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ENVIRONMENTAL, ENGINEERING AND GROUNDWATER GEOLOGISTS

ECOAST HOMES PTY LTD

PROPOSED 76 – LOT SUBDIVISION
PENQUITE ROAD, NEWSTEAD

GEOTECHNICAL ASSESSMENT

Cover photo View looking west from test pit B near Penquite Road, towards the former Eastman (Scotch College) Oval on the flood plain of Kings Meadows Rivulet.

Refer to this report as
Cromer, W. C. (2008). *Geotechnical assessment, 76 – lot subdivision, Penquite Road, Newstead.* (Unpublished report for ECoast Homes Pty Ltd by William C. Cromer Pty. Ltd., 7 April 2009; 137 pages)

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

BACKGROUND

A 76-lot residential subdivision is proposed for about 6ha of land off Penquite Road, Newstead. Development will include substantial relocation of on-site materials involving excavation on higher slopes, and filling of low-lying areas.

GEOLOGY AND SOILS

The property is mostly underlain by Tertiary sediments including weakly cemented sandstone and fissured claystone. Soils on these materials are duplex profiles of nonplastic sandy silt and slightly plastic clayey silt topsoil over plastic, slightly to moderately reactive clay subsoil.

Low lying parts on the property on the flood plain of Kings Meadows Rivulet are underlain by Quaternary alluvium over Tertiary sediments. Parts of the alluvium are low strength.

SLOPE STABILITY

In terms of Launceston Landslide Zoning, the property includes Classes II, III and IV. The Mineral Resources Tasmania Landslide Hazard mapping shows that the higher, western parts of the proposal include both a fossil or old dormant landslide zone, and a fossil or old dormant landslide.

There is no evidence of current instability.

LEVELS OF GEOTECHNICAL RISK

Most risks associated with applicable geotechnical issues are rated as Very Low, Low or Moderate. Slope instability is rated as a Low to Moderate risk. Issues which generate High or Very High risk are associated with potentially reactive soils, low strength materials, and vegetation removal. A range of recommendations is provided to help manage the risks.

MAIN RECOMMENDATION

The property is conditionally capable of supporting the proposed residential development, which should proceed subject to the recommendations in this report.

1 INTRODUCTION

1.1 BACKGROUND

ECoast Homes Pty Ltd proposes a 76-lot residential subdivision on about 6ha of land off Penquite Road in Newstead (Attachment 1).

William C Cromer Pty Ltd was commissioned by the client and engineer M. Van Der Molen to prepare a geotechnical assessment of the property, with particular reference to the risk of slope instability in relation to residential dwellings.

1.2 BASIS OF ASSESSMENT

This report is based on:

- a review of available reports, and regional-scale geological and related maps,
- discussions with Mr C. Mazengarb, Senior Geologist, Mineral Resources Tasmania (MRT),
- geotechnical investigations of the property on 17, 18 and 25 February, 2009, including a visual inspection and photographic record of the general neighbourhood,, and, on the property, inspection and photography of the soils, drainage, topography and geology, geological and topographic mapping, and the digging, logging, sampling and photography of 17 excavator test pits,
- shrink swell testing of eight undisturbed soil samples,
- laboratory testing of a selected sample for strength parameters, and
- office assessment of field data and a geotechnical risk assessment.

Where applicable, this report is in general accordance with the following guidelines and Australian/New Zealand Standards:

- Tasmanian Local Government guidelines for site and soil evaluations (wastewater) and geotechnical (slope stability) investigations (eg Attachment 1)
- Australian Geomechanics Society (2007). *Landslide Risk Management*
- Institute of Engineers Australia Tasmania Division (1996) *Recommended Practice for Site Classification to AS 2870 in Tasmania*
- AS4055 – 2006 *Wind loads for housing*
- AS1726 – 1993 *Geotechnical Site Investigations*
- AS2870 – 1996 *Residential Slabs and Footings – construction*
- AS/NZS4360 – 2004 *Risk Management*

This is a summary report supported by Attachments 1 – 14. The Attachments are an integral part of the report and shall not be separated from it.

2 PREVIOUS RELEVANT INVESTIGATIONS

All available geotechnical information relevant to the proposed subdivision is contained in unpublished correspondence and reports held by Mineral Resources Tasmania (MRT; formerly Mines Department Tasmania, MD), and on published MRT maps.

2.1 MINES DEPARTMENT LANDSLIDE ZONING MAPS

These maps were published in the 1970s to aid residential planning and development in Launceston and similar areas affected by slope instability. Five landslide zones were recognised:

Class V	Active landsides and adjacent areas No building without specialised investigation and design
Class IV	Old landslides and adjacent areas No building without specialised investigation and design
Class III	Potential landslide areas Building methods in accordance with a special code
Class II	Stable ground, but on soft rocks Strict adherence to existing building code
Class I	Stable ground on hard rocks No abnormal problems or risks

In the Launceston area, Class 1 (stable) is restricted to areas underlain by Permian sedimentary rocks or Jurassic dolerite. Class II (stable) differs from Class III (suspect) by slope angle: the former is on slopes less than 7^0, and the latter on steeper slopes.

ECoast's proposed subdivision at Newstead includes land in Zones II, III and IV. See Attachment 5 for the portion of the Landslide Zoning Map covering the proposed subdivision.

2.2 UNPUBLISHED MRT CORRESPONDENCE AND REPORTS

A search was conducted of MRT unpublished geotechnical material dating back to the 1970s, covering mainly the Newstead-Norwood-Queechy areas. It includes letters to and from consultants, lawyers, municipal councils and members of the public, as well as several Unpublished Reports prepared by MRT geologists. The latter are freely available on line at www.mrt.tas.gov.au.

Most of the offline letters, etc. were found not to be directly relevant. However, several reveal that slope instability or foundation problems were well recognised in the Newstead area in the1970s:

March 1974: Unpublished Report 1974/15. *Test pits near the intersection of Queechy Road and Penquite Road*, by W.L. Matthews
Two pages with summary logs of three test pits. Six residential flats were proposed in a single building, on land sloping between 5 to 15^0. The land to the south steepened up to the 30m high terrace on which Queechy High stands today. The terrace comprises quartz gravel, clay and sand over Tertiary-age sediments including partly consolidated lithic sand and clay. These materials were also exposed in fresh cuttings on Penquite Road, where sand makes up about half the exposed material, with interbedded clay seams dipping 23^0 to 105^0M. The report also stated :"Good exposures of the sand beds can also be seen along the access road to Scotch College recreation ground, about 200m to the north-west of the property."

On page 2, the report commented that:

- the nearest landslides to the property were about 500m north, on the ridge leading down to the flood plain of the North Esk River,
- small slumps in clays on 45^0 batters have occurred in road cuttings in Penquite Road,
- "the presence of partly consolidated sand and stiff clay suggests that the material has the capacity to bear the proposed building",
- "any slip surface which might develop around the excavation (*for the flats*) would probably extend below the depth of the planned excavation",
- "It is recommended that two or three cored drill holes or auger holes with undisturbed sampling …..be drilled to depths of 10-15m." and
- "Any fill deposited on the land should be left at a low angle."

<u>My comments</u>

- The partly consolidated sand referred to is in the present report called weakly cemented sandstone.
- The Scotch College recreation ground is presumably the former Eastman Oval, on the present subdivision. In the early 1970s, exposures of sand or sandstone along its adjacent access road were apparently more obvious than now.

July 1974: 149 and 151 Penquite Road, on the Queechy Road intersection
The properties were to be proclaimed "Landslide B", (equivalent to the later Landslide Zone IV).

February 1975: Unpublished Report 1975/18. *Damage to a house at Ellison Street, Punchbowl, Launceston*, by I. B. Jennings
Three pages, with summary logs of three auger holes, one analysis of seepage water. The 1-year old house at 1 Ellison Street suffered damage to brickwork and a garage floor. Cracks had recently been repaired, and foundations underpinned, but damage continued. Water continued to lie under the house behind the garage, and was reportedly found during underpinning. Cracked brickwork was common on other houses in the vicinity, including newly constructed ones.

The auger holes were drilled to between 3m and 6m, intersecting moist plastic and fissured clay. One hole made water overnight. The report (page 2) observed:

- "The house is built on Tertiary clay which is fissured and in places contains thin 'sandy' layers or lenses which appear to carry groundwater.", and
- "The construction of the house and its accompanying paths and driveways has changed the near-surface moisture content of the clays significantly and erratically throughout the block."

In general comments, the report noted the widespread occurrence of 'cosmetic' damage to houses, and suggested it would be less obvious if houses were built of flexible, lightweight materials instead of traditional brick veneer construction.

<u>My comments</u>

- In February 2009, a brief inspection of houses in Thelma Street and Penquite Road showed that cosmetic and sometimes reportedly more serious structural damage to brick veneer houses affects perhaps a quarter of all dwellings.

July 1979: 24 Thelma Street.
Inspected by MD. A 2.5m high, 35-40^0, unsupported cutting 12 years old exposed silty sands interbedded with clay. No undue risks to house.

October 1979: Lots 32 and 33 Punchbowl Road
Inspected by MD. Minor slipping, but upper, level parts of lots suitable for building.

November 1979: 128 Penquite Road
MD response to a slope stability query was that there was no history of landsliding on the property, which was Class III land

December 1979: 161 Punchbowl Road and 1 Ellison Street
Inspected by MD. Houses on both lots had suffered damage from reactive clays.

December 1979: Unpublished Report 1979/51. *Foundation conditions at Norwood House*, by D. J. Sloane
17 pages including nine pages of engineering logs of auger holes, a geotechnical fact map, summary logs, and a table of engineering properties of materials.
Topographically, the property containing Norwood House includes an almost flat flood plain of the North Esk River, a steep slope rising inland at about 25^0, and a flat plateau area considered suitable for development. The plateau is underlain by at least 29m of Tertiary sediments, the uppermost ones of which include clay, sandy clay and clayey sand. The clay has high plasticity and liquid limit, and linear shrinkage.

Active landsliding was occurring on the steep slope. The landslide was a headscarp failure of an older landslide. It was caused by water issuing from a clayey sand aquifer at a depth of about 13m below the plateau.

In a deeper auger hole on the property, sandstone was encountered beneath clays at the base of the steep slope, and near the Norwood sewerage treatment plant, laminated feldspathic sandstone with plant fossils is exposed.

The report stated (page 7) that it was undesirable to develop the steep slope, and that remedial measures should instead be undertaken to reduce landslide risk. These included revegetation, and drainage.

My comment

- Some of the laboratory results for material properties are included in Table 12.2 of Attachment 12 of the present report.

May 1980: Proposed subdivision off Thelma Street
Land presumably then belonging to Scotch College and forming part of the present proposal was in 1980 intended for a 13-lot subdivision. No geotechnical information was provided.

April 1984: Unpublished Report 1984/23. *Stability assessment of a proposed subdivision at Beverley Hills Road, Punchbowl, Launceston*, by P. C. Stevenson
10 pages including a geotechnical fact map, and summary and engineering logs of seven test pits
The 3.3ha of land was between Punchbowl Road and Ellison Street, and comprises Tertiary clay, “Soft sandstone” and thin ironstones. Test pits were dug up to 3.6m deep. One pit intersected “weak sandstone” and all others exposed high plasticity, highly reactive clay.

The report noted that house damage from soil shrinkage was common in the immediate vicinity, and suggested parts of the proposed subdivision not be developed unless specialised investigation and design demonstrates otherwise.

August 1984: Unpublished Report 1984/58. *Stability assessment of the Leichhardt subdivision proposal*, by P. C. Stevenson
9 pages including two maps, and four slope stability scenarios analysed by Bishops Method.
This 100ha land parcel at Relbia is outside the immediate area of interest for the present proposal, but is included because it encompassed a range of landforms including active landsliding of Tertiary clays on slopes ranging from 10 to 25^0. Some failures occurred on artificial, oversteepened slopes along the railway line.

The slope stability assessments included assumed soil properties instead of actual laboratory results.

August 1984: Unpublished Report 1984/59. *Subsurface movement in expansive clay: An alternative explanation for house cracking at Sandown Road, Launceston*, by W. R. Moore
16 pages including two maps and a cross section, two tables of material properties, an engineering log of a test trench, and two slope stability scenarios analysed by Bishops Method.
A trench was dug at Block 23, Sandown Road (off Queechy Road, Newstead) to investigate house cracking thought to be triggered by the "prolonged drought of 1982 – 1984."

The occurrence of cracked houses was "scattered", which is not inconsistent with shallow foundation movement but is inconsistent with landsliding.

Block 23 has a slope of 15^0, thought to be close to the critical angle for slope failure in Tertiary clay in the Launceston area. Inputs to slope stability analysis included an angle of friction of 20^0, cohesion of 7kPa, and bulk density of 19kN/m^3. Two scenarios were modelled: a short slope over the property, and a longer slope. With the long slope, "failure was only likely with a deep-seated slip plane in which the pore pressure was high (near total saturation with water) at the surface." Similarly, failure was only induced on the short slope with a deep-seated failure surface.

The report added (pages 9 and 10):

- "…Sandown Road and much of the spur is a stable slope."
- "A sandy clay lens has been observed …in Queechy Road….and similar sediments have been reported…from nearby Norwood…They are probably the main geological reason for many of the steeper slopes not failing around the Sandown and Queechy Road area."

and concluded (page 11):

- "The presence of a sandy clay lens or bed in the Tertiary clay would add stability to the area and make a deep slip circle type of failure unlikely. Shallow translational movement is the potential risk."

<u>My comment</u>
The current proposed subdivision includes Tertiary claystone interbedded with weakly cemented lithic sandstone. The latter is also regarded as significantly reducing the risk of deep-seated slope failure.

November 1984: Unpublished Report 1984/78. *Slope stability of a proposed subdivision, Queechy Road, Launceston,* by W. R. Moore
5 pages including three maps.
A block of land at 2 Queechy Road at the foot of the Queechy scarp was proposed for subdivision into two lots. Slope angles ranged from 10 to 25^0, with most of the property in the 20-25^0 range. Despite the steepness, no major failures have occurred. Some translational failures have caused house cracking in the area.

Building on the steeper slope would require expensive site investigation, which was probable prohibitive.

March 1990: Scotch College Staff Resource Centre
Inspected by MD. A three page report was prepared, for steep land east of Penquite Road.

2.3 MRT LANDSLIDE SUSCEPTIBILITY MAPPING SERIES

In 2004 and 2005, MRT published a series of landslide susceptibility maps of the Launceston district. See Attachment 5 for a detailed discussion of the maps and how they apply to the proposed subdivision.

3 SITE DESCRIPTION

3.1 TOPOGRAPHY AND PAST CHANGES TO NATURAL TOPOGRAPHY

The proposed subdivision (Attachments 3 and 6) has a relief of about 45m and includes several slope segments separated by changes of slope, as follows:

The flat area on the western flood plain of Kings Meadows Rivulet.
This area (Plates 1 and 2 in Attachment 9) was the former Eastman Oval, which was built decades ago using silty clay fill placed over alluvial clays. At least some (if not all) of the fill was presumably excavated on site to produce the relatively steep embankment around the northern and western sides of the oval (the 1947 aerial photograph in Attachment 4 shows the embankment is not a natural feature.

Quite recently, similar silty clay fill has been imported and placed over part of the former oval, to depths of up to about 3m (Plates 3, 4 and 5 in Attachment 9). Placement was apparently not done in an engineered (controlled) manner, so settlement and consolidation is most likely occurring. Mapped as Landslide Zone Class II (Attachment 4).

Embankment around the former oval
Arcuate, narrow, oversteepened to around 25 – 30^0 by excavation for the adjacent oval; widening to the south onto natural slopes of around 15 – 17^0. Not separately mapped as a Landslide Zone Class.

Intermediate slopes north and west of the former oval
This arcuate area ends at the break of slope of the embankment. Slope angles in the range 5 – 10^0, extending upslope to the Thelma Road boundary. Locally modified by the dumping of truckloads of inert fill (Attachment 6, and Plate 7 in Attachment 9) and excavation for the access road for Eastman Oval. Mapped as Landslide Zone Class III (Attachment 4).

Slopes greater than 10^0
Slope angles steepen to around 15 – 20^0 along the higher western boundary to the property (mapped as Landslide Zone Class IV), and there are short slope segments between about 11 – 17^0 along parts of the northern boundary mapped as Class III.

3.2 PROPOSED CHANGES TO NATURAL TOPOGRAPHY

It is proposed to alter the existing topography for residential development by redistributing substantial amounts of on-site soil. About three-quarters of the land area will be affected.

The main intentions are shown in Attachment 8, and include:

- The regrading of the former Eastman Oval by raising the low-lying parts by one to two metres (up to 3.5m in the arcuate area along the base of the embankment).
- The filling of relatively low lying areas in the middle parts near the northern boundary. In places, fill will range from 2 – 4m thick.
- The regrading and filling of the existing access road around the northern part of the former Eastman Oval.

All or most of the fill will be derived from on-site excavations:

- A substantial cut about 5m high and 100m long along part of the western boundary, supported by an engineered and drained retaining wall. Associated with this is a regrading of the hillside east of the wall, involving the removal of several metres of material near the wall, decreasing to a one-metre thick layer furthest downslope.

- A similar cut about 75m long along part of the northern boundary. Similarly, the hillside below the wall will be stripped of at least one metre of material.

3.3 DRAINAGE, FLOODING AND EROSION

Drainage
Kings Meadows Rivulet flows across a flood plain in a present-day channel south of the proposed subdivision.

An intermittent creek, now partly filled in, interrupted by the construction of Thelma Street, and captured as stormwater on the oval's access road, once flowed from the northwestern corner of the property towards the rivulet.

Flooding
A flood analysis of Kings Meadows Rivulet is outside the scope of this report, but it is presumed that the filling of the former Eastman Oval by one to two metres of soil has addressed any potential issues.

Erosion
No evidence of substantial surface or tunnel erosion was noted during site inspection or test pitting. It is inferred from this that soils are not dispersive.

3.4 BEDROCK GEOLOGY

On published geological maps
See Attachment 2. Bedrock on the published map is Tertiary-age sediments including clay, silt, sand and clayey sand with rare lignite and gravel horizons and lenses.
Source
Calver, C. R. and Forsyth, S. M (compilers) (2005). Map 3, Launceston – Geology. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania.

From site inspection
Investigations broadly support the published geology. See Attachment 7 for my geological interpretation of the property, and Attachment 11 for a detailed description of the geology and soils of the site.

<u>Tertiary sandstone and claystone</u>
The main observation is that weakly cemented lithic Tertiary sandstone crops out near Eastman Oval, and was encountered in all but three of the 17 test pits dug. The pits were at elevations ranging from 10 – 40mASL. The sandstone has variable dips and dip directions (the latter generally unrelated to present day topography), and the inference is that it is volumetrically the dominant rock type in the immediate area. At least two, and possibly many, separate beds or units, are present, interbedded with claystone. Claystone was also exposed in 10 of the 17 test pits.

<u>Quaternary alluvium</u>
Dark coloured and plastic organic clays of variable strength were exposed in test pits J and K beneath Eastman Oval. The material is interpreted as alluvium deposited on the flood plain of Kings Meadows Rivulet.

3.5 Soils

See Attachment 11. Soils on the Tertiary sediments are duplex (two-layered) and probably in part colluvial, and include:

- A topsoil (A horizon) about 0.5m thick of light coloured sandy silt (SP) or clayey silt (SP), and
- A darker, high plasticity, fissured subsoil of slightly reactive clay (CH), sandy clay (CL) or silty clay (CH) about a metre thick.

See Section 3.10 and the detailed discussion in Attachment 11 for comments on soil reactivity.

Soils on alluvial clay are uniform organic, plastic clay (CH).

3.6 Fill

Large volumes of uncontrolled fill are present on site. Three types are recognised:

- Type 1 on the floodplain of Kings Meadows Rivulet to construct the former Eastman Oval,
- Type 2 on Type 1 fill on the northern and western half of the former oval, and as separate stockpiles of loam, and
- Type 2 Inert fill as localised truckloads elsewhere

Type 1 and 2 fill is mainly moderate plasticity orange brown silty clay (CL, CH).

3.7 Summary of Material Types

Five different *in-situ* materials are identified on site:

- Unit 1 Topsoil
- Unit 2 Subsoil including minor colluvium
- Unit 3 Quaternary alluvium
- Unit 4 Tertiary claystone
- Unit 5 Tertiary sandstone (including minor laterite and granule conglomerate)

and three types of uncontrolled fill (1, 2 and 3; see above) are recognised:

3.8 Strengths and Bearing Capacities of Materials

See the engineering log sheets in Attachment 10, and the comments in Attachment 11.

No fill type currently has adequate bearing capacity for residential dwellings. The Quaternary alluvium beneath the Type 1 and Type 2 fill on the floodplain of the Kings Meadows Rivulet also as variable strength and locally inadequate nearing capacity, and may still be subject to consolidation and settlement.

All other materials, with the local possible exception of the surface 0.1 – 0.2m or so of Unit 1, have adequate bearing capacities for residential dwellings.

3.9 GROUNDWATER

See Attachment 11. Traces of shallow seepage water was observed entering test pits J and K on the flood plain of Kings Meadows Rivulet, at depths between 2 and 2.8m. It is expected that the water table throughout the flood plain is at depths less than 2m. All other tests pits were dry.

It is also expected that deeper groundwater is present in the Tertiary sandstone and claystone throughout the district, and that it flows generally east towards the floodplain of North Esk River about 0.5m east.

3.10 GENERAL COMMENTS ON AS2870 SITE CLASSIFICATIONS FOR FUTURE HOUSE SITES

See Attachment 11 for a detailed discussion, which provides site classifications in terms of AS2870 for each test pit site and the present day topography. The classifications are based on shrink-swell testing of eight subsoil clay samples. The observations are:

- On current undisturbed slopes, classifications range from Class S to Class E.
- On areas underlain by Type 1, 2 or 3 fill, Class P is appropriate.
- Where slope modifications for development remove existing soil, classifications might range from Class A to Class E depending on the exposed materials and their thicknesses.
- Where slope modifications involve fill, classifications ought to be Class P everywhere the fill is more than about a metre thick, irrespective of its texture or whether or not it has been placed in a controlled manner.
- Footings for buildings on Class H, E or P sites should be certified by a suitably qualified engineer experienced in footing design.

These are general comments intended as a guide only, and do not replace the need for site specific investigations and classifications for the footprint of every new house in the subdivision.

3.11 HISTORY OF SLOPE INSTABILITY

Documented
The northwestern part of the proposal is shown as being in Landslide Zone Class IV ("Old landslides and adjacent areas" see Section 2.1 and Attachment 4), and as including both a "Fossil or old dormant landslide" and a "Landslide Zone fossil or old dormant" on the 2005 Landslide Inventory map of Launceston (Attachment 4).

These inclusions are based mainly on topographic evidence and presumably site inspection. A search of Mineral Resources Tasmania records did not discover any reports of more detailed and site-specific subsurface investigations on or near the property.

From site inspection
The current site investigations confirm that there is inconclusive topographic evidence suggestive of large scale slope instability on parts of the steeper western slopes of the proposal. The evidence is that the western hillside and its extension north and then east towards and past the Thelma Road cul-de-sac, forms a broad amphitheatre backed locally be a gentler slope at the rear, and so could be the head region of a large old landslide. This area also corresponds roughly to the fossil or old dormant Landslide Zone shown in Attachments 5, 6, 7 and 8. Also, along the southern boundary

between test pits P and Q, there are topographic changes of slope suggestive of former movement. This area lies within the fossil or old dormant landslide shown in Attachments 5, 6, 7 and 8.

Slope instability, if it occurred at all, is inferred to have taken place perhaps thousands of years ago under a climatic regime different from the present. The inferred large scale of instability suggests that any failure zones would probably be deep-seated, and deeper than excavator test pitting could reach. (Test pitting for the present investigations with a 20t excavator was depth limited to around 4m or so, and up to 6m on pre-existing embankments. It has not revealed any subsurface evidence of instability.)

Diamond drilling is recommended on the western parts of the proposed subdivision to explore further the hydrogeology of the area, including the possibility of deep-seated materials which might contribute to instability, or might enhance stability.

3.12 CURRENT RISK OF SLOPE INSTABILITY

As far as I am aware, there is no history of recent slope instability on the proposed subdivision, or affecting the surrounding residential area. Inspection of stereographic pairs of 1947 aerial photographs (Attachment 4) did not reveal any obvious signs of instability.

Artificially oversteepened but unfailed slopes are evidence of inherent stability. For example, the 25 – 30^0 embankment around the northern side of the former Eastman Oval, and the cutting along the northern side of the access road to it, both show no signs of instability, and are presumably several decades old. The former is underlain mainly by weakly cemented sandstone which in test pits L and M both overlies and underlies fissured claystone. The latter in pits A and N comprises similar sandstone over fissured claystone. In both instances, excavation has removed support from the toe of the slopes behind, without producing instability.

Current risks have been assessed in Attachment 12, which contains detailed slope stability assessments for several scenarios on three cross sections down the steeper, western side of the proposed subdivision, and also for various more general scenarios at a potential house site. The assessments used a range of reasonable inputs for:

- Slope surface (before and after slope modification)
- Phreatic or piezometric surface
- Material types
- Material properties
- Material profiles in the subsurface
- Postulates of failure surfaces, and if appropriate,
- Modifications to the model

Table 1 summarises the results of the analyses. Figure numbers refer to those in Attachment 12. The main conclusions of these analyses are:

- The existing slope on cross section A – B is at moderate risk of failure from a relatively shallow seated failure surface (Figure 12.3).

- Deep-seated failure is most unlikely assuming the hillside is underlain only by weakly cemented sandstone (Figure 12.5).

- Deep-seated failure is likely assuming the hillside is underlain only by fissured claystone (Figure 12.10).

- The proposed slope modifications slightly enhance slope stability (Figures 12.4, 12.8)

- Cut and fill at sloping house sites might result in small-scale failure at the top of unsupported cuts, and there is a moderate risk of failure if houses are built on fill (Figures 12, 13 and 14)

Table 1 Summary of slope stability assessments

Figure	Scenario	Critical FS*	No. circles analysed	Comment
12.3	Cross section A – B. Stability of existing slope from the western property boundary to near the break of slope at about 100m distant. Multiple analysis.	1.43	755	Moderate risk of failure
12.4	Cross section A – B. Stability of modified slope from the western property boundary to near the break of slope at about 100m. Modifications include cut and fill as shown in Attachment 8. Multiple analysis.	1.53	755	Low risk of failure
12.5	Cross section A – B. Stability of existing slope from the western property boundary to near the break of slope at about 100m. Single analysis, with deep-seated failure surface.	2.77	1	Low risk of failure
12.6	Cross section C - D. Stability of existing slope from the western property boundary to near the break of slope at about 100m. Single analysis, with deep-seated failure surface.	2.52	1	Low risk of failure
12.7	Cross section C - D. Stability of existing slope from the western property boundary to near the break of slope at about 100m. Multiple analysis.	1.9	755	Low risk of failure
12.8	Cross section C - D. Stability of modified slope from the western property boundary to near the break of slope at about 100m. Modifications include cut and fill as shown in Attachment 8. Multiple analysis.	2.06	755	Low risk of failure
12.9	Cross section E - F. Stability of existing slope from the western property boundary to near the break of slope at about 170m. Multiple analysis.	2.82	755	Low risk of failure
12.10	Cross section E - F. Stability of modified slope from the western property boundary to near the break of slope at about 170m. Modifications include cut and fill as shown in Attachment 8. Sandstone assumed absent; hillside is Claystone only beneath subsoil. Multiple analysis.	1.14	755	High risk of failure
12.11	House site on 20^0 hillside. Natural slope. Multiple analysis.	2.20	807.	Low risk of failure
12.12	House site on 20^0 hillside. Modified slope (1.5m subvertical cut). Multiple analysis.	0.7	501	Lip of excavation has failed.
12.13	House site on 20^0 hillside. Modified slope (1.5m subvertical cut and fill). Multiple analysis.	2.6	1001	Low risk of failure in fill (lip of excavation has failed)
12.14	House site on 20^0 hillside. Modified slope (1.5m subvertical cut and fill; house built). Multiple analysis.	1.4	1001	Moderate risk of failure in fill (lip of excavation has also failed)

*Critical FS = critical (minimum) Factor of Safety

These conclusions support the views of previous Mines Department workers in the district, particularly those of Moore (1984; cited above), who inferred that the lack of deep-seated instability on steeper slopes in the Queechy Road area might be due to the presence of sandy clay lenses interbedded with susceptible clays, and that the main potential risk is instead shallow, translational failure.

On the proposed subdivision, sandy clays are locally present near the surface, and may be interbedded with clays at greater depths. However, a more significant likelihood is that the weakly cemented sandstones exposed near the former oval, and present in almost all test pits, are the dominant rock type present beneath the hillsides. Whether or not they are interbedded with claystones (as suggested in test pits), slope stability is enhanced.

As discussed, these possibilities should be investigated with diamond drilling.

3.13 ON-SITE DOMESTIC WASTEWATER MANAGEMENT

No on-site wastewater assessment is required. The subdivision will be sewered.

4 GEOTECHNICAL RISK ASSOCIATED WITH RESIDENTIAL DEVELOPMENT

4.1 GENERAL COMMENTS

In Table 13.1 in Attachment 13, a range of geotechnical issues has been canvassed for the proposed subdivision. The likelihood of each issue has been assessed, its consequences to property are suggested, the level of risk associated with each is proposed, and where appropriate recommendations are made to treat (manage) the risk[1]. See page 2 of Attachment 13 for an explanation of terms used.

The following paragraphs elaborate on those issues which in Table 13.1 are assessed as presenting Moderate[2], High or Very High risks.

It is stressed that risk assessment is unavoidably subjective to varying degrees, and that the acceptability of any perceived risk might vary between stakeholders.

4.2 ISSUE 1 SURFACE SOIL EROSION

Adequate runoff control will minimise the risks of soil erosion. In this regard it is expected that development will provide appropriate controls on surface runoff from hardstands, roofs, etc., and that the proposed retaining walls supporting the deep excavations along the western and northern boundaries will be engineered and adequately drained, and any seepage water directed to reticulated drains.

4.3 ISSUES 4 AND 5 SHALLOW AND DEEP SEATED LANDSLIDING

The assessment of risks associated with shallow and deep landsliding on the steeper western (and local eastern) slopes of the proposal is based on site observation, test pitting, published susceptibility maps (Attachment 5) and the slope stability risk assessments detailed in Attachment 12.

There is no evidence of current slope instability, and no reports of house damage due to slope instability in the area. Damage to houses in the district (Plates 16 – 20 in Attachment 9, and MRT records and reports) is thought to be due to reactive clay soils.

Attachment 12 shows that there is a Moderate risk of relatively shallow landsliding on natural slopes on the steeper parts of the proposal. Planned slope modifications (removal of at least a mete of soil from the hillside, and loading of its base) enhance stability and reduce the risk of failure to Low.

The slope stability assessments in Attachment 12 suggest a Low risk of deep-seated landsliding on the proposal. This is based on the stated inputs to the assessment, but it is acknowledged that the

[1] It is up to stakeholders to decide whether any evaluated risk is acceptable or not. A rough guide might be to consider all Very low and Low geotechnical risks as acceptable and not requiring treatment, Moderate risks to be acceptable or tolerable and may require treatment, and High and Very high risks as tolerable or intolerable, and generally requiring treatment. Treatment is designed to reduce risks to acceptable or tolerable levels. It may include Accepting the risk, Avoiding the risk (ie abandoning the project), Reducing the likelihood of the hazard occurring (ie stabilisation measures to control triggering circumstances), Reducing the consequences (eg suitable construction design), Monitoring and warning systems (which might help reduce the consequences of the hazard), Transferring the risk (eg requiring another authority to accept the risk or compensate for the risk, such as insurance companies), and Postponing a decision (eg if there is insufficient certainty about the risk, it might be better to do further investigations).

[2] Underlined words like High, Moderate, Unlikely, Possible etc have defined meanings, as explained on the second page of Attachment 13.

risks range from High to Very Low if, for example, the hillside is assumed to be only clay, or only weakly cemented sandstone, respectively.

Table 13.1 recommends diamond drilling be done on the western part of the proposal to refine the geological model and slope stability assessment. Risk treatments might then be modified as a result.

As a general comment, mitigating shallow (and deep seated) landslide risk ought to include some or all of the following:

- stormwater and runoff control (reducing the likelihood),
- removing soil and rock materials from the head of the slope (as planned),
- loading the toe of the slope (as planned), but not its middle and upper parts unnecessarily (reducing the likelihood),
- appropriate footings for houses (reducing the consequences),
- lightweight house construction and use of flexible materials (reducing the consequences),
- supporting excavations with engineered and drained retaining walls, and/or reducing batter angles (reducing the likelihood), and
- avoiding rigid in-ground pipework etc which might rupture or leak (reducing the likelihood),

4.4 Issue 6 Foundation movement due to reactive soils

It is Almost certain that the clayey subsoils will produce ground and possibly footing movement. The extent of movement will depend on the reactivity of the clayey materials, their thickness and depth, so that the consequences to dwellings and infrastructure could range from Insignificant to Major, and the attendant risk up to Very high. Effective treatment to mitigate the risk should include:

- classifying all future house sites in accordance with AS2870,
- avoid planting deep-rooted large trees within 20m or so of houses, and
- managing stormwater and surface runoff.

It is noted that the planned cut and fill operations during development may substantially alter soil conditions and site classification.

4.5 Issue 7 Low strength materials

Areas of fill, and perhaps parts of the low-lying alluvium buried by Types 1 and 2 fill, are expected to be of variable and probably low strength. Similarly, placement of fill during development will locally place extra loads on low strength materials, accelerating or instigating consolidation and settlement. The consequences to properties and infrastructure are potentially Major, and the attendant risks judged to be High.

Risk treatment for this issue should include:

- classifying all future house sites in accordance with AS2870, and designing footings for houses in accordance with the classification and site conditions. It is important that future classifiers are aware of the existence of this report.

    - the controlled placement of all fill in a manner appropriate for the fill type and its destination. The works should be planned prior to development, and be supervised by a suitable qualified and experienced engineer.

4.6 ISSUE 8 VEGETATION REMOVAL

It is Almost Certain vegetation on hillsides will be wholly removed during development. Though the consequences are judged relatively Minor, the attendant risk is High. Treatment should include planned selective revegetation in available public areas, avoiding trees which will grow large within nominally 20m or future houses. On moderate to steep slopes, deep rooted, small to moderate sized species are preferred. Householders should be encouraged to do the same.

4.7 ISSUE 9 FLOODING OR WATERLOGGING

Appropriate runoff control within the proposal subdivision is assumed. The issue in this instance relates more to potential flooding of Kings Meadows Rivulet. A detailed flood assessment is outside the scope of this report, but it is assumed that if necessary, risk mitigation measures (including filling low land, as proposed) would be addressed in any flood report.

5 CONCLUSIONS

5.1 GENERAL GEOTECHNICAL COMMENTS

The proposed subdivision is mostly underlain by Tertiary sediments including weakly cemented sandstone and fissured claystone. Soils on these materials are duplex profiles of nonplastic sandy silt and slightly plastic clayey silt topsoil over plastic, slightly to moderately reactive clay subsoil.

Low lying parts on the flood plain of Kings Meadows Rivulet are underlain by Quaternary alluvium over Tertiary sediments.

In terms of Launceston Landslide Zoning, the property includes Classes II, III and IV. The Mineral Resources Tasmania Landslide Hazard mapping shows that the higher, western parts of the proposal include both a fossil old and dormant landslide zone, and a fossil old and dormant landslide.

There is no evidence of current instability.

5.2 LEVEL OF GEOTECHNICAL RISK

Most risks associated with applicable geotechnical issues in Attachment 13 are rated as Very Low, Low or Moderate. (Slope instability is rated as a Low to Moderate risk). Issues which generate High or Very High risk are associated with potentially reactive soils, low strength materials, and vegetation removal. A range of recommendations is provided to help manage the risks.

5.3 CAPABILITY OF THE PROPOSAL TO SUPPORT THE PROPOSED DEVELOPMENT

The site is conditionally capable of supporting the proposed residential development. Development in accordance with good engineering practices and the following recommendations will not increase the geotechnical risk on this or other land.

Whether the recommendations are acceptable, tolerable or unacceptable to the client is outside the scope of this report. Whether or not stakeholders carry out all, some or none of the recommendations is not an issue which this report can address.

6 RECOMMENDATIONS

From a geotechnical viewpoint, residential development on the proposed subdivision off Penquite Road at Newstead should proceed subject to the following recommendations.

Recommendations to create awareness of interested parties

1. Approval to develop as proposed should include reference to this report, and indicate that geotechnical and related conditions apply. The reference to this report shall be as follows:

> Cromer, W. C. (2009). *Geotechnical assessment, proposed 76-lot subdivision, Penquite Road, Newstead.* (Unpublished report for Ecoast Homes Pty. Ltd. by William C. Cromer Pty. Ltd., 7 April 2009; 22 report pages and 142 pages of Attachments).

2. Launceston City Council shall ensure that copies of this report are available to interested parties. Interested parties include futureAS2870 classifiers of lots. To facilitate availability, both William C. Cromer as author and Ecoast Homes Pty Ltd hereby give permission for copies of the report to be made by Council, or anybody else. Note however, that 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 Ecoast Homes 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.

3. Purchasers of lots in the subdivision shall be made aware that copies of this report are available.

Fundamental geotechnical recommendation

4. Because the proposal includes moderately steep hillsides, the over-riding recommendation is that sound engineering practices shall be followed for the development including dwellings and infrastructure. Examples of sound and unsound engineering practice on hillsides are included in Attachment 13. Attachment 14 contains useful information for householders and builders.

Recommendation to manage reactive soils

5. Council shall require appropriate site investigations at or near the footprint of all future houses, and their subsequent classification in terms of AS2870. Classifiers should be aware that this report exists. AS2870 site investigations and classification reports should be sufficiently detailed to include, where necessary, site-specific modifications to the recommendations of this report.

Recommendations to enhance slope stability or reduce the consequences of instability

6. Avoid loading hillsides unnecessarily, at all scales. Remove soil as planned from hillsides, and load hillside toes as planned. Minimise cut and fill at house scale.

7. Support all excavations higher than about 0.8m with engineered, drained retaining walls. Further, unless an engineering structural stability assessment indicates it is unnecessary, the footings for any retaining structure should be located so as to maintain an angle of 45^0 or less between the footing and the point where live loads would usually be applied.

8. Avoid using fill as a weight bearing material, unless its placement is controlled.

9. Where the grades of the access road to lots exceed about 15% (8.5^0), the access shall be constructed with asphalt or concrete surfaces.

10. Where stormwater or sewer pipes are constructed on grades greater than 15% (8.5^0), they shall 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.

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

12. Control surface runoff. Direct drainage from retaining walls to reticulated stormwater pipes.

13. Consider the use of flexible rather than rigid buried pipework.

14. Encourage the use of lightweight flexible materials for house construction.

15. Revegetate (see Recommendation 14).

16. Undertake a programme of diamond drilling on selected parts of the property. Its intent is to refine the geological model and slope stability assessment in relation to deep-seated slope instability. Further recommendations might arise as a result.

Recommendations to minimise soil erosion during development

17. Control surface runoff (see Recommendation 12).

18. Prepare a soil and water management plan (SWMP) for the development process.

19. Revegetate cleared public areas as soon as possible after development starts. Avoid replanting trees which will grow large closer than about 20m to future house sites. Revegetate with small to medium sized, deep rooted species. Encourage householders to do the same.

Recommendations in relation to low strength materials

20. Ensure that all filling 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.

Recommendation in relation to unexpected subsurface conditions

21. 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

7 April 2009

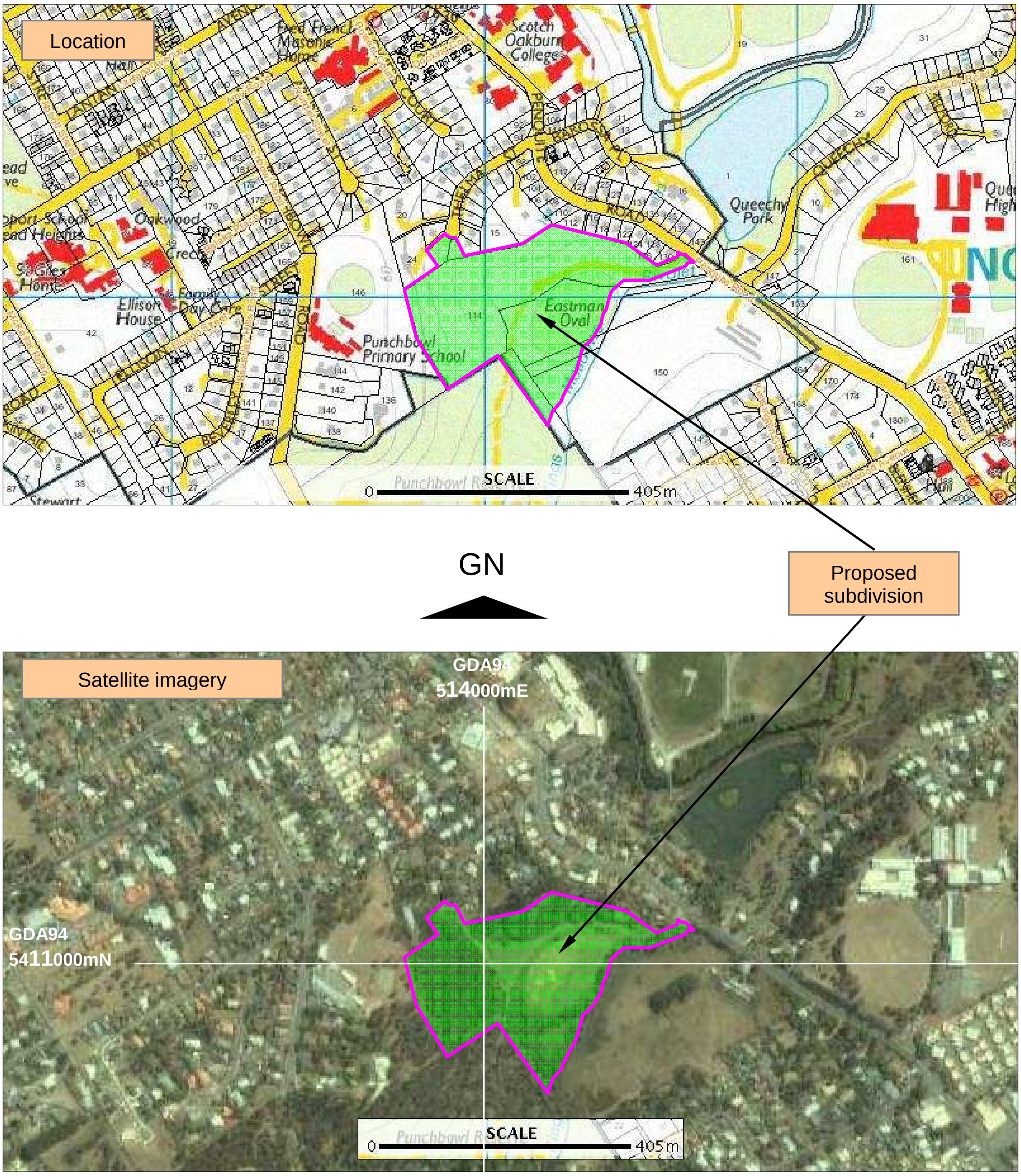
See next page for a list of Attachments to this report.

This report is and must remain accompanied by the following Attachments:

Attachment 1. Location of the proposed subdivision (1 page)
Attachment 2. District and local geology (1 page)
Attachment 3. Proposal plan and Google Earth imagery (1 page)
Attachment 4. 1947 aerial photography of the area (1 page)
Attachment 5. Landslide Zoning and Tasmanian Landslide Susceptibility Maps in relation to the proposal (5 pages)
Attachment 6. Geotechnical sketch of the proposal showing topography and test pit locations (1 page)
Attachment 7. Geological interpretation map of the proposal (1 page)
Attachment 8. Proposal plan showing proposed new contours, and areas of cut and fill (1 page)
Attachment 9. Site photographs (11 pages)
Attachment 10. Engineering logs and photographs of test pits A – Q (52 pages)
Attachment 11. Interpretation of site geology, laboratory test results, AS2870 site classification and Notes for Designers, Builders and Owners (8 pages)
Attachment 12. Quantitative slope stability assessment (13 pages)
Attachment 13. Summary of geotechnical issues, risks and consequences to development site, and suggested risk treatment practices (1 page)
Terminology used in geotechnical risk assessment (1 page), and
Examples of good and poor hillside engineering practices (2 pages)
Attachment 14. Three 4-page CSIRO pamphlets (13 pages):
CSIRO Information sheet BTF 18. *Foundation Maintenance and Footing Performance*: *A Homeowner's Guide* (replaces Information Sheet 10/91; dated 2003)
CSIRO Building Technology File No. 19. *A builder's guide to preventing damage to dwellings. Part 1 – Site investigation and preparation* (February 2003)
CSIRO Building Technology File No. 22. *A builder's guide to preventing damage to dwellings. Part 2 – Sound construction methods* (August 2003)

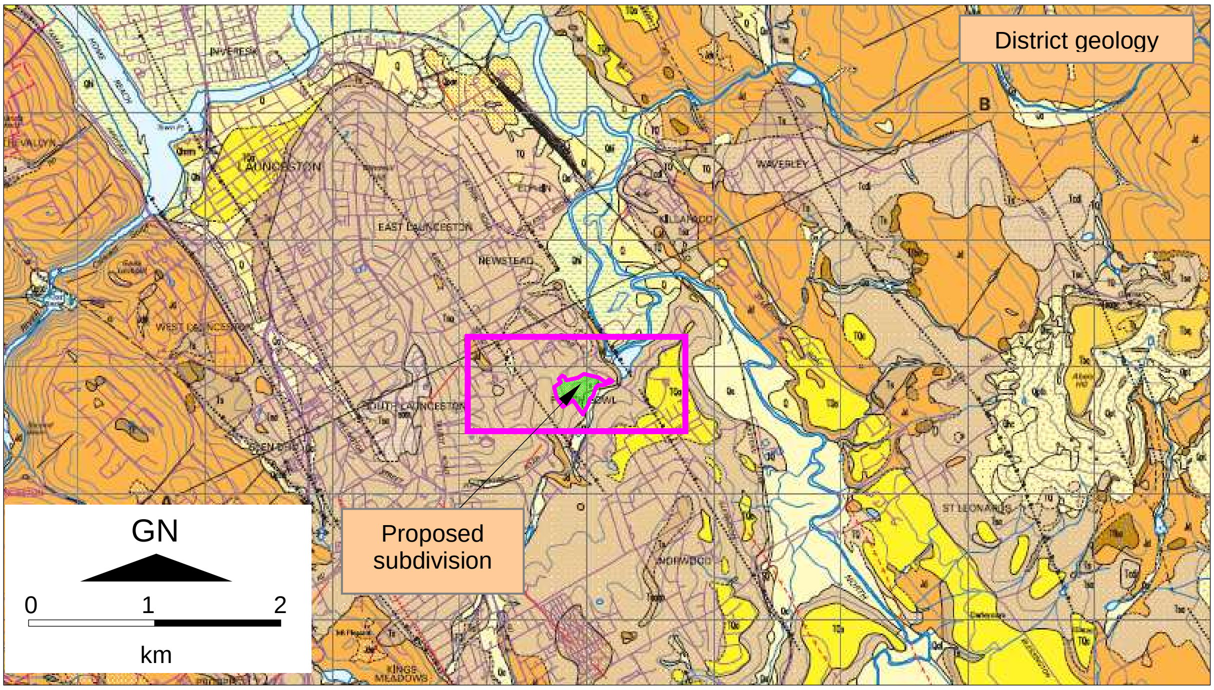
Designers, builders and developers are encouraged to read these publications, and the other Attachments to this report.

Attachment 1
(1 page)
Location of the proposed subdivision



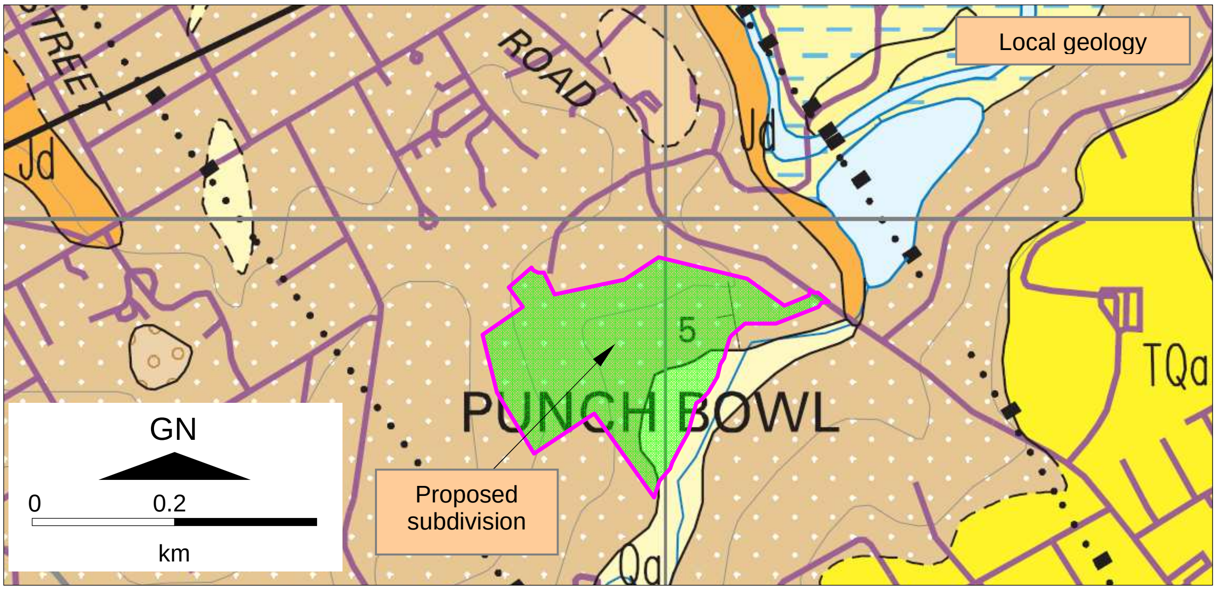
Sources: Location: www.thelist.tas.gov.au; Satellite imagery: Google Earth

Attachment 2
(1 page)
District and local geology



Source: Calver, C. R. and Forsyth, S. M (compilers) (2005). Map 3, Launceston – Geology. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania. Key to rock types – Orange = Jurassic dolerite; Brown: Tertiary partly consolidated clay, silt, sand, clayey sand with rare lignite and gravel; Bright yellow = Late Cainozoic terrace deposits of gravel and sand alluvial materials; Light yellow = Quaternary talus; Yellow+blue dashes = Quaternary estuarine deposits

Site investigations confirm that most of the proposed subdivision (below) is underlain by partly consolidated sand (weakly cemented sandstone) and claystone of inferred Tertiary age. The balance along

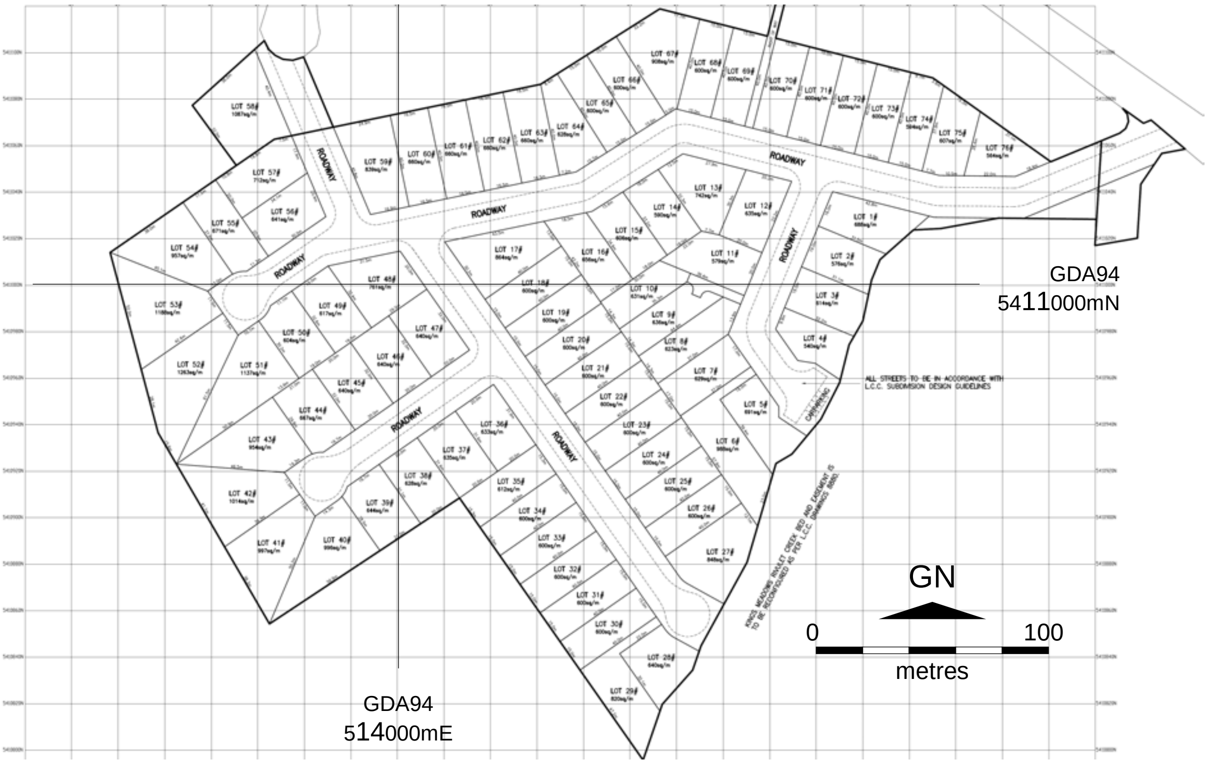


Attachment 3

(1 page)

Proposal plan and Google Earth imagery

Source for proposal plan: Meindert van der Molen Drawing # ECHO209-DA 1/8

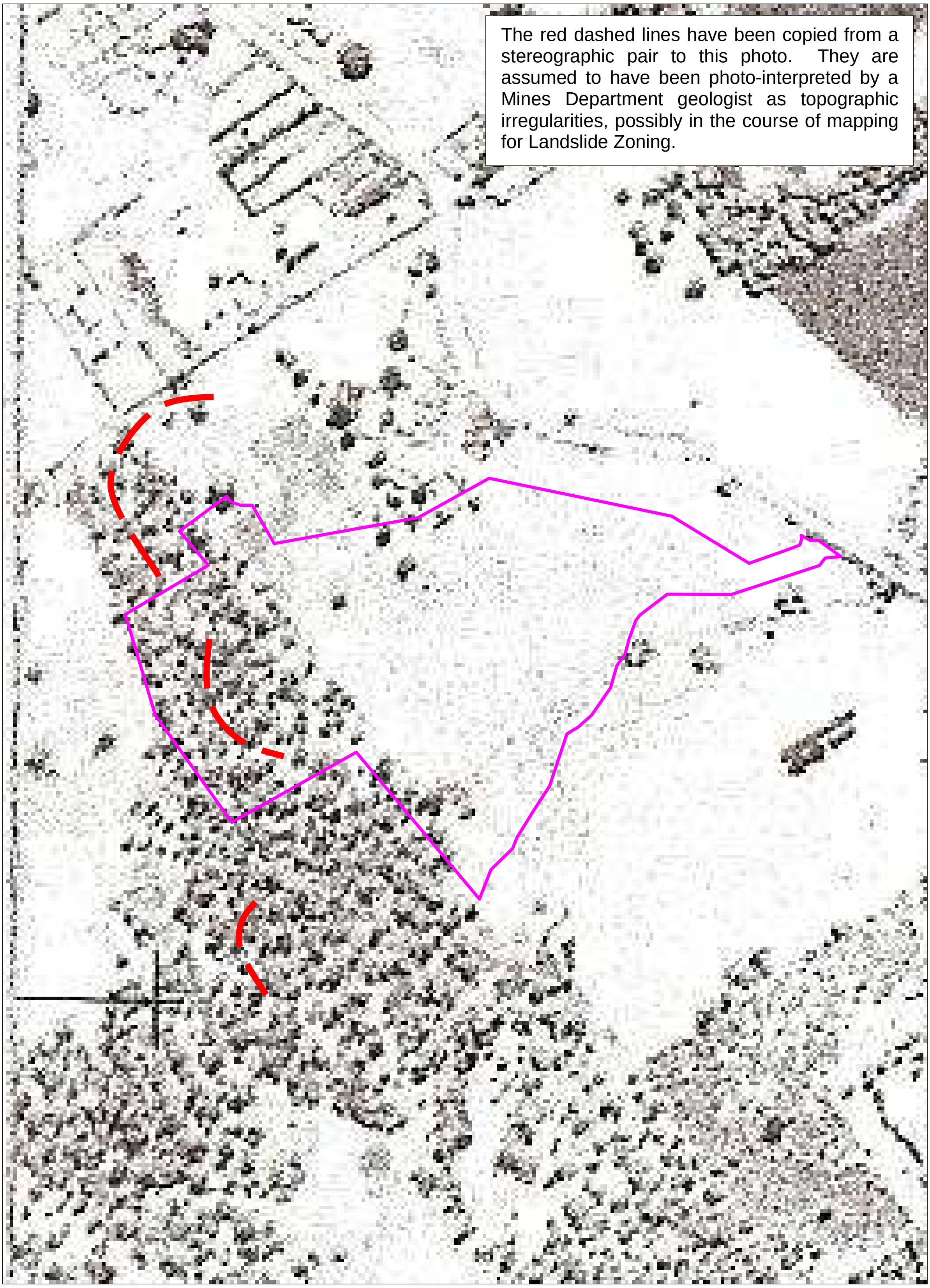


Attachment 4

(1 page)

1947 aerial photograph of the area

Mineral Resources Tasmania library: Launceston Run3 Print 20



Attachment 5

(5 pages)

Landslide Zoning, and Tasmanian Landslide Susceptibility Maps in relation to the proposal

Notes for Landslide Zoning Map

The flat ground on the former Eastman Oval is Class II. Steeper ground to the north and west is Class III. Still steeper and higher ground near the western boundary is Class IV.

Notes for Landslide Susceptibility Maps

The following pages show the proposed subdivision in relation to four landslide susceptibility maps for the Launceston area issued by Mineral Resources Tasmania in 2004 and 2005. 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
Map 2: Launceston Geomorphology
Map 4: Potential Rockfall Hazard
Map 5: Potential Landslide Hazard

Map 3 is the geological map of the Launceston area, part of which is reproduced in Attachment 2.

The following extract from the explanatory notes to Map 1 explains the purpose and limitations of the maps.

Landslide Inventory

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 provide an insight into the natural hazards that may potentially affect the area concerned. Mineral Resources Tasmania, in partnership with the Launceston City and West Tamar Councils, has produced a new landslide hazard map of the urban Launceston area and surrounds. 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.

Method

A methodology has been specially developed for these maps and will be used for other urban areas of Tasmania. It can be downloaded from the MRT website.

The methodology used is based on:

- Recording observations of land instability in- and surrounding the- study area (the landslide inventory).
- Analysis of the processes that control each landslide type.
- Computer assisted modelling that simulates each of the landslide processes to predict areas that could be affected by future landslides.

Landslide Database

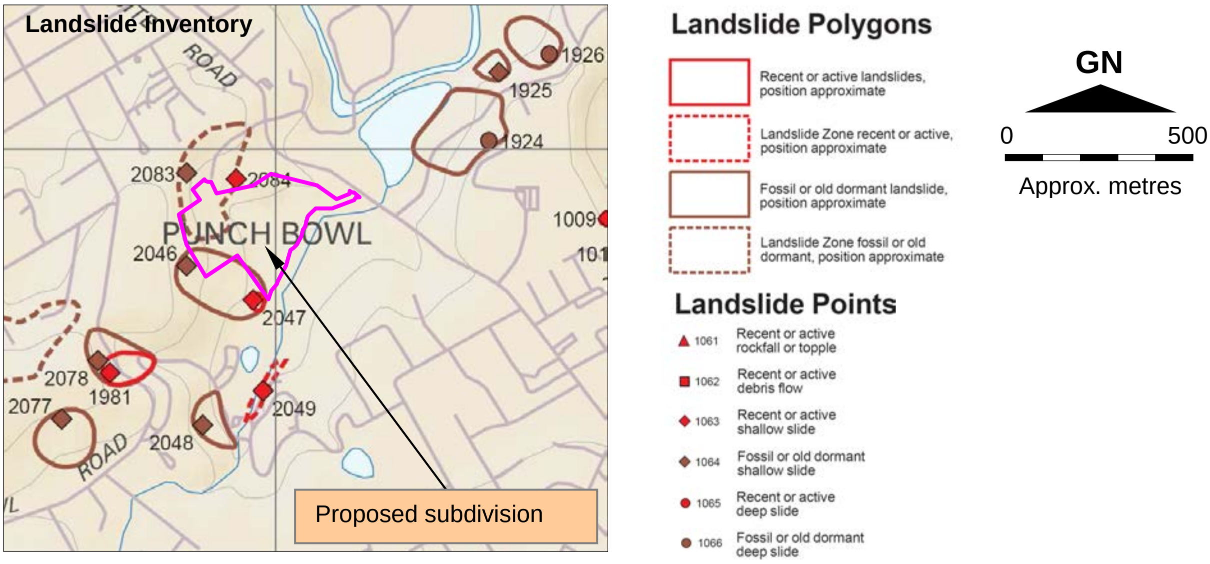
Landslide data shown on this and associated maps is sourced from a landslide database created by Mineral Resources Tasmania (MRT) for the storage of landslide related information in the State. Officially known as the 'Geohazards Module' and part of MRT's TIGER information system, the database has been built to comply with Australian and international standards for the description of landslide information. The Geohazards Module is a public database which is being developed with the view of making it available on the MRT internet site in the near future. GIS layers developed by MRT and shown on the map are supplied to each council in the area and available to the public, once the maps are completed.

Data stored within the module is sourced from both MRT records and external sources. Launceston City and West Tamar Councils provided a number of geotechnical reports to contribute to the knowledge base. However, MRT cannot guarantee that all historic information on landslides held by other parties is in its possession. Further, it is likely that there are a number of unrecognised or subsequently modified landslides in the landscape that may be revealed after these maps are published.

Map 1. Landslide Inventory

Latinovic, N. and Latinovic, M (2005). Map 1, Launceston – Landslide Inventory. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania

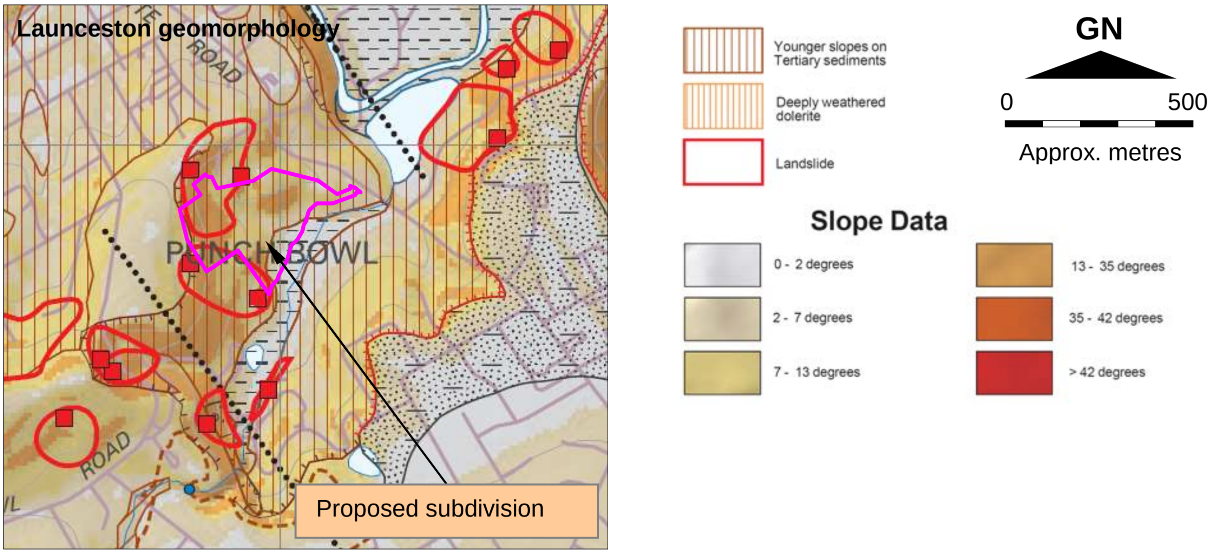
The southwestern corner of the proposed subdivision overlaps part of a "fossil or old dormant" landslide, within which are two landslide points: point 2046 (regarded as a fossil old or dormant shallow landslide), and 2047, shown as a recent or active shallow landslide. The northwestern part of the proposal is included in a fossil old or dormant Landslide Zone (the position of which is approximate) with fossil (2083) and recent (2084) shallow landslides. In the general vicinity are several other fossil old or dormant landslides and old or dormant, and active, shallow landslides. For a more detailed discussion of slope stability issues, see Attachment 9.



Map 2. Launceston geomorphology

Selkirk-Bell, J.M. and Mazengarb, C. (2005). Map 2, Launceston – Geomorphology. Tasmanian Landslide Hazard Series. Mineral Resources Tasmania

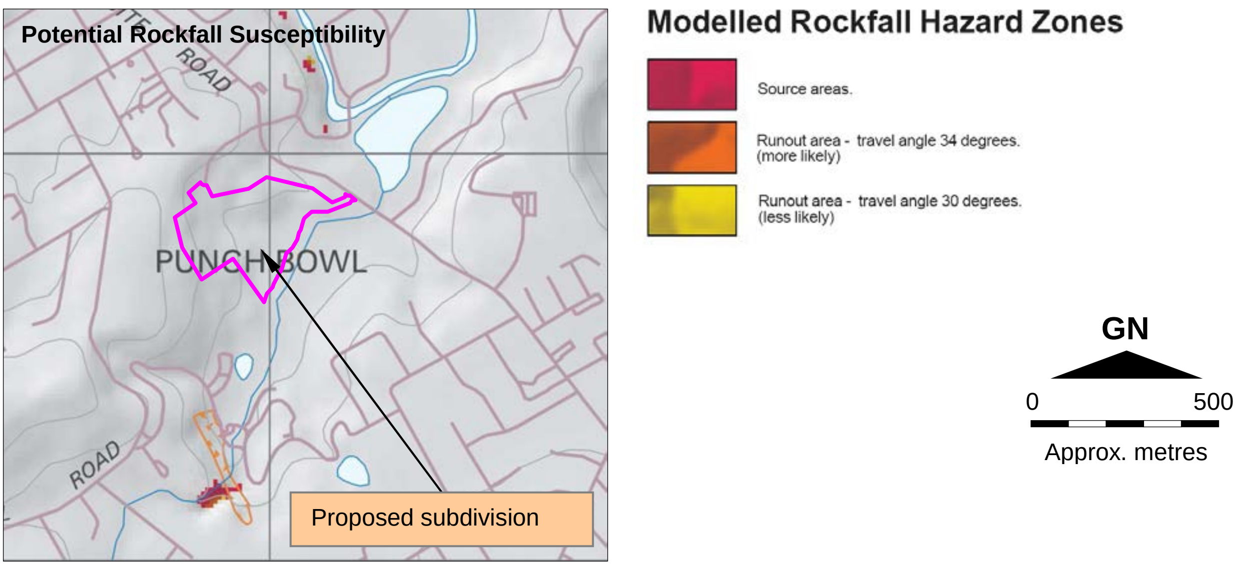
Most of the proposed subdivision is mapped as "Younger slopes on Tertiary sediments", with slope angles mainly in the range 7 – 13^0, and smaller slope segments (particularly in the west) in the 13 – 35^0 range. The floor of Kings Meadows Rivulet is mapped as a flood plain.



Map 4. Potential Rockfall Hazard

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

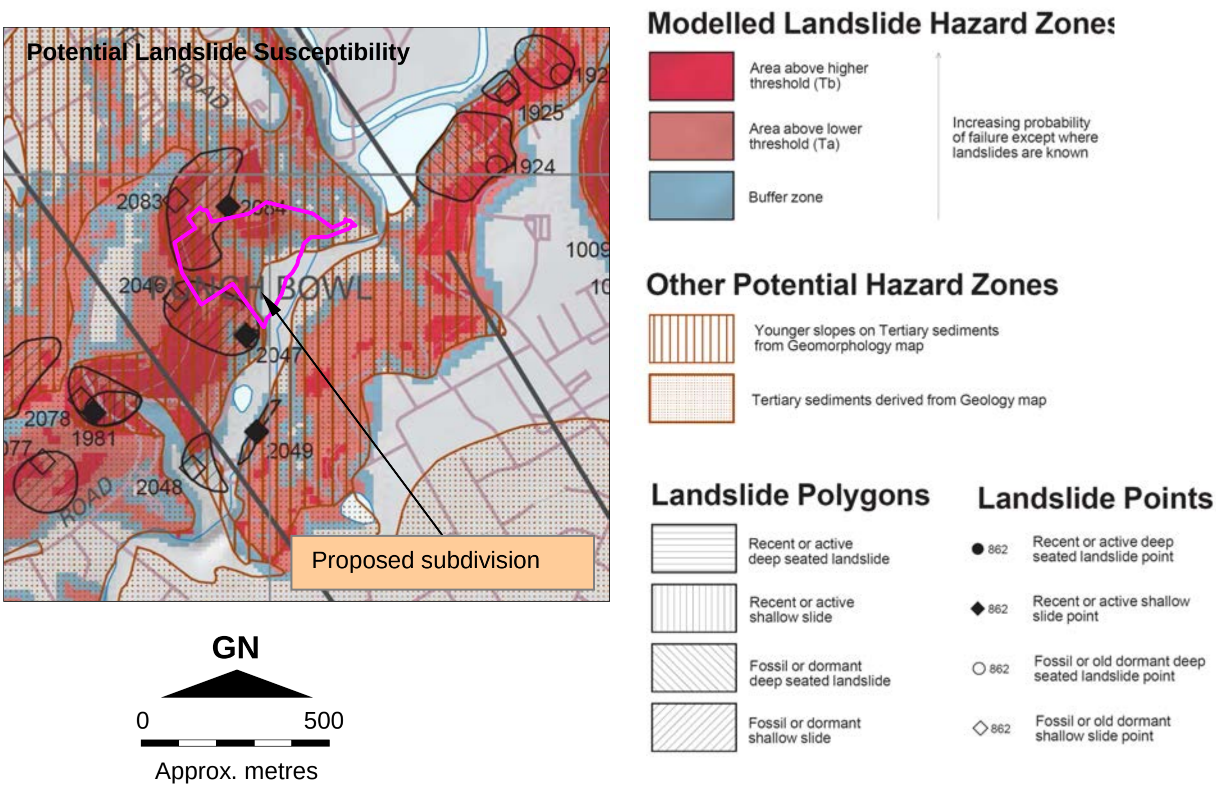
The proposed subdivision is not mapped as being susceptible to rock falls.



Map 5. Potential Landslide Hazard

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

All of the proposed subdivision mapped as "Younger slopes on Tertiary sediments" in Map 2 is regarded as susceptible to landslides. The probability of landsliding increases as the slope angle increases, so the parts of the proposal most susceptible are along the western and northern sides. The balance is a buffer zone.

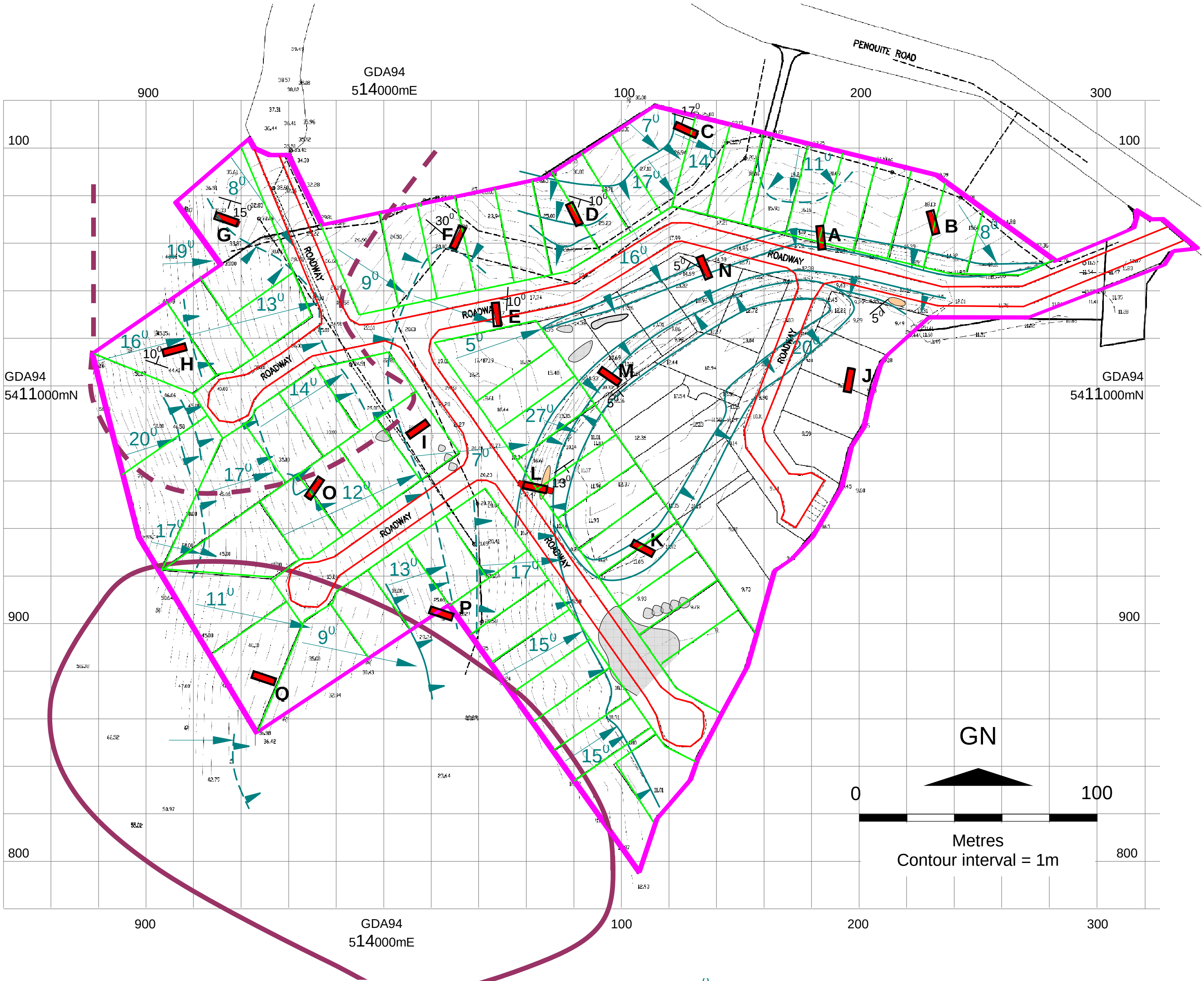


Attachment 6

(1 page)

Geotechnical sketch map of the proposal showing topography and test pit locations

Source for base map: Meindert van der Molen



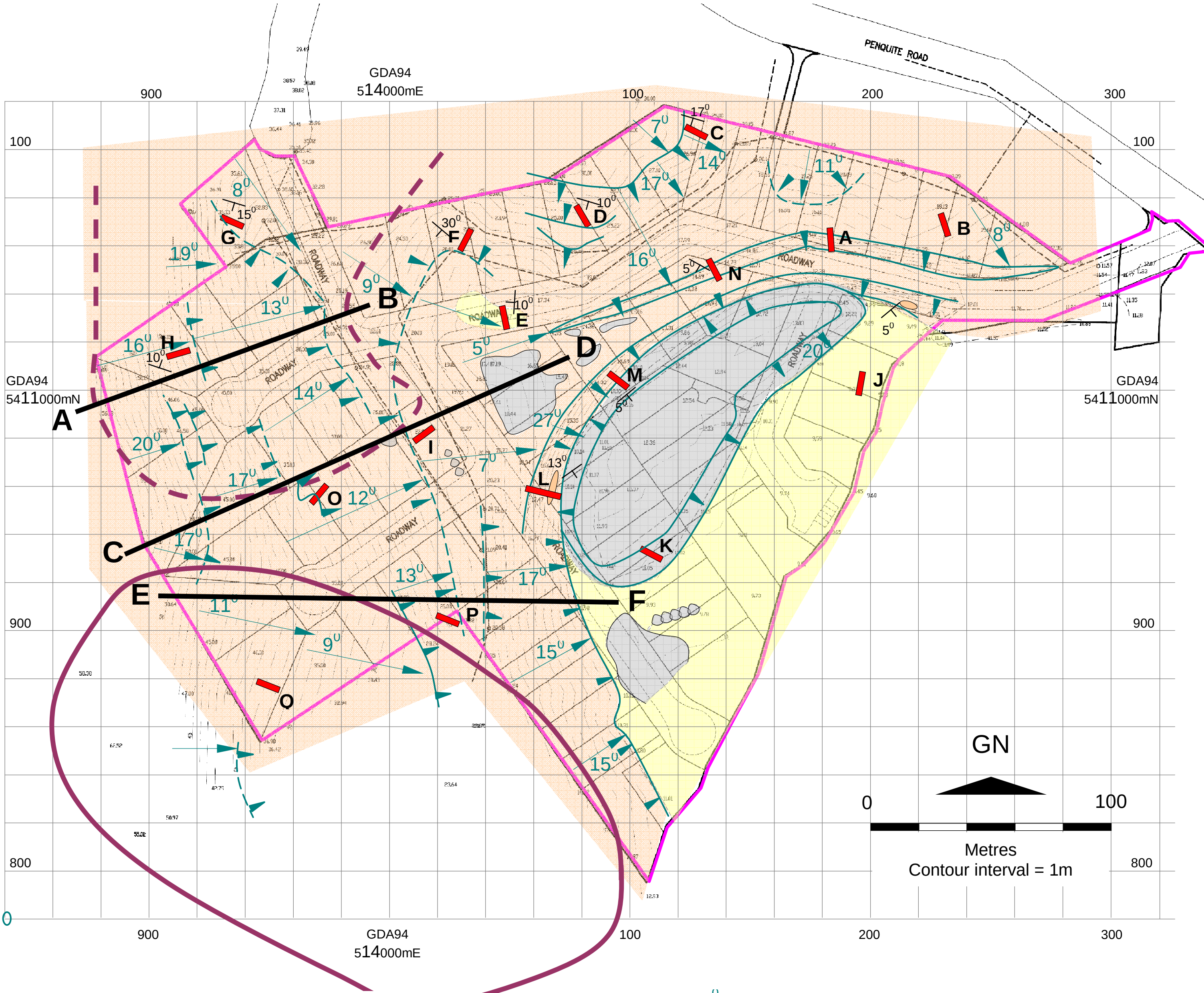
P	Test pit dug 17, 18 or 25 February 2009
	Fossil or old dormant landslide, position approximate
	Landslide Zone; fossil or old dormant, position approximate
	Recent inert fill
13°	Outcrop of Tertiary weakly cemented sandstone with dip and strike of bedding shown; dip and strike also shown for sediments when exposed in test pits
18°	Slope direction and angle
	Convex change of slope (gentle)
	Convex change of slope (abrupt)
	Concave change of slope (gentle)
	Concave change of slope (abrupt)

Attachment 7

(1 page)

Geological interpretation map of the proposal

Source for map: Meindert van der Molen



P Test pit dug 17, 18 or 25 February 2009

Inferred fossil or old dormant landslide, position approximate

Inferred Landslide Zone; fossil or old dormant, position approximate

Recent inert fill

Quaternary alluvium (covered with c. 0.5m of silty clay fill)

Tertiary claystone and weakly cemented sandstone

13° Outcrop of Tertiary weakly cemented sandstone with dip and strike of bedding shown; dip and strike also shown for sediments when exposed in test pits

18° Slope direction and angle

Convex change of slope (gentle)

Convex change of slope (abrupt)

Concave change of slope (gentle)

Concave change of slope (abrupt)

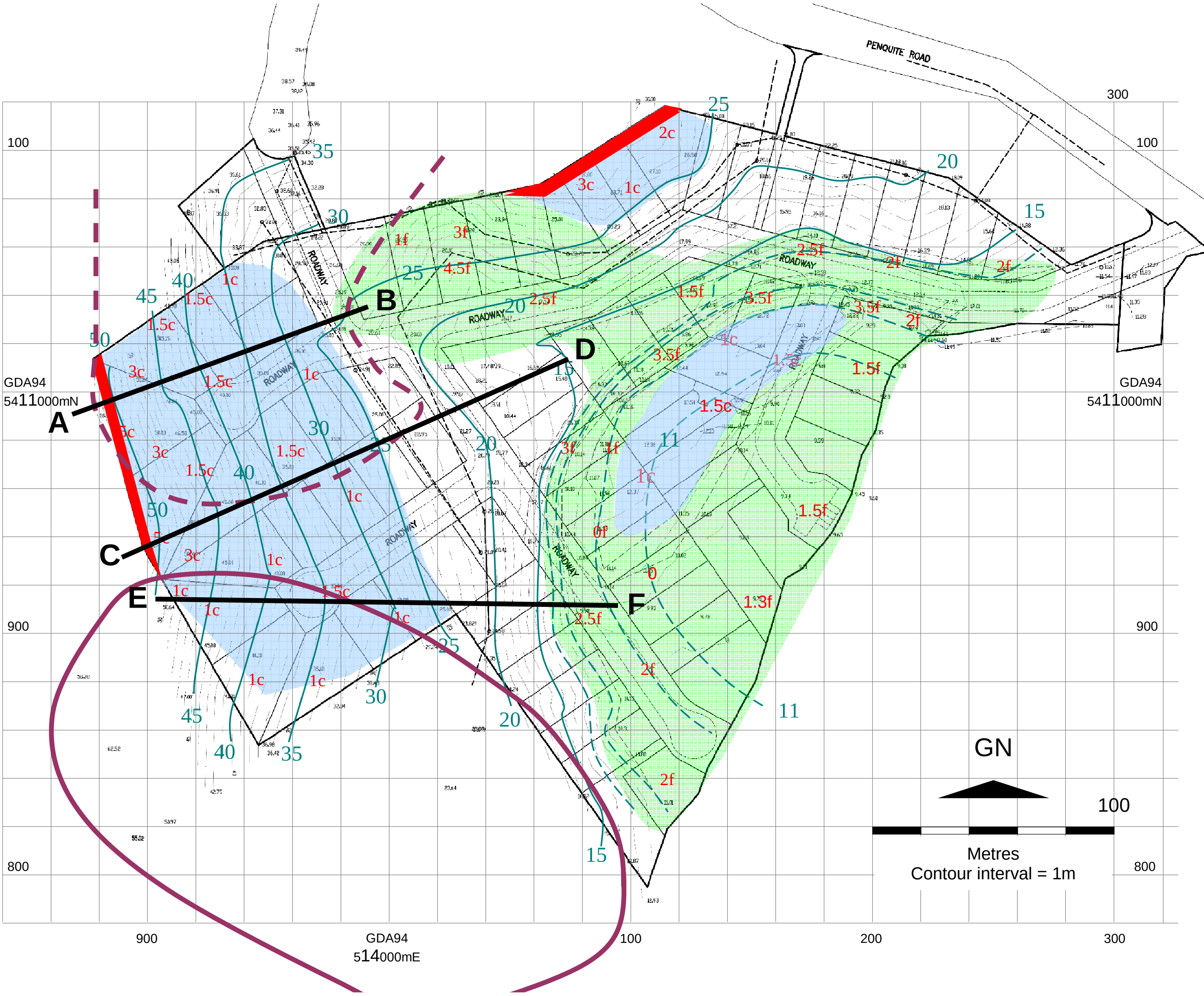
A — B Section line for slope stability analysis (see Attachment 12)

Attachment 8

(1 page)

Proposal plan showing intended new contours, and areas of cut and fill

Source for map: Meindert van der Molen



35 Proposed new contours (interval 5m; 1m between 11 and 15m) superimposed on existing contours (interval 1m)

1.3f Areas proposed to be filled (approximate; red figures are depths to be filled, in metres)

1c Areas proposed to be excavated (approximate; red figures are depths to be cut, in metres)

Proposed engineered retaining walls

Inferred fossil or old dormant landslide, position approximate

Inferred Landslide Zone; fossil or old dormant, position approximate

A B Section line for slope stability analysis (see Attachment 12)

Attachment 9

(11 pages)

Site photographs

Plate 1 (above). View looking northwest over the former Eastman Oval showing a low, raised mound of fill in the middle ground, separated from the steep embankment behind by a depression. The embankment probably represents the edge of a former channel of Kings Meadows Rivulet. The foreground is also a thin layer of fill over alluvial sediments.

Plate 2 (below). A view similar to Plate 1, looking north. The excavator is digging test pit J. Most of the foreground will be raised a metre or more, and a metre or more taken off the mound, to create building allotments.

Plate 3 (above). View looking east showing raised fill at right on the former Eastman Oval, and the embankment at left.

Plate 4 (below). Looking west from the same point as Plate 3. The raised fill is up to about 3 – 3.5m thick. The depression between it and the embankment will be filled in, and some of the mound removed, to create building allotments.

Plate 5 (above). View looking southwest showing raised fill at right on the former Eastman Oval.

Plate 6 (below). Looking southeast from near test pit G (right foreground).

Plate 7 (above). View looking east over dumped piles of inert fill (bitumen, concrete, soil) on the slope east of pit I.

Plate 8 (below). Looking east past test pit C and down the northern property boundary.

Plate 9 (above). Looking west from near test pit B and up the northern property boundary.

Plate 10 (below). Looking east towards test pit B and down the northern property boundary.

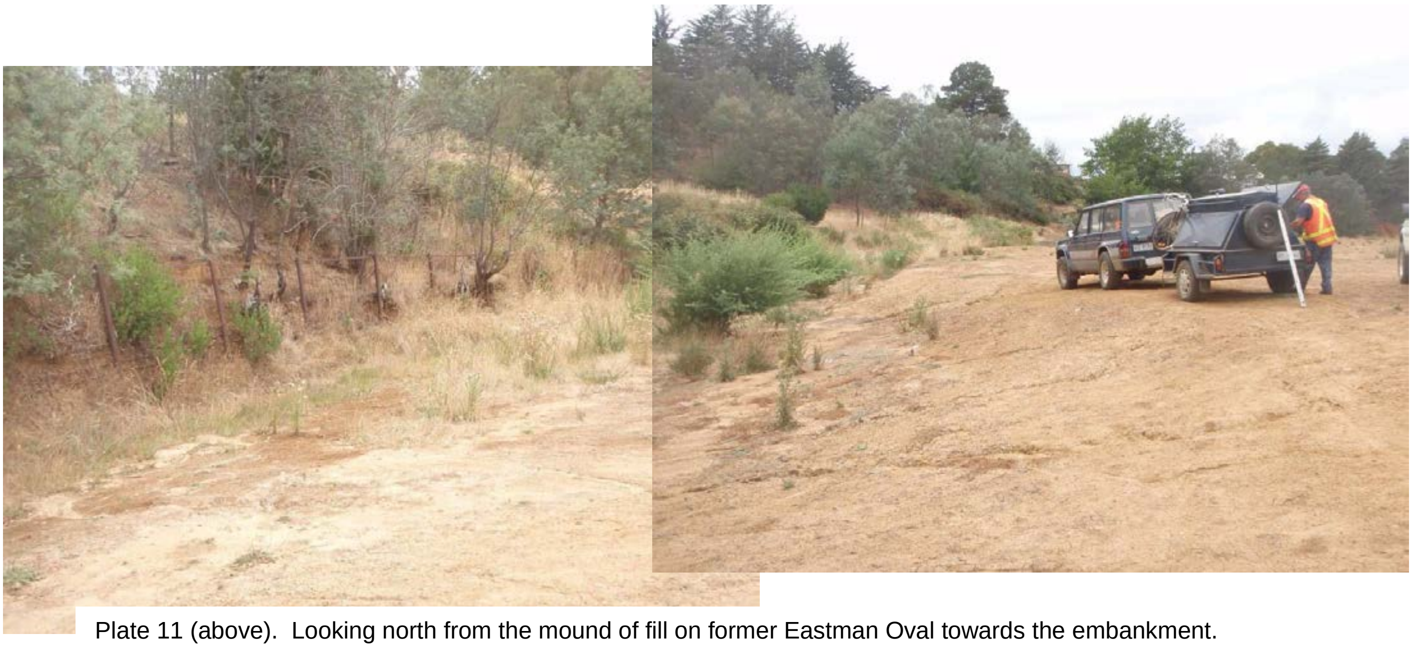


Plate 11 (above). Looking north from the mound of fill on former Eastman Oval towards the embankment.

Plate 12 (below). Weakly cemented Tertiary sandstone exposed on the embankment where test pit L was dug.

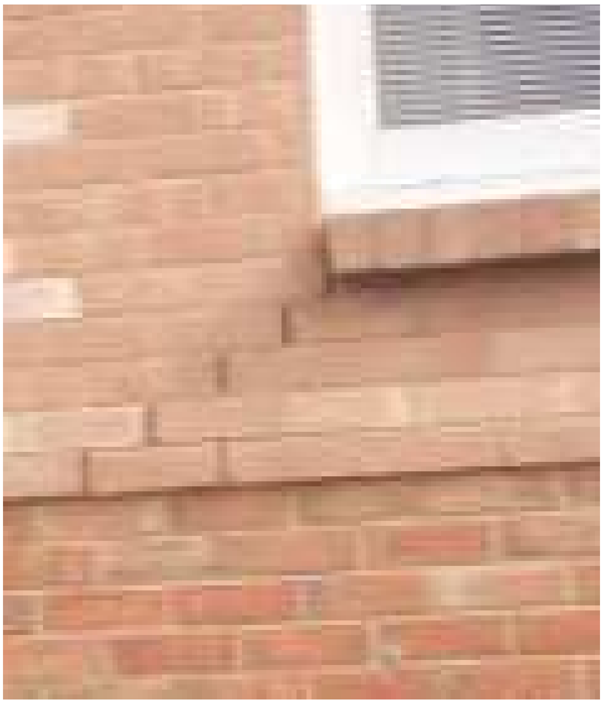
Plate 13. Test pit A exposed lateritic conglomerate (top; orange and light yellow) over dark grey mudstone (bottom). Further digging exposed sandstone under the mudstone. All materials are interpreted as Tertiary in age.

Plate 14. Digging test pit L on the embankment where Tertiary sandstone is exposed.

Plate 15. Tertiary sandstone exposed on the embankment beside the access road, about 35-40m NNE of test pit 1

Plate 16 (above). Repaired cracking of bitumen in Thelma Street, which may have been caused by soil movement.

Plate 17 (below). Damage to houses in Thelma Street and Penquite Road probably caused by footing movement on reactive clay soils.



Plates 18, 19 and 20. Damage to houses in Penquite Road probably caused by footing movement on reactive clay soils.