OB Geotechnics

Consulting Geotechnical Engineering Services

REPORT ON GEOTECHNICAL SITE INVESTIGATION

PREPARED FOR

Synthesis Organics

Three (3) Proposed Sheds

AT

Lot 2 on DP735538
736 Federal Drive, Federal, NSW 2480

22 July 2022
Project Ref: P363GI

OB Geotechnics
8/90-96 Jonson Street, Byron Bay, NSW 2481
Email: office@obgeotechnics.com.au
Web: https://www.obgeotechnics.com.au
Phone: 1300 355 740

TABLE OF CONTENTS

1 INTRODUCTION

This report presents the results of a geotechnical site investigation for three (3) new sheds at 736 Federal Drive, Federal, NSW 2480, described as Lot 2 on DP735538. The investigation was commissioned by email from Rob Rendell, on behalf of the owner, dated 15 July 2022, to complete this investigation. The commission was based on our fee proposal (Ref. P363 Federal), dated 15 July 2022. A Site Location Plan is presented as Figure 1.

A sketch design, dated 17th July 2022, prepared by SHE architects has been provided to OB Geotechnics by 'The Owner', with the location of the proposed shed building envelopes and is attached in Appendix D.

Based on the provided information, we understand that the construction of three new sheds is proposed at the above site. In addition, further lightweight structures are proposed in the downslope terrain. The purpose of the site investigation was to determine information regarding surface features and subsurface conditions to identify geotechnical site constraints and provide site classification as well as footing, earthworks, and drainage recommendations.

Specific details regarding structural loads were not provided at the time of investigation and we have assumed typical loading for this type of development. The report primarily focuses on the three (3) new shed sites. As the proposed development is on a portion of a large allotment, the geotechnical site investigation was limited to the location of proposed new sheds. A test pit was undertaken further downslope to provide a preliminary understanding of subsurface conditions for future developments.

2 INVESTIGATION PROCEDURE

The fieldwork included a geotechnical investigation, which was undertaken on 18th July 2022. The geotechnical investigation included the excavation of two test pits TP1 and TP2, at selected locations near the proposed new shed sites. TP3 was undertaken further downslope, for proposed future developments. TP1, TP2 and TP3 were excavated using a 3T excavator to 1.8m, 1.9m and 2.2m, respectively. In addition, three Dynamic Cone Penetrometer (DCP) tests DCP1, DCP2 and DCP3 were carried out adjacent to test pit sites to depths of 0.8m, 1.7m and 0.8m, respectively.

The test pits and DCP locations, as indicated on the attached Test Location Plan (Figure 2), were set out using taped measurements from existing surface features. The surface reduced levels (RLs) at the test locations, were based on interpolation between contours shown on NSW ePlanning mapping portal. The provided sketch design plan forms the basis of Figure 2.

The nature and composition of the subsoils were assessed by logging the materials recovered during drilling, using visual and tactile methods. The relative compaction/density of the subsoils was assessed by interpretation of the DCP tests results, completed adjacent to each one of the boreholes. The refusal depth of DCP tests can provide an indicative depth to bedrock, although refusal can also occur on buried obstructions, ‘floaters’, other hard layers, etc, and not necessarily on bedrock.

In addition, hand penetrometer readings were taken on cohesive soil samples at regular intervals along the exposed test pit faces. These readings were used as a guide only to confirm soil strengths and relative densities.

The investigation has been undertaken generally in accordance with AS 1726-2017[1] (Geotechnical Site Investigation). Our geotechnical engineer was on site full time during the fieldwork and set out the test locations, nominated the sampling and in-situ testing, and logged the encountered subsurface profile. Test Pit log sheets and DCP test results are attached to this report along with our report explanation notes, which describe the investigation techniques adopted and define the logging terms and symbols used.

3 RESULTS OF INVESTIGATION

3.1 Site Description

Lot 2 on DP735538 is approximately 19,900m^2 (1.99ha) and rectangular in shape, approximately 85m wide and 240m deep. The south western frontage of the site is formed by Federal Drive. Rural residential properties form the remaining site boundaries.

At the time of the investigation the site contained an existing dwelling positioned on the southwestern corner of the lot. Further downslope and to the northeast lies an existing shed. The proposed new sheds are positioned in the southeastern corner of the lot

The site landform is planar and generally slopes from the southwest to northeast at about 10°. Some steeper and flatter sections were observed along with some undulations in the terrain. Observation from existing contour maps allude to a gully, which is starts towards the centre of the lot, in the mid slope portion of the site and grades downwards to the northeast. Site cover was predominately grass with shrubs. A scatter of medium to large trees were observed towards the south boundary of the lot.

3.2 Subsurface Conditions

Reference to geological mapping by the Geological Survey of New South Wales 1:250,000 series 'Tweed Heads' sheet indicates the site is underlain by soils from the Tertiary aged Lismore Basalt of the Lamington Volcanic, which typically comprise "basalt (agglomerate, bole)".

Test pits logs depict a subsurface profile comprising a layer of topsoil, which overlie a silty clay stratum, underlain by a weathered rock profile. Roots were found in the upper 0.5m of the clay soil at each test pit. The silty clay was assessed as being generally stiff (S) to very stiff (VSt) before becoming very stiff (VSt) to hard (H) towards the extremely weathered rock intercepts. An extremely weathered rock was encountered underneath the clay layer and was assessed as being predominantly of very low (VL) strength.

Groundwater seepage was not encountered in any of the test pits on completion of drilling. In addition, moisture contents of the silty clay were observed to be less than plastic limit. It should be noted that groundwater levels can be expected to vary with seasonal and climatic conditions. For a more detailed description of the subsurface profile encountered, reference should be made to the attached test pit logs.

4 COMMENTS AND RECCOMENDATIONS

Section 4 of this report primarily focuses on providing recommendations for the three (3) new sheds in their proposed location.

Once further design development on the proposed lightweight structures downslope becomes available, OB Geotechnics can review the existing geotechnical site investigation results along with the provided information and provide specific recommendation, should it be required.

4.3 Earthworks

Specific details regarding earthworks for the proposed development were not known at the time of preparing this report. It is anticipated earthworks is to include cut and fills in preparation of the new building pads, prior to detailed excavation or augering for the installation new shed footings.

Notwithstanding the above the following geotechnical constraints are to be adhered to in order to ensure the long-term stability of the site:

- Fills are to be minimised where practicable and battered at slopes outlined in Section 4.4.

- All fills are to be 'Engineering' fill and placed and compacted as under 'Level 1 inspection and testing'. In addition, benching of the existing ground to allow for keying the engineering fill material into the natural ground prior is required.

All earthworks are to be carried out in accordance with AS 3798 – 2007[2] (Guidelines on Earthworks for Commercial and Residential Developments). Any excavations on site should be completed by reference to the Safe Work Australia Code of Practice 'Excavation Work'[3], dated March 2015.

4.1 Site Classification

Based on the results of the geotechnical site investigation, the proposed shed sites are classified as a "**Class P**" site in accordance with the provisions of AS 2870-2011[2] (Residential Slab and Footings). This is because the site is deemed to have abnormal moisture conditions due to the required presence of large trees adjacent to the proposed building envelopes.

Based on subsurface conditions, the assessed characteristic surface movement, was found to exhibit a reactivity similar to **'Class M'** in accordance with AS 2870-2011[4].

In our calculations to determine the characteristic surface movement (y_S), based on the location of the subjected site, we adopted a value for the change in soil suction at the surface (Δu) of 1.2 picofarads (pF) and a design depth soil suction change (H_S) value of 1.5m.

In addition, based on laboratory testing from nearby sites on similar soils in the area, and employing the visual tactile method, an average shrink-swell Index (I_{SS}) of 2.0% / pF has been adopted to account for the residual silty clay soils with bands of extremely weathered rock. The extremely weathered rock profile was approximated to commence at 1.5m below the existing ground level for y_s calculations.

A group of trees within the vicinity of the proposed shed envelopes was considered. A design height of a group of trees (H_{Tg}) of 15.0m and distance of trees to the buildings (D_t) of 5.0m was approximated from site observations.

Where footings are supported on the underlying rock profile a reactivity similar to **'Class A'** may be applicable.

4.2 Footings

Based on the geotechnical site investigation results, the subsurface conditions in the area of the proposed development will typically comprise topsoil over residual silty clay underlain by a weathered rock profile. No construction loads are to be supported in root affected clay soils, found in approximately the upper 0.5m as well as any non 'engineered' fill.

In order to lower the risk of instability and for uniformity of support, to limit the potential for differential settlements, we recommend that all footings are to be embedded a minimum 300mm into a stiff or better silty clay, engineered fill or weathered rock profile.

High level footings, such as stiffened rafts, pads or strips can be designed for an allowable bearing pressure of 100kPa in stiff (St) to very stiff (VSt) silty clay and 200kPa in very stiff (VSt) to hard (H) silty clay. Engineering fill also provides a suitable foundation for high level footings but will need to be placed and compacted under 'level 1' inspection and testing as outlined in AS 3798 – 2007[2]. An allowable bearing pressure of 100kPa can be adopted for foundations on engineering fill.

Should high level footings not be preferred, bored piles provide a suitable solution. All bored piles are to be founded into the stiff, or better, silty clay can be designed to an allowable geotechnical end bearing capacity of 150kPa. Bored piles found into the weathered rock can be designed to an allowable geotechnical end bearing capacity of 500kPa. An allowable geotechnical shaft adhesion of 20kPa can be adopted. However, the upper 1.5m of pile shaft adhesion should be ignored in capacity estimates to allow for load development effects.

The deep foundation system should be designed in accordance with the recommendations of AS 2159-2009[5] (Piling – Design and Installation). All structures must be adequately designed to support against any lateral forces caused by soil creep.

All footing trenches and bored piers should be excavated, cleaned out, be 'dry' and poured with minimal delay. Inspection should be carried out by geotechnical engineer for confirmation of provided bearing pressures prior to placement of concrete.

4.3 Engineering Fill

Fill required to raise site levels should comprise engineered fill. Approximately the top 0.5m of material comprising silty clay and topsoil should not be reused for engineering fill, as it was found to contain deleterious material and roots. Beyond the top 0.5m, existing natural silty clays sourced from the localised excavations may be re-used as engineered fill.

However, engineered fill may need to be imported. Engineered fill should have a maximum particle size of 75mm. Engineered fill comprising clayey materials should be compacted in layers no greater than 200mm loose thickness to a density strictly between 98% and 102% of SMDD and within 2% of Standard Optimum Moisture Content (SOMC).

Imported well graded granular material (ripped or crushed sandstone or building rubble) free of deleterious substances and having a maximum particle size of 75mm may also be used as engineered fill and compacted to a minimum density of 98% SMDD.

Engineering fill required to support buildings loads or pavements must be placed and compacted under ‘Level 1’ inspection and testing as detailed in AS 3798–2007[3].

4.4 Batter Slopes

Batter slopes presented in Table 1 are considered to be suitable for the purpose of the development. Notwithstanding this, some movement at, and behind the slope crest, as well as some localised slumping of batter faces may still occur.

Given slopes assume the batters are not underlain by lower bearing strata and with a maximum vertical height of 2.5m. In addition, slope angles are based on surcharge loadings (ie. construction machinery, traffic loadings) being well away from the crest of the embankment. As such, any permanent loads (i.e building loads) are to either 1V:1H away from the top of batter or be transferred into the underlying rock formation through piles.

All batters are to be stabilised using techniques such as vegetation and mulching or similar to minimise erosion, and by use of appropriate drainage. Properly maintained vegetation should reduce the occurrence of surface erosion by impingent rainfall. If seepage is encountered or observed coming out of the face at any stage, the embankments will need to be reassessed.

Material Description	Short Term (Maximum)	Long Term (Maximum)
‘Engineering’ Fill Batters	1V:2H (26°)	1V:2H (26°)
Silty Clay (Stiff or Better)	1V:2H (26°)	1V:2H (26°)
Extremely Weathered Rock (Very Low Strength)	1V:1.5H (33°)	1V:1.75H (30°)

Table 1: Recommended Slopes Angles for Batter

All fill batters should be overconstructed, compacted and trimmed back at no steeper than the maximum angle given in Table 1.

4.5 Drainage

Appropriately designed, constructed, and maintained surface and subsurface drainage is important to the long-term performance of the site in terms of slope stability, debris flow, soil creep and erosion.

A suitable stormwater management plan will need to be designed, implemented and verified by a qualified hydraulic engineer. This is, however, outside the scope of this investigation and report.

Nevertheless, the following recommendations, regarding drainage at the site should be considered:

- Surface drainage is to be incorporated at the top and toe of any sloping batters, through a lined swale or spoon drain. Captured water is to be directed away from the sloping terrain and building envelopes and into the designed stormwater system or at the base of designated waterways (i.e base of existing gullies).
- All stormwater collected from roofs, gutters, downpipes, and paved areas should be collected and discharged via pipes or lined channels to the designed stormwater management system.
- Stormwater storage tanks may be suitable but **must not** be positioned on the upper slope of any sloping batters. Provisions for tank overflow must be provided by the design engineer and certified by a hydraulic engineer to ensure all overflows are captured and discharged into the drainage system.

4.6 General Recommendations

Attached in Appendix E is the CSIRO Publication BFT 18 'Foundation Maintenance and Footing Performance: A Homeowner's Guide', which provides additional information that should be adopted during construction.

5 REFERENCES

1. AS 1726-2017 'Geotechnical Site Investigation', Australian Standard
2. AS 3798-2007 'Guidelines on Earthworks for Commercial and Residential Developments', Australian Standard
3. 'Excavation Work' Code of Practice, March 2015, Safe Work Australia.
4. AS 2870-2011 'Residential Slabs and Footings', Australian Standard
5. AS 2159-2009 'Piling – Design and Installation', Australian Standard

6 FURTHER GEOTECHNICAL WORK REQUIRED

Provided below is a summary of additional geotechnical engineer input required during and post construction of the proposed mitigation works:

- Level 1 testing and inspection of engineering fill (if undertaken).
- Footing inspections for new shed footings.
- Review of geotechnical report and recommendations, once further information of lightweight structures downslope becomes apparent.

7 LIMITATIONS

This report has been prepared for the geotechnical site investigation and landslide susceptibility assessment for the proposed three (3) new sheds at 736 Federal Drive, Federal, NSW 2480. The recommendations given in this report are based on both the information provided regarding the proposed development and the findings of the investigation. Should the type or location of the proposed development change, OB Geotechnics should be notified and the above recommendations may need to be revised.

Occasionally, the subsurface conditions are found to be different. This can be due to soil changes in different locations to those tested. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact the team at OB Geotechnics.

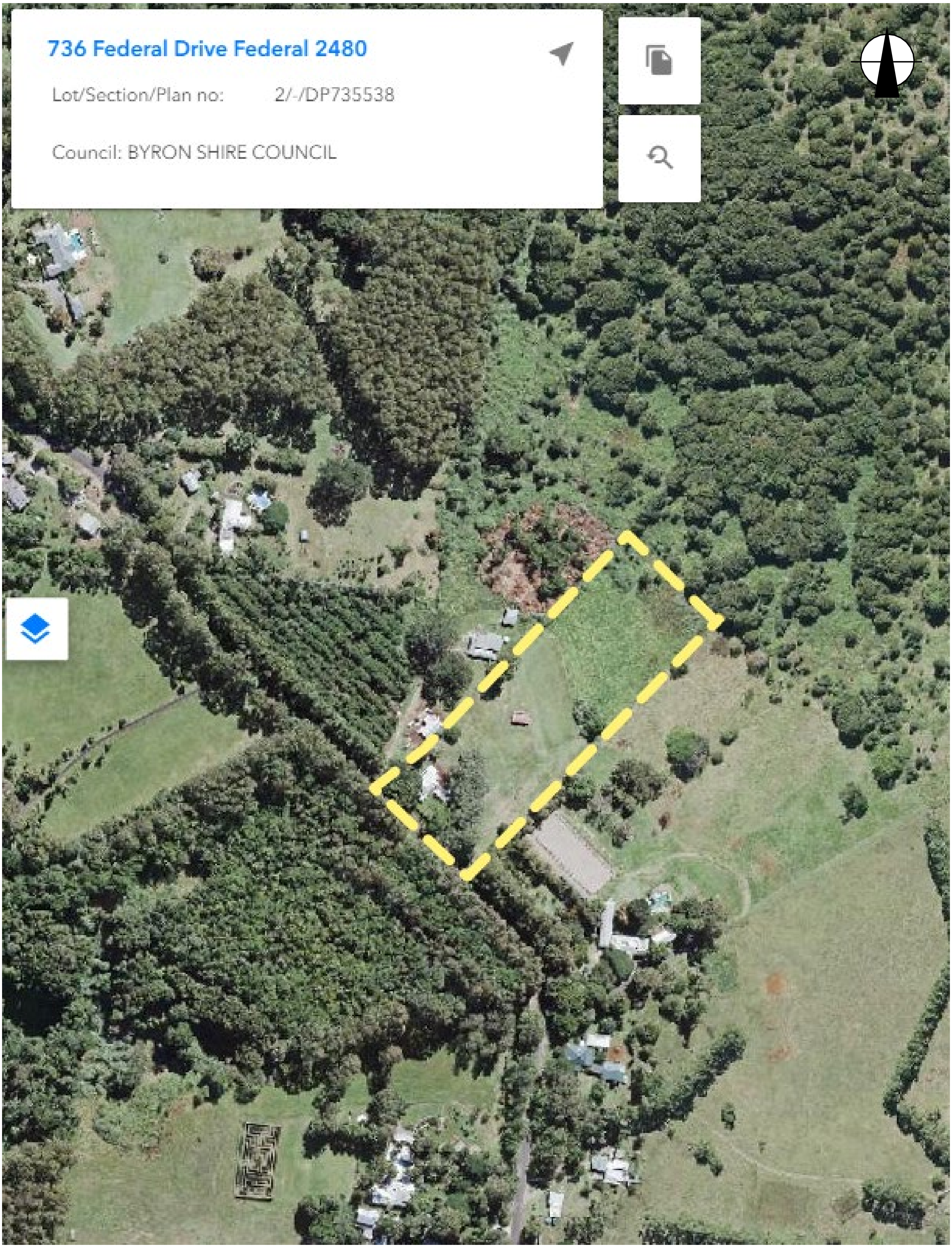
This report has been prepared for the proposed lot reconfiguration described above and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose.

For and on behalf of OB Geotechnics Pty Ltd:

Report prepared by:	Report reviewed by:
Danny Moses BEng (Hon Class 1) (Civil, Geotechnical) Geotechnical Consulting Engineer	**Dr Oded Ben-Nun** MIEAust (Civil, Structural), CPEng, RPEQ Senior Geotechnical Consulting Engineer

APPENDIX A:

FIGURE 1: SITE LOCATION PLAN
FIGURE 2: TEST LOCATION PLAN



Source: https://www.planningportal.nsw.gov.au

Title: **SITE LOCATION PLAN**

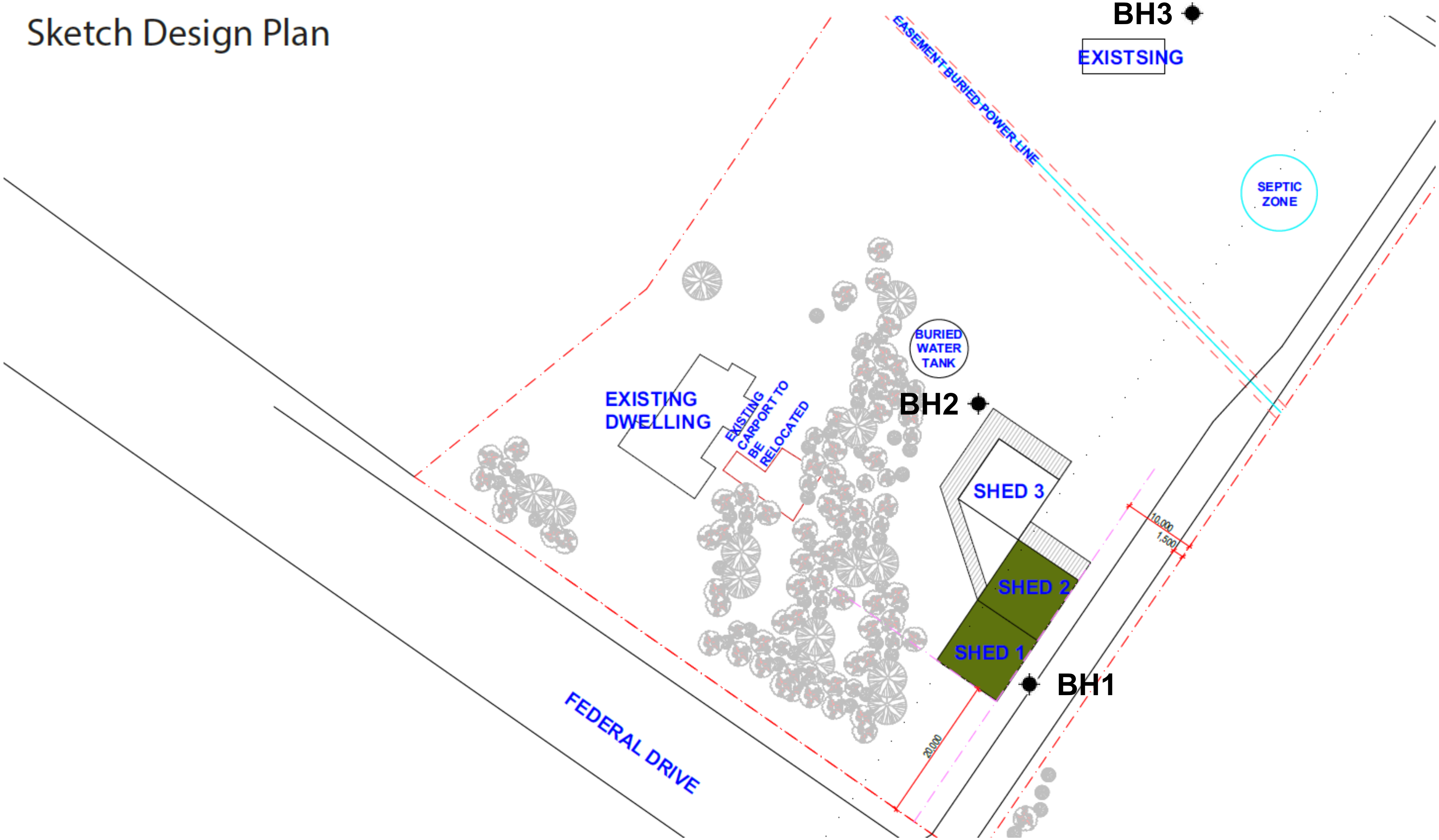
Location: 736 Federal Drive, Federal, NSW 2480

Report No: P363GI

Figure No: 1

OB Geotechnics

OB Geotechnics
Consulting Geotechnical Engineering Services



LEGEND

LOCATION OF TEST PITS

Title:	TEST LOCATION PLAN
Location:	736 Federal Drive, Federal, NSW 2480
Report No: P363GI	Figure No: 2

OB Geotechnics

OB Geotechnics
Consulting Geotechnical Engineering Services

APPENDIX B:

TEST PIT LOGS AND DYNAMIC CONE PENETRATION TEST RESULTS

TEST PIT LOG

Borehole No. TP1

Client: Synthesis Organics

Project: Geotechnical Site Investigation

Location: 736 Federal Drive, Federal, NSW 2480

Job No. P363GI | Method: 3T Exc | R.L. Surface: ≈ 180m

Date: 18/7/2022 | Logged/Checked by: DM | Datum: AHD

Groundwater Record	Samples	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition / Weathering	Strength / Rel. Density	Hand Penetrometer Readings kPa.	Remarks
		REFER TO DCP TEST RESULTS				TOPSOIL: Silty clay, high plasticity, brown				GRASS COVERED
					CL- CH	Silty CLAY, Medium to high plasticity, brown, traces of roots	MC<PL	St		
			0.5		CL- CH	Silty CLAY, Medium to high plasticity, brown	MC<PL	St - VSt	PP@0.5m 250 300 280	
			1.0						PP@1.0m 300 250 270	
			1.5		CL- CH	Silty CLAY, Medium to high plasticity, brown mottled grey and blue (bands of extremely weathered rock)	MC<PL	VSt - H	PP@1.5m 400 450 380	
						END OF TEST PIT AT 1.80m				
			2.0							
			2.5							
			3.0							

TEST PIT LOG

Borehole No.
TP2

Client: Synthesis Organics

Project: Geotechnical Site Investigation

Location: 736 Federal Drive, Federal, NSW 2480

Job No. P363GI	Method: 3T Exc	R.L. Surface: ≈ 175m
Date: 18/7/2022	Logged/Checked by: DM	Datum: AHD

Groundwater Record	Samples	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition / Weathering	Strength / Rel. Density	Hand Penetrometer Readings kPa.	Remarks
		REFER TO DCP TEST RESULTS				TOPSOIL: Silty clay, high plasticity, brown				GRASS COVERED
					CL- CH	Silty CLAY, Medium to high plasticity, brown, traces of roots	MC<PL	F- St		
			0.5		CL- CH	Silty CLAY, Medium to high plasticity, brown mottled grey and blue (bands of extremely weathered rock)	MC<PL	St - VSt	PP@0.5m 300 440 400	
			1.0					VSt - H	PP@1.0m 520 450 400	
			1.5						PP@1.5m 550 500 500	
			2.0			END OF TEST PIT AT 1.90m				
			2.5							
			3.0							

TEST PIT LOG

Borehole No.
TP3

Client: Synthesis Organics
Project: Geotechnical Site Investigation
Location: 736 Federal Drive, Federal, NSW 2480

Job No. P363GI	Method: 3T Exc	R.L. Surface: ≈ 169m
Date: 18/7/2022	Logged/Checked by: DM	Datum: AHD

Groundwater Record	Samples	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition / Weathering	Strength / Rel. Density	Hand Penetrometer Readings kPa.	Remarks
		REFER TO DCP TEST RESULTS				TOPSOIL: Silty clay, high plasticity, brown				GRASS COVERED
			0.5		CL- CH	Silty CLAY, Medium to high plasticity, light brown, bands of grey extremely weathered rock	MC<PL	VSt - H	PP@0.5m 450 500 470	
			1.0 1.5 2.0		XW	Extremely Weathered ROCK, grey iron stained		VL	PP@1.0m 550 500 490 PP@1.5m 550 500 500 PP@2.0m 560 500 600	
			2.5 3.0			END OF TEST PIT AT 2.20m				

OB Geotechnics
Consulting Geotechnical Engineering Services

DYNAMIC CONE PENETRATION TEST RESULTS

Client:	Synthesis Organics	
Project:	Geotechnical Site Investigation	
Location:	736 Federal Drive, Federal, NSW 2480	
Job No.	P363GI	Hammer Weight & Drop:
Date:	18-7-2022	9kg/510mm Rod Diameter: 16mm
Tested By:	D.M	Point Diameter: 20mm

	Number of Blows per 100mm Penetration						
Test Location	RL≈180m	RL≈175.0m	RL≈169.0m				
Depth (mm)	DCP 1	DCP 2	DCP 3				
0 - 100	1	2	1				
100 - 200	4	2	8				
200 - 300	5	4	8				
300 - 400	6	5	8				
400 - 500	6	6	8				
500 - 600	11	7	7				
600 - 700	13	7	15				
700 - 800	Refusal	10	Refusal				
800 - 900		10					
900 - 1000		8					
1000 - 1100		8					
1100 - 1200		8					
1200 - 1300		9					
1300 - 1400		9					
1400 - 1500		10					
1500 - 1600		10					
1600 - 1700		15					
1700 - 1800							
1800 - 1900							
1900 - 2000							
2000 - 2100							
2100 - 2200							
2200 - 2300							
2300 - 2400							
2400 - 2500							
2500 - 2600							
2600 - 2700							
2700 - 2800							
2800 - 2900							
2900 - 3000							

Remarks:
1. The procedure used for this test is similar to that described in AS1289.6.3.2-1997, Method 6.3.2.
2. Usually 8 blows per 20mm is taken as refusal

APPENDIX C:

REPORT EXPLANATION NOTES

GRAPHIC LOG SYMBOLS FOR SOILS AND ROCKS

SOIL

- FILL
- TOPSOIL
- CLAY (CL, CH)
- SILT (ML, MH)
- SAND (SP, SW)
- GRAVEL (GP, GW)
- SANDY CLAY (CL, CH)
- SILTY CLAY (CL, CH)
- CLAYEY SAND (SC)
- SILTY SAND (SM)
- GRAVELLY CLAY (CL, CH)
- CLAYEY GRAVEL (GC)
- SANDY SILT (ML)
- PEAT AND ORGANIC SOILS

ROCK

- CONGLOMERATE
- SANDSTONE
- SHALE
- SILTSTONE, MUDSTONE, CLAYSTONE
- LIMESTONE
- PHYLLITE, SCHIST
- TUFF
- GRANITE, GABBRO
- DOLERITE, DIORITE
- BASALT, ANDESITE
- QUARTZITE

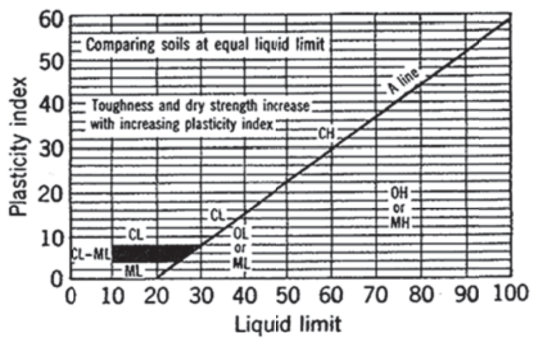
DEFECTS AND INCLUSIONS

- CLAY SEAM
- SHEARED OR CRUSHED SEAM
- BRECCIATED OR SHATTERED SEAM/ZONE
- IRONSTONE GRAVEL
- ORGANIC MATERIAL

OTHER MATERIALS

- CONCRETE
- BITUMINOUS CONCRETE, COAL
- COLLUVIUM

UNIFIED SOIL CLASSIFICATION TABLE

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

Plasticity chart for laboratory classification of fine grained soils

Note: 1 Soils possessing characteristics of two groups are designated by combinations of group symbols (eg. GW-GC, well graded gravel-sand mixture with clay fines).
2 Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity.

LOG SYMBOLS

LOG COLUMN	SYMBOL	DEFINITION
Groundwater Record		Standing water level. Time delay following completion of drilling may be shown.
	C	Extent of borehole collapse shortly after drilling.
		Groundwater seepage into borehole or excavation noted during drilling or excavation.
Samples	ES	Soil sample taken over depth indicated, for environmental analysis.
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.
	DB	Bulk disturbed sample taken over depth indicated.
	DS	Small disturbed bag sample taken over depth indicated.
	ASB	Soil sample taken over depth indicated, for asbestos screening.
	ASS	Soil sample taken over depth indicated, for acid sulfate soil analysis.
	SAL	Soil sample taken over depth indicated, for salinity analysis.
Field Tests	N = 17 4, 7, 10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'R' as noted below.
	N_c = 5 7 3R	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60 degree solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.
	VNS = 25	Vane shear reading in kPa of Undrained Shear Strength.
	PID = 100	Photoionisation detector reading in ppm (Soil sample headspace test).
Moisture Condition (Cohesive Soils)	MC>PL	Moisture content estimated to be greater than plastic limit.
	MC≈PL	Moisture content estimated to be approximately equal to plastic limit.
	MC<PL	Moisture content estimated to be less than plastic limit.
(Cohesionless Soils)	D	DRY – Runs freely through fingers.
	M	MOIST – Does not run freely but no free water visible on soil surface.
	W	WET – Free water visible on soil surface.
Strength (Consistency) Cohesive Soils	VS	VERY SOFT – Unconfined compressive strength less than 25kPa
	S	SOFT – Unconfined compressive strength 25-50kPa
	F	FIRM – Unconfined compressive strength 50-100kPa
	St	STIFF – Unconfined compressive strength 100-200kPa
	VSt	VERY STIFF – Unconfined compressive strength 200-400kPa
	H	HARD – Unconfined compressive strength greater than 400kPa
	( )	Bracketed symbol indicates estimated consistency based on tactile examination or other tests.

LOG COLUMN	SYMBOL	Density Index (I_D)	Range (%)	SPT 'N' Value Range (Blows/300mm)
Density Index/ Relative Density (Cohesionless Soils)	VL	Very Loose	<15	0-4
	L	Loose	15-35	4-10
	MD	Medium Dense	35-65	10-30
	D	Dense	65-85	30-50
	VD	Very Dense	>85	>50
	( )	Bracketed symbol indicates estimated density based on ease of drilling or other tests.		

LOG COLUMN	SYMBOL	DEFINITION
Hand Penetrometer Readings	300 250	Numbers indicate individual test results in kPa on representative undisturbed material unless noted otherwise.
Remarks	'V' bit	Hardened steel 'V' shaped bit.
	'TC' bit	Tungsten carbide wing bit.
	T_{60}	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.

LOG SYMBOLS continued

ROCK MATERIAL WEATHERING CLASSIFICATION

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

ROCK STRENGTH

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

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

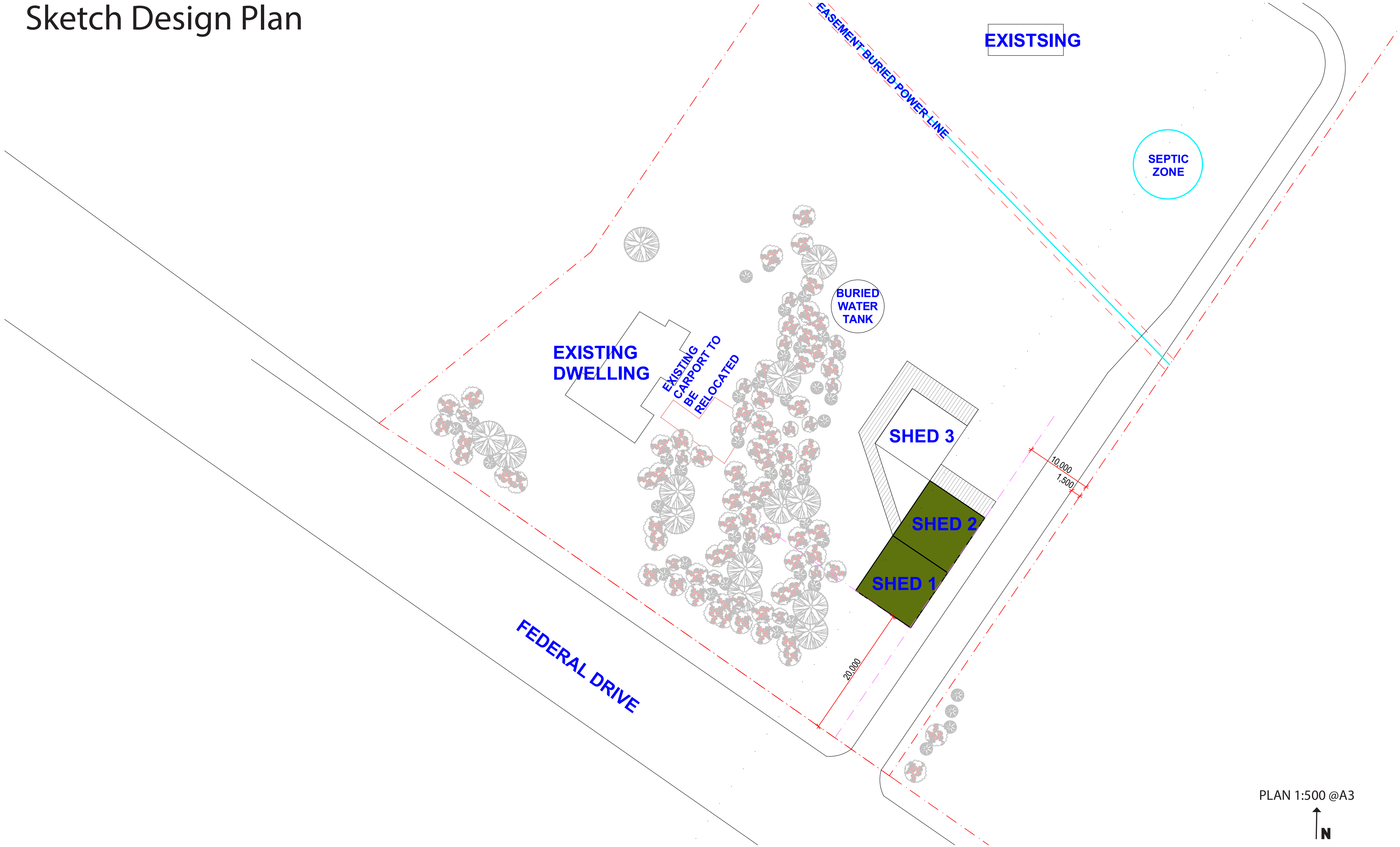
ABBREVIATIONS USED IN DEFECT DESCRIPTION

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

APPENDIX D:

DRAWINGS

Sketch Design Plan



S.H.E Architects NSW Registration 11355 2 Coachwood Court Federal NSW, 2480	Synthesis Organics Theme and Christopher 736 Federal Drive Federal NSW 2480	SKETCH DESIGN 17/07/2022 NOT FOR CONSTRUCTION		SHE ARCHITECTS SUSTAINABILITY . HEALTH . ENVIRONMENT

APPENDIX E:

GUIDANCE MATERIAL

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO PUBLISHING

BTF 18-2011 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 2870-2011, 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, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Notes
1. Where controlled fill has been used, the site may be classified A to E according to the type of fill used.
2. Filled sites. Class P is used for sites which include soft fills, such as clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soil subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
3. Where deep-seated moisture changes exist on sites at depths of 3 m or greater, further classification is needed for Classes M to E (M-D, H1-D, H2-D and E-D).

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.

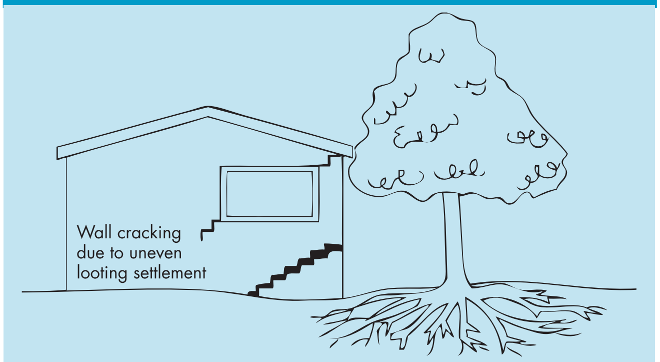
Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends 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.

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.

Trees can cause shrinkage and damage



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 causes 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 2870-2011.

AS 2870-2011 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.

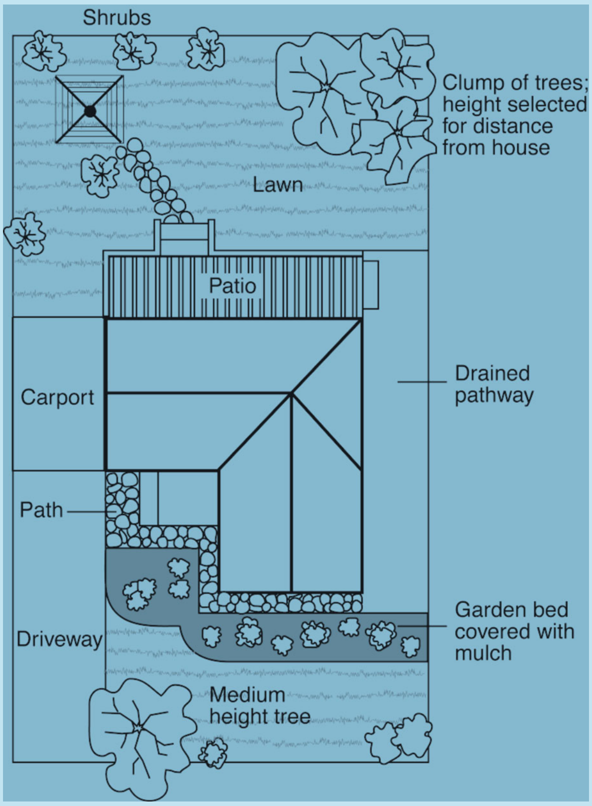
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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 should

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 depends on number of cracks	4

Gardens for a reactive site



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.

Distributed by

CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia

Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au

Email: publishing.sales@csiro.au