TOWARDS A METHODOLOGY FOR IDENTIFYING POTENTIAL SITES FOR CEMETERIES

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TOWARDS A METHODOLOGY FOR IDENTIFYING POTENTIAL SITES FOR CEMETERIES

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LIST OF ACRONYMS:

ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIAL
BA	BASIC ASSESSMENT
BCM	BUFFALO CITY MUNICIPALITY
BOD	BIOCHEMICAL OXYGEN DEMAND
CAD	COMPUTER-AIDED DESIGN
CFU	COLONY FORMING UNITS
DCP	DROP CONE PENETRATION
DEDEA	DEPARTMENT OF ECONOMIC DEVELOPMENT AND ENVIRONMENTAL AFFAIRS
DWA	DEPARTMENT OF WATER AFFAIRS
DWAF	DEPARTMENT OF WATER AFFAIRS AND FORESTRY
EA	ENVIRONMENTAL AGENCY
EAP	ENVIRONMENTAL ASSESSMENT PRACTITIONER
EIA	ENVIRONMENTAL IMPACT ASSESSMENT
FAO	FOOD AND AGRICULTURAL ORGANISATION OF THE UNITED NATIONS
GIS	GEOGRAPHICAL INFORMATION SYSTEMS
GRA2	GROUNDWATER RESOURCE ASSESSMENT PHASE 2
IDP	INTEGRATED DEVELOPMENT PLAN
JSTOR	JOURNAL STORAGE
LDO	LOCAL DEVELOPMENT OBJECTIVES
MOD. AASHTO	MODIFIED AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
NEMA	NATIONAL ENVIRONMENTAL MANAGEMENT ACT
SA	SOUTH AFRICA
S&EIA	SCOPING AND ENVIRONMENTAL IMPACT ASSESSMENT
S&EIR	SCOPING AND ENVIRONMENTAL IMPACT ASSESSMENT REPORT
SDF	SPATIAL DEVELOPMENT FRAMEWORK
SOER	STATE OF THE ENVIRONMENT REPORT
TOC	TOTAL ORGANIC CARBON
WHO	WORLD HEALTH ORGANISATION

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ABSTRACT

Due to death being an extremely sensitive issue, the topic of cemeteries and associated environmental impacts is often left outside the mainstream environmental critique. However, this is a topic becoming more prevalent as the population numbers and the death rate increases, while the amount of available land decreases.

Recent research has indicated that poorly sited cemeteries may pose a significant threat to groundwater resources with the consequential potential for severe health hazards. This has resulted in the need for a method of determining the acceptability of a given area for the establishment of a cemetery in a South African context.

Cemeteries should be sited in such a way as to mitigate potential public health and safety concerns, minimise associated environmental impacts and provide a method of body disposal that is economically viable.

This study therefore provides an integrated methodology to identify and assess a given area and rank a number of potential sites, ultimately determining a single cemetery site which proves to be acceptable for the establishment of a cemetery. Cemetery site selection should be based on the factors affecting the pollution potential of a proposed cemetery. These factors were identified and quantified based on research into the mechanisms of cemetery site pollution resulting in a number of fatal flaws and criteria deemed decisive when selecting a potential cemetery site. The assessment of a site with regards to these criteria and fatal flaws is undertaken through the use of GIS analysis software utilising data layers containing information on the site selection criteria, by investigating existing studies, literature or reports relating to the relevant area, or through field investigations.

Although these criteria are vital when determining the specific characteristics of a site in terms of its pollution potential, a method of assessing a number of potential sites with regards to these criteria is vital. To this end, a multi-criteria ranking matrix has been developed, allowing for an objective method of assessing individual sites and thus indicating which sites are more suited for the establishment of a cemetery. The ranking matrix identifies a range of values for each criterion, therefore identifying a minimum and maximum allowable value. A site is then assessed with regards to these criteria in relation to the values identified in the ranking matrix. Each criteria is assigned a score according to the site conditions. Once the criteria for each site has been assessed and scored, the results can be tallied allowing the sites to be ranked according to which site proved to be the most acceptable for a cemetery based on the findings of the application of the site selection criteria.

The methodology developed in this study is unique to previous studies in that it provides an integrated and staged approach to identifying, assessing and applying the criteria affecting the pollution potential of a cemetery. The methodology also provides a means of ranking a number of potential sites so to determine the most suitable. Furthermore, the criteria deemed as decisive in previous investigations were in most cases not quantified by the relevant authors, therefore leaving many of the criteria values up for interpretation. For this methodology to be affective, all criteria must be quantified therefore identifying maximum and minimum allowable limits for each. This study applies minimum and maximum allowable limits to these criteria, therefore aiding in the ranking process.

The integrated methodology developed was then applied to a case study where by the effectiveness in identifying a number of potential cemetery sites could be tested. Subsequent to the application of this methodology to a case study, it was concluded that an additional two criteria, not identified in previous investigations, needed to be assessed to more adequately determine the suitability or otherwise of a site for a cemetery. Ultimately, twelve major criteria have been proposed for use as the basis of the methodology.

The methodology and pertinent criteria proposed in this study should be compiled as a standard for planning authorities and consultants to use as a method of determining a number of potential environmentally sound cemetery sites.

Key words: cemetery, cemeteries, environmental impact, pollution, groundwater, health hazard, criteria, multi-criteria ranking matrix, site ranking, fatal flaw, GIS, data layer, integrated methodology, case study

1 CHAPTER 1: INTRODUCTION

South Africa faces a multitude of challenges when it comes to the sustainable placement of cemeteries. The most significant of these challenges being that until very recently cemeteries were not perceived as having any significant environmental pollution potential, as it is believed that soil provides effective isolation of the groundwater from surface pollutants (Engelbrecht, 2000). In addition planning authorities and township engineers do not always include cemeteries in Spatial Development Plans and Township designs with cemeteries traditionally being sited based on proximity to communities due to religious or cultural circumstances (WHO, 1998). This attitude towards cemeteries is a contributing factor to their inappropriate siting.

An investigation conducted by the Groundwater Division of the Geological Society of South Africa (2011) identified that more than 80% of the 5700 communities residing in rural Eastern Cape rely solely on groundwater as a potable water source (GSSA, 2011). While research by Fisher and Croukamp (1993) concluded that more than 40% of cemeteries sampled across 43 towns in the Eastern Cape are contaminating already beleaguered water resources. This coupled with the general trend of poorly funded, mismanaged and neglected cemeteries, means that there is a dire need for a method of accurately identifying a suitable cemetery site.

Investigations undertaken by Engelbrecht (2000) and Dent (2007) indicate that cemeteries need to be perceived as having significant environmental pollution potential similar to that posed by a conventional waste disposal site. Research by Fiedler *et al*., (2011) indicates that when corpses and grave contents decompose, decomposition products (e.g. gaseous products: CO, CO_2, CH_4 and liquid products: cadaverine, putrescine, NH_4 and NO_3) are released into the environment or accumulate in the grave area which may result in the contamination of groundwater supplies. Contamination of groundwater sources primarily occurs when leachate and pathogenic organisms produced by the decomposition of a buried body enters the groundwater system (Fiedler *et al*., 2001). Engelbrecht (2000) reasoned that leachate produced by a cemetery appears to be a nutrient for micro-organisms rather than a poison. It has been suggested that in many cases cemetery leachates may be more hazardous to human health than those produced by conventional waste disposal facilities (Fisher, 2001). However, the quantity of the leachate expected from a cemetery varies considerably and is directly related to the size of the cemetery (Engelbrecht, 2000).

Engelbrecht (2000) noted an increase of colony forming units (cfu) in the sampled groundwater for all microbiological indicators used and indicated that the groundwater in a cemetery is extremely microbiologically polluted compared with the expected regional groundwater quality. Pathogenic bacteria, viruses, protozoa and helminths that survive will consequently reach the groundwater. Fisher and Croukamp (1993) indicate that microbiological pollutants remain active in the water table at much greater distances from the source of contamination than originally predicted. Engelbrecht (2000) suggests that any disease caused by drinking contaminated drinking water can be transmitted through groundwater if the disease causing agent reaches the water source in infectious doses.

A significant increase for all chemical parameters above the regional groundwater quality was also encountered (Engelbrecht, 2000). Fiedler *et al*., (2011) confirmed this through an investigation of a comprehensive exhumation series in order to determine burial-related changes in matter and element content. Fiedler *et al*. (2011) noted that higher than normal levels of Nitrogen (N), Carbon (C), Zinc (Zn), Barium (Ba), Calcium (Ca) and Sodium (Na) was observed in soils below coffins. Engelbrecht (2000) however identified that inorganic and organic chemicals within the surface environment can be transformed by microbiological processes. Furthermore, bacteria not only transforms chemical compounds directly but the growth of bacteria can cause clogging and result in a change to the permeability of the aquifer material, affecting the pH and oxidation-reduction potential of the system. This change in aquifer properties may result in the precipitation or dissolution of phosphates and heavy metals, further contributing to the pollution potential of a cemetery.

Fiedler *et al*., (2011) noted that the quantity of toxic and non-degradable substances used to bed and prepare the corpses results in high concentrations of metals such as Zinc, Copper, Lead, Iron and Arsenic to be found in the vicinity of the coffin and deceased, both horizontally and vertically. Fiedler *et al*., (2011) suggests that these elevated concentrations may have relevance in terms of ecological risks and should be kept to a minimum.

As the population numbers rise, the numbers of burials increase thus escalating the need for suitable land areas for the establishment of cemeteries. Land area is becoming more difficult to find in populated areas, and in the future sufficient space for cemeteries may not be found at all. This further substantiates the need for identifying more precisely a suitable cemetery site. It may be argued that cremation as an alternative to burial would relieve the pressure on cemeteries, but this would go against the cultural beliefs of a large percentage of the South African population. Therefore, burial will remain the preferred method of interment in the short to medium terms and until cultural beliefs shift.

This study therefore proposes a method for rapidly and objectively analysing the acceptability of an area for the establishment of cemeteries in a South African context. The proposed method will provide a means of comparing a number of sites based on a common set of baseline criteria. To this end, a multi-criteria ranking system has been developed, allowing for an objective method of assessing individual sites, thus indicating which sites are more suited for the establishment of a cemetery.

1.1 Motivation for the study

In South Africa the number of deaths is currently increasing whilst the amount of available land decreases due to increasing population numbers, urban sprawl and the ongoing battle between various land-uses (Richards & Croukamp, 2004). The steadily increasing death rate and conflict between various land-uses are therefore likely to result in an increased demand for the development of many new cemetery sites, as well as the possible rehabilitation, reuse and recycling of many existing cemetery sites.

Furthermore, cemeteries in South Africa are classified as an unrecognised land use and are therefore often not integrated into town planning and Spatial Development Frameworks (SDF's). The increased demand for cemeteries and their lack of integration into planning processes and SDF's results in the *ad hoc* placement of cemetery sites which will undoubtedly further contribute to future health and environmental issues. A method of sustainably siting a cemetery must therefore be developed.

Although several previous studies exist regarding the environmental impacts and pollution potential of cemeteries in a South African context, there are few existing studies specifically relating to an integrated method of identifying and assessing the criteria affecting the pollution potential of a cemetery.

The various criteria affecting the pollution potential of a cemetery site are therefore crucial in determining the suitability of any given site for cemetery development. A method of determining and assessing these criteria therefore needs to be determined in order to ensure that cemeteries are sited in a sustainable manner.

In terms of national legislation, cemeteries are identified in Listing Notice 1 (South Africa, 2010) of the National Environmental Management Act, 1998 (Act No. 107 of 1998) as requiring the undertaking of a Basic Assessment before a cemetery can be considered as being acceptable or legal. This process however, requires the appointment of an Environmental Assessment Practitioner (EAP) which is usually very costly and these kinds of assessments are usually very time consuming. The EAP has no guidance in terms of the criteria to be considered and often will require the services of a specialist in order to adequately assess the conditions of a site. This will further contribute to the high cost of such investigations.

A method of more rapidly assessing a potential cemetery site using a specific set of criteria would aid in reducing the financial burden and the potential environmental impacts associated with the development of a cemetery.

1.2 Aim

The intent of this research project is to develop an assessment process that can be used to rapidly and accurately assess a given area, ultimately facilitating the identification of a number of potential cemetery sites that are sustainable. This will therefore reduce the potential environmental and social hazards posed by incorrectly sited cemeteries.

1.3 Objectives

- Undertake a literature review of existing literature pertaining to the criteria affecting the pollution potential of a cemetery and methods of cemetery siting, in order to understand impacts of cemetery development
- Applying the criteria in order to formulate an assessment process pertaining to the siting of cemeteries through the following sequence:
  - Determine a method of predicting the amount of land area required for a cemetery, derived from population statistics for a given area or community
  - Determine and quantify the criteria directly affecting the pollution potential and therefore the location of a cemetery
  - Develop a method of evaluating intended cemetery sites with regard to the criteria determined as affecting a cemetery's pollution potential and therefore its location

- Develop a method of ranking the intended cemetery sites based on the criteria, thus determining those which are the most environmentally acceptable
- Investigate the use of GIS software for preliminary desktop investigations and application of the criteria deemed decisive when locating a cemetery

- The methods and processes above will be applied to a case study in order to determine their applicability and benefit in terms of the sustainable siting of cemeteries. Additional criteria that are deemed “decisive” when selecting a potential cemetery site may again be identified.

The assessment process will be simple to use but scientifically based so as to adequately address as well as mitigate the potential environmental threats posed by cemeteries.

This assessment process can then be applied to future cemetery siting, ultimately providing government, environmental consultants and developers with a set of guidelines and therefore a method for determining suitable cemetery sites, so reducing the environmental or health hazards posed by incorrectly or randomly selected sites.

2 CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to review existing research and studies pertaining to the contamination potential of cemeteries and associated siting and critically evaluate whether the existing methods of cemetery siting are suitable. This chapter places emphasis on those studies relating to the physical criteria affecting the siting of cemeteries and therefore their pollution potential. Site specific criteria affecting the suitable siting of a cemetery and methods of identifying a number of potential cemetery sites based on these criteria will be determined. The criteria and methods established in this Chapter will therefore be used in the later Chapters to develop a methodology for the accurate assessment of any given area so to determine a number of suitable sites for the establishment of a cemetery.

2.2 Legislation and existing by-laws relating to the development of cemeteries in South Africa

Environmental legislation operates to regulate the interaction of humanity and the natural environment, thus reducing the impacts of human activity (NEMA, 1998). Legislation usually aims at controlling the emissions of pollutants as well as identifying the liability for exceeding permitted emissions and responsibility for cleanup in addition to providing guidelines for and limitations on the conservation, disturbance and use of resources (DWA, 2005).

Legislation that is not exclusively environmental may nonetheless include significant environmental components and integrate environmental policy decisions e.g. The Constitution of South Africa.

The constitution of South Africa is the supreme law of the country and provides a legal foundation for the existence of the Republic of South Africa. It sets out the rights and duties of the citizens of South Africa and defines the structure of the South African Government (Constitution of the Republic of South Africa, 1996). For these reasons, the Constitution should be the first piece of legislation dealt with by this study.

Apart from the Constitution, other laws protecting the environment from harm in South Africa do exist. These include nature conservation laws, water laws and air pollution laws, of which all feed off the constitution. The National Environmental Management Act (NEMA) was established to protect the environmental rights of South African citizens by creating a set of environmental principles. It protects the environment by ensuring that Government identifies all the effects or environmental impacts that a proposed development can have before taking place. NEMA also provides protection for workers that undertake environmentally harmful activities and whistle blowers who identify activities harming the environment (NEMA, 1998).

The sections discussed below identify all the existing legislation pertaining to cemeteries in South Africa and deal with legislation ranging from a national level to a local level.

2.2.1 South African Constitution

The Constitution of South Africa was certified by the Constitutional Court on the 4th December 1996 and signed by President Nelson Mandela on 10 December 1996. The Constitution came into effect on 4 February 1997, thus replacing and repealing the interim Constitution of 1993. South Africa's Constitution is one of the most progressive in the world and enjoys high acclaim internationally (Constitution of South Africa, 1996).

The Constitution created the right to the environment as a fundamental right. This means that all activities undertaken by government and private persons (including citizens, companies and associations) must be undertaken in accordance with this right. Only the Constitutional Court can set aside a law which goes against the right, meaning that only the Constitutional Court can amend a law or declare it as invalid.

The Constitution of South Africa guarantees its people basic human rights and provides guiding principles for society. The rights and the obligations in the Constitution belong to each person and community in South Africa. The South African Constitution recognises a healthy environment among other things as a basic human right, which is not the case in all countries.

The Constitution guarantees:

a) The right to an environment that is not harmful to human health or well-being (Section 24 (a))

- Everyone has this basic right and may take legal action to protect it.

b) The right to have the environment protected (section 24 (b))

Government must comply with our constitutional right to have the environment protected by taking the necessary protective steps. Government must make laws that:

- Prevent pollution and damage to the environment
- Promote conservation
- Balance economic, social and environmental development.

Government must ensure that reasonable measures are taken to protect the environment against harmful activities that may accompany social and economic development, even if such development is needed.

The constitution therefore provides a framework for protecting the environment from pollution and damage. As cemeteries are considered a source of environmental pollution and damage (Fiedler *et al*., 2011), the development and management thereof should be guided by this framework. The Constitution therefore provides guiding principles for society in aid of recognising a healthy environment as a basic human right. Thus access to a cemetery that is not detrimental to the health of the environment or surrounding communities must be considered as part of this basic human right.

In addition to the Constitution, South Africa also benefits from recently implemented environmental legislation: the National Environmental Management Act (NEMA). This new Act supports the principles of the Constitution and gives detail to the constitutional rights.

2.2.2 National Environmental Management Act

The National Environmental Management Act (NEMA) was promulgated in 1998 and supports the principles and rights enriched in the Constitution. The function of NEMA, as defined in the Act, is to provide for cooperative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote cooperative governance and procedures for coordinating environmental functions exercised by organs of state; and to provide for matters connected therewith (NEMA EIA Regulations, 2010).

The NEMA ensures that we all have a right to sustainable development where environmental factors are considered before development decisions are made.

Every person has the right to expect that the Government will make rational decisions that address the needs of people and ensure that development is socially, environmentally and economically sustainable. The environmental factors which must be taken into account include:

- Not disturbing ecosystems and cultural assets
- Not polluting and wasting resources
- Being responsible and cautious when using resources where uncertainty exists regarding the effects of such use.

EIA Regulations Listing Notice 1 of 2010 (Notice 544 of 2010) identifies activities that would require environmental authorisations through the completion of a Basic Assessment (BA) process prior to commencement of that activity. The procedure for the investigation, assessment and communication of potential impacts of activities identified in Listing Notice 1 must follow the procedure as prescribed in regulations 21 to 25 of the EIA Regulations published in terms of section 24(5) of the Act.

Listed Activities for the establishment of a cemetery are identified by the regulations pertaining to EIA's under sections 24(5), 24M and 44 of the NEMA 1998 (Act No. 107 of 1998). The Listed Activities may not commence without Environmental Authorisation from the Competent Authority, as described by the EIA Regulations (Government Notice No. 543 of 2010). The fact that cemeteries are recognised as a Listed Activity means that any cemetery having a size of 2500 m^2 or more will require the undertaking of an Environmental Impact Assessment (EIA) process in terms of NEMA of 1998, in order to be recognised as a legal cemetery. This is a significant controlling factor for the siting of cemeteries in South Africa.

A BA is a simpler, less comprehensive impact assessment than Scoping and EIA (S&EIA). A BA is usually undertaken for smaller scale developments of which the impacts are generally known and can be easily managed, and therefore less likely to result in significant environmental impacts. Regulation 15 of the NEMA requires that an applicant must appoint an EAP at their own cost to manage the application before conducting any form of assessment, whether an EIA or Basic Assessment (NEMA, 1998). An application for assessment must be made with respect to a specific activity, as identified by the Listed Activities specified in the NEMA Regulations, and must be submitted to the Competent Authority who will consider and decide upon the application. A BA and associated public participation must then be undertaken. A BA is completed on a template provided by the competent authority which is designed to assess all potential environmental impacts of the activity and possible mitigation measures. However, this assessment process is generic in that it has been designed to be used for the assessment of various activities.

Listing Notice 1 of Government Notice 544 of 2010 identifies the following activities which, accordingly, require that a BA Process be undertaken in support of an application for environmental authorisation:

- **Activity 21:**
  The establishment of cemeteries of 2500 square metres or more in size.

- **Activity 46:**
  The expansion of cemeteries by an additional 2500 square metres or more.

However, apart from the Listed Activities specifically relating to cemeteries as mentioned above, there are other Listed Activities in terms of Government Notice 544 of 2010 that may be applicable when developing a cemetery. These Listed Activities mostly relate to a cemetery’s proximity to water sources. The following Listed Activities may be applicable to the development of a cemetery:

- **Activity 11:**
  The construction of:
  (x) Buildings exceeding 50 square metres in size
  (xi) Infrastructure or structures covering 50 square metres or more -

where such construction occurs within a watercourse or within 32 metres of such a watercourse, measured from the edge of a watercourse, excluding where such construction will occur behind the development setback line.

- **Activity 18:**

  The infilling or depositing of any material of more than 5 cubic metres into, or the dredging, excavation, removal or moving of soil, sand, shells, shell grit, pebbles or rock from

  (i) A watercourse

  (ii) The sea

  (iii) The seashore

  (iv) The littoral zone, an estuary or a distance of 100 metres inland of the high-water mark of the sea or an estuary, whichever distance is the greater –

  but excluding where such infilling, depositing, dredging, excavation, removal or moving

  (a) Is for maintenance purposes undertaken in accordance with a management plan agreed to by the relevant environmental authority; or

  (b) Occurs behind the development setback line.

As evidenced by the fact that cemeteries are regarded as Listed Activities, the NEMA EIA process, together with existing by-laws and other regulations, encourages the sustainable siting of cemeteries by creating a set of environmental principles that must be adhered to, so to ensure that the environmental impacts of a development are assessed. However, the NEMA process is often long, requiring the services of a number of specialists and does not always recognise the specific issues such as groundwater contamination which are associated with a potential cemetery site (Richards & Croukamp, 2004).

Furthermore, the NEMA process imparts very little guidance relating to the selection of a cemetery site, and the impact assessment is largely left to the EAP. Although the EAP should evaluate all criteria that can potentially affect the pollution potential of a cemetery, there are no guidelines for identifying or methods for evaluating the specific criteria, thus resulting in many pertinent factors not being suitably assessed.

Cemetery siting criteria therefore needs to be formulated whereby EAP's are guided in terms of selecting the most suitable site, resulting in the least environmental impact for a cemetery. These criteria should therefore address the physical and location aspects of a site during the BA or EIA, as these greatly affect the suitability of a site. For example, the distance the cemetery should be from potable water sources or the permeability of the soil at a site which would determine a safe distance from water sources or drainage features.

2.2.3 Municipal By-laws promulgated with respect to the establishment of a cemetery

Municipal by-laws are passed by the Council of a municipality to regulate the affairs and the services the municipality provides, in its area of jurisdiction. The function of by-laws is to ensure that the municipality is an orderly one to work and live in (BCM, 2005).

The majority of local authorities in South Africa provide some by-laws pertaining to the siting of cemeteries, but these are generally very vague having very little guidance in terms of minimising the associated environmental impacts and focus more on the roles and responsibilities within the municipality. The by-laws identified below are those prescribed by local government such as Buffalo City Local Municipality (BCM) as well as those provided by government on a national level such as the Municipal Systems Act.

According to the BCM by-law (Mangaung Local Municipality, 2002), the establishment and management of a cemetery, and therefore the reservation of suitable land within the municipality, is undertaken by the acting Council. The establishment of a private cemetery may be considered by the council if certain conditions that the council may find necessary are met. Under section 10 (burial of a corpse); the caretaker is responsible for providing all graves, except brick-lined and concrete-lined graves. All corpses are required to be buried in a coffin, with the exception of certain cultural communities, and at least 1200 mm of soil must form a buffer between an adult coffin and the ground surface and 900 mm of soil for a child’s coffin. The dimensions of a grave site are as follows:

- Adults: 1820 mm deep, 2300 mm long and 760 mm wide
- Children: 1370 mm deep, 1520 mm long and 610 mm wide.

Only one corpse is to be buried in a grave site with the above dimensions, however, a maximum number of two corpses can be buried in a grave site with the dimensions:

- 2400 mm deep, 2300 mm long and 760 mm wide.

A concrete layer no less than 25 mm is to be cast between the two coffins to be buried in the same grave excavation.

The vagueness of these by-laws is evidenced above, as the conditions that the council may find necessary are not defined and apart from identifying cemetery responsibility, grave excavation size and requirements in terms of coffins, no guidelines are provided relating to the minimisation of the potential environmental impacts associated with a cemetery. These by-laws are however based on the framework governed by legislation such as the Municipal Systems Act, which aims at regulating key municipal organisational, planning, participatory and service delivery systems (Local Government Municipal Systems Act, 2000). For this reason the principles identified in the Municipal Systems Act relating to cemeteries will be highlighted.

The Municipal Systems Act is a policy framework for government which aims to empower local government to fulfil its constitutional objects. A local government notice, published in terms of section 13 of the Local Government: Municipal Systems Act, 2000 (Act 32 of 200), read with section 162 of the Constitution of the Republic of South Africa Act (Act 108 of 1996), propose several by-laws relating to cemeteries and crematoria. These by-laws have been formed to promote the establishment, conduct and control of cemeteries and crematoria within the boundaries of Municipalities of South Africa. These by-laws however, have very little influence over the pollution potential of cemeteries and only provide guidelines with respect to burial itself.

As in the case with the by-laws produced by the BCM, apart from identifying burial requirements in terms of grave depth and size the by-laws of the Municipal Systems Act again has no specific requirements in terms of minimising the potential environmental impacts associated with cemeteries. It appears as though very little environmental consideration was taken during the formation of such by-laws, with more emphasis being placed on the ownership of such land, as well as the allowances made for the different religious beliefs.

In order for a cemetery to be sustainable in terms of its pollution potential and environmental impact, various additional aspects need to be considered. These factors are environmentally and physically based and address the pollution potential of a cemetery.

2.2.4 Water-related guidelines and legislation related to cemeteries in South Africa.

Within a South African context the greatest issue regarding the siting of cemeteries is the availability of land, balanced against the cultural beliefs of the majority of South Africans (Tumagole, 2006). The majority of South Africans only believe in burial, which is to be undertaken in fairly close proximity to the existing settlements, therefore allowing frequent visiting by family members. The issue arises when available land is limited and the *ad hoc* placement of cemeteries results in environmental degradation, including the contamination of groundwater, which is the main water source for many South Africans. According the Groundwater Resource Assessment Phase 2 Project (GRA2), South Africa is globally ranked amongst the twenty most water scarce countries, with some 21% of South Africa receiving less than 200 mm/a [DWAF, 2003(a)]. The Department of Water Affairs (DWA), formally known as the Department of Water Affairs and Forestry (DWAF), identifies that groundwater accounts for 15% of the total water consumed in South Africa. This statistic however belies the fact that 300 towns and 65% of the population are entirely dependent on groundwater for their water supply.

The DWA stipulates in the policy for groundwater management that they strive to ensure that groundwater is managed in an integrated and sustainable manner, providing adequate protection to the resource and securing the supply of acceptable quality for all users (DWAF, 2000). It is evident from this policy that the DWA has the public and environment in mind by the development of a new sustainability program which meets the current and future waste disposal needs, so mitigating water contamination by poor waste disposal practices. In 1998, the then DWAF published the Waste Management Series: Minimum Requirements for Waste Disposal by Landfill. This waste management system provided a form of control system whereby a permit was required for a landfill site, where certain prerequisites were to be met and a set of standards adhered to prior to the establishment of a solid waste disposal site (DWAF, 2000). This same principal should be applied to the siting and development of a cemetery as there are currently no such controlling or permitting requirements stipulated by the DWA. Nevertheless, the DWA cannot achieve the desired results without cooperative governance (DWAF, 2000).

In 1992 the then DWAF published a document dealing with the management of and control over cemeteries as a source of water pollution, and states that “the risk of pollution posed by cemeteries to the quality of the water resource, especially the quality of drinking water, is regarded as acceptable, and in most instances negligible” (DWAF, 1992, p. 1). Although DWA recognise that cemeteries are similar to waste landfill sites, they suggest that cemeteries have little potential for pollution. The DWA have adopted a precautionary principal and acknowledge that poorly sited cemeteries may pose a pollution potential and have stipulated a number of requirements that should be adhered to thus reducing a cemetery's pollution potential. The requirements stipulated by DWA (1992) are listed below.

Graveyards should not be:

- Located below the 1 in 50 year flood line of a river
- Situated in close proximity to water bodies such as wetlands, vleis, pans, estuaries and floodplains
- Situated on unstable areas such as fault zones, seismic zones, dolomitic or karst areas where sinkholes and subsidence are likely
- Situated in or near sensitive ecological areas
- Situated in or on areas characterised by flat gradients, shallow or emergent groundwater
- Situated in areas characterised by steep gradients, or shallow bedrock with little soil cover, where stability of slopes could be a problem
- Situated in areas of groundwater recharge on account of topography and/or highly permeable soils
- Situated on areas overlying or adjacent to important or potentially important aquifers, where such aquifers are to be used for water supply purposes.

The requirements identified above are very similar to the requirements proposed by the DWAF – Draft Minimum Requirements for Waste Disposal by Landfill (2005), but are somewhat vague in that no allowable trigger limits have been set for the various requirements. A detailed assessment of each individual site should be conducted before a cemetery is approved. The present study seeks to determine and quantify the aforementioned DWAF requirements.

The identification of site specific criteria affecting the pollution potential and implementation of guidelines controlling the siting of cemeteries by government would greatly improve the assessment procedure for any potential cemetery site. Such constraints would assist in identifying potential issues at an early phase of the development.

2.3 Criteria affecting the siting and pollution potential of a cemetery

Physical criteria defining a site are of utmost importance and it is these criteria that need to be investigated before determining a suitable site for a cemetery. The physical nature of a site influences the decay and movement of contaminants within the ground and therefore the pollution potential of a cemetery. These factors, once studied and understood, can be used to identify a site which is suitable for the establishment of a cemetery.

This section identifies current studies and paradigms associated with the physical nature of a site and associated impacts, thus identifying the ideal physical factors resulting in the least environmental or health impacts. The sustainable siting of a cemetery therefore requires that the nature of the site is such that the contaminants emanating from the interred remains are sufficiently removed and dissolved to such an extent that human and environmental health is not jeopardised.

The information below addresses a number of previous investigations undertaken for cemetery developments and therefore attempts to determine the current paradigm of cemetery placement and site evaluation.

2.3.1 The selection of cemetery sites in South Africa: current guidance

Cemetery site selection should be based on the criteria affecting the pollution potential of a proposed cemetery. Although these criteria are vital when determining the specific characteristics of a site in terms of its pollution potential, a method of applying such factors is essential when assessing a number of potential sites based on how close the conditions are to ideal. There is a scarcity of research governing the selection of suitable cemetery sites in South Africa (Fisher, 2001).

Fisher (2001) identified nine pertinent geophysical criteria that need to be investigated on a site specific level before a site can be deemed as acceptable for the establishment of a cemetery. Fisher’s evaluation system was based on research into the mechanisms of cemetery site pollution, and field research was used to determine safe distances between cemetery sites and water resources, based on the movement of microbiological pollutant plumes. Fisher (2001) however does not provide a methodology of evaluating a site with regards to these criteria.

A subsequent study undertaken by Richards and Croukamp (2004) extended the nine criteria developed by Fisher (2001) by integrating other work relating to pollution associated with cemetery sites, as well as by introducing working examples of current cemetery sites. Pilot studies on selected cemeteries were used to qualify the selection guidelines and introduce groundwater and surface water monitoring techniques in order to determine the presence of pathogens, the rate of groundwater movement and the dilution rate of contaminants. Richards and Croukamp (2004) advocate ten criteria as a standard guideline for assessing any potential cemetery site in terms of geotechnical and environmental constraints. Although the authors identified pertinent criteria when selecting cemetery sites, they failed to provide a method of evaluating a site with regards to these criteria.

This study critically examines the criteria identified by Richards and Croukamp (2004) and provides a method of site assessment.

Richards and Croukamp (2004) identify the following criteria when considering the placement of a cemetery:

(a) Soil excavatibility

- The depth and ease of which the ground can be excavated
- Affects the depth of burial
- 1.8 m is the suggested minimum depth
- Methods can be implemented to mitigate the potential hazards associated with shallow burial.

(b) Soil permeability

- Controls the rate of groundwater movement
- Can be used to determine a safe distance form water sources and drainage features
- Ultimately affects the rate of decomposition as low permeability soils have a low oxygen content.

(c) Position in respect of domestic water supplies

- The distance the cemetery site is with regards to water features such as boreholes and storage dams

- Affects the location of a cemetery site due to a cemetery usually being located in close proximity to a community, as well as rural and informal settlements relying on un-purified surface and groundwater sources as a water supply
- Ideal distance from domestic water supplies is dependent on factors affecting the behaviour of the contaminant plume.

(d) Position in respect of drainage features

- The distance the cemetery site is with regards to drainage features such as lakes, dams, rivers, trams, gullies, gully heads and marshes
- Affects the location of a cemetery site
- Ideal distance from drainage features is dependent on factors affecting the behaviour of the contaminant plume
- Ideal distance from domestic water supplies is dependent on factors affecting the behaviour of the contaminant plume.

(e) Site drainage

- Related to topography
- Determines the amount of surface erosion, surface water pooling, flooding, grave destabilisation, human mobility and appearance.

(f) Site topography

- Surface features of a specific area
- Affects movement of ground and surface water, including associated erosion and mechanical and human mobility
- The ideal topography of a site is one that would minimise surface erosion and impede rapid internal drainage or pooling of water, therefore slightly inclined
- Mitigation measures, such as the orientation and spacing of graves, can be implemented.

(g) Basal buffer zones

- Impermeable layer (usually clay) emplaced at the base of the grave thus forming an impediment between the buried remains and the water table
- Acts as a filter, filtering and absorbing contaminants associated with the decomposition of the interred remains
- Thickness of the basal buffer zone should be a function of soil permeability and site excavation

- Suggested that 2.5 m should be suitable for most conditions
- The inability to emplace a basal buffer zone should be determined as a fatal flaw. Fatal flaws will be described in more detail within Section 2.3.2 below.

(h) Grave stability

- Competence of grave walls, verge and lip and therefore the ability of the ground to resist deformation, chemical and physical change
- Can be determined by soil type
- Ground must survive "stand-up time" which refers to the ability of the excavation to stand up unsupported for a required period of time.

(i) Soil workability

- The ease of which the soil of an excavation can be removed and returned back to the excavation pit in a homogeneous manner
- Once the excavation pit has been filled back in, a variation in compaction may occur, resulting in slumping of the grave fill and therefore associated pooling and increased surface water infiltration
- Can affect method of excavation
- May directly result in the contamination of groundwater.

(j) Cemetery size

- Usually determined by availability of suitable conditions, mortality rate and cost of investigation
- The greater number of corpses to be buried increases the potential for environmental contamination.

These ten criteria are vital in understanding the characteristics of a site in terms of its pollution potential and must be applied to any site selection process. However, as previously mentioned, these studies (Fisher, 2001; Richards & Croukamp, 2004) have not identified a method of assessing a number of proposed sites based on these criteria. Although the criteria in some cases have had maximum or minimum limits set, as is the case for the minimum depth of excavation and the recommended thickness of the basal buffer zone, the majority of the criteria have not been quantified. These un-quantified criteria will therefore need to be assigned minimum and maximum allowable limits, so ensuring more accurate analysis of the criteria and therefore the intended cemetery site.

It is these geophysical criteria which will form the basis of this study as these are considered fundamental in terms of cemetery site selection. The ten criteria identified above broadly address the physical nature of a potential cemetery site.

Similar to the studies presented above, the World Health Organisation (WHO) has investigated the physical factors affecting the pollution potential of cemeteries and proposed a set of conditions that are considered pertinent when siting and designing cemeteries. In 1998 the WHO commissioned a report addressing water pollution from cemeteries and the factors affecting their pollution potential (WHO, 1998). From this, the WHO have provided suggestions on the design and siting of potential burial sites. These factors are fairly generic in that they do not assess the specific characteristics of a potential cemetery site when compared to those identified by Fisher (2001) and Richards and Croukamp (2004). However, these factors identify conditions that are or are not suitable for the establishment of a cemetery and therefore may be termed fatal flaws in terms of cemetery siting. A fatal flaw is defined as a condition or factor that immediately determines an area as being unsuitable for the establishment of a cemetery. Usually an area exhibiting a fatal flaw would represent an area with the greatest potential for pollution associated with a cemetery. The following conditions have therefore been suggested by the WHO (1998) to be used in the siting and design of future cemeteries:

- No burial must occur within 250 metres from any potable water supply e.g. borehole, well or spring
- All burial should be at least 30 metres away from any other spring or watercourse and at least 10 metres from any field drain
- Burial pits or graves must be at least 1 metre away from solid rock and should maintain at least 1 metre of subsoil
- Burial pits must have at least 1 metre clearance above the water table
- Grave excavations must be filled in as soon as the remains are interred having at least 1 metre soil cover at the surface.

Thus using the aforementioned conditions, unsuitable areas may be immediately excluded from further analysis. The removal of fatal flaws allows greater focus on those areas which meet the requirements in terms of the criteria and the conditions identified above.

The WHO have identified the pollution potential of cemeteries from a variety of contamination events associated with a cemetery, attributing the potential groundwater contamination to increased amounts of naturally occurring organic and inorganic substances produced during decomposition of a corpse (WHO, 1998). The WHO have also recognised that low level water abstraction from wells or springs may have the greatest risk of contamination as viruses and pathogens are acquired and transported by infiltrating the groundwater system. The thickness of the unsaturated zone and the age, size and state of decomposition of corpses has been determined as the most important factors determining the impact of cemeteries on the environment. The unsaturated zone is defined as the portion of the subsurface above the groundwater table (Dent, 2007).

The WHO suggests that in most cases the contamination plume emanating from cemeteries may diminish rapidly enough to be considered safe (WHO, 1998). A contamination plume is defined as a mixture of waste chemicals, or leachate, and groundwater, usually in solution form (Richards & Croukamp, 2004). Therefore the WHO has identified conditions that may attribute to the potential contamination of groundwater sources.

These conditions identified by WHO (1998) have been proposed to reduce the potential impact associated with a cemetery. These factors do however identify areas not suitable for the establishment of a cemetery and it is therefore recommended that these be used as a fatal flaw within the site assessment methodology. The fatal flaws associated with a cemetery will be described in more detail in the later sections of this paper.

Although beneficial in that the WHO have set limits to the conditions with regards to proximity to surface and groundwater bodies, the conditions identified by the WHO are generic in nature in that they do not adequately assess the specific conditions of a potential cemetery site affecting a site's pollution potential.

The combination of the conditions proposed here with the criteria identified by Fisher (2001) and Richards and Croukamp (2004) would however provide a set of confining conditions that would result in a cemetery being suitably sited. An investigation into the contamination potential of a cemetery, associated with the various methods of burial should be undertaken so to understand the significance of the criteria proposed by Fisher (2001) and Richards and Croukamp (2004).

2.3.2 The factors affecting the environmental impacts of a cemetery, associated contamination and the degradation of the human body

In order to understand the complex interactions between the interred remains and the environment, various research undertaken by B. Dent was reviewed. The interactions between the interred remains and the environment are important to understand in order for the criteria identified by Fisher (2001) and Richards and Croukamp (2004) to be evaluated thus allowing for the application of minimum and maximum allowable limits.

Dent has contributed significantly to the available information pertaining to groundwater contamination, biological degradation of the human body, the effects and stages of adipocere formation and the control of cemetery impacts (Dent *et al*., 1995; Dent *et al*., 2004(a); Dent *et al*., 2004; Dent, 2007; and Dent *et al*., 2007). Adipocere is the post-mortem product which forms from body fat during later stages of decomposition, resulting from the hydrolysis or hydrogenation of adipose fats and acts as a retardant to decomposition. The formation of adipocere is favoured by anaerobic environments where there is sufficient moisture for the necessary reactions to occur (Dent *et al*., 2004).

Dent (2007) assessed the physical characteristics regarding the pollution potential of a cemetery, as almost every cemetery site has a different type of medium and experiences different infiltration and percolation effects, which ultimately affects decomposition. He also identifies the role that geohydrology has on the placement of a cemetery. The geohydrology of a particular site may vary considerably and should be taken into consideration, not only for environmental contamination reasons but also as a financial part of cemetery management. Most cemeteries require irrigation of their gardens from high cost piped water supplies which are constantly increasing in price and rarity, whereas the use of groundwater for irrigation would be a much more cost effective and sustainable source.

Dent *et al*., [2004(a)] investigated the factors enhancing adipocere formation. To determine the effects of soil type on adipocere formation, Dent and his colleagues conducted laboratory experiments to adequately control individual variables, such as soil type, moisture, temperature and air content.

The investigation concluded that adipocere formation was greatest on a body buried directly in the soil as opposed to burial in a coffin, whereas plastic coverings resulted in the liquefaction of fatty tissue and inhibited adipocere formation. The formation of adipocere was however greatest when a body was wrapped in clothing, plastic or polyester clothing.

These results are valuable as they indicate the likely effects of particular factors associated with the method of burial on the formation of adipocere in a soil environment. The method of burial therefore influences the formation of adipocere and thus has an implication on the decomposition of a corpse and therefore its pollution potential.

In a similar investigation, Dent *et al*., (2004) investigated the effect of grave soil type on the formation of adipocere. To ensure adipocere formation, each environment was prepared using factors known to result in adipocere, namely moisture, bacteria and a relatively anaerobic environment.

The findings of this investigation demonstrated that adipocere was able to form in a range of soil types. Sand and silty soil accelerated adipocere formation when kept in a temperate environment while clay and sterilised soil had had no effect on adipocere formation. These results are again useful in understanding the formation of adipocere in similar soil environments. However, these results cannot be extrapolated to soil environments with significantly variable temperatures and moisture contents. While this investigation is useful in identifying the effects of temperature and moisture on adipocere formation it cannot be used to determine the effect of soil type on adipocere formation.

In a more recent investigation, Dent (2007) classifies cemeteries as a special kind of land use, having a direct impact on the unsaturated zone. This owing to the fact that organic waste (corpse and coffin) is deliberately buried at a depth corresponding with the soil C horizon, via several excavations (graves). Dent (2007) contends that the unsaturated zone is the first barrier to protecting groundwater systems from pollutants and defines the unsaturated zone as a repository, an intermediate host and an agent of change. Dent (2007) asserts that for new cemeteries or extensions to existing ones, the impacts listed below must be assessed in terms of aquifer vulnerability and recharge zones. For appropriately sited and managed cemeteries, these impacts are likely to be minimal.

Impacts associated with a cemetery include:

- Excess groundwater (mounding, bucket effect, etc)
- Discharge of a salty plume
- Discharge of a nutrient plume (essentially inorganic forms of nitrogen)
- The potential for the spread of pathogenic bacteria and viruses.

This investigation is beneficial in that it identifies the importance of assessing the unsaturated zone, which has not been highlighted in previous studies. Furthermore, it provides an understanding of the degradation of the human body, environmental impacts of a cemetery and associated contamination.

Determining the physical factors that affect the siting and pollution potential of a cemetery is the first step to cemetery site selection. Methodologies of assessing these factors and determining their significance on a site selection process is therefore the next step. The following section identifies various methodologies proposed for the selection of a cemetery site. In some cases, various other methodologies applied to the selection of waste disposal or septic tank disposal systems will be addressed as there is often more information available and as previously mentioned a cemetery can be classified as a special form of waste disposal site (Dent *et al*., 2007).

2.4 Existing methodologies proposed for the site selection of various forms of waste disposal practices

An objective of this study is to determine a method of evaluating intended cemetery sites based on the criteria deemed as decisive. This needs to be undertaken in order to achieve the aim of the investigation, that being the development of a set of siting guidelines which will allow for the fairly rapid but accurate assessment of a given area, thus identifying a number of cemetery sites that are sustainable.

This process aims at identifying areas that are most suitable for the establishment of a cemetery, and eliminating those areas that are most unsuitable. In this way, the financial burden associated with detailed site investigations are avoided by assessing only the most suitable sites. The text below identifies a number of methods pertaining to site selection for various forms of waste disposal practises.

The Environmental Agency (EA) (2004) provides a method for assessing the potential pollution of groundwater from new and old cemetery developments using a tiered assessment process. Although this method deals specifically with the potential pollution of groundwater, the assessment process itself establishes the pollution potential of a specific site. The EA (2004) also makes use of certain beneficial controls when siting a cemetery which aid in ascertaining those areas which are considered unsuitable for the establishment of a cemetery and may therefore be viewed as fatal flaws.

The EA has developed a three-tier method of assessing the pollution potential of a cemetery. Each progressive tier represents a more detailed risk assessment for a higher risk of groundwater contamination associated with any given site (EA, 2004). Therefore sites that pose a high potential pollution risk due to factors such as location or size would need to be assessed in more detail and thus would require the application of a Tier 2 and/or Tier 3 assessment. The tiered assessment system is described below.

Tier 1 involves a risk screening phase and essentially consists of a desktop investigation. In this phase a hazard assessment is made using all available information such as maps and abstraction points. A hazard assessment should therefore identify and review potential contamination pathways and receptacles such as dolerite intrusion contact zones (pathways) and groundwater sources (receptacles). The vulnerability of potential receptors must also be determined, the most important receptacle being groundwater. The vulnerability of groundwater (including boreholes, wells and springs used for human consumption) is related to the criteria affecting the pollution potential of a site. The EA (2004) have identified the principal criteria to include: soil nature and type, depth of the water table, groundwater flow mechanism, aquifer type and proximity to abstraction points, water courses, springs and drains.   The vulnerability of a receptacle is determined by using a scoring system to prioritise the principal criteria. A qualitative assessment is then made, rating the vulnerability from high to low. Once the vulnerability of the site is known, the appropriate level of risk assessment must be determined. This will depend on factors such as, estimated burials per year and method of burial. If the overall risk is determined as being low, no further assessment may be required. A Tier 1 assessment only, is likely to be of use for an existing site requiring a minor change, with no prior history of environmental problems. In most other cases a Tier 2 assessment should be carried out. The development must however comply with certain controls (EA, 2004).

Such controls include:

- 250 m minimum distance from potable groundwater supply source
- 30 m minimum distance from a watercourse or spring
- 10 m minimum distance from field drains
- No burial in standing water.

These controls are therefore useful in the identification of areas that would not be suitable for the establishment of a cemetery and can therefore form a part of the fatal flaws associated with cemeteries.

Tier 2 involves a preliminary quantitative risk assessment with a detailed desktop investigation and preliminary site investigation. Tier 2 should be continued for those sites that are identified in Tier 1 as having an intermediate risk, or where the risks are not clearly defined. Minimum information requirements for a Tier 2 and Tier 3 assessment must include:

- A site description
- Number, type and sequence of burials
- Meteorological factors
- Soil/subsoil characteristics
- Superficial geology/ hydrology
- Solid geology and hydrogeology
- Groundwater quality
- Surface water quality
- Proximity to a water source/ resource
- Proximity to housing or other developments
- Data assessment protocols (water balance calculations).

For a site to be considered acceptable for a Tier 2, the assessment should indicate that no impact on groundwater is likely to occur.

Tier 3 involves a detailed quantitative risk assessment which is undertaken if the risk identified in the previous tiers is high or still not clearly defined. A Tier 3 category site is likely to have a high burial rate and total area, but also a high risk pollution potential where groundwater modelling techniques or other stochastic models will probably be necessary.

Direct investigations of soils and rock to 1 m below grave depth would be required, as well as hydrogeological investigations based on site-specific data. Should this information not be available, the appointment of a specialist to undertake such investigations will be required. A Tier 3 site will be deemed acceptable for the establishment of a cemetery once the assessment has indicated that there would be no impact upon the groundwater.

This method proposed by the EA (2004) is systematic in its approach while still being economical in that resources are expended only where necessary through the application of the tiered assessment process. For example, detailed investigations which have financial implications are only carried out on sites that have a high risk as opposed to sites that prove to have a low risk. However, although the method proposed by the EA (2004) is beneficial in terms of determining the potential for groundwater contamination as it provides a number of principal criteria to assess the vulnerability of receptors, as well as providing a number of controls when developing a cemetery, this method does not identify how to score or rank the sites according to these criteria. A method of ranking a number of sites based on the decisive criteria thus needs to be determined. The principal criteria proposed by the EA will not be utilised but rather the criteria identified by Richards and Croukamp (2004) as these criteria are more comprehensive and detailed allowing for a more accurate assessment of the pollution potential of a specific site.

The tiered structure of the methodology proposed by the EA (2004) will be adapted to form part of the methodology proposed in this study. As previously identified, a tiered assessment process will be beneficial in that a more detailed risk assessment is only carried out on those sites which prove to have a higher pollution potential.

In contrast to the EA, Price (2005) provides a method of assessing a number of potential sites for the establishment of a cemetery based on a number of criteria deemed decisive by Fisher (2001).

Price (2005) developed a weighted geotechnical and environmental classification system for cemeteries in rural and peri-urban areas of South Africa. Price (2005) identifies the potential pollution associated with the decomposition of bodies, specifically the pollution of surface and groundwater supplies, and relates burial to other forms of solid waste disposal. The weighted geotechnical and environmental classification system allows for the rapid analysis of a number of potential sites, ultimately providing an empirical method for comparing sites with regards to a defined set of criteria. By using an assessment matrix, an indication of the conditions of a site is obtained, and a weighted risk assessment allows for an objective rationale in deciding the acceptability or otherwise of individual sites. As the criteria identified by Price (2005) are consistent with those identified by Fisher (2001) they will not be discussed further. The use of a ranking matrix and the weighted risk assessment however, will be beneficial for the ranking of potential cemetery sites for this study and so will be elaborated on further.

The system developed by Price (2005) describes the geotechnical criteria to be considered, assigns a descriptive and numerical weighting to each, and concludes an overall acceptability class. The risk matrix was compiled by first deciding on the most important characteristics for site selection, and then ascribing a maximum numerical weighted value out of a total of 100 to indicate the level of importance ascribed to each attribute. Criteria are weighted so as to determine its level of importance with respect to potential for water pollution and overall cemetery location. Sites that score a rating of 75-100 are said to be acceptable, while scores ranging from 50 – 75 and less than 50 are said to be conditionally acceptable and not acceptable respectively.

This geotechnical and environmental classification system developed by Price (2005) is beneficial to this study as it is one of the few methodologies that provides a method of ranking a number of potential cemetery sites based on a set of defined criteria. This method of ranking individual sites removes emotive issues from the site selection process, therefore focusing on those criteria affecting the pollution potential of a specific site and allowing for the assessment of a given area by identifying a number of suitable sites which are ranked according to their potential for pollution from a cemetery. The ranking procedure proposed by Price (2005) will therefore be adapted to form part of this study's methodology.

The last methodology discussed will be that proposed by the DWA in their Draft Waste Management Series – Minimum Requirements for Waste Disposal by Landfill (2005). This method has application to this study as it provides a step by step approach to site selection based on a number of specific environmental, economic and social factors affecting the location of a cemetery.

The Minimum Requirements for Waste Disposal by Landfill is intended to be a reference framework for waste management standards in South Africa (DWAF, 2005). The DWA (2005) is a document detailing all the procedures, actions and information required from an applicant when authorising a disposal site. To ensure environmental protection, requirements are applied to different classes of disposal sites. It is these requirements, specifically relating to site selection, which will be investigated in order to determine their potential application to a cemetery site. Although this process was developed for the disposal of general waste, a cemetery can be classified as a special form of waste disposal site as previously mentioned (Fisher, 2001). The factors used for the site selection process of a landfill site by the DWA (2005) can therefore be applied to the site selection process for a cemetery.

The site selection process developed by the DWA (2005) is intended to allow for the disqualification of sites with inherent fatal flaws, on a site specific basis. The site selection process requires that alternative sites are considered and assessed, with a site being chosen on technical suitability and public acceptance. A possible shortfall with regards to the fatal flaws proposed by the DWA (2005) is that no maximum limits have been set. The application of maximum and minimum allowable limits to the fatal flaws will be investigated further in Chapter Three.

The site selection requirements are applied to the site selection process for waste storage areas, transfer stations, materials recovery plants and pre- and post-incineration areas, but are closely related to the factors affecting the siting of cemeteries and are therefore considered relevant to this study. For the purpose of this literature review, the site selection process identified below will be discussed in terms of a waste disposal site.

The objectives of the site selection process as defined by the DWA (2005) are:

- To ensure that the site to be developed is environmentally acceptable and that it provides for simple, cost effective design, which in turn provides for good operation
- To ensure that, because it is environmentally acceptable, it is also socially acceptable.

The site selection process commences with an assessment with regards to the need for a disposal site. The proposed class of landfill is then determined based on the quantity and quality of the waste, ambient climatic conditions and potential for leachate development. Candidate sites are then chosen based on the class, and therefore the required land area and the potential impact of the proposed disposal site in terms of mainly economic and environmental criteria. Through consultative and public participation processes, the acceptability of the candidate sites is evaluated. A more detailed investigation of the candidate sites may then be required should the site characteristics not be clear. A feasibility investigation is then undertaken on the site determined as being most suitable. This involves a preliminary EIA and geohydrological investigation that determines whether the impact of the site is environmentally and socially acceptable. The site selection process is only completed once a site has been accepted as feasible by the I&APs, relevant provincial authority and the relevant environmental department. The detailed site investigation and authorisation processes can then commence.

The sub-headings below identify the method proposed by the DWA (2005) for site selection.

(a) Approach to site selection

The identification of the required size and location of the site is an early consideration in site selection. An objective of this study is to identify a method of predicting the land area required for a cemetery. A method of identifying the site location as well as eliminating areas with inherent fatal flaws is utilised, aiding in the rapid and accurate analysis of a given area.

- Size of the site
  The size of the site is based on the size of the waste stream and will affect the size of the anticipated buffer zone. Future growth needs to be considered in order for adequate land to be made available to accommodate the future buffer zone.

- Site location
  This is determined by the areas to be served. With regards to waste, it is economical to establish the proposed facility as close to the generation area as possible, so reducing the transport distances and therefore costs. This consideration is an economic one rather than a Minimum Requirement and so will not be addressed further. However, existing and future land uses may influence site location, as incompatible land uses could prove to be a fatal flaw.

- Elimination of areas with inherent fatal flaws
  It is a minimum requirement that any site with an inherent fatal flaw must be excluded from the selection process.

The following may represent a fatal flaw:

- 3000 m from the end of any airport runway or landing strip in the direct line of the flight path and within 500 m of an airport or airfield boundary
- Areas below the 1 in 10 year flood line
- Areas in close proximity to significant surface water bodies
- Unstable areas
- Sensitive ecological and/or historical areas
- Catchment areas for important water resources
- Areas characterised by flat gradients, shallow or emergent groundwater
- Areas characterised by steep gradients, where stability of slopes could be problematic
- Areas of groundwater recharges on account of topography and/ or highly permeable soils
- Areas overlying or adjacent to important or potentially important aquifers;
- Areas characterised by shallow bedrock with little soil cover
- Areas in close proximity to land-uses that are incompatible with landfilling;
- Areas where adequate buffer zones are not possible
- Areas immediately upwind of a residential area's prevailing wind conditions
- Areas that, because of title deeds and other constraints, can never be rezoned to permit a waste facility
- Areas over which servitudes are held that would prevent the establishment of a waste disposal facility
- Any area characterised by any factor that would prohibit the development of a landfill except at a prohibitive cost
- Areas in conflict with the Local Development Objectives (LDO) process and the Regional Waste Strategy.

(b) Identifying candidate sites

Alternative sites must be considered before a final decision is made, in order to ensure the due consideration of all alternatives.

When identifying candidate sites, economic, environmental and public acceptance criteria must be considered. These criteria are interrelated, as one set of criteria may affect another. For example: the distance between the site and the waste generating area will have economic impacts due to the cost associated with haulage, while the public may prefer the site to be further away from residential areas.

- Economic Criteria

These criteria are related to the cost of obtaining, developing and operating a site:

a) The possible incorporation of the site into a regional waste disposal system, either immediately or in the near future
b) Economies of scale: larger sites tend to be more economically attractive
c) Distance of the landfill from the waste generating areas
d) The size of the landfill to justify the capital expenditure, the landfill must cater for the disposal of the waste stream over at least the medium term (>150 tonnes per day but < 500 tonnes per day)
e) Access to the landfill site: This is associated with cost, convenience and environmental implications, especially if a new road is to be constructed
f) The availability of on-site soil to provide low cost cover material. Importation of cover increases operating costs. Furthermore, cover shortage may reduce site life
g) The quality of the on-site soil. Low permeability clayey soils on site will reduce the cost of containment liners and leachate control systems
h) Exposed or highly visible sites. Highly visible sites will result in additional costs being incurred for screening
i) Land availability and/or acquisition costs. These are often dependent on present or future competitive land-uses, such as agriculture, residential or mining
j) Other miscellaneous economic or socio-economic issues. These might arise in particular instances, e.g. where the displacement of local inhabitants must be addressed.

- Environmental criteria

These criteria are associated with the potential threat the development poses towards the biotic and abiotic environment, particularly water resources.

a) The distance to ground or surface water. The greater this distance, the more suitable the site is in terms of lower potential for water pollution
b) The importance of ground or surface water as a water resource. The greater the resource value of the water, the more sensitive the establishment of a landfill on account of the potential for water pollution
c) The depth of soil on the site. The greater the availability of soil, the more cost effective it will be for the landfill to meet the Minimum Requirements for operation. The landfill will thus be more acceptable in terms of cover material and therefore control of nuisances
d) The quality of on-site soil. Low permeability soils reduce pollution migration and are therefore favoured
e) Valleys where temperature inversions can occur. This could promote the migration of landfill gas and odours into populated areas
f) The sensitivity of the receiving environment. The development of a site in a disturbed environment is preferable to development in a pristine environment.

➢ Public acceptance criteria

This set of criteria relate to issues associated with adverse effects on public health, quality of life and local land and property values. They may also include issues of public resistance to the development. Failure to meet the public acceptance criteria may constitute a fatal flaw.

a) The displacement of local inhabitants: This usually arouse public resistance
b) Exposed sites with high visibility: These are less desirable than sites that are secluded or naturally screened
c) The sensitivity of the environment through which the access roads must pass: The shorter the distance to the site through residential areas, the more acceptable the site
d) Prevailing wind directions: New landfills must be sited downwind of residential areas
e) The distance to the nearest residential area or any other land-use which is incompatible with landfilling: The greater the distance from incompatible land-uses, the lower the risk of nuisance problems and hence resistance to the facility

f) Buffer Zones: to protect the public from the adverse effects of groundwater contamination, a buffer zone must be provided around the development. These are separations between the site boundary and other land-uses. No development should take place within such buffer zones, and the size of the buffer zone depends on proximity to water sources, requirements of the Department and provincial authority and site specific factors affecting the environmental impact.

Through the elimination of areas with inherent fatal flaws and taking note of all the criteria and critical factors listed above, a number of candidate sites can thus be identified. These may include or be supplemented by candidate sites identified by I&AP's and should be presented on a map with a suitable scale.

The approach proposed by the DWA (2005) for the selection of a potential landfill site is systematic, focusing on not only environmental but also social and economic aspects. Several of the criteria and steps used for selecting a landfill site are not relevant to the selection of a cemetery site and therefore have been removed for the purposes of this study, with focus being made on the environmental criteria. Conversely, there are additional criteria that would be specific to the selection of a cemetery site and will therefore need to be integrated into the cemetery site selection process. This process therefore utilises the criteria developed by Richards and Croukamp (2004) allowing for their application to the cemetery site selection process.

(c) Ranking of candidate sites

The selected candidate sites need to be technically evaluated and compared, so determining their acceptability. When there are many candidate sites, a coarse screening exercise is undertaken to eliminate unsuitable sites and those displaying a fatal flaw while identifying the top ranking sites. This coarse screening exercise is usually undertaken by specialists and the results presented to I&APs in a Candidate Site Report. A discussion document or matrix can be used for the coarse screening exercise (DWAF, 2005).

The DWA site selection process is a reference framework for waste management in South Africa, in that the framework aims at proactively protecting the environment and water quality in an affordable and practical manner (DWAF, 2005). As identified previously, this method of site selection is specific to general waste disposal facilities and not cemeteries. This method will therefore need to be adapted in terms of relating it to the selection of a cemetery site. This method provides a systematic approach to site selection, including the identification and ranking of candidate sites and will therefore be utilised in this study. The elimination of areas exhibiting inherent fatal flaws is of particular significance, as this method removes areas deemed as totally unacceptable for the establishment of a specific disposal practise, thus removing the need to investigate sites that would ultimately prove to be unsustainable. The fatal flaw section will therefore be applied to a cemetery context by suggesting a number of fatal flaws directly related to a cemetery, based on the recommendations of previous studies such as those undertaken by WHO (1998), the EA (2004) and the DWA (2005).

2.5 Conclusion

From this review it has been determined that there is little published information relating to the siting of cemeteries. Various sources were however available and mainly included work done by Dent (landfill sites, cemetery processes and geological factors), as well work by Fisher (1990, 1993 & 2001) and Richards & Croukamp (2004) with regards to cemetery investigations. An additional source of information was the work done by another South African author, Tumagole (2009), on the ability of new and existing cemeteries to cope with the burial requirements of South Africa, groundwater contamination and legislation governing cemeteries. Various other sources, such as the WHO (1998), EA (2004) and various by-laws promulgated by the various municipalities are also referenced.

While National Environmental Legislation has been promulgated to assess the environmental impact associated with the location and extension of cemeteries, the process is usually long, requires the assistance of specialists and does not always recognise the specific issues associated with a cemetery site. The NEMA process therefore has very little control over the selection of a cemetery site. Local bylaws govern only the depth and size of graves in certain areas. There is no legislation regarding safe distances to water abstraction points, cut-off barriers, erosion prevention etc.

When all factors affecting the pollution potential of a cemetery are weighted against each other, the principal consideration is always groundwater contamination and it is the factors affecting its protection that will be considered when selecting a suitable cemetery site. Many sources have identified cemeteries as a definite cause for groundwater pollution, while others have not recognised cemeteries as a potential environmental issue. The majority of studies have however agreed that if not sited or developed correctly, a cemetery has the capacity to produce pollution that may result in groundwater contamination.

The cemetery siting guidelines developed in this study will be geotechnically orientated, determined by investigating the various geotechnical criteria affecting the pollution potential of groundwater through decomposing organic matter. Reference will be made to the existing legislation pertaining to the siting of landfills and the site selection process identified by the DWA (2005), the tiered assessment process developed by the EA (2004) and a method of ranking a number of proposed cemetery sites developed by Price (2005) using the criteria deemed as decisive when selecting a cemetery site by Richards and Croukamp (2004). Using all of the available and relevant studies, a set of guidelines will be developed which will specifically address the environmental hazards associated with incorrectly sited cemeteries. The guidelines for cemetery site selection developed through this study will then be applied to a case study in order to determine their applicability and effectiveness in selecting suitable and sustainable cemetery sites.

3 CHAPTER 3: METHODOLOGY

3.1 Introduction

As indicated in Chapter Two, a cemetery should be sited in a way that will address potential public health and safety concerns, minimise associated environmental impacts and provide a method of body disposal that is economically viable. To this end, the methodology developed in this chapter will:

- Synthesise a number of existing methodologies that specifically identify the pollution potential of cemeteries
- Provide a means of predicting the land area that would be required for a cemetery
- Identify the criteria affecting the location and therefore the pollution potential of a cemetery
- Provide methods of evaluating and ranking a number of potential sites based on their suitability.

No single existing investigation, as far as could be established, has provided a methodology that addresses all of these factors in an integrated manner. This study therefore provides an integrated approach where all these factors are addressed in a logical sequence. The criteria deemed as decisive by existing studies were in most cases not quantified by the relevant authors, therefore leaving many of the criteria up for interpretation. This study will apply minimum and maximum allowable limits to these criteria, therefore aiding in the ranking process, whereby each of the criteria for a specific site is allocated a score based on how close to ideal the conditions are for the establishment of a cemetery. Criteria not relating to a cemetery context, such as those developed by the DWA (2005), will also be modified in this chapter in order to have a particular relevance to this study. A cemetery case study will be used in Chapter Four to qualify the selection guidelines presented below.

3.2 Methodology for candidate site identification

A staged approach to the cemetery site selection process is proposed and forms the backbone of the methodology of the current study. This procedure will be partly based on the assessment procedures developed by the EA (2004), Price (2005) and the DWA

(2005), using the criteria deemed as decisive by Fisher (2001) and Richards and Croukamp (2004) when selecting a cemetery site (refer to Section 2.4). The assessment procedures will be refined, in terms of evaluating the pertinent site criteria and combined, such that the pollution potential of a cemetery can be comprehensively assessed on a site specific basis, thus enabling various sites to be ranked according to their suitability for the establishment of a cemetery. The methodology will ultimately result in the determination of a single site which proves to be acceptable for the establishment of a cemetery in terms of its pollution potential.

A staged approach was considered most appropriate as it provides, according to the EA (2004), a method of undertaking a more detailed risk assessment for a greater level of groundwater contamination for a cemetery on any given site.

The DWA (2005) developed a process of site selection for the establishment of waste disposal facilities, where sites are assessed and chosen based on technical suitability and public acceptance. The objective of the DWA (2005) site selection process is to ensure that the site to be developed, is environmentally and socially acceptable and that it provides for simple, cost effective design, which in turn provides for good operation. This method provides a step by step approach to site selection, identifying what issues need to be addressed and when. For this reason, this approach to site selection, together with the staged approach identified above, will form the bases of the site selection process formulated in this chapter. In order for a site to be assessed in terms of its pollution potential, the criteria affecting the pollution potential must be determined.

Fisher (2001) together with Richards and Croukamp (2004) proposed a set of ten pertinent criteria enabling the selection of an environmentally sustainable cemetery site. As indicated previously, these criteria are based on mechanisms of cemetery site pollution. The criteria will therefore be used to assess a site in relation to its pollution potential. However Fisher and Richards and Croukamp, do not assign minimum and maximum allowable limits or suggest a method assessing a proposed site in respect of the criteria. Therefore a process of evaluating a site with regards to these criteria is proposed, including the application of maximum and minimum allowable limits for each criterion.

Price (2005) developed an assessment process whereby a site is evaluated based on a number of criteria determined as pertinent. This assessment process allows for the individual criteria affecting the suitability of a site for a cemetery to be assessed and sites scored. This assessment process will be utilised as part of the staged approach mentioned above allowing individual sites to be ranked, thus resulting in an integrated approach to site selection.

The staged approach of cemetery site selection that was developed is outlined in Figure 1.

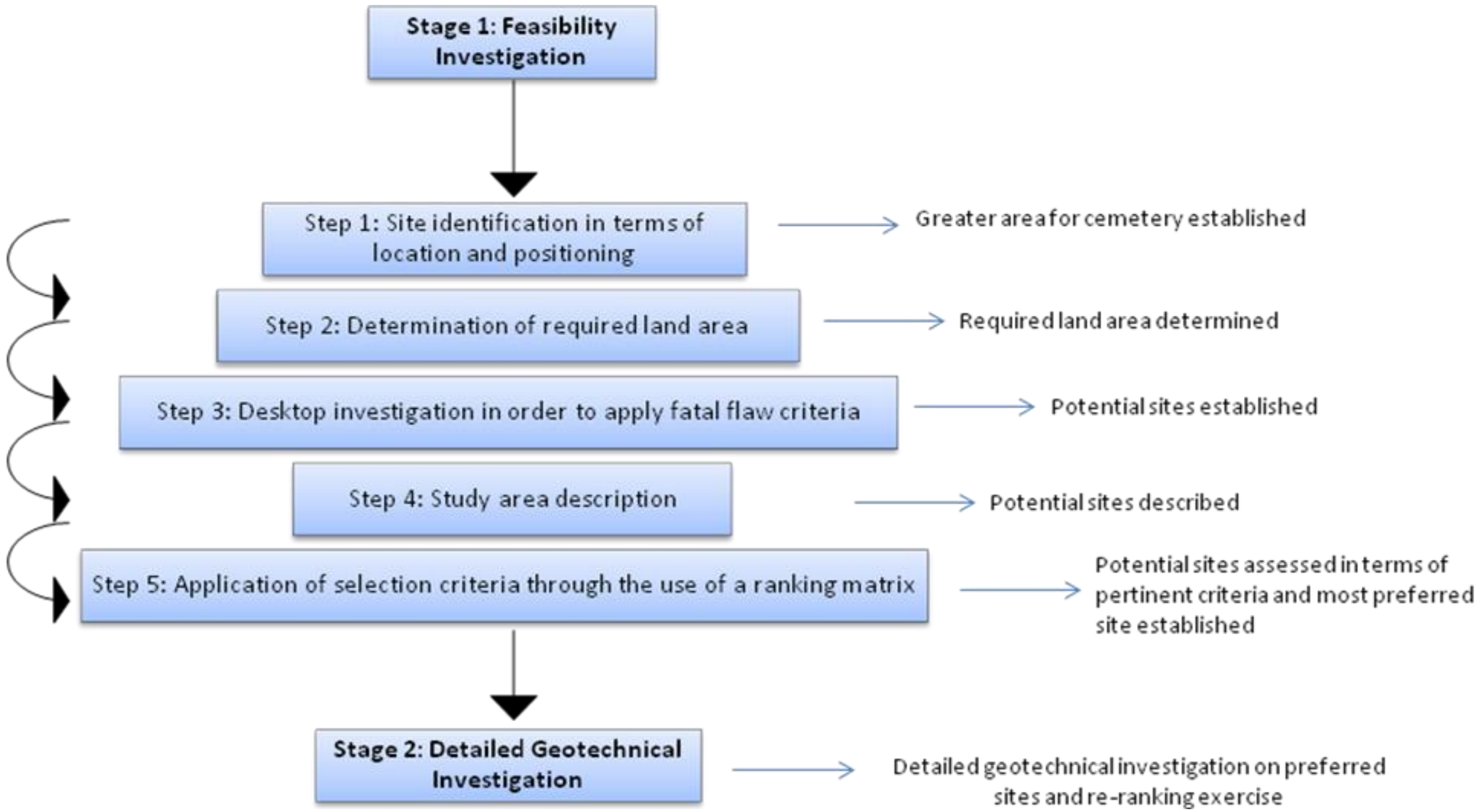

Figure 1: The staged approach to cemetery site selection.

The first stage in Figure 1 involves a **Feasibility Investigation** based on the tiered methodology proposed by the EA (2004). This stage is proposed as it rapidly and cost effectively identifies potentially suitable cemetery sites, while at the same time eliminating those that exhibit features (such as wetlands, surface water ponding and steep slope angles) not suitable for the establishment of a cemetery. This stage will be broken up into five steps, each step aimed at progressively and logically assessing the characteristics of each potential site. Ultimately this stage will determine s number of potential sites that prove environmentally feasible for the construction of a cemetery which will be carried forward through to Stage Two. The Feasibility Investigation involves the following five steps:

The **first step** involves **site identification** in terms of its location and positioning and is based on the site selection process developed by the DWA (2005). Site identification involves determining the study area for the establishment of a cemetery and is essentially determined by the communities to be served by the cemetery. It can therefore be related to the identification of a need for such a development. The study area for the establishment of a cemetery is initially based on the location of the community or communities to be served. The exact location of a site can however only be determined after the application of the subsequent steps of this methodology.

The **second step** involves **determining the required land size** for a cemetery site by using population statistics such as population size and mortality rates. This step is also based on the site selection process developed by the DWA (2005) but will utilise a formula from the City of Johannesburg, Department of Development Planning (1985) with which the required land size can be calculated without having access to any prior burial statistics. This formula is therefore beneficial in areas where population statistics have not been recorded.

This step therefore predicts the required land size of cemetery site based on population statistics such as total population, mortality rate and projected growth rate.

The third step involves a **desktop investigation** using **fatal flaws** developed by DWA (2005) and modified with recommendations from WHO (1998) and the EA (2004). Although the DWA (2005) identified a number of fatal flaws, no method of assessing a site with regards to these has been proposed. Therefore for this study, the application of the fatal flaws through a desktop investigation is proposed. A desktop investigation is a tool used at an early stage whereby existing data and information is collected from the public domain, scientific and commercial databases and any available project sources and is used to characterise a given area (Engelbrecht, 2000). The fatal flaws are criteria that would immediately render a site unsuitable for the development of a cemetery and therefore are important criteria to consider.

The fatal flaw analysis removes areas with inherent fatal flaws and thus reduces the search area and saves on time and resources spent on an area that would prove unacceptable for the establishment of a cemetery. This stage will therefore identify a number of potentially suitable sites, which do not exhibit a fatal flaw and are large enough to meet the cemetery size requirements identified in Step Two. The number of sites determined in this stage is dependent on the required land area and availability of land not exhibiting a fatal flaw. It is however recommended that a minimum of four sites should be carried forward through further investigation in Step Four, thus allowing for alternatives, should a number of sites prove unsuitable in the later steps.

Step Four involves **describing the study area** whereby areas that exhibit no fatal flaws in Step Three are described in terms of local geology, geohydrology and aquifer vulnerability. Step Four is based on the site assessment procedures developed by the DWA (2005) and Price (2005). Information relating to the study area will be obtained from secondary sources of information, such as geological and hydrological maps, accompanying brochures pertaining to the relevant areas and the tables developed by the DWA (2003). The purpose of this step ensures a better understanding of geological and geohydrological constraints faced by the study area thus allowing inferences associated with these constraints to be made with regards to the pollution potential of a site. This step will also aid in the assessment of the site selection criteria in Step Five below.

Step Five involves the **application of site selection criteria** identified by Fisher (2001) and Richards and Croukamp (2004) through the use of a ranking matrix in order to determine the suitability of a site for a cemetery. The assessment of the site selection criteria such as permeability and excavatability is made by determining the site's specific characteristics such as soil and rock properties, aquifer type and distance from water sources. The assessment of these criteria is undertaken through the use of GIS analysis software utilising data layers containing information on the site selection criteria, by investigating existing studies, literature or reports relating to the relevant area, or through field investigations. GIS data layers are visual representations of information relating to a specific factor or number of factors such as soil type and surface water bodies. These data layers can be overlaid using GIS analysis software thus producing a map of an area depicting information relating to factors to be assessed. These maps are then used to determine site characteristics such as rock and soil type and proximity to water bodies among others.

However, in order to assess the criteria mentioned above, a ranking matrix has been developed. A ranking matrix identifies a range of values for each criteria, therefore identifying a minimum and maximum allowable value. A site is then assessed with regards to these criteria in relation to the values identified in the ranking matrix. Each criteria is assigned a score according to the site conditions. Once the criteria for each site has been assessed and scored, the results can be tallied allowing the sites to be ranked according to which site proved to be the most acceptable for a cemetery based on the findings of the application of the site selection criteria. The significance of each criteria is however not equal as some criteria have a greater pollution potential than others. The significance of each criterion is determined using a flow diagram presented in Figure 2 presented in Section 3.4 on page 73 . The significance will affect the criteria value determined for each criterion through the application of a percentage. For example topography was determined as having 50% significance compared to permeability, which has 100% significance. Therefore, the score achieved by a site for topography will be reduced by half while the result achieved by a site for permeability will remain at 100%.

It is recommended that a minimum of three potential sites be identified during this step, thus reducing the number of sites by one from Step Four. The purpose of identifying three sites is to reduce the study area allowing time and resources to be more focused on sites that prove to be most acceptable while still providing alternative sites. The provision of alternative sites removes bias during the site selection process ensuring sites are selected on technical suitability and also satisfy the requirements with regards to the NEMA (2010) where the assessment of alternative sites is a requirement. A Public Participation Process should then take place whereby a meeting is held to present the top three sites and the affected communities are given the opportunity to voice their opinions and feelings with regards to the proposed sites. Undertaking the Public Participation Process ensures that communities have an opportunity to raise concerns on any potential issues and share their knowledge of site characteristics.

Stage One thus attempts to identify the broader location, cemetery size and a minimum of three potential sites.

Stage Two involves a **detailed geotechnical investigation**, following the tiered approach developed by the EA (2004). A detailed geotechnical investigation involves the determination of the behaviour of earth materials by investigating subsurface conditions and materials; the determination of the relevant physical/mechanical and chemical properties of these materials; the evaluation of the stability of natural slopes and man-made soil deposits; assessment of the risks posed by site conditions and the design of earthworks and structure foundations (Terzaghi *et al*., 1996). It is recommended that the two highest ranking sites based on the results of Stage One should be assessed in this stage, thus only spending time and resources on a minimum number of sites while still providing alternatives should the conditions of one of the sites prove to be unacceptable for a cemetery during the detailed geotechnical investigation. The two sites assessed in this stage are then re-ranked according to the findings of the detailed geotechnical investigation. The highest ranking site will therefore be proposed as the site for the construction of a cemetery.

The method of site selection developed in this Chapter will then be applied to a case study in Chapter Four, therefore testing its effectiveness in assessing a number of potential sites and determining whether or not the methodology needs to be amended.

The process in its entirety is described in more detail in the following sections.

3.3 Stage One: Feasibility Investigation

This stage aims at rapidly and cost effectively assessing the feasibility of an area for the establishment of a cemetery and therefore identifying a potentially suitable site that would have a reduced impact on the environment. The feasibility of an area will be determined through the use of a scientifically based site assessment process, using the methodology presented below.

As previously mentioned, this stage is divided up into five sub-steps as detailed below.

3.3.1 Step One: Site identification in terms of location and positioning

The area for the establishment of a cemetery would usually be determined by the location of the population to be served and is therefore related to the identification of the need for a cemetery (DWAF, 2005). The proximity of the site to the serving community is an important consideration as this will affect the distance that relatives will have to travel to pay their respects, with sites closest to the target community being preferred. In 2004, GIBB were requested by the BCM to undertake a site identification and assessment study of potential sites in the Kaysers Beach area within the southern coastal portion of BCM. As part of this investigation GIBB undertook a social consultation to determine reasonable distances relatives are likely to travel to a cemetery site in both an urban and rural setting. Social consultation was carried out via door to door discussions and the distribution of a short questionnaire. Through the social consultation it was determined that a reasonable distance that a rural and urban community is likely to travel will be in the region of 10 km and 20 km respectively and should be applied from the centre of the area to be served. GIBB however suggest that a level of leniency can be applied to these distances as some urban areas are small in extent and thus a distance of 20 km would be a great distance to travel. A 10 km distance would therefore be more suitable in these instances.

Once a need for a cemetery has been established and therefore the study area determined the required size of the cemetery must then be calculated.

3.3.2 Step Two: Size of the cemetery site

Richards and Croukamp (2004) recognise that cemetery size needs to be addressed early in the site selection process thus ensuring the assessment of land areas large enough to deal with the required burial rate for a specific area. Cemetery size is therefore discussed separately from the other criteria deemed decisive when selecting a cemetery site, which are discussed in more detail in Section 3.3.5 of this paper.

The size of any given cemetery is determined by the availability of suitable conditions (suitable drainage and bedrock conditions for example) (Richards & Croukamp, 2004). Richards and Croukamp (2004) suggest that for a cemetery site to be viable in a South African context, a minimum continuous area of at least two to three hectares which can accept burial for approximately 30 years needs to be investigated. Therefore a 30 year cemetery life expectancy has been used to determine the required land size for a cemetery in this study.

Price (2005) suggests a minimum realistic size should be one to two hectares and proposes that instead of having numerous smaller sites, each becoming a potential node for groundwater contamination, it would be better to have a regional facility servicing a larger percentage of the population.

A formula developed by the City of Johannesburg, Department of Development Planning (1985) can be used to predict the required size of a cemetery site based on variables such as total population, mortality rate and the projected growth rate of a community where burial statistics are unavailable.

The formula for predicting the required cemetery size is as follows:

Part one:

$$E=\frac{A}{1}\times\frac{B}{1000}$$

E = Total mortalities expected in the community per year

A = The total population of the community (The total population of the community in 30 years from now, using the current growth rate)

B = The mortality rate per 1000 people per year

Part two:

$$X=B_1\times C\times D_1$$

X = total surface area required for child graves

B_1 = percentage of the total mortalities are children (younger than ten years), therefore a percent of **(E)**. Usually approximately 40% of mortalities are children

C = Life expectancy of the cemetery (usually planned for 30 years)

D_1 = gross area required for a single child's grave (2.37 m^2)

Part three:

$$Y=B_2\times C\times D_2$$

Y = total surface area required for adult graves

B_2 = percentage of total mortalities are adults (older than ten years), therefore a percentage of **(E)**. Usually approximately 60% of mortalities are adult

C = Life expectancy of the cemetery (usually planned for 30 years)

D_2 = Gross area required for an adult grave (5.33 m^2)

Part four:

$$Z=X+Y$$

Z = The total area required for a cemetery

X = Total surface area required for child graves

Y = Total surface area required for adult graves

The total area required for the cemetery, determined form the above calculations, will then be used to establish whether or not the sites identified in Step Three are large enough to meet the required land size.

3.3.3 Step Three: Desktop investigation in order to apply the fatal flaw criteria

Fatal flaws are probably the most significant of all the siting criteria mentioned and therefore should be applied early in the site assessment procedure (DWAF, 2005). The method of applying a fatal flaw and therefore disqualifying unsuitable sites at this early stage has been based on the procedure proposed by the DWA (2005), in which potential areas are examined and those displaying fatal flaws removed. The fatal flaws identified by the DWA (2005), relate specifically to the disposal of waste by landfill and therefore do not all apply to a cemetery. The WHO (1998) and EA (2004) alternatively have recommended several generic conditions that should be adhered to for the establishment of a cemetery. Where necessary, the fatal flaws identified by the DWA (2005) were applied to a cemetery context using the conditions identified by the WHO (1998) and the EA (2004) while the factors having no significance were removed. A major shortfall with regards to the fatal flaws proposed by the DWA (2005), the WHO (1998) and the EA (2004) is that they are fairly broad and generic in that no maximum or minimum limits have been set. For this step to be accurate, the fatal flaws proposed below have been quantified based on existing literature, thus setting a maximum and minimum limit for each. By applying maximum and minimum allowable limits, the study area can be more accurately assessed allowing for the precise qualification and exclusion of potential sites. During the application of this methodology to a case study, the fatal flaws presented below will be tested in order to ensure that the limits which have been set are realistic and achieve the desired result.

The application of fatal flaws to the greater area of investigation identified in Step One, is usually done through a combination between a desktop investigation and preliminary field investigations. The desktop investigation often utilises GIS or CAD software to manipulate and display data thus producing maps depicting, at first glance, areas suitable or unsuitable for cemetery development. In the absence of data regarding the fatal flaws, they will need to be assessed in the field. GIS is a powerful modelling and analysis tool used to improve understanding and decision-making regarding a range of data. GIS data layers are compilations of data relating to a specific feature and are represented by visual characters such as points, lines and polygons (Esri, 2011). This GIS mapping process is termed negative mapping, whereby data layers relating to the fatal flaws are used to indicate conditions unsuitable for the establishment of a cemetery. Data layers relating to the fatal flaws will also be layered together with other features such as settlement distribution, Spatial Development Frameworks (SDF's), land-use and urban edges in order to provide a more holistic view of the area in question. The assessment of fatal flaws can however be complex and may require the services of a specialist in order to adequately detail a particular fatal flaw.

A number of potential sites will then be identified from the areas determined as not exhibiting a fatal flaw. The number of sites identified would be based on the required land area and availability of land not exhibiting a fatal flaw. It is recommended that a minimum of four sites should however be identified and carried forward for further investigation in Step Four, thus allowing for an alternative to be assessed should a number of the identified sites prove unsuitable in the later steps of this study.

The fatal flaws presented below are a culmination of the work undertaken by DWA (2005), WHO (1998) and the EA (2004) with minor additions from authors such as Price (2005) and Tumagole (2009).

The following fatal flaws will automatically disqualify a potential cemetery site due to the adverse impact on the bio-physical environment:

- The exclusion of areas falling within the 1:50 year flood line
- Areas within 500 metres of a wetland
- Areas within 250 metres of any potable water supply

- Areas within 30 metres of significant surface water bodies (such as dams, lakes and rivers) and 10 metres from any field drain (surface or subsurface drainage system used to control the water table)
- Areas within 50 metres of all unstable areas and includes fault zones, fault plains, seismic zones and dolomitic or karst areas
- Areas within 50 metres of sensitive ecological, historical or protected areas. This includes all national parks, nature reserves, forests, protected areas, Critical Biodiversity Areas (CBA) and areas of ecological and cultural or historical significance are excluded
- Areas below or greater than 2 ° - 9 ° slope angle are to be excluded
- Areas within 1 metre of the water table where a sufficient unsaturated zone separating the interred remains and the groundwater would not be possible
- Areas of groundwater recharge on account of topography and/or highly permeable soils
- Areas overlying or adjacent to important or potentially important aquifers
- Areas characterised by shallow bedrock with less than 1 metre topsoil and subsoil cover
- Areas within a 100 metres of land-uses that are incompatible with cemeteries
- Areas over which major servitudes are held that would prevent the establishment of a cemetery (e.g. Eskom and Department of Roads and Transport servitudes)
- Areas within 50 metres of any dolerite intrusions.

Once the fatal flaws have been applied and a number of potential sites identified, the next step is to describe the study area in terms of its geology, geohydrology, aquifer vulnerability and land ownership.

It is proposed that once the potential sites have been identified in this step, a meeting should be held with the relevant authorities and municipal representatives. During this meeting, the sites identified during this step will be presented and any comments collected. This will aid in the determination of any sites which may have potential conflict with regards to their position at an early stage.

3.3.4 Step Four: Site description

In Step Four, sites that were identified in Step Three are described further to provide an indication of the suitability of soils to ameliorate the leachate produced during decomposition of the human body and assess its potential impact on groundwater sources. The degree of which the concentration of contaminants is reduced (attenuation) is dependent on the type of soil and rock and therefore aquifer pollution vulnerability is based on the aquifer characteristics. The travel time of the contaminant also affects the contamination potential as the greater the travel time the greater the opportunity for contaminant attenuation (ARGOSS, 2001). The risk of contamination of the underlying aquifer depends on the underlying rock formations. For example, areas where the underlying formations are fractured and shallow ground water conditions occur will be high risk. Whereas areas characterised by shallow formations with a low permeability (i.e. soil with a high clay percentage and the bedrock is not fractured with no preferential flow paths to the regional aquifer and surface water bodies) will be low risk.

This step therefore further provides an indication of the site specific environmental conditions, geology, hydrological conditions and soil profile to be expected and allows inferences to be made in respect of a site's potential to contaminate the underlying groundwater. Furthermore, this step allows for more suitable and accurate analysis to be undertaken in Step Five. The availability and ownership of the sites must also be determined as this may greatly impact the acquisition and use of such land. Municipal land is generally preferred over private land due to most cemetery developments being commissioned by government as well as acquisition costs involved in acquiring privately owned land.

The following site characteristics need to be described:

(a) Geology

The geological rock units, including any major faults and dolerite intrusions must be identified allowing inferences to be made with regards to the characteristics of the underlying rock (lithology, porosity and associated permeability), potential and depth of groundwater properties and depth of the soil expected on site. Identifying the lithology, the porosity and permeability can be determined allowing the groundwater potential and its possible movement to be established. Faults, fractures and dolerite intrusions are also assessed as they transmit water very easily and rapidly thus increasing the permeability

(ARGOSS, 2001). These structures are therefore commonly associated with groundwater creating the potential for groundwater pollution (Price, 2005). The geology of the study area can be identified using the 1:250 000 Geological map series published by the Geological Survey of South Africa.

(b) Geohydrology

The geohydrology of a site is assessed in order of determining the pollution potential a specific site may pose on underlying groundwater reserves. A geohydrological assessment is made in order to determine the height of the water table, any structures that may affect the movement of groundwater, the proximity to existing groundwater abstraction points and the variations in yields observed at the existing groundwater abstraction points. The presence of dolerite intrusions or dolomitic or limestone units are important considerations and need to be assessed as these structures affect the movement of groundwater and therefore the pollution potential of a given site.

- Dolerite and dolomite inferences

  Dolerite intrusions represent the best targets for aquifer location as groundwater commonly concentrates along the margins of the intrusion, thus posing a threat to groundwater (Price, 2005). These areas therefore need to be protected. Price (2005) recommends that a 50 metre wide protection buffer zone be applied either side of such intrusions during the fatal flaw analysis. All areas underlain by dolerite should therefore be flagged as being potentially water-bearing and should only be developed after adequate geotechnical assessments have been completed. The presence of dolerite therefore needs to be described and documented.

  Similarly, the presence of dolomites represents a fatal flaw. Fisher (2001) notes that due to the highly variable nature of sub-surface dolomites and their association with groundwater, safe distances are almost impossible to predict in these areas. In the presence of dolomites, detailed geohydrological investigations must be undertaken to determine safe distance from such area, before the establishment of a cemetery.

- Borehole census

  A borehole census needs to be undertaken in order to identify the distance of groundwater abstraction points from the cemetery site. This factor has an influence over the distance the contaminant must travel before reaching potable water sources. These distances will be used during Step Five of this methodology, when sites are ranked with regards to their proximity to water sources (DWAF, 2005).

- Variations in borehole yield

  Variations in borehole yield can be considered as a measure of the contamination potential of a site in that a borehole with a greater yield will have a greater contamination potential than a low yielding borehole (DWAF, 2005). Information regarding borehole yield is not always available and therefore may need to be determined during the detailed geotechnical investigation undertaken in Stage Two.

(c) Aquifer vulnerability

The vulnerability of an aquifer is related to the ease of which the aquifer is affected by contaminants caused by human activities and is assessed by determining how long water takes to move from the ground surface to the water table (DWAF, 2003). The vulnerability of an aquifer is therefore related to the distance that the contaminant must flow to reach the water table, as well as the ease with which it can flow through the soil and rock layers above the water table [DWAF, 2003(a)]. The vulnerability of the aquifer is greatest in areas with high rainfall and high water tables or where cemeteries are underlain by fractures or cavernous rock (Engelbrecht, 2000). Areas of high permeability or very fine soils where anaerobic conditions prevail should be avoided for cemetery sites.

Table 1 presents the groundwater vulnerability classification system which is used to determine the vulnerability of a site based on the nature of the contamination source and underlying soils or geology. The DWA (2003) identify cemeteries as a contamination source but state that cemeteries pose a negligible threat to groundwater due to the very slow rate of decay and the rapid die-off of bacteria and viruses. However, Fisher (2001) and Dent (2007) argue that cemeteries do in fact pose a threat to aquifers and indicate that the vulnerability of an aquifer must be determined. Table 1 can be used to rapidly determine the vulnerability of groundwater aquifers by determining the ground conditions and distance to the water table through the findings of this step. High risk areas must be flagged for further investigation during the detailed geotechnical investigation undertaken in Stage Two.

Five broad classes of aquifer vulnerability are defined:

Table 1: Vulnerability of groundwater aquifers to hydrological conditions

Ground Conditions	Distance to Water Table	Vulnerability Class	Definition
Highly fractured rock	Short distance to water table (< 2 m)	EXTREME	Vulnerable to most pollutants with relatively rapid impact from most contamination disposed of at or close to the surface
Gravel or fractured rock	Medium distance to water table (2-5 m)	HIGH	Vulnerable to many pollutants except those highly absorbed, filtered and/or readily transformed
Fine sand, deep loam soils with semi-solid rock	Medium to long distances to water table (5-10 m)	MEDIUM	Vulnerable to inorganic pollutants but with negligible risk of organic or microbiological contaminants
Clay or loam soils with semi-solid rock	Long to very long distance to water table (10-20 m)	LOW	Only vulnerable to the most persistent pollutants in the very long term
Dense clay and/or solid impervious rock	Very long distance to water table (>20 m)	NEGLIGIBLE	Confining beds present with no significant infiltration from surface areas above aquifer

Source: adapted from DEA (2003; 09)

(d) Land use and land-ownership

The current land use and land-owner of a potential site is an important consideration as alignment with strategic plans is likely to affect the acquisition process, streamline the approval process and increase the possibility of a positive decision by the authorities.

Land-ownership in this case relates to the current land zoning and availability of a piece of land. The availability of land is often dependent on present or future competitive land-uses (DWAF, 2005). The number of landowners potentially affected and the heritage significance of a site will also affect site acquisition and therefore must also be considered.

Therefore the land availability and land zoning must be confirmed before carrying the proposed sites forward for further investigation. Generally municipal land is preferred over private land as cemetery developments in South Africa are most often commission by government. In addition suitably zoned land would be preferred over land zoned for other land-uses.

Land use and land ownership can be determined by sourcing and reviewing various forward planning documents, such as Integrated Development Plans (IDP's) and Spatial Development Plans (SDF's) and through consultation with local planning authorities.

3.3.5 Step Five: Application of selection criteria through the use of a ranking matrix

The criteria listed below are those that need be assessed in order to determine the pollution potential of a specific site. The criteria should be quantifiable and objective, allowing the criteria of different sites to be compared, without incorporating bias into the site selection process (Dent, 2007). Bias may occur when a particular site is favoured over another for a particular feature without considering all the factors affecting a site's suitability for a cemetery. This method aims to reduce the emotional and subjective influences that may be associated with a ranking exercise such as this. Utilising the criteria identified below, each site can be individually assessed using the ranking matrix provided in Appendix A. The ranking matrix has been developed specifically for this study.

The ranking matrix is a tool used to assign values to the criteria, allowing each site to be scored based on its specific characteristics. For example, soil permeability is assessed through the above mentioned stages and its value compared to the minimum and maximum allowable permeability ranges indicated on the ranking matrix. Permeability is then assigned a criteria value, depending on where the permeability falls within the allowable limits. Criteria values range from one to four with one being least suitable and four being most suitable. As previously mentioned minimum and maximum allowable limits must be applied to each criterion in order to ascertain how closely the criteria are to being ideal for a particular site. The determination of minimum and maximum allowable limits is detailed within the criteria section below.

The criteria affecting the siting of cemeteries include:

(a) Soil permeability

Soil permeability controls the rate of groundwater movement through the subsurface materials (Craig, 2004). When evaluating the soil permeability, a safe distance from water sources or drainage features should be determined. High soil permeability can result in rapid movement of leachate away from the grave site, while low soil permeability can inhibit the dispersion of waste products. Permeability thus also affects the rate of decomposition through the formation of an aerobic or anaerobic environment. Ideally, permeability should be sufficient to absorb and drain away leachate, but not so high that the leachate enters and pollutes the groundwater.

In order to determine the permeability limit to be used to assess a potential site, several previous studies will be drawn upon.

Magni and Du Cann (1978) investigated the acceptability of soils for pit latrine and septic tank disposal systems, in which soil properties were described and the suitability for such a system discussed. Although a cemetery cannot be directly related to a sewerage disposal system, processes of interaction between the soil and decomposing organic matter are essentially the same. Therefore, soil limits determined from their investigation will be drawn upon for this study.

In order to determine permeability without detailed geotechnical investigations Magni and Du Cann (1978) proposed a method that allows the fairly rapid prediction of a soil's permeability rage by determining the soil type (Table 2). Table 2 has been adapted to include cemetery suitability based on that proposed by Richards and Croukamp (2004).

Table 2: Unified Soil Classification System

Symbol (ASTM)	Soil Type (ASTM)	Permeability	Cemetery Suitability
GW	Well-graded gravel	1×10^{-1} to 1×10^{-3}	Totally unsuitable
GP	Poorly-graded gravel	5×10 to 1×10^{-3}	Totally unsuitable
GM	Silty gravel	1×10^{-4} to 1×10^{-7}	Partially suitable
GC	Clayey gravel	1×10^{-5} to 1×10^{-8}	Suitable
SW	Well-graded sand	5×10^{-2} to 5×10^{-4}	Unsuitable
SP	Poorly-graded sand	5×10^{-1} to 5×10^{-5}	Unsuitable
SM	Silty sand	5×10^{-4} to 1×10^{-7}	Ideal
SC	Clayey sand	5×10^{-5} to 1×10^{-8}	Ideal
CL	Lean clay	1×10^{-5} to 1×10^{-8}	Partially suitable
ML	Silt	5×10^{-5} to 1×10^{-8}	Suitable
OL/OH	Organic silt/clay	1×10^{-5} to 1×10^{-8}	Partially suitable
CH	Fat clay	1×10^{-8} to 1×10^{-10}	Totally unsuitable
MH	Elastic silt	1×10^{-7} to 1×10^{-9}	Unsuitable

Source: Richards & Croukamp (2004; 07)

However, this method is not always completely accurate as it does not take into consideration factors such as the clogging of pore spaces by introduced soil particles (Magni and Du Cann, 1978).

Magni and Du Cann also propose a method of determining soil permeability using a simple field test. This method involves excavating a number of holes in the study area using an auger. The holes should be excavated to a depth below the base of the grave excavation, and the sides roughened, so overcoming the effects of hardening created during auguring. A thin gravel layer should be emplaced at the base of the excavation, so retarding the erosive effects of water. Water is then poured into the auger excavation to a level of 300 mm above the gravel, and this water level is maintained for approximately four hours. The water in the excavation is now allowed to soak away, after which the excavation is again filled with water to a level of 150 mm above the gravel. The rate at which the water level falls is then measured, and the average rate of fall is compared with the rates identified below to infer the rate of movement of leachate through the soil and therefore its likely permeability value.

- Slower than 2 mm/hour = Low ($> 1 \times 10^{-8}$)
- 2 – 5 mm/hour = Medium (5×10^{-4} to1 $\times 10^{-8}$)
- 5 - 20 mm/hour = High ($< 1 \times 10^{-4}$)

Portable field permeameters are available to more accurately determine soil permeability in the field (Craig, 2004).

With regards to permeability limits, Magni and Du Cann (1978) proposed that the soil permeability for a septic tank system should be greater than 5×10^{-4} cm/s to be sufficiently permeable to reduce the concentration of leachate, but less than 4×10^{-3} cm/s to prevent pollution.

Tumagole (2006) recommends that for cemeteries a maximum level of upper soil permeability whereby there is a sufficient level of microbiological pollution retention would be 5×10^{-5} cm/s. However this may be increased to 1×10^{-4} cm/s in areas where water resources and abstraction points are located at a greater distance away from the cemetery than the recommended minimum or in arid regions where rain and groundwater sources are scarce and are less likely to be impacted on. A minimum level of soil permeability is therefore recommended to be 1×10^{-7} cm/s which should allow for a sufficient level of microbiological pollution retention and pollution dissipation.

Therefore, soil permeability limits should set a maximum soil permeability at 1×10^{-3} cm/s (0.001cm/s) and minimum soil permeability at 1×10^{-7} cm/s (0.000001 cm/s) with an ideal permeability being 5×10^{-5} cm/s.

Sites must then be ranked, using the ranking table provided in Appendix A. As previously mentioned each site is assigned a criteria value according to how closely the site's soil permeability is to being ideal. For example, a site with a permeability of 5×10^{-5} cm/s will be more suitable and therefore obtain a higher criteria value than a site with greater than 1×10^{-3} cm/s or less than 1×10^{-7} cm/s.

(b) Position in respect of domestic water supplies

The position of a cemetery site relative to water sources that are utilised for human consumption is of utmost importance as 33% of all deaths are caused by water-related diseases (DWAF, 2003). This is particularly relevant in rural settings where domestic water supply is obtained from boreholes and small storage dams without any purification.

A minimum distance between a cemetery and a domestic water source should therefore be set. A safe distance depends on many factors. Fisher (2001) recommends that a safe distance should be based on soil permeability, survival rates of bacteria and viruses and an estimated time for corpse decomposition. Fisher indicates that due to the highly variable nature of the factors that control the dispersion of pathogenic organisms from cemetery sites, the factors used for determining the distance of a cemetery from water resources must be conservative. Fisher indicates that conservatism has been achieved through the effects of harsh environmental conditions experienced in much of South Africa, where survival rates of pathogens are lowered, and by adding a moderate safety factor of 150 m to the calculated distance. Thus ensuring a minimum safety factor of 150 m at all times (refer to Table 3). Fisher (2001) however suggests that the 150 m safety factor may be reduced in rural areas due to minimal population numbers, increased reticulation and the presence of mostly dry environments. Fisher therefore proposes that a minimum of 50 m from local water supplies in a rural area would be suitable.

Although permeability is not easily determined by field investigations, routine sampling and indicator testing (determination of constituents) can be used to reveal the soil type. Using Table 2 an estimate of the expected permeability range based on soil type can be determined without physically testing soil permeability (Fisher, 2001). Having established the expected soil permeability for a particular site, Table 3 can be used to calculate the safe distance which is applied to a case where a particular drainage feature serves as a domestic water supply.

Table 3: Safe Distances to domestic water supplies

Soil Permeability	**Safe Distance (including 150 m safety factor)**
1×10^{-1} cm/s	465 metres
5×10^{-5} cm/s	308 metres
1×10^{-5} cm/s	182 metres
5×10^{-6} cm/s	166 metres
1×10^{-6} cm/s	153 metres
5×10^{-7} cm/s	152 metres
1×10^{-7} cm/s	150 metres

Source: Fisher (2001; 12)

Although the above table can be utilised in most conditions, the presence of dolomites should be flagged for further investigation during the detailed geotechnical investigation. Fisher (2001) indicates that due to the highly variable nature of sub-surface dolomites and their association with groundwater, safe distances are almost impossible to predict and therefore may have a significant potential for groundwater contamination.

Based on the investigation of Fisher (2001) and Price (2005) a minimum safe distance of 50 m from cemeteries to domestic water supplies can be applied in a rural setting but a minimum of 150 m should be used for larger urban cemeteries. Once a safe distance between a proposed cemetery site and domestic water supplies has been determined for a particular site using the tables above, the site can be scored on how closely it meets the required safe distance. For example, a site that meets 100% of the safe distance indicated in Table 3 will score higher than a site that meets only 80% of the required safe distance.

(c) Position in respect of drainage features

As indicated by Fisher (2001) drainage features must be protected from pollutants emanating from cemeteries. The greater the distance a proposed cemetery site is from drainage features, the greater the distance the contaminant plume must travel. As the distance increases, the filtering potential of the surrounding environment increases thus reducing the concentration of the contaminant plume. A drainage feature is defined as any natural or manmade structure, facility, conveyance, or topographic feature which has the potential to concentrate, convey, detain, retain, infiltrate, or affect the flow rate of stormwater runoff (Park, 2007). Drainage features therefore include; lakes, dams, rivers, streams, springs, gullies, wetlands and marshes.

Drainage features should be a sufficient distance from a cemetery that they do not pose a flood hazard. Flooding of a cemetery will impact on the grave integrity, grave stability and even disgorgement of already interned remains. Cemetery sites should therefore be located above the 1 in 50 year flood level. A minimum distance between cemeteries and drainage features must therefore also be allocated. The distance a proposed cemetery site is from drainage features is calculated in a similar manner to that calculated for domestic water supplies, however the safety distance is reduced to 100 metres with a further decrease for arid regions.

Fisher (2001) proposes that with the application of the following safe distances from drainage features, surface water contamination will be negligible:

Table 4: Safe distances to domestic water supplies in arid regions

Soil Permeability	Safe Distance (urban)	Safe Distance (rural)
1 x 10^{-1} cm/s	415 metres	365 metres
5 x 10^{-5} cm/s	258 metres	208 metres
1 x 10^{-5} cm/s	132 metres	82 metres
5 x 10^{-6} cm/s	116 metres	66 metres
1 x 10^{-6} cm/s	103 metres	53 metres
5 x 10^{-7} cm/s	102 metres	52 metres
1 x 10^{-7} cm/s	100 metres	50 metres

Source: Fisher (2001; 12)

As is the case for safe distances from domestic water supplies, Price (2005) indicated that for cemeteries in a rural setting the a minimum distance from drainage features can be reduced to 50 m. Price (2005) based distances from drainage features on permeability. Price therefore suggested that for areas exhibiting a high permeability, a distance greater than 120 m would be suitable, while areas with a low permeability a distance of greater than 50 m is recommended.

Based on the investigation of Fisher (2001) and Price (2005) a minimum distance of 50 m can be applied to cemeteries in a rural setting but a minimum of 100 m should be used for cemeteries in an urban setting. Using Table 4, sites can be ranked according to whether or not they meet the required safe distance from drainage features. For example, a site that meets 100% of the safe distance indicated in Table 4 will score higher than one that meets only 80% of the required safe distance.

Finally, should a drainage feature be used as a domestic water supply, the safe distances proposed for domestic water supplies should be applied.

(d) Soil excavatibility

Although excavatability does not directly affect the pollution potential of a site, the inability of a site to be excavated to any degree will limit the suitability of a potential site. For this reason soil excavatability must be considered.

Excavatibility describes the depth and ease of which the ground can be excavated. The resistance to excavation is governed by soil type, the soil's in situ density, water content and presence of pebbles, boulders or bedrock. In most instances soils can be classified into two categories of excavatability, namely easy and hard (Gulhati & Datta, 2008).

The soils falling into this category are as follows:

- Easy Excavatability: very soft to firm clays, very loose to medium dense sands and gravels
- Hard Excavatability: stiff to hard clays, dense to very dense sands and gravels, boulder deposits and weathered rock.

The depth is usually determined by method of excavation, e.g. manually or mechanically (Richards & Croukamp., 2004). Grave depth is related to soil excavatibility as the inability to excavate a site will result in a shallow grave depth.

The Buffalo City Municipality (BCM) by-laws on the disposal of human remains stipulate that a minimum depth of excavatibility should be 2.0 m for adults and 1.5 m for children, and at least 1.2 m of soil must form a buffer between an adult coffin and the ground surface and 0.9 m for a child's coffin.

A South African local government notice, published in terms of Section 13 of the Local Government: Municipal Systems Act, 2000 stipulates that no burial may take place if there is not sufficient depth to ensure that the top of the coffin is not less than 1.05 m below the surface of the ground when the grave has been filled up.

An investigation undertaken by Vass (2001) describes the process that a human body undergoes during decomposition. This investigation concluded that soil permeability effects decomposition but also the pollution potential, as the soil acts as a filter thus purifying waste water in the soil by means of filtration processes through deeper layers. It was recommended that for hygienic and sanitary protection, the coffin should be buried in soil to a depth of not less than 1.5 to 2 m.

Richards and Croukamp (2004) advise a minimum depth of excavation of at least 1.8 meters, although they suggest the depth should preferably be greater than this. The WHO (1998) on the other hand recommends that graves are to be located at least 1 m away from solid rock and should maintain at least 1 m of subsoil as well as 1 m topsoil at the surface.

It s proposed that soil excavation should not be considered as the greatest limiting factor to cemetery siting and a level of flexibility should be retained. Instead, in instances where soil excavatibility is not ideal and no other sites prove to be more suited, a method of mitigating the potential hazards associated with shallow burial should be utilised. This may include the importation of cover material, thus affectively increasing the available excavation depth. However this may have financial implications and should only be considered if no other site proves feasible (WHO, 1998).

As indicated by the WHO (1998) and the BCM by-laws (2010), a minimum limit for soil cover should be approximately 1 m. Taking into account that the average height of a coffin is 0.58 m then the depth of the entire excavation should be no less than 1.6 m, thus confirming the suggested depth proposed by Richards and Croukamp (2004), Fisher (2001) and Vas (2001).

An excavatibility assessment is tabulated below in Table 5. This excavatability assessment is based on that proposed by Fisher (2001) but has been amended to include minimum and maximum limits allowing each site to be assessed in accordance with the findings of the above mentioned authors. The proposed sites are then scored using the ranking matrix (Appendix A) based on whether or not the proposed site can be excavated to 1.6 m. A site where excavatibility is greater than 1,6 m would be more suitable for the establishment of a cemetery and thus will score higher in this regard than a site where excavatibility is less than 1.6 m.

Table 5: Excavatibility Assessment

Soil Consistency	Excavation Method	Cemetery Suitability	Depth of Excavation
Very loose and loose. Very soft and soft	Spade	Suitable, but grave stability may be a problem	> 1.6 m
Medium dense and firm	Pick and spade	Ideal	1.0 m – 1.6 m
Dense and stiff. Very soft rock	Backactor	Suitable, although weathered rock should be avoided where possible. Alternative sites should be preferred.	0.5 m –1.0 m
Soft to hard rock	Blasting	Totally unsuitable	< 0.5 m

Source: Adapted from Fisher (2001; 18)

(e) Site drainage

Site drainage is related to the topography of the site, and is considered a very important criterion. Site drainage is affected by vegetation, site excavation, levelling and construction of surface water collection and drainage systems. The ingress of surface water into graves must be minimised and stormwater run-off controlled as far as possible.

The drainage of a site will determine the amount of surface erosion, surface water pooling (increasing the risk of groundwater contamination), flooding and subsequent grave destabilization, as well as affecting human mobility and aesthetically affecting the appearance of the cemetery if marshy conditions develop (Richards & Croukamp, 2004). The slope of the site should therefore be such that it minimises surface erosion, avoid surface water pooling and allows for human and mechanical mobility on site (Price, 2005).

Site drainage is therefore an important factor affecting the pollution potential of a cemetery site and methods of determining the potential site drainage must therefore be determined. Ideally, a cemetery site should be slightly inclined so that the site drains sufficiently without rapid erosive drainage or pooling of water. Fisher (2001) suggests a gradient of between 2° and 6° as being ideal for a cemetery site with 9° being a maximum allowable slope angle for cemetery site, as this would allow for sufficient site drainage with minimum surface erosion. Price (2005) recommends that low-lying areas and poorly, naturally drained sites should be avoided completely and concurs with Fisher in that an ideal gradient would be between 2° and 6°. Price does however suggest that sites characterised by flat gradients where perched water table conditions develop, may however still prove feasible with the implementation of subsoil drainage systems (Price, 2005).

The gradient of a site can easily be determined using GIS analysis software using relevant data layers or using a topographic map, thus allowing the gradient of almost anywhere in South Africa to be determined. The area for which the gradient is to be determined must firstly be identified on a topographic map. Once the area has been determined a straight line is drawn perpendicular to the contours. For the most accuracy the line should be drawn from one contour line to another, rather than between. The line drawn is then measured and converted to meters using the scale of the map. The total elevation change along the drawn line is then determined by subtracting the elevation of the lowest contour from the elevation of the highest contour used, resulting in a elevation change in meters (Terzaghi *et al*., 1996).

Based on the studies identified above, an ideal site gradient for a cemetery would be between 2° and 6°, with 9° being a maximum allowable gradient. A visual inspection of the site must also be undertaken so as to determine the presence of erosion or surface water pooling, thus providing an indication of natural drainage of a site. Therefore, sites are then ranked, using the ranking table provided, as to how closely they are to the ideal 2° and 6° gradient and whether or not erosion or surface water pooling was identified. Sites falling between 2° and 6° and which exhibit no erosion or surface water pooling will be ranked higher than sites falling outside the 2° and 6° gradient or where erosion or surface water pooling are evident.

(f) Site topography

Topography refers to the surface features of a specific area. Surface slope affects the movement of groundwater and surface water (and therefore surface erosion) as well mechanical and human mobility on site. Ideal site topography would therefore be one which minimizes surface erosion and impedes rapid internal drainage, which occurs due to the movement of groundwater through the cavities created by grave excavation (Fisher, 1993). Although very steep or very flat gradients or topographies may be viewed as unsuitable for the establishment of a cemetery, engineering techniques such as earth removal and re-profiling may be undertaken if no other options are available. This would however have significant cost implications as an undulating site would require more civil works than a flat site.

As the topography of a site cannot always be chosen, Fisher (1993) therefore proposes that the following measures be implemented in cases where the gradient exceeds 6°:

- Graves should be orientated in such a way that their long axis is parallel to the cemetery contours
- Graves should be spaced forming a staggered diagonal grid system so to minimise surface erosion and impede rapid internal fluid movement
- Sufficient surface drainage is required, so preventing surface erosion, water pooling, flooding and subsequent destabilisation of grave verges. The implementation of drainage systems or hydrophilic plant species may be required.

These precautions should reduce surface erosion and impede rapid internal drainage which occurs due to the movement through voids created by grave excavations.

As already mentioned, topography is related to site drainage and therefore will also be ranked according to a site's gradient.

The ideal site is therefore one with a slope angle of between 2° and 9°. Therefore through the use of GIS analysis software, areas not falling within this threshold are removed. The application of this is firstly applied to the fatal flaw section where areas not falling within the threshold are removed. A site's topography is then individually assessed using the ranking system where each site can be ranked depending on how close the site's topography is to the ideal topography identified above.

(g) Basal Buffer Zone

Grave sites should be situated above the water table on impermeable bedrock, or like many landfill sites, graves should be lined with a thick layer of clay forming a basal buffer zone. The clay acts both as an aquitard as well as a filter, filtering and absorbing many contaminants into its mineral structure and forming an impediment between the decomposing corpse and the water table (Fisher, 2001).

Over time the basal buffer zone losses it filtration and absorption ability and consequently the type and thickness of this impediment must be carefully determined. The thickness of the buffer zone is determined mainly by the permeability of a soil encountered at a given site. Richards and Croukamp (2004) suggest that for a site with the recommended soil permeability of between 5×10^{-4} and 1×10^{-7} centimetres per second, a minimum buffer zone depth of at least 2,5 meters should cater for most conditions. However a greater thickness is preferred. The thickness of the basal buffer zone is therefore directly proportional to the soil permeability of a given site. Fisher (2001) and Price (2005) argue that the soils of a site should conform to ideal permeability conditions when no buffer zone is available.

The thickness of the basal buffer zone is also a function of the excavatibility of the site, in that the depth of possible excavation does not allow for a thick basal buffer zone. In this case the acceptability of the site needs to be questioned, specifically with regards to other factors such as water table depth etc.

The season during which the grave pit is excavated and the basal buffer zone established must also be taken into account as the water table fluctuates depending on whether a dry or wet season is being experienced.

Table 6: Cemetery suitability based on soil type, permeability and basal buffer thickness

Soil Type (ASTM)	Permeability	Basal Buffer Thickness	Cemetery Suitability
Well-graded gravel	1×10^{-1} to 1×10^{-3}	Greater than 2.5m	Totally unsuitable
Poorly-graded gravel	5 x 10 to 1×10^{-3}	Greater than 2.5m	Totally unsuitable
Silty gravel	1×10^{-4} to 1×10^{-7}	Less than 2.5m	Partially suitable
Clayey gravel	1×10^{-5} to 1×10^{-8}	Less than 2.5m	Suitable
Well-graded sand	5×10^{-2} to 5×10^{-4}	Greater than 2.5m	Unsuitable
Poorly-graded sand	5×10^{-1} to 5×10^{-5}	2.5m or more	Unsuitable
Silty sand	5×10^{-4} to 1×10^{-7}	2,5 metres	Ideal
Clayey sand	5×10^{-5} to 1×10^{-8}	Less than 2.5m	Ideal
Lean clay	1×10^{-5} to 1×10^{-8}	Less than 2.5m	Partially suitable
Silt	5×10^{-5} to 1×10^{-8}	2.5 metres or less	Suitable
Organic silt/clay	1×10^{-5} to 1×10^{-8}	2.5 metres or less	Partially suitable
Fat clay	1×10^{-8} to 1×10^{-10}	Less than 2.5m	Totally unsuitable
Elastic silt	1×10^{-7} to 1×10^{-9}	Less than 2.5m	Unsuitable

Source: Adapted from Fisher (2001; 13)

Table 6 presented above has been adapted from Fisher (2001) to include the basal buffer thickness and is used to rapidly predict soil's permeability range by determining the soil type. This table should be used to determine the required basal buffer thickness based on soil type and permeability. Sites are therefore ranked according to whether or not the site meets the requirements in terms of basal buffer thickness as indicated in Table 6. Therefore a site meeting 100% of the required basal buffer thickness would be scored higher than a site only meeting 50% of the required basal buffer thickness.

(h) Cemetery size

Cemetery size is determined by the availability of suitable conditions (suitable drainage and bedrock conditions), total population, mortality rate, projected growth rate of a community and cost of investigation (Richards & Croukamp, 2004). The size of the cemetery also influences its pollution potential as the greater the number of corpses being buried, the greater the potential for environmental contamination.

When considering economic factors such as the cost of the investigation, time spent on the investigation and the period that elapses before implementation, Richards and Croukamp (2004) recommends that for a site to be viable, a minimum continuous area of at least two to three hectares needs to be investigated.

Price (2005) suggests that instead of having numerous smaller sites, each becoming a potential node for groundwater contamination, it would be better to have a larger site servicing a larger percentage of rural communities, possibly combining to develop a regional cemetery facility. The notion of a regional cemetery facility would also limit the environmental impact to one measurable area. Price thus indicates that a minimum realistic size should be one to two hectares.

Convenience may also play a role as a technically suitable site may not be preferred due to its distance from the community it serves. Although technical suitability should take preference, compromises are however possible, ensuring that proposed sites are utilised (Price, 2005).

A formula developed by the City of Johannesburg Department of Development Planning (1985) has been adopted to determine the necessary land area for a cemetery site required by a community. This formula was described in detail in Section 3.3.2 and was used in this study to determine cemetery size. Using this formula the required land areas can be determined and sites can be ranked according to whether or not it meets the required size. Sites that meet more than 100% of the required land area, and therefore have room for expansion will be ranked higher than a site only meeting 50% of the required land area.

(i) Grave stability

Grave stability refers to the integrity and competence of the grave excavation side walls, verge and lip and refers to the ability of a material to resist deformation and chemical and physical change (Fisher, 2001).

According to Jennings *et al*., (1973), a medium dense to dense (non-cohesive soils) or firm to stiff (cohesive) soil should provide adequate grave stability. A soil with a reasonable amount of stability is therefore required as it must survive what is known as stand up time, grave collapse and resistance to the verge or lip of the excavation. The stand up time of an excavation refers to its ability to stand up unsupported for a minimum of a few days before being filled in, while the ability of the excavation to resist collapse must be great enough to resist the disturbance of the soil from human activity during the time of burial. The stability of the excavation verge or lip will also affect the ease at which the coffin may be lowered into the grave.

Soil consistency therefore needs to be determined. Soil consistency is the strength by which soil materials are held together or their resistance to deformation or rapture (Craig, 2004). Soil consistency can be relatively easy to estimate in the field. Consistency varies with moisture content and so the methods used depend on whether the soil sample is wet, moist or dry. Wet soil samples obtained from a site are usually found after rain events or where the water table is above surface (Jennings *et al*., 1973) and so the methods used for estimating the consistency of wet soil samples will not be considered in this assessment.

To estimate the consistency of *moist soil*, a small soil sample must be crushed using your thumb or your forefinger, or in the palm of your hand. The consistency is thus rated using the table below:

Table 7: Consistency rating of a wet soil sample

Loose	If the soil sample breaks down to individual grains
Very friable	If the soil sample crushes easily but will stick together again if pressed together
Friable	If the soil sample crushes easily under gentle to moderate pressure
Firm	If the soil sample crushes under moderate pressure but resistance is noticeable
Very firm	If the soil sample crushes under strong pressure and is difficult to do so using your figures or hand
Extremely firm	Soil sample can only be crushed bit by bit using strong pressure

Source: Jennings *et al*. (1973; 38)

A *dry-soil* sample is obtained through air-drying. A small sample is again crushed between your thumb and forefinger or the palms of your hands and the consistency is determined using the table below:

Table 8: Consistency rating of a dry soil sample

Loose	If the soil sample breaks down to individual grains
Soft	If the soil sample breaks down to powder or individual grains under slight pressure
Slightly hard	If the soil sample resists a small amount of pressure but can easily be crushed
Hard	If the soil sample resists moderate pressure and is difficult to break down using your fingers but easily broken in your hands
Very Hard	If the soil sample resists great pressure and cannot be broken using your fingers but can be broken down with difficulty using your hands
Extremely Hard	Soil sample cannot be broken using your hands

Source: Jennings *et al*. (1973; 42)

Based on the findings of the soil consistency exercise, **Table 9** below can then be used to determine cemetery suitability in terms of soil consistency.

Table 9: Grave stability based on soil consistency

Soil Consistency	**Cemetery Suitability**
Very loose and very soft	Totally unsuitable
Loose and soft	Partially suitable (if no alternatives are available).
Medium dense and dense; firm and hard	Ideal
Very dense and very hard	Suitable (although excavatibility may be hindered).

Source: Adapted from Jennings *et al*. (1973)

Therefore sites are ranked according to soil consistency identified in Table 9. A site with a medium dense and dense and hard soil consistency will be scored higher than a site with a very loose and soft soil consistency.

(j) Soil workability

Although not always considered important, the soil workability can greatly affect the pollution potential of a grave site (Richards & Croukamp, 2004). Soil workability refers to how easily a soil can be removed and returned back into the excavation pit in a homogenous manner. Often when the grave pits are backfilled it is difficult to restore the materials back to their original state of compaction, as seen in the surrounding, undisturbed soil. This irregular compaction, after time, may result in the slumping of the grave fill, resulting in surface water pooling and increased infiltration rates of surface water. This could result in the contamination of groundwater soon after interment of the corpse (Richards & Croukamp, 2004).

Apart from the environmental effects of soil workability, it may also influence the method of excavation (labour or machine) or the amount of labour (manpower) required for excavation. Richards and Croukamp (2004) suggests that where two cemetery sites are similar in condition, soil workability can be used to influence the eventual choice.

Sites are therefore ranked according to whether or not the soil can be returned to the excavation in a homogenous manner. For example, a site where soil can be returned to the excavation in a homogenous manner, with a similar compaction to surrounding soil conditions will be ranked higher than a site where soil cannot be returned back to its original condition.

3.4 Criteria Significance

The significance of each criterion is however not the same. To differentiate the significant criteria from the less significant ones, each of the criteria must be weighted relative to one another by assigning a numerical value to each. Significance is based on the specific criterion's impact on pollution and groundwater contamination and are therefore weighted based on their pollution potential rather that planning and economic considerations. Thus criteria having a higher pollution potential will be of a higher significance.

The significance rating of the criteria identified in this study is based on the following four principles (Tribal Energy and Environmental Information, 2011) and associated flow diagram presented below:

- Environmental effects associated with the criteria are not detectable or are so minor that they will neither destabilise nor noticeably alter any important attribute of a particular resource
- Environmental effects associated with the criteria are sufficient to noticeably alter important attributes of a resource but does not destabilise it
- Environmental effects associated with the criteria are sufficient to noticeably alter important attributes of a resource but through the implementation of mitigation measures does not destabilise it
- Environmental effects associated with the criteria are clearly noticeable and are sufficient to destabilise the resource.

The flow diagram below is used by applying the above mentioned principle to each criterion. For example, poor soil permeability will result in a detectable environmental effect and thus cannot have a low significance of 25%. Furthermore, even with the provision of mitigation measures poor soil permeability will noticeably alter important attributes and result in the destabilisation of a resource. Therefore soil permeability has a very high significance in that environmental effects associated with the criteria are clearly noticeable and are sufficient to destabilise the resource and is thus allocated a 100% significance rating. Another example is grave stability. Grave stability has no detectable environmental effect associated with it and therefore has a low significance of 25%.

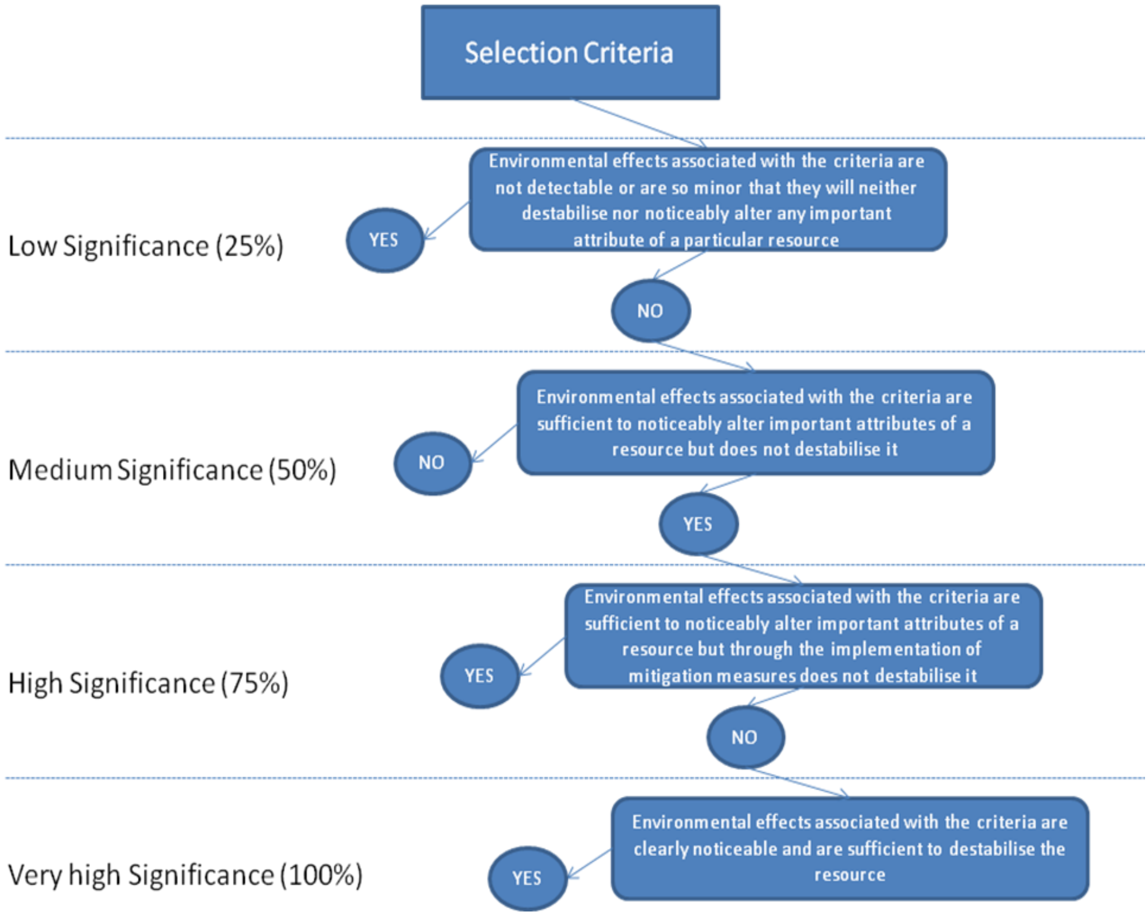

Figure 2: Diagram used to determine criteria significance

Using the significance diagram it is proposed that the criteria listed in Table 10 have the following significance ratings:

Table 10: Individual criteria significance

Criteria	Significance
Soil Permeability	100%
Position in respect of domestic water supplies	100%
Position in respect of drainage features	100%
Soil Excavatibility	75%
Site Drainage	75%
Topography	50%
Basal Buffer Zone	50%
Cemetery Size	50%
Grave Stability	25%
Soil Workability	25%

Once the significance of the criteria has been established each site is scored directly and a weighted score calculated by determining the product of the criteria significance and the score. The weighted scores for all criteria are then summed to determine the final total for each site.

It is recommended that a minimum of four sites should be identified in Step Three, thus allowing alternatives should the other sites not prove acceptable. Using the ranking matrix these sites are then scored and ranked according to how closely the site's conditions are to being ideal.

The application of the aforementioned criteria can either be made through the application of GIS analysis software where the relevant data layers exist, by investigating existing studies, literature and reports relating to the relevant area, or through field investigations. Field investigations would involve the inspection of soil profiles from cuttings and other natural exposures or erosion channels.

The potential cemetery sites will be ranked using the ranking matrix provided in Appendix A. Sites are ranked by applying a score to the previously identified criteria according to each site's specific characteristics. The highest ranking sites will therefore be the sites carried forward to the next stage of this project, namely a detailed geotechnical investigation and then licensing and completion of a Basic Assessment with Public Participation. The legislative requirements for the authorisation of the activity are detailed in Chapter Two.

To ensure that the public, especially the communities in close proximity, have an opportunity to make informed decisions, a public participation/community liaison meeting should be held for each of the top sites determined in this step. This will inform the community of the proposed development and therefore determine if there are any potential issues or public resistance to the proposed sites.

3.5 Stage Two: Detailed Geotechnical Investigation

Stage Two is undertaken on the highest ranking and therefore the most acceptable sites determined in Stage One. This stage involves a detailed geotechnical investigation aimed at confirming the findings of Stage One. It is recommended that this stage be undertaken on the two highest ranking sites thus only expending time and resources on a minimum number of sites while still providing an alternative should a site be concluded as being unacceptable during this stage. This stage usually only commences upon acknowledgement from the competent authority authorising the Basic Assessment process to commence as this stage involves more detailed and often more costly investigations.

The geotechnical Investigation involves the assessment of geological and hydrological factors and should include but is not limited to the following:

- Excavation of trial holes to determine the depth of soil, nature of soils and engineering characteristics such as clay content, liquid limits and plasticity index, linear shrinkage, heave etc.
- Dynamic Cone Penetration (DCP) tests
- Field tests to determine the *in-situ* permeability of the soils, so ensuring correct matrix classification
- Laboratory testing of soil samples to determine clay activity, permeability after compaction to 86% MOD. AASHTO (Modified American Association of State Highway and Transportation Officials) in order to simulate *in-situ* soil conditions.

During this study the water storage potential of any dolerite intrusions, specifically dolerite dykes within 50 m of the proposed site must be assessed. This can be undertaken during the desktop investigation proposed earlier if the relevant data is available for the area in question. This is however usually only determined through detailed geotechnical investigations thus forming part of this stage.

The ranking matrix will then be re-evaluated based on any new information gained from the detailed geotechnical investigation, thus accurately ranking the proposed sites from most preferred to least preferred and ultimately identifying a single preferred site. The highest ranking site is then carried forward through the post feasibility stage.

3.6 Conclusion

Previous assessment of cemeteries have concentrated on the ability of new and existing cemeteries to cope with the burial requirements, groundwater contamination and the legislation associated with these developments. However, little or no guidelines are in place for the identification and assessment of the criteria affecting the pollution potential of a cemetery.

The method proposed above therefore quantifiably and objectively assesses a number of potential cemetery sites, without emotional bias. All sites are assessed equally and so the highest scoring sites can be said to be the most acceptable. The method presented above, is somewhat different from previous methods as all the decisive criteria have been assigned a minimum and maximum allowable limit and are assessed on a site specific basis using a unified assessment process.

4 CHAPTER 4: RESEARCH FINDINGS

4.1 Introduction

The purpose of this chapter is to apply the methodology developed in the previous chapter to a case study and thus determine its applicability and benefit in terms of sustainable siting of cemeteries. Possible shortcomings may be determined and the modification or provision of additional criteria may prove to be necessary.

Stage One of the methodology developed in Chapter Three is a Feasibility Investigation. As previously mentioned, the Feasibility Investigation consists of several stages. The first stage entails site identification which involves determining the greater area for the establishment of a cemetery and is related to identification of a need for such a development.

The Buffalo City Municipality's (BCM) Cemetery Development/ Interment Division, through an investigation undertaken by GIBB (2004), have identified a crucial need for the establishment of a cemetery to service the urban component of East London within the BCM. GIBB based these findings on an investigation whereby the expected future demands for cemetery space within the BCM were projected and areas in greatest need of a cemetery identified. GIBB concluded that a great shortage of cemetery space within the urban component of East London will develop within two years from the date of their investigation.

The need for the establishment of a new cemetery site within the urban component of BCM is therefore based on the current pressures on existing formal cemeteries. Furthermore, the growing awareness within local government of the importance of ensuring that cemeteries are properly planned, developed and administered and the recognition that certain localities within the study area do not have access to properly planned cemeteries has all contributed to this need (BCM, 2011).

Step Two of the Feasibility Investigation entails determining the required land size for a cemetery site. Population figures and required space projections are based on the 2001 census information, while population growth rates and mortality rates are based on those used in the BCM Integrated Development Plan (IDP) of 2011.

Step Three entails the undertaking of a desktop investigation in order to apply the fatal flaw criteria. The fatal flaw criteria have thus been applied to the study area using GIS analysis software. Esri ArcGIS version 9.1 GIS software was utilised for this study. Data layers pertaining to each criterion have been obtained from the BCM Planning Department and were manipulated in this study to encompass the minimum and maximum allowable limits for each criterion set in Chapter Three. These data layers were then applied to the study area. The application of these data layers using GIS analysis software produces a map of the study area identifying potential sites that do not exhibit a fatal flaw and thus may prove acceptable for the establishment of a cemetery. The number of sites identified through this step is dependent on the required land area and availability of land not exhibiting a fatal flaw but it is recommended that a minimum of four potential sites be identified.

Step Four entails the description of the study area in terms of its geology, geohydrology and aquifer vulnerability using relevant existing literature. This step therefore involved a review of the 1:250 000 Geological Map Series (Kei Mouth: 3228), 1:250 000 Hydrogeological Map Series (Queenstown: 3126) and associated brochures and existing studies undertaken in the study area.

Step Five was then apply the site selection criteria to each site using a ranking matrix. Each site was first evaluated depending on how closely the site's conditions are to being ideal. The conditions of each site within the study area were determined through the use of GIS software where the data layers were available and by reviewing relevant literature and reports. All criteria were however confirmed through a brief field investigation. Criteria scores for each site were then tallied indicating the most preferred site to least preferred site.

The two highest ranking sites identified in Stage One were then carried through Stage Two where sites undergo a detailed geotechnical investigation confirming the findings of Stage One. The detailed geotechnical investigation involves the assessment of geological and hydrological factors. The two highest ranking sites identified in Stage Two should then be carried through the NEMA EIA authorisation process ultimately resulting in a site having the least environmental impact which will be recommended to be used for the establishment of a cemetery.

4.2 Stage One: Feasibility Investigation

4.2.1 Step One: Site identification in terms of the greater area to be serviced by the cemetery

Site identification at this stage merely speaks to the greater area within which the communities requiring the cemetery fall. Site location in this sense is therefore associated with establishing a need for a cemetery. Therefore, although site location is a factor that must be dealt with at an early stage, the specific site location is only determinable once all other factors (such as proximity to domestic water supplies) have been addressed.

The BCM Cemetery Division, through an investigation undertaken by GIBB (2004) has identified that there is a great shortage of cemetery space in the urban component of BCM. A crucial need to identify and reserve land suitable for the establishment of a cemetery in the urban components of East London within the BCM is thus required. GIBB (2004) identified the following sub-areas as requiring a cemetery:

- Sunrise on Sea
- Reaston
- Gonubie
- East London

For the purposes of this paper and based on the social consultations undertaken by GIBB (2004), a 20 km radius from the areas to be served by the cemetery has been allowed for. All undeveloped open areas falling within this radius would therefore be investigated. Therefore the exact site will only be determined during the final stages of this study, once all other factors have been addressed. Appendix B identifies the greater area to be investigated based on this 20 km radius from the respective communities.

These areas will therefore form the basis for further investigation. The next step is to determine the required land area for the proposed cemetery.

4.2.2 Step Two: Size of the cemetery site

This step involves determining the land size requirements for a cemetery based on the population statistics of the communities falling within the study area determined in Step

One. As indicated previously a cemetery site should be large enough to service these communities for a period of 30 years (Richards & Croukamp, 2004).

The population figures for each community are based on the 2001 Census statistics, while the growth and death rates are based on those used in the BCM IDP (2011). The population numbers for the communities falling within the study area as indicated by the Census 2001 statistics are as follows:

• Gonubie and Sunrise on Sea	-	15857
• Reaston	-	10342
• East London	-	208 661
Total		**234 860**

As indicated above the total population for the study area in 2001 is approximately 234 860. However, this figure needs to be extrapolated to the current year before utilising the formula developed by the City of Johannesburg Department of Development Planning (1985). Therefore, a formula proposed by Lutus (2010) utilised in the mathematics of population increase has been drawn upon in order to establish population numbers for the present, as well as the future, using outdated population statistics.

Thus in order to determine the current population, the outdated population number obtained from the 2001 census is multiplied by the rate of population increase (*r*). The rate of population increase is expressed as *1* (constant) plus *i* (percent population increase divided by 100) multiplied by the number of years (*n*). Therefore, current population numbers for the study area is determined using the formula presented below:

$$
\begin{aligned}
POPfuture &= POPpresent \times (r) \\
&= POPpresent \times (1+i)^{n} \\
&= 234860 \times (1+0.02)^{11} \\
&= 234860 \times (1.02)^{11} \\
&= 234860 \times (1.243374308394652) \\
&= 292\,019
\end{aligned}
$$

Therefore the current (2012) population size for the study area is approximately 292 019. This figure has been projected from a 2% annual growth rate, which is lower than the 2.7% annual growth suggested to be used with the formula developed by the City of Johannesburg Department of Development Planning, to compensate for the reduction in the growth rate and increase in mortality rate (BCM IDP 2006-2011, 2011). The BCM IDP (2011) estimates the provincial mortality rate for the province to be approximately 15 deaths per 1000 per annum, which roughly coincides with the projected figures proposed by GIBB (2004) of a 1.5-2.0% mortality rate for between 2001 and 2021. However, the Greater BCM is currently experiencing a reduction in the growth rate and an increase in mortality rate. It is therefore proposed that a mortality rate of approximately 2% be used to ensure that an underestimation of the required land area is not made.

The formula developed by the City of Johannesburg Department of Development Planning (1985) can now be used to predict the required cemetery size without knowledge of any previous burial statistics. This involves several parts as shown below.

Part one:

$$E = \frac{A}{1} \times \frac{B}{1000}$$

E = Total mortalities expected in the community per year.

A = The total population of the community (The total population of the community (A) is calculated for a period of time 30 years from present, using the current growth rate)

B = The mortality rate per 1000 people per year.

Utilising the formula prescribed by Lutus (2010), the total population of the study area in 2012 is 292 019. This number needs to be calculated for a period of 30 years from present at a growth rate of approximately 2% and a mortality rate of 20 for every 1000. Therefore, the total population of the community **(A)** calculated for a period of 30 years from present at a 2% growth rate is determined as follows:

$$\begin{aligned} POPfuture &= POPpresent \times (1+i)^{n} \\ &= 292019 \times (1+0.02)^{30} \\ &= 292019 \times (1.02)^{30} \\ &= 292019 \times (1.811361584103354) \\ &= 528\,952 \end{aligned}$$

Therefore the total population of the study area **(A)** in the next 30 years is approximately 528 952.

Then:

$$E = \frac{A}{1} \times \frac{B}{1000}$$
$$E = \frac{528952}{1} \times \frac{15}{1000}$$
$$E = 528952 \times 0.015$$
$$E = 7934$$

These figures indicate that approximately 7934 mortalities occur in the study area per year. According to GIBB (2004) approximately 70% of all deaths are adults while only 30% of all deaths are children in the East London area. The number of adult versus child deaths has an implication on the surface area required for graves as average surface area required by child graves is approximately 2.37 m^2 while the average surface area required by adult graves is roughly 5.33 m^2. Therefore 30% of 7934 equates to approximately 2380 child deaths (**B1**), while 70% of 6391 equates to approximately 5554 adult deaths (**B2**).

<u>Part two:</u>

$$X = B1 \times C \times D1$$

X = total surface area required for child graves (m^2).

B1 = roughly 30% of the total mortalities are children (younger than ten years), therefore 30% of **(E)**.

C = life expectancy of the cemetery (usually planned for 30 years).

D1 = gross area required for a single child's grave (2.37 m^2).

Then:

$$X = B1 \times C \times D1$$
$$X = (30\%\ of\ 7934) \times 30 \times 2.37$$
$$X = 2380 \times 30 \times 2.37$$
$$X = 169\ 218$$

Therefore approximately 169 218 m^2 of land surface is required over a 30 year period for child graves and associated pathways.

Part three:

$$Y = B2 \times C \times D2$$

Y = total surface area required for adult graves (m^2).

B2 = roughly 70% of total mortalities are adults (older than ten years), therefore 70% of **(E)**.

C = life expectancy of the cemetery (usually planned for 30 years).

D2 = gross area required for an adult grave (5.33 m^2).

Then:

$$Y = B2 \times C \times D2$$
$$X = (70\%\ of\ 7934) \times 30 \times 5.33$$
$$X = 5554 \times 30 \times 5.33$$
$$X = 888\ 085$$

Therefore approximately 888 085 m^2 of land surface is required over a 30 year period for adult graves and associated pathways.

Part four:

$$Z = X + Y$$

Z = The total area required for a cemetery.

X = Total surface area required for child graves.

Y = Total surface area required for adult graves.

Then:

$$Z = X + Y$$
$$Z = 169\ 218 + 888\ 085$$
$$Z = 1\ 057\ 303$$

Therefore approximately **1 057 303 m²** of land surface is required to serve the population of BCM over a 30 year period. As indicated by Price (2005) the current thinking behind cemeteries is to have a regional cemetery servicing a number of communities as opposed to numerous small cemeteries. Therefore, a single site meeting the land area requirements above will first be investigated. Should such a site not prove to be available, a number of smaller sites closer to the communities in question will be investigated.

GIBB (2004) however estimated that approximately 500 000 m^2 of land surface will be required for a period of 15 years extending from 2003 to 2018. The estimation of required land area by GIBB was calculated by adding the required area for each grave site to the width of the separating borders between individual graves and the width of internal paths. The estimation of required land area made by GIBB is very similar to the required land area calculated in this study. The minor difference in land area requirements may be explained by the reduction in the growth rate and increase in mortality rate as identified in the BCM Integrated Development Plan 2011-2016 (2011).

4.2.3 Step Three: Desktop investigation in order to apply the fatal flaw criteria

Possibly the most important phase of site determination is the identification of certain fatal flaw criteria which would render a site unsuitable for the establishment of a cemetery.

Most other investigations undertaken with regards to cemetery site selection have neglected to identify any potential fatal flaws before the assessment of a site is undertaken. The purpose of identifying any fatal flaws at this stage is to remove any unsuitable areas and sites at an early stage before any further investigations are undertaken, and thus also save on time and costs associated with such investigations.

The fatal flaw criteria are often such that they can be identified by either a brief site assessment or through the use of a desktop investigation. In this step a desktop investigation is undertaken using GIS analysis software. The use of ArcGIS version 9.1 was utilised for this study. Areas exhibiting a fatal flaw are therefore removed from the site selection process through the use of GIS analysis software and data layers related to the fatal flaw criteria. Data layers relating to the fatal flaws were obtained from the BCM Planning Department and were manipulated to represent the value of each fatal flaw below. This allowed for the production of a map of the study area (Appendix C) depicting all areas unsuitable for the establishment of a cemetery (red areas), but also identifying potential sites that can be carried through to Step Four (green areas). It was however identified that several of the fatal flaw criteria were not available as a GIS data layer and therefore could not be applied during the desktop investigation. Therefore the sites identified through the application of the fatal flaw criteria using GIS analysis software were then inspected in the field in order to confirm the presence of a fatal flaw.

The following fatal flaw criteria were however applied using GIS analysis software:

- The exclusion of areas falling within the 1:50 year flood line
- Areas within 500 metres of a wetland
- Areas within 250 metres of any potable water supply
- Areas within 30 metres of significant surface water bodies (such as dams, lakes and rivers) and 10 metres from any field drain (surface or subsurface drainage system used to control the water table)
- Areas within 50 metres of all unstable areas and includes fault zones, fault plains, seismic zones and dolomitic or karst areas
- Areas within 50 metres of sensitive ecological, historical or protected areas. This includes all national parks, nature reserves, forests, protected areas, Critical Biodiversity Areas (CBA) and areas of ecological and cultural or historical significance are excluded
- Areas below or greater than 2 ° - 9 ° slope angle are to be excluded
- Areas overlying or adjacent to important or potentially important aquifers
- Areas within a 100 metres of land-uses that are incompatible with cemeteries
- Areas over which major servitudes are held that would prevent the establishment of a cemetery (e.g. Eskom and Department of Roads and Transport servitudes)
- Areas within 50 metres of any dolerite intrusions.

Through the application of the fatal flaw criteria using GIS and associated data layers, seven potential sites were identified (Appendix D). These sites were then investigated in the field further confirming the presence of fatal flaws.

The following fatal flaw criteria were confirmed in the field once a number of sites had been identified through the application of fatal flaw criteria using GIS analysis software:

- Areas characterised by shallow bedrock with less than 1 metre topsoil and subsoil cover

- Areas within 1 metre of the water table where a sufficient unsaturated zone separating the interred remains and the groundwater would not be possible
- Areas of groundwater recharge on account of topography and/or highly permeable soils

The fatal flaw criteria that were not applied using GIS were confirmed in the field by examining soil profiles from cuttings and other natural exposed erosion channels.

Through the application of the fatal flaws using GIS and confirmation in the field, it is determined that seven potential sites meet the requirements in terms of not exhibiting any fatal flaw criteria. However, only three of the seven sites identified meet the required land size for the cemetery. It is recommended that all seven sites are carried forward for further investigation in Step Four as a site not meeting the required land area may still prove to be suitable for the establishment of a cemetery, as well as allowing for a number of alternatives to be assessed in the subsequent steps and stages.

4.2.4 Step Four: Site description

The step involves the examination of the local geology, geohydrology, aquifer vulnerability and land ownership of the sites identified in Step Three. The purpose of this step is to allow for a improved understanding of the proposed sites as well as allow for inferences to be made with regards to a site's pollution potential. Furthermore this step allows for more suitable and accurate analysis to be undertaken on the proposed sites in Step Five. This stage of the study aims at determining the geological and geohydrological characteristics of the study area using field observations, GIS analysis and previous studies done in the area. The site was described and assessed using mainly the 1:250 000 Geological Map Series (Kei Mouth: 3228), the 1:250 000 hydrological Map Series (Queenstown: 3126) and associated brochures and previous studies undertaken in the study area.

During this study it was noted that the geology, geohydrology and aquifer vulnerability remained constant over the entire study area. Due to this, the geology, geohydrology and aquifer vulnerability will be described in terms of the entire study area so to avoid repetition within the description for each potential site.

(a) Geology of the study area

The geology characterising the BCM and surrounds comprises a sequence (from oldest to youngest) of sedimentary rock of the Karoo Sequence. The Karoo Sequence was subsequently intruded by hypabyssal dolerite which in turn is overlain by Quaternary rocks of the Algoa Group and recent Aeolian dune sands (Johnson *et al*., 2006).

According to Johnson *et al*. (2006) in conjunction with the geological map 3228 Kei Mouth, the study area is characterised by the sediments of the Beaufort Group (Appendix F) and numerous large dolerite intrusions. The Beaufort Group comprises a lower Adelaide Subgroup and the Upper Tarkastad Subgroup of which the Adelaide Subgroup underlies the study area. The Tarkastad subgroup is distinguished from the Adelaide Subgroup by the abundance of both sandstone and red mudstone.

The Adelaide Subgroup is characterised by green grey and greyish-red massive mudstones, with blocky weathering (Kent, 1980).

Few, if any major geological structures, such as fractures and faults, are present in the study area and no major alluvial deposits, limestone or dolomite rock units were identified. There is therefore low risk envisaged in terms of potential sinkholes and/ or compaction problems.

Soils in the area are composed mostly of silt and sand. Erosion management is vital as soil erosion and the manifestation of erosion gullies is very common in this region (CSIR, 2004).

(b) Geohydrology of the study area

In terms of the local hydrogeology of the study area, principal groundwater occurs in intergranular and fractured rock with a median yield of approximately 0,5 to 2 litres per second. Low to medium borehole yields can be expected within the study area. This is due to the closure of major rock fractures due to a south east compression (DWAF, 1997).

Principal groundwater attenuation for the study area is said to occur in dual porosity aquifers, comprising both large infrequent principal transmissive fractures with a relatively low storage capacity, numerous secondary microfissures with a higher storativity but higher transmissivity (Kent, 1980). The microfissures are however concentrated in a near-surface upper zone resulting in a higher groundwater potential on the surface than lower levels. Lower levels are however replenished through downward leakage from shallow sections. Deeper fractures therefore have a higher transmissivity but lower storativity than lower level fractures. GIS investigations of the study area indicate that the groundwater vulnerability in the study area is said to be medium. Two boreholes were however identified within 120 metre of Site A and approximately six boreholes located within the boundary of Site G (Appendix G). The proximity of these boreholes will affect the score the site receives with regards to its position in respect of domestic water supplies. However, due to the large extent of Site G, the required safe distance may still be met and thus it does not score less than that of Site A in this regard.

The study area is characterised by three large dolerite intrusions of Jurassic age (Appendix F). The dolerite dykes are usually less than 10 m wide but can extend for many kilometres. Dolerite sills however vary in thickness from a few metres to a maximum of about 250 metres. Dolorite in the Eastern Cape is usually sub-ophitic with an average grain size of 0.8 mm. However, the dolerite in the study areas is highly ophitic with large augite crystals of approximately 2 mm in size and small plagioclase crystals approximately 0.2 mm in diameter (Kent, 1980). Dolerite intrusions often present the best targets for aquifer location, as weathered dolerite provides a receptacle for accumulating and storing groundwater (DWAF, 1997). It is for this reason that any area within 50 m of a dolerite intrusion is identified as a fatal flaw. However, as identified in Appendix F, no dolerite intrusions fall within 50 metres of any of the proposed sites.

(c) Aquifer vulnerability of the study area

DEAT (2000) provide’s a generalised soil description for the Eastern Cape region. The generalised soil description indicates that the proposed sites are characterised by soils with minimal development, are usually shallow on hard or weathered rock and with or without intermittent diverse soils. Soil depth is described as being ≥450 mm but <750 mm.

Based on the soil description above and using Table 1 presented in Chapter Three, the proposed sites are characterised as “Medium Vulnerability” with a low risk. Therefore the sites can be defined as being vulnerable to inorganic pollutants but with negligible risk of organic or microbiological contaminants.

(d) Land-use and land-ownership

The land ownership, and other pertinent information such as land cover, site location and access, will now be described in terms of each potential site identified during Step Three.

<u>Site A</u>

Central GPS co-ordinate of site = 32°58’1.43” S; 27°46’52.61” E

Site A is located approximately 17 km from East London city centre. The site falls within the Reaston area with a large factory to the east of the site, a large quarry to the south east and a small housing settlement to the south west. The site has two minor field drains/ drainage lines running in a south westerly direction, linking up with a third drainage line along the southern border of the site.

The land cover in terms of vegetation for Site A is characterised as the Albany Coastal Belt (Appendix H). The Albany Coastal Belt is an Albany Thicket Biome vegetation type that is found on gently sloping to moderately undulating landscapes and dissected hilltop slopes. It is dominated by short grasslands punctuated by scattered bush clumps or solitary *Acacia natalitia* trees. Other species present are a mixture of Fynbos, Grassland, and Succulent Karoo elements. Albany Coastal Belt is considered “least threatened” by SANBI although up to 60% of this vegetation type is considered degraded (Mucina and Rutherford, 2006).

Site A is located in an area characterised as having both a Cultivated: Temporary - Commercial Dryland and Unimproved Grassland landcover and falls on privately owned land (Appendix I).

Access to the site will be made from the Mdantsane Access Road.

<u>Site B</u>

Central GPS co-ordinate of site = 32°58’57.04” S; 27°49’29.92” E

Site B is located approximately 14.5 km from East London city centre. The site falls within the Wilsonia area with factories bordering the site to the east and north. Scenery Park is located approximately 1 km west and south of the site.

A large dam is located approximately 600 m to the west of the site with three smaller dams, thought to be associated with the surrounding industry, located approximately 250 m away.

As for Site A, Site B has a vegetation landcover characterised as Albany Coastal Belt. Site B has a landcover comprising of both natural Thicket and Bushland and Urban/ built-up land: Commercial. In terms of land ownership, Site B falls on privately owned land.

Access to the site will be made off Osmond Street.

Site C

Central GPS co-ordinate of site = 32°58'34.41" S; 27°50'5.12" E

Site C is located approximately 11.5 km from East London city centre. The site is located immediately east of Wilsonia and west of the Amalinda Nature Reserve. Several minor drainage lines run across the site in a southwards direction.

Site C is said to have a landcover consisting of both Cultivated: Temporary – Commercial Dryland and natural Thicket and Bushland. Site C again has a vegetation landcover characterised as Albany Coastal Belt and falls on privately owned land.

Access to the site is made off the N2 or Robbie De Lange Road.

Site D

Central GPS co-ordinate of site = 32°58'4.78" S; 27°51'23.55" E

Site D is located approximately 11.5 km from East London city centre within the residential area of Dawn. The site is bounded on its western side by residential houses and on the northern side by residential houses of Summerpride. A school is located approximately 100 m west of the site. No surface water features were identified.

The site's land cover is said to be both Cultivated: Temporary – Commercial Dryland and Thicket and Bushland. The vegetation landcover is classified as Albany Coastal Belt. Site D falls on privately owned land.

Access to the site is made off the N2 or Gaylard Road.

Site E

Central GPS co-ordinate of site = 32°58'30.02" S; 27°51'26.66" E

Site E is located approximately 11 km from East London city centre within the residential area of Morning Side. The site is bordered by residential homes on the north and west of the site with a school approximately 50 m from the eastern border of the site. No surface water features were identified.

Site E is characterised as having both a Cultivated: Temporary – Commercial Dryland and Urban/ Built-up Land: Residential. Site E has a vegetation landcover classified as Albany Coastal Belt and falls on privately owned land.

Access to the site is made off Main Road or Scholl Road.

Site F

Central GPS co-ordinate of site = 33°57'54.43" S; 27°52'03.22" E

Site F is located approximately 3.7 km from East London city centre directly north of Cambridge West. The proposed site falls between a meander of the Nahoon River. No other significant surface water bodies were identified.

Site F is described as having a landcover of Thicket and Bushland and is dominated by a Albany Coastal Belt vegetation cover. Site F falls on privately owned land.

Access to the site is made via Baden Powell Drive off Voortrekker Road.

Site G

Central GPS co-ordinate of site = 33°03'44.06"S; 27°46'08.98"E

Site G is located approximately 15 km from East London city centre and approximately 3.5 km west of the airport. Site G constitutes a large area with sparsely located residential small holdings and farms. Several minor drainage lines and dams were identified.

The site's land cover is said to be both Thicket and Bushland and Unimproved Grassland. The vegetation cover is described as Albany Coastal Belt and falls on privately owned land.

Access to the site is made off the R72 or R346.

In conclusion and based on the site descriptions above, site A to F are said to have a medium aquifer vulnerability with a low risk for contamination. Although dolerite is present in the study area, none of the proposed sites will be affected. In terms of landownership, all the identified sites fall on privately owned land and therefore no site is preferred over the other in this respect.

The section below describes those criteria pertinent to understanding the nature of a proposed site, which are therefore also pertinent when selecting a potential cemetery site. The criteria listed below have been determined as significant in affecting the pollution potential of a cemetery and are addressed from most significant to least significant, although all are determined as decisive when selecting a cemetery site.

4.2.5 Step Five: Application of selection criteria through the use of a ranking matrix

Ultimately this section aims at determining whether or not the criteria below are sufficient in determining the pollution potential of a proposed site and whether the criteria need to be amended or if additional criteria need to be assessed.
As identified in Chapter Two, the ranking criteria proposed by Richards and Croukamp (2004) which are to be assessed include:

(a) Soil permeability

(b) Position in respect of domestic water supply
(c) Position in respect of drainage features
(d) Soil excavatibility
(e) Site drainage
(f) Site topography
(g) Basal buffer zone
(h) Cemetery size
(i) Grave stability
(j) Soil workability.

These criteria have been assessed for each site through field investigations and assessments (as described in Chapter Three) using the ranking matrix contained in Appendix A. Through the elimination of areas with inherent fatal flaws and taking note of all the criteria and critical factors listed above, a number of candidate sites can be identified. The candidate sites are then carried through a ranking exercise where sites were ranked according to their acceptability for a cemetery.

The criteria identified above were assessed for each site using the techniques identified in Chapter Two and Chapter Three (refer to Appendix J for full ranking results). The findings are presented below:

Table 11: Criteria score per site

Criteria	Site A	Site B	Site C	Site D	Site E	Site F	Site G
Soil permeability	3	3	3	3	3	3	3
Position in respect of domestic water supply	3	3	3	3	3	2	3
Position in respect of drainage features	2	1	3	1	4	2	2
Soil excavatibility	1.5	1.5	2.25	1.5	2.25	0.75	2.25
Site drainage	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Site topography	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Basal Buffer Zone	1.5	1	1.5	0.5	1.5	1	1
Cemetery size	2	0.5	0.5	2	0.5	0.5	2
Grave Stability	0.5	0.5	0.75	0.25	0.75	0.5	0.5
Soil workability	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total	**15.5**	**12.5**	**16**	**13.25**	**17**	**11.75**	**15.75**

The ranking table presented below contains the results and findings of Step Five and scores each site independently.

Table 12: Summarised site ranking results

Candidate Sites	Ranking Matrix Total	Ranking
Site E	17	1
Site C	16	2
Site G	15.75	3
Site A	15.5	4
Site D	13.25	5
Site B	12.5	6
Site F	11.75	7

Through this assessment process Site E was determined as being most acceptable with regards to the various ranking criteria. Site E was followed by Site C, Site G, Site A, Site D, Site B and lastly Site F.

Therefore, it is recommended that Site E and Site C be carried forward through the EIA and detailed geotechnical investigation.

4.3 Stage Two: Detailed Geotechnical Investigation

As indicated in Chapter Three, this stage consists of a more detailed geotechnical investigation and is undertaken on the highest ranking and therefore most acceptable sites determined in Stage One. The geotechnical Investigation includes the assessment of geological and hydrological factors. The geotechnical investigation should include the following:

- Excavation of trial holes in order to determine the depth of soil, nature of soils and engineering characteristics such as clay content, liquid limits and plasticity. index, linear shrinkage and heave
- Dynamic Cone Penetration (DCP) tests
- Field tests to determine the permeability of the soils so ensuring correct matrix classification
- Laboratory testing of soil samples in order to determine clay activity, permeability after compaction to 86% MOD. AASHTO (Modified American Association of State Highway and Transportation Officials) to simulated in situ conditions.

During this study the water storage potential of any dolerite dykes within 50 m of the proposed site should also be assessed.

The ranking matrix will then be evaluated based on any new information gained from the detailed geotechnical investigation, thus accurately ranking the proposed sites from most preferred to least preferred, ultimately identifying a single preferred site for the establishment of a cemetery.

5 CHAPTER 5: STUDY SYNTHESIS

5.1 Introduction

The intension of this study was to develop a methodology allowing for fairly raid and accurate analysis of a given area in order of determining a number of potential cemetery sites.

Research commenced through the identification of previous investigations relating to the siting of cemeteries and other waste deposal practises. Of particular importance was the identification of the criteria affecting the pollution potential of various waste disposal practices. Through this study it was noted that there is an evident lack of literature particularly pertaining to the siting of cemeteries, as well as a lack in cemetery governance, management and administration.

As this study advanced, it was identified that groundwater was one of the greatest environmental concerns associated with poorly sited cemeteries. Due to South Africa having a large rural component, the affect of cemeteries on groundwater resources is one that needs to be assessed and controlled. A number of investigations were drawn upon to establish a scientifically based method of identifying a number of potential sites. It was noted that no single integrated method regarding cemetery site selection could be established that assessed the physical criteria affecting the pollution potential of a cemetery and provided a method of assessing these criteria for a number of proposed sites. This was something that needed to be addressed to allow for a more precise method of determining a potential site.

Three main methods of site selection of various forms of waste disposal practises were drawn upon for this study. Utilising and manipulating these methods and procedures, a staged approach to cemetery site selection was proposed. However, before a site can be suitably assessed, the criteria affecting the pollution potential of a site needed to be established. The pertinent criteria were determined through work undertaken by Fisher (2001) and Richards and Croukamp (2004). These criteria are based on mechanisms of cemetery site pollution and therefore enable a site to be assessed in relation to its pollution potential. These criteria were however often generic without identifying specific minimum and maximum allowable limits. Through research into the individual criteria and factors affecting the pollution potential of these criteria, minimum and maximum allowable limits were established.

An integrated methodology whereby the study area is determined, fatal flaws applied and pertinent criteria assessed allowing potential sites to be established was proposed.

The developed methodology was applied to a case study where by the effectiveness could be tested. The application of the methodology proved to be very effective in identifying potential cemetery sites in a given area, as a number of potential sites could be rapidly identified and assessed. However, it was determined through the application of the methodology that one of the greatest limiting factors to the investigation was the availability of data relating to the criteria and fatal flaws used to determine the suitability or otherwise of a number of proposed cemetery sites. For example, data relating to the location of boreholes and domestic water supplies is often unavailable, and this information can only be determined through social consultation where the locals are interviewed and water abstraction points determined or through consultation with the relevant DWA office.

Although the ten criteria proposed in this study proved affective in assessing a potential site, the criteria may be supplemented with additional criteria and in some cases modified allowing for an even more holistic and accurate assessment of potential sites. In one particular instance, two of the ten criteria where assessed in the same manner and therefore may be combined thus reducing the number of criteria to be assessed (i.e. site drainage and topography). Furthermore, the permeability ranges associated with soil type indicated in the unified soil classification system by Richards and Croukamp (2004) are too broad. Therefore the permeability ranges were not specific enough to allow for accurate determination of the distances that should be maintained from domestic water supplies and drainage features.

The additional criteria and those which could be combined are discussed in more detail in the relevant sections below.

5.2 Manipulation of existing criteria

Site drainage and topography both relate to the shape and profile of an area. In this study they are both assessed by determining the slope angle of the proposed site. The two are therefore a repeat of each other. As topography relates to the surface features of a site and is largely unaffected by various factors it is proposed that topography still be assessed using the slope angle of a site as proposed in this study. However, site drainage affects the movement of surface water and is affected by vegetation, site excavation, levelling and the presence of storm water management systems. Therefore it is proposed that drainage be assessed in future by a physical site inspection to determine the presence of any surface water features, signs of erosion and storm water management systems. It is proposed that site drainage be assessed using the following variables:

Site Drainage	4	Slightly inclined site: Excellent natural drainage with no visible pooling or erosion or suitable stormwater systems are in place.	75%	x	$\frac{x}{100} \times 75$
	3	Moderately flat or Moderately Steep: No storm water management system in place but site has good natural drainage and no evidence of erosion or surface water pooling			
	2	Flat or Steep site: Sufficient natural drainage with some erosion or surface water pooling visible			
	1	Very Flat or Very Steep: Rapid drainage or bad natural drainage resulting in a high degree of visible erosion or surface water pooling			

In addition to the above, this study suggested that permeability be determined using the unified soil classification system proposed by Richarrds and Croukamp (2004). This system however bases permeability on soil type and although suitable to gain an understanding of the possible permeability, the proposed permeability range is too broad and does not allow a site to be assessed accurately enough to allow for accurate determination of the distances that should be maintained from domestic water supplies and drainage features. Permeability should therefore in future be determined by a specialist capable of undertaking such an investigation or by the field test proposed in Chapter Three of this study.

All other criteria provided a suitable method of assessing the individual characteristics of a proposed number of sites and therefore remain unchanged. However, as previously mentioned, the addition of a number of criteria may allow for a more detailed site investigation and site ranking procedure.

5.3 Additional criteria that need to be considered in the site selection process

It was concluded during this study and subsequent to the application of this site selection methodology to a case study that additional criteria need to be assessed to more adequately address the suitability of a site for a cemetery. The following additional criteria need to be considered in the site selection process:

(a) Land ownership

Cemeteries in South Africa are largely government owned and thus commissioned by the local authority (BCM, 2005). For this reason, land that is owned by the local municipality and local community will be preferred over land that is privately owned due to the large acquisition costs involved. Thus it is proposed that land ownership be considered as an additional criteria used to determine the acceptability of a potential cemetery site.

Therefore it is proposed that the additional criteria of land ownership be assessed using the following variables:

Land Ownership	4	Municipal/ Communal Land	25%	x	$\frac{x}{100} \times 25$
	1	Private land			

The significance of land ownership was determined using the significance diagram (refer to Figure 2) presented in Chapter 3 and resulted in having 25% significance.

(b) Climatic water balance

When rain falls on the land surface, interactions between the land use and hydrologic cycle are present. Rain water will either re-evaporate, pool, run-off or infiltrate on or in the land and its structures (Dent, 2007).

The DWA (2005) recommends that all new landfill sites be assessed in terms of its climatic water balance. Although the climatic water balance is not a detailed water balance, it is a simple determination of whether or not significant leachate generation will occur. The climatic water balance therefore indicates whether or not the climate will result in the generation of significant leachate.

The climatic water balance (B) can be easily determined using two climatic components, namely average annual rainfall (R) and average annual evaporation (E). The climatic water balance of an area is determined by plotting average rainfall (R) and A-pan evaporation (EA) Figure 3 shown below.

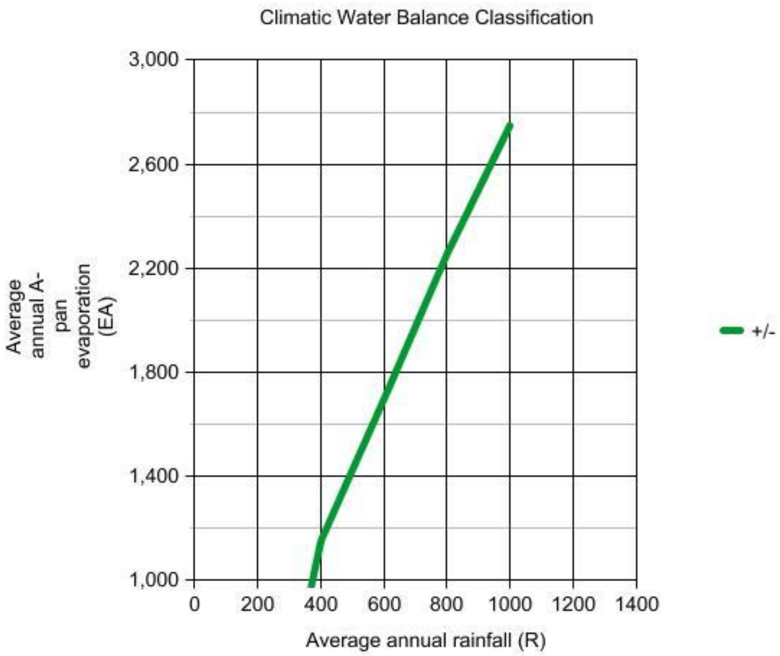

Figure 3: Method of determining the potential for leachate generation (DWAF, 2005)

If the data points plot above and to the left of the line, there should be no significant leachate generation and therefore should not pose a significant threat to groundwater. However, if the data points plot below and to the right of the line, significant leachate generation will be probable.

Although leachate generation of a landfill site is far more significant than that of a cemetery, a cemetery will generate leachate and if significant may pose a significant pollution potential. When water infiltrates the ground, it may interact with the interred remains and associated materials. Depending on the specific hydrogeological setting of the site, natural attenuation of the hydrogeochemisty and biota may or may not occur. The products produced through decay and the interaction of groundwater may travel beyond the cemeterie's boundaries depending on degree of constituent accumulation, flow paths of the water, the relative location of the remains in the cemetery and other factors.

Therefore it is proposed that the additional criteria of the climatic water balance be assessed using the following variables:

Climatic Water Balance	4	Negative climatic water balance	75%	x	$\frac{x}{100} \times 75$
	1	Positive climatic water balance			

The significance of the climatic water balance was determined using the significance diagram (refer to Figure 2) presented in Chapter 3 and resulted in having 75% significance.

Subsequent to the application of the proposed methodology to a case study, it was determined that an additional two criteria be added to the original ten criteria proposed. In addition to this, it is proposed that site drainage criteria be modified to a visual inspection of the site as opposed to the slope of a site, thus avoiding repetition. The revised criteria ranking matrix including the proposed changes can be found in Appendix K.

5.4 Conclusion

As population numbers and mortality rates increase in South Africa, further pressure is placed on existing and already stretched cemeteries. The need will therefore arise to develop new cemeteries to cope with the rise in death rates experienced in South Africa. However, poorly sited cemeteries may result in groundwater contamination by increasing the naturally occurring organic and inorganic substances to levels that render groundwater unpotable. This poses a significant health hazard to those who rely and are in contact with the contaminated water source.

A method of rapidly and accurately determining a number of potential cemetery sites has thus been devised to assist with suitable and environmentally sound cemetery sites. Twelve major criteria, deemed as decisive when determining a number of potential cemetery sites in a South African context, have been proposed for use as the basis of the methodology.

This method allows for the selection of a number of suitable cemetery sites in the shortest possible time, with the least cost and taking into consideration geotechnical and environmental constraints. However, the level of accuracy is largely dependent on the availability and accuracy of the data used, specialist investigations undertaken and the finances available to undertake such an investigation. However, having suitably placed cemetery sites alone does not ensure public health. This methodology should be utilised and legislated as a set of minimum requirements when selecting a cemetery site and supplemented with education, educating both authorities and the general public of the risks associated with poorly sited cemeteries.

The methodology and pertinent criteria proposed in this study should be compiled as a standard for planning authorities and consultants to use as a method of determining a number of potential environmentally sound cemetery sites.

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