Farm Hill
Residential Subdivision
West Hobart

Lot 47
Geotechnical Report
Addendum to 1995 Geotechnical Report

Cover photo
View looking north and upslope across Lot 47 of the Farm Hill Subdivision, June 2014.

Refer to this report as
Cromer, W. C. (2014). *Farm Hill Residential Subdivision, West Hobart: Lot 47 Geotechnical Report – Addendum to 1995 Geotechnical Report.* Unpublished report for Farm Hill Pty Ltd by William C. Cromer Pty. Ltd., 15 July 2014; 81 pages).

Important Notes
New geotechnical information is contained in this report. The information may be useful to regulators and geotechnical practitioners. Dissemination of such knowledge ought to be encouraged by practitioners and regulators.

William C Cromer as author will upload this report to his website www.williamccromer.com as a freely downloadable file.

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William C Cromer Pty Ltd may submit hard or electronic copies of this report to Mineral Resources Tasmania to enhance the geotechnical database of Tasmania.

SUMMARY STATEMENT

This report is an Addendum to a 1995 geotechnical report.

It specifies a building envelope and conditions for residential development on Lot 47 of the Farm Hill Subdivision off Forest Road in West Hobart.

1 INTRODUCTION

1.1 Background

In 1995 Environmental & Technical Services Pty Ltd produced a geotechnical report[1] for G. E. Stevens to support an application to Hobart City Council to rezone 8ha of land off Forest Road in West Hobart from Rural B to Residential 2.

The Farm Hill residential subdivision, currently being developed, is the result (Attachments 1, 2, 3, 4). Lot 47 (Attachment 2) corresponds approximately to the area recommended in Cromer (1995) for low density development because of potential and existing slope stability issues.

The present report should be regarded as an Addendum to the 1995 report. It was commissioned by Farm Hill Pty Ltd to review the 1995 work, to conduct additional site investigations as necessary, and to provide specific recommendations for a building envelope for residential development on Lot 47. This report may accompany an application to rezone Lot 47.

1.2 Scope of current investigations

The present work is in general accordance with AS1726 (1993) *Geotechnical site investigations*. It included:

- a desk top study of satellite imagery (Attachment 3),
- a manipulation of LiDAR digital elevation data[2] (Attachment 8) and
- a review of published landslide maps including landslide hazard bands (Attachments 5 and 6).

Field work for this Addendum was conducted in May and June 2014 and included:

- Site inspection and photography (Attachment 9) of excavator services trenches dug by Farm Hill Pty Ltd principally along the perimeter of Lot 47,
- The digging, logging and photography (Attachment 9) of four excavator trenches totalling over 100m in length,
- Inspection and on-site discussion with Anthony Miner, Principal Geotechnical Engineer from A. S. Miner Geotechnical, and
- Surveying by D. Miller (surveyor) of the headscarps of several landslides along the eastern side of Ross Rivulet (Attachment 7).

2 SITE DESCRIPTION

Except for the results of the current work, all geotechnical aspects of Stages 1 – 4 at Farm Hill environs are comprehensively described in Cromer (1995). Relevant extracts from that report are reproduced here as Attachment 4. The Attachment includes a geotechnical interpretation map.

Recent site and trench photographs are presented in Attachment 9.

[1] Cromer, W. C. (1995). Geotechnical Investigations of land off Forest Road, West Hobart. Unpublished report for G. E. Stevens by Environmental & Technical Services Pty Ltd September 1995.
[2] Provided by A. S. Geotechnical from currently available LiDAR

3 LANDSLIDE RISK MANAGEMENT (LRM)

Attachment 10 is a LRM for Lot 47, in general accordance with the Australian Geomechanics Society (AGS) *Landslide Risk Management* (2007)[3].

Six potential slope movement scenarios were identified in relation to Lot 47. The LRM findings are:

- Current risks to property presented by the six scenarios range from Very Low (Scenario 6) to Moderate (Scenarios 1 – 5).
- Risk treatment is warranted for some of the Moderate risks.
- after development and appropriate risk treatment, consequences to property will be in the Insignificant to Minor range, and risks to property in the Very Low to Moderate range.
- Risk to life is acceptably low for all Scenarios after development, except for one aspect of Scenario 6 (unsupported excavations behind houses) which presents an acceptable – tolerable individual risk to life.

The LRM analysis in Attachment 10 includes risk mitigation measures for these scenarios, which are incorporated in the Recommendations in this report.

Also included in Attachment 10 is a checklist of AGS (2007) items to be addressed in LRM, and a certificate of currency of the Professional Indemnity insurance for William C Cromer Pty Ltd.

4 CONCLUSIONS

From a geotechnical perspective, Lot 47 can conditionally support residential development, which is unlikely to cause instability on any other land.

All risks can be acceptably managed by the risk mitigation procedures, and with good hillside construction techniques, recommended in this report.

5 RECOMMENDATIONS

From a geotechnical viewpoint, residential development of Lot 47 at Farm Hill should proceed subject to the following recommendations.

1. Recommendations to create awareness of interested parties
1a. It is important that interested parties know that this (and the 1995) geotechnical work has been done. Approval to develop as proposed should therefore include reference to this report, and indicate that geotechnical and related conditions apply.

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[3] The five AGS documents are:
AGS (2007a). Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007
AGS (2007b). Commentary on Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007
AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007
AGS (2007d). Commentary on Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007
AGS (2007e). The Australian Geoguides for Slope Management and Maintenance. Australian Geomechanics Vol 42 No 1 March 2007

1b. The reference to this report shall be as follows:

> Cromer, W. C. (2014). *Farm Hill Residential Subdivision, West Hobart: Lot 47 Geotechnical Report – Addendum to 1995 Geotechnical Report.* Unpublished report for Farm Hill Pty Ltd by William C. Cromer Pty. Ltd., 15 July 2014; 81 pages).

1c. The planning authority shall ensure that copies of this report are available to interested parties. It is strongly suggested that this report, or a reference to its availability, be uploaded to the planning authority's website. Interested parties include future AS2870 classifiers of lots. To facilitate availability, both William C. Cromer as author and Farm Hill Pty Ltd hereby give permission for copies of the report to be made by Council, or anybody else. Note however, that hard copies of the report must be reproduced in full, not in part, and must only be copied in colour. No responsibility will be accepted by William C. Cromer Pty. Ltd. or Farm Hill Pty Ltd should stakeholders rely on information provided in black and white copies of this report, or part copies of this report whether in colour or not.

1d. As well as the planning authority, Farm Hill Pty Ltd shall ensure that prospective purchasers of lots in the subdivision are made aware that copies of this report are available.

2. Fundamental geotechnical recommendations

2a. Because Lot 47 includesinvolves moderately steep hillsides and active landslides, the over-riding recommendation is that good hillside engineering practices shall be followed for the development including dwellings and infrastructure. Examples of good and bad engineering practice on hillsides are included in Attachment 11 of this report.

2b. Architects, designers, builders, building inspectors, planning authorities, landowners and occupiers should also be aware of general geotechnical advice and information in the Australian Geomechanics Society publically available Geoguides[4]. These documents include the examples of good and bad hillside construction practices reproduced here in Attachment 11.

3. Restrictions on residential development

3a. Residential development (houses, garages, sheds, swimming pools, access drives and related infrastructure) shall be restricted to the building envelope labelled Area A in Figure 10.5 in Attachment 10, and repeated here as Figure 1.

3.b Residential development shall not occur on Landslide #874 <u>or</u> within a 20m wide buffer zone extending upslope from its headscarp (Areas C and B respectively in Figure 10.5) <u>or</u> on, and downslope to Ross Rivulet from, the steeper, undulating ground on the northern hillsides of Lot 47 (Area D in Figure 10.5 in Attachment 10, and repeated here as Figure 1).

3c. Lots created by subdivision of Lot 47 may include all or some of Areas B, C and D.

4. Recommendations about AS2870 site classification of future houses on Lot 47

4a. The planning authority shall require appropriate site investigations at or near the footprint of all future houses, and their subsequent classification in terms of AS2870 (2011) *Residential slabs and footings*.

4b. AS2870 classifiers should be appropriately qualified in accordance with the Tasmanian Director of Building Control's Certificates of Specialists or Other Persons[5]. They should read this and the 1995 geotechnical report. AS2870 site investigations and classification reports should be sufficiently detailed to allow, where necessary or appropriate, site-specific modifications to the recommendations of this report.

[4] Available on-line at http://australiangeomechanics.org/admin/wp-content/uploads/2010/11/LRM2007-GeoGuides.pdf
[5]See http://www.justice.tas.gov.au/building/publications_folder/Directors_Determination_Certificates_of_Specialists_or_Other_Persons_28_November_2012_.pdf

4c. AS2870 classifiers should anticipate a range of classifications depending on soil reactivity and thickness, depth to bedrock, the likely variability of these factors across house footprints, and the proposed designs of houses.

4d. It is strongly recommended that:

- subsurface investigations for site classification be done by excavator to help distinguish stable sandstone bedrock from floaters (some pockets of bedrock are present in colluvium), and
- footings for all houses in Lot 47 be supported on piers extended into (not onto) demonstrable Triassic sandstone bedrock This will mean footing depth is likely to vary across the footprint of a house.

4e. Footings for houses in soil on slopes steeper than about 15^0 shall be designed to resist lateral (downslope) ground movement.

5. Recommendations to enhance slope stability or reduce the consequences of instability at and near house footprints

5a. Minimise the number and height of excavations, including driveway accesses and house excavations.

5b. Do not unnecessarily overload slopes with excavated rock materials unless the underlying soil profile beneath the fill is first removed, and the fill is placed in a controlled manner. Do not use soil fill as a weight-bearing material unless it is placed in a controlled manner, and avoid oversteepening slopes with it (max. batter 1:2)

5c. Ensure that any weight-bearing fill placement during development is supervised by an appropriately qualified and experienced engineer who considers not only the final properties of the fill, but also any issues (eg consolidation and settlement) potentially affecting pre-existing low strength material on which the new fill might be placed.

5d. For excavations less than 0.8m high, create a batter angle in the soil profile no steeper than 1:2 (vertical: horizontal). Install a surface cut-off drain upslope and divert surface runoff to one or both sides of the excavation. Bedrock exposed in the excavation may be left subvertical, but any loose cobbles, boulders and joint fragments should be removed. Consider shotcreting or other ways to prevent rock falls from exposed bedrock faces, and the use of erosion control blankets and revegetation on battered soil faces.

5e. For excavations higher than 0.8m, install drained, engineered retaining walls on appropriate foundations to a suitable height, and where surface soil remains exposed above the wall, create a batter angle in the soil profile no steeper than 1:2. Bedrock exposed in the excavation behind the wall may be left subvertical, but the wall must be designed to resist lateral movement of material behind it. Install a surface cut-off drain upslope and divert surface runoff to one or both sides of the excavation, to join buried flexible stormwater pipework and hence to Ross Rivulet.

5f. Variations to the specifications in 5e (for example, using steel screen cover on rock faces, placing soil or rock berms, installing steel mesh fencing) are permissible provided they are engineer-designed and certified, the slope stability of the artificially steepened slope is not compromised, and the risks to property and life both remain Acceptable.

5g. The use of lightweight flexible materials is recommended for house construction.

6. Recommendations about surface drainage and services

6a. Control all natural surface runoff and concentrated runoff from roofs, hardstands and rainwater tank overflows. Discharge all water to Council's stormwater system. Avoid discharging drainage over or into excavations.

6b. All subsurface drainage from retaining walls or house pads shall be directed to stormwater pipework and not be permitted to discharge to the ground surface.

6c. Stormwater shall be piped in flexible pipework laid in trenches down (not across) the slope and extended (where unavoidable) through landslide #874 to discharge points in Ross Rivulet. Wherever possible, services from access roads downslope to houses shall be laid in trenches aligned directly up and down the slope, but backfilled with on-site subsoil (not screened gravel) to avoid creating permeable pathways for seepage water to accumulate at house footprints.

6d. Where stormwater or sewer pipes are constructed on grades greater than 15% (8.5^0), they should be constructed with anchors to prevent movement down the slope. Each anchor shall incorporate a pathway to allow seepage water flowing in the pipe bedding material to flow freely past the anchor and not be dammed by it.

7. Recommendation in relation to unexpected subsurface conditions

7a. William C. Cromer Pty Ltd shall be immediately contacted during development should subsurface conditions appear to significantly differ from those expected on the basis of this report.

W. C. Cromer
Principal

This report is and must remain accompanied by the following Attachments

Attachment 1.	Location, satellite imagery, cadastral parcels and planning zones (2 pages)
Attachment 2.	Subdivisional plan with Lot 47 indicated in green (1 page)
Attachment 3.	Historical satellite imagery (3 pages)
Attachment 4.	Extracts from 1995 geotechnical report (11 pages)
Attachment 5.	Published geology and landslide hazard bands (2 pages)
Attachment 6.	Tasmanian Landslide Hazard Maps in relation to the property (4 pages)
Attachment 7.	May 2014 surveyed landslide headscarps and investigation trenches on Lot 47 (1 page)
Attachment 8.	Topographic, aerial and LiDAR images of Farm Hill, showing May 2014 surveyed headscarps of landslides and 2014 service and investigation trenches (4 pages)
Attachment 9.	Site and trench photographs (11 pages)
Attachment 10.	Landslide Risk Management (18 pages)
Attachment 11.	Examples of good and poor hillside engineering practices (3 pages)

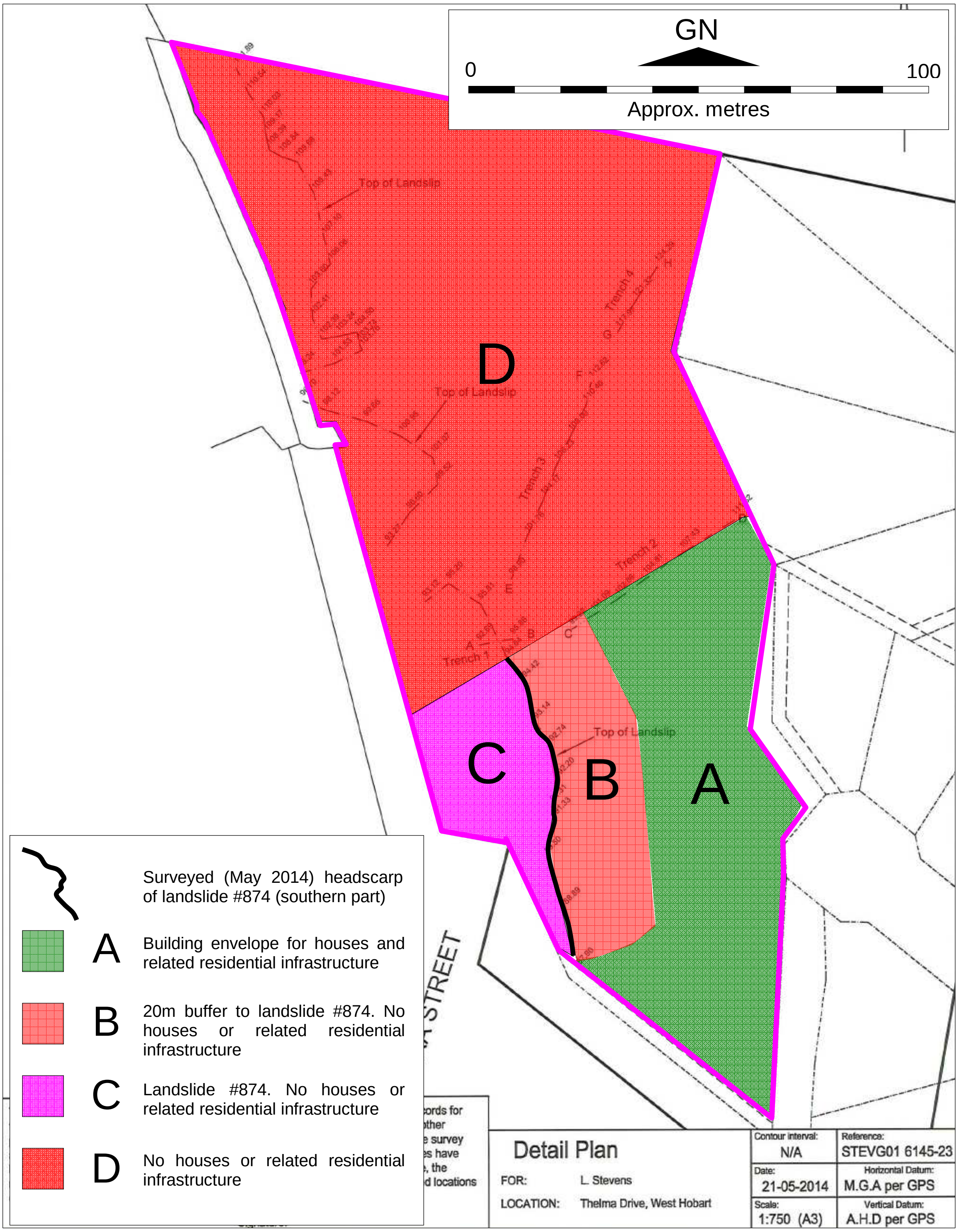


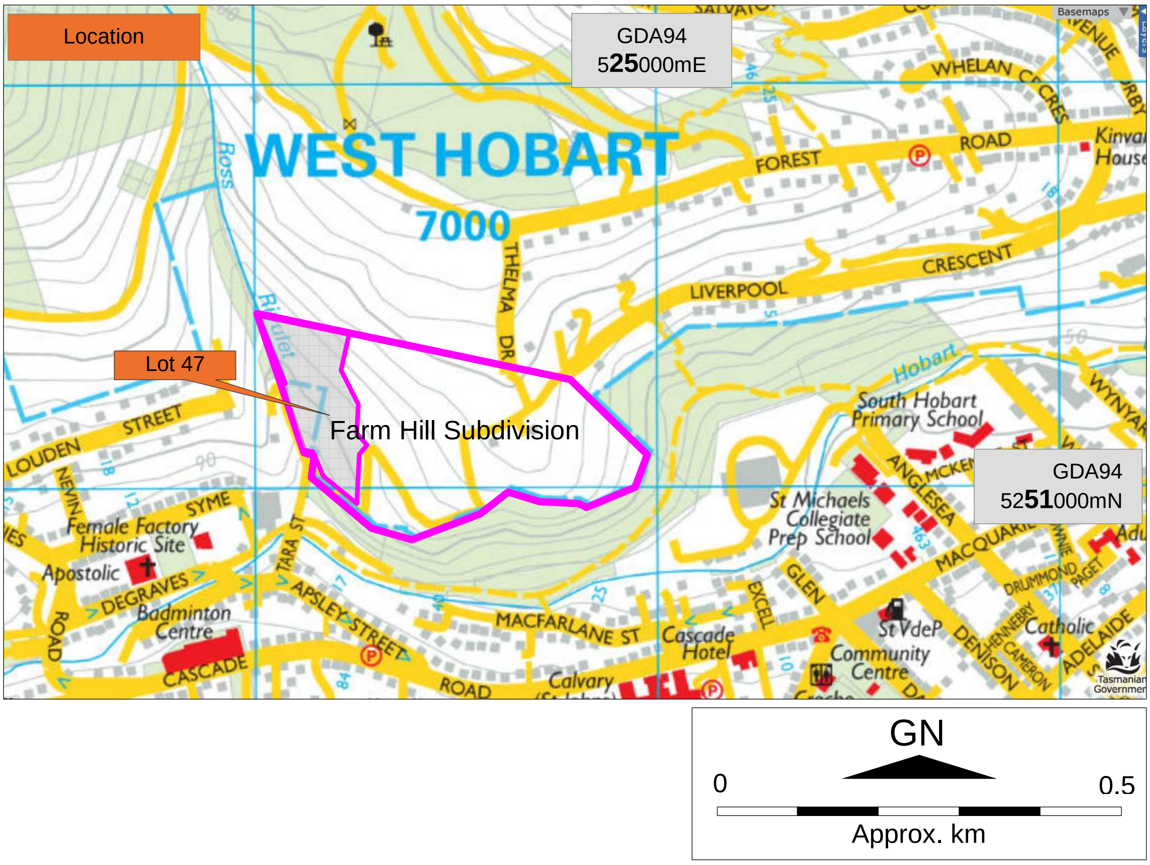
Figure 1. **Recommended building envelope (A) and no-development areas (B, C, D) for residential development of Lot 47 in Stage 4 of the Farm Hill subdivision.**
This diagram also appears as Figure 10.5 in Attachment 10 of this report.

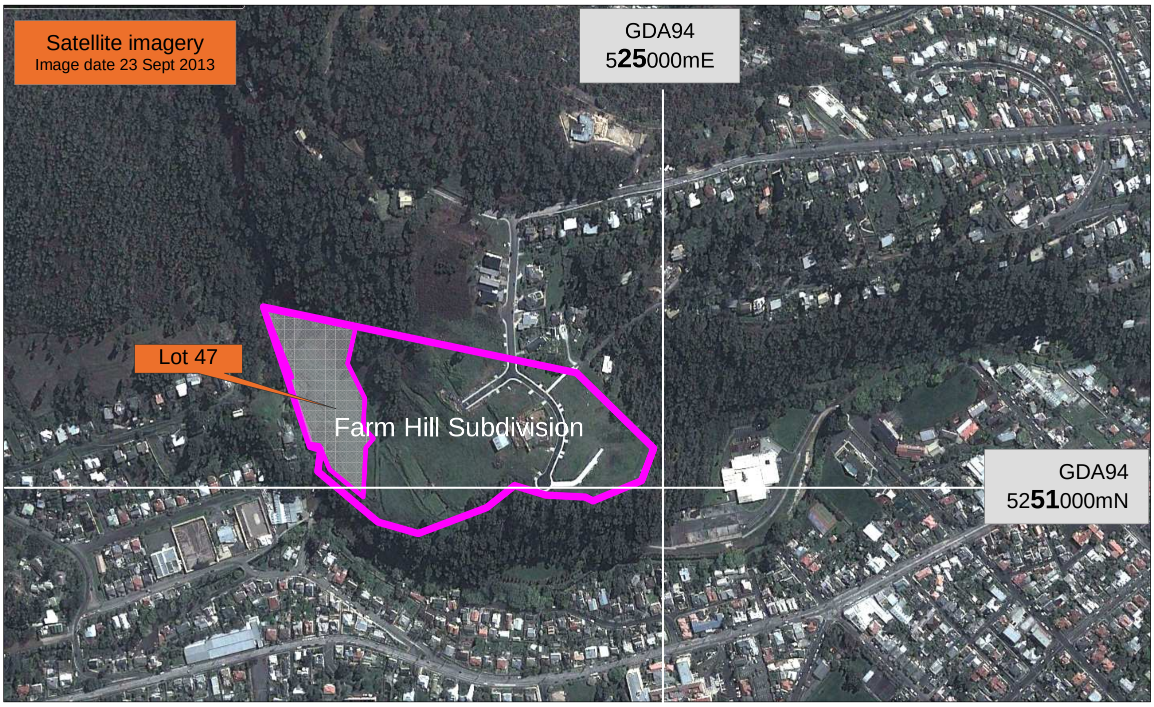
Attachment 1

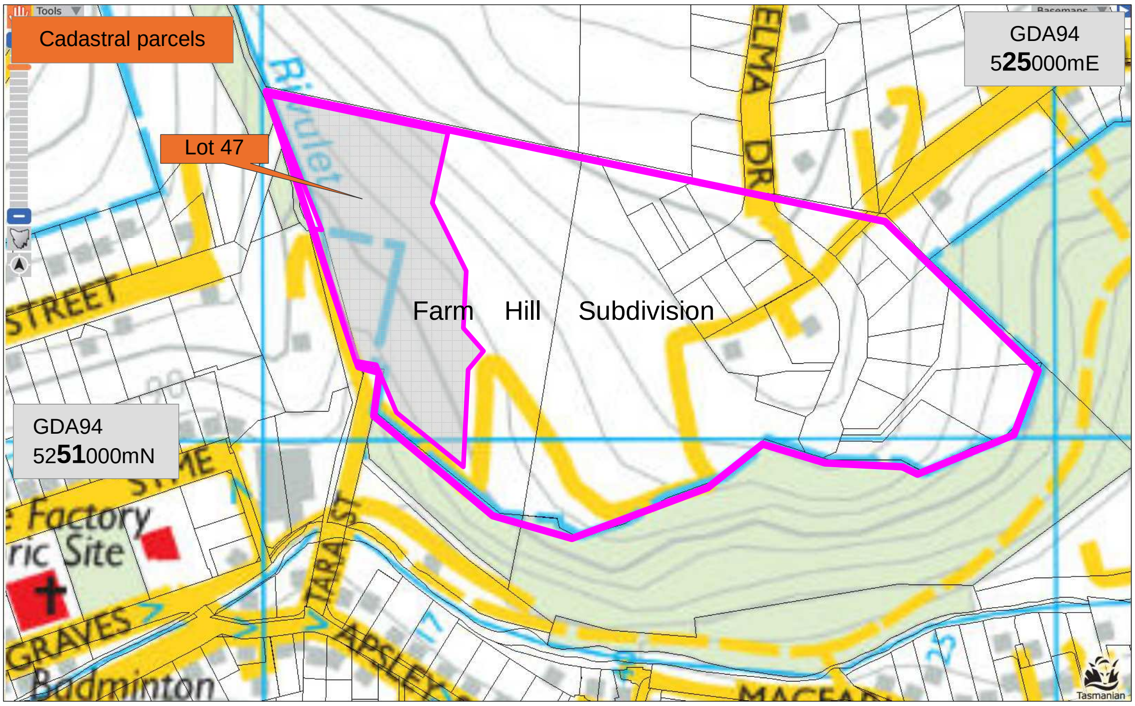
(2 pages)

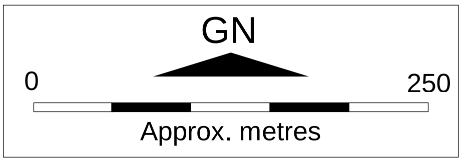
Location, satellite imagery, cadastral parcels and planning zones

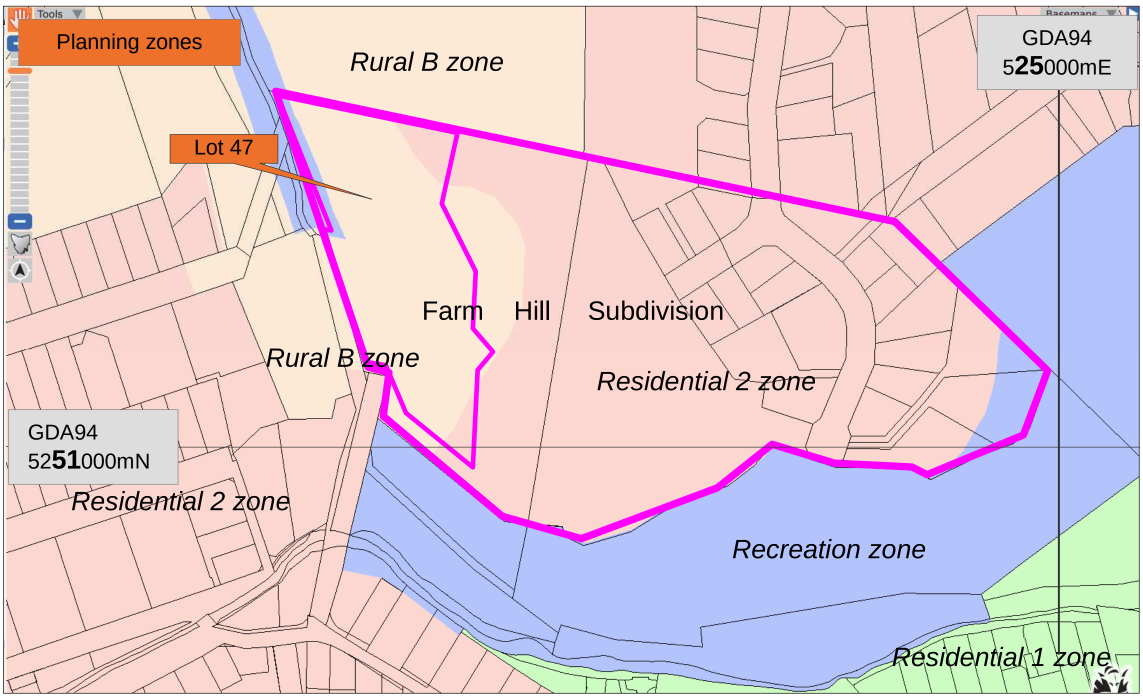
Sources www.thelist.tas.gov.au






Cadastral parcels
GDA94
525000mE
Lot 47
Rivulet
ELMA DR
STREET
Farm Hill Subdivision
GDA94
5251000mN
Factory
Site
TARA ST
GRAVES
Badminton
APSLEY


GN
0
250
Approx. metres

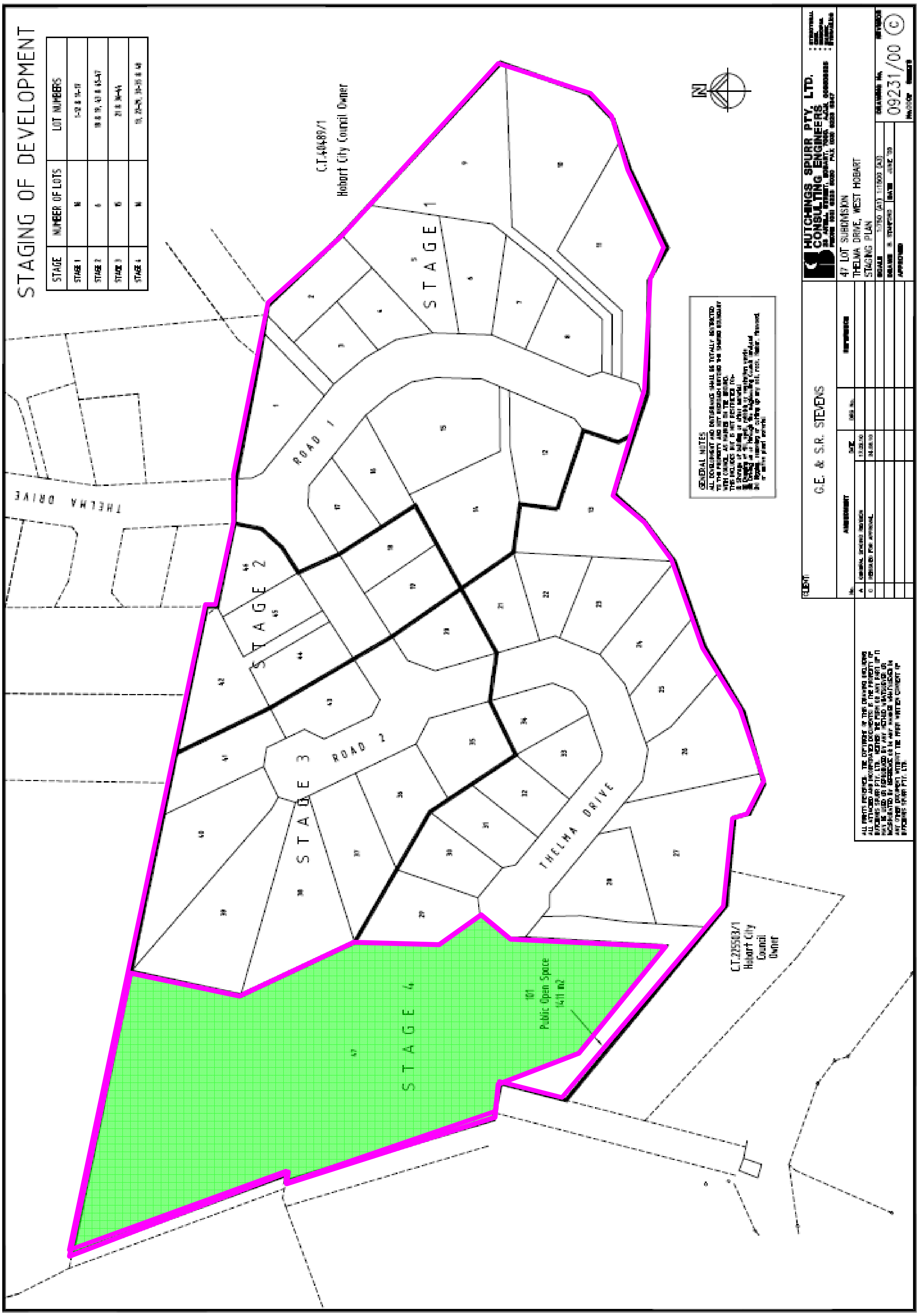

Planning zones
Rural B zone
GDA94
525000mE
Lot 47
Farm Hill Subdivision
Rural B zone
Residential 2 zone
GDA94
5251000mN
Residential 2 zone
Recreation zone
Residential 1 zone

Attachment 2

(1 page)

Subdivisional plan with Lot 47 indicated in green

Source: Hutchins Spurr Pty Ltd Consulting Engineers

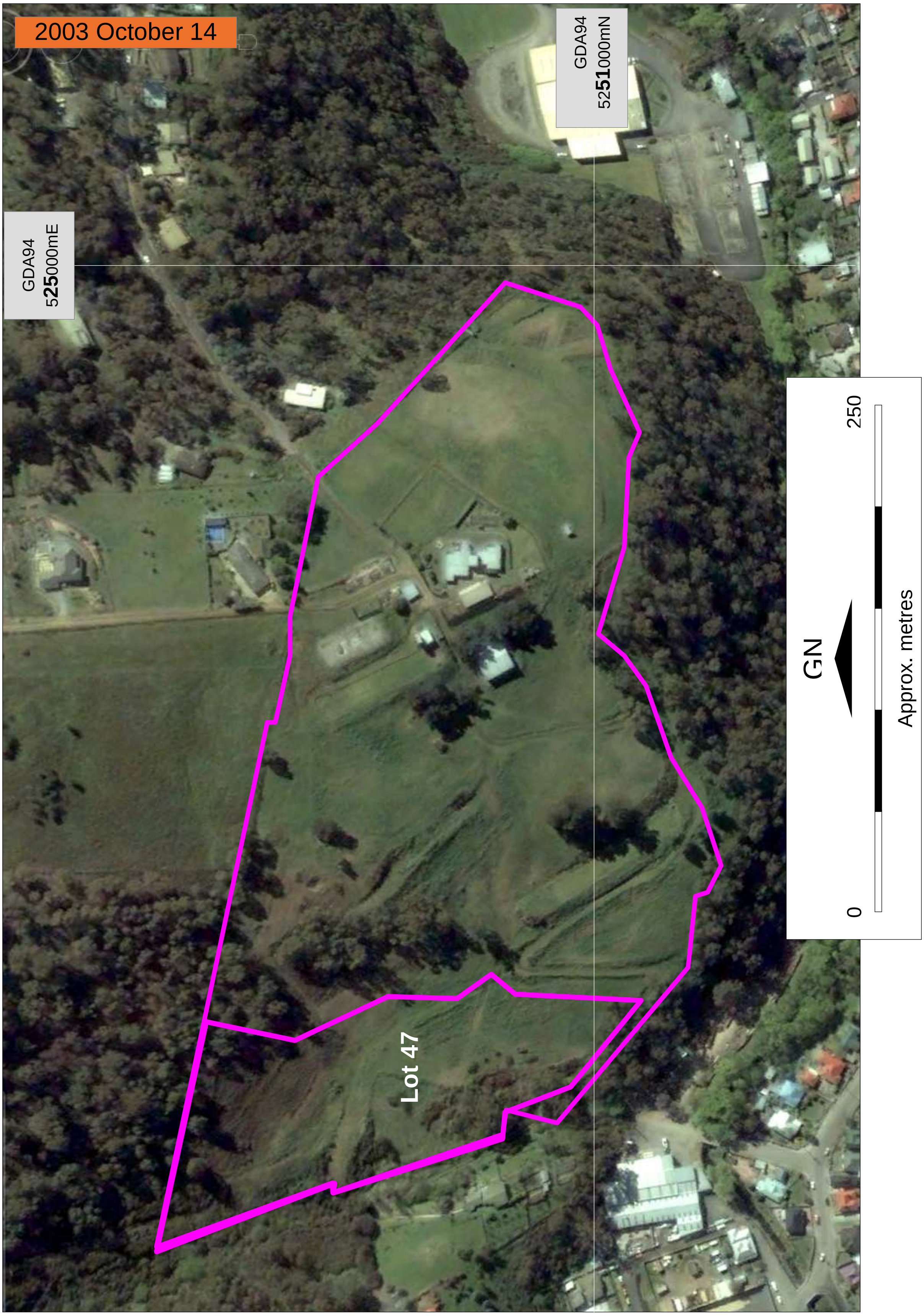


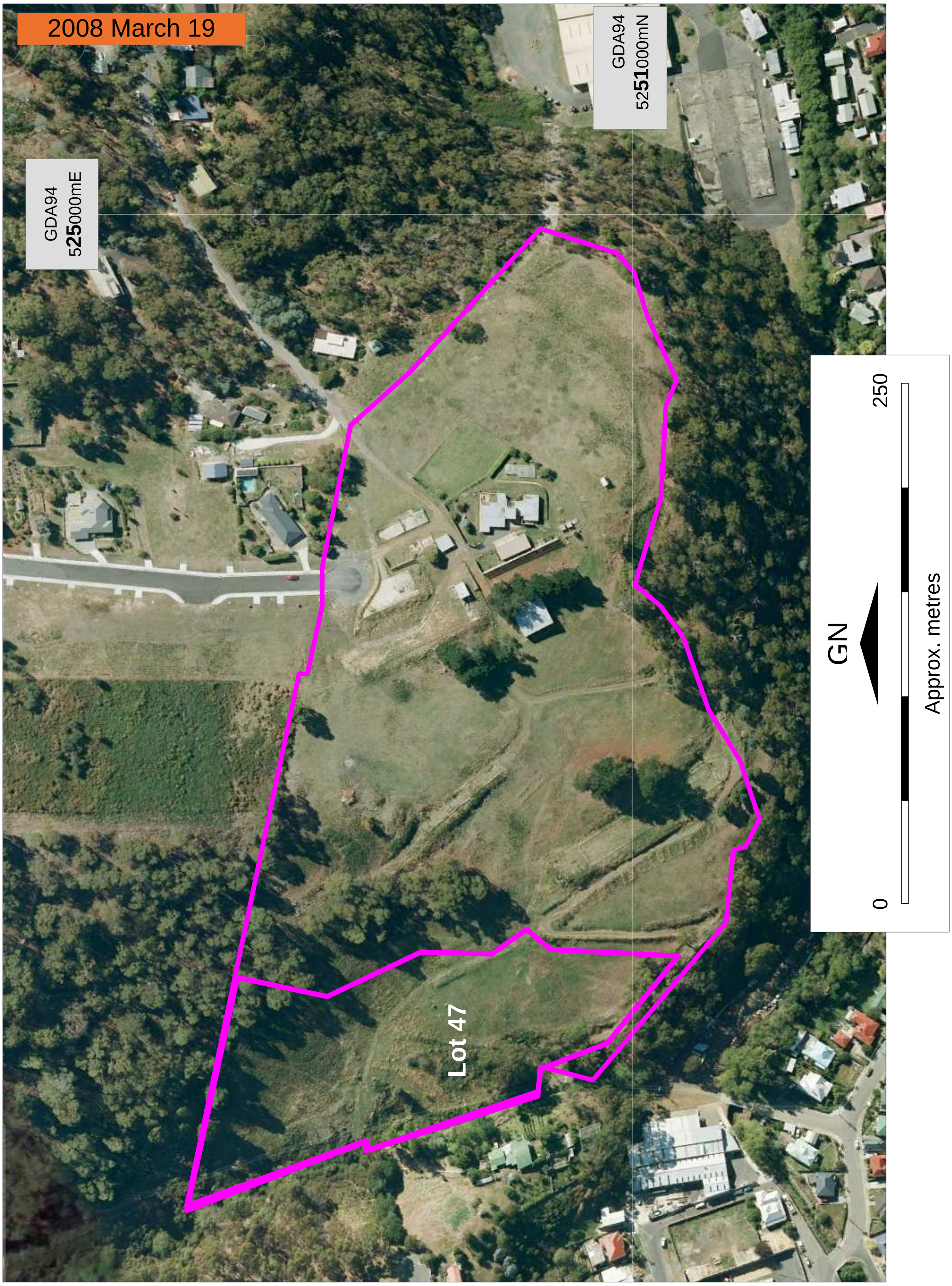
Attachment 3

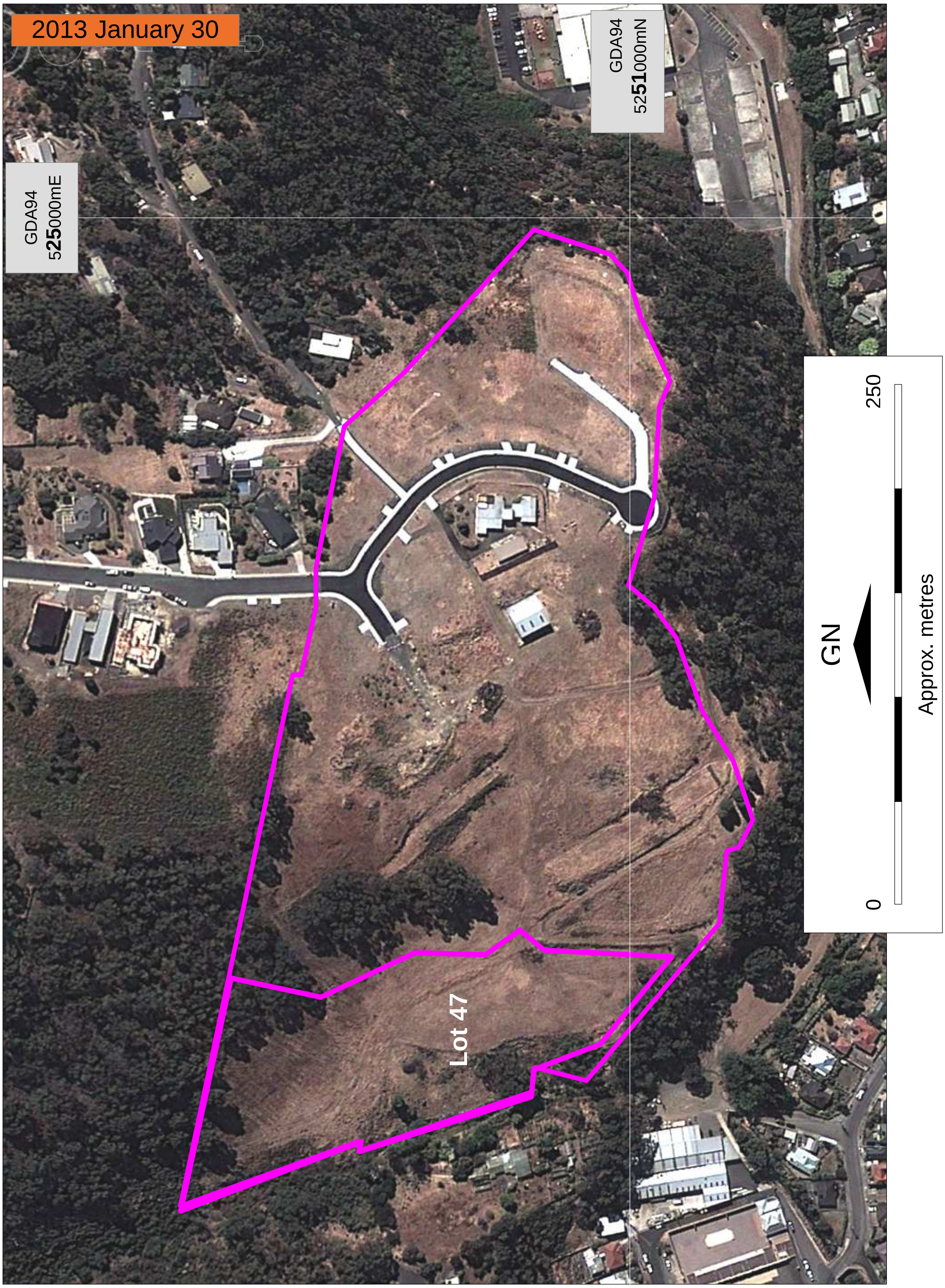
(3 pages)

Historical satellite imagery

Source: Google Earth




2008 March 19
GDA94
525000mE
GDA94
5251000mN
Lot 47
GN
0
250
Approx. metres

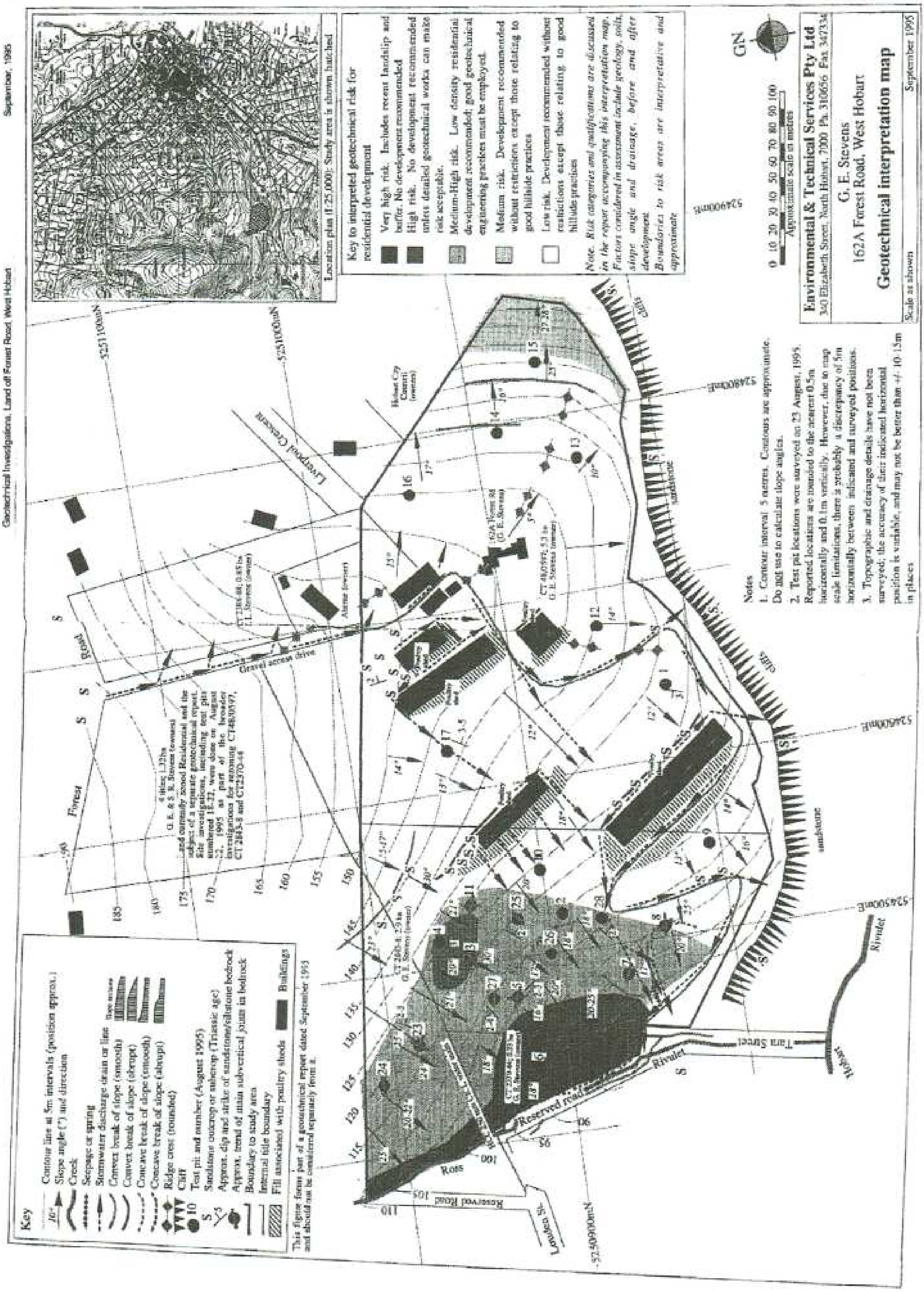

2013 January 30
GDA94
525000mE
GDA94
5251000mN
Lot 47
GN
250
0
Approx. metres

Attachment 4

(11 pages)

Extracts from 1995 geotechnical report

Source: Cromer, W. C. (1995). Geotechnical Investigations of land off Forest Road, West Hobart. Unpublished report for G. E. Stevens by Environmental & Technical Services Pty Ltd September 1995.



2. RESULTS

2.1 TOPOGRAPHY

The property (**Figure 2**) incorporates the crest and valley sides of a ridge extending downslope from Knocklofty past Forest Road to the southeast, south and southwest. The ridge terminates in a prominent sandstone cliff above the Hobart Rivulet (cover photograph). The western side is bounded by Ross Rivulet, which flows through a low break in the cliff line and joins Hobart Rivulet at Tara Street.

The land is mainly cleared to pasture, with small areas of eucalypts above an understorey of bracken fern (Plates 1 to 4 in Appendix 3). Some of the vegetation is regrowth following the 1967 Hobart bushfires.

The topography is relatively elevated. In the lower southwestern corner, elevations are about 80 metres above sea level (ASL), rising northwards to about 150 metres ASL along the northern boundary. The average slope is therefore about 13°. However, local hillside slopes range from gentle to steep. The lowest slope angles (about 5°) are along the crest of the ridge. On most of the valley sides, angles range from about 10 to 15° on the eastern flanks and 15 to 20° on the western side. Some small slope segments exhibit angles around 25 to 30°.

Over the eastern two thirds of the property, hillsides are generally smooth, and show no significant slope disruptions other than those caused by previous fencing and access tracks.

The western third of the property faces southwest towards Ross Rivulet and the Tara Street access (Plates 3 and 4). It is essentially composed of two broadly concave slope segments which join along a subtle change of slope. On the higher ground uphill, slope angles are around 20° to 25°, and locally reach 30°. Downhill from the change of slope, angles are typically 16° to 20°. This feature, incorporating in particular the lower slope segment, is possibly the scar of an ancient landslip, and is discussed further in Section 2.5.1. The landslip referred to in Section 1.2.1, located in the lower southwestern corner, has occurred on slopes of about 18° (Plate 5). A smaller possible landslip is present just upslope from the main slip, in the western corner of CT 2370-44 (Plate 6). About a hundred metres upstream, on both sides of Ross Rivulet, there is disturbed ground possibly related to minor slope failure, although the owner reports that the site was used as an access point for plant and equipment to the nearby HEC transmission line.

Elsewhere on this western third of the property, there are some localised smaller-scale topographic irregularities (Plate 7) suggestive of soil creep or solifluction[2].

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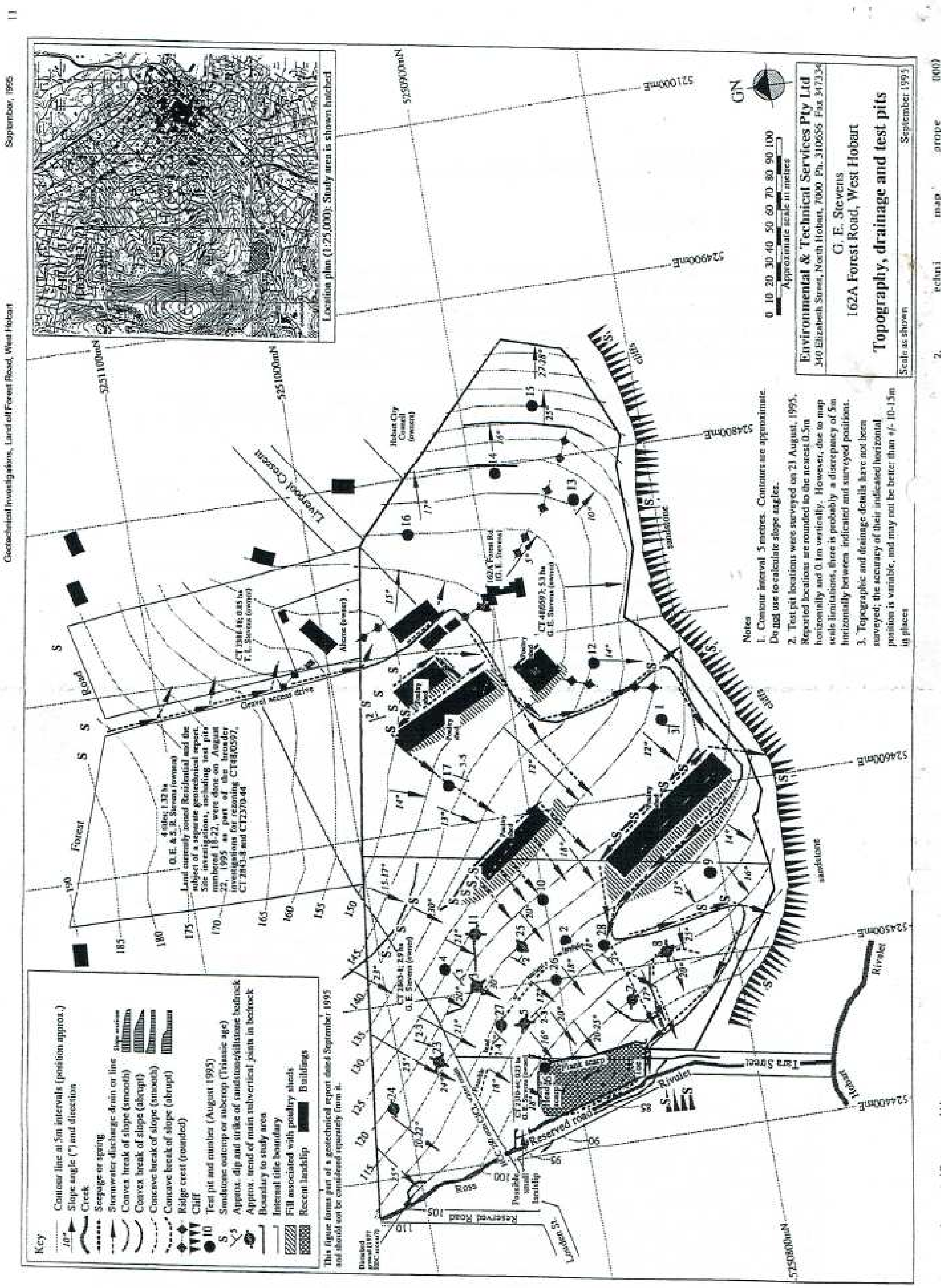
[2]Soil creep, solifluction and colluvial movements are common hillside processes, caused by gravity acting on slopes with weathered material. *Soil creep* is the almost imperceptible downslope movement of all or part of the soil profile, sometimes including the weathered bedrock beneath. It may produce small undulations and irregularities on the surface, and cause fences to lean and tree trunks to develop a knee or bend convex down the slope. *Solifluction* is another form of slow mass movement, where the weathered material is almost saturated with water. *Colluvium* is a deposit of accumulated debris on or at the base of slopes. It too may produce surface irregularities and bulges. There is a gradation between all three processes, mainly related to water content, and it may be difficult to distinguish between them. In this report, for the sake of clarity, we have used the term 'soil creep' to mean either soil creep or solifluction or both, because in each case the soil profile appears to have been essentially unaltered. We use the term 'colluvium' separately because we believe we can distinguish such material from soil in the field, typically as a jumbled mass of boulders and smaller bedrock fragments in a friable, usually dry-moist finer-grained matrix.


Geotechnical Investigations, Land off Forest Road, West Hobart
September, 1995
11
Location plan (1:25,000): Study area is shown hatched
Key
Contour line at 5m intervals (position approx.)
Slope angle (°) and direction
Creek
Seepage or spring
Stormwater discharge drain or line
Convex break of slope (smooth)
Convex break of slope (abrupt)
Concave break of slope (smooth)
Concave break of slope (abrupt)
Ridge crest (rounded)
Cliff
Test pit and number (August 1995)
Sandstone outcrop or subcrop (Triassic age)
Approx. dip and strike of sandstone/siltstone bedrock
Approx. trend of main subvertical joints in bedrock
Boundary to study area
Internal title boundary
Fill associated with poultry sheds
Recent landslip
Buildings
This figure forms part of a geotechnical report dated September 1995 and should not be considered separately from it.
Notes
1. Contour interval 5 metres. Contours are approximate. Do not use to calculate slope angles.
2. Test pit locations were surveyed on 21 August, 1995. Reported locations are rounded to the nearest 0.5m horizontally and 0.1m vertically. However, due to map scale limitations, there is probably a discrepancy of 5m horizontally between indicated and surveyed positions.
3. Topographic and drainage details have not been surveyed; the accuracy of their indicated horizontal position is variable, and may not be better than +/- 10-15m in places
0 10 20 30 40 50 60 70 80 90 100
Approximate scale in metres
GN
Environmental & Technical Services Pty Ltd
G. E. Stevens
162A Forest Road, West Hobart
Topography, drainage and test pits
Scale as shown
September 1995
Forest Road
Liverpool Crescent
Gravel access drive
Reserved road
Reserved Road
Tara Street
Linden St.
Ross
Hobart Rivulet
sandstone
cliffs
5251000mN
5250900mN
5250800mN
5251100mN
524900mE
524800mE
524600mE
524500mE
524400mE
521000mE

Other slope disruptions in the same general area may be colluvial[2] in origin (Plate 8), but some are undoubtedly the result of human intervention, including track making, fence building, bulldozer access for an adjacent electrical transmission line, and the installation of a 250 mm water main by the City of Hobart. However, in some instances it is difficult to distinguish between natural and artificial slope disruptions.

2.2 DRAINAGE

2.2.1 Surface drainage

Ross Rivulet is the main drainage line in the immediate area, forming the western boundary to the property. An un-named depression east of the eastern boundary receives some runoff from the land, and also from slopes at the western end of Liverpool Crescent.

Within the property, there are no clearly defined natural drainage channels. Instead, before development for farming, most runoff evidently discharged as overland flow over the cliff line, or to Ross Rivulet and the valley to the east.

Development has disrupted this pattern. Much of the runoff is now diverted to stormwater drains along internal access tracks. Some of it, however, is discharged in an uncontrolled manner from poultry sheds onto adjoining slopes, where it forms temporary drainage lines.

2.2.2 Subsurface drainage

Shallow subsurface drainage is related to natural infiltration of rain, and some is caused by stormwater discharge lines from tracks and poultry sheds. Test pit 28 intersected small amounts of free water at the base of the topsoil along one such line, which further downslope has produced seepages near the toe of the landslip in the southwestern corner.

Naturally occurring subsurface drainage was observed in test pit 23. Test pit 6, located at the head of the landslip and downslope from a small seepage, also intersected small amounts of free water.

It is possible that the 250 mm Council water main constructed through the property about 1973, or the trench containing it (Figure 2), is locally affecting subsurface water conditions near and downslope from it. The trench has the potential to act as a french drain collecting upslope runoff and seepage, and if so, the fractured nature of the bedrock (see below) might allow vertical infiltration of water which may surface downslope. It is also possible that the pipe itself might have leaked or is leaking. We point out that we have no direct evidence of leaks and the link, if any, between cause and effect may be very difficult to reasonably establish. We raise the possibility for future consideration if residential development proceeds.

2.3 GEOLOGY -

2.3.1 General comments

According to the Hobart geological map sheet (referred to earlier) the entire property is underlain by interbedded sandstones, siltstones and related rocks of

Triassic age. Our investigations confirm this, and indicate that sandstone, fractured to varying degrees and locally cross-bedded, is the dominant rock type. Near the property, good exposures occur at the top end of Forest Road, in sandstone cliffs along Hobart Rivulet.

The regional dip of the Triassic rocks is shown on the geological map to be northwest at 10° on Louden Street, and 6° west on Forest Road. Within the property, we have measured lesser dips in the range 2 to 4° generally towards the southeast. It is typical of cross-bedded sandstones to exhibit variable dips over short distances.

East of the property, on Liverpool Crescent, the Triassic rocks are in contact with doleritic boulder beds of presumed Tertiary age, but these have no bearing on geological conditions on Mr. Stevens' property.

2.3.2 Bedrock geology

Sandstone bedrock[3] is exposed at several locations on or near the property. It forms the cliff line along the southern boundary near Hobart Rivulet, is exposed in low cliffs at the end of Tara Street, occurs in excavations behind or near several of the poultry sheds (Plates 9 and 10), and appears to crop out in scattered locations elsewhere.

Siltstone, which is locally interbedded with the sandstone, was not observed to crop out, probably because it is less common, and is more susceptible to weathering and erosion.

Evidence that sandstone is the dominant bedrock type beneath the property also comes from the test pit data (Table 1). Sandstone (usually not interbedded with siltstone) was intersected at shallow depth in all but two pits. Siltstone (with minor sandstone) was the dominant rock type in only three of these (Nos. 6, 25 and 26), suggesting that it is present as relatively thin horizons rather than thicker units.

The sandstone is typically fine grained and moderately weathered (harder varieties are only slightly weathered), and orange, orange-brown or light yellow. Usually it is moderately to strongly fractured, with mainly discontinuous, close-spaced, open, moderately rough subvertical joints. Where observable or measurable, the dominant joint directions tend to be southeast, east and northeast - roughly parallel to the varying lines of strike of the cliff line to the south. However, local joint directions are variable, and unpredictable between test pits.

The combination of jointing and bedding surfaces, and the moderate to steep slopes in the western third of the property, is to produce partly dislodged blocks of sandstone in the top half metre or so of the bedrock beneath the soil profile (Plate 9). In some test pits which were dug deep enough, it was observed that this effect tends to decrease with depth within the bedrock. Often, there is a vertically downwards gradation between soil or colluvium containing few sandstone fragments, to the same material with many rock fragments, into strongly fractured bedrock with soil or clay in the joint openings.

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[3]Bedrock for the purposes of the present report is defined as sandstone and/or siltstone which is sufficiently unweathered so as not to exhibit soil properties (that is, it cannot be remoulded in the hand either in its natural state or by adding water). It therefore excludes all the soil profile, superficial colluvial material, and any separate or partly dislodged rock fragments of any size at any depth which are substantially enclosed by material with soil properties.

Table 1. Summary of test pit logs

Test pit	Depth dug (m)	Depth to bedrock (m)	Summary log of materials (depths in m)
1	0.8	0.7	0-0.5 sand (SP); 0.5-0.7 clayey sand, sandy clay (SC, CL); 0.7-0.8 sandstone
2	1.0	0.7	0-0.3 silty sand (SP, SM); 0.3-0.7 silty clay, clayey silt, silty sand (SM, [illegible], SP, SM); 0.7-1.0 sandstone
3	2.2	1.3	0-0.4 sand (SP); 0.4-1.2 gravelly sand with boulders (SP, GP); 1.2-2.2 [illegible]
4	2.8	2.6	0-0.5 sand (SP); 0.5-2.6 gravelly silty sand with boulders (SP, SM, GM, CL); 2.6-2.8 sandstone
5	0.9	0.8	0-0.5 sand (SP); 0.5-0.8 sand, gravelly sand and boulders (SP, SM); 0.8-0.9 sandstone
6	5.0	1.1	0-0.9 sand (SP); 0.9-1.1 clay (CH); 1.1-4.0 sand, clayey sand, gravelly sand; 4.0-5.0 siltstone
7	1.1	0.9	0-0.7 sand (SP); 0.7-0.9 sand, clay, cobbles (GP); 0.9-1.1 sandstone
8	1.2	0.7	0-0.3 sand (SP); 0.3-0.7 silty sand (SP, SM, GP); 0.7-1.2 sandstone
9	1.7	1.5	0-0.6 sand (SP); 0.6-1.5 sandy silty clay and clayey silt (CL, CH, SM, SC); 1.5-1.7 sandstone
10	1.5	1.5	0-0.4 sand (SP); 0.4-0.8 clayey silty sand (SC); 0.8-1.5 gravelly clay (CL, CH)
11	1.3	1.1	0-0.4 sand (SP); 0.4-1.1 clayey silt (SM, CL); 1.1-1.3 sandstone
12	0.7	0.6	0-0.6 sand (SP); 0.6-0.7 sandstone
13	1.8	1.6	0-0.5 sand (SP); 0.5-0.8 silty sand (SP); 0.8-1.6 sand (SP); 1.6-1.8 sand[illegible]
14	1.3	1.2	0-0.8 sand (SP); 0.8-1.2 clay (CH); 1.2-1.3 sandstone
15	2.5	2.4	0-1.1 sand (SP); 1.1-1.7 silty sand (SP); 1.7-2.4 clay and sandstone frags (CH); 2.4-2.5 sandstone
16	2.6	2.6	0-0.9 sand (SP); 0.9-1.3 silty sand (SP); 1.3-2.6 clay (CH, CL)
17	1.7	1.6	0-0.8 sand (SP); 0.8-1.6 sand and gravelly sand (SP, SC); 1.6-1.7 sandstone
23	2.2	1.1	0-0.3 sand (SP); 0.3-1.1 sand, silty sand (SP,SM, GM); 1.1-2.2 sandstone
24	1.8	1.0	0-0.3 sand (SP); 0.3-1.0gravelly sand, sand gravel (SP, GW); 1.0-1.8 sandstone
25	2.7	1.2	0-0.5 sand (SP); 0.5-1.2 sandy clay, sandy silty clay (CH, CL); 1.2-2.7 sandstone and siltstone
26	2.2	0.8	0-0.5 sand (SP); 0.5-0.8 clayey sand (SC); 0.8-2.2 siltstone and sandstone
27	2.1	0.7	0-0.3 sand (SP); 0.3-0.7 gravelly clayey sand, sandy clay (CL, SC); 0.7-2.1 sandstone
28	1.7	0.7	0-0.4 sand (SP); 0.4-0.7 sandy clay (CL, CH); 0.7-1.7 sandstone
Aver.	**1.9**	**1.2**	

Notes

1. Some soil units are variable in thickness
2. Underlined numbers in 'depth to bedrock' column indicate no bedrock to the indicated depth
3. 'Bedrock' is here defined as sandstone and/or siltstone which is sufficiently unweathered so as not to exhibit soil properties (ie the material cannot be remoulded in the hand with or without adding water). Bedrock therefore excludes the A and B soil horizons, and may or may not include the CB horizon. It excludes colluvial material, and separate or partly dislodged rock fragments of any size at any depth.

The siltstone encountered in some of the pits tends to be more weathered and more easily excavatable than the sandstone. It is typically finely laminated and cut by closer-spaced, discontinuous joints and partings along bedding surfaces.

On the western third of the property, a fairly consistent feature of the near-surface sandstone and siltstone is the presence of clay, sandy clay or clayey sand linings on many joint and bedding surfaces. These materials have apparently been deposited from soil seepage water percolating through the fractures, since they can occasionally be observed to fill wedge-shaped openings between dislodged blocks at or below the base of the soil profile, tapering into bedrock.

The clayier linings are interpreted as having implications for possible past instability, and current slope stability. Evidence from test pits suggests they are more common on the western third of the property and generally in the area inferred to be a possible ancient landslip. Clay linings were not observed in test pits 1, 9, and 12 to 16, and were only a minor feature of pits 8, 17, 24 and 27. Three of the last four are located on the periphery of the shallow valley covering most of CT 2843-8, and with the exception of pit 27 (near the centre of the valley) all the remainder are on the eastern two thirds of the property.

The clayier linings are usually moist or wet, and consist of dark grey high plasticity clay. Their thickness typically varies from less than one to ten millimetres. They tend to be discontinuous; most do not exceed the joint spacings in length (although they may be offset at joint intersections), and none was observed to extend the full length of test pits. However, several could be traced across the width of pits (about 0.8 metres) and occasionally along bedding surfaces or joints for up to a metre or so.

Clay linings on joints and bedding surfaces in sandstones are not confined to the study area. Similar features were observed in sandstones in outcrops along Forest Road, and also near the end of Salvator Road further north. In two to three metre high road cuts on Forest Road, their development is laterally irregular, and their occurrence and thickness appears to decrease with depth below a metre or so.

2.3.3 Colluvium

Material interpreted as colluvium (weathered detritus which accumulates on or at the base of slopes) was observed in test pits 3 (Plate 8), 4, 10 and 24, and possibly pit 6. There is no clear evidence that it is present in pit 6 (at the head of the landslip), although the hummocky ground immediately downslope is probably at least partly colluvial since colluvium is exposed in the road cutting at the toe of the slip.

The colluvium overlies sandstone or siltstone bedrock in all but one (No. 10) of the four or possibly five test pits in which it was exposed. In pit 10, the excavator was close to refusal at 1.5 metres in dense colluvium.

The detailed texture of the colluvium is not consistent between these pits. However, in all cases it comprises fragments, cobbles or boulders (collectively called 'clasts') of sandstone or siltstone, or both in varying proportions, in a matrix of sand, gravel, minor clay and silt. Textures include gravelly sand with 40-50% sandstone clasts in pit 3, gravelly silty sand with occasional sandstone clasts in pit 4, a gravelly clay with up to 90% sandstone and siltstone clasts in pit 10, and gravelly sand with a similar proportion of sandstone clasts in pit 24.

The colluvium was dry in pit 10, but moist to locally wet in the other three. Generally, its plasticity is low, reflecting the predominantly sandy topsoils of the property.

2.4 SOILS

2.4.1 General comments

The soils over the study area comprise duplex (two-layered), mainly residual[4] profiles on bedrock. with fairly consistent textures broadly typical of soils developed on Triassic rocks elsewhere in Tasmania.

The duplex profiles generally comprise A and B horizons (topsoil and subsoil), either resting directly on bedrock or overlying a zone of weathered rock (the CB horizon). Some profiles are not duplex but uniform in texture, where the subsoil appears to be missing or only poorly developed. In some cases, the sandy topsoil may have accumulated or been redistributed by wind transport.

The average depth of the soil profile (A+B horizons) is about 0.7 metres in the western third of the property, but significantly greater at 1.4 metres in the eastern third near pits 13-16.

Soils are described in detail in the test pit logs in Appendix 2.

2.4.2 Topsoil (A horizon)

The topsoil is typically loose, moist and friable, averaging 0.4 to 0.5 metres thick (range 0.3 to 0.7 metres) in the western part of the property, but one metre thick (range 0.5 to 1.7 metres) on the broad ridge to the east. It usually consists of a dark grey surface sand or silty sand about 0.2 metres thick (the A1 horizon) grading to a yellowish brown, grey brown or light grey sandy A2 horizon averaging 0.3 metres thick. Sandstone gravel and coarser fragments may be present, sometimes up to boulder size.

Sometimes, the A horizon rests on bedrock or colluvial material, and a B horizon is absent.

2.4.3 Subsoil (B horizon)

Where present, the subsoils over the property average about 0.3 metres thick (range 0.2 to 0.7 metres). They tend to be clay- or silt-enriched to varying degrees compared to the topsoils. Texturally they include non-plastic or low plasticity silty sand or clayey silt, and moderate to high plasticity silty clay or clay. Sandstone gravel, or fragments and boulders may be present.

2.4.4 Weathered bedrock (CB horizon)

In some test pits, weathered sandstone or siltstone exists beneath the B horizon. It is most easily recognised by its texture (mainly sand, silt or sandy silt) in conjunction

[4] Residual soils have developed mainly from the weathering of the rocks directly below them, with little or no contribution from materials further upslope.

with relict bedding and joints. In some cases (for example, in pit 6) it is difficult to distinguish from the B horizon, or colluvial material.

2.5 SLOPE INSTABILITY

2.5.1 General comments

As discussed in Section 2.1, there is surface evidence of slope instability on the western third of the property. This evidence takes the form of topographic or slope irregularities at various scales. Some of it is supported by observations in test pits and other exposures around the site.

On the larger scale, the slightly concave shape of the hillside over most of CT 2843-8 has the appearance of being formed by slope movements in the past. This mode of formation is probably shared by many other similar shaped hillsides in metropolitan Hobart.[5]

On the hillside are smaller-scale topographic irregularities. As discussed, some of these are man-made, and we have been able to distinguish most (but probably not all) of these from natural features by studying several sets of aerial photographs dating from the late 1940's.

Similar features above the same bedrock types have been observed along the hillside below Louden Street to the west, and we have noted a possible, fairly large landslip east of the property boundary at the western end of Liverpool Crescent. In both areas, residential development has encroached near or onto the inferred unstable ground.

On a smaller scale, the natural slope disruptions within the study area are several metres or tens of metres in surface extent, and from 0.5 metres to about 2 to 3 metres in vertical dimension. They have been interpreted as *soil creep* (bulges on soil-covered slopes caused by slow downslope movement of soil), *colluvial* movement (loose, mainly dry debris moving slowly downslope) and *landslips* (the relatively more rapid downslope movement of soil or debris, usually by sliding on low-strength material). The processes are facilitated by the presence of subsurface water, and their surface expressions may be difficult to distinguish from one another.

We observed no obvious surface evidence of instability on the eastern two thirds of the property.

2.5.2 Soil creep and colluvium

Probable soil creep was observed as low, subdued bulges (Plate 7) above the surrounding surface in several places on the western third of the property. Two of these, on slopes of about 17-18°, were further explored by test pitting (pits 2 and 7). It appeared that slow movement of the soil profile was or is occurring at a depth of about 0.7 metres on weathered bedrock (CB horizon) where relict joints and bedding planes contain moist clay linings.

[5] It is important to note that the inferred former instability of these areas was probably related to climatic conditions different from those now prevailing. Contributory factors might have included abundant precipitation on sparsely vegetated slopes - conditions thought to have existed at low altitudes in a colder, wetter climate during or at the close of the last glacial epoch at least 12,000 to 15,000 years ago. Generally, such failed slopes probably now exhibit better stability since unstable material has moved downslope (thus flattening out the slope profile), and the now humid climate has produced a stabilising vegetation cover.

In pits 3 to 6, 8, and 23 to 28, all dug in the same general area, the CB horizon was not identified, and in all cases, soil creep appeared to be absent. The CB horizon (where it contains moist clay linings) is therefore implicated in soil creep. Other areas of soil creep upslope from pits 27 and 11, identified from surface expression but not tested by pitting, are possibly also underlain by similar materials.

Test pits 3, 4, 10 and 24 exposed materials inferred to be colluvial in origin. Pits 3 and 4 were dug below and on a fairly prominent surface bulge (Plate 8) extending perhaps 30 to 40 metres along the slope, with an elevation of up to several metres. Aerial photographs indicate that it was present before excavations for the nearby pipeline trench, and so is a natural feature.

The colluvium in pits 10 and 24 shows no obvious surface expression.

2.5.3 Recent landslips

A landslip (Plate 5) has occurred on the extreme lower corner of the study area, covering almost all of CT 2370-44 and extending eastwards onto part of CT 2843-8. Aerial photographs do not show obvious signs of slope movement between 1947 and 1967, but some surface irregularities (implying movement) had developed by 1973. The slip appears to be bulging over the nearby access track in the 1975, 1982 and 1984 photographs. A head scarp is visible in the 1984 photograph, and by 1986 the landslip appears to attained its present shape.

We infer from this evidence that while incipient movement may have occurred earlier, noticeable movement took place sometime between 1967 and 1973, that it probably continued until about 1986, and that little or no significant movement has occurred since.

Verbal reports from the owner and a neighbour support these tentative conclusions. They have indicated that movement definitely occurred after the 1967 bushfires (when a house on the site burned down), and probably in the early 1970's.

The area is currently grassed and shrubby, and supports a few moderately sized eucalypts, suggesting that the average rate of movement has been relatively slow.

The head and eastern flank of the landslip is an obvious, arcuate scarp in sandy soil, averaging about one metre high. The toe is a bulge of colluvial debris - mainly silty gravelly sand with some clay and many sandstone boulders - up to about three metres high along the nearby access track. Internal features include hummocky ground and small arcuate steps.

Test pit 6 was dug at the head of the slip, into and beneath the exposed scarp and for several metres downslope. The total depth was 5 metres from the top of the scarp. The pit was sited to investigate the nature of the materials immediately behind and within the failed material, and to attempt to identify the location and materials on which movement had taken place.

The pit revealed a one metre thick soil profile of sandy topsoil and clayey subsoil, which although dislocated and draped across the scarp, was otherwise continuous across it. The base of the soil was wet. Immediately beneath it was a moist, friable to medium dense zone of mixed sand, clayey sand and gravelly sand three metres thick. This layer contains sandstone fragments, and relict bedding and discontinuous fractures containing moist grey clay or sandy clay linings. However, there was no evidence of continuous clay linings which might have acted as a single failure surface. The bedding appears to dip at shallow angles north into the slope behind. Very minor seepage issued from a depth of three metres. At the base of the unit is a thin horizon of fractured blocky sandstone.

This three metre thick unit is interpreted as weathered bedrock (the CB horizon).

The CB horizon overlies weathered siltstone bedrock, also containing clay linings on joints and bedding laminae. A seepage estimated at about 20 L/hour was issuing from a depth of 4.8 metres.

Landslip movement is inferred to have taken place throughout the mass of the CB unit, and possibly also the underlying siltstone, as numerous small slippages along bedding surfaces and joints, on lubricated clay linings. In this respect, the mechanism is similar to that suspected for the CB horizon in pits 2 and 7, where soil creep has occurred.

The cause of slipping on this 18° slope is very probably excess water entering the site. Observations which might help explain why this slope has recently failed (whereas nearby steeper ones have not) possibly include but may not be restricted to

- the thicker-than-normal CB horizon containing clay linings,
- disturbance related to the residential dwelling on the site for many years, including cut and fill, and possibly uncontrolled discharge of sewage, stormwater and garden water (aerial photographs show a small orchard upslope from the site),
- the burning down and demolition of the house in February 1967, possibly leaving leaking or running water pipes at a time when soil conditions were dry and cracked in places,
- the burning off of vegetation on the slope during the 1967 bushfires, and
- the installation of the council water main some forty metres upslope. As discussed in Section 2.2.2, there is no direct evidence that the trench promotes vertical, and then downslope, infiltration of seepages and runoff, or that the pipe itself is leaking. As far as has been ascertained so far, the date of its installation in 1973 may not be inconsistent with the onset of slippage.

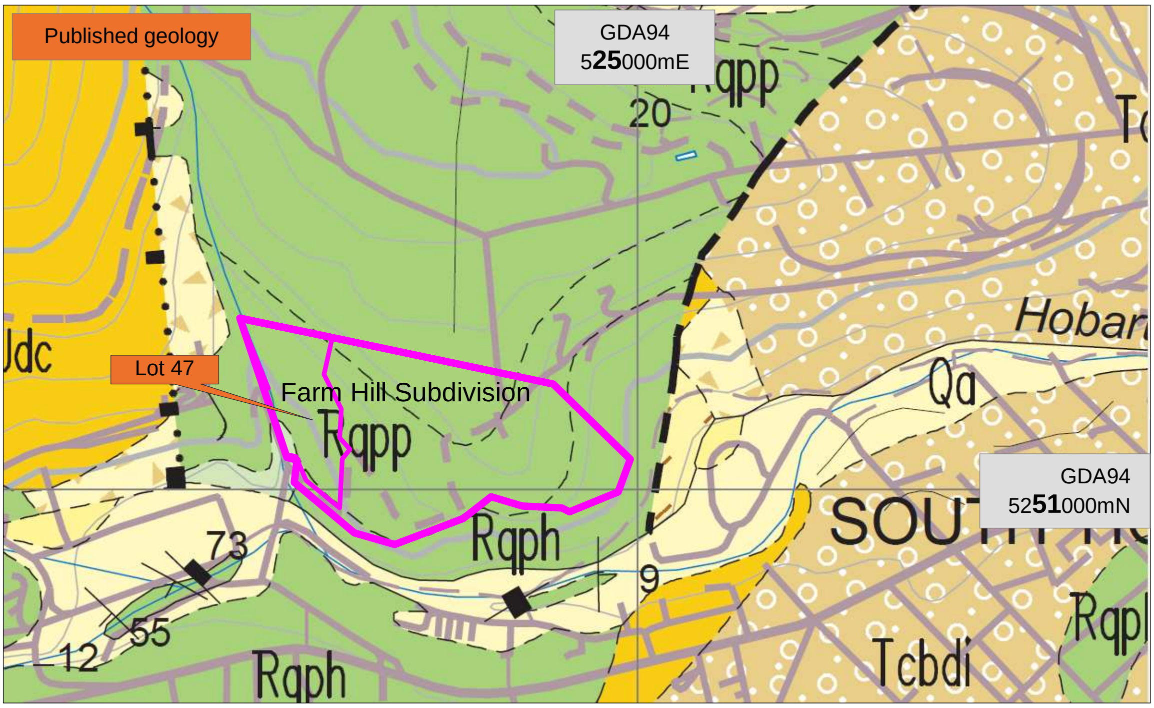
There are two other small areas upstream from this landslip, on the eastern bank of Ross Rivulet, which might also be landslips. If so, they have probably failed due to erosion of their toes by the rivulet. The first is in the corner of CT 2370-44 and is evident in aerial photographs taken in 1967. The second, not obvious in photographs, is some 50 metres further upstream. This site was used by the HEC in 1977 as an access point to work on a nearby transmission line, and may be wholly artificial.

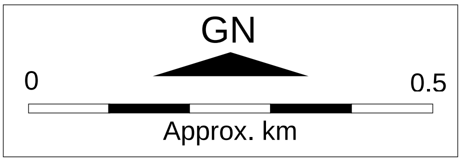
Attachment 5

(2 pages)

Published geology and landslide hazard bands

Source: Mineral Resources Tasmania and www.thelist.tas.gov.au



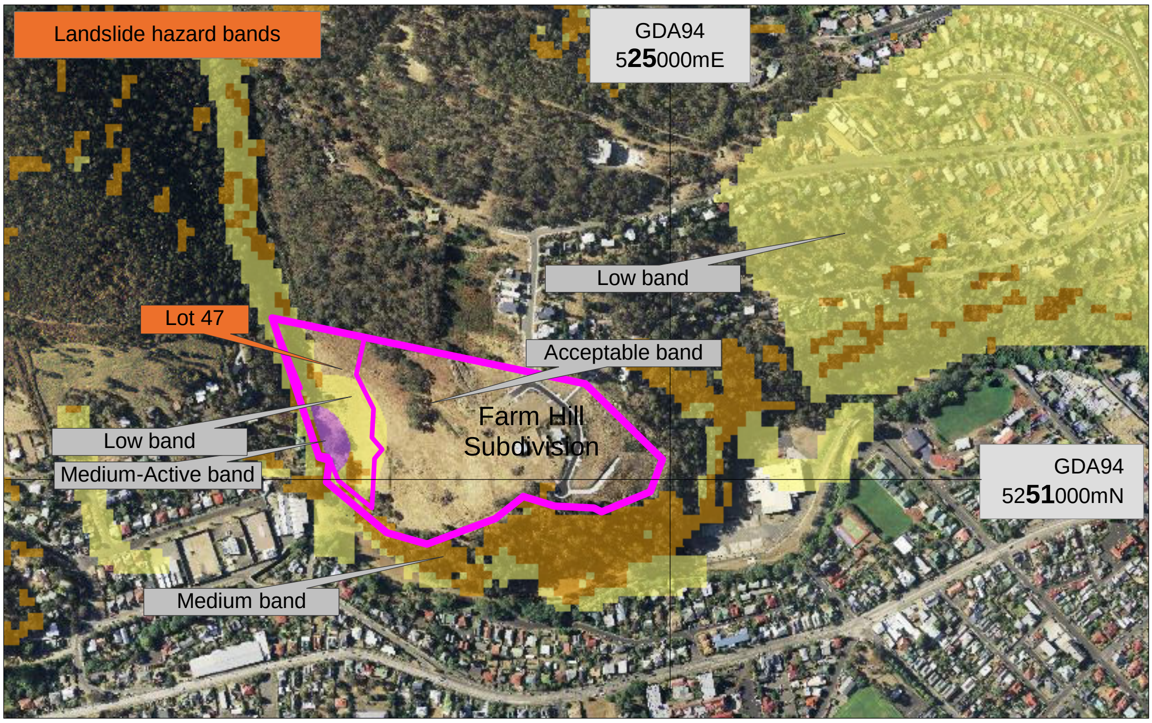


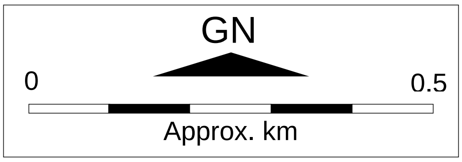
Source for geology

Forsyth, S. M., and Clarke, M. J. (compilers) 1999. Digital Geological Atlas 1:25,000 Scale Series. Sheet 5225 Hobart. Mineral Resources Tasmania

Key to rock types

Qa – Qham	*Alluvial gravel sand and clay (Qa), alluvial fans (Qaf). Alluvial and marsh deposits of modern flood plains, – gravel, sand, silt and clay commonly with organic top layer (Qham), – alluvial gravel deposits (Qhag).*
Qa – Qpao	*Alluvial terrace deposits (Qpao).*
Qa – Qpad	*Alluvial terrace deposits dominantly of cobbles and small boulders of dolerite and subordinate Parmeener clasts (Qpad).*
Tcb	*Poorly–sorted large boulder to pebble grade deposits (Tcb), – clasts dominantly of dolerite with traces to rarely dominant amounts of Parmeener mudstone and other rocks, clayey matrix (Tcbd), inferred dolerite boulder beds overlying older rocks or deposits at unknown depth (Tcbdi); clasts generally smaller and locally derived, dominantly of Parmeener rocks with subordinate dolerite in some areas, clayey or sandy matrix (Tcbs).*
Jd	*Dolerite (Jd), with orthopyroxene (Jdo), granophyre and pegmatite indicated (Jdp), dolerite inferred beneath soil or Cenozoic deposits (Jdi). Dolerite of grainsize 0 – 0.7mm (Jdvf); 0.7 – 1.5mm (Jdf); > 1.5mm (Jdmc); 1.5 – 3mm (Jdm); > 3mm (Jdc); > 6mm (Jdvc) indicated.*
Rqp	*Freshwater predominantly cross–bedded quartzose to feldspathic sandstone commonly with overturned cross–bedding and subordinate micaceous siltstone with some red–purple beds, sparse plant and vertebrate fossils (Rqp), – Knocklofty Formation (Rqph) contact metamorphosed by Jurassic dolerite (Rqphm), intervals predominantly of siltstone, shale, mudstone and sandstone indicated (Rqpc) and (Poets Road Member) (Rqpp), granule sandstone and pebbly sandstone indicated (Rqpg).*





Landslide Planning Map V2 - Hazard Bands

- Acceptable
- Low
- Medium
- Medium - Active
- High

Acceptable band
A landslide is a rare event based on current understanding of the hazard, but it may occur in some exceptional circumstances.

Low band
The area may include landslide features but their activity is unknown, and they have been judged by MRT to rank of lesser risk than those in higher bands.

Medium band
The area has known landslide features, or is within a landslide susceptibility zone, or has legislated controls to limit disturbance of adjacent unstable areas.

Medium-active band
The area has known recently active landslide features.

High band
The site is within a declared Landslip A area.

Attachment 6

(4 pages)

Tasmanian Landslide Hazard Maps in relation to the property

Notes

This Attachment shows the subject land in relation to four landslide hazard maps issued by Mineral Resources Tasmania. A portion of each map covering the property, and part of the Key to the map, are shown.

The maps are:

Map 1: Landslide Inventory and Geomorphology
Map 3: Potential Debris Flow Hazard
Map 4: Potential Rockfall Hazard
Map 5: Potential Deep Seated Landslide Hazard

Map 2, not shown here, is the geological map of the area, which is reproduced instead in Attachment 4.

The following extract from the explanatory notes to Map 5 explains the purpose and limitations of the maps.

Deep Seated Landslide Hazard

Background, Aim and Purpose

Large tracts of land throughout Tasmania are subject to slope instability and about 60 houses have been destroyed by landslides since the 1950s. Fortunately only minimal loss of life has occurred in this time but such events are highly traumatic to those directly affected and the financial cost to individuals, organisations and the State runs into many millions of dollars. Recent disasters such as the Thredbo Landslide in New South Wales, serve to remind society of the potential for loss of life even from relatively small landslides. Fortunately, landslide damage can be avoided when ground conditions are properly understood before construction proceeds and, in already developed areas, this understanding can be used to mitigate the hazard through various measures.

Regional landslide hazard maps are produced to provide an insight into the natural hazards that may potentially affect the area concerned. Mineral Resources Tasmania, in partnership with the Hobart City Council has produced the first of a new landslide hazard map series in Tasmania, using Hobart as a pilot study area. The information provided is in the public domain and anyone is free to use it provided they read and understand the caveats for use.

Hazard and Risk

According to the joint Australian/New Zealand Standard (AS/NZS 4360:1999) risk is defined as the chance of something happening that will impact upon objectives. It is measured in terms of consequences and likelihood.

The definition of risk is often expressed by the following equation:

RISK = Hazard x Vulnerability x Elements at Risk

A hazard is defined as a source of potential harm or a situation with a potential to cause loss. A hazard, such as a landslide can be measured in terms of location, volume (or area), type, velocity and likelihood with time. Vulnerability refers to the susceptibility and resilience of structures, community and the environment to the hazard. The 'elements at risk' refers to the number of those structures, people, etc exposed to the hazard.

A hazard map attempts to portray the processes operating in an area, conveying all or some of the hazard parameters, generally in a qualitative to semi-quantitative manner. Because of the uncertainties involved, the translation of regional hazard maps into risk maps is challenging and seldom precise. An indication of the likely risk level is provided for each hazard at a regional scale but this will vary in detail. However, provided the limitations of the maps are understood, hazard maps can be used for many purposes in order to achieve the overall goal of safe and resilient communities.

Caveats for Use

The following caveats shall apply to the maps.

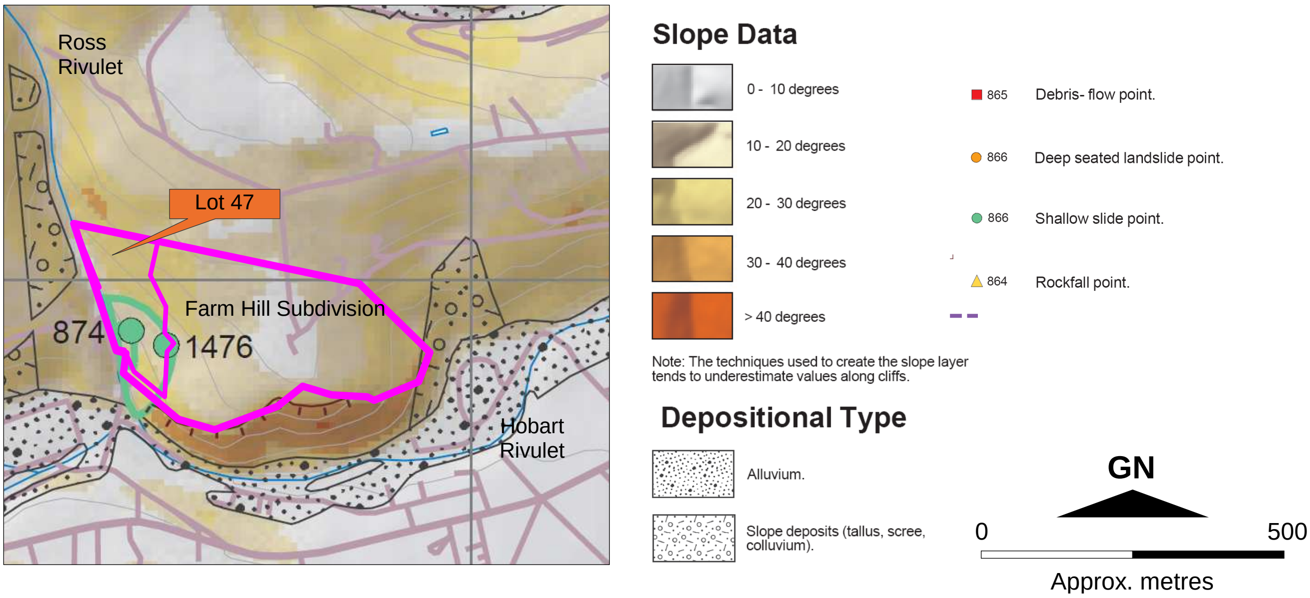
- The hazards identified are based on imperfect knowledge of ground conditions and models to represent our current understanding of the landslide process. As this knowledge improves our perception of the hazard and the depiction of the zones on the map may also change.
- These maps can be used as a guide (or flag) to the need for specific assessment in potential hazard areas.
- Planning decisions should not be made solely on the basis of the hazard zones delineated on the map.
- The scale limitations of the data should be considered at all times as exceeding this limit could lead to inaccurate decisions about the hazard.
- Specific assessment of landslide hazard and risk should be undertaken by suitably qualified and experienced practitioners in the fields of engineering geology and geotechnical engineering.
- Practitioners undertaking specific assessments should read the text and appendices attached to the maps and obtain a thorough understanding of the methodology and limitations of the maps.
- Areas where no hazard is shown can still have issues with slope instability.
- Anthropogenic influence on slopes cannot be predicted and the occurrence of slope instability resulting from the influence of human actions is specifically excluded from these maps.
- The identification and performance of cut and filled slopes have not been specifically considered in map production and their scale is such that they often cannot be resolved on the maps. The presence of such slopes should always be considered in specific assessments.

Map 1. Landslide Inventory and Geomorphology.

Mazengarb, C. (2004). Map 1, Hobart – Landslide Inventory and Geomorphology. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania

Two known shallow landslides (Nos. 874 and 1476) occupy the southern and southwestern half of Lot 47 on the Farm Hill Subdivision. Slope angles on Lot 47 are in the 20 – 30^{0} range.

Landslide Inventory and Geomorphology (grid is AMG66)

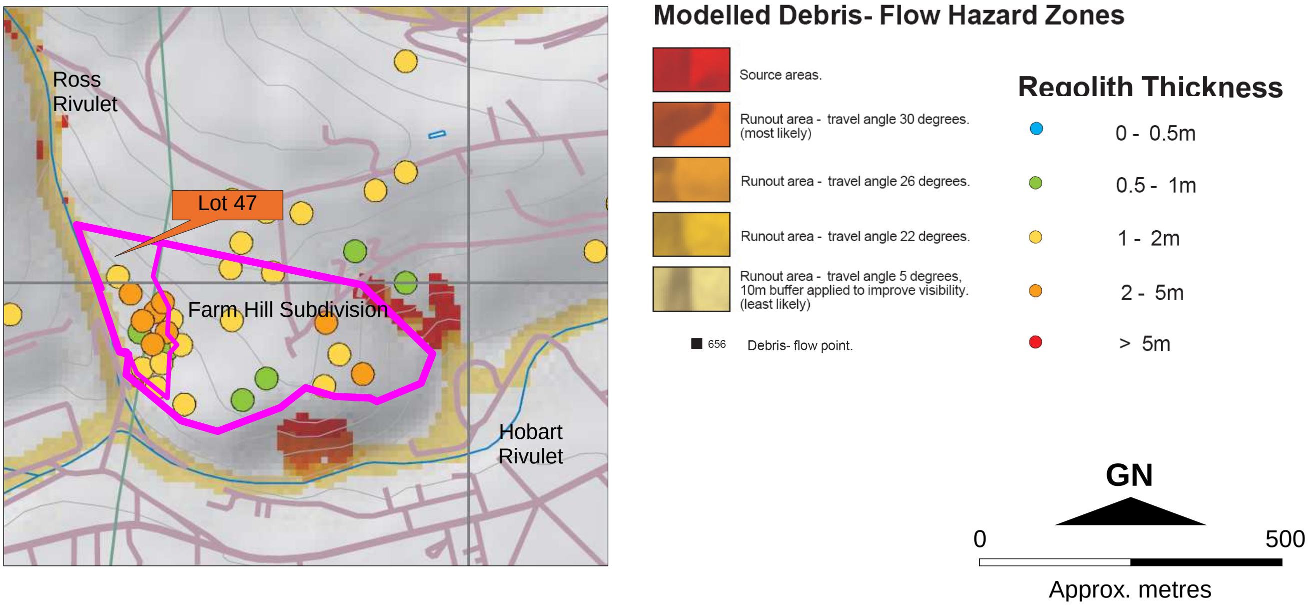


Map 3. Potential Debris Flow Hazard

Mazengarb, C. (2004). Map 3, Hobart – Potential Debris Flow Hazard. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania

Most watercourses in the area have the potential to generate debris flows at their sources, with associated runouts. Test pit data from Cromer (1995) have been used to indicate regolith thicknesses (up to 5m) on the Farm Hill Subdivision.

Potential Debris Flow Hazard (grid is AMG66)

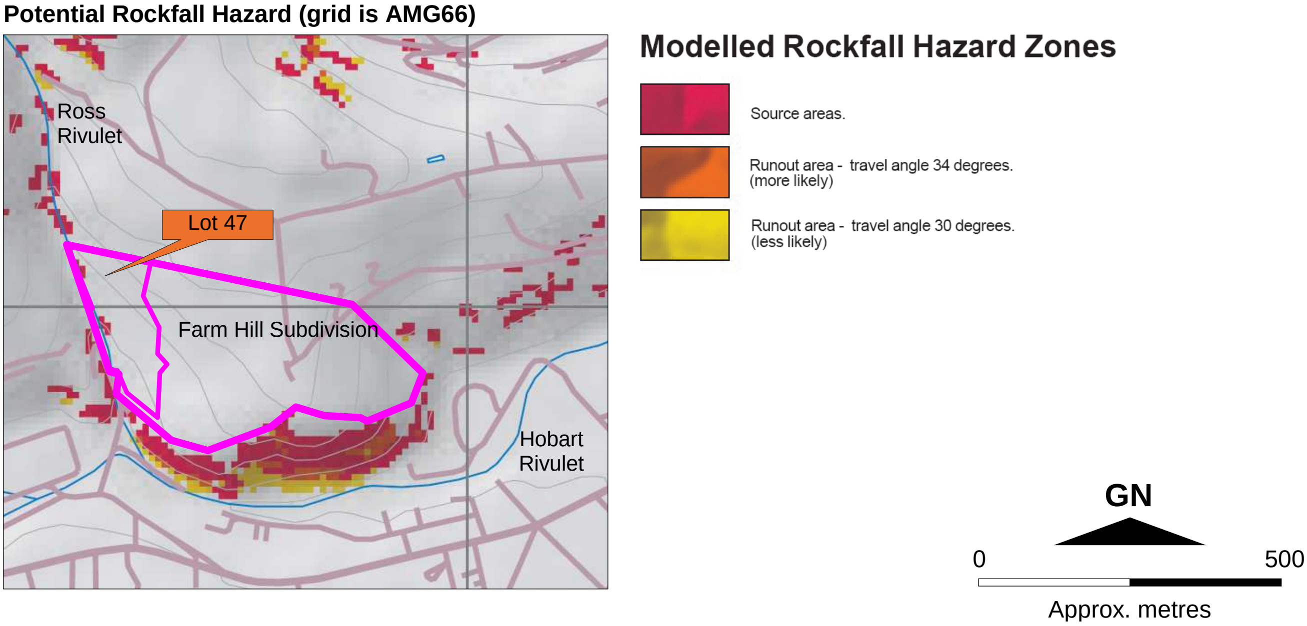


Map 4. Potential Rockfall Hazard

Mazengarb, C. (2004). Map 4, Hobart – Potential Rockfall Hazard. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania

The course of Ross Rivulet, and the sandstone cliff sections bordering Hobart Rivulet, have the potential to generate rockfalls.

Potential Rockfall Hazard (grid is AMG66)

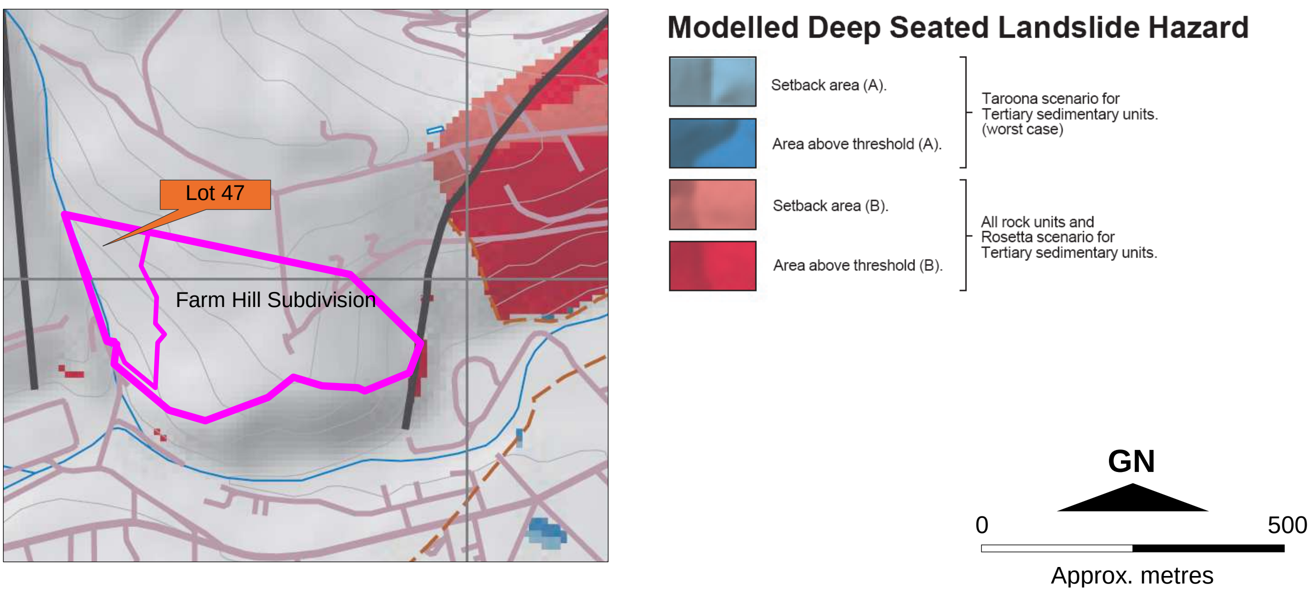


Map 5. Potential Deep Seated Landslide Hazard

Mazengarb, C. (2004). Map 5, Hobart – Potential Deep Seated Landslide Hazard. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania

The subject land is adjacent to, but not shown to be at direct risk of, potential deep seated landsliding.

Potential Deep Seated Landslide Hazard (grid is AMG66)

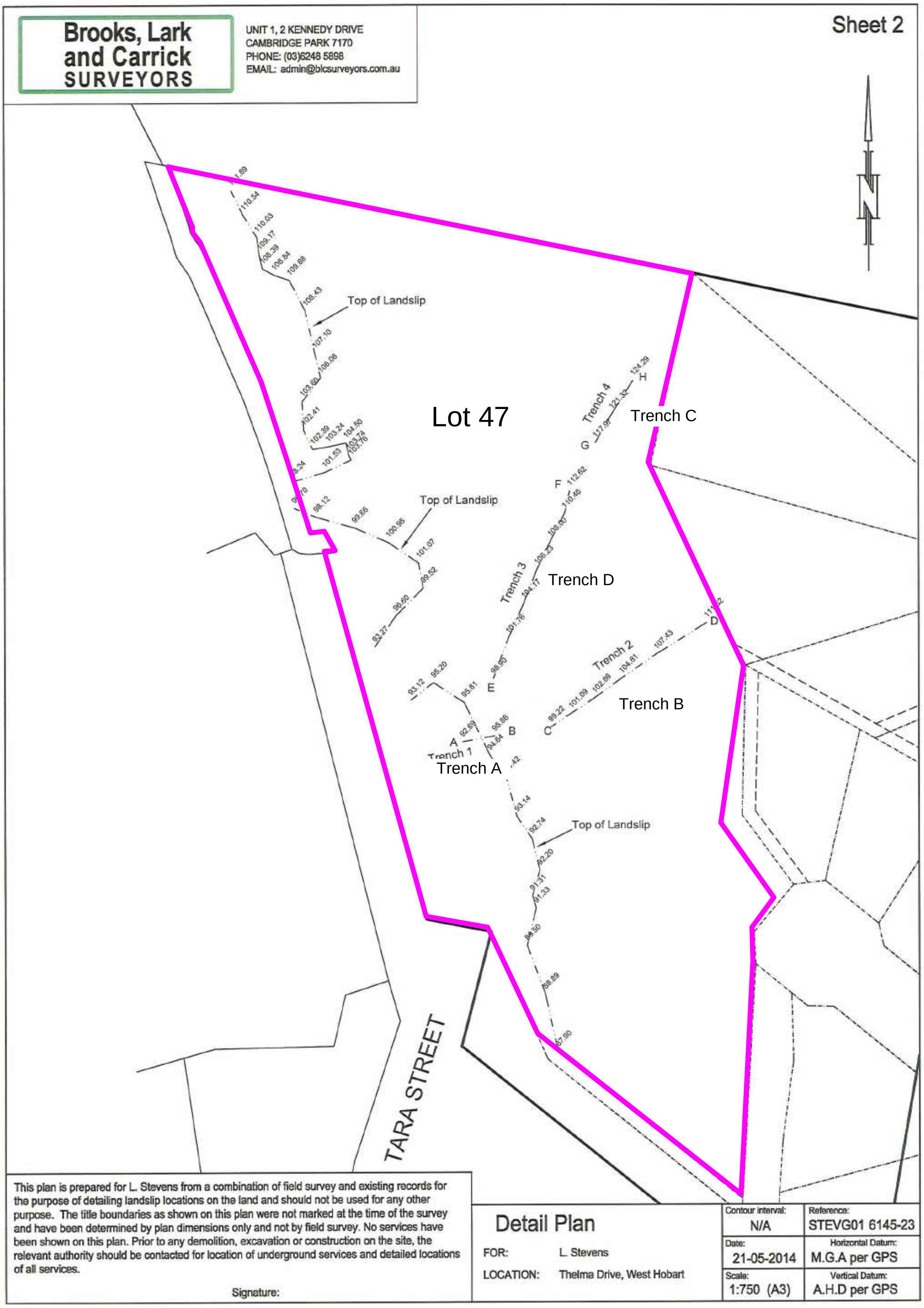


Attachment 7

(1 page)

May 2014 surveyed landslide headscarps and investigation trenches on Lot 47

Source: Brooks, Lark and Carrick Surveyors. Landslide survey points selected by William C Cromer.

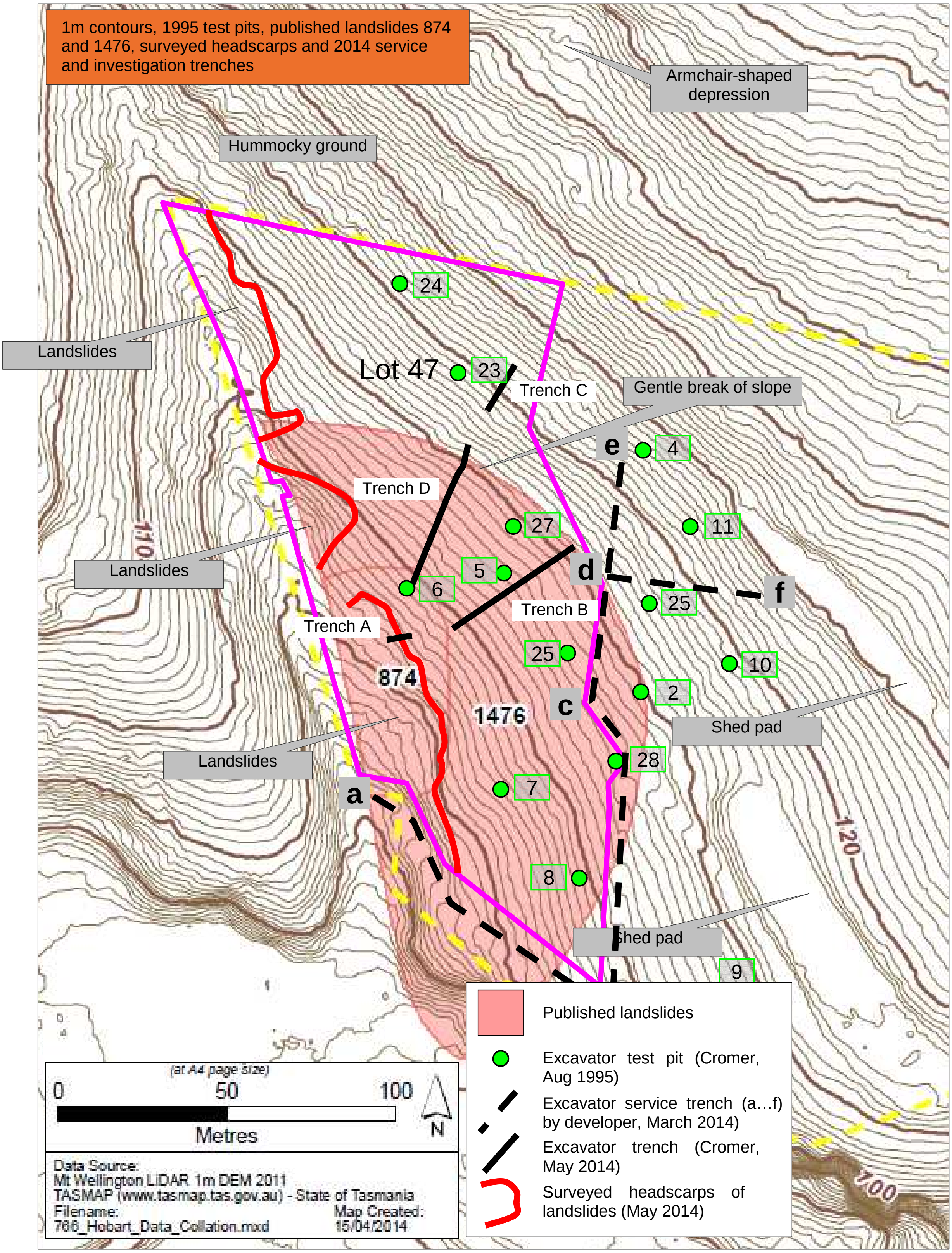


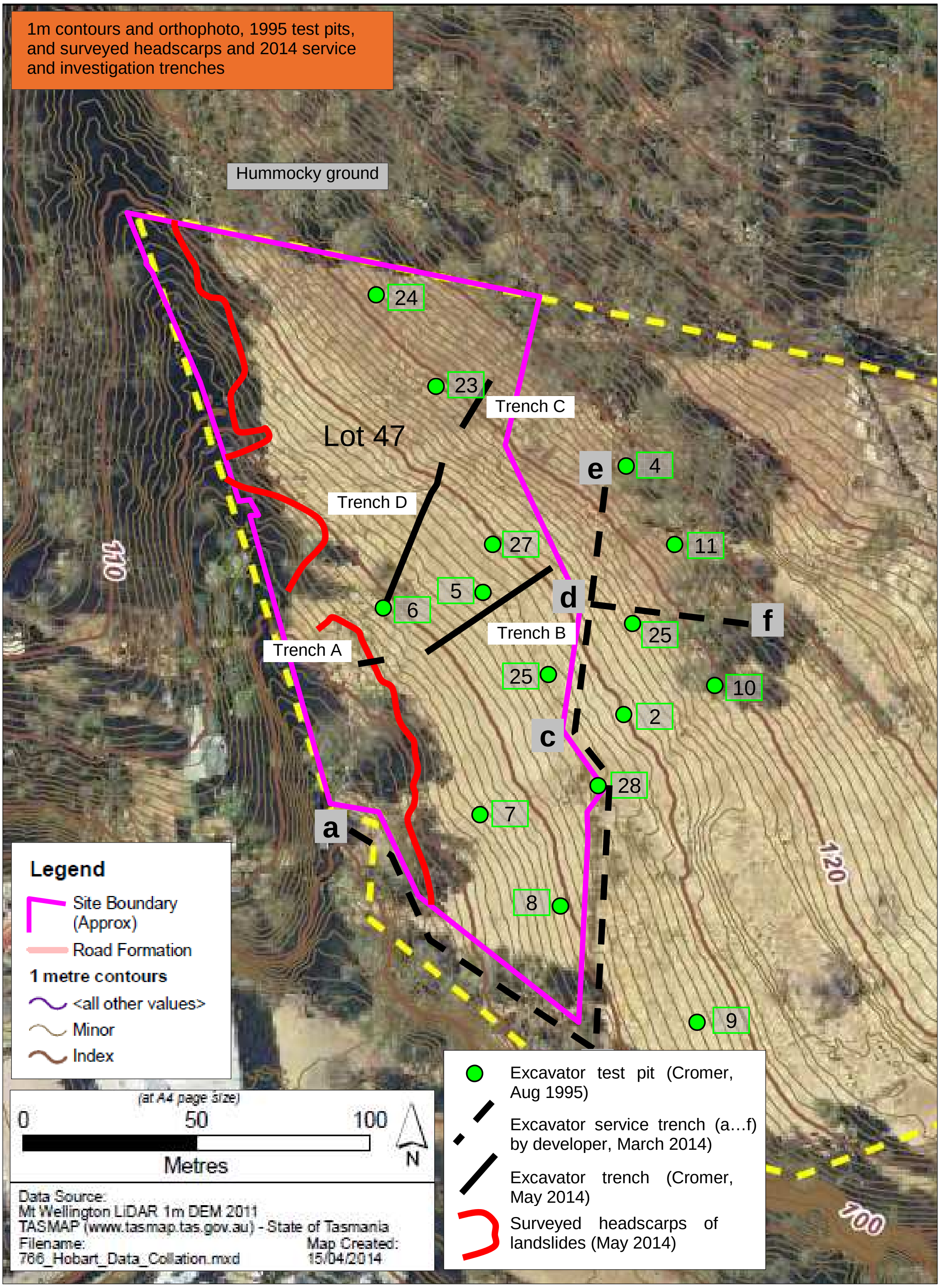
Attachment 8

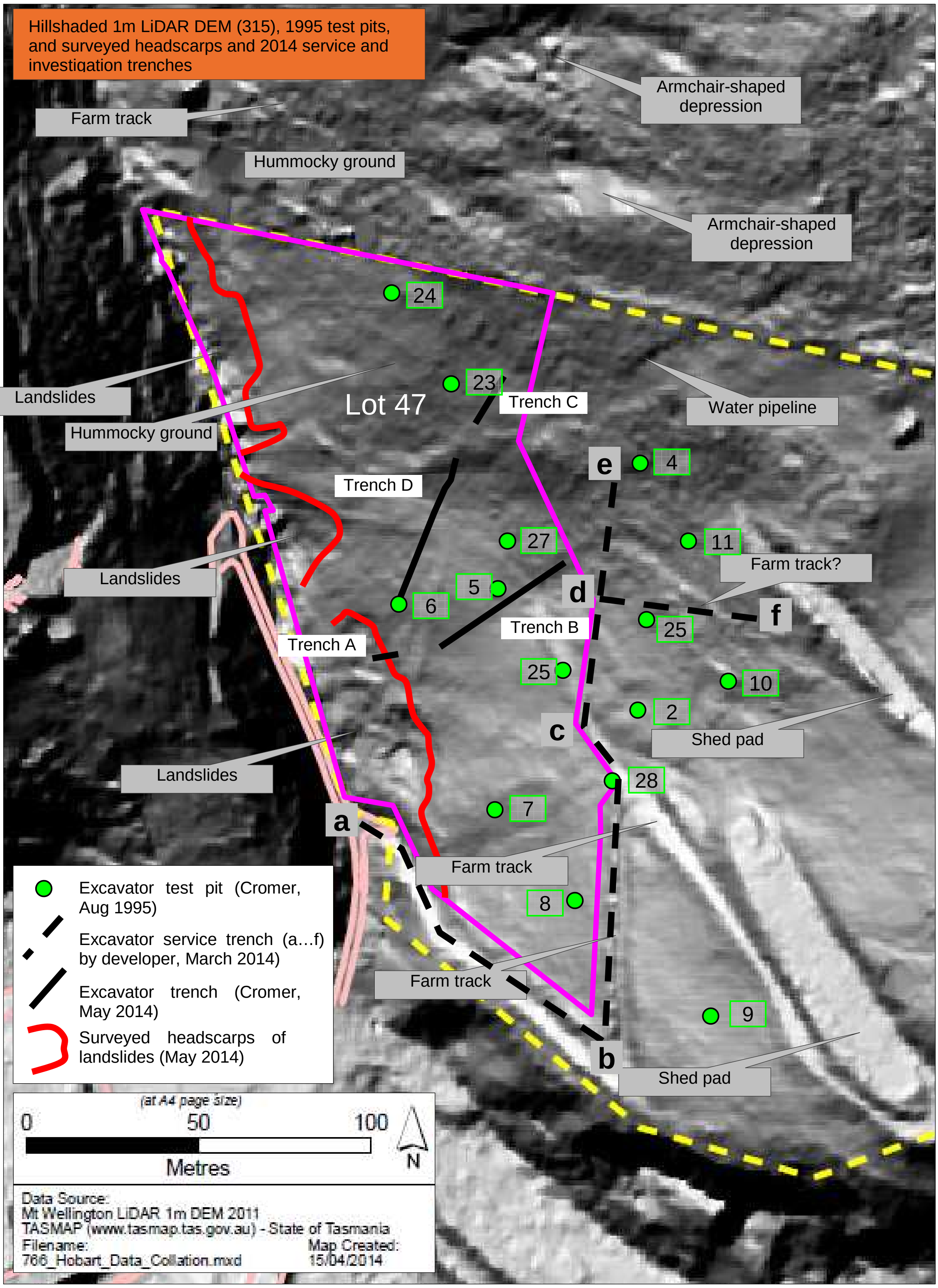
(5 pages)

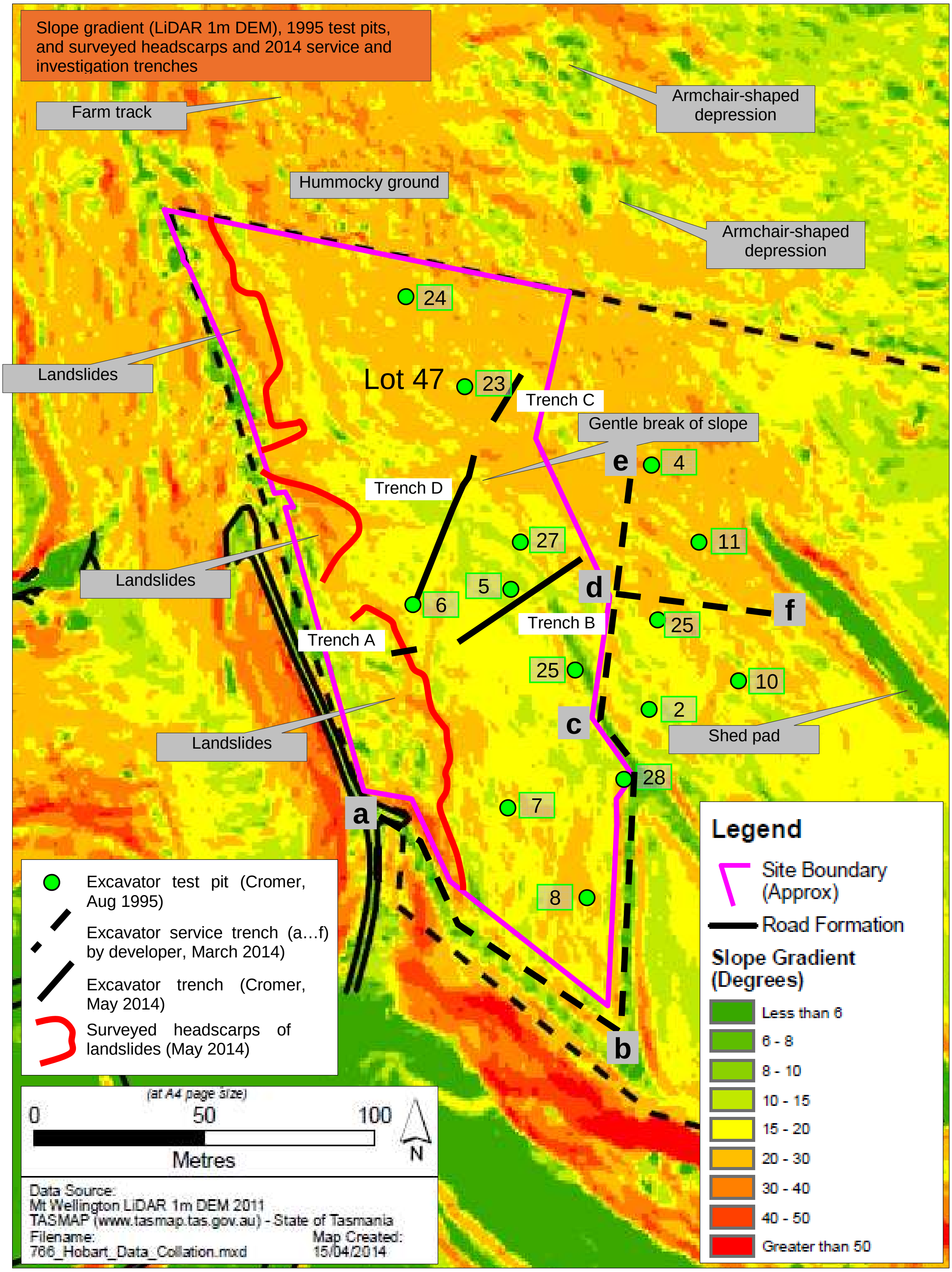
Topographic, aerial and LiDAR images of Lot 47 at Farm Hill, showing May 2014 surveyed headscarps of landslides and 2014 service and investigation trenches

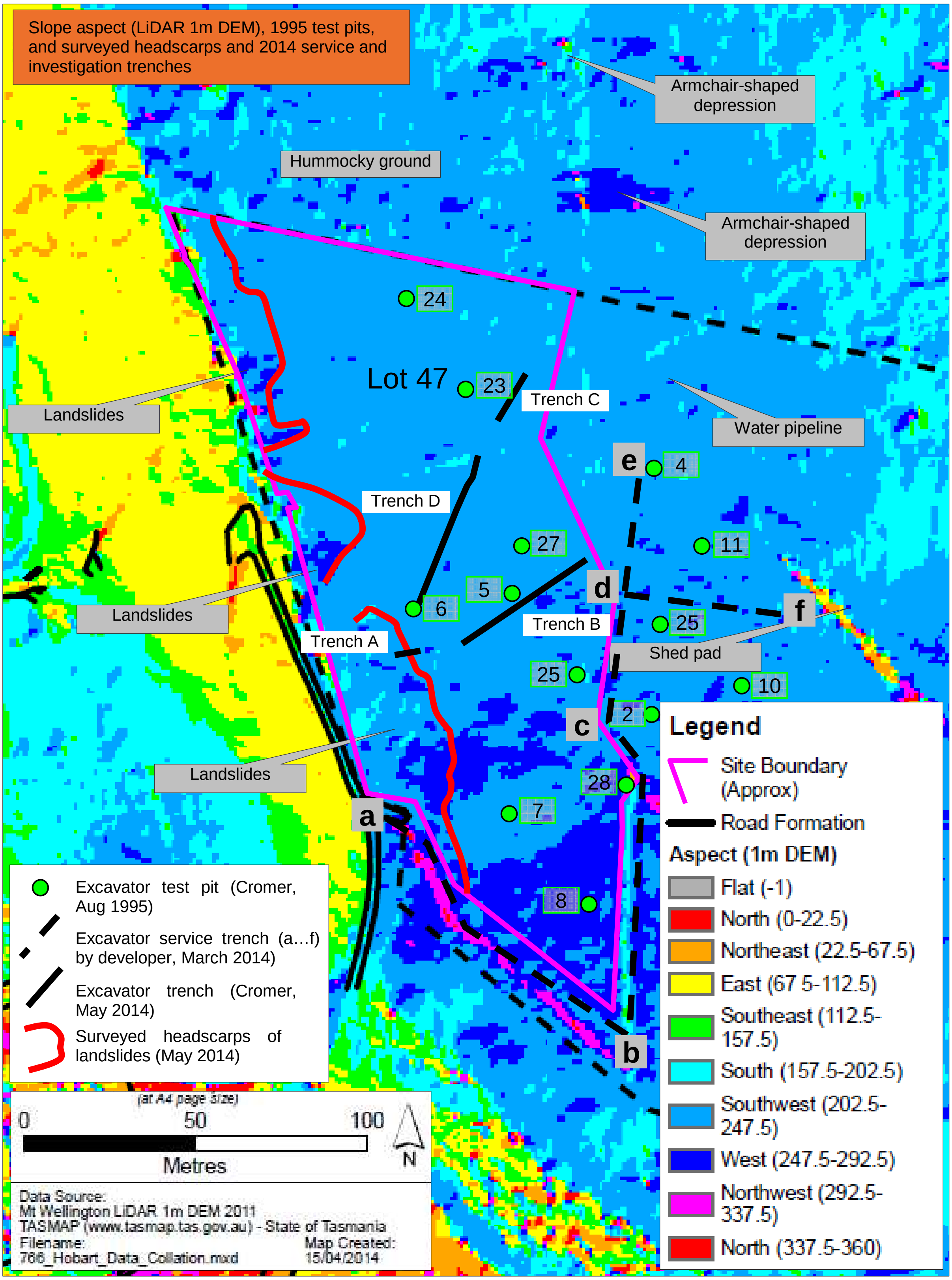
Source: adapted from a. s. miner geotechnical




1m contours and orthophoto, 1995 test pits, and surveyed headscarps and 2014 service and investigation trenches
Hummocky ground
Lot 47
Trench A
Trench B
Trench C
Trench D
a
c
d
e
f
24
23
4
27
11
5
6
25
25
10
2
28
7
8
9
110
120
100
Legend
Site Boundary (Approx)
Road Formation
1 metre contours
<all other values>
Minor
Index
(at A4 page size)
0
50
100
Metres
N
Data Source:
Mt Wellington LiDAR 1m DEM 2011
TASMAP (www.tasmap.tas.gov.au) - State of Tasmania
Filename:
766_Hobart_Data_Collation.mxd
Map Created:
15/04/2014
Excavator test pit (Cromer, Aug 1995)
Excavator service trench (a…f) by developer, March 2014)
Excavator trench (Cromer, May 2014)
Surveyed headscarps of landslides (May 2014)


Hillshaded 1m LiDAR DEM (315), 1995 test pits, and surveyed headscarps and 2014 service and investigation trenches
Farm track
Hummocky ground
Armchair-shaped depression
Armchair-shaped depression
24
Landslides
Hummocky ground
Lot 47
23
Trench C
Water pipeline
e
4
Trench D
27
11
Farm track?
Landslides
5
6
d
f
Trench A
Trench B
25
25
10
2
c
Shed pad
Landslides
28
a
7
Farm track
8
Farm track
9
b
Shed pad
Excavator test pit (Cromer, Aug 1995)
Excavator service trench (a…f) by developer, March 2014)
Excavator trench (Cromer, May 2014)
Surveyed headscarps of landslides (May 2014)
(at A4 page size)
0
50
100
N
Metres
Data Source:
Mt Wellington LiDAR 1m DEM 2011
TASMAP (www.tasmap.tas.gov.au) - State of Tasmania
Filename:
766_Hobart_Data_Collation.mxd
Map Created:
15/04/2014


Slope gradient (LiDAR 1m DEM), 1995 test pits, and surveyed headscarps and 2014 service and investigation trenches
Farm track
Armchair-shaped depression
Hummocky ground
Armchair-shaped depression
24
Landslides
Lot 47
23
Trench C
Gentle break of slope
e
4
Trench D
27
11
Landslides
5
d
6
f
Trench B
25
Trench A
25
10
2
c
Landslides
Shed pad
28
a
7
8
b
Legend
Site Boundary (Approx)
Road Formation
Slope Gradient (Degrees)
Less than 6
6 - 8
8 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 50
Greater than 50
Excavator test pit (Cromer, Aug 1995)
Excavator service trench (a…f) by developer, March 2014)
Excavator trench (Cromer, May 2014)
Surveyed headscarps of landslides (May 2014)
(at A4 page size)
0
50
100
Metres
N
Data Source:
Mt Wellington LiDAR 1m DEM 2011
TASMAP (www.tasmap.tas.gov.au) - State of Tasmania
Filename:
766_Hobart_Data_Collation.mxd
Map Created:
15/04/2014


Slope aspect (LiDAR 1m DEM), 1995 test pits, and surveyed headscarps and 2014 service and investigation trenches
Armchair-shaped depression
Hummocky ground
Armchair-shaped depression
24
Lot 47
23
Trench C
Landslides
Water pipeline
e
4
Trench D
27
11
5
d
6
Trench B
25
f
Landslides
Trench A
Shed pad
25
10
c
2
Landslides
28
a
7
8
b
Legend
Site Boundary (Approx)
Road Formation
Aspect (1m DEM)
Flat (-1)
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast (112.5-157.5)
South (157.5-202.5)
Southwest (202.5-247.5)
West (247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)
Excavator test pit (Cromer, Aug 1995)
Excavator service trench (a…f) by developer, March 2014)
Excavator trench (Cromer, May 2014)
Surveyed headscarps of landslides (May 2014)
(at A4 page size)
0
50
100
Metres
N
Data Source:
Mt Wellington LiDAR 1m DEM 2011
TASMAP (www.tasmap.tas.gov.au) - State of Tasmania
Filename:
766_Hobart_Data_Collation.mxd
Map Created:
15/04/2014

Attachment 9

(22 pages)

Site and trench photographs

The staff is graduated in 1m long white and yellow segments. The numbers are decimetres.

Plate 1 (above). View north from Wellerslie Park in South Hobart to Lot 47 on the Farm Hill Subdivision in April 2014, showing service trenches (right) and investigation trenches B and D ("V"-shaped).

Plate 2 (below). View southeast from the northwestern corner of Lot 47 at Farm Hill, over 25 – 30^0 slopes in the foreground, towards service trenches a….f (see Attachment 7).

Plate 3 (above). View south southeast from the northwestern corner of Lot 47 at Farm Hill, over 25 – 30^0 slopes in the foreground, towards service trenches a….f (see Attachment 7). The higher edge of the tree line in the centre of the photo marks the headscarp of landslide #874 (see Map 1 of Attachment 5).

Plate 4 (below). View northwest and downslope to the lower, southwestern corner of Lot 47. The higher edge of the tree line in the right middle ground marks the headscarp of landslide #874 (see Map 1 of Attachment 5).

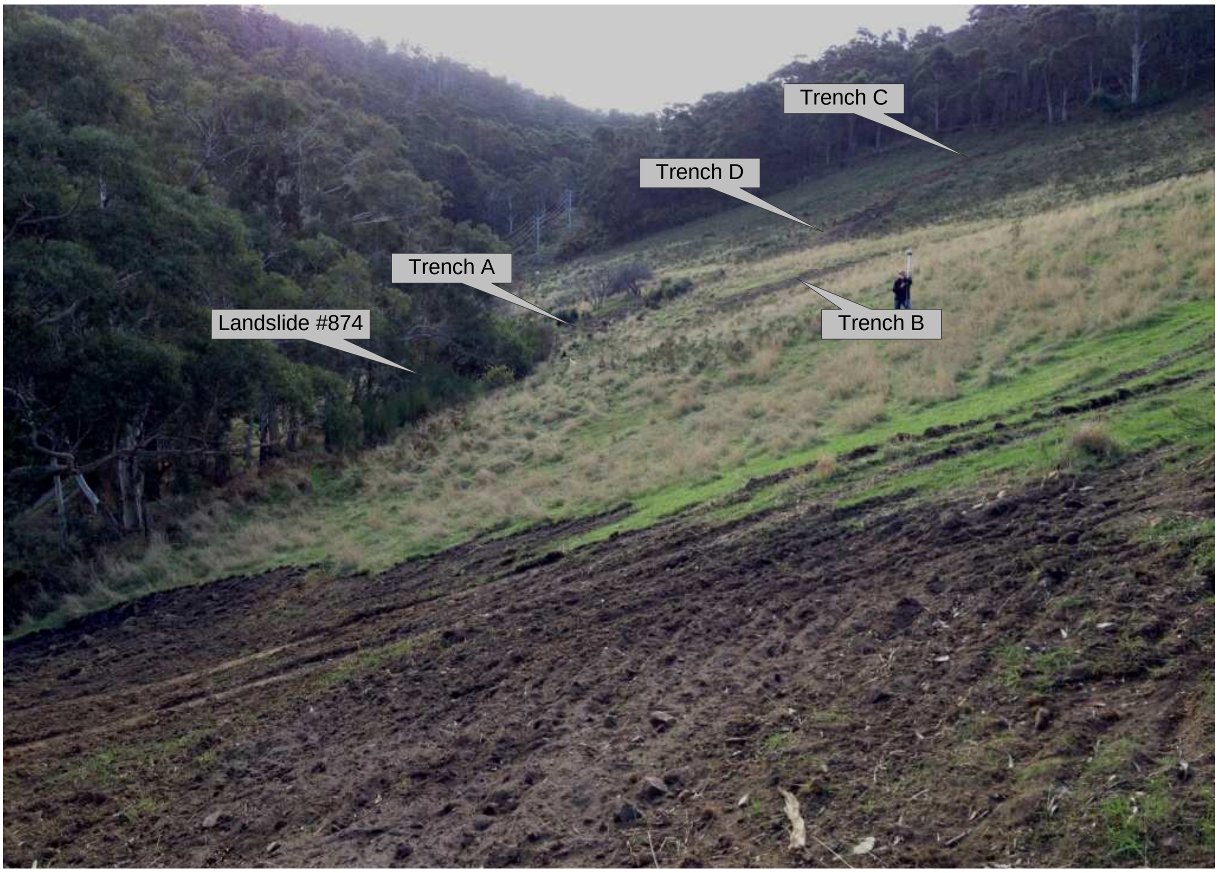


Plate 5 (above). View north over Lot 47 from its lower, southern boundary. The higher edge of the tree line in the left middle ground marks the headscarp of landslide #874 (see Map 1 of Attachment 5). Investigation trenches A,B, C and D are indicated.

Plate 6 (below). View northeast and upslope over Lot 47 from its lower, southern boundary. Investigation trenches B, C and D are indicated. Service trench a….f is partly shown.

Plate 7 (above). View north over Lot 47 from its lower, southern boundary.

Plate 8 (below). View northwest and downslope in March 2014 towards the service trench a….f. Lot 47 is the grassy slope in the background. The higher edge of the tree line in the left middle ground marks the headscarp of landslide #874 (see Map 1 of Attachment 5).

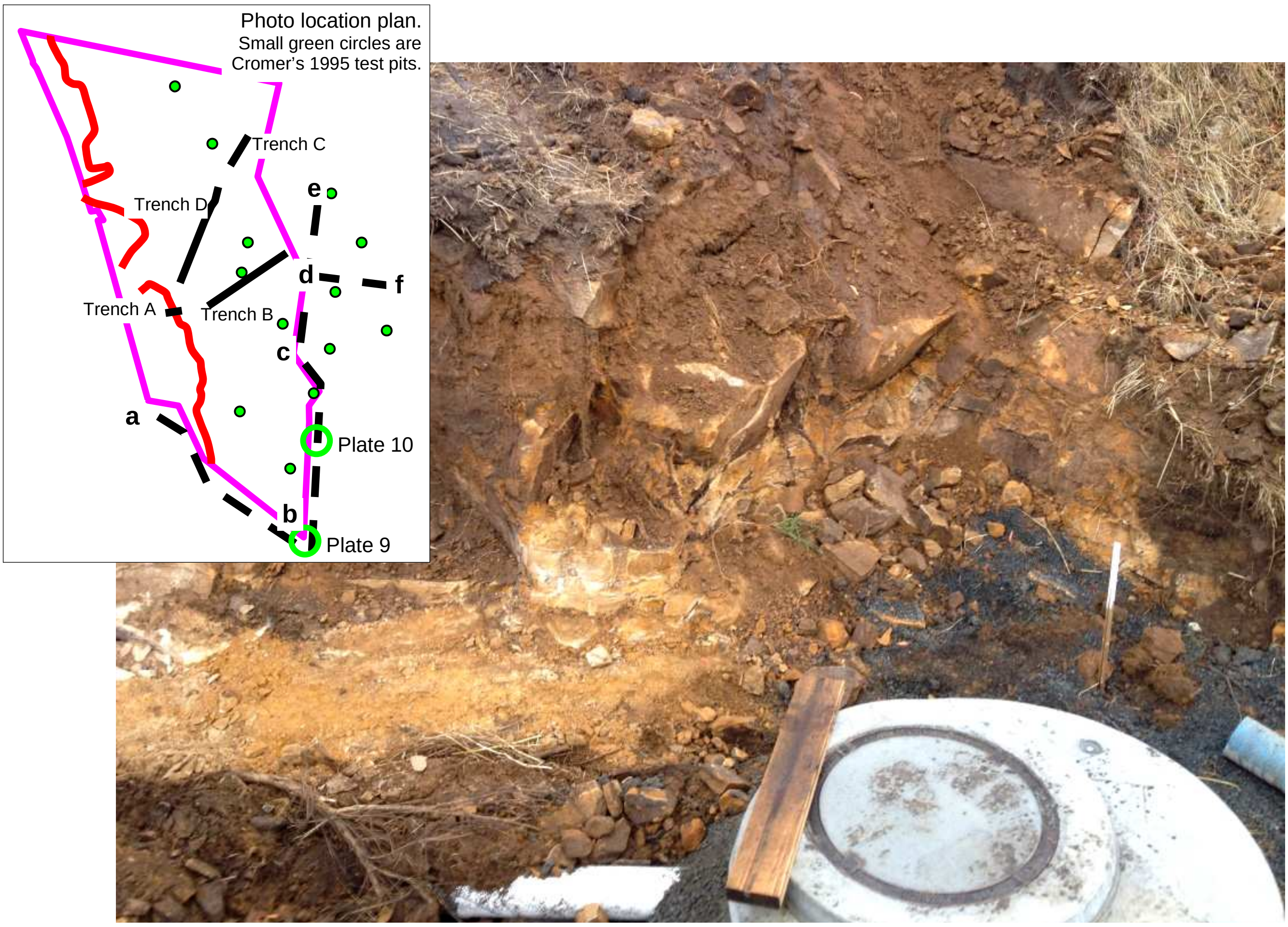


Plate 9 (above). Service trench abcdef at b, 28 March 2014. Subhorizontal Triassic sandstone bedrock exposed at depths less than 0.5m.

Plate 10 (below). Service trench abcdef between b and c. Subhorizontal Triassic sandstone bedrock exposed at depths less than 1m.

Plate 11 (above). Service trench abcdef at c. Subhorizontal Triassic sandstone bedrock exposed at depths less than 1m, but bedrock is interspersed with zones of colluvium comprising dry, friable to dense non-plastic to low plasticity sandy gravel-gravelly sand and clayey varieties.

Plate 12 (below). Service trench abcdef at c, but opposite side of trench to that in Plate 11.

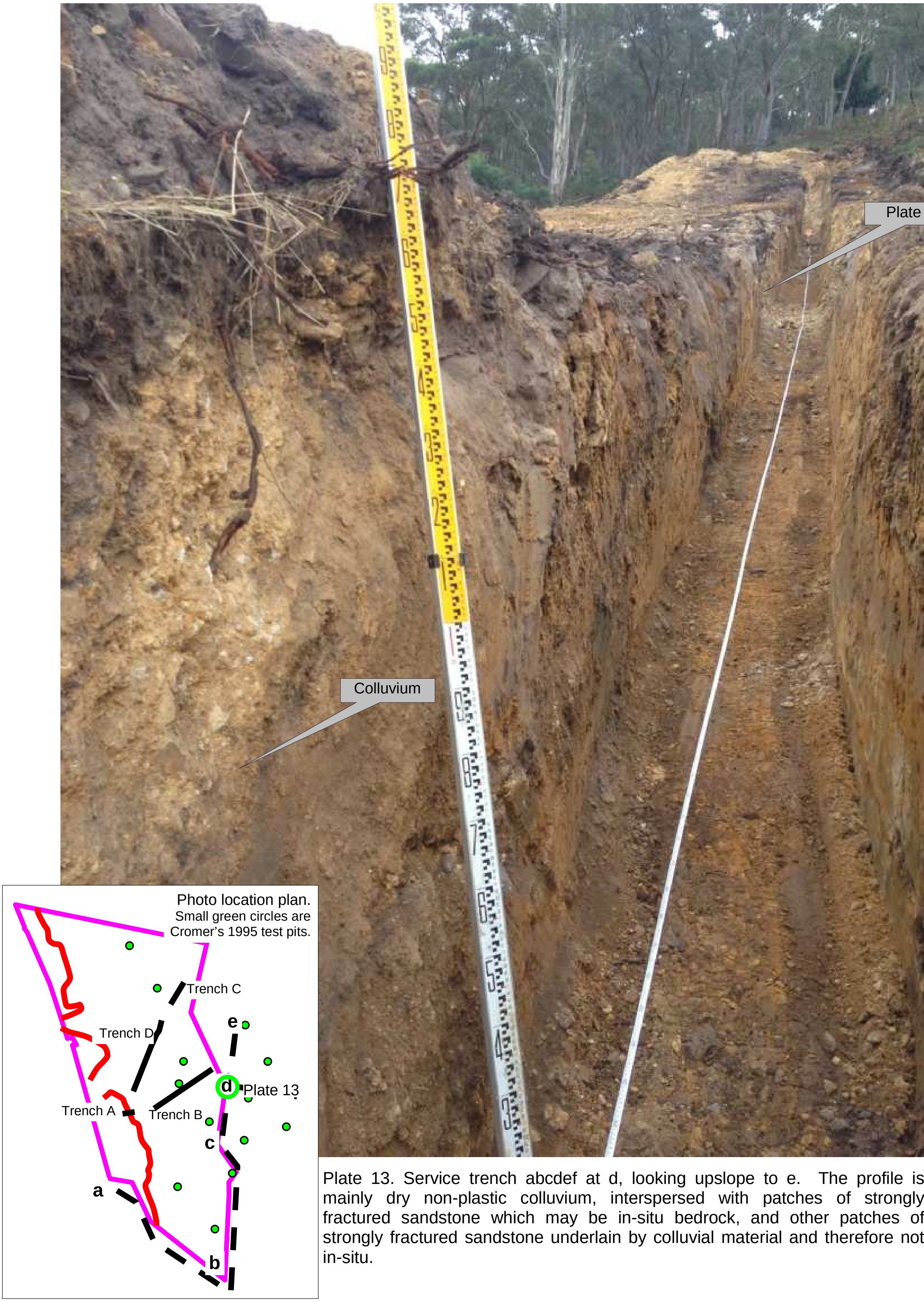


Plate 13. Service trench abcdef at d, looking upslope to e. The profile is mainly dry non-plastic colluvium, interspersed with patches of strongly fractured sandstone which may be in-situ bedrock, and other patches of strongly fractured sandstone underlain by colluvial material and therefore not in-situ.

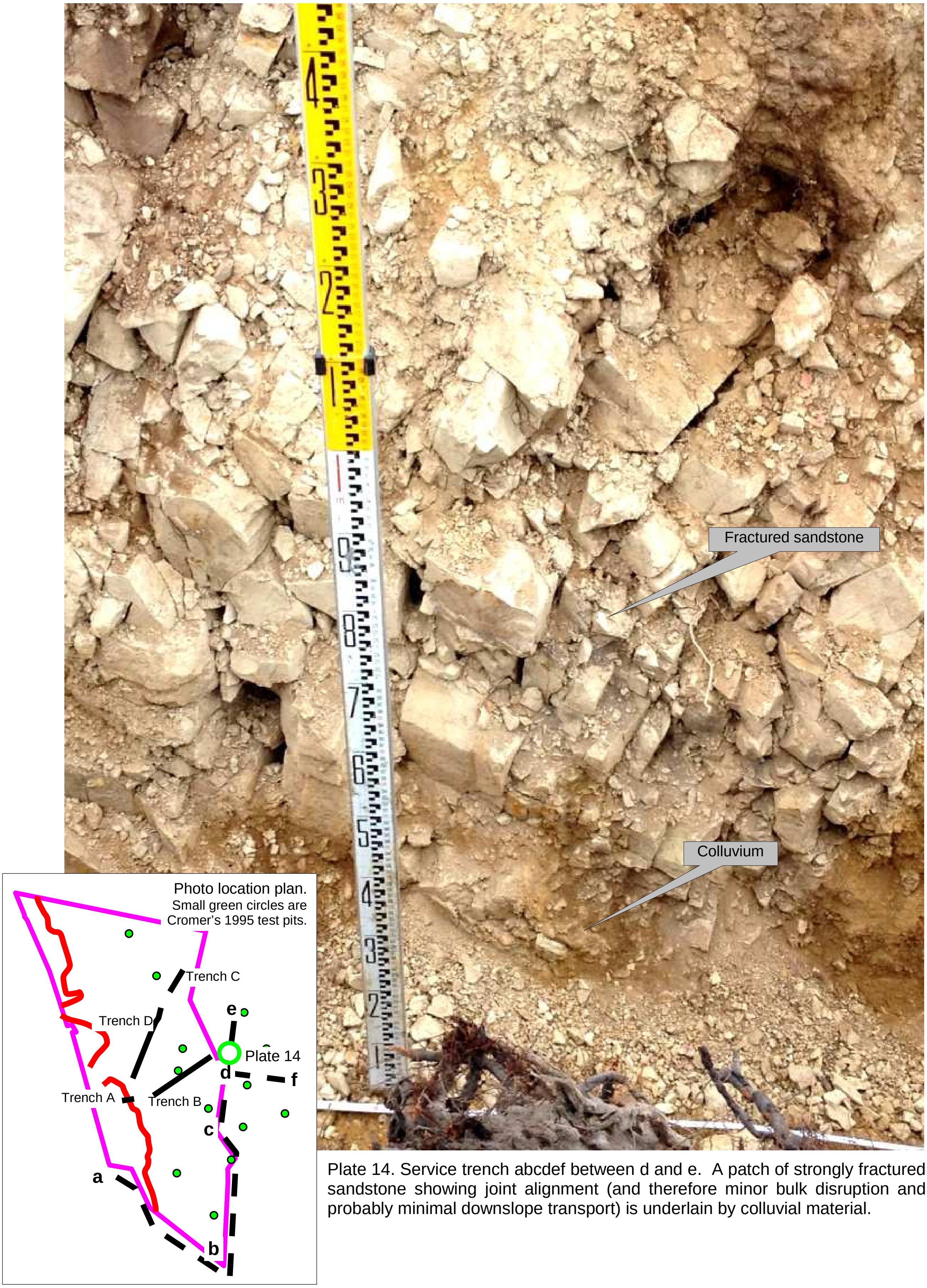


Plate 14. Service trench abcdef between d and e. A patch of strongly fractured sandstone showing joint alignment (and therefore minor bulk disruption and probably minimal downslope transport) is underlain by colluvial material.

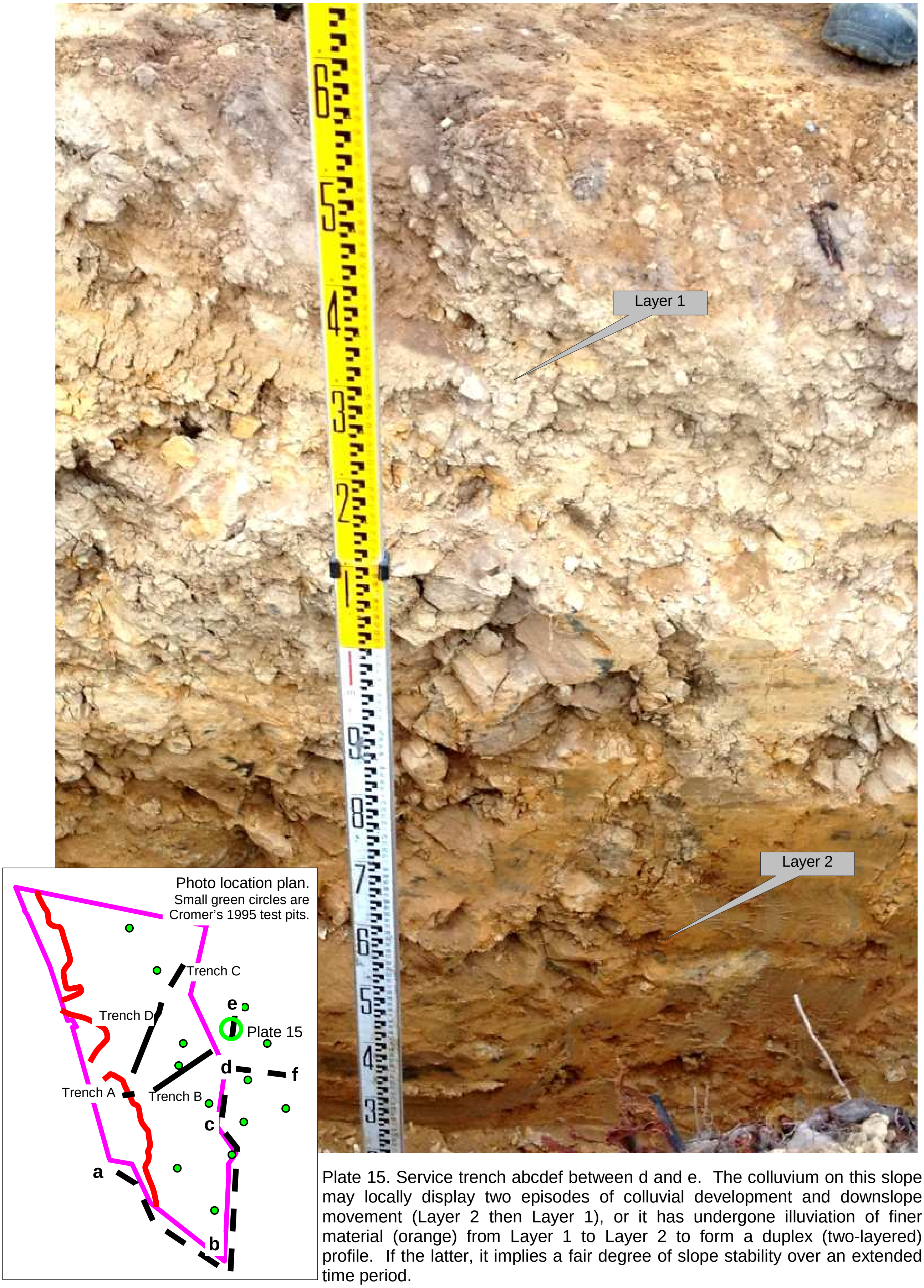


Plate 15. Service trench abcdef between d and e. The colluvium on this slope may locally display two episodes of colluvial development and downslope movement (Layer 2 then Layer 1), or it has undergone illuviation of finer material (orange) from Layer 1 to Layer 2 to form a duplex (two-layered) profile. If the latter, it implies a fair degree of slope stability over an extended time period.

Plate 16. Service trench abcdef at e, looking downslope to d. It is not clear whether the fractured sandstone exposed in the services trench at this location (and locally elsewhere along it) is in-situ or not.

Plate 17. Service trench abcdef between d and f, looking upslope towards f. The fractured sandstone exposed in the services trench at this location appears to be in-situ. A narrow fault zone about 0.5m wide crosses the trench at an oblique angle (arrowed).

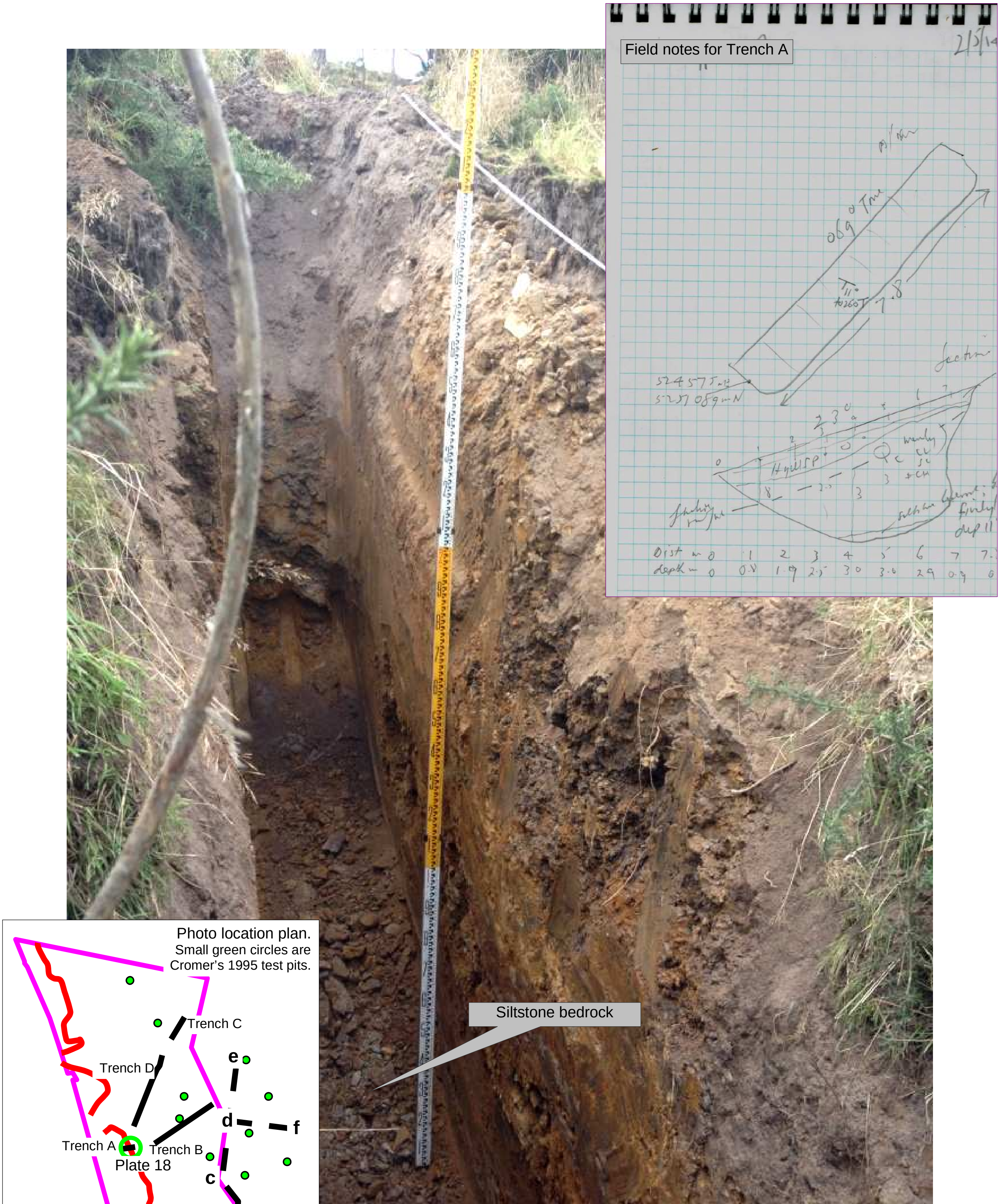


Plate 18. Investigation trench A, about 8m long, was dug across the headscarp of landslide #874. The failure surface was probably close to the camera, but not apparent. Colluvium overlies highly weathered siltstone bedrock, exposed in the base of the trench, and dipping 11^0 to 260^0T.

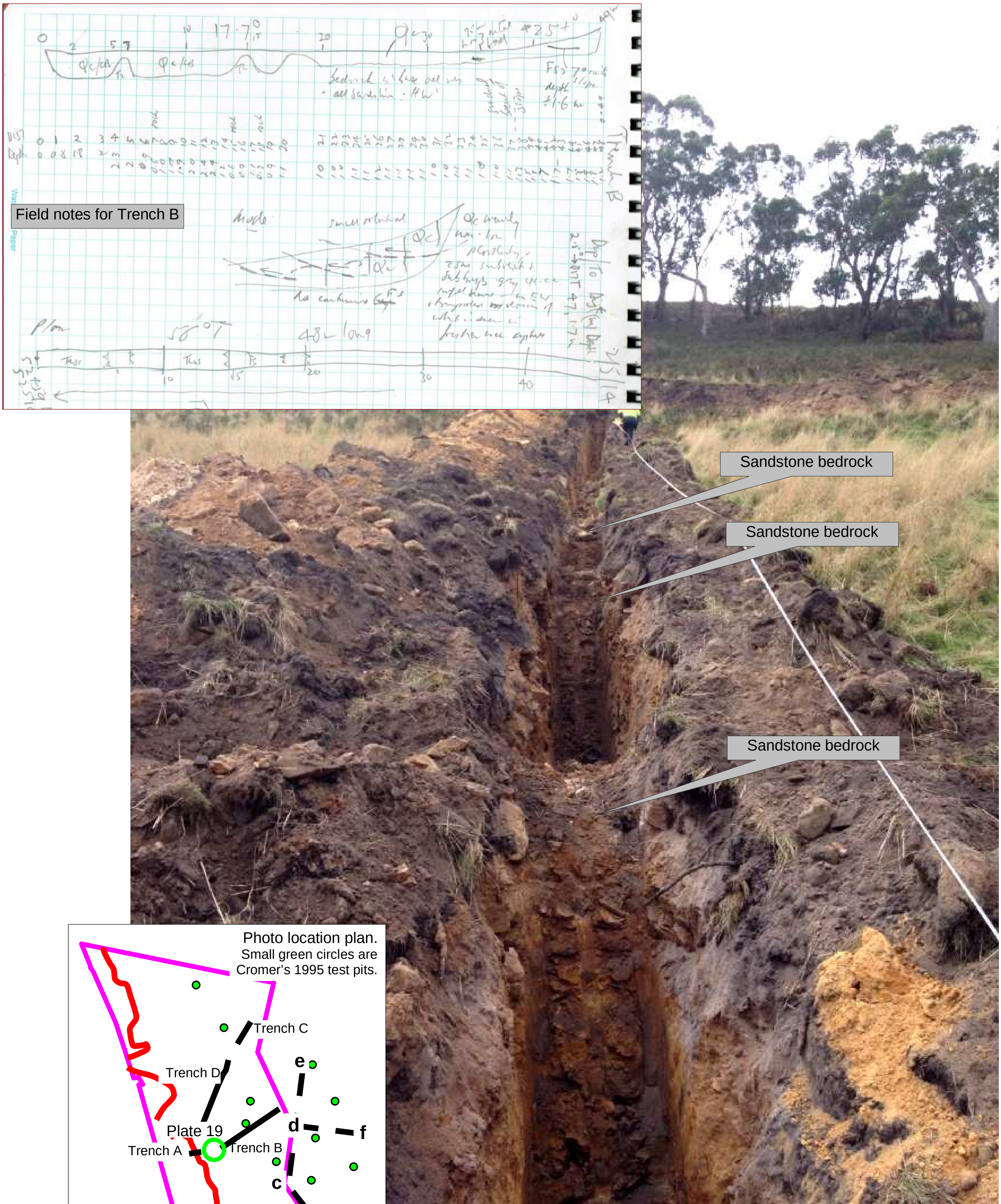


Plate 19. Investigation trench B, about 48m long, looking upslope. The slope is colluvium of variable thickness, but highly weathered sandstone bedrock was exposed along the full length of the trench at depths ranging from as shallow as 0.5m (as indicated) to about 1.8m. The dip on the bedrock is less than 5^0 to the north (into the slope).

Plate 20 (left). Investigation trench B, upslope end, showing finely bedded, highly weathered sandstone and siltstone bedrock dipping 3^0 to 017^0T. Colluvium (with some bedded sandstone) overlies the bedrock, and the boundary (red line) between them, although not very obvious, is inferred to dip towards and up to the camera in a scallop shape (the geology pick is on the boundary).

Plate 21 (below). Detail of the end of Trench B, showing grey-blue, high plasticity clay coatings several millimetres thick on a dipping joint surface. Slipping on these coatings is a likely mode of localised failure for the colluvial cover.

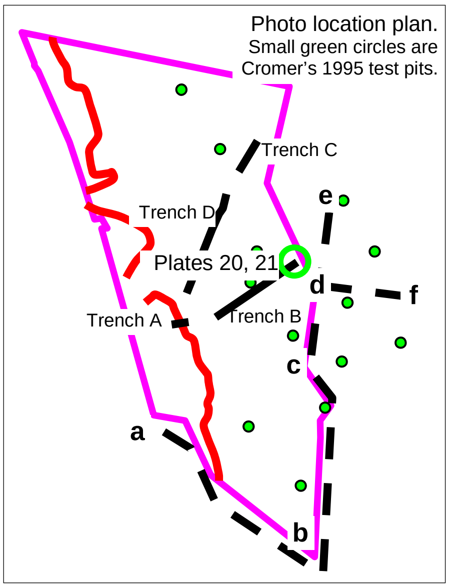


Photo location plan.
Small green circles are
Cromer's 1995 test pits.

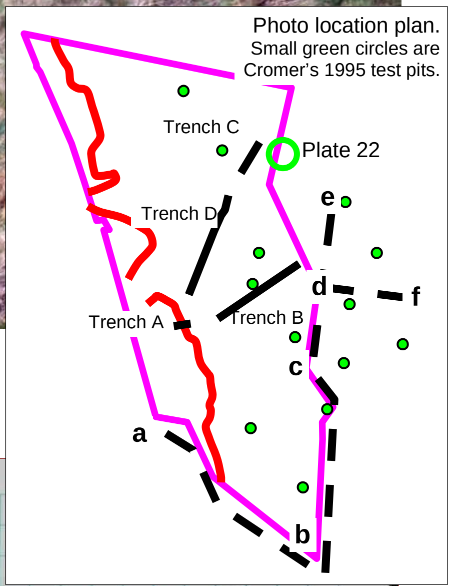
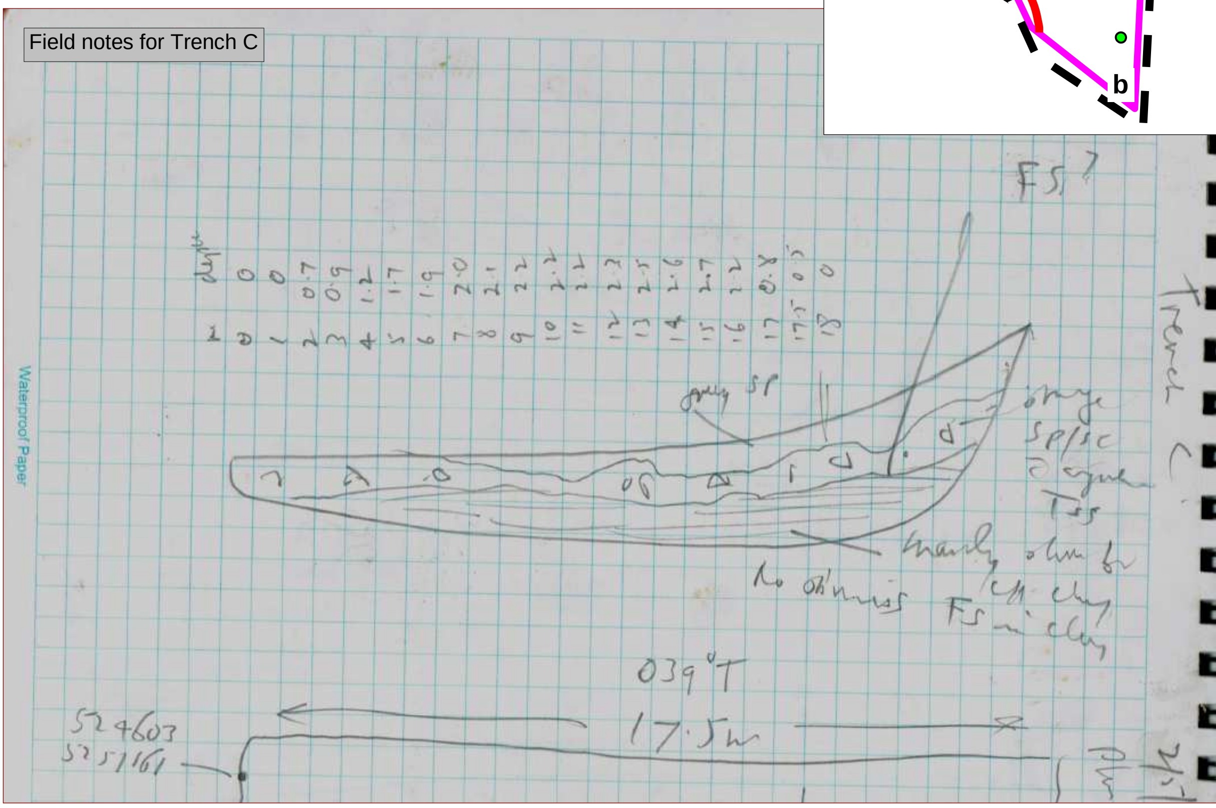


Plate 22 (above). View west at Trench C, 17.5m long. This excavation up to 2.6m deep exposed colluvial materials over high plasticity clay, with no bedrock.



Field notes for Trench C

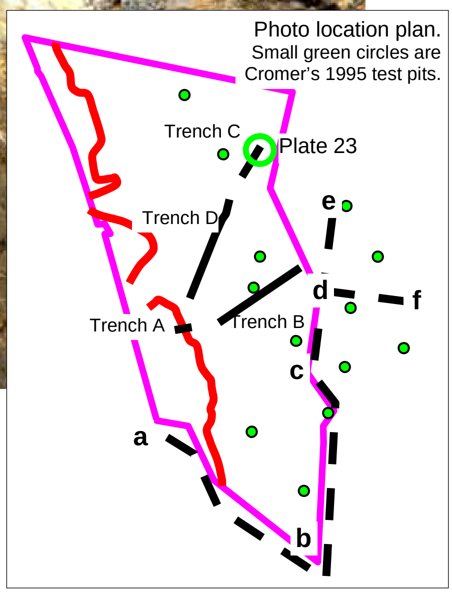


Plate 23. View north northwest at the higher end of Trench C, 17.5m long. This excavation up to 2.6m deep exposed colluvial materials over high plasticity clay, with no bedrock.

Plate 24. View downslope and along investigation trench D. Note bedrock highs in floor of trench, with colluvial material on top, and surrounding.

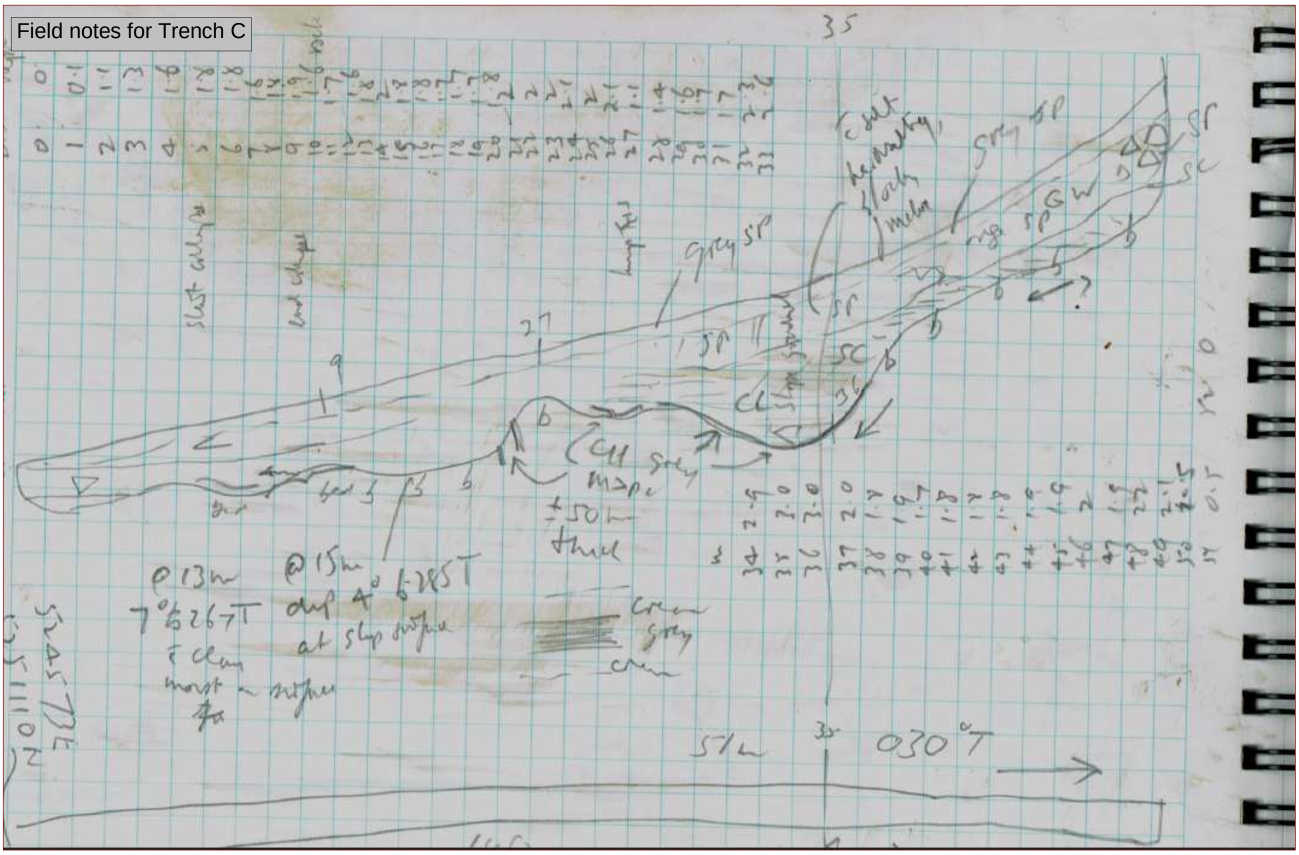
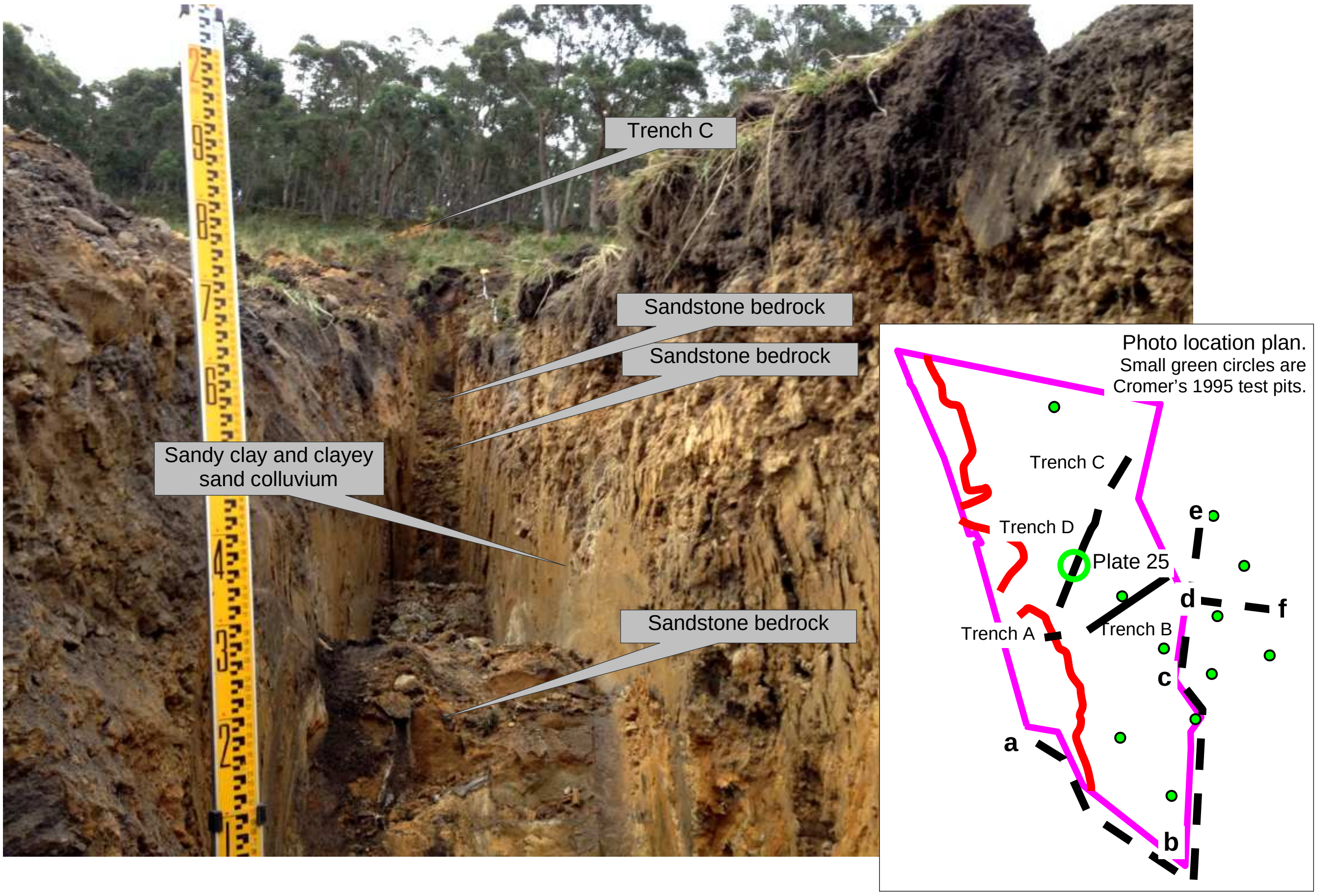


Plate 25 (below). View upslope and along investigation trench D. Note bedrock highs in floor of trench, with colluvial material on top, and surrounding. Bedrock dips measured in Trench D were: 4^0 to 285^0T, 7^0 to 267^0T.



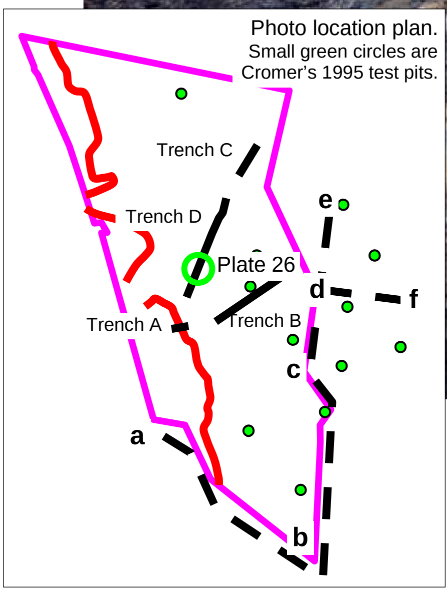


Plate 26. View upslope and along investigation trench D, showing finely bedded sandstone bedrock in floor of trench, with colluvial material on top. Local movement of colluvium over the bedrock is facilitated by grey clayey horizons on the colluvium-bedrock interface (indicated by pencil), and also probably by clayey coatings on subhorizontal joints in the bedrock itself (inset photo; the striations on the clay are finger marks).

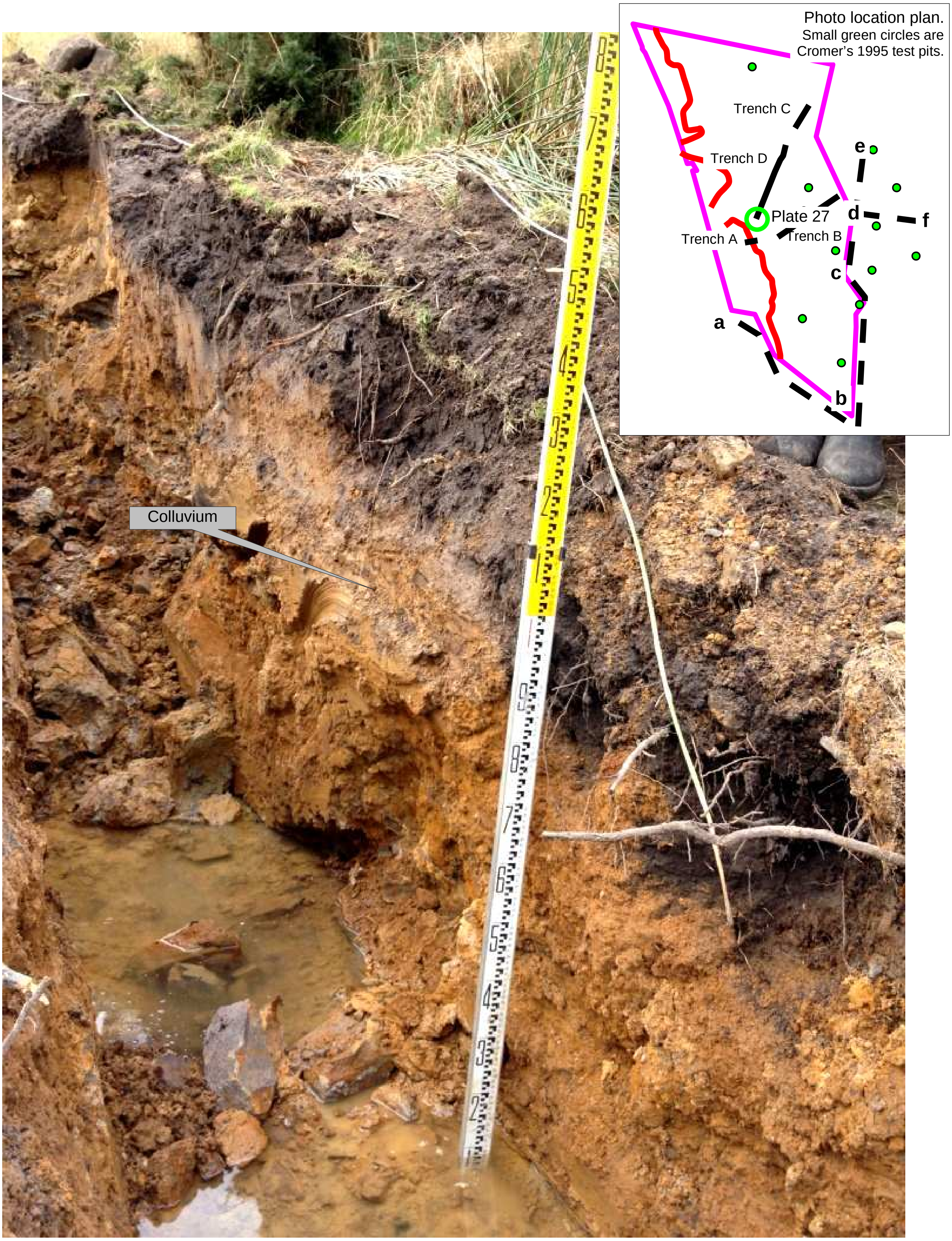


Plate 27. Shallow seepage water issued from, and accumulated at, the lower end of investigation trench D. Shown here are colluvial materials beneath organic-enriched sands soil, near the headscarp of published landslide #874. This seepage was the only instance noted in the trenches, although Cromer (1995) noted minor seepages in nearby test pit 6 at a depth of 3, and 20Lmin seepages at 4.8m

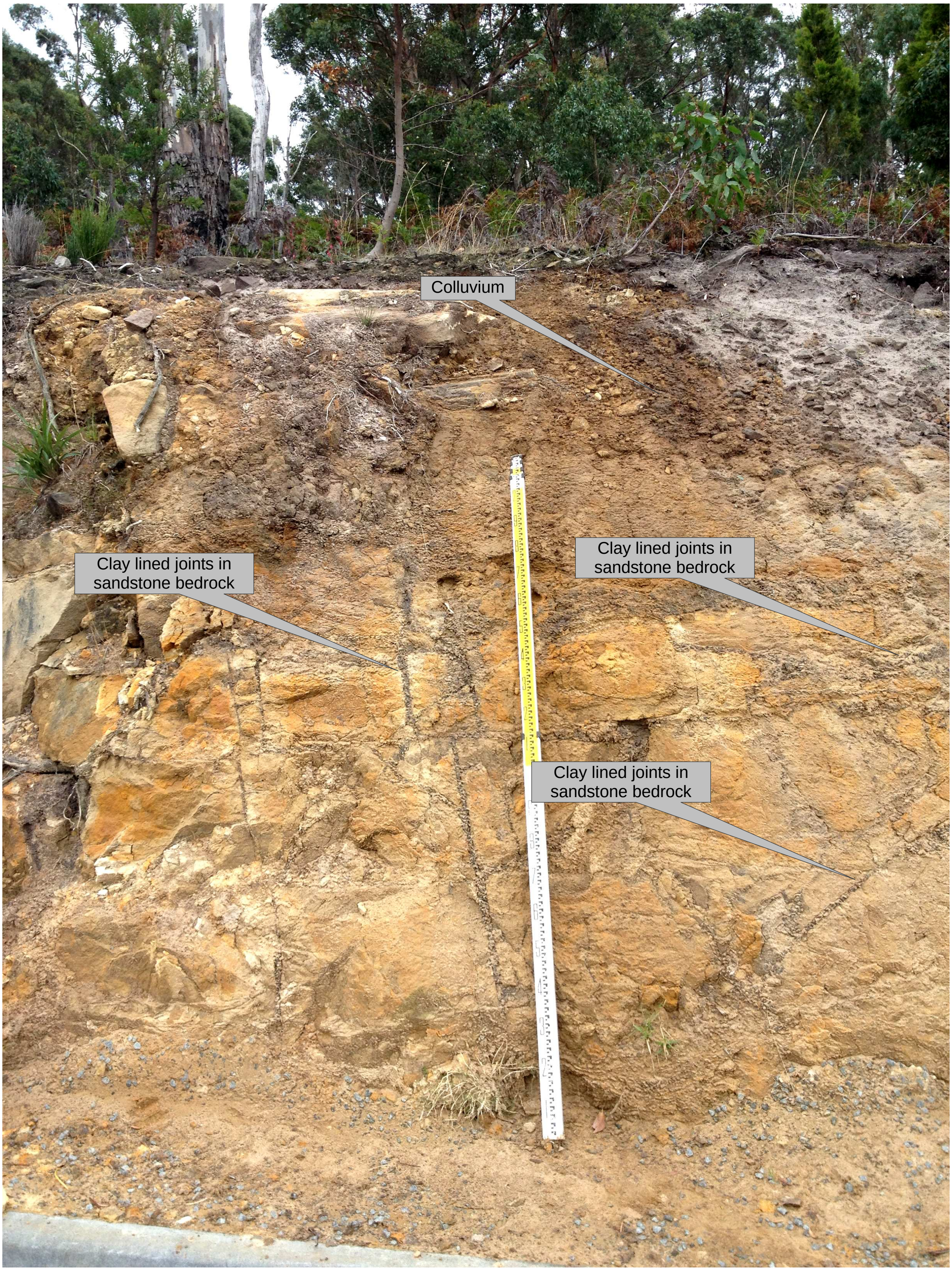


Plate 28. Triassic sandstone with joints coated with high plasticity grey clay are very common on the Farm Hill subdivision and neighbouring areas. This photograph of the cutting at the junction of Thelma Road and Forest Hill Road shows mainly subvertical, clay-lined joints, but subhorizontal and dipping ones, too. Some joint coatings taper to less than a millimetre thick, and it is inferred that they were emplaced in the liquid or semi-liquid state, filling open fractures. The origin of the clay is unclear – perhaps it represents clay enriched (B-horizons) which have been mobilised under wet conditions (cold? less vegetation cover?) and slope instability.

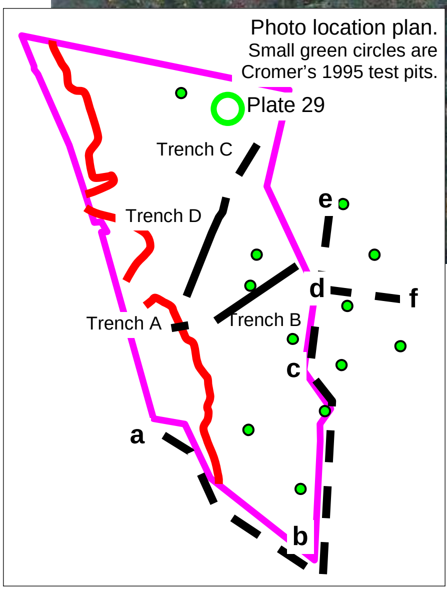


Plate 29. Curved tree trunks near the higher, northern boundary to Stage 4 suggest episodes of downslope soil movement.

Attachment 10

(13 pages)

Landslide Risk Management

This Attachment addresses slope stability (landslide) issues for Lot 47 at Farm Hill in accordance with Australian Geomechanics Society (AGS) Landslide Risk Management (2007)[6]. The process is depicted in Figure 10.1.

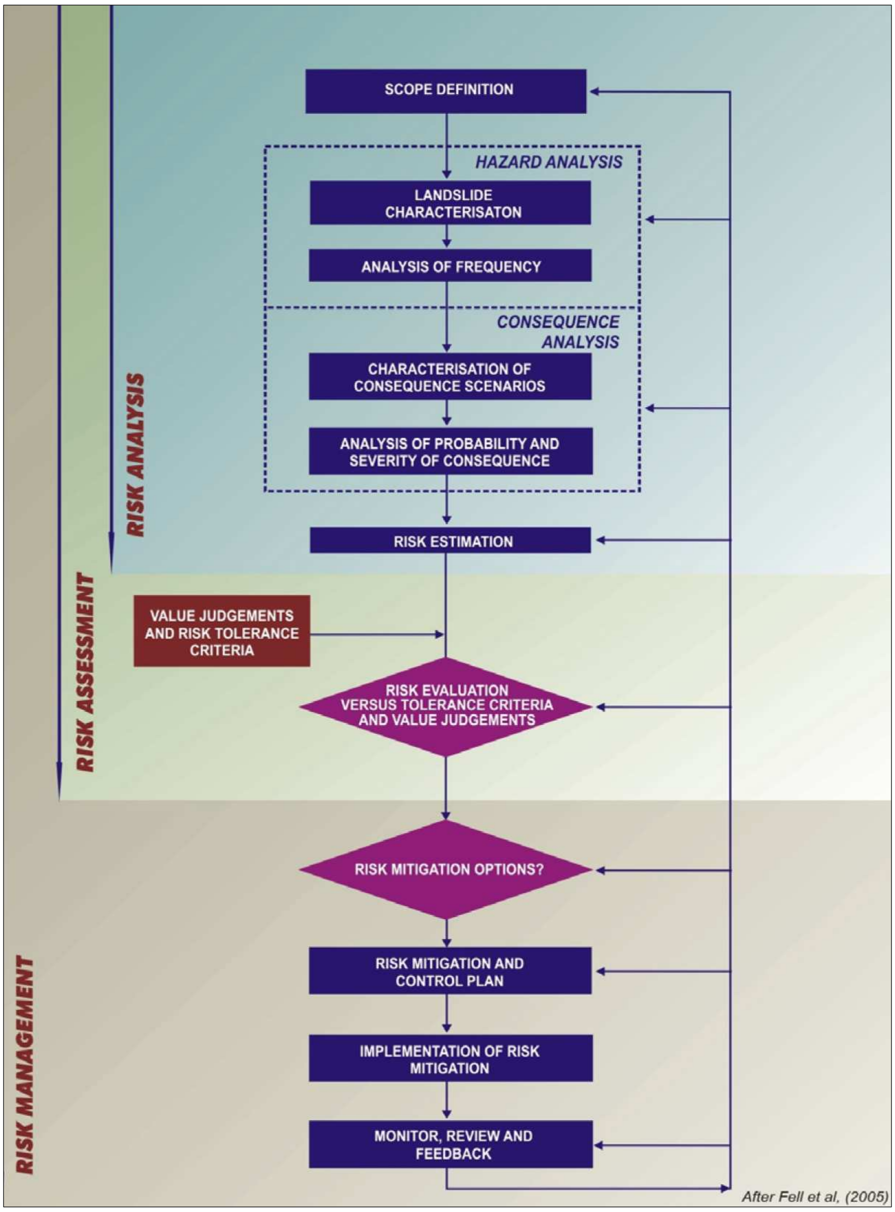


Figure 10.1. Framework for Landslide Risk Management
Source: Reproduced without amendment from AGS (2007a). Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007

[6] The five AGS documents are:
AGS (2007a). Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007
AGS (2007b). Commentary on Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007
AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007
AGS (2007d). Commentary on Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007
AGS (2007e). The Australian Geoguides for Slope Management and Maintenance. Australian Geomechanics Vol 42 No 1 March 2007

LANDSLIDE RISK MANAGEMENT (LRM)

Preliminary

Desktop review of slope instability

Unpublished evidence

Information relating to potential or actual slope instability on and adjacent to Lot 47 at Farm Hill was discussed in detail in my 1995 report[7], and some of it is included here as extracts in Attachment 4. The 1995 report also included a copy of an earlier unpublished letter[8] to G Stevens by the then Division of Mines & Mineral Resources, briefly describing a landslide on the lower, southwestern portion of the land.

The report described:

- the existing landslide,
- a larger and more subtle topographic feature surrounding the existing landslide and extending north and east on adjacent slopes, interpreted as a possible landslide, and
- several smaller landslides bordering the eastern side of Ross Rivulet.

I am unaware of any other unpublished reports relating to slope stability issues in the neighbourhood of the development.

Published evidence

The 1995 report resulted in the first landslide features listed above being added to the landslide database maintained by the Division of Mines & Mineral Resources, and then early this century onto landslide hazard and related maps maintained by its successor, Mineral Resources Tasmania (MRT). The original smaller landslide (Weldon, 1990) became #874, and the larger feature #1476[9].

The MRT Landslide Hazard Maps (Attachment 6, this report) show:

- The two known shallow landslides (#874 and #1476) occupy the southern and southwestern half of Lot 47 on the Farm Hill Subdivision. Slope angles are in the 20 – 30^0 range.
- Most watercourses in the area have the potential to generate debris flows at their sources, with associated runouts. Test pit data from Cromer (1995) have been used to indicate regolith thicknesses (up to 5m) on the Farm Hill Subdivision.
- The course of Ross Rivulet, and the sandstone cliff sections bordering Hobart Rivulet, have the potential to generate rockfalls.
- The subject land is adjacent to, but not shown to be at direct risk of, potential deep seated landsliding.

More recently, landslide hazard band maps covering all of Tasmania have been released by the Department of Premier and Cabinet, using data provided by MRT, and are available at www.thelist.tas.gov.au. The landslide hazard banding for Farm Hill and environs, reproduced here in Attachment 5, shows landslide #874 as in the "Medium – Active band, with enclosing landslide #1476 in the Low to Medium band, and the balance of Lot 47 in the Acceptable band.

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[7] Cromer, W. C. (1995). Geotechnical Investigations of Lands off Forest Road, West Hobart. Unpublished report for G. E. Stevens by Environmental & Technical Services Pty Ltd September 1995.

[8] Weldon, B. D. (1990). 4 Tara Street – proposed subdivision. Letter re landslide, signed by M. R. Hargreaves as Acting Director of Mines to G. Stevens, 162A Forest Road, 28 September 1990, 1 page.

[9] Both can be viewed on the MRT landslide map at http://www.mrt.tas.gov.au/Viewer/Exposure/E3?REQUEST=Entry&PRJ=Geohazards_Public&MODE=mrt&DELETE_DEFAULT=Y&SID=98545043&REQUEST=Entry&reload=1

Field evidence

Field evidence:

- confirms the presence of translational landslide #874, which appears to have not undergone any noticeable movement since the mid-1980s, and possibly earlier,

- confirms the presence of a series of small-scale translational landslides upslope from #874, on the eastern bank of Ross Rivulet,

- suggests that the larger feature #1476 might never have been a shallow translational landslide. Extensive trenching in 2014, described by the photographs in Attachment 9 of this report, shows the hillside comprises non-plastic or low plasticity colluvium of variable thickness (0.5 to 1.5m) over subhorizontal sandstone bedrock. Local thin lenses and horizons of moist, high plasticity clay occur in places on the bedrock/colluvium interface and probably promote small scale translational downslope movement, which may result in subtle surface undulations but nothing more significant, and

- includes the observation that the higher, steeper slopes of Lot 47 show undulating ground (and Trench C exposed over 2m of colluvial clay); these slopes may be run-out material from a previously un-mapped, relatively old and now probably inactive, moderately-sized armchair-shaped depression (shown in Attachment 8) upslope from Lot 47. On these steep slopes near the higher, northern property boundary, curved tree trunks indicate sporadic downslope soil movement (see Plate 29 in Attachment 9).

Site investigations

Addressed in the Attachments to this report.

Site plans

See Attachments 2, 3, 5, 7 and 8.

Site sections (natural scale) and slope variations

Figures 10.1a, 10.2a and 10.3a (this Attachment) are natural-scale NE – SW cross sections at three locations through the hillside including Lot 47 at Farm Hill. Figures 10.1b, 10.2b and 10.3b show the variation in slope angles down the hillside, calculated from 1m LiDAR contours for each 5m of horizontal distance. Each of these slope graphs highlights slope irregularities not readily apparent in the natural-scale cross sections. A key feature of the slopes are surface undulations with amplitudes mostly in the 0.5 – 1m range (locally up to 3m) and downslope lengths in the 5 – 50m range, which indicate shallow translational slope instability. These surface undulations are less developed on Section line 3.

The captions to all Figures are self-explanatory.

Conceptual hydrogeological model for Lot 47

Figure 10.4 (this Attachment) is a conceptual hydrogeological model for a generalised NE – SW hillside slope across Lot 47. It depicts various modes of potential slope instability, not all of which are observed or feasible.

Status of landslide #874

Landslide #874 is regarded here as an active[10], small-medium sized, rotational-translational, shallow, slow-moving earth slide. There has been no noticeable movement of it for about 30 years. The main hazard associated with possible Lot 47 residential development is upslope regression of the headscarp. Recent investigations have established that similar, smaller landslides extend upslope along the eastern side of Ross Rivulet, the full western side of the Farm Hill property boundary.

Status of landslide #1476

The trenching associated with residential development, and investigation trenches A – D, suggest Landslide #1476, as published, does not exist. Instead, the hillside is characterised by

[10] “Active” means movement has occurred since European occupation.

a variable-thickness (0.5 – 1.5m thick) veneer of colluvial soils over an undulating, shallow surface of subhorizontal Triassic sandstone bedrock. Minor, localised, very small scale (metres), very slow translational movement is probably occurring where thin discontinuous lenses of high plasticity clay occur – in colluvium, at the colluvium/bedrock interface, and in joints in the upper levels of the bedrock. The landslide should be removed from published maps and databases[11].

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Hazard Analysis

Landslide characterisation

Refer to Figure 10.5 and Table 10.1 (this Attachment) for a description of the main forms of landslide movement.

Figure 10.4 schematically shows six potential forms or scenarios (numbered red circles) of landslide movement in relation to Lot 47, under current and post development conditions. The post development conditions relate to oversteepening of existing slopes for vehicle access and house sites, and the use of uncontrolled fill, which increase the likelihood of small scale instability (Scenario 6).

The scenarios are:

Scenario 1: Rotational or translational failure
Deep-seated, in bedrock; failure surface irregular; deeper than 5m; large-scale; slow moving; potentially affecting whole hillside

Scenario 2: Rotational or translational failure
Shallow, in colluvial clays on steeper northern slopes; failure surface shallower than 5m; medium scale; slow moving; potentially affecting perhaps 25 – 50% of slope, including run-out.

Scenario 3: Translational failure
Shallow, in colluvial soils on adjoining land on steeper northern slopes; failure surface shallower than 2m; medium scale; the hazard relates to runout of failed material onto the steeper northern parts of Lot 47; slow to rapid movement

Scenario 4 Rotational or translational failure
Upslope regression of landslide #874; small scale; shallow, in colluvial soils over bedrock; failure surface less than 2m deep; slow moving.

Scenario 5 Translational failure
On clay horizons at the colluvium/bedrock interface; very small scale; very slow moving

Scenario 6 Rotational or translational failure
Very small scale failure after development, involving a range of forms including collapse of soil in excavations, or fill used beneath houses, driveways, terraces, etc; slow to rapid moving

Movements of earth and/or debris are possible.

Frequency analysis

Table 10.2 (this Attachment) lists the potential occurrence and subjective likelihood of the six identified forms of slope instability on Lot 47, under current and post development conditions.

[11] An informal request has been made to Mineral Resources Tasmania in this regard.

Figure 10.1a

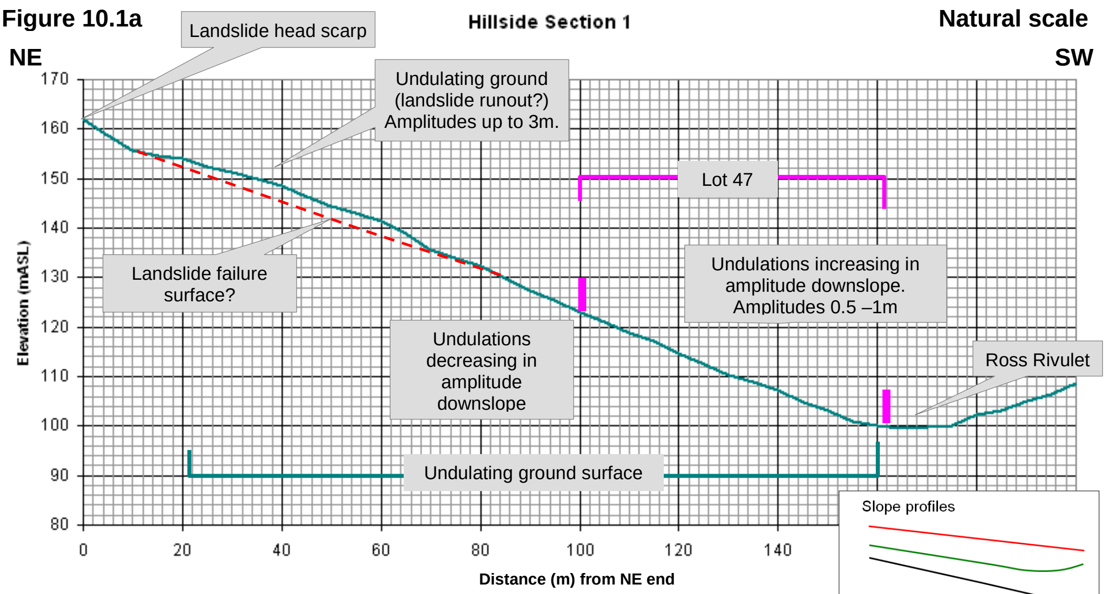
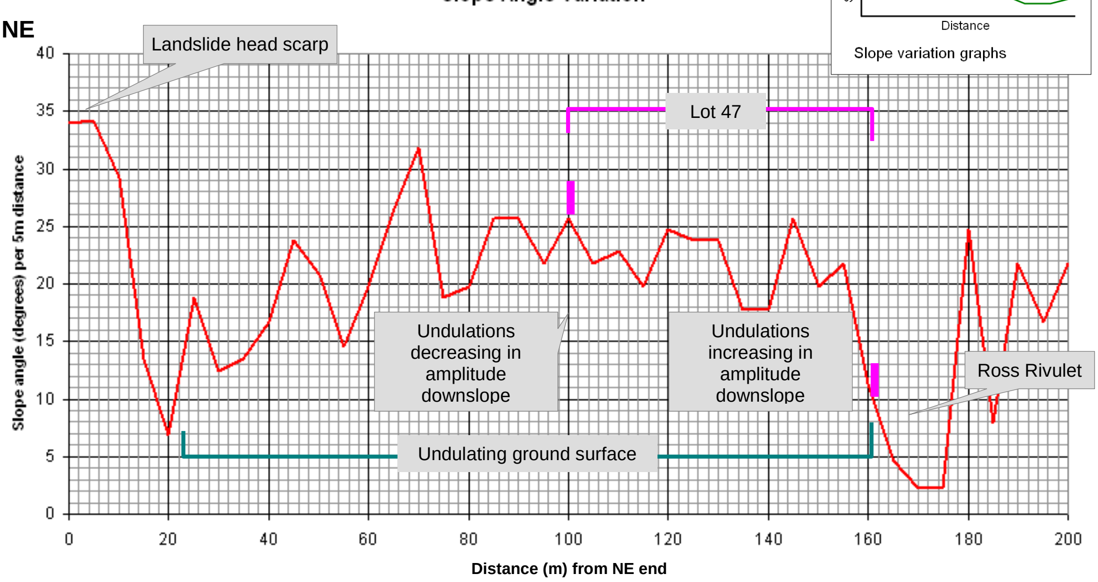


Figure 10.1b



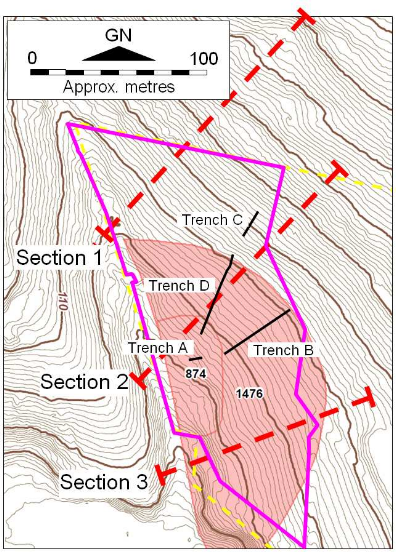
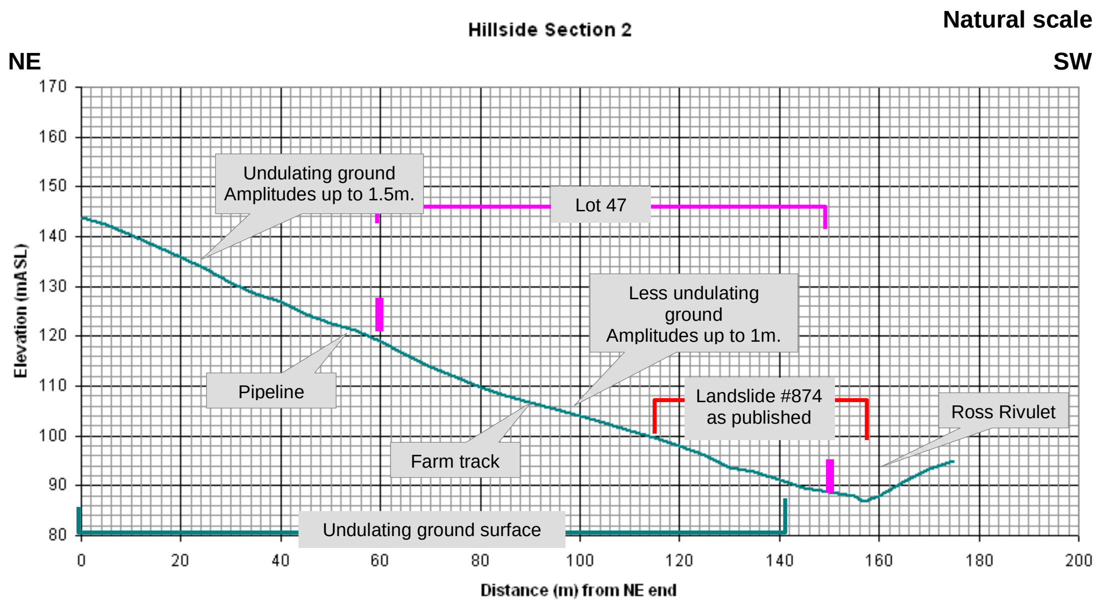
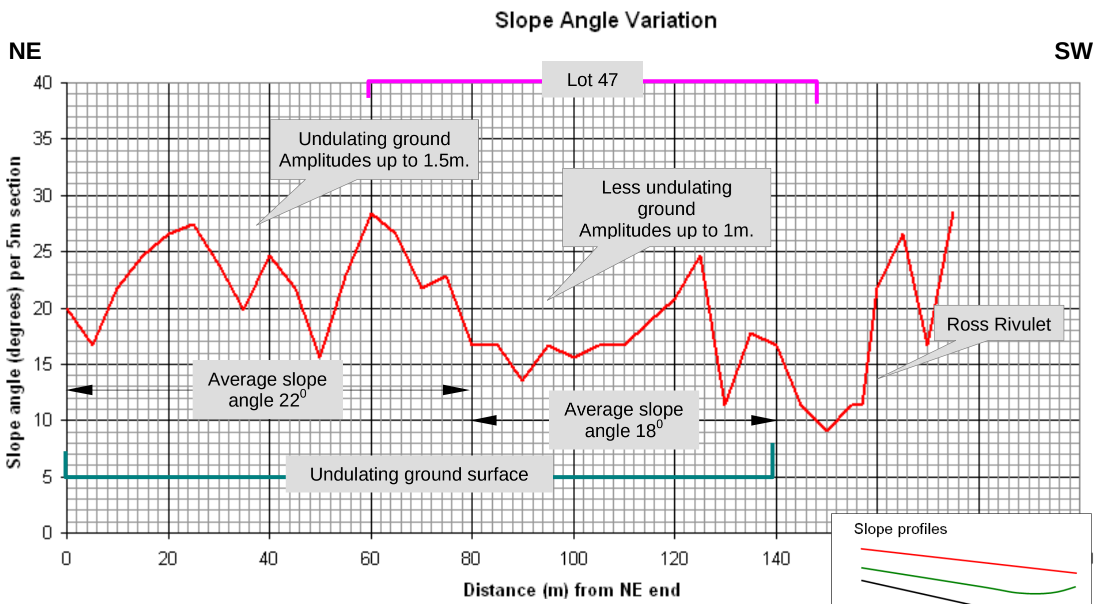
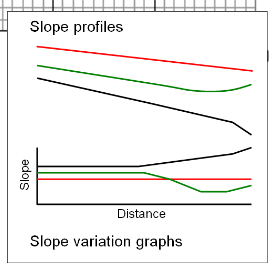


Figure 10.1a. This 200m NE – SW natural-scale section through the northwestern corner of Lot 47 and the hillside above it shows the previously unmapped landslide on higher ground, and an undulating surface on the slopes leading down to Ross Rivulet. The average slope angle is 22^0.

Figure 10.1b shows variations in slope angle, calculated each 5m (the graph for a uniformly dipping slope would be a horizontal line).
The undulations in the ground surface are readily apparent, Amplitudes downslope from the landslide are up to 3m (landslide runout?), but decrease downslope to about 0.5m before increasing towards Ross Rivulet to 0.5 – 1m. Slope angles are steep (35^0) at the headscarp of the landslide, and again on segments of undulating ground to distances up to 80m (landslide runout?), but then remain in the 20 – 25^0 range until the edge of Ross Rivulet.







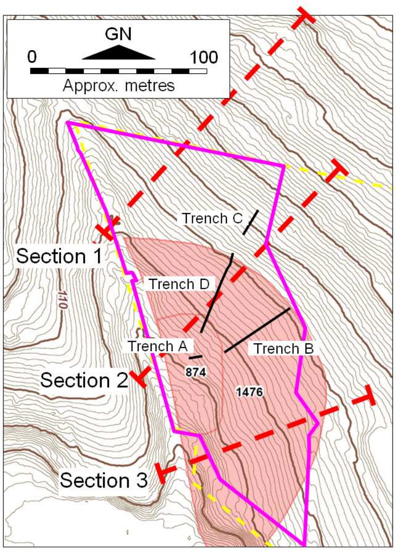


Figure 10.2a. This 175m NE – SW natural-scale section through the north-central part of Lot 47 and the hillside above it shows an undulating surface on the slopes leading down to Ross Rivulet. The average slope angle above the farm track (at a gentle break of slope) is 23^0, and 18^0 below it.

Figure 10.2b shows the variations in slope angle, calculated each 5m (the graph for a uniformly dipping slope would be a horizontal line).
The undulations in the ground surface are readily apparent, and decrease in magnitude downslope.

Figure 10.3a **Natural scale**

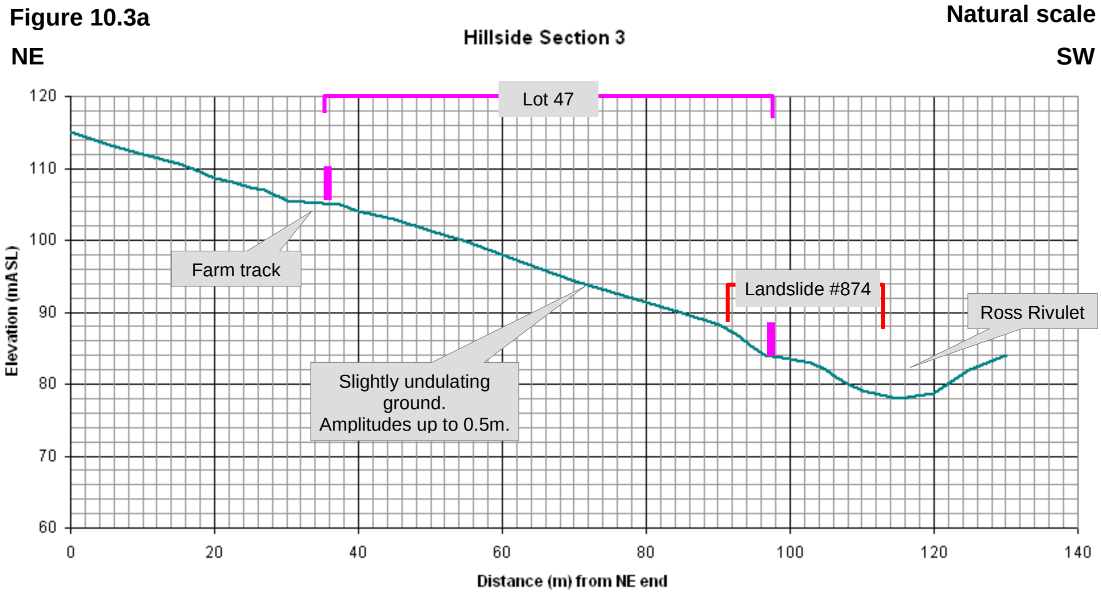
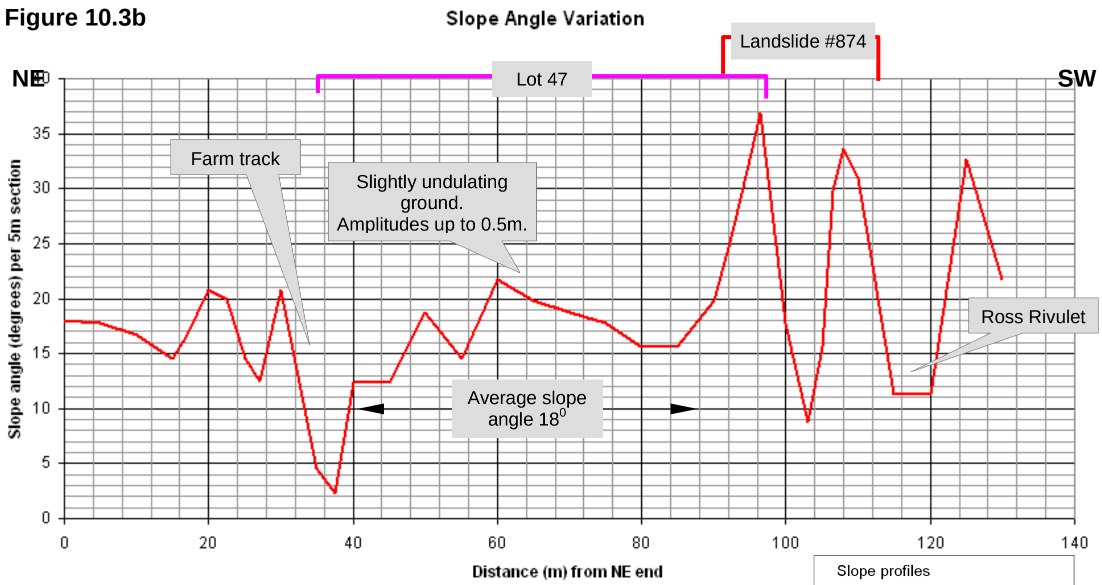
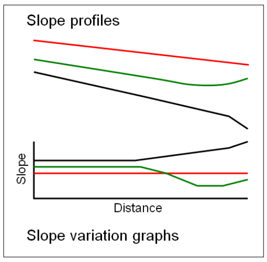


Figure 10.3b





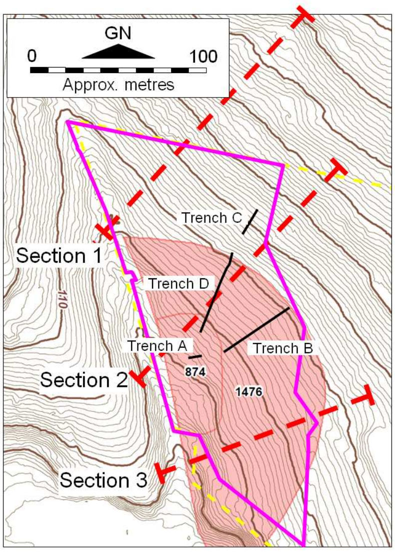


Figure 10.3a. This 130m NE – SW natural-scale section through the southern part of Lot 47 shows a slightly undulating surface between the farm track, and landslide #874 leading down to Ross Rivulet. The average slope angle below the farm track is 18^0.

Figure 10.3b shows the variations in slope angle, calculated each 5m (the graph for a uniformly dipping slope would be a horizontal line).
Surface undulations upslope from landslide #874 are less apparent than on adjacent slopes to the north, and are up to about 0.5m in amplitude.

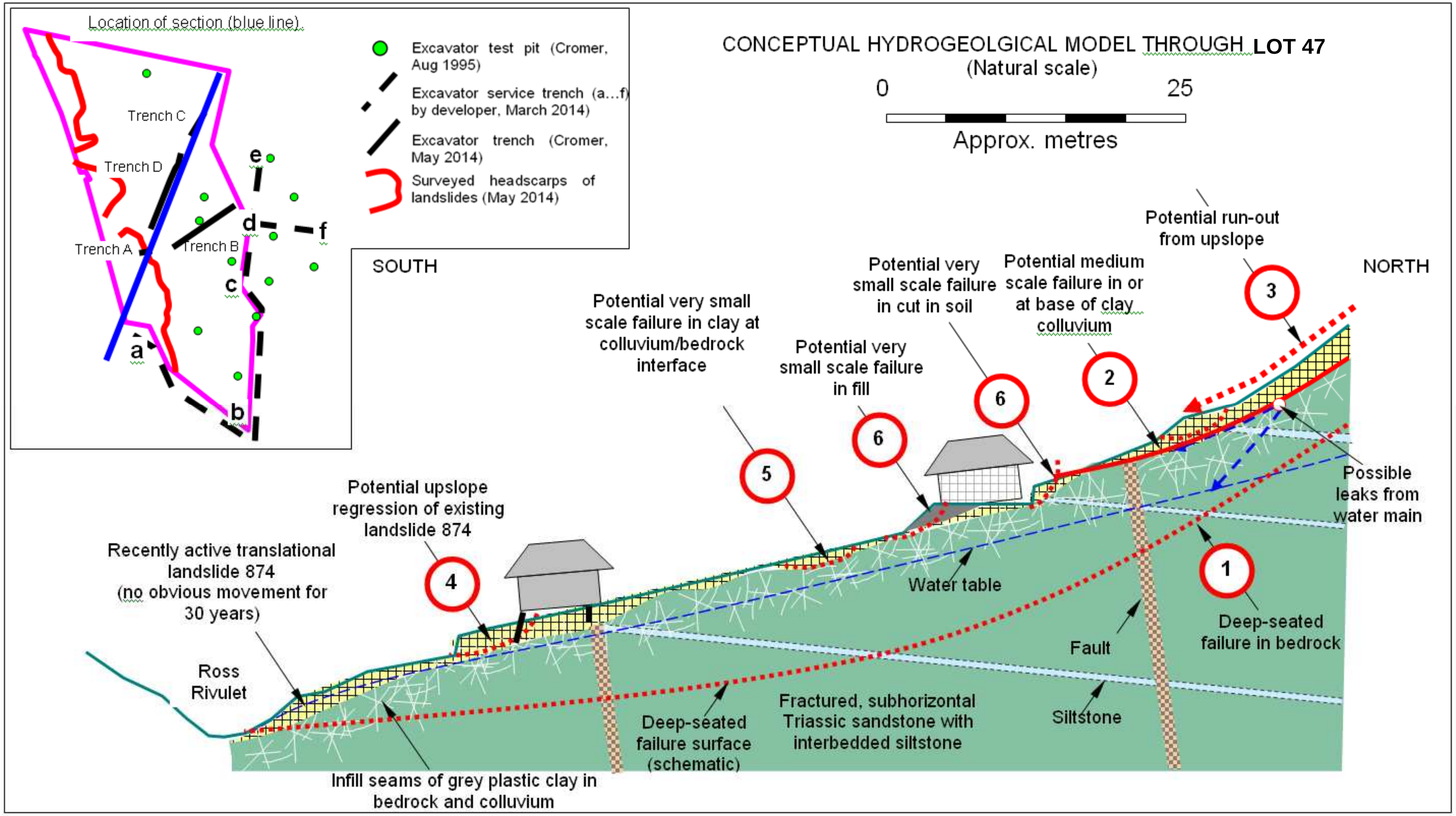


Figure 10.4. Conceptual hydrogeological model through Lot 47 at Farm Hill, based on all geotechnical evidence presented in this report. Five landslide scenarios are indicated by the numbered red circles. Scenarios 1 – 4 are pre- and post-development; scenario 5 is post-development.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

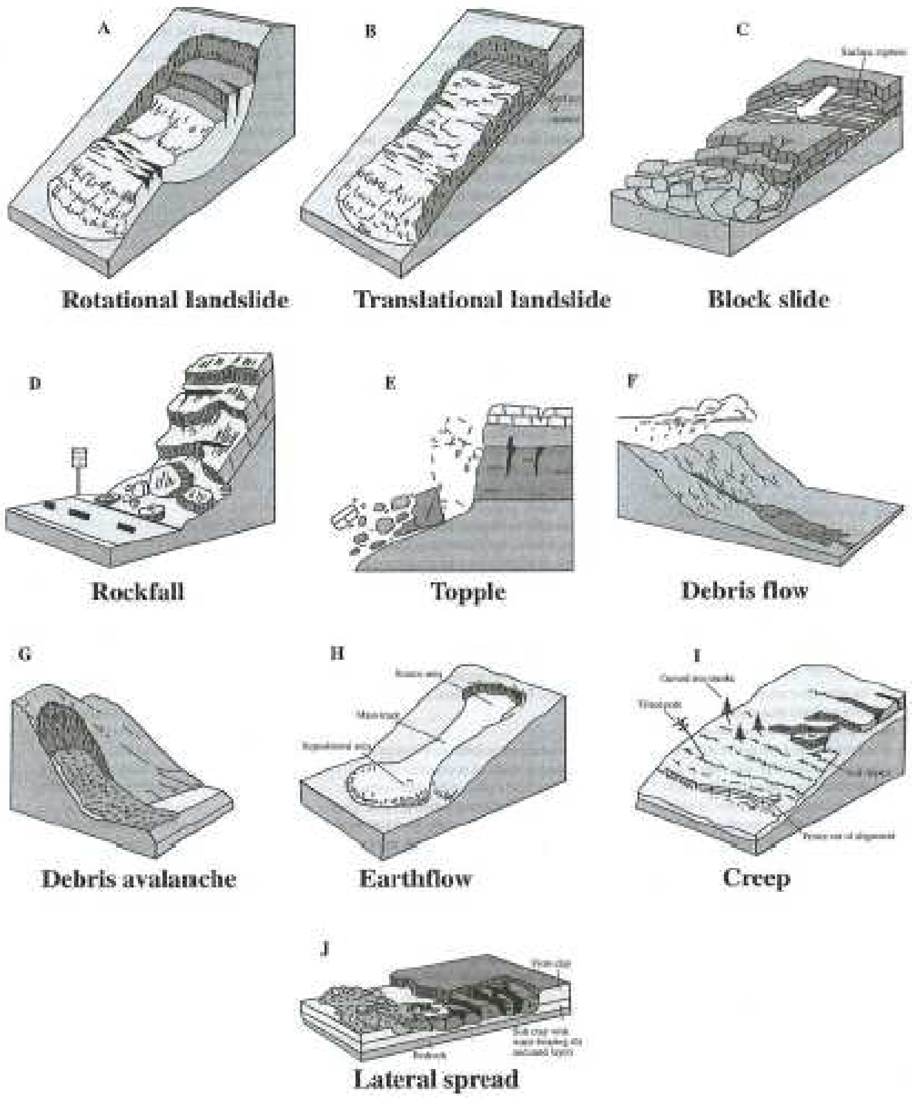


Figure B1: These schematics illustrate the major types of landslide movement.
(From US Geological Survey Fact Sheet 2004-3072, July 2004, with kind permission for reproduction.)

The nomenclature of a landslide can become more elaborate as more information about the movement becomes available. To build up the complete identification of the movement, descriptors are added in front of the two-term classification using a preferred sequence of terms. The suggested sequence provides a progressive narrowing of the focus of the descriptors, first by time and then by spatial location, beginning with a view of the whole landslide, continuing with parts of the movement and finally defining the materials involved. The recommended sequence, as shown in Table B2, describes activity (including state, distribution and style) followed by descriptions of all movements (including rate, water content, material and type). Definitions of the terms in Table B2 are given in Cruden & Varnes (1996).

Figure 10.5 Main types of landslide movement
Source: From Appendix B of AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

Consequence analysis and qualitative risk to property estimation – before and after treatment

Table 10.3 (this Attachment) is a consequence analysis and risk to property assessment for the six scenarios shown in Figure 10.4 and listed in Table 10.2. Falls, Topples, Spreads, Flows and deep-seated failures are Barely Credible under current circumstances, but Falls and Topples might become Possible after development if excavations into colluvium and/or bedrock are made for house sites (Scenario 6). The likelihoods of the remaining Rotational and translational landslides (Scenarios 1 – 5) are judged Possible, with consequences to property Medium to Insignificant. Consequences are reduced after treatment, but Risks to property remain mostly Moderate after treatment.

Scenario 6 also potentially arises (during and) after development with the use of uncontrolled fill (eg for access drives and house sites).

Table 10.1 Main types of landslide movement

Source: From Appendix B of AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly Coarse	Predominantly Fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (Deep creep)	Debris flow (Soil creep)	Earth flow (Soil creep)
COMPLEX		Combination of two or more principle types of movement		

Table 10.2 Landslide characterisation in relation to the current proposal

	Field Evidence	Actual or potential size	Potential speed	Water content	Current likelihood	Likelihood after development	Scenarios in Figure 10.4
Falls							
Rock fall	None	Small	Extremely rapid	Dry	Barely credible	Possible	6
Debris fall	None	Small	Extremely rapid	Dry to wet	Barely credible	Possible	6
Earth fall	None	Small	Extremely rapid	Dry to wet	Barely credible	Possible	6
Topples							
Rock topple	None	Small	Extremely rapid	Dry	Barely credible	Possible	6
Debris topple	None	Small	Extremely rapid	Dry	Barely credible	Possible	6
Earth topple	None	Small	Extremely rapid	Dry	Barely credible	Possible	6
Rotational or translational landslide							
Rock slide	None	Small	Slow to Rapid	Dry to moist	Barely credible	Barely credible	
Debris slide	None	Small to large	Slow to Rapid	Moist to wet	Possible	Possible	1 – 5
Earth slide	Yes	Small	Slow to Rapid	Moist to wet	Possible	Possible	1 – 5
Lateral spread							
Rock spread	None	Small	Slow	Dry to moist	Barely credible	Barely credible	
Debris spread	None	Small to medium	Slow	Moist to wet	Rare	Rare	
Earth spread	None	Small to medium	Slow	Moist to wet	Rare	Rare	
Flows							
Rock flow	None	Small to medium	Rapid	Dry to moist	Rare	Rare	
Debris flow	None	Small to large	Very rapid	Moist to wet	Rare	Rare	
Earth flow	None	Small to large	Very rapid	Moist to wet	Rare	Rare	
Complex	None	Small to large	Slow to rapid	Dry to moist	Rare	Rare	

Table 10.3 Qualitative consequences and risks to property for landslide scenarios on Lot 47 before and after treatment

		Before treatment				After treatment		
	Scenarios in Figure 10.4	Likelihood	Consequences to property	Risk to property	Proposed treatment	Likelihood	Consequences to property	Risk to property
Falls								
Rock fall	6	Barely credible	Minor	Very low	Various	Possible Note 1	Insignificant	Very low
Debris fall	6	Barely credible	Minor	Very low	Various	Possible Note 1	Insignificant	Very low
Earth fall	6	Barely credible	Minor	Very low	Various	Possible Note 1	Insignificant	Very low
Topples								
Rock topple	6	Barely credible	Minor	Very low	Various	Possible Note 1	Insignificant	Very low
Debris topple	6	Barely credible	Minor	Very low	Various	Possible Note 1	Insignificant	Very low
Earth topple	6	Barely credible	Minor	Very low	Various	Possible Note 1	Insignificant	Very low
Rotational or translational landslide								
Rock slide		Barely credible	Major	Very low				
Debris slide	1	Barely credible	Major	Very low				
	2	Possible	Medium	Moderate	No building	Possible	Insignificant	Low
	3	Possible	Medium	Moderate	No building	Possible	Insignificant	Low
	4	Possible	Medium	Moderate	House setback	Possible	Minor	Moderate
	5	Possible	Insignificant	Low	None	Possible	Insignificant	Low
	6	Possible	Medium	Moderate	Various	Possible	Minor	Moderate
Earth slide	1	Barely credible	Major	Very low				
	2	Possible	Medium	Moderate	No building	Possible	Insignificant	Low
	3	Possible	Medium	Moderate	No building	Possible	Insignificant	Low
	4	Possible	Medium	Moderate	House setback	Possible	Minor	Moderate
	5	Possible	Insignificant	Low	None	Possible	Insignificant	Low
	6	Possible	Medium	Moderate	Various	Possible	Minor	Moderate
Lateral spread								
Rock spread		Barely credible	Major	Very low				
Debris spread		Rare	Major	Low				
Earth spread		Rare	Major	Low				
Flows								
Rock flow		Rare	Major	Low				
Debris flow		Rare	Major	Low				
Earth flow		Rare	Major	Low				
Complex		Rare	Major	Low				

Note 1. These six after-development scenarios relate to excavations in colluvium and bedrock at house and similar sites, where cuts might expose several metres of materials and present possible hazards where none existed before.

Qualitative risk to life estimation – before development

No current slope instability scenarios present unacceptable risks to life.

Quantitative risk to life estimation – after development

Recommended risk treatments for development on Lot 47 are presented later in this Attachment. After treatment, it is expected that risks to life presented by most scenarios will remain acceptable.

Scenario 6 includes small-scale hazards present before development, with acceptably low risk to life. But some Scenario 6 hazards are created by development – in particular, cut and fill may potentially give rise to small-scale, rapid (earth and) rock falls from unsupported excavations which might be present at the rear of houses. The individual most at risk is assumed to be a child. This scenario (considered as three separate "sub-scenarios" depending on the size of the rock fall), is shown in the event tree in Figure 10.6.

The risks to life for these scenarios are similar, and are in the 0.7 – 1E-04 range. On the Societal Risk Graph in Figure 10.5, they plot near the Broadly Acceptable – Tolerable boundary for a single life.

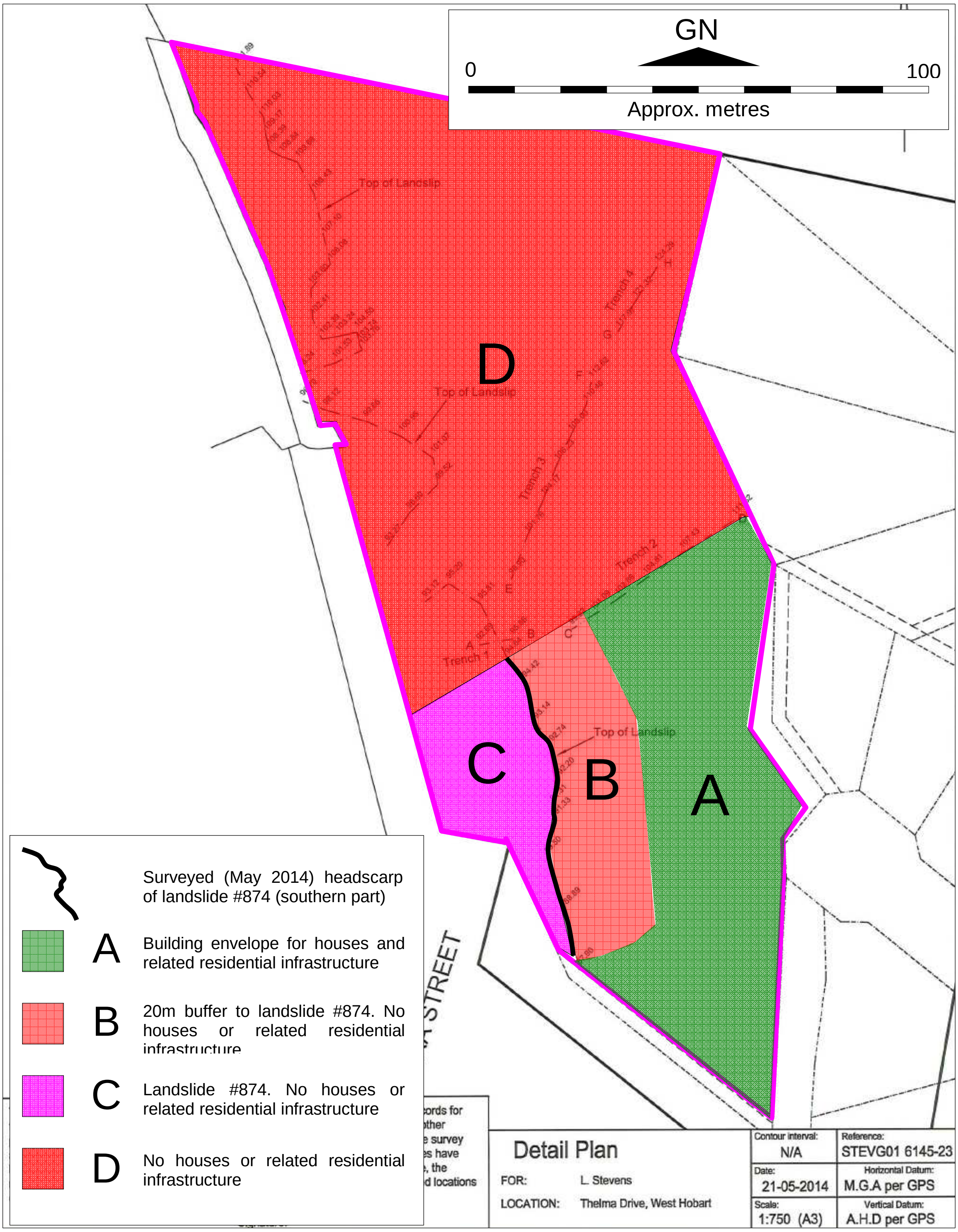


Figure 10.5 **Recommended building envelope (A) and no-development areas (B, C, D) for subdivision and residential development of Lot 47 of the Farm Hill subdivision.**

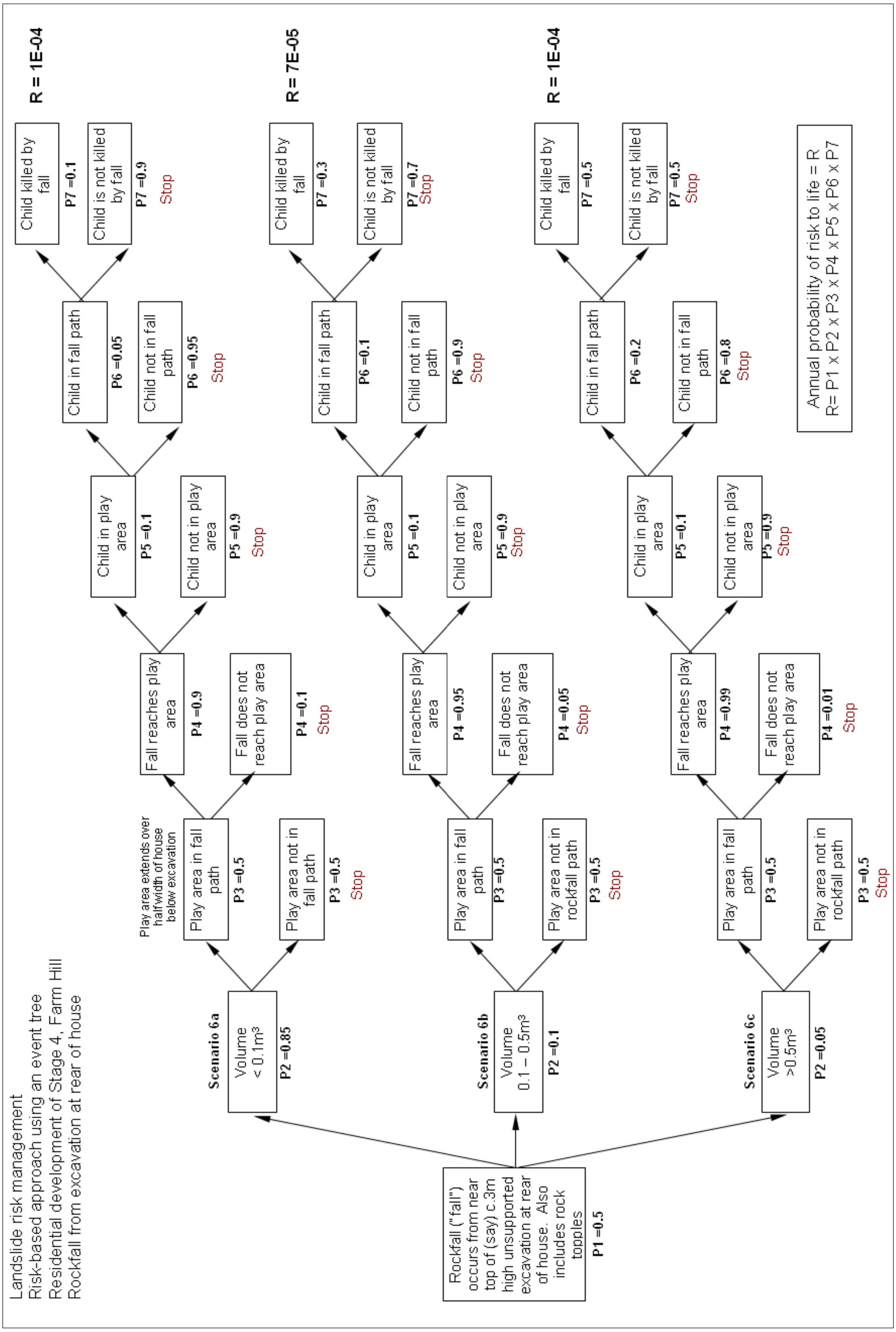


Figure 10.6 **Event tree setting out steps in assessing quantitative risk to life to a child playing at the base of an unsupported earth/rock wall at the rear of a house on a property in Lot 47 of the Farm Hill subdivision (Scenario 6 in Table 10.3). Risks are shown at right of the tree, and are compared to acceptability criteria in the Societal Risk Graph in Figure 10.7. These levels of risk should be treated or monitored.**

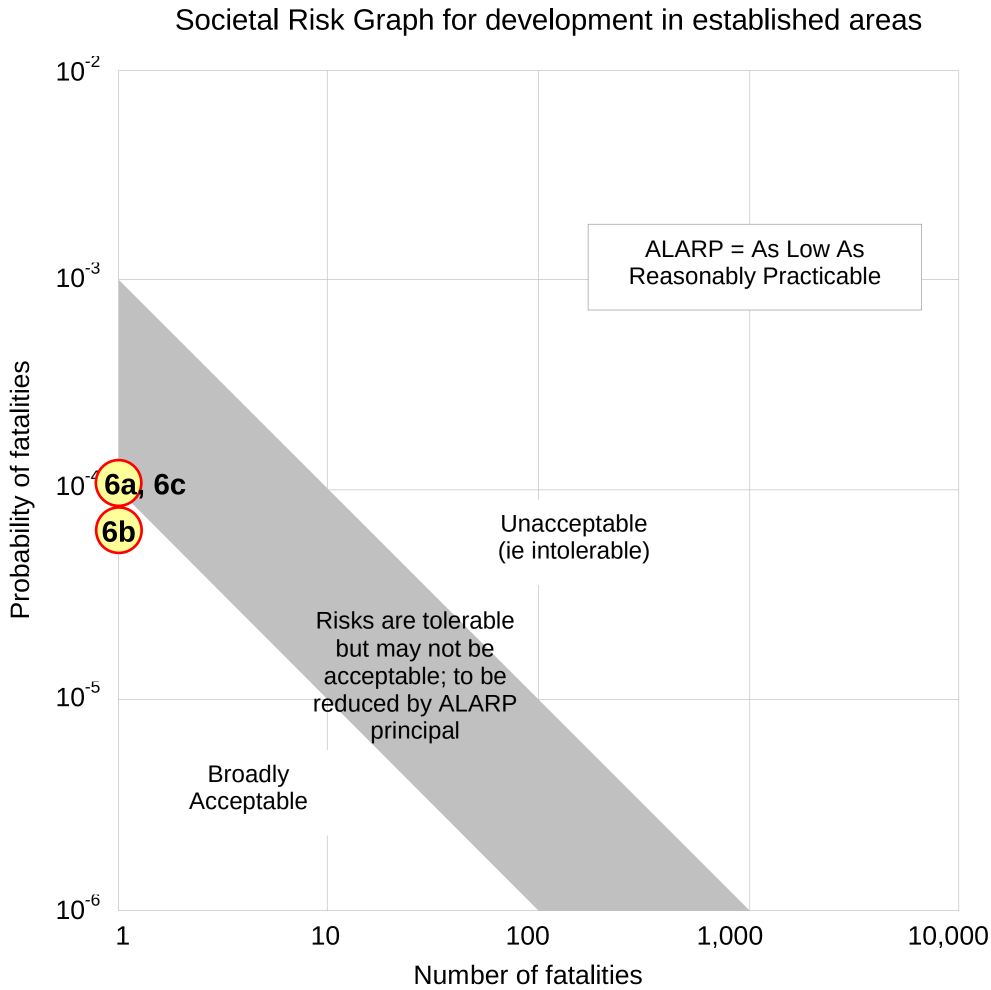


Figure 10.7 **Societal Risk Graph showing the estimated individual risks for a rock fall in an unsupported excavation at the rear of a house.**

General comments on suggested risk mitigation actions

Accepting the risk

Risks to property assessed as Moderate or above (Scenarios 2, 3, 4 and 6) ought not to be Accepted, but instead should be treated.

Risk to an individual life for Scenario 6, as Broadly Acceptable – Tolerable for the person most at risk, ought also to be treated.

Avoiding the risk

Avoiding the risk by not developing parts of Lot 47 is possible and acceptable. This treats Scenarios 2 and 3. Creating a buffer between landslide #864 and upslope development treats Scenario 4. Avoiding the risk of Scenario 6 by not excavating at house sites on hillsides is preferred, but not essential.

Reducing the frequency of the risk

Reducing the frequency of the risk by not excavating at house sites on hillsides is preferred, but not essential. Reducing the frequency can be achieved by retaining walls and reducing batter angles in oversteepened soil exposures.

Reducing the consequences of the risk

Reducing the consequences of the Scenario 6 risk can be achieved by reducing batter angles, and/or installing drained, engineered retaining walls, on all artificially steepened cuts.

Monitoring the risk
Unnecessary

Transferring or postponing the risk
Unnecessary

Suggested risk mitigation plan

General comment
Developers and property owners ought to be familiar with the examples of good and bad hillside construction practices outlined in the AGS Geoguides cited earlier, and included here in Attachment 11.

Site-specific recommendations
For the specific development of Lot 47 considered in this report, all the good hillside construction practices in Attachment 11 apply, together with the following (most of which are intended to treat identified risks):

Restricted area for residential development of Lot 47
Residential development (houses, garages, sheds, swimming pools, access drives and related infrastructure) shall be restricted to the building envelope labelled Area A in Figure 10.5.

Residential development shall not occur on Landslide #874 or within a 20m wide buffer zone extending upslope from its headscarp (Areas C and B respectively in Figure 10.5) or on, and downslope to Ross Rivulet from, the steeper, undulating ground on the northern hillsides of Lot 47 (Area D in Figure 10.5).

Excavations
Minimise the number and height of excavations, including driveway accesses and house excavations.

For excavations less than 0.8m high, create a batter angle in the soil profile no steeper than 1:2. Install a surface cut-off drain upslope and divert surface runoff to one or both sides of the excavation. Bedrock exposed in the excavation may be left subvertical, but any loose cobbles, boulders and joint fragments should be removed. Consider the use of erosion control blankets and revegetation on battered soil faces

For excavations higher than 0.8m, install drained, engineered retaining walls on appropriate foundations to a suitable height, and where surface soil remains exposed above the wall, create a batter angle in the soil profile no steeper than 30^0. Bedrock exposed in the excavation behind the wall may be left subvertical, but the wall must be designed to resist lateral movement of material behind it. Install a surface cut-off drain upslope and divert surface runoff to one or both sides of the excavation.

Variations to these specifications (for example, steel screen cover on rock faces, soil or rock berms, steel mesh fencing) are permissible provided they are engineer-designed and certified, the slope stability of the artificially steepened slope is not compromised, and the risks to property and life both remain Acceptable.

Use of fill
Where its use is unavoidable, fill shall be placed after the underlying soil is first removed, with unsupported batter angles no steeper than 1:2. Its use as a weight-bearing material should be avoided unless it is placed in a controlled manner.

Surface drainage
Control all natural surface runoff and concentrated runoff from roofs, hardstands and rainwater tank overflows. Discharge to Council's stormwater system. Avoid discharging drainage over or into excavations.

Stormwater shall be piped in flexible pipework laid in trenches down (not across) the slope and extended (where unavoidable) through landslide #874 to discharge points in Ross Rivulet. Wherever possible, services from access roads downslope to houses shall be laid in trenches aligned directly up and down the slope, but backfilled with on-site subsoil (not screened gravel) to avoid creating permeable pathways for seepage water to accumulate at house footprints.

Subsurface drainage
All subsurface drainage from retaining walls or house pads shall be directed to stormwater pipework and not be permitted to discharge to the ground surface.

House foundations
All house sites shall be investigated and classified in accordance with AS2870:2011 *Residential slabs and footings*, and by a suitably qualified practitioner (or practitioners) having due regard to the slope stability issues discussed in this report. AS2870 classifications should refer to this report. Hobart City Council shall ensure this report, or a reference to it, is available on line for all stakeholders.

It is strongly recommended that (a) subsurface investigations for site classification be done by excavator to help distinguish stable sandstone bedrock from floaters (some pockets of bedrock are present in colluvium), and (b) footings for all houses in Lot 47 be supported on piers extended into (not onto) demonstrable Triassic sandstone bedrock This will mean footing depth is likely to vary across the footprint of a house.

Adherence of this LRM to AGS (2007)

Table 10.4 lists the items required by AGS (2007c) to be addressed in LRM. Comments are included as to the relevance of the item to the current job, whether or not it has been addressed, and if not, why not. (The column "Adequacy in relation to job" is included and retained for the use of peer reviewers)

Table 10.4 Checklist for this landslide risk management

Item		AGS (2007) reference 2007c	AGS (2007) reference 2007d	Relevance to this job	Addressed in geotech report?	Adequacy in relation to job	Comments
Desktop		5.1	C5.1	Essential	Yes		Attachments 1, 2, 3,4, 5, 6 of this report. Includes review of historic satellite imagery, www.thelist.tas.gov.au topo and cadastre maps, MRT1:25,000 geology map, landslide hazard bands, landslide hazard maps
Site investigations	Inspection	5.2.2	Tables C1, C2	Essential	Yes		Several times in May and June 2014
	mapping (geomorphic)	5.2.2	Tables C1, C2	Essential	Yes		1995 report by W.C. Cromer
	mapping (geology)	5.2.2	Tables C1, C2	Essential	Yes		
	boreholes	5.2.3	Tables C1, C2		No		Test pits 1995; 100+m trenches May 2014
	test pits	5.2.3	Tables C1, C2	Either or both desirable to essential	Yes		1995 report by W.C. Cromer
	groundwater levels etc	5.2.4	Tables C1, C2	Desirable	No		No groundwater encountered except at lower endd of Trench D. No other data available. Relied on first principles re groundwater occurrence.
	cross sections	5.2.5	Tables C1, C2	Essential	Yes		See Attachment 10
	slope processes	5.2.6, 5.2.7	Tables C1, C2	Essential	Yes		1995 report by W.C. Cromer
	landslide location(s)	5.2.7	Tables C1, C2	Essential	Yes		1995 report by W.C. Cromer, Attachments
	conceptual geotech model	5.2.7	Tables C1, C2	Essential	Yes		See Attachment 10
Site plan		5.1		Essential	Yes		Several Attachments

Table 10.4 (continued)

RISK MANAGEMENT	RISK ASSESSMENT	RISK ANALYSIS	HAZARD ANALYSIS	Landslide characterisation	History of movement; current movement, velocity	5.3	Table C1(4)	Essential	Yes		See Attachment 10
					Geotechnical characterisation	5.3, Tables B1, B2, Fig B3	Table C1(5)	Essential	Yes		
					Landslide mechanisms, dimensions	5.3, Tables B1, B2, Fig B3	Table C1(6)	Essential	Yes		
					Shear mechanisms, strength of rupture surface	5.3, Tables B1, B2, Fig B3	Table C1(7)	Desirable	No		
					Assessment of stability	5.3, Tables B1, B2, Fig B3	Table C1(8)	Essential	Yes		
					Assessments of deformation, travel distance	5.3, Tables B1, B2, Fig B3	Table C1(9)	Desirable	Yes		
				Frequency analysis	Historical analysis	5.4.1b)	5.4.1(ii)	Essential	Yes		
					Empirical ranking method	5.4.1c)		Discretionary	No		
					geology/geomorphology	5.4.1d)					
					Rainfall/slope analysis	5.4.1e)	5.4.1(iii)				
					Probabilistic analysis	5.4.1f)					
					"Degree of belief"	5.4.1g)	5.4.1(iv)				
					Explanation of applied logic to frequency analysis						
					Use of event tree	5.4.1h), i)	5.4.1(v)				
					Est of annual probability	5.4.2a), b), c)	5.4.2a), b), c)	Essential	Yes		
			CONSEQUENC E ANALYSIS	Consequenc e anal	Elements at risk	6.1		Essential	Yes		
					Temporal spatial probability	6.2	C6.2	Essential	Yes		
					Consequence to property	6.3	C6.3	Essential	Yes		
					Consequence to people	6.4	C6.4	Essential	Yes		
				Risk estimation	Quantitative risk estimation to property	7.1	C7.1	Discretionary	No		
					Quantitative risk estimation to life	7.1	C7.1	Essential	Yes		
					Semi quantitative and qualitative risk estimation to property	7.2	C7.2	Essential	Yes		
					Risk matrix for property loss	7.3	C7.3	Discretionary	No		
				Risk assess	Risk evaluation against tolerable criteria for property loss	8.1, 8.2	C8.1, C8.2	Discretionary	No		
					Risk evaluation against tolerable criteria for loss of life	8.1, 8.2	C8.1, C8.2	Essential	Yes		
				Risk mitigation	Accept the risk	9.1.1a)	C9.1	Discretionary	Yes		
					Avoid the risk	9.1.1b)	C9.1	Discretionary	Yes		
					Reduce the frequency	9.1.1c)	C9.1	Discretionary	Yes		
					Reduce the consequences	9.1.1d)	C9.1	Discretionary	Yes		
					Monitor the risk	9.1.1e)	C9.1	Discretionary	Yes		
					Transfer the risk	9.1.1f)	C9.1	Discretionary	Yes		
					Postpone the decision	9.1.1g)	C9.1	Discretionary	Yes		
					Risk mitigation plan	9.1.3		Essential	Yes		

Certificate of currency for Professional Indemnity Insurance

A copy of the certificate of currency for PI insurance for William C Cromer Pty Ltd is included here as Figure 10.8.

Figure 10.8 Certificate of currency for PI insurance for William C Cromer Pty Ltd

Certificate Of Currency

Liberty International Underwriters

This Certificate confirms that the undermentioned Policy is effective on the date of issue and in accordance with the details shown:

Class of Insurance	Professional Indemnity Insurance
Policy Number	MI-BN-SPC-03-110365
Named Insured	WILLIAM C. CROMER PTY. LTD.
Policy Period	From: 31 August 2013 at 4:00pm local standard time To: 31 August 2014 at 4:00pm local standard time
Limit of Liability	$1,000,000
Excess	$10,000
Policy Wording	LIU AUS OQS PI Construction Consultants Policy Wording (03-11)
Retroactive Date	31 August 2004
Authorised by Liberty	LIBERTY MUTUAL INSURANCE COMPANY A.B.N. 61 086 083 605 [signature]
Date Of Issue	31 August 2013

This Certificate:
- Is issued as a matter of information only and confers no rights upon the holder
- Does not amend, extend or alter the coverage afforded by the policy listed
- Is only a summary of the cover provided
- Reference must be made to the current policy wording for full details
- Is current at the date of issue only

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Liberty International Underwriters is a trading name of Liberty Mutual Insurance Company (ABN 61 086 083 605). Incorporated in Massachusetts, U.S.A.
(The liability of members is limited)

Attachment 11

(3 pages)

Examples of good and poor hillside engineering practices

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.

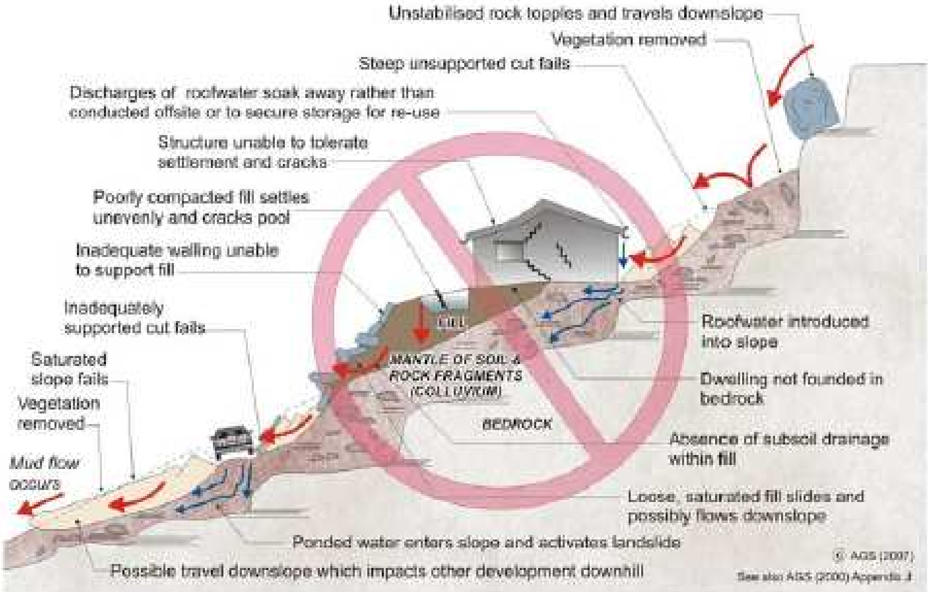
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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.

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	