

**THE HYDROGEOLOGICAL CONTEXT
OF CEMETERY OPERATIONS
AND PLANNING IN AUSTRALIA**

by

Boyd B. Dent

VOLUME I

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CERTIFICATE OF AUTHORSHIP / ORIGINALITY

I, Boyd Barr Dent, certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

The Hydrogeological Context of Cemetery Operations and Planning In Australia

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The purpose of this research has been to evaluate the potential contamination impact of cemeteries on groundwater. A comprehensive study of the groundwaters in the unsaturated and saturated zones of nine Australian cemeteries has been made, with most sampling between October 1996 and August 1998. Periodic sampling from 83 wells or ponds yielded 305 complete samples which were tested for at least 38 inorganic and 5 bacterial analytes. Other, partially complete samples were used for metals and bacterial analyses. The soils of all sites were tested for a range of analytes that might reflect or affect the presence of human decomposition products.

The within-cemetery sampling has allowed inorganic chemical characterisation of cemetery groundwaters to an amount of detail not previously attained. In the past 100 years there have been fewer than 12 sampling-based studies published on any of these matters. The forms of nitrogen feature most prominently, but three groupings of analytes are recognised as major contributors, including Na, Mg, Sr, Cl, SO₄ and forms of P; these outcomes are similar in each hydrogeological zone. This study is unique in that it has a broad focus on the environmental impacts in respect of bacterial presence and transmission, heavy metals and nutrients, and has put these into the context of cemetery management and operational practices.

Cemetery functions are best understood conceptually as a special kind of landfill but they are strongly influenced by the temporal and spatial variability of cemetery practices. Human decomposition mechanisms and products are considered in detail. This information was used to model the impacts for a large municipal cemetery over a twenty year time-frame. The previously unquantified relationship of cemetery proximity to drinking water wells has been determined and guiding principles for

cemetery location and operation have been prepared including separation distances from watertables and specification of buffer zones in different hydrogeological settings. The related issue of the disposition of cremated remains is also considered and guidelines developed for scattering of these within buffer zones.

The amounts of decomposition products leaving cemeteries are very small, and well sited and managed cemeteries have a low impact on the environment. Cemeteries should not be regarded as a detrimental landuse and the in-soil interment of human remains and re-use of graves are sustainable activities.

However, almost all cemeteries have some potential for pollution. The most serious situation is the escape of pathogenic bacteria or viruses into the environment at large. The answer to the question as to ‘whether any one cemetery pollutes?’ depends on the location and operation of the site in adherence to the affecting parameters. The question can only be resolved by a comprehensive geoscientific investigation with a focus on the hydrogeological setting. Such assessment needs to consider the effects if the practices and/or usage patterns within the cemetery change, or if there are unaccounted changes in impacting natural phenomena like floods.

ACKNOWLEDGEMENTS

The research work comprising this thesis has extended over 7½ years. This time-frame brings with it both opportunities and difficulties in terms of the on-going review of data and results, the search for related information, consideration and presentation of ideas; as well as changes to the breadth of the work and the people dealt with whilst conducting the research involved. Accordingly, there is a long list of people to be thanked for their inputs and help in making the work a reality and professionally and technically correct. The work has been widely promoted in Australia and overseas as the National Study of Cemetery Groundwaters.

Professor Michael Knight, Director of the National Centre for Groundwater Management (NCGM), was the Principal Supervisor for this research. He was the main protagonist for attempting the work and the skilful administrator who enabled it to happen within a complicated university administrative system and through his liaison with industry. He constantly supported and encouraged me throughout the years, overviewed my technical concerns, and facilitated interaction with key staff and others where it was needed. Thank you Michael for your support and friendship.

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Whilst undertaking this work I was employed by UTS as a lecturer in the Department of Environmental Sciences (formerly the Department of Applied Geology). Adjunct Prof. Brenda Franklin (previous Head of Department) was initially responsible for employing me and then enthusiastically supported my work; she was succeeded by A/Prof. Greg Skilbeck who continued in the same vein. Other colleagues and staff helped in various ways and generally supported my absences on fieldwork or other research requirements; Mrs Leighonie Callan has been of great assistance in preparing diagrams and slides for presentations, whilst Mrs Marnie Paterson also provided liaison with staff and industry; others in respect of sampling and testing are mentioned later.

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