MINIMUM REQUIREMENTS
FOR WASTE DISPOSAL BY LANDFILL

waste management series

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Second Edition 1998

MINIMUM REQUIREMENTS FOR WASTE DISPOSAL BY LANDFILL

Department of Water Affairs and Forestry
Republic of South Africa

Second Edition 1998

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This document forms part of the Waste Management Series, produced by the Department of Water Affairs & Forestry. Thus far, the series comprises:

Document 1: *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste.*

Document 2: ***Minimum Requirements for Waste Disposal by Landfill.***

Document 3: *Minimum Requirements for Monitoring at Waste Management Facilities.*

Document 1, ***Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste,*** sets out the waste classification system. In this, wastes are placed in two classes, **G**eneral or **H**azardous, according to their inherent toxicological properties. Hazardous wastes are further subdivided, according to the risk that they may pose at disposal, using a hazard rating. In this way, a less hazardous waste is distinguished from an extremely hazardous waste. Wastes with a hazard rating of 1 or 2 are very or extremely hazardous, while wastes with a hazardous, while wastes with a hazard rating of 3 or 4 are of moderate or low hazard. The requirements for pretreatment and disposal are approximately set in accordance with the waste classification. Hazardous waste prevention and minimisation are briefly addressed, because of their importance, as is handling, transportation and storage.

Document 2, ***Minimum Requirements for Waste Disposal by Landfill,*** addresses landfill classification, and the siting, investigation, design operation and monitoring of landfill sites. In the landfill classification system, a landfill is classified in terms of waste class, size of operation, and potential for significant leachate generation, all of which influence the risk it poses to the environment. Graded requirements are then set for all aspects of landfilling, including public participation.

Document 3, ***Minimum Requirements for Monitoring at Waste Management Facilities,*** addresses the monitoring of water quality at and around waste disposal facilities.

The Department of Water Affairs & Forestry intends extending the Waste Management Series. At the time of writing, the National Waste Management Strategy was being formulated, as a joint venture between the Department of Water Affairs & Forestry, the Department of Environment and Tourism, and the Danish Co-operation for Environment and Development (DANCED). Initially, three baseline study documents were drafted by South African consultants to provide data regarding waste generation, community waste and litter, and waste disposal sites in South Africa. These will form part of the series. Further work being carried out by Danish and South African Consultants, assisted by Departmental staff, will generate strategy documents which will also form part of the series.

Other documents envisaged for the series in future include Minimum Requirements for waste disposal site auditing, and the training of operators and managers of waste management facilities.

PREFACE

This document was first published for comment and application in the field in September 1994. Initially, very little comment was received and so, in 1995 and 1997, workshops were organised to involve Interested and Affected Parties (IAPs). All the feedback received from the workshops and other sources was then carefully considered by the Department of Water Affairs and Forestry (hereafter termed 'the Department') and the document was adapted accordingly. The Second Edition of the document thus supersedes the First Edition.

The response to the First Edition was mixed and tended to vary in accordance with the viewpoints of the respondents. Some felt that standards were too high while others felt they were not sufficiently stringent to protect the environment and public health. There were also those who appeared to oppose both the document and its implementation on principle.

Some had problems with the public participation process associated with the development of the document. It was therefore pointed out that this was primarily a technical document. In the early stages, its content had been developed by a team of specialists. Thereafter, throughout the development of the document, presentations had been made at local and international conferences to facilitate stakeholder input and peer review. When thought to be technically acceptable and sufficiently user friendly, the document had been launched and comment actively solicited.

Another area of concern was that the document does not deal sufficiently with the first three components of Integrated Waste Management, i.e. waste minimisation, recycling and treatment. Although the Department fully subscribes to all four components of Integrated Waste Management, this document only deals with the fourth step, i.e. disposal.
The reasons for this are:

- Regardless of how well the first three steps are undertaken, some waste will always have to be disposed of on landfills.
- Historically, many landfills in South Africa have been badly sited, designed and operated. They therefore represent significant point sources of pollution, which require priority control.
- By improving the standards of waste disposal, the cost of landfilling will increase. This will make waste disposal less attractive, which will in turn promote waste minimisation, recycling and treatment.

While much of the comment given at the workshops was valid, it was clear that in many instances respondents had not read the document to the extent that they were familiar with the content or underlying principles, many of which are complex. In other instances, it was clear that portions of the document needed to be rewritten or expanded to ensure easier understanding. Examples of issues requiring explanation included the use of size of operation rather than the physical size of a landfill for the size class (Section 3.3) and the use of the Climatic Water Balance as an *initial* means of differentiating between sporadic and significant leachate generation (Section 3.4).

A major area of confusion was caused by a misunderstanding of the principle of addressing the rule rather than the exception. The aim of the Minimum Requirements is to ensure that the same environmental standards and objectives are applied across South Africa, whilst at the same time not simply applying an indiscriminate, 'one size fits all' approach. The Minimum Requirements therefore address the rule, while still making provision for defensible deviation where site specific factors are such that the rule cannot or need not be applied. Such deviation could involve either an increase in standards or a relaxation, and would have to be properly, researched, motivated and recorded, so that it is indeed defensible. If in practice it is found that the exception proves to be the rule, consideration will be given to amending the document accordingly. It should be noted that other mechanisms used to ensure both consistency in standards and yet

flexibility include the landfill classification system, graded requirements, and, wherever possible, objective driven Minimum Requirements.

In certain instances, the document did require amendment. For example, by taking the local Climatic Water Balance into account, the co-disposal ratio between dry and liquid wastes could be made site specific. Allowance could therefore be made for the fact that in drier climates more liquid wastes can be safely disposed of than in humid climates.

In response to claims that the liner designs in the document were too stringent, these were also reassessed. During this process, however, it was determined that, in some instances, the designs were in fact not stringent enough, especially when applying the precautionary principle and where hazardous wastes were involved.

New Minimum Requirements have been added in response to comment. These include requirements for the disposal of medical waste in the absence of an incinerator (Section 10.3.6); waste reclamation or salvaging (Section 10.4.4); lagoons (Section 8.4.5); slope stability (Section 8.4.8); and public participation in the development and operation of landfills (Appendix 4.1).

In the field, it has been very encouraging to note that few problems appear to have been experienced so far with the principles upon which the Minimum Requirements are based. There have been some problems with certain details of the Minimum Requirements, for example, laying liners on slopes and achieving certain compaction densities on cover materials. However, once these issues were made known, it was possible to address them in the amendment of the document. Experience has also shown that small technical problems in the field can generally be addressed by applying the principle of defensible deviation. Problems arising from the misapplication of the Minimum Requirements in the field should be overcome in time by training and experience.

Based on this, the Minimum Requirements are considered to be both practical and implementable. This document is also achieving its objective of upgrading waste disposal practices in South Africa. This is particularly so in the case of new landfill sites, where the Minimum Requirement procedure has been followed throughout the development process. Nonetheless, there are some difficulties associated with the application of the Minimum Requirements to existing landfill sites. This may require that some compromises be made until all landfills that were established in the absence of standards are phased out.

Both proponents and protagonists have acknowledged the publication of the Minimum Requirements documents as a major step forward in promoting improved waste management standards in Southern Africa. The ***Minimum Requirements for Waste Disposal by Landfill*** document has been used as the basis for the Botswana Landfill Guidelines and is frequently used as the standard in Namibia and Swaziland. Furthermore, the International Solid Waste Association (ISWA) Working Group on Sanitary Landfills has recognised the Minimum Requirements approach developed in South Africa in their document on landfilling in developing countries.

In conclusion, the comment received on these Minimum Requirements is highly valued, as its inclusion has improved and augmented the content of the document. I therefore wish to thank all those who have contributed by submitting comment. Further written comment on the Second Edition will be very welcome.

PROFESSOR KADER ASMAL M.P.
MINISTER OF WATER AFFAIRS AND FORESTRY

SYNOPSIS

MINIMUM REQUIREMENTS FOR WASTE DISPOSAL BY LANDFILL

The ***Minimum Requirements for Waste Disposal by Landfill*** forms part of the Department of Water Affairs and Forestry's Waste Management Series. This series establishes a reference framework of standards for waste management in South Africa. It also facilitates the enforcement of the landfill permitting system provided for in terms of Section 20(1) of the Environment Conservation Act, 1989 (Act 73 of 1989).

The Act states that no person shall establish, provide or operate any disposal site without a Permit issued by the Minister of Water Affairs & Forestry and subject to the conditions contained in such a Permit. This applies to all new and operating sites. Unpermitted closed sites are controlled in terms of Sections 22, 22A, and 23 of the Water Act of 1956, (Act 54 of 1956). This Act is being phased out to be replaced by the National Water Act, 1998 (Act 36 of 1998) and the Water Services Act, 1997 (Act 108 of 1997).

In this document, the procedures, actions and information which may be required from an applicant when permitting a landfill, or written into a permit as conditions, are set out in the form of Minimum Requirements.

The objective of setting Minimum Requirements is to take pro-active steps to prevent the degradation of water quality and environment, and to improve the standard of waste disposal in South Africa. To ensure practical and affordable environmental protection, graded requirements are applied to different classes of landfill. The landfill class is determined from the waste type, size of operation, and potential for significant leachate generation. Where significant leachate is generated, leachate management is mandatory. Where hazardous waste is involved, the most stringent Minimum Requirements are applicable.
There is an important relationship between all aspects of the landfill development process. Good landfill site selection provides for simple cost-effective design, which, provided the site preparation is correctly carried out, provides for good landfill operation. This in turn ensures the environmental acceptability of the landfill. Environmental acceptability, in its turn, often relates directly to public acceptability. Minimum Requirements are therefore set for all technical aspects of landfill development, operation and closure. They are also set for involving Interested and Affected Parties (IAPs) in determining site feasibility and end-use requirements.

The requirements for public participation are integrated with the Public Scoping requirements of the Department of Environmental Affairs and Tourism's (DEAT) Environmental Impact Assessment Regulations (EIAR). The Environmental Impact Assessment (EIA), together with other necessary stages in the landfill development process, forms part of the Landfill Permit System, and has to be approved by DEAT (Province).

The Permit Holder is primarily and ultimately accountable for the landfill and any effect it may have on the receiving environment. However, the Permit Holder may appoint a Responsible Person, for example, a consultant or operator, to ensure that the appropriate Minimum Requirements are applied throughout the development, operation and closure of the landfill. The Responsible Person must be qualified to the satisfaction of the Department and must be capable of understanding and correctly applying the Minimum Requirements.

The accompanying *Figure* provides an overview of the relationship between all aspects of the landfill process, for a number of different scenarios. It also provides an overview of the permitting procedure.

From the *Figure*, it can be seen that the first step in any scenario is to classify the landfill under

consideration, whether it be proposed or existing.

Thereafter all applicable Minimum Requirements are based on this classification.

In the case of new landfills, site selection procedures eliminate sites with inherent Fatal Flaws, on a site specific basis. Site selection requires the due consideration of alternatives, in that more than one site must be considered. Site feasibility is then based on both technical suitability and public acceptance.

Site investigation will vary, depending on the landfill status. In most instances, however, it will involve a geohydrological investigation, an EIA and the determination of end-use requirements from the IAPs. Based on this information, a site design, operating plan and monitoring plan will be prepared. The design may be a new site design, an upgrade of an existing design, or closure design. In most cases, however, the basic design parameters, together with the end-use plan, must be addressed.

The results of the investigations and the design, together with certain additional information, must be collated and presented as a Permit Application Report. Based on this, the Department will consider granting a Permit to operate a landfill, either for a prolonged period, or with a view to closure.

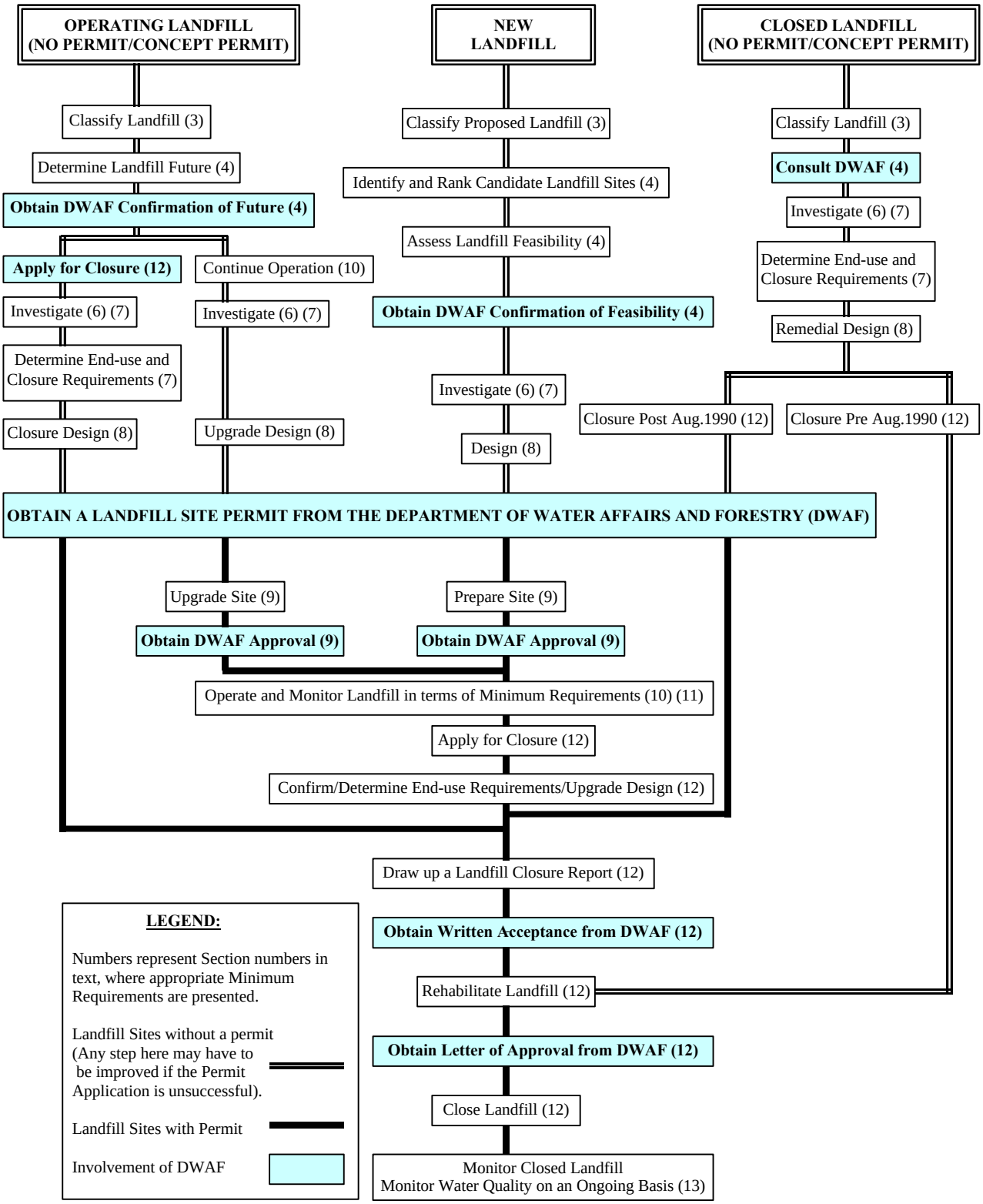
Once a Permit is granted, new landfill sites will be developed, prepared and commissioned for waste disposal, while existing sites may require upgrading and/or rehabilitation. New landfills can only be operated once the Department has approved the completed construction. Thereafter, landfills must be operated and monitored in accordance with the Minimum Requirements applicable to the class of landfill under consideration.

In the event of closure, the Permit Holder or landfill operator must inform the Department of the intention to close the facility one year before the event. The end-use requirements are then considered and the closure requirements are determined. Based on this, and on an appropriate investigation, the design is upgraded and a closure report is drawn up. The latter compares the landfill status with what is required and makes recommendations regarding rehabilitation.

Once the closure report has been accepted and the site has been rehabilitated to the satisfaction of the Department, the site may close and the end-use plan may be implemented. The closed landfill site then continues to be monitored for thirty years after closure. This period may, however, be shortened or extended, at the discretion of the Department.

Throughout the landfill development, operation and closure process, a close liaison must be maintained with the Department. At certain critical points, written consent must be obtained, before certain steps may be taken. In this way, the Department will use the Minimum Requirements to enforce waste disposal site permitting. A close liaison must also be maintained with IAPs throughout the process, to ensure public acceptance.

LANDFILL PROCESS



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B-	Water deficit climate, resulting in only sporadic leachate generation
B+	Water surplus climate, resulting in significant leachate generation
BATNEEC	Best Available Technology Not Entailing Excessive Cost
BPEO	Best Practicable Environmental Option
C	Communal Landfill
CBO	Community Based Organisation
CR	Co-disposal Ratio
DANCED	Danish Co-operation for Environment and Development
DEAT	Department of Environmental Affairs and Tourism
DOH	Department of Health
DWAF	Department of Water Affairs and Forestry
EIA	Environment Impact Assessment
EIAR	Environment Impact Assessment Regulations
EICR	Environment Impact Control Report
FML	Flexible Membrane Liner
G	General Waste or Landfill for General Waste
GCL	Geomembrane Clay Liner
H	Hazardous Waste or Landfill for Hazardous Waste
H:h	Hazardous Waste Landfill that can receive wastes with a hazard rating of 3 and 4
H:H	Hazardous Waste Landfill that can receive wastes with a hazard rating of 1 and 2
HELP	Hydrological Evaluation of Landfill Performance
IAP	Interest and Affected Parties
IEM	Integrated Environmental Management
IRD	Initial Rate of Deposition
L	Large Landfills
LDO	Land Development Objective
LEL	Lower Explosive Limit
M	Medium Landfill
MRD	Maximum Rate of Deposition

LIST OF ABBREVIATIONS (Continued)

NGO	Non Governmental Organisation
PI	Plasticity Index
RILC	Representative IAP Liaison Committee
S	Small Landfill
STP	Standard Temperature and Pressure

ACKNOWLEDGEMENTS

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*** Member of Steering Committee, First and Second Editions.

Representatives of the following organisations were also invited to form part of the Second Edition Steering Committee. However, they were unable to participate or decided rather to participate on a strategic level through the project steering committee of the National Waste Management Strategy of South Africa:

Chamber of Mines
Chemical and Allied Industries Association (CAIA)
COSATU
Environmental Justice Networking Forum (EJNF) / Earth Life Africa (ELA)
Parks Board Environmental Affairs
Regional Departmental Representatives
South African National Civics Organisation (SANCO)

Section 1

MINIMUM REQUIREMENTS - AN OVERVIEW

1.1 Background

The need for environmentally acceptable yet cost-effective waste disposal has become a priority in South Africa. This is because increasing population and urbanisation have resulted in growing waste generation, placing pressure on the environment. There is also an increasing awareness of environmental issues and a desire for a clean environment on the part of the public.

To ensure a cleaner environment, the Department of Water Affairs and Forestry[1], with whom responsibility for waste disposal is currently vested, has embarked on a programme to meet both current and future waste disposal needs. The aim of the programme is to protect the environment and the public from the impacts of bad waste disposal practices. The first step was to implement a control system, involving permits for landfill sites. To be eligible for a permit, a landfill requires to meet and maintain certain standards. To provide these standards therefore, the second step in the programme was the development of a set of standards in the form of Minimum Requirements which are applicable nationwide.

1.2 The Minimum Requirements Programme

Minimum Requirements are used by the Department to:

- **Set out minimum procedures, actions and information required from a permit applicant during the landfill site permitting process.**
- **Provide a point of departure against which environmentally acceptable waste disposal practices can be distinguished from environmentally unacceptable waste disposal practices.**
- **Provide the applicable standards or specifications that must be followed in the absence of any valid motivation to the contrary.**

1.3 Minimum Requirements for Waste Disposal by Landfill

The Minimum Requirements programme comprises projects dealing with waste management and disposal. This document covers the *Minimum Requirements for Waste Disposal by Landfill,* and it is the second document in the Waste Management Series. The other documents in the series cover the classification, handling and disposal of hazardous waste and water monitoring at waste management facilities. Further documents in the series will be published in the near future, see page ii.

In the *Minimum Requirements for Waste Disposal by Landfill,* criteria are established for the selection, investigation, design, permitting,

1* Hereafter termed ‘the Department’.

preparation, operation, closure and monitoring of waste disposal sites. In the context of this document, a waste disposal site is referred to as a *'landfill'.*

The objectives of the *Minimum Requirements for Waste Disposal by Landfill* are:

- **To improve the standard of waste disposal in South Africa.**

- **To provide guidelines for environmentally acceptable waste disposal for a spectrum of landfill sizes and types.**

- **To provide a framework of minimum waste disposal standards within which to work and upon which to build.**

The intention of the *Minimum Requirements for Waste Disposal by Landfill* project is to provide Legislators, Consultants, Permit Applicants and Permit Holders with guidelines and practical information that will assist them in complying with the Department's policy and any associated legislative requirements.

1.4 Some Characteristics of Minimum Requirements for Waste Disposal by Landfill

The approach to the Minimum Requirements is based on the Integrated Environmental Management (IEM) approach. This promotes, *inter alia*, the proactive control of pollution, by integrating environmental aspects into the planning of developments. [**Ref:** Department of Environment Affairs: *The Integrated Environmental Management Procedure,* Pretoria, 1992.] This approach has been dovetailed with the Environmental Impact Regulations (EIAR), published in Government Gazette No. 18261, September 1989.

The required processes and activities must meet the 'Best Practicable Environmental Option' (BPEO). This is the option which provides the most benefit and least damage to the environment as a whole, in both the long and the short term. It is arrived at by the due consideration of alternatives and costs.

The methods and practices used to implement the above processes and activities must be the 'Best Available Technology Not Entailing Excessive Cost' (BATNEEC), where 'excessive cost' is determined by a cost benefit analysis.

The *Minimum Requirements for Waste Disposal by Landfill* is an original document, i.e. it is not based on other documents. It was therefore necessary to establish certain principles on which the Minimum Requirements could be based, before formulating the document. The general characteristics of Minimum Requirements, therefore, are as follows:

- **The rule rather than the exception decides a Minimum Requirement**

  This is fundamental to the approach used in the formulation of this document and must be borne in mind when applying it. The principles involved in the Minimum Requirements cannot address every situation. Where exceptions exist, these must be identified and addressed in consultation with the Department.

- **Minimum Requirements tend to concentrate on objectives and principles, rather than on detail**

  This means that, although explanatory detail

is sometimes provided, Minimum Requirements generally specify the expected standard, rather than the method of achieving it

- **Numerical requirements have been used with discretion**

  The reason for this is that each situation must be considered on its merits. The inclusion of too many numerical requirements would transform the document into a prescriptive handbook. Experience has also shown that numerical requirements can be misunderstood, misapplied and/or abused.

- **The degree to which a Minimum Requirement is applicable is not specified**

  The degree to which a Minimum Requirement must be executed, in order for the end result to be acceptable to the Department, is not specified. This must be determined by site specific circumstances (see Section 1.10).

  For example, a Permit is a Minimum Requirement for all operating waste disposal sites. However, the detail required for the Permit Application will vary for different classes of landfill. With increasing size, more detail is required and hence more investigation. This is even more so in cases where hazardous waste is disposed of.

- **Accepted principles are adopted**

  Examples of accepted technical principles adopted would include the mandatory separation of the waste from the water regime, and the separation of contaminated and uncontaminated water drainage systems at a landfill site. Other examples of principles adopted would include the Polluter Pays Principle and the Precautionary Principle whereby additional provision is made in the case of risk or uncertainty.

- **Historically accepted practice is the basis for certain Minimum Requirements**

  An example of an historically accepted practice is the 2m unsaturated zone separating the waste from the ground water. Although a similar separation was widely used in the UK and the USA, there is no scientific justification for this specific thickness. Nonetheless, 2m now represents the minimum permissible separation between the waste and the ground water, as this is preferable to a lesser separation. Greater separations may frequently be required to form an acceptable barrier on account of soil conditions and other factors (see Sections 8.2.2 and 8.4.2).

- **Practicality often dictates substantially less than the ideal, so that Minimum Requirements will sometimes fall short of the ideal**

  The Minimum Requirements are frequently less stringent than standards applied in developed countries. This is to ensure practicability and sustainability under local conditions. At no time, however, will the protection of the environment be compromised.

  An example of a ‘less than ideal’ requirement would be the number of exploratory boreholes at a given site. Although the ideal would be to drill sufficient boreholes to provide a full understanding of the site for the purposes of design, this is not always possible.

Accordingly, a Minimum Requirement of at least one borehole is set for the majority of sites. The rationale for this is that one borehole provides substantially more information than no borehole at all.

- **The Minimum Requirements address basic administrative procedures**

  An example of a Minimum Requirement addressing a basic administrative procedure is the Minimum Requirement that a permit application be submitted, supported by the required technical reports (see Section 5).

1.5 Flexibility of Standards

Minimum Requirements are intended to raise the standard of waste disposal in South Africa to an environmentally acceptable level, on a national basis. They therefore provide uniform procedures, specifications and standards for waste management, to which all parties can work.

However, since site specific conditions may vary, provision must be made for defensible flexibility. The Minimum Requirements therefore can be seen as a reference framework of minimum standards to be adhered to (the rule) or deviated from (the exception).

Where site specific factors are such that the rule is not appropriate, provision is made for defensible deviation from the Minimum Requirements. Deviation from the rule may involve either an increase in standards or a relaxation. It is a Minimum Requirement, however, that any deviation be properly researched, motivated and recorded, so that it is indeed defensible, and that the environment is not threatened.

When site specific conditions are such that the Minimum Requirements prove inadequate, the Department will prescribe higher standards.

Under exceptional circumstances the Minimum Requirements may be relaxed. This may occur when, in the opinion of the Department, there is sufficient information to indicate that the Minimum Requirements can be safely amended. In such situations, the case must be properly researched and motivated, so that it can be assessed on its merits and any amendment can be defended.

1.6 The Enforcement of Minimum Requirements

Although there are some thirty six Acts which relate to waste disposal, there is little legislation in South Africa that relates directly to the environmentally acceptable development, operation and closure of landfills. However, Section 20(1) of the Environment Conservation Act, (Act No. 73 of 1989) makes provision for the permitting of landfills. The Act states that any person who operates or who intends to operate a waste disposal site must apply to the Department for a permit.

The Minimum Requirements are implemented through and enforced by the Landfill Site Permit. This is because the granting and retention of a Permit will depend on the landfill meeting the appropriate Minimum Requirements. The Minimum Requirements programme is therefore implemented within an existing legislative framework. Once a Minimum Requirement is included in a Landfill Site Permit, it is legally enforceable.

The application of the permitting system and the

Minimum Requirements to different situations is

set out in *Figure 8* and discussed in Section 5.

In the case of a proposed site or an unpermitted operating site, the Minimum Requirements are enforced during the Permit Application procedure. Those pertaining to public participation and environmental impact assessment are enforced in terms of the Environmental Impact Assessment Regulations of September 1997. All applicable Minimum Requirements must be met before a Permit can be obtained. The Department has the right to refuse to grant a Permit and, in the case of an operating landfill, to require that the landfill be closed.

In the case of a permitted site, the conditions appearing in the Permit represent enforceable standards for that specific landfill. Since Permit conditions will usually conform to or exceed the Minimum Requirements, the Minimum Requirements will also, in effect, become enforceable standards[*]. The Department has the right to amend an existing Permit.

In instances where existing landfills are unable to comply with the appropriate Minimum Requirements within an agreed period, they may have to be closed in accordance with the Minimum Requirements for closure.

All landfill sites closed after August 1990, when the permitting system came into force, have to be permitted and will thus be subject to the Minimum Requirements. Any site closed prior to August 1990 may be required to be rehabilitated in terms of the Minimum Requirements, depending on its potential environmental impact.

In the future, the enforcement of the Minimum Requirements will also be complemented and enhanced by regulations for the registration of generators and transporters of waste, and by a manifest system for the 'cradle to grave' control of hazardous waste.

1.7 The Permit Holder

Before a Permit is granted, the **Permit Applicant** is responsible for ensuring that the applicable Minimum Requirements are met. These would include those relating to site selection, investigation, design and Permit Application.

Once a Permit has been granted, the Permit Holder retains primary legal responsibility for the landfill, both during its operation and after closure. The Permit Holder retains this legal responsibility regardless of who develops or operates the site.

In executing this responsibility, the Permit Applicant or Holder may appoint appropriately qualified staff or consultants to co-ordinate, supervise and expedite different tasks. Different people will, therefore, act as the Responsible Person for different phases or facets of the landfill development and will be accountable to the Permit Applicant. Yet others will act in this capacity once the landfill is operational and they will be accountable to the Permit Holder.

1.8 The Responsible Person

The Responsible Person must ensure that all facets of the work undertaken are properly and competently directed, guided and executed, and **must therefore be appropriately qualified and experienced to the satisfaction of the**

[*] Regulations, in the form of standard Permit conditions, have been drawn up by the Department for the control of communal and small sites.

Department. Being appropriately qualified would include professional registration, where applicable and required by the Department.

As different people will act as the Responsible Person for different phases or facets of the landfill development, the person responsible for the investigatory work and design will, in most instances, not be the same person responsible for the operation of the landfill**. In every case, however, the Responsible Person will have to be capable of understanding and applying the principles and the Minimum Requirements contained in this document**. Furthermore, in the event of a particularly complex and/or high risk interpretation or design, a review by an independent consultant, acceptable to the Department, would be a Minimum Requirement.

In all phases of landfill development, there must be a contact person with whom the Department or the public can liaise. This may be the Permit Holder or the Responsible Person. During investigatory and design work, for example, the contact person may be a consultant. During the operation, the contact person, whose name and telephone number must appear on the notice board at the site entrance, could be the site supervisor, a contractor or a manager.

1.9 The Classification of Landfills

Since landfills differ from one another in terms of size, type and potential threat to the environment, a classification system has been developed, whereby landfills can be differentiated (see Section 3). Graded Minimum Requirements have then been applied to the different classes of landfill. Once a landfill has been placed in a class, only the requirements appropriate to that class need to be met. In this way the Minimum Requirements ensure environmental acceptability for the full spectrum of landfills, from a small communal operation to a regional hazardous waste landfill, in a cost-effective way.

It is the responsibility of the Permit Holder to amend the site classification appropriately, should a change in circumstances affect the classification of a landfill site.

1.10 The Degree to which a Minimum Requirement must be Executed

The landfill classification system provides a broad base from which the user can determine whether a Minimum Requirement is applicable to the landfill or not. It is not always possible or appropriate to set numerical requirements. The degree or extent to which the Minimum Requirement is applicable therefore must always be risk related and such that it meets the objective.

For example, the Minimum Requirement of an Environmental Impact Assessment (EIA) (Section 7) applies to both medium sized general waste landfills and to hazardous waste landfills. The amount of detail and the extent of the EIA will differ, however, with much more detail being required for the hazardous waste landfill.

The Responsible Person must therefore be capable of assessing the degree to which the Minimum Requirement must be carried out. **It is the responsibility of the Responsible Person to ensure that the degree of detail provided is acceptable to the Department**. In other words, that sufficient information is provided to enable the Department to make a defensible decision.

If the Responsible Person is not capable of assessing the degree to which a Requirement must be executed, he must approach the Department for clarification. This does not, however, relieve him of any responsibility.

1.11 Using this Document

To be properly understood, this document requires careful and thorough reading. This is because of its scope and complexity.

In using this document, the user must first familiarise himself with the background and the characteristics of Minimum Requirements for landfills (Sections 1 and 2). He or she must then classify the existing or proposed waste disposal operation under consideration, using the Landfill Classification System (Section 3).

The subsequent sections (4 - 12), follow a logical sequence of procedures which can be seen in the development of landfills. Site selection, investigation, design, preparation, commissioning, operation, closure and monitoring are each dealt with, consecutively, in their respective sections. The Permit Application procedure is, however, inserted after landfill selection. This is because it is at this point that the Permit Application procedure is initiated.

Figure 1 shows the sequence to be followed for the development of a new landfill site in terms of the Minimum Requirements. *Figure 2* shows how Minimum Requirements will be applied to non-permitted/concept permitted operating landfills. A Concept Permit is any Permit issued before the promulgation of the Environmental Conservation Act and will require upgrading to a full Permit.

Figure 13 (see Section 12) shows how the Minimum Requirements will be applied to the closure of landfills.

An overview of all of the above is provided in the Synopsis or *Figure 8* (see Section 5).

The process depicted in these figures has been followed as closely as possible in the structure of this document and in setting the Minimum Requirements.

Important points have been bolded in the text. It was not, however, deemed practical to highlight all of the Minimum Requirements in the text.

The Minimum Requirements for each class of landfill are therefore summarised in the form of a table at the end of each section. The user must refer to the Minimum Requirements tables to identify the Minimum Requirements applicable to the class of landfill under consideration. It is mandatory that the objectives of the procedures and specifications listed as Minimum Requirements in the tables or text be met, where indicated as such.

Table 1 shows the typical format used in tabulating Minimum Requirements, based on the Landfill Site Classification System developed in Section 3. In this format:

An **R** on the Minimum Requirements Table indicates that the Minimum Requirement applies to the class of landfill under consideration.

An **N** on the Minimum Requirements Table indicates that the Minimum Requirement does not apply to that class of landfill.

An **F**, which represents a flag, indicates that special consideration is required. The Responsible Person must therefore approach a recognised expert and/or a senior representative of the

Department, in this regard.

The text provides background to and explanation of the issues under consideration. Guidelines are also provided in the text, in order to promote good practice.

Adherence to these guidelines is not mandatory, but recommended. It is noted, however, that the Department could use these guidelines as a basis for setting site Permit conditions, in which case they become mandatory.

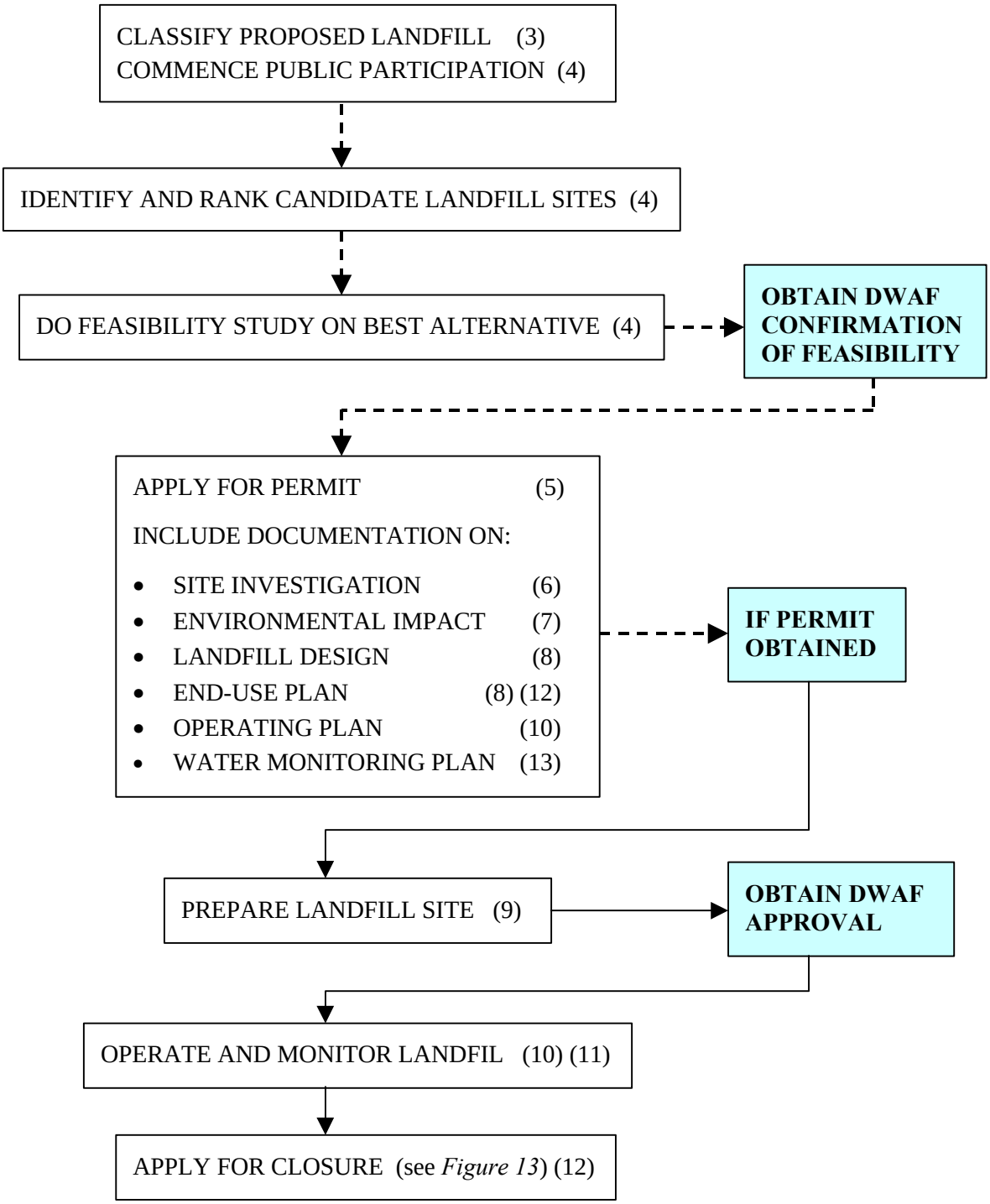
It is essential to recognise that all phases of landfilling are interrelated. For example, leachate generation is not only a function of climate; it may be affected by bad site selection (Section 4), inadequate diversion drainage design (Section 8), waste with excessive moisture content or poor operating and maintenance procedures (Section 10). All these aspects must be taken into account so as to minimise leachate generation. To facilitate this, cross-referencing, an index, figures and a list of definitions (Glossary) have been included.

It is noted that the language used in this document is colloquial English unless otherwise defined in the Glossary.

For additional information regarding landfilling, a list of recommended reading has been included at the end of this document.

FIGURE 1

Applying the Minimum Requirements to the Development of a New Landfill



LEGEND:

Numbers represent section numbers in text, where the appropriate Minimum Requirements are presented.

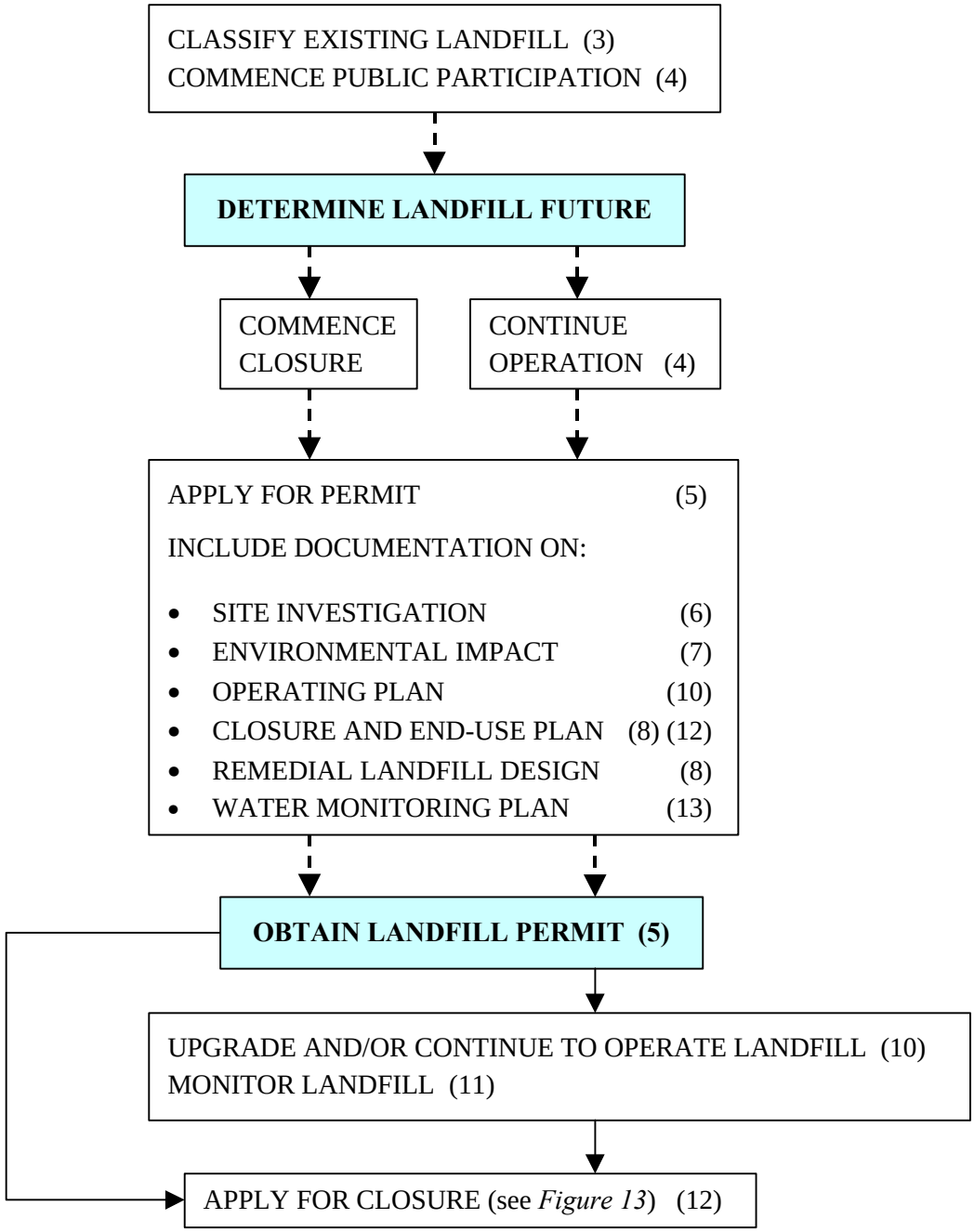
Landfill sites without permits

Landfill sites with permits

Interaction with the Department (see *Figure 6*, Section 5)

FIGURE 2

Applying the Minimum Requirements to Non-Permitted/Concept Permitted Operating Landfills



LEGEND:

Numbers represent section numbers in text, where the appropriate Minimum Requirements are presented.

Landfill sites without permits

Landfill sites with permits

Interaction with the Department (see *Figure 8*, Section 5)

In the event of closure, a landfill cannot close until it has been properly rehabilitated and an alternative facility has been made available. Consequently, a landfill may continue to operate with a view to closure.

TABLE 1
Minimum Requirements: The Typical Table Format

LEGEND **B =No significant leachate produced** **B+=Significant leachate produced** **R=Requirement** **N=Not a requirement** **F=Flag: special consideration to be given by expert and/or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1 - 4**
MINIMUM REQUIREMENTS	**B–**	**B +**	**B–**	**B +**	**B–**	**B +**	**B–**	**B +**		
Appoint Responsible Person	R	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Minimum no. of boreholes	N	N	1	1	3	3	5	5	F	F
Leachate management	N	N	N	F	N	**R**	N	**R**	**R**	**R**
Daily cover	F	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**

Section 2

WASTE DISPOSAL BY LANDFILL

2.1 The Role of Landfill in the Waste Management System

The term 'landfilling' refers to the deposition of waste on land, whether it be the filling in of excavations or the creation of a landfill above grade, where the term 'fill' is used in the engineering sense.

Historically, wastes have been disposed of on land. This is because landfilling is the cheapest and most convenient method of waste disposal. It is estimated that in excess of 95% of the waste generated in South Africa is disposed of in landfills, while the world figure is believed to be in excess of 85%.

No matter what waste minimisation technologies are implemented, whether they be for volume reduction or resource recovery, some form of residue will always remain and waste will continue to be generated. As depicted in *Figure* 3, this is ultimately disposed of in a landfill, the most commonly used method for ultimate disposal.

2.2 The Environmental Impact of Landfill

Landfilling is environmentally acceptable if properly carried out. Unfortunately, if not carried out to sufficiently high standards, landfilling has the potential to have an adverse impact on the environment. This impact may be divided into short term impacts and long term impacts:

Short term impacts

Short term impacts include problems such as noise, flies, odour, air pollution, unsightliness and windblown litter. Such nuisances are generally associated with a waste disposal operation and should cease with the closure of the landfill.

Long term impacts

Long term impacts include problems such as pollution of the water regime and landfill gas generation. Such problems are generally associated with incorrect landfill site selection, design, preparation or operation and may persist long after the landfill site has been closed.

The general objective of environmentally acceptable landfilling, therefore, is:

> **To avoid both short or long term impacts or any degradation of the environment* in which the landfill is located.**

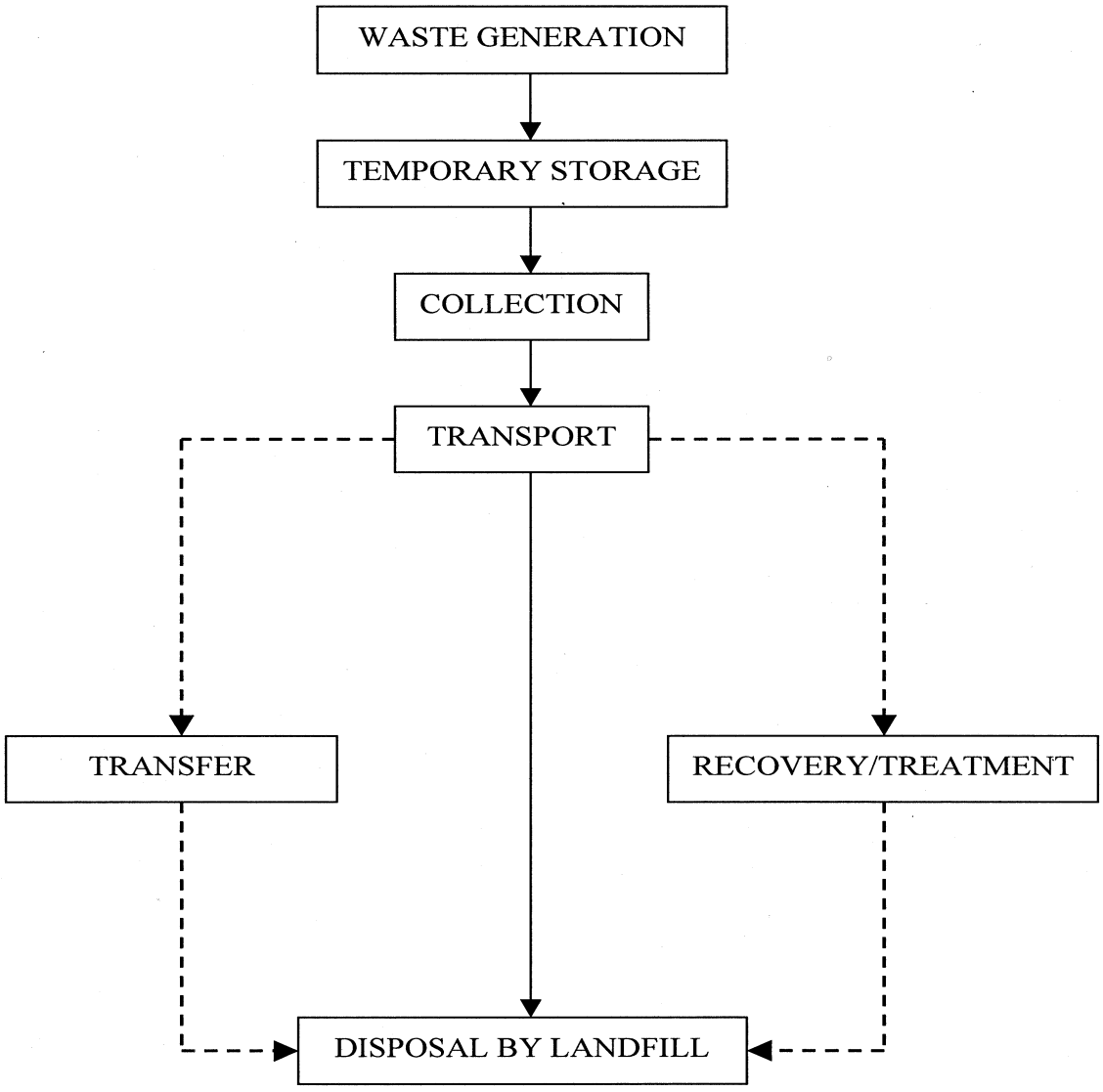
More specific objectives are pro-actively to:

> **Prevent pollution of the surface and ground water.**

* 'Environment' is used in the holistic sense and includes cultural, social, soil, biotic, atmospheric, surface and ground water aspects associated with the landfill (see Glossary).

FIGURE 3

The Role of Landfill in the Waste Management System



NOTE:

The purpose of this figure is to emphasize that landfill is the ultimate means of waste disposal. The elements and relationships depicted in the figure have therefore been simplified.

- **Ensure public acceptance by ensuring environmental acceptability.**

2.3 Overview of Environmentally Acceptable Landfilling

As is evident from *Figure* 1, the commissioning of a new landfill follows at the end of a lengthy process.

This process includes long term planning and information gathering, as well as early consultation with interested and affected parties, stakeholders, and communities. This is ongoing and may therefore continue to affect landfill design, operation and rehabilitation procedures throughout the landfill development process.

An important relationship exists between the siting, the design and the standard of operation of a landfill. **In essence, good landfill site selection provides for simple cost-effective design, which, provided the site preparation is correctly carried out, provides for good operation.**

2.3.1 Selecting a landfill site

The due consideration of alternatives is a basic IEM principle. Applied in this context, it means that a landfill site should only be selected after appropriate candidate sites have been identified and given due consideration.

The criteria which influence landfill site selection are discussed in Section 4. These will include economic, environmental and public acceptance considerations.

Economic considerations

Economic considerations include aspects such as haul distance from waste generation areas, site size, access and land availability. These affect acquisition, haul and other costs.

Environmental considerations

Environmental considerations relate to the potential threat of the operation to the physical environment, specifically to water resources. These include, *inter alia*, criteria such as site topography, drainage, soils, geohydrology and adjacent land-use.

Public acceptance considerations

Public acceptance considerations relate to the possible adverse impact of a landfill on public health or safety, quality of life, and local land and property values. Well founded public resistance may prohibit the development of a landfill site.

Experience has shown that it is often economic and public acceptance considerations that determine the general area in which a landfill is sited. Within these constraints, the optimum physical environmental option must be sought.

2.3.2 Designing a landfill

The design of a landfill is based on the outcome of the site investigation and environmental impact assessment, which are addressed in Sections 6 and 7, respectively.

The design of a landfill is covered in Section 8. If the best available site identified during the site selection process is sub-optimal from an environmental or geohydrological point of view, the subsequent site design must compensate for these shortcomings by means of appropriate engineering.
The objective in this instance is to reduce the risk

to public health or the impairment of any ecosystem or resource in the receiving physical environment to an acceptable level. In particular, the design must minimise the risk of water pollution by leachate and make provision for sufficient cover to isolate the waste body from the environment. Sufficient cover must be provided for both the landfill operation and final closure and end-use.

Prevention of water pollution

A mandatory **physical separation** between the waste and the surface and ground water regimes, as well as an effective surface water diversion drainage system, are fundamental to all landfill designs. These elements represent the first steps in the prevention of environmental pollution by waste disposal. In the case of landfills that produce significant leachate, particular attention must be paid to the need for **leachate management**.

Provision of cover

As the proper landfilling of waste requires regular covering to isolate the waste from the environment, landfills should be so sited and designed that sufficient cover is conveniently available for the duration of the operation. Any cover excavations must also be planned to ensure an adequate separation between the waste and the ground water regime once the soil has been removed.

2.3.3 Operating a landfill

The Minimum Requirements for the operation of a landfill are set out in Section 10.

The concept of sanitary landfilling was developed in order to minimise adverse impacts of the landfill operation on the environment. It is a Minimum Requirement that landfills be operated in accordance with the following sanitary landfill principles:

- **the compaction of waste, and**
- **the covering of waste on a daily basis.**

The correct application of these two principles obviates most short term adverse impacts associated with the landfill operation.

Compaction

Compaction of waste is generally achieved by passing heavy equipment over deposited waste. This reduces voids in the waste, thus reducing the chances of channelling which promotes the rapid infiltration and migration of any leachate formed. It also reduces the risk of fires, discourages vermin, controls litter, reduces the amount of cover required and increases site life.

Cover application

The application of soil or other suitable cover to compact waste also reduces litter and the risk of fire, but its main purpose is to eliminate odour. It also reduces scavenging and generally improves aesthetics**. The sanitary landfill definition specifies daily or more frequent cover**, but, in certain instances, such as small or remote sites with a shortage of cover material, this Minimum Requirement might, with the proper motivation, be appropriately amended.

Other short term impacts, such as unsightliness, dust, noise and traffic, are addressed using methods detailed in Section 10.

2.3.4 Closing a landfill

All landfills, except those closed prior to August 1990 when the permitting system came into effect,

must be permitted before they can be considered legally closed.

Closure will involve, *inter alia*, the application of final cover, topsoiling, vegetating, drainage maintenance and leachate management. In instances of poor landfill siting, design and/or operation, remedial work will be required prior to closure as part of the closure process. Any remedial design and rehabilitation must be based on appropriate investigation. After closure, the landfill can then be utilised in terms of its designed end-use.

Any landfill closed prior to 1990, the effective date of the Permit system, will also have to be rehabilitated, if this is considered necessary by the Department.

2.3.5 Monitoring a landfill

Monitoring is a control mechanism which is applied throughout the development of a landfill. During site preparation and liner placement, quality assurance and control are forms of monitoring which are implemented in terms of the Minimum Requirements objectives (see Section 9).The site is also monitored during operation, rehabilitation and after closure. Considerations include monitoring the impact of the landfill on the receiving environment; this includes gas monitoring and water quality monitoring (see Section 11 and the *Minimum Requirements for Monitoring at Waste Management Facilities).*

Both ground and surface water quality monitoring systems are set up at the landfill site investigation stage to provide pre-disposal background water quality data (see Section 13). During the design, these are formalised and expanded to address other facets of water monitoring. Water quality monitoring continues throughout the operation, and post-closure monitoring may continue for up to 30 years, or more if required, after the closure of the site.

Section 3

LANDFILL CLASSIFICATION

3.1 Introduction

In order for waste disposal to be both affordable and environmentally acceptable, the Minimum Requirements have to be adaptable. They have to suit different needs and situations in a scientifically defensible way. A village with a population of 100, for example, cannot be expected to have the same waste disposal needs, or meet the same Minimum Requirements, as a city with a population of 1 000 000.

A system for classifying landfills was therefore needed, as a basis for setting and applying the appropriately graded Minimum Requirements. This system had to recognise the inherent qualities and differences which characterise any landfill operation, i.e. the types of waste involved, the size of the waste stream and the potential for significant leachate generation.

The landfill classification system in existence at the beginning of the project used only waste type, and made no provision for size of operation or for leachate generation. In particular, the potential for significant leachate generation, the main cause of water pollution from landfills, was disregarded. A new landfill classification system was therefore formulated.

The objectives of this landfill classification system are:

- **To consider waste disposal situations and needs in terms of combinations of waste type, size of waste stream and potential for significant leachate generation.**
- **To develop landfill classes which reflect the spectrum of waste disposal needs.**
- **To use the landfill classes as the basis for setting graded Minimum Requirements for the cost- effective selection, investigation, design, operation and closure of landfills.**

Using the classification system, landfills are grouped according to:

- **the type of waste involved**
- **the size of the waste stream, and**
- **the potential for significant leachate generation.**

Note that the landfill classification system **cannot** address factors specific to a particular site, such as the sensitivity of the receiving environment. Such factors are addressed during site selection, investigation and environmental impact assessment, where any critical factor would be identified (see Sections 4.4 and 4.5). Before a landfill can be developed or permitted for continued operation, it will have to be demonstrated that any adverse environmental impacts can be addressed in the landfill design and operating plan.

3.2 Waste Class

Waste types are grouped into two classes, **G**eneral

and **H**azardous (see also the *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste)*.

Landfills are therefore also grouped into landfills suitable only for general waste, such as domestic refuse, and landfills for hazardous waste.

The waste classes are defined as follows:

(i) ***General waste (G)***

General waste is a generic term for waste that, because of its composition and characteristics, does not pose a significant threat to public health or the environment if properly managed. Examples include domestic, commercial, certain industrial wastes and builders' rubble. General waste may have insignificant quantities of hazardous substances dispersed within it, for example, batteries, insecticides, weed-killers and medical waste discarded on domestic and commercial premises.

General waste may be disposed of on any permitted landfill.

General waste can produce leachate with an unacceptably high pollution potential. This may result from waste decomposition, together with the infiltration and/or percolation of water. Therefore, under certain conditions general waste disposal sites must have leachate management systems. Therefore, in addition to being subdivided in terms of size of operation, general waste landfills are subdivided in terms of their potential to generate significant leachate.

(ii) ***Hazardous waste (H)***

Hazardous waste is waste which can, even in low concentrations, have a significant adverse effect on public health and/or the environment. This would be because of its inherent chemical and physical characteristics, such as toxic, ignitable, corrosive, carcinogenic or other properties.

The following types of waste should be regarded as potentially hazardous:

Inorganic waste

- Acids and alkalis
- Cyanide waste
- Heavy metal sludges and solutions
- Waste containing appreciable proportions of fibrous asbestos.

Oily waste

- Wastes primarily from the processing, storage and use of mineral oils.

Organic waste

- Halogenated solvent residues
- Non-halogenated solvent residues
- Phenolic waste
- PCB waste
- Paint and resin waste
- Biocide waste
- Organic chemical residues.

Putrescible organic waste

- Waste from the production of edible animal and vegetable oils, slaughter houses, tanneries and other animal and vegetable based products.

High volume/low hazard waste

- Waste that contains small quantities of highly dispersed hazardous substances. This waste presents a relatively low hazard. Examples are harbour dredge spoils, sewage sludge, soils and builders' rubble, which are contaminated by heavy metals, oils and other pollutants.

Miscellaneous waste

- Infectious waste such as diseased human/ animal tissues, soiled bandages and syringes, commonly referred to as 'medical waste'
- Redundant chemicals or medicines
- Laboratory waste
- Explosive waste from manufacturing operations or redundant munitions.

Hazardous wastes are grouped into nine classes, based on international danger groups[*]. They are also allocated a hazard rating. The hazard rating is based on acute mammalian toxicity, ecotoxicity, environmental fate, chronic toxicity and other criteria.

Hazardous waste is thus classified into:

Hazard Rating 1: Extreme Hazard
Hazard Rating 2: High Hazard
Hazard Rating 3: Moderate Hazard
Hazard Rating 4: Low Hazard.

For more information, see Department of Water Affairs and Forestry: *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste*, Pretoria, 1998. In situations where significant quantities of hazardous waste are identified, this document must be consulted, to determine the hazard rating.

The hazard ratings have different treatment and disposal requirements. Hazardous waste landfills are therefore divided into two types according to the hazard rating of the waste that they are designed to handle. **H:H** landfills can accept all hazard ratings of waste, while **H:h** landfills can only accept Hazard Ratings 3 and 4 and general wastes.

Certain hazardous wastes may be 'delisted' for disposal at an H:h landfill or an appropriately lined general waste site. This would be because the hazardous substance in the waste is of low mobility or concentration, or because the substance has been successfully treated to make it less hazardous. It must, however, be demonstrated to the satisfaction of the Department that the waste does not pose a risk to man or the environment. This would involve additional investigative testing.

Once the waste class has been established, the class of landfill and the applicable Minimum Requirements for disposal can be determined.

3.3 Size of Waste Stream or Landfill Operation

3.3.1 General waste landfills

The ultimate physical size of a landfill will depend on the amount of waste it receives over its lifetime. This is important in the context of a point source of pollution, and should therefore be addressed when undertaking an EIA at an existing or proposed site (see Section 7.5). Ultimate size is not, however, important in the classification system.

The size classification focuses on **the size of the waste stream and the consequent size of the operation**. This is because the immediate impacts of a landfill, the resources required to control them and, consequently, the Minimum Requirements applicable to the site will be dictated by the size of the operation.

The size of a landfill operation depends on the daily rate of waste deposition. This in turn relates to, amongst other things, the size of the population served. To take time and growth into account,

[*] The nine classes are set out in SABS Code 0228, which is derived from the International Maritime Dangerous Goods Code (IMDG).

landfills are classified using the **'Maximum Rate of Deposition'** or **'MRD'**[*]. This is simply the projected maximum average annual rate of waste deposition, expressed in **tonnes per day**, during the expected life of a landfill.

To calculate the MRD:

- Establish the **'Initial Rate of Deposition'** or **'IRD'**. This is the measurement of the existing waste stream in tonnes per day.
- Then, escalate the IRD at a rate which is usually based on the projected population growth for the estimated or design life of a landfill.
- The maximum average daily rate of deposition, which usually occurs in the final years of the operation, then represents the MRD.

For consistency, the IRD (and hence the MRD) is based on a five day week. If waste is disposed of on weekends, this must be quantified and clearly indicated, but for purposes of standardisation the total must still be presented as though for a five day week (i.e. a 260 day year).

Calculating the IRD

There are several ways in which the IRD or existing waste stream can be calculated.

These are as follows:

i) If the waste stream already crosses a weighbridge at an existing landfill, an average daily tonnage for the latest 260 day year can often be calculated from historical data. This single figure is then the IRD.

ii) If there is no weighbridge available, the average daily tonnage must be calculated on the basis of incoming volumes. This involves counting incoming vehicles and estimating the volumes carried in cubic metres.

Thereafter, to convert cubic metres to tonnes, an appropriate density factor must be applied. These factors may vary from 0,15 T/m^3 to more than 0,60 T/m^3, depending on waste constituents and compaction. The Responsible Person must therefore apply these factors with discretion, taking waste properties into account. In this way, an average daily tonnage or IRD can be arrived at for a given year.

iii) If there is no weighbridge available, daily tonnages may also be obtained by applying *per capita* waste generation rates to the figures for the population served. In general, these rates vary with the socio-economic standing of the population, from 0,5 kg *per capita* per day in the poor areas, to 3,5 kg *per capita* per day in the affluent areas. Again, the Responsible Person must use discretion in applying these factors to arrive at a single figure for daily tonnage or IRD.

Since waste frequently comes from different sources, it may be necessary to use a combination of the above methods in order to calculate the IRD and the MRD. It may also be useful to use more than one method for cross-checking purposes.

Calculating the MRD from the IRD

The following formula provides the basis for calculating the MRD from the IRD.

[*] This also ensures that, from inception, the Minimum Requirements apply to the ultimate size of a landfill operation.

MRD = (IRD)(1+d)^t (see Appendix 3.1)

where:

IRD = initial rate of deposition of refuse on site in T/day

d = expected annual development rate, based on expected population growth rate in the area served by the landfill

t = years since deposition started at IRD

MRD = maximum rate of deposition after t years

Examples of the application of the formula are provided in Appendix 3.1.

Using the size classification

The following table, *Table 3*, presents the landfill size classification based on the MRD. General waste landfills are divided into four size categories; **C**ommunal, **S**mall, **M**edium, and **L**arge. Where the MRD is borderline, the Responsible Person must always use the higher class.

TABLE 3
Landfill Size Classes

Landfill Size Class		Maximum Rate of Deposition (MRD) (Tonnes per day)	
Communal	**C**		<25
Small	**S**	>25	<150
Medium	**M**	>150	<500
Large	**L**	>500	

3.3.2 Hazardous waste landfills

The classification of hazardous waste landfills does **not take size into account**, but is based solely on the hazard rating of the waste (see Section 3.2 (ii) and Section 3.5).

3.4 The Potential for Significant Leachate Generation and the need for Leachate Management

To avoid water pollution, it is essential that significant leachate generation from landfills be managed by means of leachate collection and treatment systems.

All hazardous waste landfills are assumed to require leachate management systems.

General waste landfills are classified in terms of their potential to generate leachate. **This ensures that the risk of water pollution from leachate is identified at the earliest opportunity, even before a landfill site has been selected.**

Any landfill has the capacity to generate sporadic leachate in excessively wet weather conditions. It is only necessary, however, to install leachate management systems (underliners, drains and removal systems) when leachate generation could impact adversely on the environment.

A distinction is therefore drawn between general waste landfills that generate **significant** leachate and those that only generate **sporadic** leachate. Significant leachate requires to be managed by means of a proper leachate management system. Sporadic leachate, on the other hand, while requiring some management, does not warrant a costly leachate management system.

Significant leachate generation

This may be either seasonal or continuous throughout the year. It results mainly from climate and/or waste with a high moisture content.

In the case of existing landfills that do not meet the Minimum Requirements, other factors may also exist. These include fundamental problems with the landfill siting and/or drainage which result in significant ingress of ground or surface water into the waste body, and hence significant leachate generation.

Sporadic leachate generation

This is typical of arid climates and results from exceptional circumstances, such as a succession of excessively wet periods. This is often made worse by faulty site drainage. Sporadic leachate generation must always be minimised and controlled by drainage systems.

3.4.1 Determining whether significant leachate will be generated and if leachate management is required

It is a Minimum Requirement that, even before a specific landfill site is considered, the potential for significant leachate generation be assessed and any need for leachate management identified.

The potential for leachate to be generated by a landfill depends on the water balance associated with the site, i.e. the **Site Water Balance**. This is affected by such factors as rainfall, evaporation, moisture content of incoming waste and water ingress into the waste body on account of poor landfill site selection, design and operation. Of these, however, the relationship between rainfall and evaporation will, as a general rule, determine the Site Water Balance. Climate is the most common cause of leachate generation.

As ambient climate is the major uncontrollable cause of significant leachate generation at a landfill, a **Climatic Water Balance** is used as the first step in determining the potential for significant leachate generation (see Section 3.4.3).

The Climatic Water Balance indicates whether the climate in which a landfill is located will cause it to generate significant leachate or not. It is thus a tool to alert the developer, as early as possible, to the need to address leachate management in the landfill design and costing. In many instances, this may be applied even before the site for the landfill is selected.

Thereafter, **Site Specific Factors**, such as waste moisture content, and ingress of runoff and ground water into the waste body, must be taken into account (see Section 3.4.4).

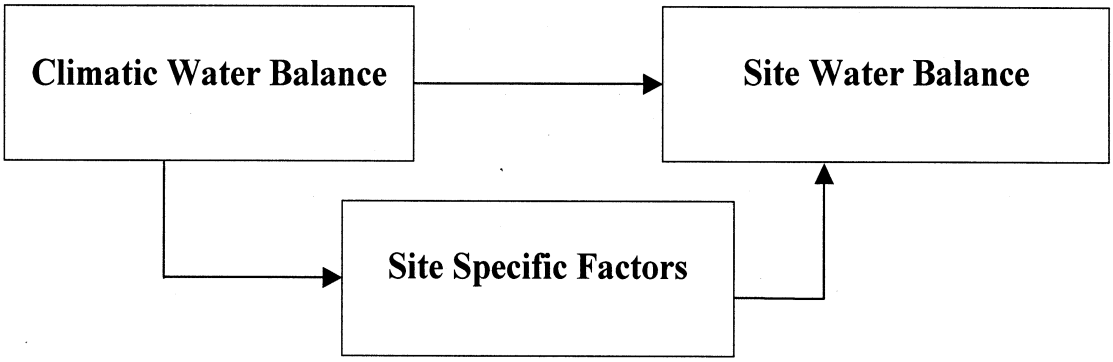
The relationship between the Climatic Water Balance, Site Specific Factors and Site Water Balance is set out in *Figure 4*.

3.4.2 Calculating the Climatic Water Balance

The Climatic Water Balance is not a detailed classical water balance, such as one that would be used to determine ground water recharge. It is a simple calculation that assists in deciding whether leachate management is required or not. It therefore provides a conservative means of determining whether or not significant leachate generation will occur.

The Climatic Water Balance (**B**) is calculated using only the two climatic components of the full water balance, namely Rainfall (**R**) and Evaporation (**E**).

FIGURE 4
Relationship between Climatic Water Balance and Site Water Balance



The data used are the precipitation and A-pan evaporation or S-pan evaporation, easily obtainable from the latest edition of the Department's evaporation and precipitation records **[Ref.** Department of Water Affairs and Forestry: Hydrological Information Publication No.13: *Evaporation and Precipitation Records*.]. The Responsible Person must identify the most representative weather station, or stations, on which to base the calculations.

The Climatic Water Balance is defined by:

B = R - E

where**:**

B is the Climatic Water Balance in mm of water
R is the rainfall in mm of water
E is the evaporation from a soil surface in mm of water.

The value of B is calculated for the wet season of the wettest year on record, as set out and illustrated by sample calculations in Appendix 3.2. **B** is then recalculated for successively drier years, because the wettest year on record may only be so on account of unseasonal rainfall, i.e. the wettest wet season does not always occur in the wettest year. This calculation is repeated until it is established whether:

B is positive for <u>*less*</u> than one year in five for the years for which data is available. If so:

- There should be **no significant leachate generation** on account of the climate.
- The site is classified $\mathbf{B^-}$.
- If the Minimum Requirements for the siting, design and operation are met and only dry waste is disposed of, **no leachate management system** should be necessary.

or, B is positive for <u>*more*</u> than one year in five for the years for which data is available. If so:

- There should be **significant leachate generation**.
- The site is classified $\mathbf{B^+}$.
- As such leachate requires management,

leachate management systems are a Minimum Requirement.

Examples of the calculation of the Climatic Water Balance are provided in Appendix 3.2. From these, it is seen that the iterative approach used eliminates problems commonly encountered when working with averages.

Note that the Climatic Water Balance indicates where a specific landfill would plot on a hypothetical climatic index that ranges from arid to humid conditions. The cut-off point between **sporadic leachate generation (B^-)** and **significant leachate generation (B^+)** is where **B** is positive for more than one in five years or for 20% of the time for which data is available. This calibration is based on long term studies and observation of numerous landfills in Southern Africa, some of which are mentioned in Appendix 3.2. It is considered to be conservative, as a site which is classified as $\mathbf{B}^+$ is, in fact, subject to $\mathbf{B}^-$ climatic conditions for 80% of the time.

The calculation is also conservative because it ignores run-off and thus assumes that all precipitation falling on the landfill will infiltrate. It also ignores any moisture storage capacity of the waste body or the cover.

3.4.3 Site Specific Factors affecting the Site Water Balance classification

As noted in Section 3.4.2, it is possible that factors other than rainfall and evaporation could affect the water balance of a landfill site. These include the moisture content of the incoming waste and the ingress of either ground or surface water into the waste body, on account of poor siting, poor drainage design or maintenance.

These factors may affect the water balance to the extent that a site which is classified as $\mathbf{B}^-$, using the Climatic Water Balance, does, in fact, generate significant leachate.

In such instances, the Responsible Person must be aware of the situation, amend the classification to $\mathbf{B}^+$ and manage leachate in accordance with the Minimum Requirements applicable to $\mathbf{B}^+$ sites. It may also be necessary to implement remedial leachate management measures in the case of existing sites which do not meet the Minimum Requirements.

Typical examples of factors other than climate that affect the Site Water Balance are:

Co-disposal of high moisture content and liquid waste

Any landfill where the co-disposal of liquids is permitted must be lined and equipped with leachate management systems that can contain, extract and treat the resultant leachate flow (see Section 10).

This is because the disposal of liquid and high moisture content waste adds extra moisture to the landfill. This superimposes a hydraulic loading on the Climatic Water Balance. Depending on the amount of additional moisture added, this usually results in significant leachate generation.

In cases where the co-disposal of high moisture content and liquid waste is intended or practised, more detailed water balance calculations are required. In such instances, the classification of the landfill is usually found to be $\mathbf{B}^+$ and leachate management is required.

Sub-optimal siting

The presence of a strategic aquifer would represent a ‘Fatal Flaw’ and prohibit the siting of a landfill (see Section 4.4). In the exceptional event that a landfill has to be developed above or adjacent to a

strategic aquifer, the Department would require that the landfill be classified as a **B**$^{+}$ landfill. This would be an application of the Precautionary Principle and an example of the implementation of higher standards in order to protect a vulnerable receiving environment.

Badly selected sites

Significant leachate generation will occur in existing landfills sited either in excavations which penetrate the ground water or in areas of ground water seepage or springs. Although leachate will not be obvious in the first case, in the second case it is likely that leachate will be observed emanating from the toe and the sides of the landfill.

Significant leachate generation may also occur in existing landfill sites which are sited in a water course or across the drainage feature of a catchment. This is because run-off water will dam up behind the landfill and infiltrate the waste body, unless there is effective diversion drainage. Where run-off, damming or water encroachment has occurred, leachate emission may continue long after the problem has been rectified by remedial design.

Badly designed and operated sites

If the Minimum Requirements for design and operation are not adhered to, significant leachate generation may result. Examples could include cover excavations which penetrate the ground water and infiltration from surface ponding on the landfill. The failure of drainage systems would also permit run-off to enter the landfill.

Conclusion

An existing landfill classified as **B**$^{-}$ using the Climatic Water Balance may therefore have a **B**$^{+}$ Site Water Balance and generate significant leachate. In this instance, the Responsible Person must amend the classification and either apply the appropriate Minimum Requirements for the amended classification or undertake remedial work as necessary. In all such instances, the Department must be kept informed.

3.4.4 Alternative methods of determining significant leachate generation

In situations where the Climatic Water Balance method is inconclusive or where Site Specific Factors are involved, a full, detailed Site Water Balance calculation may be required to establish whether or not a site will generate significant leachate. A programme such as HELP could be useful in this regard [**Ref.** Schroeder, P.R. *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Version 2, Source Code*, Vicksburg, 1989, Mississippi.].

3.5 Application of the Classification System

3.5.1 Landfill classes

The format for the Landfill Classification System is based on the three parameters discussed in this section, i.e. waste type, size of operation and Site Water Balance, see *Figure 5*.

As seen from *Figure 5*, the Landfill Classification System provides for ten different classes of landfill. These are **G:C:B^{-}, G:C:B^{+}, G:S:B^{-}, G:S:B^{+}, G:M:B^{-}, G:M:B^{+}, G:L:B^{-}, G:L:B^{+}, H:h** and **H:H**. Of the ten landfill classes, eight cater for general waste and two cater for hazardous waste.

Once the existing or proposed landfill site has been classified, the Minimum Requirements which apply to the class of landfill under consideration can be identified, using the Minimum Requirements tables.

FIGURE 5
Landfill Classification System

WASTE CLASS	G General Waste								H Hazardous Waste	
SIZE OF LANDFILL OPERATION	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3&4	H:H Hazard Rating 1-4
SITE WATER BALANCE	B^-	B^+	B^-	B^+	B^-	B^+	B^-	B^+		
MINIMUM REQUIREMENTS										

NOTES:

B^- = No significant leachate will be generated in terms of the Site Water Balance (Climatic Water Balance calculations plus Site Specific Factors), so that a leachate management system is not required.

B^+ = Significant leachate will be generated in terms of the Site Water Balance (Climatic Water Balance calculation and Site Specific Factors), so that a leachate management system is required.

h = A containment landfill which accepts **H**azardous waste with Hazard Ratings 3 and 4.

H = A containment landfill which accepts all **H**azardous waste, i.e. with Hazard Ratings 1, 2, 3 and 4.

General waste landfills

General waste landfills are sub-divided into four classes, based on magnitude of waste stream and size of operation. These classes are **C**ommunal, **S**mall, **M**edium and **L**arge. The larger the operation, the more stringent the Minimum Requirements.

The above classes of landfill are further sub-divided on the basis of the Site Water Balance. A B^- landfill is a landfill that generates only sporadic leachate and does not require a leachate management system. A B^+ landfill is a landfill that generates significant leachate. All B^+ sites, with the exception of **C**ommunal sites, require leachate management systems, comprising liners and leachate collection systems. The Minimum Requirements for B^+ landfills are more stringent than for B^- landfills.

Hazardous waste landfills

Any landfill which receives significant quantities of hazardous waste must be classified as a **H**azardous Waste Landfill. **Because of the risk posed by Hazardous Waste Landfills, they must be conservatively lined containment sites, regardless of the Site Water Balance.** Hazardous waste landfills must therefore all be separated from

the ground water regime by a liner and a leachate collection system (see Section 8).

Landfills which receive all types of hazardous wastes, including the most hazardous waste with Hazard Ratings 1 and 2, are termed **'H:H'** sites. Such landfills have to be designed, engineered and operated to the most stringent standards.

Landfills which receive less hazardous wastes with Hazard Ratings 3 and 4 are termed **H:h** sites. These sites are permitted to receive specific loadings of hazardous wastes. The design standards for **H:h** sites are higher than for **G:L:B**$^{+}$ sites, but are not as stringent as for **H:H** sites.

Mono Landfills

A mono landfill is one in which a single waste type is disposed. As in the case of multi-waste landfills, the waste type and hazard rating, the size of the waste stream and potential for generating significant leachate determine the class of landfill needed for its disposal. Mono landfills are therefore accommodated in the Landfill Classification System.

Certain 'delisted' hazardous wastes may not be co-disposed with other wastes, because of the risk of mobilisation of hazardous substances. In such cases, the delisted hazardous waste must be disposed of in a mono landfill.

Hazardous waste lagoons

Hazardous waste lagoons are not landfills. They are therefore not accommodated in the Landfill Classification System. As they do exist as a means of waste disposal, however, they are addressed, as an exception, in the Design section, Section 8.

3.5.2 Examples of landfill classes

The application of the classification system is illustrated by means of ten examples in Appendix 3.3. Although not referred to by name, these examples are based on actual case studies.

It must be noted that few general waste landfills in South Africa currently meet the Minimum Requirements for their classes. Examples of Minimum Requirements that are not met are liner design, sanitary landfill operation and final cover application. The examples in Appendix 3.3 therefore represent examples of class rather than models of landfills which fulfill the Minimum Requirements.

3.5.3 Amendment of site classification

The Permit Holder or Responsible Person must ensure at all times that the site is correctly classified. Should the class of the site change over time, the Department must be notified and the appropriate Minimum Requirements must be applied (see Section 3.4.3 and 3.4.4).

Section 4

SITE SELECTION

4.1 Introduction

The Minimum Requirements for site selection are summarised in Table 4, at the end of this Section.

Landfill site selection is the fundamental step in the development of a landfill. This step has far reaching economic, environmental and public acceptance implications. The landfill site selection process is only complete once the Department has found a site feasible on the basis of a feasibility study.

According to Section 24 of the Constitution: '**everyone has the right to an environment that is not harmful to their health or well-being**'. The establishment and operation of waste disposal sites must therefore not violate the constitutional right of the communities living in the vicinity of the site.

The objectives of landfill site selection are as follows:

- **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 landfill site selection process begins in response to an identified need for a disposal site. The classification system is then used to determine the class of landfill required to meet this need on the basis of the 'givens', i.e. the quality and quantity of the waste and the potential for significant leachate generation. Once the class, and hence also the required land area and potential impact, of the proposed landfill has been determined, candidate sites can be identified.

At this point, DEAT (Province) must be contacted, and, if necessary, a Plan of Study for Scoping must be developed and approved (see Appendix 4.1). Then, the Interested and Affected Parties (IAPs) must be notified of the necessity for and the intention to develop a landfill in the area.

The IAPs are those people or groups concerned with or affected by the development of the proposed landfill. They may be the local authorities, the relevant government departments, NGOs, adjacent residents or farmers, a residential community, or the public at large. Democratically elected representatives of the public must be regarded as IAPs and would include local, provincial and national government forums.

Using primarily environmental and economic criteria, sufficient candidate sites must be identified to ensure the due consideration of alternatives. All the candidate landfill sites identified must be evaluated to determine the most acceptable sites. These must be documented and presented to the IAPs as a 'Proposal'. Using a consultative process, the acceptability of the candidate landfill sites is reviewed and agreed. If necessary, the top sites may be subjected to a more detailed investigation to confirm their suitability.

A Feasibility Study, involving a preliminary

environmental impact assessment and geohydrological investigation, must then be carried out on the best site. This will determine whether the potential impact of the site is environmentally and socially acceptable. After this, the IAPs and communities must again be consulted for their input, and their acceptance of the proposed development must be confirmed and documented.

Should the site under consideration not prove feasible in terms of environmental acceptability or community acceptance, the next site is considered.

In the case of an operating landfill that is to be permitted, the Feasibility Study will determine whether the site should be permitted for ongoing operation or for closure. The IAPs must be consulted during the study, to obtain their input regarding the future of the landfill.

The process of landfill site selection is only completed when a site has been accepted as feasible by the IAPs, DEAT (Province) and the Department. Thereafter, detailed site investigations and the permitting process can commence.

4.2 Initiating the Public Participation Process

Public participation in waste management, as a whole, should be ongoing, and could involve education programmes, opportunities to be involved in policy making, and participation in alternative waste management programmes, such as recycling. This could be undertaken by government or NGOs.

Public involvement in the process of developing a specific landfill site begins once other waste management options have been addressed and the need for a waste disposal site has been established.

As waste disposal is an activity that may have a substantial detrimental effect on the environment, if not managed, it is subject to the Department of Environmental Affairs and Tourism's (DEAT) EIA Regulations (EIAR) [**Ref:** Government Gazette No. 18261, 5th September,1997]. *Figure 6* indicates how the Minimum Requirements for public participation in the development of a landfill (see *Figure 1*) are integrated in the EIAR process (see Appendix 4.1).

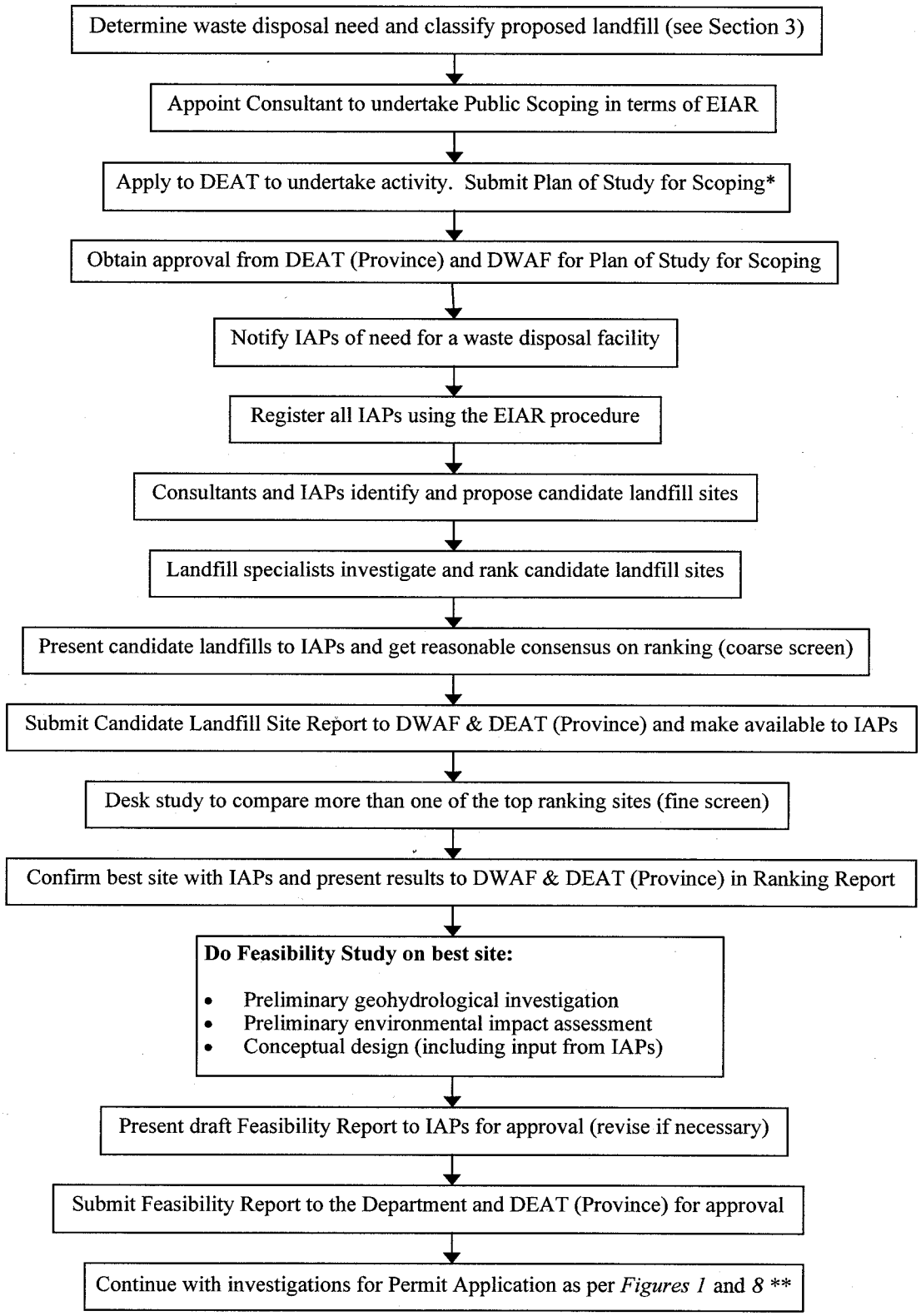
In terms of the EIAR, once the class of the required landfill has been determined, a consultant must be appointed to undertake Public Scoping. An application form and a Plan of Study for Scoping must then be submitted to DEAT (Province) and the Department for approval. Once approval has been obtained, scoping can begin. The IAPs must be notified and informed of the need for a waste disposal facility. This is the first step in the public participation process that will take place throughout the development of the landfill (see Appendix 4.1).

The IAPs involved in the public participation process may change during the development of the landfill. For example, those who wish to be involved during site selection may be completely different from those who wish to be involved during the feasibility study, which focuses on a specific site.

IAPs should be contacted and registered in accordance with the EIAR (see Appendix 4.1). They must be informed of the need for a waste disposal site in the area and reminded that as waste generators they too are responsible for creating this need. Any alternative waste management solutions that have been explored should also be presented and discussed. The implications of the landfill classification should be explained. For example, the size of the operation will provide a

FIGURE 6

Determining Feasibility of a Candidate Landfill Site



* Although in the case of certain landfills Public Scoping and an EIA would not be required by DWAF, this may be required by the DEAT (Provinces).

** The EIA must be approved by DEAT (Provinces) in terms of the EIAR.

good indication of such changes as waste tonnages, infrastructure needed, vehicle movements, and land area.

The IAPs must be informed of the proposed site selection process and they must be given the opportunity to define the extent to which they wish to participate therein. A Representative IAP Liaison Committee (RILC) could be elected to liaise with the developer or the consultant.

At this stage, candidate landfill sites may be identified by the landfill consultants, as well as the IAPs.

4.3 Approach to Site Selection

Early considerations in site selection are to identify the size and the general location of the required site.

- **Size of the site**. When the site is classified, the size of the waste stream and hence the MRD is calculated (see Section 3). This calculation gives a good indication of the physical size of landfill and hence the area of land required.

- **General site location**. This is determined by the waste generation area(s) to be served. It is economically sound practice to establish the proposed facility as close to the generation area(s) as possible, with a view to minimising transport costs. Thus, the initial area of investigation is defined by the economic radius, which will vary depending on the existing or proposed mode of waste transport. Since the location of the site relative to the waste generation area(s) is an economic consideration rather than a Minimum Requirement, it is not addressed further.

The further phases involved in the approach to site selection are as follows:

- The elimination of all areas with associated Fatal Flaws (see Section 4.4)

- The identification of candidate sites, based on the site selection criteria provided in Section 4.5.

- The ranking of candidate sites

- The carrying out of a Feasibility Study on the best option(s).

4.4 Elimination of Areas with Inherent Fatal Flaws

It is a Minimum Requirement that no landfill site be developed in an area with an inherent Fatal Flaw. The following situations may represent Fatal Flaws in that they may prohibit the development of an environmentally or publicly acceptable waste disposal facility except at excessive cost:

- **3 000m from the end of any airport runway or landing strip in the direct line of the flight path and within 500m of an airport or airfield boundary**. This is because landfills attract birds, creating the danger of aircraft striking birds.

- **Areas below the 1 in 50 year flood line**. This eliminates wetlands, vleis, pans and flood plains, where water pollution would result from waste disposal.

- **Areas in close proximity to significant surface water bodies**, e.g. water courses or dams.

- **Unstable areas**. These could include fault

zones, seismic zones and dolomitic or karst areas where sinkholes and subsidence are likely.

- **Sensitive ecological and/or historical areas**. These include nature reserves and areas of ecological and cultural or historical significance.

- **Catchment areas for important water resources**. Although all sites ultimately fall within a catchment area, the size and sensitivity of the catchment may represent a Fatal Flaw, especially if it feeds a water resource.

- **Areas characterised by flat gradients, shallow or emergent ground water**, e.g. vleis, pans and springs, where a sufficient unsaturated zone separating the waste body and the ground water would not be possible.

- **Areas characterised by steep gradients, where stability of slopes could be problematic.**

- **Areas of ground water recharges on account of topography and/or highly permeable soils.**

- **Areas overlying or adjacent to important or potentially important aquifers** (see Appendix 4.2).

- **Areas characterised by shallow bedrock with little soil cover**. These are frequently also associated with steep slopes, which may be unsuitable.

- **Areas in close proximity to land-uses which are incompatible with landfilling**. Land-uses which are incompatible with landfilling would attract community resistance and would include residential areas, nature reserves and cemeteries.

- **Areas where adequate buffer zones are not possible**. Buffer zones are discussed in Appendix 4.3.

- **Areas immediately upwind of a residential area in the prevailing wind direction(s).**

- **Areas which, because of title deeds and other constraints, can never be rezoned to permit a waste disposal facility.**

- **Areas over which servitudes are held that would prevent the establishment of a waste disposal facility;** e.g. Rand Water, ESKOM or Road Department servitudes.

- **Any area characterised by any factor that would prohibit the development of a landfill except at prohibitive cost.**

- **Areas in conflict with the Local Development Objectives (LDO) process and the Regional Waste Strategy.**

4.5 Identifying Candidate Landfill Sites

All possible alternative sites must be considered before making a final choice. It is a Minimum Requirement that sufficient candidate sites be identified to ensure the due consideration of alternatives. This will include any site put forward by the IAPs.

In identifying candidate landfill sites, numerous economic, environmental and public acceptance criteria must be considered. These criteria inter-relate, as there are always economic implications when candidate sites are sub-optimal in terms of environmental and/or public acceptance

characteristics. Also, the public will usually not accept an environmentally unsuitable landfill site.

The distance of the landfill site from the waste generation area is an example of opposing economic and public acceptance criteria. While increased distance from residential areas may be more desirable to the public, there is a cost penalty associated with increased haul distances.

4.5.1 Economic criteria

Economic criteria relate to the cost of obtaining, developing and operating a site. They include the following considerations:

- The possible incorporation of the site into a regional waste disposal system, either immediately or in the future. This tends to make a site economically more attractive.
- The economies of scale. Larger sites are economically more attractive.
- The distance of the landfill from the waste generation areas. This is directly proportional to transport costs.
- The size of the landfill. In general, if it is to be economical, the landfill must cater for the disposal of the waste stream over at least the medium term to justify the capital expenditure.
- Access to the landfill site. This has cost, convenience and environmental implications, especially if roads have to be constructed.
- 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.
- The quality of the on-site soil. Low permeability clayey soils on site will reduce the cost of containment liners and leachate control systems.
- Exposed or highly visible sites. High visibility will result in additional costs being incurred for screening.
- Land availability and/or acquisition costs. These are often dependent on present or future competitive land-uses, such as agriculture, residential or mining.
- Other miscellaneous economic or socio-economic issues. These might arise in particular instances, e.g. where the displacement of local inhabitants must be addressed.

4.5.2 Environmental criteria

Environmental criteria relate to the potential threat to the biotic and abiotic environment, particularly to water resources. They include the following considerations:

- 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.
- The importance of ground or surface water as water resources. The greater the resource value of the water, the more sensitive the establishment of a landfill on account of the potential for water pollution (see Appendix 4.2).
- 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.

- The quality of on-site soil. Low permeability soils reduce pollutant migration and are therefore favoured.

- Valleys where temperature inversion could occur. This could promote the migration of landfill gas and odours into populated areas.

- The sensitivity of the receiving environment. The development of a site in a disturbed environment, such as derelict mining land, would be preferable to a development in a pristine environment.

4.5.3 Public acceptance criteria

Public acceptance criteria relate to such issues as the possible adverse impact on public health, quality of life, and local land and property values. They also relate to potential public resistance to the development of a landfill site. Failure to meet the public acceptance criteria may constitute a Fatal Flaw. The following are important considerations:

- The displacement of local inhabitants. This will usually arouse public resistance.

- Exposed sites with high visibility. These are less desirable than secluded or naturally screened sites.

- The sensitivity of the environment through which the access road(s) passes. The shorter the distance to the site through residential areas, the more acceptable the site.

- Prevailing wind directions. New landfills must be sited downwind of residential areas.

- 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.

To protect the public from any adverse effects of a waste disposal operation, adequate buffer zones must be provided around landfills (see Appendix 4.3). Buffer zones are ‘set back distances’ or separations between the registered site boundary and residential developments. They may vary in width, depending on the classification of the landfill, the Site Specific Factors affecting the environmental impact, and the requirements of the Department and the IAPs. In general, no development may take place within a proclaimed buffer zone.

4.5.4 Critical factors

While not necessarily Fatal Flaws, economic, environmental and public acceptance criteria may be critical factors. This means that they may represent a severe constraint on the development or ongoing operation of a landfill.

A critical factor may, however, become a Fatal Flaw if it cannot be addressed to the satisfaction of the Department and/or if its presence should prevent the landfill from meeting a Minimum Requirement.

4.5.5 Procedure

By eliminating all areas with associated inherent fatal flaws, and taking note of all the criteria and critical factors listed in this section, a number of candidate landfill sites can be identified. These may include or be supplemented by candidate landfills identified by IAPs and should be presented on a map of suitable scale.

4.6 Ranking of Candidate Landfill Sites

Using the above criteria, the identified candidate landfill sites must now be technically evaluated and compared, to determine their acceptability.

In the early stages, when there are many candidate sites, a 'coarse screening' is carried out to eliminate the unsuitable sites and identify the top ranking sites. This exercise would initially be undertaken by specialists. The results will be presented to the IAPs in a report, the Candidate Landfill Site Report.

To do the coarse screening exercise, a discussion document and/or a matrix can be used.

Discussion document

A discussion document would discuss the facts pertaining to the candidate sites, using the main selection criteria, i.e. economic, environmental and public acceptance. The ranking of the sites would be motivated on the basis of these.

Site ranking matrix

A matrix can be developed with candidate sites on the one axis and selected criteria on the other (see *Figure 7*). The criteria should be appropriately weighted in order to reflect their relative importance. For example, size may be scored out of 20 whereas access may only be scored out of 5. In general, the matrix should be so designed that the following aspects are addressed:

- Environmental impact
- Safety risk (public safety, occupational health)
- Social impact
- Costs (acquisition, construction, operation and closure).

When using the matrix, each site is evaluated. Scores are assigned for each criterion and added together to provide a total for each site. Thereafter, sites are ranked from the highest to the lowest.

Candidate Landfill Site Report*

Once completed, the technical ranking must be presented to the IAPs, possibly through the RILC, for their input and for final ranking. Input may involve amendment of the ranking or the complete elimination of certain sites. The ranking will be presented in a draft Candidate Landfill Site Report.

Once the IAPs have confirmed the ranking, the Candidate Landfill Site Report, documenting the technical ranking exercise and IAP confirmation, must be submitted to the Department and to DEAT (Province) and made available to the public.

The Ranking Report

The top ranking sites themselves must now be compared to one another in a 'fine screening' exercise. In this exercise, a desk study of available information would be undertaken and a different, more detailed, matrix would probably be used for ranking. For example, each site could be ranked on an ABC system. For each criterion, the site rating best would receive an A, second best B, etc.

The results of this fine screening must be documented in a draft Ranking Report and confirmed with the IAPs.

When the top site is confirmed, the Ranking Report must be submitted to the Department and DEAT (Province) and be made available to the public.

* This report would be the equivalent of a draft of the EIAR Scoping Report.

FIGURE 7

Candidate Landfill Site Ranking Matrix

Candidate Site	Economic Criteria				Environmental Criteria					Public Acceptance Criteria				Total Score
	Distance	Size	Access	Etc.	Ground water	Surface water	Soil depth	Setting	Etc.	Distance	Visibility	Wind	Etc.	
Site 1														
Site 2														
Site 3														
Site n														

After this, the top ranking site is subjected to a more detailed investigation in the form of a Feasibility Study. This investigation is undertaken to confirm the environmental and public acceptability of the top ranking site.

4.7 The Feasibility Study and Report*

Input from the involved state departments may be desirable before subjecting the top ranking candidate landfill site to a more detailed investigation or the Feasibility Study.

The Feasibility Study is a Minimum Requirement for all **G:S, G:M, G:L, H:h** and **H:H** sites. Its aim is to confirm that the site has no Fatal Flaws. To do this, any critical factors must be identified and addressed to the satisfaction of the Department. The site must be proven to be both technically feasible and acceptable to the IAPs, before the Department will consider the site feasible for development.

In the case of an operating landfill that is to be permitted, the Feasibility Study will be used to determine the future of the landfill, i.e. whether it should be permitted for ongoing operation or for operation with a view to closure (see Section 4.7.8). It is a Minimum Requirement that the IAPs be consulted before this decision is taken.

The extent of the Feasibility Study and its presentation will depend on the class of landfill proposed, the physical complexity of the actual site, and the sensitivity of the receiving environment. Components of the study are provided below.

* This report would be the equivalent of the Scoping Report required by the EIAR.

4.7.1 Basic information

Certain information is necessary in order to provide background; this should include the following:

Landfill classification

In this section, all the information pertaining to the waste classification, the magnitude of the waste stream and the climatic and site water balances is presented. Based on this, the proposed landfill is classified, using the landfill classification system (see Section 3).

Indication of candidate landfill site procedure

In line with the IEM approach, more than one possible site should have been considered. In exceptional circumstances one site only can be considered, but these circumstances must be fully described and the exception must be motivated. In all other instances, the process of candidate landfill site identification and ranking must be described in the Feasibility Report, to the extent that the choice of the site under consideration is justified.

Site zoning

The current zoning of the site under consideration must be indicated and it must be guaranteed that it will be possible to zone it for waste disposal purposes.

Site description

The information provided in this section is usually based on both desk study information and observations from site visits. It should also include aspects forthcoming from the Preliminary Geohydrological Investigation and Environmental Impact Assessment, as well as any other information relevant to the development, design and operation of the site, e.g. topography,

drainage, aesthetics, wind direction, rainfall, existing vegetation, access, etc.

Permit Application Form

It is a Minimum Requirement that a Permit Application Form be completed and submitted in the Feasibility Report. This serves to inform the Department officially of the intention to develop a site. It is also a convenient means of presenting the information gathered in a standard format, for input into a waste disposal site registration system.

4.7.2 Preliminary Geohydrological Investigation

Normally, this is confined to the evaluation of existing information (maps and reports) and its confirmation in the field. Field confirmation will, in most instances, require testpits and, in certain instances, the drilling of a limited number of boreholes, and possibly blow yield tests. This investigation is considered the preliminary phase of the full investigation and is therefore carried out in accordance with the principles set out in Section 6. The information required is as follows:

Geology

This would include regional and local geology (stratigraphy and bedrock) as well as any structures (faults, dykes and lineations).

Soils

The soil on the site must be generally described and classified in terms of type, permeability, depth and volume available for cover material.

Borehole census or hydrocensus

All boreholes within a distance of one km from the site boundaries must be identified, with a view to recording ground water uses in the area. The purpose for which the water is used and borehole characteristics such as ground water levels, ground water quality, borehole yields, borehole depth, abstraction rates, geological logs, casing/screen details and drilling date, should be included if available. The reliability of such data should also be indicated.

From the borehole census and from consideration of any surface water usage, or potential usage, an indication should be given of the importance of water resources in the vicinity of the landfill.

Ground water

An indication of the minimum depth to ground water in the vicinity of the site, the yield and the probable flow direction must be provided from the borehole census. The importance of the ground water as a resource must also be indicated, based on a preliminary aquifer classification (see Appendix 4.2). Again, the reliability of the information provided should be indicated.

The vulnerability of any aquifer and the risk of its possible pollution should be interpreted to provide an overall assessment of the ground water regime. These issues are discussed from a monitoring point of view in the *Minimum Requirements for Monitoring at Waste Management Facilities*. [**Ref.** Department of Water Affairs and Forestry: *Minimum Requirements for Monitoring at Waste Management Facilities*, Pretoria, 1998.]

4.7.3 Preliminary Environmental Impact Assessment

The Preliminary Environmental Impact Assessment is considered to represent a preliminary phase of the full EIA described in Section 7 and is therefore to be carried out in accordance with the principles described in Section 7. While this is not a full EIA, it must re-address all the environmental siting criteria relating to the site which were considered during the candidate landfill site identification and ranking exercises.

Critical factors must be identified in the Preliminary EIA and must be discussed and addressed in the Feasibility Report. This assessment, based on the level of investigation conducted, must confirm that the identified critical factors can be addressed and that there are no Fatal Flaws.

4.7.4 Conceptual design and consideration of critical factors

The Feasibility Report must address any critical factors identified by discussing proposed solutions in the context of the envisaged conceptual design. In other instances, critical factors might be addressed by means of special operating procedures.

4.7.5 Maps and plans

The Feasibility Report must be illustrated with maps and plans. As a Minimum Requirement, the 1:50 000 topographical map and 1:10 000 orthophoto map, where available, must be included. Between them, both maps must indicate the position of the disposal site and must show the surrounding area to a distance of one kilometre, showing the 1 in 50 year flood line, position of boreholes, wells, springs, dams and water courses, archaeological, palaeontological, cultural and historical sites, important roads and transportation corridors, surrounding land uses and waste generation area served. Existing and proposed land use and development must also be indicated.

Should any other relevant maps or plans be readily available at this stage of the investigation, these could be included.

4.7.6 Further consultation with Interested and Affected Parties

It is a Minimum Requirement that at this stage, further attempts be made to notify and register IAPs who could be affected by the top candidate landfill. Even if a candidate landfill is found to be technically feasible, it is not feasible unless it is acceptable to the majority of the IAPs. Acceptance by the IAPs immediately affected by the project therefore represents a critical factor in determining the feasibility of the proposed candidate landfill site. Justified public resistance to a site may be regarded as a Fatal Flaw by the Department and DEAT (Province). These departments may, however, also overrule unjustified public resistance.

It is therefore a Minimum Requirement that those IAPs who would be immediately affected by the site under consideration be included in the consultative process. The IAPs must be identified and fully informed of the proposed development and its potential implications, so that their input can be obtained. The objective of this would be to ensure that the IAPs concerns are addressed in a responsible manner. If the acceptance of the IAPs can be obtained, the feasibility of a given candidate landfill site can be confirmed.

It is also essential that the local authority in whose area the site is located be fully involved in the consultative process. This is because, in terms of Section 39 of the Health Act 1977, the local authority is responsible for determining the zoning and/or the consent land-use associated with the proposed site. In doing this, the local authority is also responsible for controlling any future development within a buffer zone surrounding a site (see Appendix 4.3).

The consultative process must be fully documented in the Feasibility Report. A Record of Decision issued by the DEAT (Province) must also be included, confirming that the site is acceptable to the IAPs for the intended purpose.

Once the Feasibility Report has been completed, it is a Minimum Requirement that it be submitted and, where practicable, presented to the Department and the IAPs. While the Department officially receives copies of the report, it must also be made freely available to the IAPs.

The Department will co-ordinate and liaise with all other relevant local, provincial and state departments to obtain confirmation of site feasibility. Where there is any doubt regarding adequate consensus, the Department may also liaise with the IAPs.

If the Department finds the site feasible, this will be communicated to the applicant in writing. This communication could include specific directives from the respective departments.

Once written acceptance of feasibility has been obtained from the Department, the site selection process is complete. The applicant can then begin the permitting procedure and the more detailed investigations of the site.

4.7.7 Consideration of unpermitted operating landfills

There are many operating landfills in South Africa which are not permitted in terms of the Environment Conservation Act (Section 20), (see Section 5.1). These range from well run operations which have not yet been permitted to situations where uncontrolled dumping of waste has occurred on a large scale. Examples of the latter would include ‘borrow pits’ which are situated adjacent to townships and which have been developed into substantial informal and uncontrolled landfills. All unpermitted landfills must be classified and assessed in consultation with the Department, to determine the environmental risk which they pose.

In certain cases, unpermitted landfills will pose little environmental risk. This may be because of sound siting, design and operation, or simply because of the high ash and low putrescible content of the waste, or because significant leachate is not generated. Such sites could be upgraded in terms of design and operation, and permitted for continued operation in accordance with the Minimum Requirements.

Some unpermitted landfills may pose a risk to the environment because of a high pollution potential. If these cannot be upgraded to comply with the relevant objectives of the Minimum Requirements and environmental legislation, they must be closed in accordance with the Minimum Requirements and relevant environmental legislation. This usually requires site rehabilitation and the development of a replacement facility.

Where unpermitted operating landfills are to be upgraded or to continue operation until closure, it is a Minimum Requirement that the IAPs be involved in the decision making. This is also required in terms of the EIARs.

TABLE 4
Minimum Requirements for Site Selection

LEGEND B^- = No significant leachate produced B^+ = Significant leachate produced R = Requirement N = Not a requirement F = Flag: special consideration to be given by expert or Departmental representative	CLASSIFICATION SYSTEM									
	G General Waste								H Hazardous Waste	
	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3 & 4	H:H Hazard Rating 1-4
MINIMUM REQUIREMENTS	B^-	B^+	B^-	B^+	B^-	B^+	B^-	B^+		
Consult *Figure 6* and apply as appropriate	R	R	R	R	R	R	R	R	R	R
Classify proposed site	R	R	R	R	R	R	R	R	R	R
Notify IAPs of the necessity and intention to develop a landfill	R	R	R	R	R	R	R	R	R	R
Liaise with IAPs	R	R	R	R	R	R	R	R	R	R
Eliminate areas with fatal flaws	R	R	R	R	R	R	R	R	R	R
Identify candidate landfill sites	R	R	R	R	R	R	R	R	R	R
Buffer zone (m)	200	200	400	400	F	F	F	F	F	F
Minimum unsaturated zone	2m	2m	2m	F	F	F	F	F	F	F
Rank sites as indicated	F	F	R	R	R	R	R	R	R	R
Present ranked sites to IAPs	F	F	R	R	R	R	R	R	R	R
Site Feasibility Study	F	F	R	R	R	R	R	R	R	R
Site description	R	R	R	R	R	R	R	R	R	R
Complete Permit Application Form	R	R	R	R	R	R	R	R	R	R

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Preliminary Geohydrological Investigation	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Preliminary Environmental Impact Assessment	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Identify critical factors	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Assess critical factors	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Confirm no fatal flaws	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Confirm best site with IAPs and present results in Ranking Report	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Compile Feasibility Report and present to Department, DEAT (Province) & IAPs	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Departments' confirmation of feasibility	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Section 5

PERMITTING

5.1 Introduction

The Minimum Requirements for landfill site permitting are summarised in Table 5, at the end of this Section.

Landfill site permitting has been placed at this point in the document because it is at this stage, i.e. after the site has been pronounced feasible, that the Permit Application Procedure begins.

Provision is made for the permitting of landfill sites in terms of Section 20(1) of the Environment Conservation Act, (Act 73 of 1989). This section of the Act, however, only became enforceable when the Minister officially defined 'waste', in Government Gazette No. 12703 of 24 August 1990.

The Act states that no person shall establish, provide or operate any waste disposal site without a Permit issued by the Minister of Water Affairs & Forestry. Permitting thus applies to both new and existing landfill sites and to sites closed after August 1990. Landfill sites closed before August 1990, when Section 20(1) became enforceable, are controlled under Sections 22, 22A and 23 of the Water Act, 1956 (Act 54 of 1956). This Act is gradually being phased out, to be replaced by the National Water Act, 1998 (Act 36 of 1998), and the Water Services Act, 1997 (Act 108 of 1997). Sections 22, 22A and 23 of the Water Act, 1956, address the control of water pollution through remedial procedure and court action. Landfills closed after 1990 are addressed in Section 12 of this document.

Prior to 1989, concept permits were issued to landfill sites in terms of the Environment Conservation Act, (Act 100 of 1982). The issuing of concept permits was an interim measure undertaken in the absence of regulations to provide some form of control. Because of the absence of uniform systems, standards and controls, the detail of investigation and information required for the Permit Application varied with time and geographical location.

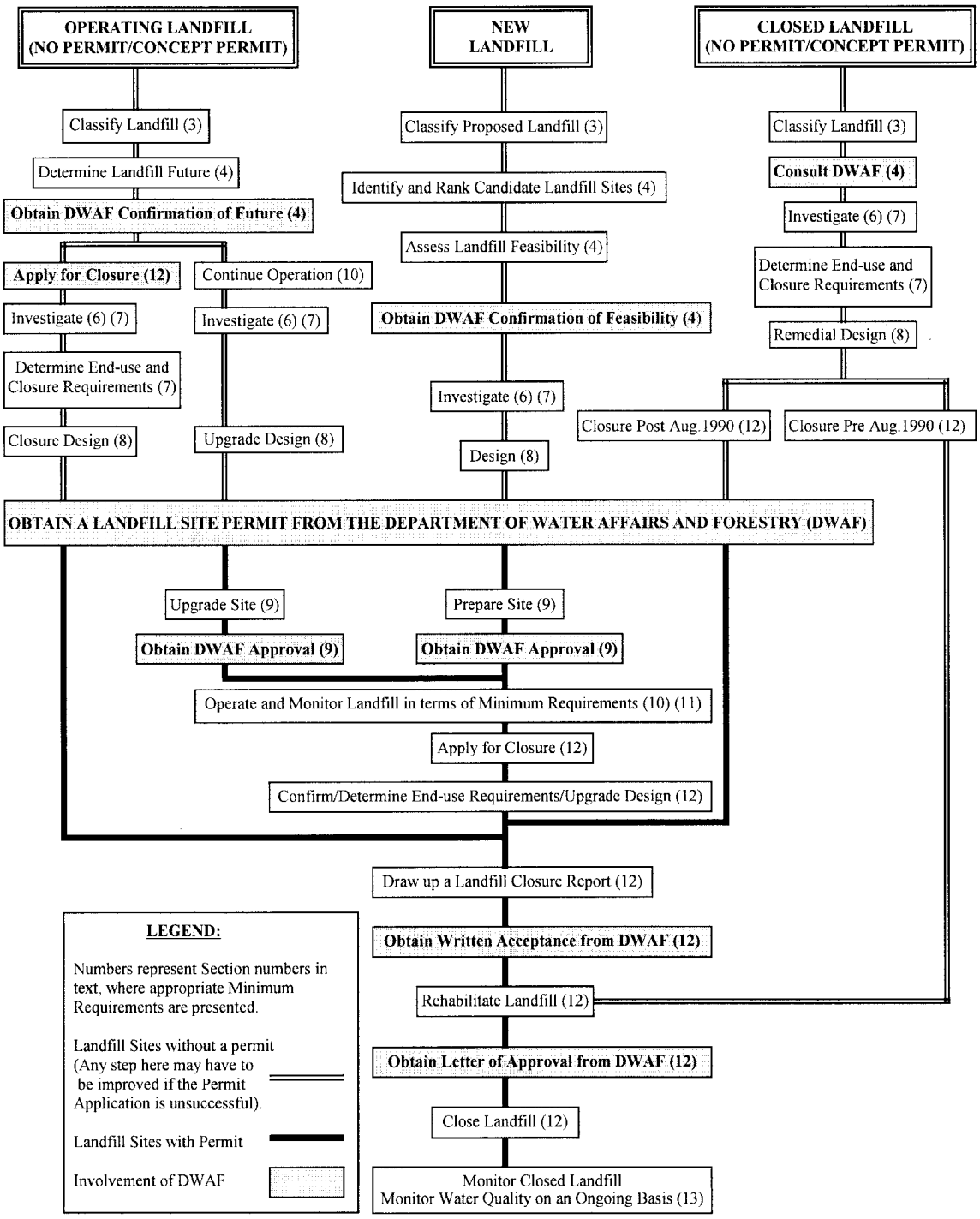
Holders of concept permits are required to upgrade their permits to the full permits discussed in this document. For this reason, operating landfill sites with concept permits are dealt with together with non-permitted operating sites (see *Figure 8*). Depending on the detail of the concept permit application and the condition of the landfill, upgrading may, however, represent a minor exercise.

The objectives of landfill site permitting are as follows:

- **To register and permit all proposed landfill sites, operating landfill sites, and landfill sites closed after August 1990.**

- **To provide a means of control and a set of conditions which ensure that the Permit Holders will design, prepare, commission, operate, close and monitor waste disposal sites nationwide, according to the relevant legislation and the Minimum Requirements.**

FIGURE 8
Applying the Landfill Permitting Procedure to Different Situations



The Permit Applicant may be the owner or operator of an existing or proposed landfill site. The application is, however, frequently made by a consultant or Responsible Person, on behalf of the applicant.

The Permit is a dynamic legal document and thus may, with time, require adaptation in order to manage the impact of the site on the environment. Throughout the life of the site, therefore, the Permit will be subject to revision and can be amended at any stage. It is the Permit Holder's responsibility to inform the Department of any changes in circumstances that may have an effect on the environment. These may be in the operation of the waste disposal facility, or in the infrastructure associated with it. This is necessary to enable the Department to amend the site-specific Permit conditions.

In terms of Section 35 of the Act, a Permit Application may be turned down. Should it be turned down, an applicant may appeal. In the case of a proposed facility, the site may not be developed if the appeal is unsuccessful. In the case of an existing landfill, should the appeal for the permitting of the continued operation of the site be unsuccessful, the site must be closed in terms of the Minimum Requirements.

The Permit Application Procedure and the implementation of Minimum Requirements are closely interlinked (see *Figure 8*) and cannot be considered in isolation. In other words, the Permit will only be granted if the landfill meets the relevant legislation and the Minimum Requirements. At the same time, the permitting procedure ensures control and that the legislation and appropriate Minimum Requirements are adhered to.

5.2 The Permit Application Procedure

Minimum Requirements are applicable from Landfill Site Selection onwards; the Permit Application Procedure, however, only commences once a landfill site has been selected and after the Department has, on the basis of the Feasibility Study, confirmed its feasibility. In the case of an existing site, the site may already be operational or even be closed before the Permit Application Procedure commences. *Figure 8* depicts the application of the landfill permitting procedure to different situations.

5.2.1 Definition of landfill class and initial approach to the Department

By means of the landfill classification system (Section 3), the applicant defines the class of landfill under consideration in terms of three parameters, i.e. waste class, magnitude of waste stream and Site Water Balance. From the waste class, it is determined whether a Permit is required for a **General waste disposal site**, or for a **Hazardous waste disposal site.**

In the case of general waste disposal sites, the applicant will deal with a Regional Office of the Department as a point of entry. In the case of hazardous waste disposal sites, the applicant will deal with the Director of Water Quality Management at the Department's Head Office, in Pretoria. The applicant may, however, obtain a Permit Application Form and relevant information from any office of the Department[*].

[*]In view of the possible changes in future environmental governance and the objective of managing the environment at the lowest possible level, the functional arrangements in this section may change.

5.2.2 Confirmation of site feasibility

In order for the Department to conduct a preliminary appraisal and to confirm the feasibility of the site, a Permit Application Form, together with certain other information, must be supplied to the Department. This serves as the formal notification to the Department of the intention to develop, to continue to operate, or to close a waste disposal site. It also provides the Department with the information necessary for it to make a decision about the feasibility or the future of the site.

For **G:C** sites, the completed Permit Application Form, together with proof of IAP acceptance, and the specified plans and maps, is the Minimum Requirement for the confirmation of site feasibility. This would include maps on which the site is demarcated.

For other sites, the Minimum Requirement for the confirmation of site feasibility may consist of the Permit Application Form accompanied by a full Feasibility Study Report (see Section 4.7). This will confirm the technical feasibility of the site, as well as its acceptability to the IAPs.

Three copies of the Permit Application Form and the requisite supporting documentation must be submitted to the appropriate office of the Department. A copy of the Feasibility Study Report will also be submitted to DEAT (Province) to ensure that the EIAR have been complied with. Thereafter, the Department, in collaboration with the relevant local authorities, DEAT and the Departmentof National Health and Population Development (DNHPD), considers the validity of the assigned classification and the feasibility of the site for future or continued waste disposal, or for closure.

5.2.3 Site visit and departmental directives

After considering the completed Permit Application Form and the documentation submitted in support of the site's feasibility, representatives from the three state departments visit the site together with the applicant.

Following the site meeting, the Department, representing the other state departments, will notify the applicant, in writing, of the following:

(i) In the case of an existing site, whether the applicant should apply for a Permit for continued operation, or whether the landfill site must be closed and hence requires to be permitted with a view to closure.*

(ii) In the case of a proposed site, whether it is feasible for waste disposal purposes. If the site is considered feasible, the applicant may proceed with the next phase, which involves drawing up the Permit Application Report. If the site is not feasible, the next best candidate site should be considered.

(iii) Whether certain site-specific requirements or environmental objectives must be met. These may relate to the interpretation of specific Minimum Requirements, or to the detail that will be required in the Permit Application Report.

In general, the amount of detail required in the reports and plans will vary with the site classification and with the complexity of the site. For example, relatively little detail will be required

* In the case of abandoned sites or sites closed before August 1990, the Department may require remedial actions. In such cases, the Department will contact the erstwhile operator or owner.

in the case of a **G:S:B⁻** site, whereas comprehensive information will be required in the case of an **H:H** landfill. It is the responsibility of the Permit Holderto ensure the provision of sufficient detail for the Department's purposes.

5.2.4 Permit Application Report

The objective of the Permit Application Report (see *Figures 1* and *2*) is to provide the Department with the information necessary for it to make a decision as to whether or not to issue a Permit.

In the case of **G:C** sites, a completed Permit Application Form, accompanied by the supporting plans and maps, and proof that an acceptable public participation process has been followed, may suffice as the Permit Application Report.

In other cases, however, a geohydrological report, an EIA, an EICR and a conceptual design will have to be completed, documented and submitted together with the Permit Application Form. The extent of the investigation will depend on the site classification, and this must be decided by the Permit Holder and Responsible Person in consultation with the Department.

In all instances, but particularly where buffer zone requirements cannot be met, the acceptance of the landfill site by the majority of the IAPs in the zone of influence, and compliance with the EIAR are pre-requisites to feasibility.

If a consensus among the IAPs cannot be reached, the Permit Applicant must defensibly demonstrate environmental conformance. This could be through appeal if the Permit is refused.

The Applicant will, using the Departmental directives and the Minimum Requirements, undertake all the investigations and exercises required to provide the necessary information. These will include:

- Site Classification (see Section 3)

  Ongoing liaison with IAPs throughout the permitting process (see Section 4 and Appendix 4.1)

- The Geohydrological Investigation and Report (see Section 6)

- The Environmental Impact Assessment and the formulation of the Environmental Impact Control Report (see Section 7)

- The development of a Landfill Design (see Section 8)

- The formulation of the Development Plan (see Section 9)

- The formulation of the Operating Plan, including a landfill monitoring programme (see Sections 10 and 11)

- The development of the Closure, Rehabilitation and End-use Plans (see Section 12)

- The development of the Water Quality Monitoring Plan (see Section 13 and *Minimum Requirements for Monitoring at Waste Management Facilities*).

The above reports and plans are collated into the Permit Application Report, which includes the Permit Application Form and an executive summary containing a motivation for the permitting of the site. The motivation must be signed by the Permit Applicant.

Three copies of the Permit Application Report, comprising the Permit Application Form supported by some or all of the above reports, are then made prepared and submitted to the appropriate office of the Department. Copies of the report must also be

available to the IAPs*.

The report may also be presented orally by the Permit Applicant (or the consultant) to representatives of the three state departments and the IAPs.

5.2.5 Issue of Permit

If the three state departments approve the Permit Application, the Department will send a signed copy of the permit to the applicant by registered post, under a covering letter on the Department's letterhead. The relevant state departments and local authorities will also receive copies of the signed Permit.

Once the signed Permit has been accepted, the Permit Applicant becomes the 'Permit Holder'.

The site must then be zoned for waste disposal and the title deeds amended to prevent building on top of the closed site.

Although the Permit Holder may, by a written agreement, use someone else (the Responsible Person, e.g. a contractor) to operate the landfill, the Permit Holder cannot relinquish responsibility and liability.

5.2.6 Appeal

Should the Permit Applicant not accept the Permit conditions, the Minister of Water Affairs & Forestry may be appealed to in the prescribed manner, within the prescribed period and upon payment of the requisite fee [Section 35 of the Environment Conservation Act, 1989]. If the appeal is successful, then the Permit conditions will be changed in accordance with the ruling. If the appeal is not successful, then the Permit Applicant will either abandon the project or accept the conditions as set out in the original Permit.

5.2.7 Site preparation

In the case of new sites, the Permit Holder may only proceed with site preparation in terms of the Permit conditions or, alternatively, with the written consent of the Department.

Where complex engineering is involved, this must be undertaken in consultation with the Department. When preparation is completed, the Permit Holder must notify the Department, in writing, of the intention to operate the landfill.

In the case of complex engineering, such as the laying of a liner at a **B**$^{+}$ or a hazardous waste disposal site, Quality Assurance will be required. Particularly in the case of hazardous waste disposal sites, a suitably qualified representative of the Department must inspect and approve each phase of development, such as the compaction of a liner or the field permeability testing. Records must also be kept of procedures carried out and the results of tests.

Before waste disposal can commence, the site must be inspected and, if it is approved by the Department, the Permit Holder will be provided with written notification of its acceptability and with consent to proceed with operations.

5.2.8 Operation and control

After site preparation, the landfill must be operated in accordance with the Permit conditions. Any applicable Minimum Requirements not specifically

*With the consent of the Department, certain confidential information that allows a Permit Holder a competitive business edge can be removed from the copies of the Permit Application Report that are available to the IAPs.

stipulated in the Permit conditions should also be adhered to. During operation, the site may be inspected by officials of the Department and representatives of the IAPs on an *ad hoc* basis (see Section 11.2). For this purpose, a landfill site Monitoring Committee must be set up.

Any infringements of the Permit conditions will be noted and the Permit Holder will be notified accordingly in writing. If there are any major transgressions or continued infringements, the Permit Holder may be prosecuted.

If a landfill significantly pollutes the surface water or ground water, the Permit Holder will, in terms of Sections 22, 22A and 23 of the Water Act, 1956 be directed to take remedial steps to prevent any further pollution. If the Permit Holder fails to comply with the directives, the Department may take temporary possession of the site, amend the Permit, or close the landfill and recover any expenses the Department may have incurred. This Water Act is gradually being phased out, to be replaced with the National Water Act, 1998 and the Water Services Act, 1997.

Anyone who contravenes the aforementioned Acts or who fails to fulfill a condition of a Permit issued to him under Section 20(1) of the Environment Conservation Act, 1989, shall be considered guilty of an offence and, on conviction, be liable to a fine not exceeding R100 000 or to imprisonment for a period not exceeding 10 years.

5.2.9 Change of ownership or operator

Should the Permit Holder intend to sell the landfill or lease the operation legally to another person, the Department must be informed, in writing, at least 60 days prior to the event. Should the Permit change hands, all legal responsibility associated with the landfill has to be vested with the new Permit Holder, who must be approved by the Department.

5.2.10 Site closure (see Section 12)

Should the Permit Holder intend to close the landfill, permission to do so must be obtained from the Department. Once all Minimum Requirements have been met, the appropriate office of the Department must be informed, in writing, at least one year prior to the intended closure date.

Closure must take place in accordance with the conditions of the Permit and the associated Minimum Requirements. Before final closure, the site must be inspected by officials of the state departments and members of the Monitoring Committee to determine whether closure should be permitted. Should further rehabilitation measures be required, the Permit Holder will be duly informed of this in writing. A site will only be considered closed once closure has been authorised by the Department.

The Permit Holder will remain responsible for monitoring the landfill for up to 30 years after closure. This period may, however, be shortened or extended at the discretion of the Department.

Should fires, exposure of decomposing waste as the result of erosion, or other problems develop on the closed landfill, the Permit Holder will still be responsible and will have to undertake remedial action to rectify such problems.

TABLE 5
Minimum Requirements for Permitting

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Depart-mental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Permit all unpermitted and concept permitted landfills	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Consult and apply *Figures 1, 2* and *8*	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Appoint Responsible Person	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Confirm site classification	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill Permit	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Deal with Department's Regional Office*	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	N	N
Deal with Department's Head Office*	N	N	N	F	F	F	F	F	**R**	**R**
Permit Application Form	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Site demarcated on a map	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Site visit by state departments	F	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Full Permit Application Report	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Feasibility Study Report	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Depart-mental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
Geohydrological Report	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Geological Report	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Environmental Impact Assessment	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Environmental Impact Control Report	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill conceptual Design	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill technical Design	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Approval of Design by the Department	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Development Plan	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Operation and Maintenance Plan	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Closure/Rehabilitation Plan	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
End-use Plan	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Water Quality Monitoring Plan	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Amend title deed to prevent building development on closed landfill	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Report change in operation infrastructure	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Report change of ownership	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Site inspection prior to commis-sioning	N	F	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Note: * In view of the possible changes in future environmental governance and the objective of managing the environment at the lowest possible level, these functional arrangements may change.

Section 6

SITE INVESTIGATION

6.1 Introduction

The Minimum Requirements for site investigation are summarised in Table 6, at the end of this Section.

A site investigation is a Minimum Requirement for all sites (see *Figure 8*). A preliminary investigation would have been completed as part of the Feasibility Study (Section 4). Now, further detailed investigations and reports are required for the purposes of the Permit Application. The detailed site investigation and the assessment of potential environmental impacts (Section 7) usually take place in parallel.

In the case of a new site, the site investigation required would be commensurate with the class of landfill under consideration. In the case of an unpermitted or concept permitted operating site, or of a closed site, the Department may require a full site investigation similar to that required for a new site. The extent of the investigation would, however, depend on the amount of investigation already undertaken, on what is required to meet the objectives of site investigation and on the potential environmental impacts associated with the site. This section outlines the investigation that would be required for a new landfill site.

The objectives of the site investigation are:

- **To ensure that no Critical Factors or Fatal Flaws were overlooked in the preliminary investigation.**

- **To provide a sound basis for risk assessment and for the design, operation and monitoring of the landfill by obtaining adequate geological, geohydrological and geotechnical information for the site.**

6.1.1 The basic approach to site investigation

To ensure that a site investigation complies with the Minimum Requirements, the following criteria must be satisfied:

- **The Responsible Person**

The Responsible Person(s) in charge of all investigatory work shall be appropriately qualified and experienced in order to execute, direct and guide all aspects of the investigation in a professional manner.

- **Extent and detail of investigation**

Enough data must be gathered and analysed to ensure that additional exploratory work is unlikely to add significantly to the level of understanding considered necessary for the site under investigation. The scope of the investigation should also be such that all reasonable queries and requirements of the IAPs are adequately addressed.

- **Liaison with the Department**

The Responsible Person must liaise with the Department throughout the investigation. This is because the depth or extent of the investigation

will vary, depending on the class of site. It is the duty of the Responsible Person to ensure the right levels of investigation and to ensure that the Department is provided with the information it requires to make a decision. Furthermore, under certain circumstances or at certain points in the investigation, the Department may have specific requirements. For example, additional geophysical surveys, pump and recharge tests and even tracer studies might be required by the Department, particularly where sites are proposed in or close to dolomitic areas or near other strategic water resources. Finally, the Department must be kept informed of progress.

6.1.2 The scope of a site investigation

Three areas are covered by the investigation and the subsequent report. These are:

- **Physical geography**, or the observable surface features associated with the site and surrounds
- **Sub-surface aspects**, or phenomena situated underground, which have to be exposed by means of excavation or drilling before they can be assessed
- **Miscellaneous issues**, such as surface or underground mining, associated with the site.

This section serves as a general guide to landfill site investigation. Depending on circumstances, it may be necessary to investigate additional aspects.

6.2 Physical Geography

This part of the investigation deals with what can be observed on or adjacent to the site.

6.2.1 Extent of investigation

The Responsible Person must define and validate the physical area and the extent of the site investigation, taking all relevant issues into account. This would include consideration of potentially affected areas, e.g. the effect on the water quality of a dam downstream of the proposed landfill.

6.2.2 Topography and surface drainage

Appropriate topocadastral data must be provided. This must include all significant topographic features. Most important are the drainage patterns, including seasonal and perennial streams and the distances to the nearest important water courses, wetlands and rivers. Rock outcrops and surface soil must also be recorded here.

Surface water quality (see Section 13.2.2)

Background water quality sampling will be required.

In the case of a proposed landfill, the pre-disposal background quality of the surface water must be determined prior to waste disposal. Surface water quality must be determined by sampling both upstream and downstream of the proposed site. Analysis of the samples must be performed to the satisfaction of the Department. This data will provide background information on surface water quality prior to any landfill activities.

In the case of operating or closed sites, a comparison of upstream and downstream surface water quality is necessary to indicate possible pollution of the surface water by the landfill.

Surface water usage

A survey must be conducted to assess the purpose for which the surface water is used and to assess

the strategic or community value of the water body.

6.2.3 Infrastructure and man-made features

Infrastructure such as waste generation areas, roads, railways or airports must be indicated. Of particular importance in the consideration of sites for landfill, are earthworks which affect the natural drainage system and/or result in spoil which could serve as cover. Elements such as sewage works, cemeteries or existing waste dumps that could cause or are already causing water pollution, should also be indicated.

6.2.4 Climate

Relevant climatic data must be provided to classify the site (see Section 3.4). Records of monthly rainfall and pan evaporation, wind speed and direction, preferably in the form of a wind rose, must be obtained from the nearest meteorological stations to the site.

6.2.5 Vegetation

All existing vegetation on the site must be described, whether it be original indigenous vegetation or exotic vegetation, plantations, crops or fallow agricultural land.

Most information in Section 6.2 can be obtained from published or easily obtainable works, including topographic and other maps, orthophotos, reports and books, climatic statistics, existing airphotos, etc. Published information must, however, be verified, updated and elaborated upon by on-site observation. The latest available information must always be used.

6.3 Sub-surface Features

As indicated, access to sub-surface features such as soil and rock profiles or ground water is usually gained only by excavation. This could include testpitting, augering and percussion drilling.

Geophysical techniques may be used to guide the siting of testpits and boreholes. These give initial insight into the geological and geohydrological characteristics of a site. Geophysical techniques are particularly useful in the location of water-bearing features such as dykes, faults and geological contacts.

The principles relating to the drilling of exploration boreholes are discussed in Appendix 6, which addresses the location of the borehole(s), the depth of drilling and the construction of permanent monitoring wells.

Although the ideal would be to drill sufficient boreholes to provide a full understanding of the site for the purposes of design, this is not always possible. A Minimum Requirement of at least one borehole is therefore set for the majority of sites. The rationale for this is that one borehole provides substantially more information than no borehole at all. This information would include accurate measurements of the depth to and characteristics of the ground water and some detail about the properties of the soil. It would also include insight into the geology, stratigraphy and geohydrology associated with the site. This borehole could also provide access to the ground water for both water quality monitoring and possibly for future extraction.

Where three dimensional information is required, for example when determining the phreatic surface and ground water flow direction, the Minimum Requirement is three boreholes. This is because

three boreholes would, **as a rule**, provide this information, by triangulation. At most of the larger sites, however, more than three boreholes would be necessary.

The depth of drilling must ensure that all geological and geohydrological structures relevant to the nature of the investigation are identified and adequately penetrated and probed. The depth must be such that subsequent deeper drilling would not reveal any new or unexpected information that could significantly alter or negate previously drawn conclusions.

6.3.1 Soils

Quality and quantity

Soil on a site serves both to provide cover material and to separate the waste body from the ground water. Consequently, it has to be properly qualified and quantified both for the purposes of design and for the Department's information.

Access to the first 3m to 6m of the soil profile is usually gained by properly shored testpits or trenches. If greater depths are required, auguring may be used. The soil profile is then defined using the MCCSSO System [**Ref:** Jennings *et al*, 1973].

In calculating the quantity of soil, data from testpits and trenches may be supplemented with information from the borehole profiles (see Section 6.3.2).

In situ permeability and other geotechnical tests (see Section 8.3)

Any natural soil layer that is suitable for use as a liner material, or that will separate the waste from the ground water, should be tested for permeability. Examples of suitable test methods are borehole infiltration tests of various types, double ring infiltrometer tests and tests using the Guelph *in situ* permeameter.

Other tests may include soil indicator tests for the purpose of soil identification (particle size analysis, Atterberg limits and clay content), as well as compaction tests (Standard Proctor).

It may be necessary to measure the shear strength of soils to establish the stability of cut slopes.

The compaction characteristics and permeability of any soils destined to be used as cover layers should also be determined.

6.3.2 Geology

Stratigraphy and lithology

The information required in this section is available from published or existing geological maps and reports. It must, however, be supplemented in all cases with field data, comprising borehole logs or profiles and the interpretation thereof.

The site must first be described in terms of the Regional Geology. This indicates where it fits into the regional stratigraphy, e.g. the Witwatersrand Super-group or the Karoo Sequence. Thereafter, the stratigraphic and lithological features adjacent to and immediately beneath the site must be examined and described. This should be illustrated with appropriate maps and cross sections.

The depth and extent of the investigation should be sufficient to provide the necessary understanding of the basic geology, commensurate with the nature of the investigation, and to identify any critical factors or potential Fatal Flaws (see Appendix 6).

All boreholes must be suitably examined and profiled according to accepted standards, as contained in the latest guidelines for profiling of percussion boreholes or diamond core holes.

[**Ref.** SAIEG Sub-Committee for Standardised Percussion Borehole Logging. *Ground Profile No. 59*, July 1989].

Tectonics, lineaments and structures

The presence and disposition of any geological faults, joints and fractures and other linear features, resulting from the intrusion of dykes or from steeply dipping strata, must also be described and indicated on the maps and cross sections referred to above. Appropriate airphoto interpretation, using the best (not necessarily the latest) aerial photography should be undertaken and reported on where considered relevant.

6.3.3 Geohydrology

All available geohydrological data and any factors affecting the ground water in the area must be identified and must form part of the site investigation report. This information should also be sufficient to undertake the appropriate risk assessment in respect of potential future ground water pollution, (see Section 5, *Minimum Requirements for Monitoring at Waste Management Facilities)*.

Ground water morphology and flow

The depth of any aquifer, ground water phreatic surface or perched water surfaces must be determined. Where applicable, the seasonal fluctuations, particularly the position of the wet season high elevation, must also be determined.

The gradient and general flow direction(s) of the ground water and other relevant data must be determined and possibly illustrated by appropriate maps and cross sections. In addition, all significant geological features and inferred structures must be explored to determine the possible presence and importance of preferential ground water flow paths.

Investigation of aquifers (See Appendix 4.2)

Since strategic aquifers (sole source, major or special) represent Fatal Flaws, any aquifer associated with a proposed landfill must be investigated to ensure that it does not represent a strategic water source (see Section 3, *Minimum Requirements for Monitoring at Waste Management Facilities*). The aquifer must initially be investigated to determine its yield, depth and other characteristics, as these are critical parameters when assessing its strategic value.

During drilling, blow yield tests are carried out, providing an initial indication of yield. Where yield is considered by the Responsible Person to be significant, step tests must be undertaken. Thereafter, a four hour pump test, or less in the case of low yielding aquifers, is undertaken and recovery is monitored. The processing of this data provides a reasonable indication of the yields of boreholes in the vicinity of the site, and hence of the potential of the associated aquifer. Based on this initial assessment, aquifers must be classified using the system included as Appendix 4.2.

If yields are in excess of 5ℓ/sec, or if the aquifer is significant in terms of Appendix 4.2, the Department must be informed and further testing must be undertaken. To determine the yield of an aquifer accurately, extensive pump testing and monitoring over a long period are required. In such cases it might also be necessary to determine the type, depth, thickness and lateral extent of the aquifer. Aquifer vulnerability, in terms of the Department's groundwater policy must also be addressed.

Ground water quality (see Section 13.2.1)

A clear understanding of the ground water regime in the vicinity of the site is a prerequisite to the establishment of a ground water monitoring system

By taking into account the requirements for future monitoring during the investigatory stage, it may be possible to avoid duplication and unnecessary expenditure at a later stage.

In the case of a proposed landfill, the background quality of the ground water, both upgradient and downgradient of the proposed site, must be determined prior to any waste disposal. A comparison of pre-disposal and post-disposal ground water quality then provides an indication of the impact of the landfill on ground water quality.

In the case of existing landfills, where no such pre-disposal background values exist, a comparison of upgradient and downgradient concentrations is used as a means of assessing the impact of the landfill on ground water quality (see Section 13). Results should be compared with the values and parameters set out in Government Notice No. R.991, 18 May 1984.

Ground water usage

A survey of existing boreholes and wells (a hydrocensus) must be conducted. Abstraction rates, yield, depth, age and the purpose for which the water is used must also be obtained, with a view to assessing the strategic or community value of the water resource. A clear indication must be given of the perceived reliability of such survey data and a definite distinction made between guesswork and factual information. Cognisance must also be taken of the source of the information.

Sensitive areas

Where landfill sites are considered or proposed in areas which are characterised by aquifers with potentially strategic value, or where ground water is or may be used in the future, special caution must be exercised. In such instances, the Department may require the services of a qualified geohydrologist who may use specialised techniques.

6.3.4 Miscellaneous sub-surface issues

Undermined areas

Underground mines must be identified, delineated and examined to establish the effect of their presence on ground water flows and potential subsidence. Where appropriate, a risk assessment must be undertaken by a recognised specialist.

Earth tremors

The risks and implications of mining-induced or other tremors must be addressed. If the landfill is to be sited in an area where natural earthquakes occur, their effect must also be taken into account in a risk assessment.

Rehabilitated open-cast mines

Open-cast mines associated with the site, whether rehabilitated or otherwise, must be identified, delineated and properly described.

Potential for future mining

The possibility of future mining activities should be assessed.

Sinkholes and surface subsidences

Areas where sinkholes or surface subsidences occur should have been avoided during the site selection process as these usually constitute Fatal Flaws (see Section 4.4). There are, however, instances where sinkholes or surface subsidences will occur, for example, in cases of existing sites or where subsidence occurs on an adjacent geological formation.

In these cases, a dolomitic risk assessment must be undertaken by a recognised specialist. The severity

and the real extent of any sinkholes or surface subsidences in the vicinity of the site must be examined to determine their influence on the site and whether they constitute a Fatal Flaw. The risk of future occurrences of sinkholes and the formation of surface depressions must also be addressed.

Where sinkholes and surface subsidences do occur, the Council for Geoscience, the Dolomitic Water Association, the Government Mining Engineer, and the relevant divisions at Regional and Local Authorities should be consulted for information. These and other authorities should also be kept informed with regard to the findings of the investigations and proposed developments.

6.4 The Geohydrological Report

As seen from Section 5.2.4, a Geohydrological Report is, in most instances, required as part of the Permit Application Report. This report should define the scope and objectives of the geohydrological investigation and indicate the methodology used.

The objective of the report is to demonstrate to the Department that the geohydrology associated with the site is such that a landfill can safely be developed and operated in the environment under consideration. This is achieved using the information obtained from the investigations detailed in Sections 6.3.2 and 6.3.3. Alternatively, the Geohydrological Report might indicate certain areas of vulnerability which require further investigation or special attention. In such cases, these would be addressed in the Environmental Impact Assessment (EIA) and the Environmental Impact Control Report (EICR) (see Section 7).

6.5 Potential for Landfill Gas and Air Quality Problems

During the process of waste decomposition, gases are generated which are collectively referred to as landfill gas. Landfill gas is typically malodorous and usually comprises a major component of methane, generated in the methanogenic phase of waste decomposition. Where methane concentrations reach between 5% and 15% of atmospheric gas, landfill gas represents an explosion hazard, as well as a potential health risk.

The Responsible Person must be aware of the problems associated with landfill gas and must ensure, during the site investigation, that there is no way in which gas can migrate from the landfill site under consideration to a structure where it could accumulate and represent an explosion hazard (see Section 8.2.3).

Typical paths of migration could include porous rock or soil strata, underground services, or even paving. With the prescribed buffer zones for new sites, gas migration problems are unlikely. However, at operating or closed sites potential gas problems must be investigated and addressed in the ElA and the EICR.

Regarding air quality problems, odours from landfills may migrate considerable distance under certain weather conditions, such as temperature inversion. The investigation must therefore address these eventualities, especially in the case of hazardous waste landfills. Where appropriate these ust also be addressed in the EIA and the EICR.

TABLE 6
Minimum Requirements for Site Investigation

LEGEND B^- = No significant leachate produced B^+ = Significant leachate produced R = Requirement N = Not a requirement F = Flag: special consideration to be given by expert or Departmental representative	CLASSIFICATION SYSTEM									
	G General Waste								H Hazardous Waste	
	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3 & 4	H:H Hazard Rating 1-4
MINIMUM REQUIREMENTS	B^-	B^+	B^-	B^+	B^-	B^+	B^-	B^+		
Appoint Responsible Person	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Examine scope to address requirements of IAPs	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Physical Geography Delineate physical area to be investigated	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Describe topography and surface drainage	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Determine surface water quality	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Assess purpose and importance of water source by hydrocensus (1 km radius)	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Describe man-made features	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Record of monthly rainfall	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Describe wind speed and direction	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Describe vegetation existing on site	N	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Sub-Surface Features Testpits to indicate depth of soil and/or the presence of ground water	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

LEGEND **B⁻ = No significant leachate produced** **B⁺ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B⁻**	**B⁺**	**B⁻**	**B⁺**	**B⁻**	**B⁺**	**B⁻**	**B⁺**		
Geophysics	N	N	N	F	F	F	**R**	**R**	**R**	**R**
Drill one borehole	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Drill three or more boreholes	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Description of soil using MCCSSO	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
In situ permeability tests	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Geology Describe stratigraphy and lithology	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Identify tectonics, lineaments	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Geohydrology Determine ground water morphology and flow	N	F	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Determine ground water quality	N	F	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Determine ground water usage	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Investigation of aquifers	N	F	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Appropriate pump testing	N	F	N	F	**R**	**R**	**R**	**R**	**R**	**R**
Investigate mining subsidences	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Geohydrological report	N	F	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Investigate potential gas migration	N	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**

Section 7

THE ASSESSMENT AND MITIGATION OF ENVIRONMENTAL IMPACTS

7.1 Introduction

The Minimum Requirements for the assessment and mitigation of environmental impacts are summarised in Table 7, at the end of this Section.

Once a candidate landfill site has been found feasible for development by the Department, further detailed investigation and reporting are required as part of the Permitting Procedure (see *Figure 8*). The assessment of the potential environmental impacts of a landfill usually takes place in parallel with the detailed site investigation discussed in Section 6.

The objectives of the assessment of potential environmental impacts are:

To identify the various ways in which an existing, proposed or closed landfill will affect its receiving environment

To ensure that the identified impacts can be eliminated or mitigated (minimised) by means of proper design and operation, combined with ongoing monitoring.

There are two stages in assessing the potential impact of a landfill on the environment. These are the Environmental Impact Assessment and the Assessment of the Environmental Consequences of Failure.

Environmental Impact Assessment. This makes use of accepted methodology to assess the potential impacts of a site on the environment. Since the environment includes the social environment, the Environmental Impact Assessment (EIA) must include wide consultation with the IAPs. The Department of Environmental Affairs and Tourism (DEAT) has published regulations for the preparation of EIA's, the Environmental Impact Assessment Regulations (EIAR). [**Refs.** Government Gazette, No.18261 of 5 September 1997, No. R1182 and R1183]. The EIA must comply with the EIAR and be approved by DEAT (Province).

Assessment of the Environmental Consequences of Failure. This assesses the consequences of the escape of contaminants from a landfill site in the event of design failure. Risk assessment is also discussed in Section 5, *Minimum Requirements for Monitoring at Waste Management Facilities*.

There are two stages in formulating appropriate responses to, or mitigation of, identified impacts or risks:

Response Action Plan. This contingency plan outlines and records any rapid responses that should be carried out in the event of design or operational failure, or a natural disaster. Such a plan would be based on the examination of the Environmental Consequences of Failure.

Environmental Impact Control Report.
The Environmental Impact Control Report (EICR) indicates how the potential impacts, identified above, are catered for in the design, operation and monitoring. It also includes the EIA, the Environmental Consequences of Failure and the Response Action Plan. Each of these four stages is dealt with in more detail below.

7.2 Environmental Impact Assessment (EIA)

The aim of the EIA is to identify which aspects of the environment could be adversely affected by the development of a proposed landfill. Based on this, the design, operation and monitoring of the landfill are optimised, while taking economic considerations into account.

This is to ensure that the surrounding environment and affected communities suffer the least possible adverse impacts.

Most EIA methods depend on, or have as their starting point, a checklist of considerations that should form part of the design process. Appendix 7 provides a typical checklist of environmental and design considerations for environmentally acceptable landfills. The checklist has been divided into a number of sections, dealing first with the selection and investigation of the landfill site, and second with the possible adverse impacts to be eliminated or controlled by the design, operation and monitoring. It may simply be used as a checklist, or, depending on the level of investigation, it may be used to identify interactions between site characteristics, design and operation, and their potential impacts on the environment.

In order to identify interactions, use is often made of a two dimensional environmental impact identification matrix (see *Figure 9*).

These matrices usually list the project results along the horizontal axis and the possible impacts on various aspects of the environment on the vertical axis. In order to be effective, the matrices normally have to be large and complex. A simple example is provided in *Figure 9*.

Actions and impacts would include those linked to the following phases of the project:

Site preparation and construction
Operation
Closure and rehabilitation
After-use.

The actions and impacts that make up the axes of the matrix must be selected by a qualified team with multi disciplinary representation. The team could also include representatives of the IAPs, i.e. the Representative Landfill Monitoring Committee (see Section 4.6). The matrix must also be scored by the team, each rating being the result of rational discussion and consensus.

The main objective of the EIA is to identify and evaluate any potential adverse impacts of the project on the environment, before the landfill is developed. The impact of the landfill should not be considered in isolation, however. Cognisance of the impact of other developments in the area should be taken into consideration, so that any cumulative impact is assessed. In the unlikely event that any Fatal Flaws were overlooked in the Feasibility Study, these should now become evident. As described in Section 4.3, a Fatal Flaw is any identified adverse impact that represents a **'no go'** situation, i.e. any impact that will, by itself, invalidate the use of the site. Negative impacts that cannot be eliminated or suitably mitigated by design at acceptable cost to the project, represent Fatal Flaws.

FIGURE 9
Environmental Impact Matrix

ACTIONS OR RESULTS OF LANDFILLING POSSIBLE IMPACTS ON:	Blowing Dust, Odour and Air Quality	Noise during Operational Hours	Additional Traffic on Roads	Litter	Leachate Production and Water Pollution	Salvagers	Etc.
Agriculture							
Recreation							
Residential Areas							
Surface Water							
Ground Water							
Archaeological Site							
Indigenous Forest							
Industrial Development							
Etc.							

Once the EIA has been scored, the interpretation of the results must be documented in a report. The report must describe how each adverse impact and its implications will be monitored, mitigated or, preferably, eliminated, by the design, operation and monitoring of the landfill. This report is referred to as 'The Environmental Impact Control Report' (see Section 7.5). DEAT (Province) will require to approve the EIA section of the report, in terms of the EIAR.

7.3 Assessment of the Environmental Consequences of Failure

Following the assessment of the adverse impact of the landfill on the receiving environment, the landfill design will have to be adjusted to reduce or eliminate these potential impacts. Thereafter, it is also necessary to consider the environmental consequences of the failure of any of the environmental defence measures, such as the liner or leachate collection system, or even failure in the case of a fire. These considerations must be reported in the EICR.

There are three major possible pathways for the escape of contaminants from a landfill site. Contaminants may escape via:

Air flow or wind
Surface water flow
Ground water flow

Figures 10, 11 and *12* provide flow charts for

assessing the consequences of the escape of a contaminant by any of these three pathways. Where required, it is necessary to follow each chart through for the design of a particular landfill and, to justify the design, its environmental defence measures and its backup measures in the event of failure. In other words, it must be demonstrated that any consequences of a failure of the first line of environmental defences will not have an unacceptably adverse effect on the environment, either in the short or long term. [**Ref.** *Figures 10, 11* and *12* are based on the USEPA document: EPA/540 - *Human Health Manual*, Vol 1 "Risk Assessment Evidence for Superfund", 1989.]

7.4 Response Action Plan

In the event of failure in the design and/or operation, it is appropriate in certain instances, specifically for hazardous waste disposal sites, to have a Response Action Plan to deal with the situation rapidly and efficiently. While this is a procedure which must be addressed in the Operating Plan (see Section 10.2.3), it should also be included in the Environmental Impact Control Report.

7.5 Environmental Impact Control Report (EICR)

The objective of the EICR is to explain what steps will be taken to ensure that the disposal site will not have an adverse effect on any component of the receiving environment. The report will encompass the EIA, the Design, the Operating Plan, the Monitoring Plan and the Closure Plan.

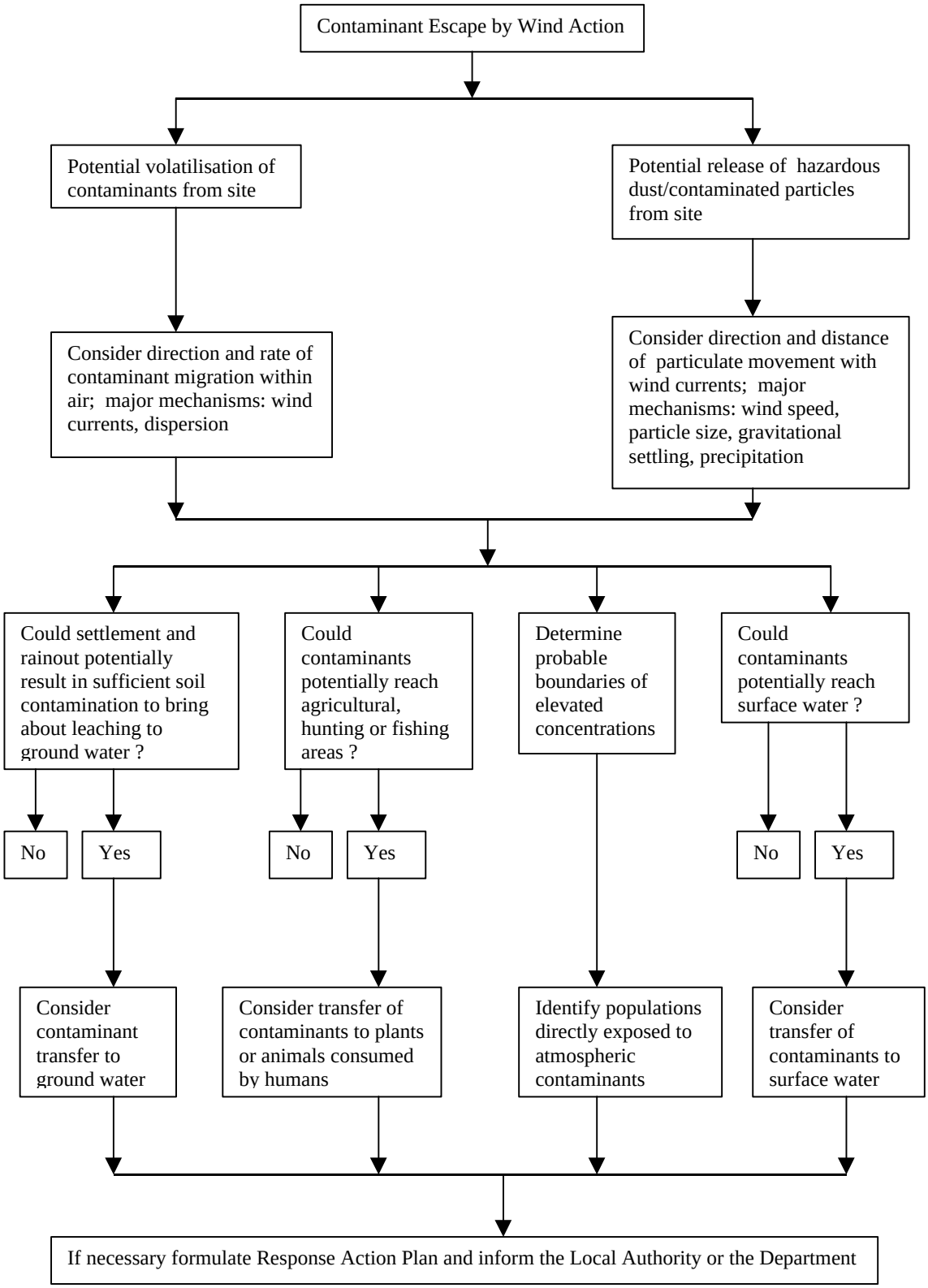
The more detailed components of the EICR include:

- The environmental impact identification matrix
- An interpretation of the matrix
- The assessment of the environmental consequences of failure
- The Response Action Plan, where appropriate.

It will also include:

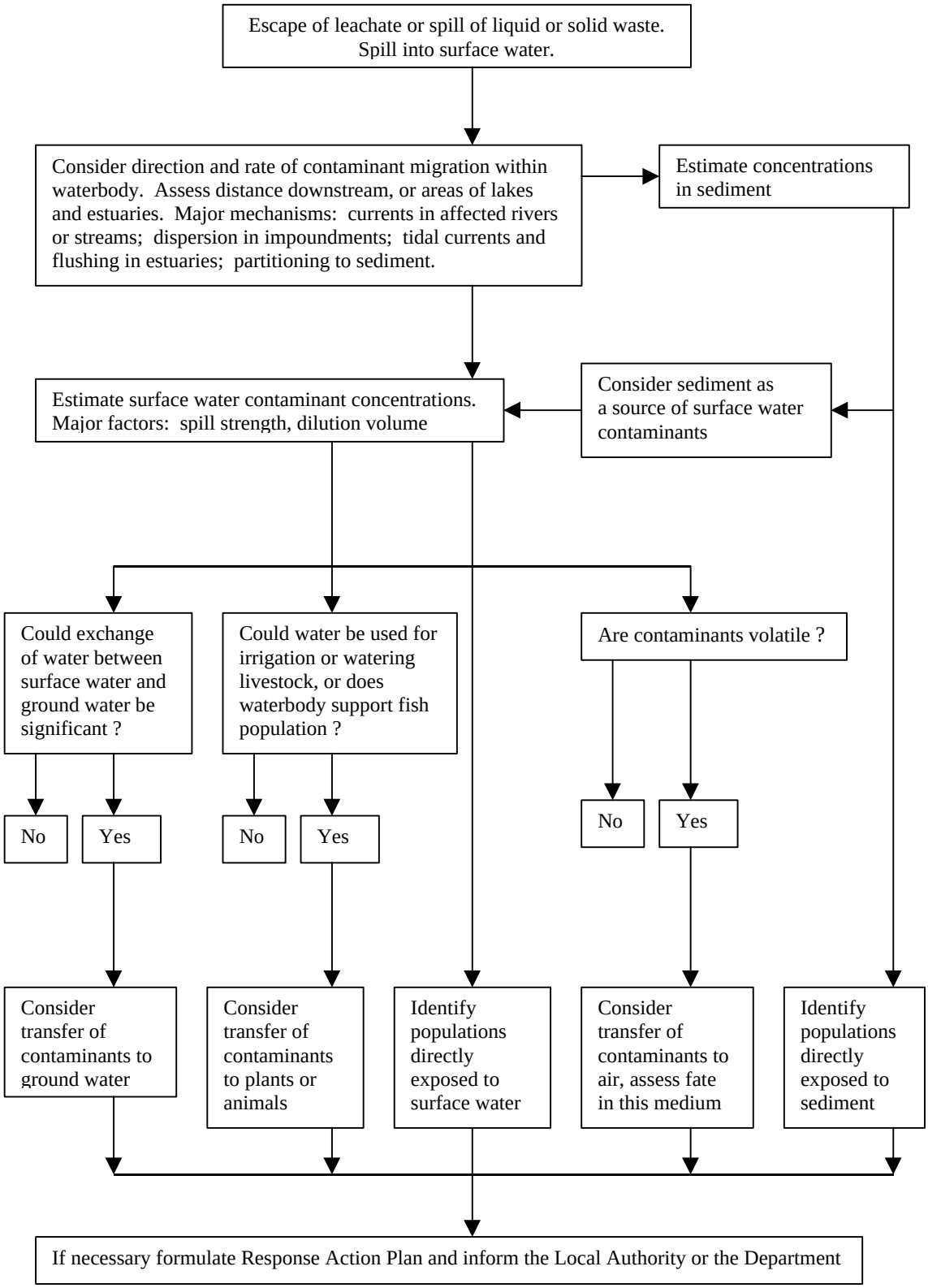
- The identification of the ultimate physical size of the disposal site.
- The identification of the physical environment which may be affected by the disposal site.
- An assessment of the nature and extent of the physical, economic and social interests which may be affected by the disposal site.
- The landfill design and management principles proposed for the reduction of the above adverse environmental impacts.
- A description of the construction and operation of the site, with particular reference to environmental protection measures.
- A proposed monitoring strategy intended to substantiate the efficiency of the design and the management principles envisaged.

FIGURE 10
Environmental Consequences of Failure: Air Flow



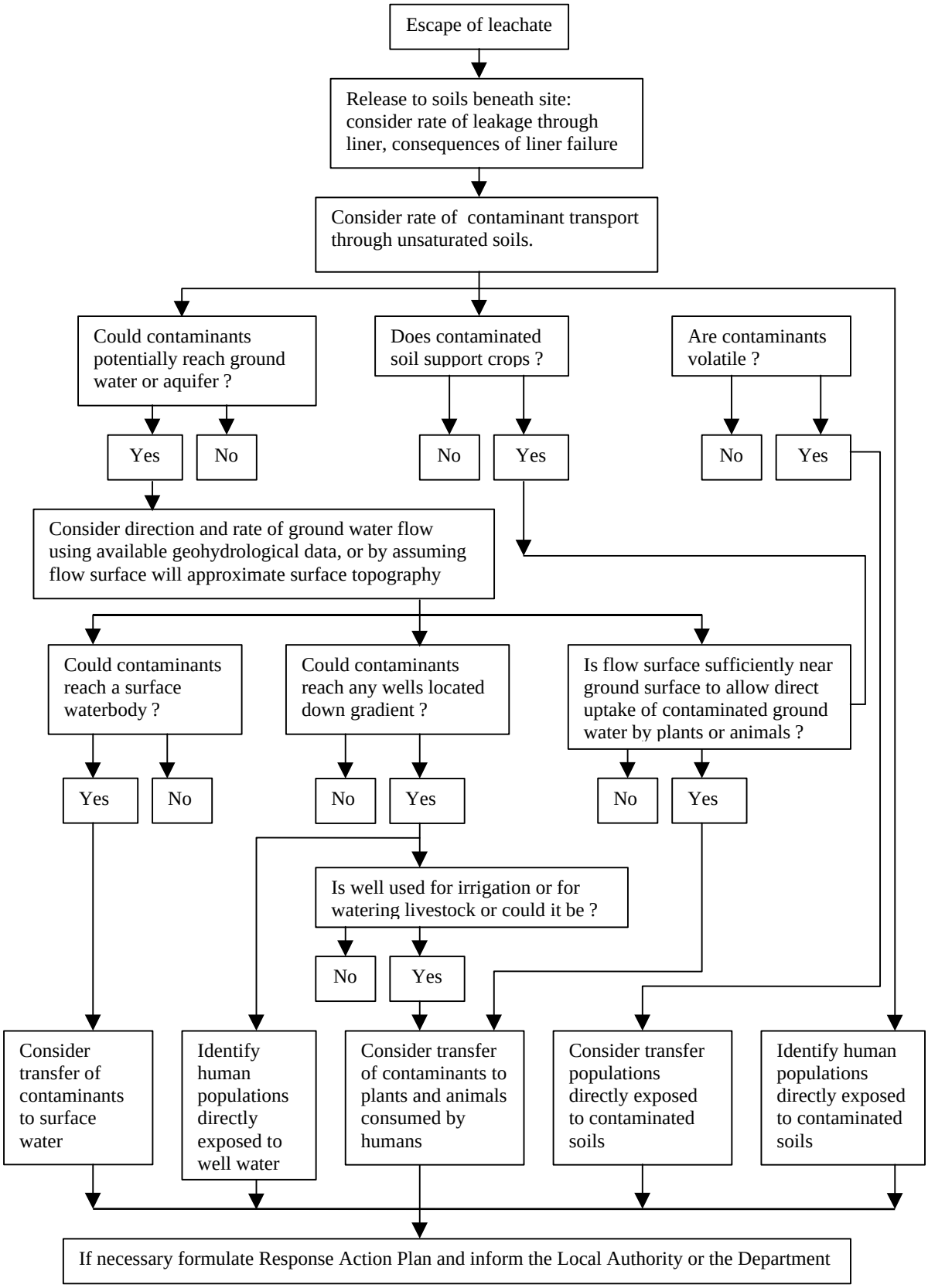
After USEPA document, EPA/540 – Human Health Manual, Vol. 1, 'Risk Assessment Evidence for Superfund', 1989

FIGURE 11
Environmental Consequences of Failure: Surface Water Flow



After USEPA document, EPA/540 – Human Health Manual, Vol. 1, 'Risk Assessment Evidence for Superfund', 1989

FIGURE 12
Environmental Consequences of Failure: Ground Water Flow



After USEPA document, EPA/540 – Human Health Manual, Vol. 1, 'Risk Assessment Evidence for Superfund', 1989

TABLE 7
Minimum Requirements for the Assessment and Mitigation of Environmental Impacts

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Environmental Impact Assessment	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Environmental Consequences of Failure	N	N	N	F	N	F	**R**	**R**	**R**	**R**
Response Action Plan	N	N	N	F	F	F	**R**	**R**	**R**	**R**
Environmental Impact Control Report	N	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**

Section 8

LANDFILL DESIGN

8.1 Introduction

The Minimum Requirements for landfill design are summarised in Table 8, followed by Tables 8.1 and 8.2, at the end of this Section.

Once the site has been selected (Section 4), investigated and assessed (Sections 6 and 7), the next step is to carry out the design of the landfill. The landfill design is based on the outcome of the Site Investigation and the EIA.

The general objective of landfill design is to provide a cost-effective, environmentally acceptable waste disposal facility.

More specific objectives include:

- **The mitigation of any adverse impacts identified in the Site Investigation and EIA.**
- **The prevention of leachate pollution of adjacent ground and surface water.**
- **The provision of sufficient cover material to ensure an environmentally and aesthetically acceptable operation.**

If the best available site, identified during the site selection process, is sub-optimal from an environmental or geohydrological point of view, the subsequent site design must compensate for these shortcomings by means of appropriate engineering. Where there is an environmental risk associated with the chosen site, the design must be upgraded to compensate (see Section 1.3). Such compensatory design must be to the satisfaction of the Department, and will usually be in excess of the Minimum Requirements, in order to protect sensitive aspects of the environment.

In the case of operating or closed landfill sites, design upgrading or remedial design might well be required. In such instances, the principles and Minimum Requirements set out in this section must be applied.

In both the above instances, i.e. a sub-optimal site or an operating site requiring remediation, the design must take the risks to the environment into account.

The Responsible Person who carries out the design must have qualifications and experience that are acceptable to the Department. For example, in the case of a **B**$^{+}$ site and all hazardous waste disposal sites, the responsibility for the plans has to be accepted by a registered Professional Engineer. Furthermore, regardless of the site classification, the Responsible Person must be capable of interpreting and applying the results of the investigation. **In particular, he/she must understand the implications of all aspects of the Site Water Balance**. He/she must also be capable of providing the design details appropriate for the class of site, and to the satisfaction of the Department.

This section takes the reader step by step through the design requirements. Not all sites will, however, require the same level of detail for their design.

There are two stages of design:

Conceptual Design

The Conceptual Design addresses the principles of the intended design, but does not include detailed specifications. It includes all aspects of the design that will affect the successful operation and subsequent closure of the landfill in an environmentally acceptable manner. In the case of most general waste landfills, the design submitted as part of the Permit Application is the Conceptual Design, which may then be upgraded to an 'as-built' technical design, showing measurements and levels.

Technical Design

The Technical Design is based on the Conceptual Design. Where necessary, it is also based on the results of tests on soils, construction materials and waste. The Technical Design includes detailed specifications of materials, measurements and procedures, as well as detailed drawings. In the case of all landfills for which liners are required, a technical design must be submitted as part of the Permit Application. The Technical Design, together with the associated bills of quantities, also forms the basis for contractual tendering and construction, and may therefore be required when commissioning a landfill.

Where no liner is involved, only a conceptual design is required for permitting and, indeed, commissioning. Where a liner is involved, however, a technical design is a practical necessity as well as being a Minimum Requirement for permitting.

8.2 Conceptual Design

The following components, i.e. the site classification, airspace and site life, are common pre-requisites for all landfill designs. They are therefore addressed under Conceptual Design.

8.2.1 Confirmation of site classification

It is a Minimum Requirement that confirmation of site classification and in particular the Site Water Balance, precedes design. This is because the classification of a landfill site determines the Minimum Requirements applicable to its design. As set out in Section 3, the composition and magnitude of the waste stream, the potential for significant leachate generation and hence the need for leachate management, must all be confirmed. Any intended landfill disposal options, such as co-disposal and encapsulation must be addressed (see Section 9, *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste)*.

Type of waste

The present and projected future waste stream must be analysed to assess the types and composition of waste involved. From this, the associated risk of disposing of these wastes by landfill can be assessed. Where hazardous waste is involved, the hazard ratings must be confirmed (see Section 3.2).

Size of waste stream

The size class of the landfill, and hence the projected size of the operation, is dependent on the magnitude of the waste stream. This is determined by calculating the Maximum Rate of Deposition (MRD), as explained in Section 3.3.1. and illustrated by means of examples in Appendix 3.3.

Reassessment of the water balance

In the case of a general waste landfill, it will have been classified as either $\mathbf{B}^+$ or $\mathbf{B}^-$ (see Section 3.4). If, in the light of additional information, there is <u>any</u> doubt regarding a $\mathbf{B}^-$ classification, i.e. if there is the possibility that significant leachate could be

generated, then the water balance affecting the landfill should be substantiated at this stage by means of a full water balance analysis.

8.2.2 Cover, airspace and site life

The potential volume or airspace of a site is calculated first by quantifying the volume of cover material available and then by applying a cover to waste ratio of between 1:4 and 1:6 by volume, to arrive at the total airspace. This means that for every $1m^3$ of cover available, between 4 and $6m^3$ of compacted waste can be disposed of.

Cover availability is thus a major factor determining the air space at a given site, if it is to be operated in accordance with sanitary landfill principles.

The cover excavation design must therefore make provision for adequate cover material. This cover is for use both as daily cover in the operation and for final capping. Particular attention must be paid to providing sufficient material for capping the landfill, as this is a deficiency at many operating landfills and can have costly economic implications.

In assessing the quantity of available cover, careful attention must be given to the Minimum Requirement that there must always be an acceptable minimum physical separation between the waste body and the highest seasonal level of the ground water (see Section 8.4.2).

The available airspace can also be dictated by the shape of the final landform, which depends on the base area or 'footprint' of the landfill, the slopes of the sides and the maximum acceptable height. There is therefore a balance between the cover availability and the physical airspace available.

The potential life of the site can be estimated by comparing the airspace utilisation with the available airspace. Airspace utilisation is based on the quantities of waste to be received, projected over the estimated period during which the site will operate. Various methods for calculating landfill site life are included in Appendix 8.1.

8.2.3 Site layout

The site layout must be designed with the landfill's closure and end-use closely in mind. The end-use, in particular, may decide the final shape or contours of the landfill, and this may influence the site layout and the Operating Plan. **For this reason, the IAPs must be consulted to determine the preferred end-use of the site.**

The site layout design will typically comprise plans and sections, indicating existing, excavated and final contours. The following aspects would be addressed and in many instances would have to be indicated on plans:

Access

The requirements for road access to the site and other necessary infrastructure must be assessed (see Sections 10.2 and 10.4).

Surface hydrology and drainage design

Surface hydrology design will include surface drainage and storm water diversion drains, to meet the requirements of the Water Act. This includes the separation of unpolluted from polluted surface water and the containment of polluted water on site in impoundments. Also, where leachate is generated, it must be contained separately from water which is only slightly polluted through contact with the waste.

Containment

In the case of hazardous waste disposal sites, the design must make provision for containment of

hazardous waste. This implies the complete separation of the waste body and any associated leachate from the surrounding soil or rock strata, by means of a liner and a leachate collection system.

Leachate management system (B^+ landfills)

Leachate management is necessary in the case of **B^+** and hazardous waste disposal sites, where significant leachate is generated. The design includes a liner underlying the site, as well as leachate collection and treatment measures. It must make provision for the control of significant seasonal or continuous leachate generation, predicted by means of the Climatic Water Balance, or the Site Water Balance.

Leachate detection system (B^- landfills)

Leachate management is not necessary at **B^-** landfill sites, provided that they are properly designed and operated. However, if this is not the case, and significant leachate is generated as a result of poor drainage or the disposal of high moisture wastes, it must be detected as soon as possible.

Leachate detection systems at **B^-** sites comprise rudimentary liners (see *Table 8.1* and Appendix 8.2).

These are sloped toward toe drains at the lowest point of the landfill, unless site topography also dictates the use of finger drains* to channel any leachate to the lowest point.

Monitoring systems

Monitoring systems for surface and ground water pollution should be indicated (see also Section 13). This will include the positions of both surface water sampling points and monitoring boreholes.

Gas management (see Section 8.4.5) and gas and air quality monitoring systems are required if, in the Site Investigation and the Risk Assessment, landfill gas migration and accumulation are found to represent a potential safety hazard or odour problem, or if an operating or closed site is situated within 250m of residential or other structures.

Gas monitoring systems could comprise gas monitoring boreholes or other monitoring devices approved by the Department. Their positions must be indicated on the layout plan.

Layout and development plans

The Layout and Development Plans should have a scale of 1:1 000 and a contour interval of 1m. They must show where the following aspects of the landfill operation will be situated, and/or how they will be staged:

- Infrastructure (including fences and buildings)
- Site access and drainage
- Excavation and stockpiling of cover
- Screening berms and screening vegetation (tree belts)
- Cell construction sequence
- Deposition sequence and phases (including physical dimensions and timing for each phase).
- In the case of hazardous waste landfills, the laboratory, treatment and encapsulation facilities.

* Finger drains are drains within the zones of selected free draining waste, initially placed on the base of the landfill.

Progressive Rehabilitation Plan

The Progressive Rehabilitation Plan should indicate when areas should reach their final level and how they will be progressively restored, by means of final cover or capping, topsoiling and vegetating. The type of vegetation envisaged should also be described.

8.2.4 Preliminary Closure Plan

A Preliminary Closure Plan, including an End-use Plan and possibly a Landscaping Plan, should be indicated.

8.2.5 IAP involvement

The Layout, Development and Progressive Rehabilitation Plans should take into consideration the needs of the IAPs. For example, the deposition sequence should ensure the least possible impact on the IAPs living close to the landfill.

When the Conceptual Design is complete, the design should be presented to and discussed with the IAPs, in order to inform them and to obtain any further input that might be forthcoming. Such input could include making opportunities for job creation during design implementation.

8.3 Testing of Soils, Construction Materials and Waste

Some *in situ* and laboratory testing of on-site soils and rock may have been done during the landfill site investigation (Section 6), to assess the suitability of soils for cover and linings. In the design stage, more specific testing may have to be performed, to enable the technical design of the landfill to be carried out.

8.3.1 Soil permeability

In situ permeability testing, using a double-ring infiltrometer or Guelph permeameter, may have to be performed on some, or all, of the following:

- The soil and/or rock immediately underlying the landfill. It may be necessary to seal the rings to the surface being tested.
- The unsaturated zone that will ultimately separate the waste from the ground water. This may require the testing of different soil strata.

Testing for compatibility of soils and leachate may also be necessary to assess the effect of leachate on permeability (see Section 8.4.3 and Appendix 8.2). Such tests would be performed in a laboratory.

8.3.2 Compaction properties

The compaction properties for any soil or modified soil proposed for use in lining or capping layers must be established according to the Standard Proctor Compaction Test (see Section 8.4.3).

8.3.3 Shear strength tests

Where appropriate, shear strength testing of soils must be performed to enable the overall stability and the permissible angle of cut slopes to be assessed. This is especially the case where extensive cut slopes or trench systems are envisaged.

Where excavated areas require lining, the side slopes should be such that it is possible to lay the required liner. Some geomembranes have a low interfacial friction with soil, as well as with waste. Any inclined surface covered by a liner incorporating a geomembrane must be investigated for possible interlayer slippage. This could be

slippage of the geomembrane on its supporting layer, slippage between the geotextile and a protective geofabric, or slippage of a soil protective layer overlying the geomembrane.

All three types of interface can have very low angles of interface friction. Designs should be based on residual shear strengths of interfaces within the lining system, measured under saturated conditions. These are best measured by means of a ring shear box which is taken to a shear deformation of at least 360^{o} rotation. Slopes must be graded to achieve a factor of safety against slippage of at least 1.3. This should also take into account the effects of pore pressure arising from an accumulation of liquid or leachate above the liner.

8.3.4 Geomembrane and geotextile tests

Geomembrane liners (sometimes referred to as flexible membrane liners or FMLs) must comply with the requirements of SABS Specification 1526 Type I geomembranes. The geomembrane thicknesses specified in Appendix 8.2 shall be **minimum thicknesses**, as measured in accordance with the SABS Specification 1526 test method. Where adequate data is not available, geomembranes, composite liners and geotextiles (or geofabrics) will have to be tested for strength, interface friction, durability and compatibility with identified components of waste and leachate. Depending on the details of the proposed landfill, the Department may call for additional performance criteria.

Because of potential clogging by biological slimes and chemical precipitation, geotextiles through which landfill leachates must seep, should be used with caution.

Testing and quality assurance of geosynthetic liners are Minimum Requirements in the case of **B**$^{+}$ and hazardous waste disposal sites.

Any geomembrane used in a capping layer should also comply with the requirements of SABS Specification 1526 Type III geomembranes, to ensure that biaxial strains due to settlement of the waste body are accounted for.

8.3.5 Waste tests

Testing of waste may be performed to assess likely leachate composition, field capacity, compressibility under load, compatibility with materials of construction used in the landfill, and compacted density. If necessary, shear strength tests must be performed on the waste to assess the overall stability of the landfill.

8.4 Technical Design

The Technical Design quantifies all necessary aspects of the Conceptual Design. It also gives predicted answers concerning the future performance of the landfill. Specifically, it takes into account the vulnerability of the environment to pollution. It thus provides the necessary protection from all potential impacts identified in the EIA and in the Risk Assessment, and forms part of the EICR.

The Technical Design must be approved by the Department either in the Permit or in an official letter before construction may begin. The aspects of the design which follow are considered to require particular attention.

8.4.1 Design of upslope cut-off drain systems and contaminated drainage systems

These must be designed to the requirements of the Water Act. Drains must divert or contain the peak design storm of 50 year return period for the particular catchment area. The system must effect-

ively separate unpolluted water, that has not come into contact with waste, from polluted water. The upslope cut-off drains must divert clean storm water around the site and into the natural drainage system.

Polluted water, on the other hand, must be collected in toe drains, retained on the site and managed in accordance with the Department's directives. This may include controlled release, recycling and evaporation or treating with any leachate that has been collected.

The liner design for a contaminated water pond at a general waste disposal site must correspond with those for a **G:B$^+$** site of the same size, minus the leachate collection layer (see Appendix 8.2). The liner design for a contaminated water pond at a hazardous waste disposal site must correspond with the liner design for the landfill itself, minus the top leachate collection layer.

The design of all such impoundments must also ensure a 0,5m freeboard in the event of a one in fifty year storm of 24 hour duration.

8.4.2 Design of the separation between the waste body and the ground water

It is a Minimum Requirement that there always be an acceptable physical separation between the proposed waste body and the wet season high elevation of the ground water. This applies whether cover excavations take place on site or not.

The minimum permissible separation is 2m. This is to ensure that, particularly in rural areas, waste is not deposited into excavations where the unsaturated zone has been significantly reduced or where the water table has been breached. While this separation is likely to be acceptable in the case of clayey soils, a substantially thicker separation may be required in the case of more permeable, sandy soils.

It must be emphasised that the primary protection of the environment from the effects of a landfill is the result of careful siting (Section 4). However, cases may arise where siting of a landfill near an important aquifer is unavoidable. In such cases, the separation between the waste body and the ground water may require to be upgraded to provide additional protection. This may take the form of supplementing the thickness or upgrading the liner (see Section 8.4.3).

At this stage there is no set methodology for calculating the thickness of the separation between the waste body and the seasonal high elevation of the ground water. Consequently, there is frequently controversy and/or uncertainty associated with determining this separation. The design of the separation should therefore be treated as a 'flag', i.e. it must receive special attention by a recognised expert and be acceptable to the Department.

Depending on site and ground water conditions, it may be necessary to address the problem of seepages from perched water tables and springs, entering the site. This can be achieved through sound drainage engineering.

8.4.3 Design of the lining system

As seen from Section 8.4.2, a mandatory physical separation between the waste body and the ground water regimes is fundamental to all designs. Because of the potential toxicity of leachate, it can be seen (Section 3.4) that all **B$^+$** sites, i.e. those that generate significant leachate, require leachate management which involves the construction of liners. Similarly, adopting the Precautionary Principle, the Minimum Requirements require minimal liners at **B$^-$** landfills. This is, however, not

to manage, but to detect the presence of leachate. In the case of all hazardous waste sites and lagoons, however, the Minimum Requirements require a substantial liner and leachate management system to be provided, regardless of the Climatic Water Balance.

In the case of hazardous waste landfills, the liner design also takes cognisance of the hazard rating of the waste that can be accepted (see Sections 6 and 7, *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste)*. For instance, an **H:H** landfill can accept all hazardous waste with a hazard rating of 1 through to 4, while an **H:h** landfill is limited to less hazardous substances with ratings 3 and 4. The liner design for **hazardous waste encapsulation cells** shall be as for an **H:H** landfill.

The lining system is additional to the separation or unsaturated zone comprising soil or rock between the wet season high elevation of the ground water and the landfill. Soil used for the construction of the liner may be excavated from the unsaturated zone. However, any soil used for a compacted soil liner must have a minimum Plasticity Index (PI) of 10 and a maximum that will not result in excessive desiccation cracking. The maximum particle size must not exceed 25mm.

A lining layer, constructed of compacted soil of low permeability, must be so constructed that it permits no more than a specified maximum rate of flow of leachate to pass through its layers. Clay liners must be compacted to a minimum dry density of 95% Standard Proctor maximum dry density, at a water content of Proctor optimum to Proctor optimum +2% (see Appendix 8.2).

In addition, the following supplementary information is required:

- Full particle size analysis (sieve and hydrometer tests).
- Double hydrometer test.
- Atterberg limits.
- Shear strength tests in terms of effective stresses on soil compacted at Proctor optimum water content to Proctor maximum dry density. Soils are to be either drained or undrained, with measured pore pressures on saturated soil.
- Permeability measurements in triaxial cells are also required on saturated soil, compacted as above.

The maximum outflow rates in the clay layers are measured in metres per year and are as follows:

Class **G:B**$^{+}$ landfills:	Measured outflow rate must not exceed 0,3 m/y (1×10^{-6} cm/s)
Class **H:h** landfills:	Measured outflow rate must not exceed 0,1 m/y (3×10^{-7} cm/s)
Class **H:H** landfills:	Measured outflow rate must not exceed 0,03 m/y (1×10^{-7} cm/s)

Because the liner will usually have to be designed at a time when only laboratory test data are available, the expected outflow rate will usually have to be based on permeability coefficients measured in the laboratory on specimens constituted in the laboratory (requirements for laboratory permeability tests are given in Appendix 8.2). These estimates must, however, be validated by field tests once the liner has been constructed. It must also be remembered that small-scale laboratory measurements could underestimate the permeability of a liner by as much as two orders of magnitude.

To validate the design, *in situ* permeability tests using double ring infiltrometers must be carried out on every compacted soil layer that forms part

of a liner. The diameter of the inner ring of such an infiltrometer must be at least 600mm, while the diameter of the outer ring must be twice that of the inner ring. The infiltrometer must be covered and sealed with plastic sheeting to prevent the evaporation loss of moisture.

Liners for **H:h** and **H:H** landfills and for hazardous waste lagoons are composite clay and geomembrane liners. The clay components of these liners must fully meet the above maximum outflow rates and must be shown to comply with these prior to installing the geomembranes.

Every liner system is made up of a series of elements that can be assembled in various ways to provide the necessary degree of protection to the ground water system. The detail and variation associated with each liner component, is described in Appendix 8.2, which includes diagrams depicting the liner systems for each class of landfill, as well as the specifications for the various component liner layers.

By using the landfill classification system, *Table 8.1*, at the end of the section, indicates the minimum liner requirements for each class of landfill. Liner profiles in *Table 8.1* and Appendix 8.2 are from the waste body downwards, however, in *Table 8.1*, the construction sequence is indicated by the numbers in the left hand margin.

8.4.4 Design of leachate collection, leakage detection and leachate treatment system

As stated in Section 3, all landfills have the potential to generate sporadic leachate. In all landfills, therefore, the base must be so sloped that any leachate formed, even sporadic leachate, is directed to a control point.

In cases of significant leachate generation, a leachate management system is a Minimum Requirement. This involves keeping significant leachate out of the environment by means of leachate collection, removal and treatment.

Leachate collection

Leachate collection is usually achieved using a graded underliner and drains which lead to a collection point or sump. Depending on soil quality, the underliner may be an engineered low permeability natural soil or clay liner, a geomembrane liner, or both.

The leachate collection system is a system of drains, bunds or trenches covered by the leachate collection layer (referred to in *Table 8.1* and Appendix 8.2). It is equipped with suitable drains or collection pipes that direct the gravity flow of leachate or leakage to defined collection points or sumps, from which it can be collected for treatment (see *Figure A.8.9* in Appendix 8.2).

Collected leachate must be treated to a quality standard that complies with the relevant legislation and is acceptable to the Department, before being released into the system.

The liner design for leachate ponds at hazardous waste disposal sites must be the same as the liner for a hazardous waste lagoon (see Appendix 8.2.). In the case of leachate ponds at **G:B**$^{+}$ sites, these must be lined to the same specification as the landfill liner, minus the leachate collection layer, but with the addition of a 2mm thick geo-membrane liner, laid directly on the surface of the uppermost clay layer.

Any drain, whether open or covered, that is used to transfer leachate from the leachate collection system to the leachate ponds or to the sewer must be properly lined. This should be by means a properly laid 2mm thick geomembrane liner with

joints welded to the same specification as for a hazardous waste liner, or equivalent.

Leakage detection system

The leakage detection system is designed to intercept any leachate that passes the barrier of the upper liner. This leakage is then directed to separate leakage collection sumps, where the quantity and quality can be monitored and from which accumulated leakage can be removed. This system is designed to fulfill the requirement for the 'early warning' monitoring of leachate given in Section 6 of the *Minimum Requirements for Monitoring at Waste Management Facilities.* To do this in **B**$^-$ landfills, finger and toe drains are used for leachate detection, in the event that leachate does appear, contrary to the site classification.

In the case of **B**$^-$ landfills, significant leachate should not be generated, so that leachate management systems are not required (see Sections 3.4.1 and 3.4.2). If, however, it is found that a site which is classified **B**$^-$ does generate significant leachate, it must be reclassified to **B**$^+$. The appropriate Minimum Requirements for **G:B**$^+$ landfills, especially those for leachate management systems, must then be applied. (See Section 3.5.3).

Leachate treatment system

The leachate treatment system will depend on the leachate composition and on the most appropriate method of treatment. This could be on-site chemical, physical or biological treatment, and/or off-site treatment where leachate is passed into a sewer or pipeline for treatment elsewhere. It is a Minimum Requirement that all hazardous waste and **G:B**$^+$ landfills have leachate treatment facilities acceptable to the Department.

The technical design of any of the above systems must be agreed with the Department, prior to construction. The same applies to contaminated water ponds or evaporation ponds (see Section 8.4.1).

8.4.5 Design of hazardous waste lagoons

Lagooning of hazardous waste liquids is not regarded as a form of landfilling. Nonetheless, lagoons are controlled under Section 20 of the Environment Conservation Act and thus require a Permit. Until separate requirements are developed, therefore, hazardous waste lagoons must follow the full landfill site Permitting Procedure.

This form of disposal **is not encouraged**, and will only be condoned if can be proven that unacceptable odours or hazardous vapours will not arise from the evaporating liquid. At the end of its operating life, a lagoon must either be emptied or be filled with an absorbent solid material so that it can be sealed by a capping layer and rehabilitated.

In view of their importance, design requirements for the lining of lagoons have also been included in this section and in Appendix 8.2.

Lining for hazardous waste lagoons

The Minimum Requirements for the linings of hazardous waste lagoons are shown in Appendix 8.2. It will be seen that the leachate detection and collection systems for lagoons are combined. Otherwise, the requirements are similar to those for H:H landfills, but more stringent, in that two geomembrane liners are required in the liner. These more stringent requirements are set because the hazardous waste in a lagoon is not dispersed, absorbed and ameliorated by dry general waste, as in the case of a co-disposal landfill and also because of the hydraulic head.

Slopes of sides and floor

The floor of a hazardous waste lagoon, and hence its leakage detection and collection layer, must

slope at a minimum of 5% towards the leakage collection sump.

The side-slopes of the impoundment must not be steeper than 1 vertical on 3 horizontal and, depending on geotechnical factors, may have to be flatter than this. The factor of safety (F) against slipping of the geomembrane liner on its underlying compacted soil layer must in every case be calculated from the following expression, and should be at least 1.5.

$$F = \frac{((- (_w) \cdot \tan *}{(\cdot \tan \$}$$

where:

(= bulk unit weight of compacted soil liner layer

$(_w$ = unit weight of liquid in lagoon or leachate in mono-landfill ($10kN/m^2$, at least).

* = effective angle of interfacial friction (soil on geomembrane), measured by means of special shear box tests for the soil, geosynthetics, and geomembrane interfaces under consideration (see Section 8.3.3).

$ = angle of side slope.

Cover or capping

Hazardous waste lagoons must either be emptied or filled with absorbent material, before they can be capped. The design specification must be based on site specific conditions and agreed with the Department. The design will be at least as stringent as that for hazardous waste landfills in Appendix 8.2.

8.4.6 Gas management systems

Although landfill gas has been recognised as a source of odour and as a potential explosion hazard, few gas management systems have been constructed in Southern Africa to date. Most of those that have been constructed have been designed to extract gas by applying a suction to a system of perforated pipes within the landfill. Such active gas extraction significantly reduces the odour problem and the potential explosion hazard. If the collected gas is not used for energy or chemical feedstock, it must be flared off.

Passive gas management may, however, also be used to achieve cheaper gas management. This may include the construction of impervious migration barriers adjacent to the landfill and passive venting from boreholes and perforated pipes within the landfill. The resultant gas may be flared or passed through filters to remove odour.

If there is a need for gas management, the system and its design specifications must be agreed with the Department, prior to construction (see Section 8.2.3).

8.4.7 Design of final cover or capping

The capping layer of a landfill serves the following purposes:

(i) It separates the waste body from the atmospheric environment. The cap is the only layer protecting and isolating the waste from the long term effects of wind and water erosion, burrowing animals, etc.

(ii) It limits and controls the quantities of precipitation that enter the waste. It should also allow water to leave the landfill by evapotranspiration and vent landfill gas in a safe manner.

When comparing the capping designs with the corresponding liner design, it must be realised that the cap works in conjunction with the liner by limiting the long term generation of leachate.

As is the case for a liner system, a landfill capping or final cover system is also made up of a series of elements. The capping system is designed to maximise run-off of precipitation, while minimising infiltration and preventing ponding of water on the landfill.

Table 8.2 at the end of this section uses the landfill classification system to indicate how the number of components will vary with class of landfill. The detail and variation associated with each cover component are described in Appendix 8.2. This also includes diagrams depicting each of the cover or capping systems under consideration.

8.4.8 Stability of slopes

The construction of landfills usually involves excavating into natural soils. This can be unsafe, particularly with trench systems. It is therefore necessary to analyse the stability of these cut slopes to ensure that they are safe against shear failure.

The stability of a slope depends on its slope angle or inclination, on its overall height and on the properties of the material of which it is composed. In the case of slopes cut into natural soils, the geotechnical properties of the soils should be determined by means of *in situ* or laboratory shear tests. The stability of the slope must be analysed by a qualified geotechnical engineer.

The stability of the outer slopes of landfills should also be checked, especially when the slopes are steep, or high, or both. Data on the slope design properties of solid waste is not readily available. A survey has shown that the following values are appropriate to slope stability calculations for potential shearing through the waste:

Cohesion	:	c^1 = 25 kPa
Angle of shearing resistance	:	M^1 = 15°
Unit weight of refuse	:	(= 10kN/m^3

Note that these parameters will not apply to waste/liner or waste/soil interfaces, but apply only to shearing through waste.

A stability chart for preliminary assessment of landfill slope stability by shearing through the waste is given in *Figure A.8.12* in Appendix 8.2.

It is, however, very likely that the critical zone for shearing may be the underlying natural soil, or a geomembrane to soil surface. This possibility must be carefully investigated (see also Section 8.3.3, Shear strength tests).

8.5 Erosion from Landfill Surfaces

Soil slopes can erode very severely through the action of both wind and water. The outer slopes of a landfill should be equipped with crest walls and stormwater channels to prevent water from cascading down the slopes from the next horizontal top surface. Outer slopes should be made as flat as possible and should not have an uninterrupted length along the slope exceeding 20m. Wherever possible, the length of an outer slope should be broken into shorter lengths by incorporating berms or step-backs.

The stormwater channels to which surface water flow on slopes should be directed must be paved or armoured. The channels are laid on the completed surface of the landfill by grading the surface towards the drains. Berms on outer slopes should also be provided with collection drains where it is necessary to drain water down a slope, e.g. to drain the top surface of the landfill. The surface between drains should be stabilised by

means of well-established vegetation, in order to avoid erosion.

8.6 Final Landfill Profile

The final landfill profile should comprise gentle slopes as described in Section 8.5 and should be moulded unobtrusively into the surrounding topography.

The final profile should facilitate the implementation of the End-use Plan.

Where the landfill is sited in an excavation, the final level should be above the natural ground level by at least 10% of the maximum depth of waste. This is to ensure that, with settlement, the landfill surface does not subside below the natural ground surface and form a hollow in which runoff water will collect.

TABLE 8
Minimum Requirements for Landfill Design

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**h** **Hazard Rating 3 & 4**	**H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Appoint a Responsible Person	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Conceptual Design Confirm site classification	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Assess cover volume	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Indicate unsaturated zone after cover excavation	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Determine available airspace	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Estimate airspace utilisation	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**h** **Hazard Rating 3 & 4**	**H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Estimate site life	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Address any impacts identified by investigation and/or by the IAPs	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Site layout design	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Surface drainage design	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Development Plan	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Closure/Rehabilitation Plan	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Design of leachate management system	N	N	N	**R**	N	**R**	N	**R**	**R**	**R**
Design of the toe drains	N	**R**	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Monitoring system design	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
End-use Plan	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Testing of soils and materials	N	N	N	F	F	F	F	F	F	F
Technical Design Surface hydrology and drainage design	N	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**
Consult lining requirements in *Table 8.1* /Appendix 8.2	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Water quality monitoring system	N	F	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Leachate detection system	N	F	F	N	**R**	N	**R**	N	N	N

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**h** **Hazard Rating 3 & 4**	**H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Leachate treatment system	N	N	N	F	N	**R**	N	**R**	**R**	**R**
Leachate management and monitoring system	N	F	N	**R**	N	**R**	N	**R**	**R**	**R**
Gas management and monitoring system	N	N	N	N	F	F	F	F	F	F
Consult cover requirements in *Table 8.2*/Appendix 8.2	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Stability of slopes	N	N	F	F	F	F	F	**R**	**R**	**R**
Erosion control design	N	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Design drawings and specifications	N	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**
Approval of Technical Design	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**

TABLE 8.1
Minimum Requirements for Liner Components

LEGEND B^- = No significant leachate produced B^+ = Significant leachate produced R = Requirement N = Not a requirement	CLASSIFICATION SYSTEM										
	G General Waste								H Hazardous Waste		
	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3 & 4	H:H Hazard Rating 1-4	Lagoons
LINER COMPONENTS	B^-	B^+	B^-	B^+	B^-	B^+	B^-	B^+			
12 Waste body	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
11 Dessication protection	N	N	N	N	**R**	N	**R**	N	N	N	N
10 Leachate collection layer	N	N	N	**R**	N	**R**	N	**R**	**R**	**R**	N
9 Cushion layer	N	N	N	N	N	N	N	N	**R**	**R**	**R**
8 1,5mm or 2mm geomembrane	N	N	N	N	N	N	N	N	**R**	**R**	**R**
7 Compacted clay liner	N	N	N	N	N	**R**	N	**R**	**R**	**R**	**R**
6 Geotextile layer	N	N	N	N	N	**R**	N	**R**	**R**	**R**	**R**
5 Leakage detection layer	N	N	N	N	N	**R**	N	**R**	**R**	**R**	**R**
4 Cushion layer	N	N	N	N	N	N	N	N	N	N	**R**
3 1mm geo-membrane liner	N	N	N	N	N	N	N	N	N	N	**R**
2 Compacted clay liner	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
1 Base preparation layer	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Note: Numbers 1 - 12 indicate order of construction.

TABLE 8.2
Minimum Requirements for Capping Components

LEGEND B^- = No significant leachate produced B^+ = Significant leachate produced R = Requirement N = Not a requirement	CLASSIFICATION SYSTEM									
	G General Waste								H Hazardous Waste	
	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3 & 4	H:H Hazard Rating 1-4
CAPPING COMPONENTS	B^-	B^+	B^-	B^+	B^-	B^+	B^-	B^+		
5 Layer of Topsoil	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
4 Compacted Clay Layer	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
3 Geotextile Layer	N	N	N	N	N	**R**	N	**R**	**R**	**R**
2 Gas Drainage Layer	N	N	N	N	N	**R**	N	**R**	**R**	**R**
1 Shaped and Compacted Waste Surface	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Note: Numbers 1 - 5 indicate order of construction.

Section 9

SITE PREPARATION AND COMMISSIONING

9.1 Introduction

The Minimum Requirements for site preparation and commissioning are summarised in Table 9, at the end of this Section.

This section sets out the Minimum Requirements for the preparation of a landfill facility or any extension to an existing landfill. The preparations must ensure that the commissioned facility will conform to the intended design, operational requirements and end-use, as stated in the Permit.

The objectives of site preparation and commissioning are:

- **To establish the infrastructure and facilities necessary for the landfill to be operated in terms of the Permit conditions; and**

- **To prepare the site to the stage that it is ready to receive waste and to operate as an environmentally acceptable disposal facility for a pre-determined minimum period.**

The development of the site is a process that will continue throughout its operating life (see Section 10). Site preparation and commissioning represent the first stages of site development. The need for site preparation will exist at all new sites or extensions, but the degree and complexity will vary from site to site. In general, the larger **B^+** general waste disposal sites and the hazardous waste disposal sites will require more preparation than the **B^-** and smaller general waste disposal sites. It is up to the Responsible Person to confirm the site classification and to ensure that the standard of preparation meets the appropriate Minimum Requirements.

If they differ from the Permit, the final details of the site design must be approved by the Departmentbefore construction may begin.

9.2 Boundaries

The co-ordinates of the landfill site must be accurately indicated on a proper plan and, in certain instances, where positive identification is lacking, the actual boundaries must be certified by a registered land surveyor.

9.3 Design Drawings, Specifications and Bills of Quantities

The design drawings, specifications and bills of quantities will have been produced according to the Minimum Requirements for landfill design (see Section 8), certified by a suitably qualified Responsible Person and approved by the Department. The drawings, specifications and bills of quantities together form the basis for the site preparation, and none shall be read independently from the others.

9.4 Contractor

Where a contractor is used, he/she must be competent and able to carry out all the works in full conformity with the design, specification, drawings and bills of quantities. Suitably qualifiedspecialist sub-contractors may also be used to carryout any special work. The contractor must be a registered employer and must be in good standing with the relevant authorities.

9.5 Quality Control Programme and Supervision

Prior to the commencement of any construction, the Responsible Person shall provide the contractor with the quality control programme for all activities to be carried out on the site. The programme, together with independent checks carried out by the Responsible Person and the Department, shall be sufficient to ensure conformance with the design, specifications and drawings. The correctness of the facility and the quality of the construction must be attested to by the Responsible Person on completion of the construction activities.

- The construction of leachate containment elements must be supervised on a full time basis by the Responsible Person or his delegated representative.

- The construction of all elements of hazardous and **G:L** sites as well as all liner construction must be supervised on a full time basis by the Responsible Person or his delegated representative.

- Particular attention must be paid to the quality control of any liner system.

The contractor must carry out a minimum of four sand replacement density tests per 3000m^2 of any compacted 150mm thick layer. Sufficient Standard Proctor compaction tests must be performed to cover any variability of material that may arise. Density tests using a nuclear device will be considered acceptable, provided the results have been proved to be consistent with sand replacement tests. Sand replacement tests will be considered to be the reference standard for measurement.

Because the permeability of a soil depends on both the density and the compaction moisture content, the results of all density tests must satisfy the following requirements:

(i) Dry density equal to or greater than 90 % of Standard Proctor maximum dry density

(ii) Moisture content within the range Standard Proctor optimum to Standard Proctor optimum plus two percent.

For capping layers, the compaction water content requirements are the same, but the density requirement is relaxed to 85% of Proctor maximum dry density.

- Other earthworks must comply with the requirements of the appropriate SABS 1200.

- Geomembrane liners should carry the SABS 1526 mark or meet with the requirements relevant to the category of liner required, and must be supplied, delivered and installed in accordance with the requirements of the mark and the suggestions contained in the addenda to the specification.

9.6 Environmental Requirements and Conservation of Natural Resources

The contractor must conform to the environmental requirements of the site and the design at all times during the preparation of the landfill site facility. The minimum of disturbance to the local flora and fauna, as well as the generation of minimum nuisance, must be ensured. Natural resources, such as topsoil and general cover, shall be stockpiled and maintained for future use where necessary and as directed by the Responsible Person.

9.7 Extent of Site Preparation

The site preparation will include the construction of the initial works and sufficient development to allow for the effective commissioning and operation of the site for a **pre-determined minimum period**.

9.8 Setting Out

The works shall be set out according to the design drawings and specifications, and setting out shall be confirmed prior to the start of actual construction.

9.9 Occupational Health and Safety Act

All operations shall be carried out in strict conformity with the Occupational Health and Safety Act (1994).

9.10 Approval of Preparation and Constructed Works

On completion of the construction phase, all the works shall be approved by the Responsible Person. The Department and other relevant authorities may then carry out a full inspection of the site and an examination of all relevant records. It is a Minimum Requirement that, where critical work such as the construction of liners is involved, records be maintained. Such records must include details of materials used and the results of field tests. Provided all construction has been carried out in full conformity with the design specifications and drawings, and to the satisfaction of the Department, a letter giving permission to commence the operation of the waste landfill will be handed over by the Department.

TABLE 9
Minimum Requirements for Site Preparation and Commissioning

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Competent contractor	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Quality control programme and supervision	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Boundaries certified	N	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Conservation of natural resources and environmental requirements	F	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Compliance with Occupational Health and Safety Act	F	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Records be kept of materials and tests during construction	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Approval of constructed works by the Department	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Section 10

LANDFILL OPERATION

10.1 Introduction

The Minimum Requirements applicable to the different classes of landfill are summarised in Table 10, at the end of this Section.

This section sets out the Minimum Requirements for the operation of landfill sites. Additional information regarding landfill operation may be found in Chapter 9 of *Landfill Design, Construction and Operational Practices* [**Ref:** UK Department of Environment *Waste Management Paper 26B*, HMSO Publications, 1995].

In terms of the Environment Conservation Act, only an approved landfill, which has been issued with a Permit in terms of Section 20(1) of the Act, may operate (see *Figure 7*). In the case of new landfills and extensions, site preparation and construction have to be approved by the Department prior to the operation commencing.

The objectives of the Minimum Requirements for landfill operation are:

- **To ensure that all waste is disposed of in an environmentally and socially acceptable manner.**

- **To ensure that the disposal operation is acceptable to those whom it affects.**

The operation must thus conform to both the Permit conditions and to the Minimum Requirements associated with the site classification.
It is the duty of the Responsible Person to ensure that the Minimum Requirements for the operation of a landfill site are applied to the degree commensurate with its class and hence to the satisfaction of the Department.

10.2 Facilities and Resources required for Landfill Operation

There must be sufficient facilities and resources to ensure that the landfill operation can conform to both the Permit conditions and the relevant Minimum Requirements. For example, there should be sufficient trained staff to monitor, control and record incoming waste where required.

10.2.1 Signposting and road access

Signs in the appropriate official languages must be erected in the vicinity of the landfill, indicating the route and distance to the landfill site from the nearest main roads. These traffic signs must conform to the requirements of the Road Ordinance. Suitable signs must also be erected
on site, to direct vehicle drivers appropriately and to control speed.

A general notice board must be erected at the site entrance. This must also be in the appropriate official languages, stating the names, addresses and telephone numbers of the Permit Holder and the Responsible Person, the hours of operation, and an emergency telephone number. It is of particular importance that the sign clearly states the class of landfill and the types of waste that can be accepted. Wastes that cannot be accepted must also be stated. It must be stated that disposal of non-acceptable waste types is illegal and can lead to prosecution.

In the case of hazardous waste landfills, clearly visible signposts warning of the associated hazards must be erected along the fence line at intervals not exceeding 100m.

Road access to the site must be maintained at all times, in a manner suitable to accommodate the vehicles normally expected to utilise the facility. All roads, particularly on-site roads, must be so surfaced and maintained as to ensure that waste can reach the working face with the minimum of inconvenience in all weather conditions. Two-way traffic must also be possible in all weather conditions. Unsurfaced roads must be regularly graded and watered to controldust. No mud from the site may be tracked onto public roads.

10.2.2 Controls

Waste acceptance

One of the purposes of the landfill classification system is to ensure that general waste disposal sites receive only the general waste for which they are designed and that all hazardous waste is disposed of only on hazardous waste disposal sites.

Prior to waste being accepted at general waste disposal sites, it must be inspected by suitably qualified staff and the transporter must confirm that it is general waste. In the case of doubt,
any industrial waste should be considered as potentially hazardous until proven otherwise, see *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste*. The operator at the working face must also ensure that no hazardous wastes (e.g. hazardous liquids, sludges, solids or even sealed drums) are disposed of. Such controls are particularly important at general waste landfill sites in the vicinity of industrial areas. In the event of hazardous waste being intercepted at a general waste landfill site, it must be diverted to a hazardous waste landfill site. The source, vehicle registration and a description of the waste must be reported immediately to the Department.

In the event that medical wastes are intercepted at either a general or a hazardous waste landfill site, it is a Minimum Requirement that the Responsible Person or the Permit Holder immediately contact the Department for a directive in this regard.

At hazardous waste sites, all new enquiries for disposal of dry and liquid hazardous waste must be submitted to the Responsible Person with representative samples and a completed waste information sheet. Each load of such waste which subsequently arrives at the site must be sampled and tested for correlation with results of the original enquiry, prior to disposal. Waste which does not conform to the original specifications must be properly identified by testing in a laboratory, prior to its disposal on site. Any discrepancies must be reported to the client and appropriate steps must be taken to ensure the proper disposal of the waste.

If a waste cannot be identified, the precautionary principle must be applied and the waste must be regarded as falling into the most hazardous category. This is particularly important in the case of **H:h** sites which are only permitted to accept waste with Hazard Ratings 3 and 4. Any unidentified wastes or wastes with Hazard Ratings of 1 and 2, arriving at an **H:h** site, may not be accepted and must be referred to an **H:H** site.

A report on all wastes received, by the hazardous waste disposal site, must be sent to the Department on a quarterly basis by the Site Operator. It must classify all hazardous wastes in terms of the hazardous waste classification system and outline the disposal method used. See *Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste*.

Special care and consultation with the Department are necessary in the disposal of delisted hazardous wastes at **H:h**, **G:L:B**$^{+}$ and **G:M:B**$^{+}$ sites (see Section 10.3.3).

Access control

In order to facilitate the above waste acceptance procedures, access to the site must be controlled. It is therefore a Minimum Requirement that vehicle access to a site be limited to a single controlled

entrance, to prevent the unauthorised entry and illegal dumping of waste on the site. The site entrance must comprise a lockable gate which must be manned during hours of operation. Additional security, after operating hours, is required at all hazardous waste disposal sites, and general waste disposal sites where appropriate.

In addition to the gate, all sites must have the portion of the site currently in use adequately fenced and/or secured. In the case of medium and large general landfills and hazardous landfills, fences must be 1,8m with an overhang and must be constructed of galvanised steel wire, or of other suitably sturdy and durable material. Where normal fencing is removed, or is not practicable because of continued theft despite security measures, barbed wire fences, earth berms and/or shallow trenches must be used to prevent vehicle access. In all events, however, the site boundaries must be clearly demarcated and measures must be taken to prevent unauthorised vehicle access.

Collection of disposal tariffs

Since the Minimum Requirements increase the standards of waste disposal, they also increase the cost. In order to offset these costs, waste disposal tariffs should be levied and collected at all landfill sites, from medium size upward. Tariffs should be displayed on the notice board. They should be based on mass, where a weigh bridge exists, or on estimated volumes.

Security

In addition to access control, suitable security must be provided to protect any facilities and plant on site.

It is a Minimum Requirement that unauthorised pedestrian access be strictly prohibited at hazardous waste disposal sites, although this may be difficult in some instances. Primarily for the purpose of protecting public health and safety, waste reclamation and squatting should be discouraged at general waste disposal sites. It is a Minimum Requirement that no reclamation be allowed at hazardous waste disposal sites. Since fencing is not always effective, additional measures may be necessary in order to achieve this Minimum Requirement.

10.2.3 Operating Plan

An Operating Plan is a site specific document that will be developed as part of the Landfill Permit Application Procedure (see *Figures 1* and *2*). It describes the way in which the landfill is to be operated, commencing at the level and detail of daily cell construction and continuing through to the projected development of the landfill with time. Everything pertaining to the operation of a landfill should therefore be included in the Operating Plan, which is subject to regular update.

The complexity of the Operating Plan will vary with the class of site; this varies from a very simple plan, in the case of a **G:S** site, to a very detailed and sophisticated document for an **H:H** site.

The Operating Plan would include, *inter alia*, the phasing, the excavation sequence, the provision of wet weather cells, site access and drainage. It would also include all operation monitoring procedures (see Section 11.5) and a plan for mitigatory actions in response to problems detected by monitoring.

In drawing up the Operating Plan, cognisance must be taken of the input of IAPs during the Feasibility Study and Permit Application Procedure. If necessary, certain issues, for example, the phasing of the operation, must be discussed and agreed with the IAPs, to whom access to the final plan will be given. In addressing the monitoring of operation, the Operating Plan must make reference to the role of the Monitoring Committee, which is to include IAPs (see Section 11).

In the case of all hazardous waste disposal sites, a Response Action Plan is required to form part of the

Operating Plan (see Section 7.4). The Response Action Plan will detail procedures to be followed in case of failure in the design or operation. It will also include an emergency evacuation plan. For hazardous waste landfills the Operating Plan must also address all items stipulated in the Major Hazard Installation Regulations, governed under the Occupational Health and Safety Act 1993, (Act No. 85 of 1993). All failure modes and effects must be quantified in a risk assessment, and on-site and off-site emergency plans developed.

10.2.4 Resources

Adequate facilities, equipment and suitably trained staff are required in order to ensure an ongoing environmentally acceptable waste disposal operation. It is therefore a Minimum Requirement that there be sufficient resources to meet the Minimum Requirements relating to the operation.

Infrastructure

The facilities at a landfill site will vary in accordance with the size of the operation. In the case of a **G:C** site, only access control would be a Minimum Requirement. Larger sites would typically have services such as water, sewerage, electricity, telephones, security and infrastructure such as weighbridges, site offices and plant shelters. In the case of hazardous waste disposal sites, an on-site laboratory would be a Minimum Requirement.

Plant and equipment

The plant and equipment on site must be commensurate with the size and type of the operation. The type of equipment employed for all phases of the operation must therefore be of suitable capacity and construction. Typically, larger sites would have a combination of purpose-built landfill compactors, bulldozers, front-end loaders and trucks to transport cover material. In the case of smaller sites, however, less would be required.
For example, a small bulldozer or a tractor combination system would be sufficient to compact and cover waste at a **G:S** site.

The Minimum Requirement is to provide sufficient suitable equipment, drivers and back-up to ensure environmentally acceptable waste disposal at all times. The plant and equipment must provide the means whereby the waste can be disposed of in accordance with the Minimum Requirements. It must also be maintained in good order, so as not to cause nuisances such as noise and air pollution.

Staff

It is a Minimum Requirement that the operation of all landfill sites be carried out under the direction of a Responsible Person. This may be a gate controller in the case of a **G:C** site, a site foreman in the case of a **G:S** site, a site superintendent in

the case of a **G:M** site and a landfill manager with a post-matric or tertiary qualification in the case of a **G:L** site. In the case of **H:h** sites and **H:H** sites, the Responsible Person must have the academic equivalent of a BSc Degree with a Chemistry major and suitable experience. He/she must also be fully *au fait* with the Hazard Rating system and its application.

The Responsible Person must, in all cases, be supported by suitably qualified and competent staff. This staff complement would be commensurate with the size and type of the operation, as well as with the facilities and plant involved.

Sufficiently qualified staff and back-up are required to ensure that the Minimum Requirements relating to the operation are met. Where applicable, the Responsible Person must also ensure that the requirements of the Occupational Health and Safety Act are met, with regard to visitors and site staff.

10.3 Landfill Operation

Waste deposition is considered mainly in terms of sanitary landfill principles. In the case of hazardous waste, however, more stringent waste acceptance procedures, pre-treatment, co-disposal and encapsulation are addressed.

As indicated in Section 2, the majority of waste in South Africa is disposed of by landfill. Some 90% of this waste is general waste. The principles of sanitary landfilling and the variations on this method thus apply predominantly to general waste. These principles are, however, also applied to hazardous waste landfills in conjunction with other procedures, such as co-disposal, waste load allocations, pre-treatment etc.

10.3.1 Principles of sanitary landfilling

Landfills must be operated in accordance with the following sanitary landfill operating principles (see also Section 2.3.3):

- waste must be compacted, and
- covered at the end of each day's operations.

Compaction

Compaction is best achieved if the waste is spread in thin layers and compacted by a purpose-built landfill compactor. This compaction procedure is a Minimum Requirement at **G:M, G:L** and hazardous waste disposal sites. At smaller sites, where purpose-built equipment is not available, the best practicable compaction is required.

Daily cover

The sanitary landfill definition specifies daily cover. It is therefore a Minimum Requirement that the waste be fully covered at the end of each working day. In certain instances, such as existing small or remote sites with a shortage of cover material, the Department may allow this Minimum Requirement to be appropriately amended. The consent of the IAPs would, however, be necessary before relaxation could be considered.

Most sanitary landfill operations are based on a series of trenches or cells which are prepared to receive the waste. In either case, the general layout must be in accordance with the Operating Plan. Waste is deposited in trenches or cells, spread, compacted and covered, so that each day's waste is effectively isolated from the environment.

The material to be used for cover may be on-site soil or builders' rubble. With the approval of the Department, ash or other artificial covering can be used. In all cases, a strategic stockpile of cover, enough for at least three days, should be maintained close to the working face for use in emergencies. Suitable equipment and resources must also be available to ensure that there is sufficient cover material, so that no area is left uncovered at the end of the day's operation.

In the case of proposed sites, it is a Minimum Requirement in terms of both siting and design that provision be made for sufficient cover for a sanitary landfill operation, throughout the projected life of the facility.

It is a Minimum Requirement that daily or periodic cover be sufficient to isolate the waste from the environment. A minimum thickness equivalent to the effective covering of 150mm of compacted soil is required. This thickness may, however, have to be increased in the case of poor quality cover.

If the area is to be left for an extended period, but ultimately to be covered again with waste, the compacted thickness of this intermediate cover must be increased to 300mm. This is not as thick

as final cover, but affords the additional protection required in the longer term.

10.3.2 Methods of landfilling: General waste

Sanitary landfilling principles can be applied using the following methods:

Trench system

In Class **G:C** and **G:S** landfills, where relatively small volumes of waste are disposed of, trenches are often made in preference to cells. Such trenches must be excavated on an ongoing basis during the operation.

Nonetheless, this must always be done in accordance with the original design parameters and the Operating Plan. There must always be sufficient trench capacity on site to accommodate at least two week's waste.

Trenches must always be suitably fenced or protected, and off-loading must be such that persons or vehicles cannot accidentally fall into the excavation.

Waste is deposited into the trench, spread and compacted as much as possible, until it reaches a depth of between 0,5m and 1,0m. With the trench method, daily covering is always a Minimum Requirement, as spoil from the excavation makes this possible.

Standard cell operation

The basic landfill unit is a cell of compacted waste which, when completed at the end of each day, is entirely contained by cover material. The sides are usually formed by 1,5m to 2,0m high berms, constructed from soil, rubble, or sloped waste covered by daily cover. A series of adjoining cells of the same height is termed a lift.

The working face is the active part of the landfill, where waste is deposited by incoming vehicles. The working face must be kept as small as possible for control and covering purposes. The width, however, is determined by the manoeuvring requirements of the vehicles depositing waste. It should thus be sufficiently wide to avoid traffic congestion. There must also be sufficient cell capacity on site to accommodate at least one week's waste.

Where the cell system is applied, best compaction results are obtained when the waste is deposited at the bottom of the working face and worked up a 1 in 3 slope. Cover is then deposited and spread on the top of the cell during the day and extended to cover the working face at the end of the day. This is termed the Ramp Method.

Wet weather cell

An easily accessible wet weather cell must be constructed close to the site entrance or close to an all weather road, for use under abnormally wet weather conditions. The wet weather cell must have sufficient capacity to accommodate one week's waste.

The cell should be constructed in the same manner as the standard cell. It should, however, have a well drained gravel type base in order to ensure vehicle access in wet weather. As far as possible, the wet weather cell should be operated in the same manner as the standard cell.

Special cells for putrescible waste

Special cells may be constructed for the disposal of putrescible general wastes, food or restaurant wastes. Such waste should be deposited and covered immediately with a layer of soil at least 0,5m thick. This is to prevent odours and to discourage uncontrolled salvaging. Alternatively, such waste may be deposited at the base of the working face and covered immediately with other waste. The latter method has the advantage of not disrupting the standard operation.

Methods other than cell operation

'End tipping' is the method whereby waste is pushed over the edge of an extended advancing face. This is not permitted on a normal landfill because it results in slope instability, minimal compaction and many other related problems. Exceptions to this may include some **G:C** and **G:S** sites, where waste has to be end-tipped into trenches.

The Area Method may be used at certain waste disposal sites, where large volumes of non-putrescible dry general waste are disposed of and where compaction is not critical. This method involves the spreading of waste in a 0,5m layer over a large area. Wastes suited to such disposal methods include ash, slag, rubble, bark and shredded fibre. This method differs from end tipping in that the waste is spread laterally in thin layers in a controlled manner, as opposed to being pushed haphazardly over an extended slope.

10.3.3 Methods of landfilling: Hazardous waste

Hazardous wastes are disposed of on **H:H** or **H:h** landfills, depending on their hazard ratings.

H:H landfills are specifically designed to accept wastes of Hazard Rating 1 or 2. They may, however, also accept all other wastes, including those with Hazard Rating 3 or 4 and general waste.

H:h landfills are designed to accept hazardous waste with Hazard Rating 3 or 4. They may also accept general wastes, but they may **not** accept wastes with Hazard Rating 1 or 2. In cases where a waste is unidentified, the precautionary principle is applied and the worst case is assumed, see *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste*. The waste would therefore be assigned a hazard rating of 1 and diverted to an **H:H** site.
It is a Minimum Requirement that hazardous waste landfills be designed and lined to the standards for **H:H** and **H:h** sites set out in Section 8.4.3. and Appendix 8.2. The requirements for hazardous waste site design and construction are intended to provide the most stringent level of containment. These requirements may apply to the whole site, to a specially lined or engineered cell, or to a section of the landfill designed specifically to accommodate hazardous waste.

Pre-treatment of hazardous wastes

The properties of certain hazardous wastes are such that they cannot be safely deposited directly into a landfill. In such cases, the wastes must be pre-treated to render them immobile, less toxic or less reactive. See also *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste.*

A variety of treatment options exist. These are often interrelated but may be generally categorised into physical, chemical and biological treatment methods. Chemical processes include neutralisation, precipitation, fixation and oxidation. Physical processes include incineration, blending and encapsulation. Biological processes include aerobic and anaerobic degradation of organic materials. Once a waste has been pre-treated, the residue is disposed of in accordance with its hazard rating on the appropriate landfill.

Unidentified wastes are also regarded as unacceptable for landfilling and will require identification, followed by appropriate treatment, pre-treatment or encapsulation.

Delisting of hazardous wastes

Delisting of hazardous wastes, involves treatment and/or hazard rating tests to confirm that the waste is of such low mobility or concentration, that it can be reclassified to a lower hazard rating. Such delisted wastes can then be safely disposed of on a lower class of landfill. In this regard, however, the landfill may not have less than a **G:M:B$^+$** liner and

leachate management system design.

Co-disposal

Co-disposal refers to the mixing of liquid and dry wastes or to the mixing of general and hazardous wastes. Co-disposal ratios of liquid to dry waste are addressed in Appendix 10.1.

Liquid wastes may be co-disposed with dry waste in order to soak up excess liquid and to avoid pool formation or unauthorised lagoon situations. General waste is frequently disposed of at hazardous waste landfills with a view to establishing a substrate in which to excavate trenches into which liquid hazardous waste is deposited. Co-disposal may also be used to advance the anaerobic degradation of leachate and to reduce its toxicity and that of any hazardous wastes involved.

Miscellaneous

Three alternative types of waste disposal are grouped under this heading as they do not constitute standard landfilling practice. These are mono-disposal, lagooning and encapsulation.

Mono-disposal refers to the disposal of a single waste type into a dedicated facility. Where a waste can be re-used, mono-disposal is a preferred option as it allows the waste to be easily reclaimed in the future. Mono-disposal may also be used as a way of delisting certain hazardous wastes, by ensuring that they are not disposed of with other wastes, which enhance their mobility. Although only one waste type is involved, a mono-disposal landfill must meet all the Minimum Requirements associated with its class.

Lagooning, which is the practice of disposing of liquid wastes in lined lagoons, is sometimes classed as landfilling. Although lagooning is considered to be beyond the scope of this document, Section 8. and Appendix 8.2. do refer to the design of lagoons. Since there are no set procedures for the operation of lagoons, it is a Minimum Requirement that such operations be approved by the Department prior to commencement in order to ensure environmental and public health protection.

Encapsulation is the practice of containing waste in concrete capsules. This is because, on account of the extreme hazards involved, certain wastes cannot be disposed of directly into a landfill. Where encapsulation is practised it is a Minimum Requirement that the Permit Holder submits the specifications to the Department for approval, prior to commencement (see *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste* Section 9.2.3.).

Standard operating procedures

It is a Minimum Requirement that the off-loading of hazardous waste and co-disposal operations be executed under the jurisdiction of the Responsible Person. The Responsible Person must ensure that appropriate standard operating procedures are adhered to. Aspects include:

- Ensuring the use of protective clothing (e.g. gloves, goggles and breathing apparatus) by workers

- Ensuring that no incompatible wastes, for example those which could cause explosions or the generation of poisonous gas, (e.g. cyanide and hydrochloride acid) are co-disposed

- Ensuring that the hazardous waste load allocation as specified in the Permit is not exceeded, see also *Minimum Requirements for the Handling, Classificationand Disposal of Hazardous Waste*

- Ensuring that the correct liquid/solid co-disposal ratio is adhered to, see Appendix 10.1.

- Ensuring immediate and/or daily covering

- Ensuring that there are no free liquid surfaces left at the end of the day's operation.

It is also essential that the Responsible Person and the workers know and can execute the content and the requirements of the Response Action Plan for the site, in case of an emergency.

10.3.4 Co-disposal

In order to regulate the practice of co-disposal, it is a Minimum Requirement that documentation be drawn up describing the waste load allocations and liquid co-disposal ratios. An operating procedure and a Response Action Plan, suitable for the hazardous waste disposal operation under consideration, are also Minimum Requirements**. The waste load allocations, liquid co-disposal ratios, operating procedure and Response Action Plan must be written into the Environmental Impact Control Report. This must be presented to, and accepted by the Department before the operation commences.**

Co-disposal of General and Hazardous waste

Where general waste is disposed of on hazardous waste landfills, the standard cell operations at a general waste landfill apply. Co-disposal could be by mixing general and hazardous waste at the working face, spreading on deposited waste prior to covering, or mixing in trenches excavated in *in situ* waste. Where trenches or engineered cells are used, they must always be suitably protected and off-loading must be such that persons or vehicles cannot accidentally fall into the trench or cell.

Co-disposal of liquid and solid waste

Any landfill where the co-disposal of liquids is permitted requires to be lined and equipped with a leachate management system which can contain, extract and preferably treat the resultant leachate flow.

Liquid wastes may be co-disposed by end tipping into trenches excavated into the waste body, or into engineered cells containing predominantly solid waste. The co-disposed waste is subsequently covered with dry general waste, which may also be end tipped. It is a Minimum Requirement that, by the end of the working day, there is sufficient dry waste in the cell to permit vehicle trafficability and covering activities. There must be no lagooning or free liquid surfaces which create odours and possibly air pollution. In order to achieve this, an appropriate solid/liquid waste co-disposal ratio is required. Where trenches excavated into the waste body remain filled with liquid, they must be secured and covered by a constructed frame cover.

Calculation of the site specific solid/liquid co-disposal ratio

The variation of the co-disposal ratio, i.e. the ratio of solid to liquid waste, has both economic and environmental implications.

Increasing the volume of dry waste reduces leachate generation, potential environmental impacts and leachate management costs. However, expensive landfill airspace associated with lined landfill sites is used up by the dry general waste. Reducing the volume of dry waste saves airspace utilisation, but creates a greater need for leachate management, including additional lined airspace for storage of leachate in leachate ponds. If too much liquid is disposed of, the situation could prove environmentally unacceptable and leachate management could become very expensive.

It is therefore in the interests of the landfill operator to optimise the co-disposal ratio by minimising the sum of the airspace utilisation and liquid management costs. The co-disposal ratio used, however, must ensure that the operation is environmentally acceptable, i.e. that all leachate is managed and that there are no free liquid surfaces, causing odour and possibly air pollution problems. Also, the build up of a hydraulic head within the

landfill can affect its stability and therefore must be avoided by operating the landfill at the appropriate co-disposal ratio.

In order to take site specific factors into consideration and to allow efficient utilisation of additional liquid storage capacity in landfills situated in arid **B**$^-$ areas[1], no co-disposal ratio is prescribed. The approach rather is to link co-disposal to the concept of the Water Balance and to limit leachate generation to manageable quantities, taking local climate into account. This applies to the co-disposal of hazardous liquids in hazardous waste landfills as well as the possible co-disposal of non-hazardous or delisted liquids at **G:M:B**$^+$ and **G:L:B**$^+$ sites.

It is therefore a Minimum Requirement that no more than 200mm/year of leachate be generated at a given landfill site.

The rationale behind this approach is that a landfill which receives liquids in a **B**$^-$ climate will (all things being equal) produce less leachate than an identically operated landfill in a **B**$^+$ climate. It is therefore possible to co-dispose of more liquid per ton of dry waste in a **B**$^-$ area without necessarily producing any more leachate than is produced under identical conditions in a **B**$^+$ area.

In general, a landfill in a **B**$^-$ area may produce leachate sporadically, but will not necessarily produce leachate in an average year. However, in wetter **B**$^+$ areas of the country, significant leachate will be produced even in a drier than average year, even if no liquids are co-disposed. In either case, the approach is to limit leachate generation to 200 mm/year over the area of the waste body, or to a figure for which the leachate treatment capacity may be designed.

Because there may be existing or future need to dispose of liquid wastes in wet areas, a nominal limit to leachate produced, under typical wet season weather conditions at any co-disposal site, is set at 200 mm per year. This allows for limited co-disposal of liquid wastes in wet areas such as Richards Bay, but very much more effective liquid waste co-disposal in drier areas such as Gauteng.

The limit of 200 mm per year is a figure which will ensure socially and environmentally acceptable conditions. It may only be exceeded if it can be shown that the overall design of the landfill, the leachate management system and the leachate treatment system can easily accommodate this flow.

Regardless of the co-disposal ratio used or the amount of leachate generated, **it is a Minimum Requirement that there are no free liquid surfaces on the landfill and that the fill is trafficable.**

The theory underlying the approach to co-disposal and examples of its application in typical South African weather conditions is set out in Appendix 10.3.

10.3.5 Disposal of medical wastes

The disposal of medical wastes at any landfill site is prohibited. Incineration of medical waste is a prerequisite to disposal. The ash must be disposed of under dry conditions at an approved hazardous waste site, unless negotiated otherwise with the Department.

In the event of an emergency, and in the interests of public health and the environment however, the Department will consider applications for the disposal of medical waste into a specially constructed dry cell within an approved site. Such disposal would be under controlled conditions and for a limited period of time, and it is a Minimum Requirement that the Department be approached

[1] Any landfill in a **B**$^-$ area that practices co-disposal must be equipped with an appropriate liner and leachate management system.

for directives in this regard and that all key role players and IAPs be consulted.

Where past practice has been to dispose of medical waste on general waste landfills, the Department must be informed and consulted for directives for the future management of the situation (see the *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste*, Section 9.4.1.).

10.4 Other Elements of the Operation

10.4.1 Excavation for cover

Where cover is excavated on site, the Responsible Person must ensure that the separation between the floor of the excavation and the wet season high elevation of the ground water, as specified in the design, is maintained (see Section 8.2.2). This will ensure that an adequate separation between the future waste body and the ground water will be maintained, should the excavation be used for waste disposal in the future.

Excavations must also be properly drained to avoid ponding of accumulated surface water, especially near the waste body. Where the base of such an excavation forms the base of the landfill, it should be sloped to direct leachate to a control point. In all cases, but particularly in the case of **B**$^{+}$ and hazardous waste landfills, the base should also be appropriately lined (see Section 8.4.3).

10.4.2 Drainage

The principles of landfill site drainage are as follows:

- Upslope run-off water must be diverted away from the waste, to prevent water contamination and to minimise leachate generation.

- Where contaminated water or leachate does arise on a site, it must be managed. This means that it must be kept out of the environment. This also applies to the drainage from wash bays and spills at hazardous waste landfills.

- Clean, uncontaminated run-off water must not be permitted to mix with, and increase the volume of, contaminated water.

The principles of the main drainage system are presented in the site design (see Section 8.4.1). All upslope cut-off and toe drains, must be in place before the landfill is commissioned.

The following are Minimum Requirements:

- Run-off and storm water must always be diverted around one or both sides of the waste body, by a system of berms and/or cut-off drains.

- Water contaminated by contact with waste, as well as leachate, must be contained within the site. If it is to be permitted to enter the environment, it must conform or be treated so as to conform to the Special or General Effluent Standards in terms of the Permit. [**Ref.** *Government Gazette,* No. 9225, 18 May 1984].

- The bases of trenches and cells must be so designed that water drains away from the deposited waste. Alternatively, cells must be so orientated as to facilitate drainage away from deposited waste. The resulting contaminated water, together with all other contaminated run-off arising from the landfill, must be stored in a sump or retention

dam. It may be pumped from the dam and disposed of if it conforms to the Special, General or Specific Effluent Standards stipulated in the Permit.

- A 0,5m freeboard, designed for the 1 in 50 year flood event, must always be maintained in the case of contaminated water impoundments and drainage trenches.

- All temporarily and finally covered areas must be graded and maintained to promote run-off without excessive erosion and to eliminate ponding or standing water.

- Clean, uncontaminated water, which has not been in contact with the waste, must be allowed to flow off the site into the natural drainage system, under controlled conditions.
- All drains must be maintained. This involves ensuring that they are not blocked by silt or vegetation.

10.4.3 Control of nuisances

Nuisances resulting from the landfill operation should be controlled as follows:

Burning of waste

At present, the burning of waste takes place at many small landfills in South Africa, to reduce the volume of waste and its attraction to vermin and livestock. The burning of waste is considered unacceptable, however, because of aesthetics, odours, and the potential of health dangers from air pollution. On account of these adverse impacts, therefore, the Department prohibits the burning of waste at landfill sites.

Possible exceptions to this Minimum Requirement would be **G:C** and **G:S** landfills in rural areas, provided that they are at least a 1,000m downwind of residential areas. In such cases, special permission to burn waste must be obtained. This would be subject to the acceptance of the IAPs, the local authority and the Department of Environmental Affairs and Tourism.

Where burning is permitted, proper procedures must be followed to protect public health and safety, and to prevent the degradation of the environment. Efficient burning to obtain complete combustion without smouldering would therefore be a Minimum Requirement and all relevant occupational safety requirements would have to be met. Details and guidelines in this regard are included in Appendix 10.2.

Accidental fires on landfills where burning is not permitted must be extinguished immediately. Appropriate operational procedures, involving the spreading and smothering of burning waste, rather than the application of water, must be implemented.

At a hazardous waste landfill site a major fire may be classified as major incident in terms of the Major Hazard Installation Regulations governed under the Occupational Health and Safety Act 1993, (Act No. 85 of 1993). The employer shall therefore implement all items of these regulations, which include among others a risk assessment and development of on-site and off-site emergency plans. The risk assessment shall include studies on dispersion of possible hazardous combustion products and on-site and off-site exposure levels.

Litter

It is a Minimum Requirement that all litter be contained within the site. This may be achieved by applying the sanitary landfill principles of compaction and cover. On sites characterised by high winds, however, movable litter fences are a Minimum Requirement. Windblown litter must be picked up and removed from fences and vegetation on a daily basis.

Odours

Odours must be combatted by good cover

application and maintenance. Furthermore, the prompt covering of malodorous waste to reduce odour problems is a Minimum Requirement. In extreme cases, odour suppressants such as spray curtains may be required.

Where breaches in the cover from which significant volumes of landfill gas escape are identified by their odour, proper investigation is a Minimum Requirement. This may be followed by properly engineered passive or active gas venting and flaring, to alleviate odour problems.

Noise

All equipment used on site must conform to the local authority's by-laws concerning noise levels and hours of operation. In the absence of by-laws, national regulations on noise control must be complied with.

Vermin and disease vectors

It is a Minimum Requirement that landfill sites be kept free of vermin. Appropriate measures must be taken to eliminate or minimise disease vectors such as rats or flies.

Dust

Unsurfaced roads and ungrassed or unpaved areas, which give rise to dust problems, must be regularly watered to restrict dust to levels which do not pose a nuisance to workers or users of the facility.

10.4.4 Waste reclamation

At present, both uncontrolled salvaging and controlled reclamation take place at many landfills. While the ethic of reclamation from the waste stream is supported, reclamation at landfills can endanger the health and safety of the reclaimers. On account of the risks to health and safety, therefore, **the Department discourages waste reclamation at landfill sites.** Specifically, it is a Minimum Requirement that no waste reclamation be permitted at hazardous waste sites.

Should the Permit Holder wish to allow controlled reclamation at a general waste disposal site, however, permission can be obtained as part of the Permit Application or as an amendment to an existing Permit. In this case, guidelines and Minimum Requirements are provided, in order to ensure safe and controlled working conditions. **Notwithstanding, it is noted that responsibility for the safety of any reclaimers on the site vests with the Permit Holder, who will be required to enter into an indemnity agreement with the Department.**

It is a Minimum Requirement that any reclamation operation be formalised in the Operating Plan. This would include regular consultation with and registration of reclaimers and the provision of appropriate safety measures. Safety measures would include the separation of reclamation from compaction and covering activities, and the provision of safety clothing. Details and guidelines regarding the above are included in Appendix 10.3.

10.4.5 Leachate and gas management

In **B**$^{+}$ landfill sites, significant leachate is generated and leachate management is mandatory. The design for such sites will include a leachate management system. As with the drainage system, however, the leachate management system requires to be maintained and continuously adapted and developed, as the landfill develops. Where treatment is involved, a whole separate operating procedure must also be adhered to. This procedure would be written up in the Operating Plan.

At **B**$^{-}$ sites, any sporadic leachate generated on account of unusual circumstances must be both reported to the Department and properly controlled (see Section 10.4.2). This could also include leachate recycling.

Where a gas management system exists at a site (see Section 8.4.4), it must be correctly operated, maintained and monitored to ensure that any landfill gas emanating from the site is properly managed.

10.4.6 Progressive rehabilitation of completed areas

The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a Minimum Requirement. Capping should be implementedon all areas where no further waste deposition will take place, and vegetation should commence as soon as possible.

Screening berms are the first areas where vegetation must be established. This ensures that waste disposal operations take place behind vegetated berms. These are extended upwards in advance of the disposal operation to ensure continued screening. This is referred to as the 'rising green wall' approach.

All final levels and slopes must be in accordance with the landfill design and the End-use Plan. Slopes should not be steeper than 1 in 2,5, as this will promote erosion.

10.4.7 Final cover

Immediately on completion of an area, the final cover must be applied. The thickness of the final cover must be consistent and in accordance with the design (see Appendix 8.2). The final cover must comprise material capable of supporting the vegetation called for in the End-use Plan. In order to prevent erosion and improve aesthetics, re-vegetation should commence as soon as possible after applying the final cover.

All covered surfaces on the landfill must be so graded as to promote run-off to prevent ponding. Re-vegetation must commence as soon as is practically possible after the final cover has been placed, in order to rehabilitate on an ongoing basis.

10.4.8 Public Participation in the operation

As noted in Appendix 4.1. the standard of operation at a given landfill may be monitored and enforced by a Monitoring Committee. This should comprise representatives of the Department, the operator and representatives of those affected by the landfill. The objective of this committee is to provide a mechanism whereby the needs and concerns of the IAPs can be addressed in the operation of the facility. In the interests of transparency, IAPs should, through the Monitoring Committee, be given access to the site and information relating to the operation.

10.5 Hazardous Waste Lagoons

As discussed in Section 8, lagooning is not regarded as a form of landfilling. Nonetheless, hazardous waste lagoons are controlled under Section 20 of the Environment Conservation Act.

This form of disposal **is not encouraged**, and is regarded as an exception. Operating procedures for lagooning have not yet been drawn up. Consequently the Responsible Person should liaise directly with the Department regarding the operation of lagoons. Lagoons can only be considered for approval if nuisance related odours or hazardous vapours do not arise from the evaporating liquid.

TABLE 10
Minimum Requirements for Landfill Operation

LEGEND B^- = No significant leachate produced B^+ = Significant leachate produced R = Requirement N = Not a requirement F = Flag: special consideration to be given by expert or Departmental representative n/a = Not applicable	CLASSIFICATION SYSTEM									
	G General Waste								H Hazardous Waste	
	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3 & 4	H:H Hazard Rating 1-4
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Facilities & Resources										
Signposting	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
All weather roads	N	N	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Controls										
Waste acceptance procedure	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Fencing	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Control of vehicle access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Site security	N	N	F	F	F	F	**R**	**R**	**R**	**R**
Operating Plan	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Response action plan	N	N	N	N	F	F	F	F	**R**	**R**
Waste load allocations	N	N	N	N	N	F	N	F	**R**	**R**
Liquid Co-disposal ratios	N	N	N	N	N	F	N	F	**R**	**R**
Encapsulation specifications	N	N	N	N	N	N	N	N	**R**	**R**
Resources & Infrastructure										
Weighbridge	N	N	F	F	R	R	**R**	**R**	**R**	**R**
Collection of Waste disposal tariffs	N	N	F	F	R	R	R	R	R	R
Site office	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Laboratory	N	N	N	N	N	N	N	N	**R**	**R**
Adequate plant and equipment	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G General Waste								**H Hazardous Waste**	
Responsible Person	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Sufficient qualified staff	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill Operation Compaction of waste	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Daily cover	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Two week's cell or trench capacity	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Protection of unsafe excavations	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
One week's wet weather cell capacity	N	N	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Immediate covering of putrescibles	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
End-tipping prohibited	N	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**
Three days' stockpile of cover	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Final cover	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Waste reclamation prohibited	F	F	F	F	F	F	F	F	**R**	**R**
Any reclamation operation formalised in Operating Plan	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	n/a	n/a
Registration of reclaimers	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	n/a	n/a
Protection of reclaimers	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	n/a	n/a
Protective clothing	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	n/a	n/a
Control of nuisances	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Waste burning prohibited	F	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Draining water away from the waste	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Contaminated run-off contained	F	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**
Leachate contained	N	F	F	**R**	F	**R**	F	**R**	**R**	**R**

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G General Waste								**H Hazardous Waste**	
Storm water diversion measures	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
0,5m freeboard for diversion and impoundments	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Grading cover/avoiding ponding	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
General site maintenance	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Sporadic leachate reporting	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill gas control	N	N	F	F	F	F	F	F	F	F
Rehabilitation and vegetation	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Section 11

LANDFILL OPERATION MONITORING

11.1 Introduction

The Minimum Requirements for landfill operation monitoring are summarised in Table 11, at the end of this Section.

The general objective of landfill operation monitoring is to verify that the landfill conforms to the required standards and the site Permit conditions. More specific objectives are:

- **To ensure that the accepted site design is properly implemented.**
- **To function as a control measure to ensure that the operation conforms to the required standards.**
- **To quantify any effect that the operation has on the environment, and, in particular, any effect on the water regime.**
- **To serve as an early warning system, so that any problems that arise can be *timeously* identified and rectified.**

The standards referred to in the second objective are those required by the Minimum Requirements and the site Permit. They might include the proper compaction and covering of waste, the integrity of drainage systems and the consideration of site impact.

Monitoring serves to quantify any effect of the operation on the environment, especially the water regime, and act as an early warning system, so that any problems that arise can be identified and rectified. Such problems would include mal-functioning drainage systems, cracks in the cover, leaking liners, and ground or surface water pollution. Any problems identified must be rectified as soon as possible.

In addition, monitoring serves as a performance indicator, and hence as a control or management tool, for the landfill operator.

In this context, monitoring is a general term used as described above. Monitoring may be carried out by means of site inspections or audits, data collection, sampling, analysis and interpretation. It also involves monitoring the response of IAPs.

11.2 Background

At present, there are six ways in which waste disposal sites may be monitored or audited:

- A Landfill Monitoring Committee which includes IAPs may be formed to assist in monitoring landfill operations, to identify problems and to keep the public informed of activities/developments on the landfill (see Appendix 11). Landfill Monitoring Committees are a Minimum Requirement at all Hazardous and Large landfills.
- The Department undertakes routine inspections of waste disposal sites throughout the country

and identifies situations which are unacceptable.

- Clients frequently audit the operation of private sector hazardous waste landfills to ensure that their waste is being properly disposed of. This is because they remain responsible for the waste which they generate, in terms of the Duty of Care principle.

- The Institute of Waste Management may be used by a Permit Holder to audit a site for the purposes of accreditation.

- Permit Holders use consultants to conduct external audits of their facilities or to monitor their operations or those undertaken by contractors on their behalf. It is a Minimum Requirement that all Hazardous and Large landfills have two external audits each year.

  Finally, Permit Holders may undertake internal inspections or audits of their own facilities.

  The above applications of auditing, or monitoring, may be used individually, or in various combinations. However, they all provide means of control. At present, there are no clearly defined and agreed methodologies for landfill site auditing. However, Minimum Requirements for auditing and monitoring of waste disposal facilities will be addressed in a separate document as part of the Waste Management Series (see Preface).

11.3 The Required Extent and Frequency of Monitoring

The extent and frequency of monitoring will

depend on the site classification and will be indicated in the permit. It is the duty of the Responsible Person to ensure that the Minimum Requirements for operation monitoring are applied to a degree commensurate with the class of landfill, the situation under consideration and the risk of polluting the environment, more specifically the water regime. See also Sections 7.2 and 7.3 of this document, and Section 5 of the *Minimum Requirements for Monitoring at Waste Management Facilities*.

Monitoring must be carried out to the satisfaction of the Department, and the Responsible Person may be required to provide additional information. This could include detail about airspace utilisation and cover volumes used or waste stream data analyses. The information required would be determined by site-specific needs and the Responsible Person would have to liaise with the Department in this regard.

11.4 Landfill Site Auditing

The waste disposal operation is usually monitored by means of a landfill site audit. All landfills should be audited and inspected to ensure the maintenance of acceptable standards.

At hazardous waste landfills, the audit committee may consist of the Permit Holder, or the Responsible Person, the Department's regional or national office inspectorate and, where applicable, the relevant consultant(s). In some instances IAPs from the Landfill Monitoring Committee may also be included. At general waste landfills, the audit committee may be reduced. All audit committees should be set up in consultation with the Department.

The initial frequency of the audit must be agreed upon by all the parties concerned, during the planning stages when the IAPs are consulted. Audits should occur at twelve month intervals for small sites, six month intervals for medium sites, three month intervals for large sites and monthly intervals for hazardous waste sites. Where problems occur, this frequency may be reviewed in consultation with the Department and the IAPs.

General aspects of a landfill site audit would include consideration of site security, site access, condition of roads and traffic control. The actual waste deposition would be addressed in terms of cell construction, waste deposition, spreading, compaction and covering. At hazardous waste sites, pretreatment and co-disposal would also be addressed.

Operating procedures as specified in the Operating Plan would also be carefully appraised, as would aspects such as drainage, litter control and aesthetics. Similarly, all site specific Permit conditions and design requirements would be addressed.

Details of how such an audit is conducted are not addressed here, as the Department has not yet standardised the auditing format. The audit programme should, however, include the following:

- A checklist of items to be audited
- A report on the findings of the audit
- A record of performance.

A record of any identified problem areas and the recommended actions to rectify these problems must be submitted to the Responsible Person for implementation.

The audit results must be made available to the IAPs through Landfill Monitoring Committees, so that any problems identified can be discussed and addressed. A record of complaints received and actions taken, must also be maintained.

11.5 Other Monitoring

In addition to the landfill site audit, monitoring may comprise the collection, processing and interpretation of certain data. The required data, the format and the frequency with which it must be presented to the Department would be specified in the Permit conditions. Most of the procedures outlined here would be included in the Operating Plan, which would also make provision for certain actions to be taken in response to any problems identified during monitoring.

11.5.1 Gate or weighbridge recording procedures

Landfill site operators, facility users and the Department will all require waste disposal records for different reasons. Over and above the measurement of incoming waste for commercial purposes, records are also necessary for site management and control. Such records are obtained from record keeping at the gate or weighbridge.

The method of waste recording must be appropriate to the nature and the volume of the wastes entering the site. Such data bases are sometimes termed ‘dynamic records’. The degree of sophistication required will be dependent on the class of site involved. In general, however, records must be kept of all waste entering the site. Waste must be categorised by the number of loads (defined by volume or mass), the type of waste and the source. Hazardous waste must also be defined in terms of its hazard rating (see Section 3). Records must be kept on both a daily and a cumulative basis. Such historically factual records are sometimes termed ‘static records’. These should be maintained and archived.

With the accumulation of records, a data base must be established and maintained at the landfill site. In the case of hazardous waste landfills this must be extended to the recording of the position of all hazardous waste disposed on site, on a weekly basis,

in terms of both plan and elevation, i.e. in three dimensions. In the case of the encapsulation of waste with a Hazard Rating of 1, the exact co-ordinates of the encapsulation cells must be recorded.

11.5.2 Volume surveys

At all landfills, some idea of the remaining volumetric capacity is required. In the case of **G:C** and **G:S** sites, distances may be paced or tape-measured. At all other sites, however, surveys must be performed with the appropriate instruments and accuracy. The entire site must be surveyed prior to commencement of waste disposal and annually thereafter.

11.5.3 Collection and processing of other data

Certain climatic statistics must be collected and analysed for control purposes and for the successful operation of landfills where co-disposal of waste with a high moisture content or liquids takes place. These may include rainfall from rain gauges, wind speed and direction, and A-pan evaporation rates. Such information would provide the insight required to manage the site water balance.

11.5.4 Leachate and water quality monitoring (see Section 13)

Regular sampling and analysis of leachate, ground and surface water, and the interpretation of the findings, must be ensured by the Permit Holder. Records must be maintained of any impact caused by the landfilling operation on the quality of the water regime in the vicinity of the site**. This is required by the Department in terms of the Permit conditions**. Additional samples may be taken at other times, if this is considered necessary.

Leachate and water quality monitoring is also addressed in Section 13 of this document and the *Minimum Requirements for Monitoring at Waste Management Facilities*.

11.5.5 Gas monitoring

Landfill gas has a distinctive and unpleasant odour, which is frequently the reason for complaints by IAPs. Landfill gas can, however, also result in an explosion hazard, where methane gas reaches concentrations of between 5% and 15% of atmospheric gas composition. The risk of gas explosion must therefore be continually monitored. If monitoring indicates that there is any safety risk on account of landfill gas accumulation and/or migration, controls must be considered in consultation with the Department.

While gas monitoring is a Minimum Requirement at all Hazardous and Large landfills, monitoring systems must be installed whenever potential gas problems exist (see Section 8.2.3). These must be monitored at three monthly intervals during the operation and at the discretion of the Department after site closure. If the soil gas concentrations exceed 1% by volume at Standard Temperature and Pressure (STP), the Department must be informed.

Methane concentration in the atmosphere inside buildings on or near the site should not exceed 1% (by volume) in air, i.e. 20% of the Lower Explosive Limit (LEL). If the methane levels are found to be between 0,1% and 1% in air (i.e. between 2% and 20% of the LEL) then regular monitoring must be instituted. If levels above 1% (i.e. 20% of LEL) are detected, then the building must be evacuated and trained personnel consulted.

Methane levels on landfill boundaries should not exceed 5% in air (i.e. the LEL). This should apply to the air above the surface and also to the air in a hole dug into the earth on the boundary.

If the methane levels are found to be between 0,5% and 5% in air (i.e. between 10% of LEL and LEL) then regular monitoring of the boundary should be instituted. If the methane levels are found to be greater than 5% in air, then a permanent venting system should be implemented.

Apart from explosion potential, however, landfill gas also contains a wide range of volatile organic compounds that are classified as hazardous air pollutants. Where significant landfill gas is present, therefore, samples must be taken at various positions at the landfill site, and characterised for volatile organic compounds. Sampling can be direct at gas wells, or using the techniques outlined in Section 11.5.6. The volatile organic compound compositions of the landfill gas must then be subjected to occupational and environmental health risk assessments. This must be done at the discretion of the Department to ensure against unacceptable health risks to workers or communities.

Gas monitoring should continue after landfill closure, until the Department is satisfied that landfill gas no longer represents a risk.

11.5.6 Air quality monitoring

At all landfills there is some risk of dust and the escape of contaminants by wind action (see *Figure 9*). Hazardous air pollutants may therefore be dispersed from a landfill site as dust, or as gaseous substances. These have to be monitored separately.

Dust monitoring

Because of many sources of dust and variations in wind characteristics and other meteorological parameters, ambient air monitoring for dust concentrations at landfill sites has limitations. It is preferable to characterise the possible sources of dust on the landfill site in terms of hazardous metals, anions, and semi-volatile organic compounds that are normally particulate-associated, and then to model dispersion. This approach entails sampling of dust that can be suspended, using a sampling approach that would ensure statistically that samples are representative of all possible sources of hazardous substances.

Chemical analyses must cover all substances that may be relevant to the materials and activities, using validated methods in a formal quality assurance structure. Mathematical modelling of dust released from an area source, using the source profiles of hazardous substances, must then be conducted to provide the necessary information to assess human exposure, and health risks. The mathematical dispersion modelling has to be done at the beginning of the monitoring programme, and the model can then be used with new input data after each analytical survey. The on-site dust at the landfill site must be characterised at least once per year, or more frequently when activities on the site may change the dust compositions.

The Department may request analyses of dust sources, followed by mathematical dispersion modelling and human health risk assessment, at more frequent intervals if hazardous substances are present at levels that may lead to unacceptable health risks to workers or communities.

Monitoring for releases of volatile substances

Volatile substances include organic and inorganic substances. These may be released as constituents in the landfill gas, or through mass transfer from the liquid or solid phases of the waste to the gas phase. There are four basic assessment approaches for assessing emission rates of hazardous substances from landfill sites, i.e.:

(i) Direct measurement technologies
(ii) Indirect measurement technologies
(iii) Fenceline monitoring and modelling technologies
(iv) Predictive emission modelling.

Direct measurement using a surface emission isolation flux chamber has been selected as the preferable technique in the USA to characterise area source facilities with hazardous fugitive emissions, and is recommended for use in South Africa. It can be used on any liquid or solid surfaces that are accessible for testing. The location and number of test points must be adequate to enable calculation of the emission rates of substances from the total area. Sampling and analysis must cover the complete range of substances that are relevant to the source. The
data must then be used in a mathematical dispersion model to predict exposure levels for the quantification of occupational and environmental health risks.

Sampling and analytical techniques that are used to monitor emission rates of hazardous substances must satisfy data quality objectives, i.e. the technologies must be applicable for testing area source emission rates, and must account for the key factors that influence the variability in the area source estimate. The frequency of sampling and analysis would depend on the level of identified risk, but must be at least once per year when activities and waste profiles do not change. After changes that could influence the emissions profiles, measurements must be made to establish the new profiles and associated occupational and environmental health risks.

11.5.7 Monitoring of rehabilitated areas (see Section 12.8)

Completed areas require ongoing inspection and maintenance. This includes the repair of cracks and erosion gullies which allow water to access
the waste and from which malodorous gases escape, and the filling in of settlement depressions and/or cavities caused by fire. Ongoing maintenance of the established vegetation is required for a period specified by the Department (see
Sections 12.7 to 12.9).

11.5.8 Health of workers

In terms of the Occupational Health and Safety Act, the Employer is responsible for the health and safety of the people under his or her jurisdiction. Whenever workers or waste reclaimers are exposed to waste on a regular basis, a health risk may exist. This risk is, however, greater at a hazardous waste landfill than at a general waste landfill. The Responsible Person must therefore use his or her discretion in applying the Act and monitoring the health of workers. In the case of the hazardous waste landfill sites, this will involve medical examinations.

TABLE 11
Minimum Requirements for Landfill Operation Monitoring

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Responsible Person	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill Monitoring Committee	N	N	F	F	F	F	**R**	**R**	**R**	**R**
Conduct Audits	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Conduct external Audit twice per annum	N	N	N	N	N	N	**R**	**R**	**R**	**R**
Appropriate records and data collection	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Record deposition rate	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Waste stream records	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill volume surveys	N	N	N	N	**R**	**R**	**R**	**R**	**R**	**R**
Collect climatic statistics	N	N	N	F	N	**R**	N	**R**	**R**	**R**
Water quality monitoring	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Gas monitoring and control	N	N	F	F	F	F	**R**	**R**	**R**	**R**
Air quality monitoring	N	N	F	F	F	F	F	F	**R**	**R**
Monitoring of progressively rehabilitated areas	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Ongoing maintenance	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Section 12

REHABILITATION, CLOSURE AND END-USE

12.1 Introduction

The Minimum Requirements for rehabilitation, closure and end-use are summarised in Table 12, at the end of this Section.

Closure is the final step in the operation of a landfill. In order to close a landfill properly, however, closure must be preceded by rehabilitation, to ensure that the site is environmentally acceptable. The site must also be rendered suitable for its proposed end-use, as determined during permitting and set out in the End-use Plan (see Section 8.2.4). Where bad practice has occurred, this must be rectified by means of remedial measures.

Once the operation has ceased, aftercare is necessary to ensure sustained acceptability.

The objectives of landfill closure are:

- **To ensure public acceptability of the implementation of the proposed End-use Plan.**

- **To rehabilitate the landfill so as to ensure that the site is environmentally and publicly acceptable and suited to the implementation of the proposed end-use.**

Where it is intended to close a landfill, the Permit Holder must inform the Department of this intention at least one year prior to closure. This is because certain procedures must be implemented and criteria met before closure.

If the site is permitted, it must be rehabilitated in accordance with the Permit conditions and the relevant Minimum Requirements for closure. If, however, the site does not have a Permit, it must be permitted with a view to closure*. In this event, the emphasis of the Permit Application is on closure design and rehabilitation.

Regardless of whether a landfill is permitted or not, it must be investigated before rehabilitation and closure can commence, so as to identify any closure requirements that must be implemented, see *Figure 13*.

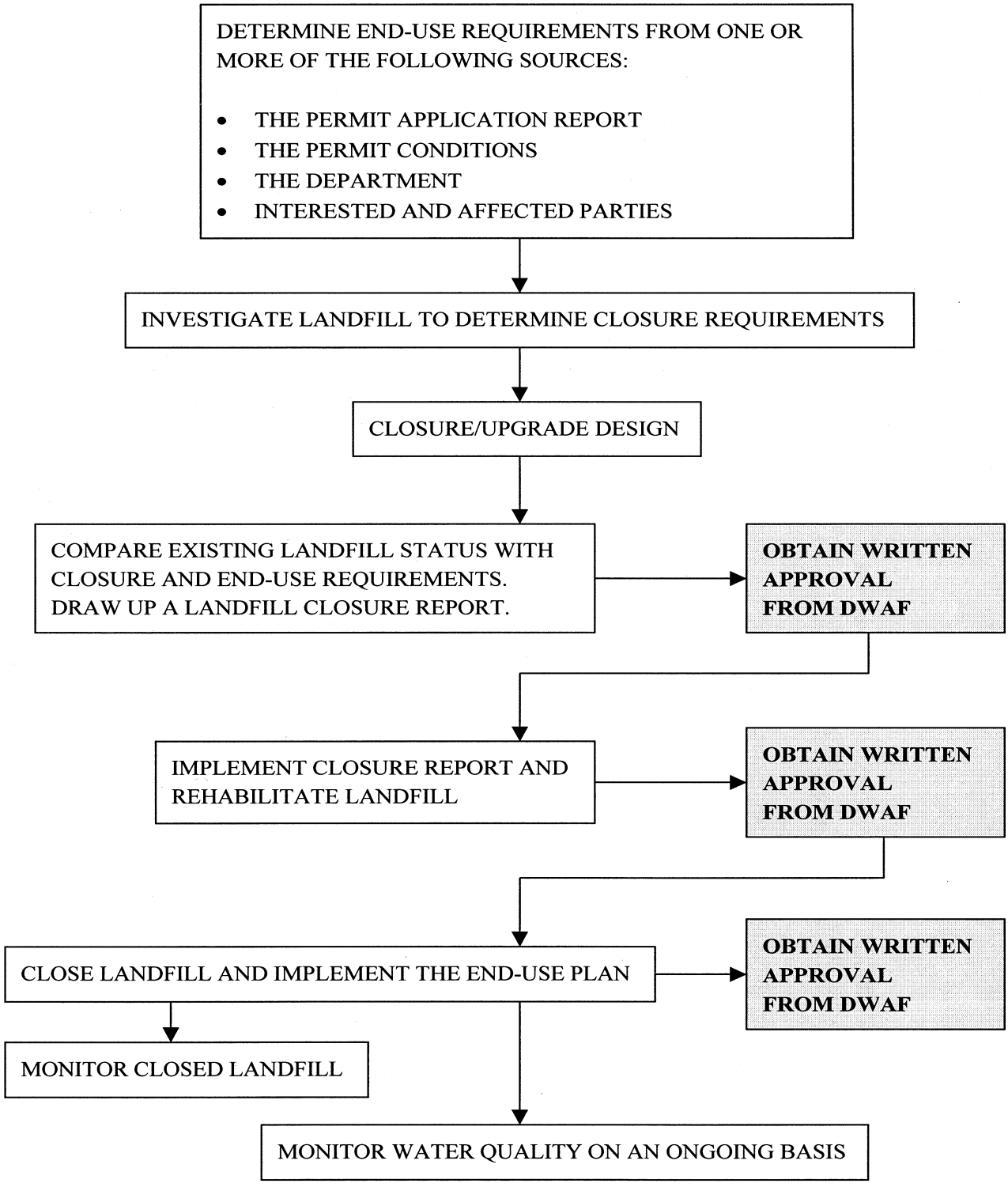
Based on the results of the investigations, a closure or upgrade design may be drawn up and presented in a Closure Report. Also in this report, the current status of the landfill is compared with the identified end-use and closure requirements, and recommendations are made regarding required rehabilitation. The Closure Report must be approved by the Department and the IAPs before rehabilitation can commence.

Once the landfill has been rehabilitated in accordance with the Closure Report, the Permit Holder must notify the Department in writing of the intended closure of the site, at least 60 days prior to the event. Should the Department approve the condition of the landfill, the Permit Holder will be provided with written permission to close the site. The site may then be closed and the End-use Plan

* All landfills except those closed prior to August 1990, when the legislation came into effect must be permitted before they can be considered closed.

FIGURE 13

Applying the Minimum Requirements to the Closure of Landfills



may be implemented. Thereafter, the site must be monitored on an ongoing basis.

12.2 Determination of End-use Requirements

The end-use of a landfill refers to its after-use, i.e. how it will be developed after closure, to fit into the environment.

The most common landfill end-use is open space, which may be used for sport and recreation. Other end-uses also exist and will be accepted if they are safe. Only approved structures will, however, be permitted on top of or adjacent to a closed landfill, because of the problem of ongoing settlement and the possible generation of methane gas.

No public access will be permitted onto closed hazardous waste landfills, because of the hazardous nature of the wastes contained therein. This must be clearly indicated by signposting. In exceptional circumstances, where very conservative designs are involved, however, relaxations may be motivated and considered.

The end-use requirements are determined from the requirements of the IAPs and the Permit. The IAPs are consulted regarding their end-use requirements during the feasibility study. The End-use Plan is then drawn up as part of the design and included as part of the Permit Application Report. With the granting of a Permit, the Department endorses the End-use Plan and may include additional requirements.

The Permit Application Report, together with the Permit, therefore represent the initial source from which end-use requirements can be determined. With time, however, the situation associated with the landfill may well have changed. The end-use requirements must therefore be reassessed and redefined. Consequently, before closure, the IAPs must again be consulted regarding the end-use.

12.3 Investigation of the Landfill to Determine Closure Requirements

The closure investigation must be carried out to identify the causes of any existing problems and to provide the basis for the closure requirements. The extent of the investigation will depend on the amount of investigation already completed, the existing problems and the potential environmental impact of the site. The investigation would adhere to the principles set out in Section 7.

Closure requirements are those rehabilitation measures that must be taken to render a landfill environmentally suited to its proposed end-use. Where problems have resulted from bad practice, remediation is required. This may include remedial work with regard to drainage, leachate management and cover integrity. The closure requirements are included in the remedial or Closure Design.

12.4 Closure Design

The Closure Design takes all closure requirements into account and should adhere to the design principles set out in Section 8. In the case of unpermitted operating or closed landfills, it may represent the first landfill design submitted, while in the case of a permitted landfill it will involve amendment to an existing design. Closure Designs usually entail remedial design. In some cases, where landfills were not designed or operated in accordance with the Minimum Requirements, significant remediation may be required. In all cases, the Department must be consulted.

Aspects addressed in the Closure Design would typically include the following:

- Remedial design to address identified problem areas
- Final shaping, landscaping and revegetation
- Final landfill cover or capping design
- Permanent storm water diversion measures, run-off control and anti-erosion measures
- Any infrastructure relating to the End-use Plan.

In considering each of the above aspects, reference must be made to any earlier End-use Design. Any variations from the original concept must be noted and their effect analysed. The design must ensure that the closed landfill complies with the Minimum Requirements and the relevant legal requirements.

In the case of a landfill that was not designed in accordance with the Minimum Requirements, it will be necessary to assess all the above features. If these are non-existent or inadequate, they must either be designed from the beginning or appropriate remedial measures must be designed which, when implemented, will ensure that the closed landfill complies with the Minimum Requirements for closure.

12.5 Closure Report

The state of a landfill at closure will seldom comply with the desired end-use and closure requirements, reflected in the Closure Design. The Closure Report therefore compares the current status of the landfill with the Closure Design and End-use requirements. Based on this comparison, recommendations are made regarding measures to upgrade the existing condition of the landfill to that desired.

Recommendations of the Closure Report involve the implementation of the Closure Design and would typically include details of rehabilitation measures. The Closure Report would also include details of management, inspection, monitoring and maintenance plans.

12.6 Written Acceptance

Written acceptance of both the Closure Design and the Closure Report must be obtained from the Department. In order to obtain this, an inspection of the landfill by the Responsible Person and a representative of the Department will be required. Once the Closure Design and the Closure Report have been accepted by the Department and the IAPs, site rehabilitation may commence.

12.7 Rehabilitation of Landfill

The rehabilitation of the landfill will ensure that the final condition of the site is environmentally acceptable and that there will be no adverse long term effects on the surrounding areas, the water regime or the population. It includes final cover, capping, topsoiling and vegetating. Any long term leachate, gas, storm water and erosion control systems required should also be in place and in working condition before the landfill is closed.

In a landfill designed and operated in accordance with the Minimum Requirements, progressive rehabilitation will have been carried out (see Sections 8 and 10). In instances of poor landfill siting, design and/or operation, however, extensive remedial work may be required prior to closure. This will be detailed in both the Closure Design and the Closure Report.

12.8 Closure and Implementation of the End-use Plan

The closure of a landfill will only be considered once the Department is satisfied that the rehabilitation of the site has been properly carried out. This will include the implementation of the Closure Design and the carrying out of all the recommendations contained in the Closure Report. This will be assessed at a final site inspection attended by representatives of all the relevant state departments and the Monitoring Committee.

It is seldom possible or necessary to implement the End-use Plan prior to gaining approval for closure. However, all of the preparations necessary to implement the End-use Plan and to maintain the landfill in an environmentally acceptable condition must have been completed before closure.

Once the Department is satisfied with the status of the rehabilitated landfill site, it will issue the Permit Holder with a letter approving the closure of the facility. This letter will allow the operator to physically close the landfill and will state that no further waste can be accepted. It will also set conditions for the implementation of the End-use Plan and for the ongoing inspection and maintenance of the landfill.

12.9 Ongoing Inspections and Maintenance of the Landfill

The long term environmental impacts, public health, safety and nuisance problems associated with a landfill may persist long after the site has been closed. Ongoing inspections and maintenance are therefore required after site closure to ensure that such problems do not continue unidentified and unabated, and that the End-use Design is properly implemented.

Ongoing inspections must be carried out at regular intervals to monitor cover integrity, subsidence, fires, vegetation, drainage, erosion, and any other aspects of the closed site which could cause nuisances. Post-closure water quality monitoring must also take place (see Section 13). The inspections will be carried out at six or twelve monthly intervals, as specified in the Minimum Requirements *Table 12*.

In the case of hazardous waste disposal and **G:L:B**$^{+}$ sites, the frequency of inspections or post closure audits will be determined in consultation with the Department. The frequency will be determined on a site specific basis, and monitoring will continue for a period stipulated by the Department, as written into the approval of the Site Closure report.

Based on the findings of the ongoing inspections, maintenance would address the following aspects:

Integrity of cover

The integrity of a landfill cover can be breached by several mechanisms, including settlement, fires and erosion.

Settlement takes place continuously in a landfill because the waste is subject to ongoing decomposition. While good compaction will ensure that such settlement is reasonably uniform, any uneven settlement will result in cracks or depressions in the cover. In landfills where fires have occurred, it is possible that smouldering fires can undermine areas which then either subside or collapse. Alternatively, erosion caused by surface water run-off can also expose waste.

In the event of the landfill cover being breached, three main effects may occur. First, relatively large concentrations/volumes of flammable landfill gas may vent to the atmosphere, with associated odour problems and a danger of fire or even explosion.

Second, exposed and/or undermined smouldering waste may create dangerous, unsafe situations. Third, surface water may be channelled into depressions, where it may collect and infiltrate the waste, or it may gain access to the waste directly via the breaches. Both of these situations could result in the generation of leachate.

Post-closure monitoring must therefore address all the above aspects of landfill cover integrity. Wherever there are breaches, these should be identified, the cause investigated and the situation rectified by infilling.

Drainage systems

It is essential to ensure that drains are not excessively eroded or filled with silt or vegetation. They must function in order to ensure that excess surface water does not enter the waste body.

Subsidence

Any subsidence or cracks, due to settlement or any other cause, must be identified and rectified by infilling.

Fire

Any fires that result on the site should also be identified, exposed and smothered with soil as soon as possible.

Vegetation

Vegetation planted for the purposes of rehabilitation, erosion control, beautification or the end-use must be maintained to ensure that it achieves its purpose.

Security

It is essential to ensure that illegal access and dumping does not occur on the closed waste disposal facility.

12.10 Ongoing Monitoring and Public Participation

Any gas or water monitoring systems must be maintained and monitored on an ongoing basis, after the landfill site has closed. Gas monitoring should comply with both the Permit conditions and those set out in Section 11.5.5.of this document, while water monitoring should be carried out in accordance with Section 13.

Post closure monitoring may be carried out under the auspices of a Monitoring Committee. Where this is the case, the results of ongoing monitoring should be submitted to the Monitoring Committee and made available for public scrutiny.

The public may, through the Monitoring Committee, also monitor the landfill and report any problems that are observed to the Responsible Person.

TABLE 12
Minimum Requirements for Rehabilitation, Closure and End-use

LEGEND **B⁻ = No significant leachate produced** **B⁺ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B⁻**	**B⁺**	**B⁻**	**B⁺**	**B⁻**	**B⁺**	**B⁻**	**B⁺**		
Determine/reassess End-use Requirements	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Investigate landfill to determine closure requirements and to identify impacts	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Obtain input on End-use Design by IAPs	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Confirmation of End-use Design by Department	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Design for upgrade/ rehabilitation, if necessary	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Design final shaping and landscaping	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Design final cover or capping	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Design permanent storm water diversion	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Design anti-erosion measures	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Closure Report	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

LEGEND **B^- = No significant leachate produced** **B^+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Communal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Compare actual condition of landfill to required condition	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Written acceptance of Closure Report	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Ongoing leachate management	N	N	F	**R**	F	**R**	F	**R**	**R**	**R**
Ongoing gas management	N	N	F	F	F	F	F	F	F	F
Ongoing inspection and maintenance	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Implementation of Closure Report/Rehabilitation	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Application for Permission to Close Letter approving closure	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Inspection and Monitoring Frequency intervals (in months)	12	12	12	12	6	6	F	F	F	F
Cover integrity	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Integrity of drainage	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Control of ponding	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Control of fire	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Monitoring vegetation	N	N	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Monitoring security and prevention of illegal dumping	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Section 13

WATER QUALITY MONITORING

13.1 Introduction

The Minimum Requirements for water quality monitoring are summarised in Table 13, at the end of this Section.

In this section, water quality monitoring at landfills is addressed. It is also addressed, in more detail, in the *Minimum Requirements for Monitoring at Waste Management Facilities*.

Water quality monitoring, as has been indicated at relevant points in the text, begins before the commissioning of a landfill site and continues throughout and beyond its operation. Since post-closure water quality monitoring may continue for up to 30 years after the closure of a landfill, it can be seen to represent the final step in the landfill process.

The objectives of water quality monitoring are:

- **To enable the Permit Holder to comply to the relevant Permit conditions and legislation.**
- **To indicate any escape of leachate into the water environment**.
- **To serve as an early warning system, so that any pollution problems that arise can be identified and rectified.**
- **To quantify any effect that the landfill has on the water regime.**

The Department requires a Water Quality Monitoring Plan as part of the permitting requirements. This involves background analyses, detection monitoring, investigative monitoring and post-closure monitoring. The Water Quality Monitoring Plan ensures that the water quality in the vicinity of a landfill is regularly monitored and reported upon throughout its life, so that, where necessary, remedial action can be taken.

Water quality monitoring is the responsibility of the Permit Holder, who must ensure that the level and the extent of monitoring is commensurate with the class of site under consideration, and hence in accordance with the Department's requirements.

13.2 Pre-operation Monitoring

Water quality and level monitoring must commence before the landfill operation begins and before any waste is disposed of. Monitoring will therefore start during the site investigation, when all accessible surface and ground water in the vicinity of the proposed landfill is sampled and analysed (see Section 4.6.2). The objective of this is to provide the pre-disposal background or datum against which future water quality can be measured.

Pre-operation monitoring sampling points must, together with any proposed monitoring points, be formalised and indicated as the monitoring systems in the site design (see Section 8.2.3). This would then be submitted as part of the permitting procedure.

It is at the investigation and design stages that the future monitoring systems are established and recorded. Pre-operation monitoring therefore forms the basis for water quality monitoring during the operation and even after closure.

13.2.1 Surface water monitoring system

During the site investigation, surface water quality in any associated drainage feature is monitored both upstream and downstream of the proposed landfill. Sampling points must be selected at representative, easily identified sites. While a single upstream sampling point may suffice, the size and complexity of the site, i.e. its class, will determine the number of downstream sampling points required.

The sampling points upstream of the proposed landfill will provide ambient background values. The sampling points downstream of the proposed landfill will ultimately indicate any pollution resulting from the site.

13.2.2 Ground water monitoring system

The ground water monitoring system, which comprises boreholes, is addressed in Sections 6 and 8, as well as in Appendix 6. For more detail in this regard, the reader is referred to the *Minimum Requirements for Monitoring at Waste Management Facilities*.

13.2.3 Leachate monitoring system

The Permit Holder must ensure that the extent of the proposed monitoring system is commensurate with the class of site under consideration. Cases in point would be **B**$^{+}$ and hazardous waste disposal sites, which would require leachate management systems. In such cases, leachate collection systems would form part of the design and provision would have to be made for future leachate monitoring.

13.2.4 Parameters

For consistency and for comparative purposes, the same water quality parameters are analysed for in both surface and ground water monitoring. *Table 13.1* sets out the parameters. Other parameters should, however, be added by the Responsible Person, should they be relevant at a specific site.

13.2.5 Sampling

Ground water sampling methods and the treatment and storage of samples are those advocated in the *Minimum Requirements for Monitoring at Waste Management Facilities* and those advocated by Weaver in 'Groundwater Sampling'. [**Ref**. Weaver, J.M.C., *Groundwater Sampling*. Water Research Commission Project No. 339 TT 54/92.] Surface water sampling methods are somewhat simpler, however, in that grab samples may be taken from the surface water sampling points.

In the case of both surface and ground water sampling, clean bottles should be used. These should be rinsed with the sample water, prior to taking the sample. Sample treatment prior to analysis would be the same in both cases and is indicated in the above references.

The analysis of the samples must be performed in accordance with the South African Bureau of Standards (SABS) methodology. [**Ref**. Standards Act, Act 30 of 1982.] Alternatively, the analyses may be performed using an equivalent method which is to the satisfaction of the Department.

13.2.6 Reporting

The ground and surface water quality results from the pre-operation monitoring, together with the annotated designs of the monitoring systems, must be submitted to the Department as part of the

Permit Application Report, i.e. the Water Quality Monitoring Plan (see Section 5.2.4).

13.3 Operation Monitoring

Once a landfill is operational, water monitoring for level and quality must take place in accordance with the Permit Conditions and any subsequent requirements that the Department may have.

Operation monitoring involves monitoring the water regime in the vicinity of the landfill. This is done by means of the monitoring systems included in the design section of the Permit Application Report (see Section 13.2.1). Monitoring may include the sampling and analysis of surface water, ground water and leachate. The above systems may, however, have to be expanded to accommodate changed circumstances.

The impact of the landfill on water quality is assessed by making a comparison between the pre-disposal, upgradient, or ambient background, and the downgradient concentrations monitored. This will indicate whether there is a pollution problem due to contaminated surface water or leachate leaving the site. Where complex situations are involved, a specialist should be consulted.

The methodology for sampling both surface and ground water at an operating landfill would be the same as that used during pre-operation monitoring.

Operation monitoring may comprise two types of monitoring, i.e. detection monitoring and investigative monitoring.

13.3.1 Detection monitoring

Detection monitoring is routine monitoring carried out every six months. The parameters used in detection monitoring are limited to indicator parameters, intended to indicate the presence of pollution, see *Table 13.2*.

Detection monitoring should also include any substance that has or will be disposed of on the landfill in significant concentrations.

13.3.2 Investigative monitoring

If detection monitoring indicates possible pollution, with an increasing trend in the parameter concentrations with time, the Department may require further monitoring. This would be referred to as investigative monitoring and would involve monitoring the range of parameters included in *Table 13.1*, together with any other parameters deemed necessary. The sampling interval in the case of investigative monitoring would generally be monthly, or as determined by the Department.

Investigative monitoring may be enhanced by tracer or isotope studies, and the interpretation of water quality monitoring results may be enhanced by the use of Piper or Durov Diagrams. (See *Minimum Requirements for Monitoring at Waste Management Facilities.*)

13.3.3 Leachate

Where significant leachate is generated at $\mathbf{B}^+$ or hazardous waste disposal sites, it must be sampled from the appropriate places in the leachate collection system. Sampling frequency and the parameters tested for should be the same as for surface and ground water monitoring, unless otherwise stipulated in the Permit or by the Department.

Where sporadic leachate is generated at a $\mathbf{B}^-$ site, the Department must be informed. If directed by the Department, the Permit Holder may have to have such leachate sampled and analysed.

13.3.4 Reporting

The above analyses must be presented in the format stipulated in the Site Permit, and the Permit Holder must maintain records of all analyses undertaken.

13.4 Post-closure Monitoring

Since a landfill can continue to pollute the ground and surface water regime long after the site has been closed, post-closure water quality monitoring must be ongoing.

The approach and systems for ground and surface water monitoring, described in Sections 13.2 and 13.3, should be used for this purpose. The emphasis in the case of post-closure monitoring, however, would be more on ground water monitoring, unless circumstances or the Department dictated otherwise.

In the case of some $\mathbf{B}^-$ sites, most $\mathbf{B}^+$ sites and all hazardous waste disposal sites, post-closure water quality monitoring must continue for 30 years after site closure, unless otherwise agreed with the Department. Ongoing liaison with the Department must continue throughout this period, with regular reports as specified in the Permit.

13.5 Public Participation

The results of the water quality monitoring results must be available for scrutiny by the Monitoring Committee.

TABLE 13

Minimum Requirements for Water Quality Monitoring

LEGEND B^- = No significant leachate produced B^+ = Significant leachate produced R = Requirement N = Not a requirement F = Flag: special consideration to be given by expert or Departmental representative	CLASSIFICATION SYSTEM									
	G General Waste								H Hazardous Waste	
	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3 & 4	H:H Hazard Rating 1-4
MINIMUM REQUIREMENTS	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**	**B^-**	**B^+**		
Designate a Responsible Person	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	
Pre-operation Monitoring Surface water monitoring	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Ground water monitoring	N	N	F	**R**	F	**R**	**R**	**R**	**R**	**R**
Background results reported in Permit Application Report	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Water analysed in accordance with parameters in *Table 13.1*	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Sample analysis in accord with SABS methodology or equivalent	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Operation Monitoring Surface water monitoring	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Ground water monitoring	N	F	**R**	F	**R**	**R**	**R**	**R**	**R**	**R**
Leachate monitoring	N	F	N	**R**	N	**R**	N	**R**	**R**	**R**
Report sporadic leachate	F	F	F	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Post-Closure Monitoring Post-closure surface water monitoring	N	F	N	**R**	F	**R**	**R**	**R**	**R**	**R**
Post-closure ground water monitoring	N	F	N	**R**	F	**R**	**R**	**R**	**R**	**R**

TABLE 13.1
Suggested Parameters for Background and Investigative Monitoring

Ammonia (NH_3 as N)	Electrical Conductivity (EC)
Alkalinity (Total Alkalinity)	Free and Saline Ammonia as N (NH_4-N)
Lead (Pb)	Magnesium (Mg)
Boron (B)	Mercury (Hg)
Cadmium (Cd)	Nitrate (as N) (NO_3-N)
Calcium (Ca)	pH
Chemical Oxygen Demand (COD)	Phenolic Compounds (Phen)
Chloride (Cl)	Potassium (K)
Chromium (Hexavalent) (Cr^{6+})	Sodium (Na)
Chromium (Total) (Cr)	Sulphate (SO_4)
Cyanide (CN)	Total Dissolved Solids (TDS)

TABLE 13.2
Suggested Parameters for Detection Monitoring

(a) **Bi-annually for:**	(b) **Annually for:**
Alkalinity (Total Alkalinity)	Calcium (Ca)
Ammonia (NH_3 - N)	Fluoride (F)
Chemical Oxygen Demand (COD)	Magnesium (Mg)
Chlorides (Cl)	Sodium (Na)
Electrical Conductivity (EC)	Sulphate (SO_4)
Nitrate (NO_3 - N)	
pH	
Potassium (K)	
Total Dissolved Solids (TDS)	

LIST OF APPENDICES

Appendix 3.1

METHOD FOR CALCULATING MAXIMUM RATE OF DEPOSITION (MRD) AT A LANDFILL SITE (Section 3)

It is assumed that the site will expand annually at a constant growth rate and that the maximum rate of deposition will be attained during the final year of operation. Under such circumstances, the Maximum Rate of Deposition (MRD) can be calculated from the relationship:

$$MRD = (IRD)(1+d)^t$$

Where MRD = the maximum rate of deposition in tonnes/day during the final year of operation.
IRD = the initial rate of deposition in tonnes/day and would either be measured or estimated from appropriate information.
d = the expected (constant) annual increase in the rate of deposition and would usually be based on the anticipated population growth rate.
t = the period or planned life of the site expressed in years.

Example 1

A site is required to serve a community for a period of 15 years. The IRD = 350 T/day and the expected annual growth rate, d, is 3%. What will the MRD and, hence, the site classification, be?

$$MRD = 350\ (1 + 0{,}03)^{15}$$
$$= 350 \times 1{,}558$$
$$= 545 \text{ T/day}$$

The MRD is greater than 500 T/day and the site therefore will classify as Large (**L**).

Example 2

A trench site currently receives 0,3 T/day of refuse. It will obviously start as a communal operation and compaction of the refuse will be minimal. A comparatively high (constant) growth rate of 5% is assumed. Determine the MRD after a period of 10 years:

$$MRD = 0{,}3\ (1 + 0{,}05)^{10}$$
$$= 0{,}3 \times 1{,}629$$
$$= 0{,}5 \text{ T/day.}$$

Hence, for d = 5% the site will remain a **'C'** site. But suppose **d** rises to 10%? Then

$$MRD = 0{,}3\ (1 + 0{,}10)^{10}$$
$$= 0{,}3 \times 2{,}594$$
$$= 0{,}8 \text{ T/day}$$

The site will therefore remain a **'C'** or Communal classification as the MRD of 0,8 T/day is less than 1T/day.

Appendix 3.2

EXAMPLES OF CALCULATIONS OF THE CLIMATIC WATER BALANCE (Section 3)

It must be emphasised that the Climatic Water Balance is calculated from the two climatic components of the full water balance, namely Rainfall (R) and Evaporation (E). The Climatic Water Balance (B) is defined by:

B = R - E

where:

B is the climatic water balance in mm of water.

R is the rainfall in mm.

E is the evaporation from a soil surface, taken as 0,70 x A-pan evaporation in mm or 0,88 x S-pan evaporation in mm.

The factor of 0,70 used to convert A-pan evaporation to soil evaporation was arrived at by examining the predictions of all available soil evaporation formulae. From this evaluation, it became clear that a simple factor 0,70 x A-pan evaporation gives a result that is very close to predictions of most of the soil evaporation formulae. The factor 0,88 applied to S-pan evaporation gives values equivalent to those for A-pan figures. To allow for the effects of extreme weather conditions, the rainfall and evaporation figures for the calculation of **B** are selected as follows:

(i) **B** is first calculated for the wet season of the year having the maximum recorded rainfall.

This procedure may give problems, as evaporation records for very wet years are sometimes incomplete because the evaporation pans overflow. If there is an evaporation figure missing for a particular month, the figure is assumed to be the mean of those for the months before and after.

(ii) The value of **B** is calculated for the wettest six month period for the area under consideration, whether it falls within the period

May to October or
November to April

Where there is no well-defined wet or dry season, **B** is calculated for both of these periods.

If on the basis set out above, **B is negative,** the site will, even in extreme conditions, have an annual water deficit, so that, provided only dry waste is disposed of and the landfill is correctly designed and operated, only sporadic leachate will be generated.

If **B is positive**, the site may at least have a seasonal water surplus under extreme conditions. There will be a possibility that significant leachate may be generated seasonally. Leachate management may be required.

B is then re-calculated for successively drier years to establish how **B** varies. This is because evaporation varies from year to year and also because a year may be wet because of unseasonal rain during the dry season. It is quite common for the maximum positive value of **B** to occur in a year other than the wettest year on record.

The calculations must be repeated until it becomes clear that:

1. B is positive for less than one year in five for which data is available; or

2. B is positive for more than one year in five for which data is available.

If case 1 applies, the site is classified as B^- and no leachate management system will be required in terms of the Climatic Water Balance, while, if case 2 applies, the site is classified as B and leachate management <u>will</u> be required in terms of the Climatic Water Balance.

In borderline situations, a full, detailed water balance calculation using a programme such as HELP will be required.

The results of sample calculations illustrating the application of this principle are the following:

1. Johannesburg International Airport (November to April)

1.	For the wettest year,	(1966/67) B = 764 – 0,70 x 1170	=	–	14mm
2.	For the 2nd wettest year,	(1974/75) B = 855 – 0,70 x 1135	=	+	60mm
3.	For the 3rd wettest year,	(1975/76) B = 777 – 0,70 x 982	=	+	90mm
4.	For the 4th wettest year,	(1979/80) B = 734 – 0,70 x 1256	=	–	145mm
5.	For the 5th wettest year,	(1971/72) B = 760 – 0,70 x 1091	=	–	4mm
6.	For the 6th wettest year,	(1977/78) B = 716 – 0,70 x 1043	=	–	14mm
7.	For the 7th wettest year,	(1963/64) B = 715 – 0,70 x 1272	=	–	175mm
8.	For the 8th wettest year,	(1957/58) B = 584 – 0,70 x 1199	=	–	255mm
9.	For the 9th wettest year,	(1970/71) B = 589 – 0,70 x 1096	=	–	178mm
10.	For the 10th wettest year,	(1960/61) B = 569 – 0,70 x 1233	=	–	294mm

Out of the 23 years on record, **B** has been positive on two occasions, close to zero on two and well into the negative on at least 5 occasions. Hence **B** is unlikely to be positive in more than 1 year in 5, on average. Any site situated in the climate represented by the above statistics would be classified $\mathbf{B^-}$. Detailed observations on two landfills near Johannesburg International Airport have confirmed that they are unlikely to produce significant leachate except in quite exceptional weather circumstances.

2. Cape Town International Airport (May to October)

1.	For the wettest year,	(1976/77)	B = 553 – 0,70 x 556	=	+	164mm
2.	For the 2nd wettest year,	(1973/74)	B = 635 – 0,70 x 588	=	+	223mm
3.	For the 3rd wettest year,	(1961/62)	B = 447 – 0,70 x 558	=	+	56mm
4.	For the 4th wettest year,	(1967/68)	B = 477 – 0,70 x 554	=	+	89mm
5.	For the 5th wettest year,	(1958/59)	B = 358 – 0,70 x 642	=	–	91mm
6.	For the 6th wettest year,	(1975/76)	B = 454 – 0,70 x 568	=	+	56mm

For at least 5 years of the 23 years on record, **B** has been positive. On average, **B** will be positive in more than 1 in 5 years. This is a case where a site represented by the above statistics would be classified as $\mathbf{B}^+$, for which leachate management would be required.

Detailed observations on a landfill near Cape Town International Airport have confirmed that leachate is indeed produced every wet season, although the quantity produced is relatively small.

3. Durban International Airport (November to April)

1.	For the wettest year,	(1957/58)	B = 1172 – 0,70 x 1011	=	+	464mm
2.	For the 2nd wettest year,	(1960/61)	B = 920 – 0,70 x 1017	=	+	208mm
3.	For the 3rd wettest year,	(1975/76)	B = 938 – 0,70 x 1201	=	+	142mm
4.	For the 4th wettest year,	(1970/71)	B = 644 – 0,70 x 978	=	–	41mm
	But to May and October of 1971		B = 578 – 0,70 x 652	=	+	122mm
5.	For the 5th wettest year,	(1967/68)	B = 797 – 0,70 x 1084	=	+	38mm
6.	For the 6th wettest year,	(1964/65)	B = 420 – 0,70 x 1024	=	–	297mm
	But for May to October of 1965		B = 702 – 0,70 x 624	=	+	265mm

For at least 6 years of the 23 on record, **B** was positive. Any landfill in this area would be classified as $\mathbf{B}^+$ and leachate management would be required as, on average, **B** will be positive in more than 1 in 5 years.

4. Bloemfontein Airport (November to April)

1.	For the wettest year,	(1975/76)	B = 845 - 0,88 (857)	=	+	91mm
2.	For the 2nd wettest year,	(1973/74)	B = 854 - 0,88 (978)	=	–	7mm
3.	For the 3rd wettest year,	(1971/72)	B = 634 - 0,88 (1066)	=	–	295mm
4.	For the 4th wettest year,	(1962/63)	B = 614 - 0,88 (1033)	=	–	295mm

5.	For the 5th wettest year,	(1974/75) B = 537 - 0,88 (941)	=	–	291mm
6.	For the 6th wettest year,	(1966/67) B = 503 - 0,88 (1230)	=	–	579mm

For the wettest year, **B** is positive. From the 2nd to the 6th wettest years, however, **B** is negative, as is the case for the remaining twelve years on record. This is therefore a water deficit area. Any site situated in the climate represented by the above statistics would be classified as **B^- and would not generate significant leachate on account of the climate**. This is borne out by observations in the field.

5. Rustenburg (North West) (November to April)

1.	For the wettest year,	(1975/76) B = 1045 – 0,88 x 815	=	+	328mm
2.	For the 2nd wettest year,	(1966/67) B = 1018 – 0,88 x 902	=	+	224mm
3.	For the 3rd wettest year,	(1960/61) B = 777 – 0,88 x 857	=	+	22mm
4.	For the 4th wettest year, (S–pan not on record)	(1977/78) B = 808 – 0,70 x 1304	=	–	105mm
5.	For the 5th wettest year,	(1974/75) B = 777 – 0,88 x 894	=	–	10mm
6.	For the 6th wettest year,	(1970/71) B = 692 – 0,88 x 949	=	–	143mm
7.	For the 7th wettest year,	(1954/55) B = 783 – 0,88 x 847	=	+	37mm
8.	For the 8th wettest year,	(1955/56) B = 639 – 0,88 x 923	=	–	173mm

Here, **B** is positive on 4 occasions out of 26 years and close to zero (–10mm) on 1. No leachate management would be required according to the Minimum Requirements, but the Department might well insist on a detailed water balance calculation.

6. Comparison of Calculations using A– and S–pan data

1.	Repeat e.g. 1.10 above	B = 569 – 0,88 x 939	=	–	257mm (–294mm by A–pan)
2.	Repeat e.g. 2.1 above	B = 553 – 0,88 x 448	=	+	159mm (+164mm by A–pan)
3.	Repeat e.g. 3.1 above	B = 1172 – 0,88 x 805	=	+	464mm (+464mm by A–pan)
4.	Repeat e.g. 4.3 above	B = 1018 – 0,70 x 1061	=	+	275mm (+224mm by S–pan)

Hence calculations from A– and S–pan data give comparable results.

Appendix 3.3

EXAMPLES OF LANDFILL CLASSES (Section 3)

1. G:C:B$^-$

This is a site situated on the East Rand. The site receives only general waste from a rural community (domestic and no high moisture content waste) and has an IRD of 0,80 T/day. The site life is only expected to be 7 years and therefore the MRD is 0,86 T/day. This is calculated as follows:

MRD	=	IRD $(1 + d)^t$	d	=	1% per annum
	=	$0,80\ (1 + 0,01)^7$	t	=	7 years
	=	0,86 T/day			

The site is situated in a water deficit area, as calculated for the figures from Johannesburg International Airport Station, and therefore the site is classified as **G:C:B$^-$**.

2. G:C:B$^+$

This site is situated close to Cape Town and serves a small farming community. The site receives only general waste and no high moisture waste. The IRD is 0,40 T/day and the site is expected to last twelve years. The MRD is therefore calculated as follows:

MRD	=	IRD $(1 + d)^t$	d	=	3% per annum
	=	$0,40\ (1 + 0,03)^{12}$	t	=	12 years
	=	0,57 T/day			

According to the Climatic Water Balance (Cape Town International Airport), the site falls into a water surplus area, indicating that significant leachate will be generated. The site classification is therefore G:C:B$^+$.

3. G:S:B$^-$

This site serves a small town in the northern Free State. Dry domestic waste is disposed of on the site. The IRD is 13,6 T/day and the MRD is calculated as follows:

MRD	=	IRD $(1 + d)^t$	d	=	1% per annum
	=	$13,6\ (1 + 0,01)^2$	t	=	2 years
	=	13,9 T/day			

The site is only expected to last another two years and therefore the size classification remains **S**. The Climatic Water Balance (Bloemfontein), as calculated from statistics, shows a water deficit area and therefore only sporadic leachate is expected. The site is classified **G:S:B$^-$**

4. G:S:B$^+$

This site is a landfill serving an industry on the East Rand. It has an IRD (current rate of deposition used as the IRD in this example) of 22,0 T/day. The site has a remaining life of 3 years and no significant growth is anticipated. For the purpose of calculating the MRD, however, an annual growth rate of 1% has been assumed.

MRD	=	IRD $(1 + d)^t$	d	=	1% per annum
	=	$22,0\ (1 + 0,01)^3$	t	=	3 years
	=	22,7 T/day			

This means that the site falls into the **S**mall category. The Climatic Water Balance, based on Johannesburg International Airport weather station statistics, indicates a water deficit area. However, 91% of the waste disposed has a high moisture content of 71%. The remaining 9% comprises generally dry waste. According to the IRD of 22,0T, this implies that 8,3T (m^3) of water is disposed of daily. It is clearly evident from the high moisture content of 71% that the so-called 'field capacity' of the waste will be consistently exceeded and that significant leachate will be generated as a result, regardless of the Climatic Water Balance. The site is therefore classified as **G:S:B$^+$**.

5. G:M:B$^-$

This is a regional site in the northern Free State. Only dry general (domestic and industrial) waste will be disposed of on the site. When the site was permitted in 1991, the IRD was 305,5 T/day. The MRD was calculated for the projected 17 year life with an annual growth rate of 3%:

MRD	=	IRD $(1 + d)^t$	d	=	3% per annum
	=	$305,5\ (1 + 0,03)^{17}$	t	=	17 years
	=	504,9 T/day			

Because the MRD just exceeded the 500 T/day limit, the site was classified in 1991 as a Medium operation.

Climatic Water Balance calculations, based on Bloemfontein statistics, show that the site is situated in a water deficit area. The site was therefore classified as **G:M:B$^-$** when the Permit Application was submitted. However, due to the delays in implementing the design, the size of the site should be confirmed. The classification may change to **G:L:B$^-$**.

6. G:M:B$^+$

This site serves a town in the Eastern Cape Border region. General domestic and industrial waste is disposed of on the site. The current IRD is 415 T/day. With an expected 1% annual growth rate, the MRD is calculated as follows:

MRD	=	IRD (1 + d)	d	=	1% per annum
	=	$415\ (1 + 0{,}01)^{16}$	t	=	16 years
	=	487 T/day			

The MRD remains within the **M**edium size classification. The climate statistics from East London show the water balance to be water surplus, on average through the year. Furthermore, the site was constructed over a natural drainage course, which resulted in the waste body becoming saturated and significant leachate being produced. The site is therefore classified as **G:M:B$^+$**.

7. G:L:B$^-$

This site is a regional facility in Gauteng. The site only receives domestic and general industrial waste. The IRD is 600 T/day. The site is expected to last 20 years at a growth rate of 1,5% per annum. The MRD is calculated as follows:

MRD	=	$IRD\ (1 + d)^t$	d	=	1,5% per annum
	=	$600\ (1 + 0{,}015)^{20}$	t	=	20 years
	=	808 T/day			

The Climatic Water Balance for the area, based on Johannesburg International Airport Statistics, is a water deficit region. The site is therefore classified as **G:L:B$^-$**.

8. G:L:B$^+$

The site is situated in Mpumalanga bordering Swaziland and Mozambique. The site receives waste from an industrial plant, offices and a few residences where no further growth is expected. The IRD, and hence the MRD, for the initial 5 year phase is 300 T/day.

From year 6 onwards, the IRD will become 615 T/day. As no growth is expected, the MRD for the remaining 12 years of the expected site life is therefore also 615 T/day.

Although the site classifies as a **M** for first five years of its life, i.e. the first phase, the MRD for 12 out of 17 projected years is in excess of 500 T/day. The site is therefore classified as **L**.

The Climatic Water Balance, based on the statistics from the Lomati weather station, shows that there is a positive water balance for 3 out of 8 years, thus showing a marginally water surplus area. Furthermore, the majority of the waste has a high moisture content (more than 50%). This would affect the

hydraulic load and thus the water balance, contributing to the generation of significant leachate. The site is therefore classified as **G:L:B$^+$**.

9. H:h

Example 1

This is a large, well run site in Gauteng. The site receives predominantly domestic waste. Sewage sludge, however, is co-disposed with the solid waste on the site. The sewage sludge in this case is classified as a hazardous waste, with hazard ratings of 3 or 4, according to '*Minimum Requirements for Handling, Classification and Disposalof Hazardous Waste*', and therefore the site is classified as **H:h**. The landfill is classified as a containment landfill which accepts hazardous waste with hazard ratings of 3 or 4 and it must therefore be lined and have a leachate collection system.

Example 2

This site is a large waste disposal site in the Cape Peninsula which has several experimental containment cells, lined with geomembrane for the disposal of hazardous waste. The waste disposed of in the lined cells has hazard ratings of 3 or 4 and the site is therefore classified as **H:h**.

The two examples given above are situated in different Climatic Water Balance areas, one water deficit and the other water surplus. This is to illustrate that, regardless of the Climatic Water Balance, containment, i.e. leachate collection and a liner, is necessary when waste with hazard ratings of 3 or 4 are disposed of.

10. H:H

Example 1

This landfill serves a large town in the central Free State. The site receives mainly domestic waste. Hazardous waste, however, with Hazard Rating 1 is also disposed of on the site. According to the Minimum Requirements, such a landfill should be designed, engineered and operated to the most stringent standards. The site must be a containment landfill, i.e. with a liner and a leachate collection system. The site is therefore classified as **H:H.**

Example 2

This landfill is a site in Gauteng which handles hazardous waste with Hazard Ratings 1 to 4. The site has a liner and leachate collection system to ensure that it is a containment site. The site is classified as **H:H.**

Both of the above examples are sites situated in water deficit areas. The Climatic Water Balance is again not taken into account, as containment is a prerequisite regardless of the Climatic Water Balance.

Appendix 4.1

PUBLIC PARTICIPATION (Section 4)

1. Introduction

When the Minimum Requirements were first published in 1994, public participation in the development of landfills was an arbitrary process and there were no authoritative guidelines. The guidelines used in the document were the *Integrated Environmental Management* (IEM) procedure, published by the Department of Environmental Affairs and Tourism (DEAT) in 1992. In 1996, however, the Constitution was published. In terms of Sections 24 and 32 of the Bill of Rights, and because of public demand, public participation in landfill development projects became mandatory, even though no regulations or guidelines existed. These were, however, provided by the EIA Regulations (EIAR) which were promulgated in Government Gazette No. 18261, 5th September 1997. Guidelines were published in April 1998 [**Ref**: DEAT: *Guideline Document, EIA Regulations, Implementation of Sections 21, 22 and 26 of the Environment Conservation Act*, Pretoria, 1998.] The inclusion of public participation in the Minimum Requirements for the development of landfills is based on constitutional law and the EIA regulations. Entrenched in our Constitution is the requirement that the public be consulted and informed of any development that may have an effect on their quality of life. In terms of Section 20 of the Environment Conservation Act, 1989, waste disposal is an activity that may have a substantial detrimental effect on the environment. It is therefore subject to the EIA process.

In addition to the above requirements, practical considerations of public participation also play a role in the successful development and operation of a landfill. The participation and acceptance of Interested and Affected Parties (IAPs), or those concerned with or affected by an activity, is a factor vital to the success of that activity. Public resistance to a landfill can become a Fatal Flaw. By involving the public and obtaining their approval, they take some degree of responsibility for a development, and assurance of its continuance and sustainability is increased. A further advantage to be gained from public involvement and approval is the additional input obtained from the public, often in the form of specific, local knowledge.

The objectives of this appendix are to:

Give effect to the Bill of Rights in the Constitution of South Africa.

Provide guidelines for integrating the landfill permitting procedure with the EIAR. This has been achieved to the extent that there are no contradictions. Areas of overlap and some different terminologies will, however, exist.

Provide guidelines for public participation in the development of a landfill so that:

the IAPs are given fair and adequate opportunity to be involved in the development of a landfill.
where all the requirements for public participation have been met, a landfill development is not unreasonably delayed or obstructed.

2. Principles of Public Participation

The objective of an EIAR process is to resolve any negative impacts and to enhance positive aspects of development proposals.

The basic principles are:

- **The IAPs must be consulted and given opportunities to participate in projects**. The community spirit, public opinion and the will of the people must be recognised. Local people must therefore be involved in a project and encouraged to take ownership of it. They must be given the opportunity to participate in the planning and execution of those areas of a project that could have an adverse impact on them.

- **The IAPs must be given the opportunity to be involved during the earliest planning stages of a project**. Adequate notification must be given. In particular the IAPs must be allowed to reasonably define the extent to which they wish to be included in the planning of a project and thus to define the formal participation process they wish to see followed. They must not be confronted with an accomplished fact.

- **The IAPs must be informed and empowered, so that they can contribute effectively to the decision making process**. This can be done by giving IAPs access to the relevant information, whether through meetings, presentations, discussions or reports and documents.

- **The information on which decisions are taken must be sufficient.** This means that the information provided to the IAPs must be sufficiently detailed, accurate and understandable, so that the IAPs can contribute effectively.

- **There must be consideration of alternative options**. The development proposal must provide for 'the due consideration of alternatives'. It must therefore contain alternative options for reaching the same goal, including the option of no development. The IAPs must also be allowed to add more options. The information supplied in support of the different options should be sufficient to enable valid evaluation.

- **The adjudication process must be fair and just**. Adjudication must be public and informal, but orderly. Reasons for decisions should always be given and must be sufficient to illustrate that the input of all parties was taken into account and given appropriate weight.

3. Mechanisms for Identifying IAPs

Different decisions will have to be made at the various stages of the landfill process. The objective is to identify those IAPs who might reasonably wish to become involved in making that specific decision. IAPs would include the democratically elected representatives of the people, government departments, provincial government departments, local authorities, waste generators, residents in the nearby vicinity, water users, local water authority, local communities, Non-Government Organisations (NGOs)

(especially the typical watchdog NGOs), Community Based Organisations (CBOs), the Institute for Waste Management and others. In landfills that have already been developed, informal salvagers would be considered to be IAPs.

The identification of an unreasonably wide range of IAPs, or the wrong IAPs, will waste time and money. It is therefore important to identify legitimate community representatives. Those IAPs who might be affected materially or who might have a legitimate interest in a decision should be identified. It will not always be necessary to involve people who are only marginally affected by or who have only a tenuous interest in a decision.

4. Mechanisms for Contacting IAPs

As a minimum, the EIAR require that IAPs be notified and asked to come forward by adverts in the local or regional press. In addition, the democratically elected representatives of the public (e.g. local councillors) should be used to contact IAPs. Other means of notification are publications, television, radio, pamphlets, exhibitions, newsletters, direct mail, telephone and public notices.

In contacting IAPs and obtaining input from a disadvantaged community, such issues as literacy levels, language barriers, level of community structures, and social and cultural biases must be taken into account. IAPs from disadvantaged communities can be notified and identified using traditional methods of community participation; or by appointing locally based organisations to hold meetings, workshops and interviews; or by means of illustrated posters; or loudhailers; or by identifying key players and traditional leaders within the communities.

5. Mechanisms for Involving the IAPs

Registration, public meetings, workshops, 'open houses', telephone canvassing, newspaper advertisements, surveys and questionnaires, and advisory groups are all mechanisms to ensure IAP notification and involvement.

Not all IAPs will wish or need to be involved to the same extent. The following tiered approach can therefore be used when involving the IAPs.

Registration of IAPs and the formation of a Representative IAP Liaison Committee (RILC) are very useful means of involving IAPs. The RILC would act as a representative body of local residents, transfer information back to the community, help to resolve issues relating to the landfill development and provide a stable body of IAPs with whom the developer and the Department can communicate.

6. Time Management

Effective participation requires time and the commitment of financial resources from both the landfill

developer and the affected public. For this reason, it is important that there be some consensus regarding what constitutes 'enough' or 'sufficient' public participation, so that the process does not drag on indefinitely. To address this, the principles underpinning public participation and the mechanisms for involving the public have been linked to a coherent structure or framework in the EIAR. Similarly, Minimum Requirements for public participation have been included at relevant points in the landfill development process, as expressed in the text and below, to provide a logical series of steps that must be taken to ensure that the IAPs are adequately involved.

In addition to ensuring that the public participation process is defined, it is also important to ensure that time is not wasted by, for example, those who have unreasonable objections or hidden agendas. Input from IAPs should therefore be submitted through a RILC, or individually submitted in writing. IAPs should also be encouraged to put forward problems or complaints in a positive way, wherever possible. Negative statements should be discouraged and positive suggestions for change or solutions to identified problems should be sought.

A public meeting should not be seen as a decision taking body, but rather as a means of exchanging information and obtaining public opinion. In order to obtain the most from a public meeting, participants should be encouraged to put forward all ideas and suggestions, however unnecessary these may initially appear to be. To avoid unnecessary debate, the essence of the idea should be put forward in writing, as this forces the proposer to crystalise the thought. An illiterate person may have to be assisted in this regard.

It is very important that the IAPs are convinced that their suggestions have been carefully considered. Suggestions must therefore be acknowledged, carefully listened to, debated, and reasons for decisions should be provided. Formal submissions of comment and suggestions, by means of a RILC are again recommended. However, it is also important that a cut-off date be set, after which no further inputs will be accepted unless it can be demonstrated that:

- the information is new
- the information is important
- there is good reason why it was not brought forward previously.

Adequate prior notification of the cut-off point must be given.

It is very important that the Department and DEAT (Province) remain objective outsiders from the public participation process. In this way, they can be seen by both developer and IAPs to function as a fair and impartial judge. Where issues cannot be resolved, the final decision must be taken by the Department and the DEAT (Province).

7. Applying the principles of public participation to the landfill development process

7.1 **Site selection** (Section 4)

The landfill development process begins in response to a defined need for a disposal site. The classification system is used to determine the class of landfill required on the basis of the 'givens', i.e. the type of waste, the size of waste stream, and the ambient climatic conditions. As soon as the need has been defined, a consultant must be appointed to undertake Public Scoping in terms of the EIAR. An application form to undertake an activity and a Plan of Study for Scoping must be submitted to DEAT (Province) and the Department.

Once approval has been obtained, IAPs must be notified and informed of the need for and intention to develop the required class of waste disposal site in the area.

The IAPs and their representatives should be informed of the purpose of and need for the landfill, the proposed actions, general location, timing, method of operation and likely impacts. Issues of concern to the IAPs should be identified and discussed. These would usually include health, property values, aesthetics or other environmental concerns.

The IAPs should be registered according to an IEM/EIAR process, and a RILC should be set up, to facilitate liaison.

Sufficient candidate landfill sites should be identified to ensure the due consideration of alternatives. These may be identified and proposed by the IAPs, as well as the landfill consultants. Candidate sites will therefore include any sites put forward by the IAPs through the RILC, or in writing to the developer.

Landfill specialists will now investigate and technically rank the candidate landfills, taking into consideration issues identified by the IAPs. The developer may wish to take out an option on the top ranking sites at this stage to prevent the sudden escalation of land prices.

Once the provisional ranking of candidate landfill sites has been completed, further IAPs who could be affected by the top candidate landfills should be notified and registered.

The candidate landfills must be presented to the IAPs and reasonable consensus on the ranking must be obtained. The ranking of the candidate landfill sites should be reviewed using a consultative process. If necessary, the top ranking sites may have to be subjected to a more detailed investigation to confirm the ranking. IAP input may involve the complete elimination of certain sites and the addition of others. The local authority must be fully involved at this stage, as it will be responsible for determining the zoning and/or the consent land-use associated with the candidate site. The local authority is also responsible for controlling any future development within the buffer zone surrounding the site.

Once the ranking of candidate landfill sites has been amended and/or accepted by the IAPs, the top ranking sites are subjected to a more detailed investigation in the form of a Feasibility Study. This investigation will confirm the environmental and public acceptability of the site.

It is a Minimum Requirement that, as part of the Feasibility Study, those IAPs who would be immediately affected by the site under consideration be included in the consultative process.

The consultative process, and proof that public resistance does not represent a Fatal Flaw must be fully documented in the Scoping Report. This, together with the geohydrological investigation, the preliminary Environmental Impact Assessment Report, and the Conceptual Design, will be included in the Feasibility Report.

Where operating sites are to be permitted for ongoing operation or closure, upgrading is often required. It is a Minimum Requirement that the IAPs be involved in decision making regarding the future of the landfill. The results of this consultative process will also be documented in the Scoping Report. This forms part of the Feasibility Report.

Once the draft Feasibility Report has been drawn up, it should be presented to the IAPs for comment and input. After IAP comments has been included and addressed, the Feasibility Report must be submitted to the Department and DEAT (Province).

The Feasibility Report must also be freely available to the IAPs.

When a site has been accepted as feasible by the IAPs and the departments, the Permitting Procedure can commence. Both the Department and the IAPs should be kept informed of progress.

7.2 **Site permitting** (Section 5)

The Permit Application Report should document the findings of the following exercises, which are addressed in the next section:

- Site Investigation
- Environmental Impact Assessment
- Risk Assessment
- Landfill Design
- End-use Plan
- Operating Plan
- Water Monitoring Plan.

The Permit Application Report should be written in such a way that it is easily understandable and must be presented to the IAPs, possibly by means of an oral presentation**.** With the consent of the Department, certain confidential information that allows a Permit Holder a competitive business edge may be removed from the copies of the Permit Application Report. Copies are then made available to the IAPs.

7.3 **Investigation, impact assessment, and design** (Section 6, 7, 8)

The scope of the site investigation should be such that all the queries and requirements of the IAPs are adequately addressed.

During the Environmental Impact Assessment, the selection of the actions and impacts that make up the Matrix should be determined by a team that includes representatives of the IAPs. The matrix will also be scored by the team.

The site design must address the negative impacts identified during the investigations or by IAPs.

The site layout must be designed with the landfill's closure and end-use in mind. For this reason, the IAPs must be consulted to determine the preferred end-use of the site.

When the Conceptual Design is complete, it should be presented to and discussed with the IAPs, in order to inform them and to obtain any further input that might be forthcoming, for example, job creation.

7.4 **Site preparation** (Section 9)

During site preparation and commissioning, the necessary infrastructure and facilities are established and the site is prepared to receive and dispose of waste.

On completion of the construction phase, the Department will carry out an inspection of the site and an examination of all relevant records. If relevant, the IAPs could be involved in this. Provided all construction has been carried out in full conformity with the design specifications and drawings, and to the satisfaction of the Department, permission will be given to commence operation.

7.5 **Site operation and operation monitoring** (Section 10 & 11)

The landfill operation must ensure that all waste is disposed of in an environmentally acceptable manner and in conformance with the Permit Conditions. It is essential that contact with the IAPs be maintained throughout the operation, so that any complaints or fears which the IAPs may have concerning the standard of operation or impacts, such as odours, can be readily addressed.

During operation, contact with the IAPs, commensurate with the class of landfill, should be maintained. Landfill Monitoring Committees must be formed to enable ongoing communication with IAPs (see Appendix 11). The terms of reference for each committee should be determined by themselves, but could include the following:

- The monitoring of operations on the site, including hours of operation, gate controls, types of waste disposed of, at the site, leachate management, air and water quality complaints about the site, any investigations and remedial action required on the site and the quality of life of people affected by the site.

- The identification, investigation and remediation of problems on site.

- Keeping the public informed of activities/developments on the site and disseminating consensus information.

The committee should meet more regularly when problems are experienced and expert advice should be sought as the need arises.

7.6 **Site closure** (Section 12)

The objective of the landfill closure procedure is to ensure that the End-use Plan is publicly acceptable in both the short and the long term. Thereafter, the objective is to ensure that the landfill is rehabilitated so that it is environmentally acceptable and suited to the implementation of the proposed end-use.

The IAPs should be notified and informed that the site is nearing the end of its life, so that they can be included in the determination of rehabilitation, closure and end-use.

A Closure Report that takes into consideration the results of consultation with the IAPs must then be drawn up. This should be submitted to the Department as part of the closure procedure, and made available to the public.

The landfill will only be considered closed once the Department and the IAPs are satisfied that the rehabilitation of the site has been properly carried out. This will be assessed at a final site inspection attended by representatives of all the relevant state departments and the IAPs.

After closure, the Monitoring Committee should continue to monitor the integrity of cover, drainage systems, subsidences, fire, vegetation and security.

7.7 **Water quality monitoring** (Section 13)

Water quality monitoring will be carried out in terms of the Minimum Requirements and the Permit conditions. Records of monitoring results must be maintained and should be available to the IAPs or Monitoring Committee, if required.

Appendix 4.2

AQUIFER CLASSIFICATION (Section 4)

Aquifers must be classified in terms of their existing and/or potential value as a resource, and hence their sensitivity to pollution. The criteria for classification are potential sustained yield, water quality and significance:

Potential sustained yield

Yields from boreholes are used as a basis for a quantitative aquifer classification. The following index is suggested:

Yield	Low	Medium	High*	Very high
Range	<1ℓ/sec	1-5ℓ/sec	5-20ℓ/sec	>20ℓ/sec
Potential usage	Stock, garden, domestic	Limited development potential	Small community	Large-scale water supply

Water Quality

In order for an aquifer to be considered for one of the above uses, which may include agricultural, domestic, ecological, industrial or recreational, the water quality must be suited to the proposed use.

Significance

The significance or potential significance of an aquifer is assessed as follows:

Sole source aquifer	An aquifer, which is used to supply 50% or more of urban domestic water for a given area for which there are no reasonably available alternative sources should this aquifer be impacted upon or depleted.
Major aquifer	High-yielding aquifer of acceptable quality water.
Minor aquifer	Moderately yielding aquifer of acceptable quality or high yielding aquifer of poor quality water.
Non-aquifer	Insignificantly yielding aquifer of good quality or moderately yielding aquifer of poor quality or aquifer which will never be utilised for water supply and which will not contaminate other aquifers.
Special aquifer	An aquifer designated as such by the Minister of Water Affairs after due process.

Source: Aquifer Classification Project. Department of Water Affairs and Forestry. January 1998.

* It is noted that yields in excess of 5ℓ/sec are seldom found. Where such yields are encountered, the holes have usually been sited scientifically and are located on very favourable structures, such as faults or along igneous dykes.[**Ref.** Department of Water Affairs and Forestry: *Minimum Requirements for Monitoring at Waste Management Facilities*, Pretoria, 1998].

Classification

Aquifers are classified first by their yield, i.e. low, medium, high and very high, and thereafter by their significance.

Note:

The hydraulic characteristics of any aquifer that could be affected by landfill leachate must be ascertained by means of pumping tests.

Appendix 4.3

BUFFER ZONES
(Section 4)

Buffer zones are separations between the registered landfill site boundary and any adjacent residential or sensitive development. They are established to ensure that a landfill operation does not have an adverse impact on quality of life and/or public health. The establishment and maintenance of buffer zones, or set back distances, is enforceable in terms of the Health Act, 1977 (Act 63 of 1977), which makes provision for measures necessary to prevent any nuisance, unhygienic or offensive condition that is harmful to health.

The width of the buffer zone is prescribed for Communal and Small landfills. For other landfills, however, the width of the buffer zone is dependant on the classification of the landfill and any Site Specific Factors that may affect its environmental impact. Factors such as topography, micro-climatic conditions, waste types, alternative site screening methods, the Operating Plan and the results of consultation with the IAPs must all be taken into consideration when determining the width of the buffer zone. In the case of Large and Hazardous waste landfills, scientific investigation, which could include air dispersion modelling and health risk assessments, may be required by the Department. Consequently, the width of a given buffer zone will ultimately be approved by the relevant government departments, on the basis of investigations undertaken, motivations presented and public acceptance.

In certain cases, it may also be possible to meet buffer zone requirements by progressively moving the operation away from future residential or other sensitive developments. In this way, the required set back distance can be maintained, as the operation moves away before the development occurs. Mitigatory measures, such as site screening, special operational measures and restricted operating times, can also be presented as motivation for reducing set back distances. These would, however, have to be agreed upon by all parties concerned.

In considering buffer zones, the present and future land-use must be addressed. In general, a proclaimed buffer zone must comprise unpopulated land and no development may take place within it, during the operation of a landfill. At the discretion of the local authority and the relevant government departments, however, such land-uses as agriculture or certain industrial developments may be permitted within a buffer zone.

To ensure against encroachment and consequent conflicts of interest, measures to control future development and land-use within buffer zones should be implemented as soon as a candidate site is deemed feasible. In order to do this, the Permit Holder, who is usually the local authority, may acquire ownership of the land, or enter into a contractual agreement with the owner. For example, a servitude may be registered against the title deeds of the land, thus limiting the usage of the area to that stipulated in the permit.

Throughout the operation of the landfill facility, agreed buffer zones must be maintained. Existing land-use and any developments must thus be carefully monitored and strictly controlled.

Appendix 6

NOTES ON EXPLORATION BOREHOLES (Section 6)

1. Introduction

The objective of exploration boreholes is to provide both geological and geohydrological information. This information, on which the site design will be based, is used to assess the risk and site complexity. Where possible, exploration boreholes should be sited so that they can also be used for water quality monitoring (see Section 13 and *Minimum Requirements for Monitoring at Waste Management Facilities)*. However, this should be of secondary importance in the context of site investigation.

The number of boreholes required would be commensurate with the nature of the investigation and would comply with the Minimum Requirement in this regard. The geological data required includes stratigraphy, lithology, structure and permeability. The geohydrological data required includes depth to the regional ground water phreatic surface, perched surfaces, seepages and the importance of the ground water resource. The latter involves aquifer characteristics and sustainable yield.

2. Location

The location of the boreholes is determined by the information required on the type and distribution of the underlying soil and rock strata, and also by the need to identify features such as geological contacts, faults, joint patterns, water bearing features, aquifers and intrusive dykes. The location of the exploration boreholes should thus be based on the experience of the Responsible Person, assisted by available geological and geohydrological data. This data would be obtained from published maps and reports, and from the data obtained during the preceding phases of the investigation, such as geophysics. In this regard, it is noted that the findings from one borehole could significantly affect the siting of future boreholes or, in fact, the approach to the whole investigation.

Finally, boreholes must be so sited, drilled and constructed that they do not unnecessarily penetrate impermeable layers or create conduits for the migration of leachate pollution to ground water bodies.

3. Depth of Drilling

The depth of exploration depends on the depth of the proposed cover excavation and the depth of the geological and geohydrological features of interest. In general, boreholes should extend to at least twice the depth of the base level of the proposed cover excavation, in order to disclose any unfavourable zones which may affect the stability of the sideslopes. In areas of unfavourable geology, such as areas underlain by dolomitic bedrock and areas underlain by faulted bedrock or highly permeable soils, the boreholes should be drilled to a minimum depth of 25m below the base level of the proposed excavation. Unless one requires to prove the underlying geology, this depth is sufficient if no ground water is encountered.

In the absence of information indicating the need for greater depths, boreholes should be drilled to 10m beyond the first water strike, representing the true ground water phreatic surface. It should be noted that local ground water surfaces, representing water perched on relatively impermeable, near surface layers, are common in certain geological settings in parts of Southern Africa. The presence of these perched water surfaces may be determined from a borehole census prior to drilling, by monitoring (where possible) the rate of inflow of water into the borehole immediately subsequent to drilling and by pump testing.

Whatever approach is followed, the Responsible Person must be able to fully justify the depths of the investigatory drilling/probing on both geological and geohydrological grounds.

The most important aspect of the depth of drilling is to ensure that all geological and geohydrological structures relevant to the nature of the investigation are identified and adequately penetrated and probed.

In all cases where test drilling is required, it will be incumbent upon the Responsible Person to ensure that all test holes, when evaluated as a unit or group of data, have been drilled to a sufficient depth. The Responsible Person must therefore be able to justify the depths of the investigatory drilling/probing on both geological and hydrological grounds.

The depth of a test hole or suites of test holes must be such that subsequent deeper drilling beyond the chosen depths will not reveal any new or unexpected information that could significantly alter or negate the previously drawn conclusions on the geology, hydrogeology and other related matters concerning the drilling investigation.

This approach clearly implies that all test holes need not necessarily be drilled to the same depth. As an example, one or more properly planned deep holes, (say) in the region of 50m to 75m, may be adequate to prove conclusively that all remaining boreholes (and monitoring boreholes for that matter) need only be drilled to (say) 40m, or some lesser depth as the case may be.

4. Construction

Boreholes drilled using conventional rotary air-percussion techniques should provide adequate information for a geological or geohydrological investigation. The boreholes should be drilled with a starting diameter in the order of 150mm to 165mm and with a minimum diameter of 125mm. This diameter allows for the installation of casing with an internal diameter of more than 110mm, which is the minimum required for the installation of a conventional submersible pump.

Slotted Class 9 PVC casing should be installed in boreholes which are to be included in the ground water monitoring system. A concrete slab, 750mm square and 150mm thick, should be cast at the top of the borehole. It is essential that a locking mechanical cap be fitted to all monitoring boreholes, to avoid vandalism and contamination. For the construction of boreholes in various geological settings, refer to the *Minimum Requirements for Monitoring at Waste Management Facilities*.

Boreholes located beneath landfills, or boreholes which inadvertently penetrate impermeable layers or access ground water bodies, should be sealed off by pressure grouting from the base up, or by some other appropriate method.

Appendix 7

CHECKLIST OF DESIGN AND ENVIRONMENTAL CONSIDERATIONS (Section 7)

The following is intended to represent a general checklist. It provides a convenient checklist when considering the Minimum Requirements. The Responsible Person will, however, decide on items required for a particular site.

1. Selection of landfill site

Access from refuse source
Availability of construction and cover materials
Buffer zones
Elevation relative to refuse source
Existing mineral rights
Geology, e.g. fault zones, seismic impact zones, dolomitic areas where subsidence is possible
Life of landfill site
Microclimate, exposure to wind, etc
Pedology

Potential for:

Adequate cover material
Adequate screening
Agriculture
Expansion of system
Environmental reclamation or abandonment
Nature conservation
Industrial development
Ranching and grazing
Recreation
Reclamation of existing environmental damage
Silviculture
Urban development or human settlement
Use for other waste disposal

Proximity to:

Agriculture, ranching or silvicultural development
Airfields or landing strips
Existing or potential recreational areas
Existing or potential main transport routes
Existing or potential main utility routes

Existing or potential major surface water supplies, or aquifers
Existing surface or underground mine workings
Historical, cultural or natural interest areas
Ground-water recharge areas
Recreational areas
Refuse generation area, i.e. economic radius
Urban development or human settlements

Consideration of:

Seasonal and long term variations of hydrology
Scenic value of site
Sensitive ecology
Sub-surface hydrology and flow
Topography of site and area between site and refuse source
Underlying mineral resources
Unique natural resources: *Fauna*, *flora*, breeding grounds, etc.
Unique physical features: Archaeological or historical sites
Unique cultural features: Religious association, etc.
Visibility of site

2. Geotechnical and geohydrological exploration of landfill site

Abandoned quarries
Abandoned underground workings
Abandoned utilities
Airphoto interpretation
Anisotropy of soil
Aquifers - depth, yield, potential or actual exploitation
Artesian water
Cavernous dolomites
Collapsible soils
Depth to bedrock
Depth to water table
Dispersive soils
Dykes
Erodability of soils
Erosion channels or pipes
Expansive clays
Excavatability
Faults
Filled areas
Ground water morphology and phreatic surface
Ground water quality
Ground water abstraction and use
Hard-pan layers (pedogenic horizons, e.g. calcrete and ferricrete)
In situ permeability of ground profile

In situ strength of soil
Mining - undermining, rehabilitated opencast pits, potential for future mining
Rock Outcrops
Seismic activity
Slaking mudstones or shales
Slickensided clays
Soil profiles, rock profiles
Soluble constituents in soils
Stratigraphy and lithology
Tailings and other mine waste deposits - presence, potential for exploitation
Tectonics, lineaments and structures

3. Information for design of landfill

Foundation and cover design data:

Bedrock permeability
Cation exchange capacity
Coefficient of consolidation
Compaction characteristics of *in situ* soil
Compressibility or swell potential
Dispersibility under influence of exchanged cations
Effective stress strength parameters
Erodability of compacted soil
Ground water profile
Ground water chemistry
In situ horizontal and vertical permeability of soils*
Permeability of compacted soil*
Stability of cut slopes
Hydrological design data (annual and monthly)
Rainfall intensity and duration
Pan evaporation
Streamflow
Infiltration and run-off
Wind velocity and direction

Information relating to closure or possible after-use of site:

Agricultural land
Game park
Grazing land
Playing fields (football, golf, etc.)
Recreational site

*This should also take into account the change in permeability that could result if leachate or some other liquid waste were used as the permeating fluid.

4. Possible Adverse Impacts to be Eliminated or Controlled by Design/Operation

Access
Blowing litter
Dust nuisance
Fire hazard (and associated air pollution and danger to humans and animals)
Gas generation and migration
Interference with stream or spring flow
Land sterilisation by siltation and/or salinisation
Odour or smell
Slope failures
Soil erosion
Visual intrusion
Water pollution by leachate, erosion, siltation.

Appendix 8.1

CALCULATING LANDFILL SITE LIFE (Section 8)

METHOD A

Site life is calculated by comparing the total available airspace with annual airspace utilisation.

1. Calculating Available Airspace in m^3

(i) In the case of a proposed landfilling operation where the availability of suitable cover material represents a limiting factor, the quantity of cover is used to determine the total available airspace.

Based on the fact that a well run waste operation would require a volumetric ratio of cover material to waste of about 1:4, the total airspace is obtained by multiplying the volume of available cover material by a factor of 5. Alternatively, the total volume of waste that can be accommodated will be given by multiplying the available volume of cover material by a factor of 4. This represents a somewhat rudimentary approach, as the cover to waste ratio is approximate, the compaction density of the waste is estimated and no allowance is made for the effect of 'bulking' or 'debulking' on the volume of potential cover material.

ii) In the case of an existing landfill, where the availability of cover material is not the determining factor, the total available airspace will be the volumetric difference between the existing surface and the final landform. Of this volume, 4/5 will be available for waste according to the assumptions made previously.

2. Calculating Annual Airspace Utilisation

Airspace utilisation is calculated from the IRD. The IRD, expressed in T/day, is multiplied by 260 days (based on a 5 day week) to determine the annual tonnage of waste. By dividing this figure by the average density of the waste (between 0,75 T/m^3 to 1,20 T/m^3 depending on waste type and compaction efficiency), the volume of waste to be deposited in the first year is determined. By multiplying this volume by 5/4, the total airspace utilisation for the first year is obtained. Airspace utilisation for subsequent years is obtained by escalating the IRD for each year. This is then cumulated.

3. Calculating Landfill Site Life

The landfill site life is arrived at by matching the available airspace volume for the landfill, arrived at in **1** above, with the cumulative airspace utilisation, in **2** above .

Example

The proposed landfill site has an area of 400m by 565m available for cover excavation. The average depth of excavatable cover is 2,5m. The initial rate of deposition (IRD) for a new landfill site is 350 T/day, and the waste generation area has an expected growth rate of 3%.

1. Calculate available airspace in m^3:

Available volume of cover	=	565m x 400m x 2,5m
	=	565 000m^3

Using a cover to waste ratio of 1:4, calculate the total available airspace as:

	=	565 000m^3 x 5
	=	2 825 000m^3

2. Calculate annual airspace utilisation in m^3:

IRD	=	350 T/day
Annual rate of deposition	=	350 T/day x 260 days/annum
	=	91 000 T/annum

Using a compacted density of 0,75 T/m^3, the airspace used by the waste:

$$= \frac{\text{91 000 T/annum}}{\text{0,75 T/m}^3}$$

$$= \text{121 333 m}^3\text{/annum}$$

Allowing for the airspace used by both waste and cover, using a cover to waste ratio of 1:4:

	=	121 333 m^3/annum x 5/4
	=	151 667 m^3/annum

This figure is then escalated by multiplying the previous year's airspace total by 1,03 for 3% growth, and these are cumulated, as shown in the following spreadsheet.

The available airspace is then matched to the closest cumulative airspace used total, to give the approximate site life, as shown in the following spreadsheet.

Year	Annual Airspace Utilisation, including cover, per annum [m3]	Cumulative Airspace Utilisation, including cover, per annum [m3]	Available Airspace Match [m3]
1	151667	151667	
2	156217	307884	
3	160904	468788	
4	165731	634518	
5	170703	805221	
6	175824	981044	
7	181098	1162143	
8	186531	1348674	
9	192127	1540801	
10	197891	1738692	
11	203828	1942520	
12	209943	2152463	
13	216241	2368703	
14	222728	2591432	
15	229410	**2820841**	**2825000**
16	236292	3057134	
17	243381	3300515	
18	250682	3551197	
19	258203	3809400	
20	265949	4075349	

The approximate site life of the proposed landfill is therefore **15 years**.

METHOD B

To calculate the site life from the initial rate of deposition, IRD, it is necessary to know the expected average growth rate, the available total volume (airspace) of the site and the expected average density of the waste.

The volume of the waste, Vr is calculated from the total volume as follows:

$$Vr = (1 - R)VT$$

where: R is the average ratio of cover to total airspace, usually taken as 1:5
VT is the total volume of airspace of the site

In this example therefore,

$$Vr = (1-1/5)VT = 4/5VT = 0,8VT$$

The total mass of waste, Mr is given by:

$$Mr = \rho Vr$$

where: ρ is the average density of the compacted waste.

The value of ρ will depend on the degree of compaction achieved at the site but a value of 0.75 T/m3 is recommended for conventionally compacted sites.

The total mass of waste, Mr is related to the initial rate of deposition (IRD) and the assumed average annual growth rate as follows:

$$Mr = IRD \cdot \frac{(1 + I)^n - 1}{I}$$

where: I = average growth rate per year*
n = time period or life of the site in years

For the purpose of calculating the expected site life, the above equation is rewritten in a more convenient form, viz:

$$n \log (1 + I) = \log \left(\frac{MrI}{IRD} + 1 \right)$$

or:

$$n = \log \left(\frac{MrI}{IRD} + 1 \right) / \log(1 + I)$$

*Strictly, the average growth rate over the life of the site.

alternatively, in terms of total airspace and compaction, characteristics ((and R) where M_r = (RV_T, the above equation becomes:

$$n = \log \frac{(RV_T I + 1}{- IRD} / \log(1 + I)$$

Example

Determine the life span of a proposed site with a total volume (airspace) of 2 821 000 m^3 determined by accurate survey:

The anticipated average growth rate is 3% per annum (0.03), the average density of the compacted fill is taken as 0.75 T/m^3 with a cover to waste ratio 1:4. The IRD is 350 T/day or 91 000 T/Y for an assumed 260 day working year.

$$n = \log \frac{0.75 \times 0.8 \times 2\,821\,000 \times 0.03}{91\,000} + 1 / \log(1 + 0.03)$$

$$= \log 1.558 / \log 1.030$$

$$= 0.193 / 0.013$$

$$= 15 \text{ years life span}$$

Appendix 8.2

DESIGN OF THE LINING AND CAPPING SYSTEMS, PERMEABILITY TESTS AND SLOPE STABILITY CHART (Section 8)

DESIGN OF THE LINING SYSTEMS

As discussed in Section 8, every liner system is made up of a series of elements. Liner requirements, and hence the number and sequence of liner components, will vary with the class of landfill under consideration. The detail and variation associated with each liner component is described below, and the various liner designs are depicted in *Figure A.8.1* through *Figure A.8.8*.

These elements are as follows, generally working down from the underside of the waste body:

O layer: A desiccation protection layer consisting of 150mm of soil, gravel, rubble or other similar material that completely covers the B layer for **G:M:B**$^{-}$ and **G:L:B**$^{-}$ landfills and protects it from desiccation and cracking until it is covered by waste. Under certain circumstances, the thickness of the O layer may need to be increased.

A layer: A leachate collection layer comprising a 150mm thick layer of single-sized gravel or crushed stone having a size of between 38mm and 50mm.

B layer: A 150mm thick compacted clay liner layer. This must be compacted to a minimum density of 95% Standard Proctor* maximum dry density at a water content of Proctor optimum to optimum +2%. Permeabilities must be such that the outflow rates stated in Section 8.4.3 are not exceeded. Interfaces between B layers must be lightly scarified to assist in bonding the layers together.

The surface of every clay liner layer must be graded towards the leachate collection drain or sumps (see 8.4.4) at a minimum gradient of 2% for general waste disposal sites and 5% for hazardous waste disposal sites. At the discretion of the Department, B layers may be replaced by a geomembrane, a GCL, or a composite liner.

C layer: This is a layer of geotextile laid on top of any D layer to protect it from contamination by fine material from above.

D layer: A leakage detection and collection layer. This is always below a C layer and above a B layer in **B**$^{+}$ and hazardous waste landfills. In lagoons it is underlain by an E layer which protects the second FML or geomembrane. It has a minimum thickness of 150mm and will consist of single-sized gravel or crushed stone having a size of between 38mm and 50mm.

* 0,945*l* cylindrical mould, 2,5kg hammer dropped 300mm. Compaction in 3 layers each compacted with 25 blows (compactive effort = 595kNm/m^3).

E layer: This is a cushion of 100mm of fine to medium sand or similar suitable material which is placed immediately above any F layer to protect it from mechanical damage.

F layer: A geomembrane or flexible membrane liner (FML) which must be laid in direct contact with the upper surface of a compacted clay B layer. A geomembrane is a Minimum Requirement for all hazardous waste landfills and lagoons. In the case of an **H:h** landfill it is a 1,5mm thick geomembrane, underlain by four B layers. In the case of an **H:H** landfill it is a 2,0mm thick geomembrane, underlain by four B layers. In the case of a hazardous waste lagoon, there are two geomembranes. The first is 2,0mm thick underlain by four B layers and the second is 1,0mm thick, underlain by two B layers*.

The geomembrane thickness specified shall be minimum thickness, as measured in accordance with the SABS Specification 1526 test method.

G layer: This is a base preparation layer consisting of a compacted layer of reworked in-situ soil with a minimum thickness of 150mm and constructed to the same compaction standards as a B layer. Where the permeability of a G layer can be proven to be of the same standard as a B layer it may replace the lowest B layer.

The surface of every G layer must be graded towards a leachate collection drain or sump in the case of $\mathbf{B}^+$ landfill or to a central channel on the down gradient side of a $\mathbf{B}^-$ landfill, from which sporadic leachate can be collected if it occurs. The central channel must contain a prism of A layer material so as to act as an efficient leachate collector or finger drain. The minimum gradient must be 2% for **G** sites and 5% for **H** sites.

* When a geomembrane is laid over a B layer compacted to 95% Standard Proctor maximum dry density of water content of Proctor optimum to optimum +2%, consideration must be given to the following situation. Condensation from the clay liner under the geomembrane could lubricate the interface and facilitate slippage on slopes.

LANDFILL LINER DESIGNS

General B⁻ Landfills

FIGURE A.8.1
G:S:B⁻ Landfills

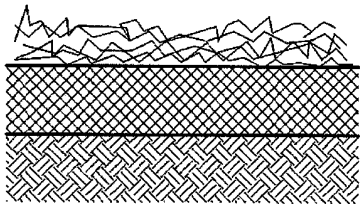


FIGURE A.8.2
G:M:B⁻ Landfills

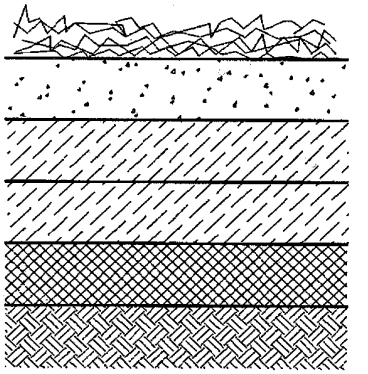
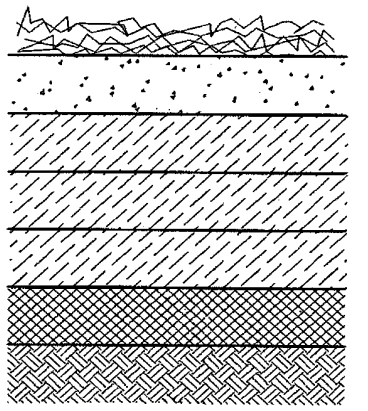


FIGURE A.8.3
G:L:B⁻ Landfills



LANDFILL LINER DESIGNS (continued)

General B^+ Landfills

FIGURE A.8.4
G:S:B^+ Landfills

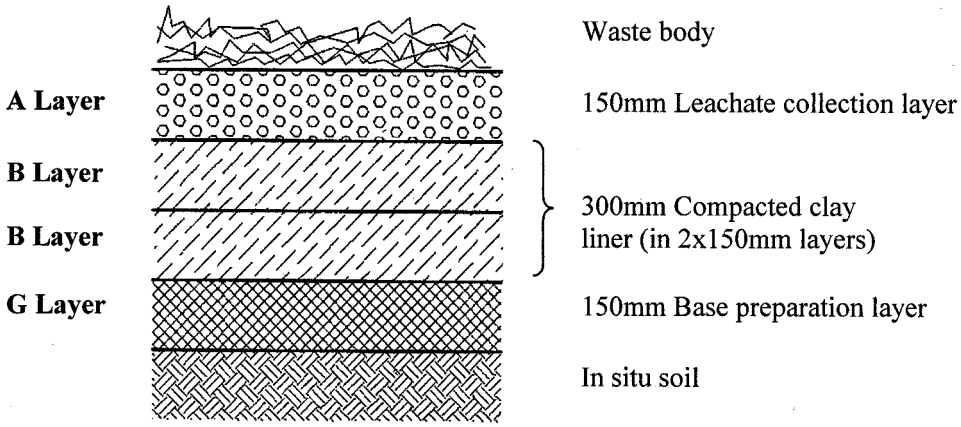
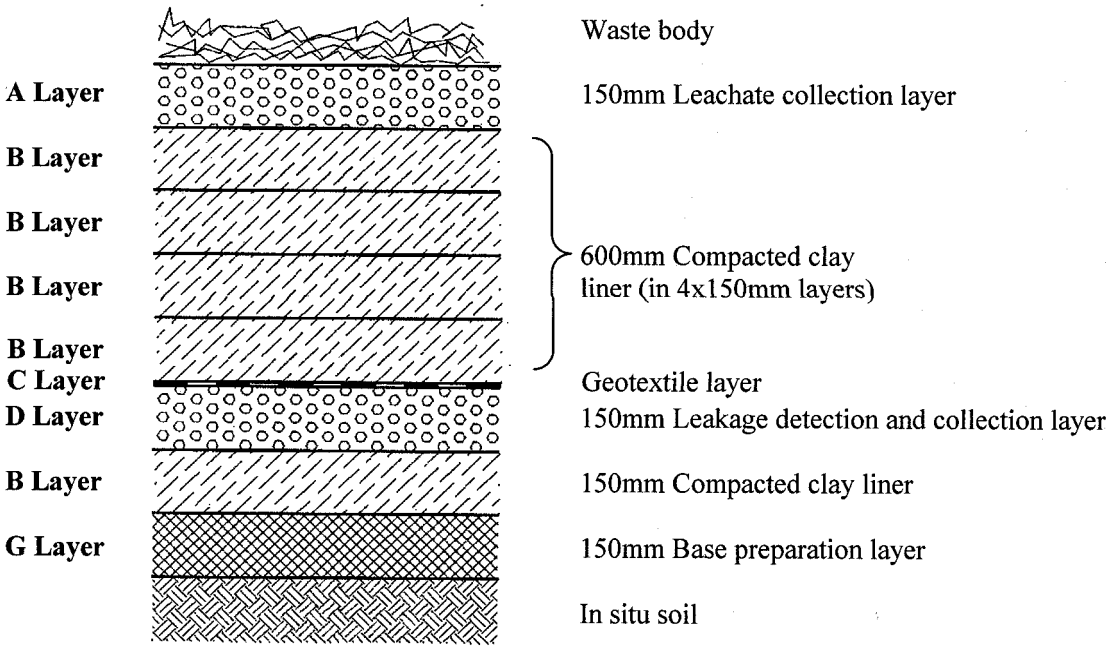


FIGURE A.8.5
G:M:B^+ and G:L:B^+ Landfills

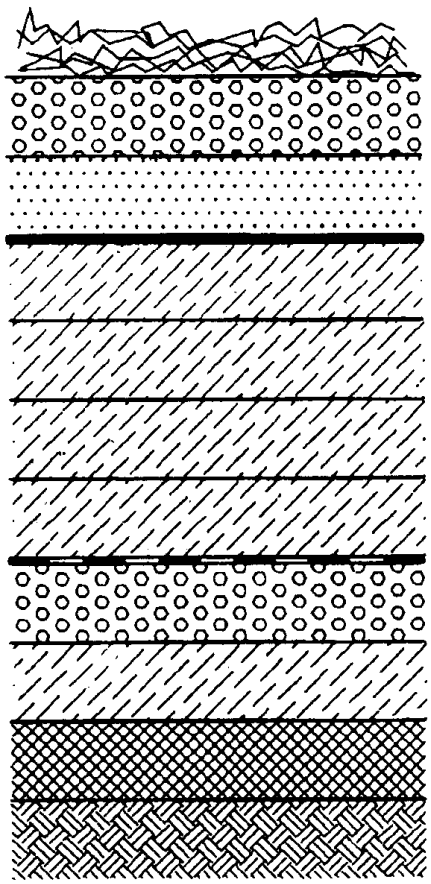


LANDFILL LINER DESIGNS (continued)

Hazardous Waste Landfills

FIGURE A.8.6

H:h Landfills

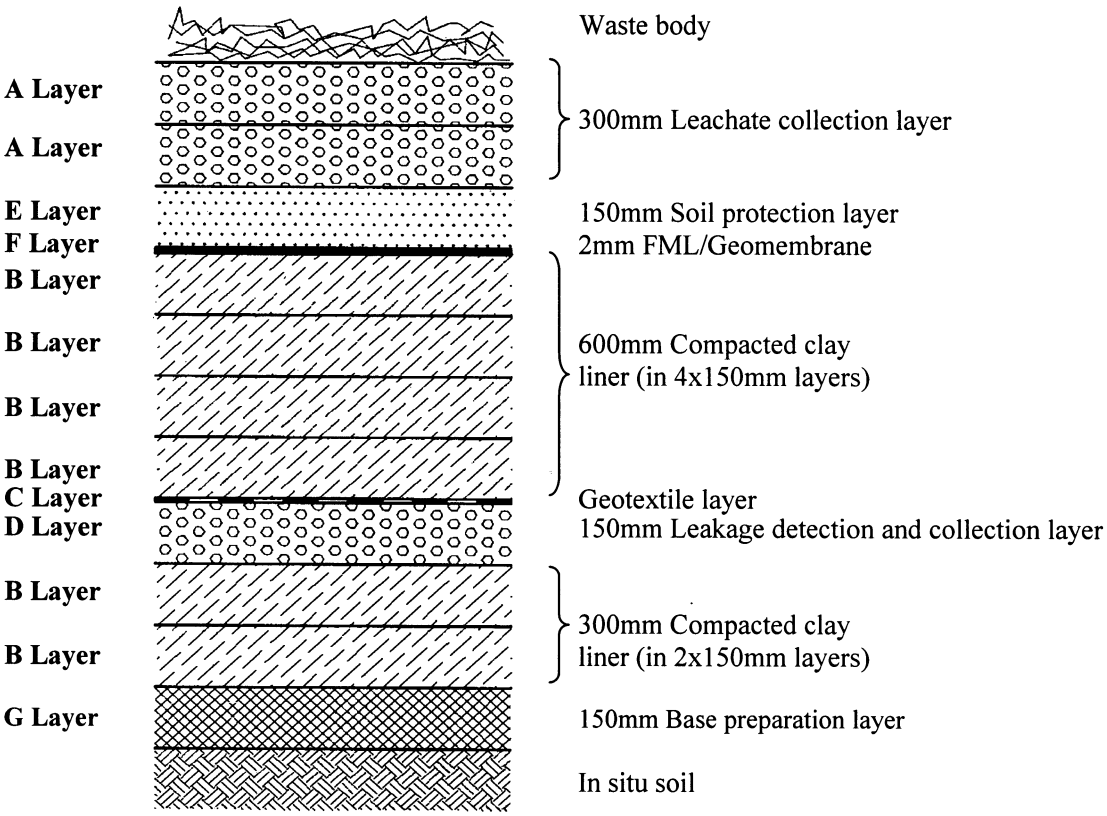


	Waste body
A Layer	150mm Leachate collection layer
E Layer	150mm Soil protection layer
F Layer	1,5mm FML/Geomembrane
B Layer B Layer B Layer	600mm Compacted clay liner (in 4x150mm layers)
C Layer	Geotextile layer
D Layer	150mm Leakage detection and collection layer
B Layer	150mm Compacted clay liner
G Layer	150mm Base preparation layer
	In situ soil

LANDFILL LINER DESIGNS (continued)

Hazardous Waste Landfills

FIGURE A.8.7
H:H Landfills and Encapsulation Cells



LAGOON LINER DESIGNS

FIGURE A.8.8

Hazardous Waste Lagoons

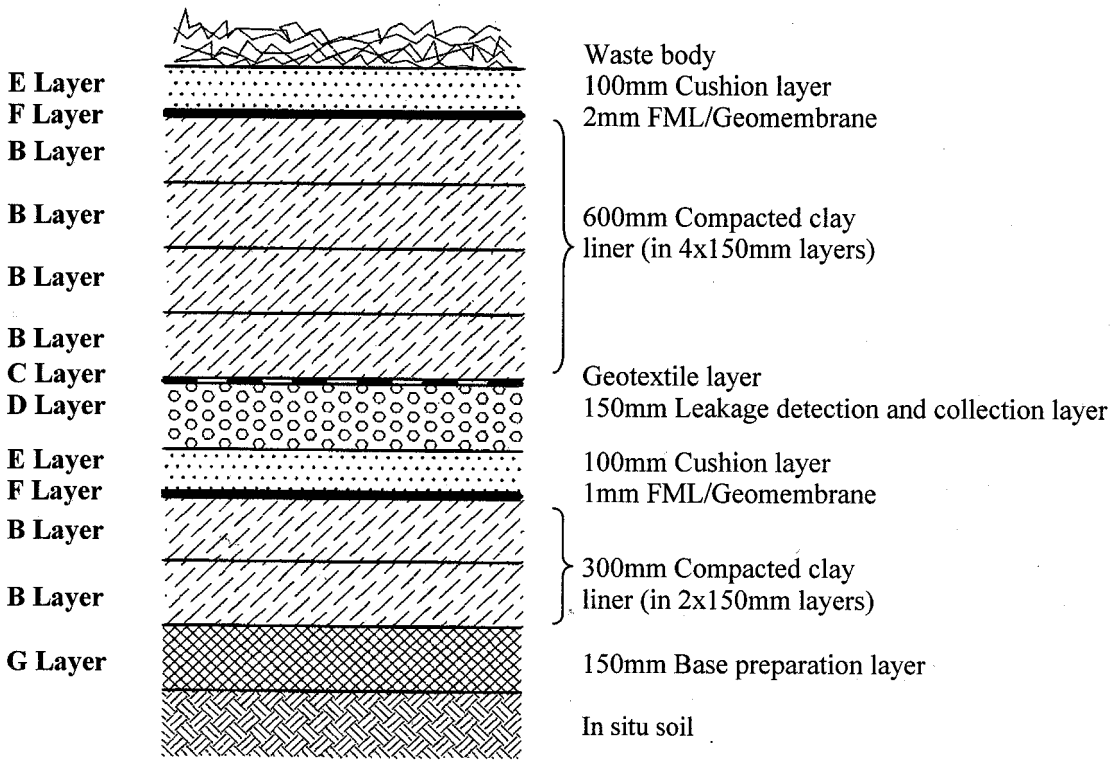
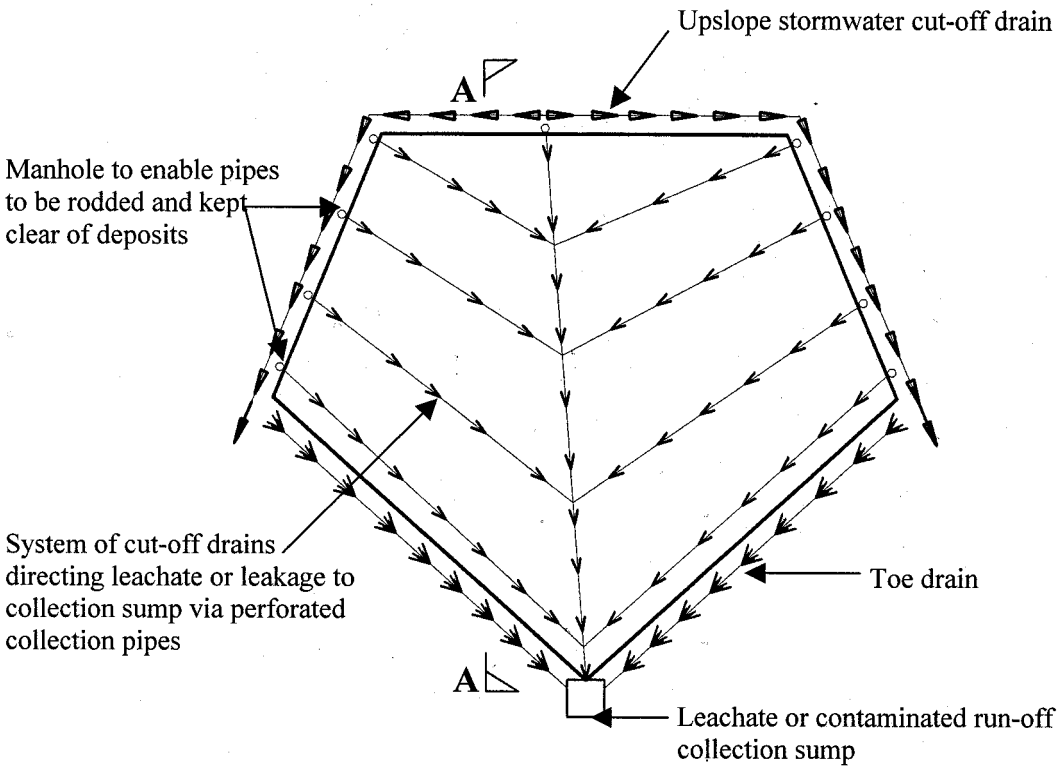
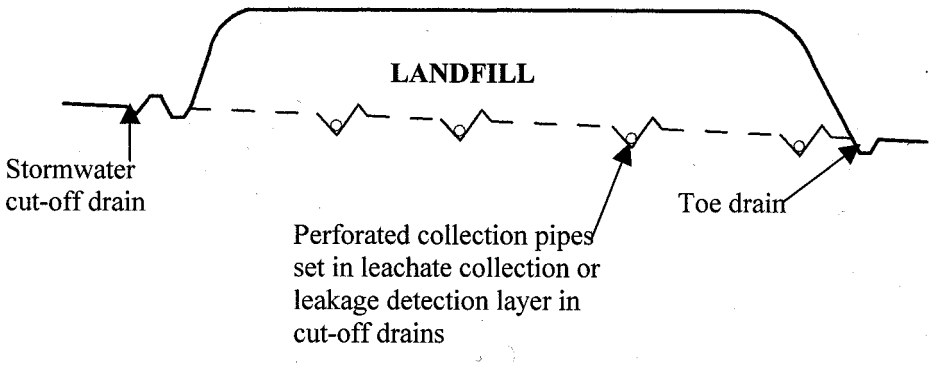


FIGURE A.8.9
Typical leachate collection system



Plan of landfill showing typical drainage systems



Section A-A through landfill

Design of the final cover or capping system

Like the liner system, a capping or final cover system is also made up of a series of elements. The capping system is designed to maximise run-off of precipitation, while minimising infiltration and preventing ponding of water on the landfill. As discussed in the main text, each of the cover or capping systems is made up of a series of elements. Cover requirements, and hence the number and sequence of components, will vary with the class of landfill under consideration. The detail and variation associated with each component is described below, and the various cover designs are depicted in *Figure A.8.10* through to *Figure A.8.12*.

The elements are as follows:

U layer: A 200mm thick layer of topsoil planted with local grasses and shrubs. The layer must be lightly compacted after spreading. In arid regions, this can be substituted with a layer of natural gravel.

V layer: A compacted 150mm soil cap layer. Any soil used in a V layer must have a Plasticity Index of between 5 and 15 and a maximum particle size of 25mm. This will be compacted to the maximum density reasonably attainable under the circumstances to ensure the required impermeability. This must not be less than 85% of Proctor maximum dry density at a water content of Proctor optimum to Proctor optimum +2%. The saturated steady state infiltration rate into a compacted soil V layer should not exceed 0,5m/y, as measured by means of an *in situ* double ring infiltrometer test. The surface of every V layer must be graded initially at a minimum of 3% to shed precipitation.

At the discretion of the Department, V layers may be replaced by a geomembrane, a GCL, or a composite liner.

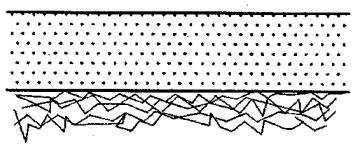
W layer: Shaped and compacted upper surface of waste body. (If available, it may prove useful to cover the waste surface with builders' rubble before compacting).

X layer: A gas venting layer having a minimum thickness of 150mm and consisting of single sized stone or gravel of between 25mm and 50mm in size. The X layer must be connected to a gas management system.

Z layer: This is a layer of geotextile laid on top of any X layer to protect the X layer from contamination.

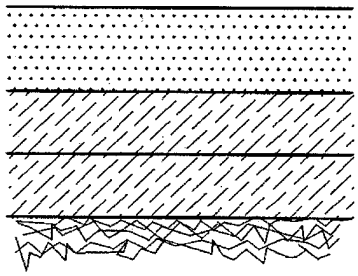
COVER OR CAPPING DESIGN

FIGURE A.8.10
G:C and G:S:B$^-$ Landfills



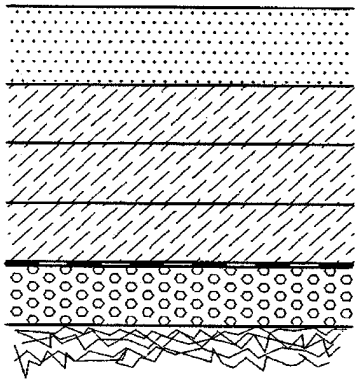
U Layer	200mm Topsoil
W Layer	Waste body compacted

FIGURE A.8.11
G:S:B$^+$, G:M:B$^-$ and G:L:B$^-$ Landfills



U Layer	200mm Topsoil
V Layer	300mm Compacted clayey soil (in 2x150mm layers)
V Layer	
W Layer	Waste body compacted

FIGURE A.8.12
G:M:B$^+$, G:L:B$^+$ and Hazardous Landfills



U Layer	200mm Topsoil
V Layer	450mm Compacted clayey soil (in 3x150mm layers)
V Layer	
V Layer	
Z Layer	Geotextile layer
X Layer	150mm Foundation and gas drainage layer
W Layer	Waste body compacted

NOTE:

The design of covers is highly dependent on site specific circumstances, e.g. nature of waste (wet, dry, putrescible). Although the primary function of the cover is to keep water out of the waste body, the cover design will also be affected by the gas management philosophy adopted and the preferred materials and technology (e.g. clay, GCLs and FMLs) for the given situation. Cover designs should be based on the above figures. However, at the discretion of the Department, components and configurations may be varied.

PERMEABILITY TESTS

All permeability tests must be chosen to give the most realistic permeability results for the material or strata under consideration.

Size of Tests

The size of the test (specimen or test hole geometry etc.) must make proper allowance for the size of the constituent particles and structural features of the material or strata.

Number of Tests

The number of tests or of test locations (in the case of field tests), should provide a realistic upper bound value or range of values. Where possible, more than one type of test should be performed.

Flow Gradient

Darcy's Law is only approximately true for soils. Laboratory permeability measurements should be carried out in a triaxial cell with flow gradients not exceeding 3, to ensure realistic permeability results.

Duration of Tests

Tests should be run for a sufficient length of time to achieve a steady-state flow condition.

The Permeating Fluid

Whenever possible, a sample of leachate from similar waste to that to be disposed of, or a sample of the liquid waste to be disposed of, must be used to determine the soil permeability or that of the liner material to be used. Where leachate cannot be used, a standard synthetic leachate should be used in preference to clear water. However, whatever the permeating fluid, a suitable chemical analysis should accompany the results.

In the case of hazardous waste disposal sites, the Responsible Person must satisfy the Department of the chemical compatibility of the proposed liner with the wastes and leachate that will come into contact with it. Specifically, it must be shown that the latter will not cause the permeability of the liner to increase significantly with time.

Warning

Waste and leachate may be toxic, or infectious, or both. It should only be handled by staff who are adequately trained and aware of the dangers, and who are equipped with adequate protective clothing. Most soil testing laboratories are not adequately equipped or sufficiently knowledgeable to handle leachate safely. Bacterial or fungal infections from contact or even the proximity of waste or leachate are difficult to treat and cure without extensive medical tests and medication. They may cause serious and permanent damage to health and even result in permanent disability.

CHART FOR PRELIMINARY ASSESSMENT OF STABILITY OF SLOPES OF COMPACTED WASTE WHERE SHEARING WILL OCCUR THROUGH THE WASTE

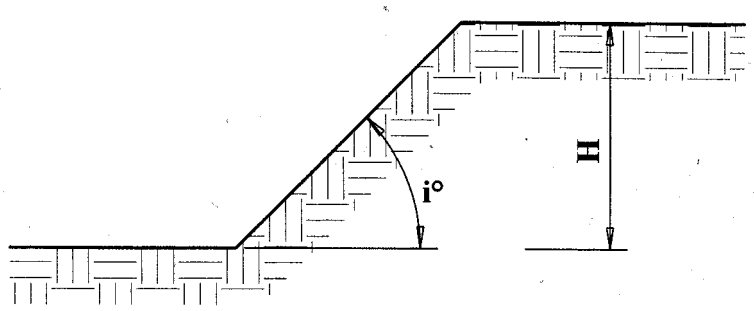
The chart below (*Figure A.8.13*) is based on the following parameters for the waste:

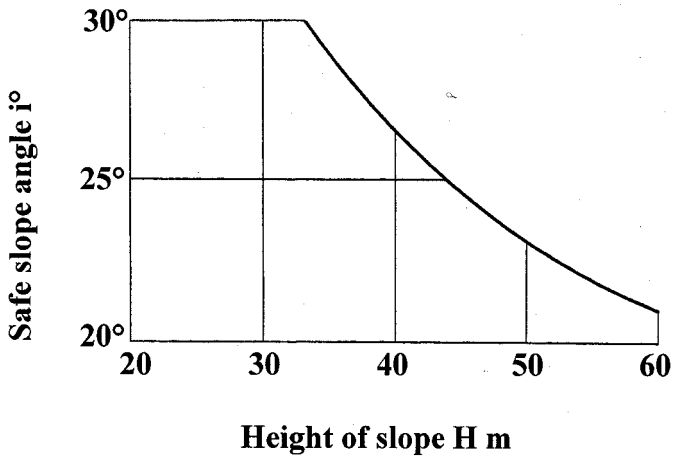
Cohesion	:	c^1 = 25 kPa
Angle of shearing resistance	:	N^1 = 15°
Unit weight	:	(= 10kN/m^3
Factor of safety	:	F = 1.25

Caution:

The chart should only be used for preliminary assessments of the stability of proposed slopes. If there is anything unusual about the slope, it should be properly analysed. The user must ensure that shearing through the waste will be the critical mode of failure of the slope.

FIGURE A.8.13
Chart for preliminary slope stability assessment





Appendix 8.3

CHECKLIST OF LANDFILL DESIGN AND OPERATING CONSIDERATIONS (Sections 8 and 10)

The following is intended to represent a convenient checklist for use when considering the Minimum Requirements. The Responsible Person will, however, decide on items required for a particular site.

- Environmental Impact Control Report
- Site Design Plan
- Permit Application Schedule
- Permit to Operate the Landfill
- Detailed Site Design and Preparation Documentation
- Approval of Site preparation
- Final Site Drawings
- Operating Plan
- Phased Development Plan and Drawings
- Closure Plan and Drawings
- Rehabilitation Plan
- Closure Plan
- End-use Plan

- Responsible Person
- Laboratory staff
- Supervisor
- Weighbridge operators
- Treatment plant operators
- Drivers
- Landfill plant operators
- Traffic controllers
- Security guards
- Labourers

- Waste sampling
- Weighbridge interface
- Reference files (data base)
- HazChem codes
- RSA code
- Laboratory analysis
- Prescriptions
- Documentation
- Special Disposal Procedures
- Collection certificates
- Safe disposal certificates

- Site laboratory (to analyse waste)
- Computerised data base and manifest system
- Toilets, wash basin
- Ablution block with showers
- Gate control office and record of all entrants
- Weighbridge
- Site office
- Temporary storage areas
- Resource recovery plant
- Container park
- Liner
- Capping System
- Leachate collection system
- Leachate treatment system
- Safety equipment
- Mobile shower
- Emergency
- Fire extinguishers
- Protective clothing
- Gas masks and canisters.

Items which will require regular attention include:

- Roads and signs
- Buildings
- Fences
- Cover
- Drainage
- Mobile and fixed plant
- Vegetation
- Leachate collection systems
- Leachate treatment systems
- Safety equipment
- Fire breaks
- Landfill gas emission
- Specialised Equipment.

Appendix 10.1

CALCULATION OF CO-DISPOSAL RATIOS (Section 10)

Liquids may be co-disposed with 'dry' waste on an **H:H**, **H:h**, **G:M:B**$^+$ or **G:L:B**$^+$ landfill. In any such case, the landfill must be equipped with a leachate management system and the leachate flow that results must be contained, extracted and treated. The solid/liquid waste co-disposal ratio must be calculated according to the following procedure:

1. In order to calculate the co-disposal ratio, the following approach should be adopted:

1.1	The water content of the incoming 'dry' waste on a dry mass basis is and its field capacity on a dry mass basis is	w f
1.2	The height of lift of the landfill above the landfill base or nearest intermediate cover layer is	H (m)
1.3	The wet density of the "dry" waste is and the density of water is	ρ (kg/m^3) ρ_w (kg/m^3)
1.4	The rainfall or precipitation at the site is and the evaporation from the landfill is where A is the A-pan evaporation and e is a factor (less than 1) to convert pan evaporation to evaporation from a landfill surface.	R (m/y) E = eA (m/y)

1.5 For a column of waste of unit cross section, H in height,

the mass of dry waste is

$$\frac{\rho H}{(1+w)} \quad \text{(kg)}$$

and mass of water is

$$\frac{\rho Hw}{(1+w)} \quad \text{(kg)}$$

1.6 The co-disposed liquids, as a proportion of the dry solids are y
and thus the total mass of liquids in the column is

$$\frac{(w+y)\rho H}{(1+w)} \quad \text{(kg)}$$

1.7 The mass of liquids at field capacity of the waste is

$$\frac{f(H}{(1+w)} \text{ (kg)}$$

1.8 The nett precipitation per year per m^2 will be

$P_n = (R - eA)(_w$(kg).....(1)

1.9 Thus the liquids in excess of field capacity in the first year after lift H is disposed are

$$\frac{(w+y)(H}{(1+w)} + (R-eA)(_w - \frac{f(H}{(1+w)} = \text{Leachate} = L \text{ (kg)}$$

$$L = \frac{(w+y-f)(H + P_n(1+w)(_w}{(1+w)} \text{.... .....(2)}$$

1.10 The co-disposal ratio is defined as

$$CR = \frac{\text{mass of dry waste}}{\text{mass of liquid disposed}}$$

$$CR = \frac{(H}{(l+w)} \div y \frac{(H}{(l+w)} = \frac{1}{y} \text{ .....(3)}$$

By combining the expressions for L and CR, it can be shown that

$$CR = \frac{(H}{L(1+w)+(H(f-w)-P_n(1+w)(_w} \text{.....(4)}$$

1.11 Using the expressions for CR and L (equations 2, 3 and 4) one can investigate the expected yearly leachate for any site.

2. Method for calculating co-disposal ratios:

2.1 The actual values of **w**, **f** and **(** used in the design of any co-disposal landfill will depend on the wastes being received at each site and on the compaction achieved in the landfill. Every attempt should be made to measure these parameters for each specific site. In the absence of more specific information, the following interim values may be used, once permission has been motivated for and obtained from the Department of Water Affairs and Forestry:

w = 30% by dry mass
f = 50% by dry mass
(= 750 kg/m^3

However, in the case of **H** sites, it is a Minimum Requirement that site specific parameters are determined. These parameters are to be re-determined for the site should the characteristics of the

incoming waste change, either as a result of the waste sources changing, or as a result of seasonal changes.

2.2 The value of **e** for these calculations should be taken as 0,7, i.e., the same factor that is used in the Climatic Water Balance.

2.3 The approach taken by the Minimum Requirements is as follows.The operational value of CR is selected, using equations (3) and (4) so that on average no more than 200mm of leachate per year will be produced. In a succession of wet years more than 200mm of leachate will appear but this is not a matter for concern as co-disposal sites at which this approach is allowed will all be lined and have leachate management systems that will have to have design capacity for a succession of wet years.
For 200mm/y (0,20m/y) of leachate, on average, equation (4) becomes:

$$CR(L=200) = \frac{(H}{0,20(1+w)+(H(f-w)-P_n(1+w)(_w} \quad \text{.....(4a)}$$

2.4 The set of six graphs that follows, illustrates the effects of the variables **w** and **f** on the co-disposal ratio for a limiting average leachate production of 200mm/year and various values of P_n. These can be used as a means for selecting a suitable co-disposal ratio and for preliminary sensitivity studies of the design figures. The results should, however, always be checked by applying equations (2) and (4).

3. Examples

3.1 Suppose that for an **H:H** co-disposal landfill

w = 25%
y = 0,80, i.e. CR = 1,25
f = 0,5
(= 0,75 T/m^3
H = 5 m
R = 730 mm/y
eA = 0,7 x 2230 = 1561 mm/y
(w = 1 T/m^3

Using equation (2),

$$L = \frac{(0,25+0,80-0,50)(0,75)(5)+(0,73-1,561)(1,25)(1)}{1,25}$$

L = 0,819 T/m^2/y = 819 mm/y

If, however, w = 0,10 and f = 0,65 (i.e. the characteristics of the incoming waste change)

$$L = \frac{(0,10+0,80-0,65)(\ 0,75)(5)+(0,73-1,56)(1,1)(1)}{1,25}$$

L = 0,0196 = 20 mm/y

A further slight change of the input parameters to w = 0,15 results in

L = 148 mm/y

Hence equation (2) can easily be used for sensitivity analysis.

3.2 For the above figures and w = 0,15, f = 0,65 and L = O (i.e. to avoid the production of leachate on average) using equation (2), y will have the values given by:

O = (y+0,15-0,65)0,75(5)+(0,73-1,56)(1,15)
O = (y-0,5)-0,255
y = 0,755

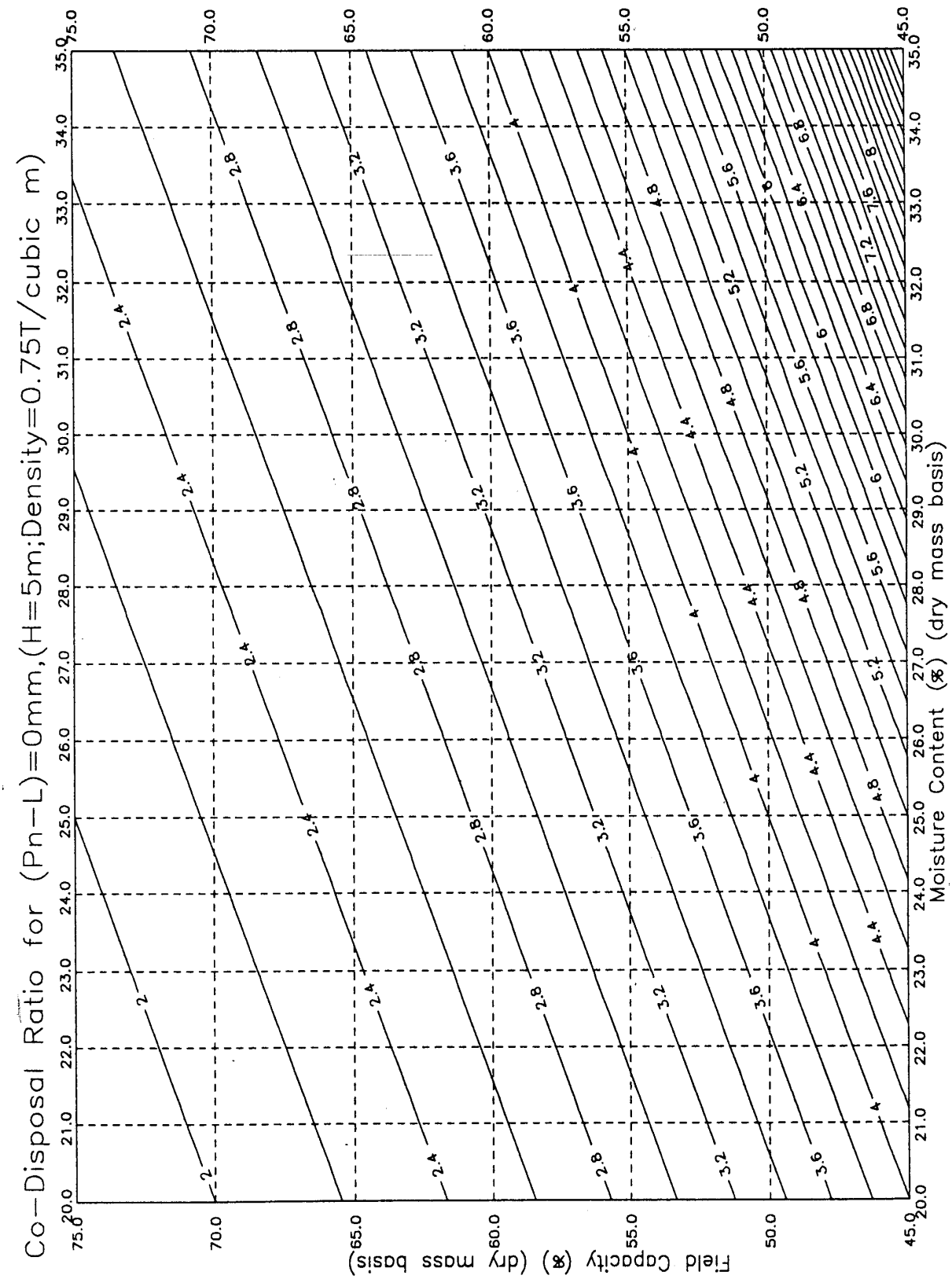
and CR = $\frac{1}{y}$ = 1,32

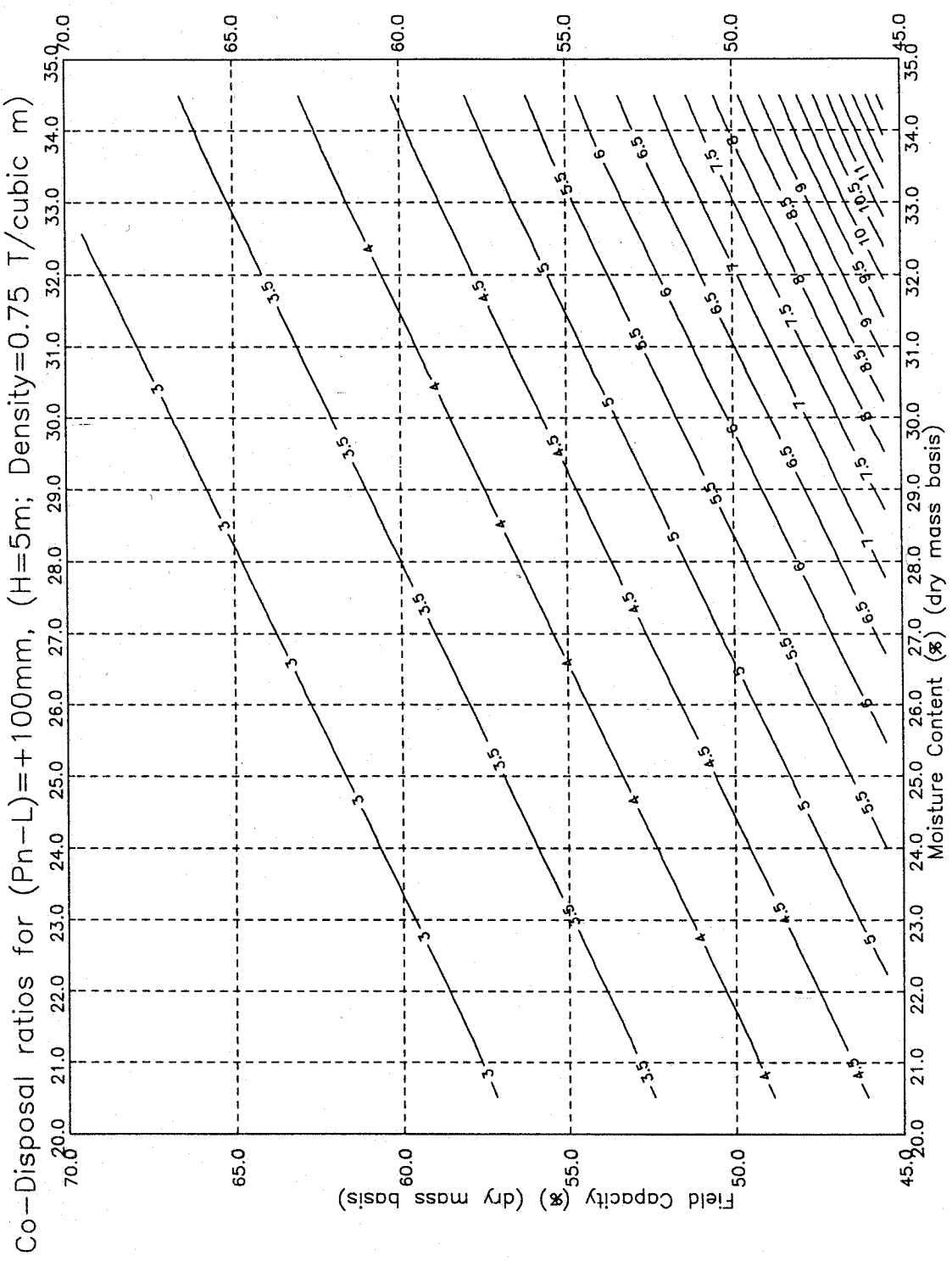
Hence a very small increase in CR from 1,25 to 1,32 will inhibit average leachate production entirely.

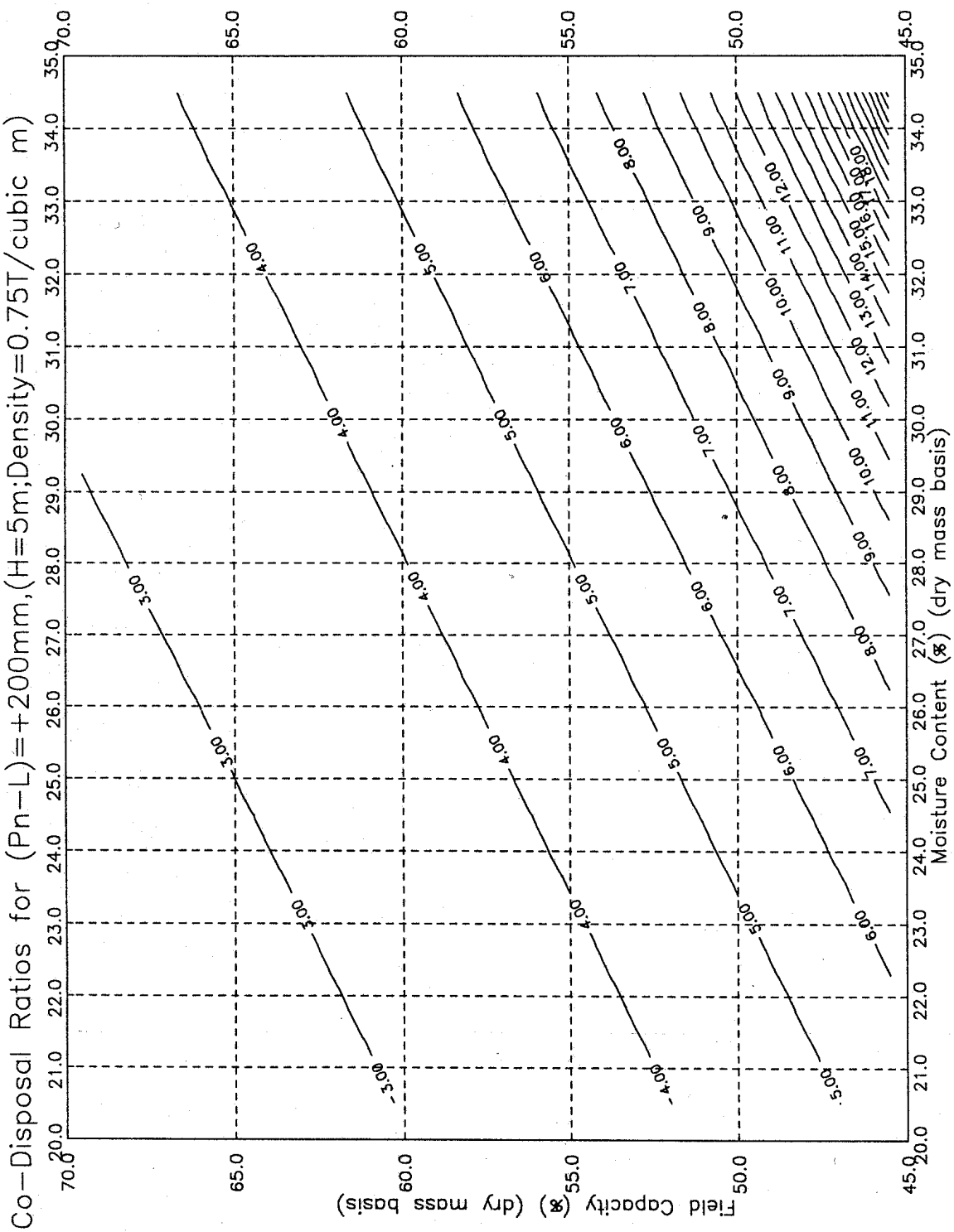
3.3 For 200mm/y of leachate on average,

If w = 30%
f = 0,65
(= 0,75 T/m^3
H = 5 m
($_w$ = 1 T/m^3
P_n = +0,12m/y, using equation (4a)

$$CR(L=200) = \frac{0,75(5)}{0,20(1,3)+0,75(5)(0,35)-0,12(1,3)1,0} = 2,6$$


Co-Disposal Ratio for (Pn-L)=0mm,(H=5m;Density=0.75T/cubic m)
Field Capacity (%) (dry mass basis)
Moisture Content (%) (dry mass basis)


Co-Disposal ratios for (Pn-L)=+100mm, (H=5m; Density=0.75 T/cubic m)
Field Capacity (%) (dry mass basis)
Moisture Content (%) (dry mass basis)


Co-Disposal Ratios for (Pn-L)=+200mm,(H=5m;Density=0.75T/cubic m)
Moisture Content (%) (dry mass basis)
Field Capacity (%) (dry mass basis)
70.0
65.0
60.0
55.0
50.0
45.0
20.0
21.0
22.0
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0
31.0
32.0
33.0
34.0
35.0
3.00
4.00
5.00
6.00
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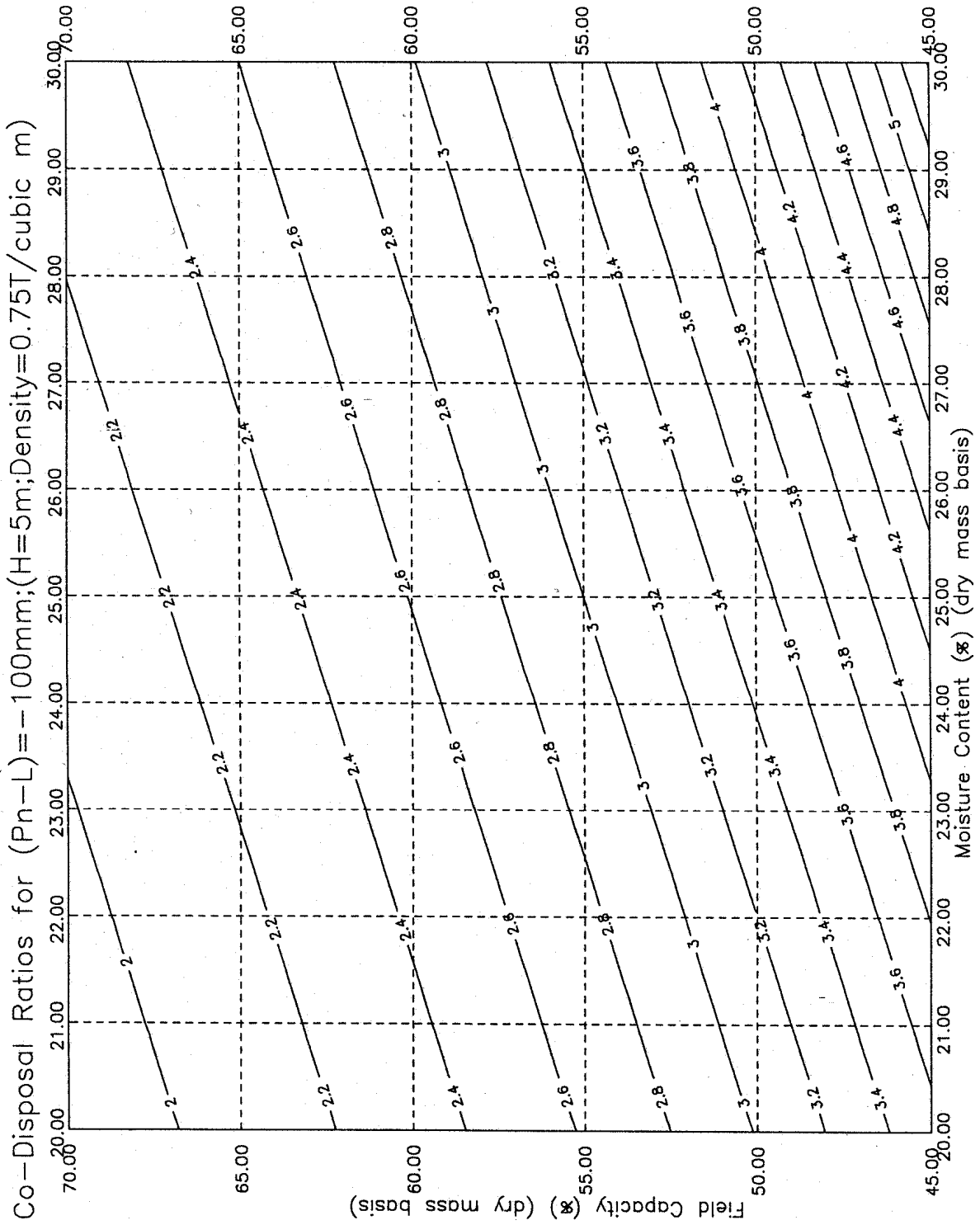
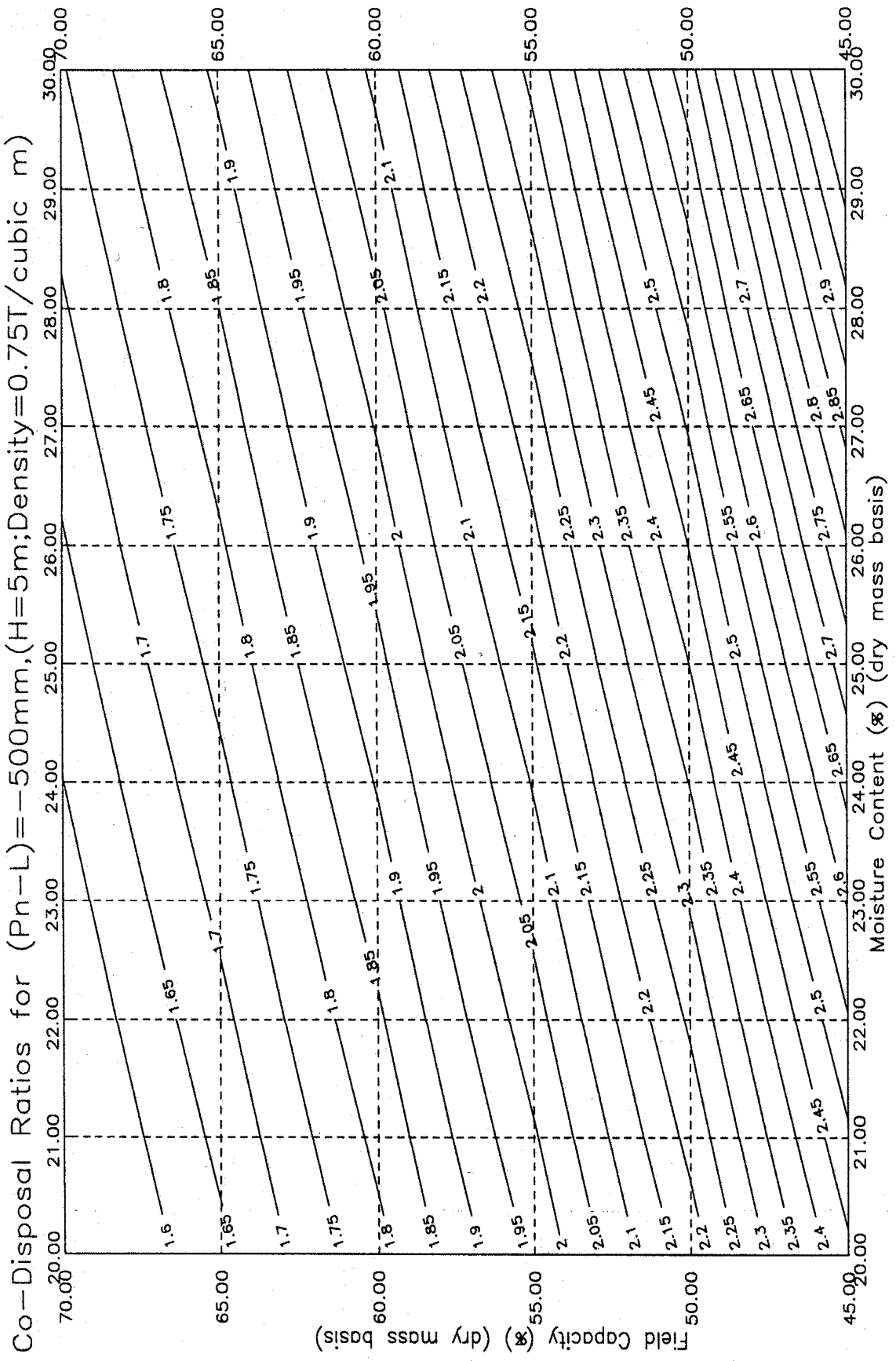
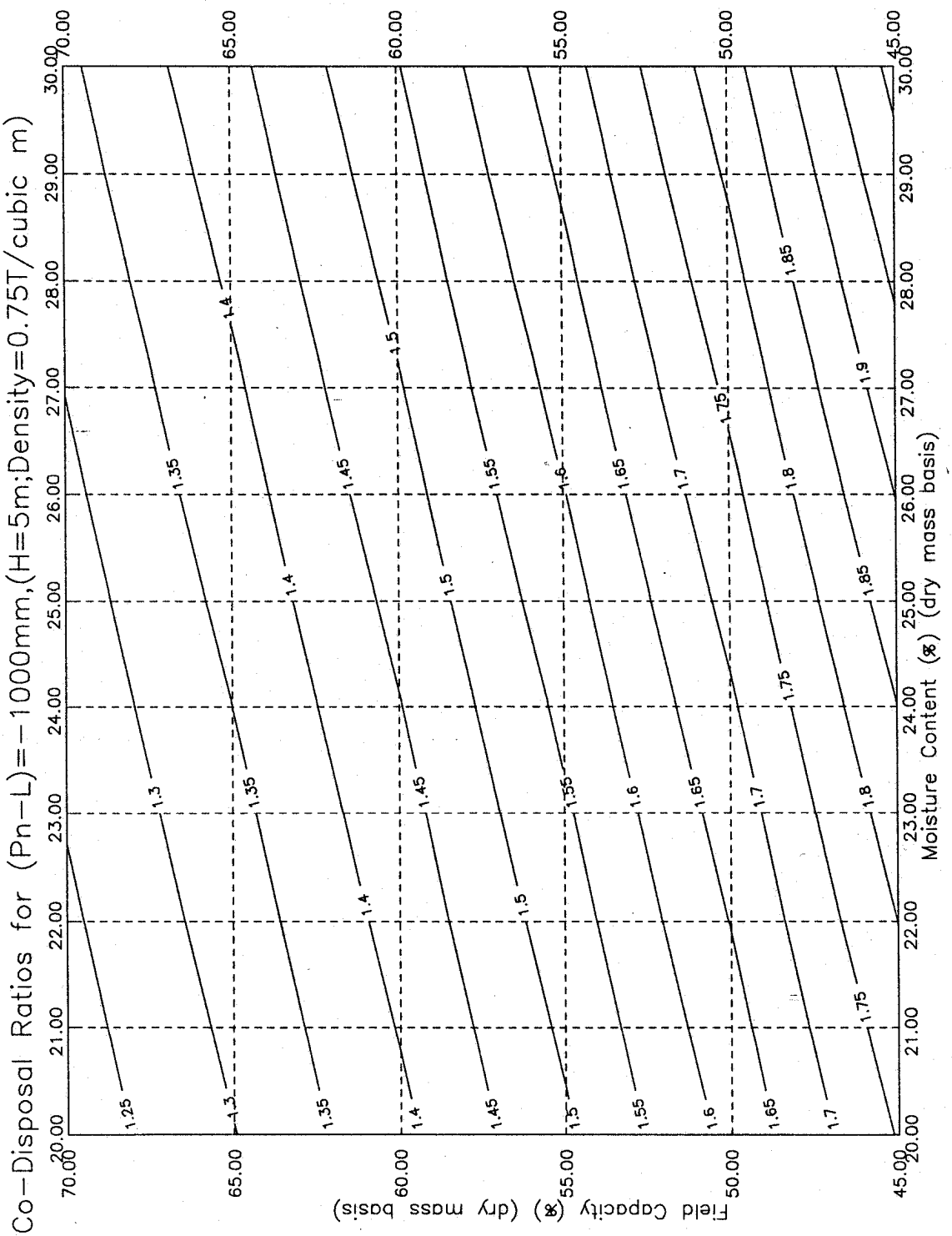
15.00
16.00
17.00
18.00


Co-Disposal Ratios for (Pn-L)=-100mm;(H=5m;Density=0.75T/cubic m)
Field Capacity (%) (dry mass basis)
Moisture Content (%) (dry mass basis)
70.00
65.00
60.00
55.00
50.00
45.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
29.00
30.00


Co-Disposal Ratios for (Pn-L)=-500mm,(H=5m;Density=0.75T/cubic m)
Field Capacity (%) (dry mass basis)
Moisture Content (%) (dry mass basis)
70.00
65.00
60.00
55.00
50.00
45.00
30.00
29.00
28.00
27.00
26.00
25.00
24.00
23.00
22.00
21.00
20.00


Co-Disposal Ratios for (Pn-L)=-1000mm,(H=5m;Density=0.75T/cubic m)
Moisture Content (%) (dry mass basis)
Field Capacity (%) (dry mass basis)
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
29.00
30.00
70.00
65.00
60.00
55.00
50.00
45.00
1.25
1.3
1.35
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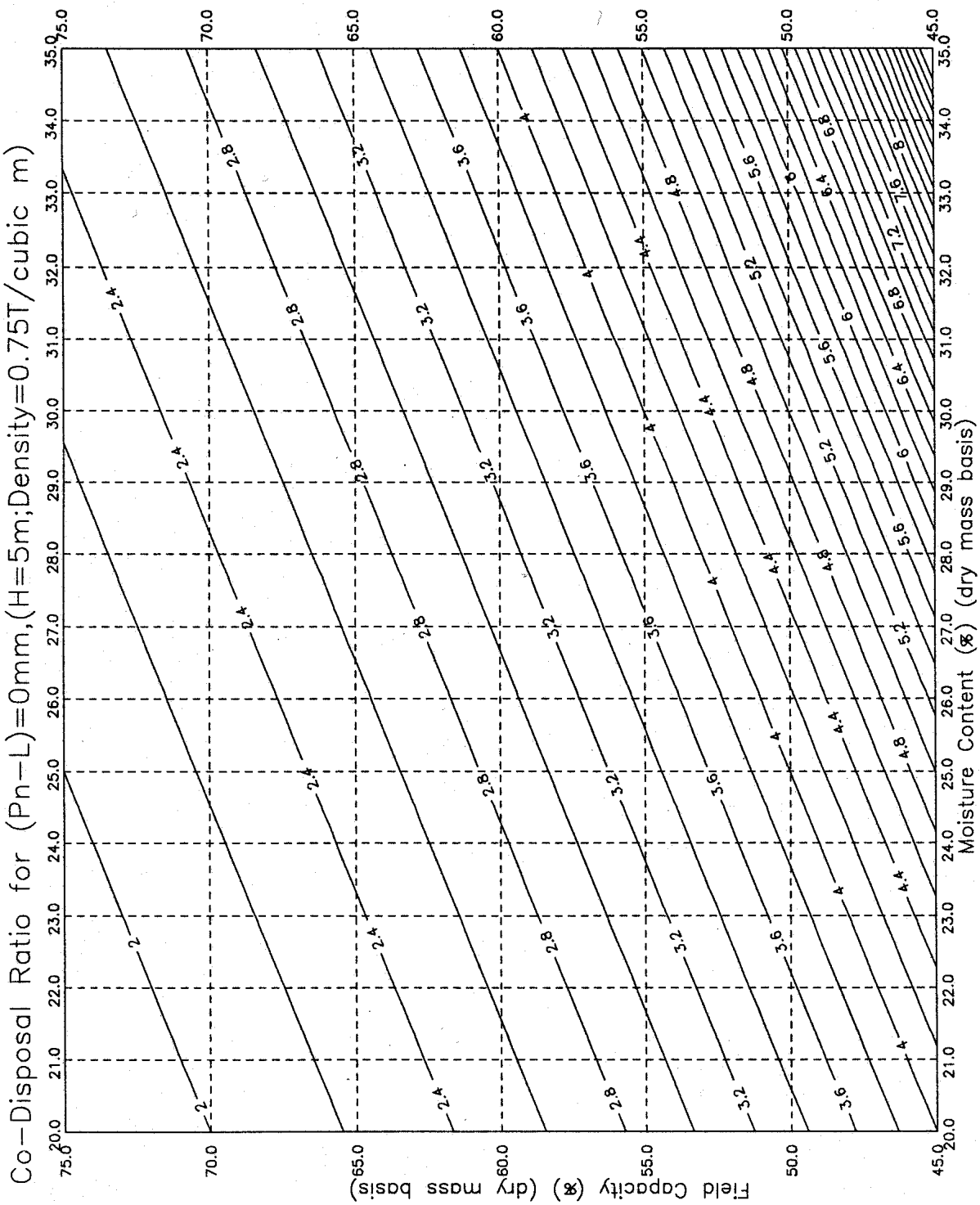
1.5
1.55
1.6
1.65
1.7
1.75
1.8
1.85
1.9


Co-Disposal Ratio for (Pn-L)=0mm,(H=5m;Density=0.75T/cubic m)
Field Capacity (%) (dry mass basis)
Moisture Content (%) (dry mass basis)

Appendix 10.2

WASTE BURNING (Section 10)

This appendix provides additional information and guidelines to supplement the Minimum Requirements in the text of Section 10.4.3, **Burning of waste**.

Efficient burning depends on the combustibility of the material being burned and the amount of oxygen available. In order to promote efficient burning the following steps are recommended:

1. Removal of Wastes not suited to Burning

It is recommended that all non combustible wastes and less combustible wastes be separated from those wastes to be burned and landfilled directly.

Non combustible wastes such as soil, building wastes or ash should be set aside for use as cover or direct placement in the landfill. Less combustible wastes such as moist waste and semi combustible materials, should also be landfilled directly and not burned.

2. Ensuring Adequate Oxygen

In addition to minimising the non-combustible wastes, adequate oxygen in the burning process must be ensured. The more oxygen available, the less smoke generated and the more complete the process. Where an oxygen deficiency exists, smouldering, smoke, unpleasant odours and potentially harmful emissions may result.

In order to ensure adequate oxygen in the burning process, it is recommended that:

i) Waste should be deposited some distance from the main waste body and be burned in small controlled fires, rather than allowing the whole waste body to burn in an uncontrolled manner.

ii) The small controlled fires created should be tended and turned with long metal rakes when necessary to facilitate better aeration.

3. Handling after Burning

Before burned waste can be handled or covered, it must be completely extinguished. Failure to completely extinguish burning waste could result in uncontrolled burning over large areas and ongoing smouldering which is difficult to extinguish. In addition to the environmental impacts of the above, the handling of burning waste by landfill plant could also be extremely dangerous.

Regular visits by an operator with a tracked loader are essential to tidy up the fringes of the deposits, to move any non combustible waste into the landfill and to cover with soil. Completely burned waste should, as far as possible, be handled the same way as unburned wastes using the sanitary landfill principles of compaction and cover.

4. Health and Safety Aspects

Loads of waste should be inspected before ignition to identify any materials which present obvious safety hazards. There are essentially two types of hazard which can readily be avoided:

- Risk of explosion - from aerosol cans, gas cylinders and closed containers of any kind.

- Risk of toxic fumes - from certain plastics such as PVC and polyurethane (PU) and also from pesticides and pharmaceuticals. The plastics may not be easy to identify but certain objects will be, namely plastic channelling, pipes, flower pots and flexible foam. These materials may all contain PVC or PU. The precautionary principle should be adopted and any suspect materials removed.

Site personnel should always remain upwind from any burning waste. A simple windsock made from waste textile will indicate wind direction if necessary. They should also stand clear of the burning waste to avoid risk of injury from minor explosions which may occur.

Site personnel should wear suitable protective clothing, including gloves, boots and overalls, together with smoke masks and goggles if necessary.

Fire fighting equipment should be available on all sites at which controlled burning is authorised, subject to suitable arrangements being able to be made for its security.

Appendix 10.3

WASTE RECLAMATION (Section 10)

This Appendix provides additional information and guidelines to supplement the Minimum Requirements in the text in Section 10.4.4, which relates to reclamation.

Uncontrolled salvaging at the working face of the landfill is unacceptable, for both safety and health reasons. It also interferes with the proper operation of the facility, making it difficult to compact and cover waste. This together with the accumulation of recyclable materials also adversely affects the aesthetics of a site. For this reason, the Department would like to prohibit waste reclamation at landfills. However, since landfills do represent an important resource base for a sector of the population, informal salvaging cannot be eliminated. In the National Waste Management Strategy, this dilemma has been identified as a Key Issue. The view at the time of writing was that until informal salvaging can be eliminated, it should be discouraged, formalised and controlled, to minimise safety and health risks.

Discouraging salvaging at the working face

Once salvaging takes place at a landfill, it is usually very difficult to eliminate. Any attempts to achieve this, usually involve confrontation and the need for ongoing policing.

Waste recovery at source (i.e. at the waste generator's premises) is the most efficient way of reclaiming from the waste stream. It also provides a means of discouraging salvaging at the workface by reducing the recyclable components within the waste. Waste generators producing reclaimable material should therefore be identified and where possible reclamation should take place before the waste arrives at the disposal site.

Formalisation and control of on-site reclamation

Any waste reclamation operation on a landfill must be formalised and controlled. The activity must therefore be included in the Operating Plan. Where informal salvaging or waste reclamation takes place on a landfill site, the first step in formalising the process would entail the identification of leaders and the formation of a committee with whom to communicate. Thereafter, all reclaimers must be registered and controlled by the leaders or committee, who would be accountable to the Permit Holder. Alternatively, proper contracts can be set up.

Method of controlled on-site reclamation

Waste reclamation and sanitary landfilling are not compatible activities, as reclaimers require access to the waste while sanitary landfilling aims at confining it. Also, having reclaimers working in the vicinity of heavy machinery is unsafe. Waste reclamation must therefore be separated from waste compaction and covering activities.

To achieve this separation, an area can be set aside within the site fence but outside the disposal area. In this area, the public can dispose of bulky wastes such as lounge suites, cupboards and appliances (‘white goods’),

so that waste reclamation can take place away from the disposal operation. Such an area would, however, have to be controlled and unwanted waste would have to be cleared to the landfill on a regular basis, for such an operation to be acceptable.

Where reclamation has to take place on the landfill itself, it must be operated using two working areas or cells. In one, waste can be deposited and spread for reclamation purposes, whilst in the other, waste remaining after reclamation may be compacted and covered. The size of the working areas and the frequency with which they are alternated would depend on numerous factors and would have to be optimised on a site specific basis.

Health and safety aspects

In terms of the Occupational Health and Safety Act, 1993 (Act 85 of 1993), the operator of the landfill is responsible for the safety and well being of the waste reclaimers on the site. The operator must therefore ensure that the reclaimers, as a minimum, wear suitable protective clothing, in particular industrial gloves and boots with protective soles. They should also wear highly visible tunics. If this equipment is provided by the Permit Holder, it could also become an effective means of identification and of ensuring that reclaimers are registered.

Ongoing communication with reclaimers

In order for controlled reclamation to work in an efficient and safe manner, it is essential for the reclaimers to understand and to adhere to the system in operation at the landfill. Regular meetings must therefore be held between the landfill operators and the reclaimers or their representatives, in order to educate them and negotiate with them where applicable. At this forum, health and safety issues should receive the highest priority.

Appendix 11

LANDFILL MONITORING COMMITTEE (Section 11)

During the landfill site selection process, and also the design and commissioning of the facility, Interested and Affected Parties (IAPs) participate by means of a Representative IAP Liaison Committee (RILC) (see Section 4.2 and Appendix 4.1). Once the landfill is established and operating, however, there is the need for a Landfill Monitoring Committee.

The objective of a Landfill Monitoring Committee is to provide a forum for:

Enabling the community to effectively participate in and monitor the operation, rehabilitation, closure and ongoing monitoring of a landfill.
Discussing and addressing the concerns of the community regarding the landfill site, especially those people living in the immediate vicinity.

The Landfill Monitoring Committee would:

Act as a representative of, and official means of communication, with the community.
Act as the 'eyes and ears' of the Department.
Monitor compliance or non compliance to Permit conditions and the Minimum Requirements.
Observe and monitor the impacts of the site on the environment.

The reason for discussing the Committee in this appendix is to:

Facilitate recognition of the Committee as a formal and legitimate structure for Interested and Affected Party (IAP) involvement in the development of a landfill site.
Ensure that Landfill Monitoring Committees function consistently throughout South Africa.

Membership

Voluntary IAPs, including both individuals and representatives of organisations, would have been appointed or elected onto the RILC. These IAPs would usually also become Landfill Monitoring Committee members.

When necessary, further IAPs can be elected or appointed. IAPs, who have not been elected but who are interested in joining the committee or attending meetings, may do so at any time.

It is compulsory that the Permit Holder and officials representing the relevant state, provincial, regional and local government departments be members of the Landfill Monitoring Committee.

Political parties may not be represented and there may be no conflict of interest in the representation of member organisations.

Meetings

The quorum for a meeting should be at least six participants, comprising three from the compulsory member organisations (i.e. the Department, Permit Holder, other) and three from the voluntary membership. If there is no quorum, the meeting should be adjourned for at least 30 days, and notice regarding the details of the meeting should be given to all members of the Landfill Monitoring Committee. In the event that there is no quorum at the adjourned meeting, those present could constitute a quorum.

Matters requiring decision making by means of voting, as well as matters relating to a change in the Terms of Reference may only be dealt with at a meeting where a full quorum is present.

Minutes should be taken at all meetings. These should be written up and circulated to all members.

The Functions of the Landfill Monitoring Committee

The Landfill Monitoring Committee has the following functions:

Monitoring the establishment, operation, rehabilitation and closure of the landfill site.
Reviewing audit results and have it demonstrated that audit recommendations have been implemented within an agreed time frame.
Reviewing monitoring results from ongoing monitoring programmes.
Making recommendations to the Department, the Responsible Person, or any other relevant authority.
Meeting with local, provincial and national government officials, to discuss such issues as nuisances, complaints, landfill conditions or permit compliance.
Requiring that officials provide answers regarding actions taken to address identified problems.
Recommending that conditions be written into the Permit or that changes be made to Permit conditions.
Ensuring that such recommendations are incorporated into the Permit or addressed at the Monitoring Committee meetings.
Holding meetings at which the Permit Holder, the Department, and the IAPs can report back.
Ensuring that report back meetings end in action.
Requesting that special meetings be held for a specific purpose.
Conducting site visits, at least twice a year, and participating in external audits.
Conducting workshops for reporting back to community and re-election of members.
Delegating investigations or discussions to subcommittees - who would then report back.
Receiving information on such issues as environmental impacts or waste disposal practices, so that members are empowered to make decisions regarding the Committee matters.

The Duties of the Landfill Monitoring Committee

Amongst others, the Landfill Monitoring Committee has the duty to:

- Formulate a Terms of Reference and Code of Conduct, under which the Committee can operate. This would address such issues as conduct at meetings or conflict resolution
- Inform the Department of any irregularities and/or problems.
- Inform IAPs of the activities of the Landfill Monitoring Committee at a public information workshop, held at least once a year.

Disseminate information regarding the site and the proceedings of the Committee to the communities they represent.
Keep a record of proceedings and decisions.

Accountability, responsibility and liability of members

All members must act in a responsible manner, and are accountable to society at large.

As the committee is a monitoring committee, and not a management committee, it is not legally responsible for the operations, or the consequences resulting from the operations, of the landfill. Final accountability and responsibility for the landfill lies with the Permit Holder.

Members that have been elected by constituencies are accountable to the constituencies they represent, and are responsible for keeping these constituencies informed of proceedings. As part of ongoing public participation, regular meetings, site visits, workshops and information sessions should be held. These would be organised by the Committee.

Participation by a member in the proceedings of the Landfill Monitoring Committee should not be interpreted as a waiver of such a person's right to challenge any issue pertaining to the site outside the forum of the committee, unless such an issue had already been resolved by consensus on the Committee.

The Department is responsible for the enforcement of legislation pertaining to waste disposal sites, and must take steps to ensure that permit conditions are complied with.

All the proceedings of the Landfill Monitoring Committee must be recorded and made available to the public.

Costs

Reasonable costs incurred for the effective functioning of the Landfill Monitoring Committee would be met by the Permit Holder. These costs would include the cost of the venue, administrative costs, and, where necessary, the costs of a consultant facilitator.

Voluntary members of the Landfill Monitoring Committee would not receive payment for their services on the Committee.

GLOSSARY

The language used in this document is generally colloquial English. However, the meaning of terms may vary in different contexts and terms may also have scientific connotations. The following list therefore defines, in colloquial terms, certain terminology as it is used in the context of this document.

Ambient Background: Ambient background water quality refers to surface water sampled upstream or ground water sampled upgradient of a landfill site. In both cases, these samples reflect water that has not been contaminated by leachate from the landfill.

Aquifer: Water-bearing strata of fractured or permeable rock, sand or gravel. When capable of sustaining community water or other needs, such strata may be considered to represent strategic water resources, requiring protection from pollution (see also *Minimum Requirements for Monitoring at Waste Management Facilities*).

Attenuation: In this context, attenuation is the process of reducing leachate concentrations by means of natural physical, chemical and biochemical processes such as dilution, oxidation and cell synthesis. Natural systems have an attenuation capacity which may render small volumes of contaminants (leachate) insignificant. However, when this capacity is exceeded, pollution results.

Audit Team: Those who attend the audit or site inspection and assist in compiling the audit report.

Audit: A site inspection at which the condition of the site on that day is appraised in terms of a number of predetermined criteria.

BATNEEC: Best Available Technology Not Entailing Excessive Cost. The term ‘Best Available’ implies technology that is proven, accepted and accessible. ‘Technology’ refers to the process itself and how the process is implemented (including management). "Excessive cost" is cost effective in the context of the specific operation.

Bill of Quantities: This is a list of the tasks involved and an estimation of the quantities of the materials needed for the construction of elements of the landfill design.

BPEO: Best Practicable Environmental Option. BPEO is the outcome of a systematic consultative and decision-making procedure that emphasises the protection of the environment across land, air and water. It establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole at acceptable cost in the long term and as well as the short term.

Buffer Zones: Buffer zones are separations between the boundaries of registered landfill sites and residential developments. They may vary between 500m and 1000m in width, depending on the classification of the landfill. No residential development may take place within a proclaimed buffer zone. At the discretion of the local authority and the state departments, however, developments such as industrial development may be permitted.

Cell: This is the basic landfill unit of compacted solid waste which, when completed at the end of

each day, is entirely contained by cover material. The sides may be typically formed by 1,5m to 2,0m high soil or rubble berms, or sloped covered waste. Cell width is determined by the manoeuvring requirements of vehicles depositing waste at the working face.

Channelling: This is a term used to describe the rapid flow of water through a waste body via preferential conduits or paths of least resistance. Channelling results in the early formation of low concentrate leachate prior to the waste body reaching its field capacity.

Climatic Water Balance: The Climatic Water Balance refers to a simplified calculation, involving only figures for precipitation and pan evaporation, obtained from published data. It is used only to indicate the climatic conditions under which leachate management is needed, on account of the generation of **significant leachate**. Where no **Site Specific Factors** such as high moisture content waste and ingress of ground or surface water exist, the Climatic Water Balance coincides with the Site Water Balance. (See **Site Water Balance** and **Water Balance**.)

Closure: The act of terminating the operation of a landfill. Closure is preceded by rehabilitation and followed by end-use and post-closure monitoring.

Closure Requirements: Those measures that must be taken to address problem areas and to render a landfill environmentally acceptable once it is closed.

Co-Disposal (General with Hazardous waste): The mixing and joint disposal of Hazardous (**H**) and General (**G**) waste in the same landfill. The co-disposal of general waste with hazardous waste as a means of facilitating disposal on a hazardous waste landfill is acceptable, whereas the co-disposal of any significant quantity of hazardous waste with general waste on a general waste landfill is unacceptable.

Co-Disposal (Liquid with Dry waste): The mixing of high moisture content or liquid waste with dry waste. This affects the water balance and is an acceptable practice on a hazardous waste landfill site. This is only acceptable on a general waste landfill site when the liquid is not hazardous and the site is equipped with leachate management measures.

Co-Disposal Ratio: This indicates the volumetric ratio of compacted solid waste to liquid waste. The co-disposal ratio is linked to the Water Balance and is site specific. The co-disposal ratio must be such that no more than 200mm/year of leachate is generated at a given site, there are no free liquid surfaces and the fill is trafficable.

Community: The people living in the vicinity of a proposed, planned or developed activity.

Compaction: The process whereby the volume of waste is reduced, using a purpose built compactor or other suitable machine.

Composite Liner: An assembled structure of geosynthetic materials and low permeability earth materials (clay or benotinite), placed beneath a landfill to form a barrier against the migration of leachate into the underlying soils and ground water.

Concept Permit: Any landfill permit issued before the promulgation of the Environmental

Conservation Act, 1989 (Act 73 of 1989). Concept permits require upgrading to full permits (see **Permit.**)

Conceptual Design: A design that addresses the principles of the intended design, but does not include detailed specifications.

Containment: The separation of the waste body and any associated leachate from the underlying soil, rock and water regime, by means of a liner and a leachate collection system.

Contaminate: The addition of foreign matter to a natural system. This does not necessarily result in pollution, unless the attenuation capacity of the natural system is exceeded.

Cover: The material used to cover waste. Cover material is usually soil, but may comprise builders' rubble, ash or other suitable material. Daily cover is usually 150mm thick, intermediate cover is usually 300mm thick and final cover or capping is usually 500mm thick. Final cover may form part of a special capping design and, as is the case with intermediate cover, must be able to support vegetation.

Critical Factor: A factor which potentially represents a severe constraint on the development or ongoing operation of a landfill. Such factors require further investigation. If a critical factor cannot be satisfactorily addressed, it may become a Fatal Flaw.

Delisting: The reclassification of a hazardous waste for disposal on a lower class of landfill. This would only be allowed by the Department, based on proof of low mobility or concentration, or proof of successful treatment to render it less hazardous.

Detection Monitoring: This is routine water monitoring carried out bi-annually, using a limited number of indicator parameters, with a view to indicating pollution from the landfill.

Development Plan: A plan indicating the phasing of the development of a landfill from the landfill preparation, through the operation (which is usually divided into areal phases), to the final closure, rehabilitation and end-use. The phasing, and hence the Development Plan, forms part of the design.

Duty of Care: This requires that any person who generates, transports, treats or disposes of waste must ensure that there is no unauthorised transfer or escape of waste from his control. Such a person must retain documentation describing both the waste and any related transactions. In this way, the person retains responsibility for the waste generated or handled.

Encapsulation: The procedure for disposing of hazardous wastes not suitable for direct landfilling. This procedure involves the isolation of the wastes in sealed, reinforced concrete cells or capsules. The capsules are then located in a demarcated area of an **H** class site.

End-use Plan: The purpose for which the area of the rehabilitated and closed landfill is used. This may be as a park, playing fields, or other suitable land-use.

End-use Requirements: These are the measures required to upgrade or rehabilitate a landfill site to render it suitable for the proposed end-use.

Engineered Cell: A cell which is designed and engineered to contain hazardous waste. It is underlain by a liner to prevent the waste or the leachate from the waste coming into contact with the environment.

Environment: Environment is defined as i) the natural environment, consisting of air, water, land and all forms of life, ii) the social, political, cultural, economic and working context and other factors that determine people's place in and influence on the environment, and iii) natural and constructed spatial surroundings.

Environmental Impact Assessment (EIA): An investigation to determine the potential detrimental or beneficial impact on the surrounding communities, *fauna*, *flora*, water, soil and air, arising from the development or presence of a landfill.

Environmental Impact Control Report (EICR): A report which details how any detrimental impacts, identified in the Environmental Impact Assessment, can be prevented or ameliorated by means of landfill site design and operation.

Fatal Flaw: A factor or situation which prevents the development of an environmentally acceptable waste disposal facility, except at prohibitive cost.

Finger drain: A simple open drain within zones of selected free draining waste, initially placed in the invert of the landfill cell, for the purpose of leachate detection and collection.

Flag: A symbol which draws attention to an aspect of investigation, design or operation that requires special attention by a recognised expert.

Flexible Membrane Liner (FML): (see **Geomembranes**).

General Waste: Waste that does not pose an immediate threat to man or the environment, i.e. household waste, builders' rubble, garden waste, and certain dry industrial and commercial waste. It may, however, with decomposition, infiltration and percolation, produce leachate with an unacceptable pollutionpotential (see **Waste**).

G Landfill: A landfill designed to accept only general waste. Depending on the Site Water Balance, it may or may not have a leachate management system.

Geomembranes: Very low permeability synthetic membrane liners and barriers used with any geotechnical engineering-related material so as to control fluid migrations in a man-made project, structure or system. Synthetic membranes include flexible membrane liners (FMLs).

Geosynthetic Clay Liner (GCL): A manufactured composite barrier system comprising of layers of clay materials (e.g. bentonite) and geosynthetic materials (e.g. geotextiles and/or geomembranes) to form a single sheet for use as a liner.

Geotextile: A permeable, polymeric, woven, non-woven or knitted material used in geotechnical and civil engineering applications. A cloth or felt made of natural or synthetic fibres and designed to act as a drainage or filtration element.

Ground Water: Water occupying pores in the soil and cavities and spaces in rocks in the saturated zone of the profile. This water may rise from a deep, magmatic source or be due to the infiltration of rainfall (recharge).

Guideline: While not requirements, guidelines are recommended actions which represent good practice. They are not enforceable, but may form the basis for site specific permit conditions in which case they become mandatory.

Hazard Rating: A system for classifying and ranking hazardous wastes according to how great a hazard they present. This is based on Mammalian Acute and Chronic Toxicity, Ecotoxicity and Environmental Fate. Based on this, Hazardous Waste is classified into: Hazard Rating 1: Extreme Hazard; Hazard Rating 2: High Hazard; Hazard Rating 3: Moderate Hazard; and Hazard Rating 4: Low Hazard. [**Ref.** Department of Water Affairs and Forestry: *Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste,* Pretoria, 1993].

Hazardous Waste: Waste, other than radioactive waste, which is legally defined as hazardous in the state in which it is generated, transported or disposed of. The definition is based on the chemical reactivity or toxic, explosive, corrosive or other characteristics which cause, or are likely to cause, danger to health or to the environment, whether alone or when in contact with other waste. *After UNEP definition* (see **Waste**).

Hazardous Waste (alternative definition): Waste that may, by circumstances of use, quantity, concentration or inherent physical, chemical or infectious characteristics, cause ill-health or increase mortality in humans, fauna and flora, or adversely affect the environment when improperly treated, stored, transported or disposed of (see **Waste**).

Hazardous Waste Landfill: A containment landfill, designed specifically for the disposal or co-disposal of hazardous waste.

HELP: The Hydrological Evaluation of Landfill Performance - computer model.

Initial Rate of Deposition (IRD): The initial waste stream ordeposition rate for a landfill site, expressed in T/day, for a 260 day year (see **Maximum Rate of Deposition**).
Integrated Environmental Management (IEM): A management approach designed to ensure that the environmental consequences of development proposals are understood and adequately considered in the planning process.

Interested and Affected Parties (IAPs): Interested and Affected Parties are those people who will be affected in some way by the development of the proposed landfill. They may be represented by adjacent residents or farmers, a residential community, the public at large or local, provincial and national government forums.

Investigative Monitoring: Investigative water quality monitoring is monitoring which uses an extended range of parameters in order to investigate any leachate pollution identified by Detection Monitoring.

Lagoon: A lagoon is a lined dam constructed to contain liquid waste.

Landfill (v): To dispose of waste on land, whether by use of waste to fill in excavations or by creation of a landform above grade, where the term 'fill' is used in the engineering sense.

Landfill (n): The waste body created by landfilling. This may be above or below grade, or both.

Landfill Development Process: This is the development of a landfill from its inception or siting, through its investigation, design, permitting, preparation, commissioning, operation, closure and end-use. Monitoring takes place throughout the above process and may continue for up to 30 years after closure.

Landfill Methods:

Area Method:
A method whereby non-putrescible waste is spread in layers not exceeding 0,5m in thickness. This method does not provide maximum compaction, but does have an application in certain industries.

End Tipping:
The practice of tipping or pushing waste over the edge of an extended slope and thus extending the landfill laterally. This is unacceptable in most operations, as little or no waste compaction is achieved. The resulting slopes are thus frequently unstable and subject to burning.

Ramp Method:
The practice of working waste up a 1 in 3 slope in thin layers not exceeding 0,5m in thickness. This is consistent with sanitary landfilling, using cells. Maximum compaction is achieved by passing over the waste at least five times with a purpose built landfill compactor.

Landfill Operation Monitoring: The auditing and assessing of a waste disposal operation to determine whether it conforms to the site design and to the Minimum Requirements.

Leachate: An aqueous solution with a high pollution potential, arising when water is permitted to percolate through decomposing waste. It contains final and intermediate products of decomposition, various solutes and waste residues. It may also contain carcinogens and/or pathogens. (Sporadic/Significant)

Leachate Detection System: A system for detecting leachate at **B**$^{-}$ landfills. It comprises rudimentary liners, sloped towards 'finger drains' at the lowest point of the landfill.

Leachate Management: The collection and drainage of leachate to a point where it can be extracted for treatment. This requires a system of under-drains and liners and, in certain instances, is synonymous with containment.

Lift: A series of adjoining cells of the same height, and at the same level, in a landfill.

Liner: A layer of low permeability material placed beneath a landfill and designed to direct leachate to a collection drain or sump, or to contain leachate. It may comprise natural materials, synthetic materials, or a combination thereof (see also **FML** and **Geomembranes**).

Maximum Rate of Deposition (MRD): The projected maximum rate of waste deposition during the expected life of a landfill, expressed in T/day, for a 260 day year (see **Initial Rate of Deposition**).

MCCSSO: A standard system of soil profiling, which describes the soil in terms of Moisture, Colour, Consistency, Structure, Soil type and Origin.

Medical Waste: Wastes emanating primarily from human and veterinary hospitals, clinics and surgeries, also from chemists and Sanitary Services. They may comprise, *inter alia*, sharps (used hypodermic needles and scalpel blades), malignant tissue, body parts, soiled bandages and liner, and spent or outdated medicines or drugs. They have the ability to affect and infect other living organics, and are considered hazardous.

Minimum Requirement: A standard by means of which environmentally acceptable waste disposal practices can be distinguished from environmentally unacceptable waste disposal practices.

Mitigate: To reduce an impact to meet the objectives of a Minimum Requirement.

Mono-landfill: A landfill that accommodates one type of waste.

Monitoring: The process of checking for changes in status or trends over time. This may be achieved by compiling successive *audit* or *water quality* analyses results.

Monitoring Committee: A committee comprising the Permit Holder or his or her authorised representatives (*Responsible Person)*, the Department and IAPs. The function of the Monitoring Committee is to monitor the operation of the landfill and to disseminate information to relevant people e.g. the public.

Operating Plan: A site-specific document which describes the way in which the landfill is operated. The Operating Plan commences at the level and detail of daily cell construction and continues through to the development and excavation sequence, access and drainage within a given phase of the Development Plan.

Outflow Rate: The rate at which leachate will pass through a liner, taking account of the head of leachate likely to accumulate over the liner. Outflow rate is measured in m^3/year, m^2/year or m/year.

Permeability (Primary): The rate per unit area at which fluid will pass through a porous material under a unit flow gradient. The constant of proportionality K in Darcy's Law is the permeability and is measured in m/year or cm/sec, which is synonymous to hydraulic conductivity.

Permeability (Secondary): The rate per unit area at which fluid will pass through macro features of a soil such as paleo-root canals, termite tunnels and rodent burrows, under unit flow gradient.

Permit: The Permit issued by the Departmentfor the operation or closure of a landfill, in terms of Regulation 1549, promulgated under the Environmental Conservation Act, 1989 (Act 73 of 1989) (see **Concept Permit**).

Permitting: The act of issuing a Permit.

Permit Holder: The person who, having obtained a Permit to operate a waste disposal site, in terms of Section 20(1) of the Environmental Conservation Act, is legally responsible for the site, both during operation and after closure.

Permit Procedure: The procedure to be followed and the necessary investigations to provide the Department with the necessary information so that a Permit can be issued.

Phreatic Surface: A surface defined by the levels at which the ground water will come to rest in a series of boreholes drilled in an area. The surface indicates the levels at which the pressure in the ground water is atmospheric.

Precautionary Principle: Where a risk is unknown; the assumption of the worst case situation and making provision for such a situation.

Pre-disposal background: This is water quality monitoring which takes place before a landfill is commissioned and thus reflects the pollution status of the water regime prior to waste disposal. This monitoring includes upstream and downstream surface water, as well as upgradient and down gradient ground water. It may be used as a datum against which to compare all future water quality.

Rehabilitation: The restoration of a landfill site to a state which is publically and environmentally acceptable, and which is suitable for the implementation of the agreed End-use Plan.

Remediation: The rectification of problems, caused by bad practices, through the implementation of remedial measures.

Response Action Plan: A plan intended to counter or minimise the adverse effects of any malfunction of a landfill design element with immediate effect. A Response Action Plan is usually associated with the disposal of Hazardous waste.

Responsible Person: The Permit Holder or his legally appointed representative who takes responsibility for ensuring that all or some of the facets of any of the following are properly directed, guided and executed, in a professionally justifiable manner: investigatory work, design, preparation, operation, closure and monitoring.

Risk: The probability of dangerous substances contained in the waste, leached therefrom, or released by emission, entering into the air, the surface environment or the water regime in unacceptable quantities or concentrations. The consequences of such occurrences could be manifested as a threat to public health or as the impairment of an eco-system or resource.

Risk Assessment: The identification of possible impacts of a landfill on the environment so that they can be addressed in the design.

Sanitary Landfilling: A method of disposing of waste on land without causing nuisances or hazards to public health or safety. Sanitary landfilling uses the principles of engineering to confine the waste to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operations or at such less frequent intervals as may be acceptable.

Saturated zone: The saturated zone is the portion of the soil or rock profile situated below the phreatic surface. In this zone, the soil pores are filled with water, as opposed to those in the unsaturated zone, where the pores are filled with gas and water (see **unsaturated zone**).

Shear strength: The shear strength of a soil (or waste) is the sum of the frictional resist1ance between the soil grains (or particles of waste) and the cohesion imparted by the finer fractions (clay and silty)

Significant: Factors or considerations are termed significant when they are important, because they are of consequence. For example, they will have a detectable influence on a process, the environment, or the end result.

Significant leachate generation: Seasonal or continuous leachate generation resulting mainly from climate and/or waste moisture content. In the case of existing landfills, significant leachate generation may also result from poor site selection and/or design. It is essential that significant leachate generation be managed by means of leachate collection and treatment if water pollution is to be avoided.

Site Specific Factors: Factors peculiar to a specific site that must be takin into consideration when applying the Minimum Requirements.

Site Water Balance: The water balance of the landfill. The site water balance will be affected by ambient climatic conditions and by site specific factors such as the moisture content of incoming waste, landfill siting and site drainage (see **Water Balance**).

Sporadic leachate generation: Leachate generation resulting from abnormal circumstances, e.g. excessively wet periods, the temporary deposition of wet or saturated waste, or poor site drainage (where this can be remedied). Sporadic leachate generation is not considered to warrant the provision of a leachate management system.

Standard: A measure by which the accuracy of quality of others or degree of excellence is judged, or a model for imitation. (Not used in legal sense.)

Surface water: Water (usually rainfall) which flows across the ground surface towards and in man made and natural drainage features such as drains, rivers, streams, lakes and ponds.

Technical Design: The Technical Design is based on the Conceptual Design. It includes detailed specifications of materials, measurements and procedures, as well as detailed drawings.

Unsaturated Zone: The unsaturated zone, also referred to as the vadose zone, is the portion of the soil or rock profile situated above the phreatic surface. In this zone, the soil pores are filled with gas and water, as opposed to those in the saturated zone, where pores are filled with water (see **saturated zone**)

Waste: An undesirable or superfluous by-product, emission, or residue of any process or activity which has been discarded, accumulated or stored for the purpose of discarding or processing. It may be gaseous, liquid or solid or any combination thereof and may originate from a residential, commercial or industrial area. This definition excludes industrial waste water, sewage, radioactive substances, mining, metallurgical and power generation waste. *After definition in Government Gazette No. 12703, August 1990*. (See **General Waste** and **Hazardous Waste**).

Waste Body: This refers to the body of waste (and cover) that is contained in the landfill. Because it is subject to decomposition, it has the potential to generate leachate and must therefore be adequately separated from the water regime.

Waste Load Allocations: This term refers to volumes of hazardous waste permitted on certain landfills. Such allocations are calculated taking both the nature of the waste and the specific site characteristics into account. [**Ref.:** Department of Water Affairs and Forestry: *Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste*, Pretoria, 1993].

Waste Disposal (v): The act of disposing of waste. In the context of this document, only waste disposal on land is addressed.

Waste Disposal Site: In the context of this document, a waste disposal site is referred to as a landfill, because the vast majority of all waste is ultimately disposed of on land, whether it be in trenches or other excavations, or above grade.

Water Balance: In the context of this document, the term Water Balance refers specifically to the water balance within the landfill system, i.e. total inputs equal the total outputs plus the moisture stored in the landfill. Inputs may include precipitation, moisture inherent in incoming waste, run-off, surface water and ground water. Outputs may include evaporation, transpiration and leachate. Water may also be stored within the landfill and augmented by water generated from bio-chemical reactions. All these factors would have to be taken into account in a classical Volumetric Water Balance Calculation (see **Climatic Water Balance** and **Site Water Balance**).

White Goods: Bulky waste such as old washing machines, fridges and stoves.

Working Face: The active part of the landfill; where waste is deposited by incoming vehicles, then spread and compacted on the sloped face of the cell by a compactor. The width of the working face is determined by manoeuvring requirements of the vehicles depositing waste.

REFERENCES

Constitution of the Republic of South Africa, 1993 (Act 200 of 1993).

Council for the Environment: *Integrated Environmental Management in South Africa*, Joan Lötter

Department of Environmental Affairs and Tourism: *Guideline Document, EIA Regulations, Implementation of Sections 21, 22 and 26 of the Environment Conservation Act*, Pretoria, 1998.

Department of Water Affairs and Forestry: *Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste*, Pretoria, 1998.

Department of Water Affairs and Forestry: *Minimum Requirements for Monitoring at Waste Management Facilities*, Pretoria, 1998.

Department of Water Affairs and Forestry: *Waste Management Legislation Procedures and Guidelines*, Pretoria, 1990.

Department of Water Affairs and Forestry: Hydrological Information Publication No. 13: *Evaporation and Precipitation Records*.

Department of Environment Affairs: *The Integrated Environmental Management Procedure*, Pretoria, 1992.

Figures 7, 8 and 9 are based on the USEPA document: EPA/540 - *Human Health Manual*, Volume 1, "Risk Assessment Evidence for Superfund", 1989.

Government Gazette, No. 15529, pg 67, Notice 171 of 1994, 4 March 1994.

Government Gazette, No. 9225, 18 May 1984.

Jennings, J.E., Brink, A.B.A. and Williams, A.A.B., "Revised Guide to Soil Profiling for Civil Engineering Purposes in South Africa", Civil Engineer S.A., Vol. 15, 1973.

Lamb, T.W. and Whitman, R.V. *Soil Mechanics*, (Wiley), New York, 1968.

Mills, C.A., & Ball J., "Trends in the Use of Geophysical Techniques in the Assessment of Waste Disposal Sites", *Proceedings of the IWM International Conference: WasteCon '92, Rand Afrikaans University,* Johannesburg, November 1992.

Parsons, R. and Jolly, J. The Development of a Systematic Method for Evaluating Site Suitability for Waste Disposal Based on Geohydrological Criteria. *WRC Report 485/1/94, Water Research Commission,* Pretoria, 1994.

SAICE: *Guidelines for Public Participation in the Planning of Civil Engineering Projects*, Environmental Engineering Division, Johannesburg, August 1993.

SAIEG Sub-Committee for Standardised Percussion Borehole Logging: *Ground Profile No. 59*., July 1989.

Schroeder, P.R., *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Version 2,* Source Code, Vicksburg, Mississippi, 1989.

Standards Act, Act 30 of 1982.

The American Society of Civil Engineers (ASCE): *Sanitary Landfill Manual of Practice,* 1959. Original definition.

USEPA document: EPA/540 - *Human Health Manual,* Vol 1, "Risk Assessment Evidence for Superfund", 1993.

Weaver, J.M.C., *Groundwater Sampling*, Water Research Commission Project No. 339 TT 54/92.

RECOMMENDED READING

U.K., Department of the Environment, Waste Management Paper No. 26B, *Landfill Design, Construction and Operational Practices*, HMSO Publications, 1995.

U.K., Environmental Agency, Waste Management Paper No. 26E, *Landfill Restoration and Post Closure Management, Consultation Draft*, August 1996.

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