Broadcrest Consulting Pty Ltd

7 Sherry St, Mona Vale, NSW

Site Classification

January 2022

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Wastewater | Stormwater | Flood | Environmental | Geotechnical | Acoustic | Structural

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Document controls

Approval and Authorisation

Title	7 Sherry St, Mona Vale, NSW Site Classification
Authored on behalf of Broadcrest Consulting Pty Ltd by:	Kurtis Ferry Engineer: Environmental and Geotechnical
Signed:	
Dated:	27.01.2022

Document Status

Date	Internal Reference	Document Status	Prepared by	Reviewed by
27.01.2022	1682-GEO-01-A	For release	K. Ferry	C. Hudson

Contents

1 SITE DESCRIPTION

The proposed development is located at 7 Sherry St, Mona Vale, NSW. The investigation will accompany a Development Application to demolish an existing and construct a new residential dwelling, pool and retaining walls. This assessment considers the proposed building envelope only.

A desktop study was conducted on the 17/01/2022 to identify site features and constraints for the site inspection. A site inspection was carried out on the 18/01/2022 which involved a visual assessment of the site, thin-wall tube sampling and DCP testing.

Figure 1.1: Satellite image of site (NSW Spatial Data 2021)

1.1 Desktop Investigation

The desktop investigation utilises a combination of public and private data sources to identify features on a site. These features can individually or collectively add geotechnical constraints during a development. Appendix A contains the full set of maps obtained for the review. Analysis of Lidar data is performed to obtain raw 1m contour lines, slope heat maps, slope landforms and rainfall flow paths. References are provided for all other data sources.

The primary constraining features are assessed to determine the likely impact it will have on the site investigation and development as a whole (minor, moderate or high). The impact rating of a feature is based on pre-existing criteria or through professional judgement and is assessed in context with all other features. The impact ratings are defined in Table 1.1 below.

Table 1.1: A summary of the factors assessed during the desktop investigation.

Factor Assessed	Description	Limitation
Slope	Gentle fall (3-10%) across proposed building envelope	Minor
Rainfall	Monthly evaporation exceeds rainfall for majority of the majority of the year (except May and June).	Minor
Salinity	Salinity: Low (Hawkesbury sandstone HGL mapping)	Minor
Acid sulphate soils	No mapped acid sulphate risk	Minor
Geology	Burralow Formation – Interbedded laminate, shale and quartz, to lithic sandstone quartz	Minor
Soil Landscape	Watagan	Minor
Soil Formation	Colluvial	Minor
Run-on	Minor surface run-on	Minor
Site-drainage	Good natural and road drainage	Minor
Existing bore logs	Nil	Nil
Surrounding Services	Existing residences and utilities	Minor

Table 1.2: Legend for Geotechnical Constraints

Impact	Description
Minor	This feature has been assessed and deemed to have little geotechnical impact
Moderate	This feature requires consideration. It may require detailed investigation or planning
Major	This feature requires careful consideration and evaluation prior to further work

2 SITE INSPECTION AND SITE CLASSIFICATION

A site inspection was conducted on the 18.01.2022 by Broadcrest consulting engineer Kurtis Ferry. Rain had fallen within the previous 24 hours prior to the inspection. Photographs were taken of the site for future reference. The general inspection methodology was as follows:

1. Identification of the development area
2. Observations of the site landform
3. Observations of the ground surface conditions
4. Observations of potential geotechnical limitations
5. Borehole sampling and DCP testing

Table 2.1 summarizes the factors assessed during the site investigation which may lead to a problem site.

Table 2.1: A summary of the factors assessed during the site investigation

Factor Assessed	Description	Limitation
Existing Fill	>800mm of sand OR > 400mm all other soil types	Minor
Fill contents	Fill containing wood, organic material or building waste	Minor
Planned fill	Depth of soil / compatibility	Minor
Soil strength	Low strength soils and/or saturated soils	Minor
Trees	Trees (current or removed) in or within 20m of building envelope	Minor
Existing buildings	Any buildings (current or demolished) within the building envelope	Moderate
Floating rocks	Floating boulders, soil containing gravel, colluvial soils leading to false bedrock depth measurements	Nil
Excavatability	Conditions limiting excavation on the surface or subsurface	Nil
Subsurface flow	Subsurface flow or water seepage potential	Minor
Existing bore logs	Existing bore logs showing information of concern	Nil
Corrosion	Marine environment or corrosion risk from sea spray	Minor
Erosion	Soil susceptibility to erosion	Minor
Existing Movement	Trees, roads, kerbs, pavements, masonry walls, fences, and/or ground surfaces	NA

2.1 Borehole sampling

Borehole drilling was conducted using thin-wall tube sampling to 1.5m or refusal. DCP testing was conducted to refusal (25+ blows/100mm). The encountered conditions consisted of fine SAND to 0.7m over fine sandy CLAY to 1.4m (terminated). DCP results suggest the clay continues to ~ 2.2m (DCP refusal). The soil was slightly moist at the time of inspection. The borehole results and locations are provided in Appendix B.

Figure 2.1: Borehole 1 sample

DCP testing was completed to provide guidance on the allowable bearing capacity of the soil. The structural engineer shall use the raw test result data along with the soil classification provided in this report to determine the allowable bearing capacity specific for the project requirements. The results of the DCP testing are provided in Appendix B of this report.

2.2 Site Classification

- The development is likely to experience **High Soil Reactivity (H1).**
- The soil is likely to experience reduced bearing capacity when wet. DCP testing was conducted to refusal at 2.2m.
- For the proposed development on the site, based on the above, it is recommended that the structural engineer select a footing system compatible with **Type P Soil Classification** (AS 2870-2011) due to the demolished house and unknown soil conditions below.
- Post demolition, the soil underlying the building should be verified against the findings of this report. If any variation, including fill, is identified further advice should be sought.

2.3 Retaining wall

A new retaining wall is proposed along the northern and eastern boundaries, ranging in depth from 0.3m to 1.0m. The following geotechnical parameters shall be used for the design of retaining walls:

Table 2.2: Earth pressure coefficients

Material	Ka		Kp	K_0
	Temporary	Long term		
Sand	0.35	0.39	2.88	0.52
Sandy CLAY	0.32	0.36	3.12	0.48

Notes:

1. Flat ground behind the retaining wall has been assumed
2. No wall friction has been assumed
3. Parameters should be adjusted to account for groundwater where appropriate

Retaining wall specifications:

- All surcharge loading shall be outside of the zone of influence (Figure 2.2)
- The retaining wall may be constructed using a King-post design (post and sleeper).
- The retaining wall shall be constructed using either
  - Steel posts and sleepers, or, wooden posts and sleepers.
- The maximum centres of the posts should be no more than 1.6m
- The pier depth shall equal the wall height (i.e, for a 1.0m wall, the pier depth embedment shall be 1.0m).
- The pier width shall be a minimum dimeter of 300mm
- The concrete shall have
  - minimum strength of 20MPa at 28 days
  - Max slump of 100mm
  - Max aggregated size of 20mm

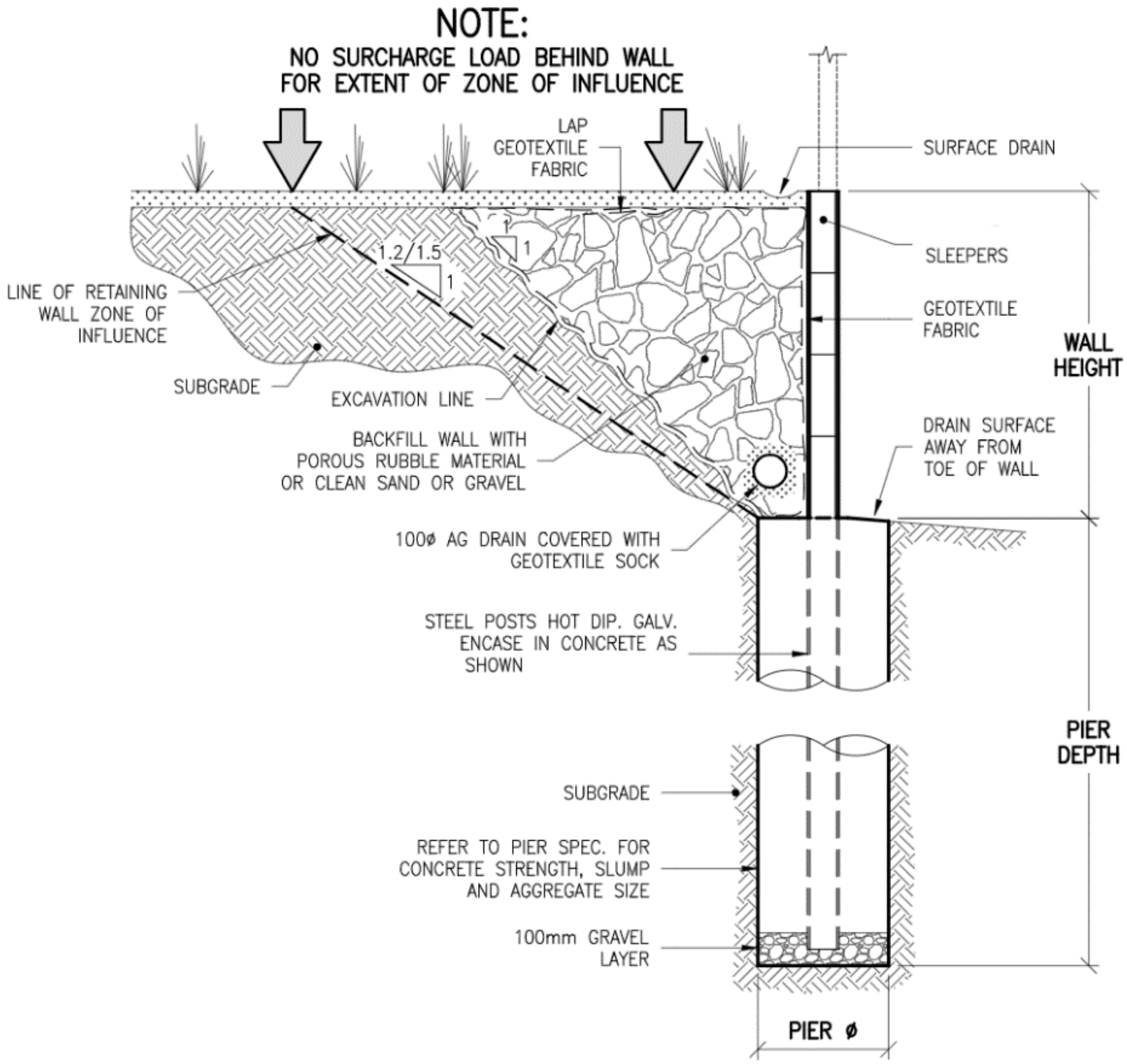

Figure 2.2: Standard king post retaining wall design

3 LIMITATIONS OF THIS REPORT

This report has been prepared subject to a number of limitations. These include:

The application of conditions of approval or impacts of unanticipated future events could modify the outcomes described in this document. In particular, the occurrence of earthquakes of any magnitude, extreme rainfall events or the effects of climate change have not been considered but should they occur, may have a significant impact on the site. The client agrees that such events are possible but nevertheless accepts the risk that they pose;

The findings contained in this report are the result of discrete/specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site/sites at all points;

In preparing this report, Broadcrest Consulting Pty Ltd has relied upon certain verbal information and documentation provided by the client and/or third parties. Broadcrest Consulting Pty Ltd did not attempt to independently verify the accuracy or completeness of that information. To the extent that the conclusions and recommendations in this report are based in whole or in part on such information, they are contingent on its validity. Broadcrest Consulting Pty Ltd assume no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to Broadcrest Consulting Pty Ltd; and

This report is not to be relied upon for any purpose other than that defined in this report.

4 REFERENCES

- Australian Standard 1726 (2017) Geotechnical site investigations.
- Australian Standard 2870 (2011) Residential slabs and footings.

Appendix A: Spatial Data Report

Broadcrest Consulting
MAPPING & SPATIAL SERVICES

LOCATION: 7 Sherry St, Mona Vale

REPORT 1682

DATE 25.1.2022

SITE AREA 0.0714 ha (approx)

BROADCREST
MAPPING & SPATIAL SERVICES
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Broadcrest Consulting Pty Ltd | ABN: 622 508 187

Client	Map
R & A Gillespie	Site Aerial Photograph
Location	**LGA**
7 Sherry St, Mona Vale LOT:	NORTHERN BEACHES COUNCIL

Data Source	Scale
	1:1,500
Base map	**Project**
DFSI Spatial Services Imagery | © Department of Finance, Services & Innovation 2017 Open Street Maps | Creative Commons 3.0 - OpenStreetMap Contributors	1682

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Client R & A Gillespie	**Map** Site Location with Terrain
Location 7 Sherry St, Mona Vale	**LGA** NORTHERN BEACHES COUNCIL

Data Source
Geoscience Australia | Obtained on 18.07.2018
Creative Commons 3.0 - Commonwealth of Australia

Base map
DFSI Spatial Services Imagery | © Department of Finance, Services & Innovation 2017
Open Street Maps | Creative Commons 3.0 - OpenStreetMap Contributors

Scale
1:1,000

Project
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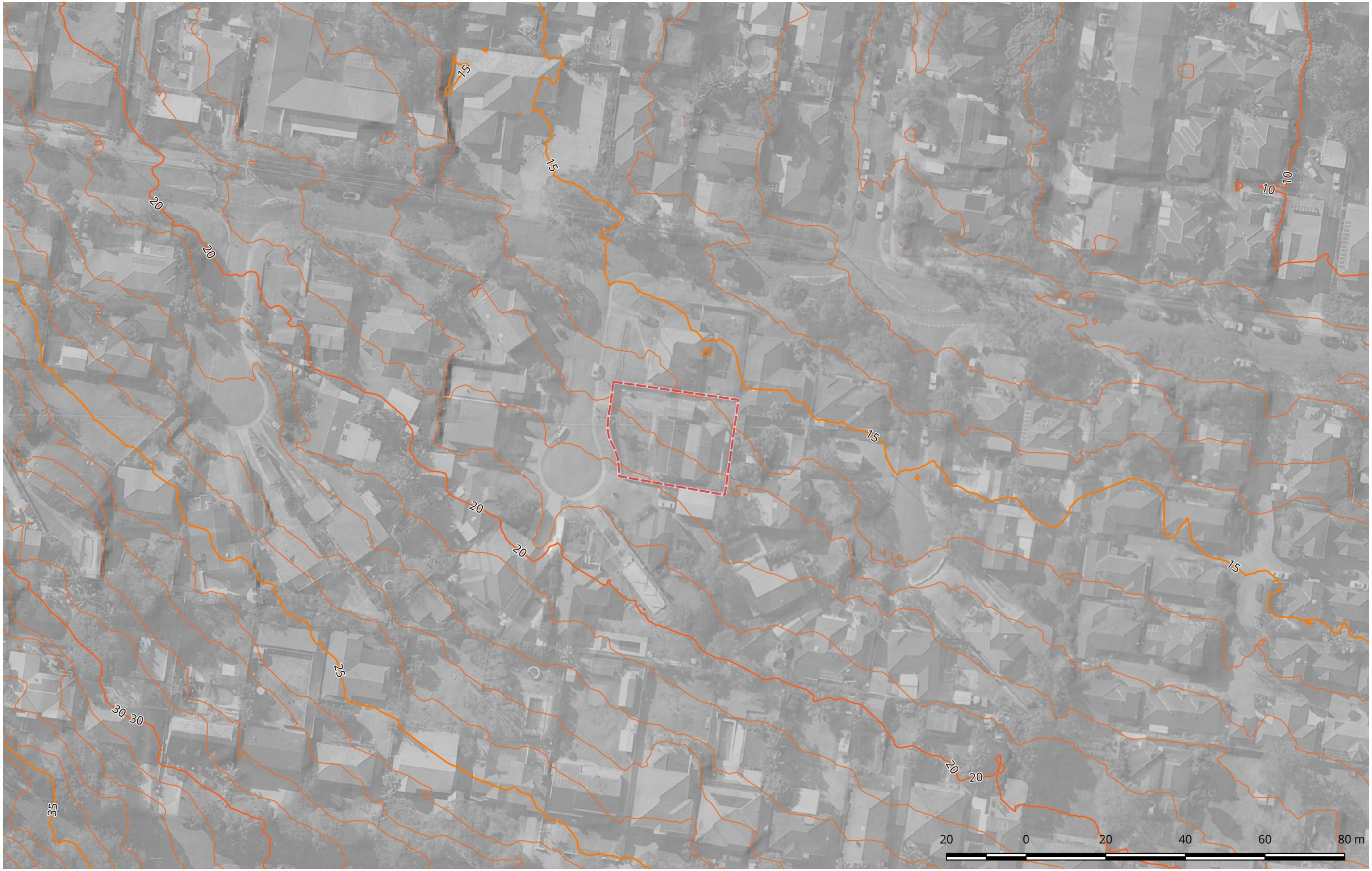

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Client R & A Gillespie	Map Topography
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source
Derived from LiDAR Data | Geoscience Australia | Obtained on 18.07.2018
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Base map
Open Street Maps | Obtained on 25.1.2022
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Scale
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Project
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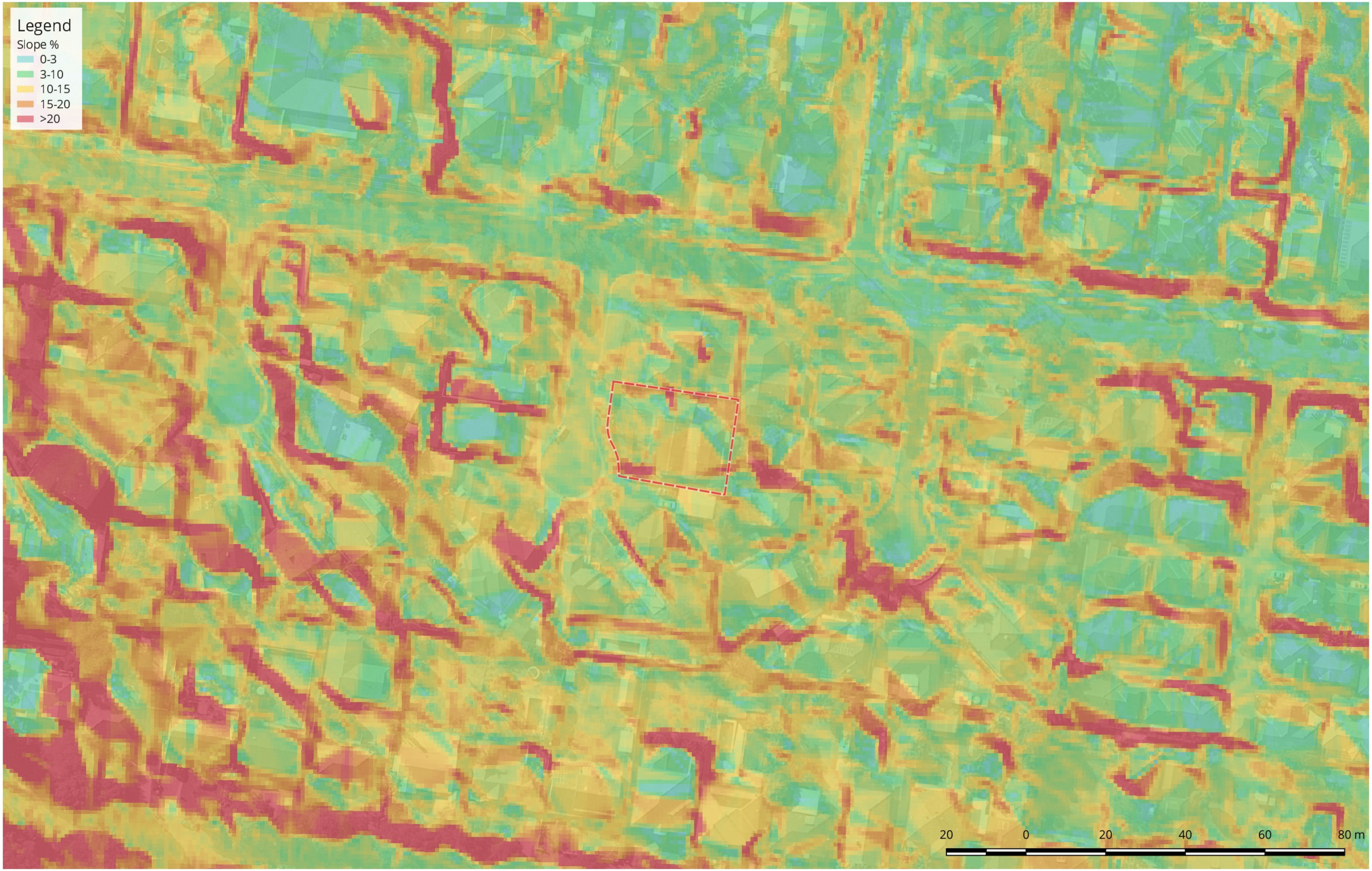

BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	**Client** R & A Gillespie	**Map** Slope Heat Map	**Data Source** Derived from LiDAR Data | Geoscience Australia | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia	**Scale** 1:1,000
	Location 7 Sherry St, Mona Vale	**LGA** NORTHERN BEACHES COUNCIL	**Base map** DFSI Spatial Services Imagery | Obtained on 25.1.2022 © Department of Finance, Services & Innovation 2017	**Project** 1682

BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	Client: R & A Gillespie	Map: Land Zone Map	Data Source: NSW Planning and the Environment | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia	Scale: 1:1,000
	Location: 7 Sherry St, Mona Vale	LGA: NORTHERN BEACHES COUNCIL	Base map: Open Street Maps | Obtained on 25.1.2022 Creative Commons 3.0 - OpenStreetMap Contributors	Project: 1682

ID	NAME	LEVEL
	No data in mapped area.	

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Client R & A Gillespie	**Map** Heritage Listed Sites
Location 7 Sherry St, Mona Vale	**LGA** NORTHERN BEACHES COUNCIL

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
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Base map
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Client R & A Gillespie	Map Bushfire Prone Land
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source NSW Planning and the Environment | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia	Scale 1:1,000
Base map Open Street Maps | Obtained on 25.1.2022 Creative Commons 3.0 - OpenStreetMap Contributors	Project 1682

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Client R & A Gillespie	Map Soil Landscapes
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source
Office of Environment and Heritage | Obtained on 18.07.2018
Creative Commons 3.0 - State of NSW and Office of Environment and Heritage
Base map
Open Street Maps | Obtained on 25.1.2022
Creative Commons 3.0 - OpenStreetMap Contributors

Scale
1:1,000
Project
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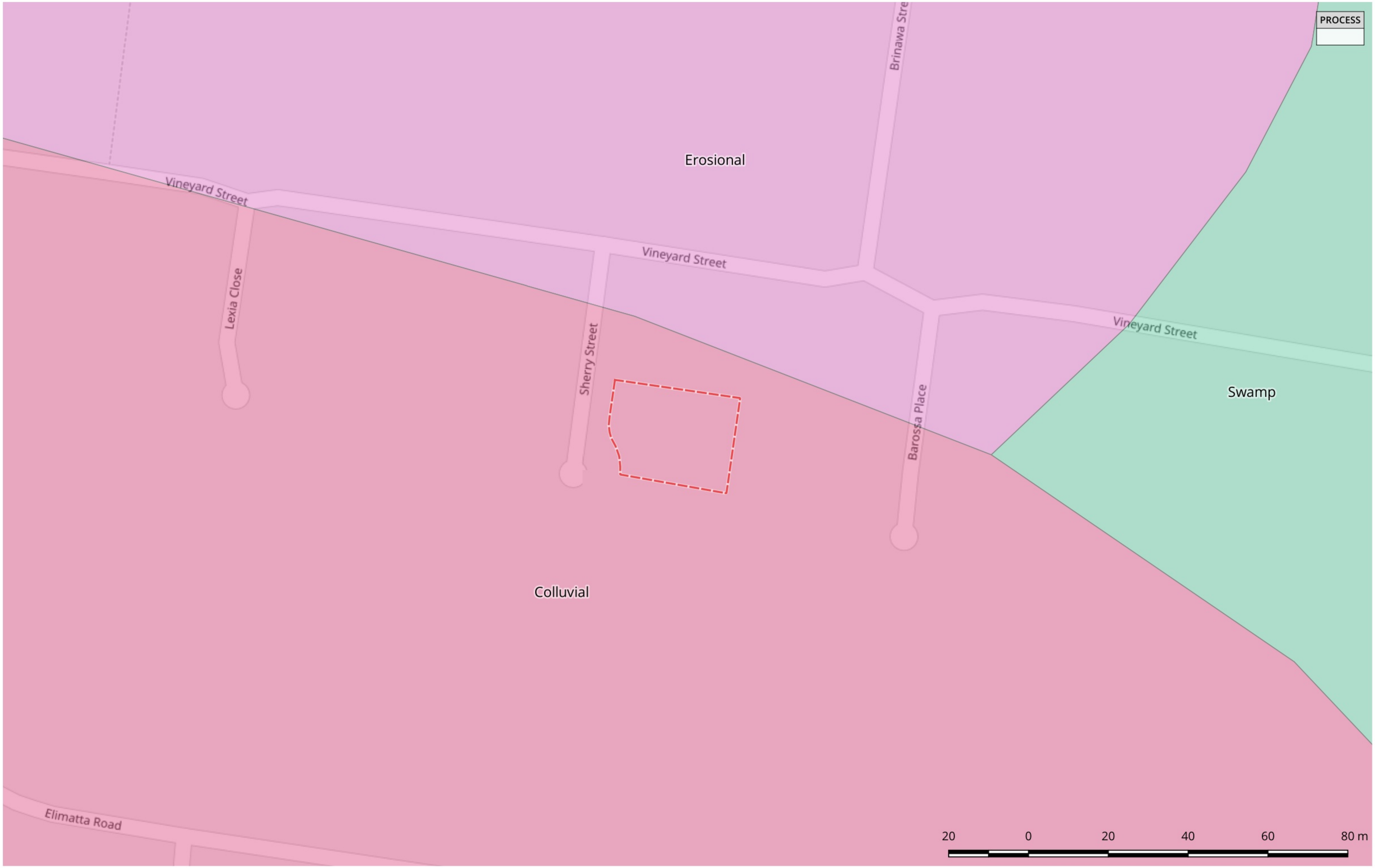

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Client R & A Gillespie	Map Soil Formation
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source
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Base map
Open Street Maps | Obtained on 25.1.2022
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Scale
1:1,000
Project
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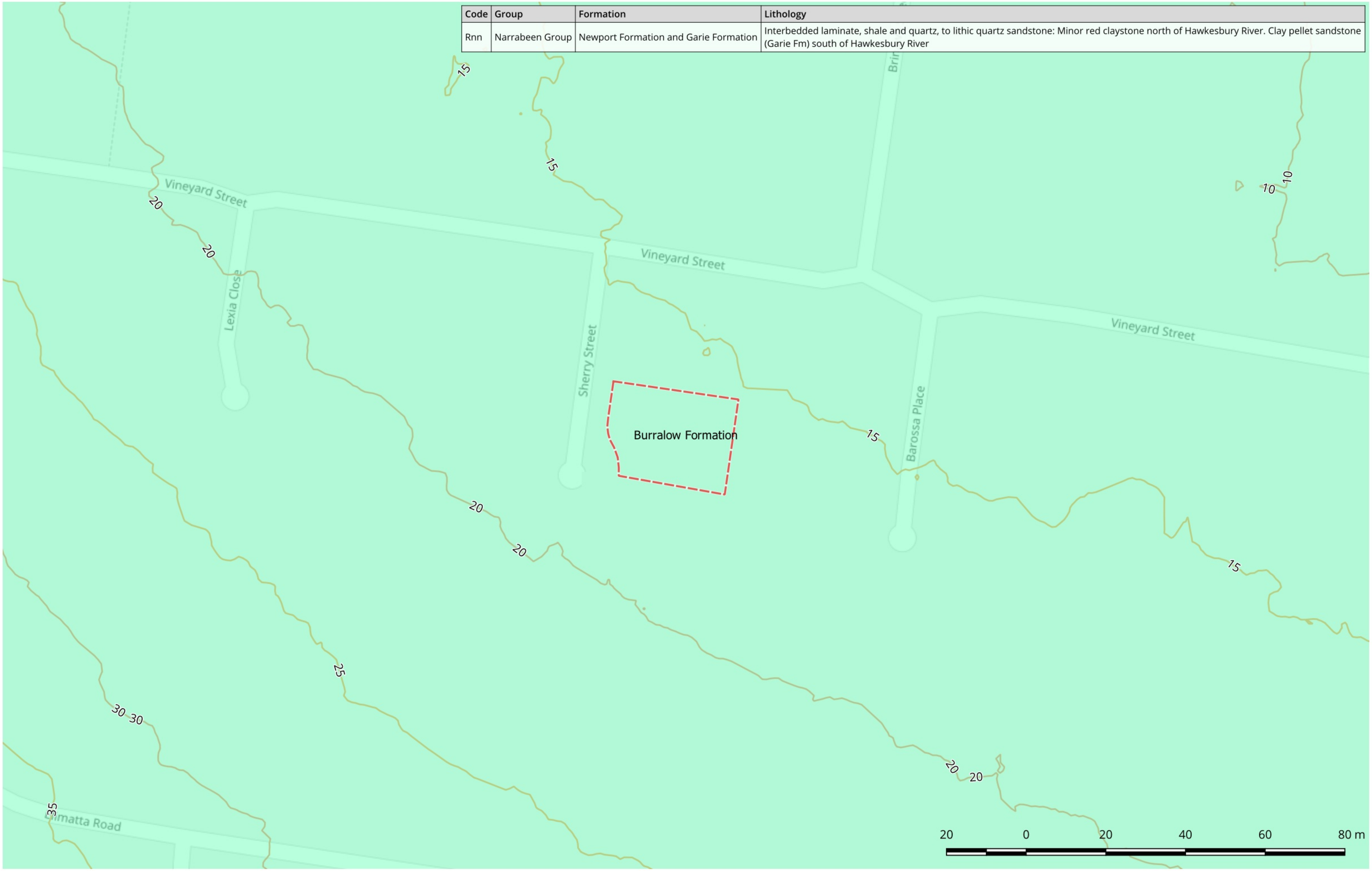
Code	Group	Formation	Lithology
Rnn	Narrabeen Group	Newport Formation and Garie Formation	Interbedded laminate, shale and quartz, to lithic quartz sandstone: Minor red claystone north of Hawkesbury River. Clay pellet sandstone (Garie Fm) south of Hawkesbury River



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Client R & A Gillespie	Map Geology (1:100,000 Mapping)
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
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Base map
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Scale
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OBJECTID	Ovall_Haz	HGL_Name	Salt_Land	Salt_Load	Stream_EC	Shape_Length	Shape_Area
No Data in Mapped Area							

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Client R & A Gillespie	Map Hydrogeological Landscapes
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source
Office of Environment and Heritage | Obtained on 18.07.2018
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Base map
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Project
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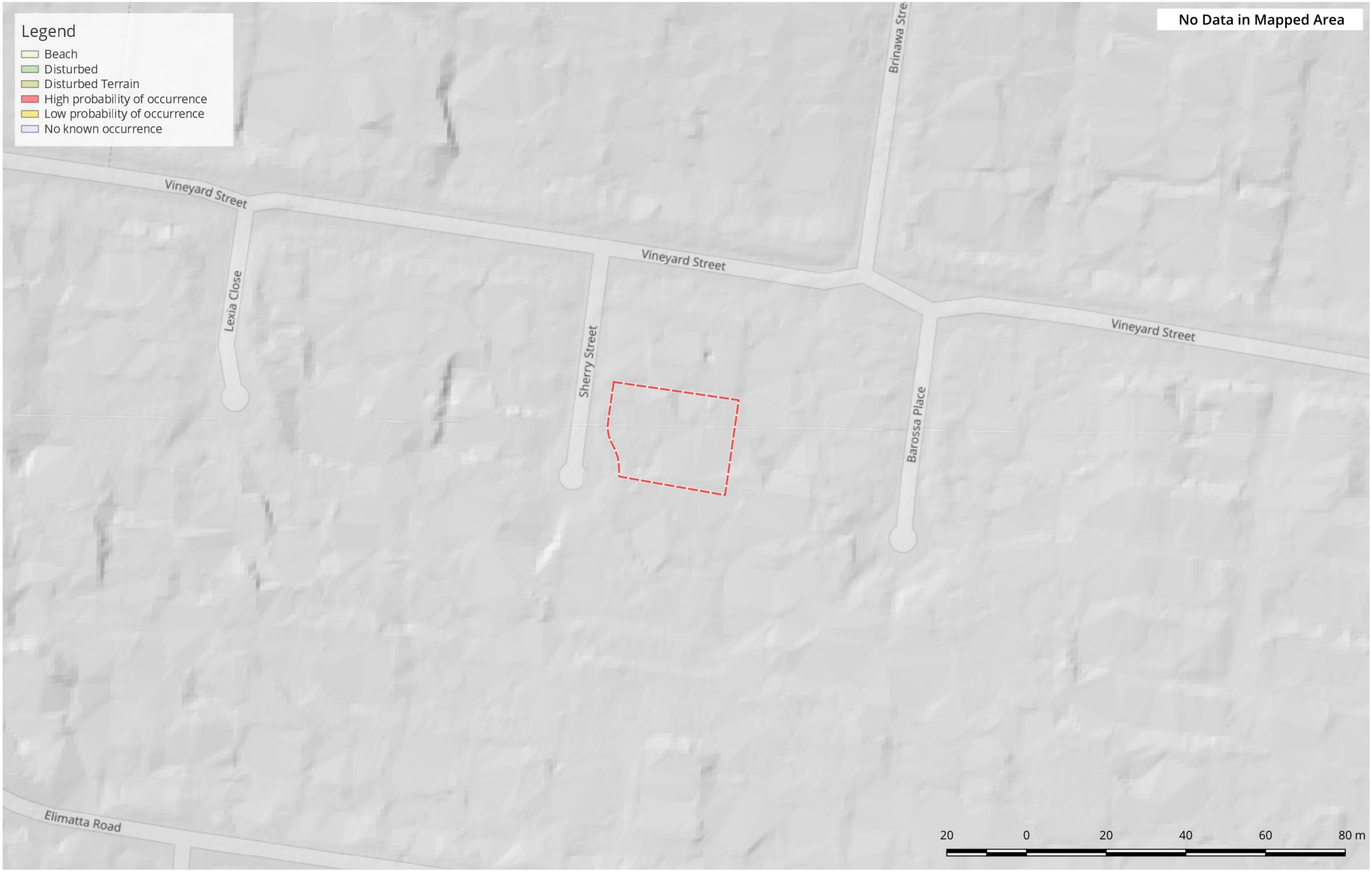

BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	Client R & A Gillespie	Map Acid Sulfate Risk map	Data Source NSW Planning and the Environment | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia	Scale 1:1,000
	Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL	Base map Open Street Maps | Obtained on 25.1.2022 Creative Commons 3.0 - OpenStreetMap Contributors	Project 1682

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Client	Map
R & A Gillespie	Watercourses and Hydrology
Location	**LGA**
7 Sherry St, Mona Vale	NORTHERN BEACHES COUNCIL

Data Source
Department of Finance, Services & Innovation | Obtained on 25.1.2022
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Base map
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BROADCREST MAPPING & SPATIAL SERVICES broadcrest.com.au | contact@broadcrest.com.au | 1300 554 945 Broadcrest Consulting Pty Ltd | ABN: 622 508 187	Client R & A Gillespie	Map Rainfall Overland Flow Paths	Data Source Derived from LiDAR Data | Geoscience Australia | Obtained on 18.07.2018 Creative Commons 3.0 - Commonwealth of Australia	Scale 1:1,000
	Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL	Base map Open Street Maps | Obtained on 25.1.2022 Creative Commons 3.0 - OpenStreetMap Contributors	Project 1682

HydroCode	Depth	Strata Description	Bore Data
No data in mapped area.			

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Client R & A Gillespie	Map Groundwater Bores
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source
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Project
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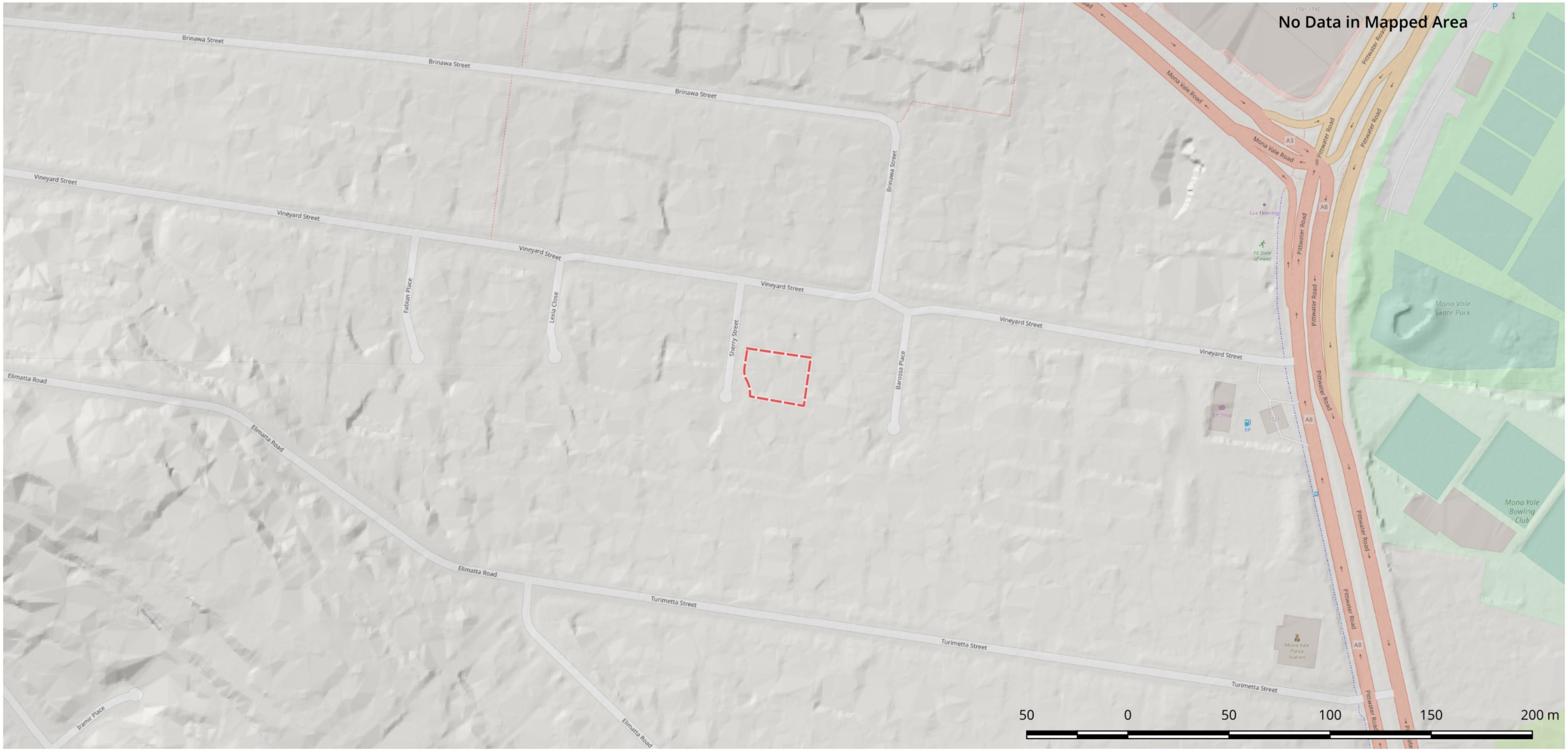

ID	Date	Hazard	Synopsis	Impact Comments
No data in mapped area.				

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Client R & A Gillespie	Map Recorded Landslides
Location 7 Sherry St, Mona Vale	LGA NORTHERN BEACHES COUNCIL

Data Source
NSW Planning and the Environment | Obtained on 18.07.2018
Creative Commons 3.0 - Commonwealth of Australia

Base map
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1:2,250

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Appendix B: Borelogs and DCP results

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Client R & A Gillespie	**Project** 1682-GEO
Location 7 Sherry St, Mona Vale	**Drawing ID / Revision** 1682-GEO-01 / 01-A

Drawing Name
Site Overview with borehole locations

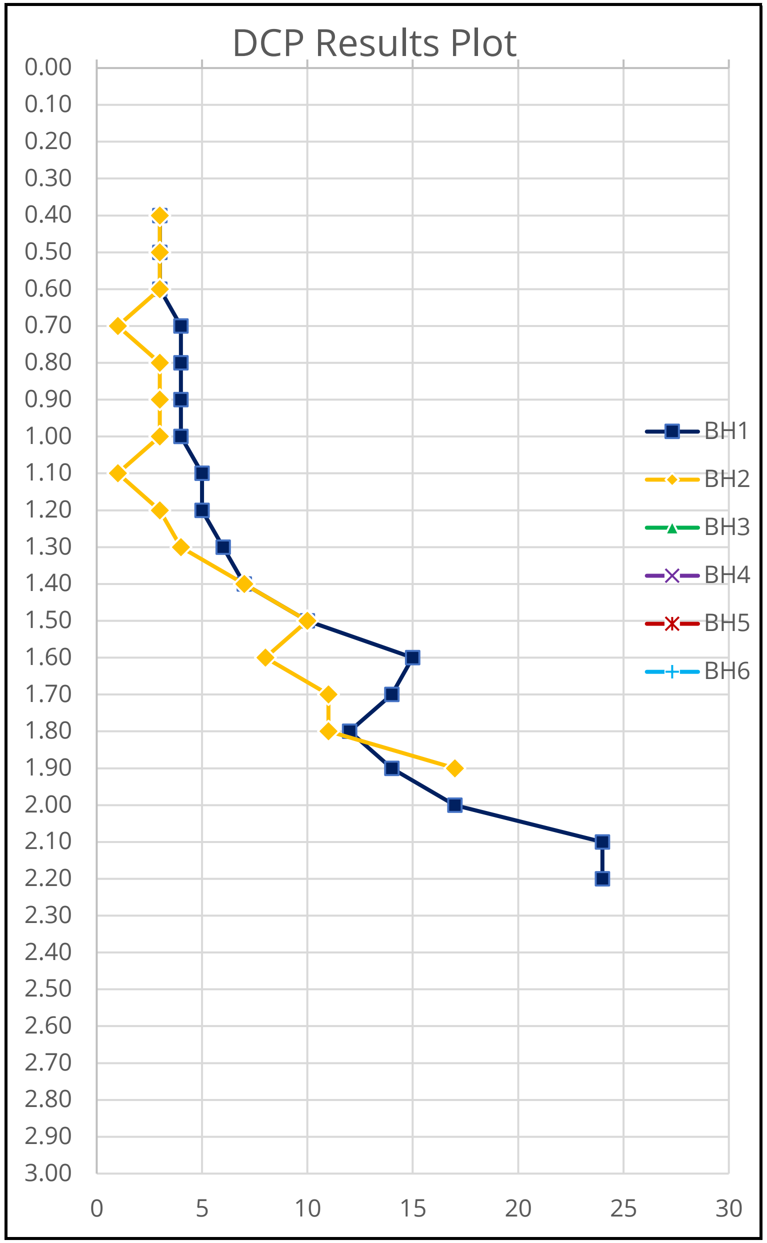
Base map
Spatial Services | Obtained on 2022-02-02
Creative Commons 3.0 - Commonwealth of Australia

Scale
1:500

Broadcrest Consulting Pty Ltd - Bearing Capacity

Depth			Blows / 100mm					
			BH1	BH2	BH3	BH4	BH5	BH6
0.00	-	0.10						
0.10	-	0.20						
0.20	-	0.30						
0.30	-	0.40	3	3				
0.40	-	0.50	3	3				
0.50	-	0.60	3	3				
0.60	-	0.70	4	1				
0.70	-	0.80	4	3				
0.80	-	0.90	4	3				
0.90	-	1.00	4	3				
1.00	-	1.10	5	1				
1.10	-	1.20	5	3				
1.20	-	1.30	6	4				
1.30	-	1.40	7	7				
1.40	-	1.50	10	10				
1.50	-	1.60	15	8				
1.60	-	1.70	14	11				
1.70	-	1.80	12	11				
1.80	-	1.90	14	17				
1.90	-	2.00	17					
2.00	-	2.10	24					
2.10	-	2.20	24					
2.20	-	2.30						
2.30	-	2.40						
2.40	-	2.50						
2.50	-	2.60						
2.60	-	2.70						
2.70	-	2.80						
2.80	-	2.90						
2.90	-	3.00						
20th Percentile			**4**	**3**				

Soil Classification					
BH1	BH2	BH3	BH4	BH5	BH6
O	O				
S	S				
sC	sC				
		DCP only			



Appendix C: Foundations Maintenance Guidelines

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).

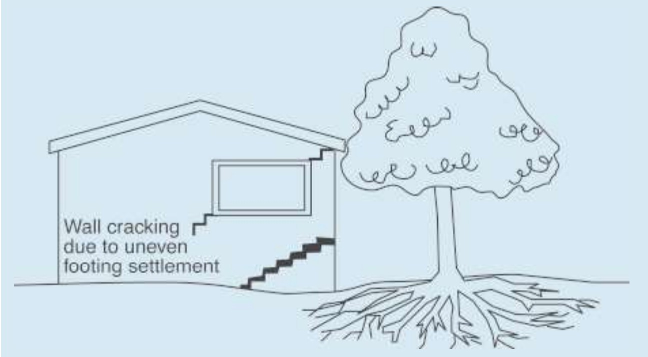
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

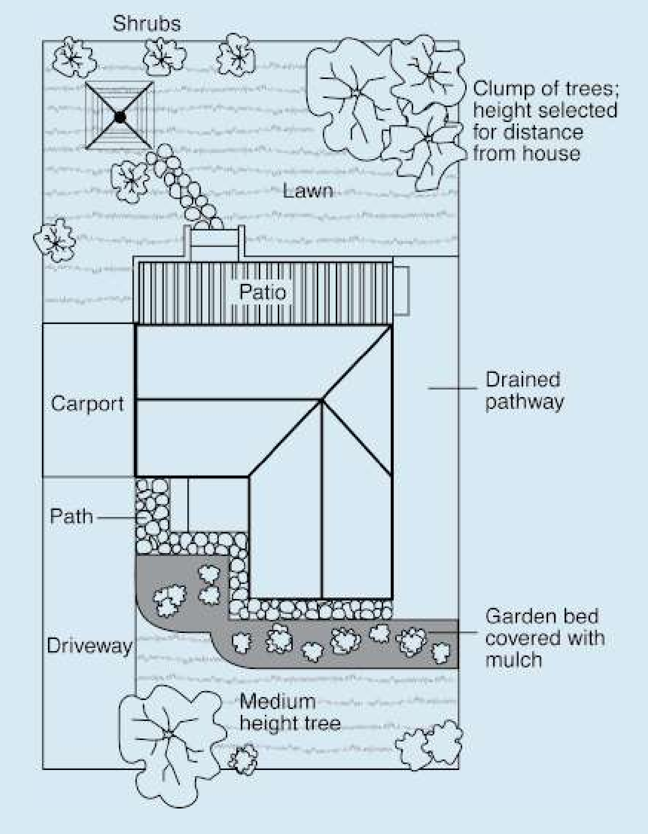
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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