the site conditions and chemicals that the building will be exposed to, so that a suitable type of building material can be chosen and installed. Careful site supervision and quality control is then required to ensure consistency in the production of mortar and other products mixed on site or at batching plants.

Bricks Resistant to Salt and Water

Bricks that are less susceptible to damage from salt and water:

- are less permeable so the salt and water cannot penetrate
- do not contain excessive amounts of salts, thus are not adding more salt to the process
- have good internal strength so that they can withstand the physical stress created by the formation of salt crystals

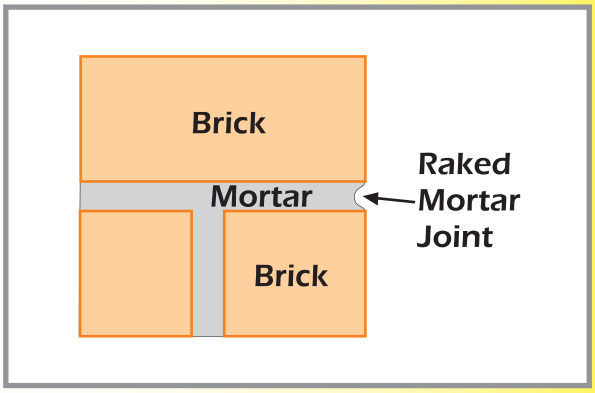
The Building Code of Australia (BCA), Part 3.3.1, requires masonry units to be classified and used in the exposure conditions appropriate to their classification. Table 3.3.1.1 of the BCA states exposure class is "Suitable for use in all classifications including severe local conditions such as:

a) below the damp-proof course in areas where walls are expected to be attacked by salts in the groundwater or brickwork itself (salt attack or salt damp)

.....

c) In retaining walls."

The BCA also gives the ratio of cement, lime and sand suitable for mortars, prohibits raked mortar joints in areas requiring exposure class bricks, and requires mortar to be made with potable, not salty, water.



Methods to test the properties of bricks can be found in Australian Standards. Australian Standard 4456.6 Masonry Units and Segmental Pavers - Methods of Test - Determining Potential To Effloresce, compares couples of masonry units where one brick of the pair has been soaked in water for 7 days and then air dried, and the other brick is untreated. A ranking is then given to each batch of bricks (nil, slight, moderate, heavy or severe) based on the amount of efflorescence on the outer surface of the treated unit. This test gives an indication of the amount of salt accumulated in the brick from the production and storage process.

Australian Standard 4456.1 Masonry Units and Segmental Pavers - Method of Determining Resistance to Salt Attack, is a test that is used to classify a brick's resistance to salt attack. Bricks are soaked in a salt solution of either sodium sulphate or sodium chloride and then dried. This is repeated up to 40 times and the amount of damage assessed by comparing the weight of the bricks before and after the process. Bricks are then rated as 'exposure', 'protected' or 'general purpose' class. Satisfactory performance of a sample in a sodium sulphate solution usually guarantees satisfactory performance in a sodium chloride solution but not vice versa. This is presumably due to the sulphate chemical reactions mentioned previously.

Concrete Resistant to Salt and Water

Durability of concrete depends on internal factors such as constituents as well as external factors such as design and construction.

Permeability is a very important factor with regard to rising damp. The more permeable the concrete, the less durable it will be. Permeability depends on pore size, pore distribution and the continuity of pores. Voids are formed by excess water in the mix, incomplete compaction, and incomplete curing which allows concrete to dry out prematurely.

In order to improve the durability of concrete in moist saline environments, consider:

- Proper compaction of the concrete
- Reducing the water cement ratio
- Proper curing procedures and duration
- Choice of appropriate concrete materials (ie cement type, sands and aggregate) for the site conditions
- Increasing the concrete cover over steel reinforcement
- Minimising cracks
- Minimising ponding of water on or next to concrete
- Minimising turbulence of any water flowing over a concrete structure
- A smooth surface
- Increasing the cement content
- Using a quality assurance certified supplier

All other factors being equal, increasing the strength of concrete will decrease its permeability. As there is no standard test for permeability in cement, strength is often used as an 'indicator' of permeability. However, this is an oversimplification and should not be used as the only specification or design criteria for ensuring concrete structures are durable in salinity hazard landscapes.

Preventing Salt and Water Moving into the Building

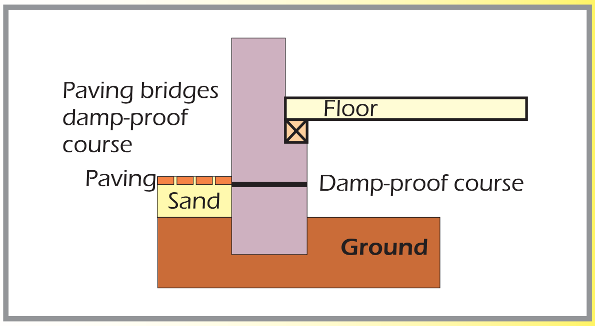
A damp-proof course is a layer of water impermeable material commonly installed in buildings close to ground level. In the past, damp-proof courses have been made of various materials including coal tar, slate, metal and mortars containing chimney soot. Today, it is common for the damp proof course to be a polyethylene sheeting laid in a mortar joint of the brick work.

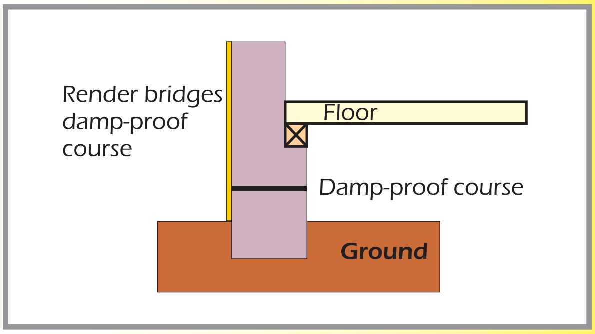
Installation of polyethylene sheeting in mortar joint of the brick work - Photo: DIPNR

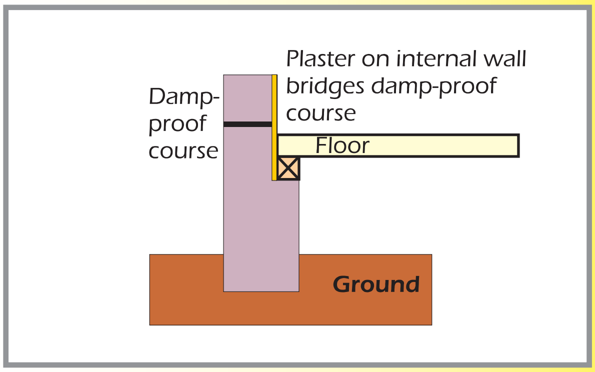
A damp-proof course should restrict any damage from rising damp to the area below the damp-proof course. However, a damp-proof course (DPC) may:

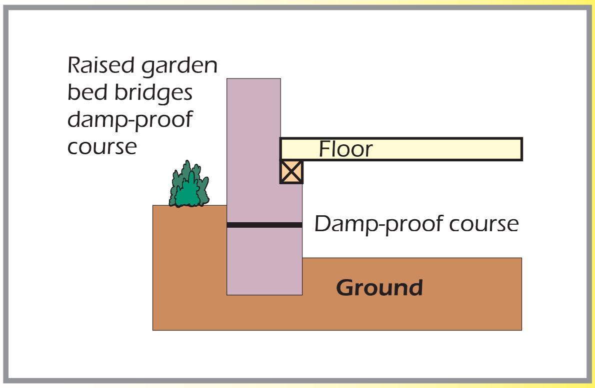
- break down due to chemical decomposition
- be cracked or penetrated during installation
- be broken by the differential settling of the building
- be incorrectly installed
- be bridged by pointing or rendering
- be bridged by the installation of garden beds and paving
- be bridged by mortar droppings in the wall cavity
- be bridged by renovations or additions, eg incorrect replacement of a timber floor with sand and a concrete slab

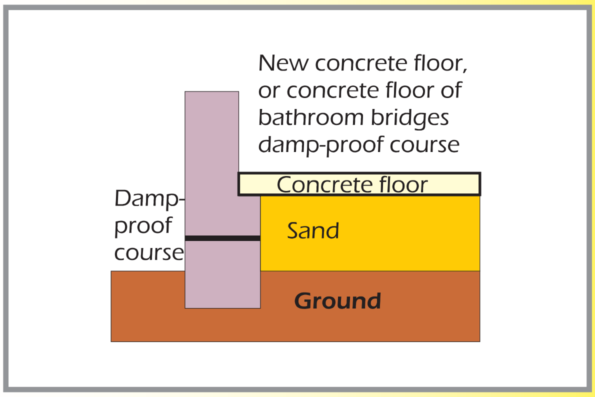
Once the damp-proof course is bridged or broken, water and any salts it contains are able to move upwards. This significantly increases the difficulty and cost of repairing salinity damage to buildings. Correctly installing and maintaining a durable damp-proof course is therefore an important technique in controlling salt damage to buildings.



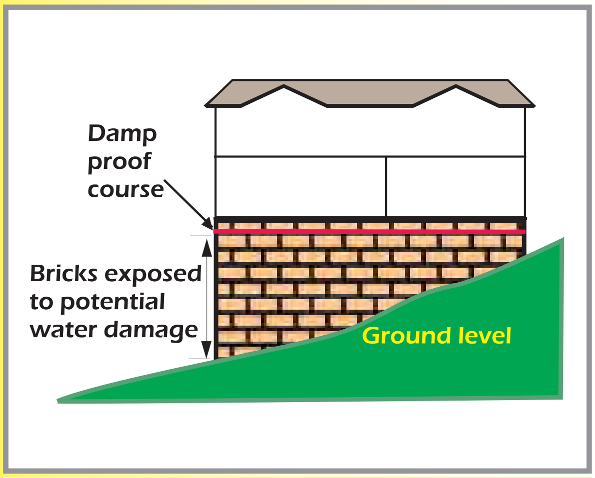








Source: Department of Environment and Natural Resources (1995), Rising Damp and Salt Attack, State Heritage Branch and City Of Adelaide.



The location of the DPC is also important.

The South Australian Salt Damp Research Committee, in their Second Report (1978), stated, " Protection against salt damp is dependent upon each link in a continuous chain - competent design and specifications, painstaking construction, skilled supervision, good housekeeping and maintenance by the owner/occupier". It is logical that this theory holds true today.

Damp-proof course has been bypassed by rendering
Photo: NSW Agriculture

Damp-proof course limiting damage to lower three bricks
Photo: DIPNR

[1] Wagga Wagga City Council, 1999 Building In A Saline Environment and Lume E. (1998), Concrete In Saline Groundwater Environments, Cement and Concrete Association of Australia,

It is common practice at present in NSW to construct buildings with concrete floors essentially laying at ground level. Under the concrete slab, there is usually a layer of sand and a vapour-proof plastic that acts as the damp-proof course for the concrete slab. A damp-proof course is also installed in a mortar joint of the brickwork forming the walls of the building.

The sand layer provides a number of functions in relation to salinity. Firstly, it helps prevent membrane puncture from hard material in the underlaying soil. It also decreases the capillary rise of any soil moisture since the sand grains are quite far apart ie there are large pore spaces. Increasing this sand layer is one method that has been suggested[1] to increase the protection of structures from salinity.

Previously, floors rested on bearers and joists, supported by piers. This type of construction has less building material in contact with possible salt and water sources in the ground. It more readily allows ventilation, evaporation and the concentration of salts to occur in the soil rather than building materials. It is also less likely to impact on natural salt and water processes.

The Australian building code presently requires a minimum clearance of 400mm between the ground and suspended floors to allow ease of access for termite inspection. This also allows a visual inspection for salinity damage to piers.

Damage discovered during a building inspection

A damp-proof membrane should be laid under concrete slabs and marked " AS 2870 concrete underlay, 0.2 mm High impact resistance". A vapour-proof plastic layer used under concrete slabs should be printed with the words "AS 2870 concrete underlay, 0.2 mm - Medium impact resistance". The Building Code of Australia recommends damp-proof membranes in South Australia and areas prone to rising damp and salt attack. The extra cost is around $50 for a 140m^2 house. Damp-proof membranes are more resistant to puncturing and stop water if there is no hydrostatic pressure.

Care should be taken when installing the damp-proof membrane to ensure it extends completely under the whole slab and up the sides to at least finished ground level. This prevents moisture moving in from the sides or through gaps. AS 2870 only permits 'vapour', not 'damp', barriers to be terminated at the internal face of external beams. The standard also sets requirements for the lapping of joints and taping of penetrations for pipes or plumbing fittings. However local plumbers and builders may not be aware of salinity hazard areas or of the importance of this work in such areas.

Care should also be taken laying the reinforcing and walking on the laid membrane prior to pouring of the concrete slab as these activities may result in small holes. Puncturing the membrane to allow excess water from the concrete to escape and speed up curing is also poor practice. Short curing times usually result in a more permeable concrete slab more susceptible to salt damp attack. If the water table is sufficiently high after construction or during the life of the building, then the puncture holes will allow moisture under the slab to move into the slab.

Maintaining Good Drainage on a Building Site

The movement of water at various scales needs to be considered with respect to the mobilisation of salt. On a catchment scale, water may be entering a groundwater system kilometres away from where the water returns to the surface. Along the way this water may have picked up salt from the rocks and soils it has passed through. In this situation, on-site action as well as work further up the catchment where the water is getting into the groundwater system could be more cost effective.

On a subdivision scale, decisions such as whether to use septic tanks, irrigate treated effluent, infiltrate stormwater, supply piped potable water, and how much native vegetation to retain, all impact on the salt and water movement. A salt and water balance should be undertaken to estimate the impact of the development on the salinity processes on and off site. If the environmental, social and economic costs are too high, an alternative decision should be made with respect to the aspect of the development causing the excess salt and water. Alternatively a long term monitoring, evaluation and management plan could be put in place to deal with potential adverse impacts.

On an individual house lot scale, construction and maintenance decisions such as:

- whether to cut or fill the site
- whether the ground is reshaped to slope away from the building
- how the site is landscaped
- how the landscaping is watered
- how much of the site is hard surfaces vs pervious surfaces
- whether a path is provided around the perimeter of the house and sloping away from the building
- what stormwater drainage is provided behind retaining walls
- whether pools, taps, and downpipes are regularly checked for leaks

all affect the amount of water on the site and how it is moving around the structure to be protected from salinity damage.

Water flow obstructed by urban development
Diagram: DIPNR- Greener Subdivision project

Water flow not obstructed by urban development
Diagram: DIPNR- Greener Subdivision project

The Building Code of Australia

The Building Code of Australia (BCA) includes some requirements for building in saline environments. For example, in Volume 2 of the BCA, clauses 3.3.1.5(b), 3.3.1.6 and 3.3.1.7(b). The BCA also references Australian Standards that contain requirements for buildings in a saline environment. Some examples of these Standards (AS 2159, AS 2870, AS 3700 and AS 3600) are detailed in the next section of this booklet.

There are some inclusions that are aimed at providing protection against moisture in general. These include:

- Part of Objective 2.2 of the BCA is to protect the building from damage caused by external moisture entering a building.
- Functional Statement 2.2.2 Weatherproofing and Dampness, includes "construction to provide resistance to moisture from the outside and moisture rising from the ground". This doesn't apply to class 10 buildings unless construction contributes to the weatherproofing of a class 1 building. Class 1 buildings being residences and class 10 being outbuildings and associated structures such as verandahs, garages, swimming pools, flag poles and carparks.
- Performance Requirement P2.2.3 for Dampness relates specifically to moisture from the ground and requires prevention of
  - unhealthy or dangerous conditions, or loss of amenity for occupants
  - undue dampness or deterioration of building elements.

This performance requirement does not apply to a class 10 building where in the particular case it is judged that there is no necessity for compliance.

However, the current provisions contained in the BCA related to preventing dampness were not intended to provide protection against rising salt damp (salt attack/salinity) and were aimed at providing protection against moisture in general. At the Australian Building Code Board's 2001 National Technical Summit, the issue of urban salinity was discussed and it was agreed that a review of the BCA requirements to prevent moisture penetration was necessary, with consideration to developing suitable requirements for buildings in saline areas. The Australian Building Codes Board (ABCB) has established a Technical Working Group to review and comment on salt attack documents and proposals as they are produced or acquired by the ABCB.

In South Australia there are currently three additional requirement for the barriers installed to prevent ground moisture entering the building:

- a high resistance to moisture penetration
- a high resistance to damage during construction and
- a high resistance to degradation by dissolved salts.

Typical slab on ground construction. - Photo: DIPNR

Australian Standards

There are various Australian Standards that have provisions that assist in the management of salinity. For example:

- **AS 1547 - 2000 On Site Domestic Waste Water Management** has a performance requirement for on-site waste water systems to avoid surface and groundwater pollution. The standard recommends construction and installation is undertaken only after suitable site investigations that include such things as changes in the groundwater table and sodicity.

  On-site waste water disposal adds extra salts to the soil as well as extra liquid to the groundwater system. This can result in on-site and off-site impacts if not properly considered. More information on salinity and effluent is provided in the Septic Safe Technical Reference Sheet published by the Department of Local Government, 'Consideration of Soil Salinity When Assessing Land Application of Effluent' by Dr Robert Patterson. More information on site investigations for salinity is provided in the Local Government Salinity Initiative booklet, 'Site Investigations for Urban Salinity' by the former Department of Land and Water Conservation. (2002)

- **AS 2159 Piling Design and Installation** provides table (6.1) Exposure Classification For Concrete Piles. Soil conditions are listed as non-aggressive, mild, moderate, severe or very severe, based on test results for pH, chlorides, sulphates and soil resistivity, for permeable soils which are below the groundwater table and for low permeability soils or all soils above the groundwater table. Various notes of caution are attached to the table such as the impact of magnesium or ammonium ions which, in the presence of sulphates, increase the aggressiveness of the soil on concrete. This standard also recommends site specific design of concrete for sulphate attack noting that dense, well compacted, low permeable concrete of the correct type is more important than a high characteristic strength.

  Extracts from this standard are provided in the Local Government Salinity Initiative booklet, 'Site Investigations for Urban Salinity'.

- ***AS 4419 Soils For Landscaping and Garden Use*** sets a requirement for the appropriate labelling of low density and organic soils with an electrical conductivity of 2.5dS/m or 1.2dS/m for soil blends and natural soils. The labelling is to give clear information about salinity and the types of plants that will tolerate high salinity. There is also a note that expert advice should be sought as removal or dilution of salts depends on various factors such as the amount of salt present, depth and permeability of the soil.

  This highlights the need to be careful when importing extra salts on to a site. Once present, salt is usually difficult to remove. This is not only important for plant growth and soil structure, but also for infrastructure. Unwashed sands, bricks made with salty clays, concrete made with salty bore water, or bore water used to suppress dust all import extra salt onto a site. Building materials stored on salty ground or exposed to salty winds or rain for extended periods may also pick up salts. Once concentrated within a building, salt may appear as efflorescence, cause corrosion to metals or cause physical and chemical damage to building materials even though the surrounding soil is showing low levels of salt. Many salts are hygroscopic, attracting water from sources such as dew. The salts are then easily mobilised within the structure causing the area of damage to increase until the salt is removed.

- ***AS 3798 Guidelines For Earthworks For Commercial and Residential Development*** contains various snippets of information that relate to salinity, for example:
  - Site investigations should include identification of special areas relating to groundwater.
  - Unsuitable materials for fill include those materials containing substances that can be dissolved or leached out [salt].
  - Moisture content of fill should not be increased with saline water without field or laboratory trials. This should also be avoided in areas where steel will be buried or where revegetation will occur or areas that are to be later covered by bitumen.
  - Special consideration of saline, chemically aggressive or polluted soils is needed to determine if they are suitable for fill.

Typical earthworks on a residential building site
Photo: DIPNR

- ***AS 3660.1 Termite Management - New Building Work***, aims to deter the concealed entry of termites into new buildings above the termite barrier. However, as termites can damage soft concrete, enter through mortar joints and are attracted to damp areas, some of the recommendations for termite protection are also relevant for salinity protection. For example:
  - Perimeter paths and areas under the house should be graded to prevent ponding.
  - For slab on ground construction, concrete should be compacted and cured. This enhances the structural performance of the slab and increases resistance to penetration by termites.
  - How to lay a barrier membrane to ensure the whole building is effectively protected without gaps.
  - Finish a barrier membrane flush with the outside face of render rather than inside face.

  Often render is applied over the edge

of the damp-proof course or termite barrier effectively providing a bridge for moisture or termites. Cutting the render at the height of the membrane is an ineffective solution. Over time, dust, dirt and salt crystals can easily bridge a small horizontal cut in the render.

- **AS 3700 Masonry Structures**, provides a table for durability requirements for exposure environments which includes the minimum salt attack resistance of masonry units, minimum mortar classification, minimum durability of built components and minimum cover to reinforcement.

Non exposure grade bricks used in a garden wall
Photo: NSW Agriculture

- **AS 2870 Residential Slabs and Footings** presently requires:
  - a design life of 50 years (clause 1.4.2)
  - drainage to be designed and constructed to avoid the ponding of water against or near footings. A graded fall of 50mm minimum away from the footing over a distance of 1m even on the ground uphill from the slab on cut and fill sites is required (clause 5.2.1)
  - 40mm cover to reinforcement
  - concrete to be vibrated and cured for at least 3 days in known salt damp areas (clause 6.4.8)
  - careful detailing of damp-proof courses in high salt damp areas (clause 5.3.4)
  - Damp-proof membranes to be extended under the edge beam to ground level (clause 5.3.3.3)

  and provides an advisory note to use damp-proof membranes in South Australia and areas prone to rising damp and salt attack (clause 5.3.2).

  A committee was formed in early 2003 to review the requirements of this standard.

- **AS 3600 Concrete Structures.** This standard contains a detailed section on durability considerations.

  Due to the levels of salts and water that accumulate over time in dryland salinity hazard areas it could be argued that the concrete requirements for moderately aggressive to aggressive environments detailed in AS 3600 should be considered for concrete structures. The following table compares the differences in requirements for the different environments.

  These requirements are for a design life of 50 years yet in many cases it would be desirable to construct longer lasting homes and buildings.

Some of the construction and product standards have recommendations that can be overridden by professional expertise based on experience with the product. It is therefore important that members of the design and construction industry become more aware of the processes and impacts of urban salinity.

	non aggressive environment	B2 (moderately aggressive environment)	C (aggressive environment)
concrete strength	20M Pa	40M Pa	50M Pa
curing time	3days	7days	7days
cover to reinforcing	40mm	45mm	50mm

Salinity and the Electricity Industry

Concrete poles are being used increasingly within the electricity supply industry because of their low maintenance requirements, long life and cost effectiveness. These power poles are often constructed of concrete with internal steel reinforcing. Rust stains, cracking and spalling of the concrete have been observed in situations where the alkalinity of the concrete and the cover of the concrete over the steel reinforcing have not been adequate to protect the internal steel from corrosion. This corrosion is caused by saline soils, galvanic couples between the reinforcing steel and dissimilar metals, and stray direct electric current.

Since the late 1960s it has become common practice for steel structures in the electricity industry to have their foundations encased in concrete in order to limit corrosion. Concrete cover of at least 70mm is recommended.

Source: Electricity Association of NSW, (1997), Corrosion In The Electricity Supply Industry

Electricity supply pole with salinity vegetation indicators
Photo:DIPNR

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Author

Sian McGhie, Department of Infrastructure, Planning and Natural Resources

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Melissa Ryan, Department of Infrastructure, Planning and Natural Resources

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).

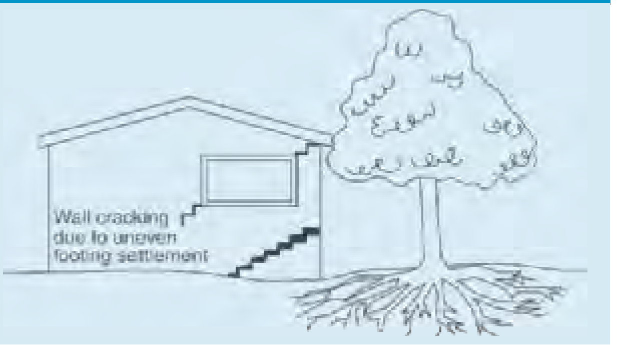
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

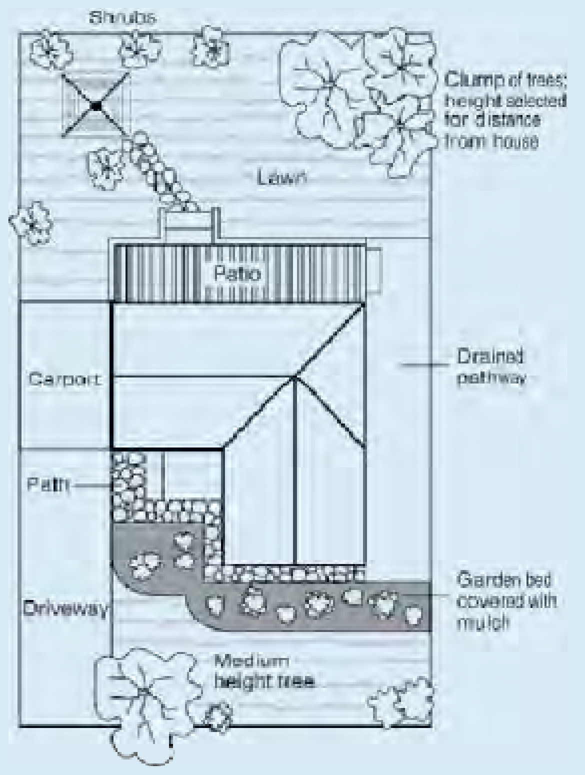
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

Gardens 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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Email: publishing.sales@csiro.au