Centre for eResearch and Digital Innovation

Gilgai and reactive soil geohazards in the City of Melton

Including the Planning Application for a Place of Worship at 171-197 Harkness Rd, Harkness

Prepared by: Associate Professor Peter Dahlhaus, Principal Research Fellow
Prepared for: Melton City Council

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Gilgai and reactive soil geohazards in the City of Melton

Including the Planning Application for a Place of Worship at 171-197 Harkness Rd, Harkness

Authored by:	**Prepared for:**
Peter Dahlhaus Centre for eResearch and Digital Innovation Federation University Australia P.O. Box 691 Ballarat VIC 3353 Web: www.cerdi.edu.au Email: p.dahlhaus@federation.edu.au	Melton City Council P.O. Box 21 Melton VIC 3337 Web: www.melton.vic.gov.au Project contact: Steve Finlay, Co-ordinator Statutory Planning

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Limitation:

The document has been compiled using the author's expert knowledge, due care and professional expertise. All the interpretations within the report are based on data and information available in the public domain, or that which has been provided by Melton City Council. The discussion and findings of the report relies on the physiographical, geological, geophysical, and hydrological data (including mapping and boring records) made available by the Victorian Government departments and agencies. Almost all these data have been verified by the author.

This document has been prepared for use by Melton City Council in accordance with the project brief between Federation University Australia and Melton City Council. The author and Federation University Australia accept no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

Document history and status

Version	Date	Description	By	Approved
Final V1	31 August 2018	Report to Council	PGD	PGD

Table of Contents

Executive Summary

From 1983 to 1987 an investigation program was undertaken by the State Government to provide essential geological information for use by planners and engineers working in the Melton Development Area. The work was extensive, collating all the known data from previous and contemporaneous investigations (over 800 sampled locations), and included a substantial drilling and testing program (~ 250 sites) in areas where little was known of the geological materials. This complete body of work was provided to the Shire of Melton in 1988, specifically to guide the strategic planning, site investigation practices, and sustainable development of the urban area. It has been publicly available since 1988 through the Geological Survey of Victoria and the RMIT Library, and is now freely available online.

Three main geohazards are recognised, *viz:* large areas of highly to extremely reactive soils in West Melton and north of Melton central, substantial areas of gilgai soil development in West Melton, and an area of soil subsidence in the north-west at Harkness. These geohazards pose risks to building foundations and the integrity of underground services. The risk is exacerbated by the fact that the geohazard is region-wide, and therefore extends beyond the boundaries of individual allotments. Since all development, both private and public, changes moisture distribution in the deep reactive soils, the landscape and hydrological changes on one property may, in time, result in a deep-seated expansive soil response on a neighbouring property. Of concern is the establishment of trees and garden irrigation near the allotment boundaries, including street trees and nature strips.

The closer urban development on the highly to extremely reactive soils in the West Melton area has resulted in damage to structures, the most notable recent cases are where a building was ordered to be demolished and replaced (Major consequence) and another ordered to undergo considerable repair (Moderate consequence). Since the likelihood of the geohazard is Certain, the risk of damage to houses and other built infrastructure is Moderate to Very High. The risks will increase in severity with the predicted climate change scenarios for the region.

The site for the proposed development of a Place of Worship at 171 – 197 Harkness Road, Harkness, has been previously investigated by the State Government for its potential development as a regional cemetery and for housing subdivision. Both potential land-uses were deemed unsuitable because of the presence of obvious geohazards: highly to extremely reactive soils, gilgai development and collapsing/subsiding soils.

Using the information and data from the previous investigations, an assessment of the proposed development for a Place of Worship, based on the current concept plans, has been completed. Adopting a risk management framework, the risk of damage to the development from the geohazards at the site is regarded as High to Moderate, depending on the engineering and design adopted. The risk of the development increasing the severity of the geohazards on the neighbouring properties is Moderate.

Arguably there are very few sites on Earth that could not be built on with a suitably engineered solution. Hence it can be argued that the risk at the proposed development site could be reduced by mitigating the consequences through engineered solutions. However, this would require a geotechnical investigation, engineering design and landscape design beyond that normally considered for a development of this type, because it would require a collective 'neighbourhood design' approach to mitigating deep-seated soil movements. The proposed Place of Worship and landscaping would, over time, impact on the neighbouring cemetery development, just as the neighbouring cemetery development would also ultimately impact on the proposed Place of Worship.

It is recommended that the Council considers embedding geohazard information in the Planning Scheme so that potential developers are alerted to the associated risks. In addition, the Melton community could be made more aware of the risks associated with the geohazards through the dissemination of information, especially using online maps.

1 Introduction

This report has been prepared in response to the Project Brief commissioned on 11 July 2018 between the Melton City Council and Federation University Australia (FedUni) to report on the latent ground conditions in relation to a proposed development at Harkness and the Melton area in general. The project follows from a meeting between Associate Professor Peter Dahlhaus (the author), Principal Research Fellow at the Centre for eResearch and Digital Innovation (CeRDI) at FedUni and the senior management at Melton City Council on 11 May 2018.

In the 1980s the Victorian Government completed engineering geological mapping for the Melton Development Area, in which the author played the key role. The City of Melton at its meeting on 30 April 2018, considered a planning permit application (PA2017/5728) for a Place of Worship on land known as 171-197 Harkness Road, Harkness. At the meeting, Council resolved (in part) that they *"Consult with Dr Dahlhaus, through Federation University, on possible use of the land described and ask of his availability to give Councillors a full briefing on potential for Harkness Road, Gilgai affected developments"*.

The applicants have since lodged an Application for Review with the Victorian Civil and Administrative Tribunal (VCAT) against Council's failure to determine the application within the prescribed time. VCAT has advised Council that the hearing is to be conducted over four days commencing on 22 October 2018.

Melton is situated on the Werribee Plains, a volcanic plain that forms part of the Victorian Western Plains (Joyce et al., 2003). Reactive soils are a well-documented geohazard of the Werribee Plains, especially at Melton (Dahlhaus & O'Rourke, 1992; Neilson et al., 2003; Walsh et al., 1976) since they can result in distress to engineered structures and may be considered a limitation to development.

1.1 Scope

Four project deliverables are outlined in the scope document:

1. Outline the work previously completed by the Geological Survey of Victoria during the 1980s for the Regional Cemeteries Trust, Urban Land Authority and Melton Development Area.

   This component involves revisiting the original reports documenting the extent of the work completed by the Geological Survey of Victoria during the 1980s, mostly contained in nine unpublished reports, a report to the Victorian Parliament, a Masters thesis and three book chapters.

2. Review and detail the relevance of the above investigations in relation to the current proposed development for a Place of Worship at Harkness, specifically:

   a) The suitability of the land for the proposed development in terms of the geology and soil conditions (latent ground conditions).

   b) An assessment of the hazard and risk posed by the latent ground conditions on the proposed development.

   c) An assessment of the hazard and risk posed to the neighbouring properties by the proposed development especially in consideration of the latent ground conditions.

   With a specific focus on the Planning Application for a Place of Worship at 171-197 Harkness Road, Harkness, the previous work can be reassessed to consider the suitability of the land for development. This is placed within a risk context using the Australian Risk Management Standard to assess the risks posed to the development (by the latent ground conditions) and the risks posed to the surrounding environments (by the proposed development). While this report can detail the geohazards, assess the risks, and discuss high-level options for risk mitigation, the acceptability of the risks, and specific or detailed recommendations for risk mitigation are considered outside of the brief, as these would need to be negotiated between the developer and Council.

3. Considering the previous investigations, the subsequent development of the Melton area, and the predicted climate change scenarios, broadly reassess the overall hazards and risks posed by the latent ground conditions in the City of Melton.

   This component examines the larger body of work for the Melton Development Area in the context of the history of development and geohazard issues that have arisen by the changes to the Melton landscape over the past 32 years and in consideration of the future changing climates. The project will detail the geohazards, assess the risks, and discuss high-level options for risk mitigation.

4. Provide recommendations for consideration by Council.

   This project deliverable consists of a comprehensive report, with an executive summary, and recommendations for consideration by the Melton City Council. The findings of the project will be presented to Council as required.

1.1.1 Author

Peter Dahlhaus has spent the past 40 years in engineering geology, environmental geology and hydrogeology working in private and public sectors, investigating the geology, geomorphology, soils, groundwater and geohazards in south west Victoria. He has been influential in applying his scientific knowledge to direct policy on soils, salinity and catchment management. Peter is well-known as a science communicator by his students and community groups, and as an independent advisor to Catchment Management Authorities, water authorities and municipalities in the region. He is a Principal Research Fellow at FedUni, leads projects in the national Cooperative Research Centre for High Performance Soils, and is a collaborator in international soil data exchange projects.

Peter completed his research Master of Applied Science degree at RMIT on the Melton mapping project in 1988 (thesis title *"Engineering geological mapping for the urban development of Melton, Victoria"*). He also holds a Bachelor of Applied Science from RMIT and a PhD from Flinders University. His credentials can be found at: www.cerdi.edu.au/peter_dahlhaus

2 Engineering Geological Mapping for the Melton Development Area: 1983 - 1987

From 1982 to 1988 the author was employed as a Geologist by the Geological Survey of Victoria (GSV) division of the State Government Department of Industry, Technology and Resources. During that time, he carried out extensive engineering geological investigations at Melton. The investigations took approximately four years to complete (1983 - 1987) and were carried out by a team of professionals and skilled assistants that the author led.

2.1 General overview

The project was commissioned by the Ministry for Planning and Environment and the Melbourne and Metropolitan Board of Works. It was recognised that standard geological maps lacked the relevant information required for engineering and planning. Therefore, the aim of the project was to map the engineering geological conditions of the land within the Shire of Melton that was designated as the Melton Development Area, to determine the geological parameters, limitations and suitability of the land for the proposed urban development as the satellite City of Melton.

To some extent the work was guided by the end users, that included the Shire of Melton and the geotechnical industry in general. The Melton Shire Engineer, for example, required to know the depth to rock so that contract specifications could be realistically written for the installation of sewerage and storm-water systems. The Building Surveyor required to know the extent of any hazards affecting building foundations such as reactive soils or filled land (Dahlhaus, 1988).

The geological and geotechnical investigations, and engineering geological mapping of the Melton Development Area, included examining the records of 1115 bores and test pits in the designated area. Of these, 32 test pits were excavated, and 214 bores were drilled, logged and sampled specifically for the GSV projects. Intact soil cores (50mm diameter) were taken from all the 214 bores (~1,700 metres of core in total), all of which the author personally logged and described. The resulting maps were based on these soil profiles in addition to a comprehensive suite of tests on 206 soil samples, which were added to a substantial volume of soil test data from other contemporaneous studies (such as those for the freeway, roads, sewerage, etc.) at Melton. Information was collated from the various sections within the GSV, Road Construction Authority, Railway Construction Board, State Electricity Commission, Public Works Department, State Chemistry Laboratories, Melton Sewage Authority, Housing Industry Association, Farley and Lewers Pty Ltd, CRA Exploration Ltd and private groundwater bores.

In addition to the large engineering geological mapping project, two further and discrete investigations were undertaken in the north western sector of the Melton Development Area, now Harkness. These were investigations into land owned by the Urban Land Authority and the Regional Cemeteries Trust. These surveys included additional drilling, sampling and testing (Dahlhaus, 1984, 1985), as well as seismic geophysical surveys to determine the depths of the soil cover (Killey, 1985).

The spatial coverage of all this work is illustrated in Figure 1 and a summary listed in Table 1 .

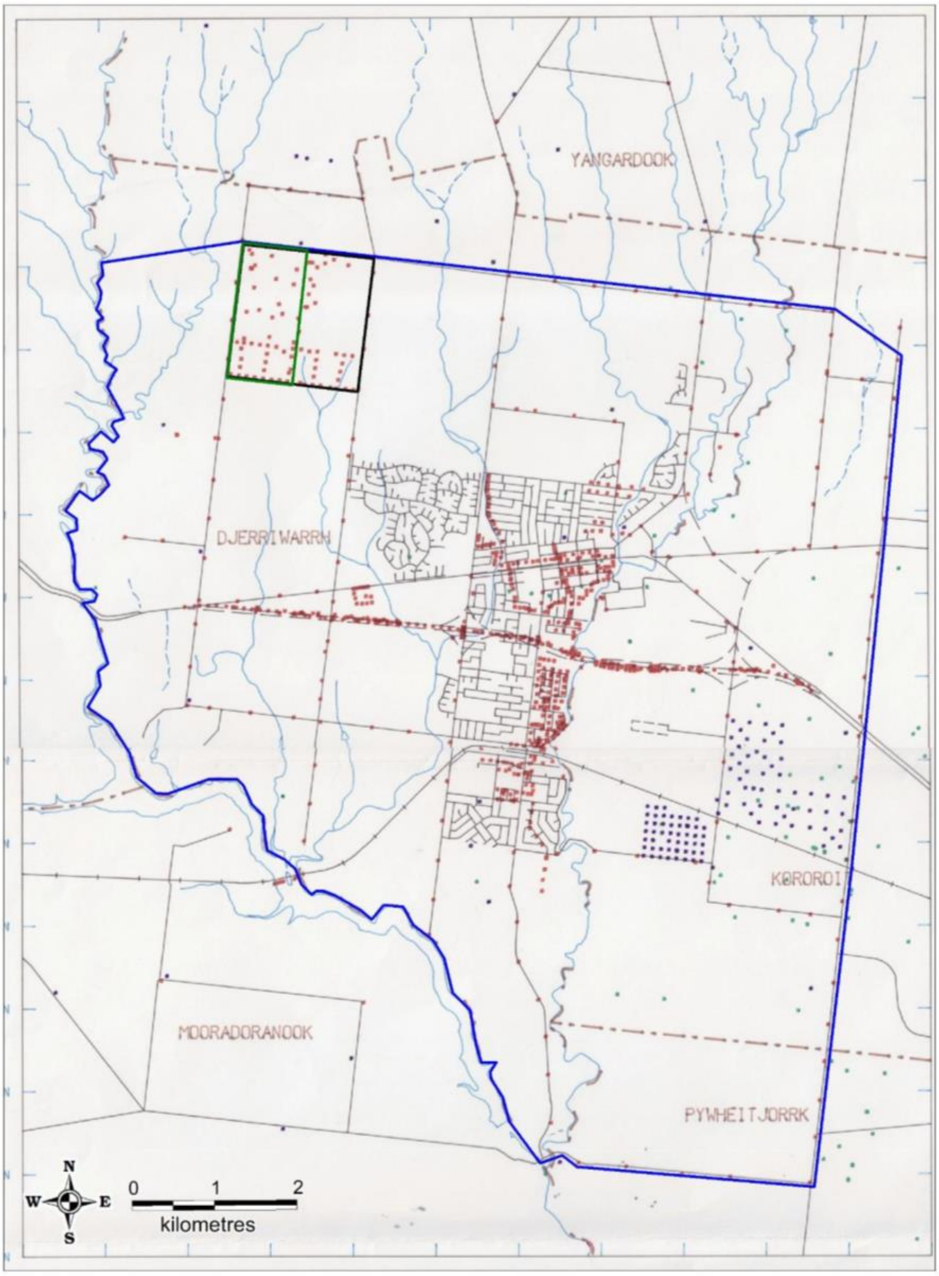


Figure 1. Locations of the Geological Survey of Victoria investigations

Note: The base map is extracted from Dahlhaus (1986f) and shows the bore locations as dots: geotechnical = red, groundwater = green, mineral/stone exploration = purple. The blue line represents the boundary of the Melton Development Area investigation, the black line bounds the Regional Cemetery investigation and the green line bounds the Urban Land Authority investigation.

Data Sources (prior to 1983)

Organisation	No. & type	Project
Geological Survey	14 water bores 9 mineral bores 1 geotechnical bore	Government drilling 1894 - 1982
Road Construction Authority	179 bores 49 test pits	Melton Freeway (1980-1983)
	17 bores	Basalt survey (1966)
Public Works Department	5 test pits	Melton High School (1974)
	2 test pits	Melton Environmental School (1977)
	18 test pits	Melton Technical School (1978; 1981)
	15 bores	Melton TAFE (1980)
	2 bores	Melton CGCS (1980)
	5 bores	Wedge Park Primary School (1980)
State Electricity Commission	3 bores	Substation (1979)
VicRail	6 bores	Melton rail bridge (1981)
Melton Sewage Authority	342 bores	Sewerage lines (1972-77)
Farley & Lewers Ltd	100 bores	Quarry investigation
Housing Industry Association	25 bores	Distressed housing investigations (1979-83)
Private groundwater bores	77 bores	Pre-1983

Drilling statistics (including the 1983 – 1987 studies)

Bore/pits by Geological Survey of Victoria					
Parish	Number of bores/pits	Total depth (m)	Average depth (m)	Maximum depth(m)	Minimum depth(m)
Djerriwarrh	193	1119.78	5.80	63.09	0.25
Kororoit	56	530.92	9.48	97.50	0.50
Mooradoranook	4	79.19	19.80	72.54	1.20
Pywheitjorrk	8	11.00	1.38	4.10	0.65
Yangardook	9	256.17	28.46	53.98	1.60
Melton map area total	270	1997.06	7.40	97.50	0.25
Bores by other organisations					
Drilled by	Number of bores/pits	Total depth (m)	Average depth (m)	Known maximum depth(m)	Known minimum depth(m)
Melton Sewage Authority	340	1127.1	3.3	11.4	0.2
Road Construction Authority	209	876.71	4.19	17.15	0.8
Farley and Lewers	104	2470.24	23.75	62.50	15.24
Others	192	n.a.	n.a.	169	0.5
Melton map area total	845				

Soil Tests (for the GSV investigations 1983 – 1987)

Test	Number of tests	Average result	Maximum result	Minimum result
Liquid Limit	145	69	155	14
Plastic Limit	88	21	33	12
Linear Shrinkage	167	17	27	1
Free Swell	176	185%	900%	30%
Specific Gravity	81	2.59t/m^3	2.98t/m^3	2.29t/m^3
Percent gravel	136	13%	58%	1%
Percent sand		24%	70%	1%
Percent silt		30%	63%	7%
Percent clay		47%	91%	2%
Percent fines		56%	99%	14%
X-ray diffraction	36			

All data sourced from Dahlhaus (1988)

Table 1. Statistics of the investigation works undertaken.

2.1.1 Publication of the work

The investigations were documented in a series of reports, a thesis and three book chapters:

The two reports that are specific to land in north west Melton:

- Dahlhaus, P.G. (1985) An engineering geological investigation of the Urban Land Authority's property, Melton. *Geological Survey of Victoria Unpublished Report 1985/50*. Department of Minerals and Energy, Victoria, Melbourne. 33p. (GSV UR 1985/50) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:6144
- Dahlhaus, P.G. (1984) Engineering geological investigation of proposed cemetery site at Melton. *Geological Survey of Victoria Unpublished Report 1984/77*. Department of Minerals and Energy, Victoria, Melbourne. 99p. (GSV UR 1984/77). Part available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:6078

  GSV UR 1984/77 was also reproduced in:

  Mortuary Industry and Cemeteries Administration Committee (1985) Investigations into Cemetery Management and the Provision of Cemetery Reserves. *Fourth Report to Parliament*. November 1985. National Library of Australia listing: http://trove.nla.gov.au/version/21913363

The seven reports that cover the Melton Development area:

- Dahlhaus, P.G. (1986a) Engineering geology of Melton - a review. *Geological Survey of Victoria Unpublished Report 1986/1*. Department of Industry, Technology & Resources, Victoria, Melbourne. 77p. (GSV UR 1986/1) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15924
- Dahlhaus, P.G. (1986g) Engineering geology of Melton - the Melton Development Area. *Geological Survey of Victoria Unpublished Report 1986/2*. Department of Industry, Technology & Resources, Victoria, Melbourne. 8p. (GSV UR 1986/2) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15930
- Dahlhaus, P.G. (1986b) Engineering geology of Melton - drilling, testing and mapping program. *Geological Survey of Victoria Unpublished Report 1986/3*. Department of Industry, Technology & Resources, Victoria, Melbourne. 39p. (GSV UR 1986/3) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15941
- Dahlhaus, P.G. (1986d) Engineering geology of Melton - geology and geomorphology. *Geological Survey of Victoria Unpublished Report 1986/4*. Department of Industry, Technology & Resources, Victoria, Melbourne. 34p. (GSV UR 1986/4) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15942
- Dahlhaus, P.G. (1986c) Engineering geology of Melton - engineering geology. *Geological Survey of Victoria Unpublished Report 1986/5*. Department of Industry, Technology & Resources, Victoria, Melbourne. 47p. (GSV UR 1986/5) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15943
- Dahlhaus, P.G. (1986e) Engineering geology of Melton - map presentation of data. *Geological Survey of Victoria Unpublished Report 1986/6*. Department of Industry, Technology & Resources, Victoria, Melbourne. 11p. (GSV UR 1986/6) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15951
- Dahlhaus, P.G. (1986f) Engineering geology of Melton - summary. *Geological Survey of Victoria Unpublished Report. 1986/7*. Department of Industry, Technology & Resources, Victoria, Melbourne. 12p. (GSV UR 1986/7) Available online at: http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15947

A Master of Applied Science thesis that documents the entire body of work:

- Dahlhaus, P.G. (1988) Engineering geological mapping for the urban development of Melton, Victoria. M.App.Sci. thesis. Applied Geology, R.M.I.T., Melbourne. 190p. RMIT Research Repository: *https://researchbank.rmit.edu.au/view/rmit:162471* National Library of Australia listing: *http://trove.nla.gov.au/version/45649788*

  The thesis was examined by Mr Stuart Morris QC (Senior Member of the Planning Appeals Board at the time and later President of VCAT) and Mr John Brumley (Senior Geologist at the State Electricity Commission at the time and later Associate Professor at RMIT). Both examiners graded the thesis as passed without amendments.

Three book chapters that document the expansive soils geohazard at Melton:

- Neilson J.L., Peck W.A., Wood, P.D., Dahlhaus P.G., Miner A.S., Brumley J.C., Kenley P.R., Wilson R.A., Willman C.E. and Rowan J.N. (2003) Geological Hazards. Chapter 20 in: *Geology of Victoria.* (ed. Birch W.D.), Geological Society of Australia Special Publication 23. Geological Society of Australia, Victorian Division. pp. 573-592. *http://vic.gsa.org.au/Publications/books.html*
- Dahlhaus P.G. & O'Rourke M. (1992) The Newer Volcanics. in, *The Engineering Geology of Melbourne.* (eds. W.A. Peck, J.L. Neilson, R.J.Olds & K.D. Seddon), A.A. Balkema, Rotterdam. pp. 205-212. National Library of Australia listing: *http://trove.nla.gov.au/version/27465871*
- Dahlhaus P.G. (1991) Engineering and Environmental Geology. Chapter 7 in, *Introducing Victorian Geology* (G. Cochrane, G. Quick & D. Spencer- Jones, eds.) Geological Society of Australia, Vict. Division. pp.265-304. National Library of Australia listing: *http://trove.nla.gov.au/version/7976168*

2.1.2 Shire of Melton involvement

At the completion of the project, the work was presented at a seminar of the Australian Geomechanics Society, a branch of the Institution of Engineers Australia, on the 11th March 1987 (Appendix A). The seminar was attended by representatives from the Shire who actively participated in the discussion during the evening.

The Department of Industry, Technology and Resources passed copies of all the GSV Reports to the Shire of Melton. The Deputy Shire Manager/Shire Engineer responded that *"...the valuable information contained in these reports ... is expected to both greatly assist the strategic planning for the long-term Melton Urban Area and also the development of policies and practices for site investigations for both building and engineering works."* (Letter dated 7/3/1988 - Appendix B).

In addition to the investigations completed by the GSV at Melton, there were other regional projects undertaken by the Land Protection Service (formerly the Soil Conservation Authority) of the Department of Conservation, Forests and Lands, and the Melbourne and Metropolitan Board of Works. Contemporaneous site-specific investigations include those by the Road Construction Authority, Public Works Department and others (Table 1). All these projects were aimed at providing information for best-practice urban planning.

2.2 Significance of the previous work

At the time of its completion the mapping represented a rare global example where such extensive regional investigations had been completed specifically to inform government and municipal planners. The intention was to identify the constraints to development posed by the latent ground conditions, which would then guide the appropriate development for the different areas of the landscape.

2.2.1 Geohazard recognition and mapping

Geohazards are a geological process that result in risk of property damage or loss of life, most obviously seen as earthquakes, volcanic eruptions and landslides. While many geohazards are episodic events (e.g. rockfalls or tsunamis) the most widespread and prevalent geohazards are continual natural processes such as reactive soils, soil salinization or land subsidence.

The identification and mapping of the geohazards in the Melton Development Area was among the first in Australia and among only a few examples in the world at the time. The identified geohazards at Melton are reactive soils, gilgai development and collapsing soils.

2.2.1.1 Reactive soils

Reactive soils, also termed shrink-swell soils or expansive soils, are those where the soil materials respond to moisture by expanding when wet and shrinking when dry. They are a significant geohazard in Victoria, causing around 90% of all cracking in houses (Neilson et al., 2003). The amount of movement in the soil primarily depends on the type and volume of specific clay minerals present in the soil, the distribution of those clay minerals in the soil profile, the depth of the soil profile, and the volume of moisture change in the soil profile.

The investigations in the Melton Development Area found high volumes of the most reactive clay minerals, known as montmorillonites, widely distributed throughout deep soil profiles across the entire area, apart from the north east where alluvial gravels occurred along the Toolern Creek. The most highly reactive soils occur across the western half of the area, as well as localities in the central and northern areas. In the south eastern quadrant, the soils are younger and thinner, hence the thickness of reactive clay minerals has not developed as much.

To determine the clay mineral type and properties, the investigation used a combination of soil mechanical tests: liquid limit, plastic limit, Plasticity Index, free swell and linear shrinkage, in combination with soil mineralogy determinations by the State Chemistry Laboratories. The test results showed that the properties of some of the sampled soils were so extreme in their reactivity (i.e. shrink-swell behaviour) that they plotted off the chart in the Australian Standard soil classification and are considered extremely plastic in global terms[1]. The most extreme (liquid limit >140, free swell >400%, linear shrinkage ≥25%) occur around Gloaming Ride, Thrice Lane and Minns Road. Others in the same extreme category are found along Harkness Road, north of the freeway.

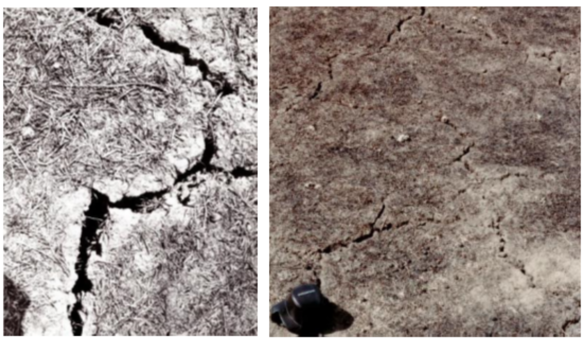


Figure 2. Typical shrinkage features
(photos: P. Dahlhaus, 1983, Melton)

[1] It should be noted that the soil properties used to measure the expansiveness of the clay at Melton (Table 1) record some of the highest values globally, beyond of the range of values classified as 'extremely high plasticity' by the International Commission on Engineering Geological Mapping (Dahlhaus, 1986b; 1988; I.A.E.G., 1981). They literally plot off the charts.

2.2.1.2 Gilgai development

Gilgai is the term given to landforms (or micro-relief) that appear as subtle mounds and depressions in the landscape. The term is taken from an Australian Aboriginal word for waterhole, since the depressions sometimes contained pools of water. Recognised around the world, gilgai form in reactive soils through the repeated cycles of shrinking and swelling (Figure 3).

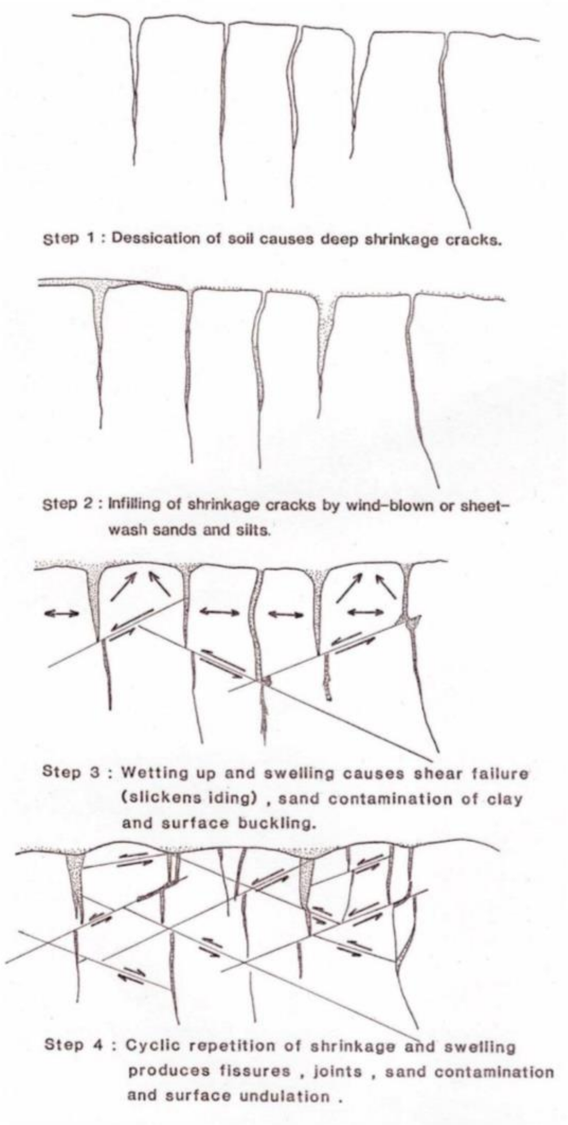


Figure 3. The process that leads to the formation of gilgai.

Sourced from (Dahlhaus, 1986d) and published in Dahlhaus & O'Rourke (1992 - Figure 5).

At Melton, the gilgai was recognised in earlier surveys by the Soil Conservation Authority, who mapped large tracts of West Melton and northern Melton as 'gilgaied basalt plain' based on aerial photography and ground observations (SCA, 1978). The gilgai process causes fissuring of the clays, ingestion of fine grained sands deep into the profile, and forms subtle mounds and hollows at the surface. Since the latter 19th century, the micro-relief of hollows and mounds has been subdued by continual ploughing of the land, although the pattern is still recognisable in aerial images (Figure 4). Most of it is now obscured under urban development.

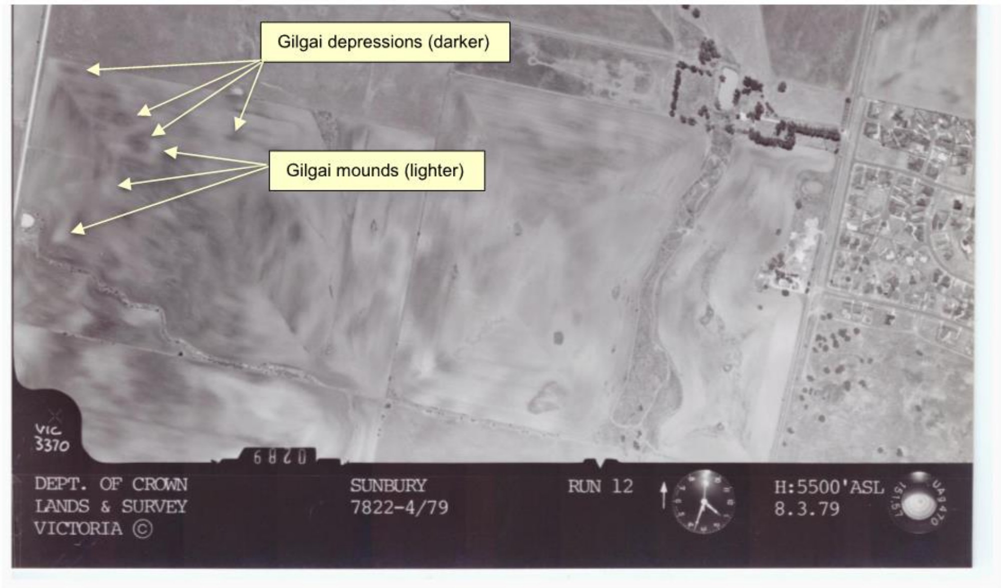


Figure 4. Part of an aerial image of West Melton taken in March 1979 in which the mosaic pattern of the gilgai is clearly visible. *Sourced from Dahlhaus (1988 - Plate 18).*

Figure 5. Polished shear surface, or slickenside, in a clay core sample from Melton

Sourced from: (Dahlhaus, 1986d; 1988)

Figure 6. Surface depressions of gilgai features at Harkness, 1984 – 1985.

Source: Dahlhaus (1985)

2.2.1.3 Collapsing soils

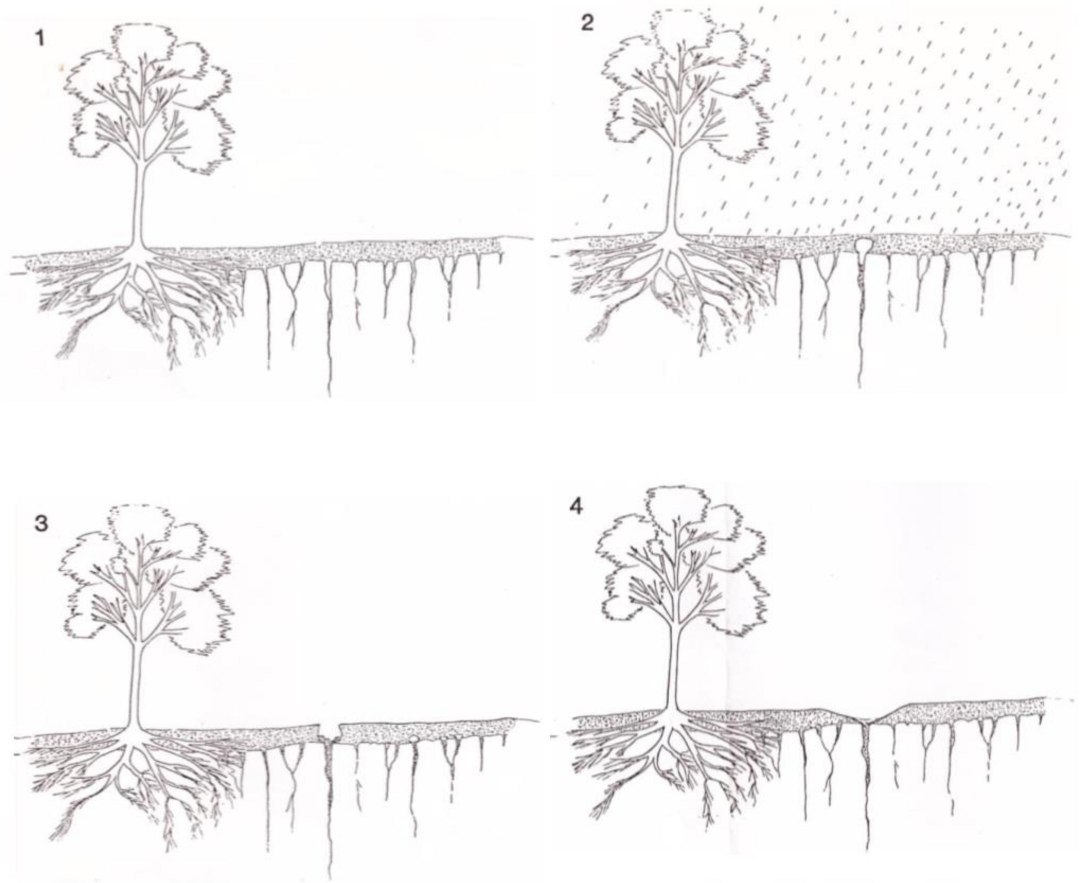
Collapsing soils are geohazards in which the soil surface collapses, often suddenly, to form a sinkhole or pothole. Collapsing soils have varied causes, both natural (e.g. slaking and dispersion of soil) to man-made (e.g. subsidence over underground mine cavities). Collapsing soils are recognised in the north-west of the Melton Development Area and were designated as the 'sinkhole plain' by the Soil Conservation Authority (SCA, 1978). Most of this area has now been included in the Melton Gilgai Woodlands nature Conservation Reserve.

This area was intensively examined by the author in both the investigations for the Health Commission for the proposed Melton Regional Cemetery (1984), and the Urban Land Authority (1985) for potential subdivision. Those investigations included numerous bores, including two deeper bores (>15 metres), excavation pits and geophysical exploration for subsurface profiling. The mechanical and physical properties of soil samples were determined, as was the clay mineralogy of selected samples. Groundwater was recorded over one year, during which time the watertable remained in the fractured basalt below the soil profile.

Anecdotal observations recorded in 1984 from the neighbouring resident of 60 years, Mr T Minn, revealed that the subsidence was continuously active, and also occurred on his farm paddocks that were ploughed each year. Active subsidence was observed by the author during the three years of the investigation (Figure 7). The depressions appear to evolve from a small sinkhole into a larger saucer-shaped depression over time.

In this area a relatively thin layer of sand and gravel overlies thick clay-rich subsoils and this profile provides a proposed mechanism for the subsidence (Figure 8). The conceptualisation fits with most observed features, especially the numerous fissures seen in all soil cores extracted from all bores drilled at the site. Fissuring was logged through the full depth of the profile - over nine metres in places - many fissures filled with sand with tree rootlets along the fissures, and many with polished surfaces (termed slickensides) caused by movement (shear failure of the soil).

Figure 7. Recently collapsed soils at Melton (Harkness) in 1985.
(right) in the Harkness Road reserve and (below) in the Melton Gilgai Woodlands nature Conservation Reserve.
Sourced from: Dahlhaus (1986d)



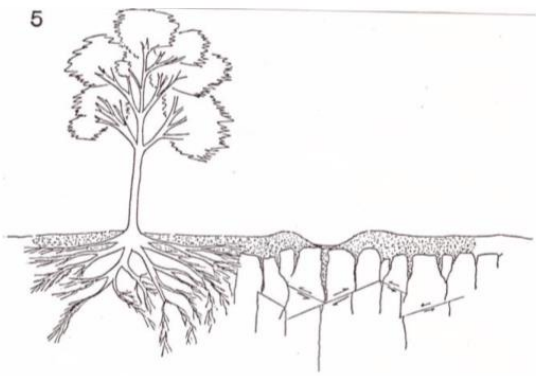


Figure 8. A proposed mechanism for the soil subsidence observed at Melton (Harkness).

1. *The deep, clay-rich, highly reactive subsoil is desiccated by the vegetation, causing deep shrinkage cracks that are obscured by the overlying (unreactive) silty, sandy topsoils.*
2. *The topsoil falls into the soil cracks, assisted by rainfall infiltration. The weakly cemented top soil arches across the subsoil crack, creating a void.*
3. *The topsoil collapses forming a 'sinkhole'.*
4. *The sides of the sinkhole are eroded into a saucer-shaped depression.*
5. *The subsequent swelling of the subsoil creates shear stresses, slickensides and fissures to buckle the surface into typical gilgai relief.*

Sourced from: Dahlhaus (1986d)

2.2.2 Site classification mapping

The mapping of site classification at the regional scale was the first undertaken in Australia and was based on the inaugural Australian Standard AS2870-1986 for Residential Slabs and Footings. The standard was introduced following the 1982-83 drought during which the number of cracked houses in Victoria reached epidemic proportions. The standard introduced a 'site classification' for residential housing that rated the reactivity of the clay using soil profiles, climate zones and soil mechanical properties.

Almost all the Melton Development Area is rated as Highly Reactive sites (Class H), with some Extremely Reactive sites (Class E). Moderately Reactive sites (Class M) are mapped where thicker alluvial gravels overlie the basalt along Toolern Creek and at Exford. The north west corner where soil collapse occurs is rated as Problem sites (Class P).

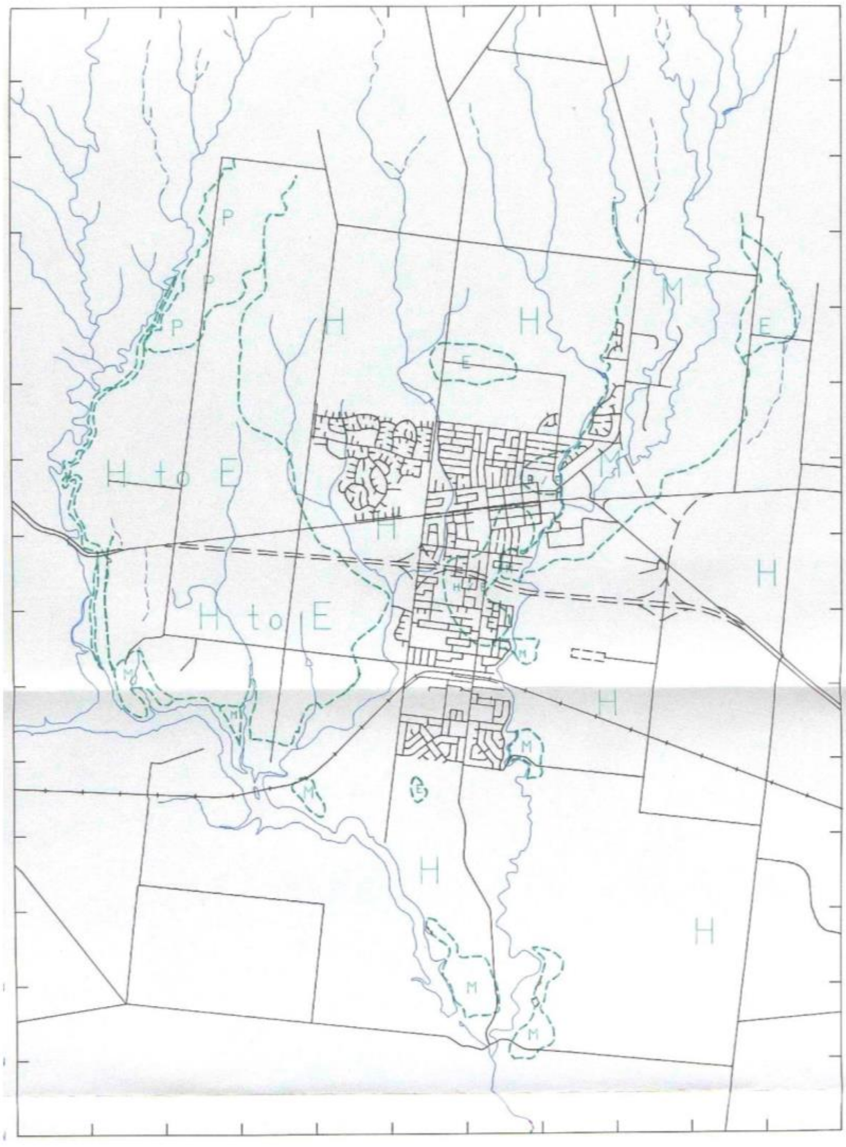


Figure 9. Site classification based on AS2870-1986. (from Dahlhaus, 1986c)

2.2.3 Computerised mapping

The engineering geological mapping project used computer aided drafting, that was the first undertaken in the GSV and among the first in Victorian Government departments.

Since shallow rock was considered an economic constraint to urban subdivision and the installation of services at Melton, statistical methods, known as kriging, was used to develop soil thickness maps (Figure 10). The soil thickness maps were also useful in assisting the site classification mapping, since the depth of soil is a determinant on how much heave can be expected at the surface.

The following maps were produced for the engineering geological mapping folio:

- Location and documentation of investigation sites
- Surface geology and geomorphology, and subsurface geology
- Soil depth and rockhead contours
- Standing groundwater level (depth to watertable and water table elevation)
- Sand and gravel potential
- Site classification
- Engineering geology units

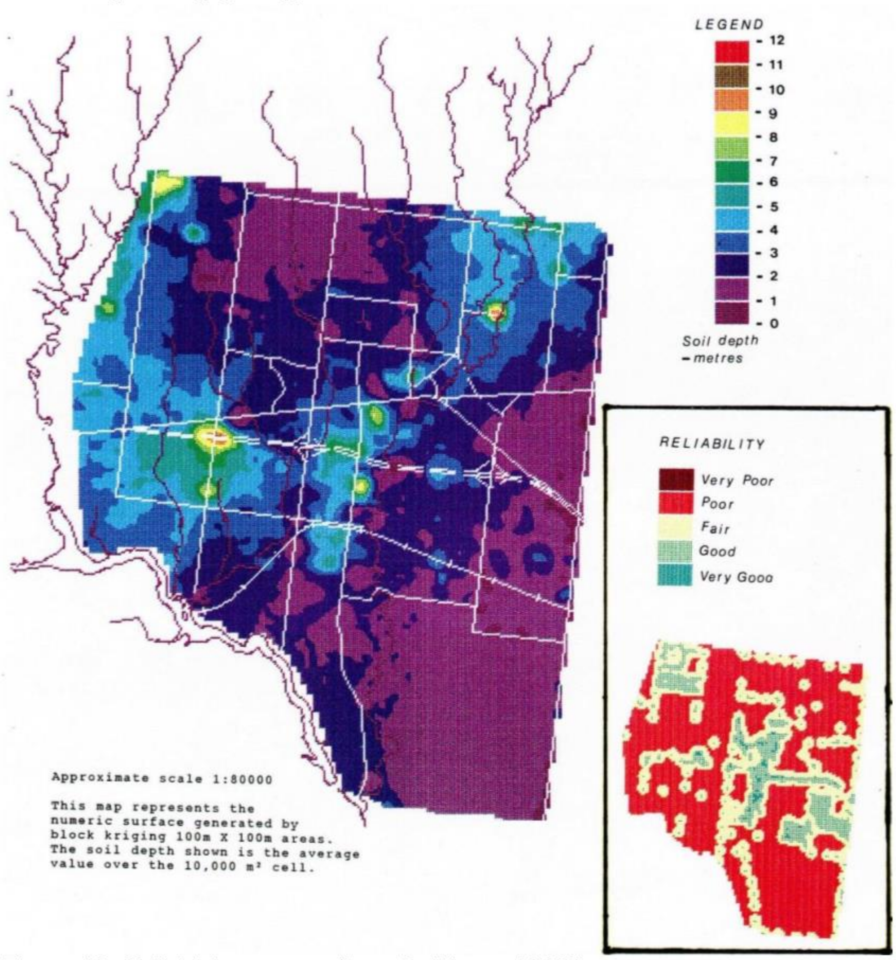


Figure 10. Soil thickness map (from Dahlhaus, 1986f)

2.3 Summary

The four-year investigation program was undertaken by the State Government to provide essential geological information for use by planners and engineers working in the Melton Development Area. Specifically, the investigation aimed to identify the constraints to urban development posed by the latent ground conditions.

1. The work was extensive, collating all the known data from previous and contemporaneous investigations (over 800 sampled locations), and included a substantial drilling and testing program (~ 250 sites) in areas where little was known of the geological materials. It represents perhaps the most comprehensive repository of data for any suburb in Melbourne (outside of the Central Business District and Yarra Delta).
2. Three main geohazards are recognised, *viz*: large areas of highly to extremely reactive soils in West Melton and north of Melton central, substantial areas of gilgai soil development in West Melton, and an area of soil subsidence in the north-west at Harkness. These geohazards pose limitations to development, especially on building foundations and the integrity of underground services.
3. Statistical methods and computerised mapping techniques were used to interpolate and map the thickness of the soil in the Melton Development area. Assessments of the suitability for urban development were made, including an attempt at delineating the site classes designated in the inaugural Australian Standard AS2870-1986 (Residential slabs and footings).
4. This complete body of work was provided to the Shire of Melton in 1988, specifically to guide the strategic planning, site investigation practices, and sustainable development of the urban area. It has been publicly available since 1988 through the GSV and the RMIT Library and is now freely available online.

3 Planning Application for a place of worship at Harkness

This section of the report refers specifically to a Planning Application for a Place of Worship (mosque) at 171 – 197 Harkness Road, Harkness. The components of the application provided to the author by the City of Melton are appended (Appendix C). The proposed developments include a building, access road, carparking and landscaping.

3.1 Latent ground conditions

The engineering geological mapping investigations mapped reactive soils, gilgai development, and soil subsidence as geohazards at the site of the proposed development. The subsidence is attributed to gilgai processes in the deep, clay-rich subsoils that are obscured by the gravel and sand overlying the clays, until the unpredicted collapse of the surface.

The area was intensively investigated for both the Health Commission for the proposed Melton Regional Cemetery (1984), and the Urban Land Authority (1985) for potential subdivision. The cemetery investigation ruled out the area as suitable for cemetery development (Figure 11) due to the unpredictable occurrence of soil collapse, topographic development of mounds and hollows, and the number of trees (Dahlhaus, 1984). The subsequent investigation for the potential subdivision noted the following challenging constraints (Dahlhaus, 1985):

> *Expansive clay*
>
> *The presence of thick expansive clay soil poses a hazard to the development of the site. Buildings, roads and sewerage systems are susceptible to serious damage from the season movements of the soil. No preferred locations which would avoid the clays can be chosen for building construction. The only viable solution would be to have building foundations engineer-designed to tolerate considerable season movements.*
>
> *Subsidence*
>
> *The most obvious problem for development of the site is the active subsidence. Roads, housing, and sewerage systems would be seriously damaged by sinkhole development. The unpredictability of the sinkholes makes the siting of any structures hazardous. It is likely however, that areas of the site could be found where the potential for subsidence would be lower.*

The report goes on to suggest that the ground replacement, that is, removing the soil to a depth of at least one and a half metres under a building and at least three metres beyond the building footprint might provide a solution, but it is not guaranteed because the potential for subsidence remains, albeit mitigated in its depth at the surface. Road construction would require stabilisation treatment of the subgrade materials, impervious surface paving, good drainage and no trees or shrubs in the road reserve. Sewage disposal would also require alternatives, including above ground treatment works and the disposal of treated water in a manner that did not infiltrate it into the subsoil to cause gilgai processes.

Unsurprisingly, given the limitations and constraints of the ground conditions, the area was classified a Class P (Problem) in AS2970-1986 (Figure 12). The original standard is now superseded by AS2870-2011, which defines:

> *"Sites with inadequate bearing strength or where ground movement may be significantly affected by factors other than reactive soil movements due to normal moisture conditions shall be classified as Class P. Class P sites include soft or unstable foundations such as soft clay and silt or loose sands, landslip, mine subsidence, collapsing soils and soils subject to erosion, reactive sites subject to abnormal moisture conditions and sites that cannot be classified in accordance with Clause 2.1.2."* (page 17).

Hence the Class P remains the current classification given the site conditions.

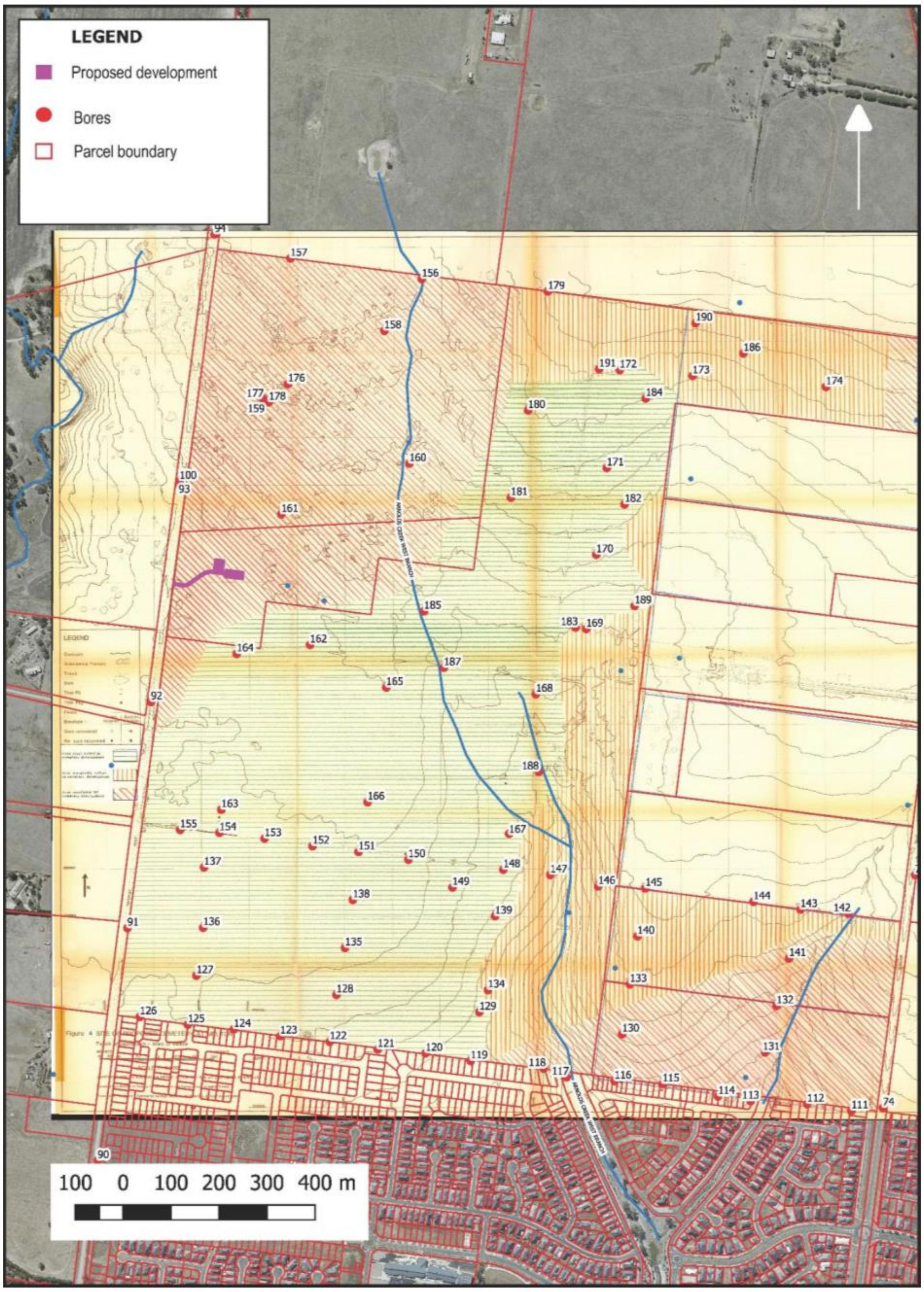


Figure 11. Mapped suitability for the proposed cemetery (1984).

Red is unsuitable, orange is marginal, and green is suitable. Overlain with the current cadastre and proposed development

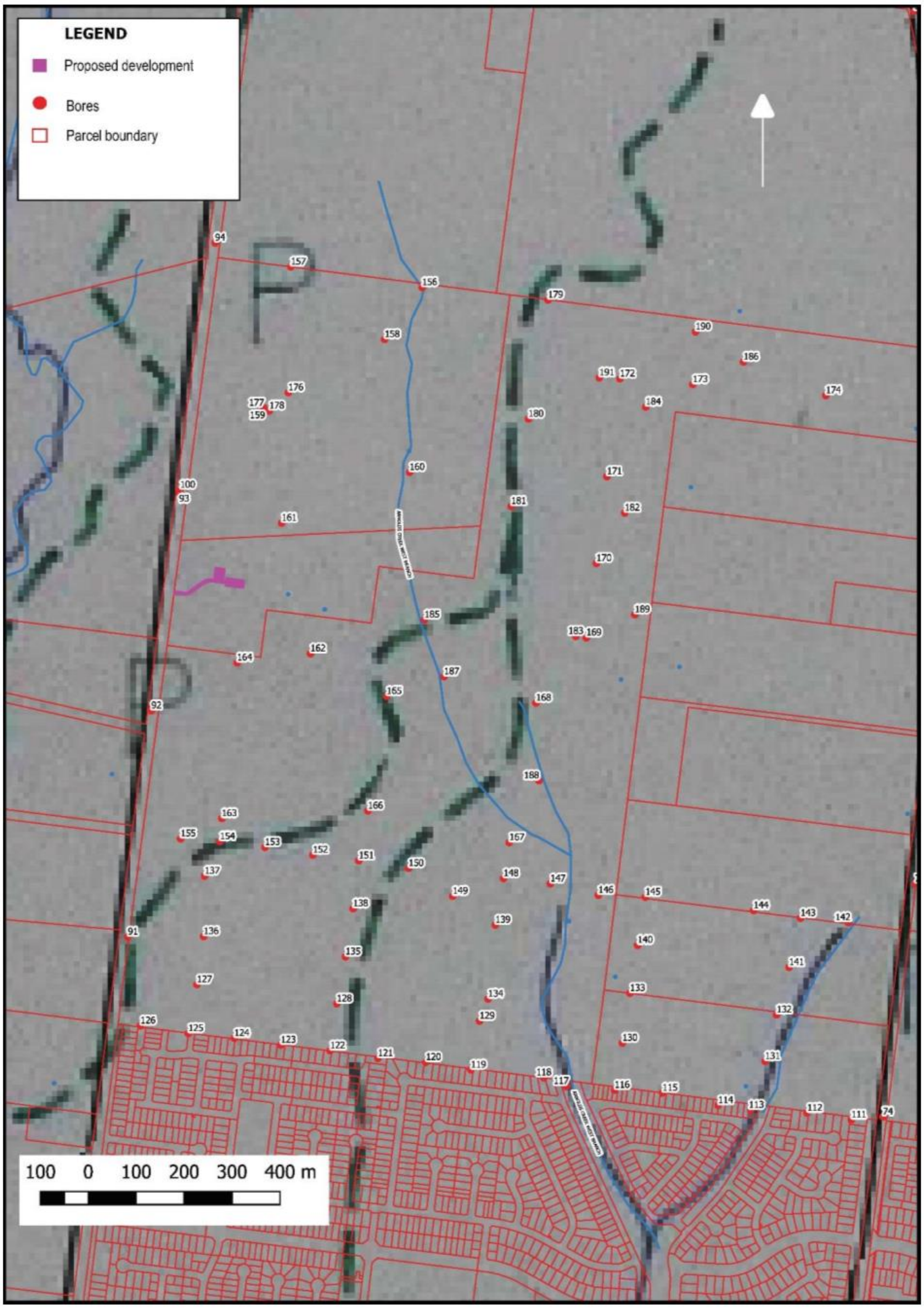


Figure 12. Proposed site classification for the Harkness area (1986).

The proposed development lies in the polygon designated as Class P (Problem soil).

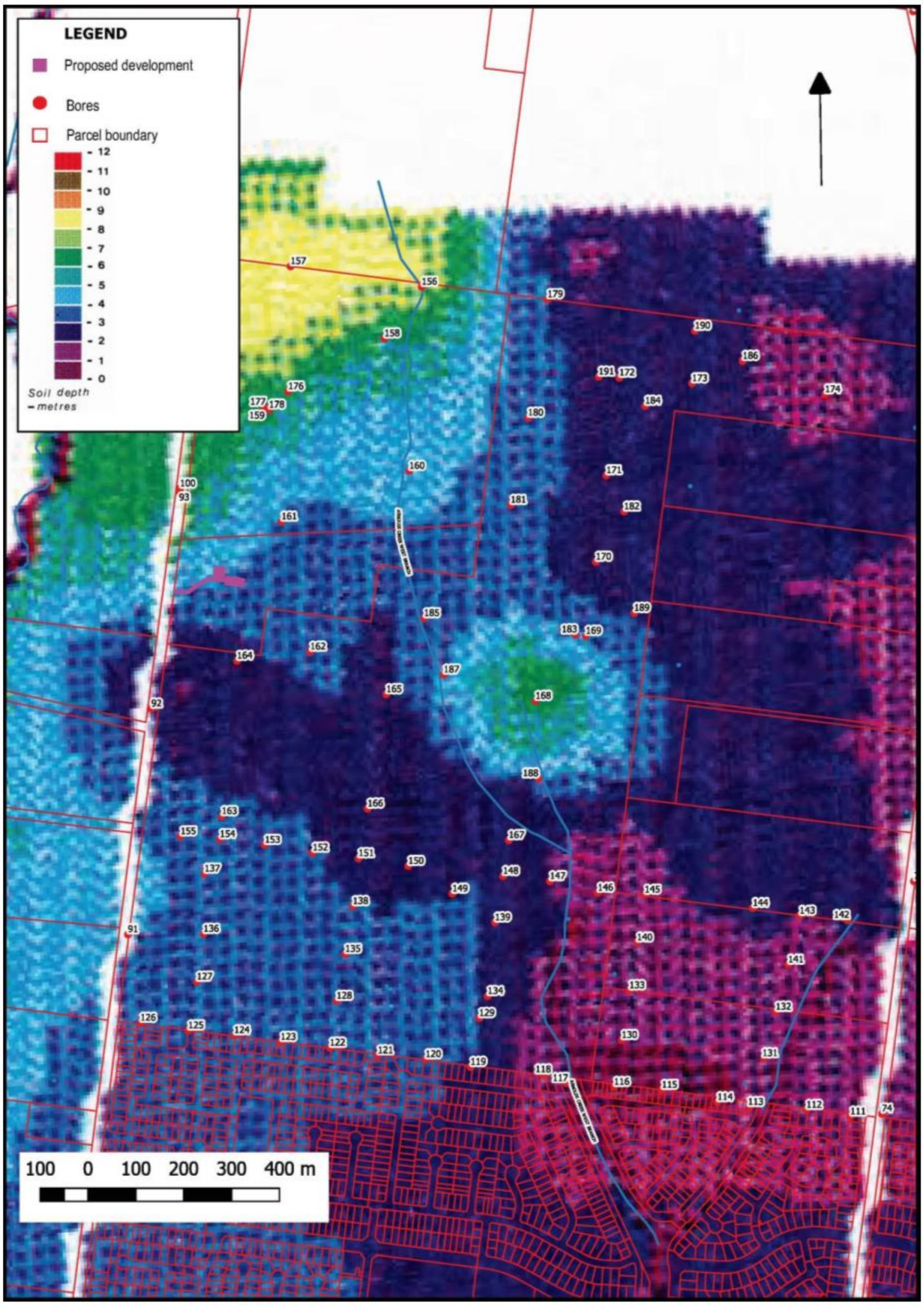


Figure 13. Enlarged view of the modelled soil thickness map (1986), with the bore locations. The proposed development is underlain by soils modelled as around four metres thick.

3.2 Hazard and risk

Although risk management terminology is defined by the International Organisation for Standardisation (ISO, 2002, 2018) and the Australian/New Zealand Standard on Risk Management – AS/NZS ISO 31000-2009 (Standards Australia, 2009) the standard definitions are not strictly used in the geotechnical industry and local government policies. In particular, 'risk', the standard definition of which is "the chance of something happening that will have an impact upon objectives", is often interchanged with 'hazard', which is "a source of potential harm or a situation with a potential to cause loss".

Risk identification is the equivalent of a hazard assessment, in that it requires an analysis of what can happen, where in the landscape it is likely, and when it could occur. Once it is established what, where and when a geohazard may occur, the causes and scenarios also need to be considered. Risk assessment requires the estimation of both the likelihood of the geohazard impacting on an asset and the consequence of that impact on the asset. In all cases the geohazard risk assessment should estimate both the likelihood of the geohazard impacting on a development; and the likelihood of a development impacting on geohazard processes. The standard indicates that this estimation can be qualitative, semi-quantitative, or quantitative (Standards Australia, 2009).

For most geohazard risk assessments, likelihood is stated in terms of the frequency of an event, such as the indicative annual probability of a landslide (Australian Geomechanics Society, 2007). However, unlike event-based geohazards, the frequency of reactive soils, gilgai processes and subsiding soils are continuous, and a qualitative estimation of likelihood can only be stated in terms of probability (Table 2).

Descriptor	Description
Certain	A geohazard exists at the site and is likely to persist for the life of the project; or a reactivation of an existing dormant geohazard processes is certain during the life of the project
Probable	Either the onset of a geohazard or reactivation of an existing dormant geohazard processes can be expected to occur during the life of the project
Possible	Either the onset of a geohazard or reactivation of an existing dormant geohazard processes are not expected to occur during the life of the project
Improbable	Either the onset of a geohazard or reactivation of an existing dormant geohazard processes is conceivable, but highly unlikely to occur during the life of the project

Table 2. Likelihood (probability) scale (based on Standards Australia, 2009).

Similarly, the consequence of the actual or predicted geohazard on the proposed development and the consequence of the proposed development on the geohazard processes both need to be considered. This would typically involve an examination of the design elements such as the type and purpose of a building (e.g. domestic residence, agricultural outbuilding, factory, etc.), construction materials and design elements (e.g. architectural, engineering and building detail), landscaping proposals (e.g. proposed garden plants, watering systems, area of impervious surfaces), wastewater, drainage and stormwater design, and the proposed occupation rate and use of the development.

Consequence may be quantified in terms of triple bottom line (i.e. economic, environmental and social) cost. It may include the site value, number of species lost, health and well-being impact, or other measures as appropriate. However, the quantification of the damage to an asset through on-going geohazards has many uncertainties, and therefore qualitative estimations of consequence are usually adopted (Table 3) in most planning applications. The uncertainties arise from the insidious nature of geohazard damage to an asset and the long period over which it occurs. The effects of soil movement on building foundations and construction materials often may only appear over prolonged wetting and drying cycles and is complicated by the site maintenance, landscaping and climate changes over time (i.e. it is non-linear). Similarly, the degradation of neighbouring assets by the introduction of more or less soil moisture, or by changes to the regolith materials, may also be a relatively slow and unpredictable process.

Descriptor	Description
Severe	Irreversible damage, huge cost (e.g. permanent abandonment, permanent loss of urban infrastructure services, native species extinction, etc.)
Major	Extensive damage, major cost (e.g. destruction of built infrastructure, destruction of urban services, habitat loss, etc.)
Moderate	Some damage, high cost (e.g. damage to built infrastructure, loss of recreational amenity, invasive species, etc.)
Minor	Little damage, low cost (e.g. episodic building and infrastructure repairs, loss of garden or landscaping components, etc.)

Table 3. Consequence scale (based on Standards Australia, 2009)

The risk is then described as a function of the likelihood and the consequence. In a qualitative example, these may simply be combined in a matrix:

Risk				
Likelihood	Consequence			
	Severe	Major	Moderate	Minor
Certain	Very high	Very high	High	Moderate
Probable	Very high	High	Moderate	Low
Possible	High	Moderate	Low	Low
Improbable	Moderate	Low	Very Low	Very Low

Table 4. Matrix for determining the level of risk (based on Standards Australia, 2009)

Risk evaluation is the process by which decisions are made on whether the risk is acceptable, whether risk treatment is required, and to set priorities. The standards and guidelines note that risk generally is categorised into three levels, viz: acceptable, tolerable and intolerable. An acceptable risk is one which fits with the specified criteria and does not need further treatment. A tolerable risk is one which is too high to be acceptable, but can be tolerated under certain conditions, such as where treatment measures are undertaken, or liability is transferred. Intolerable risks are those which are unacceptable or too costly to treat. Risk evaluation often includes a consideration of issues such as cost of treatment, business or public confidence, public reaction, politics, availability of alternatives, environmental impact, availability of insurance, and fear of litigation (Burgman, 2005).

For some geohazard risks, the evaluation criteria are established by the standards (e.g. building codes, materials standards, environmental standards), the regulators (e.g. government agencies), the asset managers (e.g. government, municipalities, corporations), the proposed developers, or the owners.

3.2.1 Hazards and risks to the proposed development

From the previous engineering geological investigations, it is clear that geohazards exist at the site and are certain to persist for the life of any project. Hence in terms of the risk identification, the likelihood of a geohazard is 'Certain'.

The consequence of the identified geohazards impacting on the proposed development is to a large extent dependent on the engineering and design of the elements at risk. These include the building foundations, building structure, wastewater processing plant, stormwater conduits and disposal, service conduits for communications and energy, roads, carparks, landscaping elements, and all the site modifications.

The closest bores to the site are designated as Djerriwarrh 93, 100, 161 and 164 (Figure 13). Bores 93 and 100, in the Harkness Road reserve north west of the site, show >4.2 metres and 7.5 metres of moist, very stiff, mottled yellow-brown and grey sandy silty clay. Bores 161 and 164, to the north east and south east respectively, show 3.2 metres of moist, stiff, fissured, mottled yellow brown and grey, silty clay overlying extremely weathered basalt. In both cases, the clay is fissured to the full depth of the bore, with soil shear (slickensides) evident. From these bores it is interpolated that the thickness of clay under the site would be around four metres (Figure 13). Four metres of highly to extremely reactive clay creates considerable seasonal movement (shrink-swell) and poses a challenge to the engineering and design of the development.

The movement creates gilgai microrelief at the surface (Figures 6 & 14). Gilgai is defined in the Australian Standard AS2870-2011 Residential Slabs and Footings Section 1.8.29 as:

"*Soil surface feature associated with reactive clay sites, characterised by regularly spaced and sized depressions on virgin land.*

NOTE: Gilgais are formed by extreme, reactive soil movements. Soil profiles may vary markedly across sites with gilgais" (page 11).

The Commentary to the Standard (AS2870, 2011 - Section C2.4.4) states:

"Gilgais are undulating surface structures which are indicative of highly expansive soils, and which give rise to variability of soil layering over relatively short distances. Where gilgais are recognized, more boreholes will be required per site to determine adequately the site classification." (page 115).

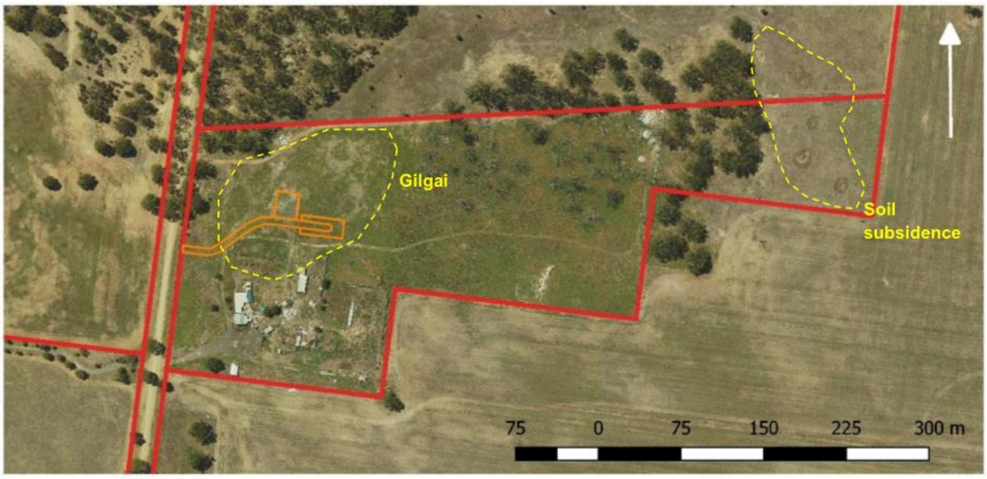


Figure 14. Some of the more obvious geohazards at the proposed development site as seen in aerial imagery. (source Melton City Council. Imagery captured January 16, 2018)

The soil collapse features are obvious on the east of the Applicant's site (Figure 14) and subtle gilgai depressions are noted on the western side, confirming[2] that the likelihood of geohazards at the site is Certain (Table 2). The consequence of the geohazards will depend entirely on the engineered solution. This would require a detailed geotechnical investigation to inform the potential engineered solutions and landscape design elements. The most challenging of these is the enduring management of soil moisture, which is the trigger for the geohazard processes. Hence, the wastewater disposal, runoff and storm water management, vegetation species selection and siting, garden irrigation, and the extents of the impervious surfaces are the most critical design considerations. However, even if the development could be engineered and designed to reduce the consequences of the geohazards to Moderate or Minor (Table 3), the risk remains High to Moderate (Table 4).

3.2.2 Hazards and risks from the proposed development

The relatively thick regolith at the Applicant's property exhibits three-dimensional movement over distances of many metres, as observed by the subtle gilgai development. The reactive soils, gilgai development and collapsing/subsiding soils constitute geohazards that must be considered within the context of the landscape, just as other geohazards are (e.g. salinity, floods, earthquakes, landslides, groundwater contamination, etc.), since geohazard processes are not always confined within property boundaries. Landscape and hydrological changes on one property may, in time, result in a deep-seated expansive soil response on a neighbouring property, especially where a development has occurred that has changed the pre-existing soil hydrology regime. Hence it is conceivable that the development may cause a risk to assets on neighbouring properties.

The Certain likelihood of the geohazard presence, is confirmed by the observations, soil thickness and tests, and observed features in the soil cores that confirm that the gilgai process (Figure 3) is ubiquitous and deep-seated across the neighbouring sites. Shrinkage cracks appearing in summer can extend from the surface to the entire depth of the soil profile, in some cases up to eight metres, as described in detail in the previous investigation reports. Rainfall runoff, irrigation water and wastewater infiltration can quickly penetrate down the cracks and sand-filled fissures, both laterally and vertically and the resulting swelling of the soil at depth may also occur some metres away from the point of infiltration.

Soil suction ensures that moisture is ultimately redistributed in three dimensions. Soil moisture is in very slow flux, with capillary forces constantly moving water through the soil pores from wetter pores to drier pores. Since the same geohazards are present on all properties in the area, the likelihood of the processes continuing is Certain, especially with climate change models predicting more frequent and severe droughts and wet periods (CSIRO, 2015), which will amplify the shrink-swell process of the reactive soils (Leao, 2014).

The consequences of this are quite challenging to predict, because they depend on how the proposed development is designed and to some degree on what happens over time on the neighbouring properties. The future management of the Melton Gilgai Woodlands nature Conservation Reserve and the proposed Melton Regional Cemetery are also unknown at the present. In a worse-case scenario, the storm water runoff from paved areas and the infiltration of water from the development, or the landscaping and tree planting on the site, may ultimately exacerbate the gilgai processes on the neighbouring lands. In a best-case scenario, the soil moisture changes from the proposed development may have a small to negligible additional impact on the neighbouring properties.

While it is certain that the deep reactive soil will respond (in three dimensions) to the proposed development, the consequences on the neighbouring properties are likely to be Minor (Table 3), hence the risk of the development increasing the severity of the geohazards on neighbouring properties remains Moderate (Table 4).

[2] A site inspection on 30/8/2018 also confirmed the presence of the geohazards seen in Figure 14

3.3 Summary

1. The site for the proposed development of a Place of Worship at 171 – 197 Harkness Road, Harkness, has been previously investigated by the State Government for its potential development as a regional cemetery and for housing subdivision. Both potential land-uses were deemed unsuitable because of the presence of obvious geohazards: highly to extremely reactive soils, gilgai development and collapsing/subsiding soils.
2. Using the information and data from the previous investigations, an assessment of the proposed development for a Place of Worship, based on the current concept plans, has been completed. Adopting a risk management framework, the risk of damage to the development from the geohazards at the site is regarded as High to Moderate, depending on the engineering and design adopted. The risk of the development increasing the severity of the geohazards on the neighbouring properties is Moderate.
3. Arguably there are very few sites on Earth that could not be built on with a suitably engineered solution. Hence it can be argued that the risk at the proposed development site could be reduced by mitigating the consequences through engineered solutions. However, this would require a geotechnical investigation, engineering design and landscape design beyond that normally considered for a development of this type, because it would require a collective 'neighbourhood design' approach to mitigating deep-seated soil movements. The proposed Place of Worship and landscaping would, over time, impact on the neighbouring cemetery development, just as the neighbouring cemetery development would also ultimately impact on the proposed Place of Worship.

4 Revisiting the geohazard mapping at Melton

This section of the report briefly looks at the original engineering geological mapping project in the context of the urban development of Melton over the past 32 years since the investigations were completed and reported.

As described in Section 2.2, the principal geohazard at Melton is the Highly Reactive to Extremely Reactive soil (Figure 9), which can be identified at the surface by the development of gilgai microrelief, where the soils are thicker (Figure 10). In the Harkness area, where the gilgai processes are present under the blanket of sandier topsoil, soil collapse and subsidence can be seen.

The geohazard of reactive soils and gilgai development has long been recognised, and is well researched and documented in the national and international scientific literature (e.g. Aitchison et al., 1954; Beckman et al., 1970; Hallsworth & Beckman, 1969; Jones & Jefferson, 2012; Neilson et al., 2003; Walsh et al., 1976). The Australian Standard (AS2870, 1986, 1996, 2011), developed specifically to address the issue for housing foundations, takes a site-specific, engineering approach focused on the detail of soil material properties (such as the instability index I_{pt}, soil shrinkage index I_{ps} or the characteristic surface movement y_s) at a specific site. Yet it is clear from the number of distressed housing failures in Melton and other Melbourne suburbs that the standard has limitations (e.g. Van der Woude, 2017; Whitby, 2016), and is a topic regularly reported in the media (e.g. Bleby, 2016; Carey, 2011; Danckert, 2015; Ilanbey, 2015; Johanson, 2014a, 2014b, 2014c; Lucas, 2014; March, 2012).

Perhaps the most notable of those reported in the media are the two relatively recent cases in West Melton where builders were required to pay considerable amounts in compensation. In the case of Softley v Metricon Pty Ltd, the builder was ordered to pay for the demolition and rebuilding of the house (Macnamara & Cameron, 2014; Warren et al., 2016), which would be classed as a Major consequence (Table 3), hence the risk is Very High (Table 4). In the case of Watson v Richwall Pty Ltd, the builder was ordered to pay more than $60,000 to repair the house (Walker, 2015), which is a Moderate consequence, hence a High risk. These are two of the many cases that involve property damage caused by reactive soils at Melton that have been brought before VCAT over the past years.

The thicker highly to extremely reactive soil in Melton West exhibits the most obvious three-dimensional movement over distances of many metres, as observed by the subtle gilgai development before urban development (Figure 4; Dahlhaus, 1988; SCA, 1978). Therefore, these expansive soils constitute a whole of landscape geohazard, like salinity or floods. The current development footprint over the area (Figure 15) has extended suburban development over about half of the area with the thicker, highly to extremely reactive soils (Figure 15). This suburban development is underlain by an uneven blanket of residual soil, which is interpolated to be two to five metres thick with heterogeneous and anisotropic properties due to the way it has evolved through geologic time. This blanket of reactive soil continues to respond (in three dimensions) to the incremental urban development and the temporal climatic and anthropogenic moisture variations. It is perhaps analogous to a gel-filled quilt of uneven thickness and consistency, slowly responding to changes brought about by urban development at the surface. Buildings, pavements, drainage, landscaping, trees, and utility trenches all change the moisture distribution of the regolith. Areas that were once open to rainfall percolation are now covered by impervious surfaces, and other areas, such as those adjacent to lakes, or parks and gardens are now receiving more water percolation than previously. This slow response of the regolith to the altered soil hydrology extends beyond the boundaries of any individual property. It is a whole of landscape feature.

In other words, the landscape and hydrological changes on one property may, in time, result in a deep-seated expansive soil response on a neighbouring property, especially where close urban development has occurred that has changed the pre-existing soil hydrology regime.

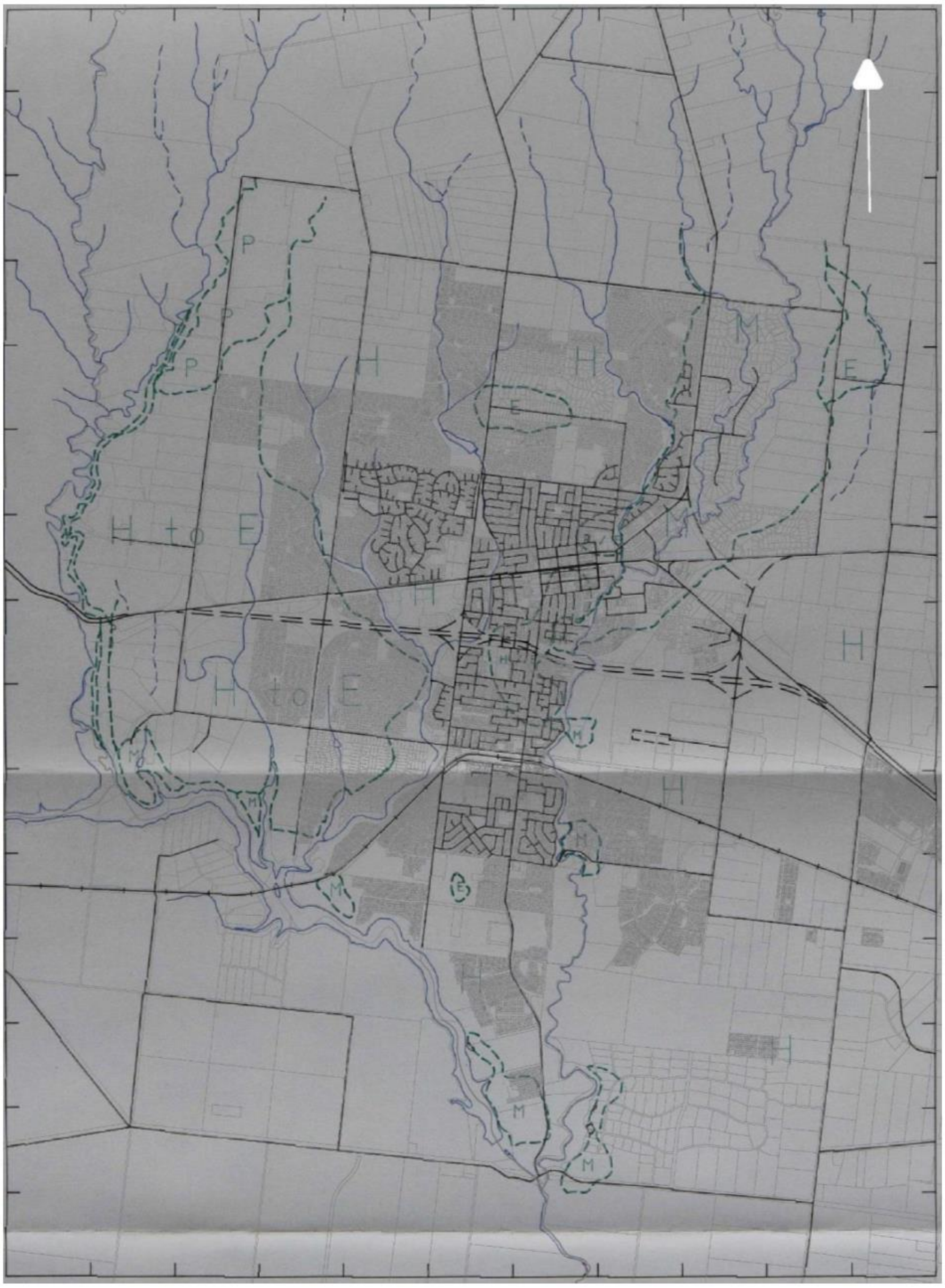


Figure 15. The original 1986 Site Classification mapping overlain with the current Melton cadastre (in grey).

This is particularly a problem where trees and garden irrigation are in close proximity to the allotment boundaries and includes street trees and nature strips. The Eucalyptus trees planted along the roadsides throughout the West Melton estates (e.g. Panorama Drive, Merrystowe Way, Arjun Avenue, etc.), have the potential, in my opinion, to cause considerable damage to infrastructure in the future. Eucalyptus trees are a known problem in areas of highly expansive soils (e.g. AS2870, 2011; Cameron, 2001; Jones & Jefferson, 2012).

Regrettably the four-year investigation funded by the State Government and aimed specifically at guiding the strategic planning, site investigation practices, and sustainable development of the Melton urban area, has not resulted in better consideration of the risks resulting from the mapped geohazards. Geological data does not lose its currency and the data and observations of 1983-1987 (or any historic time for that matter) are still as relevant today as they were at the time they were recorded.

Planning Scheme overlays, such as the Flood Overlay, Erosion Management Overlay or Salinity Management Overlay are used to alert property purchasers, developers, planners and landowners to geohazards at the municipal landscape scale. They help to ensure that critical information is not overlooked, they guide geotechnical investigations and result in appropriately engineered developments. No such overlay exists for expansive soils. However, the Melton City Council has the option to use other components of the Planning Scheme, such as a framework or provision, to alert the developers to the presence of geohazards and the appropriate risk mitigation measures.

In addition, the publication of information fact sheets, videos, etc. or simply alerting developers and home purchasers to the available information are other measures that could be utilised. Most municipalities have adopted web-based tools to assist residents and developers in finding the appropriate information, like the 'Near Me' mapping tool used by the Melton City Council. Perhaps developing that further to provide more detailed information (e.g. Visualising Ballarat http://www.visualisingballarat.org.au/) could improve access to the required information.

Recent research recognises that the predicted climate change for Victoria will exacerbate the expansive soil geohazard in most of the urban growth priority zones, including Melton (Leao, 2014). Without alerting future developers and home owners to the risks and how to mitigate them, the nature and extents of the expansive soils at Melton may keep VCAT busy for decades to come.

4.1 Summary and recommendation

1. The closer urban development on the highly to extremely reactive soils in the Melton area has resulted in damage to structures, especially in West Melton, where the soil thickness is greatest. The most notable recent cases are where buildings were ordered to be demolished and replaced (Major consequence) or to undergo considerable repair (Moderate consequence). Since the likelihood is Certain, the risk of damage to houses and other built infrastructure is Moderate to Very High. The risks will increase in severity with the predicted climate change scenarios for the region.
2. The risk is exacerbated by the fact that the geohazard is region-wide, and therefore extends beyond the boundaries of individual allotments. Since all development, both private and public, changes moisture distribution in the deep reactive soils, the landscape and hydrological changes on one property may, in time, result in a deep-seated expansive soil response on a neighbouring property. Of particular concern is the establishment of trees and garden irrigation in close proximity to the allotment boundaries, including street trees (especially Eucalypt spp.) and nature strips.
3. It is recommended that the Council considers embedding geohazard information in the Planning Scheme so that potential developers are alerted to the associated risks. In addition, the Melton community could be made more aware of the risks associated with the geohazards through the dissemination of information, especially using online maps.

5 References

Aitchison, G. D., Sprigg, R. C., & Cochrane, G. W. (1954). *The soils and geology of Adelaide and suburbs*. 37p.

AS2870. (1986). *Australian Standard. Residential slabs and footings*. Standards Australia p.

AS2870. (1996). *Australian Standard. Residential slabs and footings*. Standards Australia 83p.

AS2870. (2011). *Australian Standard. Residential slabs and footings*. Standards Australia 176p.

Australian Geomechanics Society. (2007). Landslide Risk Assessment and Management. *Australian Geomechanics, 42*(1), 1-182.

Beckman, G. G., Hubble, G. D., & Thompson, C. H. (1970). *Gilgai forms, distribution and soil relationships in north-east Australia*. Paper presented at the Symposium on soils and earth structures in arid climates, 21-22 May, Adelaide.

Bleby, M. (2016, April 6 2016). Home builder Metricon loses Supreme Court appeal against slab heave ruling. *The Australian Financial Review*. Retrieved from https://www.afr.com/real-estate/home-builder-metricon-loses-supreme-court-appeal-against-slab-heave-ruling-20160406-gnzxvb

Burgman, M. A. (2005). *Risks and Decisions for Conservation and Environmental Management*. Cambridge, U.K.: Cambridge University Press.

Cameron, D. A. (2001). The extent of soil desiccation near trees in a semi-arid environment. In D. G. Toll (Ed.), *Unsaturated Soil Concepts and Their Application in Geotechnical Practice* (pp. 357-370): Springer Netherlands.

Carey, A. (2011, December 22, 2011). Owners find homes are cracking under pressure. *Domain*. Retrieved from https://www.domain.com.au/news/owners-find-homes-are-cracking-under-pressure-20111221-1p5or/

CSIRO. (2015, 27th August 2013). Welcome to OzClim. Exploring climate change scenarios for Australia. Retrieved from http://www.csiro.au/ozclim/home.do

Dahlhaus, P. G. (1984). *Engineering geological investigation of proposed cemetery site at Melton*. Department of Minerals and Energy, Melbourne, Victoria, Australia. 99p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:6078

Dahlhaus, P. G. (1985). *An engineering geological investigation of the Urban Land Authority's property, Melton*. Department of Minerals and Energy, Melbourne, Victoria, Australia. 33p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:6144

Dahlhaus, P. G. (1986a). *Engineering geology of Melton - a review*. Department of Industry, Technology & Resources, Melbourne, Victoria, Australia. 77p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15924

Dahlhaus, P. G. (1986b). *Engineering geology of Melton - drilling, testing and mapping program*. Department of Industry, Technology & Resources, Melbourne, Victoria, Australia. 39p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15941

Dahlhaus, P. G. (1986c). *Engineering geology of Melton - engineering geology*. Department of Industry, Technology & Resources, Melbourne, Victoria, Australia. 47p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15943

Dahlhaus, P. G. (1986d). *Engineering geology of Melton - geology and geomorphology*. Department of Industry, Technology & Resources, Melbourne, Victoria, Australia. 34p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15942

Dahlhaus, P. G. (1986e). *Engineering geology of Melton - map presentation of data*. Department of Industry, Technology & Resources, Melbourne, Victoria, Australia. 11p.

Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15951

Dahlhaus, P. G. (1986f). *Engineering geology of Melton - summary*. Department of Industry, Technology & Resources, Melbourne, Victoria, Australia. 12p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15947

Dahlhaus, P. G. (1986g). *Engineering geology of Melton - the Melton Development Area*. Department of Industry, Technology & Resources, Melbourne, Victoria, Australia. 8p. Retrieved from http://geology.data.vic.gov.au/searchAssistant/document.php?q=parent_id:15930

Dahlhaus, P. G. (1988). *Engineering geological mapping for the urban development of Melton, Victoria.* (M.App.Sci. Research), Royal Melbourne Institute of Technology (RMIT), Melbourne. Retrieved from https://researchbank.rmit.edu.au/view/rmit:162471

Dahlhaus, P. G. (1991). Engineering and Environmental Geology. In G. C. Cochrane, G. W. Quick, & D. Spencer-Jones (Eds.), *Introducing Victorian Geology* (pp. 265-304). Melbourne: Geological Society of Australia, Victoria Division.

Dahlhaus, P. G., & O'Rourke, M. (1992). The Newer Volcanics. In W. A. Peck, J. L. Neilson, R. J. Olds, & K. D. Seddon (Eds.), *Engineering Geology of Melbourne* (pp. 205-212). Rotterdam: A.A.Balkema.

Danckert, S. (2015, March 27, 2015). Home builder Metricon may face more claims after ‘slab heave’ verdict. *The Australian Business Review*. Retrieved from https://www.theaustralian.com.au/business/property/home-builder-metricon-may-face-more-claims-after-slab-heave-verdict/news-story/8372c9bb5f33d4bf195a4019b53c1562

Hallsworth, E. G., & Beckman, G. G. (1969). Gilgai in the Quaternary. *Soil Science, 107*(6), 409-420.

I.A.E.G. (1981). IAEG Commission on Engineering Geological Mapping: Rock and soil description and classification for Engineering Geological Mapping. *Bulletin of the International Association of Engineering Geology, 24*, 235-274.

Ilanbey, S. (2015, January 27 2015). Dreams down the drain. *Melton Star Weekly*.

ISO. (2002). ISO/IEC Guide 73:2002 Risk Management - Vocabulary - Guidelines for use in standards. In. Geneva, Switzerland: International Organisation for Standardisation.

ISO. (2018). ISO 31000:2018 Risk Management - Guidelines. In (pp. 16). Geneva, Switzerland: International Organisation for Standardisation.

Johanson, S. (2014a, April 2 2014). Slater & Gordon calls for taskforce to act on faulty house slabs. *The Sydney Morning Herald*. Retrieved from https://www.smh.com.au/business/slater--gordon-calls-for-taskforce-to-act-on-faulty-house-slabs-20140401-35wbz.html

Johanson, S. (2014b, 22 August 2014). Thousands affected by 'slab heave' report blunder. *The Sydney Morning Herald*. Retrieved from https://www.smh.com.au/business/thousands-affected-by-slab-heave-report-blunder-20140822-107dh6.html

Johanson, S. (2014c, 8 June 2014). Thousands of suburban home owners facing financial ruin. *The Age*. Retrieved from https://www.theage.com.au/national/victoria/thousands-of-suburban-home-owners-facing-financial-ruin-20140607-39q4z.html

Jones, L. D., & Jefferson, I. (2012). Expansive Soils. In *ICE manual of geotechnical engineering. Volume 1, geotechnical engineering principles, problematic soils and site investigation* (pp. 413-441). London: Institution of Civil Engineers, ICE Publishing.

Joyce, E. B., Webb, J. A., Dahlhaus, P. G., Grimes, K. G., Hill, S. M., Kotsonis, A., Martin, J., Mitchell, M. M., Neilson, J. L., Orr, M. L., Peterson, J. A., Rosengren, N. J., Rowan, J. N., Rowe, R. K., Sargeant, I., Stone, T., Smith, B. L., White, S., & Jenkin, J. J. (2003). Geomorphology. In W. D. Birch (Ed.), *Geology of Victoria* (Vol. Geological Society of Australia Special Publication 23, pp. 533-561): Geological Society of Australia (Victoria Division).

Killey, W. L. (1985). *Melton seismic refraction investigation*. Department of Minerals and Energy, Melbourne. p.

Leao, S. (2014). Mapping potential risk for housing damage from ground movement due to climate change *International Journal of Environment and Sustainable Development, 5*(4), 387-393.

Lucas, C. (2014, 11 December 2014). Metricon ordered to rebuild four-year-old cracking Melton West home. Waffle 'slab heave' thought to be undermining thousands of new homes. *The Age*. Retrieved from https://www.theage.com.au/national/victoria/metricon-ordered-to-rebuild-fouryearold-cracking-melton-west-home-20141211-1257il.html

Macnamara, J., & Cameron, R. (2014). *Softley v Metricon Homes Pty Ltd (Building and Property) [2014] VCAT 1502* Victorian Civil and Administrative Tribunal, Melbourne. 35p. Retrieved from https://www.vcat.vic.gov.au/sites/default/files/resources/softley_v_metricon_homes_pty_ltd.pdf

March, S. (2012). Auditor-General considers building industry insurance probe. Retrieved from http://www.abc.net.au/news/2012-02-24/auditor-general-considers-building-industry-insurance-probe/3851192

MICAC. (1985). *Investigations into Cemetery Management and the Provision of Cemetery Reserves. Fourth Report to Parliament*. Mortuary Industry and Cemeteries Administration Committee, Victoria. 169p.

Neilson, J. L., Peck, W. A., Wood, P. D., Dahlhaus, P. G., Miner, A. S., Brumley, J. C., Kenley, P. R., Wilson, R. A., Willman, C. E., & Rowan, J. N. (2003). Geological Hazards. In W. D. Birch (Ed.), *Geology of Victoria* (Vol. Geological Society of Australia Special Publication 23, pp. 573-592). Melbourne: Geological Society of Australia, Victorian Division.

SCA. (1978). *Erosion and its control during the urban development of the Melton area* Soil Conservation Authority, Kew, Victoria. p.

Standards Australia. (2009). AS/NZS ISO 31000:2009 Risk Management - Principles and guidelines. In (pp. 36). Sydney: Standards Australia and Standards New Zealand.

Van der Woude, F. (2017). *Australian Standard AS 2870 – Time for a change*. Paper presented at the Australian Geomechanics Society, Victorian Symposium 2017, Melbourne. https://raftslabs.com.au/wp-content/uploads/2018/01/AGS-Vic-2017-Symposium-paper.pdf

Walker, R. (2015). *Victorian Civil and Administrative Tribunal. Civil Division. Building and Property List. Watson v Richwall Pty Ltd. Order.* Victorian Civil and Administrative Tribunal. , Melbourne. 18p.

Walsh, P. F., Holland, J. E., & Kouzmin, T. (1976). *The classification of expansive behaviour of Melbourne soils for domestic construction*. CSIRO (Australia) Division of Building Research, Cement and Concrete Association & Australian Engineering and Building Industries Research Association (AEBIRA) 11p.

Warren, C. J., Tate, J. A., & Robson, A. J. A. (2016). *Metricon Homes Pty Ltd v Softley and Another. Court of Appeal. [2016] VSCA 60, 49 VR 746* Victorian Supreme Court of Appeal Melbourne p. Retrieved from https://victorianreports.com.au/judgment/view/49-VR-746

Whitby, M. (2016). The Hidden Agendas Behind Australia's Failed Building Industry. *Sourceable: Industry News & Analysis.* Retrieved from https://sourceable.net/the-secrets-and-hidden-agendas-behind-australias-failed-building-industry/

Appendix A - Geomechanics Society Seminar 1987

The Institution of Engineers Australia
Victoria Division,
191 Royal Parade
PARKVILLE, VICTORIA, 3052
Telephone: (03) 347 1088
Telex: AA31737 IEAVIC

IEAust

VICTORIA DIVISION NEWSLETTER REGISTERED BY: AUSTRALIA POST PUBLICATION NUMBER VBG 5447

AUSTRALIAN GEOMECHANICS SOCIETY

VICTORIA GROUP

"ENGINEERING GEOLOGICAL MAPPING – THE MELTON PROJECT"

Mr. Peter Dahlhaus of the Geological Survey, Department of Industry, Technology and Resources, will speak on the major project of engineering geological mapping which he has completed at Melton, using E.D.P. methods and innovative computer plotting techniques. A major issue of expansive clays and resulting problems with house foundations will be mentioned. Geological, geomorphological and geomechanical factors will be integrated.

WEDNESDAY 11TH MARCH, 1987

Venue: Clunies Ross House, (Auditorium 4), 191 Royal Parade, Parkville.

Time: 6.00P.M.

Refreshments in Sciences Club at 5.30P.M.

A. Abbs,
Hon.Secretary.
652.7102

Appendix B – Shire of Melton letter 1988

In reply please quote: 80/30/30

Phone enquiries: LAM/lcn

SHIRE OF MELTON

Cnr. High & Yuille Streets,
Melton,
Victoria 3337
(P.O. Box 21)

(03) 747 7200
DX 33005
MELTON.
FAX
(03) 743 9970

7th March, 19898

10 MAR 1988
DEPT. OF INDUSTRY TECHNOLOGY & RESOURCES

The General Manager - Minerals,
Department of Industry, Technology & Resources,
P.O. Box 173,
EAST MELBOURNE - 3002

Attention: Mr. J.L. Neilson

Dear Sir,

Re: Reports on the Engineering Geology of the Melton Growth Area

I refer to your letter dated 16th February, 1988 and copies received of the seven unpublished reports on the above subject.

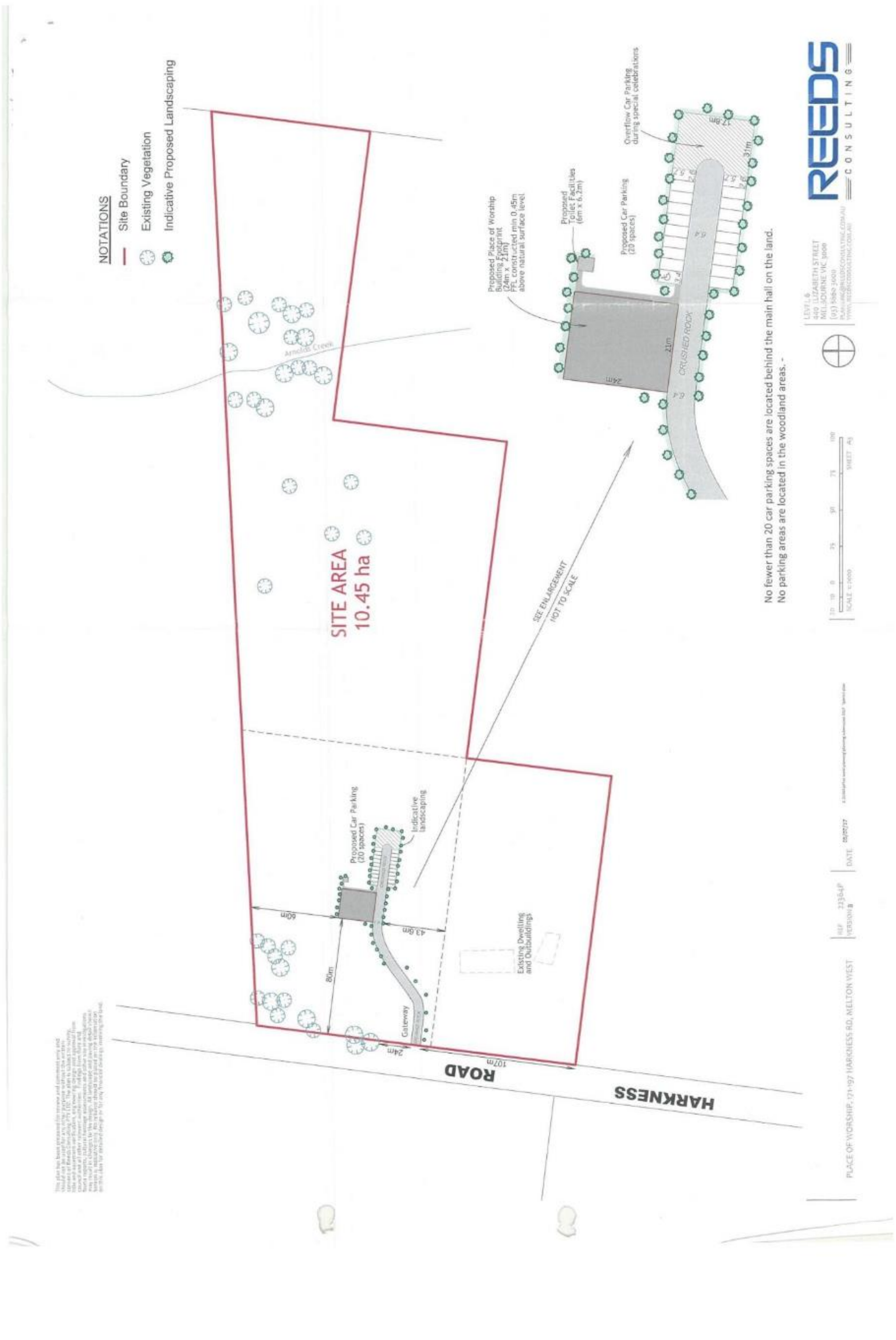
Council wishes to express its appreciation to the Department and Mr. Peter Dahlhaus regarding the valuable information contained in these reports which is expected to both greatly assist the strategic planning for the long-term Melton Urban Area and also the development of policies and practices for site investigations for both building and engineering works.

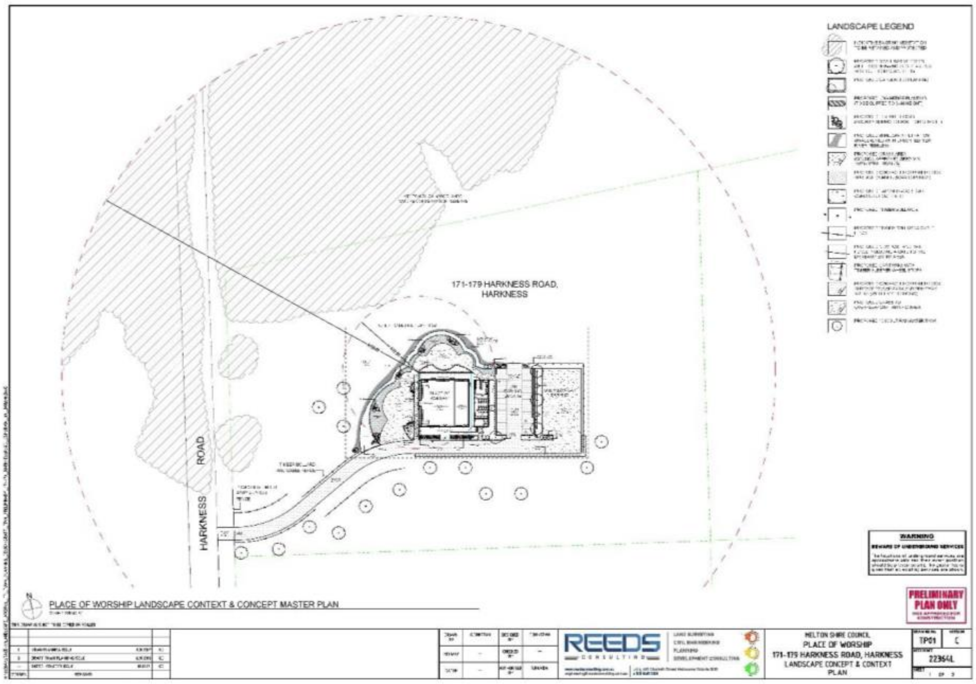
Yours sincerely,

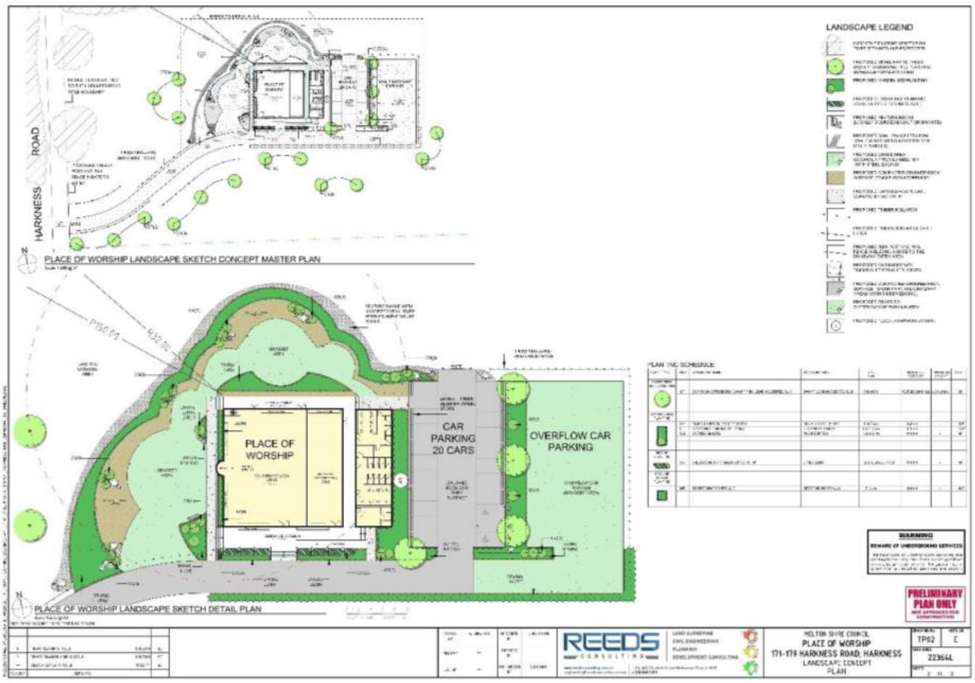
LINDSAY A. MERRITT
DEPUTY SHIRE MANAGER/SHIRE ENGINEER

Peter – for your information
John Neilson

Appendix C – Proposed development (Place of Worship)







Dahlhaus, P. 2018 Gilgai and reactive soil geohazards in the City of Melton. Federation University Australia.

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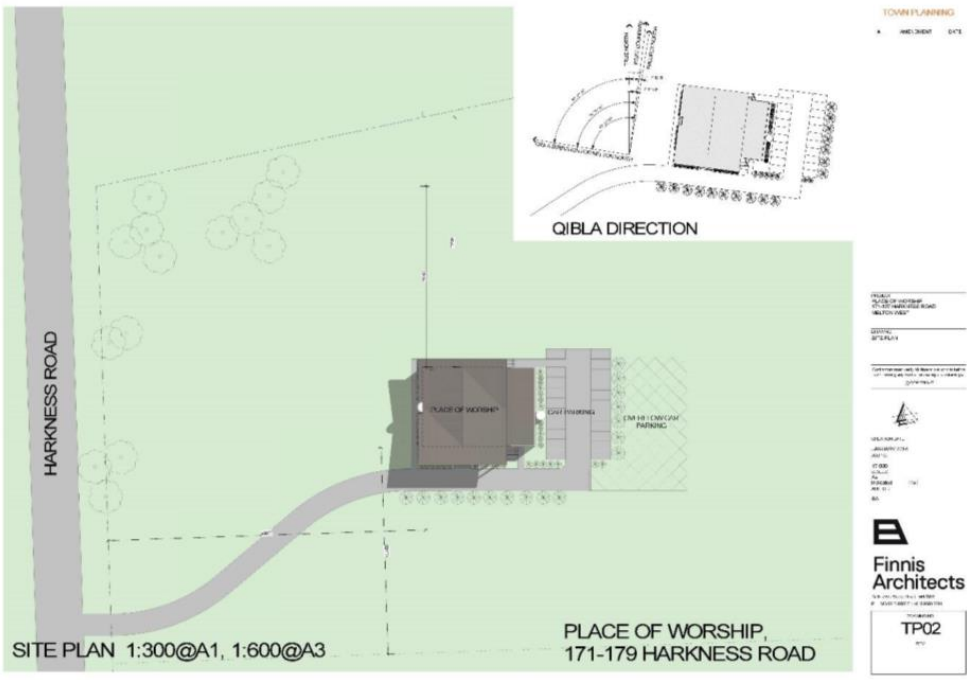
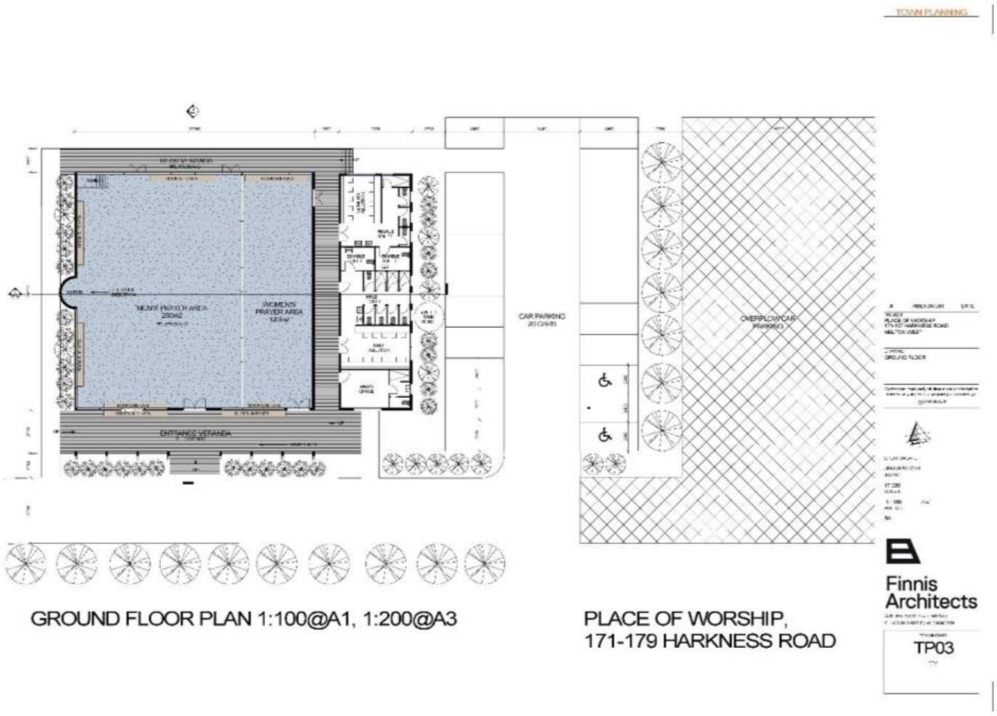
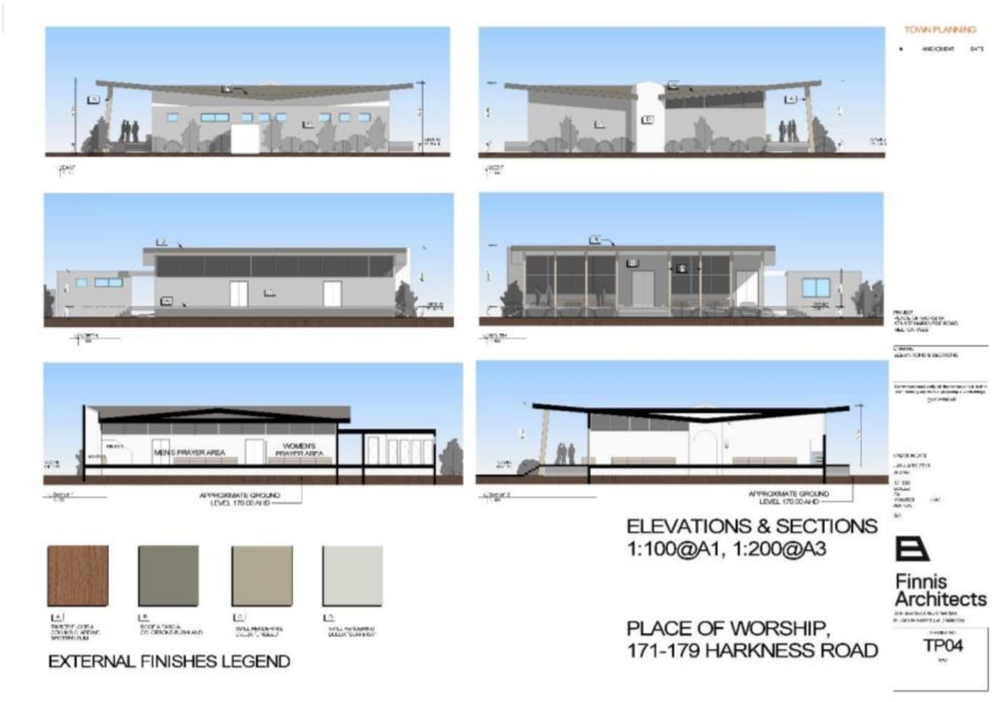
Page 38


TOWN PLANNING
EXTERNAL VIEW
DRAWING LIST
TP01 COVER PAGE
TP02 SITE PLAN
TP03 GROUND FLOOR
TP04 ELEVATIONS & SECTIONS
DEVELOPMENT SUMMARY
ENTRY VERANDAHS: 170 m2
PRAYING AREA: 400 m2
AMENITIES: 123 m2
TOTAL BUILT AREA: 693 m2
SITE AREA: 104,500 m2
SITE COVERAGE: 0.66%
INTERNAL VIEW
PLACE OF WORSHIP,
171-179 HARKNESS ROAD,
Finnis Architects
TP01


TOWN PLANNING
QIBLA DIRECTION
HARKNESS ROAD
SITE PLAN 1:300@A1, 1:600@A3
PLACE OF WORSHIP,
171-179 HARKNESS ROAD
Finnis Architects
TP02


TOWN PLANNING
CAR PARKING
OVERFLOW CAR
ENTRANCE VERANDA
MENS PRAYER AREA
WOMENS PRAYER AREA
GROUND FLOOR PLAN 1:100@A1, 1:200@A3
PLACE OF WORSHIP,
171-179 HARKNESS ROAD
Finnis Architects
TP03


TOWN PLANNING
MENS PRAYER AREA
WOMENS PRAYER AREA
APPROXIMATE GROUND LEVEL 170.00 AHD
ELEVATIONS & SECTIONS
1:100@A1, 1:200@A3
PLACE OF WORSHIP,
171-179 HARKNESS ROAD
EXTERNAL FINISHES LEGEND
Finnis Architects
TP04

GOLDER

EXPERT REPORT

171-197 Harkness Road, Harkness, VIC

PRIVILEGED & CONFIDENTIAL

Prepared for the purposes of legal advice

Submitted to:

Kate Morris

Harwood Andrews
Level 5
707 Collins Street
Melbourne
VIC 3008

Submitted by:

Golder

Building 7, Botanicca Corporate Park 570 – 588 Swan Street Richmond, [illegible]
Australia

+61 3 8862 3500

18113175-001-R-Rev0

20 December 2018

Distribution List

1 copy Harwood Andrews

1 copy Golder Associates Pty Ltd

Table of Contents

FIGURES

APPENDICES

1.0 INTRODUCTION

1) My name is Mr Darren Ross Paul and I am a Principal of Golder Associates Pty Ltd [**Golder**] working from their Melbourne Office at Building 7, Botanicca Corporate Park, 570-588 Swan Street Richmond, Victoria 3121. I have been requested to provide an expert report with respect to the proposed development at 171-197 Harkness Road [**Site**], to assist Melton City Council [**Council**] in relation to a planning permit application (PA2017/5728). Golder has been engaged by Harwood Andrews in a letter dated 19 November 2018 (reference 2KXM:5AKT 21804177), a copy of which is attached in Appendix A.

2) Harwood Andrews act on behalf of Council in relation to this matter.

3) Golder is an international consulting company specialising in geotechnical and geoenvironmental engineering.

1.1 Summary of qualifications and experience

4) I am a Principal Engineering Geologist and a Principal of Golder based in the Melbourne office.

5) I have a BSc degree (1999) in Science and a BE (H1) (1999) degree in Civil Engineering, both from the University of Melbourne, and an MSc (2004) in Engineering Geology from Imperial College, London. I have in excess of 19 years of experience in teaching and practising in engineering geology and geotechnical engineering.

6) I specialise in the identification and assessment of geological hazards, including landslide, collapsible ground and reactive soils. I have undertaken many geological hazard assessments throughout Victoria and overseas associated with a variety of projects ranging from residential scale to very large infrastructure and mining projects.

7) My qualifications and experience are set out in the Curriculum Vitae in Appendix B.

1.2 Documents provided

8) Golder has been provided with the documents listed below which I have relied upon in compiling this report:

   a) 2 no. aerial photographs of the Site dated 14 September 2018;
   b) Cadastral and Melways maps of the area:
   c) Zone and overlay controls:
      i. Bushfire management overlay;
      ii. Environmental significance overlay;
      iii. Planning zones.
   d) The following extracts which I understand to be from the Melton Planning Scheme:
      i. Clause 35.05 Green Wedge A Zone;

ii. Clause 42.01 Environmental Significance Overlay;
iii. Clause 44.06 Bushfire Management Overlay;
iv. Schedule 1 to the Environmental Significance Overlay;
v. Schedule to Clause 35.05 Green Wedge A Zone.

e) Report titled "Gilgai and reactive soil geohazards in the City of Melton" version 1 dated 31 August 2018 [**Dahlhaus Report**], by Dr Peter Dahlhaus [**Dr Dahlhaus**];

f) Minutes from Council meeting dated 30 April 2018;

g) The following documents which I understand to be in relation to the original planning application:

i. Application form dated 5 July 2017;
ii. Set of drawings showing site layout, cross-sections of proposed structure, etc.
iii. Report titled "Land Management Plan: 171-197 Harkness Road, Melton West" version Final 2 dated 11 November 2015, by Ecology & Heritage Partners.
iv. Report titled "Mosque, 171-197 Harkness Road, Melton West" reference Rp 001 R01 2015405ML dated 18 November 2015, by Marshall Day Acoustics.
v. Report titled "Planning Report 171-197 Harkness Road, Harkness" dated July 2017, by Reeds Consulting.
vi. Set of drawings showing site layout, cross-sections of proposed structure, etc., referred to as being "endorsed under PA12-3458";
vii. Certificate of title.

h) Letter from Reeds Consulting to Council (reference 22364P) dated 23 August 2017.

i) The following documents which I understand to be in relation to a revised planning application;

i. Certificate of title;
ii. Architectural drawings;
iii. Landscaping drawings;
iv. Report titled "Bushfire management statement, 171-197 Harkness Road, Melton West" dated October 2018, by Ecolink Consulting.
v. Report titled "Planning Report 171-197 Harkness Road, Harkness (PART)" version 2 dated October 2018, by Reeds Consulting.
vi. Letter from Reeds Consulting to Council (reference 22364P) dated 29 October 2018.

1.3 Questions

9) I have been asked to provide a report addressing the following (refer Harwood Andrews letter reference 2KXM:5AKT 21804177 dated 19 November 2018, a copy of which is attached in Appendix A).

1. Provide a peer review of the Dahlhaus Report.

2. Provide a preliminary opinion on:

a. Whether the proposed development is likely to cause or significantly contribute to subsidence at the Site or other sites.

b. Whether the risk (if any) of the proposed development causing or contributing to subsidence could reasonably be managed through design and construction measures; and

c. The likely impact on the environment (land, buildings and people) in respect of any residual risk of subsidence.

10) A summary of my responses to these questions is provided in Section 6.0 and further detail to support my opinion is presented below.

1.4 Other information

11) In preparing this report I have generally assumed as fact the information contained in the various reports and documentation listed at Section 1.2.

12) Other assumptions that I have made in undertaking analysis or forming my opinion are set out in the relevant sections of this report.

13) I undertook a visual inspection of the Site on 10 December 2018.

2.0 BACKGROUND

14) My understanding of the Site and the proposed development, based on the information contained in the various reports and documentation listed at Section 1.2, is presented below.

15) The Site is bounded to the west by Harkness Road. The land surrounding the Site is used mainly for agricultural purposes. The land to the north of the Site is a conservation reserve, whilst the proposed future use of the land to the east and south is as a cemetery.

16) The Site has an area of 1.57 ha, and is approximately 98 m wide and 160 m long in the north-south and east-west directions, respectively.

17) Council is currently considering a planning application for the use and development of the Site as a place of worship (mosque) with parking for twenty cars.

18) Based on the architectural drawings referenced in Section 1.2, the proposed mosque is a portal frame type structure.

19) Based on the Reeds Consulting report dated October 2018 (referenced in Section 1.2):

- The footprint of the proposed mosque is 24 m x 21 m and is set back a minimum of 80 m from Harkness Road and 60 m from the north boundary of the Site[1].
- The driveway and carpark will be of crushed rock.
- The site is known to be susceptible to the effects of reactive soils including gilgai formation and soil subsidence.

20) I note that, based on the landscaping drawings referenced in Section 1.2, the proposed mosque is located approximately 20 m from the north boundary of the Site and have assumed this offset in my assessment.

3.0 SITE VISIT

21) A summary of the observations of the Site visit which I undertook on 10 December 2018 is presented below.

22) In general, the observations I made of the ground surface are consistent with the site being underlain by high to extremely high plasticity soils. The shallow depressions and high aperture shrinkage cracks are consistent with terrain susceptible to gilgai formation, including collapse features. The gilgai features appear to be more intense in the vicinity of vegetation, noting that the currently proposed location of the mosque is within a part of the Site which is not vegetated.

23) The surface of the Site is gently undulating with round depressions, some of which are up to 0.5 m deep (Figure 1). These features are consistent with gilgai features.

[1] Refer comment below in relation to the distance indicated on the landscaping drawings.

Figure 1: Depressions on western side of Site indicative of gilgai, view west towards Harkness Road

24) Shrinkage cracks are evident on the ground surface over most of the Site. In the extreme case, the cracks have apertures greater than 100 mm (Figure 2).

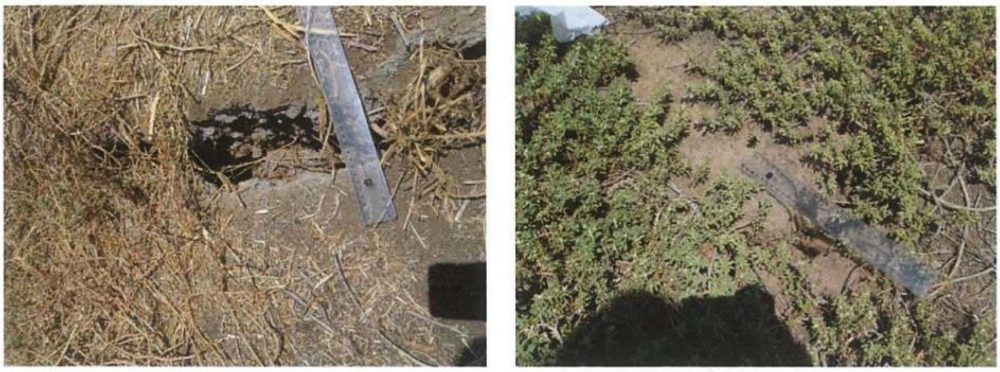


Figure 2: Examples of shrinkage cracks, some of which have apertures greater than 100 mm

25) The intensity of gilgai features and surface cracking appears to be greater in the vicinity of trees. There are extensive gilgais and evidence of ground cracking on the eastern side of the Site in the vicinity of sparse vegetation (Figure 3).

Figure 3: Depressions indicative of Gilgai formation near vegetation, eastern side of the Site, view to east

26) There are existing buildings towards the southern side of the Site, comprised of sheds and a timber framed, weatherboard house (Figure 4). The weatherboard house shows some evidence of ground movement, however generally appears to be intact.

Figure 4: Dilapidated weatherboard house, view towards south

27) Based on a an observation of a series of holes of about 300 mm diameter, there appears to have been some recent excavation at the approximate location of the proposed mosque (Figure 5). Fill assumed to have been removed from the excavation appears to have been placed adjacent to these holes.

Figure 5: Circular excavation near location of proposed mosque

28) There are subtle gilgai features at the location of the proposed mosque (Figure 6). However, these features are not as pronounced as they are on other parts of the Site.

Figure 6: Approximate location of proposed mosque, view to east.

4.0 REVIEW OF DAHLHAUS REPORT

29) I have reviewed the Dahlhaus Report. The subsequent section provides a discussion on those points with which I agree, and those points for which I have a query or offer a different opinion.

4.1 Points with which I agree

30) The site is underlain by highly to extremely reactive soils. Changes in the soil moisture condition within the soils leads to soil volume changes. The process of shrink-swell associated with reactive soils is well described in the Dahlhaus Report (Section 2.2.1.1)[2].

31) There are surface depression features on the site indicative of gilgai development. These are caused by a process involving soil moisture changes and the washing of fines into fissures. This process is well described and illustrated in the Dahlhaus Report (Section 2.2.1.2)[3].

32) There are features on the site indicative of soil collapse. These are caused by the collapse of soils into fissures as described in the Dahlhaus Report (Section 2.2.1.3)[4]. These features are typically up to 2 m in diameter (refer to Figure 7 of the Dahlhaus Report).

[2] Section 2.2.1.1, Page 12
[3] Section 2.2.1.2, Page 13
[4] Section 2.2.1.3, Page 15

33) Structures built on the site, including buildings and services may be susceptible to the effects soil volume changes, including gilgai formation and collapsible soil.

34) The hazards presented by the reactive soils underlying the site could be mitigated through engineering means, noting that further investigations would be required in order to provide sufficient information to inform design those engineering measures.

35) Due to the high reactivity of the soils, the investigation and design of engineering measures would be more intensive that what might usually be required for a development of this type.

36) The previous studies relied upon by the author including those undertaken by the geological survey in the 1980's are to my knowledge the most comprehensive studies undertaken of geohazards associated with reactive soils in the Harkness area.

37) There is potential for development to change the hydrogeological conditions and rate of surface water infiltration in the vicinity of the development. This can alter the prevailing seasonal volume changes in of the reactive soils.

38) A Class P classification based on Australian Standard AS2970-1986, *Residential Slabs and Footings* is applicable to this site due to the highly reactive soils and potential for soil collapse.

4.2 Points I query or disagree with

39) The initial stage of the risk assessment would usually be to define the hazard that is being assessed noting that there appear to be no clear hazard definitions in the Dahlhaus Report. Examples of hazard definitions for this site could include:

a. 'soil shrink and swell movements occur which exceed the design limits of the building'

b. 'gilgai features develop under the footprint of the building'.

c. 'soil collapse occurs under the footprint of the building',

40) It would be usual to state the assumptions on which risk assessment is being made in order to allow the consequences to be assessed. Although the Dahlhaus Report notes that the consequences to the structure entirely depend on the mitigation measures in place, it would be usual to state the assumed measures, or 'pre-mitigation' conditions in order to assess the consequence. The 'pre-mitigation' conditions would generally be based on what a typical structure, without site specific mitigation measures would comprise. Such assumptions do not appear to be set out in the Dahlhaus Report. In this case, an assumption would need to made about the form and foundation type of the proposed building. Examples of assumptions of the 'pre mitigation' conditions could include:

a. The proposed mosque will be a portal framed structure supported on a stiffened slab designed for a Class E site as defined in Australian Standard AS2870-2011.

b. Stormwater and surface drainage, including roof runoff will be piped to a legal point of discharge.

c. The access road will have a gravel surface and be unsealed.

41) In undertaking the risk assessment presented in the report, Section 3.2.1[5] of the Dahlhaus Report describes the likelihood of a geohazard as certain. This comment appears to be related to the assessment that the site is underlain by reactive soils and therefore subject to a continuous process of shrink swell and gilgai development. In Section 3.2 of the Dahlhaus Report[6], a comment is made that *"risk assessment requires the estimation of both the likelihood of the geohazard impacting on an asset and the consequence of that impact on the asset"*. The presence of the geohazard alone does not constitute a certain likelihood that the asset will be impacted. For example, whilst soil collapse could occur in the area, it is not certain that soil collapse will occur beneath the building slab or footings within its lifetime, nor that the expansive soils or gilgai formation will exceed the ground movement limits for which the building is designed. In my opinion, the assessment of likelihood should accompany a clear hazard definition and assumptions about the structure to which the risk is being assessed. In this case, the assessed likelihood of 'certain' may overstate the likelihood that a geohazard impacts the asset.

42) The Dahlhaus Report states[7] that "even if the development could be engineered and designed to reduce the consequences of the geohazards to Moderate or Minor (Table 2), the risk remains High to Moderate. It is not clear as to which of the hazards described in the report that this statement applies. For example, whether it applies to reactive soil, gilgai formation, collapsible soil or all three. With reference to my comments above, the hazard and consequences to the structure should be defined and the risk assessed for each hazard. In my opinion it may be possible to achieve a residual risk lower than High to Moderate as described in the Dahlhaus Report.

43) The Dahlhaus Report states[8] *"Whilst it is certain that the deep reactive soil will respond (in three dimensions) to the proposed development, the consequences on the neighbouring properties are likely to be Minor (Table 3), hence the risk of the development increasing the severity of the geohazards on neighbouring properties remains Moderate (Table 4).* This statement appears to assume that the proposed development is certain to change the magnitude or intensity of the soil reaction on adjacent sites and that the consequences of this change will be Minor. I consider the likelihood assessment of 'certain' to be an over-estimate. Whilst it may be certain that the proposed development will induce a three-dimensional response in the soil, I do not consider it certain that this response will cause the soil reaction to be of greater magnitude or intensity 80 m to the southern boundary or more than 20 m to the northern boundary. With competently engineered drainage and landscaping, I would consider it feasible to reduce offsite impact from the development to levels that

[5] Section 3.2.1, Paragraph 1.
[6] Section 3.2, Paragraph 2.
[7] Section 3.2.1, Page 27, Final sentence
[8] Section 3.2.2, Page 27, final paragraph

are not significant or noticeable. Noting that the assessment should consider the likelihood of impact on an assessment, a lesser likelihood than certain would be appropriate and lower risk than moderate would be applicable.

44) The Dahlhaus Report states that[9] *"The proposed Place of Worship and landscaping would over time, impact on the neighbouring cemetery development, just as the neighbouring cemetery development would ultimately impact on the proposed Place of Worship".* Whilst I acknowledge that there is potential for such impact, given the 80 m separation between the proposed Place of Worship and cemetery, I do not consider impact to the extent that there are noticeable and undesirable consequences to the neighbouring property to be a certainty. If suitable drainage controls are in place and landscaping is designed to be cognisant of the soil reactivity hazards, I consider it feasible that offsite impacts could be mitigated to insignificant levels.

5.0 POTENTIAL RISK MITIGATION MEASURES

5.1 General

45) The Dahlhaus Report identifies three primary geohazards to which the proposed development could be susceptible. These are summarised below, noting that the geohazards described are consistent with my site observations:

- Highly to extremely reactive soils.
- Gilgai development.
- Soil subsidence.

46) My comments below describe measures which could potentially be adopted at the Site to mitigate risks associated with these hazards.

47) I note that these options should not necessarily be considered in isolation. The adoption of a number of these options in combination may be appropriate. My comments on these are in no way meant to be exhaustive, but are provided as a general overview only to provide an indication of the type of measures that could be adopted at this site.

48) The performance of a structure (whether that be a mosque, a carpark, etc.) is typically considered in the context of the Serviceability Limit State (SLS) and the Ultimate Limit State (ULS). The SLS is concerned with the functioning of the structure, its appearance, and the comfort of the people utilising it (for example, the formation of cracks in non-loadbearing structural elements, uneven floor surfaces, etc.). The ULS is concerned with the safety of the structure and the people utilising it (for example, collapse of the structure).

[9] Section 3.3, Page 28, Paragraph 3.

49) There is typically a higher degree of interpretation in assessing when a structure has failed in SLS than in ULS. For example, a crack in a non-loadbearing structural element may be acceptable to some people but may not be acceptable to others, whereas the collapse of the structure is likely to be unacceptable to all.

50) Furthermore, the assessment of when a structure has failed in SLS must consider the intended purpose of the structure. For example, a crack in a non-loadbearing structural element in a warehouse is likely to be acceptable to most people, but may not be acceptable to most people in a mosque where the internal decorations are likely to be more valuable (either monetarily or spiritually).

51) The assessment of the likely performance of a structure in the ULS must be based on calculation and the experience of a suitably qualified and experienced structural engineer. I have not undertaken such calculations, and such calculations lie outside my area of expertise.

52) For these reasons, my comments below on the suitability of the options set out above with respect to the SLS and ULS are in general terms only.

53) The options for mitigating the effects of ground movement are based on four principles, which are set out below along with means by which this may be achieved. Further detail is subsequently provided with respect to these methods.

Isolate the Structure from the Expansive Soils

54) The structure could be supported on piles advanced to the basalt rock underlying the expansive soils and the structure supported on a suspended slab with a void between the slab and ground. This form of structure would be analogous to a piled offshore structure such as jetty which remains in place whilst the water moves below it. Consideration would need to be given to providing flexible services and service connections to the building given services in the ground could move relative to the building. In this case, movement of the structure could readily be engineered to achieve ULS and SLS.

'Float' the structure on the Expansive Soils

55) The structure could be supported on a stiffened slab designed to move with the soil, noting that this is the method used by most houses on sites underlain by reactive soils. Notwithstanding this, the movement at this site is expected to be particularly high, requiring a stiffened slab with deepened beams more substantial than is typically provided for houses on reactive sites. Some movement will occur, requiring flexible service connections, and it is possible for the building to tilt over time. This approach is analogous to a ship, which retains its structural integrity whilst moving in response to waves beneath it. Whilst it is likely that ULS will be achieved with this method, it may be more difficult to achieve SLS, depending on the movement tolerance of the internal building elements and decorations.

Provide a Flexible Structure

56) The building on the southern part of the allotment is a timber framed building which appears to have been in place for some time. This building has likely undergone movement, however due to its flexible timber construction has remained intact. A flexible building, by design, will move with the soil. This approach is unlikely to achieve SLS if there are movement sensitive decorations and finishes within the structure such as tiling or masonry. This approach is analogous to an inflatable raft which can cope with very large waves and remains serviceable, but is flexible and deforms to cope with the movement.

Remove or Replace the Reactive Soil

57) The reactive soil could be excavated, removed from beneath the proposed building footprint and replaced with non-reactive soils. Alternatively, the soil could be mixed with a stabilising material, typically lime to reduce its reactivity. Given the depth of soil expected, this approach may not prevent all movement, but if combined with another measure, such as a stiffened slab, may reduce the ground movement to a tolerable level. It is feasible to achieve ULS and SLS using this method.

5.2 Founding of the structure on a suspended slab

58) I understand from the Dahlhaus Report[10] that the depth from the existing ground surface to rock level is approximately 4 m. Due to the limited depth which piles would be required to be constructed such that they found on the underlying rock, I consider the ground conditions at the Site to be favourable to the adoption of this approach and suitable to limit ground movement such that ULS and SLS criterial are achieved.

59) This approach would act to isolate the structure from the reactive soils and the potential for collapse features adversely affecting the structure.

60) This approach is compatible with the portal frame type structure of the mosque, as piles can be located at the locations of the columns supporting the portal frame at the perimeter of the mosque.

61) Intermediate piles located across the footprint of the structure would likely be required to support the suspended slab with piles designed to account for uplift imposed by swelling soil and a void between the slab and ground.

62) Flexible service connections would be required to cope with differential movement between the structure and surrounding soil.

5.3 Founding of the structure on a stiffened slab

63) An example of a stiffened slab is presented in Figure 7.

[10] Figure 13 page 23

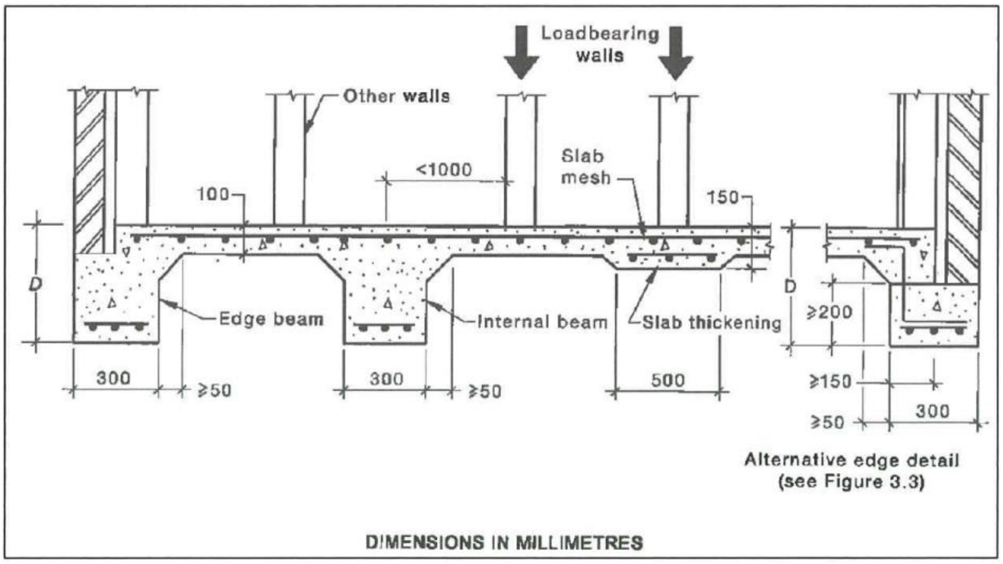


Figure 7: Example of a stiffened slab (Figure 3.1 from AS2870 (2011))[11]

64) If appropriately designed, I consider that a stiffened slab could:

- Reduce movement of the structure such that the risk of damage to the structure in ULS is acceptable.
- Depending on the movement sensitivity of finishes, reduce the movement of the structure such that the risk of damage to the structure in SLS is acceptable. Some cracking caused by movement should be expected with this form of construction. If finishes highly sensitive to cracking are proposed, for example marble finishes, this cracking may not be acceptable.
- Span potential zones of collapsible soils.

65) Although (as stated above) I have not undertaken design calculations, I consider it likely that a stiffened slab with deepened beams designed for the magnitude of movement expected on this site has the potential to be more financially onerous than other design options.

66) As stated in Section 2.0, I understand that the proposed mosque is a portal frame type structure, and therefore that the supporting columns will be located at the perimeter of the structure. As a stiffened raft would be required across the entire footprint of the mosque, this would appear to be an inefficient use of materials (i.e. the volume of concrete and reinforcing steel would likely be high compared to alternative footing options).

[11] This is provided for information only – the standard designs presented in AS2870 (2011) may not be adopted at Class P sites unless validated by calculation.

67) The dimensions of the footing required (i.e. the volume of concrete and steel) to limit the movement of the footing to acceptable levels are likely to be high.

5.4 Construction of a lightweight structure founded on a flexible footing system

68) This option may be suitable for a structure which is resilient to significant ground movements in both the SLS and the ULS. Based on the intended purpose of the structure (i.e. a mosque), it may be the case that the internal decorations of the mosque are not resilient to significant ground movements.

69) In the SLS, I consider that significant movements could be expected to occur, with a significant risk of damage to internal walls and fixtures.

70) I consider that near surface pad footings are unlikely to be acceptable due to the risk of collapsible soils. Should a collapse feature develop at the location of a pad footing, the subsequent localised movement of the pad footing would likely be excessive in both the SLS and ULS.

71) I conclude that the construction of a lightweight structure founded on a flexible footing system is unlikely to be practical for a development of this type.

5.5 Soil treatment or replacement

72) The treatment of the soil at the Site could include a number of potential options, including:

- Removal of the reactive soil at the site and replacement with non-expansive fill.
- Chemical stabilisation (for example, use of lime and cement).
- Other ground improvement techniques such as jet-grouting.

73) If adopted, the depth of removal of the soil at the Site will require an assessment of the potential movements which could occur following soil removal. Mitigation of the risk of collapsible soils would likely require a significant depth of the soil to be removed. Removal of the soil across the entire Site would not be required, but could be limited to certain areas, for example, the footprint of the mosque, the carpark, etc.

74) Although there is evidence to suggest that lime stabilisation is not effective for footings (Houston *et al.*, 2011[12]), it is commonly used for pavements. Therefore, such an approach may be suitable for the driveway and carpark.

[12] Houston, S.L., Dye, H.B., Zapata, C.E., Walsh, K.D. and Houston, W.L. (2011). Study of expansive soils and residential foundations on expansive soils in Arizona. Journal of Performance of Constructed Facilities, 25(1), 31-44.

5.6 Ongoing inspection and maintenance

75) I consider that a valid approach (likely to be adopted in combination with some of the approaches described above) would be to accept that significant ground movements may occur at the Site, and to allow for ongoing inspection and maintenance works.

76) This approach is unlikely to be suitable for the structure (i.e. the mosque itself), as the effects of significant ground movements on the structure and the cost of subsequent maintenance works are unlikely to be acceptable. However, this approach may be acceptable for the crushed rock driveway and parking area, where ongoing maintenance may simply involve periodic minor filling works such as grading and gravel re-sheeting.

5.7 Underground services at the Site (including plumbing and drainage)

77) My comments in relation to the underground services to the proposed structure, principally plumbing and drainage are presented below. These should not be considered to be exhaustive.

78) I note that the information provided in Section 5.6.3 and 5.6.4 of AS2870 (2011) in relation to drainage and plumbing requirements, respectively, may be useful to those responsible for the design of the plumbing and drainage at the Site.

79) Drains should be fitted with flexible joints to accommodate the total range of differential movements which are anticipated to occur. The maximum differential movement is likely to be greater where a stiffer footing system for the mosque is adopted, compared to if a more flexible footing system is adopted.

80) The depth at which underground conduits are located should be based on an assessment of likely ground movement and should consider the allowable movement which the conduit may tolerate.

81) Soil treatment (refer Section 5.5) may be adopted as a means of reducing the risk to underground conduits.

82) As outlined in the Dahlhaus Report[13], "*it is likely…that areas of the Site could be found where the potential for subsidence would be lower*". I recommend that, where possible, underground conduits are located in such areas of the Site, however, detailed geotechnical investigations would be required to identify these locations.

83) It is unclear to me if sewage generated at the Site will be removed from the Site via sewer, or if it will be treated at the Site and the excess effluent allowed to percolate into the ground. If the latter is the case, then due to the potential for swelling ground movements caused by the increase in moisture content, I consider that the percolation of the excess liquid should be allowed to occur at a sufficient

[13] Section 3.1 page 20

distance from the proposed mosque, driveway and carpark, and from neighbouring properties or a surface irrigation system used in conjunction with secondary treatment. However, I note that the increase in moisture content due to the percolation of effluent is likely to be significantly lower than that due to episodic rainfall events and seasonal changes.

6.0 RESPONSE TO SPECIFIC QUESTIONS

6.1 Question 1

Provide a peer review of the Dahlhaus Report.

84) My review of the Dahlhaus Report is set out in Section 4.0. In summary, I agree with the description of the hazards that have been identified on the site, including reactive soils, gilgai formation and collapsible soils. These features are consistent with my site observations.

85) I consider the risks to be overstated because:

a. No assumption has been made as to the structure to which the risk is being assessed

b. The hazard being assessed is not defined, for example, the hazard could be that surface movement exceeds those for which the structure has been designed.

c. Whilst the reactive soils are present beneath the structure, for the purposes of the risk assessment, the estimate of likelihood is not defined by the fact that such soils are present. Rather the likelihood should be an estimate of the probability that the design assumptions and requirements are exceeded. For example, the likelihood that ground movement exceeds that for which the structure has been designed.

6.2 Question 2

Provide a preliminary opinion on:

1. Whether the proposed development is likely to cause or significantly contribute to subsidence at the Site or other sites.

86) I do not consider it certain, as estimated in the Dahlhaus Report that the proposed development will increase the magnitude or severity of subsidence on adjacent sites. I consider it feasible that with appropriate drainage and landscaping designed to be cognisant of the reactive soils underlying the site, that the change in risk from soil subsidence on adjacent sits could be insignificant.

87) If designed appropriately, I consider that the risk of the proposed development causing or significantly contributing to subsidence at the Site could be reduced to a tolerable level.

88) Appropriate drainage across the Site and grading of the vegetated areas adjacent to the driveway and carpark may be undertaken to avoid increasing the surface water run-off and associated soil moisture

change on neighbouring sites. Furthermore, as the proposed development, driveway and carpark are offset a considerable distance from the neighbouring sites, I do not consider that an effect on neighbouring sites to be a certainty, and could be insignificant with appropriate controls.

2. Whether the risk (if any) of the proposed development causing or contributing to subsidence could reasonably be managed through design and construction measures; and

89) In my opinion risks associated with ground subsidence could be managed through design and construction measures. Options for managing the risks to the structure include supporting the structure on a suspended slab which is piled to rock, providing a stiffened raft or through ground improvement methods such as excavation and replacement of expansive soils.

90) Options for managing the risks to the unsealed gravel access road and carpark could include adopting an observation and maintenance approach whereby the surface is periodically graded and re-levelled.

91) Additional investigation will be required to inform design of the risk mitigation measures. The footing system, drainage and services are likely to require more engineering and incur a greater cost than would typically be required on a site without the geohazards to which this site is susceptible.

3. The likely impact on the environment (land, buildings and people) in respect of any residual risk of subsidence.

92) There are reactive soils underlying the site and the processes of soil shrink/swell, ground collapse and gilgai formation will remain a hazard on this site and the surrounding sites irrespective of the development.

93) The proposed development will impact these processes to some extent by changing the surface drainage and infiltration rates, by removing topsoil in some areas and through landscaping and vegetation.

94) I consider that through appropriate investigation and competent engineering design, the impact that the proposed development could cause to the natural processes associated with reactive soils can be managed such that risks to the environment, land, buildings and people can be managed to within tolerable levels.

Signature Page

Golder Associates Pty Ltd

Darren Paul
Principal

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APPENDIX A

Letter of Instruction

Expert Witness Code of Conduct

HARWOOD ANDREWS

Our ref: 2KXM:5AKT 21804177
Contact: Kate Morris
Direct Line: 03 9611 0142
Direct Email: kmorris@ha.legal
Principal Lawyer: Kim Piskuric

Level 5, 707 Collins Street
Melbourne VIC 3008

DX 30970

PO Box 633
Collins St West VIC 8007

T 03 9620 9399
F 03 9620 9288

ABN 98 076 868 034

harwoodandrews.com.au

Certified B Corporation

19 November 2018

Darren Paul
Golder Associates

Email: dpaul@golders.com.au

Dear Darren,

Planning permit application PA2017/5728
171-197 Harkness Road, Harkness
Our client: Melton City Council
Land owner/permit applicant: Melbourne Islamic Centre Ltd

We act for Melton City Council (**Council**) in relation to planning permit application PA2017/5728 (**Permit Application**).

The Permit Application relates to land at 171-197 Harkness Road, Harkness (**Land**) and seeks permission for the use and development of the Land as a place of worship.

Council has not resolved a position on the Permit Applicant yet but is concerned about the stability of the Land.

To assist us in advising Council in this matter, we are instructed to brief you to provide a fee proposal to:

(1) Peer review the report *Gilgai and Reactive Soil Geohazards in City of Melton* (including the Planning Application for a Place of Worship at 171-197 Harkness Road, Harkness) dated 31 August 2018 (**Dalhaus Report**); and

(2) Provide a preliminary opinion on:
 2.1 whether the proposed development is likely to cause or significantly contribute to subsidence either on the Land or other land;

 2.2 whether the risk (if any) of the proposed development causing or contributing to subsidence could reasonably be managed through design and construction measures; and

 2.3 in respect of any residual risk of subsidence, the likely impact on the environment (land, buildings and people).

We would request you provide the above peer review and opinions as soon as practicable after the festive period.

Brief of documents

All documents are provided in the attached electronic brief of documents for your consideration. Please advise if you would like us to provide you with a hard copy of the same.

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Further Background

Land
The Land is located within the Green Wedge A Zone (**GWAZ**) and the Bushfire Management Overlay (**BMO**) and Environmental Significance Overlay – Schedule 1 (**ESO1**) apply.

The Land is located to the south of the Melton Gilgai Woodlands Nature Conservation Reserve and north of land reserved for a future public cemetery.

Permit Application
The Permit Application requires a permit under the GWAZ,[1] BMO[2] and ESO1.[3]

A copy of the original Permit Application material is contained in your brief.

When considering the Permit Application, Council became aware that the Land and its surrounds may be subject to subsidence. On 30 April 2018, Council resolved to:

1. *set it aside for a period of no less than four months to give time for Council Officers to source expert opinions and advice from the Regional Cemeteries Trust, State Government of Victoria and other expert witnesses into future development of the land described above;*
2. *consult with Dr Dahlhaus, through Federation University, on possible use of the land described and ask of his availability to give Councillors a full briefing on potential for Harkness Road, Gilgai affected developments; and*
3. *undertake further community consultation.*

Subsequently, Council engaged Dr Dalhaus[4] to advise on the potential reactive soils and gilgai in the City of Melton with specific reference to the Land. A copy of the Dalhaus Report is contained in your brief.

Links to the work referred to and relied upon in the Dalhaus Report are contained in that document.

VCAT Proceeding
In May 2018, the Melbourne Islamic Centre Ltd (**Permit Applicant**) applied to the Victorian Civil and Administrative Tribunal (**VCAT**) for review of Council's failure to grant a permit within the prescribed time pursuant to section 79 of the *Planning & Environment Act 1987* (**P&E Act**).

Before a merits hearing, the Tribunal listed the proceeding for a preliminary hearing to determine whether a Cultural Heritage Management Plan (**CHMP**) was required pursuant to the *Aboriginal Heritage Regulations 2018* (**AH Regulations**). The Tribunal found a CHMP was required on the basis the proposed place of worship use is a 'high impact use' for the purpose of the AH Regulations and the activity area of the proposed use included the area of the Land within an area of cultural heritage sensitivity.

Consequently, the Tribunal dismissed the application for review for want of jurisdiction, vacated the hearing and found the Permit Application remains to be decided with the Council.

Amended Permit Application
On 29 October 2018, the Permit Applicant submitted a request to amend to Permit Application pursuant to section 57A of the P&E Act. This request limits the activity area of the proposed use and development to an area of the Land wholly outside the area of cultural heritage sensitivity. As a result, a CHMP is no longer required to be approved under the AH Regulations before Council decides the Permit Application. A copy of the section 57A application material is contained in your brief.

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[1] To use of land for a place of worship pursuant to clause 35.05-1 and for buildings and works associated with a place of worship pursuant to clause 35.05-5.
[2] To construct a building and to construct or carry out works pursuant to clause 42.01-2.
[3] To construct a building and to construct or carry out works associated with a place of worship land use pursuant to clause 44.06-2.
[4] Dr Dalhaus is an Associate Professor of Federation University and an expert in hydrogeology, engineering geology, and environmental geology.

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Your fees

Our client will remain responsible for your fees. We request that your fee proposal and any tax invoices be addressed to the client, using the following contact details:

Melton City Council
c/o Harwood Andrews
Email: atansley@ha.legal

You should not commence any substantive work until we confirm that your fee proposal is approved.

Legal professional privilege

Your professional opinion is sought in the context of us providing legal advice to our client about this matter. Consequently, your advice by virtue of your being engaged by us, attracts legal professional privilege.

To ensure that legal professional privilege is maintained, please keep our engagement of you confidential until we instruct you to the contrary.

If you have any queries or require any further information, please contact Kate Morris (9611 0142; kmorris@ha.legal) or Allison Tansley (9611 0197; atansley@ha.legal).

Yours faithfully,

Kate Morris

HARWOOD ANDREWS

Encl.

BRIEF TO EXPERT

Planning permit application PA2017/5728
171-183 Harkness Road, Harkness
Melton City Council

Land	
1.	Aerial photographs
2.	Melway and cadastral maps
3.	Zoning and Overlay maps
Melton Planning Scheme	
4.	Zone and overlay controls: ▪ Green Wedge A Zone ▪ Environmental Significance Overlay – Schedule 1 ▪ Bushfire Management Overlay
Dalhaus Report	
5.	Gilgai and reactive soil geohazards in City of Melton (including the Planning Application for a Place of Worship at 171-197 Harkness Road, Harkness) report prepared by Dr Peter Dalhaus dated 31 August 2018
Council documents	
6.	Council Minutes including officer report dated 30 April 2018
Permit Application	
7.	Original permit application, comprising: ▪ Application form; ▪ Certificate of Title; ▪ Plans prepared by Reeds Consulting, Rev B, dated 5 July 2017; ▪ Planning report prepared by Reeds Consulting dated July 2017; ▪ Noise report prepared by Marshall Day dated 18 November 2015; ▪ Land Management Plan prepared by Ecology & Heritage Partners dated November 2015.
8.	Response to request for further information, comprising: ▪ Letter from Reeds Consulting
9.	Section 57A amendment application (following remission of the Permit Application from the Tribunal), comprising: ▪ Letter from Reeds Consulting dated 29 October 2018; ▪ Certificate of Title; ▪ Architectural Plans prepared by Finnis Architects, Rev A, 15 October 2018; ▪ Landscape Plans prepared by Reeds Consulting, Rev D, dated 8 October 2018; ▪ Amended Planning report prepared by Reeds Consulting dated October 2018; ▪ Bushfire Management Plan prepared by ecolink Consulting dated October 2018.

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APPENDIX B

Curriculum Vitae of Mr Darren Paul

Darren Paul

Engineering Geologist, Principal

PROFESSIONAL SUMMARY

Darren is an Engineering Geologist with 19 years' experience. He has undergraduate qualifications in civil engineering and geology and postgraduate qualifications in engineering geology. He has extensive experience in managing geotechnical investigations for tunnels, buildings, roads, pavements and other infrastructure, developing ground models and undertaking assessment of ground related hazards, principally landslides.

Throughout his career Darren has been involved in slope stability assessments for many different applications including for town planning, roads, rail, coasts and pipelines. He has been an RMS accredited assessor for over 12 years and has undertaken in excess of 150 slope risk assessments for road batters in Queensland, New South Wales and Victoria. Darren has published and presented peer reviewed papers on planning for landslides and is regularly called on to provide peer review of geotechnical and landslide risk assessments associated with planning applications. He is the manager and instructor of the Australian Geomechanics Society Field Techniques for Landslide Assessment course and active within the landslide assessment community within Australia.

Some major projects Darren has been involved with include the Burnley Tunnel in Melbourne, Eureka Tower in Melbourne, Ballarat to Melbourne fast rail link, Nakheel Tower Dubai, the PNG LNG Plant site in PNG and Melbourne Metro.

EMPLOYMENT HISTORY

Golder Associates
Principal Engineering Geologist (January 2007 – Present)
Geotechnical Group Leader (January 2008 to March 2013)

Project Manager for a variety of geotechnical projects within Australia and the Middle East, including high rise structures, landslide risk assessment and slope stabilization. Tasks include client liaison, design of geotechnical investigations, engineering analysis and provision of recommendations. As geotechnical team leader, manager of 54 people of all levels. Active role in development of training program for graduate staff.

Golder Associates
Engineering Geologist (December, 1999 to December, 2006)

Site geologist for geotechnical site investigations. Conducted geotechnical investigations for a variety of projects in Australia and South East Asia and the Middle East. Extensive experience in field investigation of soil and rock, groundwater sampling and testing, geological mapping and construction inspection. Junior project manager involved in organising site investigation work, preparing technical reports, undertaking engineering analysis and design.

Education

Master of Science in Engineering Geology (Distinction), Imperial College, London, 2004

Diploma of Imperial College, London, 2004

Bachelor of Engineering (Civil) (Hons 1) University of Melbourne, 1999

Bachelor of Science (Geology) University of Melbourne, 1999

Certifications

Chartered Geologist

Geological Society of London, Fellow

Chartered Professional Engineer

Institution of Engineers Australia, Fellow

International Association of Engineering Geology, Member

Australian Geomechanics Society, Member, National Chair 2014 - 2015

Monash University, Teaching Fellow

Registered Engineer PNG

Awards

Richard Wolters Prize. International Award of the IAEG

Victorian Young Engineer of the Year, Engineers Australia, 2008

Glossop Award, Geological Society of London, Runner Up, 2007

Lapworth Medal, Dux of Imperial College Engineering Geology Masters Course, 2004

Rae and Edith Benett Travelling Scholarship, University of Melbourne, 2003

Australian Geomechanics Award for Best Paper 2014

SAF Pond Scholarship, awarded by the Australian Army, 1996

PUBLICATIONS

Albrecht, R.A., Tutton, M.A., Paul, D.R., Bohra, N. Managing Geotechnical Risk at an LNG Development in Papua New Guinea., Proceedings of World Gas Congress, Paris, 2015.

Benson, N.D., Haberfield, C.M., Paul, D. Geotechnical Design and Construction of Invert Anchors Proceedings of the 12th Australian Tunnelling Conference, 2005.

Haberfield, C.M., Paul, D.R., Ervin, M.C., Chapman, G.C., Cyclic loading of barrettes in soft calcareous rock using Osterberg Cells, Frontiers in Offshore Geotechnics, Gourvenec and White (eds.), Balkema, 2011.

Haberfield, C.M., D.R. Paul and M.C. Ervin. Geotechnical design for the Nakheel Tall Tower. ISSMGE Bulletin, Vol 2, Issue 4, pp. 5-9, 2008.

Miner, A.S., Paul, D.R., Parry, S., Flentje, P. What does Hazard mean? Seeking to provide further clarification to commonly used landslide terminology, Proceedings of the 12th Congress of the IAEG, Torino, 2014.

Parry, S., Baynes, F.J., Culshaw, M.G., Eggers, M., Keaton, J.F., Lentfer, R., Novotny, J., Paul, D. Engineering Geological Models: IAEG Commission 25, Bulletin of Engineering Geology and the Environment, Vol 73, 3, 2014, pp. 689 - 706.

Paul, D.R., A simple method of estimating ground model uncertainty for linear infrastructure projects, Proceedings of the 13th Congress of the IAEG, San Francisco, USA, 2018.

Paul, D.R., Miner, A.S., Fifteen years of slope stability and risk assessment for local government planning in Victoria, a discussion of common mistakes and shortcomings, Australian Geomechanics Society Victoria Symposium, Melbourne 2016.

Paul, D.R., Barrett, S., Stewart, P.S., Webster, M.W., The Geological Evolution of the Jolimont Valley, Melbourne, Victoria, Australian Geomechanics, Vol. 49, No 2, June 2014. (winner Australian Geomechanics Award for best paper, 2014)

Paul, D.R., Skelley, M., Daniel, G., Sinkhole formation in central Victorian alluvial gold mining areas, Proceedings of the 11th Australia New Zealand Conference on Geomechanics, 2012.

Paul, D.R., C.M. Haberfield and M.C. Ervin. Laboratory and in situ stiffness assessment in weak carbonate rock, Dubai, UAE. Proceedings of the 11th Congress of the IAEG, 444, 2010.

Paul, D.R., Haberfield, C.M., Foundation Investigation in Weak Slaking Rock, Darwin Australia, Australian Geomechanics Society, Foundation Symposium, Sydney 2008.

Paul, D.R., Ervin, M.C., Haberfield, C.M., Landslide Risk Assessment for Residential Dwellings on Known Landslides, Proceedings of the 10th Australia New Zealand Conference on Geomechanics, 2007.

Paul, D., Barrett, S., Jones, T., Bennett, A., Development of Geotechnical Units and Geotechnical Design Parameters for the Melbourne Formation, 16th Australasian Tunnelling Conference, Sydney, 2017.

Srithar, S., Paul, D., Settlement behaviour of a mined, waste backfilled site, Proceedings of the 19th International Conference on Soil Mechanics and Ground Engineering, Seoul, 2017.

PROJECT EXPERIENCE – SLOPE STABILITY

Caraar Creek Landslip Assessment
Melbourne, Australia
Investigation for potential instability on a proposed housing development site. Required historical review, geomorphological and geological mapping.

Warburton Slope Stability Assessment
Warburton, Australia
Mapping of landslips in an area with a long history of instability. Historical review, geomorphological mapping and zoning of areas based on potential instability

South Gippsland Highway Slope Stability Assessment
Leongatha, Australia
Slope stability assessment of proposed cuts along a realignment of an existing highway. Involved historical review, rock slope mapping, geomorphological mapping and computer analysis.

Doncaster Quarry Stability Review
Melbourne, Australia
Slope stability assessment of a former quarry proposed as a landfill development. Review of previous stability assessments, new rock face mapping, collation of data and stability analysis.

Ben Cairn Estate
Don Valley, Victoria, Australia
Risk Assessment for residential estate upon which a large scale landslip has been identified. Required extensive geomorphological mapping, liaison with landowners and conduct of a risk assessment, Provided advice to the Shire of Yarra Ranges with respect to future planning within the Estate.

Dutton Way Coastal Stability Assessment
Portland, Victoria, Australia
Stability assessment of coastal cliffs along a major road in Portland. Provided advice to the Glenelg Shire Council on risks associated with cliff erosion and slope instability. Recommended remedial and support measures.

Shire of Yarra Ranges Landslip Review
Yarra Ranges, Victoria, Australia
Review of planning applications for the Shire of Yarra Ranges with respect to landslip. Requires site visits, stability assessment, geomorphological mapping and preparation of expert witness statements for VCAT.

Landfill Slope Stability Assessment

Analysis of the stability of numerous landfill slopes within South Australia and Western Australia composed of composites of synthetic liners and clay.

Council Trench Reserve
Bacchus Marsh, Victoria, Australia
Slope stability analysis with respect to rockfall within a public reserve at Bacchus Marsh. Involved geomorphological mapping and risk assessment. Provided advice to the Council Trench Reserve Committee on appropriate ways to lower the risk associated with rockfall within the Council Reserve.

Road Batter Assessment
Shire of Yarra Ranges, Victoria, Australia

Assessment of four road batters that failed after heavy rain in February 2005. Performed basic site investigation and assisted in the development of a remedial system.

Scoresby Clay Quarry

Scoresby, Victoria, Australia

Slope stability assessment within a former quarry for which residential development is proposed. Required geomorphological mapping and slope stability analysis.

Study Tour

UK and Greece

Visited and studied numerous major landslides during Masters Degree Course. Including Folkestone Warren and the Isle of Sheppey in the UK and the Makassar Landslide in Greece.

Royal Avenue Beach Sandringham

Sandringham, Victoria, Australia

Detailed slope stability risk assessment in accordance with the Australian Geomechanics Society Guidelines. Involved site assessment, review of available information, reporting in writing and presentation to local council.

RTA Slope Risk Assessment

New South Wales, Australia

Undertook week long training course to become accredited slope risk assessor for Roads and Traffic Authority in New South Wales. Conducted detailed slope risk assessment of 30 road cuttings and fill embankments in the Coffs Harbour region of New South Wales.

City of Moreland

Victoria, Australia

Development of the Moreland City Council Erosion Management Overlay including expert witness evidence to the planning panel.

DPLTI Victoria

Victoria, Australia

Development of Alpine Shire Erosion Management Overlay and input to the drafting of the Erosion Management Overlay Schedule.

Frankston City Council

Victoria, Australia

Development of Erosion Management Overlay for Frankston City Council and review of planning application submitted under the overlay.

Valley Lake,

Niddrie., Victoria Victoria, Australia

Supervision of rock scaling works and installation of support measures

PNG LNG Expansion Project

Western Province, Papua New Guinea

Geomorphological mapping of PNG highlands area and route assessment for proposed gas pipeline. Included geological traverses to ground truth assessment made using remote sensing imagery, identification of landslides and routing nomination of pipeline routes to avoid landslides

Cosgrove 3 Quarry

Cosgrove, Victoria, Australia
Assessment of quarry stability associated with redevelopment of the quarry as a landfill.

Grampians Peaks Trail
Grampians National Park, Victoria, Australia
Landslide risk assessment for proposed walkway. Included rock fall analysis and advice on mitigation measures.

Apollo Bay – Proposed Resort
Apollo Bay, Victoria, Australia
Landslide risk assessment for proposed walkway. Included rock fall analysis and advice on mitigation measures.

Baw Baw Shire – Development of Erosion Management Overlay
Victoria, Australia
Review of Baw Baw Shire erosion management overlay and recommendations for improvements to the overlay and its administration.

Palmerston Highway
Far North Queensland, Australia
Road batter slope stability assessments for major highway in tropical area of Queensland. Included recommendations for remedial works.

Lamington National Park
Gold Coast, Queensland, Australia
Stability assessment of road batters following major rainfall event which damaged and blocked road. Included development of remedial designs.

PROJECT EXPERIENCE – TUNNELS

Melbourne Metro
Victoria, Australia
Geotechnical lead for the proposed 9 km long Melbourne Metro tunnel project. Involved preparation of the site conditions report and development of geotechnical ground models along the length of the tunnel. This information has been used to develop reference designs for the project.

East-West Link
Victoria, Australia
Developed ground models as part of tender submission for proposed east-west road tunnels. Involved compilation of information, development of 3D model and long sections.

Westgate Tunnel
Victoria, Australia
Desk study and development of ground models for road tunnel associated with the Westgate Tunnel. Ground model included complex ground conditions not previously encountered in Melbourne.

North-East Link

Victoria, Australia

Peer review of geotechnical investigation information and ground model compiled for proposed freeway tunnels in Melbourne Suburbs.

Burnley Tunnel Remediation Works

Victoria, Australia

Involved extensively in site supervision and quality control for the installation of up to 5000 ground anchors as part of remediation works for the Burnley Tunnel. Heavily involved in monitoring anchor stressing including supervision of stressing and acceptance testing. Performed extensive analysis of testing results. Worked closely with recognised world experts in the field of ground anchor installation and stressing to help develop testing and acceptance criteria. Exposed to various types of ground anchors including threadlock bar and strand anchors.

Eastlink Tunnels

Victoria, Australia

Geological Mapping of cut batters for tunnel portals. Required mapping and presentation of the mapping data in a format that would be useful for designers and planners.

Greece Study Tour

Greece

Attended a study tour in Greece during which numerous NATM, and TBM tunnels were visited. Including tunnels of the Egnatia Highway, the Athens Metro, the Acheloos Diversion Tunnel and the Athens to Corinth Highway.

PROJECT EXPERIENCE – MAJOR BUILDINGS

Federation Square Site Investigation

Victoria, Australia

Investigation for proposed piling works through highly compressible soils. Required drilling and sampling on a union controlled site.

Hospital

Victoria, Australia

Investigation for proposed hospital redevelopment. Involved exploratory drilling, footing exposures, slope stability assessment and rock face mapping.

Eureka Tower

Victoria, Australia

Supervision of bored pile construction for an 88 storey building. Involved verifying founding materials, base cleaning methods monitoring construction progress.

Charlton Silos

Charlton, Victoria, Australia

Site investigation to investigate reasons behind measured settlement of wheat silos. Required drilling and sampling materials, and investigating evidence for settlement.

Waste Water Treatment Plant

Victoria, Australia

Investigation aimed at investigating reasons for settlement of a newly built water clarifier. Involved drilling in compressible soils, cone penetrometer testing and investigating reasons for settlement.

Processing Facility

Boort, Victoria, Australia

Investigation for proposed olive processing facility on highly reactive clays. Involved exploratory test pits, and investigation of potential fill borrow areas.

700 Collins Street

Victoria, Australia

Site investigation for proposed high rise building. Required environmental sampling, soil and rock drilling and sampling and pressuremeter testing.

Commonwealth Games Swim Centre

Victoria, Australia

Site investigation for the proposed swim centre for the Melbourne 2006 Commonwealth Games. Involved drilling and testing in granites, siltstones and sands.

Freshwater Place

Victoria, Australia

Supervision of bored pile construction for a 60 storey building. Involved on site pile design, verification of test methods, liaison with contractor and clients.

15 Claremont Street

Victoria, Australia

Project management of site investigation for 5 storey residential development. Provided advice on foundation and pile design.

966 Stud Road

Victoria, Australia

Project management of site investigation for large scale industrial and commercial development.

Evolution on Gardiner

Northern Territory, Australia

Project management of site investigation for a 33 storey building in Darwin. Difficult ground conditions encountered requiring non-standard testing and analysis.

573 St Kilda Road

Victoria, Australia

Project management of site investigation for a 30 storey building in Melbourne. A weak layer at depth required non-standard investigation, testing and analysis.

Tooronga Village Shopping Centre

Victoria, Australia

Undertook geotechnical desk study for proposed shopping centre redevelopment. Project manager for additional geotechnical investigation work undertaken to assess ground conditions at the site.

Nakheel Tall Tower

Dubai, United Arab Emirates

Geotechnical Project Manager for proposed high rise building. At over 1000 m high, on completion the Al Burj tower is proposed to be the highest and heaviest building in the world and will be founded in weak sedimentary rock. Duties included supervising the site investigation, training local drilling crews in appropriate sample management, selection of laboratory tests and formulation of an engineering geological model for the site. Special site specific investigative techniques were developed and implemented for this project and specialized testing designed and carried out. Involved in liaison with the piling contractor, construction supervision, geotechnical design and analysis.

Office and Housing Facilities

Port Moresby, PNG

Manager of extensive geotechnical investigations for office and housing facilities for the PNG LNG project. Involved investigating hazards associated with challenging ground conditions in a nearshore and onshore setting, management of drilling, test pit and laboratory testing programs.

PROJECT EXPERIENCE – ROADS AND PUBLIC INFRASTRUCTURE

Webb Dock

Victoria, Australia

Project manager for review of existing subsurface information at Webb Dock. Developed ground models and estimated loading history for the dock area.

Melbourne City Link Groundwater Monitoring

Victoria, Australia

Monitoring of the water table response to ongoing works within the Burnley Tunnel. Involved extensive fieldwork and data management.

Victorian Regional Rail

Victoria, Australia

Project Manager for major geotechnical investigation along 50 km long new railway corridor. Involved planning and coordination of major geotechnical investigation, including selection of testing methods, and compilation of ground models for use in conceptual design.

Birrarung Marr

Victoria, Australia

Monitoring of the effects of earthworks on ground movement. Required the use of inclinometers, magnetic extensometers and vibrating wire piezometers. Also involved processing and interpretation of results.

Calder Freeway Site Investigation

Victoria, Australia

Investigation of site conditions for proposed freeway. Required extensive drilling, in situ tests, sample management and laboratory testing.

Melbourne - Ballarat Fast Rail Project

Victoria, Australia

Geotechnical Investigation for realignment of rail track. Included drill supervision, geological mapping, test pit, and interpretation of geological information.

Karebbe Hydroelectric Dam

Sulawesi, Indonesia

Site investigation and review of existing geotechnical and geological information for a roller compacted concrete dam. Required the formation of a geological model for the proposed dam site and identification of relevant geotechnical issues.

PROJECT EXPERIENCE – MARINE WORKS

East Arm Port

Northern Territory, Australia

A litigation concerned with unexpected ground conditions associated with the East Arm Port, Darwin, Northern Territory. Required review of geological and geotechnical information gathered during the project and the development of a brief to lawyers.

Moonee Ponds Creek Realignment

Victoria, Australia

Conduct and interpret a series of cone penetrometer tests in an area of very soft sediments and assess the likely rates of consolidation and settlement under the influence of filling operations.

Terminal, Port Giles

South Australia, Australia

Offshore site investigation for proposed dredging works. Involved coring and sampling of calcareous sands and limestones in difficult drilling conditions.

Footbridge

Victoria, Australia

Project Manager for site investigation of proposed footbridge. Involved organizing and supervising marine drilling operations.

PROJECT EXPERIENCE – PAVEMENTS

Flemington Racecourse Pavement

Victoria, Australia

Pavement investigation for temporary haul road associated with an undertrack tunnel. Involved shallow boreholes and DCP tests along the length of the proposed alignment.

Wharf Pavement, Docklands

Victoria, Australia

Ground investigation and preliminary design for major container terminal to be constructed over soft marine sediments.

PROJECT EXPERIENCE – MINING, OIL AND GAS

Hellyer Mine Adit Plug

Tasmania, Australia

Assessment of the proposed location for a water tight plug in the main adit of an underground mine. Involved underground joint mapping, rock coring and in-situ rock permeability testing.

Ginko Sand Mine

New South Wales, Australia

Study to assess the suitability of proposed dredging operations within a heavy mineral sands deposit. Involved drilling large diameter sand cores, sampling and strength testing.

Mercury Sand Mine

Victoria, Australia

Geotechnical investigation for a proposed sand mining operation. Involved assessment of the geotechnical properties of the materials, and their suitability for dredging operations.

Quarry Feasibility Study

Victoria, Australia

Desk study and drilling program to define resource distribution and feasibility for a proposed basalt quarry. Included research of existing information, geological mapping, formation of a geological model and design of the drilling program.

Montrose Quarry

Victoria, Australia

Hydrogeological assessment in relation to proposed dewatering of quarry. Supervision of borehole drilling and in-situ permeability testing.

Bendigo Mining Ore Processing Facility

Victoria, Australia

Major site investigation for proposed ore processing facility at the New Bendigo Gold Mine. Involved designing and implementing a geotechnical investigation, design of pit slopes and specification for slope reinforcement.

Snapper Sand Mine

New South Wales, Australia

Project Manager for geotechnical investigation of proposed heavy minerals sand mine. Involved design of geotechnical investigation specification of laboratory testing and detailed slope stability analysis.

Ballarat Gold Mine

Victoria, Australia

Site geologist for hydrogeological investigation. Required underground Lugeon testing within boreholes of up to 200 m depth.

Sulfur Springs

Marble Bar, Western Australia, Australia

Hydrogeological investigation for mine water supply in remote area in Pilbara. Required specialised remote area equipment to be mobilised.

Ardmore Phosphate Deposit

Dajarra, Queensland, Australia

Geological mapping, ground model development and design of pit slopes for proposed open cut phosphate mine.

PNG LNG Processing Plant Site

Port Moresby, Papua New Guinea

Project manager of extensive geotechnical investigation for LNG processing plant. Included development of geotechnical model for onshore and offshore plant components. Implementation of data management systems for the extensive data obtained during the three years over which the investigation was undertaken.

LNG Expansion Project

Port Moresby, Papua New Guinea

Geomorphological mapping of PNG highlands area and route assessment for proposed gas pipeline. Included geological traverses to ground truth assessment made using remote sensing imagery.

Longford Gas Conditioning Plant

Victoria, Australia

Geotechnical investigation, ground characterisation and recommendation of parameters for an extension to a gas conditioning plant.

Simandou Railway

Guinea, West Africa

Undertook desk study for 630 km railway line. Included terrain mapping and characterisation, development of geological models, identification of geohazards and development of a comprehensive risk register for the railway which traversed through challenging terrain.

Nambonga Portal

Morobe Province, PNG

Landslide hazard assessment and ground model development for mine portal within the highlands of Papua New Guinea, including fault identification and development of engineering parameters.

St Ives Gold Mine

Western Australia, Australia

Geotechnical Investigation and pit slope design for 80 m high slopes in soils. Required development of a 3D model, geotechnical and hydrogeological characterisation.

GOLDER

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