Attachment 11

(8 pages including this page)

Interpretation of site geology and soils, laboratory test results, and generalised AS2870 classifications

Geological setting

The proposed subdivision (Attachment 1) lies within the Tamar Graben, an elongate NNW – SSE trending trough underlain by Jurassic dolerite and Lower Parmeener Supergroup rocks and infilled with Tertiary and Quaternary sediments (Attachment 2).

The Tertiary sediments (sometimes referred to as the Launceston Beds) are a sequence of non-marine materials comprising mainly sand, weakly cemented sandstone, clay, claystone, and mudstone, but also variously including conglomerate, laterite, carbonaceous beds and granule beds. Some horizons are fossiliferous. In the deeper parts of the graben, they may be several hundred metres thick, but locally thin rapidly near basin margins.

Geology of the proposed subdivision (Attachment 2)

The interpreted geology of the subdivision is shown in Attachment 7. This is based mainly on test pitting, because the Tertiary beds are not well exposed on the subdivision, or the immediate area.

Two main Tertiary rock types are recognised: a weakly cemented light coloured lithic sandstone, and a dark coloured fissured claystone. Minor rock types recognised in some test pits include granule conglomerate and laterite.

Also present along and near the course of Kings Meadows Rivulet are Quaternary alluvial sediments.

Tertiary rocks

Lithic sandstone

Weakly cemented lithic sandstone crops out in two locations along the low escarpment along the northern and western side of the former Eastman Oval (Attachment 7). At the eastern end, light yellow sandstone dips southeast at 5^0 (Attachment 9, Plate 15); 150m west, orange brown sandstone dips also southeast at 13^0 (Plate 12). In both instances, the sandstone exhibits relatively high strength and crops out on slopes of up to about 30^0.

Similar weakly cemented, relatively high strength sandstone was also exposed in all but three of 17 test pits. The exceptions were pits I, K and Q. Excavation produces an irregular blocky fracture in test pits and hand specimen which is not evident in surface exposure. The material is sometimes thinly bedded, is usually friable and crumbly in the hand, and is Very Dense[1]. Plant impressions are locally present.

Several Plates in Attachment 10 show the lithic sandstone *in situ* in test pits, and as a spoil from excavation.

Fissured claystone

The claystone does not crop out, but was exposed in test pits A, B, C, G, H, I, L, M, N and O (it is not clear whether in some pits near-surface occurrences of clay are colluvial soil or weathered claystone, or both). It is black, or dark olive grey, or sometimes brown or olive brown. Generally, it is strongly fissured, with an irregular blocky fracture producing roughly equidimensional and sometimes platy joint blocks up to about 50 - 75mm in diameter, and occasionally polished defect surfaces. In all instances it was dry or slightly moist, and of a Hard consistency.

Locally the claystone is interbedded with thin siltstone or sandstone horizons.

Several Plates in Attachment 10 show the claystone *in situ* in test pits. A detail photograph from Pit A in Attachment 10 shows the claystone/sandstone contact.

[1] The 20 tonne excavator with a 1.3m general purpose bucket and 6 teeth frequently found it slow digging in the sandstone.

<u>Sandstone and claystone are interbedded</u>
It is established that there is at least two, and probably more, sandstone beds beneath the subdivision. Similarly, it is likely, but not established, that two or more claystone beds are also present and interbedded with sandstone.

The relationships between the two rock types is illustrated are various test pits, as follows:

Pit A: Two sandstone beds, above and beneath a 2.5m thick claystone unit; subhorizontal
Pit B: Two sandstone beds, above and beneath a 2.2m thick claystone unit; no dip measured
Pit C: A sandstone unit least 2.5m thick beneath claystone; dip 17^0 to 180^0M
Pit D: A sandstone unit; dip 10^0 to 180^0M
Pit E: A sandstone unit beneath clay; dip 10^0 to 260^0M
Pit F: A sandstone unit beneath clay; possible dip 30^0 to 210^0M
Pit G: A 1.3m sandstone unit above claystone; dip 15^0 to 180^0M
Pit H: A sandstone unit beneath claystone; dip 10^0 to 360^0M
Pit J: A sandstone unit beneath clay
Pit L: A 3.9m weathered sandstone/conglomerate unit above claystone; dip 13^0 to 130^0M
Pit M: A 1.4m sandstone/granule conglomerate unit above claystone: dip 5^0 to 120^0M
Pit N: A 4.4m sandstone unite above claystone; dip 5^0 to 190^0M
Pit O: 1.4m sandstone below clay and above clayey siltstone; variable steep S dips
Pit P: Clayey sandstone beneath sandy clay; no dip measured

<u>Variable dip and strike of beds</u>
The list above shows that dips (with the exception of the 30^0 dip in pit F) range from 5^0 to 17^0, and dip directions (with the exception of the 360^0M direction in pit H) range from 120^0M to 260^0M (ie southeasterly to westerly).

A close examination of the dip directions and topographic slope directions in Attachment 7 indicate that there is no consistent relationship between them (Table 11.1[2]). This is significant from a slope stability viewpoint: if dip directions are similar to slope directions, it is possible the former are the result of slope failure. However, with the exception of pit N (where the dip and slope directions are effectively identical), dip directions on the Tertiary sediments differ by 45^0 to 315^0 from slope directions. This suggests their varied attitude is related to structural controls (basement form and post-depositional faulting, etc) rather than slope instability.

Table 11.1 Dip directions of Tertiary sediments compared to topographic slope directions

Pit	Dip direction (degrees mag)	Slope direction (degrees mag)	Difference (degrees)	Dip angle (degrees)	Slope angle (degrees)	Difference (degrees)
A	horizontal	165	not applic	0	11	11
C	180	120	60	17	14	3
D	180	130	50	10	17	7
E	260	75	185	10	5	5
F	210	165	145	30	10	20
G	180	90	90	15	8	7
H	360	45	315	10	16	6
L	130	90	40	13	8	5
M	120	120	0	5	5	0
N	190	145	45	5	16	11

Quaternary alluvium
Test pit J exposed about 1.5m of dark organic and plastic clayey alluvium overlying inferred Tertiary sediments, and beneath about 0.8m of fill and soil. Test pit K established at least 2m of similar material beneath 0.8m of fill. The alluvium was of variable moisture content and strength.

[2] Dip angles and slope angles are also included in Table 11.1, but the differences between them are not really relevant from a slope stability perspective.

Soils

Duplex soils on Tertiary sediments

Soils over most of the subdivision are predominantly duplex (two-layered), comprising a topsoil of light coloured, non-plastic sandy silt (SP) or low plasticity clayey silt (CL) averaging about 0.5m thick, over a subsoil of darker, fissured, high plasticity, reactive clay (CH), sandy clay (CL) or silty clay (CH). The subsoil averages about one metre thick.

It is inferred that the soils are at least partly colluvial in origin ie they have formed by the downslope movement of soil and weathered rock.

Organic alluvial soils

Dark grey to black organic clay soils have formed on alluvial clays in the flood plain of Kings Meadows Rivulet.

Fill

Three instances of fill are recorded:

- Between about 0.2 and 0.8m of orange brown silty clay (CL, CH), sandy clay (CL, CH) and clayey silt (CL) has been placed, presumably in an uncontrolled fashion, over alluvium on the floodplain of Kings Meadows Rivulet to construct the former Eastman Oval.

- A substantial volume of orange brown silty clay (CL, CH), sandy clay (CL, CH) and clayey silt (CL) has been placed, presumably in an uncontrolled fashion, on earlier fill over about the northern and western half of the former Eastman Oval. The fill is lensoid in cross section, and is up to about 3m thick. Separate loads of darker, sandy silt loam have been stockpiled further upstream where the floodplain narrows near the southern property boundary.

- Relatively small volumes of inert fill (concrete, bitumen, rock fragments and soil) have been dumped by truckload over intermediate slopes above the flood plain of the rivulet (Attachments 6 and 7)

Groundwater

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.

Summary of on-site materials

On the basis of the foregoing, 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 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

Strengths and bearing capacities of materials

General strength correlations are summarised in Table 11.2. Estimated relative densities for coarse-grained (sandy) materials and unconfined compressive strength (q_{u}) values for fine-grained (clayey) materials on the subdivision are summarised in Table 11.3.

Table 11.2 Strength correlations

Consistency	Field Test	Undrained Shear Strength c_u Torvane (kPa)	Unconfined Compressive Strength q_u Pocket Penetrometer (kPa) *	Dynamic Cone Penetrometer blows/100 mm *	CPT Resistance MPa
Very soft	Easily penetrated >40 mm by thumb. Exudes between thumb and fingers when squeezed in hand.	<12	<25	<1	<0.2
Soft	Easily penetrated 10 mm by thumb. Moulded by light finger pressure	12 - 25	25 - 50	<1 - 1	0.2 - 0.4
Firm	Impression by thumb with moderate effort. Moulded by strong finger pressure	25 - 50	50 - 100	1 - 2	0.4 - 0.8
Stiff	Slight impression by thumb cannot be moulded with finger.	50 - 100	100 - 200	2 - 4	0.8 - 1.5
Very Stiff	Very tough. Readily indented by thumbnail.	100 - 200	200 - 400	4 -8	1.5 - 3.0
Hard	Brittle. Indented with difficulty by thumbnail.	>200	>400	>8	>3.0

* Note pocket penetrometer may overestimate q_u by a factor of 1.5 - 2.0

Table 11.3

		Relative densities and estimated unconfined compressive strengths (kPa) of on-site materials
Unit 1	Topsoil	Medium dense
Unit 2	Subsoil including minor colluvium	>200
Unit 3	Quaternary alluvium	25-100
Unit 4	Tertiary claystone	>200
Unit 5	Tertiary sandstone (including minor laterite and granule conglomerate)	Very dense
	Fill type 1	100
	Fill type 2	25-100
	Fill type 3	25-100

Arising from Table 11.3, it is inferred that

- 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 has 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.

AS2870 site classification

Soil reactivity and shrink swell testing

The high plasticity clayey materials (Units 2 and 3) are likely to be reactive. Units 1 and 5 are expected to be non-reactive. Unit 3 may locally be reactive.

The shrink swell index (I_{ss}) is a measure of reactivity. Undisturbed 50mm diameter drive tube samples were collected from Unit 2 materials in eight pits (B, C, F, G, H, I, P, Q) and tested[3] to determine their Shrink-Swell Indices (I_{ss}) to estimate reactivity and to assist in generalised AS2870 classification. Test results are summarised in Table 11.4.

Table 11.4 Results of shrink swell testing

Test pit	Depth interval (m)	Description	Initial moisture content (%)	Swelling strain (%)	Shrinkage strain (%)	Shrink swell index (Iss, %)
B	1.2-1.5	Silty CLAY (CH); coarsely mottled orange and reddish orange; high plasticity	31	2.3	4.8	3.3
C	0.8-1.1	Silty CLAY (CH); mottled olive brown and orange; blocky fracture; mod-high plasticity	15	1.2	2.3	1.6
F	0.9-1.2	Sandy CLAY (CH): mottled orange, red, grey; low plasticity	15	1.7	1.1	1.1
G	1-1.3	Sandy CLAY (CH): grey and bright orange; low to mod plasticity	20	5.1	2.6	2.8
H	0.9-1.2	Silty CLAY (CH): olive brown; high plasticity	19	7.6	2.3	2.4
I	1.0 -1.3	Silty CLAY (CH): olive brown flecked with red; high plasticity	23	4.1	2.0	2.3
P	1.2-1.5	Silty CLAY (CH): bright orange; trace sand; mod plasticity	20	3.0	2.0	1.9
Q	0.9-1.2	CLAY (CH): patchy orange and grey; high plasticity	19	2.5	3.1	2.4
		Average	**20**	**3.6**	**2.4**	**2.2**

The I_{ss} values from the eight Unit 2 samples ranged from 1.1 – 3.3% (low to moderate reactivity; average 2.2%). The lowest values (1.1%) came from a sandy clay.

On this basis it seems reasonable (and conservative) to adopt a range of (say) 2 – 3.5% as likely to include most I_{ss} values for Unit 2 materials across the proposed subdivision (Table 11.5). The Unit 3 alluvium might exhibit a similar range, and the Unit 4 fissured claystone a slightly higher reactivity.

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[3] Although William C. Cromer Pty. Ltd. is not NATA registered, testing was performed essentially in accordance with AS1289.7.1.1-1998. Methods of testing soils for engineering purposes. Method 7.1.1. Soil reactivity tests – Determination of the shrinkage index of a soil – Shrink-swell index. *Standards Australia*. From the Shrink-Swell index, the maximum ground surface movement can be estimated, and hence the site classification.

Table 11.5 Adopted I_{ss} values for the subdivision

Unit.	Material	USCS	Interpretation	Assumed Iss (%)
1	Silty SAND	SP	Topsoil	0
2	CLAY, silty CLAY	CH, CL	Subsoil	2-3.5
3	CLAY	SP	Alluvium	2-3.5
4	CLAY	CL	Tertiary claystone	3-4
5	SAND	CH	Tertiary sandstone	0
	CLAY	CH	Fill type 1	2-3.5
	CLAY	CH	Fill type 2	2-3.5

These I_{ss} values have been applied to the test pit logs in Attachment 10 to estimate the possible range of ground surface movement at each test pit location. These are summarised in Table 11.6, where the contribution from each layer is listed.

Table 11.6 Estimated ground surface movements and AS2870 class at test pits

	Estimated contribution to ground surface movement (mm)								
	Type 1 Fill	Type 2 Fill	Unit 1 Topsoil	Unit 2 Subsoil	Unit 3 Alluvium	Unit 4 Claystone	Unit 5 Sandstone	Total movement	AS2870 class
Adopted Iss (%)	2-3.5	2-3.5	0	2-3.5	2-3.5	3-4	0	(mm)	
Pit A	Absent	Absent	0	Absent	Absent	No contrib	0	0	S
B	Absent	Absent	0	Absent	Absent	10-15	0	10-15	S
C	Absent	Absent	0	Absent	Absent	15-30	0	15-30	S-M
D	Absent	Absent	0	15-25	Absent	Absent	0	15-25	S-M
E	Absent	Absent	0	16-28	14-22	Absent	0	30-50	M-H
F	Absent	Absent	0	30-55	Absent	Absent	0	30-55	M-H
G	Absent	Absent	0	20-35	Absent	0	0	20-35	M
H	Absent	Absent	0	23-40	Absent	3-6	0	25-45	M-H
I	Absent	Absent	0	23-40	Absent	3-6	Absent	25-45	M-H
J*	10-18	Absent	Absent	15-26	6-11	Absent	0	30-55	M-H
K*	10-18	13-22	Absent	Absent	9-15	Absent	Absent	30-55	M-H
L	Absent	Absent	Absent	15-25	Absent	0	0	15-25	S-M
M	Absent	Absent	Absent	15-25	Absent	0	0	15-25	S-M
N	Absent	Absent	Absent	15-25	Absent	0	0	15-25	S-M
O	Absent	Absent	Absent	15-25	Absent	25-45	0	40-75	H-E
P	Absent	Absent	Absent	15-25	Absent	Absent	0	15-25	S-M
Q	Absent	Absent	0	15-25	Absent	15-25	Absent	30-50	M-H

Notes

1. Suction base is 2.0m, so that deeper materials contribute nothing to ground surface movement.
2. Water table assumed at 1.5m in pits J, K
3. AS2870 classes and ground surface movement

Class S	0 -20mm
Class M	20-40mm
Class H	40-70mm
Class E	>70mm

The predicted ground surface movements are mainly in response to the depth to, and thickness, of reactive Unit 2 subsoil and Unit 4 claystone. It is not surprising therefore to find a range of AS2870 classes, from S to E, over the proposed subdivision. Note also that areas underlain by fill more than about a metre or so thick (depending on texture) will attract a Class P classification. Class P is also recommended whenever variability exceeding one class unit (eg from S to H) exists across a footprint.

Footings for buildings on Class H, E or P sites should be certified by a suitably qualified engineer experienced in footing design.

The classes also relate to the current unaltered soil profiles. Classifications will change if house sites are altered by, for example, cut and fill. Furthermore, the planting, growth, or removal of large trees influences soil moisture and hence ground surface movements.

These classifications are generalised, and not intended to replace appropriate site-specific investigations and AS2870 classification at the location of each new house.

Notes for designers and builders

Variability of subsurface conditions'

Expect variability across the site. Subsurface conditions encountered during construction which appear to differ significantly from those described here should be immediately brought to my attention.