TGE Taylor Geotechnical Engineering
Geotechnical Civil Engineers & Project Managers

REPORT ON GEOTECHNICAL INVESTIGATION

PROPOSED RESIDENTIAL DEVELOPMENT

91 FLORIDA ROAD PALM BEACH

CLIENT: ALEX & KIKI HILL

PROJECT: TGE22046

DATE: 20 NOVEMBER 2020

Taylor Geotechnical Engineering
Geotechnical Civil Engineers & Project Managers

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APPENDICIES

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LRT

Report TGE22046

20 November 2020

REPORT ON GEOTECHNICAL INVESTIGATION
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91 FLORIDA ROAD PALM BEACH

1. INTRODUCTION

This report details the results of a geotechnical investigation undertaken on the site of proposed residential development at 91 Florida Road Palm Beach. Robert Jones Architects, architects and project managers for the development, requested the investigation on behalf of Alex & Kiki Hill, property owners. The investigation was carried out by Taylor Geotechnical Engineering Pty Limited on 4th November 2020 in accordance with Proposal tgeP2029 dated 15th October 2020.

The proposed development comprises alterations and additions to the existing residence including construction of a new double carport with roof and storage room under, an extension to the upper and lower levels of the eastern side of residence and modification to the ground floor (upper) level layout. The aim of the investigation was to provide information on subsurface and site conditions for assessment of geotechnical risk and to assist with planning and design.

The investigation comprised visual and photographic survey and inspection of exposed strata, drilling of test bores, in-situ testing of the subsurface strata and engineering assessment and analysis. Details of the fieldwork are given in the report, together with comments relating to design and construction practice.

2. SITE DESCRIPTION

The site is located on the western side of Florida Road in Palm Beach and consists of a single block with an area of approximately 1316 m^2 and the shape and dimensions as shown on Drawing 1 in Appendix 1. It is located on the eastern side of the Palm Beach peninsular towards the southern end of Palm Beach. Ground slopes fall to the east, with average ground slopes of approximately 14 degrees from the front (eastern) boundary to the front of the residence increasing to 20-25 degrees across the rear (western) section of the site from the rear of the residence to the rear boundary. The site has neighbouring properties to the north and south with rear access to Livistona Lane to the west and eastern frontage to Florida Road. The site viewed from Florida Road is shown in Photo 1 in Appendix 3. The front section of the site is grassed (see Photo 2) with several established trees scattered either side of a sandstone path that leads to a single storey timber clad with metal roof structure. There are several sandstone outcrops scattered across the site with large outcrops at both the front (see Photo 6) and rear (see Photo 3) of the residence. The western section of the site has several terraced gardens with some sandstone outcrops scattered amongst them (see Photo 4).

Reference to the Sydney 1:100,000 Geological Sheet indicates that the site is located close to the geological boundary between the Newport Formation from the Narrabeen Group, of the Triassic Period, and Hawkesbury Sandstone also of the Triassic Period. The Newport Formation typically comprises interbedded laminite, shale and quartz to lithic-quartz sandstone. The rocks of this formation typically weather to form moderately reactive sandy and silty clay soils but highly reactive clay soils are possible. The Hawkesbury Sandstone formation typically comprises medium to coarse grained quartz sandstone with very minor shale and laminite lenses. The rocks of this formation typically weather to form low and moderately reactive sandy clay soils but highly reactive clay soils are possible.

The results of the investigation indicate that the Hawkesbury Sandstone formation is likely located just west, upslope, of the site and that the site is underlain by the Newport Formation. Numerous sandstone outcrops are located across the western areas of the site, likely boulders that have been dislodged from upslope cliff lines and have come to rest across the western areas of the site.

3. FIELD WORK METHODS

The field work for this investigation comprised drilling of three test bores, insitu testing of the sub-surface strata and a geotechnical inspection and photographic survey of the site, detailing the location of any geological features or hazards that may affect site stability and pose an unacceptable risk of landslide or instability.

Dynamic penetrometer tests (DPT's) were conducted at each bore location and one additional location, testing from the surface to a maximum depth of 2.4 m or prior refusal. The penetrometers were conducted in order to determine the depth to bedrock (if within 2.4 m) and provide an estimate of the strength of the near surface strata. The DPT's were conducted in accordance with test method AS1289.6.3.2.

4. FIELD WORK RESULTS

Details of the conditions encountered in the test bores are given in the test bore report sheets in Appendix 2 and are summarised below. The bores were drilled with a 100 mm diameter hand auger to depths of 0.4 m to 1.6 m. The location of the test bores and DPT's are shown on Drawing 1 – Site Plan, in Appendix 1 with Bore 1 located in the approximate position of the proposed carport at the rear of the site and Bores 2 and 3 located in the location of the proposed eastern extension.

The sub-surface conditions encountered in the bores was relatively similar with each bore summarised as follows:

Bore 1 encountered topsoil consisting of silty sand to a depth of 0.3 m underlain by extremely low strength sandstone. The test bore was terminated at a depth of 0.5 m due to auger refusal on the sandstone. The dynamic penetrometer test conducted at this location indicated highly weathered extremely low and very low strength sandstone to a depth of approximately 1.5 m with refusal encountered at 1.65 m, likely on low strength sandstone.

Bore 2 encountered topsoil consisting of silty sand to a depth of 0.20 m underlain by a thin layer of clayey sand to 0.3 m then sandy clay layers to 1.0 m underlain by silty clay layers to 1.5 m where extremely low strength sandstone was encountered. The test bore was terminated at a depth of 1.60 m due to auger refusal on the sandstone.

Bore 3 encountered silty sand topsoil to 0.2 m then clayey sand filling with sandstone rubble and some building rubble. The bore was terminated at 0.4 m due to auger refusal within the filling but the dynamic penetrometer test indicated the likely presence of weathered sandstone at 1.5 m.

The results of the DPT's indicate that the natural clay soils underlying the eastern section of the building footprint are generally in a firm to stiff condition becoming stiff to very stiff just above the upper horizon of the weathered rock profile with the weathered rock profile generally at a depth of 1.5 m across the eastern sections of the development area.

Groundwater was not observed in the bores at the time of the investigation but allowance should be made for runoff and groundwater seepage during construction due to local topographic conditions, should rain events be experienced during the construction period.

Several sandstone outcrops (likely boulders) were observed on the western areas of the site and are likely scattered across the areas upslope of the site.

5. PROPOSED DEVELOPMENT

It is understood that the proposed development for this site comprises alterations and additions to the existing residence including construction of a new double carport with roof that will access Livistona Lane to the rear of the site, an extension to the upper and lower levels of the eastern side of residence and modification to the ground floor (upper) level layout.

Reference to Robert Jones Architects Development Application plans dated October 2020 indicate that the concrete slab for the carport will be at RL 42.20 with the lower level floor at RL 30.65 and the upper level floor at RL 34.07.

6. COMMENTS

6.1 Inferred Geological Profile

The results of the field work and knowledge gained from previous work in the area indicates that the geological profile underlying the site consists of sandy topsoils and clays over a relatively shallow bedrock profile consisting of fine grained sandstone, siltstone and shale from the Newport Formation within the Narrabeen Group. The results of the field work indicate that the upper horizon of the weathered bedrock profile is approximately 1.5 m below the existing ground surface levels across the eastern areas of the proposed building platform area and 0.5-1.0 m across the western upslope area where the carport will be located. There are several large sandstone outcrops at the front and rear of the residence, likely boulders that have been dislodged from upslope cliff lines.

6.2 Stability Risk Assessment

The results of the geotechnical investigation indicated that the site is currently performing well with no evidence of recent instability. Possible hazards identified that exist currently and as a result of the proposed development and the assessment of their likelihood, consequence and risk to property and life are presented in Tables A and B in Appendix 4. A description of the terms used in Tables A and B is given in Appendix 5.

Assessment of the site has been made in accordance with the methods and requirements as outlined by the Australian Geomechanics Society Landslide Taskforce, Landslide Practice Note Working Group paper titled 'Practice Note Guidelines for Landslide Risk Management 2007', and Northern Beaches Council's Geotechnical Risk Management Policy.

The results in Table A indicate that the assessed risk to property is Very Low and Low for existing site conditions and for site conditions resulting from the proposed development which is considered acceptable. We have also calculated the risk to life based on the indicative annual probabilities associated with the likelihood of instability and found that the risk to life is acceptable for all hazards considered.

The proposed development for this site, when assessed in accordance with the requirements of the Geotechnical Risk Management Policy, is considered to have achieved the 'Acceptable Risk Management' criteria for both property and life and that the site is suitable for the proposed development to be carried out provided that the recommendations provided in this report are adopted.

Some guidelines for hillside construction and examples of both good and poor hill side construction practice are given in Appendix 6.

6.3 Excavation

Review of the architectural plans indicates that only very minor excavation will be required with excavation of 1-1.5 m required at the front of the existing residence with the excavation generally involving trimming of the large sandstone boulder underlying the front section of the residence. This boulder consists of medium to high strength sandstone and care should be taken when excavating adjacent to existing foundations. It is likely that temporary propping of the front section of the residence will be required until the rear wall of the lower extension is complete.

If excavation faces are not to be retained they should be trimmed to a gradient that will ensure stability in both the short term during construction and the long term over the design life. The following table lists suggested batter slopes for materials likely to be encountered during excavation.

Table 1 - Batter Slopes

Material	Safe Batter Slope (H:V)	
	Short Term/ Temporary	Long Term/ Permanent
Compacted filling	1.5:1	2.5:1
Sandy and clayey soils	1.5:1	2:1
Clayey Sandstone (extremely low strength)	1:1	1.5:1
Sandstone / Siltstone (very low & low strength)	0.5:1	0.75:1 *
Sandstone / Siltstone (medium or higher strength)**	Vertical *	0.25:1 *

* Dependent upon jointing and the absence of unfavourably oriented joints
** Unlikely to be encountered within the depth of excavation.

6.4 Foundations

The results of the field work indicate that weathered bedrock is at relatively shallow depth below the existing ground surface levels and as such any new foundations for the development should be founded within the bedrock. It is recommended that shallow piers, founding in the weathered sandstone bedrock, be used to support the eastern extension to the residence and the double carport and storage structure at the rear of the site with the piers dimensioned based on founding in extremely low strength sandstone, with an allowable bearing pressure (for serviceability) of 600 kPa, increasing to 1000 kPa if founded in very low strength sandstone and 1500 kPa if founded in low strength sandstone. A minimum embedment of 0.5 m into the sandstone bedrock is recommended.

Settlement is expected to be less than 1% of the footing width for footings founded in sandstone bedrock.

A geotechnical engineer should inspect and verify the founding strata for any new footings at the time of construction.

Some additional information on performance and maintenance of footings for residential developments is given in CSIRO BTF 18 which is enclosed in Appendix 7.

6.5 Retaining Walls

Where space limitations preclude the battering of either cut or filled slopes, it will be necessary to provide support to the cut or filled embankments using an appropriate "engineer designed" retaining wall system. The rear wall of the lower level extension will be required to act as a retaining wall.

Pressures acting on retaining walls can be calculated based on the parameters listed in Table 2 for the materials likely to be retained.

Table 2 - Retaining Structures Design Parameters

Material	Unit Weight (kN/m^3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (K_a)	At Rest (K_o)	
Residual clayey soils and filling	20	$\phi' = 25°$	0.35	0.5	2.0
Very low and low strength rock (jointed)	22	$\phi' = 20°$	0.25	0.4	400 kPa
Low strength rock	22	$\phi' = 20°$	0.20		2000 kPa
Medium or better strength rock	22	$\phi' = 30°$	0.1		6000 kPa

* Ultimate design values

Retaining walls should be designed for free draining granular backfill and appropriate surface and subsoil drains to either divert or intercept groundwater flow which otherwise could provide surcharging on the walls and additional pressures which may cause damage or failure of the walls. Reinforced core filled concrete block walls would be appropriate.

6.6 Site Drainage

In order to maintain an acceptable level of risk of landslide it is crucial to control site drainage from both upslope areas and on the site itself. It is recommended that the existing stormwater drainage system be assessed for adequacy including all existing drainage infrastructure such as stormwater pipes and pits, roof gutters and down pipes. If the strata overlying bedrock is allowed to become saturated due to inadequate drainage or a broken service pipe, then the risk of slip or erosion would be significantly increased.

6.7 Design Life of Structure

We have interpreted the design life requirements specified within Councils Geotechnical Risk Management Policy to refer to structural elements designed to support the house, proposed garage and the adjacent slope, control stormwater and maintain the risk of instability within acceptable limits.

Specific structures that may affect the maintenance and stability of the site in relation to the proposed development are considered to comprise:

- Retaining structures to support embankments/terraces adjacent to the lower ground floor,
- Stormwater and subsoil drainage systems,
- Rainwater and or Sewage Tanks,
- Maintenance of trees on this and adjacent properties.

These features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 – 1966 (70 years)) In order to attain a design life of 100 years as required by the Councils Geotechnical Risk Management Policy, it will be necessary for the structural and geotechnical engineers to incorporate appropriate design and inspection procedures during the construction period and the property owner adopt and implement a maintenance and inspection program. A recommended program is given below and includes those in Table C enclosed in Appendix 8.

- The site is inspected 12 months after the development is complete to verify that there have been no changes to the site stability by both the Structural Engineer and Geotechnical Consultant (at the same time, same day).

- The conditions on the block don't change from those present at the time this report was prepared, except for the changes due to this development.
- There is no change to the property due to an extraordinary event external to this site, and the property is maintained in good order and in accordance with the guidelines set out in;
    a) CSIRO BTF 18 (see Appendix 7) and,
    b) The Australian Geomechanics article "Geotechnical Risk Associated with Hillside Development" Number10, December 1985.

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to a relevant professional (e.g. structural engineer or geotechnical engineer).

6.8 Geotechnical Verification

In order to verify design bearing capacities and founding strata for footings and retaining walls (if required), a certification schedule will be required. In order for any footings to be certified, and thus comply with Northern Beaches Council development policy conditions (completion of Form 3), a geotechnical engineer or engineering geologist must inspect and verify the founding strata for any new footings and retaining walls at the time of construction to ensure that they comply with the certification schedule.

7.0 CONDITIONS RELATING TO MONITORING OF DESIGN AND CONSTRUCTION

In order to comply with Northern Beaches Council conditions and to allow the completion of Forms 2 and 3 required as part of the construction and post construction certification requirements of the Geotechnical Risk Management Policy, it will be necessary for Taylor Geotechnical Engineering Pty Limited to carry out the following:

1. Review the structural design drawings for compliance with the geotechnical recommendations in this report (for Form 2 Part B sign off).

2. Inspect any excavations for every 1.5 m depth interval to assess the need for specific stabilisation requirements.

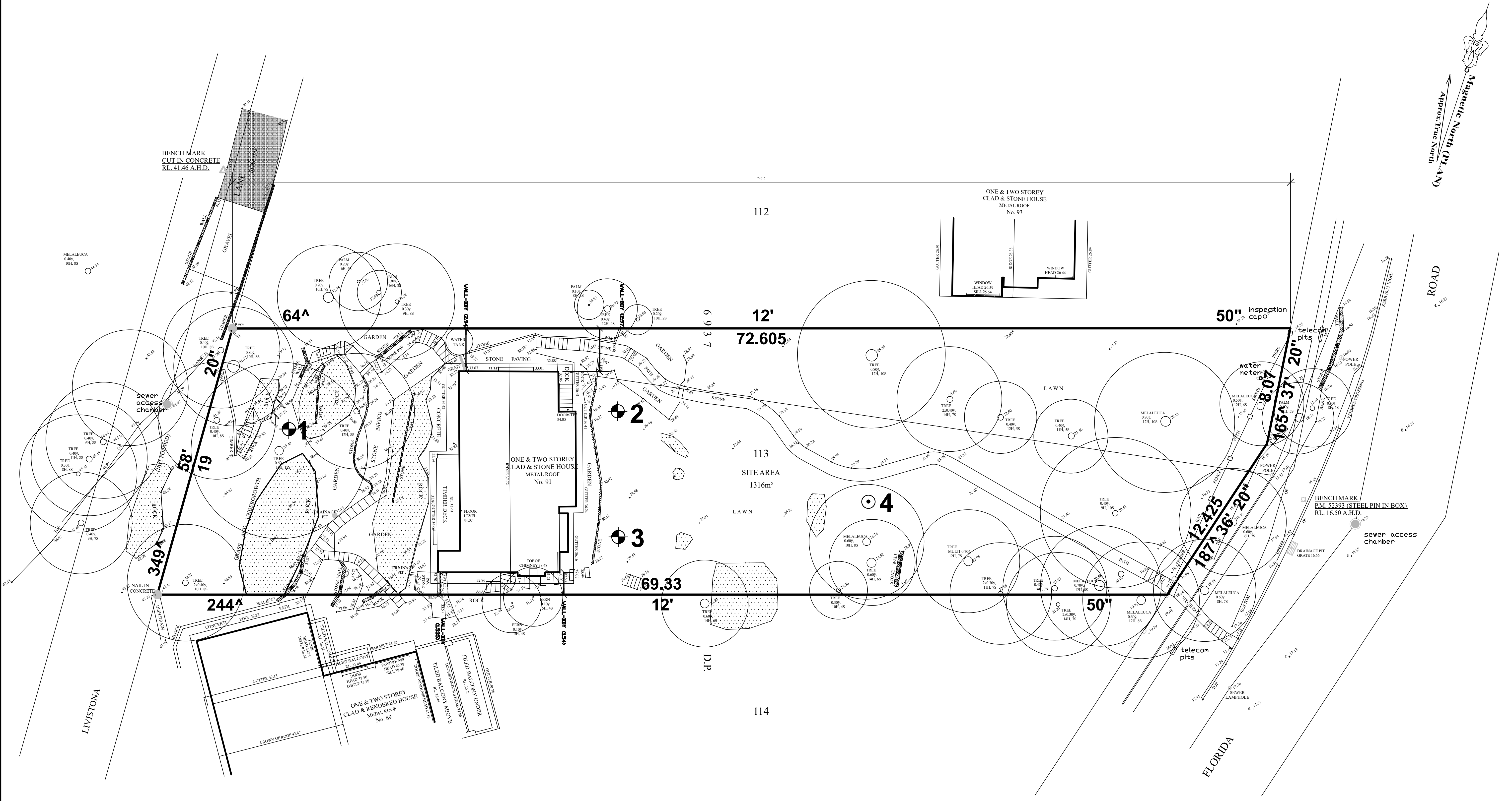
3. Inspect retaining wall construction to ensure compliance with recommendations made in this report (for Form 3 sign off).

4. Inspect all footings prior to the placement of steel and concrete (for Form 3 sign off).

TAYLOR GEOTECHNICAL ENGINEERING PTY LIMITED,

Lachlan Taylor
MIEAust. CPEng. NER
Principal Geotechnical Engineer

Appendix 1



Approximate location of test bore.

Approximate location of dynamic penetrometer test only.

Approximate location of sandstone outcrop.

Note: Survey carried out by others.

TGE *Taylor Geotechnical Engineering* Geotechnical Civil Engineers & Project Managers	*Taylor Geotechnical Engineering Pty Ltd* *PO Box 1906* *Dee Why NSW 2099* *taylorgeotech@bigpond.com* *ABN: 22 120 426 155* *Phone: (02) 9999 6625* *Fax: (02) 9999 6650* *Mobile: 0407 984 128*	Drawing 1 - Site Plan Proposed Residential Development 91 Florida Road Palm Beach	Project: TGE22046 20 November 2020 Scale: As Shown

Appendix 2

TEST BORE REPORT

CLIENT: Alex & Kiki Hill
DATE: 4-Nov-2020
Bore No: **1**

PROJECT: Proposed Residential Development
PROJECT No.: TGE22046

LOCATION: 91 Florida Road Palm Beach
SURFACE LEVEL: RL = 39.0*

Depth (m)	Description of Strata	Sampling & In Situ Testing			
		Type	Depth (m)	Blows/150mm N Value	Core Recovery%
0.00	TOPSOIL - Dark brown silty sand with some sandstone gravel.				
0.30	SANDSTONE - Extremely low & very low strength, orange brown & yellow brown, fine to medium grained sandstone.				
0.50	TEST BORE DISCONTINUED AT 0.5 METRES. Auger refusal on sandstone.				

RIG: Hand Auger
DRILLER: Taylor
TYPE OF BORING: 100mm diameter auger
LOGGED: Taylor
GROUND WATER OBSERVATIONS: No Free Groundwater Observed.
CHECKED: [signature]
REMARKS: *RL interpolated from survey plan.

SAMPLING & IN SITU TESTING LEGEND
D = Disturbed auger sample
B = Bulk sample
Ux = x mm dia. Tube Sample

Taylor Geotechnical Engineering

TEST BORE REPORT

CLIENT: Alex & Kiki Hill | DATE: 4-Nov-2020 | Bore No: **2**

PROJECT: Proposed Residential Development | PROJECT No.: TGE22046 |

LOCATION: 91 Florida Road Palm Beach | SURFACE LEVEL: RL = 30.1*

Depth (m)	Description of Strata	Sampling & In Situ Testing			
		Type	Depth (m)	Blows/150mm N Value	Core Recovery%
0.00	TOPSOIL - Dark brown silty sand.				
0.20	CLAYEY SAND - Loose, grey brown, fine to medium grained clayey sand.				
0.30	SANDY CLAY - Firm, yellow brown, fine to medium grained sandy clay.				
0.55	SANDY CLAY - Stiff, yellow brown, orange brown & grey fine to medium grained sandy clay.				
0.75	SANDY CLAY - Stiff, grey, orange brown & yellow brown fine to medium grained sandy clay.				
1.00	SILTY CLAY - Stiff to very stiff, grey & orange brown silty cllay.				
1.30	SILTY CLAY - Stiff to very stiff, red brown, grey & orange brown, silty clay with some ironstone.				
1.50	SANDSTONE - Extremely low strength, red brown, orange brown & grey, fine to medium grained sandstone.				
1.60	TEST BORE DISCONTINUED AT 1.6 METRES. Auger refusal on sandstone.				

RIG: Hand Auger | DRILLER: Taylor

TYPE OF BORING: 100mm diameter auger | LOGGED: Taylor

GROUND WATER OBSERVATIONS: No Free Groundwater Observed. | CHECKED: [signature]

REMARKS: *RL interpolated from survey plan.

SAMPLING & IN SITU TESTING LEGEND

D = Disturbed auger sample

B = Bulk sample

Ux = x mm dia. Tube Sample

Taylor Geotechnical Engineering

TEST BORE REPORT

CLIENT: Alex & Kiki Hill — DATE: 4-Nov-2020 — Bore No: **3**

PROJECT: Proposed Residential Development — PROJECT No.: TGE22046 — 1 of 1

LOCATION: 91 Florida Road Palm Beach — SURFACE LEVEL: RL = 29.8*

Depth (m)	Description of Strata	Sampling & In Situ Testing			
		Type	Depth (m)	Blows/150mm N Value	Core Recovery%
0.00	TOPSOIL - Dark brown silty sand.				
0.20	FILLING - Grey brown, fine to medium grained clayey sand with sandstone rubble and clay pipe pieces.				
0.40	TEST BORE DISCONTINUED AT 0.4 METRES. Auger refusal in filling.				

RIG: Hand Auger — DRILLER: Taylor

TYPE OF BORING: 100mm diameter auger — LOGGED: Taylor

GROUND WATER OBSERVATIONS: No Free Groundwater Observed. — CHECKED:

REMARKS: *RL interpolated from survey plan.

SAMPLING & IN SITU TESTING LEGEND

D = Disturbed auger sample

B = Bulk sample

Ux = x mm dia. Tube Sample

Taylor Geotechnical Engineering

RESULTS OF DYNAMIC PENETROMETER TESTS

CLIENT: Alex & Kiki Hill

DATE: 4 November 2020

PROJECT: Proposed Residential Development

PROJECT No: TGE22046

LOCATION: 91 Florida Road Palm Beach

SHEET: 1 of 1

	PENETRATION RESISTANCE BLOWS / 150mm									
TEST LOCATION	**1**	**2**	**3**	**4**						
DEPTH (m)										
0.00 - 0.15	2	1	1	3						
0.15 - 0.30	3	2	2	3						
0.30 - 0.45	4	2	2	4						
0.45 - 0.60	10	2	8	4						
0.60 - 0.75	6	3	5	5						
0.75 - 0.90	8	4	5	5						
0.90 – 1.05	6	5	5	8						
1.05 – 1.20	6	4	Refusal	9						
1.20 – 1.35	6	5		7						
1.35 – 1.50	8	6		8						
1.50 – 1.65	21	7		15						
1.65 – 1.80	Refusal	10		Refusal						
1.80 – 1.95		15/50mm								
1.95 – 2.10										
2.10 – 2.25										
2.25 – 2.40										
2.40 – 2.55										
2.55 – 2.70										
2.70 – 2.85										
2.85 – 3.00										

TEST METHOD: AS 1289.6.3.2, CONE PENETROMETER YES

AS 1289.6.3.3, FLAT END PENETROMETER

TESTED BY: Taylor

REMARKS:

Taylor Geotechnical Engineering

Appendix 3

Photo 1 – View of site from Florida Road, looking west.

Photo 2 – View of eastern section of site, looking east.

Photo 3 – View of large sandstone outcrop at rear of residence, looking south.

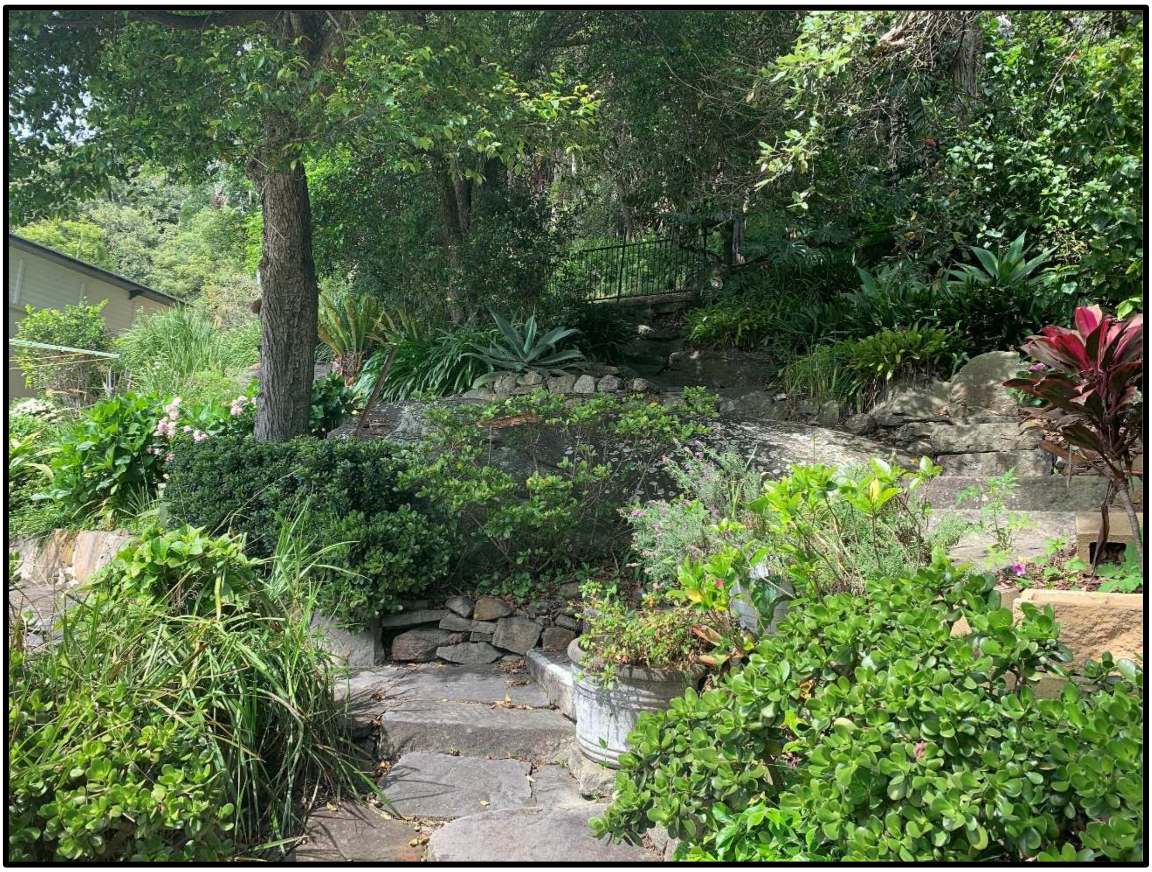


Photo 4 – View of terraced gardens in the western section of the site, looking south west.

Photo 5 – View of site from rear boundary, looking east.

Photo 6 – View of sandstone outcrop under front section of residence.

Appendix 4

Table A - Risk Assessment for Property

Hazard	Likelihood	Consequence	Risk Level	Comments
Failure of existing retained terraced garden beds across western area of site upslope of residence.	Rare	Minor to insignificant	Very Low	Walls are generally less than 0.6 m and show no signs of movement.
Failure of existing embankment across front boundary of site.	Unlikely	Insignificant	Very Low	Embankment is not excessively steep and less than 1.5 m in height and is well vegetated.
Global slope failure across western section of site.	Rare	Major	Low	Shallow bedrock profile drainage to be incorporated into the proposed development.

Table B - Risk Assessment for Life

Hazard / Factor	Failure of existing retained terraced garden beds across western area of site upslope of residence.	Failure of existing embankment across front boundary of site.	Global slope failure across western section of site.
Likelihood	Rare	Unlikely	Rare
Indicative Annual Probability	10^{-5}	10^{-4}	10^{-5}
Persons at risk	a) People in rear courtyard on western side of residence.	a) People in front of property.	People in residence.
Number of People Considered	a) 2	a) 2	4
Probability of Spatial Impact	a) 0.5	a) 0.3	0.5
Proportion of time affected area is used	a) 2hr / day = 0.084	a) 0.5hr / day = 0.0208	16hrs / day = 0.66
Probability of not Evacuating	a) 0.1, warning likely	a) 0.1, warning likely	1, warning unlikely
Vulnerability	a) 0.2 unlikely to be buried	a) 0.2 unlikely to be buried	0.5, structure unlikely to collapse
Risk of Person most at risk	a) $8.4 x 10^{-9}$	a) $1.25 x 10^{-8}$	$1.65 x 10^{-6}$
Total Risk	$1.68 x 10^{-8}$	$2.5 x 10^{-8}$	$6.6 x 10^{-6}$
Risk Evaluation	Acceptable	Acceptable	Acceptable

Appendix 5

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

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}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	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: – 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.

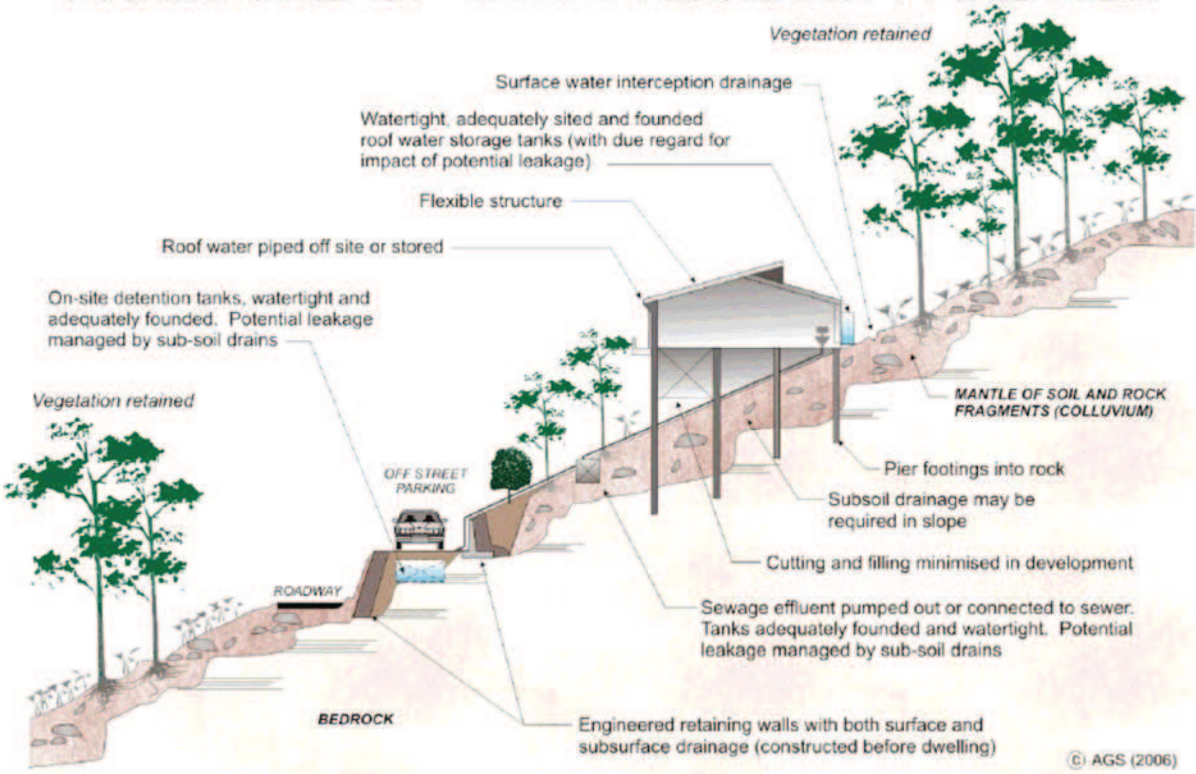
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Appendix 6

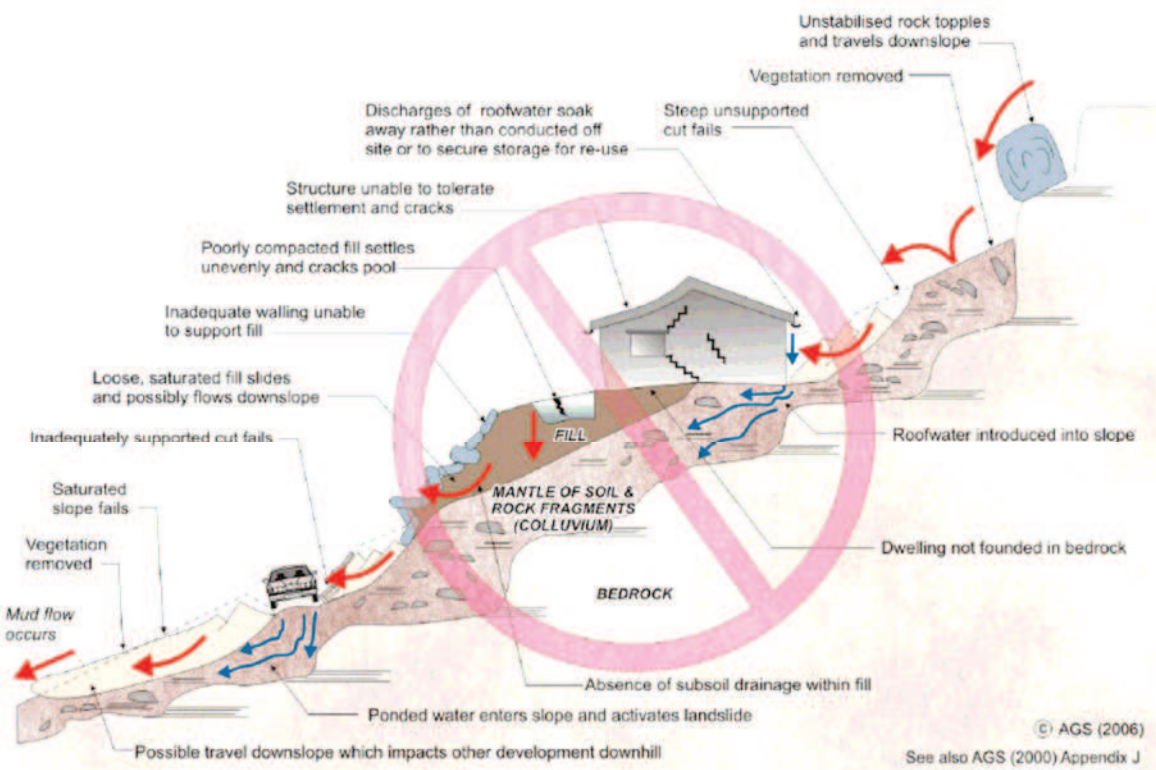
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	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



Appendix 7

Foundation Maintenance and Footing Performance: A Homeowner's Guide

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

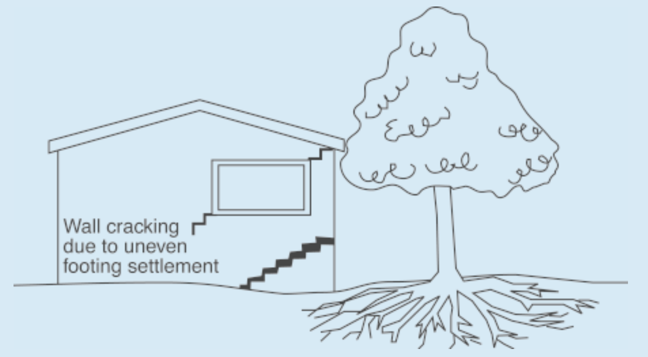
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

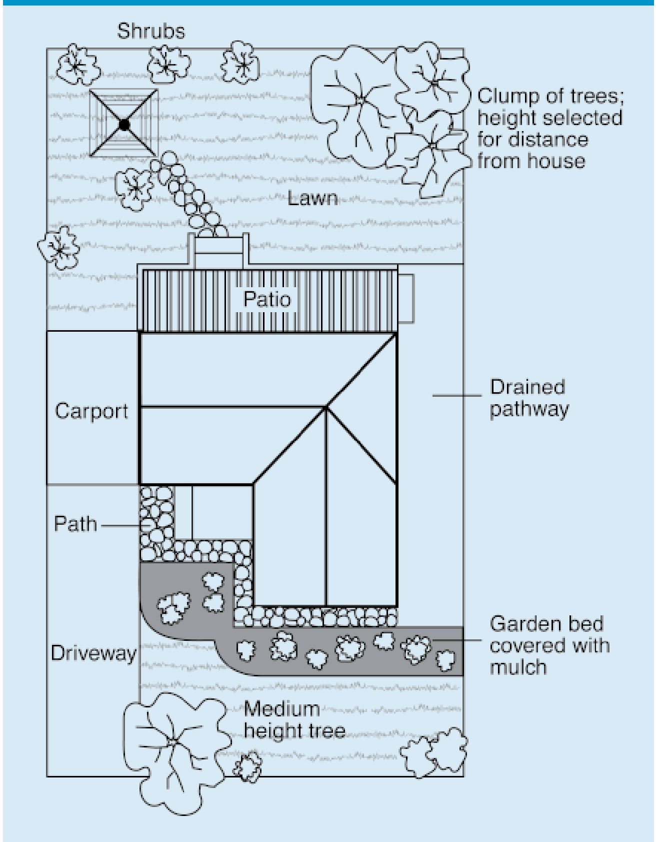
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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Appendix 8

TABLE C – RECOMMENDED MAINTENANCE AND INSPECTION PROGRAM

Structure	Maintenance / Inspection Item	Frequency
Stormwater Drains	Owner to inspect to ensure that the drains and pipes are free of debris and sediment build-up. Clear roof gutters, surface grates and drainage pits.	Every year or following every major rainfall event.
Retaining Walls	Owner to inspect walls for deviation from as constructed condition.	Every two years or following a major rainfall event.
Rainwater Tanks	Owner to inspect for leaks from tank.	Every year
Large Trees on site	Arbourist to check the condition of trees to ensure stability.	Every five years or after a major storm event.
Slope stability	Hydraulics (stormwater) & geotechnical consultants to check site stability at the same time and provide report.	One year after construction is completed.

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1 – To be submitted with Development Application

Development Application for____

Name of Applicant

Address of site _91 Florida Road Palm Beach__

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, **LACHLAN TAYLOR** *on behalf of* **TAYLOR GEOTECHNICAL ENGINEERING PTY LIMITED**
(Insert Name) (Trading or Company Name)

on this the **20th November 2020** certify that I am a geotechnical engineer ~~or engineering geologist or coastal engineer~~ as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.
I have:

Please mark appropriate box

■ Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ I am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ Have examined the site and the proposed development/alteration in detail and am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements for Minor Development/Alterations.

☐ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: **TGE22046 Report on Geotechnical Investigation 91 Florida Road Palm Beach**

Report Date: **20th November 2020**

:

Author: **Lachlan Taylor**

Author's Company/Organisation: **Taylor Geotechnical Engineering Pty Limited**

Documentation which relate to or are relied upon in report preparation:

Robert Jones Architects DA Edition architectural plans dated October 2020
Bee & Lethbridge Pty Ltd survey plan Drawing No. 21704 dated 22/06/2020

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ....

Name ...**LACHLAN TAYLOR**...

Chartered Professional Status **CPEng MIEAust NER**.........

Membership No. **2145895**...

Company...**Taylor Geotechnical Engineering Pty Limited**

ENGINEERS AUSTRALIA
Lachlan Taylor
MIEAust CPEng
Chartered Professional Engineer
Membership No. 2145895

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for____
Name of Applicant

Address of site **91 Florida Road Palm Beach** ____________________

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: **TGE22046 Report on Geotechnical Investigation 91 Florida Road Palm Beach**

Report Date: **20th November 2020**

Author: **Lachlan Taylor**

Author's Company/Organisation: Taylor Geotechnical Engineering Pty Limited

Please mark appropriate box

- ■ Comprehensive site mapping conducted **4th November 2020** (date)
- ■ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- ■ Subsurface investigation required
  - □ No Justification ....
  - ■ Yes Date conducted ...**4th November 2020**

Geotechnical model developed and reported as an inferred subsurface type-section
Geotechnical hazards identified

- ■ Above the site
- ■ On the site
- ■ Below the site
- ■ Beside the site

- ■ Geotechnical hazards described and reported
- ■ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - ■ Consequence analysis
  - ■ Frequency analysis
- ■ Risk calculation
- ■ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
- ■ Design Life Adopted:
  - ■ 100 years
  - □ Other .... specify
- ■ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ■ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- □ Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ....

Name ... **LACHLAN TAYLOR** ....

Chartered Professional Status...**CPEng MIEAust NER** ...

Membership No. ...**2145895**......................................

Company... **Taylor Geotechnical Engineering Pty Limited**

ENGINEERS AUSTRALIA
Lachlan Taylor
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