PROPOSED LAWN CEMETERY AND CREMATORIUM

DOCUMENT DESCRIPTION	
Title	**Amended Groundwater Constraints Plan**
Brief Scope	This document provides an amended plan of the grave burial area that demonstrates compliance with relevant groundwater management standards (including the World Health Organisation).
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AUTHOR	
Company	Martens & Associates Pty Ltd
Author	Dr D. Martens

SITE	
Address	Lot 1 DP 529885, No. 2207 – 2223 Elizabeth Drive, Luddenham, NSW
Local Government Area	Penrith City Council

PREPARED

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CONTENTS

1 INTRODUCTION

1.1 Scope

This report has been prepared to accompany the amended plan of grave burial sites and serves the following primary purposes:

1. Outlines relevant performance standards for protection of hydrological systems from cemeteries.

2. Summarises groundwater investigative work which has been undertaken on the project to date.

3. Provides comment in response to matters raised during the Joint

1.2 Performance Standards

1.2.1 Vertical Grave Separation to Groundwater

The World Health Organisation (WHO, 1998) published a briefing note on the impact of cemeteries on the environment and public health[1]. The report noted the following (at p 7):

> "*An unsaturated soil layer has been found in past studies to be the most important line of defence against the transport of [internment] degradation products into aquifers. In acts as both a filter and an adsorbent. It can also reduce the concentrations of some microorganisms and decomposition compounds that occur during the putrification of human corpses.*"

The WHO then recommends that:

> "*The base of all burial pits on the site must maintain a minimum of one metre clearance above the highest natural water table*".

This is the accepted design standard in NSW.

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[1] World Health Organisation (1998) *The Impact of Cemeteries on the Environment and Public Health*

1.2.2 Horizontal Set-back to Bores

There are no formally adopted national guidelines which relate to groundwater abstraction bore set-back distances to grave sites, and it has been our experience that these are determined on the basis of a merit based technical assessment (e.g. using field groundwater investigations and supplemented with groundwater modelling). WHO (1998 at p9) make the following comment:

> *"The draft conditions given below could be used to site and design a future well managed cemetery:*
>
> 1. *Human or animal remains must not be buried within 250 m of any well, borehole or spring from which a potable water supply is drawn."*

Significantly, the condition is draft and relates to a genuine potable water supply bore.

Dent (2002)[2] represents one of the most recent and comprehensive analysis on the matter of planning cemeteries in Australia within the context of groundwater conditions and impacts. It is worth noting that Dent is a referenced authority for the WHO (1998) report. Dent (2002) recommends (at p 404) the following:

> *"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."*

Clearly, Dent (2002) is also dealing with potable water supplies. However, putting this to one side, the recommendation for 100 days travel time from the cemetery boundary after groundwater modelling is relevant as this is the point in time at which potentially harmful pathogens from the grave would be inactivated / eleminated.

1.2.3 Surface Water Setbacks

The WHO (1998) recommends the following in relation to surface water set-backs:

> *"The place of interment should be at least 30 m away from any other spring or watercourse and at least 10 m from any field drain."*

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[2] Dent, B. B. (2002) *The Hydrogeological Context of Cemetery Operations and Planning in Australia*, PhD thesis, University of Technology, Sydney

In relation to farm dams, WHO (1998) do not give any specific advice. However, it would be reasonable and sensible to adopt the 30 m buffer, due to the similarity and interdependency of these environments.

1.2.4 Groundwater Depth Contour Constraint

Based on the various above criteria, a minimum depth to groundwater of 2.4 m would be required based on:

1. 0.9 m soil cover over the coffin
2. 0.5 m allowance for the coffin
3. 1.0 m allowance for separation to groundwater

For the purposes of design at this site, we have adopted a groundwater depth criteria of 3.0 m, providing for a 25 % margin of safety.

2 SUMMARY OF GROUNDWATER CONDITIONS

2.1 Field Testing

The development site has been the subject of extensive sub-surface exploration over more than a year. Field investigations are summarised as follows:

1. Physical documentation of soil, geological groundwater conditions

    a. Geotechnique – 6 monitoring wells and 12 backhoe test pits

    b. Martens & Associates – 19 monitoring wells and 32 drilled boreholes

2. Determination of groundwater permeability (K_{sat}) at 9 locations, by way of bore testing, throughout the site.

3. Determination of groundwater variability by way of manual 'dip' measurement and continuous groundwater level monitoring between the period 19 December 2012 and 25 September 2013 (some 9 months).

4. Collection of groundwater quality samples at 11 monitoring bores throughout the site.

2.2 Groundwater System at Site

The groundwater system consists of the following broad properties at the site:

1. Within the proposed burial areas, it is generally contained within both clays and underlying shales.

2. Groundwater is very slow moving with field permeability (K_{sat}) testing ranging from near to zero, and up to 0.19 m/d (maximum value recorded).

3. Groundwater gradients are generally shallow at around 2-3 %.

4. In lower elevations and within larger overland flow path drainage depressions, groundwater is generally closer to the surface than in other locations. Depths to groundwater are > 6 m over the northern ridge line.

2.3 Groundwater Model

A numerical groundwater model was used to collate all field data and assist with plotting groundwater depth contours. Importantly, the model was calibrated against the highest

observed groundwater level at each monitoring bore. Annexure A provides the locations of all groundwater monitoring test sites and provides the position of the adopted 3 m groundwater depth contour, noting that this is based on and recalibrated against all available and most recent data collected at the date of preparing this report.

2.4 Groundwater Quality

Table 1 provides a summary of existing groundwater quality (in terms of salinity) at the site. Data reveals very high salinity levels which arise out of the significant shale deposits below the site. Similar quality would be expected on land adjoining the site given similar geological and hydrogeological conditions.

Table 1: Groundwater salinity levels at the site during the site monitoring period.

ID	Electrical Conductivity (µS/cm)	Salinity (mg/L)
All bore monitoring data	8,737	5,827
Bores in overland flow paths (MW1, MW3, 110, 119)	3,667	2,446
Bores not in overland flow paths (MW2, MW4, MW5, 116, 120,118a, 123b)	12,117	8,081

Potential uses for groundwater are typically [and quickly] assessed on the basis of salinity[3]. Applying the criteria in Table 2, it is clear that shallow groundwater at the site would not be capable of providing potable water in accordance with the Australian Drinking Water Guidelines (2011)[4].

Further to this observation, it is also clear that groundwater would be brackish, irrespective of whether it was collected from bores located in 'wetter' drainage depressions (where lower salinity surface water recharge rates are higher) or in 'drier' elevated land. Indeed, irrigation with brackish water would result in accumulation of salt in local soils and is likely to cause dieback of irrigated vegetation and could lead to accelerated soil erosion.

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[3] Expressed as total dissolved solids or TDS in mg/L.

[4] National Water Quality Management Strategy, *Australian Drinking Water Guidelines* 6 (2011) National Health and Medical Research Council.

Highly brackish water would also be detrimental to a range of livestock such as beef and dairy cattle, horses, pigs and poultry. Once salinity levels exceed in the order of 3,000 – 6,000 mg/L, loss of production and decline in animal condition and health is expected[5].

Table 2: Summary of water uses on the basis of salinity.

Class	**Salinity (mg/L)**	**Irrigation Suitability[6]**	**Suitable for Potable[7]**
Fresh	< 1,000	500 – 1,000 can have detrimental effects on sensitive crops	0 - 600 good 600 – 900 fair 900 – 1000 poor
Brackish	1,000 – 5,000	1,000-2,000 adverse effects on many crops, requiring careful management practices	1000-1200 poor > 1,200 unacceptable / unpalatable
Highly Brackish	5,000 – 15,000	2,000 – 5,000 can be used for salt tolerant plants on permeable soils with careful management practices	No
Saline	15,000 – 30,000	Not suitable	No
Sea Water	30,000 – 40,000	Not suitable	No

[5] *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000) Volume 1

[6] NSW Department of Conservation and Land Management (1992) W*hat Do All the Numbers Mean, A Guide for the Interpretation of Soil Test Results*, Section 5.2.3.

[7] National Water Quality Management Strategy, *Australian Drinking Water Guidelines* 6 (2011) National Health and Medical Research Council

3 COMMENTARY

3.1 Compliance with Performance Standards

The following comments are offered:

1. All burial sites are located on land where the groundwater table is deeper than 3 m. This means that all burial sites will be able to achieve a minimum separation of 1 m between the base of the grave and the groundwater table.

2. The groundwater travel time from any grave site to the site boundary is significantly > 100 days (in the order of years). No off-site bores, for potable or non-potable purposes, are affected.

3. All burial sites are located at a setback distance of ≥ 30 m to any overland flow path or watercourse.

4. All burial sites are located at a setback distance of ≥ 30 m to any farm dams.

The above demonstrates that the proposed location of burial sites complies with the various relevant adopted cemetery design standards.

3.2 Impact on Surface Water

During the JRPP meeting, a question was posed by the panel in relation to groundwater resurfacing after a burial, thereby resulting in decomposed materials possibly being brought to the surface. In response to this, we note that:

1. Burial sites are located in positions where groundwater depth is > 3 m below ground and that whilst the near ground surface may become saturated during extended rainfall (e.g. top 20-30 cm), groundwater is not expected to rise to the surface; and

2. There would be a minimum of 900 mm of soil cover over the body, as required by the NSW Health, ensuring that there is more than sufficient filtration of any rising water.

A further question was posed at the JRPP meeting in relation to the potential impact on off-site dams downslope of the site. These are located in the order of 200 m away from the nearest proposed burial plots. This is well in excess of the WHO (1998) recommended 30 m setback, and no impact is expected.

3.3 Transport of Pathogens

During the JRPP meeting, various residents expressed a concern that pathogens in the bodies of people buried in graves could be transported off-site and contaminate downslope water bodies. In particular, concerns were raised in relation to the transport *Salmonella* and *Campylobacter*.

In addressing this concern, it is important to note the following:

1. Pathogens will be absorbed and deactivated by the soil and aquifer system once they leave a putrifying body.

2. In relation to *Salmonella* and *Campylobacter*, the buried body must actually contain the pathogen in order for there to be any possible risk. Given that only a very small proportion of the population is likely to be infected with these pathogens, actual concentration doses to the surrounding soil and groundwater environment would be extremely low. It is worth noting that the WHO (1998) do not list these pathogens as common in the human intestine.

3. In terms of survival rates in groundwater, *Salmonella* and *Campylobacter* maintain survival rates similar to (as in the case of *Salmonella*[8]) to or significantly less than (as in the case of *Campylobacter*[9]) *E. coli*, a common gut bacteria which can persist in groundwater [assuming Sydney soil temperatures] in the order of 30-75 days. This represents sub-surface travel distances in the order of 1-2 m away from the grave site.

The above comments demonstrate that the proposed burial plot setbacks to dams, watercourses, groundwater (both vertical and horizontal) and property boundaries are more than adequate to protection downstream and adjoining property users and land-use activities.

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[8] ESR Christchurch Science Center (2013) *Survival of Salmonella and Campylobacter in groundwater and sunlight-exposed sea and river water* - web based research note

[9] Cook, K. L and Bolster, C. H (2007) Survival of *Campylobacter jujuni* and *Escherichia coli* in groundwater during prolonged starvation at low temperatures, *Journal of Applied Microbiology* 103, 573-583

4 ANNEXURE A – TEST LOCATIONS AND 3M GROUNDWATER DEPTH PLAN

LEGEND:

- EXISTING GROUNDWATER WELL BY GEOTECHNIQUE
- ADDITIONAL GROUNDWATER WELL BY MARTENS
- BOREHOLE (BH) BY MARTENS
- SITE BOUNDARY
- 3m GROUNDWATER DEPTH CONTOUR
- PROPOSED 2M BURIAL PLOT
- S.L / W.L — SURFACE LEVEL mAHD / MEAN GROUNDWATER LEVEL mAHD
- -1.81m — MEAN DEPTH (M) TO GROUNDWATER

martens

SITE BOUNDARY

ELIZABETH DRIVE

BH123 A+B+C
S.L 69.45
W.L(A) 65.29
W.L(B) 67.58
W.L(C) 67.26

BH124
S.L 63.9

BH121
S.L 67.7

BH122
S.L 63.73

BH120
S.L. 66.75
W.L 65.45

BH119
S.L 69.0
W.L 68.14

BH118 A+B
S.L 69.7
W.L(A) 65.84
W.L(B) 66.93

MW1
MW2
MW4
MW5
S.L 74.0
W.L 72.23

BH116
S.L 73.7
W.L 70.54

BH117
S.L 73.5

BH128
S.L 72.65
DRY TO 69.61

BH111
S.L 78.35
DRY TO 72.25

BH112 A+B
S.L 77.5
W.L(A) 73.1
W.L(B) DRY TO 73.87

BH114
S.L 90.35
DRY TO 86.09

BH127
S.L 90.2

BH113
S.L 94.1

BH115
S.L 86.2

BH109
S.L 88.55

BH126
S.L 86.5

BH110
S.L 80.6
W.L 79.92

MW3
S.L 80.4
W.L 80.34

BH108 A+B
S.L 96.3
DRY TO 89.98

BH101
S.L 85.3

BH125
S.L 88.7

MW6
S.L 86.2
W.L 83.65

BH107
S.L 95.4
DRY TO 91.79

BH102
S.L 88.8

BH106
S.L 93.03
DRY TO 89.03

BH103
S.L 96.2

BH105
S.L 90.2

BH104
S.L 97.15
DRY TO 91.45

LINE OF 25M VEGETATION BUFFER ZONE REFER TO LANDSCAPE PLAN

PROPOSED VEGETATION TO BUFFER ZONE. REFER TO LANDSCAPE ARCHITECTS DETAILS

EXISTING NATURAL WATER COURSE

BOUNDARY 185° 20' 20" 714.725m

BOUNDARY 95° 30' 10" 475.480m

BOUNDARY 204° 02' 10" 427.160m

BOUNDARY 291° 58' 10" 152.405m

BOUNDARY 287° 44' 40" 123.565m

BOUNDARY 12° 43' 40" 500.265m

BOUNDARY 0° 02' 50" 226.160m

BOUNDARY 358° 02' 10" 252.245m

0 30 60 90 120 150
UNITS - METRES

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	KT	**PLAN - TEST LOCATIONS** **2207-2223 ELIZABETH DRIVE, LUDDENHAM**	Drawing No./ID: **SK001**
Approved:	GT		
Date:	24/10/2013		
Scale @A3:	1:3000	6/37 Leighton Place, Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767 Email: mail@martens.com.au Internet: http://www.martens.com.au	Project: P1203651 | File: JD06V03 | Revision: B