Keith Skinner c/o Space Landscape Designs

# Proposed Retaining Wall to Driveway
# 114 Whale Beach Road, Whale Beach NSW

## Geotechnical Assessment

Our ref: 6386-G1
1 April 2021

Your trusted engineering professionals

## Document Authorisation

**Proposed Retaining Wall to Driveway**
**114 Whale Beach Road, Whale Beach NSW**
**Geotechnical Assessment**

Prepared for Keith Skinner

Our ref: 6386-G1
1 April 2021

For and on behalf of
**AssetGeoEnviro**


Mark Bartel

**Mark Bartel**
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## Document Control

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## Contents

# 1. Introduction

## 1.1 General

This report presents the results of a Geotechnical Assessment for a proposed retaining wall to a driveway at 114 Whale Beach Road, Whale Beach (the Site). The assessment was commissioned on 5 February 2021 by Mr Keith Skinner. The work was carried out in accordance with the proposal by AssetGeoEnviro (Asset) dated 29 January 2021, reference 6386-P1.

We understand that it is proposed to extend an existing driveway and constructing a new retaining wall at the Site. A Development Application (reference DA2020/1186) was lodged and included the following studies in support:

- Geotechnical Investigation by White Geotechnical Group (WGG), reference J2915 dated 20th November 2020.
- Arboricultural Impact Assessment Report by Urban Armour, reference 200831_114 Whale_AIA dated 31 August 2020.

The geotechnical report by WGG assessed that the tree immediately above the existing driveway presents an unacceptably high risk with respect to property and life and recommended that the tree be removed, and the ground supported by a retaining wall. It is noted that the WGG report does not provide a breakdown as to how the assessed risk to life was obtained.

The report by Urban Armour assessed that the soil below the woody/structural roots and trunk of the abovementioned tree appeared to be eroding, which may be undermining the tree's root system and the tree may be unstable. The report recommended that the tree be removed as part of the construction.

Northern Beaches Council has refused the application as advised by letter dated 10 December 2020 including their Development Application Assessment Report, citing that "…there was sufficient soil volume to support the existing trees and that the ongoing erosion was minor and did not impact the stability of the trees." It is noted that Council did acknowledge that the property lies within a geotechnical landslip area but then did not specifically address the risk of instability of this tree in accordance with the methods in AGS 2007[1] which is required under Council's "Geotechnical Risk Management Policy for Pittwater – 2009".

The objective of the Geotechnical Assessment is to provide a more detailed assessment of the risk of instability with respect to the tree in question with regard to risk to property and life as per Council requirements, in support of an appeal against Council's determination.

## 1.2 Scope of Work

The following scope of work was carried out to achieve the project objectives:

- A review of existing regional maps and reports relevant to the site held within our files.
- Visual observations of surface features by a Senior Principal Geotechnical Engineer from Asset with experience in carrying out landslide risk assessment and analysis.
- Engineering assessment and reporting as per AGS 2007.

[1] Landslide Risk Management, Australian Geomechanics, Vol 42, No. 1, March 2007.

This report must be read in conjunction with the attached "Important Information about your Geotechnical Report" in Appendix A. Attention is drawn to the limitations inherent in geotechnical assessments and the importance of verifying the subsurface conditions inferred herein. Slope instability considerations presented in this report must be read in conjunction with the attached GeoGuides for Slope Management and Maintenance.

# 2. Site Description

## 2.1 Site Geology & Topography

The site is located on the south western side of Whale Beach Road in Whale Beach as shown in the attached Figure 1.

Regionally, the site is located within moderately sloping terrain with an overall slope of about 20° to 25° to the north east.

The 1:100,000 Sydney Geological Map indicates the site is underlain by the Newport Formation of the Narrabeen Group with Hawkesbury Sandstone indicated in higher elevation parts of the site (south-western portion). In the general Pittwater area, cliff line development includes erosion and detachment of sandstone blocks from the original cliff line and forming talus deposits including sandstone boulders within a soil matrix.

Regional geotechnical hazard mapping has been carried out within the Pittwater Council municipality by GHD LongMac, and the results of the mapping are presented in Pittwater Council's GRMP. The maps indicate the front, north-eastern part of the site lies within an area mapped as Hazard Zone 3, and the rear, south-western part lies within an area mapped as Hazard Zone 1, as shown in Figure 1. It is also noted that Whale Beach Road in front of the site and slope north of the road are also mapped as Hazard Zone 1. Further information on Pittwater Hazard Mapping is provided in Appendix A.

We are not aware of any recorded slope instability affecting the subject site or immediate adjoining site.

## 2.2 Site Features – Front Part of Site

The site is approximately 20m wide by approximately 67m to 70m long and is bounded by Whale Beach Road to the north and residential developments to the west, south, and east, as shown in Figures 1 and 2. A Concrete driveway provides access from Whale Beach Road to the adjoining property to the west and to the front of the property, as shown in Figures 2 and 3. It is proposed to widen the driveway and construction a new retaining wall as indicated in Figures 2 and 3.

An un-retained steep cut (estimated slope angle of about 60° to 70° below horizontal) up to about 2.7m high is present along the southern side of the driveway with sandstone flagging placed against the lower part, as shown in Photos 1 and 2.

The tree in question is located at the top of this cut. The tree has developed a lean of about 6° downslope over the lower part of the trunk as indicated in Photo 3, although the upper part of the tree and canopy appear to be approximately vertical.

The material exposed in the cut comprises topsoil over residual clays up to about 1m thick over weathered sandstone bedrock. The clays are desiccated, and the sandstone bedrock is generally extremely to highly weathered and of extremely low to low strength. There were no obvious signs of instability in the cut other than erosion as noted below.

Closeup photos of the base of the tree trunk, exposed roots, eroded soils and rock, and sandstone flagging are shown in Photos 4 to 9. The erosion has extended in beneath the outside base of the tree by approximately 400mm distance (Photos 6, 7, and 8) and also around the eastern side of the tree (Photo 9). Erosion mechanisms include:

- desiccation cracking of clay soils leading to subsequent spalling of blocks of clay;
- surface water flow washing away soil particles;
- rock fragments breaking off along planes of weakness (e.g. bedding planes and joints) aided by temperature changes; and
- tree roots growing into soils and defects in the rock causing dislodgement.

The tree roots supporting the subject tree are partly exposed as previously noted, including a significant vertical root down the face of the cut and a series of horizontal roots.

An exposure of sandstone bedrock in the cutting to the east of the tree is shown in Photo 10, indicating bedding dipping to the east, and the presence of sub-vertical inclined joint with soil infill and a tree root growing in the joint.

For comparison, a driveway cut in sandstone bedrock was observed to the east of the Site adjacent to the driveway up to № 110 and 112 Whale Beach Road (see Photos 11 and 12). The remnant trunk of a tree was observed at the top of this cut, with an exposed vertical tree root down the face of the cut, in a very similar arrangement to the tree in question.

An interpreted section through the tree in question is provided in Figure 4.

### 2.3 Condition of Existing Tree

The Urban Armour report assessed that the existing tree (Tree ID #1) is a mature aged class tree which has a Safe Useful Life Expectancy (SULE) of between 5 and 15 years, and further notes that "The tree is located on a significant slope and at the time of inspection, the soil below woody/structural roots and trunk appeared to be eroding, which may be undermining the tree's root system and the tree may be unstable."

## 3. Landslide Risk Assessment

A landslide risk assessment has been carried out for the front part of the site, in particular, the tree in question at the top of the cut adjacent to the driveway, using the methods of AGS 2007.

The basis of the assessment undertaken for this site and important factors relating to slope conditions and the impacts of the development that commonly influence the risks of slope instability are discussed in the attached "Important Information about your Slope Instability Risk Assessment", and the attached GeoGuides.

The assessment has been carried out by:

- Consideration of the likely slope failure mechanisms and the likely initiating circumstances that could affect the elements at the site. The type and mode of landslide failure has also been classified.
- **Risk to Property.** For each case, the likely consequences with respect to the current development have been considered. The current assessed probability of occurrence of each event has been estimated on a qualitative basis. The consequences and probability of occurrence have been combined for each case to provide the risk assessment.
- **Risk to Life.** For each case, the risk for the person most at risk is assessed based on multiplying the indicative annual probability of the occurrence of the hazard, the probability of spatial impact, the temporal probability, the vulnerability, and the probability of not evacuating. The risk is then compared with acceptable and tolerable risk criteria.

The following potential hazard / event has been identified for this site:

A. Topple of tree (downslope to north).

For this hazard / event, the elements of development on / adjacent to the site that are at risk are the existing driveway, Whale Beach Road and footpath, and associated site development comprising services and utilities including overhead power / communications lines. Risk to persons includes those using the driveway in front of the tree, pedestrians on the footpath, and road traffic, either during the tree topple event, or afterwards (for persons in a vehicle that could potentially crash into the fallen tree). We have not considered the electrocution hazard that could apply in the event of fallen power lines. Table A provides our risk assessment for the site with respect to risk to property, and Table B provides our risk assessment for the site with respect to risk to life. Further explanation is provided below.

## 3.1 Risk to Property

The potential tree topple is likely to cause very little damage to property, assessed to be less than 0.1% of the value of the property. The consequence is therefore assessed to be 'Insignificant'.

The assessed likelihood based on a life expectancy of 5 to 15 years suggests an indicative annual probability of $2x10^{-1}$ to $6.7x10^{-2}$, which falls in the category of 'Almost certain'. We note that this likelihood of topple is based on the life expectancy. However, erosion of up to about 400mm extent under the tree has already occurred and further erosion is inevitable, to the extent that a topple is expected within the next 5 years, which is still in the category of 'Almost certain'.

For a combination of the above factors, the assessed risk to property is **Low**. This meets the minimum acceptance criteria for Northern Beaches Council with respect to risk to property.

## 3.2 Risk to Life

For the 'Risk to Life' calculation, we have taken the assessed likelihood assuming a 15-year life expectancy. We note that it is possible that further erosion of the soils and rock beneath the tree and its roots could result in loss of support and toppling within the next 5 years, and we have included this likelihood as an alternative.

A probability of spatial impact of 1 is assigned (i.e. assuming that a person as defined by temporal probability will be in the path of the tree).

An overall temporal probability is calculated assuming that the person is in the path of the falling tree during a nominal 5 second event out of a 12-hour time period (i.e. excluding night time when persons are likely to be asleep). For the case where a car runs into a fallen tree, the temporal probability becomes 1 but the vulnerability reduces considerably. This secondary calculation would require further assessment by traffic consultants / engineers and is outside the scope of this assessment.

A vulnerability of 1 is assigned (i.e. it is assumed that the tree would cause death if it struck a person). It is possible that a person might see the tree falling with sufficient warning to then avoid being struck, and an alternative value of 0.5 is adopted for the best-case scenario.

We have assumed that the falling tree would happen with sufficient speed such that the probability of avoiding the strike is very low (i.e. Probability of not evacuating = 1).

The combination of the above assessed factors gives a risk of $3.88 \times 10^{-6}$ for the best-case scenario and $2.31 \times 10^{-5}$ for the worst-case scenario, which are both **Tolerable** as per AGS 2007 definition. We note that this is higher than the acceptance criteria for Northern Beaches Council with respect to life, which is **Acceptable**.

## 4. Conclusion & Recommendations

Based on the observations, assessments and interpretations described above, it is our opinion that the risk of instability posed by the tree in question does not meet Northern Beaches Council's minimum requirements with respect to risk to life.

Underpinning or provision of additional support to the tree is not considered to be feasible without further jeopardising the stability of the tree. Whilst such measures, if possible, would reduce erosion from the base and roots of the tree, they would not extend the life expectancy of the tree.

We therefore recommend prompt removal of the tree by a licensed and experienced tree removal contractor in accordance with Council and SafeWork NSW requirements.

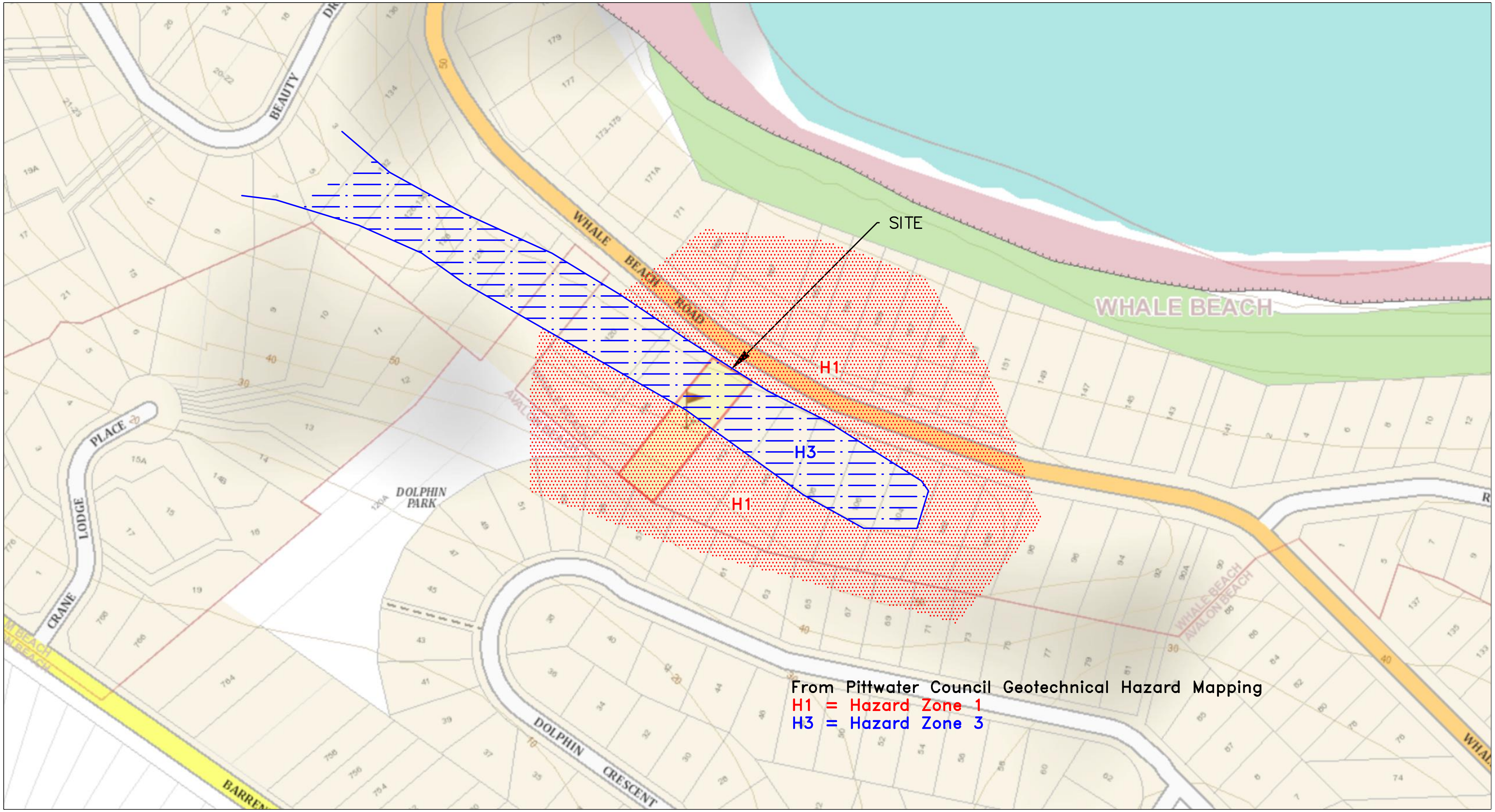
## 5. Limitations

In addition to the limitations inherent in geotechnical assessments (refer to the attached Information Sheets), it must be pointed out that the recommendations in this report are based on assessed subsurface conditions from limited observations.

This report and details for the proposed development should be submitted to relevant regulatory authorities that have an interest in the property (e.g. Council) or are responsible for services that may be within or adjacent to the site (e.g. water, power, gas), for their review.

Asset accepts no liability where our recommendations are not followed or are only partially followed. The document "Important Information about your Geotechnical Report" in Appendix A provides additional information about the uses and limitations of this report.

# Figures

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| A | 5.2.2021 | Initial issue |

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Geotechnical Assessment – Proposed Retaining Wall to Driveway
114 Whale Beach Road, Whale Beach NSW
for Space Landscape Designs

Site Locality & Geotechnical Hazard

drawn: MAB
date: 5.2.2021
checked: AT
scale: 1:2,500 A4

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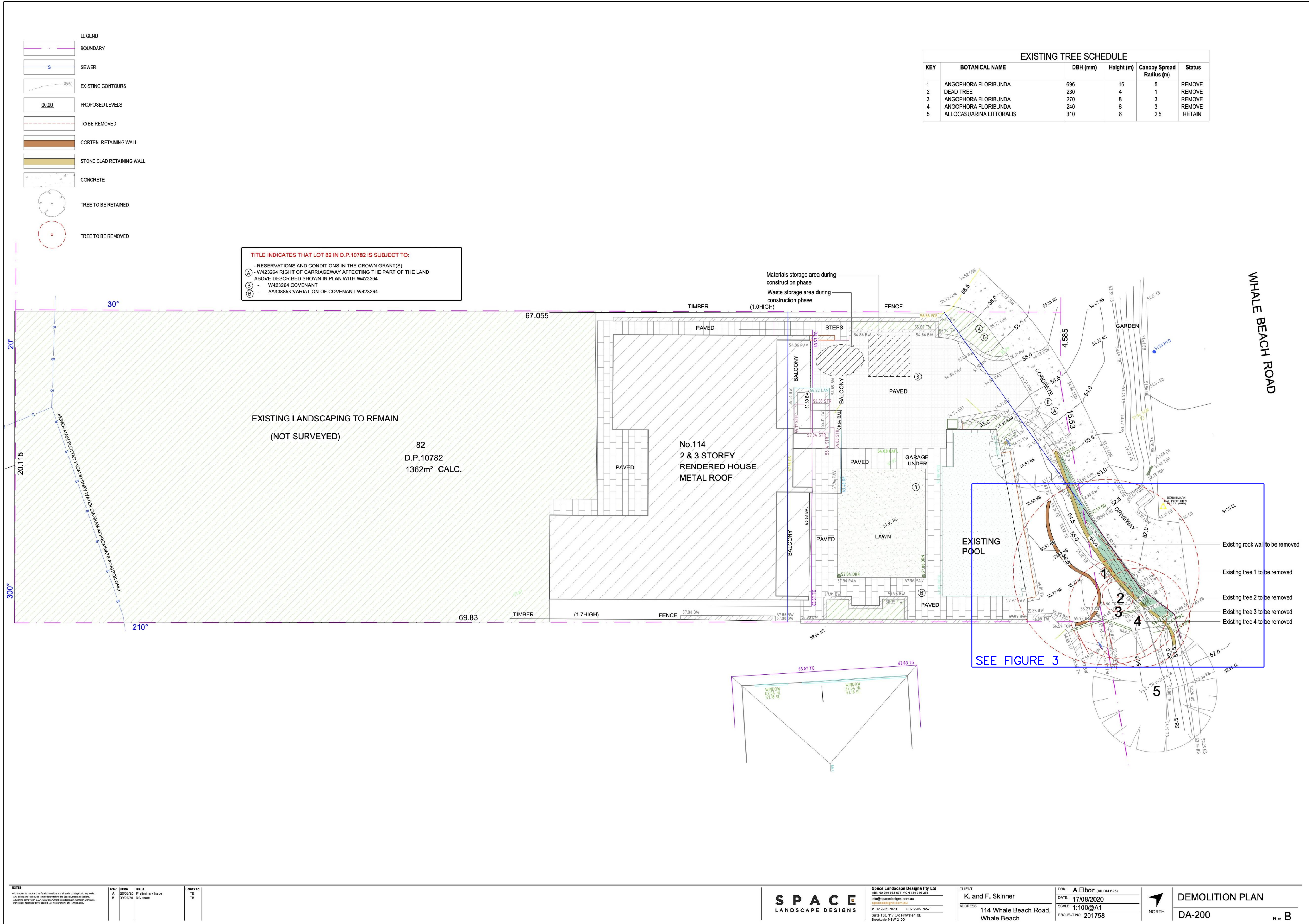
fig: 1
issue: A




| EXISTING TREE SCHEDULE | | | | | |
|---|---|---|---|---|---|
| KEY | BOTANICAL NAME | DBH (mm) | Height (m) | Canopy Spread Radius (m) | Status |
| 1 | ANGOPHORA FLORIBUNDA | 696 | 16 | 5 | REMOVE |
| 2 | DEAD TREE | 230 | 4 | 1 | REMOVE |
| 3 | ANGOPHORA FLORIBUNDA | 270 | 8 | 3 | REMOVE |
| 4 | ANGOPHORA FLORIBUNDA | 240 | 6 | 3 | REMOVE |
| 5 | ALLOCASUARINA LITTORALIS | 310 | 6 | 2.5 | RETAIN |

0 1:250 10m

Approximate only – subject to detail survey.
Source: Space Landscape Designs, Project 201758, Dwg DA-200, dated 17/08/2020.
This drawing is used to illustrate geotechnical features only and must not be used for any other purpose. Copyright of source drawing remains with Space Landscape Designs.

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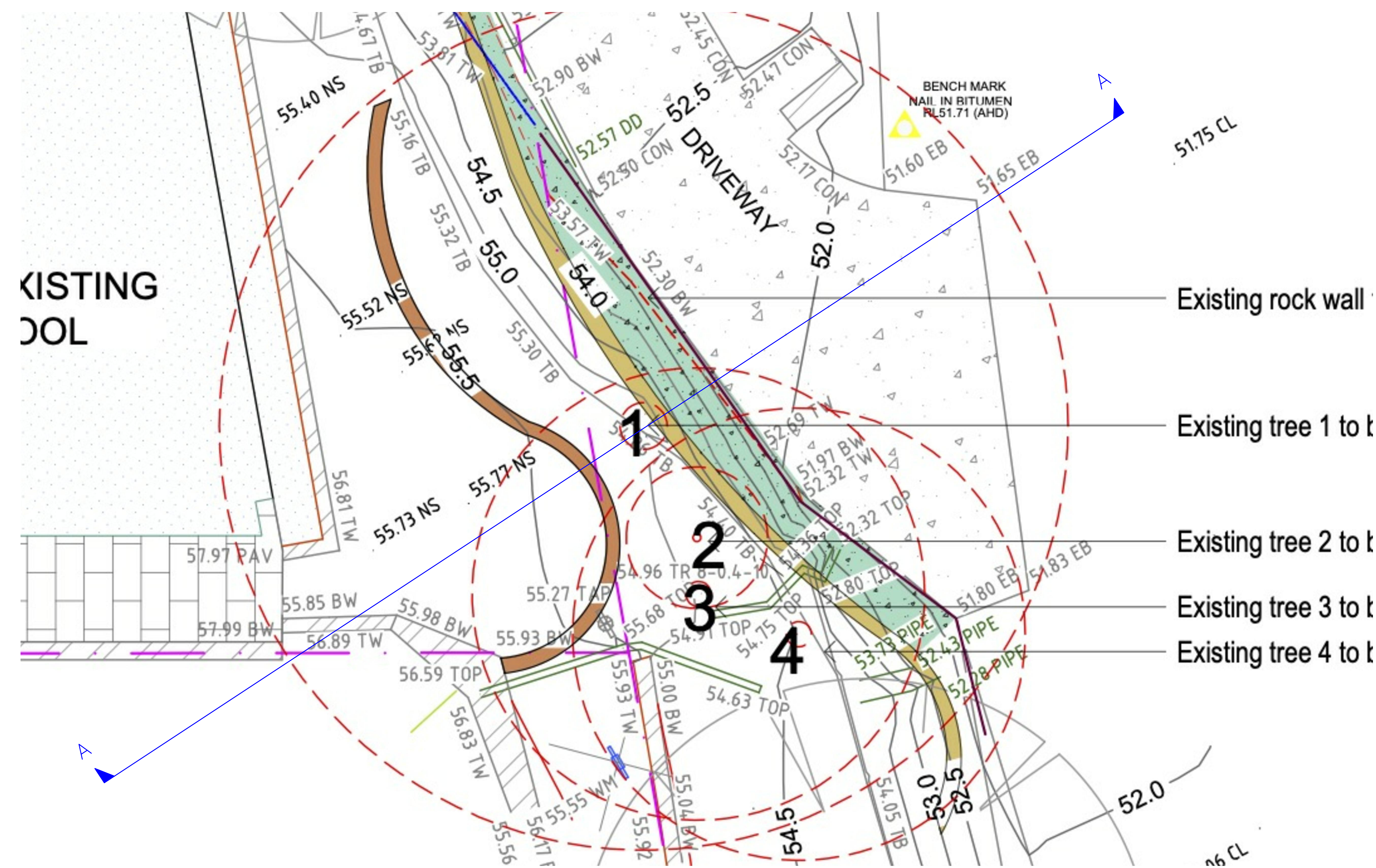
Site Plan

drawn: MAB
date: 5.2.2021
checked: AT
scale: 1:250 A3
job no.: 6386
fig: 2
issue: A

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Site Plan – Front Part

| | | | |
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| drawn: MAB | job no.: 6386 | | |
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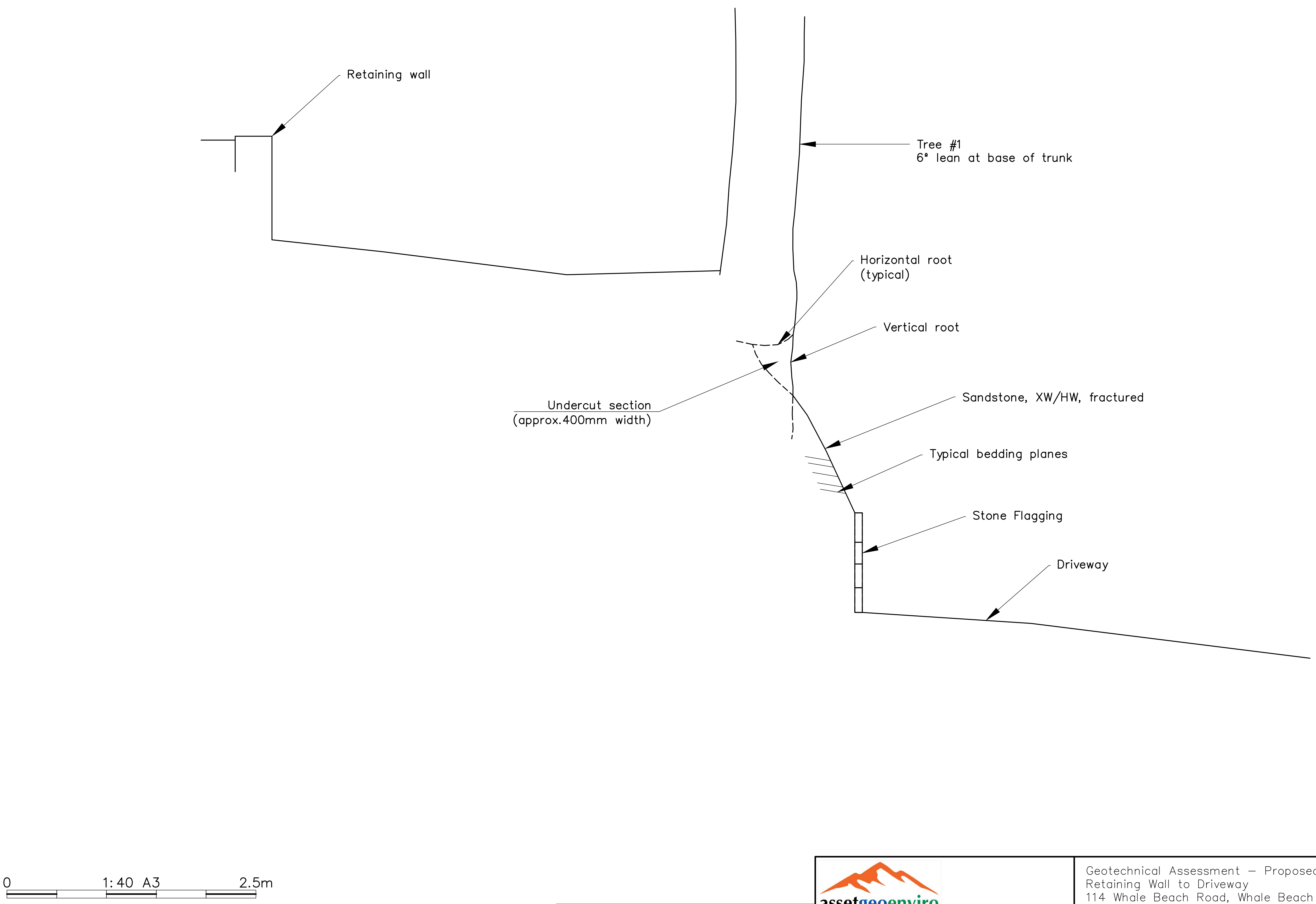


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Interpreted Section A–A

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# Appendix A

Important Information about your Geotechnical Report
Important Information about your Slope Instability Risk Assessment
GeoGuides (pp1-17)
Pittwater Geotechnical Hazard Zones
Soil & Rock Explanation Sheets

## Scope of Services

The geotechnical report ("the report") has been prepared in accordance with the scope of services as set out in the contract, or as otherwise agreed, between the Client and Asset Geotechnical Engineering Pty Ltd ("Asset"), for the specific site investigated. The scope of work may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

The report should not be used if there have been changes to the project, without first consulting with Asset to assess if the report's recommendations are still valid. Asset does not accept responsibility for problems that occur due to project changes if they are not consulted.

## Reliance on Data

Asset has relied on data provided by the Client and other individuals and organizations, to prepare the report. Such data may include surveys, analyses, designs, maps and plans. Asset has not verified the accuracy or completeness of the data except as stated in the report. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations ("conclusions") are based in whole or part on the data, Asset will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Asset.

## Geotechnical Engineering

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared for a specific client, for a specific project and to meet specific needs, and may not be adequate for other clients or other purposes (e.g. a report prepared for a consulting civil engineer may not be adequate for a construction contractor). The report should not be used for other than its intended purpose without seeking additional geotechnical advice. Also, unless further geotechnical advice is obtained, the report cannot be used where the nature and/or details of the proposed development are changed.

## Limitations of Site Investigation

The investigation program undertaken is a professional estimate of the scope of investigation required to provide a general profile of subsurface conditions. 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 behavior 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.

The engineering logs are the subjective interpretation of subsurface conditions at a particular location and time, made by trained personnel. The actual interface between materials may be more gradual or abrupt than a report indicates.

Therefore, the recommendations in the report can only be regarded as preliminary. Asset should be retained during the project implementation to assess if the report's recommendations are valid and whether or not changes should be considered as the project proceeds.

## Subsurface Conditions are Time Dependent

Subsurface conditions can be modified by changing natural forces or man-made influences. The report is based on conditions that existed at the time of subsurface exploration. Construction operations adjacent to the site, and natural events such as floods, or ground water fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. Asset should be kept appraised of any such events, and should be consulted to determine if any additional tests are necessary.

## Verification of Site Conditions

Where ground conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the report that Asset be notified of any variations and be provided with an opportunity to review the recommendations of this report. Recognition of change of soil and rock conditions requires experience and it is recommended that a suitably experienced geotechnical engineer be engaged to visit the site with sufficient frequency to detect if conditions have changed significantly.

## Reproduction of Reports

This report is the subject of copyright and shall not be reproduced either totally or in part without the express permission of this Company. Where information from the accompanying report is to be included in contract documents or engineering specification for the project, the entire report should be included in order to minimize the likelihood of misinterpretation from logs.

## Report for Benefit of Client

The report has been prepared for the benefit of the Client and no other party. Asset assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of Asset or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own inquiries and obtain independent advice in relation to such matters.

## Data Must Not Be Separated from The Report

The report as a whole presents the site assessment, and must not be copied in part or altered in any way.

Logs, figures, drawings, test results etc. included in our reports are developed by professionals based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These data should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

## Partial Use of Report

Where the recommendations of the report are only partially followed, there may be significant implications for the project and could lead to problems. Consult Asset if you are not intending to follow all of the report recommendations, to assess what the implications could be. Asset does not accept responsibility for problems that develop where the report recommendations have only been partially followed if they have not been consulted.

## Other Limitations

Asset will not be liable to update or revise the report to take into account any events or emergent circumstances or fact occurring or becoming apparent after the date of the report.

# Important Information about your Slope Risk Assessment

## Basis of The Assessment

Our assessment of the stability of the land is presented in the framework of Landslide Risk Management (Australian Geomechanics Society, Vol 42, No 1, March 2007). The attached GeoGuides provide further information on landslide risk management and maintenance.

This assessment is based on a visual inspection of the property and also the immediate adjoining land. Limited subsurface investigation may also have been undertaken as part of this appraisal. Slope monitoring has not been carried out within or adjacent to the property for the purpose of this appraisal. The opinions ex- pressed in this report also take into account our relevant local experience.

The property is within an area where landslip and/or subsidence have occurred, or where there is a risk that slope instability may occur. Important factors relating to slope conditions and the impact of development which commonly influence the risks of slope instability are discussed herein.

An owner's decision to acquire, develop or build on land within an area such as this involves the understanding and acceptance of a level of risk. It is important to recognise that soil and rock movements are an ongoing geological process, which may be affected by development and land management within the site or on ad- joining land. Soil and rock movements may cause visible damage to structures even where the risk of slope failure is considered low. This report is intended only to assess the risk of slope failure, apparent at the time of inspection.

Our opinion is provided on the present risk of slope instability for the land specifically referenced in the title to this report. Foundations suitable for future building development are discussed in relation to slope stability considerations. Limited foundation advice may be provided. If so, advice is intended to guide the footing design for the proposed development. However, this report is not intended as, is not suitable for, and must not be used in lieu of a detailed foundation investigation for final design and costing of foundations, retaining walls or associated structures.

## Limitations of The Assessment Procedure

The assessment procedures carried out for this appraisal are in accordance with the recommendations in Landslide Risk Management (Australian Geomechanics Society, Vol 42, No 1, March 2007), and with accepted local practice.

The following limitations must be acknowledged:

- the assessment of the stability of natural slopes requires a great degree of judgment and personal experience, even for experienced practitioners with good local knowledge;
- the assessment must be based on development of a sound geological model; slope processes and process rates influencing land sliding or landslide potential will vary according to geomorphologic influences;
- the likelihood that land sliding may occur on a given slope is generally hard to predict and is associated with significant uncertainties;
- different practitioners may produce different assessments of risk;
- actual risk of land sliding cannot be determined; risk changes with time;
- consequences of land sliding need to be considered in a rational framework of risk acceptance;
- acceptable risk in relation to damage to property from landslide activity is subjective; it remains the responsibility of the owner and/or local authority to decide whether the risk is acceptable; the geotechnical practitioner can assist with this judgment;
- the extent and methods of investigation for assessment of landslide risk will be governed by experience, by the perceived risk level, and by the degree to which the risk or consequences of land sliding are accepted for a specific project;
- the assessment may be required at a number of stages of the project or development; frequently (due to time or budget constraints imposed by the client) there will be no opportunity for long-term monitoring of the slope behaviour or groundwater conditions, or for on-going opportunity for the slope processes and performance of structures to be reviewed during and after development; such limitations should be recognised as relevant to the assessment.

## Development on Slopes

Some risk of slope instability is always attached to the development of land on slopes.

Guidelines for hillside construction and examples of good practices for hillside developments are described in the attached GeoGuides.

# 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).

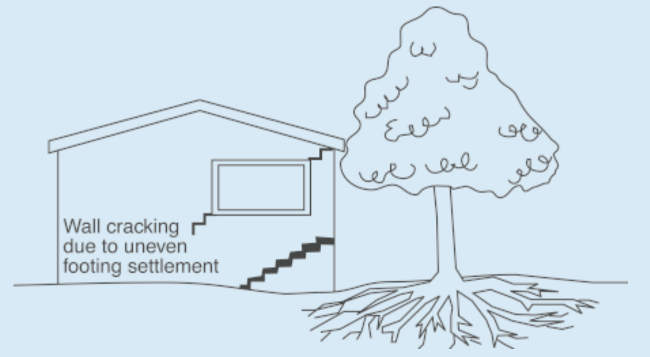
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

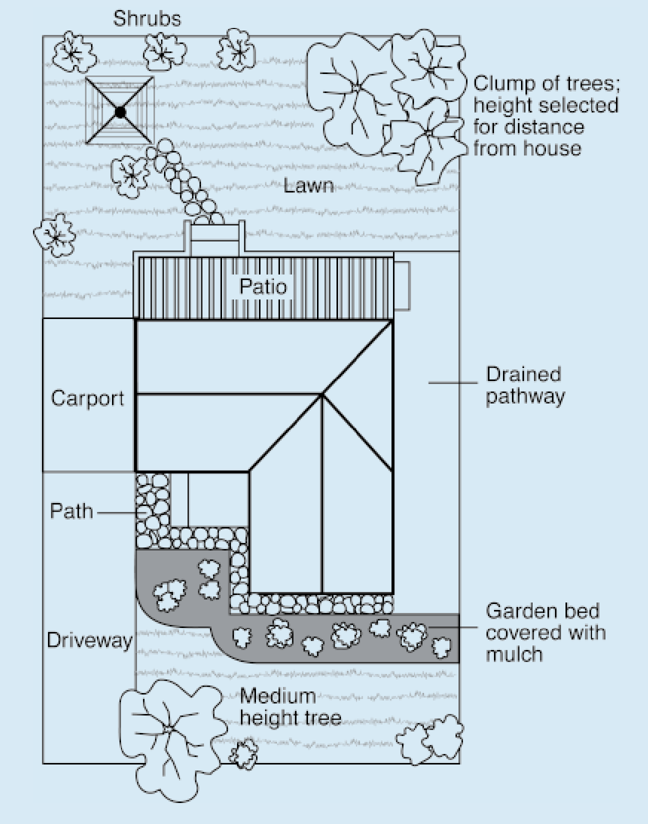
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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# GEOTECHNICAL HAZARD ZONES & HAZARD MAPPING

## GEOTECHNICAL HAZARD ZONES

1. The extent of Geotechnical Hazard Zones are shown for individual properties on the Geotechnical Risk Enquiry.
2. The Geotechnical hazards have been zoned, based on their assessed 'likelihood' of occurrence at each hazard location, as defined in Table T1 herewith.
3. Geotechnical Hazard Zones, H1, H2 and H3 have been delineated as follows:

| | |
|---|---|
| **H1** | **HAZARD ZONE 1**: Area where the likelihood of instability is assessed to be Level A, B or C on Table T1 |
| **H2** | **HAZARD ZONE 2**: Area where the likelihood of instability occurring is assessed to be Level D on Table T1 |
| **H3** | **HAZARD ZONE 3**: Area where the likelihood of instability occurring is assessed to be Level E of Table T1 |

**Table T1: Qualitative Measures of Likelihood of Instability Occurring**

| Level | Descriptor | Description | Indicative Annual Probability |
|---|---|---|---|
| A | ALMOST CERTAIN | The event is expected to occur over the design life | $10^{-1}$ |
| B | LIKELY | The event will probably occur under adverse conditions over the design life | $10^{-2}$ |
| C | POSSIBLE | The event could occur under adverse conditions over the design life | $10^{-3}$ |
| D | UNLIKELY | The event might occur under adverse circumstances over the design life | $10^{-4}$ |
| E | RARE | The event is conceivable but only under exceptional circumstances over the design life | $10^{-5}$ |
| F | BARELY CREDIBLE | The event is almost fanciful over the design life | $10^{-6}$ |

4. Hazard Zone H1 denotes geotechnical hazards with the highest likelihood of occurrence.
5. Hazard Zoning is based on the results of geotechnical mapping and aerial photo interpretation carried out between January and April 2006. Modifications to site conditions and refinements to available data may enable zone/boundary amendments from time to time subject to geotechnical confirmation.
6. The Geotechnical Hazard Zoning is identified on the Mapping:
   i. *"Geotechnical Hazard Mapping of the Pittwater LGA-2007" prepared by GHD-Geotechnics (this is a large A3 document and is available for loan through Council's Library, or available on CD through Council and;*
   ii. *Geotechnical Hazard Mapping P21DCP-BC-MDCP2002 (This map is in A1 format and is based on the "Geotechnical Hazard Mapping of the Pittwater LGA-2007" and maps the Geotechnical Hazard Zones H1, H2 and H3).*
7. The Geotechnical Hazard Mapping does not represent geotechnical audits of individual properties. Site specific geotechnical advice should be sought as and where applicable to address development, construction and ongoing stability issues.

## GEOTECHNICAL HAZARD MAPPING

1. The extent of geotechnical mapping encompasses the urban areas of the Pittwater LGA. The mapping has identified and located geotechnical hazards as well as their possible impact areas.
2. Geotechnical instability hazards can comprise uncontrolled, unretained, or poorly retained fill, slope instability (landslides/debris slides), cutting/excavation instability and boulders/rockfalls. Multiple hazards can occur.

   2.1 **Unretained/Partially Retained Fill**

   This hazard type encompasses fill embankments for roads as well as fill embankments for building platforms and infrastructure works. Some fills date back over many decades and they mostly comprise "uncontrolled' fills.

   2.2 **Slope Instability (Landslip/Debris Slides)**

   Slope instability hazards encompass potential landslides and debris slides that can occur on natural and man-modified hill slopes. These hazard sites are characterised by field evidence of previous slope movements such as ground surface disruptions, hummocks and irregularities and tensional features such as cracking or scarps. They are also generally characterised either intermittently or perennially by the presence of seepage concentrations and/or poor drainage conditions.

   2.3 **Cuttings/Excavations**

   This hazard type occurs at locations where excavations have previously cut into a hillside, for the construction of roads, to create building sites and for other infrastructure constructions.

   The cutting excavations vary in the nature of their exposed soil and rock materials, in height, face angle and in geotechnical (stability) conditions. Some are partially supported by retaining structures that have not been engineer-designed.

   Some cuttings display signs of deterioration caused by weathering and erosion or a paucity of drainage provisions.

   2.4 **Rockfalls**

   This hazard type can constitute the displacement of an individual 'floater'/boulder or the failure of a larger rock mass to create numerous moving blocks or boulders of varying scales. Hazardous individual rock masses are typically either detached or a least partially 'under-cut' through natural weathering patterns or uncontrolled excavation. Potential rockfall masses comprise either groups of boulders, or masses of rock characterised by fracturing into blocks and slabs. Rockfall hazards cover a range of stability conditions dependent upon their geometry and their position on a cliff or slope, both of which influence their possible trajectories.

3. Factors that can affect the future performance of a geotechnical instability hazard, include natural weathering and erosion, drainage or seepage concentrations, excavation or disturbance, tree and root growth into rock mass fractures and the general clearing of vegetation.
4. The geotechnical mapping does not include the documentation of small scale or localised mechanisms (for example scouring), or general maintenance requirements, not did it include detailed 'audit' style reviews of individual structures or properties.
5. In addition to the identification and location of geotechnical hazards, a zoning system has been applied to the geotechnical mapping observations in order to allow hazards to be classified in terms of their likelihood of occurrence. In accordance with current industry practise and the Pittwater 21 DCP (Appendix 5), geotechnical hazards can be assessed in terms of their 'likelihood' or occurrence and their 'consequence', which, when combined provide an assessed 'Risk Level'.
6. The level categories and terminologies adopted for these assessments can be referenced in the Australian Geomechanics Journal (AGS 2007 [a,b,c,d,e]) 'Landslide Risk Management', Volume 42, No 1, March 2007.

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## Log Abbreviations & Notes

### METHOD

| borehole logs | | excavation logs | |
|---|---|---|---|
| AS | auger screw * | NE | natural excavation |
| AD | auger drill * | HE | hand excavation |
| RR | roller / tricone | BH | backhoe bucket |
| W | washbore | EX | excavator bucket |
| CT | cable tool | DZ | dozer blade |
| HA | hand auger | R | ripper tooth |
| D | diatube | | |
| B | blade / blank bit | | |
| V | V-bit | | |
| T | TC-bit | | |

* bit shown by suffix e.g. ADV

***coring***
NMLC, NQ, PQ, HQ

### SUPPORT

| borehole logs | | excavation logs | |
|---|---|---|---|
| N | nil | N | nil |
| M | mud | S | shoring |
| C | casing | B | benched |
| NQ | NQ rods | | |

### CORE–LIFT

| | |
|---|---|
| \| \| \| | casing installed |
| ⊢⊣ | barrel withdrawn |

### NOTES, SAMPLES, TESTS

| | |
|---|---|
| D | disturbed |
| B | bulk disturbed |
| U50 | thin-walled sample, 50mm diameter |
| HP | hand penetrometer (kPa) |
| SV | shear vane test (kPa) |
| DCP | dynamic cone penetrometer (blows per 100mm penetration) |
| SPT | standard penetration test |
| N* | SPT value (blows per 300mm)<br>* denotes sample taken |
| Nc | SPT with solid cone |
| R | refusal of DCP or SPT |

### USCS SYMBOLS

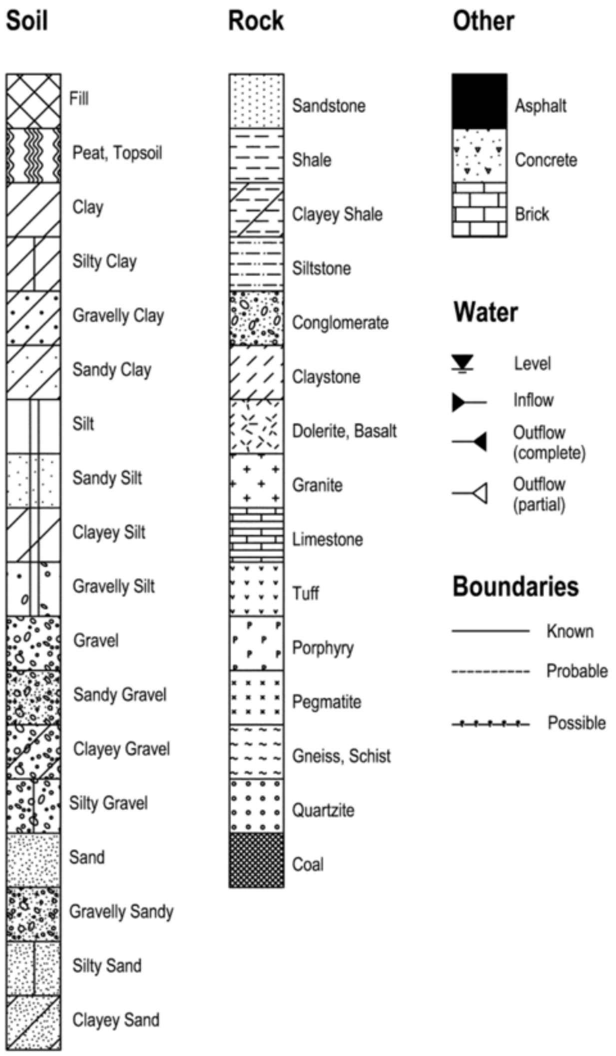
| | |
|---|---|
| GW | Gravel and gravel-sand mixtures, little or no fines. |
| GP | Gravel and gravel-sand mixtures, little or no fines, uniform gravels |
| GM | Gravel-silt mixtures and gravel-sand-silt mixtures. |
| GC | Gravel-clay mixtures and gravel-sand-clay mixtures. |
| SW | Sand and gravel-sand mixtures, little or no fines. |
| SP | Sand and gravel sand mixtures, little or no fines. |
| SM | Sand-silt mixtures. |
| SC | Sand-clay mixtures. |
| ML | Inorganic silt and very fine sand, rock flour, silty or clayey fine sand or silt with low plasticity. |
| CL, CI | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays. |
| OL | Organic silts |
| MH | Inorganic silts |
| CH | Inorganic clays of high plasticity. |
| OH | Organic clays of medium to high plasticity, organic silt |
| PT | Peat, highly organic soils. |

### MOISTURE CONDITION

| | |
|---|---|
| D | dry |
| M | moist |
| W | wet |
| Wp | plastic limit |
| Wl | liquid limit |

| CONSISTENCY | | DENSITY INDEX | |
|---|---|---|---|
| VS | very soft | VL | very loose |
| S | soft | L | loose |
| F | firm | MD | medium dense |
| St | stiff | D | dense |
| VSt | very stiff | VD | very dense |
| H | hard | | |
| Fb | friable | | |

## Graphic Log




| WEATHERING | | STRENGTH | |
|---|---|---|---|
| XW | extremely weathered | VL | very low |
| HW | highly weathered | L | low |
| MW | moderately weathered | M | medium |
| SW | slightly weathered | H | high |
| FR | fresh | VH | very high |
| | | EH | extremely high |

### RQD (%)

$$= \frac{\text{sum of intact core pieces} > 2 \times \text{diameter}}{\text{total length of core run drilled}} \times 100$$

### DEFECTS:

| type | | coating | |
|---|---|---|---|
| JT | joint | cl | clean |
| PT | parting | st | stained |
| SZ | shear zone | ve | veneer |
| SM | seam | co | coating |

| shape | | roughness | |
|---|---|---|---|
| pl | planar | po | polished |
| cu | curved | sl | slickensided |
| un | undulating | sm | smooth |
| st | stepped | ro | rough |
| ir | irregular | vr | very rough |

***inclination***
measured above axis and perpendicular to core

# Soil and Rock Explanation Sheets (2 of 2)

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## AS1726-2017

Soils and rock are described in the following terms, which are broadly in accordance with AS1726-2017.

## Soil

### MOISTURE CONDITION

| Term | Description |
|---|---|
| Dry | Looks and feels dry. Fine grained and cemented soils are hard, friable or powdery. Uncemented coarse grained soils run freely through hand. |
| Moist | Soil feels cool and darkened in colour. Fine grained soils can be moulded. Coarse soils tend to cohere. |
| Wet | As for moist, but with free water forming on hand. |

Moisture content of cohesive soils may also be described in relation to plastic limit ($W_P$) or liquid limit ($W_L$) [>> much greater than, > greater than, < less than, << much less than].

### CONSISTENCY OF FINE-GRAINED SOILS

| Term | Su (kPa) | Term | Su (kPa) |
|---|---|---|---|
| Very soft | < 12 | Very Stiff | >100 – ≤200 |
| Soft | >12 – ≤25 | Hard | > 200 |
| Firm | >25 – ≤50 | Friable | – |
| Stiff | >50 – ≤100 | | |

### RELATIVE DENSITY OF COARSE-GRAINED SOILS

| Term | Density Index (%) | Term | Density Index (%) |
|---|---|---|---|
| Very Loose | < 15 | Dense | 65 – 85 |
| Loose | 15 – 35 | Very Dense | >85 |
| Medium Dense | 35 – 65 | | |

### PARTICLE SIZE

| Name | Subdivision | Size (mm) |
|---|---|---|
| Boulders | | > 200 |
| Cobbles | | 63 – 200 |
| Gravel | coarse | 19 – 63 |
| | medium | 6.7 – 19 |
| | fine | 2.36 – 6.7 |
| Sand | coarse | 0.6 – 2.36 |
| | medium | 0.21 – 0.6 |
| | fine | 0.075 – 0.21 |
| Silt & Clay | | < 0.075 |

### MINOR COMPONENTS

| Term | Proportion by Mass: *coarse grained* | *fine grained* |
|---|---|---|
| Trace | ≤ 15% | ≤ 5% |
| With | >15% – ≤30% | >5% – ≤12% |

### SOIL ZONING

| | |
|---|---|
| Layers | Continuous across exposures or sample. |
| Lenses | Discontinuous, lenticular shaped zones. |
| Pockets | Irregular shape zones of different material. |

### SOIL CEMENTING

| | |
|---|---|
| Weakly | Easily broken up by hand pressure in water or air. |
| Moderately | Effort is required to break up by hand in water or in air. |

### USCS SYMBOLS

| Symbol | Description |
|---|---|
| GW | Gravel and gravel-sand mixtures, little or no fines. |
| GP | Gravel and gravel-sand mixtures, little or no fines, uniform gravels. |
| GM | Gravel-silt mixtures and gravel-sand-silt mixtures. |
| GC | Gravel-clay mixtures and gravel-sand-clay mixtures. |
| SW | Sand and gravel-sand mixtures, little or no fines. |
| SP | Sand and gravel sand mixtures, little or no fines. |
| SM | Sand-silt mixtures. |
| SC | Sand-clay mixtures. |
| ML | Inorganic silt and very fine sand, rock flour, silty or clayey fine sand or silt with low plasticity. |
| CL, CI | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays. |
| OL | Organic silts |
| MH | Inorganic silts |
| CH | Inorganic clays of high plasticity. |
| OH | Organic clays of medium to high plasticity, organic silt |
| PT | Peat, highly organic soils. |

## Rock

### SEDIMENTARY ROCK TYPE DEFINITIONS

| Rock Type | Definition (more than 50% of rock consists of …..) |
|---|---|
| Conglomerate | ... gravel sized (>2mm) fragments. |
| Sandstone | ... sand sized (0.06 to 2mm) grains. |
| Siltstone | ... silt sized (<0.06mm) particles, rock is not laminated. |
| Claystone | ... clay, rock is not laminated. |
| Shale | ... silt or clay sized particles, rock is laminated. |

### LAYERING

| Term | Description |
|---|---|
| Massive | No layering apparent. |
| Poorly Developed | Layering just visible. Little effect on properties. |
| Well Developed | Layering distinct. Rock breaks more easily parallel to layering. |

### STRUCTURE

| Term | Spacing (mm) | Term | Spacing |
|---|---|---|---|
| Thinly laminated | <6 | Medium bedded | 200 – 600 |
| Laminated | 6 – 20 | Thickly bedded | 600 – 2,000 |
| Very thinly bedded | 20 – 60 | Very thickly bedded | > 2,000 |
| Thinly bedded | 60 – 200 | | |

### STRENGTH (NOTE: Is50 = Point Load Strength Index)

| Term | Is50 (MPa) | Term | Is50 (MPa) |
|---|---|---|---|
| Extremely Low | <0.03 | High | 1.0 – 3.0 |
| Very low | 0.03 – 0.1 | Very High | 3.0 – 10.0 |
| Low | 0.1 – 0.3 | Extremely High | >10.0 |
| Medium | 0.3 – 1.0 | | |

### WEATHERING

| Term | Description |
|---|---|
| Residual Soil | Material is weathered to an extent that it has soil properties. Rock structures are no longer visible, but the soil has not been significantly transported. |
| Extremely ….. | Material is weathered to the extent that it has soil properties. Mass structures, material texture & fabric of original rock is still visible. |
| Highly ….. | Rock strength is significantly changed by weathering; rock is discolored, usually by iron staining or bleaching. Some primary minerals have weathered to clay minerals. |
| Moderately ….. | Rock strength shows little or no change of strength from fresh rock; rock may be discolored. |
| Slightly ….. | Rock is partially discolored but shows little or no change of strength from fresh rock. |
| Fresh | Rock shows no signs of decomposition or staining. |

### DEFECT DESCRIPTION

| Type | |
|---|---|
| Joint | A surface or crack across which the rock has little or no tensile strength. May be open or closed. |
| Parting | A surface or crack across which the rock has little or no tensile strength. Parallel or sub-parallel to layering/bedding. May be open or closed. |
| Sheared Zone | Zone of rock substance with roughly parallel, near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. |
| Seam | Seam with deposited soil (infill), extremely weathered insitu rock (XW), or disoriented usually angular fragments of the host rock (crushed). |

| Shape | |
|---|---|
| Planar | Consistent orientation. |
| Curved | Gradual change in orientation. |
| Undulating | Wavy surface. |
| Stepped | One or more well defined steps. |
| Irregular | Many sharp changes in orientation. |
| **Roughness** | |
| Polished | Shiny smooth surface. |
| Slickensided | Grooved or striated surface, usually polished. |
| Smooth | Smooth to touch. Few or no surface irregularities. |
| Rough | Many small surface irregularities (amplitude generally <1mm). Feels like fine to coarse sandpaper. |
| Very Rough | Many large surface irregularities, amplitude generally >1mm. Feels like very coarse sandpaper. |

| Coating | |
|---|---|
| Clean | No visible coating or discolouring. |
| Stained | No visible coating but surfaces are discolored. |
| Veneer | A visible coating of soil or mineral, too thin to measure; may be patchy |
| Coating | Visible coating =1mm thick. Thicker soil material described as seam. |

# Appendix B

Site Photos

**Photo 1**

View looking south showing driveway entrance in front of site, and subject tree at top of driveway cut

**Photo 2**

View looking east down driveway showing tree at top of driveway cut

**Photo 3**

View of base of tree taken from top of bank upslope of driveway. Note lean of trunk measured at about 6°

**Photo 4**

View of driveway cut showing base of tree trunk and exposed roots

**Photo 5**

View of driveway cut showing base of tree trunk and exposed roots, with sandstone flagging over toe of cut

**Photo 6**

Closeup view of base of tree and exposed roots taken from front. Note erosion of soil and rock from base of tree and beneath exposed roots.

**Photo 7**

Closeup view of base of tree and exposed roots taken from eastern side. Note erosion of soil and rock from base of tree and beneath exposed roots. Erosion measured to extend approx. 400mm beneath outer base of tree trunk.

**Photo 8**

Closeup view of eroded soils and rock beneath horizontal root extending west.

**Photo 9**

Closeup view of eroded soils from eastern side of tree. Note desiccation cracking in clayey soils.

**Photo 10**

View of exposed sandstone in cut to east of tree. Note bedding dipping to the east, and presence of sub-vertical inclined joint infilled with soil and tree root.

**Photo 11**

View of driveway cut for № 110 & 112 Whale Beach Road to the east, showing remnant tree at top of slope.

**Photo 12**

Closeup view of remnant tree in Photo 11. Note vertical exposed remnant roots.