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Geotechnical & Environmental Services

GEOTECHNICAL SITE INVESTIGATION

4571 BRUNY ISLAND - MAIN ROAD

PROPOSED VISITOR ACCOMMODATION

Client: Nic Danger

Certificate of Title: 33162/1

Investigation Date: 01/05/2026

Refer to this Report As

Enviro-Tech Consultants Pty. Ltd. 2026. Geotechnical Site Investigation Report for a Proposed Visitor Accommodation, 4571 Bruny Island - Main Road. Unpublished report for Nic Danger by Enviro-Tech Consultants Pty. Ltd., 01/05/2026.

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In some cases, variations in actual Site conditions may exist between subsurface investigation boreholes. This report only applies to the tested parts of the Site at the Site of testing, and if not specifically stated otherwise, results should not be interpreted beyond the tested areas.

The Site investigation is based on the observed and tested soil conditions relevant to the inspection date and provided design plans (building footprints presented in Attachment A). Any Site works conducted outside the scope of the provided Site plans have not been assessed. Subsurface conditions may change laterally and vertically between test Sites, so discrepancies may occur between what is described in the reports and what is exposed by subsequent excavations. No responsibility is therefore accepted for any difference in what is reported, and actual Site and soil conditions for parts of the investigation Site which were not assessed at the time of inspection.

This report has been prepared based on provided plans detailed herein. Should there be any significant changes to these plans, then this report should not be used without further consultation which may include drilling new investigation holes to cover the revised building footprint. This report should not be applied to any project other than indicated herein.

No responsibility is accepted for subsequent works carried out which deviate from the Site plans provided or activities onsite or through climate variability including but not limited to placement of fill, uncontrolled earthworks, altered drainage conditions or changes in groundwater levels.

Footing exposure classification is presented on a layer-by-layer basis. In practice, some layers may be removed during excavation or replaced as part of site cuts and fills, while others may be incorporated within the building envelope. The information should therefore be regarded as guidance only, and the designer must assess the actual founding conditions and make the final determination of concrete strength, curing and cover requirements.

At the time of construction, if conditions exist which differ from those described in this report, it is recommended that the base of all footing excavations be inspected to ensure that the founding medium meets that requirement referenced herein or stipulated by an engineer before any footings are poured.

Site Investigation

The Site investigation is summarised in Table 1.

Table 1 Summary of Site Investigation

Client	**Nic Danger**
Project Address	4571 Bruny Island - Main Road
Council	Kingborough
Planning Scheme	Interim Planning Scheme
Inundation, Erosion or Landslip Overlays	None
Proposed	Visitor Accommodation
Investigation	Fieldwork was carried out by an Engineering Geologist on the 1/5/2026
Site Topography	The broader Site slopes approximately 18% to the north, while local bench areas surrounding the visitor accommodation range from approximately 8° to 13°
Site Drainage	The Site receives overland flow runoff directly from the south.
Soil Profiling	A single investigation hole was direct push sampled around the proposed visitor accommodation (Appendix A):
Investigation Depths	The target excavation depth was estimated at 2.3 m. Borehole BH01 was direct push sampled to 1.9 m (ending in DOLERITE) Borehole logs and photos are presented in Appendix B & C.
Soil moisture and groundwater	Recovered soil at the site was dry at the time of the investigation. Groundwater was not encountered.
Geology	According to 1:250,000 Mineral Resources Tasmania geological mapping (accessed through The LIST), the geology comprises of: Jurassic Dolerite and related rock.
Wind load classification	The AS 4055-2021 Wind loads for Housing classification is summarised.
Region	A
Terrain category:	TC1
Shielding Classification:	PS
Topographic Classification:	T0
Wind Classification:	**N2**
Design Wind Gust Speed (Vh,u) m/s	40

Investigation Summary

Site Classification

In accordance with AS 2870 – 2011 and after thorough consideration of the known details pertaining to the proposed building and associated works (hereafter referred to as the Site), the geology, soil conditions, soil properties, and drainage characteristics of the Site have been classified as follows:

CLASS P based on the following problematic ground conditions identified at the site:

- Fill encountered/proposed at the site at a thickness greater than 0.8 m
- Class 1 dispersive soils are present at the Site with CLASS P foundation conditions requiring specialised management measures to mitigate erosion hazards

Notwithstanding the problematic soil conditions observed/proposed at the Site, the soil would be classified as Class H1.

Future Building Work Foundations

Concentrated loads including but not limited to slab edge or internal beam or strip footings shall be supported directly on piers or pads which are founded on the dolerite bedrock at depth of up to 1.8m depth or greater (below problem soil layers with an allowable bearing capacity of 300 kPa).

Landslide Assessment

The landslide assessment identified that the proposed visitor accommodation is located outside the primary area of mapped Low Landslide Hazard Overlay, with the overlay mainly affecting existing benched cut and fill areas adjacent to the building. The assessed hazards are limited to small-scale localised instability of existing batters and potential erosion associated with dispersive soils, rather than deep-seated landslide movement. Shallow dolerite bedrock was encountered at BH01, no evidence of active landslide movement or tunnel erosion was observed, and the overall landslide risk is considered low under current Site conditions, subject to standard drainage and surface stabilisation measures. The assessment has considered all areas of the Site accessible to occupants, staff and visitors of the proposed visitor accommodation, including the existing building, the vehicle access driveway, parking areas, and the surrounding outdoor usable areas. No part of the Site routinely accessed by users of the visitor accommodation is located within the mapped Low Landslide Hazard Area, and the residual landslide risk to users of the Site is accordingly considered low.

Scope of Works

The proposed development comprises a change of use from an existing residential dwelling to visitor accommodation at the Site. The Site is partially affected by the Kingborough Interim Planning Scheme 2015 Landslide Hazard Code, with a mapped Low Landslide Hazard Area applying to portions of the existing benched terrain located adjacent to and downslope of the existing dwelling.

Although the proposed visitor accommodation area is located outside of the mapped landslide hazard overlay, the development triggers the Landslide Code due to the proximity of historical cut and fill earthworks associated with the existing benched Site configuration. Accordingly, a geotechnical assessment has been undertaken to assess whether the existing terrain and historical earthworks present an unacceptable landslide hazard risk to the proposed use.

The scope of works completed for this assessment generally included:

- Review of available aerial imagery, topographic mapping, and the Kingborough Interim Planning Scheme 2015 landslide hazard overlay mapping.
- Site walkover inspection to document existing terrain conditions, slope geometry, vegetation, drainage conditions, and evidence of historical earthworks or instability.
- Assessment of the existing benched landform, including historical cut and fill areas located upslope and downslope of the existing dwelling.
- Drilling of borehole BH01 within the upper bench/cut-fill transition area to assess existing earthworks, landslide hazard conditions, and foundation Site classification parameters for potential future building works on the upper pad.
- Logging of subsurface conditions in accordance with AS 1726 Geotechnical Site Investigations, including soil classification using the Unified Soil Classification System (USCS).
- Assessment of soil strength, consistency, moisture conditions, and the presence of fill or highly weathered materials.
- Laboratory testing including Emerson dispersion testing to assess the presence and severity of dispersive soils within the subsurface profile.
- Assessment of slope conditions relative to the mapped Low Landslide Hazard Area and consideration of the potential for shallow instability associated with historical uncontrolled earthworks.
- Preparation of a geotechnical and landslide hazard assessment addressing the applicable requirements of the Kingborough Interim Planning Scheme 2015 Landslide Hazard Code.
- The assessment also provides a preliminary foundation Site classification for potential future building works on the upper bench/pad area near BH01. While no dwelling is currently proposed in this location as part of the visitor accommodation application, the borehole and soil testing results have been used to inform likely foundation conditions for any future structure in this area.

Preliminary Assessment Context

The investigation identified that the mapped Low Landslide Hazard Overlay primarily affects existing benched terrain associated with historical excavation and filling, rather than the proposed visitor accommodation footprint itself.

The Site generally comprises a series of stepped benches formed through historical uncontrolled cut and fill earthworks. The principal area of geotechnical relevance is the cut/fill transition zone adjacent to BH01, where moderately to severely dispersive soils were identified within both fill and natural soil horizons.

No clear evidence of active large-scale landslide movement was observed at the time of inspection. However, the presence of dispersive soils and historical uncontrolled earthworks has the potential to contribute to localised erosion or shallow instability if drainage conditions are not appropriately managed.

Mapped Geology

The Site is mapped by Mineral Resources Tasmania (MRT) within the Jurassic Dolerite geological unit, based on the 1:250,000 geological mapping series. The mapped unit comprises Jurassic-aged tholeiitic dolerite with locally derived granitoid float.

Jurassic Dolerite is widespread throughout southern Tasmania and commonly forms steep hillslopes and elevated terrain due to its relatively high strength and resistance to weathering. The material typically weathers variably, with near-surface profiles often comprising residual clayey soils, highly weathered dolerite, colluvium, and locally reworked slope deposits overlying stronger dolerite bedrock at depth.

At the Site, subsurface conditions encountered during drilling generally comprised fill overlying clay-rich residual soils and highly weathered materials interpreted to be derived from dolerite weathering. Refusal encountered at depth within BH01 is interpreted to represent dolerite bedrock or extremely weathered rock associated with the regional Jurassic Dolerite geology.

The existing benched terrain and cut/fill landforms present across the Site are considered to reflect historical earthworks undertaken within the weathered dolerite profile, rather than large-scale natural landslide morphology associated with the regional geology.

Topography

The Site is located on sloping ground with a series of existing benched areas formed by previous cut and fill earthworks.

Near the proposed visitor accommodation, the natural ground surface falls from approximately 24.5 m AHD to 22.5 m AHD across a horizontal distance of about 15 m. This equates to:

- 2 m vertical fall over 15 m horizontal distance
- Gradient of approximately 13%
- Approximate slope angle of 7.6°

This indicates a gentle to moderately inclined slope in the vicinity of the proposed visitor accommodation.

Further upslope, above the existing upper cut, the slope steepens between the 30 m and 32 m contours. The measured horizontal distance between these contours is approximately 8.6 m, which equates to:

- 2 m vertical rise over 8.6 m horizontal distance
- Gradient of approximately 23%
- Approximate slope angle of 13.1°

The upper portion of the Site is therefore moderately inclined and steeper than the ground immediately surrounding the visitor accommodation.

The Site has been modified by historical earthworks, forming a stepped or benched landform. The benches themselves are relatively level; however, they are separated by localised cut and fill batters.

The upper cut batter is estimated to be approximately 1.5 m high and inclined at about 45 degrees. The lower cut/fill batter is estimated to be in the order of 2.5 m high and inclined at approximately 35 to 45 degrees.

Overall, the desktop topographic assessment indicates that the proposed visitor accommodation is located on or adjacent to relatively gentle benched terrain, while steeper modified ground is present upslope and downslope within the existing cut and fill areas.

Site Soil Conditions

The geology of the Site has been documented and described according to Australian Standard AS 1726 for Geotechnical Site Investigations, which includes the Unified Soil Classification System (USCS). Soil layers, and where applicable, bedrock layers, are summarized in Table 2.

The Site is underlain by a combination of historical fill, residual clay soils, and weathered Jurassic Dolerite. Exposed materials within the upper cut batter indicate the presence of highly to extremely weathered dolerite within the near-surface soil profile.

BH01 encountered fill materials extending to approximately 1.0 m depth. The fill profile comprised Clayey GRAVEL with silt and trace sand near the surface, underlain by Silty Sandy CLAY and Sandy CLAY fill containing gravel and sand-sized doleritic material. The fill soils were generally massively structured and ranged from very loose near surface to stiff and very stiff with depth.

Table 2 Soil Summary Table

#	Layer	Details	USCS	BH01
1	Clayey GRAVEL	FILL: Clayey GRAVEL with silt, trace sand, light olive brown, well sorted, roots; angular gravel; massively structured, VL	GC	0-0.1 DS@0.0
2	Silty Sandy CLAY	FILL: Silty Sandy CLAY trace gravel, dark grey, mottled light olive brown, well sorted, medium plasticity, medium to coarse grained sand, roots; massively structured, S-VSt	CI	0.1-0.6 DS@0.4
3	Sandy CLAY	FILL: Sandy CLAY, olive grey, well sorted, high plasticity, fine to medium grained sand; massively structured, St-VSt	CH	0.6-1 DS@0.8
4	Silty Sandy CLAY	Silty Sandy CLAY trace gravel, dark grey, well sorted, medium plasticity, medium to coarse grained sand; massively structured, St	CI	1-1.2 DS@1.1
5	Sandy CLAY	Sandy CLAY, olive, well sorted, high plasticity, fine grained sand; massively structured, VSt-H	CH	1.2-1.8 DS@1.6
6	DOLERITE	DOLERITE Bedrock		1.8-1.9 DS@1.8 REF

Consistency[1]	**VS** Very soft; **S** Soft; **F** Firm; **St** Stiff; **Vst** Very Stiff; **H** Hard. Consistency values are based on soil strengths AT THE TIME OF TESTING and is subject to variability based on field moisture condition
Density[2]	**VL** Very loose; **L** Loose; **MD** Medium dense; **D** Dense; **VD** Very Dense
Rock Strength	**EL** Extremely Low; **VL** Very Low; **L** Low; M Medium; **H** High; **VH** Very High; **EH** Extremely High
PL	Point load test (lump)
DS	Disturbed sample
PV	Pocket vane shear test
FV	Downhole field vane shear test
U50	Undisturbed 48mm diameter core sample collected for laboratory testing.
REF	Borehole refusal
INF	DCP has continued through this layer and the geology has been inferred.

Below the fill profile, natural residual soils encountered from approximately 1.0 m depth comprised Silty Sandy CLAY and Sandy CLAY derived from weathered dolerite. These soils were generally olive to dark grey in colour, moderately to highly plastic, and stiff to hard in consistency.

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[1] Soil consistencies are derived from a combination of field index, DCP and shear vane readings.

[2] Soil density descriptions presented in engineering logs are derived from the DCP testing.

Dolerite bedrock was inferred from approximately 1.8 m depth, with borehole refusal encountered at approximately 1.9 m depth. The shallow refusal depth indicates relatively shallow bedrock beneath the upper bench area.

Overall, the Site conditions are consistent with a modified weathered dolerite slope profile, comprising historical uncontrolled fill overlying residual clay soils and shallow Jurassic Dolerite bedrock.

Landslide Risk Assessment

The assessment has considered the existing benched landform, historical cut and fill earthworks, shallow bedrock conditions encountered in BH01, and the presence of dispersive soils within the profile. The assessment is focused on the existing cut and fill areas affected by, or located adjacent to, the mapped Low Landslide Hazard Area.

BH01 encountered dolerite bedrock at approximately 1.8 m depth, with borehole refusal at approximately 1.9 m depth. This indicates relatively shallow competent material beneath the upper bench area. Under the current Site conditions, the probability of significant slope instability affecting the existing benches or proposed visitor accommodation use is considered very low.

Slope instability and erosion scenarios have been considered in Table 3.

The assessed instability scenarios are limited to small-scale, localised batter features associated with existing historical earthworks. The presence of shallow dolerite bedrock beneath the upper bench reduces the potential for deeper-seated instability under the current Site conditions.

No tunnel erosion was observed during the Site inspection. However, laboratory testing indicates that dispersive soils are present within the Site profile, including severely dispersive materials in some layers. On this basis, the risk of tunnel erosion is considered low under current conditions, provided exposed dispersive soils are appropriately managed and surface water is not allowed to concentrate on or discharge over exposed batters.

Compliance with Kingborough Interim Planning Scheme 2015 – E3.0 Landslide Code

The proposed development involves a change of use from an existing dwelling to visitor accommodation. Under Clause E3.0 Landslide Code, visitor accommodation is defined as a Vulnerable Use.

The Site is partially affected by the mapped Low Landslide Hazard Area overlay, identified as “remaining slopes 11–20 degrees”. The mapped overlay primarily affects existing benched terrain and historical cut/fill areas adjacent to the existing dwelling and proposed visitor accommodation area, rather than the primary building footprint itself.

The usable areas of the Site that will be accessed by occupants, staff and visitors of the visitor accommodation, including the existing dwelling, the vehicle access driveway and parking areas, and the immediately surrounding outdoor areas, are located outside the mapped Low Landslide Hazard Area. No part of the Site routinely accessed by users of the visitor accommodation falls within the mapped overlay, and the landslide risk to users of these areas is considered low.

Assessment of the proposal has therefore been undertaken against Clause E3.6.2 P2 of the Kingborough Interim Planning Scheme 2015.

Table 3 Summary of slope stability and tunnel erosion risk scenarios for the existing cut and fill areas within the mapped Low Landslide Hazard Area.

Scenario	Description	Landslide / erosion mechanism	Scale of feature	Likelihood	Consequence	Risk level	Management required
Scenario 1 – Instability of lower cut/fill batter	Localised instability of the cut/fill batter between the lower and middle bench areas. This area includes historical fill and modified ground associated with the existing terraced Site layout.	Shallow slumping, ravelling, or localised movement of fill or near-surface soil on the existing batter.	Small-scale, localised batter instability only. Not representative of a deep-seated landslide mechanism.	Rare to Unlikely	Minor	Low	No, for slope stability under current conditions.
Scenario 2 – Instability of upper cut batter	Localised instability of the upper cut batter above the upper bench area. This cut exposes weathered dolerite-derived soils and highly to extremely weathered material.	Shallow cut-face instability, minor slumping, erosion, or localised ravelling from the exposed cut face.	Small-scale cut batter instability only. Not representative of a deep-seated landslide mechanism.	Rare to Unlikely	Minor	Low	No, for slope stability under current conditions.
Scenario 3 – Tunnel erosion in dispersive soils	Development of tunnel erosion within exposed dispersive soils, particularly where runoff is concentrated or where exposed cut faces remain unvegetated.	Internal erosion and piping/tunnel formation within dispersive clay soils, potentially leading to localised surface collapse or erosion features.	Localised erosion feature. Potentially progressive if unmanaged, but no tunnel erosion was observed at the time of inspection.	Unlikely	Minor	Low	Yes. Management required to reduce erosion risk associated with dispersive soils.

Kingborough Interim Planning Scheme 2015 Performance Criteria

Based on the desktop assessment, Site inspection, subsurface investigation, and laboratory testing, the proposed visitor accommodation is considered to satisfy the intent of Clause E3.6.2 P2 of the Kingborough Interim Planning Scheme 2015 Landslide Code.

The identified hazards are limited to small-scale localised instability and potential erosion associated with historical cut and fill earthworks. These risks are considered low under current conditions and are capable of feasible and effective management through standard drainage and surface stabilisation measures. The proposal is therefore considered to present a tolerable level of landslide risk, as presented in Table 4.

The assessment has considered all areas of the Site that may be accessed by occupants, staff and visitors of the proposed visitor accommodation, including the existing dwelling, the vehicle access driveway and parking areas, and the surrounding outdoor usable areas. These areas are located outside the mapped Low Landslide Hazard Area, with the mapped overlay confined to existing benched cut and fill batters that do not form part of the usable areas of the Site. No part of the Site routinely accessed by users of the visitor accommodation falls within the mapped overlay, and the landslide risk to users of the Site is therefore considered low.

Table 4 Assessment of compliance with Clause E3.6.2 P2 of the Kingborough Interim Planning Scheme 2015 Landslide Code for the proposed visitor accommodation development.

E3.6.2 P2 Requirement	**Assessment**
No part of the vulnerable use is in a High Landslide Hazard Area	The proposed visitor accommodation is not located within a High Landslide Hazard Area. The Site is only affected by a Low Landslide Hazard Area overlay associated with existing benched terrain and slopes generally between 11° and 20°.
Landslide risk to occupants, staff, visitors and emergency personnel associated with the vulnerable use is either acceptable risk, or capable of feasible and effective treatment through hazard management measures, so as to be tolerable risk	The assessment identified only low-risk, localised instability scenarios associated with historical cut and fill batters. No evidence of active landslide movement or tunnel erosion was observed at the Site. Shallow dolerite bedrock encountered at BH01 reduces the likelihood of deep-seated instability. The overall landslide risk under existing conditions is considered low and capable of effective management through minor erosion and drainage controls. All areas of the Site accessed by occupants, staff and visitors, including the existing dwelling, the vehicle access driveway, parking and surrounding outdoor usable areas, are located outside the mapped Low Landslide Hazard Area.
Landslide risk takes into consideration the ability of occupants and visitors to protect themselves, evacuate if required, and respond to instructions in an emergency	The proposal involves use of an existing building in an accessible developed area with existing vehicle access and established benched terrain. The identified hazards relate only to localised batter instability and potential erosion features, rather than rapid large-scale landslide hazards. The risk to occupants and emergency personnel is therefore considered low. The vehicle access driveway, parking and outdoor areas used by occupants and visitors are located on gently benched terrain outside the mapped Low Landslide Hazard Area, allowing users to move about the Site, evacuate and respond to instructions in an emergency without exposure to a rapid landslide hazard.

Recommendations

General

For Class P and H2 Sites, the designer should be a qualified engineer experienced in the design of footing systems for buildings.

Dispersive soil Management

Findings

The results presented in Appendix F indicate:

- The Emerson dispersion results indicate that the subsurface profile is generally dispersive, with severe dispersive conditions identified in Layers 2, 3 and 5.
- Layer 1, comprising fill, returned an Emerson Class 3 result and is considered moderately dispersive.
- Layers 2, 3 (fill) and 5 returned Emerson Class 1 results and are considered severely dispersive.
- Layer 4 returned an Emerson Class >4 result and is not considered dispersive.
- The results indicate that severely dispersive soils are present at multiple depths beneath the Site, including within the natural soil profile below the fill.

Site specific recommendations

Dispersive soils were identified within the Site profile, including severely dispersive soils in Layers 2, 3 and 5. Management is therefore required where these materials are exposed or may be affected by concentrated surface water flow.

The following measures are recommended:

- Exposed dispersive soils on the upper cut batter should be covered with topsoil and revegetated to reduce erosion risk and prevent tunnel erosion from developing.
- Surface water should be directed away from exposed cut batters and fill faces wherever practicable.
- Concentrated runoff should not be discharged directly over exposed dispersive soil surfaces.
- Existing drainage paths should be maintained so that stormwater is conveyed in a controlled manner around the benched areas.
- Any future excavation into the dispersive soil profile should be promptly stabilised by covering exposed surfaces with suitable non-dispersive topsoil, mulch, erosion matting, or equivalent surface protection.
- Disturbed areas should be revegetated as soon as practicable following any future earthworks.
- No tunnel erosion was observed at the time of inspection; however, exposed dispersive soils should not be left untreated, particularly on the upper cut batter.

For further guidance, general recommendations are presented in Appendix H.

Soil Exposure Classification

The soil has been tested for salinity impacts on footings in accordance with AS 2870, as well as preliminary pH testing as a proxy to potential sulphate aggressivity.

- For an exposure classification of A1, it is recommended to utilize concrete with a minimum strength of 20 MPa, provide at least 40 mm cover without a membrane (30mm with), and ensure curing for no less than three days.

Plumbing

Refer to hydraulic design drawings for detailed plumbing advice and requirements.

Refer to Table 5 to assess soil movement (Ys) around pipework for different depth ranges.

It is strongly recommended that gypsum is applied in the based on any service trench cuts at a rate of 1.5kg/m2.

*Table 5 Millimetres soil movement (Ys) for determining plumbing requirements for various soil depths **

Building	Profiles	P*	E Ys >75	H2 Ys 60-75	H1 Ys 40-60	M Ys 20-40	S Ys 0-20	A Ys 0
Dwelling	BH01	YES			0-0.5	0.5-1.2	1.2-1.8	1.8-3

* Depths in this table are based on surfaces at the time of testing and do not allow for the influence of any additional fill added to the soil profile unless the Iss calculation depth has been modified based on the proposed cut and fill (see 'Footing Minimum Target Depths'). Where additional fill is proposed (and not indicated in the attached plans) Enviro-Tech are to be advised of final FFL's so the Site classification can be recalculated according to the specific fill reactivity and thickness used in the design.

Class M

When pipework service trench excavations intercept the Class M depth range as shown in Table 5, and all plumbing recommendations herein have been implemented, all stormwater and sanitary plumbing drains should have fittings set at their midposition during installation to allow 0.5ys movement in any direction. Pipe wrappings can be used at critical points.

AS3500.2:2021 Appendix G of AS3500.2:2021 should be referred for general advice.

Site Drainage

As part of the building design plan, drains are recommended upslope of earth retaining structures, soil cuts, filled areas and the proposed building Site to capture and divert Site stormwater flow.

Due to the presence of the dispersive soils stormwater absorption trenches need to be avoided at the Site.

Surface drainage shall be considered in the design of the footing system, and necessary modifications shall be included in the design documentation. The surface drainage of the site shall be controlled from the beginning of the preparation and construction of the site. The drainage system shall be completed after the completion of the building construction.

Ideally, the areas around the footprint of the building should be graded or drained so that the water cannot pond against or near the building. As soon as footing construction has been completed, the ground immediately adjacent to the building should be graded to a uniform fall of 50mm minimum away from the building over the first metre. The final provision of paving to the edge of the building can greatly limit soil moisture variations due to seasonal wetting and drying.

Temporary Site Drainage

It is recommended that drainage protection works (cut off drains/mounds) are put in place above (upgradient of) the work area to prevent water and sediment from accumulating in and around footings and reduce the risk of erosion and instability around any proposed earth retaining structures.

Permanent Cut Batters – Soil and Rock

To ensure that cuts remain serviceable, it is recommended that unretained cuts in soil do not exceed 1V: 2H and unsupported batters in bedrock do not exceed 1V: 1H. Before cuts are approached by workers, cuts must be appropriately scaled to remove any loose soil and rock. The bedrock should not be increased beyond 2.0 m height relative to depth below natural level, without inspection by a suitably qualified person to ensure that these cuts are safe to work under.

Filling Works

- In the case where either of the following conditions occur, the Site is classified as Class P (AS 2870 Clauses 2.5.2 and 2.5.3), in which case footings are to be designed in accordance with engineering specifications:
    - FILL OTHER THAN SAND exceeds 0.4 m depth.
    - SAND FILL exceeds 0.8 m depth.
- It is recommended that footing (edge beams, internal beams, and load support thickenings) concentrated loads are transferred through the fill to target founding layers.
- Subject to engineering advice, edge beams, internal beams, and load support thickenings may need to be founded on natural ground.
- SAND or FCR is always recommended rather than fill containing SILT or CLAY.
- Compacted CLAY or SAND FILL on well drained slopes should not exceed 1V:2H unless supported by an engineered retaining wall.
- Compacted SILT fill on well drained slopes should not exceed 1V:4H unless supported by an engineered retaining wall.
- Compacted stable rock fill on well drained slopes should not exceed 2V:3H unless supported by an engineered retaining wall.
- Any proposed filling works must be in accordance with AS 3798 'Earthworks for Residential and Commercial Developments'.
- Before placing fill for landscaping, all topsoil should be removed from the filled area.
- Fill in embankments shall be keyed 150mm into natural ground.

Long-term erosion management

The following measures are generally recommended for maintaining long-term erosion stability of soil slopes:

- Slopes exceeding 1V: 4H and up to 1V: 3H will need to be effectively stabilised with mulch/topsoil mixes, drill/broadcast seeding, hydroseeding or soil binders.
- Slopes up to 1V:2H can be stabilised with straw mulching.
- Slopes exceeding 1V: 2H and up to 1V:1.5H may be effectively stabilised with hydromulching
- Slopes exceeding 1V:1.5H but no greater than 1V: 1H will generally require measures such as erosion control blankets.

Earth-Retaining Structures

Any excavations higher than 1.0m and exceeding the recommended batter angle should be supported with a retaining wall engineered that allows free drainage of the retained soil and rock.

Building Pad Preparation

Any organic matter or other deleterious materials will need to be removed from the building envelope.

Topsoil containing grass roots must be removed from the area on which the footing will rest.

Earthworks should be carried out in accordance with AS 3798 'Earthworks for Residential and Commercial Developments'. Unsuitable materials in structural fill are listed in AS 2870 Section 4.3.

The base of the excavation must be generally level but may slope not more than 1:40 to allow excavations to drain.

Footing Preparation

Footing excavations must be free of loose earth, tree roots, mud or debris immediately before pouring concrete, ensuring the footing is appropriately seated on the target layer.

Foundation Maintenance

Details on appropriate site and foundation maintenance practices from the CSIRO BTF 18 Foundation Maintenance and Footing Performance: A Homeowner's Guide are presented in Appendix I of this report along with Australian Geoguide (LR8) Hillside Construction Practice (Appendix J).

K Taylor

Kris Taylor, BSc (hons)

Environmental & Engineering Geologist

Notes About Your Assessment

The Site classification provided and footing recommendations including foundation depths are assessed based on the subsurface profile conditions present at the time of fieldwork and may vary according to any subsequent *Site works* carried out. *Site works* may include changes to the existing soil profile by cutting more than 0.5 m and filling more than 0.4 to 0.8 m depending on the type of material and the design of the footing. All footings must be founded through fill *other than* sand not exceeding 0.4 m depth or sand not exceeding 0.8 m depth, or otherwise a Class P applies (AS 2870 Clauses 2.5.2 and 2.5.3).

For reference, borehole investigation depths relative to natural soil surface levels are stated in borehole logs where applicable.

In some cases, variations in actual Site conditions may exist between subsurface investigation boreholes. At the time of construction, if conditions exist which differ from those described in this report, it is recommended that the base of all footing excavations be inspected to ensure that the founding medium meets the requirement referenced herein or stipulated by an engineer before any footings are poured.

The site classification assumes that the performance requirements as set out in Appendix B of AS 2870 are acceptable and that site foundation maintenance is carried out to avoid extreme wetting and drying.

It is the responsibility of the homeowner to ensure that the soil conditions are maintained and that abnormal moisture conditions do not develop around the building. The following are examples of poor practises that can result in abnormal soil conditions:

- The effect of trees being too close to a footing.
- Excessive or irregular watering of gardens adjacent to the building.
- Failure to maintain Site drainage.
- Failure to repair plumbing leaks.
- Loss of vegetation near the building.

The pages that make up the last six pages of this report are an integral part of this report. The notes contain advice and recommendations for all stakeholders in this project (i.e. the structural engineer, builder, owner, and future owners) and should be read and followed by all concerned.

References

AS 1289.6.3.2-2003 Soil strength and consolidation tests - Determination of the penetration resistance of a soil - 9 kg dynamic cone penetrometer test, Standards Australia, Sydney, Retrieved from SAI Global

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Appendix A Mapping

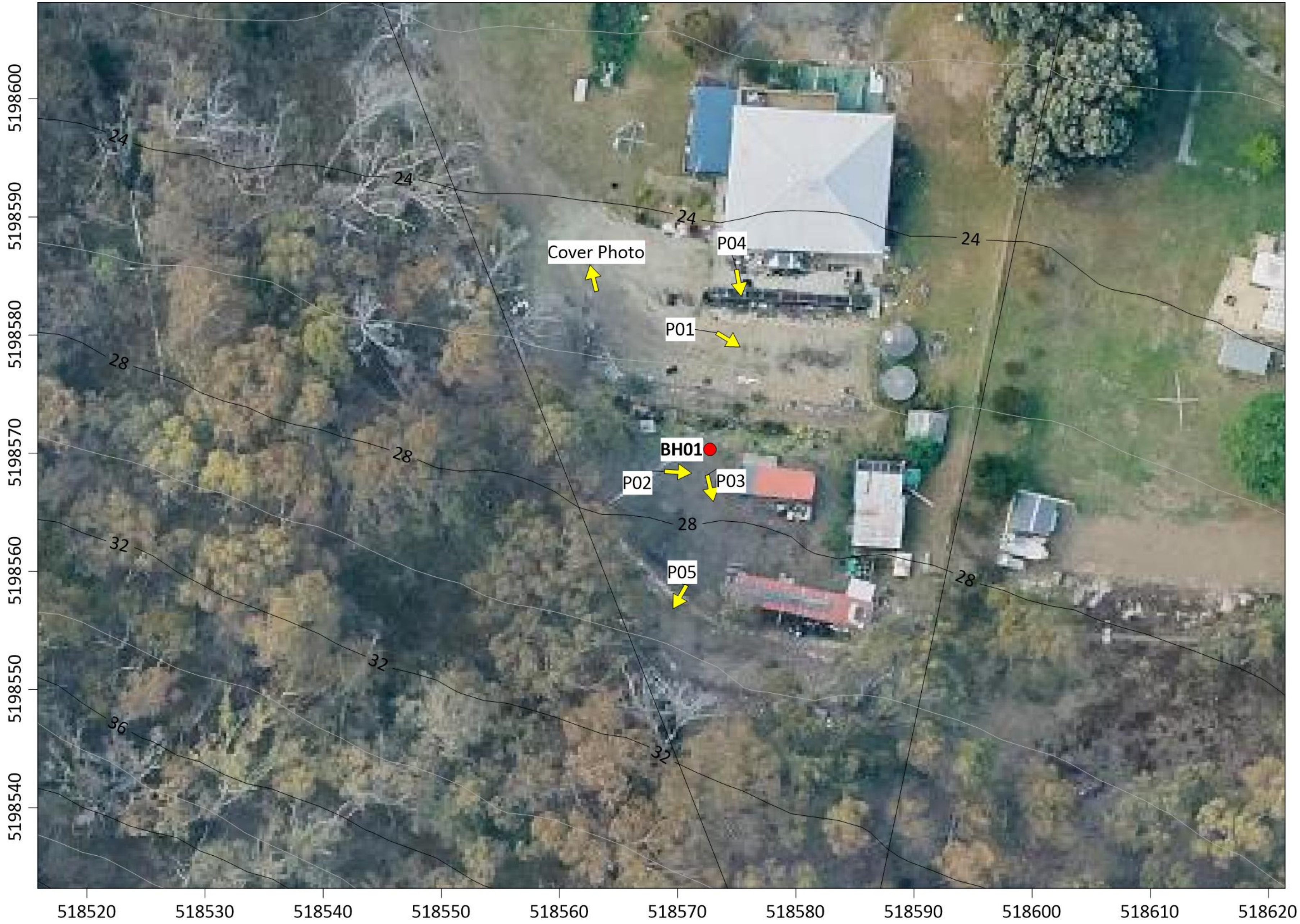


Figure 1 Site Borehole Locations

Appendix B Site Photos

Photo 1 Gravelled lower/middle bench area with water tanks visible downslope. The photograph shows the relatively level pad area and provides context for the cut/fill transition located upslope toward BH01.

Photo 2 Upper bench area looking downslope across vegetation and existing Site features. The photograph shows the stepped nature of the Site, with the visitor accommodation area located nearby but not directly shown. BH01 is indicated by the red flag near the crest of the batter.

Photo 3 Exposed cut batter at the rear of the upper bench, showing previous excavation into soil/weathered material. This cut forms part of the uncontrolled earthworks assessed for stability.

Photo 4 View of the cut/fill face between the upper and lower bench areas, with the lower retained gravel area in the foreground. The photograph shows the earthworks and batter geometry upslope of the lower bench.

Photo 5 Close-up of exposed soil/weathered material within the cut batter of the upper bench, showing the nature of the near-surface materials encountered in the historical earthworks area.

Appendix C Borehole Logs

enviro·tech CONSULTANTS

Positioning: GDA94 & mAHD

ASSESSMENT: Geotechnical Site Investigation
STRUCTURE: Visitor Accommodation
EASTING: 518572.7
NORTHING: 5198570.3
ACCURACY
HORIZ: 0.1m **VERT:** 0.1m

Borehole : BH01
DATE TESTED: 1/05/2026
LOGGED BY: Y. Karki
ELEVATION: 28.7

LOCATION: 4571 Bruny Island - Main Road -
CLIENT: Nic Danger

EQUIPMENT: AMS Powerprobe 9120 RAP
ESTIMATED GROUND m (m AHD):

DEPTH (m)	GRAPHIC	DESCRIPTION	DENSITY CONSIST. STRENGTH	LAYER	ELEVATION (mAHD)	MOISTURE Index	MOISTURE %	Well	SAMPLE	TEST	Cu (kPa)	UCS (kg/cm²)
0.0	GC	FILL: Clayey GRAVEL with silt, trace sand, light olive brown, well sorted, roots angular gravel; massively structured	very loose	1	28.6	Dry	5		DS			
	CI	FILL: Silty Sandy CLAY trace gravel, dark grey, mottled light olive brown, well sorted, medium plasticity, medium to coarse grained sand, roots massively structured	soft to very stiff	2	28.4 28.2		20		DS			
0.5	CH	FILL: Sandy CLAY, olive grey, well sorted, high plasticity, fine to medium grained sand massively structured	stiff to very stiff	3	28.0 27.8		14		DS			
1.0	CI	Silty Sandy CLAY trace gravel, dark grey, well sorted, medium plasticity, medium to coarse grained sand massively structured	stiff	4	27.6		8		DS			
1.5	CH	Sandy CLAY, olive, well sorted, high plasticity, fine grained sand massively structured	very stiff to hard	5	27.4 27.2 27.0		10		DS			
		DOLERITE Bedrock grey		6	26.8							

Direct Push Sampler Refusal on DOLERITE Bedrock

End of borehole at 1.9m depth.

(IS50 MPa) (CBR) NSPT	NDCP/100mm
(1)	1.0
(1)	1.0
(3)	1.9
(14)	8.0
(9)	6.0
(7)	5.0
(6)	4.0
(7)	5.0
(7)	5.0
(6)	4.0
(4)	3.0
(4)	3.0
(9)	6.0
(15)	11.0
(12)	7.0
(12)	7.0
(9)	6.0
(14)	8.0
(REF)	REF

GROUNDWATER: Not Encountered

PAGE 1 of 1

TESTING: Penetrometer: AS 1289.6.3.2

DCP Blows per 100mm. For penetrometer blows per 100mm <1, distance travelled per blow is measured and converted back to blows per 100mm

DS: disturbed sample; PV: pocket vane; PP: pocket penotrometer; FV(Ømm): downhole field vane; U50: undisturbed 50mm sample; REF: DCP refusal

Appendix D Core Photographs

BH01

*** 1 metre core tray length**

Appendix E Explanatory Notes

USCS Soil Classification Methodology

Soil classification was undertaken in accordance with the Unified Soil Classification System (USCS) and AS 1726 – Geotechnical Site Investigations, using a combination of particle size distribution and plasticity assessment. This process was applied consistently to all soil layers encountered.

1. Particle Size Distribution (Wet Sieve Analysis)

Particle size analysis was performed by wet sieving in accordance with Australian Standard sieve sizes:

- Gravel fraction: >2.36 mm
- Sand fraction: 0.075 mm to 2.36 mm
- Fines fraction (silt + clay): <0.075 mm

Samples were soaked (often overnight) to fully disperse fines prior to sieving. Wet sieving is particularly effective for Tasmanian soils, which are often dispersive, ensuring accurate quantification of the fines fraction. The oversize fraction (>63 mm) was excluded from the mass percentages before classification.

2. Plasticity Assessment

Plasticity of the fines fraction was determined using:

- Laboratory Atterberg limits, where available, with liquid limit (WL) and plasticity index (PI) plotted on the Plasticity Chart (AS 1726) to determine the fines classification (silt vs clay) and plasticity level (low, medium, high).
- Field index tests (where Atterberg limits were not available), following Table 1 & Table 2:
    - Dry strength – resistance of dried soil to crushing.
    - Dilatancy – reaction of a moist soil pat to shaking.
    - Toughness – resistance of a soil thread near the plastic limit.

Table 1 Field Assessment of Fine-Grained Soils (adapted from AS 1726 Table 7)

Dry Strength		Dilatancy (reaction to shaking)		Toughness (consistency near plastic limit)	
None	The dry specimen crumbles into powder with mere pressure of handling.	None	No visible reaction or change in the specimen.	Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Low	The dry specimen crumbles into powder with some finger pressure.	Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear during squeezing.		
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.			Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface.	Rapid	Water appears quickly on the surface of the specimen during shaking and disappears during squeezing.	High	Considerable pressure is required to roll the thread near the plastic limit. The thread and the lump have very high stiffness.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.				

Table 2 Identification of Fine-Grained Soils by Visual–Tactile Methods (adapted from AS 1726 Table 8)

Soil description	**Identification of inorganic fine-grained soils**		
	Dry Strength	**Dilatancy**	**Toughness and Plasticity**
SILT	None to low	Slow to rapid	Low or thread cannot be formed
Clayey SILT — Clay/silt mixtures of low plasticity	Low to medium	None to slow	Low to medium
Silty CLAY — Silt/clay mixtures of medium plasticity	Medium to high	None to slow	Medium
High plasticity CLAY	High to very high	None	High

3. Classification Hierarchy

3.1 Fine- vs Coarse-Grained determination

- Fine-grained soils: More than 35% (by mass) passes the 0.075 mm sieve → classify using Table 3
- Coarse-grained soils: More than 65% (by mass) is retained on the 0.075 mm sieve → classify using Table 4.

3.2 Coarse-grained soils (Table 4):

1. **Determine Gravel vs Sand:**
    - Gravel (G*) – more than 50% of the coarse fraction is retained on the 2.36 mm sieve.
    - Sand (S*) – less than 50% of the coarse fraction is retained on the 2.36 mm sieve.
2. **Assign fines modifiers:**
    - ≤5% fines: “Clean” gravels/sands (GW, GP, SW, SP).
    - 5–12% fines: Dual classification (e.g., SP-SM, GW-GM).
    - ≥12% fines: Silty or clayey modifiers (GM, GC, SM, SC) based on fines plasticity from Atterberg limits or field index tests.

3.3 Fines classification for coarse-grained soils

When coarse-grained soils contain ≥12% fines, the fines fraction is classified as silty or clayey based on:

- Atterberg limits where available; or
- Field index tests (Table 1 & Table 2) where Atterberg limits are not available.

3.4 Fine-grained soils (Table 3)

Fine-grained soils are those with >35% (by mass) passing the 0.075 mm sieve.

- With Atterberg limits available: WL and PI are plotted on the Plasticity Chart (AS 1726) to determine plasticity level (low, medium, or high) and USCS classification (ML, CL/CI/CH, MH, OL, OH).
- Where Atterberg limits are not available: The fines are classified directly in accordance with Table 3 by comparing field index test results (dry strength, dilatancy, toughness) to the criteria given for each USCS group. This allows direct assignment of ML, CL/CI/CH, MH, or OL/OH without reference to the A-line.

Organic soils (OL, OH) are identified based on colour, odour, and fibrous texture in addition to field index characteristics.

4. Integration of Results

The final USCS group symbol for each layer was determined by integrating:

- The proportion of gravel, sand, and fines from wet sieve analysis.
- The classification of the fines fraction using either Atterberg limits or field index methods.
- The classification hierarchy in Table 3 & Table 4.

This combined approach ensures that soil classification is both quantitatively accurate and fully compliant with AS 1726, while allowing consistent classification whether laboratory Atterberg limit testing is available.

Table 3 Classification of Fine-Grained Soils (adapted from AS 1726 Table 10)

Major Division	Group Symbol	Typical names	Field classification of silt and clay			Laboratory classification
			Dry strength	Dilatancy	Toughness	% <0.075
SILT and CLAY (low to medium plasticity, %)	ML	Inorganic silt and very fine sand, rock flour, silty or clayey fine sand or silt with low plasticity	None to low	Slow to rapid	Low	Below A line
	CL, CI	Inorganic clay of low to medium plasticity, gravelly clay, sandy clay	Medium to high	None to slow	Medium	Above A line
	OL	Organic silt	Low to medium	Slow	Low	Below A line
SILT and CLAY (high plasticity)	MH	Inorganic silt	Low to medium	None to slow	Low to medium	Below A line
	CH	Inorganic clay of high plasticity	High to very high	None	High	Above A line
	OH	Organic clay of medium to high plasticity, organic silt	Medium to high	None to very slow	Low to medium	Below A line
Highly organic soil	Pt	Peat, highly organic soil	—	—	—	—

Table 4 Classification of Coarse-Grained Soils (adapted from AS 1726 Table 9)

Major Division	Group Symbol	Typical names	Field classification of sand and gravel	Laboratory classification
GRAVEL (more than half of coarse fraction is larger than 2.36 mm)	GW	Gravel and gravel–sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤5% fines, Cu > 4, 1 < Cc < 3
	GP	Gravel and gravel–sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤5% fines, fails to comply with above
	GM	Gravel–silt mixtures and gravel–sand–silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥12% fines, fines are silty

Major Division	Group Symbol	Typical names	Field classification of sand and gravel	Laboratory classification
	GC	Gravel–clay mixtures and gravel–sand–clay mixtures	'Dirty' materials with excess plastic fines, medium to high dry strength	≥12% fines, fines behave as clay
SAND (more than half of coarse fraction is smaller than 2.36 mm)	SW	Sand and gravel–sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤5% fines, Cu > 6, 1 < Cc < 3
	SP	Sand and gravel–sand mixtures, little or no fines, uniform sands	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤5% fines, fails to comply with above
	SM	Sand–silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥12% fines, fines are silty
	SC	Sand–clay mixtures	'Dirty' materials with excess plastic fines, medium to high dry strength	≥12% fines, fines are clayey

Standard Methodology for Determination of Soil Reactivity and Index of Shrink–Swell (Ips) for SIFE Investigations

1. Introduction

This methodology outlines the procedures adopted by Enviro-Tech Consultants Pty. Ltd. for determining soil reactivity and deriving the Index of Shrink–Swell (Ips) for each soil layer in accordance with the principles of AS 2870. The method combines Australian Standard testing procedures with enhanced correlation techniques developed from an extensive dataset of over 2,000 field and laboratory tests.

The approach ensures consistent, accurate classification of soil reactivity across a wide range of soil types. By combining standard and modified testing procedures, it enables calculation of profile movement for complex soil profiles, accounting for groundwater levels, bedrock depth, and particle size distribution.

2. Sampling and Preparation

2.1 Undisturbed Sampling

Undisturbed samples are collected using a thin-wall sampler to preserve natural soil structure and in-situ moisture conditions when performing shrink–swell testing. A 45 mm diameter core sampler is used for these tests to ensure uniformity and comparability between results. Most other laboratory testing is carried out on disturbed samples, which is one of the advantages of the linear shrinkage and modified linear shrinkage testing methods.

2.2 Sample Identification

All samples are assigned a Unified Soil Classification System (USCS) code using accurate laboratory and field identification techniques in accordance with AS 1726 (detailed procedure included herein). This classification underpins the correlation methods described in later sections.

2.3 Moisture Content Measurement

Field moisture content is recorded at the time of sampling, providing baseline data for correlation to laboratory shrink–swell results.

3. Standard Testing Procedures

3.1 Shrink–Swell Testing

Shrink–swell testing is performed on cohesive soils in accordance with the relevant Australian Standard method for determining the shrink–swell index. This test provides the primary Ips value for these soil types.

3.2 Linear Shrinkage Testing

Linear shrinkage testing is carried out in accordance with the Australian Standard method, which determines shrinkage from a soil prepared at its liquid limit. This standard approach typically excludes a proportion of the sandy fraction.

4. Secondary Modified Linear Shrinkage Method

4.1 Rationale

In practice, the relationship between shrink–swell test results and standard linear shrinkage results is often inconsistent, particularly for non-cohesive or marginally cohesive soils. To improve correlation, a secondary modified linear shrinkage method has been developed.

4.2 Modified Moisture Basis

Instead of preparing samples solely at the liquid limit, this method uses a "modified moisture" content representative of upper-range field moisture conditions for each USCS soil type. These values are derived from a dataset of over 2,000 samples collected predominantly during winter or immediately thereafter, representing the highest seasonal moisture levels without crossing into "abnormal moisture conditions" as defined in AS 2870.

4.3 Application to Non-Cohesive Soils

This approach enables reactivity assessment of sandy and silty soils that are unsuitable for shrink–swell testing due to their inability to remain intact during testing, but which still display measurable reactivity.

5. Gravel and Cobble Fraction Adjustments

5.1 Gravel Fraction

For all materials, the sand fraction is retained in testing, and the gravel fraction is re-added into the calculation. Because gravel has negligible moisture absorption, its proportion is used to adjust shrinkage values downwards.

5.2 Cobbles

Where cobbles are present:

- 0–35% cobbles: shrinkage is scaled according to the proportion of soil matrix between cobbles.
- 35% cobbles: shrinkage is considered negligible, as the soil matrix is insufficient to impart meaningful reactivity.

6. Correlation and Calibration

6.1 Dataset Development

Extensive correlation has been undertaken between:

- Standard shrink–swell results
- Standard linear shrinkage results
- Modified linear shrinkage results

6.2 USCS-Based Correlation

Accurate USCS classification is the key input variable. Once correlations are established for each USCS class, Ips values can be assigned to future samples based solely on classification and moisture parameters, without requiring repeated shrink–swell testing.

7. Predictive Modelling and Database Search Method

Enviro-Tech Consultants maintains a large and continuously expanding database of soil test results, including shrink–swell, linear shrinkage, particle size distribution, USCS classification, and detailed field descriptions (e.g., colour, texture, structure).

When assessing a new Site, we search this database for comparable sites using multiple parameters:

- Geology – parent material type and origin
- USCS classification – precise laboratory classification

- Soil colour and descriptive features – matching field logging records
- Particle size distribution – percentage gravel, sand, and fines

This multi-parameter search allows us to identify highly similar soils and adopt Ips values from past testing at those sites with confidence. The approach reduces the need for repeated shrinkage or shrink–swell testing where soils are well represented in the database, while still meeting the requirements for reliable reactivity estimation.

8. Compliance with AS 2870 – Clause 2.3.2 (C2 & C3)

Our predictive approach aligns directly with the requirements of AS 2870 Clause 2.3.2:

c (ii): We maintain and utilise a database of past test results to estimate soil reactivity for sites with similar soil and geological conditions.

C (iii): Testing is repeated at regular intervals to ensure correlations remain valid. At minimum, reactivity testing is conducted once every 50 sites, but in practice we test far more frequently – typically at least once every 20 sites, and rarely more than six months between tests. On average, new verification testing is undertaken approximately monthly.

This compliance ensures that our methods are both technically robust and standards-compliant, providing clients with defensible, high-quality results.

9. Calculation of Profile Movement

9.1 Ips Values per Layer

An Ips value is determined for each soil layer based on test results or correlations.

9.2 Adjustment for Groundwater and Bedrock

Where groundwater or bedrock occurs within the profile, Ips values are reduced for the affected layers in accordance with AS 2870 principles.

9.3 Design Suction Change Depth (Hs)

Given the lack of statewide, high-resolution climatic data for Tasmania, a conservative Hs value of 3.0 m is adopted for all sites, in preference to regionalised values. This ensures a cautious approach where actual depth of suction change cannot be accurately modelled.

9.4 Surface Suction Change (Δus)

A standard surface suction change of 1.2 is applied in calculations, in line with AS 2870.

10. Advantages of the Modified Method

- Allows for reactivity assessment across all soil types, including non-cohesive sands and silts.
- Provides consistent correlation between laboratory and field methods.
- Enables accurate whole-profile movement estimation based on standardised USCS classification.
- Incorporates gravel and cobble fraction corrections for more realistic movement predictions.
- Reduces reliance on repeat laboratory shrink–swell testing for every sample.
- Fully compliant with AS 2870 Clause 2.3.2 (C2 & C3).

11. Limitations

- The method assumes accurate USCS classification and field moisture determination.
- The modified linear shrinkage method requires prior calibration for each USCS type.
- Adoption of a conservative Hs value may slightly overestimate movement in some locations.

12. Conclusion

This methodology blends rigorous Australian Standard test procedures with enhanced, data-driven correlation techniques, enabling Enviro-Tech Consultants Pty. Ltd. to deliver accurate, consistent, and site-specific soil reactivity assessments across Tasmania. The inclusion of >2,000 test results, gravel and cobble adjustments, predictive modelling from a comprehensive database, and modified moisture testing provides a robust basis for predicting profile movement in varied geological conditions, while maintaining strict compliance with AS 2870.

Appendix F Soil and Rock Testing

Dynamic Cone Penetrometer (DCP)

Dynamic cone penetrometer (DCP) testing was conducted according to AS 1289.6.3.2 with the results presented in Appendix C.

Soil Characterisation

Table 6 summarises the soil classification results for each layer encountered, including particle size distribution, plasticity assessment, and the assigned USCS group symbol.

Classifications were undertaken in accordance with AS 1726 – Geotechnical Site Investigations using the methodology provided in the Explanatory Notes section of this report.

Particle size distributions were determined by wet sieve analysis, and fines classifications were based on Atterberg limits where available, or on field index tests (dry strength, dilatancy, toughness) in accordance with AS 1726 Tables 7, 8, 9, and 10.

Full explanatory notes and reference tables are provided in Explanatory Notes section of this report.

Table 6 Summary of the Soil Characterisation

Layer	Soil	Borehole	Depth From (m)	Field Moisture %	Gravel %	Sand %	Fine %	Analysed Plasticity	Assigned USCS
1	Clayey GRAVEL	BH01	0	5	69.6	6.5	23.9		GC
2	Silty Sandy CLAY	BH01	0.4	20.3	6.9	45.3	47.8	M	CI
3	Sandy CLAY	BH01	0.8	13.9	0.9	34.1	65	H	CH
4	Silty Sandy CLAY	BH01	1.1	8.3	4.1	44.6	51.3	M	CI
5	Sandy CLAY	BH01	1.6	10.4	0.1	55.1	44.8	H	CH

Soil Dispersion (Emerson aggregate test)

Select soil samples were tested for dispersion susceptibility using the Emerson Class number method according to AS1289.3.8.1. The results presented in Table 7 demonstrate that:

- The Emerson dispersion results indicate that the subsurface profile is generally dispersive, with severe dispersive conditions identified in Layers 2, 3 and 5.
- Layer 1, comprising fill, returned an Emerson Class 3 result and is considered moderately dispersive.
- Layers 2, 3 (fill) and 5 returned Emerson Class 1 results and are considered severely dispersive.
- Layer 4 returned an Emerson Class >4 result and is not considered dispersive.
- The results indicate that severely dispersive soils are present at multiple depths beneath the Site, including within the natural soil profile below the fill.

Table 7 Summary of the Emerson class results.

Layer	Soil	Depth	Sample ID	Emersion Class	Date Tested	Water	pH
1	FILL: Clayey GRAVEL with silt, trace sand	0	BH01 0.0	Class 3	8/05/2026	DI 14°C	
2	FILL: Silty Sandy CLAY trace gravel	0.4	BH01 0.4	Class 1	8/05/2026	DI 14°C	6.1
3	FILL: Sandy CLAY	0.8	BH01 0.8	Class 1	8/05/2026	DI 14°C	6.3
4	Silty Sandy CLAY trace gravel	1.1	BH01 1.1	Class >4	8/05/2026	DI 14°C	5.8
5	Sandy CLAY	1.6	BH01 1.6	Class 1	8/05/2026	DI 14°C	7.2

Soil Aggressivity Testing (Footing Exposure Classification)

Soil samples from across the Site were assessed for potential aggressivity to concrete in accordance with the requirements of AS 2870:2011 – Residential Slabs and Footings (Clauses 5.5.1–5.5.3). Testing was undertaken to determine the salinity exposure class and provide an indicative assessment of sulphate soil potential.

The results are summarised in Table 8 which presents the sampling depth and location, soil texture classification, electrical conductivity (EC1:5), salinity factor (K), calculated saturated extract electrical conductivity (ECe), and the corresponding salinity exposure class (Table 5.1, AS 2870). Soil pH values were also measured and used as a conservative indicator of potential sulphate aggressivity, together with the assigned soil condition class, to derive an indicative sulphate exposure class (Table 5.2, AS 2870).

It is noted that the sulphate assessment has been undertaken on the basis of pH values only, and therefore represents a conservative assumption. Where soils exhibit pH < 5.5 or are otherwise classified within B or C exposure classes, confirmatory laboratory testing of sulphate concentrations may be warranted to refine the exposure classification and confirm appropriate concrete durability requirements.

Salinity testing has been undertaken in accordance with the relevant guidelines and provides a direct basis for assigning salinity exposure classification.

Where aggressive soils are discerned, detailed recommendations for the management of aggressive soils, including concrete strength, curing and reinforcement cover requirements, are presented in Appendix G.

Table 8 Soil Aggressivity Assessment in Accordance with AS 2870:2011

Layer	Location	Depth	Saline Soil Determination					Sulphate Soil Potential^		
		From (m)	USDA Soil Texture Class	EC1:5 mS/cm	K*	Ece dS/m	Exposure Class	pH1:5	Soil Condition Class	Exposure Class
1	BH01	0.0	Clay	0.07	5.5	0.39	A1	7.3	B	A1
2	BH01	0.4	Sandy clay loam	0.27	7.5	2.03	A1	6.1	B	A1
3	BH01	0.8	Clay	0.18	5.5	0.99	A1	6.3	B	A1
4	BH01	1.1	Sandy clay loam	0.34	7.5	2.55	A1	5.8	B	A1
5	BH01	1.6	Sandy clay	0.43	6.0	2.58	A1	7.2	B	A1

^ Preliminary findings based on soil pH only. Further sulphate testing required to rule out sulphate soil exposure risks

*Electrical conductivity of the 1:5 soil–water extract (EC1:5) was measured at 25 °C and converted to an equivalent saturated paste extract (ECe) using texture-based conversion factors (ECe = k × EC1:5) following Slavich, P.G. & Patterson, R.A. (1990). Estimating the electrical conductivity of saturated paste extracts from 1:5 soil:water suspensions and texture. Australian Journal of Soil Research, 28, 453–463.

Appendix G Geotechnical Interpretation

Footing Minimum Target Depths

Footing design for the proposed structures are to consider the depths of limiting layers at the base of potentially problematic soils. Where practical/allowable, thickened beams may be deepened through problematic soil layers according to engineering specifications (Table 9). Table 10 should be referred to where only 50 kPa allowable bearing capacity is required.

Table 9 also presents a summary of the estimated soil depths and associated layers where less than 5mm of vertical soil movement can be expected due to soil moisture fluctuations from normal seasonal wetting and drying cycles. Where 5mm tolerances are required, concentrated loads including but not limited to slab edge or internal beam or strip footings shall be supported directly on piers in accordance with minimum target layer depths presented in Table 9, with considerations given to required bearing capacities in accordance with Table 10.

All footing depth, soil movement, and bearing capacity calculations presented in this section are based on interpretive I_{PS} or I_{SS} values derived from field and laboratory data, as outlined in the Explanatory Notes section of this report. These values are used to infer soil reactivity in the absence of direct measurement, in accordance with industry best practice.

Table 9 Soil characteristic surface movements and recommended footing minimum target depths

Footing design parameters	BH01
Ys Calculation Depth	0m^
Surface movement Ys (mm)	50
Soil reactivity class	H1
Base of problem soil layer (m)*	
Layer at base of problem soil*	
Pier/Footing minimum target depth (m)#	1.9^
Pier/footing minimum target layer#	6
Allowable bearing capacity at min target depth (kPa) #	300

\- No problem layers encountered

^ Calculations relative to surface of borehole at the time of investigation

~ Calculated based on revised soil profile depth/thickness following indicative cut and fill. Inferred fill reactivity indicated (Iss value) which is typically based on more reactive soils expected to be encountered within inferred cut.

* Base of problematic soil layer depth below top of borehole surface at the time of testing to achieve 100 kPa allowable bearing capacity or greater.

Target soil layer depth where Ys values from normal wetting and drying cycles are estimated at less than 5mm vertical movement. >minimum bored pier depths (see bearing capacity table for bored pier design depths).

Soil and Rock Allowable Bearing Capacity & End Bearing Capacity

Soil allowable bearing capacity was calculated from correlations with DCP blow counts. A recommended safety factor of 3 is applied in accordance with AS 2870. Where high clay and silt content is observed in the soil, soil allowable bearing capacity is determined from undrained shear strengths using field vane correlated DCP values. Interpretive bearing capacity values are presented in Table 10.

Table 10 Soil allowable bearing capacities and problematic ground conditions.

Depth below investigation surface (m)	Allowable Bearing Capacity (kPa)
	BH01
0	FILL^
0.1	FILL^
0.2	FILL^
0.3	FILL^
0.4	FILL^
0.5	FILL^
0.6	FILL^
0.7	FILL^
0.8	FILL^
0.9	FILL^
1	**140***
1.1	**140**
1.2	**240**
1.3	**>300**
1.4	**280**
1.5	**280**
1.6	**240**
1.7	**>300**
1.8	**DOLERITE**

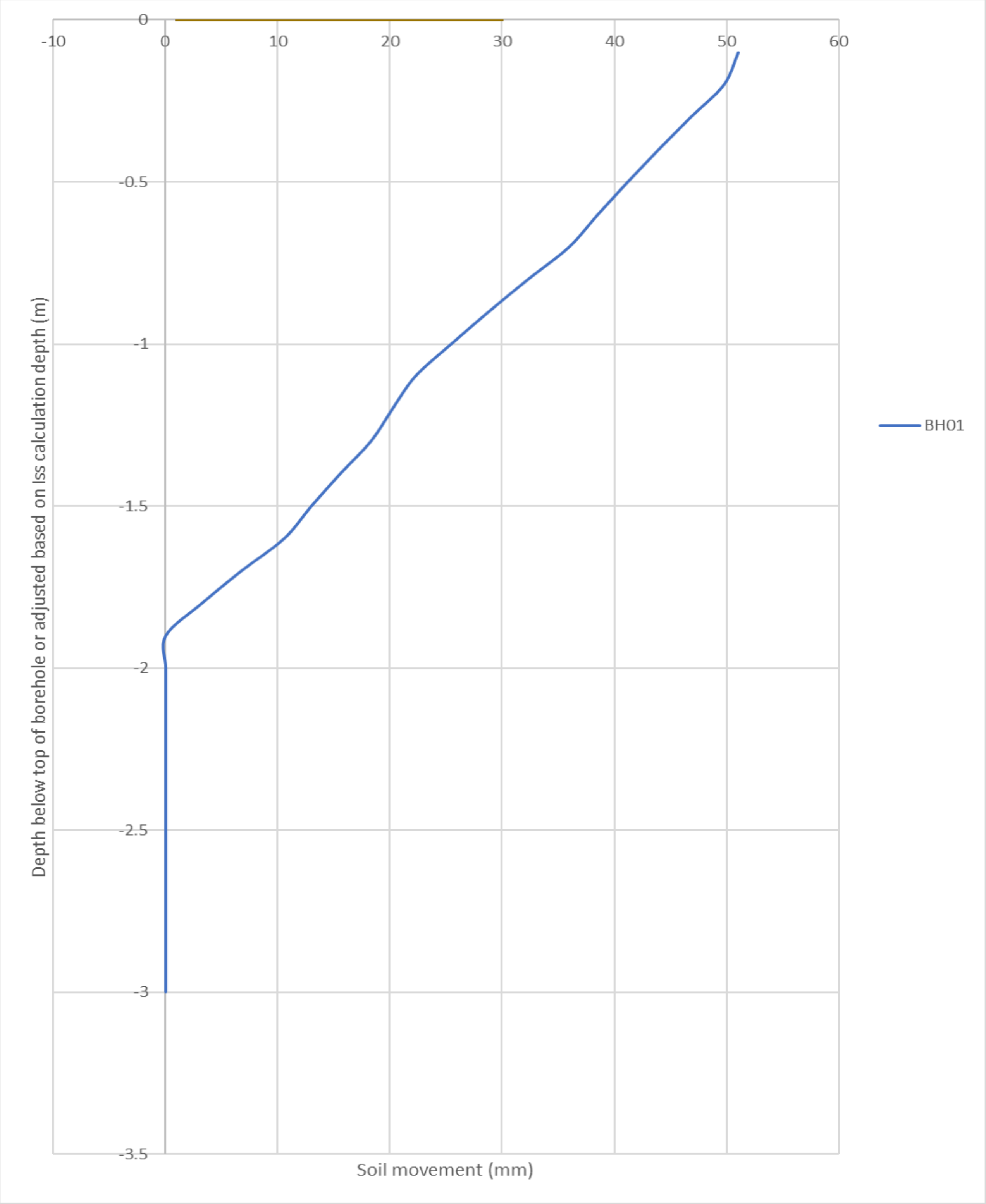
Correlations drawn from DCP and vane shear testing.
REF - Penetrometer Refusal
^ Footings to be founded through the FILL
~ Problematic soil layer attributed to loose, soft, or low allowable bearing capacity soil (<100 kPa)
*Soil layer expected at the base of problematic soil layers at test location (or at surface where problematic soils not encountered) to achieve 100 kPa allowable bearing capacity or greater.

Characteristic Soil Movement (Ys)

The characteristic soil movement (soil reactivity) from wetting and drying cycles is calculated according to AS 2870 Section 2.3. The calculations are based on Iss % testing results or correlations with linear shrink data and are based on complete soil profiles for boreholes drilled within the building Site. In the case of where cut and fill are proposed and building finished floor levels (FFL) are made available, the Iss value is recalculated based on the FFL and estimated cut and fill as per Table 9.

According to AS 2870 Section 2.3, calculations consider the depth of groundwater and bedrock. Soil characteristic movements based on lab testing are presented in Figure 2.

Figure 2 Calculated Characteristic Soil Movement Based on Soil Testing



Concrete Durability Requirements

The soil aggressivity testing results presented in Table 8 have been interpreted in Table 11 to provide indicative requirements for minimum concrete strength, curing duration and reinforcement cover in accordance with AS 2870:2011. This table builds on the previous classification summary by applying the relevant durability provisions to each individual soil layer encountered across the Site.

From these results presented in Table 11, it is generally discerned that in all investigated areas of the Site:

- For an exposure classification of A1, it is recommended to utilize concrete with a minimum strength of 20 MPa, provide at least 40 mm cover without a membrane (30mm with), and ensure curing for no less than three days.

Table 11 Interpretation of Soil Aggressivity Results – Minimum Concrete Strength, Curing and Cover

Layer	Location	Depth	Exposure Classification		Minimum Concrete	Minimum Days Curing	Cover~
		From (m)	Salinity	Sulphate^	Strength f'c (MPa)^		
1	BH01	0.0	A1	A1	20	3	40-40
2	BH01	0.4	A1	A1	20	3	40-40
3	BH01	0.8	A1	A1	20	3	40-40
4	BH01	1.1	A1	A1	20	3	40
5	BH01	1.6	A1	A1	20	3	40-40

^Sulphate class is conservatively estimated from soil pH and further testing is required on soil samples to confirm if the low pH is attributed to sulphate or other anions within the soil. If pH conditions are attributed primarily to sulphate, then the indicated exposure classification is expected to be reliable but subject to sulphate concentration threshold presented in AS 2870.

Where a damp-proofing membrane is installed, the minimum reinforcement cover in non-A1 saline soils may be reduced to 30 mm

' Where a damp-proofing membrane is installed, the minimum reinforcement cover in non-A1 sulphate soils may be reduced by 10 mm.

Appendix H General Advice - Dispersive Soil Management

The Site may be susceptible to tunnel erosion if subsurface drainage is not adequately managed. Tunnel erosion typically initiates in excavated cuts; however, it can also develop where dispersive soils are exposed through excavation, leading to the release of pore water and concentrated groundwater discharge. Additional contributing factors may include broken pipes, ineffective stormwater infrastructure, or unmanaged surface flows. If left unaddressed, these conditions can result in progressive subsoil loss, potentially undermining footings or causing settlement-related damage to the structure.

Tunnel erosion typically progresses upslope, initiated by the dissolution and removal of highly dispersive Class 1 and Class 2 soil layers. As tunnels enlarge, they can undermine surrounding soils that may not be dispersive but are still susceptible to collapse due to loss of subsoil support. If unmanaged, tunnel erosion can extend beyond property boundaries, posing a risk to nearby infrastructure including buildings, roads, and underground services. For further background on the management of Emerson Class 1 soils, refer to the Department of Primary Industries, Parks, Water and Environment (DPIPWE, 2009) guidance document.

Dispersive soils should be managed through a combination of drainage control and ground treatment measures. These may include overland flow management, controlled cut and fill practices, and, in more severe cases, the installation of sand barriers to interrupt subsurface flow paths. Where dispersive soils are exposed—particularly on batters or in excavation faces—chemical treatment using gypsum or lime may be employed to improve soil cohesion and reduce erosion potential. Application rates should be guided by Emerson Class test results, as outlined in Table 12.

Gypsum and hydrated lime are proven effective in mitigating erosion in dispersive soils by displacing sodium ions on clay particles and replacing them with calcium. This cation exchange improves soil structure, increases shear strength, and enhances resistance to tunnel and surface erosion. The effectiveness of treatment is influenced by the soil's properties; higher application rates of gypsum are typically required for soils with greater cation exchange capacity, elevated pH, and lower Emerson Class numbers. Application guidelines should be based on laboratory test results, including Emerson Class assessment, to ensure appropriate treatment dosages.

Table 12 Prescribed gypsum and hydrated lime application rates – see Emerson soil testing results

Dispersive soil Emerson class	**Gypsum/Hydrated Lime Application Rate pH < 7.5**	**Gypsum Application Rate pH > 7.5**
Class 3	0 to 0.3 kg/m2	0.2 – 0.5 kg/m2
Class 2	0.5 kg/m2	1.0 kg/m2
Class 1	1.0 kg/m2	1.5 kg/m2

Where practicable, vehicle driveways and parking areas should be located on level or gently sloping terrain to minimise the need for deep excavation and reduce disturbance to dispersive soils identified on Site.

<u>General Recommendations</u>

To minimise disturbance and erosion in areas where Class 1 dispersive soils have been identified, the following measures are recommended:

- **Drainage Control:** Construct soil cut-off mounds or shallow interceptor trenches in non-dispersive soils, no deeper than 0.2 m above the interface with Class 1 dispersive soils. These should be positioned upslope of any proposed cuts to divert surface water before it reaches vulnerable areas.
- **Chemical Treatment:** Apply gypsum or hydrated lime to exposed dispersive soils where surface water movement is expected—particularly on freshly cut embankments, filled areas, service trenches, and zones where topsoil has been removed.
- **Surface Protection:** Cover all severely dispersive soils with either impermeable surfacing (e.g. paving) or a layer of non-dispersive topsoil to reduce erosion and limit moisture ingress.
- **Batter Stabilisation:** Place non-dispersive topsoil over freshly cut batters to protect against surface erosion and reduce the likelihood of tunnel initiation.
- **Remediation of Existing Tunnels:** Where tunnel erosion has already occurred, additional stabilisation of natural or constructed drainage gullies may be required. This may include the use of sand barriers and, in more severe cases, geotextile-wrapped drainage rock structures. When correctly designed, such barriers can intercept subsurface flow, promote controlled surface discharge, and direct water away from at-risk areas.

Key Management Measures for Dispersive Soils in Cut Embankments:

Surface water drainage can erode dispersive soils in embankment cuts. Groundwater discharge may worsen tunnel erosion by accelerating the development of secondary porosity—where subsurface flow progressively enlarges voids within the soil mass, leading to tunnel formation and internal instability. Management considerations:

- **Topsoil Removal Risks:** Earthworks commonly begin with the removal of non-dispersive topsoil, which often acts as a natural protective layer. Once removed, the underlying dispersive soils become highly vulnerable to erosion.
- **Barrier Construction in Cut Slopes:** Where excavation is necessary, erosion can be mitigated through immediate installation of physical barriers:
  - Place a sand layer (sand barrier) over exposed dispersive soil within the cut to interrupt flow paths.
  - Construct an earth retaining wall in front of the cut to contain soil and stabilise the slope face.
- **Timely Implementation:** All erosion control measures must be implemented immediately following excavation to prevent the initiation of tunnel erosion.
- **Use of Retaining Structures:** Low-height retaining walls (e.g., timber sleeper walls) constructed at the base of cut faces can assist in retaining eroding soils and maintaining the effectiveness of sand barriers.

Sand Barriers

To manage dispersive soils exposed in cut slopes, the following layered treatment is recommended:

- **Chemical Stabilisation:** Apply gypsum or hydrated lime at application rates specified in Table 7, based on Emerson Class testing.
- **Sand Layer:** Install a minimum 100 mm thick layer of clean, free-draining sand to act as a barrier and interrupt preferential flow paths.
- **Topsoil Cover:** Place a layer of non-dispersive, free-draining topsoil (such as loam) over the sand barrier to retain the sand in place and facilitate effective revegetation or application of surface treatments.
- **Erosion Control:** Implement surface erosion protection measures as outlined in the Erosion Control section to prevent wash-off and maintain system effectiveness.

Retaining Walls

The following measures are recommended when constructing retaining walls in areas with dispersive soils:

- Retaining walls should be founded on bedrock or non-dispersive soils to reduce the risk of tunnel erosion and structural instability.

- Where walls are constructed in Class 1 dispersive soils, freshly cut surfaces may be treated with gypsum or hydrated lime at application rates specified in Table 7 to reduce erosion potential.

Drainage

Effective drainage is critical in dispersive soil environments to prevent erosion, tunnel formation, and structural damage. The following measures are recommended:

- Divert surface water away from cut and fill slopes to reduce infiltration into dispersive soils.
- A sealed toe drain is essential to prevent water from soaking into freshly cut dispersive soils and migrating through dispersive fill layers beneath paved surfaces.
- For optimal surface drainage over Class 1 soils, install concrete spoon drains in preference to earthen swales to minimise erosion risk.
- Where earthen swale drains are used, stabilise Class 1 soils with gypsum or hydrated lime at a rate adjusted to soil pH. A liner (e.g. 20 mm bentonite layer) beneath topsoil and turf may be used to limit vertical water infiltration.
- Subsurface drains installed in Class 1 soils should be backfilled with a sand mix containing 2% gypsum or hydrated lime to inhibit dispersion and maintain flow pathways.
- Non-perforated drainage pipes should be used to divert water away from identified groundwater discharge points, limiting further erosion.

Filling

The use of dispersive soils as fill presents a significant risk for tunnel erosion, especially where water movement is poorly controlled. The following measures are recommended to reduce risk and ensure long-term stability:

- Dispersive soil used as fill is highly susceptible to tunnel erosion, particularly when exposed to concentrated surface or groundwater flow.
- Groundwater can migrate along the base of and within fill layers, initiating erosion of dispersive materials and undermining overlying structures.
- All proposed filling, especially within or near building footprints, should be carefully managed. This may involve either:
    - Removal of Class 1 dispersive soil from beneath the structure, or
    - Chemical treatment of dispersive fill using gypsum or hydrated lime, applied to the surface of each compacted lift.
    - Preventing water from intercepting dispersive soil by liming the fill or with careful drainage management
- When chemically treating fill:
    - Use 300 mm thick lifts with full application rates as specified in Table 7.
    - For 150 mm thick lifts, halve the application rate accordingly.
- Ensure compaction is achieved close to optimum moisture content, particularly in areas adjacent to footings and structures.
- Paved surfaces over filled areas significantly reduce the risk of tunnel erosion, if cut-off drains are installed to prevent water ingress at the fill base.
- Where feasible, spoon drains and pavement edges at the toe of cut batters should be founded on non-dispersive soil or bedrock to intercept all surface water and eliminate seepage pathways.
- If topsoil is removed prior to filling, and it is classified as slightly dispersive (Class 3) or non-dispersive (Class 4 or higher), it may be replaced with a liner or imported non-dispersive material to protect the dispersive fill beneath.

Roofed and Paved Area Stormwater Management

All captured water on-site, including roof runoff, must be managed to remain at the surface and be evenly dispersed downslope across the Site. Roof runoff must be directed to detention tanks, with overflow discharged via surface irrigation—not into soakage pits. Due to the absence of non-dispersive topsoil, imported loam is required in irrigation areas. Irrigation must either:

1. Be delivered just below the surface, draining directly into the imported loam without contact with dispersive soils; or
2. Be applied via above-ground sprinklers onto imported loam to prevent erosion and maintain surface stability.

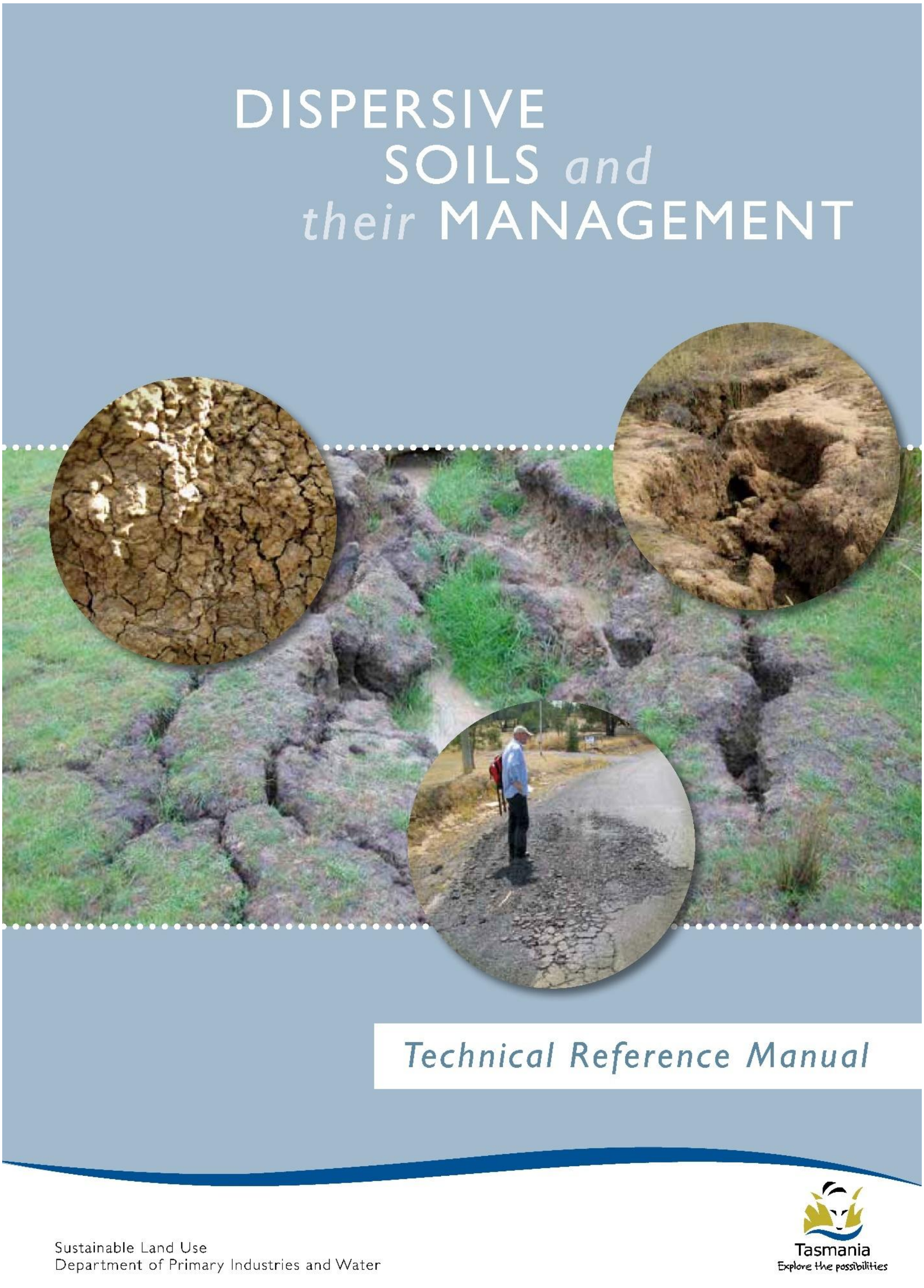
Runoff from pavements and other impervious surfaces must either be captured and redirected into detention tanks for controlled redistribution.

For driveways, runoff should be directed via cross-slope or in-slope alignment into lined side drains or swales. These must convey collected water to designated redistribution areas —such as detention tanks with surface irrigation or into distribution swales. Overflow must be dispersed across imported loam soils which is not located upgradient or downgradient of existing structures and ensuring water is not concentrated near foundations or fill. If distribution swales are used, they must be lined, constructed with low gradients, and designed to promote sheet flow rather than concentrated runoff. Distribution swale overflow must discharge onto non-dispersive imported loam soils.

Service Trenches

An effective measure to prevent stormwater ingress into backfilled service trenches is to ensure the trench surface is well sealed with non-dispersive soils or stable topsoil. As an additional site-specific recommendation, service trenches should be backfilled with compacted sand, which will help prevent water channelisation and reduce the risk of tunnel erosion along trench alignments.

DPIPWE 2009 Dispersive Soils and their Management. Technical Reference Manual. Sustainable Land Use Department of Primary Industries Water and Environment.



DISPERSIVE SOILS *and* *their* MANAGEMENT

Technical Reference Manual

Sustainable Land Use
Department of Primary Industries and Water

Tasmania
Explore the possibilities

4.1 MANAGEMENT OPTIONS FOR TUNNEL EROSION

Past efforts to repair tunnel erosion in agricultural landscapes have relied on mechanical destruction of the tunnel system by deep ripping, contour furrowing, and contour ripping. Unfortunately many of these techniques either failed or resulted in tunnel re-emergence in an adjacent areas (Floyd 1974, Boucher 1995). The use of these 'agricultural' techniques is inappropriate in peri-urban areas where tunnel repair requires a low incidence of re-failure due to the potential for damage to infrastructure. Experience with the construction of earth dams using dispersive clays, demonstrates that repair and prevention of tunnel erosion in urban and peri-urban environments is best achieved using a combination of,

- Identification and avoidance of dispersive soils.
- Precise re-compaction.
- Chemical amelioration.
- Sand blocks and barriers.
- Topsoil, burial and revegetation.

4.2 IDENTIFICATION AND AVOIDANCE OF DISPERSIVE SOILS

The risk of tunnel erosion resulting from construction activities on dispersive soils can often be reduced or eliminated by identifying and avoiding areas containing dispersive soils. The presence and severity of dispersive soils can vary enormously over short distances (Figure 13). In many instances, large scale (ie 10 x 10 or 20 x 20 meter grid) soil survey and screening of soils for dispersion, (using the Emerson crumb test - section 3, Appendix I) can be used to site dwellings and infrastructure away from dispersive soils. Advice should be sought from a suitably qualified and experienced engineer or soil professional.

4.3 COMPACTION

Ritchie (1965) demonstrated that the degree of compaction within the dam wall was the single most important factor in reducing dam failure from piping (tunnel erosion). A high degree of compaction reduces soil permeability, restricting the movement of water and dispersed clay through the soil matrix, which decreases the severity of dispersion and restricts tunnel development (Vacher *et al.* 2004). However, dispersive soils can be difficult to compact as they lose strength rapidly at or above optimum moisture content, and thus may require greater compactive force than other soils (McDonald *et al.* 1981). Bell & Bryun (1997) and Bell and Maud (1994) suggest that dispersive clays must be compacted at a moisture content 1.5 -2% above the optimum moisture content in order to achieve suficent density to prevent piping (Elges 1985).

Construction of structures such as earth dams and footings for buildings with dispersive soils require geotechnical assessment and advice from a qualified and experienced engineer, in order to determine compaction measures such as the optimal moisture content, number of passes, and maximum thickness of compacted layers.

Normal earth moving machinery including bull-dozers, excavators and graders do not provide sufficient compactive force to reduce void spaces or achieve adequate compaction in dispersive soils. A sheepsfoot roller of appropriate weight is usually required to compact dispersive soils. By comparison a D6 dozer applies only 0.6 kg/cm^2 pressure compared to 9.3 kg/cm^2 for a sheepsfoot roller (Sorensen 1995).

Figure 13. The severity (or sodium content) and depth of dispersive subsoils can vary considerably over short distances. (a). At this site highly dispersive subsoils exist meters away from (b) non-dispersive soils.

4.4 CHEMICAL AMELIORATION

Initiation of tunnel erosion is predominantly a chemical process, so it makes sense to use chemical amelioration strategies when attempting to prevent or repair tunnel erosion in dispersive soils. Despite the widespread use of gypsum and lime to treat sodic soils in agriculture, the use of gypsum and lime to treat tunnel affected areas has been relatively rare (Boucher 1990).

Hydrated lime (calcium hydroxide) has been widely used to prevent piping in earth dams. Rates of application have varied depending on soils and degree of compaction used in construction. Laboratory testing usually indicates that only around 0.5 – 1.0% hydrated lime is required to prevent dispersion, however difficulties with application and mixing necessitate higher rates of application (Moore *et al.* 1985). Moore *et al.* (1985) cite examples of the use of hydrated lime to control piping in earth dams at rates between 0.35% (N.S.W. Australia) and 4% (New Mexico). Elgers (1985)**,** and McElroy (1987) recommend no less than 2% hydrated lime (by weight of the total soil material) to prevent dispersion within dam embankments, while Bell and Maud (1994) suggest that 3% - 4% by mass of hydrated lime should be added to a depth of 0.3m on the upper face of embankments. In alkaline (pH >7.0) soils (most sodic subsoils in Tasmania are neutral or alkaline) the effectiveness of hydrated lime is reduced by the formation of insoluble calcium carbonate (Moore *et al.* 1985), such that gypsum is preferred to hydrated lime. It is important to note that agricultural lime (calcium carbonate) is not a suitable substitute for hydrated lime due to its low solubility (McElroy 1987). Also note that excessive applications of lime may raise soil pH above levels required to sustain vigorous plant growth.

Gypsum (calcium sulphate) is more effective than lime for the treatment of dispersive soils as it increases the electrolyte concentration in the soil solution as well as displacing sodium with calcium within the clay structure (Raine and Loch 2003). Gypsum is less commonly used than hydrated lime in dam construction and other works due to its lower solubility, and higher cost. Elges (1985) recommends that in construction, a minimum of 2% by mass of gypsum be used. Bell and Maud (1994) present a means of calculating the amount of gypsum required to displace excess sodium and bring ESP values within desired limits (normally < 5). Be aware that application of excessive amounts of gypsum may cause soil salinity to temporarily rise beyond the desired level for plant growth.

NOTE:

- Use of gypsum in Tasmania is covered under the Fertiliser Act 1993, which has established the allowable limit for cadmium and lead at 10 mg/kg and 5 mg/kg for mercury.
- Gypsum is usually imported into Tasmania from Victoria or South Australia, which have different standards for allowable heavy metal content.
- Purchasers of gypsum should check with suppliers to ensure that gypsum imported into Tasmania is compliant with current regulations.

Alum (aluminium sulphate) has been effectively used to prevent dam failure and protect embankments from erosion. Application rates are not well established. Limited data suggests mixtures of 0.6 – 1.0% (25% solution of aluminium sulphate) (Bell and Bruyn 1997, McElroy 1987) to 1.5% (Ouhadi, and Goodarzi 2006) of the total dry weight of soil may be appropriate. Alum is however highly acidic (pH 4-5), and thus alum treated soils will need to be capped with topsoil in order to establish vegetation (Ryker 1987). Soil testing is required to establish appropriate application rates for Tasmanian soils.

Long chain polyacrylamides have been shown to increase aggregate stability, reduce dispersion and maintain infiltration rates in dispersive soils (Levy *et al.* 1992, Raine and Loch 2003). However the effect is highly variable between various polyacrylamide products and the chemical and physical properties of the soil. The benefit of polyacrylamides is generally short due to their rapid degradation (Raine and Loch 2003). Further advice and laboratory testing should be conducted before using polyacrylamides to protect earth dams from piping failure.

Note that appropriate application rates for gypsum, hydrated lime, alum and polyacrylamides have not been established for dispersive soils in Tasmania. Extensive laboratory assessment of materials used for the construction of dams or embankments is required before locally relevant 'rules of thumb' can be established for the use of these products.

4.5 SAND BLOCKS AND SAND BARRIERS

Sand filters were first developed to prevent piping in earth dams. Sand filters prevent dam failure by trapping entrained sand and silt, blocking the exit of the tunnel and preventing further tunnel development (Sherard *et al.* 1977). Following the work of Sherard *et al.* (1977), Richley (1992 and 2000) developed the use of sand blocks to prevent tunnel erosion during installation of an optical fibre cable in highly dispersive soils near Campania, Tasmania. The sand blocks work slightly differently to the sand filters in that they allow the free water to rise to the surface through the sand. The use of sand blocks has recently been modified by Hardie *et al.*, (2007) to prevent re-initiation of tunnel erosion along an optical fibre cable near Dunalley. Modifications to the original technique developed by Richley (1992 and 2000) include (Figure 14 &15);

- Upslope curved extremities to prevent the structure from being by-passed.
- Geotextile on the downslope wall to prevent collapse or removal of sand following settlement or erosion.
- Application of gypsum (around 5% by weight) to ensure infiltrating water contains sufficiently electrolyte to prevent further dispersion.
- Earth mound upslope of the structure to prevent run-on entering the sand blocks.

Figure 15. (a) Installation of sandblock perpendicular to a service trench. Note securing of geotextile to the optical fibre cable to prevent water flowing past the sand block. (b) Sandblock before final topsoiling.

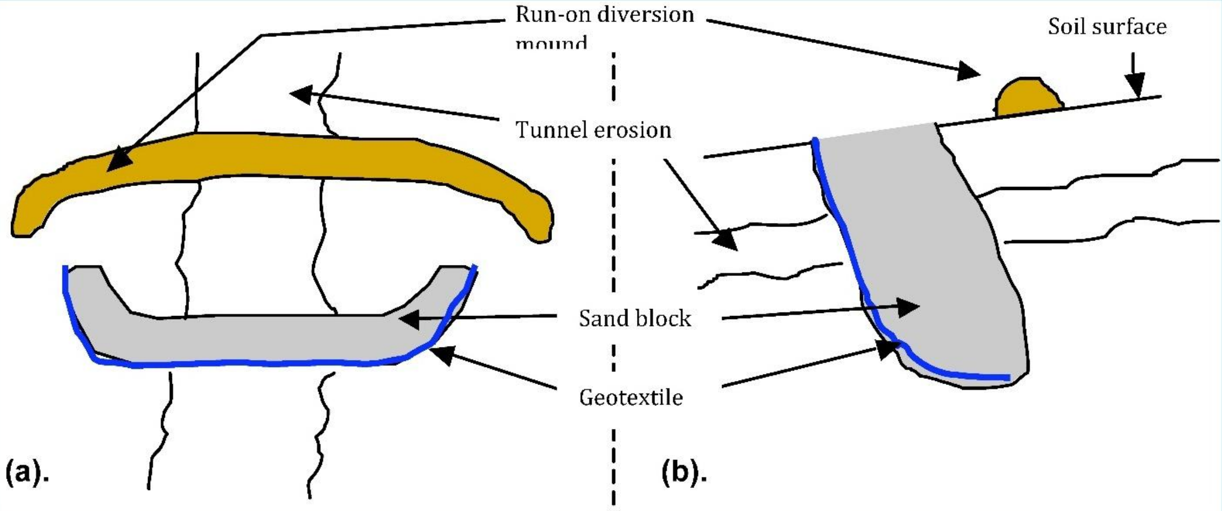


Figure 14. Modified sand block design. (a) plan view, (b) cross section view. The depth of the sand block is determined by the depth of dispersive soils or tunnel erosion. The span length of the structure is determined by the width of the tunnelling.

4.6 USE OF TOPSOIL / BURIAL AND REVEGETATION

Topsoil or burial of exposed dispersive soils reduces the likelihood of subsoil dispersion and initiation of tunnel erosion by;

- Providing a source of salt to increase the electrolyte content of infiltration water.
- Preventing desiccation and subsoil cracking.
- Promoting even infiltration.
- Providing a protective cover from raindrop impact.
- Providing a suitable medium for revegetation.

Topsoil minimises the interaction between water and dispersive clays by providing both a physical and chemical barrier. Topsoil also reduces soil desiccation and development of surface cracks (Sorensen 1995). It is suggested that exposed dispersive subsoils be covered with at least 150mm of non dispersive topsoil and sown with an appropriate mix of grass species. In some cases it will be necessary to protect the topsoil from erosion with 'jute' cloth or similar product.

The suitability of planting trees in tunnel affected areas is influenced by the amount of annual rainfall and frequency of soil cracking resulting from desiccation. Boucher (1995) recommends the preferred option for revegetation of reclaimed tunnel erosion is a widely spaced tree cover in association with a combination of perennial and annual pastures, rather than a dense stand of trees or pasture alone. Experience in Tasmania suggests that in low rainfall areas, or areas in which existing trees or shrubs cause soil drying and cracking, the preferred option for revegetating tunnel affected land is a dense healthy pasture. In high rainfall areas, dense plantings of trees have been successfully used to repair or stabilise tunnel erosion for example Colclough (1973) successfully used Pinus radiata to stabilise tunnel-gully affected land in a moderate rainfall area near Tea Tree, Tasmania.

5.0 ACTIVITIES THAT INCREASE THE RISK OF EROSION ON DISPERSIVE SOILS

ACTIVITIES THAT INCREASE RISK OF INITIATING TUNNEL EROSION, INCLUDE;

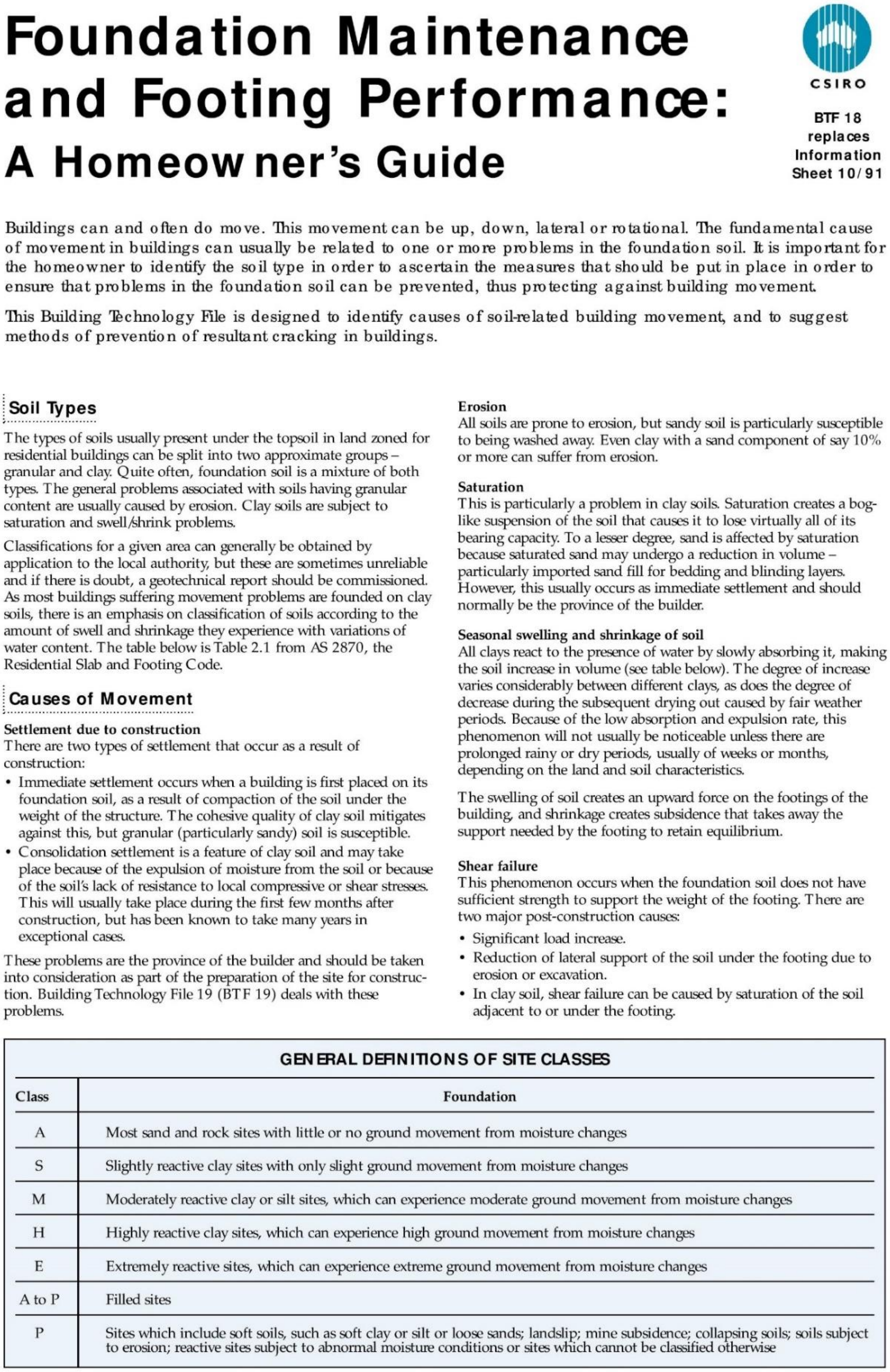
- Removal of topsoil.
- Soil excavation or expose of subsoils to rainfall.
- Supply of services via trenches.
- Construction of roads and culverts in dispersive subsoils.
- Installation of sewage and grey water disposal systems in dispersive subsoils.
- Dam construction from dispersive soils.

OPTIONS FOR REDUCING THE RISK OF TUNNEL EROSION DURING CONSTRUCTION AND DEVELOPMENT WORKS ON DISPERSIVE SOILS INCLUDE,

- Where possible do not remove or disturb topsoil or vegetation.
- Ensure that dispersive subsoils are covered with an adequate layer of topsoil.
- Avoid construction techniques that result in exposure of dispersive subsoils.
- Use alternatives to 'cut and fill' construction such as pier and post foundations.
- Where possible avoid the use of trenches for the supply of services ie water & power.
- If trenches must be used, ensure that repacked spoil is properly compacted, treated with gypsum and topsoiled.
- Consider alternative trenching techniques that do not expose dispersive subsoils.
- Ensure runoff from hard areas is not discharged into areas with dispersive soils.
- If necessary create safe areas for discharge of runoff.
- If possible do not excavate culverts and drains in dispersive soils.
- Consider carting non-sodic soil to create appropriate road surfaces and drains without the need for excavation.
- Ensure that culverts and drains excavated into dispersive subsoils are capped with non-dispersive clays mixed with gypsum, topsoiled and vegetated.
- Avoid use of septic trench waste disposal systems; consult your local council about the use of alternative above ground treatment systems.
- Where possible do not construct dams with dispersive soils, or in areas containing dispersive soils.
- If dams are to be constructed from dispersive clays, ensure you consult an experienced, qualified civil engineer to conduct soil tests before commencing construction.
- Construction of dams from dispersive soils is usually possible, using one or a combination of: precise compaction, chemical amelioration, capping with non-dispersive clays, sand filters and adequate topsoiling.

With all forms of construction on dispersive soils, ensure you obtain advice and support from a suitably experienced and qualified engineer or soil professional before commencing work.

Appendix I Foundation Maintenance & Footing Performance (CSIRO)



Foundation Maintenance and Footing Performance:

A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

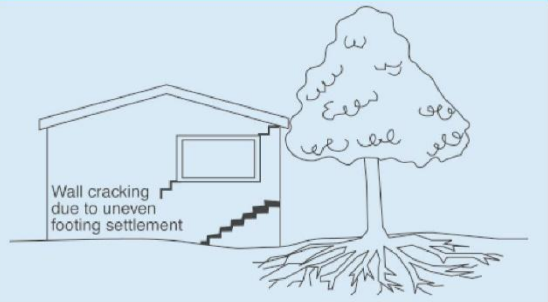
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

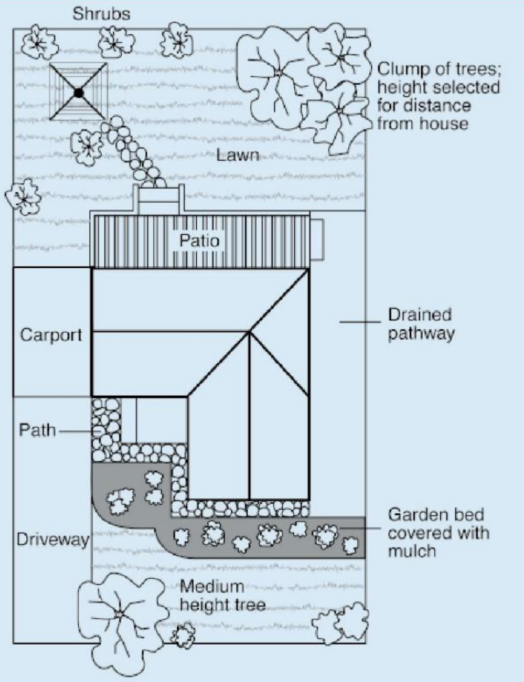
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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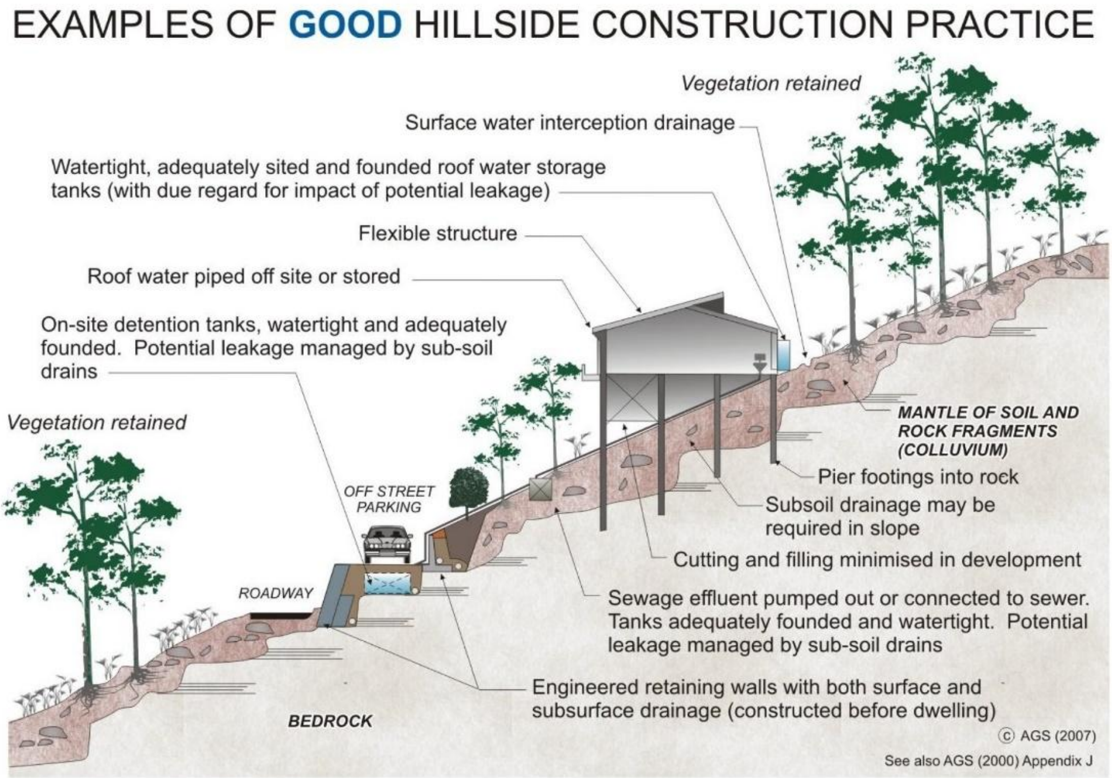
Appendix J Examples of Good Hillside Construction (AGS LRM LR8)

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

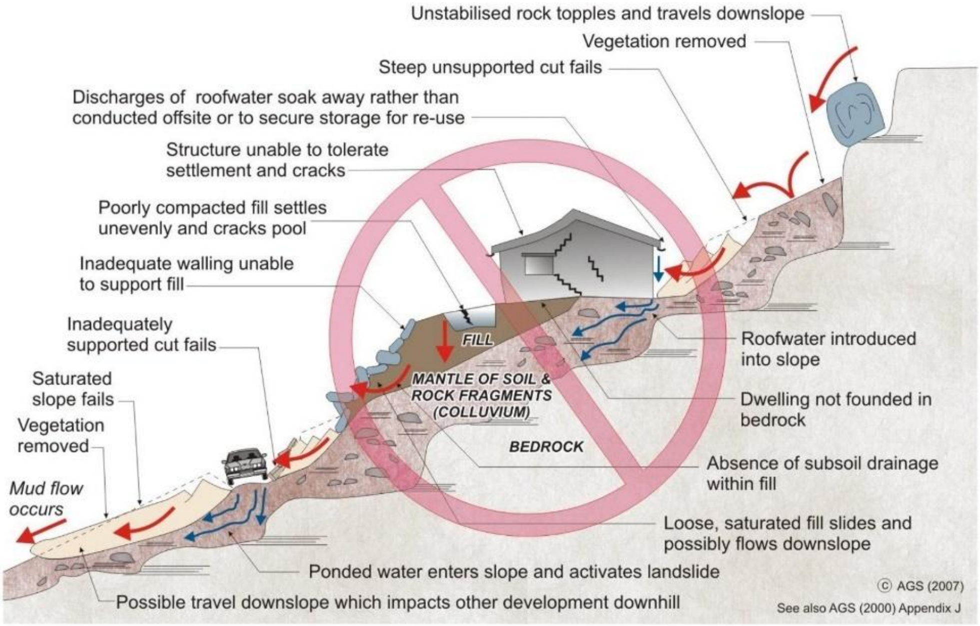
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF **POOR** HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal

GeoGuide LR10 - Coastal Landslides

- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

CERTIFICATE OF QUALIFIED PERSON – ASSESSABLE ITEM

Section 321

Form **55**

To: Nic Danger — *Owner /Agent*
4571 BRUNY ISLAND MAIN RD — *Address*
LUNAWANNA 7150 — *Suburb/postcode*

Qualified person details:

Qualified person: Kris Taylor

Address: 445 Macquarie Street
Hobart 7004

Phone No: 0476 595 889

Fax No:

Licence No: NA

Email address: office@envirotechtas.com.au

Qualifications and Insurance details: Bachelor of Science with Honours in Geology. Lloyd's Underwriters: soil and rock mechanics, soil and rock testing

(description from Column 3 of the Director's Determination - Certificates by Qualified Persons for Assessable Items

Speciality area of expertise: Geo-technical Reports

(description from Column 4 of the Director's Determination - Certificates by Qualified Persons for Assessable Items)

Details of work: Geotechnical Site Investigation

Address: 4571 Bruny Island
Main Road 7150

Lot No: 4571

Certificate of title No: 33162/1

The assessable item related to this certificate: Geotechnical Site Investigation written in accordance with AS1726 by a geotechncial practitioner with appropriate experience, training and qualifications.*

(description of the assessable item being certified)
Assessable item includes –
- *a material;*
- *a design*
- *a form of construction*
- *a document*
- *testing of a component, building system or plumbing system*
- *an inspection, or assessment, performed*

Certificate details:

Certificate type: Geotechnical including landslide risk assessment in accordance with “Practice Note Guidelines for Landslide Risk Management 2007” published by the Australian Geomechanics Society.*

(description from Column 1 of Schedule 1 of the Director's Determination - Certificates by Qualified Persons for Assessable Items n)

This certificate is in relation to the above assessable items, at any stage, as part of – *(tick one)*

● building work, plumbing work or plumbing installation or demolition work

OR

○ a building, temporary structure or plumbing installation

In issuing this certificate the following matters are relevant –

Documents: Enviro-Tech Consultants Pty. Ltd. 2026. Geotechnical Site Investigation for a Proposed Visitor Accommodation, 4571 Bruny Island - Main Road. Unpublished report for Nic Danger by Enviro-Tech Consultants Pty. Ltd., 01/05/2026.

Relevant calculations:

References: - AS1726-2017 Geotechnical Site Investigations

Substance of Certificate: *(what it is that is being certified)*

- An assessment of:
- Foundations for proposed building structures.*

Scope and/or Limitations

The Geotechnical Site Investigation applies to the Site and Project Area as inspected and does not account for future alteration to foundation conditions as a result of earth works, drainage condition changes or variations in site maintenance which are not included within the provided plans.

***This report contains soil classification information prepared in accordance with AS2870 as well as AS2870 extracts which may be used as general guidance for plumbing design. The hydraulic designer is to use their own judgment in the application of this information and this report must be read in in conjunction with hydraulic plans for the proposed development.**

I certify the matters described in this certificate.

	Signed:	*Certificate No:*	*Date:*
Qualified person:			1/05/2026