4 March 2025
Our ref: S2530_SCS_01_Rev0

Client: Arkh Design

Via email: jon@arkhdesignstudio.com

Attention: Jon Ormaza

Proposed Development – 48 Park St, Narrabeen NSW 2101
Geotechnical Investigation & Slope Instability Risk Assessment

1 Introduction

1.1 PROJECT DESCRIPTION

At the request of Arkh Design (the client), Fortify Geotech Pty Ltd (Fortify) carried out a geotechnical site investigation in accordance with AS2870-2011 “Residential Slabs & Footings”, and a qualitative slope instability risk assessment for the proposed development at 48 Park St, Narrabeen NSW 2101. It is understood that the proposed new dwelling will comprise three floors including a basement garage area with excavations up to ~2.0m below current surface levels.

The proposed site is vacant and has recently undertaken tree removal across the site, with a total area of approximately 518 m². The site is bounded by Park Street to the east, and residential developments on all other sides, with a staircase connecting the upper and lower sections of Clartke St along the northern boundary of the Site. Figure 1 illustrates the Site’s location.

To establish the site subsurface conditions, a handheld hydraulic push-tube was used to excavate one borehole on the property, designated BH1. One (1) Dynamic Cone Penetrometer (DCP) tests was also conducted, adjacent to the location of the boreholes. Figure 2 is an aerial photograph showing the approximate borehole location.

The soil profiles were visually logged in accordance with the Unified Soil Classification System (USCS) and AS1726-2017. Definitions of geotechnical engineering terms used in the report on the test pit logs, including a copy of the USCS chart, are provided in Appendix B.

1.2 SCOPE OF INVESTIGATION

The aim of the investigation was to:

- Identify subsurface conditions including the extent and nature of any fill materials, soil strata, bedrock type and depth, and groundwater presence.
- Description of the site geology/subsurface conditions including existing fill, bedrock and groundwater.
- Provide site classification to AS2870-2011 “Residential Slabs & Footings”.
- Recommend building footing types, founding strata and allowable bearing pressures.
- Any other relevant geotechnical information, including excavation conditions, stable temporary and permanent excavation batter slopes, suitability of excavated material for use in controlled fill platforms and advise for construction of building platforms, and retaining wall advice.

- Slope stability risk assessment (including the description of any geological hazards and main topographical features) and recommendations for slope stabilisation.
- Advise on site drainage.

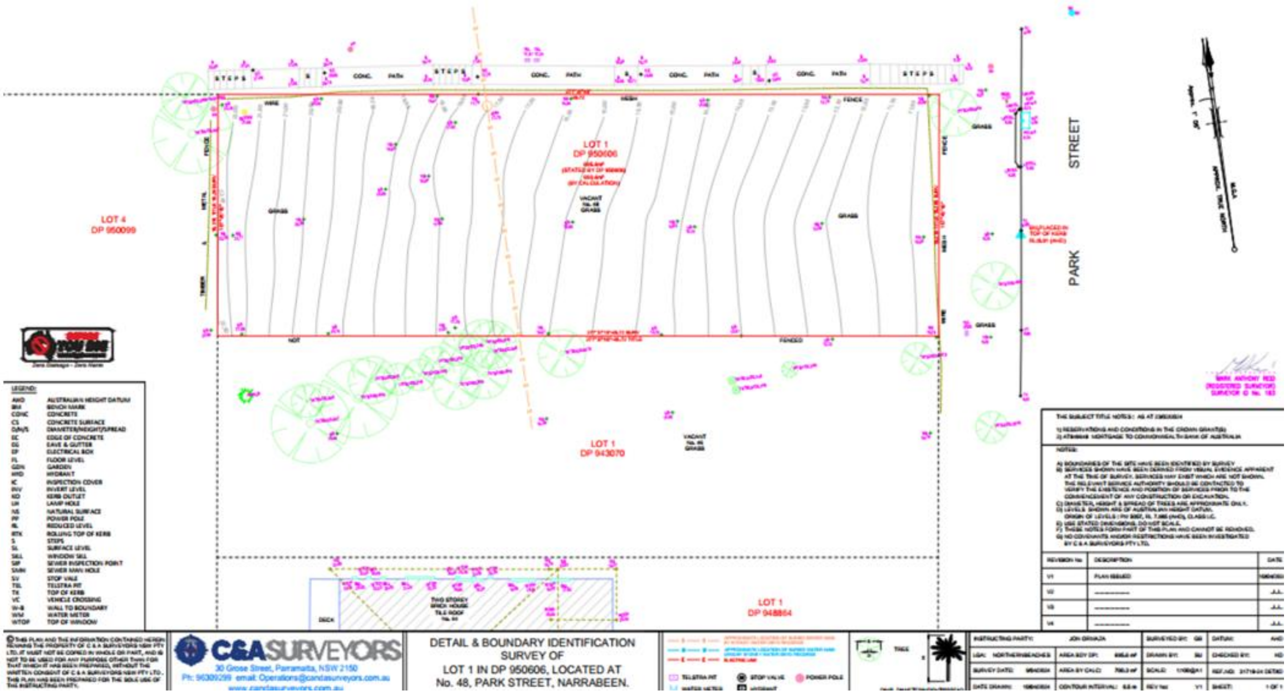
1.3 SITE DESCRIPTION & TOPOGRAPHY

The site is located at 48 Park St, Narrabeen NSW 2101. The ~518m^2 site is presently vacant and is overgrown with vegetation. The site is bound by existing residential developments to the south and west, a pedestrian accessway (staircase) to the north and Park Street to the south. The ground surface slopes towards the east of the site beside Park Street.

The topography of the site consists of a slope with an average angle of approximately 15°, dipping to the east,. The slope is covered by vegetation, with some trees present outside the footprint of the proposed boundary. Plate 1 below shows a detailed survey of the existing site from C&A Surveyors, dated: 10/04/2024.

The sloping site appears to be completely covered by soil, with no rock visible during the inspection.

Plate 1: Project Surveyors detail survey plan of the site.



1.4 SITE GEOLOGY

The geological information provided by the Department of Regional NSW (Reference 1) indicates the area to be underlain by Middle Triassic age Newport Formation consisting of interbedded laminite, shale and sandstone; white quartz to quartz-lithic, very fine- to medium-grained sandstone; minor shale breccia and pebble polymictic conglomerate (at base of sandstone units); minor red clays.

An extract of the geology map showing the proposed development site is shown in Figure 3 at the end of this report.

2 Investigation Results

2.1 SUBSURFACE PROFILE

The subsurface conditions at the location of the proposed property were investigated by one borehole, designated BH1. The engineering logs are included in Appendix A and can be referred to for more detail. The inferred subsurface profile is summarised in Table 2-1.

Table 2-1: Subsurface Profile Summary

Geological Profile	Depth Interval (m)	Unit	Description
TOPSOIL/ FILL	0 – 0.3	Unit 1: Sandy SILT/CLAY	**Sandy SILT/CLAY;** dark brown, fine to medium sand, low to medium plasticity, yellow brown, with fine gravel.
RESIDUAL	0.3 – 1.7	Unit 2: CLAY	**Sandy CLAY:** medium to high plasticity, pale grey mottled yellow brown, trace fine sand.

2.2 DYNAMIC CONE PENETROMETER (DCP) TESTING

To determine the density/relative consistency of the subsurface profile, one Dynamic Cone Penetrometer (DCP) test was conducted on 14 February 2025, adjacent to the borehole, in accordance with AS1289.6.3.2 "Determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test". The DCP results are shown in Table 2-2. The DCP test were taken from existing ground surface level. The approximate location of the borehole and the DCP test is shown in Figure 2.

Table 2-2: DCP Test Results

Depth below existing ground surface (m)	Blows per 100 mm penetration
	DCP 1
0.1	2
0.2	2
0.3	3
0.4	2
0.5	4
0.6	3
0.7	3
0.8	4
0.9	3
1.0	3
1.1	4
1.2	3
1.3	2
1.4	4
1.5	5
1.6	6

Depth below existing ground surface (m)	Blows per 100 mm penetration DCP 1
1.7	6
1.8	7

The test results for DCP 1 indicate the subsurface profile at this location comprises predominantly firm to stiff material to ~0.4 m, and stiff materials to 1.5m, further stiff to very stiff soil be encountered at the termination depth of 1.8 m.

2.3 GROUNDWATER

Permanent groundwater was not encountered within the investigation depth and the encountered soils had a moisture content less than the plastic limit of the soil or was dry. However, groundwater levels may fluctuate depending on climate conditions and temporary, perched seepage flows may be encountered at shallower depths following rainfall events.

3 Slope Instability Assessment

Natural hill slopes are formed by processes that reflect the site geology, environment and climate. These processes include down slope movement of the near surface soil and rock. In geological time all slopes are 'unstable'. The area of influence of these down slope movements may range from local to regional and are rarely related to property boundaries. The natural processes may be affected by human intervention in the form of construction, drainage, fill placement and other activities.

3.1 METHOD OF RISK ASSESSMENT

The following sections of the report outline the slope instability risk assessment carried out for the site. The assessment is qualitative, based on the guidelines provided in the Australian Geomechanics Journal Vol 42 March 2007, and has been adopted by the NSW Department of Infrastructure, Planning and Natural Resources. This uses a matrix approach to determine the risk level of each hazard based on the likelihood and consequences of each hazard occurring.

The risk assessment is undertaken by the recognition of surface features supplemented by information on the regional and local subsurface profile and with the benefit of experience gained in similar geological environments. It involves the following components:

1. Identification on the potential site slope hazards that may damage property and/or cause loss of life (Hazard Identification).

2. Estimation of the likelihood of each hazard occurring (Likelihood of Hazards Occurring).

3. Assessment of the potential consequences to property and people of these hazards occurring (Consequences of Hazards).

4. Evaluation of the significance of the assessed risks against criteria of acceptability (Significance of Risks).

Following the risk assessment, options for the treatment of the risk are provided as a guide to the owner, administrator and regulatory authorities who will need to decide whether to avoid or accept the risk, or to treat the site to reduce the likelihood and/or consequences of the hazards.

A flowchart, included in the Australian Geomechanics Journal, Vol 42, March 2007, paper on "Landslide Risk Management Concept & Guidelines" 2007 (Reference 2), which shows the processes of risk assessment/risk management is copied here in Appendix B. Appendix C provides guidelines for hillside construction.

3.2 HAZARD IDENTIFICATION

A landslide is defined as "the movement of a mass of rock, debris or earth down a slope". Apart from ground subsidence and collapse, this definition is open to the movement of material types including rock, earth and debris down slope. The causes of landslides can be complex. However, two common factors include the occurrence of a failure of part of the soil or rock material on a slope and the resulting movement is driven by gravity. For further information regarding types of landslides please refer to Appendix B – Landslide Terminology from Australian Geomechanics Practice Note Guidelines for Landslide Risk Management 2007.

For 48 Park St, Narrabeen NSW 2101, the potential hazards listed in Table 3-1 have been considered in this assessment.

Table 3-1: Landslide Hazard Identification

Hazard Description	Justification
Large Scale Translational Slide	To our knowledge, there have been multiple landslips in the Narrabeen area, with the closest being on Walker Ave, <500m from the site at 48 Park Avenue, Narrabeen. However, from publicly available information, these failure mechanism tend to form in areas where the underlying geology comprises Alluvial Valley deposits. The Site covered by this assessment sits on residual soils above the Newport Formation. Existing trees outside of the footprint of the proposed development and on adjacent properties are all vertical, with little to no slanted growth. However, it is understood that mass clearance of vegetation has been undertaken within the last year across the site, including the removal of substantial tree cover. For a large-scale slide to happen there would need to be an extreme combination of unfavourable triggering conditions such as earthquakes, extreme rainfall, saturated soils, mass clearance of vegetation, unsupported excavations etc. Given the moderate slopes on and around the property and no known history of slope instability in this geological formation, such an event is considered "Unlikely".
Circular / Shallow Translational Failure in Underlying Soil Mass	Extending in from the western boundary, the upper 2-3m of the site comprises an increased slope of ~45°. A fallen wooden fence, present along this boundary suggests evidence of an unstable batter slope. Site observation suggests that either localised circular failures or shallow translational failures have occurred and/or are in progress, resulting in the downslope movement of soil and the wooden structure to the east (downslope). The current development proposals indicate plans substantial filling in the area, which would cover this slope entirely. However, in its current state, the steep slopes in this area, in combination with adverse site conditions, i.e. saturated soils post a rainfall event and/or rainwater run-off, are likely the cause of the observed signs of instability. As such, this event is considered "Almost Certain".

Hazard Description	Justification
Surface Erosion	For much of the site, there are presently no signs of surface erosion, probably in part due to the surface vegetation and good surface drainage. This is with exception of the above-mentioned batter slope along the western boundary. Surface runoff during high rainfall could be substantial along this boundary, so if the vegetation were to be removed and surface water-flow paths were allowed to develop, surface erosion would be “Likely”.
Failure of Retaining Wall	There are no retaining walls within the property. However, there is a block retaining wall (circa 3.5 m in height) and concrete crib wall, set ~3 m back from the property boundary in the public space to the north. Based on the provided Architectural DA plans, the proposed basement excavation appears to be outside of the zone of influence of the wall and therefore unlikely to undermine the existing wall. However, this should be confirmed prior to construction. Visual inspection suggests no signs of deterioration or undue stress on the wall. Given the above, the likelihood of a retaining wall failure along the property boundary is considered “Unlikely”.
Soil Creep	Soil Creep can occur where residual clayey/silty soils overlie shallow bedrock. In this case, the gradient slope angle along most of the site is moderate and there is no evidence of creep visible on the site. Such an event is considered “Unlikely”.

3.3 CONSEQUENCES OF HAZARDS OCCURING

For 48 Park St, Narrabeen NSW 2101, the consequences of the potential hazards listed in Table 3-1 have been summarised in Table 3-2 and classified using the AGS table of qualitative measures of vulnerability and consequences in Appendix B this report.

Table 3-2: Landslide Hazard Consequence

Hazard Description	Justification
Large Scale Translational Slide	Theoretically, a large-scale slide could occur with little or no warning, and the consequences to property and people would depend on the volume of the slide material, its velocity, and whether or not people are present, or in the downslope dwelling at the time. We consider the consequences of such a rare event to be “**Major**”, i.e. theoretically, there is the possibility of a fatality in the dwelling and/or the imposition of significant damage to the proposed structure in the rare event of this occurring.
Circular / Shallow Translational Failure in Underlying Soil Mass	The consequence of a circular/shallow translational failure in underlying soil mass along the western boundary occurring is inferred to be “**Medium**”. In the case of such a failure, the neighbouring property to the west would likely be impacted, along with any structures (currently an out of ground pool) or persons at the top of the slope at the time of the failure event. The chance or temporal probability of persons being in the area during an earth slump is possible, and the risk of loss of life is unlikely. The consequences for persons are therefore rated as “**Minor**”.

Hazard Description	Justification
Surface Erosion	If such an event develops and occurs, small cobbles may wash out of erosion gully slides and rolled downhill. The consequential damage to a structure and persons would be "**Insignificant**".
Failure of Retaining Wall	If a retaining wall failed, damage may well result to the structures above, depending on many factors. In general, the consequences can be rated as "**Major**". The chance of persons being injured or of loss of life is moderate and the consequences to persons are therefore also rated as "**Major**".
Soil Creep	The risk of soil creep has not been identified at the site and no foundations of structures above the slope are likely to be affected by this hazard. Therefore, the consequential damage to a structure or persons is considered "**Insignificant**".

3.4 RISK ESTIMATION

A summary of estimated risk to property and life for each of the potential hazards identified in the previous sections is provided in Table 3-3. The resulting risk level was derived using the AGS risk analysis matrix presented in Appendix B.

Table 3-3: Estimated Risk Levels of Hazards

Potential Hazard	Assessed Likelihood	Assessed Consequences	Risk Level
Large-Scale Translational Slide	Unlikely	To Dwelling - Major	Medium
		To People in/adjacent to dwelling – Major	Medium
Circular / Shallow Translational Failure in Underlying Soil Mass	Almost Certain *(Unlikely*)*	To Dwelling - Medium	Very High *(Low*)*
		To People in/adjacent to dwelling - Minor	High (*Low**)
Surface erosion	Likely	To Dwelling – Insignificant	Low
		To People in/adjacent to dwelling - Insignificant	Low
Failure of Retaining Wall	Unlikely (*Rare**)	To Dwelling – Major	Medium (*Low**)
		To People in/adjacent to dwelling – Major	Medium (*Low**)
Soil Creep	Unlikely	To Dwelling - Insignificant	Very Low
		To People in/adjacent to dwelling - Insignificant	Very Low

* Should the risk treatment measures presented in Section 3.6 be adopted, the assessed likelihood and risk level will be adjusted as listed.

3.5 SIGNIFICANCE OF RISKS (RISK EVALUATION)

Risk evaluation is the process by which owners, administrators and relevant regulatory authorities can decide whether the potential risks (See Table 3-3) are acceptable, and/or whether these can be feasibly eliminated or reduced by remedial treatment. Implications of each level of risk are described in Appendix B.

In this case, the overall risk to property and people is assessed to be “Very Low” to “Very High”. However, provided that during design and construction adequate care is given to the overall stability of the site and the impact of construction on any adjacent retaining wall, the overall risk to property and people is re-assessed as “Very Low” to “Medium”.

Provided the design and construction of the proposed development is undertaken in accordance with accepted procedures for hillside construction, and treatments are carried out to reduce the potential hazards, the risk is no higher than normally acceptable for residential development.

3.6 RISK TREATMENT

To maintain and/or reduce the risk level of slope stability during the construction of the proposed new dwelling and subsequent occupation, the following measures are recommended to be implemented:

- Ensure footings are founded on subsurface material of adequate strength (stiff natural soils or preferably weathered bedrock).
- Remove the unstable soil mass along the failed slope on western boundary and either regrade this area or incorporate a retaining wall into the development proposals to provide adequate support.
- Maintain adequate drainage of the site and ensure drains are free-flowing.
- Periodic inspection of the slope for signs of erosion developing and remediate as necessary.

Some useful guidelines on hillside construction, prepared by the Australian Geomechanics Society, are presented in Appendix C.

4 Site Classification

The upper soils generally are moderately reactive in terms of potential shrink-swell movements that may occur due to seasonal ground moisture changes. The characteristic ground surface movement “Ys”, as defined by AS2870 for the range of extreme dry to extreme wet moisture conditions is estimated to be between 20mm-40mm for the encountered subsurface profile. The site is therefore Class “M” (moderately reactive).

Normal moisture conditions are those caused by seasonal and regular climatic effects. Should earthworks (cut or fill) be undertaken on the site, or other activities which may cause abnormal moisture conditions to impact the soils within or near the building envelope beyond those addressed herein, the site classification shall be reassessed.

Deemed-to-comply footing designs provided by AS2870-2011 are applicable specifically to residential-style one and two-storey structures, or buildings with similar loads and superstructure stiffness.

5 Structure Foundations

Footings and pads should be designed in accordance with the principles of AS2870-2011. For structures founded at existing grade, footings, including thickened sections of slabs forming footings should be founded below any topsoil and fill material and founded in underlying rock. A depth of ~0.4 m from existing levels may be required to reach a suitable founding stratum. Footings could be founded on piers extending bedrock, as the bedrock placement depth is.

Recommended allowable end-bearing pressures and shaft adhesion values for various footing systems and likely foundation materials are provided in Table 5-1.

Table 5-1: Recommended Allowable End-Bearing Pressures for Footings

Foundation Material Type	Depth Below Existing Surface Level	Allowable End-Bearing Pressure			Allowable Shaft Adhesion on Bored Piers and Anchors	
		Strips	Pads	Bored Piers	Downward loading	Uplift
Newly Placed Controlled Fill	-	100kPa	125kPa	N/A	N/A	N/A
Firm to Stiff Soil	0.3	90kPa	110kPa	N/A	13kPa	10kPa
Stiff to Very Stiff Soil	1.5	160kPa	200kPa	280kPa*	22kPa	17kPa

* Assumes a minimum pile embedment of 5 diameters into the material.

It is recommended that footings are inspected by a geotechnical engineer prior to the pouring of concrete to ensure that footings are founded in adequate material.

6 Excavation Conditions & Use of Excavated Material

It is understood that excavations up to ~2.0 m are required for the proposed development. The excavations are expected to be through existing fill and residual soils. The fill and residual soils are readily diggable by backhoe and medium sized excavator to at least 1.7 m depth.

Any low/medium plasticity natural soils can be used in controlled fill construction of building platforms, provided any rock particles are broken down to <75mm size and the fill is environmentally suitable for re-use on site. Topsoil and existing uncontrolled fill material should not be used in controlled fill construction; however, it can be used for landscaping.

If imported fill is required, a suitable select fill material would include a low or medium plasticity soil such as clayey sand or gravelly clayey sand, containing less than 35% fines less than 0.075mm size (silt and clay), and no particles greater than 75mm size.

7 Site Drainage

Permanent groundwater was not encountered in the investigation boreholes and the encountered soils had a moisture content less than or near the plastic limit or were dry. The permanent groundwater table is expected to be below the proposed excavations. Temporary perched seepages may occur after rainfall but can be easily managed by redirecting them to the water canal adjacent to the site.

Suitable surface drainage should be provided to ensure rainfall run-off or other surface water cannot pond against buildings or pavements. Drainage should be provided behind all retaining walls, and subsoil drains should be installed along the upslope sides of access roads and carparks.

Should you require any further information, please contact our office.

Yours faithfully,

Fortify Geotech Pty Ltd

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Graduate Geotechnical Engineer

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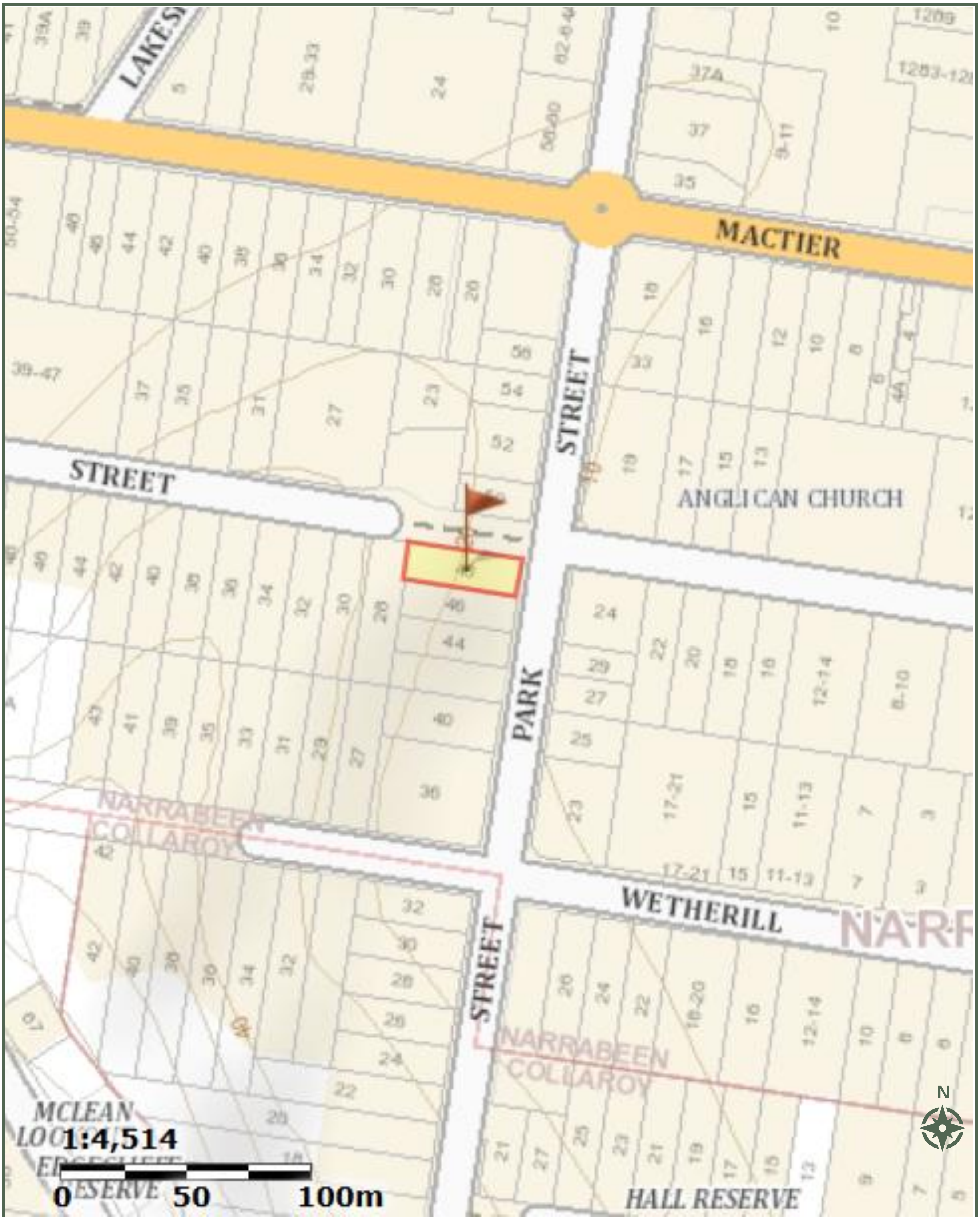
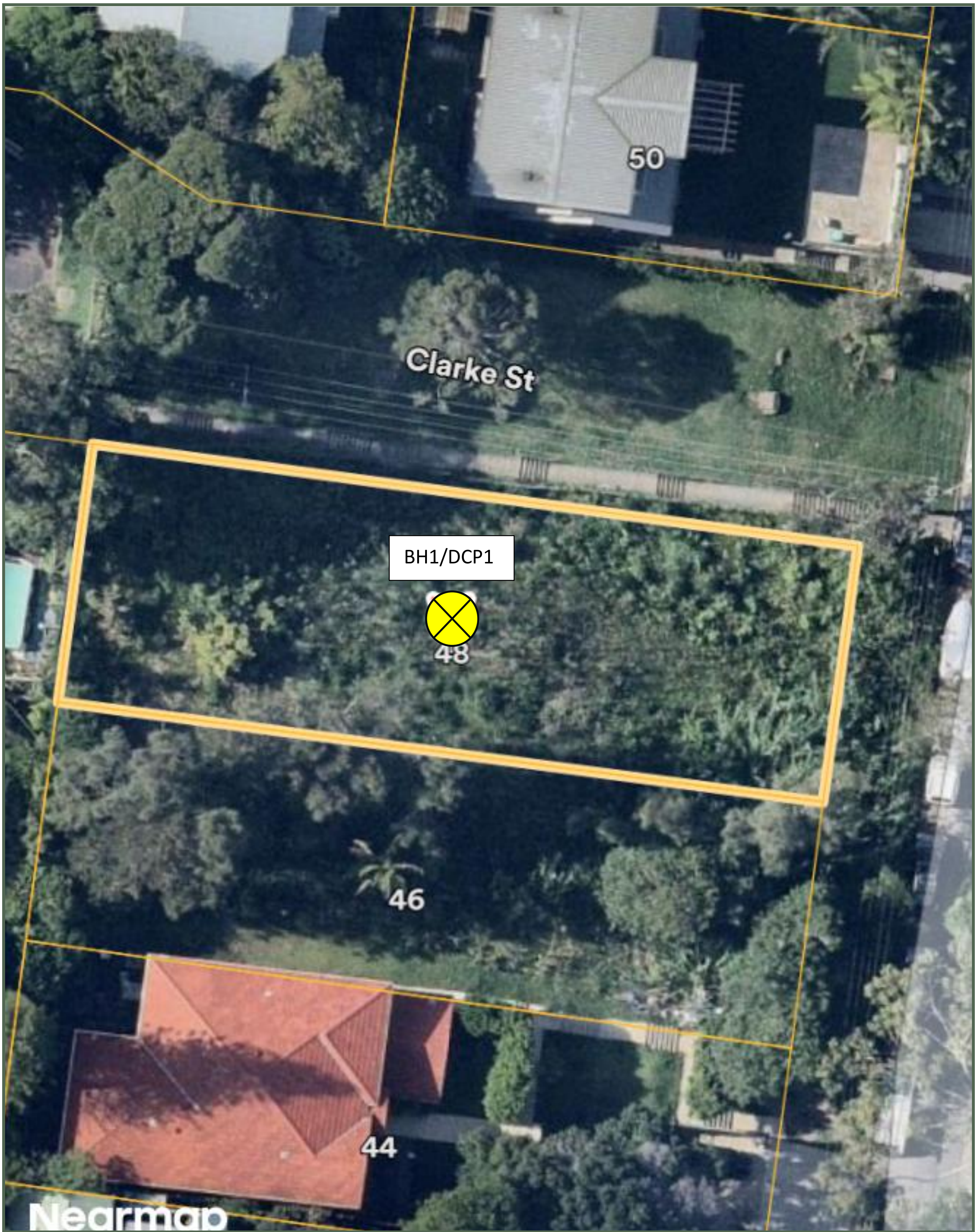
NSW PE Registration # PRE0002314



SITE LOCALITY	S2530	FIGURE 1



AERIAL PHOTOGRAPH AND BOREHOLE LOCATION	S2530	FIGURE 2

39 Sydenham Road, Marrickvile NSW 2204
PO Box 9225, Deakin ACT 2600

Consulting Engineers

(02) 9188 4033
FortifyGeotech.com.au

Overlay of Geological Map Showing Proposed Site	S2530	FIGURE 3

N

SITE PHOTOGRAPH OF BOREHOLES	S2530	FIGURE 4.1

SITE PHOTOGRAPH OF FAILED SLOPE AT WESTERN BOUNDARY	S2530	FIGURE 4.2

REFERENCES

Reference 1. Department of Regional NSW, NSW Seamless Geology - https://data.nsw.gov.au/data/dataset/nsw-seamless-geology - Accessed on 1/04/2025

Reference 2. Landslide Risk Management Concepts and Guidelines 2007 - https://landsliderisk.org/wp-content/uploads/2017/04/ags_2007c2.pdf - Accessed 4/04/2024

Reference 3. Standards Australia, “AS2870 – Residential Slabs & Footings”, 2011.

Appendix A

Borehole Logs

FORTIFY GEOTECH

Borehole Log

Borehole No.	**BH1**
Sheet	1 of 1
Job No.	S2530

CLIENT: Arkh Design

PROJECT: Proposed New Dwelling
48 Park St, Narrabeen NSW 2101

Equipment Type : Pushtube
Hole Diameter : 50mm

Location : See report

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Sample No.	Water	Method/ Casing	RL (m)	Depth (m)	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Moisture Condition	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered			0.1		ML	**Sandy SILT**:dark brown, fine to medium sand.	M	F-St	DCP 2	TOP SOIL
				0.3		CL	**Sandy CLAY** :low to medium plasticity, yellow brown, fine to medium sand, with fine gravel.	*w*<PL		2, 3	FILL
				1.0		CL	**CLAY**: medium to high plasticity, pale grey mottled yellow brown, trace fine sand,.	*w*<PL		2	RESIDUAL
									St	4, 3, 3, 4, 3, 3, 4, 3, 2, 4, 5	
							becoming pale grey, mottled red.				
				1.7					St-VSt	6, 6	
				2.0			BOREHOLE TERMINATED AT 1.7m Target depth			7, 8	
				3.0							

Field Test Results: Dynamic Cone Penetrometer Test, Results in Blows per 100mm

Logged By : EM Date : 25/2/25 Checked By : Date :

BOREHOLE/EXCAVATION LOG S2530.GPJ EXC.GDT 26/2/25

Appendix B

Extracts from National Landslide Risk Management Framework for Australia 2007 & Practice Note Guidelines for Landslide Risk Management 2007

- B1 - Flowchart of Landslide Risk Management
- B2 - Qualitative Terminology & Risk Matrix

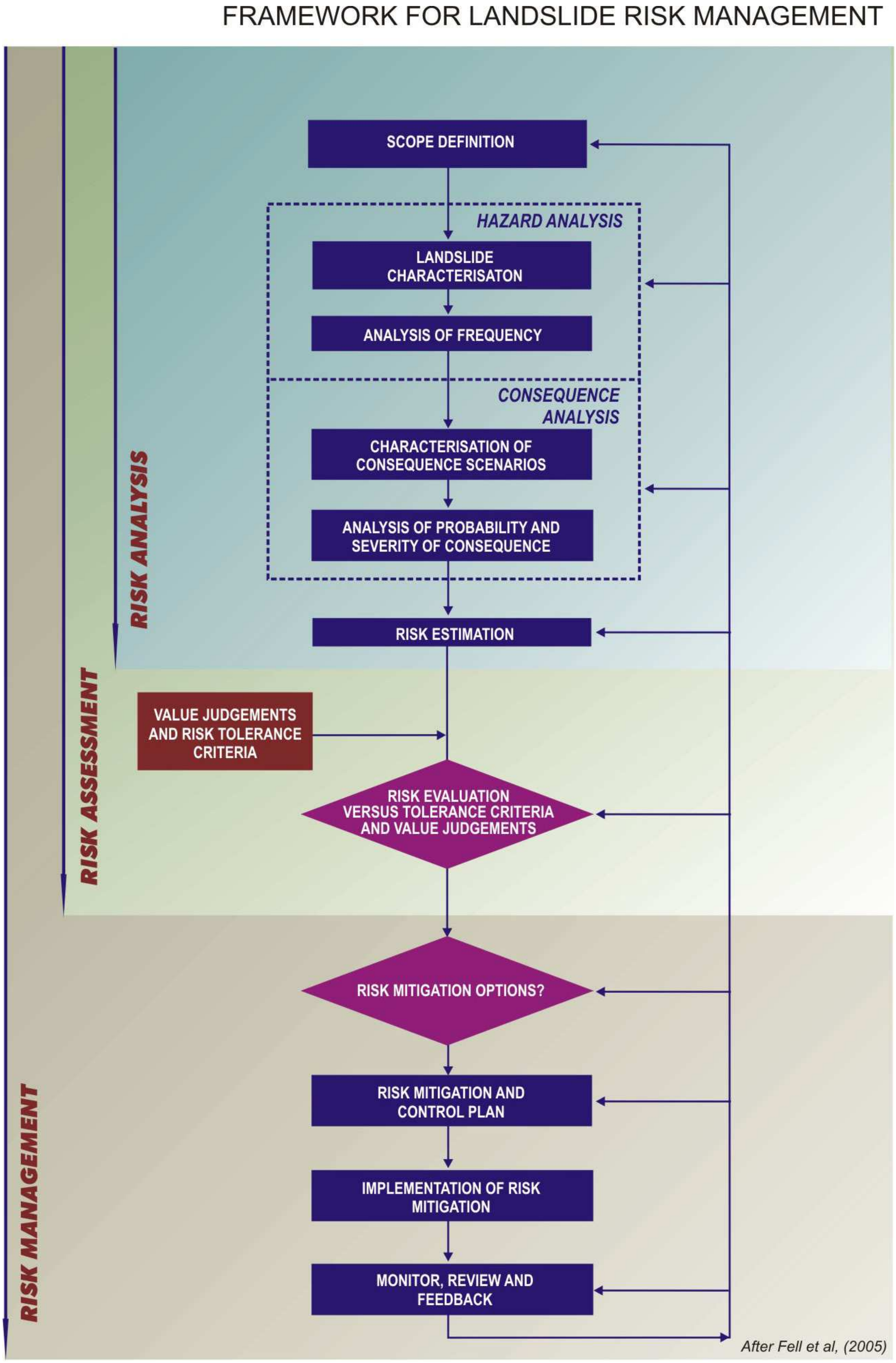


Figure 2: Abbreviated flowchart for Landslide Risk Management.
Ref: AGS (2007a, 2007c)

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		**Implied Indicative Landslide Recurrence Interval**		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**					
10^{-1}	5×10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5×10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5×10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5×10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5×10^{-6}	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

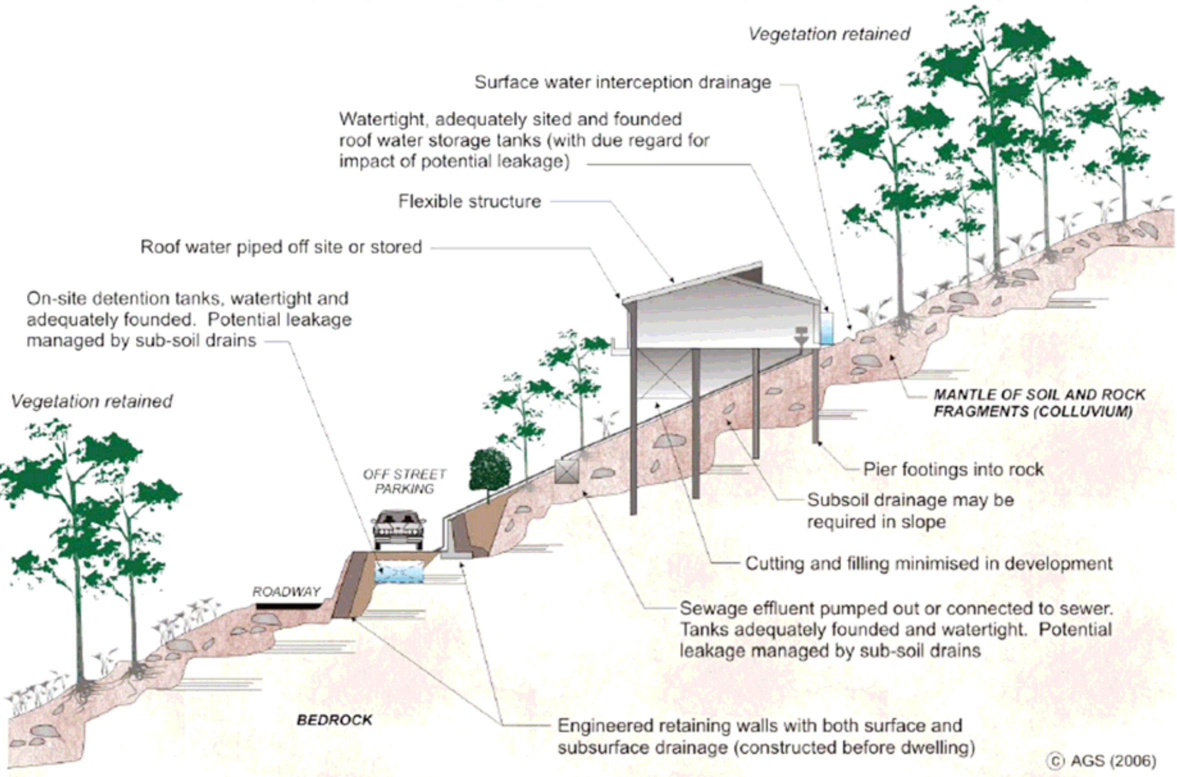
Appendix C

Guidelines for Hillside Construction

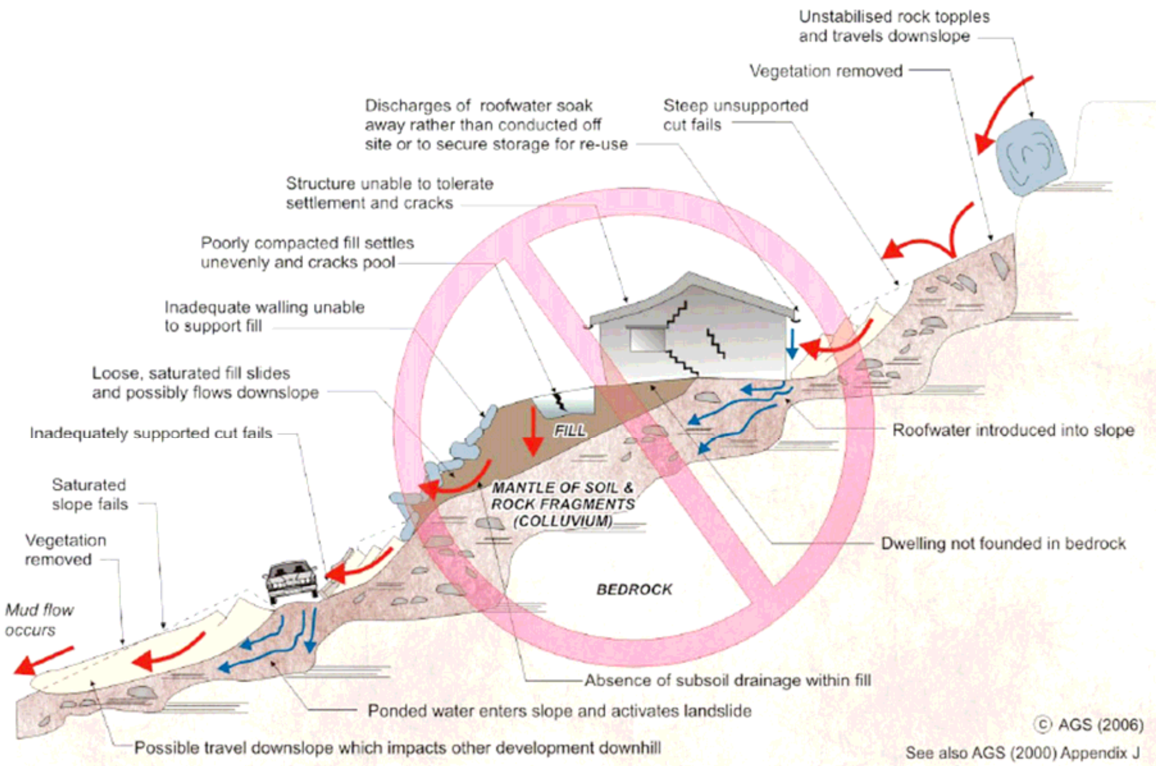
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	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



Foundation Maintenance and Footing Performance: A Homeowner's Guide

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.

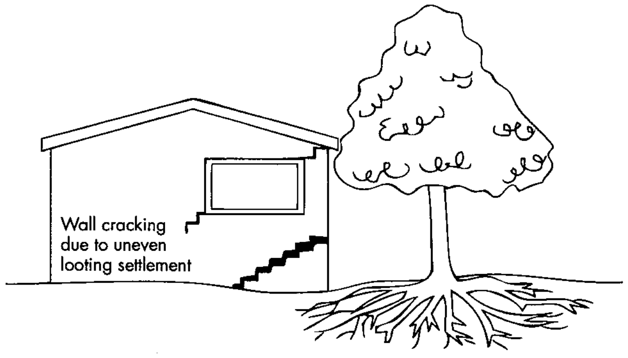
Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends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

Trees can cause shrinkage and damage



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 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

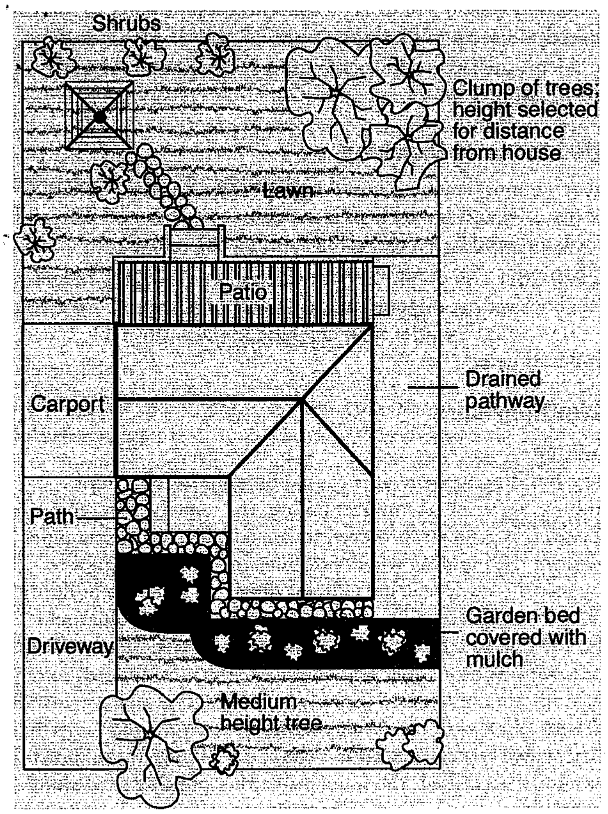
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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Appendix D

Limitations in the Use and Interpretation of this Report

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Consulting Engineers
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Limitations in the Use and Interpretation of this Geotechnical Report

Our Professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors/purchasers of the site and/or for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross- sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observes in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and the recommendations considering the changed conditions and time lapse.

The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual. Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

The boring logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at the other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations. In making an assessment of a site from a limited number of boreholes or test pits there is the possibility that variations may occur between test locations.

The data derived from the site investigation program and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report: nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.