red earth
geosciences

Geoscientific Investigation (with special emphasis on groundwater attributes) - Proposed Macarthur Memorial Park at Varroville, NSW

for

THE TRUSTEE FOR
THE CATHOLIC METROPOLITAN CEMETERIES TRUST
(ABN 85 744 325 709)

November 15, 2014
Project Number 1403

This report has been prepared by Dr Boyd B. Dent,

Principal,

Red Earth Geosciences (ABN 57 980 897 591).

www.RedEarthGeo.com.au

Red Earth Geosciences provides a service as a sole trader consultancy specialising in matters of environmental hydrogeology, engineering geology and geoscientific data analysis.

REVISIONS TABLE	
Date & Version	**Changes**
Original draft 30 Nov 2014	
3/12/14; draft v2	Removed irrelevant references; corrected typographic errors in pit logs
12/12/14 final	Insert of high quality aerial photo scans and additional groundwater data (Table 3); added 2-sentence discussion following analysis of this data

CONTENTS

Abbreviations

BoM – Australian Bureau of Meteorology

EC – electrical conductivity (µS/cm)

USCS – Unified Soil Classification System

Geoscientific Investigation (with special emphasis on groundwater attributes) - Proposed Macarthur Memorial Park at Varroville, NSW

Introduction

Red Earth Geosciences (REG, Consultant) was requested to assess land at Varroville (Campbelltown District), NSW, for its suitability to be developed as a cemetery. The services of REG were particularly sought because of the special expertise of the Principal Consultant – Dr Boyd B. Dent (Appendix E) a recognised expert practitioner in such developments.

At the time of this engagement, the cemetery development concept is still a proposal developed by the Catholic Metropolitan Cemeteries Trust (Proponent). The Proponent had submitted exhaustive planning-related studies – for which this work is an addendum - to Campbelltown City Council in relation to the proposed development; and, specifically in respect of the need to alter zoning permissions to include cemetery development for the proposed lands. The various studies and documents related to their approach have been considered in review for the present work and are referred to as necessary herein.

Following planning-type reviews of their submission, the Proponents have been requested by the Joint Regional Planning Panel (JRPP) for the Western Division to comment specifically in the context of the following condition relative to a "Gateway" determination:

1. *The geological conditions of the site are investigated, and it is confirmed that ground water protection, can be achieved by reference to compliance with accepted standards for burial plots, such as those of the World Health Organisation.*

The studies reported on herein are specifically designed to provide the information required by the JRPP. To achieve that purpose, however, it was necessary to undertake a significant geoscientific investigation of the site. The answers required for the JRPP are not simplistic and cannot be developed from a simplistic approach. Accordingly, the work done has been extensive and has consequences beyond that required for the JRPP and goes significantly – *but not completely* - towards greater site understanding relevant to its future development.

The outcomes of this study importantly support the Proponent's intentions and applications and find in all respects that the site is broadly suitable for the proposed development. The concerns raised in JRPP's Condition 1 are naturally met on the site.

Location

The site comprises a parcel of rural grazing land of about 113 ha which surrounds but excludes an enclosed residence, known as "Varroville House", and is referred to as 166 – 176 St Andrews Road, Varroville, NSW: specifically being Lot B of Deposited Plan DP 370979, Lot 22 of Deposited Plan DP564065 and Lot 1 of Deposited Plan DP218016 (NSW Land Titles Office), Figure 1.

Precise location information, land ownership issues and the nature of restrictions and in development of the site are discussed in the Proponent's document – "Planning Proposal" by Urbis (2013).

Work Undertaken

The work undertaken for this study and reported-on herein comprised:

* an extended desk-top review of the site, its setting, geoscience associations, and implications for the development; limited review of archived aerial photographs; review of groundwater information from the NSW Office of Water; review of geological and soils maps, official reports and other related information (e.g. climate-, community-, council- and research- related);

* an intensive 2 day site inspection and shallow surface investigation (24 Pits), together with a generalised inspection of the district on 1st and 2nd October 2014;

* comprehensive discussions with the Proponent and review of documents supplied by the Proponent: being, the "Planning Proposal" (Urbis, 2013) and 9 detailed Appendix reports thereto; plus preliminary geotechnical reports by SMEC (2008) and Douglas Partners (2013);

* updated research and report reading for The World Health Organisation (WHO), the UK Environment Agency, and government health- and

environment- related entities for Scotland, Northern Ireland, USA, South Africa, Canada and Australia

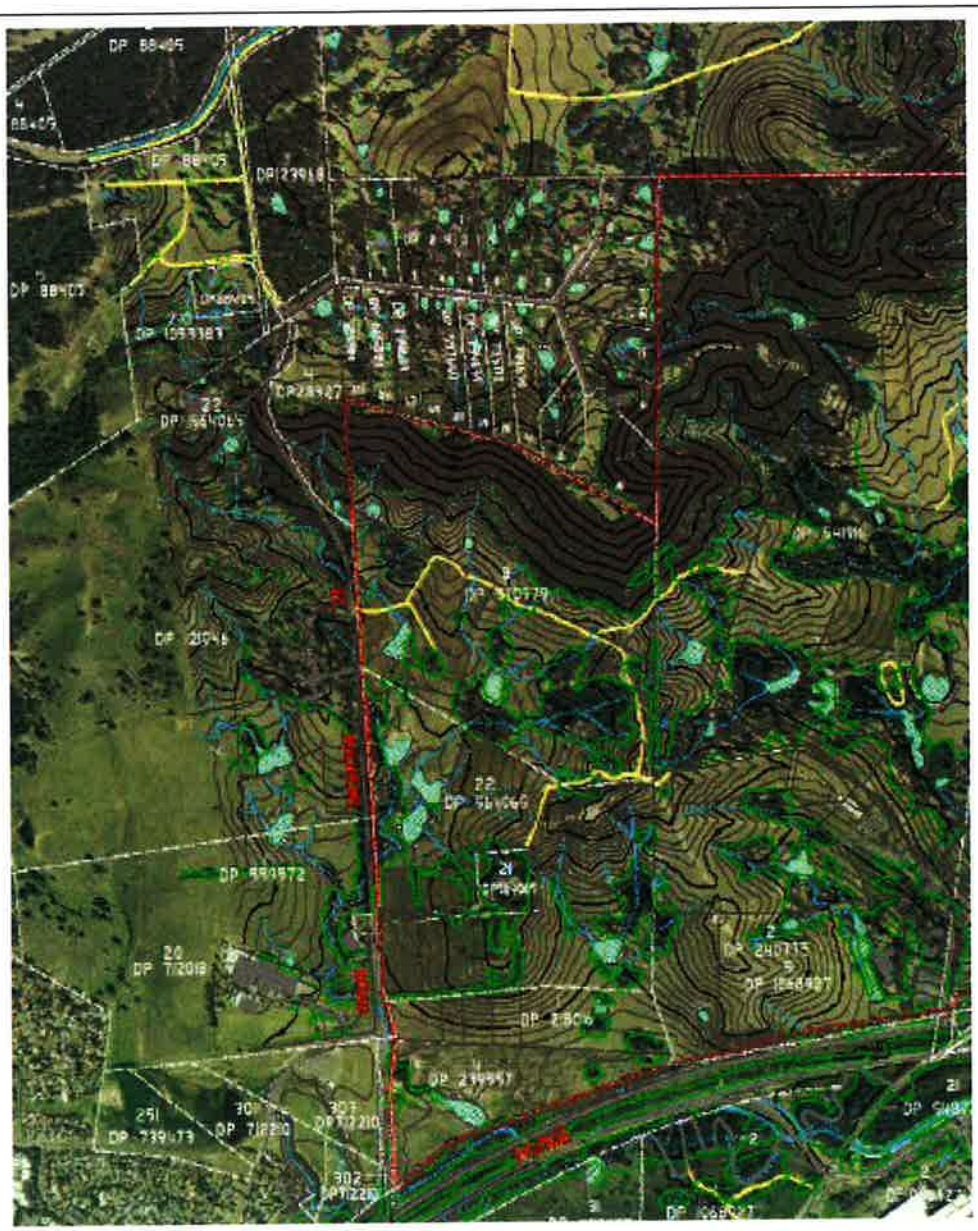


Figure 1. Location – central portions in image - on a cadastral and topographic base map extracted from SMEC (2008) report for the land owners. (original scale 1:5000; arrow shows approximate North)

Geology and Physiography

The most recently published large scale geological map relevant to the site is the Wollongong-Port Hacking 1:100000 Sheet (Geol. Surv. NSW, 1985). Geological understandings of this region are now well-settled and there has been little modification in the Campbelltown District generally since the 1970s. Part of the map has been extracted as Figure 2 and shows the Varroville location.

The strata of the region comprise a well-known sedimentary rock sequence with minor igneous intrusions to the south of the central area of the Sydney Basin. The site is founded within rocks of the Triassic aged Bringelly Formation, the youngest of the conformable strata of the Wianamatta Group. This particular site also hosts an extensive, unnamed, lithic sandstone Member of the formation and this is referred to in the work of Pogson and Chesnut (1968) – see further discussion later.

There are no known major geological structures identified near the site, and geological structure present is likely to be limited to tight jointing, reflecting the regional pattern. During the site inspection, only one set of joints was able to be measured satisfactorily. This was in the excavated hillside at S 34° 00′ 07.7″ E 150° 49′ 33.7″ where grey siltstone and darker grey carbonaceous shale, hosting a 0.4 m thick lens/bed(?) of lithic sandstone which contained joints (weathered and open to 1 cm) at about 1.2 m centres with strike 090° and dip 90° [*an absolutely 'classic' measurement*]. The strata are known to dip gently and generally to the NNW-NW.

The Bringelly Formation is comprised of a number of different lithologies including, grey siltstone, grey shale, grey claystone, brownish lithic sandstone, beige/grey laminite, dark grey – black carbonaceous siltstone/claystone/shale. Most of these lithological variations were observed during the pit excavations – see the logs in Appendix A. Lithological facies are not continuous across the site and this will affect some developmental issues – discussed later.

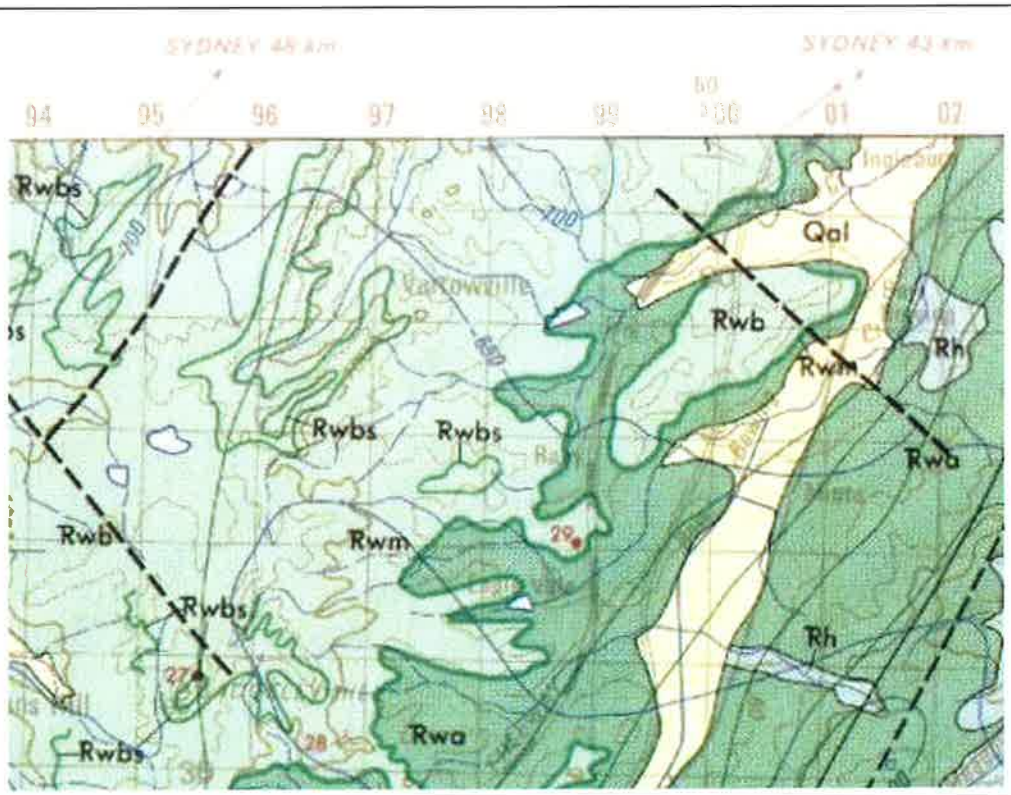
The site is subject to no special seismic hazard compared to that for the surrounding region which could be described as 'modest' at the most: and is the same as that for the Sydney CBD (Leonard et. al, 2013).

Physiographically, the site is made up of 3 'provinces': (1) a north elevated ridge line at the boundary with steep sides formed over the unnamed lithic sandstone Member; (2) a northeast middle area made up

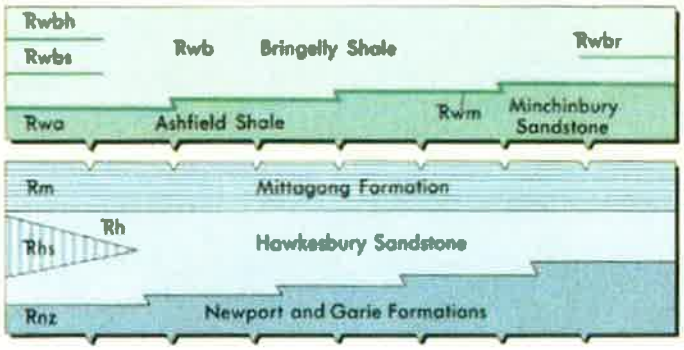
of a spine ridge again developed over lithic sandstone and erosion-resistant strata; (3) the remainder being (i) most of the site south and west of provinces 1 and 2, as well as (ii) south and east of 2, and being gently undulating country with slopes typically in the 3 to 5 degree range. This landform arrangement and zoning issues will highly influence the development of the site.

Two geotechnically-focused reports have previously been prepared for the site and associated lands to the northeast – SMEC (2008) and Douglas Partners (2013). Both of these reports were of an initial desktop style and generally described the site's geological context and aspects of future development. Neither report addressed the hydrogeological setting or matters of site groundwater presence and relevant proposed operations.

Further specific investigations for larger constructed features as buildings, roadworks and major earthworks, have not been made during the present investigations. Such matters need to be addressed with more detail of the proposed development.



Triassic Age Sediments – Partial Stratigraphic Column Only



WIANAMATTA GROUP Rw (undifferentiated)

Rwb	*Shale, carbonaceous claystone, laminite, coal in parts.*
Rwbh	*Mt Hercules Sandstone Member - fine to medium grained quartz-lithic sandstone.*
Rwbr	*Razorback Sandstone Member - fine to medium grained quartz-lithic sandstone.*
Rwbs	*Unnamed sandstone member - fine to medium-grained quartz-lithic sandstone.*
Rwm	*Fine to medium-grained lithic sandstone.*
Rwa	*Laminite and dark-grey siltstone.*

MITTAGONG FORMATION

Rm	*Interbedded shale laminite and medium-grained quartz sandstone.*

HAWKESBURY SANDSTONE

Rh	*Medium to coarse-grained quartz sandstone, very minor shale and laminite lenses.*
Rhs	*Claystone, siltstone, and laminite ("shale lenses").*

Figure 2. Extract of digital Wollongong-Port Hacking 1:100000 Geological Map and legend (after Geol. Surv. NSW, 1991). Figure scale is expanded to1:83333, North at top, grid lines 1000 metre centres on AMG Zone 56.

Site Landscape and Investigation

Data from the Environment and Heritage (NSW Dept., 2014) shows that the site host 3 types of identifiable soil landscapes. These generally conform to the physiographic province concept identified previously:

(A) Luddenham Soil Landscape – equivalent to province (1)

(B) Blacktown Soil Landscape – equivalent to most of the site proposed for development - province (3–i)

(C) South Creek Soil Landscape – equivalent to a very minor part of province (3-ii), if at all.

The Soil Landscape mapping at a scale of 1:100000 done by the former Soil Conservation Service in 1990 is a valuable way of interpreting 'lumps' of landscape – i.e. parts that share many similar characteristics and thus behave in similar ways. In the site-specific context one of the most useful concepts from this mapping is in terms of landscape response and limitations.

The Luddenham Soil Landscape is considered to be 'erosive'. It is associated with the ridgeline and lithic sandstone bedrock and steeper site slopes. This landscape is subject to soil erosion hazard, localised impermeable plastic and reactive clay soils, as well as mass movement hazard (Hazelton and Tillie, 1990). The site conforms with this understanding.

The Blacktown Soil Landscape is considered to be 'residual'. It is associated with the gently undulating site areas hosting broad, rounded crests and slopes with gentle slopes generally less than 5% (about 3°). The hosted soils are moderately reactive with highly plastic subsoils and low soil fertility (Hazelton and Tillie, 1990). Once again the site conforms generally with this understanding but appears to also host a larger percentage of slightly steeper slopes.

The South Creek Soil Landscape possibly occurs in the northeast corner of the site, and land between the Hume Freeway and the southern site boundary. It is of little consequence to future development since it is associated with drainage structures – e.g. Dam 10 (Travers bushfire & ecology 2013) and buffer zones for the cemetery development: but this mapping boundary needs to be confirmed in the field.

The present investigation has found that soil conditions, and consequently underlying bedrock types, are extremely variable across the site. The

depths of soils, the degree of soil development, the amount of soil profile disturbance, and the consistency of soil profiles all vary greatly; to a degree not previously encountered by this Consultant in hundreds of previous site inspections. The resultant agglomeration of natural settings is at variance with typical and expressed wisdom about soil depths and predictions of these. The essential driver of variation is considered to be the variable bedrock lithologies; yet the various landscape parts are otherwise 'performing' consistently to the norm and as expected.

The soil profile has been carefully documented for all 24 Pits (Appendix A). These show that soil depths encountered ranged from 0.75 m – on ridge areas – to a maximum 2.5 m in foothill slope swales. More typically, in the majority of the prosed cemetery burial areas soils were between 1.35 and 2.20 m deep – Figure 3.

The predominant soil textures observed were a sandy clay, clayey sand or highly plastic clay, occasionally silty parts, which would be classified as SC, SP, CH or MH-CH in the Unified Soil Classification System (USCS). These soils types have all been successfully used for interments around the World, with sandy and silty clays, and clayey and silty sands, providing the most suitable substrates. These substrates encourage body decomposition with fair to good drainage characteristics at grave invert level, good workability for cemetery operations and a low transmission environment for microbiological leachate factors. The more plastic and purer clay soils provide poor drainage, retard moisture in graves and are more encouraging of microbiological factor survival in the grave. The combination of soil context and cemetery operations has been extensively considered by the Consultant and his work widely reported: the relevant matrix of factors considered is presented as Appendix B (Dent, 2003).

All these soils types have a negative correlation with aquifer development and groundwater movement, i.e. they are not suitable in this context as groundwater permeates at a very slow rate in these matrices. Further, in respect of surface recharge alone, this takes a long time to percolate downwards into the profile following infiltration. The soils tend to remain moist in the upper layers if not adversely affected by evapotranspiration. The site soils are currently adversely affected by evapotranspiration issues.

To assist the Proponent in developing the cemetery concept, it is recommended that a more detailed investigation of soil depths, profile classifications in terms of the Unified Soil Classification System – especially at various proposed grave invert levels, be made.

Figure 3. Site Investigation - PIT locations and Soil Depths – 1st & 2nd October 2014.

Blue flag – approximate pit location from field GPS; Px - PIT number; -x.xx soil depth (m). (base image - Google Earth, 2014)

Historical Landscape Evaluation

An examination of early site aerial photographs e.g. Figure 4 from 1947 shows that for at least 87 years the site has been substantially cleared of native vegetation; in fact there is much more residual forest on the site today than there was in that year - or even 1955 – 1978. Large parts of the site appear bare while that amount under direct paddock cultivation was very small. Waterways were largely devoid of trees but appear to have been wetter areas at the time (based on photographic contrast; earliest known rainfall data exists from 1959).

Figure 4. Extract of 1947 aerial photograph of the site
- original scale approx. 1:12000 (NSW Dept. for Lands image 2014)

What is clear in the 1947 photograph is, that hillside seepage associated with the upper remnant sandstone ridge forming the north and north-western and elevated boundary area of the site, has only a very modest diffuse seepage zone at the approximate basal geological boundary of the sandstone. In the northwestern most corner of the site, the extent of this seepage is the most pronounced. Instability, as earthflows and/or slumps, is already present on these hillsides.

Many of the dams now identified on the site (see Travers bushfire & ecology "watercourse assessment" report) were not present in 1947; e.g. Dams 7, 8, 10, 11; while Dams 2, 3, 4, 5 appear to be much smaller if indeed they all exist. This implies that the need for on-site farm water has increased with more recent farming practices, possibly supporting the idea of generally rapid site drainage with accompanying reduced soil water and retention except along drainage lines.

By 1961 (Figure 5) further dams had been built and Dams 2, 3, 4, 5, expanded to a size commensurate with what is seen today. The site appears less degraded at that time with more isolated tree plantings and clear definition of the instability in the elevated areas.

The Campbelltown District was extensively investigated by the Geological Survey of NSW during the late 1960s and early 1970s with a view to the development of the satellite City of Campbelltown. At that time, resources of value to the construction industry were identified as well as engineering geological matters relating to the development of the area. Careful attention was paid to slope instability and maps were prepared with the idea of informing zoning decisions for development (e.g. see Pogson and Chesnut, 1968); and these were subsequently acted upon. These matters are discussed in terms of landscape aspects later.

Pogson and Chesnut (1968) also recorded useful observations about the presence of groundwater in the geological sequence observed as follows:

Despite variations in grainsize the sandstones and shales both have low permeabilities and groundwater movement through the sequence is restricted. There does not appear to be evidence of either concentration of groundwater within the sandstones or of concentration along the shale/siltstone/sandstone interfaces. It is likely however that free groundwater sometimes occurs at the interface of unweathered and weathered material (i.e. at the base of the soil profile). Zones of disturbance have been noted at this point in the profile in road cuttings. Similar

(extracted from Pogson and Chesnut,1968)

Figure 5. Extract of 1961 aerial photograph of the site - original scale approx.1:13000. (NSW Dept. for Lands image, 2014)

These reported observations are relevant to the following discussion about the presence of groundwater on the site, as developed from the present investigations.

Groundwater Presence at this Site

It was a surprising that during the current investigation almost no groundwater was observed on site (see Appendix A - Pit Logs). That which was seen comprised the most minor and insignificant amounts of free moisture on bedding planes, generally in deeper, weathered bedrock – in Pits 5, 18, 19, and 23. This is despite a concerted effort being made to inspect locations such as drainage lines where groundwater would be preferentially located. For the geological environment and imposed landscape at this site – namely a well-weathered, residual landscape with some high-level earthflows developed on a low dipping well-bedded sedimentary rock sequence of laminites, siltstone, shale and lithic sandstone – it would be reasonably expected that:

1. groundwater, probably as perched watertables and inter-flow, would be seen at the bedrock-soil interface (a zone of transition in material structure);

2. spring systems or diffuse seeps would be present in the elevated areas adjacent to the highest ridgeline where more resistant strata (typically sandstone) overlies the argillaceous (clayey) rock sequence;

3. interflow along decaying and charcoaled tree roots within pits;

4. gully soaks or ephemeral seep areas in gullies/stream beds;

5. seeps associated with earthflow phenomena;

6. on earth and rock fracture planes in pits.

The Consultant is very familiar with investigations in the exact countryside represented by the site (through studies e.g. Dent 1973, and numerous consulting reports in private practice), but has not encountered this situation for groundwater before. This is considered to be a significant matter which requires consideration and explanation especially since it

affects future operations and design of the cemetery, and impacts on the answer required for the JRPP Condition1.

It is quite normal for a district-level watertable to be absent. In this site's hydrogeological setting a saturated zone will be observed at some considerable depth (possibly tens of metres), but a watertable is precluded from developing by the argillaceous nature of the sedimentary sequence which does not readily permit the infiltration of surface water, nor the percolation of groundwater. The expected groundwater presence would then be seen in terms of the phenomena 1,2,3,4 from the preceding list as a minimum; *at least in some* places/Pits on this large site.

The observations made might be accounted for by:

A. a longer term drought, either as sustained low amounts of rainfall and/or increased evaporation;

B. superb surface drainage;

C. good surface drainage and a lowly impermeable topsoil/pasture; this latter aspect may be due to compacted/untilled topsoils, or an excessive presence of clay particles or particular clay minerals;

D. the presence of deep rooting trees with excessive evapotranspiration habits;

E. extensive bush and tree plantings.

The site comprises degraded farmland with some remnant vegetation clusters, free-grazing cattle (soil trampers) and extensive invasion by large stands of African Olive trees; these trees are especially in the more elevated areas and on some gullies. It might be expected that cleared pasture land will permit more infiltration than the original forested landscape, but in this case - possibly not, because of the trampled clayey soils.

It was also observed that several gullies have had tanks (of various sizes) and/or nick points cut into their thalwegs – presumably with the intent of providing longer-term water storage from captured flow. Not all of these were documented during this investigation, and some were noted to not

be holding water, but Table 1 lists some of those observed. [In future investigations this inventory should be completed and analysed for any potential effects that might occur to overland flows.]

Table 1

Some tanks and scoured nick points in streams

Feature	Easting (MGA)	Northing (MGA)	Elevation (m)
excavated pit in stream	298728.483	6235595.312	74
excavated pit in stream	298759.155	6235587.088	72
dry scour in stream	298968.113	6235669.203	80
scour in stream	298984.315	6235689.52	82
scour in stream	298988.816	6235695.163	82
scour in stream	298890.771	6235568.806	74

Aspects of Drainage

In the report by Travers bushfire & ecology "Watercourse Assessment" (ref A13060W) the consultant refers to his field inspection of the site on 26 June 2013. In the report there are a number of photos of watercourses - #5 to 13 incl. where their captions refer to inspection being made "<12 hours after heavy rain", and that in these locations there is "no evidence of drainage".

According to the Mt Annan meteorological Station records (BoM, 2014) there had been substantial rainfall in the District immediately preceding the inspection: 24/6/13 – 27.2 mm, 25/6/13 – 11 mm, 26/6/13 – 39 mm (distribution throughout the day unknown). Images of other watercourses and dams on the site show runoff and pooling consistent with their landscape role.

These observations are important and supportive of the concept of considerable rapid drainage of the site's surface and reduced infiltration. For infiltration to be rapid enough to match the observations, the site soils

could not be composed of the clays and sandy clays that *are* present: a very deep porous soil (like variations of sand) would be required.

African Olive

The African Olive tree (various as: *Olea africana* and *Olea europaea ssp. cuspidata*) is widespread on the site; its presence is comprehensively discussed in Travers bushfire & ecology (2013). In that report, the African Olive is described as a very invasive, exotic weed that displaces native trees and vegetation because it very effectively competes for space and light. It is considered to be well established on the site and has brought about degradation of native vegetation communities and is present as its own – "Vegetation Community 3".

Some additional research for relevance has been undertaken. The plant is a well know pest in Australia and seems to be especially significant and aggressively established in the region including Camden and Campbelltown (Regional Weeds Advisory Committee, 2008). Knowledge of its growth habits primarily derives from the USA and is discussed by Connell & Catlin (2005). Of particular interest is the root system growth which is described in the following extract, and depicted in their diagram.

ROOT SYSTEMS AND COMPONENTS

Roots and root systems consist of a number of components. A framework consisting of relatively few large roots extends both laterally and vertically (fig. 7.1). From this root framework there are branching and rebranching laterals of decreasing diameter. This branched network terminates with the tips of recently formed fine roots. Root systems are shorter vertically and more spreading than the aboveground growth, a profile especially common in species that are adapted to arid or semiarid conditions. Olives are commonly planted on shallow soils, and roots are frequently restricted to the top 3 to 4 feet (0.9 to 1.2 m); even in deeper soils they tend to remain shallow rooted. As with other orchard species, olives generally have approximately 70 percent of their roots in the top 2 feet (0.6 m) of soil.

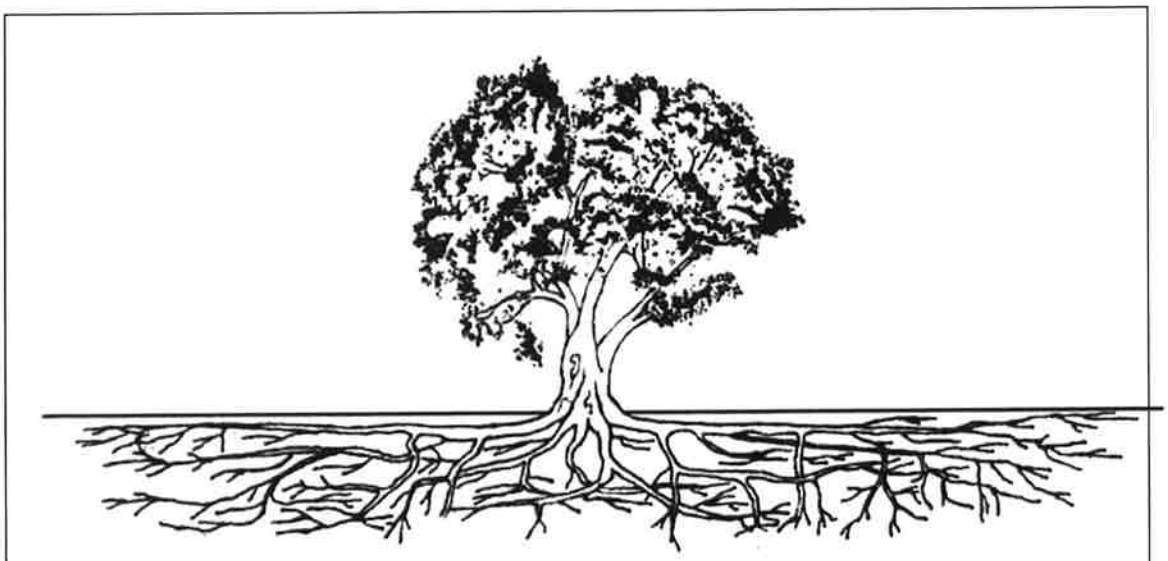


Figure 7.1. Form of root system expected for a mature olive tree.

Extracted from: Connell & Catlin 2005 (after Google Books)

As Spennemann (1998) points out, the root spread is up to 3 times the canopy spread and this facilitates the survival of this pest in arid and semi-arid areas, yet its root system is mostly within 1.2 m of the surface and concentrated within the top 0.6 m. In fact the tree is so adaptable to drought conditions and high temperatures, it has a natural longevity of 40 – 50 years (conservatively estimated) in all sorts of Australian environments (Hall et al., 1972).

This widespread tree/bush species is thus likely to be a significant agent to the consumption of groundwater in many parts of the site's soils; including the expected slope seepage in the elevated escarpment areas. When finally removed during site development, it could be reasonably expected that there will be associated changes in the soil moisture – and groundwater regime – present on much of the site. Extensive replanting with suitable native species (discussed elsewhere) will be a priority in order to try and maintain a semblance of existing conditions*: this replanting would have a substantially beneficial effect for the proposed cemetery operations. It is expected that the loss of this pest alone will lead to some wetting-up of some of the site's soils.*

Other Aspects

During cemetery operations the land will be considerably disturbed in several ways: primarily by the digging of graves, but also by the making

of road and paths, establishment of gardens and irrigation of lawns and gardens where used. Consequently, the compacted, degraded host farmland of the present will be transformed. These works and operations will encourage infiltration of the rainfall and irrigated waters into the soils which will considerably wet-up.

Consequently, a good attention to surface and sub-surface drainage, consistent with managing sloping, clay-based sites will be required as per standard construction techniques. The operation of graves as 'buckets' (discussed elsewhere), will also become an important consideration to be managed and has an impact on groundwater considerations – the primary matter of this report. *The effects of this phenomenon – full soil profile disturbance - on aspects of cemetery management at this site should not be underestimated.*

Rainfall

The district is unfortunately not well-served with official weather records. There are 3 stations registered by the Australian Bureau of Meteorology (BoM) which can be used to provide some insights for the site. These are listed in Table 2 and Figure 8.

Table 2

Weather Stations – Campbelltown District

Station#	Station Name	Latitude	Longitude	Elevation (m)	Approx. Distance to site (km)[1]	Records available Month/year
068081	Campbelltown Swimming Centre	34.08S	150.82E	75	8.42	10/1959 to 12/1984
068160	Kentlyn, Georges River Rd	34.05S	150.88E	115	7.10	6/1966 to present (missing 7/1988-11/2000)
068254	Mt Annan Botanical Garden	34.07S	150.77E	134	8.96	6/2005 to 9/2014

1. For this study, the site location is referenced by "Varroville House".

The records available are discontinuous from October 1959 until the present day and reflect places in similar, but different geographical settings up to 9km from the site … but still on the eastern side of the Nepean River and the Great Dividing Range.

Evaporation records are not available, however the BoM map indicates that the site lies in the zone of average annual pan evaporation of 1400 – 1600 mm in concert with most of the coastal strip of NSW (BoM 2006). This means that open water e.g. farm dams and bare land, are likely to experience significant losses: rainfall in warmer period is likely to be of limited helpfulness as infiltration and ultimately supplementation to groundwater.

The typical site rainfall pattern is likely to be represented by the Kentlyn records (Station# 068680) shown in Figure 6 extracted from BoM records. The winter period is noticeably drier on average – except that for August 2014 this was an exceptionally wet month. This significant increase in rainfall does not appear to have induced noticeable infiltration or aid percolation of groundwater at the site.

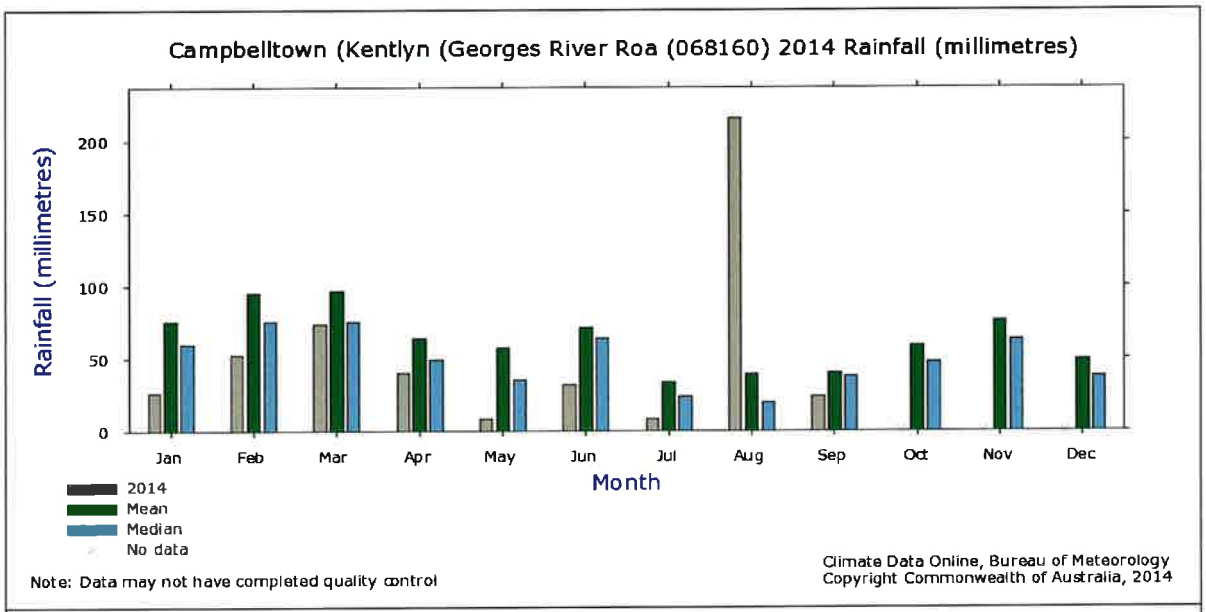


Figure 6. Summary rainfall data – Kentlyn Station (#068160) BoM for all records and 2014 to end September. ("Roa" = Road misspelt) All data is from June 1966 to Present (refer Table 2).

The available rainfall data for all Stations has been collated and presented in Figure 7 which shows the annual amounts and Stations' averages. The data has then been re-interpreted in terms of the residual rainfall mass (RRM) and subsequently graphed where applicable.

The RRM analysis is commonly used for understanding rainfall patterns as they relate to infiltration and groundwater response: notably whether the site is showing signs of increasingly wetting-up (*when the curve is rising*), drying (*when the curve is falling),* or maintaining a constant situation (*when the curve is approximately steady)*.

These analyses can be coupled with other available information – in this case – some historical aerial photographs; or ground observations. For example, the earlier aerial photographs of 1955, 1961 and 1975:-

* 1955 (Figure 8(a))

* 1961 (Figure 5) taken during a period of 'wetting-up' and the landscape looks well-vegetated and drainage lines show vegetation reflecting more moisture present; 1960 and 1961 had been years with average or better annual rainfall;

* 1975 (Figure 8(b)) similar to the above; wetting-up times, land well nourished with certain areas looking considerably moister and drainage lines well-delineated; 1975 and 1974 had been years with average or better annual rainfall.

Moving to the present, the rainfall patterns lately have been average or lower for a few years with the RRM steady to decreasing. The analysis can be coupled with the evidence of the present site investigation. Consequently, the outcome from this methodology is not particularly dramatic, however, the general idea encapsulated here is supportive of the existing soil profile showing no free moisture.

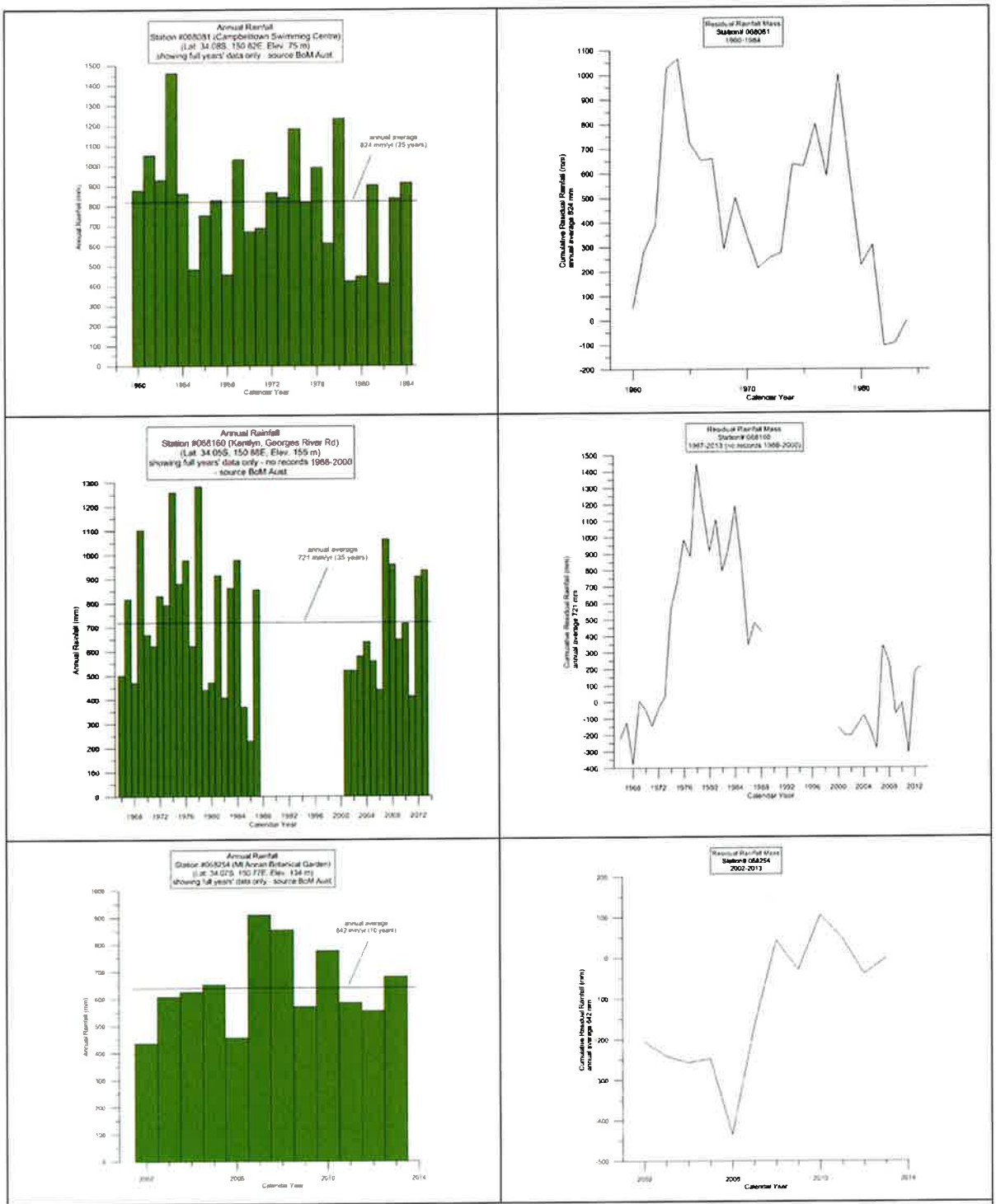


Figure 7. Rainfall data: left column yearly totals – all data 3 stations; right hand column plots of residual rainfall mass for these data

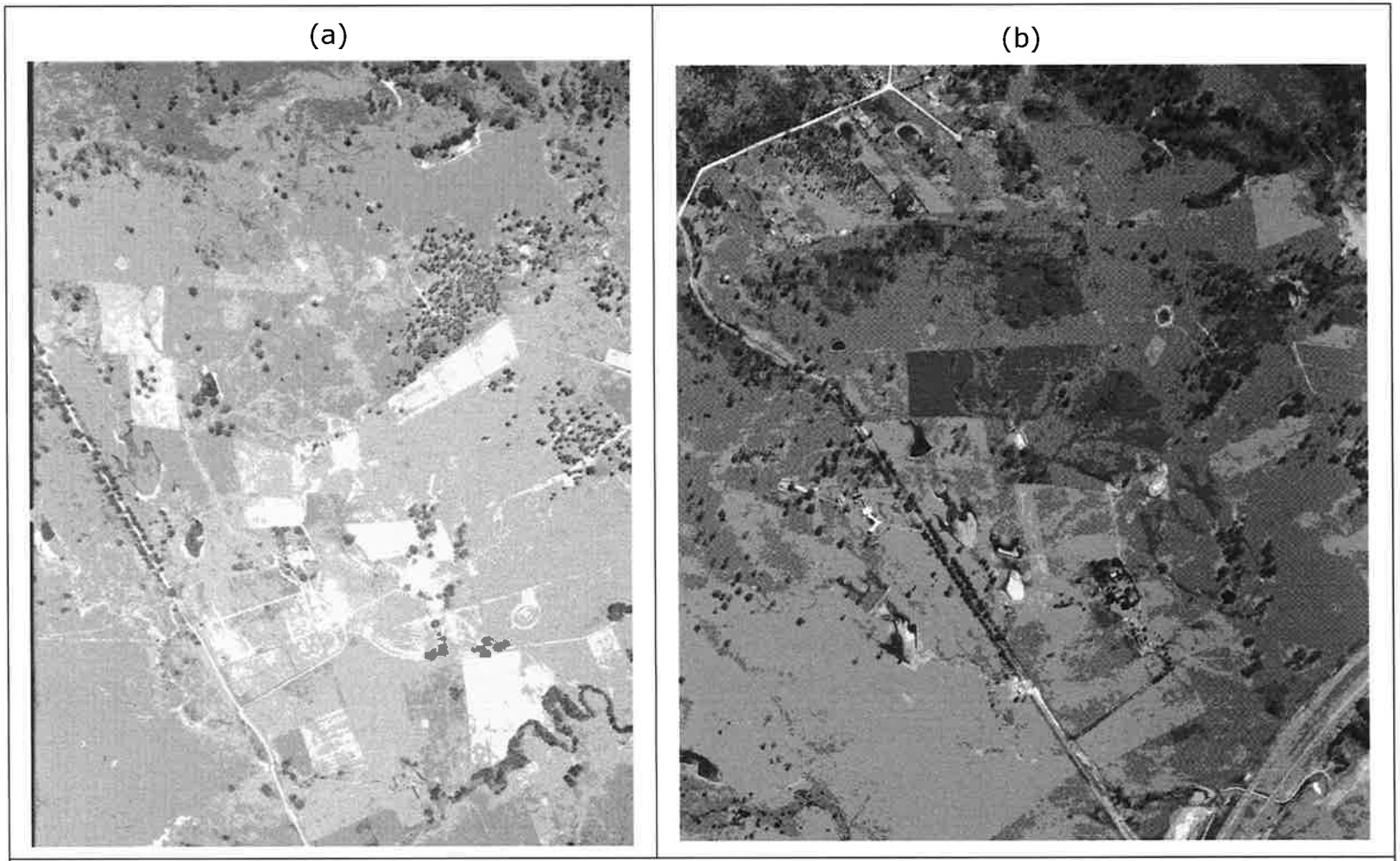


Figure 8. Extracts from District aerial photographs for dates of 1955 (a) - original scale 1:15360, and 30/11/1975 (b) - original scale 1:40000. (NSW Dept. of Lands image 2014)

Groundwater

The management of all groundwater in NSW is vested in the Office of Water. All groundwater (and surface water) systems are now subject to imposed conditions of a Water Sharing Plan established under the Water Management Act of 2000 and Regulations. The protection of groundwater is also controlled by the Environment Planning and Assessment Act of 1979 and the Contaminated Land Management Act 1997. Essentially there is a tranche of public policies and legislation which controls the use, taking and protection of groundwater, aquifer interference, surface runoff and stored waters. Specifically these instruments are aimed at preserving water supplies, ensuring water availability for the environment, ensuring adequate and sustainable supplies for agriculture and industries, as well as protecting environment and public health.

The site is subject to the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011. Within this, the site is subject to the rules for the Lower Georges River and Bunbury Curran Creek Management Zones 2011 (the site lies within the Georges River Catchment). Development of the site must accord with the general conditions of the Plan and regulations; however, there are no known or listed aquifer systems for the site and there are no additional special provisions for groundwater abstraction or usage at the site. Immediate drainage systems are not subject to any special flow management criteria. There is no municipal water source associated with the site.

Thirteen (13) registered groundwater works (bores) have been noted within approximately 2.5 km of the site's centre -Table 3. None of these bores occurs within the sub-catchment identified for the site. The closest ones GW104349 and GW109050 – at 1.2 and 1.5 km respectively, have yielded very small flows of saline water; the first from shale bedrock the other of unknown source (Dept. Water and Energy for NSW - Pinneena, 2009). From the limited data for all 13 bores, it is clear that some small quantities of artesian water have been tapped from sandstone underlying the shales from at least 50 m (GW106942) and 58 m (GW104349). This information reinforces the concepts of: no regional watertable, and the presence of a good aquiclude represented by the shale/argillaceous lithologies of the Wianamatta Group rocks.

Developments like that proposed need to be assessed for their likely impacts on potable groundwater supplies. This is not an issue for the site which is not prospective for groundwater supplies.

Table 3. Bore Census

Bores within approximately 2.5 km of the site centre

(extract from online records and *Pinneena*, NSW Office of Water 2014 and 2009)

Groundwater Works #	Easting (MGA)	Northing (MGA)	Date established	Completed depth (m)	SWL[1] (m–bgl)	Approx. yield (L/s)	EC[2] (µS/cm)	Approx. distance (km) from site and direction	Geology
GW035211	296393	6234071	01/09/1968	60.9	n/a[3]	n/a	n/a	2-2.3 SW	0-0.6 topsoil; 0.6-60.96 shale mostly black
Lat & Lon (degree)	34.01426S	150.79505E							
GW104349	300880	6235141	28/06/2002	60.5	1.3	3.4	6300	1.5 E	0-5 clay, 5-58 shale, 58-60.5 sandstone[4]
Lat & Lon (degree)	34.00544S	150.84385E							
GW109050	298451	6236794	15/07/2008	240	70	0.1	8300	1.2 NNW	n/a
Lat & Lon (degree)	33.99011S	150.81795E							
GW109180	296332	6234503	08/08/2008	264	80	0.161	2200	2-2.3 SW	n/a
Lat & Lon (degree)	34.01035	150.79449							
GW106942	301163	6236651	26/09/2003	263	28.0		"fresh"	1.9 NE	0-1 topsoil; 1-50 shale; 50-243 sandstone
Lat & Lon (degree)	33.9919S	150.8473E							

GW111675	435257	6314886	01/10/2011	84.0				1.8 NNE	0-84.0 shale
Lat & Lon (degree	33.3032S	146.3046E							
GW111676	300517	6237341	01/10/2001	150		0.05		1.8 NNE	0-91 shale; 91-150 sandstone
Lat & Lon (degree	33.9856S	150.8404E							
GW111677	300553	62373694	18/04/2012	300		0.40		1.8 NNE	0-89 shale; 89-96 sandstone; 96-300 sandstone/shale
Lat & Lon (degree	33.9854S	150.8408E							
GW111854	299116	6238256	24/2/2012	9.93				2.1 N	0-2.5 clay; 2.5-9.93 shale
	33.9771S	150.8255E							
GW112433	n/a	n/a	n/a	8.90				1.8 N	0-3.0 clay; 3.0-8.90 shale
GW113061	n/a	n/a	n/a	8.50				1.7 NNW	0-1 soil; 1-7 clay; 7-8.5 shale
GW113114	n/a	n/a	n/a	n/a				2.0 N	n/a

Notes:

1. m-bgl - metres to Standing Water Level below ground level when drilled
2. EC – electrical conductivity is a measure of salinity
3. n/a - information not available from Pinneena (NSW Dept. Wat. & Energy)
4. this bore probably located in shallow, recent alluvium at surface; yield from sandstone beneath shale

Description of Pre-Development Groundwater System

* No shallow permanent system; probable development of ephemeral and spatially variable systems at the soil/weathered rock transition zone; potential for small ephemeral perched watertables.

* No deeper aquifer systems recognised for the site or nearby; nearest likely fractured rock aquifer system probably associated with Hawkesbury Sandstone formation at depth.

* Factors affecting the nature of the shallow environment – dense sandy clay and clayey sand, and clay soils of 1.2 - 2.0 m thickness over variously weathered bedrock of argillaceous rocks – laminite, siltstone, claystone, shale; and lithic sandstone.

* Surficial zone with rapid runoff characteristics or high evapotranspiration characteristics depending on vegetation association.

* No groundwater dependent ecosystems (GDEs) present.

Description of Post-Development Groundwater System
(cemetery with interments in suitable locations to 1.8 - 2.0 m)

> Development of cemeteries takes time; they show spatial [3-dimensional] and temporal variation over a large area with a very small mass per disturbed volume (grave): indicative values for interred materials per allocated grave spaces are - 0.8% of volume by mass or about 5.4% of volume for volume (Dent, 2003).

* Graves are typically backfilled with the natural material excavated to form them. The volume of material increases ('bulks up') because it is disturbed and an excess results. The grave infill is less dense and looser than the originally excavated material so it preferentially favours water infiltration, even under grassy covering. In poorly drained soils, or under conditions of heavy surface water loads, the grave can work as a 'bucket'. Infiltrated groundwater mounds, albeit temporarily until is seeps away in the usual manner. The mounding can drive the shallow flow system and prolongs drying out of the grave base. Further seepage is preferentially horizontal rather than vertical. Seepage rates at grave invert level for properly located graves are very slow – typically measurable in parts of a

centimetre per annum (tenths of a metre per decade) away from edge of the grave excavation.

* Probable long term development of some shallow seepage systems with diffuse discharge due to the grave inverts being located high in the landscape and extra loadings of infiltrated water as a result of the development. Areas will be discontinuous. Seepage rates will be extremely low; typically less than tenths of a metre per decade.

* No change in percolation aspects for deeper fractured rock, any potential aquifer system; no GDEs.

* There is the likelihood of ephemeral perched watertables and interflow at the soil/weathered rock transition zone developing. Seepage rates will be low; the effect may be seen in nearby grave excavations. Evapotranspiration and 'phytoremediative' plantings will ensure consumption of much of this groundwater.

> Cemeteries of the modern era are not contaminated sites in the usual understanding of the term: they are *a special kind of landfill* (Dent and Knight 1998). The wastes interred are essentially organic in nature. In the general case the decay of the interred remains produces a necro-leachate which is slightly salty, contains nitrogen-based nutrients, organic acids and a microbial load reflective of the remains. The environmental conditions at the grave base are primarily anaerobic; this together with the adsorptive properties of the soil matrix discourages survival of many microbiological agents. The presence of substantial clay minerals (soils) assists in the retardation of particle and solute flow from the grave base and lower sides.

Nevertheless, there is a tendency in some investigative and regulatory domains to treat proposed cemeteries as being potentially contaminated sites; and existing cemeteries as contaminated sites. This is quite an erroneous concept given the nature of the necro-leachate and the way that decay in cemeteries actually works (see for instance Dent, 2003 and the works of numerous authors since). For example, there is no basis for comparison of cemeteries today to those of the US Civil War where the use of arsenic and mercury as embalming agents was widespread. For properly sited and managed cemeteries there is very little risk of contamination (Dent, 2003) - see also Appendix D.

The issue partly relates to definitions in the Contaminated Land Management Act 1997 (NSW) which indicate that any buried substance may be a potential contaminant (see Appendix C). Fortunately the same Act and other legislation allow for Site-Specific Assessment of risks where no formulaic approach is applicable; and methods of assessing the situation that might be more relevant can be introduced. This is considered to be the relevant approach for this site.

> *For the proposed site there is no recognisable groundwater system of concern which can be affected by the proposed operations. Accordingly, aspects of* contamination *in relation to groundwater would be appropriately considered from cemetery-specific guidelines developed by health agencies and other jurisdictions.*

The World Health Organisation (WHO)

The JRPP Conditon 1 specifically refers to accepted standards for burial plots such as by organisations like the WHO.

Unfortunately the WHO has no relevant guidelines as such and publishes only 4 documents that relate to the matter. Three of these documents rely heavily on the Consultant's research work to inform them, while the fourth is more generalised in its approach; they are discussed below.

1. Morgan (2004), wrote about infectious diseases from bodies following natural disasters. This work is widely referenced. His comments regarding burial and groundwater water refer to fine textured soils with a sand-clay mix being preferable, burials at least 30 m from springs or watercourses, 250 m from wells or any source of drinking water; however, states that "there are no accepted standards, and distances are best chosen based on local hydrogeological conditions" (Morgan 2004).

> *The site and development proposals comply with these ideas in every respect.*

2. Üçisik and Rushbrook (1998), discuss the impact of cemeteries on the environment and public health. Their work is usually referenced as an early summary of relevant comprehensive studies. They recommend draft conditions that mirror those of Morgan, but in addition suggest that burials should be 10 m from any field drain, and that burial pits must maintain 1 m of subsoil below the bottom of the burial and maintain a

minimum 1 m above the highest natural water table. They conclude that; "The pollution potential from cemeteries is present, but in a well managed cemetery with suitable soil conditions and drainage arrangements, the risk is probably slight" Üçisik and Rushbrook (1998).

The authors' conceptualisation concerning a 1 m freeboard of subsoil is really a mis-interpretation of the Consultant's recommendation that burials be not emplaced in bedrock and is only otherwise equal to the separation from the watertable. The idea of the freeboard is irrelevant in the absence of the watertable - such as at this site*; it is also specifically negated by the presence of lowly permeable clayey soils. However, the concept of not burying into bedrock pockets and thereby exacerbating the 'bucket effect' remains valid.*

3. Fisher and Reed (2013), "Disposal of Dead Bodies in Emergency Conditions" one of a number of documents in a series of Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies. This document draws heavily on the work by Morgan et al. (2006) which includes contributions by the Consultant. These documents provide generalised advice to cater for a wide range of possibilities, and discuss burials for varying multiples of deaths; but have generalised recommend disposal in a trench at least 200 m from any water source and at least 2 m above the water table.

The recommendations are not applicable to the site because it is designed for a different purpose and will be managed properly in all aspects. Furthermore a watertable is not present.

4. Taylor and Allen (2006) have written a chapter in a major WHO publication – "Protecting Groundwater for Health" edited by Schmoll et al. (2006). The considerations presented here are quite simplistic and largely limited to cross—referencing aspects of the previous publications. The authors do, however, in reinforcing the work of others, make the point that: "Animal and human remains, although not considered a waste product, represent a risk to local groundwater because of the proliferation of microorganisms that occurs during the process of corpse decomposition ...." (Taylor and Allen, 2006). They also concluded that "evidence obtained from emergency operations ..... dead bodies do not pose an appreciable risk for public health in areas where there are no endemic diseases ..." (Taylor and Allen, 2006).

The ideas revisited in this document support the preceding statements as to relevance for the Proponent's site.

In summary, the studies endorsed by WHO are not prescriptive for cemetery developments. However, they do recognise and advise on suitable protection for drinking water and groundwater resources. All the recommendations accord with best practice and design ideas to be implemented by the Proponents; see also Appendix D. Groundwater abstraction for consumption, hence groundwater resources, including for the environment, are not relevant matters of concern for the site.

The Environment Agency UK

Extensive work related to the design and citing of cemeteries with special reference to groundwater issues has been carried out by the Environment Agency of the United Kingdom (EA). The work has gone through a number of iterations and was commenced in about 1998 shortly after the Consultant commenced his initial cemetery-based studies which were also used to inform the EA's considerations.

The primary document referenced is: "Pollution Potential of Cemeteries R&D Technical Report P223" (Young et al. updated 2014). This work is widely referred to by others and has been used as the basis of further policy and guideline development in other jurisdictions (which is further discussed later). The studies arose in response to European Union Groundwater Directive (80/86/EEC) concerning the protection of groundwater, and are heavily orientated towards UK experience and practice.

The Guidelines set out proposals for developing a risk assessment of a site based on the vulnerability of groundwater to pollution. This vulnerability depends on matters like the presence of an aquifer, potential pathways for necro-leachate mobilisation, attenuation factors of the natural setting, burial practices and so on. The document provides a suitable example description of vulnerability assessment:

> "For example, a site located directly on a Major Aquifer, with an unsaturated zone of less than 5 metres, could be considered highly vulnerable, whereas a site on a Non-Aquifer, with no superficial deposits, would represent a low vulnerability class."
>
> (Young et al., 2014, p34)

The proposed site accords directly with the description for a low vulnerability class.

In such a case – for 'Low risk' sites, the following statements are brought to bear:

> "Where it is evident from Stages 1 and 2 that the risks of development are likely to be low, then the proposal should be accepted without the need for a more detailed assessment. It may be necessary to request compliance with industry best practice, possibly through the use of Planning Conditions, for example -" No burials within 10 metres of any field drain"."
>
> (Young et al., 2014, p36)

A relevant example is developed and overall guidelines presented:

> "The second proposal is for a low input site on a clay subsoil. Because of the low permeability of the soil, an open grave may collect water during times of heavy rain. However, the water trapped in the hole does not connect with any groundwater body from which a supply may be taken, and a Planning Condition to the effect that any accumulated water should be pumped from a grave before the burial takes place, would provide adequate environmental protection.
>
> In summary, for a site assessed as low risk the appropriate operational safeguards are:
>
> - No burials within Protection Zone 1 around a spring, well or borehole;
> - Minimum distance from grave(s) to well, borehole or spring used for water supply - 250 metres.
> - Minimum distance from grave(s) to other springs or watercourses - 30 metres;
> - Minimum distance from grave(s) to a field drain - 10 metres;
> - No burial into standing water, base of grave to be above local water table.
>
> In certain situations, for example where a thick unsaturated zone with good attenuating properties is known to be present, local knowledge may allow some relaxation of the minimum distance from a water supply source, without an automatic need to move to a complete intermediate risk assessment."
>
> (Young et al., 2014, pp36 and 38)

The above situation mirrors the proposed site and all conditions specified would be met by the site and its subsequent operations.

Scotland and Northern Ireland

In Scotland and Northern Ireland the EA's Guidelines have been adapted to reflect local geological conditions, for example karst landscapes in Ireland and glacial drifts or moraine deposits in Scotland.

The Scottish Environment Protection Agency (SEPA) has developed Environmental Policy Number 19 in respect of groundwater protection (SEPA, 2009). In Section J they have developed generalised guidance for cemetery development – extracted below.

J2.3 **SEPA recognises that the burial of corpses is an activity which may lead to the input of polluting substances into groundwater. In the event of a clear and serious risk to groundwater being identified as a result of burial at a cemetery or private burial ground, SEPA will prevent or control the activity using it's powers of enforcement under regulation 28 of the Water Environment (Controlled Activities) (Scotland) Regulations 2005 (as amended).**

J2.4 **SEPA recommends that bodies should not be buried:**

- **Within 250 metres of any spring, well or borehole used as a source of drinking water;**
- **Within 50 metres of any other spring, well or borehole;**
- **Within 50 metres of any watercourse;**
- **Within 10 metres of any field drain.**

J2.5 **In respect of the burial sites SEPA recommends:**

- **There should be no standing water in the bottom of the burial pit when first dug (this assessment should not be carried out when raining);**
- **There should be no sand or gravel at the bottom of the burial pit;**
- **There should be at least one metre of subsoil below the bottom of the burial pit;**
- **The burial pit should be deep enough to give at least one metre of covering soil.**

(extracted from SEPA, 2009)

The SEPA notes also make mention of the potential development of cemeteries on lands previously drained for agricultural use, and the vulnerability of such drains in providing pathways for pollutant transport. This situation does not apply on the proposed site.

The SEPA policy accords with the EA Guidelines except in the reference to a freeboard of subsoil below grave invert as discussed in the WHO documents. The reason for this recommendation is not clear; however, it is not relevant for the propose site. Otherwise, all conditions specified would be met by the site and its subsequent operations.

The Northern Ireland Environment Agency (NIEA) has developed Guidance Notes in respect of cemeteries and the water environment (NIEA, 2009). The following extracts from their Guidance Notes indicate the concerns to be addressed.

Risk Assessment

The final risk assessment will be based upon data and knowledge gained from the desktop assessment and the intrusive site investigation. The scope of the risk assessment required will be dependent on site specific factors such as the local vulnerability of groundwater and the scale of the site proposed.

Guidelines for planning cemeteries

Once you have gathered all the information above, this will allow you to start planning the layout of the proposed burial site. The following should be taken into consideration when doing this:

- Burial plots should be at least 250 m away from a borehole, spring or well used for the supply of drinking water and/or bottling of mineral water.
- Burial plots should be at least 50 m away from all other boreholes, springs or wells.
- Burial plots should be at least 50 m away from a river, canal, lake, wetland or the coast.
- Burial plots should be at least 10 m away from field drains (this also includes old agricultural drainage systems no longer in use as they can act as preferential pathways).
- If bedrock is encountered in the trial pit, that area of the site should not be used for burials
- The area of the site is not suitable for burial if there is standing water at the bottom of the burial pit when first dug.

(extracted from NIEA, 2009)

The indicative Guidelines mirror those of SEPA, and once again reflect the mis-understanding of freeboard subsoils; but in other respects would be met by the development as proposed.

South Africa

In South Africa the Department of Water Affairs and Forestry (DWAF) have prepared Guidelines for a number of situations in respect of

protecting groundwater from contamination. The Guidelines are somewhat simplistic and are primarily focused on the need to protect all drinking water supplies – surface- or ground- waters. The context of the development of the Guidelines is explained thus:

> Groundwater has historically been given limited attention, and is not perceived as an important water resource, in South Africa. This is reflected in statistics showing that only 13 % of the nation's total water supply originate from groundwater. Because of the highly distributed nature of the water demand in rural and informal peri-urban settlements, regional schemes are, in most instances, not economically feasible. And because of decreasing available river and spring flows during low flow and drought periods, as well as wide-spread problems of surface water pollution in rural areas, groundwater will be the most feasible option for a large part of the new water demand.

(extracted from DWAT, 2004)

The relevant section for cemeteries is extracted below.

Guidelines

When selecting a site for a cemetery or animal burial ground:

- Choose an area with deep, low permeability soils.
- Ensure that seepage from decaying corpses will not enter the water table directly.

Avoid areas:

- That contain open surface water.
- Where shallow or emergent groundwater exists (albeit seasonally).
- That are located up slope, close to a water source.
- In or adjacent to recharge areas for important aquifers.
- In dips or hollows where surface water could collect or stormwater flows could occur.
- Below the 1-in-50 year floodline of a river.
- Close to wetlands, vleis, pans, estuaries and floodplains.
- That are unstable, such as fault zones, seismic zones, dolomitic or karst areas where subsidence and / or sinkholes are likely to occur.
- With shallow soils over bedrock or with exposed bedrock.
- With coarse sands or gravel.
- Where soil collapsing and sliding could occur, such as steep embankments and steep slopes where soil overlies sloping impermeable bedrock.
- In or near sensitive ecological areas.

(extracted from DWAF, 2004)

These Guidelines don't further inform the considerations for the proposed site save that they reinforce the concepts of burial in lowly permeable soils and insurance that necro-leachate will not directly access the watertable. Once again these are conditions easily met by the proposed site.

Conclusion

A comprehensive desk-top evaluation, site inspection and shallow sub-surface investigation has been undertaken for the proposed cemetery development at Varroville. This has been an extended preliminary study with a particular focus on groundwater issues. In addition, a response to requirements of the JRPP Condition 1 has been expounded.

The proposed site is very large, about 113 ha, and hosts 3 different landscape provinces with some notably different characteristics which will influence site development and which are also intimately tied to historic aspects also considered in the site development. The Proponent's development plans and proposals for land rezoning and planning approval are dealt with in extensive other documentation; but this report should be viewed in support of that application.

The site's primarily proposed burial areas comprise an undulating residual landscape with rounded slopes and spurs developed on the Bringelly Shale formation of the Wianamatta Group. This is a sedimentary rock sequence which has exhibited a very great variability of lithologies on the site. The bedrocks are argillaceous in nature, naturally hosting a variety of clay minerals. Upon weathering, the bedrock has typically developed moderately deep clay rich soils which have a very low permeability. The depths of soils and nature of the soil profiles are however, vastly variable across the site; especially where related to lithic sandstone bedrock and this will influence some proposed development.

The site is subject to the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011, which permits regulation of all surface- and ground- water present. During the investigation it was noted that there was an unexpected absence of free groundwater throughout the site, even in locations where it would normally be expected (e.g. larger drainage lines). This absence has been explained by an unusual combination of surface drainage characteristics, the heavy clayey soils, high evapotranspiration characteristics and prevailing weather conditions.

The site does not host a permanent watertable and will at best show variable, discontinuous, ephemeral and perched watertables from time to time; most likely in the upper weathered bedrock. Some inter-flow at the soil-weathered rock boundary might be expected if parts of the site wet-up. The soils and bedrock are universally lowly permeable and any groundwater movement will be exceeding slow, of the order of parts of a centimetre per year on average.

There is no groundwater resource present or related to the site. There is no recognised underlying aquifer system and no groundwater abstraction sites on or near the site; there are none in the sub-catchments developed on site.

The proposed cemetery development will have a negligible effect on the natural groundwater aspects. The pathways available for movement of any pollutant (including pathogen) load from decomposing bodies are extremely limited, and comprised of a soil matrix which will rapidly attenuate them.

The site has been generally evaluated in terms of published Guidelines from various World-wide jurisdictions in respect of its potential effect on groundwater. In particular, any guidance provided by WHO has been examined in detail: however, it is the Guidance of the Environment Agency UK that is considered to be the most relevant. In every respect the site would meet any concerns in those Guidelines.

There is a minor issue, often repeated, in respect of a freeboard of subsoil beneath the grave invert. This is considered to derive from the need for a 'catch-all' requirement where unspecified soil types are involved in the cemetery planning. It is also a mis-interpretation of the otherwise clear concept of separating grave inverts from any watertable. The clayey soils of the site would in all case obviate the need for further consideration of this issue; however the concept of burying directly into bedrock is valid.

The site represents a very suitable situation for the development of a large cemetery complex.

*

References

Australian Bureau of Meteorology (BoM), 2014, Monthly Climate Statistics for various climate stations, from website –

http://www.bom.gov.au/climate/data/stations/

and evaporation specific data (2006), from website -

http://www.bom.gov.au/jsp/ncc/climate_averages/evaporation/index.jsp

Connell, J.H. & Catlin, P.B., (2005) Root physiology and rootstock characteristics, In, Ferguson, L & Sibbert, G.S. (eds) 2nd Ed, Olive Production Manual, University of California, Agriculture and Natural Resources Publication 3353, from p 39

Dent, B.B., 1973, The engineering geology of the The Oaks – Picton District, N.S.W., B.Sc. thesis, Univ. N.S.W., unpub.

Dent, B.B., 2003, The Hydrogeological Context of Cemetery Operations and Planning in Australia, PhD thesis, University of Technology, Sydney; (pub. Online through Aust. library thesis system, and in various extracts and referred papers and articles)

Dent, B.B. and Knight, M.J.K., 1998, Cemeteries: A Special Kind of Landfill. The context of their sustainable management, Groundwater: Sustainable Solutions, International Groundwater Conference, IAH, Melbourne Feb., 451-456

Department of Water Affairs and Forestry (DWAT) Republic of South Africa, 2004, Guidelines on Protecting Groundwater from Contamination

Department of Water and Energy for NSW, [now NSW Office of Water], 2009, Pinneena GW 3.0 (historic groundwater data on DVD)

Environment and Heritage (NSW Govt. Dept.), 2014, online interactive map at http://www.environment.nsw.gov.au/eSpadeWebapp/

Fisher, J. and Reed, B., 2013, Disposal of Dead Bodies in Emergency Conditions, (WHO_TN_08_Disposal_of_dead_bodies.pdf) from www.who.int/water_sanitation_health

Geological Survey of NSW, 1985, Geological Series Sheet 9029-9129 (Ed. 1) Wollongong-Port Hacking, NSW Dept. Mineral Resources

Google Earth, 2014, aerial image extracted from internet-based geospatial software

Hall, N., Boden, R., Christian, C.S., Condon, R., Dale, F., Hart, A., Leigh, J., Marshall, J., McArthur, A., Russell, V. and Turnbull, J., 1972, The Use of Trees and Shrubs in the Dry Country of Australia, Aust. Govt. Publishing Service, Canberra

Hazelton, P.A. and Tillie, P.J., 1990, Soil Landscapes of the Wollongong-Port Hacking 1:100000 Sheet, Soil Conservation Service of NSW, 150pp

Leonard, M., Burbidge, D. and Edwards, M., 2013. Atlas of Seismic Hazard Maps of Australia, Record 2013/041, Geoscience Australia, Canberra.

Morgan, O., 2004, Infectious disease risks form dead bodies following natural disasters, Pan Am. J. Pub. Health 15 (5), 307-312

Morgan, O., Morris, T.B. and Van Alphen, D. (ed.), 2006, Management of Dead Bodies after Disasters: A Field Manual for First Responders, Pan American Health Organisation, USA; available at http://www.paho.org/english/dd/ped/DeadBodiesFieldManual.pdf

Northern Ireland Environment Agency (NIEA), 2009, Cemeteries, Burials & The Water Environment, Guidance Notes; www.ni-environment.gov.uk

Pogson, D.J. and Chesnut, W.S., 1968, Preliminary geological investigation of land instability in the Municipality of Campbelltown, Rept. Geol. Surv. N.S.W., G.S. 1968/103 unpub.

Regional Weeds Advisory Committee, 2008, Regional Weed Management Plan: African Olive Management Plan for the Sydney Region, NSW Dept. Primary Industries, 11pp

Scottish Environment Protection Agency (SEPA), 2009, Groundwater Protection policy for Scotland v3, Environmental policy Number 19, 57pp

SMEC Testing Services Pty Ltd, 2008, Geotechnical Assessment South West Business Park for Cornish group Pty Limited C/- Lean & Hayward Pty Limited, Rept. No. 08/1633, 10pp

Spennemann, D.H.R., 1998, The Spread of Olives on Wagga Wagga Campus – Heritage and Eradication Options, The Johnstone Centre Rept. No 120, Charles Sturt University, 30pp

Taylor, R. and Allen, A., 2006, Waste disposal and landfill: Potential hazards and information needs, *in*, Schmoll, O., Howard, G., Chilton, J. and Chorus, I. (Eds), Protecting Groundwater for Health; Managing the quality of Drinking-water sources, WHO

Travers bushfire & ecology, 2013, Ecological Constraints Assessment, File No A13060F, 77pp – presented as Appendix C in the Proponent's submissions

Urbis Pty. Ltd., 2013, Macarthur Memorial Park, Planning Proposal, 166-176 St Andrews Road, Varroville, Rept. No. SA5073-Final Report, 48pp

Üçisik, A. S. and Rushbrook, P., 1998, The Impacts of Cemeteries on the Environment and Public Health, An Introductory Briefing, EUR/HFA target 23, WHO Regional Office for Europe

Young, C. P., Blackmore, K.M., Reynolds, P. and Leavens, A., 2014, Pollution Potential of Cemeteries, Draft Guidance, Environment Agency, R&D Technical Report P223, 71pp

*

Appendix A

Pit logs

RED EARTH GEOSCIENCES - PIT LOG

LIST OF ABBREVIATIONS AND ACRONYMS

abbreviation	description
br	brown
deg	degrees
diam; Ø	diameter
dk	dark
Fe	iron; probably as iron oxide and/or hydroxy- concretions or ironstone gravel or pisoliths; also used with staining
lt	light (colour)
Mn	manganese (black oxide mineral form, usually as veinlets or dendrites)
mod	moderately
mot	mottled, mottles, mottling
occ	occasional, occasionally
slts	siltstone
ss	sandstone
yell	yellow
SW, MW, HW, EW	weathering grades in engineering geology – Slightly Weathered; Moderately Weathered; Highly Weathered; Extremely Weathered

MEANING OF TERMS

complete	Pit excavation ended at this level; does not imply that excavation beyond this point was impossible with the equipment used; usually means that an intact bedrock has been reached
damp	Damp soils are not fully saturated but they are not dry; particles may clump together, but soil probably can't be shaped (cf moist)
gravel	Gravel is a particle size larger than coarse sand; descriptions of lithology are not always included; gravel may derive from colluvium, alluvium or weathered bedrock (in residual settings); gravelly pieces may be iron-impregnated
moist	Moist soils have a large amount of moisture bonded to the particles; the particles/matrix clump/s together and can usually be shaped; there is no free moisture

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No 1**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** S34.00088	**Longitude (WGS-84) (hD.d):** E150.81858	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298534.289	
Logged: BBD	**Strike of PIT (deg):** 045M	**Northing (MGA):** 6235601.164	
Approx surface dimensions (m): 2.30 x 0.8	**Maximum depth (m):** 2.53	**elevation (m) (AHD):** 53	
Approx site slope (deg): 6.5	**Weather – and/or Adverse conditions:** fine, sunny ~ 21deg, strong breeze		

DESCRIPTION	SAMPLES (all)
0 - 0.3 lt brown, silty topsoil 0.3 - 1.1 moist, stiff, red-br, sandy clay 1.1 - 2.1 moist, stiff, red-br, some yell-grey mottling, clay; rootlets to 1.4 2.1 - 2.5 dry, stiff, grey, clay 2.5 - 2.53 complete in HW, dark grey with yell-br mottling, shale	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated:	1 Oct 2014	**PROJECT No 1403**		**PIT No**	**2**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**			
Position method:	GPS handheld	**Latitude (WGS-84) (hD.d):** S33.99873		**Longitude (WGS-84) (hD.d):** E150.81862	
Method and orientation:	Backhoe with 750 mm wide bucket; parallel to contour			**Easting (MGA):**	298532.905
Logged:	BBD	**Strike of PIT (deg):**	059M	**Northing (MGA):**	6235839.696
Approx surface dimensions (m):	2.0x0.9	**Maximum depth (m):**	1.55	**elevation (m) (AHD):**	90
Approx site slope (deg):	6	**Weather – and/or Adverse conditions:**	Fine, sunny ~ 21deg, strong breeze		

DESCRIPTION	SAMPLES (all)
0 - 0.25 dry, brown, sandy clay topsoil 0.2 - 0.4 red-br, occ. Fe gravel, silty clay 0.4 - 1.05 moist, mod stiff, red-br & yell-br mottled clay 1.05 - 1.3 dry, yell-grey, sandy clay 1.3 - 1.55 complete in MW iron-rich, grey, siltstone; possibly minor sandy lenses; plant fossils Very hard digging, surprisingly dry, locate on spur	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No 3**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** S33.99870	**Longitude (WGS-84) (hD.d):** E150.81800	
Method and orientation: Backhoe with 750 mm wide bucket; perpendicular to contour		**Easting (MGA):** 298475.562	
Logged: BBD	**Strike of PIT (deg):** 157M	**Northing (MGA):** 6235841.803	
Approx surface dimensions (m): 1.7x0.75	**Maximum depth (m):** 1.95	**elevation (m) (AHD):** 87	
Approx site slope (deg): 13-14	**Weather – and/or Adverse conditions:** Fine, warm, strong breeze		

DESCRIPTION	SAMPLES (all)
0 - 0.75 dk br, sandy clay and clayey sand topsoil; minor gravel; A horizon – mixed; likely incorporates about 0.3 m thick zone of slide debris 0.75 - 1.25 very moist, yell-br sandy clay with minor Fe/shale sand; minor charcoal roots 1.25 - 1.57 moist, mod stiff, beige & yell-br, sandy clay 1.57 - 1.85 moist, br br-black & red-br mottled, sandy clay 1.85 - 1.95 complete in hard, dk br, sandy siltstone Surficial instability present	nil

GROUNDWATER CONDITIONS

Excavated into slump area looking for groundwater; none seen, but noticeably moister

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No 4**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** S33.99954	**Longitude (WGS-84) (hD.d):** 150.81906	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298575	
Logged: BBD	**Strike of PIT (deg):** 069	**Northing (MGA):** 6235750	
Approx surface dimensions (m): 2.2x0.98	**Maximum depth (m):** 1.6	**elevation (m) (AHD):** 79	
Approx site slope (deg):	**Weather – and/or Adverse conditions:** Fine, warm, strong breeze		

DESCRIPTION	SAMPLES (all)
0 - 0.55 dry, dk br silty topsoil, with variable transition to: 0.55 -0.8 mod stiff, red-br clay; rootlets to 0.7 0.8 – 1.0 moist, red-br and yell-br mottled sandy clay 1.0 -1.12 stiff, red-br and grey clay 1.12 – 1.32 dry, br gravelly sandy clay; pieces of broken bedrock 1.32 – 1.55 dry, stiff, mottled red-br and grey clay 1.55 -1.6 complete in very hard grey sandy siltstone (difficult excavation) Minor gravel in lenses throughout profile; horizon transitions variable	nil

GROUNDWATER CONDITIONS

No free groundwater

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No** 5
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00016		**Longitude (WGS-84) (hD.d):** 150.81902
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour			**Easting (MGA):** 298573
Logged: BBD	**Strike of PIT (deg):**		**Northing (MGA):** 6235681
Approx surface dimensions (m): 2.3x0.95	**Maximum depth (m):** 2.1		**elevation (m) (AHD):** 79
Approx site slope (deg): 6 (2 long)	**Weather – and/or Adverse conditions:** Fine, warm, strong breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.4 dk br clayey sand and sandy clay topsoil, irregular horizon boundary 0.4 – 0.65 variable, red-br, br, yell-br clay and sandy clay 0.65 – 1.05 moist, mot dk red-br clay 1.05 – 1.55 moist, grey and lt grey with yell-br and red-br mot sandy clay with broken weathered bedrock (MW-HW sandy siltstone with minor free water on bedding) 1.55 – 1.8 dry, hard, dk grey MW siltstone with carbonaceous pieces. (Dry layer of weathered bedrock) Continued excavation: 1.8 – 2.1 complete in damp, soft grey claystone with iron staining and accumulations	nil

GROUNDWATER CONDITIONS

Minor free moisture on weathered bedrock pieces

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No** 6
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00183	**Longitude (WGS-84) (hD.d):** 150.81989	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298657	
Logged: BBD	**Strike of PIT (deg):** 153	**Northing (MGA):** 6235498	
Approx surface dimensions (m): 2..3x0.8	**Maximum depth (m):** 2.13	**elevation (m) (AHD):** 74	
Approx site slope (deg): 4	**Weather – and/or Adverse conditions:** Fine, warm		

DESCRIPTION	SAMPLES (all)
0 – 0.38 lt br, red-br and lt grey mixed sandy topsoil and sandy clay 0.38 – 0.91 mixed horizon of red-br sandy clay, blocky, isolated gravel pieces; rootlets to 0.52 0.91 – 1.13 dry, mot red-br and grey-br gravelly sandy clay 1.13 – 1.63 stiff, lt grey and yell-grey sandy clay 1.63 – 1.93 mot dk red-br, yell-br and grey-br HW siltstone with gravel pieces 1.93 – 2.13 complete in soft, grey SW siltstone	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No 7**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00251	**Longitude (WGS-84) (hD.d):** 150.81989	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298659	
Logged: BBD	**Strike of PIT (deg):** 066	**Northing (MGA):** 6235422	
Approx surface dimensions (m): 2.35x0.85	**Maximum depth (m):** 2.6	**elevation (m) (AHD):** 69	
Approx site slope (deg):	**Weather - and/or Adverse conditions:** Fine, warm		

DESCRIPTION	SAMPLES (all)
0 – 0.62 mixed, yell-br to lt br, sandy clay and clayey sand topsoil 0.62 – 1.34 moist, stiff yell-grey clay with minor Fe gravel 1.34 – 1.95 moist, mod stiff, red-br sandy clay with minor gravel 1.95 – 2.2 moist, mod stiff, dk yell to mid grey mot, sandy clay 2.2 – 2.6 complete in moist, lt grey with yell-br mot, HW siltstone/laminite with pieces of angular sandstone to 70 mm diam (below change of slope leading to watercourse with dam)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No 8**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00115	**Longitude (WGS-84) (hD.d):** 150.82069	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298729	
Logged: BBD (logged from surface)	**Strike of PIT (deg):** 142	**Northing (MGA):** 6235575	
Approx surface dimensions (m): 2.35x0.8	**Maximum depth (m):** 2.65	**elevation (m) (AHD):** 72	
Approx site slope (deg): 3	**Weather – and/or Adverse conditions:** Fine, warm		

DESCRIPTION	**SAMPLES (all)**
0 – 0.25 br sandy topsoil 0.25 – 2.35 moist, red-br sandy clay; highly consistent; minor Fe pisoliths to 3mm Ø 2.35 - 2.65 complete in damp, soft, crumbly red-br and black (Mn veinlets) and calcite blebs silty sandstone Remarkably different soil not seen elsewhere on site; extremely consistent horizon – reminiscent of weathered dyke material; possible sill or intrusive structure. Pit not entered for logging.	nil

GROUNDWATER CONDITIONS

No free water seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No 9**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 33.99965	**Longitude (WGS-84) (hD.d):** 150.82080	
Method and orientation: Backhoe with 750 mm wide bucket; perpendicular to contour		**Easting (MGA):** 298736	
Logged: BBD	**Strike of PIT (deg):** 098	**Northing (MGA):** 6235741	
Approx surface dimensions (m): 2.4x0.8	**Maximum depth (m):** 1.55	**elevation (m) (AHD):** 81	
Approx site slope (deg): 4	**Weather – and/or Adverse conditions:** Fine, warm		

DESCRIPTION	SAMPLES (all)
0 – 0.25 dk br silty clay topsoil 0.25 – 0.8 moist, mod stiff, yell-br occ red-br mot, sandy clay 0.8 – 0.95 stiff, red-br clay; rootlets to 0.9 0.95 – 1.5 red-br and grey mot, sandy clay with slts gravel 1.5 – 1.55 complete in dry, grey occ red-br mot, HW siltstone	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 1 Oct 2014	**PROJECT No 1403**		**PIT No 10**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 33.99890	**Longitude (WGS-84) (hD.d):** 150.82064	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298719	
Logged: BBD logged from surface	**Strike of PIT (deg):** 102	**Northing (MGA):** 6235824	
Approx surface dimensions (m): 2.2x0.8	**Maximum depth (m):** 2.25	**elevation (m) (AHD):** 83	
Approx site slope (deg): 13.5	**Weather – and/or Adverse conditions:** Fine, warm		

DESCRIPTION	SAMPLES (all)
0 - 0.6 moist, br and dk br sandy clay and silty clay topsoil (very moist in top 0.3m) 0.6 -1.4 damp, red-br and br sandy clay 1.4 – 2.2 moist, stiff, red-br clay and sandy clay 2.2 - 2.25 complete in moist, HW lt grey, occ red-br mot, siltstone; rootlets to 2.25m (logged from surface; at toe of landslip)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 11**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 33.99952	**Longitude (WGS-84) (hD.d):** 150.82201	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298847	
Logged: BBD	**Strike of PIT (deg):** 086	**Northing (MGA):** 6235758	
Approx surface dimensions (m): 3.3x0.8	**Maximum depth (m):** 2.15	**elevation (m) (AHD):** 84	
Approx site slope (deg):	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	**SAMPLES (all)**
0 – 0.45 dry, sandy and silty topsoil, uneven horizon thickness 0.45 – 1.1 variable horizon, blocky in parts, mot red-br sandy clay and br clayey sand 1.1 – 1.5 moist, stiff, red-br clay 1.5 - 2.0 grey with red-br mot, sandy clay 2.0 – 2.15 complete in dry, hard grey shale with sandy facies (laminite)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

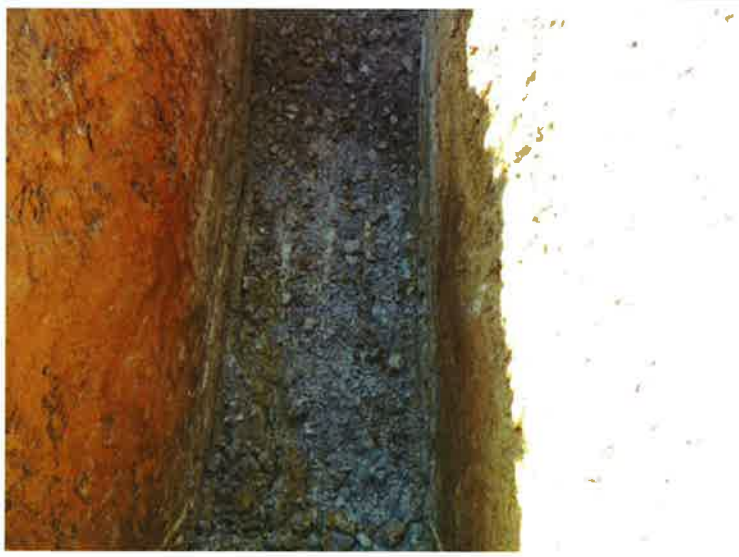
RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 12**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00149	**Longitude (WGS-84) (hD.d):** 150.82252	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298899	
Logged: BBD	**Strike of PIT (deg):** 124	**Northing (MGA):** 6235541	
Approx surface dimensions (m): 2.3x0.8	**Maximum depth (m):** 1.6	**elevation (m) (AHD):** 75	
Approx site slope (deg): 3	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.3 variable, br sandy and clayey topsoil, irregular horizon boundary 0.3 – 0.8 moist, mod stiff, red-br and br sandy clay 0.8 – 1.05 moist, stiff red-br clay and sandy clay; rootlets to 1.0 1.05 – 1.3 red-br, yell-br and grey mot sandy clay 1.3 – 1.5 moist, yell-br with grey mot gravelly sandy clay 1.5 – 1.6 complete in HW grey siltstone with sandy lenses and some yell-br mot; moister and softer in parts (laminite)	nil

GROUNDWATER CONDITIONS

None seen



COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 13**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00038	**Longitude (WGS-84) (hD.d):** 150.82301	
Method and orientation: Backhoe with 750 mm wide bucket; perpendicular to contour		**Easting (MGA):** 298942	
Logged: BBD partially logged from surface	**Strike of PIT (deg):** 043	**Northing (MGA):** 6235665	
Approx surface dimensions (m): 2.4x0.76	**Maximum depth (m):** 3.1	**elevation (m) (AHD):** 81	
Approx site slope (deg): 3.25	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.2 approx – br topsoil 0.2 – 2.5 very uniform, moist, generally stiff, red-br and dk br sandy clay and clayey sand with minor gravel lenses; Mn veinlets 1.3 – 2.7; rootlets to 2.3 2.5 – 2.7 moist, very soft, EW grey shale with Mn veinlets (bedrock); Excavation continued – logged from surface 2.7 – 3.1 complete in HW lithic sandstone	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 14**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 33.99904	**Longitude (WGS-84) (hD.d):** 150.82400	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 299030	
Logged: BBD	**Strike of PIT (deg):** 072	**Northing (MGA):** 6235815	
Approx surface dimensions (m): 2.8x0.8	**Maximum depth (m):** 2.1	**elevation (m) (AHD):** 94	
Approx site slope (deg): 11.5	**Weather - and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 - 0.3 modified, dry, sandy and silty topsoil; included colluvium with cobbles to 100mm diam 0.3 - 0.57 damp, crumbly mot red-br and yell-br sandy clay; rootlets to 0.5 0.57 - 0.75 stiff, grey with yell mot, clay 0.75 - 1.15 dry, hard, HW-MW grey siltstone Excavation continued in hard digging conditions 1.15 - 2.1 complete in MW grey laminite (location below bank/terrace in old grapevine cultivation area; foot of steeper slopes generally and on a spur)	nil

GROUNDWATER CONDITIONS

None seen

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 15**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 33.99962	**Longitude (WGS-84) (hD.d):** 150.82453	
Method and orientation: Backhoe with 750 mm wide bucket; perpendicular to contour		**Easting (MGA):** 299080	
Logged: BBD	**Strike of PIT (deg):** 105	**Northing (MGA):** 6235752	
Approx surface dimensions (m): 2.1x0.83	**Maximum depth (m):** 1.25	**elevation (m) (AHD):** 94	
Approx site slope (deg): 9.5	**Weather - and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.2 variable, dry, br sandy topsoil 0.2 – 0.65 variable, moist, mod stiff, sandy clays and clayey sands 0.65 – 0.95 moist, stiff, mot red-br and grey clay 0.95 – 1.05 dry, stiff, yell-br and red-br mot grey clay 1.05 – 1.25 complete in EW-HW grey siltstone; rootlets present (excavation on steeper slope)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 16**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00078	**Longitude (WGS-84) (hD.d):** 150.82578	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 299199	
Logged: BBD	**Strike of PIT (deg):** 163	**Northing (MGA):** 6235626	
Approx surface dimensions (m): 2.5x0.8	**Maximum depth (m):** 1.45	**elevation (m) (AHD):** 101	
Approx site slope (deg): 7	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.15 dry, blocky, poorly developed br silty/sandy/clayey topsoil 0.15 – 0.70 moist, mod stiff, red-br and br mot sandy clay and clayey sand 0.70 – 1.35 mixed, yell-br clay and gravelly sandy clay; rootlets to 0.75 1.35 – 1.45 complete in hard, MW grey carbonaceous siltstone (near top of hill, unlikely to be deep soil)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 17**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00238	**Longitude (WGS-84) (hD.d):** 150.82415	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 299052	
Logged: BBD	**Strike of PIT (deg):** 000	**Northing (MGA):** 6235445	
Approx surface dimensions (m): 2.45x0.8	**Maximum depth (m):** 2.25	**elevation (m) (AHD):** 79	
Approx site slope (deg): 5	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.33 br sandy and silty topsoil 0.3 – 0.95 br and red-br sandy clay; rootlets to 0,85 0.95 – 1.7 stiff, red-br with grey mot clay 1.7 – 2.05 mot red-br and grey gravelly sandy clay 2.05 – 2.25 complete in damp, grey HW siltstone with Fe concretions	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 18**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00239	**Longitude (WGS-84) (hD.d):** 150.82325	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298969	
Logged: BBD	**Strike of PIT (deg):** 027	**Northing (MGA):** 6235442	
Approx surface dimensions (m): 2.6x0.8	**Maximum depth (m):** 1.95	**elevation (m) (AHD):** 75	
Approx site slope (deg): 3	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.35 moist, sandy and clayey topsoil; major roots to 0.25 0.35 – 0.70 br sandy clay 0.70 – 1.15 moist, red-br occ grey mot, clay; rootlets to 1.15 1.15 – 1.75 moist, yell-red-br sandy clay 1.75 – 1.95 complete in dk br and yell-br mot HW lithic sandstone with minor free moisture (Pit in swale leading to dam; major drainage line; checking for groundwater – which was much less than anticipated)	nil

GROUNDWATER CONDITIONS

Very minor amount of moisture in broken, weathered bedrock

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 19**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00359	**Longitude (WGS-84) (hD.d):** 150.82299	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298948	
Logged: BBD	**Strike of PIT (deg):**	**Northing (MGA):** 6235309	
Approx surface dimensions (m): 2.3x0.8165	**Maximum depth (m):** 1.1	**elevation (m) (AHD):** 75	
Approx site slope (deg): 4.5	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.3 br sandy silt topsoil 0.3 – 0.6 moist, red-br sandy clay 0.6 – 0.9 moist, red-br clay; rootlets to 0.65 0.9 – 1.05 moist, soft red-br and yell-br and grey mot gravelly sandy clay 1.05 – 1.1 hard, MW-HW grey siltstone with free moisture on bedding planes Excavation continued to 1.6 complete in dry, very hard SW grey siltstone. At 1.35 black, highly carbonaceous shale lens with free moisture 0.15 thick	nil

GROUNDWATER CONDITIONS

Minor free moisture on bedding planes in uppermost weathered bedrock

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 20**
Record if logged date different to excavated date:	**All Coordinates Approximate - unless stated (may be derived from geodetic software):**		
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00494	**Longitude (WGS-84) (hD.d):** 150.82710	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 299330	
Logged: BBD	**Strike of PIT (deg):** 078	**Northing (MGA):** 6235167	
Approx surface dimensions (m): 2.4x0.75	**Maximum depth (m):** 1.2	**elevation (m) (AHD):** 72	
Approx site slope (deg):	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.2 br silty sand topsoil 0.2 -0.6 dry, stiff, red-br, yell-br and grey mot sandy clay 0.6 – 0.8 dry, stiff, grey and dk grey, lt grey and yell-br mot gravelly sandy clay; roots to 0.65 0.8 – 1.2 complete in dry, hard, lt grey, MW-SW sandy siltstone (laminite)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 21**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00634	**Longitude (WGS-84) (hD.d):** 150.82726	
Method and orientation: Backhoe with 750 mm wide bucket; perpendicular to contour		**Easting (MGA):** 299348	
Logged: BBD	**Strike of PIT (deg):** 165	**Northing (MGA):** 6235012	
Approx surface dimensions (m): 2.5x0.8	**Maximum depth (m):** 1.6	**elevation (m) (AHD):** 65	
Approx site slope (deg): 5	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.4 variable, br silty and sandy topsoil, horizon boundary irregular 0.4 – 1.1 red-br sandy clay occ sandy and gravelly lenses; charcoalised roots 1.1 – 1.55 moist, firm, red-br and grey mot sandy clay 1.55 – 1.6 Complete in lt grey an yell mot, MW-SW sandy siltstone with Fe staining and concretions (laminite) (surface has been moderately terraced)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 22**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00754	**Longitude (WGS-84) (hD.d):** 150.82824	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 299442	
Logged: BBD	**Strike of PIT (deg):** 175	**Northing (MGA):** 6234881	
Approx surface dimensions (m): 2.6x0.8	**Maximum depth (m):** 1.35	**elevation (m) (AHD):** 58	
Approx site slope (deg): 3	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	**SAMPLES (all)**
0 – 0.35 variable, br sandy clay and clayey sand topsoil 0.35 – 0.75 moist, stiff, yell-br sandy clay 0.75 – 1.2 dry, dk br and grey mot occ yell-br broken and weathered siltstone pieces in clay (C horizon) 1.2 – 1.35 complete in dry, lt grey HW siltstone	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 23**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00793	**Longitude (WGS-84) (hD.d):** 150.82474	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 299119	
Logged: BBD	**Strike of PIT (deg):** 158	**Northing (MGA):** 6234831	
Approx surface dimensions (m): 2.3x0.8	**Maximum depth (m):** 1.76	**elevation (m) (AHD):** 72	
Approx site slope (deg): 4.5	**Weather - and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 - 0.25 dry, br silty sandy topsoil 0.25 - 0.6 moist, stiff, red-br sandy clay with minor gravel 0.6 - 0.7 dry, stiff, red-br and yell-br mot gravelly sandy clay 0.7 - 1.05 moist, red-br mot, HW-MW, grey siltstone bedrock with moisture on bedding; rootlets to 0.75 Excavation continued to 1.76 50 - 150 mm thick bed of moist, carbonaceous shale with free moisture on bedding planes; quickly transitions to very hard, MW, dk grey shale	nil

GROUNDWATER CONDITIONS

Free moisture in limited bed of deeper weathered bedrock

COMMENTS & PHOTO NOTES (if any)

RED EARTH GEOSCIENCES - PIT LOG

Dated excavated: 2 Oct 2014	**PROJECT No 1403**		**PIT No 24**
Record if logged date different to excavated date:		**All Coordinates Approximate - unless stated (may be derived from geodetic software):**	
Position method: GPS handheld	**Latitude (WGS-84) (hD.d):** 34.00516	**Longitude (WGS-84) (hD.d):** 150.82278	
Method and orientation: Backhoe with 750 mm wide bucket; parallel to contour		**Easting (MGA):** 298932	
Logged: BBD	**Strike of PIT (deg):** 165	**Northing (MGA):** 6235134	
Approx surface dimensions (m): 2.35x0.76	**Maximum depth (m):** 1.45	**elevation (m) (AHD):** 66	
Approx site slope (deg): 5	**Weather – and/or Adverse conditions:** Fine, clear sky, warm, slight breeze		

DESCRIPTION	SAMPLES (all)
0 – 0.25 variable, br silty and sandy topsoil, variable horizon boundary 0.25 – 0.7 stiff, red-br and occ yell-br mot, sandy clay 0.7 – 1.3 yell-br and dk br and grey mot sandy clay and clayey sand with minor gravel; rootlets to 0.95 1.3 -1.45 complete in very hard, MW, grey sandy siltstone and sandy lenses (laminite)	nil

GROUNDWATER CONDITIONS

None seen

COMMENTS & PHOTO NOTES (if any)

Appendix B

Soil Grid
Suitability of Soils for Interments

(extracted and modified from Dent, 2003)

Soil Grid – Suitability of Soils for Interments

(together with conditions for depth of burial, separation from permanent watertables, conditions relevant to springs and ephemeral watertables, buffer zones, well-head protection limits; indicative examples used)

USCS	GC	SW	SP	SM	SC	ML	CL	CH
encourages decomposition	fair - good	good	good	good	fair-good	some	no	no
encourages drainage	good	good	good	fair	fair	slight	no	no
general workability	poor	good to poor		good	good	fair, check for mass movement	fair, check for mass movement	poor, check for mass movement
pH > 8 special precautions in karst	decomposition fair	fair – poor, enables soft tissue decomposition, preserves bone				poor, retards decomposition		
pH 4 - 8	good	good	good	good	good	good	good	good
pH < 4	generally poor, enables excess mobilisation of metals, significant loss of bone, variable negative effects on decomposition							
CEC < 40	poor	good - fair			poor, value is too low			
CEC > 40	good	fair	fair	fair	good - poor	poor, does not aid decomposition, possible swelling problem		
encourages bacterial/viral Transmission (T) Survival (S)	high T low S	high T	high T	mod T fair S	low T mod S	low T high S	no T high S	no T high S
grave invert separation from watertable	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0
buffer zone downgradient or topographically low	20	20	20	20	10	10	10	10

buffer zone upgradient or topographically high	10	10	10	10	5	5	5	5
distance to downgradient water well	100 days 200 m	100 days 200 m	100 days 200m	100 days 200 m	200m unlikely	200m unlikely	n/a	n/a

Notes to Table

General:

A. any number of interments may be made in the one grave space: emplacement is only limited by safe working and excavation conditions;
B. there is no impediment to emplacing remains vertically orientated;
C. interred remains need not be coffinated;
D. the grave invert level (lowest-most base of grave) should be at least 1 m above any permanent, ephemeral or fluctuating watertable, and at least 1.2 m in sandy soils;
E. the minimum thickness of soil cover entirely above the last interment should generally be not less than 0.9 m of clayey soils and at least 1 m of sandy soils;
F. the finished backfill above all grave spaces should be permanently sloped to shed water away from the present and adjacent grave/s and in the direction of natural site drainage;
G. the nearest horizontal distance of any interment part to the cemetery boundary (the buffer zone) should be not less than 10 m in clayey soils and not less than 20 m in sandy soils if topographically downhill or hydraulically downgradient; and half these values if topographically uphill or hydraulically upgradient.

Appendix C

Extract of Guidelines by NSW Environment Protection Agency

Guidelines for the Assessment and Management of Groundwater Contamination

1.5 Definition of groundwater contamination

Contamination of land, which includes groundwater, is defined in the CLM Act and the EP&A Act as:

> 'the presence in, on or under the land of a substance at a concentration above the concentration at which the substance is normally present in, on or under (respectively) land in the same locality, being a presence that presents risk of harm to human health or any other aspect of the environment'.

In practice, however, groundwater is considered to be contaminated where any substance or waste has been added at above natural background concentration, and represents, or potentially represents, an adverse health or environmental impact. For the purpose of these guidelines, any undesirable change in groundwater quality constitutes an adverse environmental impact.

In relation to the POEO Act, these guidelines also refer to the term 'pollution'. The dictionary of the POEO Act defines 'pollution of waters' to include:

> 'placing in or on, or otherwise introducing into or onto waters (whether through an act or omission) any matter whether solid, liquid or gaseous, so that the physical, chemical or biological condition of the waters is changed'.

Extracted from:

CONTAMINATED SITES

Guidelines for the Assessment and Management of Groundwater Contamination

Published by:
Department of Environment and Conservation NSW
59–61 Goulburn Street
PO Box A290
Sydney South 1232
Ph: (02) 9995 5000 (switchboard)
Ph: 131 555 (environment information and publications requests)
Ph: 1300 361 967 (national parks information and publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

DEC 2007/144
ISBN 978 1 74122 366 8
March 2007
Printed on recycled paper

Appendix D

General Best Practice Guidelines

(extracted from Dent, 2003)

Summary of Cemetery Planning and Practices

- Proper burial and management practices impose little effect on the environment and re-use is a sustainable activity
- Depth of burial is only limited by site conditions and ability to safely excavate; but this does not imply mass burials
- There are no separate issues for burials without coffins; however, plastic coffins, liners and bodybags should be disallowed
- No burials should lie at the cemetery boundary - buffer zones are needed; 5 -10 m in clayey soils, 20 m or more in sandy soils
- The invert of a grave and hence the deepest burial depth, must be at least 1m above any level to which a watertable fluctuates - more in clean coarse sandy or gravelly soils
- The influences of perched and ephemeral watertables and springs need to be taken into account: don't bury near springlines and never in swampland
- The best soils for cemeteries in order to favour decomposition and with good decay product attenuation are well drained clayey sands
- New sites and extensions should be properly evaluated geoscientifically: floodplains, swamps, clifflines, shallow soils (to some extent), drainage areas to lakes or waterways, some fills - are not suitable areas
- Drinking water wells should be at least 200 m (default) horizontally from any cemetery or 100-day travel days from the boundary after groundwater modelling
- Develop cemeteries from the outside-in and around the perimeter first
- Preserve and plant deep-rooting native trees and shrubs - particularly in buffer zones.

B. Dent

Appendix E

Statement of Consultant's Expertise

RESUME AND CAPABILITY STATEMENT (Jul2014rg)

Dr Boyd Barr DENT

Managing Principal
Red Earth Geosciences

Ph W: +61 (0)2 9446 7905

Mob: 0439 939 187

Email: bdent@redearthgeo.com.au
boyddent@tpg.com.au

Website: www.redearthgeo.com.au

Skype: boyd.dent

Linkedin: http://au.linkedin.com/in/boyddent

EXPERTISE OVERVIEW

Engineering Geologist (Roads, Dams and Slopes), Hydrogeologist (Environment & Resources)

* primary expertise is in the conceptualisation, delineation and assessment of the properties and behaviour of soil, rock and groundwater systems. This experience has been valuably utilised by resource, commercial development, government and others in review and development of various mine, landfill, housing, water resources, and data proposals:

* about twenty-five years aggregate engagement in the geosciences leading to development of a broad understanding of applied projects and research, with a strong capacity for working with data and diverse information; a particular interest in statistical analysis and evaluation related to the practice of environmental hydrogeology:

* a strong affiliation to the resource development industries and the fundamental evaluation of hydrogeological issues confronting coal, CSG, CCS and geothermal proponents and developers; and, other miners in mine, quarry or other resource development, including exhaustive historical and to-date evaluation of groundwater monitoring, scoping studies of groundwater issues, as well as numerical modelling:

* in 2007 reviewed the PhD research for a student at University of Canterbury wherein NZ Coal Seam Gas water waste stream was contrasted with Worldwide knowledge of the time. Subsequently provided advice to AGL about community-based monitoring of fugitive gas from CSG-related operations in rural and community water resources:

* international reputation in environmental hydrogeology recognised by the World Health Organisation and practitioners in the UK, Germany, Poland, USA, Canada, Brazil, and Jamaica, as a specialist in cemetery processes and geological factors - extensively referenced; provided international advice, consulting and guidance:

* commercial experience at a senior national level representing prestigious company in industry council (Australian Council of Recyclers). National role in developing and marketing several innovative plastic products (Smorgon Plastics Recycling); established successful processing plant as a joint NSW Corrective Services – industry partnership. Responsible for a team comprising Plant Manager and 2 Shift Supervisors:

* sales and business development experience with thermal- and innovative acoustic-insulation products for national manufacturer (ACI Insulation) (product responsibility for the new product/market – "Studio Quilt"); transferred to oversee development of joint Industry-VicRoads acoustic barriers business (GRC composites):

* represented University of Technology, Sydney (UTS) in establishment negotiations for the CRC Cotton Catchment Communities (extension) and CRC Care ('Contamination Assessment and Remediation of the Environment'); participated in extensive series of scoping studies (groundwater program) for 'Cotton', principal author/investigator for several reports; participant in initial management formulation of the design and operational aspects of 'Care':

* university research activities and supervision comprised the delineation of the geological setting of closed municipal landfills in the Greater Sydney Area, restoration of abandoned oil shale mining sites, vulnerability of spring-based water supply (NW Sydney), and investigation of the geoscientific context of human decomposition:

* first appointment to the newly created position (and Group) at Monash University to develop research and training specifically focussed on the brown coal mining industry in Gippsland, Victoria. The special emphases in this work were geotechnics, engineering geology and hydrogeology from mine- to regional- scale. The work involved close liaison with the three large Latrobe Valley (Victoria) mines, government regulators and related agencies, consultants, and other industries; as well as supervision of PhD students:

* SRK Consulting: role involved provision of peer-review for due diligence reporting for diamond and gold developments in WA, and a copper prospect in Qld; a major input in the pre-feasibility planning and investigation for a 'green-field' coal development in eastern Russia, where hydrogeological investigations included studies of geotechnical stability and dewatering issues in permafrost, and re-opening of cut-off coastal lagoonal systems. Responsible for the project management of a significant resource/geotechnics review related to the future mining of brown coal in the Latrobe Valley; provided major contributions for groundwater monitoring establishments at 4 proposed open pits in the Hunter Valley (NSW).

EDUCATION

Doctor of Philosophy (Science), 2003, University of Technology, Sydney (PhD)
[Thesis: The Hydrogeological Context of Cemetery Operations and Planning in Australia]

Master of Science (Hydrogeology and Groundwater Management), 1995, University of Technology, Sydney (M.Sc.)
[Thesis: Hydrogeological Studies at Botany Cemetery, New South Wales]

Certificate in Marketing Practice, 1989, University of Technology, Sydney

Graduate Diploma in Education (Secondary Science), 1977, Kuring-gai CAE (Dip Ed)

Bachelor of Science (Applied Geology), 1974, The University of New South Wales (B.Sc.)
[Thesis: The Engineering Geology of the The Oaks - Picton District, NSW]

PROFESSIONAL AFFILIATIONS

Member, International Association of Hydrogeologists (MIAH)
(previously held positions of President and Secretary, NSW Branch; Treasurer for joint Aust IAH-NZHS Conference Committee 2005)

Member, Geological Society of Australia

Member, National Groundwater Association (USA)

Member, International Medical Geology Association;
(Aug 2013 elected to the management committee position of Webmaster)

PUBLICATIONS AND REPORTS

Over 20 refereed papers in International Journals and conference proceedings dealing with the geoscientific context of cemetery investigations and planning, and latterly the rock mass properties of brown coal. Numerous reports, un-refereed articles, invited lectures and presentations to international and national groups, as well as articles for trade magazines and professional associations' newsletters.

Over 12 public, major site investigation reports for the NSW Department of Main Roads concerning road relocation and construction and, for the NSW Department of Public Works concerning new dam sites and dam construction, water supply augmentation, large building sites and slope stability. Tens of small site investigation reports, and numerous substantial investigation and review reports prepared whilst in various consulting practices (engineering geology, hydrogeology, general geosciences), and from consulting as an academic.

EMPLOYMENT HISTORY

2/2013 – present:
Managing Principal, Red Earth Geosciences

10/2012 – 1/2013:
Principal Consultant - Hydrogeology, SRK Consulting (Australasia) Pty Ltd

8/2010 – 9/2012:
Senior Research Fellow, Monash University (Gippsland Campus)
Geotechnical & Hydrogeological Engineering Research Group (GHERG)
School of Applied Sciences and Engineering

8/2007 – 7/2010:
Principal Consultant (Proprietor), Red Earth Geosciences

1/2007 - 7/2007:
Director of Technical Services, Atlantis Corporation
(initially engaged part-time while exiting UTS during teaching semester)

1993 – 5/2007:
Lecturer, Department of Environmental Sciences, University of Technology, Sydney (UTS);
initially appointed - Tutor, then Associate Lecturer, Department of Applied Geology

1991 - 1992:
Consultant (environmental marketing) (Managing Director), Tugboat PEM Pty Ltd

2/1990 – 5/1991:
Marketing and Environmental Affairs Manager (national role), Smorgon Plastics Recycling;
initially appointed - Sales Manager (NSW)

1988 -1990:
Manager, ACI Insulation (GRC Composites Division);
initially appointed - Sales Engineer, ACI Insulation (NSW)

Roles prior to 1988 included as an Engineering Geologist (dams specialty) for the NSW Public Works Department; Consultant Engineering Geologist (hillside development and land stability specialist) for a Sydney-based consulting company; Scientific Officer (Engineering Geology – new road route investigations) for NSW Department of Main Roads; Assistant to the Quality Control Manager, Pioneer Concrete (NSW); and some years as a high school science teacher.

RECORD OF OTHER KEY CONSULTING PROJECTS

(from Red Earth Geosciences and selected others)

* confidential review and scoping studies for Clean Coal Victoria (DPI formerly a branch of Dept. of Primary Industries) regarding strategic coal pit development plans and geotechnical issues for key road infrastructure in the Latrobe Valley (Apr – Jul 2013)

* engaged by DPI Victoria to assist in the re-write and re-orientation (to risk-based) of the Guidelines for Development and Management of Quarries

* engaged by NSW Solicitor General to provide expert opinion about traditional and associated cemetery land uses in regional NSW (Nov 2010 - Jun 2011)

* NSW Office of Water ('NOW'; formerly 'DWE') provide project management of major update by development of database readings and manipulation tools for all existing state groundwater models (Sept 2009 – Dec 2010)

* hydrogeological evaluation of existing and prospective conditions for Gloucester Coal Limited – new developments at two existing Gloucester Basin (NSW) coal mines. Two-stage hydrogeological evaluation, then numerical modelling for proposed pits; advice on environmental monitoring; design and installation of monitoring and pump-test bores then testing; advice on deep level groundwater issues (Nov 2007 - Nov 2009)

* review of NSW State Groundwater Database (DWE) for project associated with National Water Initiative (BoM) (Mar - Jun 2009)

* expert advice regarding hydrogeological setting for Cadia Mine (NSW) and implications for development of new underground mine (May 2009)

* review all previous investigations then prepare predictive numerical model for NSW Dept Commerce & Nambucca Shire Council water supply upgrade – new borefield in river alluvium (Nambucca River) (Mar 2008 – Aug 2009)

* provide expert opinion and review assistance into controversial planning aspects of land use adjacent to Eastern Suburbs Memorial Park, NSW (Mar 2008 – ongoing)

* expert review of hydrogeological investigations and development proposals for commercial non-putrescibles landfill in disused hard-rock quarry in Western Sydney (Mar 2009 & 2010)

* provision of expert advice to Hunter Water, delineation of a new site and design and locate alluvium fill for same - replacement cemetery at Munni NSW, where existing rural cemetery is to be inundated by Tillegra Reservoir (Feb - Jul 2007)

* independent review of hydrological setting and stormwater management practices for Melaleuca Estate Pty Ltd for major land sub-division at Nelson Bay NSW (Sept – Dec 2007)

* acted as an Independent International Expert for controversial cemetery development on rural land comprised of cobbly clay colluvium over karst terrain associated with municipal water supply in Jamaica; including fieldwork and review of regional groundwater system; investigation was required to be finalised prior to court determinations about compensation – politically sensitive (Jan – May 2007)

* participated as a member of Expert Review Panel for the NSW Natural Resources Commission in respect of Lachlan Valley Groundwater Sharing Plans; reviewed the underpinning science and conclusions with respect to allocations and their effects (Oct 2006)

* team member for preparation of major scoping studies of natural resources data in river catchments relating to activities of the Australian cotton industry; hydrogeology and hydrogeochemistry; specifically responsible for Darling, Lachlan, Gwydir and Macquarie Rivers' studies (Mar 2006 – Oct 2007)

* nine month investigation of groundwater pathways and contaminated fill impacts from Warringah Golf Course onto otherwise lowly impacted catchment areas - Wakehurst Golf Club Ltd (Mar – Nov 2006)

***