15 March 2017

McCloy Group
Suite 1, Level 3, 426 King Street
NEWCASTLE WEST NSW 2309

Attention Jon Hines

Dear Jon,

RE: PROPOSED SUBDIVISION – BILLY'S LOOKOUT – STAGE 8
FISHERMANS DRIVE, TERALBA
SITE CLASSIFICATION (LOTS 801 TO 837)

1.0 INTRODUCTION

Qualtest Laboratory NSW Pty Ltd (Qualtest) is pleased to present this site classification report on behalf of McCloy Group (McCloy), for Stage 8 of the proposed residential subdivision of Billy's Lookout, to be located at Fishermans Drive, Teralba.

Based on the brief and drawing provided by the client, Stage 8 is understood to comprise of 37 residential allotments (Lots 801 to 837).

The report provides site classification with respect to reactive soils, in accordance with the requirements of AS2870-2011 '*Residential Slabs and Footings*', for Stage 8 (Lots 801 to 837), following completion of site regrade works.

2.0 DESKTOP STUDY

The scope of work has included a review of the following reports completed by Qualtest.

- Site Classification report, 'Proposed Subdivision, Billy's Lookout – Stage 8, Fishermans Drive, Teralba, (Report Reference: NEW15P-0070-AC, dated 17June 2016).
- Level 1 Site Regrade Assessment report, 'Proposed Subdivision, Billy's Lookout – Stage 8, Fishermans Drive, Teralba, (Report Reference: NEW16P-0090-AA, dated 9 March 2017).

Reference should be made to the reports outlined above for full details of site description, subsurface conditions, field work conducted, engineering logs of test pits, laboratory testing results, site supervision and density testing carried out:

3.0 FIELD WORK

Following the completion of site regrade works, additional field work investigations were carried out on 17 February 2017 to assess the depth, composition and properties of the controlled fill material placed on lots during site regrade works, and comprised of:

- Drilling of 10 boreholes (BH801 to BH810), using a 4 tonne tracked excavator with 250mm diameter auger attachment, to depths of up to 1.5m;
- Bulk disturbed samples, undisturbed samples (U50 tubes), and small bag samples were taken for subsequent laboratory testing;

Investigations were carried out by an experienced Principal Geotechnician from Qualtest who located the boreholes, carried out the testing and sampling, produced field logs of the boreholes, and made observations of the site surface conditions:

Approximate borehole locations are shown on the attached Figure AG1, which also includes test pit locations from the previous investigations conducted on site.

Engineering logs of the boreholes have been kept on file for reference, with a summary of the profiles encountered presented in Table 1 and Table 2 below.

4.0 SITE DESCRIPTION

4.1 Site Regrade Works

Site re-grading works were conducted on lots 800 to 835 (as shown on Figure AG1), between the dates of 29 June 2016 and 10 October 2016.

Prior to filling, re-grade areas were stripped of all topsoil and unsuitable material to expose suitable natural residual foundation profile. Re-grade works then consisted of filling with approved site fill to finish design levels.

Filling was performed using site material won from excavations cut from around the site, which comprised a blend of Colluvium (Silty SAND / Clayey SAND) site won from within Stage 8, with Residual Soil / Weathered Rock (Sandy Clay / Extremely Weathered Sandstone) won from cuts excavated within Stages 7 and 8, and approved borrow area in Stage 9.

As the geotechnical testing authority engaged for the project, we state that the filling performed for the regrade areas (lots 800 to 835,), was carried out to Level 1 criteria as defined in Clause 8.2 – Section 8, of AS3798-2007, '*Guidelines on Earthworks for Commercial and Residential Developments*'.

4.2 Subsurface Conditions

Reference should be made to the previous reports outlined in Section 2.0 for full details of site description, subsurface conditions, field work conducted, engineering logs of test pits, laboratory testing results, site supervision and density testing carried out.

Table 1 presents a summary of the typical soil types encountered on site during the field investigations, divided into representative geotechnical units. The units adopted have remained consistent with those previously provided, with the addition of Controlled Fill.

Table 2 contains a summary of the distribution of the above geotechnical units at the borehole locations.

No groundwater levels, water inflows were encountered in the boreholes during the limited time that they remained open on the day of the field investigations.

It should be noted that groundwater conditions can vary due to rainfall and other influences including regional groundwater flow, temperature, permeability, recharge areas, surface condition, and subsoil drainage.

TABLE 1 – SUMMARY OF GEOTECHNICAL UNITS AND SOIL TYPES

Unit	Soil Type	Description
1	FILL	Gravelly Sandy CLAY – low to medium plasticity. Encountered in TP211 which was excavated near the edge of a recently constructed fill platform. (Encountered in previous investigations).
1A	CONTROLLED FILL	Gravelly Sandy CLAY – low to medium plasticity, yellow brown with mixtures of Silty SAND / Clayey SAND - fine to coarse grained, grey / pale brown, fines of low to medium plasticity, some fine to medium grained gravel in places. Typically, of very stiff to hard consistency.
2	TOPSOIL	Silty SAND and Clayey SAND - fine to coarse grained, brown to grey, fines of low plasticity and low to medium plasticity, trace of fine grained gravel in places, root affected.
3	SLOPEWASH / COLLUVIUM	Silty SAND / Clayey SAND - fine to coarse grained, grey / pale brown, fines of low to medium plasticity, some tree roots, some fine to medium grained gravel in places. SAND - fine to medium grained, grey.
4	RESIDUAL SOIL	Sandy CLAY, medium and medium to high plasticity, variable colours such as pale brown, orange to pale brown, pale grey, grey, and brown to red, sand fine to coarse grained or fine to medium grained. Typically, of very stiff to hard consistency. CLAY and Clayey SAND in places. Some tree roots in places
5	EXTREMELY WEATHERED (XW) ROCK	Extremely Weathered SILTSTONE and SANDSTONE, excavating as Clayey Sandy GRAVEL - fine to coarse grained, angular / sub-angular, grey to pale grey with pale brown, fines of low to medium plasticity. Some pockets of very stiff to hard CLAY and Highly Weathered SILTSTONE in places. Breaks down into Clayey SAND in places.
6	HIGHLY WEATHERED (HW) ROCK	SANDSTONE, fine to medium or fine to coarse grained, variable colours such as pale grey to white, grey, orange, pale brown, variable estimated strength ranging from very low to very high. Pebbly SANDSTONE and SILTSTONE in places. Fractured in places. Extremely to Highly Weathered in places.

TABLE 2 – SUMMARY OF GEOTECHNICAL UNITS ENCOUNTERED AT BOREHOLE LOCATIONS

Location	Unit 2 Topsoil	Unit 1A Controlled Fill	Unit 3 Slopewash / Colluvium	Unit 4 Residual Soil	Unit 5 XW Rock	Unit 6 HW Rock
	Depth in metres (m)					
Current Geotechnical Assessment (Ref: NEW15P-0070A-AG, February 2017) Assessment of Controlled Fill material						
BH801	0.00 - 0.20	0.20 – 1.50	-	-	-	-
BH802	0.00 - 0.20	0.20 – 1.50	-	-	-	-
BH803	0.00 - 0.20	0.20 – 1.50	-	-	-	-
BH804	0.00 - 0.20	0.20 - 0.90	-	0.90 - 1.50	-	-
BH805	0.00 - 0.20	0.20 - 0.80	-	0.80 – 1.50	-	-
BH806	0.00 - 0.20	0.20 – 1.10	-	1.10 – 1.50	-	-
BH807	0.00 - 0.15	0.15 – 0.70	-	0.70 - 1.50	-	-
BH808	0.00 - 0.20	0.20 - 0.40	-	0.40 - 1.50	-	-
BH809	0.00 - 0.20	0.20 – 1.10	-	1.10 - 1.50	-	.
BH810	0.00 - 0.20	0.20 – 0.70	-	0.70 - 0.50	-	-

5.0 LABORATORY TESTING

Samples collected during the field investigations were returned to our NATA accredited Warabrook Laboratory for testing which comprised of:

- (4 no.) Shrink / Swell tests;
- (6 no.) Atterberg Limits tests.

Proposed shrink/swell testing of a number of samples were replaced by Atterberg Limits classification tests due to the friable nature of the site soils.

Results of the laboratory testing have been kept on file for reference, with a summary of the Shrink/Swell and Atterberg Limits test results presented in Tables 3 and 4.

The tables also include a summary of laboratory testing information (where applicable) from the previous Geotechnical Assessment works carried out by Qualtest.

The results of laboratory testing indicate that the residual soils tested from the site generally contain fines of medium plasticity to high plasticity, whilst the re-blended regraded fill material is of low to medium plasticity, with soil profiles typically being slightly to moderately reactive.

TABLE 3 – SUMMARY OF SHRINK / SWELL TESTING RESULTS

Location	Depth (m)	Material Description	I_{ss} (%)
Previous Investigations (February 2016 & June 2016)			
TP114	0.80 - 1.05	(CH) CLAY- Residual	3.7
TP120	0.90 - 1.20	(CI) Sandy CLAY- Residual	2.1
TP206	0.55 - 0.70	(CI) Sandy CLAY- Residual	2.1
TP207	0.40 - 0.60	(CI) Sandy CLAY- Residual	1.1
TP208	0.50 - 0.90	(CI) Sandy CLAY - Residual	1.5
TP210	0.50 - 0.65	(CL) Sandy CLAY- Residual	0.6
TP212	0.60 - 0.76	(CL) Sandy CLAY- Residual	0.7
Current Investigations (Following Site Regrade - February 2017)			
BH805	0.40 - 0.90	(CL) Sandy CLAY- Residual	3.0
BH806	0.40 – 0.80	(CL) Sandy CLAY- Fill	1.5
BH807	0.40 – 0.90	(CL) Sandy CLAY- Fill	0.9
BH808	0.30 – 0.70	(CL) Sandy CLAY- Fill	1.0

TABLE 4 – SUMMARY OF ATTERBERG LIMITS TESTING RESULTS

Location	Depth (m)	Material Description	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)
Previous Investigations (June 2016)						
TP205	0.35 - 0.50	(CH) Sandy CLAY	54	21	33	11.5
TP209	0.70 - 0.80	(CL) Sandy CLAY	28	9	19	2.5
TP211	0.20 - 0.40	(CL) Sandy CLAY	34	16	18	7.0
Current Investigations (Following Site Regrade - February 2017)						
BH801	0.30 - 0.70	CONTROLLED FILL: (CL) Gravelly Sandy CLAY with some (SM) Silty SAND & (SC) Clayey SAND	27	13	14	7.0
BH802	0.30 - 0.70		26	14	12	4.0
BH803	0.50 - 0.90		29	12	17	4.5
BH804	0.60 - 0.90		29	12	17	5.0
BH809	0.20 - 0.60		25	14	11	3.0
BH810	0.30 - 0.60		18	12	6	1.5

6.0 SITE CLASSIFICATION TO AS2870-2011

Based on the results of the field work, laboratory testing, and Level 1 site supervision and testing carried out, residential lots located within the proposed Stage 8 of the Billy's Lookout subdivision located off Pitt Street and Fishermans Drive, Teralba, as shown on Figure AG1, are classified in their current condition in accordance with AS2870-2011 'Residential Slabs and Footings', as shown in Table 5.

TABLE 5 – SITE CLASSIFICATION TO AS2870-2011

Lot Numbers	Site Classification
800 to 837	**M**

A characteristic free surface movement of 20mm to 40mm is estimated for lots classified as Class 'M' in their existing condition. The effects of changes to the soil profile by additional cutting and filling and the effects of past and future trees should be considered in selection of the design value for differential movement.

If site re-grading works involving cutting or filling are performed after the date of this assessment, the classification may change and further advice should be sought.

Footings for the proposed development should be designed and constructed in accordance with the requirements of AS2870-2011.

The classification presented above assumes that:

- All footings are founded in controlled fill (if applicable) or in the residual clayey soils or rock below all non-controlled fill, topsoil material and root zones, and fill under slab panels meets the requirements of AS2870-2011, in particular, the root zone must be removed prior to the placement of fill materials beneath slabs;
- The performance expectations set out in Appendix B of AS2870-2011 are acceptable, and that site foundation maintenance is undertaken to avoid extremes of wetting and drying;
- Footings are to be founded outside of or below all zones of influence resulting from existing or future service trenches;
- The constructional and architectural requirements for reactive clay sites set out in AS2870-2011 are followed;
- Adherence to the detailing requirement outlined in Section 5 of AS2870-2011 '*Residential Slabs and Footings*' is essential, in particular Section 5.6, 'Additional requirements for Classes M, H1, H2 and E sites' including architectural restrictions, plumbing and drainage requirements;
- Site maintenance complies with the provisions of CSIRO Sheet BTF 18, *"Foundation Maintenance and Footing Performance: A Homeowner's Guide"*, a copy of which is attached in Appendix C.

All structural elements on all lots should be supported on footings founded beneath all uncontrolled fill, layers of inadequate bearing capacity, soft/loose, wet or other potentially deleterious material.

If any areas of uncontrolled fill of depths greater than 0.4m are encountered during construction, they should be designed in accordance with engineering principles for Class 'P' sites.

7.0 LIMITATIONS

The findings presented in the report and used as the basis for recommendations presented herein were obtained using normal, industry accepted geotechnical design practices and standards. To our knowledge, they represent a reasonable interpretation of the general conditions of the site.

The extent of testing associated with this assessment is limited to discrete test locations. It should be noted that subsurface conditions between and away from the test locations may be different to those observed during the field work / site supervision works, and used as the basis of the recommendations contained in this report.

If subsurface conditions encountered during construction differ from those given in this report, further advice should be sought without delay.

Data and opinions contained within the report may not be used in other contexts or for any other purposes without prior review and agreement by Qualtest. If this report is reproduced, it must be in full.

If you have any further questions regarding this report, please do not hesitate to contact Alan Cullen or the undersigned.

For and on behalf of Qualtest Laboratory (NSW) Pty Ltd

Jason Lee
Principal Geotechnical Engineer

Attachments:

Figure AG1 – Site Regrade and Approximate Test Location Plan
CSIRO Sheet BTF 18 - Foundation Maintenance and Footing Performance

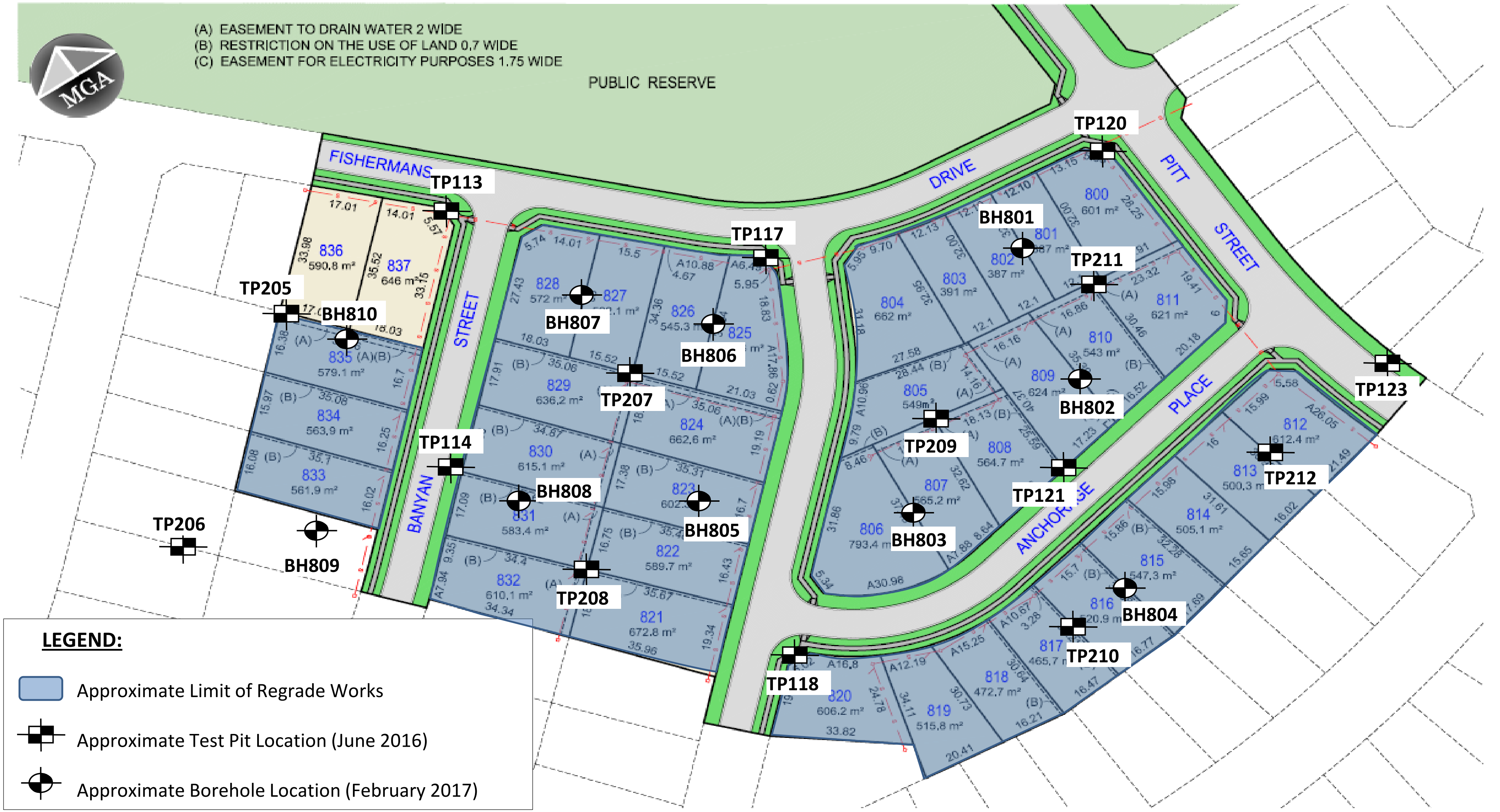


Figure based on sales plan for Billy's Lookout - Stage 8 provided by client.

Qualtest LABORATORY (NSW) PTY LTD

Client:	McCLOY GROUP	Drawing No:	FIGURE AG1
Project:	PROPOSED SUBDIVISION - BILLY'S LOOKOUT - STAGE 8	Project No:	NEW15P-0070A
Location:	FISHERMANS DRIVE & PITT STREET, TERALBA	Scale:	AS SHOWN
Title:	SITE REGRADE & APPROXIMATE TEST LOCATION PLAN	Date:	9 MARCH 2017

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).

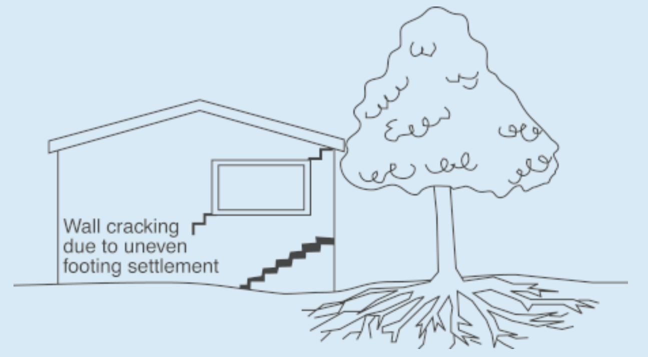
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

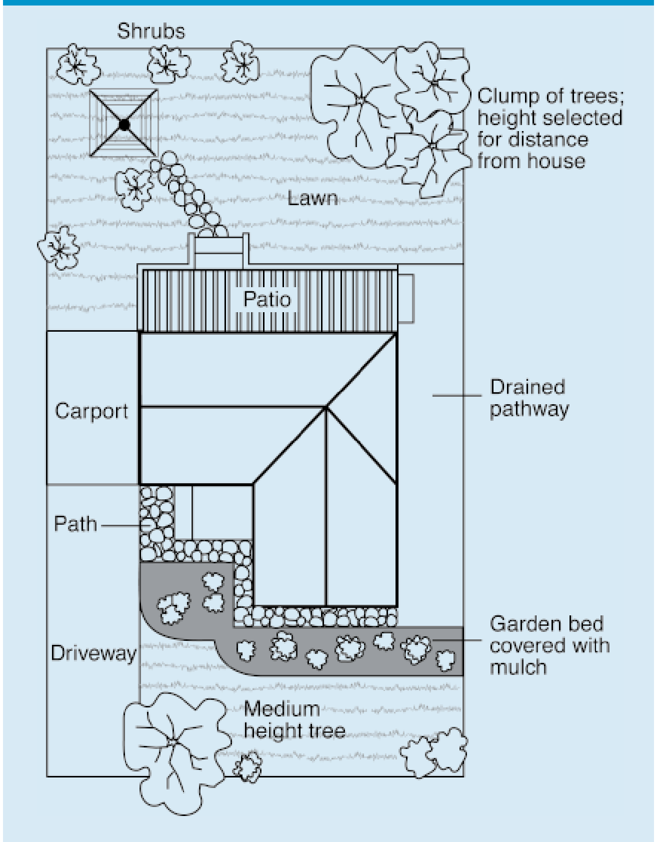
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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