FOUNDATION EARTH SCIENCES

GEOTECHNICAL INVESTIGATION REPORT

15 De Lauret Avenue, Newport NSW 2106

Prepared for

Simon Nasht

Reference No. G679-1

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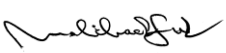
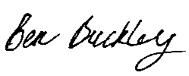
Author		Lubos Melicharek	3/11/2023
Reviewer		Ben Buckley	3/11/2023

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1.0 INTRODUCTION

The purpose of additional geotechnical investigation on the above site was to assess the site's surface and subsurface conditions in relation to previously carried geotechnical assessment and to provide updated geotechnical data recommendations for the design and construction of the newly constructed alterations and additions residential development. This report interprets and presents findings of the field site investigation that was carried out during the geotechnical visit and detailed appraisal. Details of the site are summarised below in Table 1.

Table 1: Summary of Details of the Site

Site	Details
Location	15 De Lauret Avenue, Newport NSW 2106
Lot/DP	Lot 144 in DP 225585 / No. 15 De Lauret Avenue
Local Council	Northern Beaches Council / Pittwater Council
Shape & Slope	Trapezoidal shape and sloping towards southwest
Existing Structures	Residential dwelling and existing carport
Closest Watercourse	Old Mangrove Bay approximately 180m to the west
Special Features	Land is sloping from De Lauret Avenue towards the south and west
Neighbouring Properties	Northeast Residential properties De Lauret Avenue Southeast No. 17 De Lauret Avenue and Public Reserve Lot 154 Southwest Residential properties and Prince Alfred Parade Northwest No. 13 De Lauret Avenue residential dwelling
Geology Map	Sydney 1: 1:100,000 Geological Series Sheet 9130, Edition 1, 1983, from the Geological Survey of New South Wales
Primary Geology	Qha- Quaternary Age soils consisting of silty to peaty quartz sand, silt and clay. Ferruginous and humic cementation in places. Common shell layers and partial marine deposits
Secondary Geology	Rh – Hawkesbury Sandstone comprising medium to coarse grained quartz sandstone, very minor shale and laminite lenses, located approximately at the boundary and across the southern side
Proposed Development	Construction of new proposed additions and alterations dwelling, with demolishing of existing house and carport, and retaining of the foundations and retaining structures of the existing house

2.0 AVAILABLE INFORMATION

Following information was made available to Foundation Earth Sciences ("FES") during the preparation of this additional geotechnical report:

- Davies Geotechnical Consulting Engineers "Report on Slope Instability Risk Appraisal Residential Alterations, No. 15 De Lauret Avenue, Newport, NSW; prepared for Mr & Mrs Nasht, Reference: R/08-040.B, and dated 18th September 2008 ("Davies Report")
- Architectural "Design Plans", Lot 144, No. 15 De Lauret Ave, Newport, Drawing Nos. SK.000, SK.001, SK.100, SK.101-102, SK.201-202, SK.301-303, SK.601-604, prepared by Molitor Architects, Job No. 2202, dated 18/08/2023 ("ARCH Plans")
- Survey Plan Pittwater Council "Plan of Detail, Contours & Levels", Lot 144 DP225585, No. 15 De Lauret Avenue, Newport, Reference: 666, Issue A, dated July 2007, and prepared by Richards & Loftus Surveying Services.

3.0 FIELDWORK AND LABORATORY TESTING

Following scope of work was carried out during the investigation:

- Review of Dial-Before-You-Dig ("DBYD") plans.
- Hand auger drilling of six (6) boreholes, identified as DCP1 to DCP6.
- Six (6) Dynamic Cone Penetrometer ("DCP") tests identified as DCP1 to DCP6 inclusive.
- Collection of field soil samples for potential laboratory testings.
- Field assessment of potential landslide areas and geotechnical observations.
- Subsurface conditions and strength of underlying soil layers.
- Sandstone rock appraisal and geotechnical parameters for foundations.

The approximate locations of boreholes with DCP tests are shown on "Site Plan" and attached as Appendix A. The results of DCP tests are annexed as Appendix B, and "Foundation Maintenance and Footing Performance: A Homeowner's Guide" as Appendix C respectively.

4.0 SITE CONDITIONS AND GEOLOGY

4.1 Ground Profile

Ground profiles encountered within the boreholes and DCP tests are summarised in Table 2. However, reference should be made to the results of DCP tests for further details on site.

Table 2: Summary of Ground Profile

Unit	Details	Depth (m)			
		DCP1/2	DCP3/4	DCP5	DCP6
Fill	Gravelly Silty Clay and Sandy Clay, medium plasticity, brown, and moderately compacted	0.0 – 0.5	0.0 – 0.6	0.0 – 0.4	0.0 – 0.8
Residual	Gravelly CLAY, low to medium plasticity, dark brown, red/grey, stiff to very stiff and hard	0.5 – 0.8	0.6 – 1.1	0.4 – 0.6	0.8 – 1.5
Rock[1]	SANDSTONE fine to medium grained, and assessed low strength	>0.8	>1.1	>0.6	>1.5

Note: [1] Ground profile as investigated and confirmed with the boreholes and DCP tests.

4.2 Groundwater

No groundwater seepage was observed during the auger drilling and DCP testing. There are expected groundwater seepages generally at the sandstone bedrock levels and these should not be detrimental to the development of the site as steep slopes will not allow for potential ponding or retention of water during the periods of heavy inclement weather.

Further, it should be noted groundwater seepages within the subject site may be relevant to piezometric head at the investigated locations, local and seasonal fluctuations, rainfall, prevailing weather conditions and future developments of the site areas and landforms.

5.0 DISCUSSIONS AND RECOMMENDATIONS

5.1 Slope Stability and Risk Assessment

The slope instability risk appraisal for No. 15 De Lauret Avenue was exhaustively performed at 5.0 Clause of Davies Report, and the conditions on this site were observed without potential movements or any signs of instability, with compared photographic evidence dated 18.6.2008, 13.8.2008, and 9.10.2023. The observations confirmed Mr Warwick Davies general and pre-development, post-development stability assessment and recommendations as fully unchanged, with detailed descriptions and conclusions still valid in October 2023. Davies Report forms the basis for Pittwater / Northern Beaches Council ("NBC") final assessment with formed conclusions and recommendations to be fully adopted during the Development Application ("DA") process. Detailed descriptions of the site also remained unchanged compared to Davies Report, and there were no signs of additional movements or instability observed at the current site conditions.

The assessed risks are subject to maintenance and improvement of the present site conditions with structural engineer plans strictly incorporating gabion retaining walls into the proposed dwelling to be reinforced with the existing site retaining structures. It is imperative and to be expected there will be limited earthworks performed on this site and all current footings will be utilised during the new proposed alterations and additions residence construction. The preliminary proposed development is detailed on a set of architectural drawings ARCH Plans and the proposed construction comprises new renovations and alterations with demolishing of car parking platform and old dwelling frames. The details provided in ARCH Plans confirm the location and extent of the proposed alterations within the predominantly southern portion of the existing residential dwelling.

5.2 Excavations and Earthworks

The slopes observed and further confirmed in Davies Report to be potentially affected by slope instability or potential movements are located primarily at northern and north-eastern portion of the site. These steep slopes are not to be affected during the proposed alterations and reconstruction in accordance to current proposed ARCH Plans. Bulk earthworks are to be of a limited nature and during commencement of the excavations full details and site visit by a project geotechnical engineer is recommended as to confirm the site conditions.

Retaining structures as described in Clause 5.1 of this report are not to be modified and it is anticipated the proposed excavations will not have any potential impact on the adjoining properties, with controlled risk mitigation and full-time supervision of the undertaken limited earthworks on this site. Prior to commencement of excavations, assessment shall be carried out by a qualified excavation contractor to identify a suitable excavation method. The ground profile summarised in Table 2 should be used for design of foundation system only.

Vibration Management Plan ("VMP") may be considered to be developed to allow monitoring of the potential vibration effects caused by excavation activities, on neighbouring properties and road carriageway located along the site boundaries. It is recommended, if required, that a suitably qualified consultant is engaged and monitor proposed excavations on the site.

5.3 Dilapidation Survey

Dilapidation survey report on all structures and road carriageway located within the zone of influence (theoretical failure plane) is recommended to be carried out by a qualified structural engineer prior to commencement of construction or any site earthworks activities.

5.4 Temporary Batter Slope

Temporary batter slopes can potentially be considered at boundaries, where neighbouring structures and road carriageway are located outside the zone of influence and sufficient space existed in between the site and excavation boundaries. Suitable shoring system then may be designed and constructed based on the ground conditions recommended in this report. There might be neighbouring structures at the adjoining lots such as cellar, garage etc. which may have to be protected during the site limited excavations. Recommended potential maximum temporary batter slopes are provided in Table 3.

Table 3: Maximum Temporary Batter Slope

Ground Profile	Temporary Batter Slope (Horizontal: Vertical)
FILL (Clayey)	2: 1
Residual SOIL (Clay)	1.5: 1
SANDSTONE Rock	1: 1

Note: Excavation shall be carried out in stages with maximum excavation height of 1.0m. Inspection of batter slope as soon as excavation of each stage will be carried by project geotechnical engineer to check batter slopes.

Drainage system should be installed as per structural design drawing prior to commencement of the backfilling process. Backfilling can be carried out using granular type material compacted in layers not exceeding 150mm thickness to 95% Standard Maximum Dry Density, provided settlement can be tolerated without any structures or services within the backfill.

5.5 Design of Retaining Walls

Where retaining walls will have to be used for the stabilising of earth mounds or areas with filling required, also where temporary batter slope is considered not possible, piles drilled and socketed into the underlying rock levels are recommended. The pressure distribution on cantilever retaining structures may be assumed to be triangular and estimated as follows:

$$\boldsymbol{\rho_h = \gamma k H + q k}$$

ρ_h = Horizontal pressure (kN/m^2)
γ = Wet density (kN/m^3)
k = Coefficient of earth pressure (k_a or k_o)
H = Retained height (m)
q = Surcharge pressure behind retaining wall (kN/m^2)

For the design of flexible retaining structures with possible lateral movements acceptable, an active earth pressure coefficient is recommended. Should it be critical to limit the horizontal deformation of a retaining structure, use of an earth pressure coefficient at rest should be considered. Recommended parameters for the design of potentially required retaining structures are presented in the Table 4.

Table 4: Retaining Walls Design Parameters

Ground Profile	Unit Weight (kN/m^3)	Effective Cohesion c' (kPa)	Angle of Friction ϕ(°)	Modulus of Elasticity E_{sh} (MPa)
FILL (Clayey)	18	0	26	8
Residual SOIL (Clay)	20	5	24	15
SANDSTONE Rock	22	10	28	75

5.6 Stormwater Drainage and Groundwater Seepages

It should be noted groundwater seepages across this site may change rapidly with the climate and development variations. Based on the encountered ground conditions, it is anticipated that groundwater seepages are not likely to pose limitations or affect directly the planned excavation works. Gabion retaining walls and all other structures currently present on the site were assessed to be not affected in long-term by site surface run-off and there are currently no signs of potential instability caused by excessive subsurface groundwater streams.

FES recommends monitoring of seepages, if encountered, to be implemented during the excavation works to confirm the capacity of the designed site drainage system. The suitable drainage system should be provided on the site and behind the planned retaining structures.

5.7 Site Lot Classification

The assessment of lot classification was carried out in accordance with Australian Standard AS 2870-2011. The subsurface conditions encountered within the boreholes and DCP tests indicate that existing ground is slightly to moderately reactive to moisture changes. However, due to very steep sloping nature and presence of loose fill, the site is classified as “Class P”.

It means the site may experience some future land sliding issues or potential high or excessive settlement. It is therefore recommended that an alternative foundation system primarily based on piled foundations should be adopted. Refer to sections “Foundations” of this report.

It is recommended that design and construction should comply with the recommendations given by the CSIRO publication, "Foundation Maintenance and Footing Performance: A Homeowner's Guide" annexed as Appendix C.

5.8 Foundations

The foundation levels of the proposed newly constructed alterations and additions residential dwelling development are anticipated to be within SANDSTONE bedrock geology and strata ground profile. It is strictly recommended due to the site slopes and potential soft ground areas that the foundation systems are designed for PILES to be drilled into the underlying SANDSTONE bedrock. Table 5 provides preliminary design parameters recommended for shallow and pile foundations.

Table 5: Foundation Design Parameters

Ground Profile	Allowable End Bearing Capacity (kPa)	Allowable Shaft Adhesion Compression (kPa)
FILL (Clayey)	N/A	N/A
Residual SOIL (Clay)	100	N/A
SANDSTONE Class V	700	70
SANDSTONE Class IV	1000	100

Note: Minimum embedment depth of 1.0m for deep foundations and 0.5m for shallow foundations. Clean rock socket and roughness of at least grooves of depth 1mm to 4mm with width greater than 5mm and with spacing of 50mm to 200mm. Shaft Adhesion in Tension is 50% of Compression for piles.

Piles will also be used to increase the resistance against the lateral seismic and wind loads. Shallow and pile foundations can be designed in accordance with Australian Standards AS2870-2011 and AS2159-2009, respectively.

It is critical and strictly recommended that all foundations are founded on the same stratum to minimise potential differential settlements.

5.9 Site Earthquake Classification

Based on the ground conditions and details of the proposed development, in accordance with Australian Standard AS 1170.4-2007, the site can be classified as "Rock" (Class Be) for design of foundations and retaining walls embedded in the underlying bedrock.

This is subject to foundation system of the development will be extended and socketed into the underlying bedrock geology. The Hazard Factor (Z) is 0.08.

6.0 CONCLUSIONS

This report presents the findings of the geotechnical investigation and recommendations for the proposed structures of new alterations and additions residential development at No. 15 De Lauret Avenue, Newport NSW 2106. It considers that the proposed development is feasible in this site if the recommendations provided in Davies Report and this FES report are considered in design and construction of this development.

For and on behalf of Foundation Earth Sciences

Prepared by

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CPEng and NER (Civil and Geotechnical Engineering)

Reviewed by

Ben Buckley
Director

7.0 LIMITATIONS

The assessment of the subsurface profile within the proposed site and the recommendations presented in this report are based on supplied and field obtained information available. Recommendations and advice presented in this report on soil and rock site conditions are indicative as limited areas were assessed on site. Site inspection by a consulting geotechnical engineer or engineering geologist is recommended when construction works are carried out to confirm the condition of founding materials that geotechnical assessment recommends.

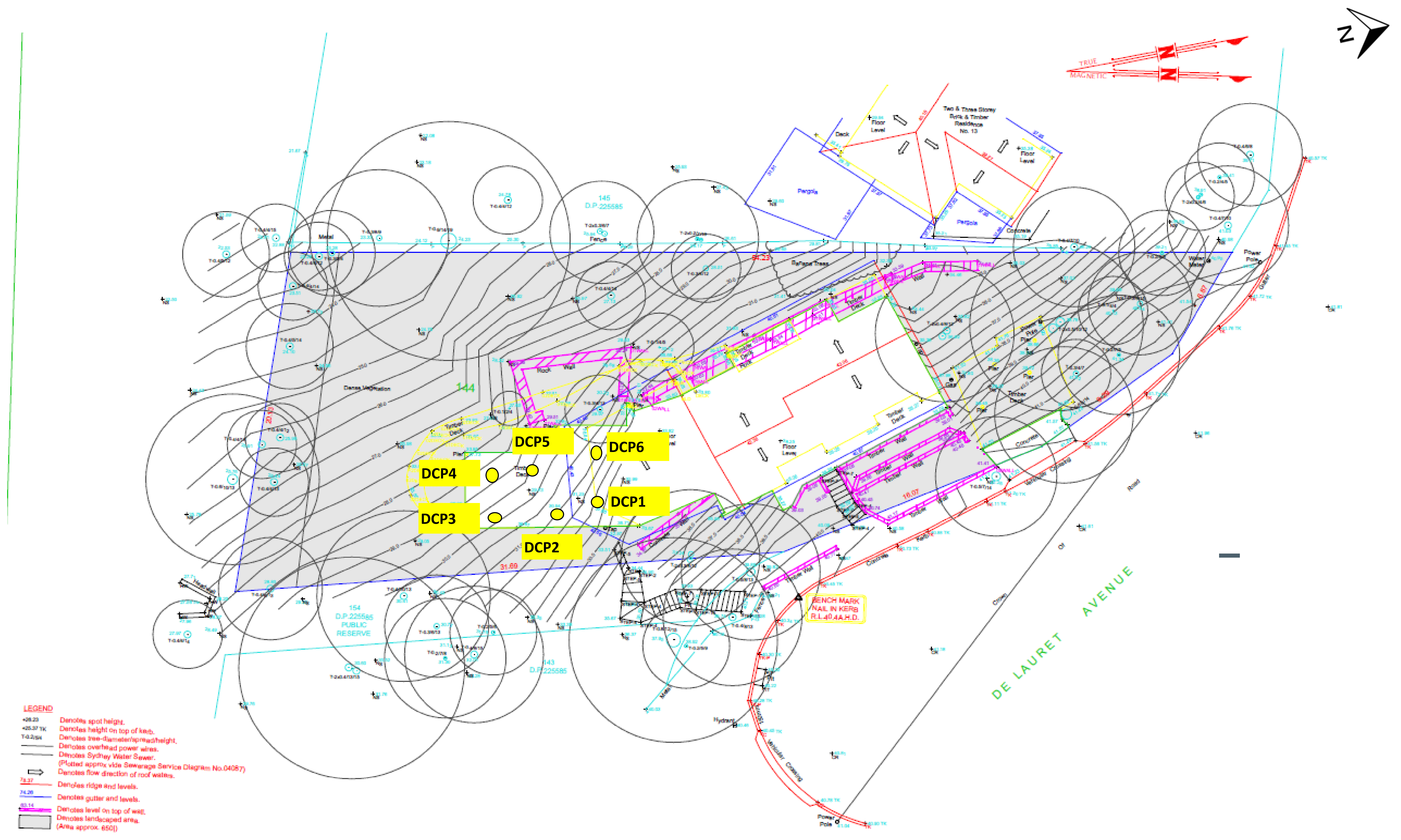
There is a possibility that the actual geotechnical and groundwater conditions across the site may differ from the inferred geotechnical assumptions and derivations on which our recommendations are presented in this report. In that case, FES should be contacted for further advise and review of the information provided in this report. FES does not accept any liabilities for the conditions not accessible during the preparation of this report. Any ensuring liability resulting from use of this report by third parties cannot be transferred to FES.

8.0 REFERENCES

1. Australian Standard – AS1726-1993 “Geotechnical Site Investigation”.
2. Australian Standard – AS 1170.4-2007 “Structural Design Actions – Part 4: Earthquake actions in Australia”.
3. Australian Standard – AS 2870-2011 “Residential slabs and footings”.
4. Australian Standard – AS 2159-2009 “Piling - Design and installation”.
5. Pells, P.J.N, Mostyn, E and Walker, B F – Foundations on Sandstone and Shale in the Sydney Region, Australian Geomechanics Journal, Dec 1998.
6. Pells, P.J.N, Douglas D.J, Rodway, B, Thorne C, McManon B.K – Design Loadings for Foundations on Shale and Sandstone in the Sydney Region. Australian Geomechanics Journal, 1978.
7. Journal and News of the Australian Geomechanics Society Volume 42 No 1 March 2007 – Australian Geomechanics Society.

Appendix A

Site Plan



Legend		DRAWN	Site Plan
Site Location (red line)	FOUNDATION EARTH SCIENCES	KV	
Testing Locations (yellow circle)		Figure	Simon Nasht
		Appendix A	
		Job #	15 De Lauret Avenue, Newport NSW
		G679	

Appendix B

Results of Dynamic Cone Penetrometer Tests

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Results of Dynamic Cone Penetration Tests

Client:	Simon Nasht	Ref No:	G679
Project:	Proposed Residential Additions Alterations Development	Test Date:	9/10/2023
Location:	No. 15 De Lauret Avenue, Newport NSW	Sheet:	1 of 1

Depths (mm)	Test No.				Depths (mm)	Test No.			
	DCP1	DCP2	DCP3	DCP4		DCP5	DCP6	-	-
0-100	1	4	↓ 1	2	0-100	2	2		
100-200	↓ 1	2	↓	1	100-200	1	1		
200-300	↓	1	3	1	200-300	1	4		
300-400	2	1	1	3	300-400	3	3		
400-500	4	3	1	2	400-500	3	5		
500-600	5	6	3	4	500-600	17	6		
600-700	12	11	7	8	600-700	Bouncing	8		
700-800	24	19	11	14	700-800		8		
800-900	Bouncing	Bouncing	10	12	800-900		12		
900-1000			14	26	900-1000		11		
1000-1100			22	Bouncing	1000-1100		14		
1100-1200			Bouncing		1100-1200		10		
1200-1300					1200-1300		13		
1300-1400					1300-1400		16		
1400-1500					1400-1500		21		
1500-1600					1500-1600		Bouncing		
1600-1700					1600-1700				
1700-1800					1700-1800				
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3500-3600					3500-3600				
3600-3700					3600-3700				
3700-3800					3700-3800				
3800-3900					3800-3900				
3900-4000					3900-4000				

Note: Refer to Site Plan for the test locations
T = Terminated
B = Bouncing
R = Refusal

Appendix C

Guide to Home Owners & AGS Hillside Guidelines

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).

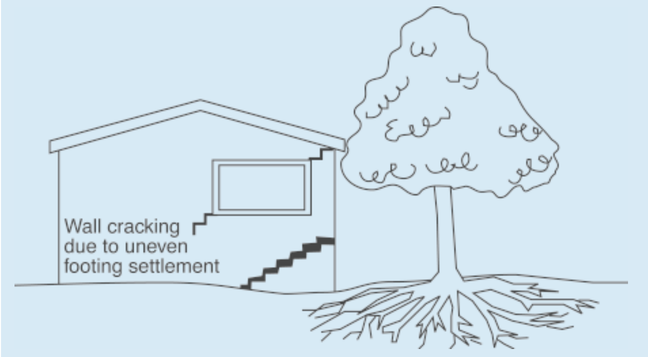
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

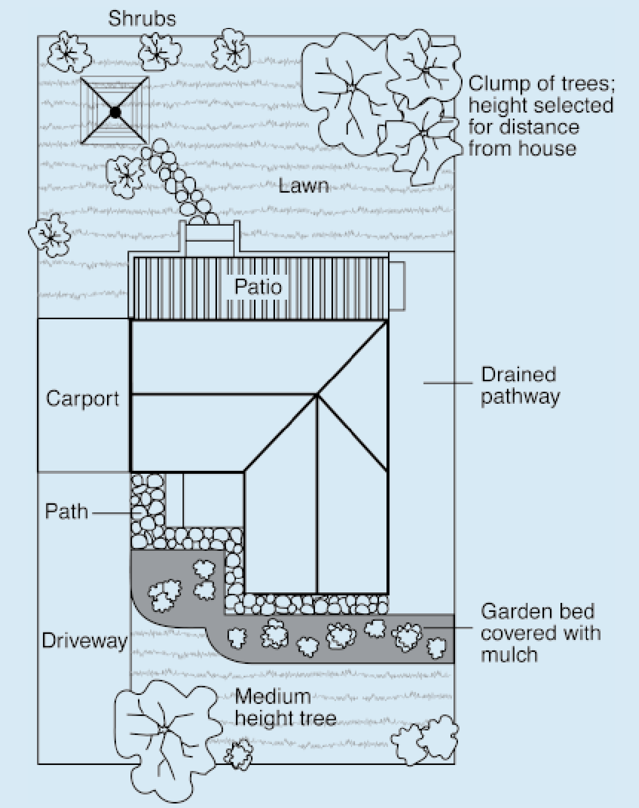
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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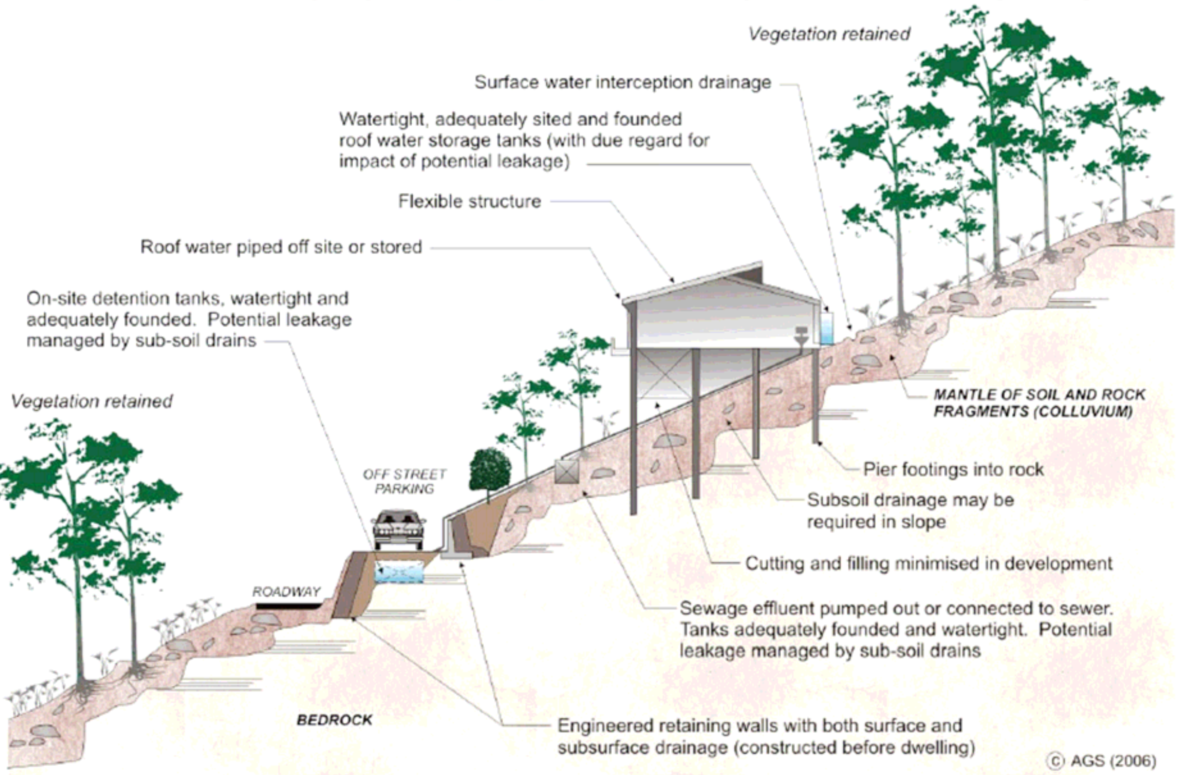
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE