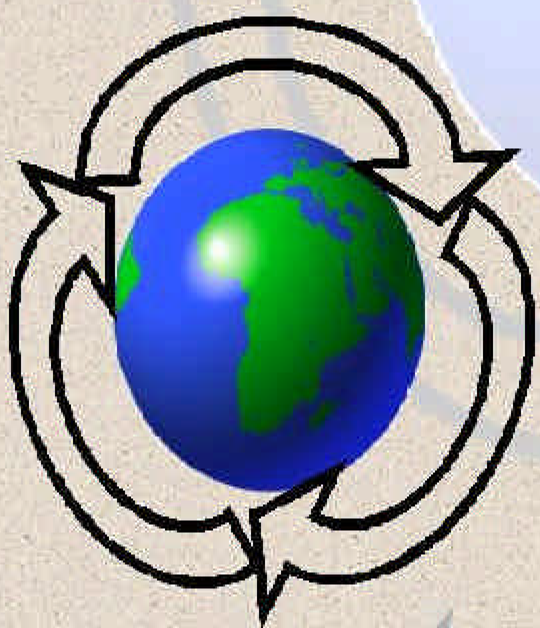
MINIMUM REQUIREMENTS FOR WATER MONITORING AT WASTE MANAGEMENT FACILITIES



waste management series

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Second Edition 1998

MINIMUM REQUIREMENTS FOR WATER MONITORING AT WASTE MANAGEMENT FACILITIES

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

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, General or Hazardous, 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 hazard rating of 3 or 4 are of moderate or low hazard. The requirements for pre-treatment and disposal are appropriately set in accordance with the waste classification. Hazardous waste prevention and minimization 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 Water Monitoring as Waste Management Facilities*****, addresses the monitoring of water at and around waste disposal facilities.**

The Department 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 and Forestry, the Department of Environmental Affairs and Tourism, and funded by the Danish Cooperation 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 include Minimum Requirements for waste disposal site auditing, and the training of operators and managers of waste management facilities.

PREFACE

This document has become necessary in view of the deteriorating groundwater quality at many waste management facilities in South Africa. In terms of the Reconstruction and Development Programme of the Government, supply of water of acceptable quality is one of the cornerstones. Knowledge of water quality distribution and protection of our water resources can only be accomplished through a comprehensive and standardized monitoring programme. It is the intention for this document to provide the framework within which this can be accomplished.

The Department of Water Affairs and Forestry considers monitoring as a requirement for Environmental Impact Assessment, which in turn is an important component in the Integrated Environmental Management Procedure for the establishment of waste management facilities.

This document is a practical manual on "minimum" requirements for monitoring at waste management facilities. The term "minimum" refers to the lower limit that must be complied with. "Monitoring" refers to the meaningful measurement of a variable(s) on a once-off basis during initial impact assessments, or on a routine basis thereafter.

It is likely that the minimum monitoring requirements stipulated in this document will be surpassed in many instances. The waste manager should bear in mind that at all waste sites, the norm should be "to conduct sufficient investigations and monitoring, to understand the short-, medium- and long-term impact that waste management may have on the groundwater regime".

This document is one of a series. The other two documents in this waste management series deal with the management and disposal of General and Hazardous waste.

Monitoring procedures to be followed are recommended in this document. These procedures are not necessarily the only ones acceptable, but experience has shown that they work well.

Deviations from recommended procedures should be cleared with the Department of Water Affairs and Forestry.

Implementation of the Minimum Monitoring Requirements is possible under existing legislation. Co-operation between companies that handle waste and relevant governmental departments is essential. Public involvement and participation is crucial in acceptance and implementation of these requirements.

Appeal against compliance with the minimum monitoring requirements, based on sufficient motivation, will be considered in instances of specific merit. Application, after a risk assessment has been made, may be made to the Department of Water Affairs and Forestry.

In conclusion, the comment received on these minimum requirements is highly valued, as its inclusion has improved and augmented the contents 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

Groundwater is a limited and strategic resource in South Africa. It must therefore be protected from undue contamination. Protection of water resources requires systematic and organized monitoring. This document “Minimum Requirements for Water Monitoring at Waste Management Facilities”, is an attempt to:

- Standardize monitoring procedures.
- Provide specifications for monitoring design.
- Provide mechanisms for communication between waste management companies and authorities.

In the compilation of this document, the unique nature of the South African situation has been considered. Throughout this document, the emphasis is on what could reasonably be achieved, without compromising on information that would lead to early detection of water pollution.

All procedures recommended in this document are essentially standard practice in South Africa. Waste Management Companies should therefore be familiar with the necessary procedures and requirements and should not have serious difficulties in complying with such monitoring. In instances where the Department has issued waste management permits, such as for general and hazardous waste, the reporting mechanism to the Department has been established. In other situations, such as mining for instance, reporting is through existing mechanisms, such as their Environmental Management Programme Report (EMPR).

The installation of groundwater monitoring systems requires specialized knowledge, and consultation with an appropriately qualified geohydrologist is a requirement.

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GLOSSARY FOR DOCUMENT TITLE

Several terms, mainly relating to the title of this document, need clarification.

Minimum requirement
The lower limit which must be complied with. The right to appeal against compliance with the prescribed minimum requirements, based upon sufficient motivation, exists.

Monitoring
The meaningful measurement of a variable(s) on a once-off basis during initial impact assessments, or on routine basis.

Compliance monitoring
Monitoring done in compliance with permit conditions.

Geohydrological investigation
Investigation of the groundwater system on a once-off basis, probably as part of a wider impact assessment, or routine monitoring.

Waste Management Facility
All wastes or products stored on a temporary or permanent basis, that could impact on surface or groundwater quality, by leaching into or coming in contact with water, are referred to a "Waste Management Facilities". See also the Waste Management Documents, "Minimum requirements for waste disposal sites" and "Minimum requirements for the handling and disposal of hazardous waste".

Managerial information
Information generated during monitoring at a waste management facility for the purpose of defining a management strategy, for measuring performance or for use in mitigation.

Monitoring facilities for recording variables, thus facilitating the comprehensive description of the area monitored, in terms of time, space and variables recorded. *Monitoring networks must extend beyond zones of impact.*

ACKNOWLEDGEMENTS

Apart from having received contributions from representatives on the Steering Committee and their organizations, this document has been circulated as widely as possible, to ensure general acceptance within the waste and geohydrological community. All contributions received are hereby gratefully acknowledged.

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Representatives of the following organizations were invited to form part of the Second Edition Steering Committee. However, they were either unable to attend or elected, at this stage, to partake 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 Network Forum (EJNF) . Earth Life Africa (ELA)
Parks Board Environmental Affairs
South African National Civics Organization (SANCO)

Section 1

BACKGROUND INFORMATION

1.1 Introduction

Monitoring the effect that waste management facilities have on the water quality of surface and groundwater resources is a complex and multi-disciplinary task. Numerous methodologies exist for monitoring of this kind. Facilities required for a specific situation will depend on the:

- Type of waste
- Amount of waste
- Potential for leachate formation
- Vulnerability of groundwater resources
- Potential for groundwater usage

South African groundwater systems differ in many ways from those overseas. Monitoring methodologies and requirements that have been developed overseas do not necessarily apply to the South African situation. This could lead to confusion and result in unnecessary expenditure. To ensure co-ordinated and meaningful water quality monitoring in South Africa, a re-evaluation of the situation has become necessary.

The departure point in this document is on "what could reasonably be achieved", considering the uniqueness of the South African situation in the general and specific sense. The principle of "batneec" (best available technology, not entailing excessive cost) is subscribed to throughout this document. Consideration is also given to existing policy documents by governmental departments. Examples of the latter are the Environmental Conservation Act, Act 73 of 1989, dealing with general and hazardous waste and activities under the EIA regulations, the EMPR (Environmental Management Programme Report) of the mining industry, the Water Services Act, Act 108 of 1997 and the National Water Bill of 1998.

It stands to reason that the contents of this document will have to be upgraded as new policy documents become available, or as monitoring techniques improve. For that reason, this document has been structured in a modular fashion and sections can easily be upgraded or replaced.

Many of the requirements as specified in this document deviate from those stipulated in classic textbooks. These deviations do not contradict well-established methodologies, but modifications have been introduced in accordance to the "batneec" principle of South African conditions. This should not deter those who want to follow more stringent procedures from doing so.

This is a grass roots level document. Apart from listing monitoring requirements, the intention is to explain:

- Groundwater behavior
- Reasoning behind monitoring
- Principle of risk assessment
- Installation of a monitoring system
- Principles of water sampling
- Principles of indicator variables
- Principles of data evaluation.

Much of the information contained in this document is therefore of an informatory nature. Only items that have been printed in *Italics* are actual minimum requirements or definitions which relate to requirements.

Section 2

POLICY AND STRATEGY FOR GROUNDWATER QUALITY MANAGEMENT IN THE RSA

2.1 Mission and policy goals

The Department's water quality management policy serves both surface and groundwater resources. The special nature of groundwater dictates a more specific resolution of the mission and strategic objectives of the resource. The Department has thus adopted the following mission for groundwater quality management:

To ensure that groundwater quality is managed in an integrated and sustainable manner that provides adequate protection to the resource and secures the supply of acceptable quality for all recognized users.

The emphasis that is placed on the protection of the groundwater quality management mission is significant and reflects the recognition of the vulnerability of the resource. This mission is underpinned by three policy goals. These are as follows:

- To minimize, at source, the impact of development on groundwater quality by the imposition of regulating controls and incentives.
- To manage such impacts as do inevitably occur in such a manner to at least ensure fitness for use of groundwater by recognized beneficial users.
- To restore groundwater quality, where practicable to at least fitness for use by recognized beneficial users.

The three policy goals, when achieved together, will on the one hand achieve fitness for use and on the other ensure that degradation of groundwater quality which can reasonably be prevented does not occur.

The groundwater quality management goals can only be achieved if management of groundwater quality is integrated with surface water quality management. Water quality management is in turn an integral part of water resource management.

2.2 Groundwater Quality Management Policies

The Department intends implementing a differentiated approach to the protection of groundwater quality. This means, in practice, that the relatively stringency and acceptable risk levels for impact minimization measures that will be required for potentially polluting sources will depend on the nature of the affected resource.

The approach will be based on the country's groundwater resources firstly in terms of importance and secondly in terms of vulnerability. This classification will provide the basis for the implementation of differentiated source-based regulatory controls.

Groundwater resources which represent the only source of water for communities will be afforded special status and will enjoy the highest level of protection.

In order to conserve limited manpower and capacity, regulatory controls will be focused on those activities that represent the most significant threat to the groundwater resources of the country. These activities include:

- Groundwater abstraction and dewatering.
- Disturbance and damage to aquifers.
- Waste disposal from urban, commercial farming, industrial and mining sectors.
- Diffuse sources of pollution associated with urban and rural development specifically around boreholes.
- Underground storage tanks.

In those instances where groundwater quality deterioration is inevitable, such as where mines locally depress groundwater levels or affect water quality, the Department will only allow such impacts if the proponent has exhausted all reasonable options to avoid the impact and where the rights of the other water users will not be affected.

The Department will only intervene directly to control abstraction and dewatering where appropriate. The utilization of groundwater for private domestic consumption and agricultural purposes will not specifically be controlled unless community interests are at stake.

2.3 Aquifer Classification

In order to apply its policy of differential protection to aquifers, the Department has developed a classification scheme for South African Aquifers.

This scheme recognizes:

- The high value of sole-source aquifers in South Africa.
- The need for a pragmatic approach which allows for site-specific factors to be considered.

It is important to note that the concepts of Major, Minor and Poor Aquifers are relative and that yield is not quantified. Within any specific area, all three classes of aquifers should therefore, in theory, be present. In the siting of new waste facilities, a geohydrological map will be required to distinguish between aquifer regions. A proposed new waste site must be within a Poor Aquifer Region.

This classification system is included below:

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 region	High-yielding aquifer of acceptable quality water
Minor aquifer region	Moderately yielding aquifer of acceptable quality or high yielding aquifer of poor quality, or aquifer which will never be utilized for water supply and which will not contaminate other aquifers.
Poor aquifer region	Insignificantly yielding aquifer of good quality or moderately yielding aquifer of poor quality, or aquifer which will never be utilized for water supply and which will not contaminate other aquifers.
Special aquifer region	An aquifer designated as such by the Minister of Water Affairs, after due process

It is a requirement that all future waste facilities be sited on Poor Aquifer Regions. In the event that this is not possible, a risk assessment and extensive motivation should be submitted to the Department of consideration.

Section 3

SOUTH AFRICAN AQUIFERS

A basic understanding of the nature and occurrence of groundwater in South Africa aquifers is a prerequisite for the design of monitoring systems at waste management facilities. This chapter provides a general introduction on the topic.

3.1 Aquifer types

Definition: An aquifer is an underground formation, capable of yielding sustainable amounts of water for the potential user(s) thereof. No upper or lower limit is placed on the aquifer yield. In the wider definition, an aquifer only becomes a groundwater resource once it is tapped.

Three types of aquifers are generally recognized, namely porous flow aquifers, fracture flow aquifers and dolomitic (karst) aquifers.

3.1.1 Porous aquifers (Primary aquifers)

Only about 10% of the South African aquifers are of the type where porous flow is the dominant flow mechanism. In these instances, flow is around grains of sand and clay, which make up the aquifer. Examples of such aquifers are:

- Coastal sands, gravels and other unconsolidated material along the South African coast, such as those along the west coast at Port Nolloth, Doringbaai, Lambertsbaai, Langebaan, Atlantis, Cape Flats, Gansbaai, Bredesdorp, Stilbaai, Alexandria, Kenton On Sea, Boesmansriviermond, Kidds Beach and Richards Bay (Kok, 1991).

- Sands and gravels along stream beds, such as those along the Crocodile and Caledon Rivers, at De Aar, De Doorns, Rawsonville, Pietersburg, Messina and Makatini Flats.

Typical characteristics of porous flow aquifers are:

- They are usually shallow unconfined systems and the groundwater surface in the aquifer is at atmospheric pressure.
- They mostly consist of unconsolidated material, usually less than 30 metres thick.
- They contain 1 – 20% water by aquifer volume.
- Recharge is commonly a relatively large percentage of the rainfall and may amount to between 15 – 30% of the annual total.
- Geohydrological characteristics of the aquifer do not vary greatly over short distances.
- Contaminant transport through porous flow aquifers is comparatively slow because of the high effective porosity.
- Significant attenuation of pollutants could occur within the clayey portion (matrix) of the aquifer, where present.
- Borehole yield from porous flow aquifers is mainly a function of the clay percentage within the aquifer. The higher the percentage clay, the lower the yield.

3.1.2 Fracture aquifers (Secondary aquifers)

The term, fracture flow, has generally become accepted amongst geohydrologists, for the description of groundwater movement through a variety of secondary structures in rock. Geologically, these structures may be defined as joints, cracks, fractures and faults. In underground mines, water-bearing fractures are also called fissures.

The degree of fracturing of rocks in South Africa is a function of the tectonic history of the rocks, as well as the rock composition. Competent rocks, such as dolerite and quartzite, for instance, fracture more readily than incompetent or ductile rocks, such as dolomite and shale.

The degree of fracturing in an aquifer is not necessarily a measure of the degree to which the aquifer can transmit water. Many of the fractures are tight, because of compression forces acting within the earth’s crust. Usually, at depths deeper than 60 metres below surface, less than 1% of the fractures transmit significant amounts of water. Exceptions occur within quartzintic rocks, where significant yields are possible at greater depths.

Typical characteristics of fracture flow aquifers are:

- These are present as either unconfined or confined aquifers. In the latter instance, the aquifer is overlain by sediments or rock of a confining nature, thus limiting direct recharge from rainfall.
- They are shallow systems, usually less than 60 metres thick, with a maximum of 200 metres in exceptional instances.
- Although deeper fracture flow systems do exist, the quality of the water within these systems is generally not acceptable for human consumption.
- They contain between 0,001 – 0,1% water by aquifer volume.
- Recharge from rainfall is generally low and totals between 1 -–5% of the annual rainfall.
- Characteristics of the aquifer vary greatly over short distances.
- Contaminant transport through fracture flow aquifers is comparatively fast.
- There is hardly any attenuation of pollutants in the fractures.
- Borehole yields from fracture flow aquifers vary greatly within a few metres.

A combination of fracture flow and porous flow mechanisms often exists in a single aquifer. Two examples of aquifers of this type are sandstone and weathered granite.

Sandstone has an inherent permeability of its own, and water can, to a lesser or greater extent, flow around the grains within the sandstone, depending on their degree of cementation. All sandstones in South Africa are fractured. These fractures are usually the dominant flow mechanism within the sandstones. When a pollutant enters a sandstone aquifer, the fractures within the sandstone will therefore be the dominant mechanism along which the contaminant will be transported.

Granite is an igneous rock and, like all other igneous rocks, impermeable to groundwater flow in its unfractured and fresh state. However, granite weathers comparatively easily. Weathering usually starts along fractures in the granite, eventually affecting large areas within the granitic mass. When weathered, crystals within the rock disengage and water can flow around individual crystals within the granite. Depending on the degree of weathering, the groundwater flow mechanism within a granite mass may therefore dominantly be fracture flow or porous flow.

3.1.3 Dolomitic aquifers

Dolomite is a crystalline rock, unstable in acid environments. Dissolution channels that develop along fractures within dolomite may extend to surface and give rise to a typical karst topography, which has a very significant influence upon recharge characteristics of the aquifer. Dolomitic aquifers that are not protected by overlying geological formations are particularly vulnerable to pollution because of their thin soil cover and high transmissive characteristics.

3.2 Groundwater utilization

Groundwater is utilized extensively by smaller communities in South Africa. At least 140 communities are wholly dependent on groundwater as their source of supply, emphasizing the need for aquifer protection.

Conjunctive use of groundwater as a supplementary water source to surface water supplies is the case in at least another 160 instances. The largest of these schemes are groundwater supply from the West Rand dolomite into the Rand Water Board water supply and groundwater from the Crocodile River alluvial deposits.

Nearly all farmers are totally dependent on groundwater for their drinking-water supply. In most farming operations, groundwater forms an integral part of stock-farming, garden irrigation and, in some instances, irrigation of crops.

Groundwater is an important resource that is not currently fully utilized. Its importance will increase with time.

3.3 Aquifer yield

Yields from boreholes in South Africa may – typically be classified according to their potential for use and the following index is suggested:

Index	Range	Potential Use
Low Yield	<1*l*/sec	Stock, Garden, Domestic
Medium Yield	1 – 5 *l*/sec	Limited development potential
High Yield	6 – 20 *l*/sec	Small Community
Very High Yield	>20*l*/sec	Large-scale water supply

In terms of the South Africa aquifer classification system (Chapter 2), the high yield and very high yield categories in the above table would undoubtedly fall within the 'Major aquifer' category. Medium yield corresponds to the 'Minor aquifer' category and low yield would normally fall within the 'Poor aquifer' class.

However, vast areas of South Africa have boreholes that yield less than 1 *l*/sec on average. Large areas underlain by Karoo sediments and most other sedimentary basins in South Africa fall into this class. Also in this yield category are unweathered igneous and metamorphic rocks. In these areas, the physical limits for aquifer classification will therefore move down and a 'Poor aquifer' will typically yield less than 0,01 l/s, for instance. It is important to realize that the current aquifer classification system for South African aquifers does not specify yields for specific categories. Local conditions and variations in aquifer yield will determine the limits for aquifer classification.

Yields in excess of 5 *l*/sec are generally hard to come by in South Africa. Boreholes with such high yields have usually been sited scientifically and are located on very favourable structures, such as faults or along dolerite dykes.

Dolomitic rocks, particularly where solution channels exist, usually yield vast amounts of water. Such yields may exceed 100 *l*/sec in many instances. In the gold-mining industry, for instance, where dolomitic water is abstracted, yields are in excess of 500 *l*/sec.

Examples of favourable yield characteristics for the major aquifer types in South Africa are provided below:

Aquifer	Typical yield (one standard deviation)
Alluvial deposits	3 – 8 *l*/sec
Coastal sands	3 – 16 *l*/sec
Karoo sediments	1 – 3 *l*/sec
Karoo dyke contacts	3 – 6 *l*/sec
Table Mountain Sandstone	1 – 10 *l*/sec
Dolomite (karst)	20 – 50 *l*/sec
Granite (weathered)	5 – 10 *l*/sec

The above values are for favourable yield conditions from boreholes sited scientifically. These values should not be used for planning or design purposes, since the actual aquifer yield depends on local conditions.

In view of the limited thickness of South Africa aquifers, their long-term potential yield is a function of the amount of water recharged to the groundwater from rainfall, from impoundments and, in rare instances, from streams. Recharge quantities generally range between 1 -–5% of the annual rainfall. Higher recharge percentages are usually the case where a thin soil cover is present, such as on dolomitic and certain unconfined aquifers.

3.4 Aquifer vulnerability

South African aquifers are extremely vulnerable to pollution, because:

- Almost all usable groundwater in South Africa occurs within 60 metres of the surface.
- Recharge to South African aquifers occurs freely through infiltration from rainfall, ponds and from seepage through dumps.
- Fracture flow systems, which constitute about 90% of our aquifers, are capable of transmitting contaminants at rates of between 10 1000 times faster than porous flow systems.
- Pollution within aquifers follows preferential flow-paths usually emanating into streams. The water-table gradient, fractures and geology dictate these flow-paths.

Section 4

SEQUENTIAL STEPS FOR THE DESIGN OF A MONITORING SYSTEM

The design of monitoring systems for waste management facilities should follow a certain sequence of events. The following is a summary of actions recommended in the following chapters and appendices in this document:

(i) Obtain information on disposal practices, volumes and type of waste.

(ii) Obtain available information on the topography, stream flow, fountains, dams, geology, existing boreholes, wells and excavations (see Chapter 6 of the Minimum Requirements for Waste Disposal by Landfill). Sample surface and groundwater for chemical analyses to determine the presence of pollutants, if any, at existing points. Obtain information on other human activities that could be affected by the disposal of the waste. Delineate possible pollution plumes at existing waste sites.

(iii) Perform a risk assessment and decide on the level of the impact study and the monitoring facilities that will be required (see Chapter 5 and Appendix A).

(iv) Perform geophysical investigations to locate groundwater barriers and aquifers (see Chapter 6 of the Minimum Requirements for Waste Disposal by Landfill).

(v) Drill boreholes at positions as determined by (i), (ii), (iii) and (iv). Record geological and geohydrological information from boreholes. If necessary, perform tests such as hydraulic conductivity, aquifer yield and water quality profiling in boreholes. Study characteristics of rainwater penetration into waste. Install, if required, early warning devices underneath new disposal sites (see Chapter 6).

(vi) Perform water sampling from holes. Analyse for elements typically found within the natural and waste environments (see Appendices B, C and D).

(vii) Document data or enter it into the computerized database, Waste Manager, for processing and interpretation. Interpret data, extract tables and graphs, identify and investigate anomalies (see Appendix E).

(viii) Present report, database and recommend methods and frequency of sampling to the client. Specify equipment to sample water from boreholes.

(ix) Include information in the application for a waste management permit in the case of general or hazardous waste. In the case of mining, include information in the EMPR. In other instances, submit information to the Department.

(x) Train on-site personnel in the use of the database, the sampling equipment and in the interpretation of the data. Provide facilities for the client to report to the Department in terms of their permit conditions.

Where actual conditions are at variance with that assumed here or of a complex nature and do not conform to a specific situation, it may be advisable to discuss the matter with a senior representative of the Department.

Section 5

RISK ASSESSMENT

It is a minimum requirement that a risk assessment, to determine the risk of water becoming polluted, be performed at all waste sites before the installation of a monitoring system. This serves to ensure that the design of the monitoring system is adequate. The prescribed methodology for risk assessment is included in Appendix A.

In the case of disposal facilities that have been cited and developed in accordance with the Minimum Requirements for Waste Disposal by Landfill, most or all of the information required to carried out a risk assessment should be readily at hand. In the case of older sites that do not pre-scribe to the minimum requirements, certain additional exploratory work may have to be undertaken.

5.1 Goals for Risk Assessment

A groundwater pollution risk assessment serves two valuable purposes:

- It provides a numerical value or visual aid with respect to the groundwater pollution potential for a particular waste management facility. Existing or potential sites evaluated by these means can therefore be ranked in terms of suitability or remedial priorities.

- Monitoring facilities can be prescribed according to the results of the risk assessment. Particularly, the density and locality of monitoring points should be in relation to the rating obtained from the risk assessment procedures.

5.2 Dominant issues

Assessment of the risk for a waste management facility to pollute the groundwater regime is the first step in the design of a suitable groundwater monitoring system. This risk differs from site to site and monitoring facilities have to be adapted accordingly. The dominant issues in risk assessment are:

- Potential for groundwater usage.
- Aquifer vulnerability.
- Toxicity and other properties of the waste.
- Quantities of waste.
- Potential for leachate generation.

5.2.1 Potential for groundwater usage

The potential for groundwater utilization from a specific aquifer may change with time. A groundwater resource that presently seems unimportant may, in future, be a valuable asset. In the siting of any waste management facility, aquifers within a specific area should be ranked and those least likely to be of future use must first be considered for waste disposal.

5.2.2 Aquifer vulnerability

Aquifer vulnerability relates to a number of factors, the most important of which are:

- Climate, precipitation and surface water run-off.
- Nature and composition of the unsaturated zone, in the case of unconfined aquifers.
- Aquifer characteristics, such as hydraulic conductivity, water quality and regional groundwater flow directions and degrees of confinement in the case of confined aquifers.
- Liner design, leachate management and other precautionary or control measures.

Many examples of aquifer degradation from waste disposal already exist in South Africa. The dolomitic aquifer in the south-western Gauteng and the Karoo aquifers in parts of the Northern Free State and Mpumalanga are but two examples of areas where groundwater quality degradation had to be allowed in exchange for development. From this, it can be seen that development inevitably leads to groundwater quality deterioration.

A policy of differentiated protection is inevitable for South African aquifers.

Differential protection can only be implemented after an impact study and a risk assessment has been made.

5.2.3 Toxicity of the waste

The potential for different wastes to pollute water resources differs greatly, depending on the composition of the waste and its potential for degradation with time. South African legislation broadly classifies waste under two categories, namely general and hazardous waste. Between these two categories lies a continuum, with a transition from what could be described as non-toxic to toxic. When referring to a level of toxicity, then the constituent itself must be considered and also the potential user of the water, e.g. human, animal, aquatic life, or irrigation. The Department gives more information on waste classification and its toxicity in the other two documents of this series.

5.2.4 Quantity of waste

Toxicity and quantity of waste go hand in hand. Experience has shown that it is easier to dispose of, manage and contain small quantities of waste than large quantities.

The risk for groundwater pollution is usually greater at large waste disposal facilities, where it is often impossible to prevent groundwater pollution because of the nature and scale of operations.

5.2.5 Potential for leachate generation

It is theoretically possible, by using synthetic liners, to completely contain leachate from a waste site. This is, however, mostly impractical and very costly. It is also now generally accepted that all liners leak to a lesser or greater (or to some) extent. In reality, therefore, leachate that is generated in a disposal site may eventually reach the groundwater regime. This should be taken into account in the risk assessment (see Minimum Requirements for Waste Disposal by Landfill, Chapter 8 – Design).

5.2.6 Liner Design

Leachate generation is often considered as an essential component of the degradation of wastes. All hazardous waste disposal sites and certain general waste sites, need to be equipped with the appropriate liner design and leachate management system (see Minimum Requirements for Waste Disposal by Landfill, Chapter 8). A risk assessment is again essential when determining the degree to which leachate generation needs to be controlled at a particular site.

Section 6

FACILITIES FOR MONITORING

6.1 Introduction

The main purpose and endeavours of a monitoring system, concerned with the control of pollution and the migration of hazardous liquids, are to:

- Provide reliable and irrefutable data on the quality and chemical composition of the groundwater.
- Detect and quantify the presence and seriousness of any polluting substances in the groundwater at the very earliest stage possible.
- Detect the possible release or impending release of contaminants from the waste facility.
- Provide a rational comparison between the predicted and actual flow and solute transport rates.

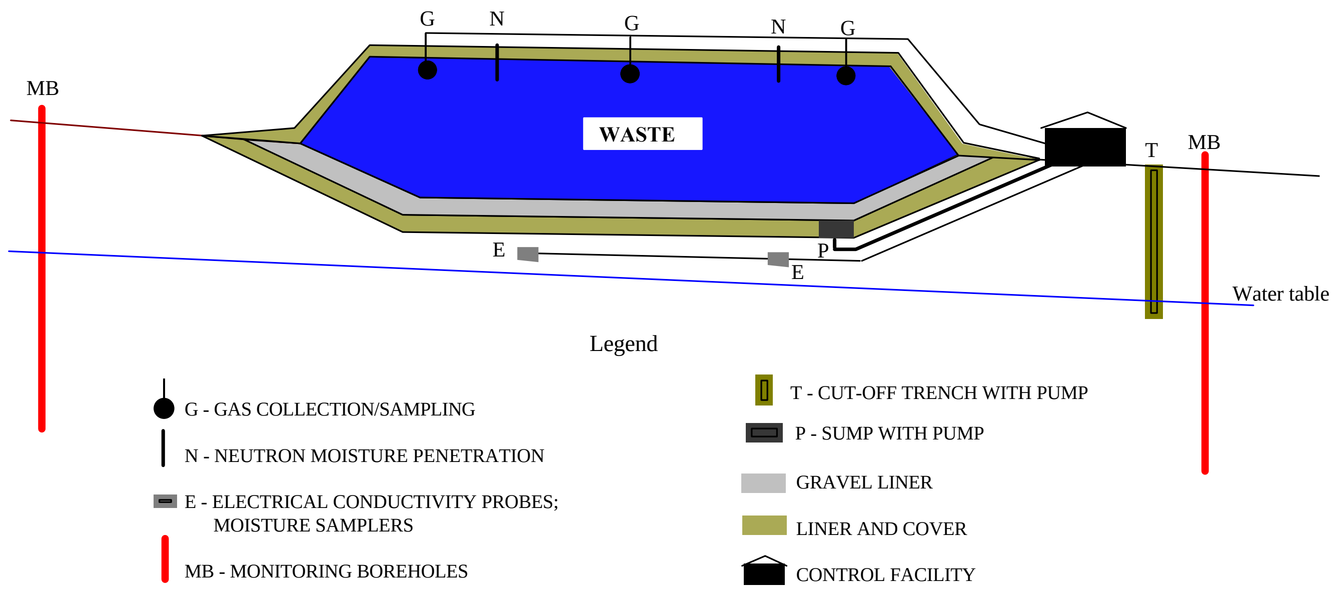
Provide an ongoing and reliable performance record for the design and control system(s) for effectively controlling pollution.

To achieve the above objectives, it may be necessary to employ two separate monitoring systems in cases where the generation of hazardous leachate may be a problem. The two monitoring systems are:

- Early Warming Monitoring Systems
- Regional Monitoring

A schematic presentation of these monitoring options, in relation to a waste site, is show below.

Idealized section through a waste facility, showing monitoring facilities and pollution control measures



The main difference between these two monitoring systems is that the Early Warning Monitoring System forms part of the disposal design and is independent of the groundwater regime as well as of any direct geohydrological considerations.

Regional Monitoring Systems, on the other hand, are entirely dependent on geohydrological considerations and, in fact, cannot be installed successfully in the absence of such knowledge.

Not all monitoring options need to be applied at every site. The initial risk assessment will suggest the monitoring methodology to be applied, as well as the density of the monitoring network.

Table 6.1 lists minimum monitoring requirements against various waste management activities. Also indicated on this table, is a frequency for monitoring. Table 6.2 provides details on monitoring networks.

For each of the waste environments in these tables an attempt has been made, based on South African experience, to select only those monitoring methodologies that would provide meaningful results. This explains the general absence of monitoring selections within the unsaturated zone. It has been found that specialized equipment such as pressure/vacuum lysimeters and electrical conductivity probes soon becomes dysfunctional. Direct measurement of water quality from leachate collectors is more reliable.

Monitoring of the groundwater system (Table 6.1) seems very extensive at first glance, but this is not the case. Once a borehole has been drilled, water levels, quality, yield and usage can easily be ascertained. Yield is usually only measured once.

6.2 Early Warning Systems

Early warning systems comprise measurements done on top of a disposal dump, within the dump itself and directly underneath the dump in the unsaturated zone. Such monitoring usually includes:

- Rainfall: Rainfall that infiltrates into a waste dump increases the overall pollution potential from that dump. *Rainfall for the past 24 hours must be recorded at 8h00 every morning.*

- Evaporation potential: The amount of potential evaporation from free-standing water can be determined by measuring water losses from a Class A evaporation pan, or calculated by using a suitable equation such as Penmann. In view of difficulties that industries have in accurately monitoring the potential evaporation for a specific locality, *the measurement of pan evaporation is only a requirement at hazardous disposal sites.* For all other sites, approximate evaporation potential values can be obtained from the Department.

- Run-off: The amount of water flowing off a disposal site, or a larger complex such as a mine or a power station, is an important component in the calculation of water and salt balances for the site or complex. *Run-off quantities and qualities must be recorded continuously, when specified in the permit*.

- Leachate Collection/Toe Seepage: Analysis of leachate from leachate collectors or toe seepage is considered to be the most important early warning indicator. Leachate collectors are part of the design detail for certain waste management facilities. *Samples must be collected, preserved and analyzed according to specifications in this manual.*

- Rehabilitation: *Rehabilitation on top of waste must be done as soon as is reasonably possible or otherwise specified in the permit*. This will limit ingress of water, thus reducing the volume of leachate to be dealt with.

- Gas monitoring: *Gas monitoring must be done at Landfill and Hazardous sites where indicated in Table 6.1.* Suggestions for gas monitoring are included in the document on Minimum Requirements for Waste Disposal by Landfill, Section 11.5.5.

6.3 Regional Monitoring Systems

Regional monitoring refers primarily to measurements done in the vicinity of the waste facility, up to such distances as may be required by the specific monitoring system. Monitoring is usually done at:

- Boreholes.
- Fountains, dams, pans streams and rivers.

Table 6.1. Minimum monitoring requirements at various types of waste management facilities

	At or near surface monitoring								Within waste or unsat. zone						Groundwater monitoring							
Monitoring Requirements → / Waste environment ↓	Rainfall	Evaporation	Run-off (volume, quality)	Water infiltration on waste	Toe seepage from waste	Soil cover on waste	Vegetation on waste or soil	Bioassaying	Pressure vacuum lysimeters	Gas samplers	Electrical conductivity probes	Leachate collectors	Temperature within waste	Special detectors	Special monitoring holes	Other holes	Groundwater levels	Groundwater chemistry	Borehole yield	Groundwater usage	Fountain seepage	Water balance
Mines – Reactive environment	d		d																			m
Slimes (Slurry)				m	m	y	y					m			yes	yes	m	3m	y	y	m	m
Ore discards			d	m	m	y	y					m			yes	yes	m	3m	y	y	m	m
Rock Discards (opencast)				m	m	y	y								yes	yes	m	3m	y	y	m	m
Rock discards (other)					m	y	y								yes	yes	y	y	y	y	y	y
Mine water (impoundment)				m	m										yes	yes	3m	3m	y	y	m	m
Mine water (discharged)			d					y														w
Mines – Inert environment	d		d												no	yes	y	y	y	y	y	m
Slimes (slurry)					m										no	yes	y	y	y	y	y	m
Rock discards					m										no	yes	y	y	y	y	y	y
Ore discards					m										no	yes	y	y	y	y	y	y
Mine water (discharged)			d																			d
Coal fired power stations	d		d												yes	yes	3m	3m	y	y	m	m
Coal stockpiling					m							m			yes	yes	3m	3m	y	y	m	m
Ash disposal (slurry)					m										yes	yes	3m	3m	y	y	m	m
Ash disposal (dry)				m			y								yes	yes	3m	3m	y	y	m	m
Dirty water systems					m										yes	yes	3m	3m	y	y	m	m
Water discharged			d					y														
General waste																						
Large (>500 t/d)	d		d		m	y	y	y		m		m			yes	yes	3m	3m	y	y	m	m
Medium (26 – 500 t/d)	d		d		m	y	y			m					yes	yes	y	3m	y	y	m	m
Small (1 – 25 t/d)					m										yes	yes	y	3m	y	y	m	
Informal (<1 t/d)					m										no	yes	y	3m	y	y	m	
Sewage																						
Unlined maturation ponds			d												yes	yes	y	3m	y	y	m	
Sludge			d																			
Hazardous waste	d	d	d	m	m	m	m	y	m	m		m		m	yes	yes	m	m	y	y	m	y
Waste irrigation	d		d	m	m	m	m	y							yes	yes	m	m	y	y	m	m
Agriculture (feed lots)	d		d												yes	yes	m	m	y	y	y	
Agriculture (diffuse sources)															no	yes	y	y	y	y		
Septic tanks and pit latrines															no	yes	y	y	y	y		
Underground storage tanks															yes	yes	m	m	m	m	m	
Urban development	d		m												no	yes	y	y	y	y		
Industries	Refer to specific waste above, such as general, hazardous, irrigation, impoundment																					
Radioactive waste	As specified by the CNS in collaboration with the DWA&F																					

Explanation of codes: d = daily monitoring; w = weekly monitoring; m = monthly monitoring; 3m = 3-monthly monitoring; y = yearly monitoring

Monitoring boreholes

The main objective in placing a monitoring borehole is to intersect groundwater moving away from a waste management facility.

In porous flow aquifers

In porous flow aquifers monitoring boreholes should be located on either side of the waste facility, in the direction of the groundwater gradient. If very little is known about the groundwater gradient, then at least one monitoring borehole should also be placed at the lowest topographical point.

In cases where the aquifer consists of weathered granite or other igneous rock, geophysical methods should be used to determine the size, shape and orientation of the aquifer.

In fracture flow aquifers

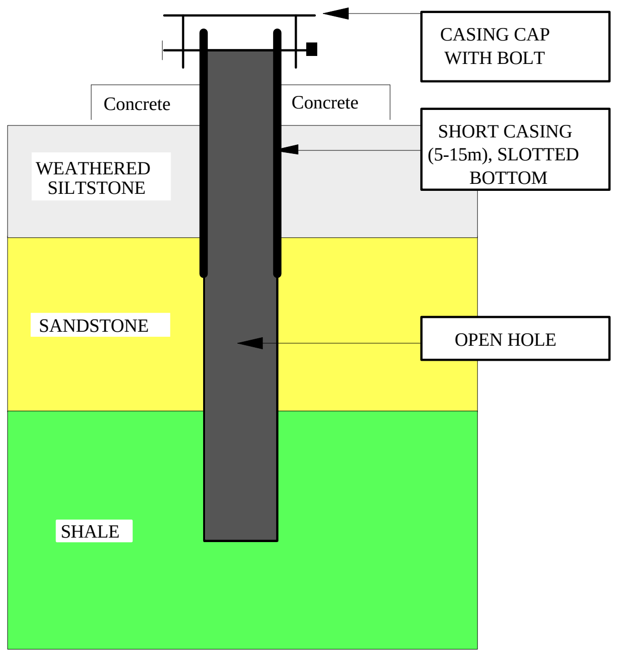
Fractures and other lineaments such as dolerite dykes may be identified by using aerial photos, satellite images, airborne magnetics; followed by ground geophysics such as magnetic, electro-magnetic, resistivity and ground penetrating radar. These are specialized techniques and should preferably be applied by geohydrologist.

Borehole design

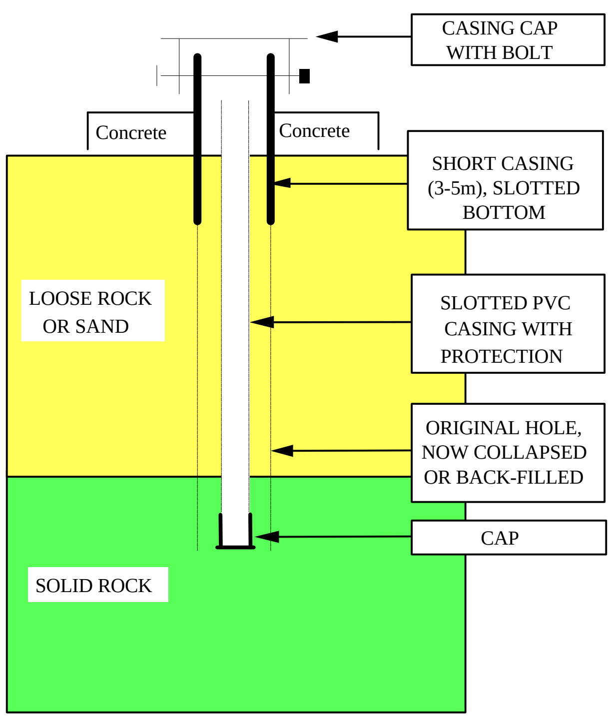
The local geology dictates the borehole construction. Examples of equipped boreholes are included on this and the following page.

Data required from boreholes are:

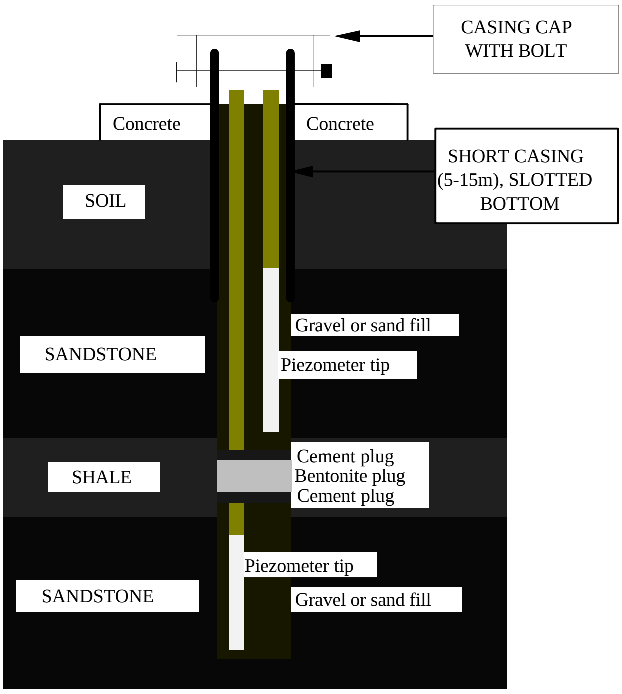
- *Geological log.*
- *Water intersections (depth and quantity).*
- *Construction information (depth of hole and casing, borehole diameter, method drilled, date drilled).*
- *Use of water, if not solely for monitoring; frequency of abstraction; abstraction rate and whether other water sources are readily available.*
- *Water quality (see chapter on chemical analyses).*



Typical installation required
for monitoring boreholes into solid rock,
average depth 40 metres.



Typical installation for monitoring boreholes
into the loose material such as sand,
gravel, discards or rock spoil at the opencast mines



Typical installation of piezometer tubes in a monitoring borehole

Borehole type

- *Boreholes must be drilled by a drilling technique that will not introduce pollution into the aquifer.*

- Air-percussion drilling, without the addition of chemicals, is recommended. This allows the collection of rock chips and measurement of water yield, while drilling.

- In instances of difficult drilling, degradable chemicals may be introduced.

- Upon completion of drilling, the hole and the inside of the casing should be flushed.

Hole diameter

- *Monitoring boreholes must be of a diameter that will allow easy access to the aquifer, for the purpose of water sampling and for lowering other test instruments.*

- The diameter of the smallest submersible pump available in South Africa is 100 mm. Holes should therefore preferably have diameters larger that 110 mm. In smaller holes or during specialized sampling, pneumatic samplers or special small diameter pumps may be used. For newly drilled monitoring holes, a diameter of 110 – 165 mm is suggested.

Hole depth

- *A monitoring hole must be such that the section of the groundwater most likely to be polluted first is suitably penetrated, to ensure the most realistic monitoring results.*

- This implies that monitoring holes will at least extend through the weathered zone, the aquifer below and 5 m into the non water-yielding formation deeper down. The latter is intended to act as a sump where material that falls down the borehole will accumulate, without affecting the performance of the monitoring system.

- Groundwater depth commonly ranges from 5-10 m below surface in high rainfall areas, to more than 50 m below surface in dry areas of Namaqualand. Weathering can be recognized by brownish discolouration of the rock. Commonly, weathering extends to 5 – 15 m below surface. A depth of 40 – 60 m for boreholes, to monitor groundwater quality, should therefore be sufficient, except in special instances.

Casing, screens and filters

- *The materials used for casing, screens and filters in contact with water must be compatible with, and resistant to chemical attack by the water being monitored.*

- *Casing, screens and filters must allow easy access for monitoring purposes and may in no way block the flow of water through the borehole.*

- The top of a casing in a monitoring borehole should rise between 30 – 40 cm above the general ground surface, to ensure that surface run-off does not flow into the borehole during flood conditions.

- The casing should preferably be of slotted PVC or a polymer suitable for the particular application, protected by a short steel casing at surface. Where monitoring holes are to be installed in loose material such as sand, gravel, deposited waste or rock spoil, collapse of the holes may have to be prevented by means of properly designed borehole screens.

- *A security cap must be fitted to prevent accidental or willful interference with a monitoring borehole.* Caps fitted with bolts or secured by other mechanical means may have an advantage over locks that can be broken and vandalized.

- The borehole number should be engraved onto the cap and casing or stamped onto a suitable rustproof tag set into the concrete block.

- The bottom of the casing should extend only a couple of metres into the solid rock. If the groundwater level is shallow and is likely to rise within the casing, then the casing must be slotted to ensure lateral groundwater flow through the casing. A minimum slot density of 1% is required.

- A concrete block around the top of the casing, to protect the casing and borehole, as well as to prevent surface pollution from flowing down the side of the casing, is essential. *Required minimum dimensions for the concrete block are 750 mm x 750 mm x 150 mm.*

Borehole protection

- *Monitoring boreholes must be adequately protected to prevent accidental damage of the holes.*

- Destruction of a monitoring facility results in a break of the data sequence. Securing of monitoring boreholes should therefore be a high priority. It is recommended that monitoring boreholes should be secured by fencing. Sufficient markings should be posted to prevent accidental damage of the holes.

Groundwater levels

- Groundwater levels must be recorded on a regular basis to within an accuracy of 0,1 m, using an electrical contact tape, float mechanism or pressure transducer, in order to detect any changes or trends.

Piezometer tubes

- *Piezometer tubes must allow easy access for water sampling over the whole depth of the aquifer.*

- Piezometer tubes are installed for various reasons, into monitoring boreholes. Piezometer tubes are access tubes. These tubes are usually installed to different horizons within a borehole, and sealed off from the other horizons by cement and bentonite clay. The minimum recommended diameter for water sampling is 63 mm.

- Regional groundwater levels are indicative of the direction of groundwater movement. A change in the natural water-table gradient indicates that external forces are acting upon the aquifer. Such forces may be groundwater abstraction through nearby boreholes or recharge from impoundments.

Water sampling and preservation

- *Water must be sampled and preserved according to procedures prescribed in Appendices B and C.*

Pumping and/or packer tests

- *Where considered necessary by the geohydrologist or design engineer, pumping and/or packer tests must be carried out on boreholes, to obtain additional data on the geohydrological conditions at that particular position.*

Fountains, wells, dams, pans, streams and rivers

- *Water sources around a waste management facility, within a radius as suggested by the risk assessment, must be sampled and preserved for chemical analysis.*

- *Flow from fountains and in streams must be estimated. If pollution occurs as a result of waste management, then continuous recording of flow and water quality should be done.*

Water/salt balances

- *Water/salt balances: In instances where excess water is present and this water may have to be discharged into public streams, water and salt balances are required. At larger complexes such as mines, power stations or large industries, this usually implies water and salt balances for each of the contributing components, such as for raw water intake; for materials brought onto, removed from or disposed of on site; and for rainwater contribution and run-off.*

6.4 Monitoring Networks

Monitoring networks at waste management facilities must allow monitoring of the system on a representative basis (see Table 6.2). The key to successful monitoring is the linking of point information into larger systems. Referred to as monitoring networks.

Monitoring networks operate on local, regional and national scales. A local monitoring network is intended for the single waste management facility, whereas regional monitoring relates to a combination of waste management facilities, such as those usually present at mines, power stations, other large industries and large municipalities. Monitoring on a national scale, could, for instance, be meaningful in terms of salt loads within catchments.

Monitoring on all these levels is necessary. However, for the purpose of this document, i.e. minimum monitoring requirements at waste management facilities, emphasis is only on the local monitoring network. *Local monitoring networks should extend beyond pollution plumes to allow for the delineation of plumes and investigations into the pollution migration rate.*

In Table 6.2, the same waste environments as those in Table 6.1 are listed. For each of these environments, borehole-monitoring networks are suggested. The typical number of boreholes, their spacing and suggested monitoring frequency is indicated.

Table 6.2 Recommended monitoring distances and frequencies for different types of waste environments.

Environment	No. Holes	Distance From Waste	Monitoring Frequency
Mines – Reactive Environment			Samples from boreholes every 3 months. Sample monthly from streams above and below mine. If pollution from mine occurs, install recorders in streams above and below mine measure daily flow, EC and pH. Sample farmers' boreholes 1-5 km radius, initially and when problems are expected.
Slimes (Slurry)	1-3	50-25- m downstream	
Ore discards	2-5	50-500 m downstream and above into water accumulations	
Rock discards (opencast)	1/250 ha		
Rock discards (other)	1-3	50-200 m downstream	
Mine water (impoundment)	2-6	50-1000 m downstream	
Framers' boreholes		Within 1-5 km from mine workings	
Mines – Inert Environment			Monthly from streams above and below mine. If pollution from mine occurs, install recorders in streams above and below mine measure daily flow, EC and pH. Sample farmers' boreholes 1-2 km radius, initially and when problems are expected.
Slimes (Slurry)	0-1		
Ore discards	0-1		
Rock discards (opencast)	0-1		
Rock discards (other)	0-1		
Mine water (impoundment)	0-1		
Framers' boreholes		Within 1-2 km from mine workings	
Coal Fired Power Stations			Samples from boreholes every 3 months. Monthly from streams above and below power station. If pollution occurs in streams, install recorders in streams above and below power station measure daily flow, EC and pH. Sample farmers' boreholes 1-5 km radius, initially and when problems arise
Coal stockpiling	2-3	50-500 m downstream	
Ash disposal (wet)	2-3	50-500 m downstream	
Ash disposal (dry)	2-3	50-500 m downstream	
Dirty water systems	2-3	50-500 m downstrem	
Private boreholes	2-3	Within 1-5 km from mine workings	
General Waste			Samples from boreholes every 6 months or as specified in permit. Sample water-supply boreholes 1-5 km radius initially and when problems are expected. Sample surface water as specified in permit. Sample monthly for Leachate, if any.
Large (>500 t/d)	3-6	20-200 m surrounding	
Medium (150 – 500 t/d)	2-3	20-200 m downstream	
Small (25 – 149 t/d)	1-2	20-200 m downstream	
Communal (<25 t/d)	0-1	20 m downstream	
Private boreholes	2-3	Within 1-5 km from waste	
Sewage			Samples from boreholes every 3 months. Samples monthly from streams above and below sewage works.
Unlined maturation ponds	1	20-50 m downstream	
Sludge	1	20-50 m downstream	
Hazardous waste	5-10	10-200 m surrounding	Site-specific constituents at frequencies recommended by impact study
Waste Irrigation	3-6	50-500 m downstream and above	Samples from boreholes every 3 months. Monthly samples from streams above and below.
Agriculture – feed lots	2-3	50-200 m downstream	Samples from boreholes every 3 months. Monthly samples from streams above and below
Agriculture – diffuse sources	0		Samples from existing water-supply boreholes when problems are expected.
Septic tanks and pit latrines	0		Samples from existing water-supply boreholes when problems are expected.
Urban development	0		Monthly EC in streams above and below development

Section 7

ANALYTICAL VARIABLES

Water samples must be analysed by a recognized analytical laboratory that uses approved analytical procedures.

In instances where permits have been issued, permit conditions will specify the frequency of analyses and constituents to be tested for.

For sites presently not regulated by permit, the following guidelines may be used:

The range of elements that may be found by analysis of a waste environment is very extensive. For the purpose of this document, the required analysis are grouped under two headings:

- Comprehensive analysis
- Indicator analysis

7.1 Comprehensive analysis

For all new sites and first time monitoring at existing sites, a comprehensive analysis is required.

It is essential that accurate background levels, for as wide a range of constituents as possible, be established at the outset. This will usually include a complete macro analysis as well as an analysis for the trace elements that could reasonably be expected to be present within the environment tested.

7.2 Indicator analysis

Indicator analysis may be performed once comprehensive analyses have been completed. This process may continue until undesirable trends are uncovered.

This will keep analytical costs to a minimum, but still provide enough information upon which further action can be initiated, if necessary. Depending on the type of waste handled, so-called “pollution indicators” for each of these environments may be identified. Examples are the:

- General and special variables for discharge of industrial effluent into public streams, such as electrical conductivity (EC), Na, SO_4.
- The so-called swage variables, such as COD, NH_4, PO_4.
- Hazardous waste disposal variable, such as VOC, THM, CR_{6+}
- General waste disposal variables, such as COD, Cl, NO_3, NH_4.
- Mine pollution variables, such as pH, EC, Mn, SO_4.
- Power station pollution variables, such as Na, SO_4.
- Agricultural variables, such as pesticides, herbicides, NO_3.

Apart from this distinction according to the type of waste environment, another dimension can be introduced by classifying contaminants into four classes, namely:

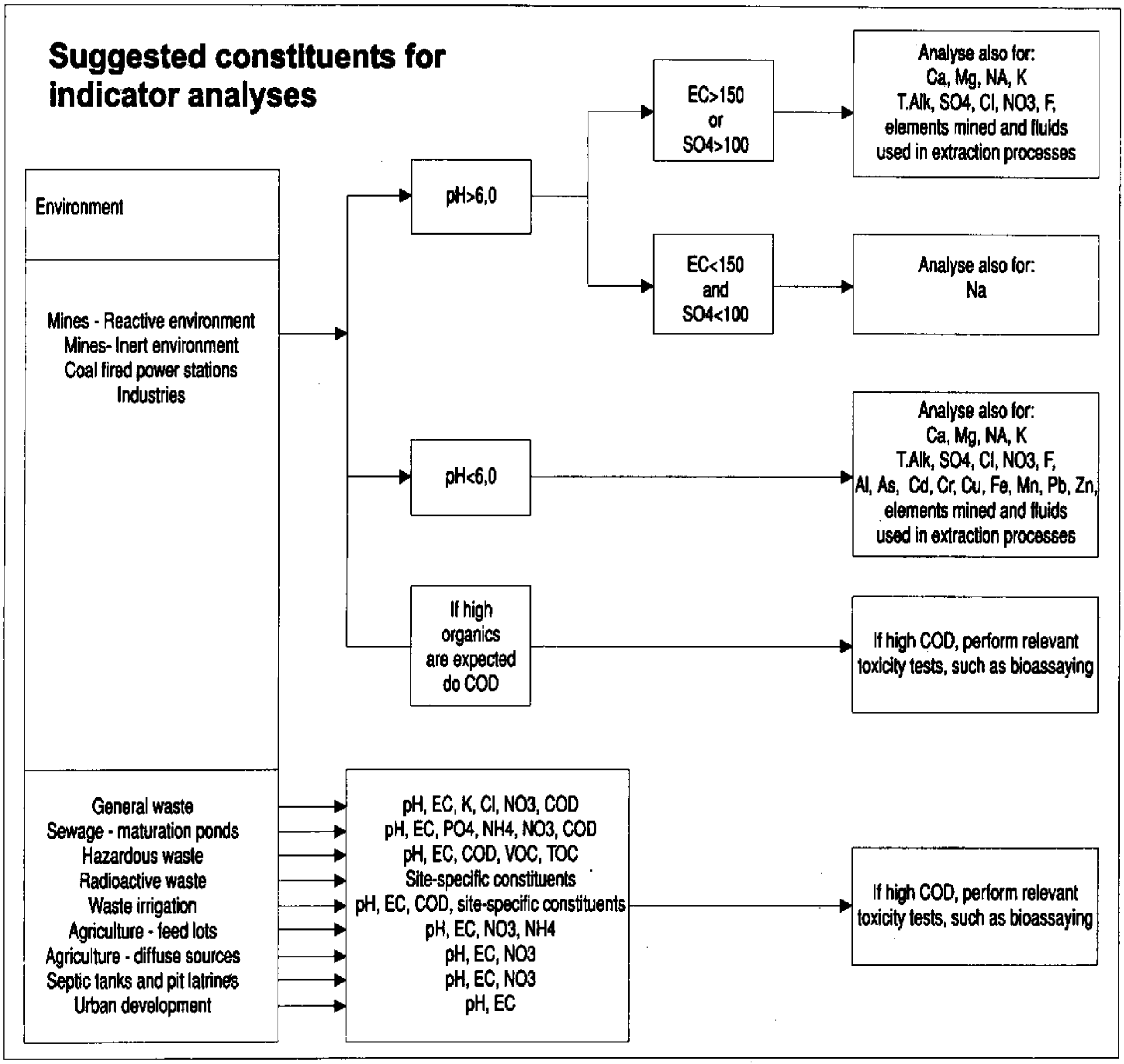
- Physical, such as pH, EC, alkalinity and acidity.

- Aesthetic, such as iron, manganese, odor and taste.

- Other inorganic, such as high TDS and heavy metals.

- Other organic, such as toxic or carcinogenic compounds.

Analysis of physical, aesthetic and inorganic variables is easily performed. Qualitative and quantitative analysis of organic constituents are extremely complex. In view of these complexities and the high cost associated with chemical analyses, the list of variables to be tested for under these minimum monitoring requirements, should be kept as short as possible. Once pollution is detected, more elaborate tests may be performed. The following table suggests minimum monitoring requirements for chemical analyses:



It is up to the discretion of the individual, which other parameters are to be analyzed for. E. coli should be analyzed for in instances where biological contamination is expected. Ammonia, nitrate and nitrite are meaningful parameters to analyze for in all environments of human and animal waste. Many modern analytical laboratories are using multi-element analytical techniques such as ion chromatography. In these instances, the full chromatographic spectrum should be considered, on condition that this is available at the same price as the required indicator constituent.

Section 8

DATA STORAGE, PROCESSING, INTERPRETATION AND REPORTING

8.1 Introduction

Data generated during groundwater quality monitoring are of two types, namely:

- Data generated once-off
- Data generated during follow-up monitoring.

Typical data that is generated once only are details on monitoring hole construction, geology, borehole depth and yield from water intersections in the hole.

Follow-up monitoring, such as groundwater levels, water chemistry, water abstraction from boreholes, waste composition, tons of waste disposed of, rainfall, surface run-off and rehabilitation progress constitute by far the majority of the observations to be made.

8.2 Data Storage

The Directorate of Water Quality Management of the Department has acquired computerized data storage facilities, into which all information on waste disposal facilities may be entered. The software, Waste Manager, has been developed to meet South African requirements. This software is available from the following WEB site:

ftp://igs-nt.uovs.ac.za/wastemanager

The municipality, industry, power station or mine may also use the Waste Manager software, which runs on a PC. Information on up to ten waste disposal facilities, for any one locality, may be entered into the database.

Also available within Waste Manager, are facilities to table and graph information as well as to report to the Department.

8.3 Processing and Interpretation

Waste Manager also has the capability for data processing and interpretation. This relates mainly to comparisons of performance between waste disposal facilities on a regional basis.

The table below provides a breakdown of the main features within the software packages.

For those not using the software package, the following action will be required after each sampling episode:

- Plot or update line graphs for the following variables: tons of waste, population served, water chemistry. Identify trends and anomalies. Investigate anomalies.

- Tabulate information according to examples provided by the Department in the permit for waste disposal site.

8.4 Reporting to the Department

Submission of information for incorporation into the data base at the Department can be done on computer diskette by those who have copies of Waste Manager or by submitting reports, including graphs and tables.

It is essential that the information being reported to the Department has been checked and evaluated by the waste disposal company before they submit the results. Reporting should be six-monthly or at the frequency prescribed in the waste disposal permit.

In terms of the above issues, the following requirements apply:

Data must be stored in such a way as to be easily accessible for to the waste manager and for the Department.

Data must be processed and interpreted after each sampling exercise.

Reporting frequency to the Department will be specified in the waste management permit conditions. Otherwise, the reporting frequency is six-monthly.

Section 9

IMPLEMENTATION AND MANAGEMENT

9.1 Introduction

A breakdown of the degree of initiative and response, which will be required to implement and manage monitoring facilities in South African are, illustrated below:

Statistics on sites adequately equipped with monitoring facilities.

Environment	Sites equipped	Routinely monitored
Mines – Reactive environment	35%	15%
Mines – Inert environment	0,5%	<0,1%
Coal fired power stations	90%	90%
General waste	10%	5%
Sewage – maturation ponds	<0,1%	<0,1%
Hazardous waste	50%	50%
Radioactive waste	100%	100%
Underground tanks	1%	1%
Waste irrigation	15%	10%
Agricultural – feed lots	1%	<0,1%
Agricultural – diffuse sources	3%	<0,1%
Septic tanks and pit latrines	1%	<0,1%
Urban development	1%	<0,1%

Note: These are approximate percentages based on information available in 1997.

It is encouraging to note that many of the industries already have, without requirement by legislation to do so, installed monitoring systems of their own. Many of them already sample, store and process information according to standards compatible with those of the Department.

Implementation and management of monitoring systems is a formidable task, and can only be accomplished if all parties concerned co-operate. Four levels of implementation and management are recognized:

- Public participation
- Company level
- Local authority level
- Governmental level

9.2 Public participation

Public participation has for many years been ignored as input. This has now changed and without their participation, success with a venture of this magnitude cannot be achieved.

9.3 Company level

Monitoring programmes, on a company level, at each of the waste types described in Chapter 6, should be the first initiative. Individual sites for waste management within municipal boundaries, with a nominated responsible party, are also classified under this category.

Essential issues are:

- Environmental awareness on company management level.
- Acquisition of qualified people to manage waste facilities and liaise with the Department.
- Installation of suitable monitoring systems.
- Compliance monitoring, i.e. routine monitoring by the company, within permit stipulations.
- Remedial action, which is often almost impossible, is the responsibility of the waste management company.

9.4 Local authority level

Within municipal boundaries, one or more waste management facilities usually exist. These are municipal or private dumps, sewage treatment facilities and urban water run-off.

The following responsibilities lie with local authorities:

- Performing an annual survey of all waste management facilities within their boundaries.

- Ensuring the waste management companies comply with waste management permit conditions.
- Co-ordination of waste management activities.
- Receiving and evaluation of monitoring reports.
- Planning and co-ordination of future waste disposal, providing adequate waste disposal facilities, well in time for the application of waste management permits from the Department.

9.5 Departmental level

The responsibilities of the Department are:

- To receive and process waste management permit applications. To issue waste management permits.
- To perform routine field checks.
- To receive and process monitoring reports.
- Possible responses will be: issuing of acceptance letters; requesting additional information; requesting re-evaluation of monitoring systems; requesting contaminant clean-up; requesting a financial bond to guarantee successful clean-up and closure of the site.
- To maintain a national computerized data base on waste management facilities, which may be used for the co-ordination of waste management in South Africa and water quality management on a local and catchment level.
- To initiate training, guidance, public relations programmes and to provide support for the waste management community to ensure co-operative and successful management of the waste stream.

Section 10

SUGGESTED READING MATTER

The following is a list of reading matter, suggested for individuals or companies wishing to broaden their knowledge on water quality monitoring and the environment. The numbers below refer to the different chapters in this document on which the literature has a bearing.

1 Background Information

Council for the Environment, 1989. Integrate environmental management is South Africa. ISBN 0-621-12496-6. Council for the Environment, Private Bag X447, Pretoria 0001.

Council for Industrial Research (CSIR), 1991. The situation of waste management and pollution control in South Africa. Report to the Department of Environment Affairs by the CSIR programme for the Environment, Pretoria. Report number CPE 1/91. CSIR, P O Box 395, Pretoria 0001.

Department of Water Affairs and Forestry, 1997. Policy and strategy for management of groundwater quality in the RSA – Water quality management series. Department of Water Affairs and Forestry, Private Bag X313, Pretoria 0001.

Department of Water Affairs and Forestry, 1998. Minimum requirements for the handling, classification and disposal of hazardous waste. Waste Management Series, Document 1. Department of Water Affairs and Forestry, Private Bag X313, Pretoria 0001.

Department of Water Affairs and Forestry, 1998. Minimum requirements for waste disposal by landfill. Waste Management Series, Document 2. Department of Water Affairs and Forestry, Private Bag X313, Pretoria 0001.

Environmental Protection Agency, 1984. Groundwater protection strategy. EPA, Office of Groundwater Protection, Washington, DC 20460.

Environmental Conservation Act, No. 73 of 1989.

Minerals Act, No. 50 of 1991.

Water Services Act, No 108 of 1997

National Water Bill, 1998.

2 Mission, policies and strategies for groundwater quality management

Department of Water Affairs and Forestry, November 1992. Groundwater quality management policies and strategies for South Africa. Open File Report.

3 South African aquifers

Department of Water Affairs and Forestry – Numerous geohydrological reports are available upon request, for specific aquifers and municipalities using groundwater. Directorate of Geohydrology, DWA&F, Private Bag X313, Pretoria 0001.

Kok, T.S., 1991. The potential risk of groundwater pollution by waste disposal. Biennial Groundwater Convention of the Groundwater Division of the Geological Society of South Africa and the Borehole Water Association of Southern Africa.

National Groundwater DataBase for South Africa – Point information for more than 100 000 boreholes is available from the Directorate of Geohydrology, DWA & F, Private Bag X313, Pretoria 0001.

Water Research Commission – Many groundwater research reports, usually of a specialized nature, are available. WRC, P O Box 824, Pretoria 0001.

4 Risk assessment procedures

Environmental Protection Agency, 1985. DRASTIC - A standardized system for evaluating groundwater pollution potential using geohydrological settings. EPA-report 600/2-85/018.

Environmental Protection Agency, 1991. WHPA, a modular semi-analytical model for the delineation of wellhead protection areas, Version 2.0. EPA, Office of Groundwater Protection, Washington, DC 20460.

Environmental Protection Agency, 1991. VIRALT, a modular semi-analytical and numerical model for simulating viral transport in groundwater. EPA, Office of Drinking Water, Washington, DC 20760.

Parsons, R and Jolly, J., 1994. 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, P O Box 824, Pretoria 0001.

4 Facilities for monitoring water quality

Borehole Water Association. Know your borehole, Borehole Water Association of Southern Africa, P O Box 1338, Johannesburg 2000.

Environmental Protection Agency, 1985. Groundwater monitoring strategy. EPA, Office of Groundwater Protection, Washington, DC 20460

Everett, L.G., 1984. Groundwater monitoring: Guidelines and implementing a groundwater quality monitoring programme. Genium Publishing Corporation, N.Y.

Everett, L.G., 1985. Groundwater monitoring: Handbook for coal and oil shale development. Developments in Water Science, No.24, Elsevier, N.Y.

Department of Water Affairs and Forestry. Groundwater – Guideline for Boreholes. DWA & F, Private Bag X313, Pretoria 0001.

Weaver, J.M.C., 1992. Groundwater sampling. Research report to the Water Research Commission. ISBN 1 874858 44 6.

6 Indicator variables and chemical analyses

American Public Health Association, APHA, AWWA (1985). Standard methods for the examination. ISBN 0-87553-131-8.

South African Bureau of Standards (SABS) Methods and specifications for water analyses – Refer to Appendix D of this document. SABS, Private Bag X191, Pretoria 0001.

7 Data storage, processing, interpretation and reporting

Department of Water Affairs and Forestry, 1991. Compliance monitoring manual, Version 2.0. DWA & F, Private Bag X313, Pretoria 0001.

Environmental Protection Agency, 1988. EPA workshop to recommend a minimum set of data elements for groundwater. Report number EPA 440/6-99-005. EPA, Office of Groundwater Protection, Washington, DC 20460.

Institute for Groundwater Studies, 1994. Waste Manager – A computerized data storage, processing and reporting system. Institute for Groundwater Studies, UOFS, Bloemfontein 9300.

8 Implementation and management

Environmental Protection Agency, 1986. Pesticides in groundwater: Background Document. Report number EPA 440/6-89-002. EPA, Office of Water, Washington, DC 20460.

Environmental Protection Agency, 1989. Wellhead protection programs: Tools for local governments. Report number EPA 440/6-89-002. EPA, Office of Water, Washington, DC 20460.

Environmental Protection Agency, 1990. Progress in groundwater protection and restoration. Report number EPA 440/6-90-001. EPA, Office of Water, Washington, DC 20460.

Appendix A

RISK ASSESSMENT PROCEDURES

The required intensity of monitoring at waste management facilities, in terms of time and space, must be determined before a monitoring system is designed. This must be done by performing a risk assessment, determining the risk that the aquifer underneath and adjacent to a waste management facility will be polluted by leachate emanating from the waste. A risk assessment therefore forms the corner stone of a monitoring system design.

For purpose of standardization, two procedures are suggested to in this report. These are the WASP and AQUAMOD. Each of these procedures is intended for different levels of risk assessment and they follow in succession upon each other.

WASP (Waste-aquifer separation procedure)

Parsons and Jolly (1994) have developed the WASP procedure under contract for the Water Research Commission (WRC). It is intended to be used for the calculation of a site-suitability index for waste disposal. The site-suitability index can be viewed in the same sense as the risk of groundwater being polluted from a waste management facility. High site-suitability indices are associated with high risks of the aquifer being contaminated. A computer programme by Parsons and Jolly (1994), for the calculation of the site suitability index, is available from the WRC as part of the report.

The WASP procedure, has developed for the WRC, is intended only for general and hazardous waste. It should be adapted to include other wastes also considered in this document. It consists of a threefold evaluation. Step one relates to the waste itself. Following this, the zone or barrier between the waste and the underlying aquifer is evaluated. This includes an evaluation of the soil. Lastly, the aquifer itself is evaluated. In general terms, this risk assessment is an evaluation of the risk associated with the vertical seepage of leachate, from the waste into the aquifer.

Within each of these components, several subcomponents are embedded.

In the case of the waste itself, there are subcomponents such as the toxicity and tonnage of waste. In terms of waste toxicity, it is sufficient to classify waste into broader classes, such as garden and building rubble; domestic; domestic and industrial; domestic and liquid; and hazardous. In specific instances, toxicity tests by means of bio-assaying, may be conducted.

In terms of the unsaturated barrier zone between the waste and the aquifer, subcomponents such as thickness, hydraulic conductivity and porosity – all relating to the rate at which leachate can permeate through the barrier zone to reach the aquifer are considered. While the thickness of the unsaturated zone can be ascertained in the field through drilling, it is generally more difficult to obtain accurate assessments of the hydraulic conductivity and porosity distribution. The WASP evaluation makes provision for the level of accuracy to which a parameter value is known. It should therefore be possible to perform the evaluation on estimated values for a start. The advantage of doing this lies in the ease with which several areas can be compared with each other, to make a semi-educated selection for further investigation.

The risk within the aquifer is quantified by considering issues such as the present use, potential for future use and the availability of alternative water sources.

All of these components are finally related to each other by extracting a single numeric value that represents the risk of an aquifer being affected by waste disposal. The higher the score, the greater the risk. As a guideline, the following range of values and the associated risk for to the aquifer is suggested:

Score	Risk Rating
<4,0	Very Low
4,0-5,4	Low
5,5-6,8	Medium
6,9-8,2	High
>8,3	Very High

The above scale should be taken as a first approximation of the potential risk to pollute the underlying groundwater resources. The onus remains on the waste manager to prove that the system is adequately monitored.

In terms of monitoring, the intensity to which monitoring has to be done is directly related to the risk that a waste site may pollute an aquifer. The first step towards the design of a monitoring system is therefore to perform the above risk assessment. Sites with low risks will have to install the minimum number of monitoring boreholes, as indicated in Table 6.2. Sites with high risks will have to be evaluated extensively and all the recommended monitoring devices will have to be installed.

For more information, it is recommended that the readers obtain the complete documentation and programme on the WASP procedure from the Executive Director, WRC, P O Box 824, Pretoria 0001.

Alternatively, this software can be obtained by accessing the following WEB site:

ftp://igs-nt.uovs.ac.za/wasp

Numerical modelling

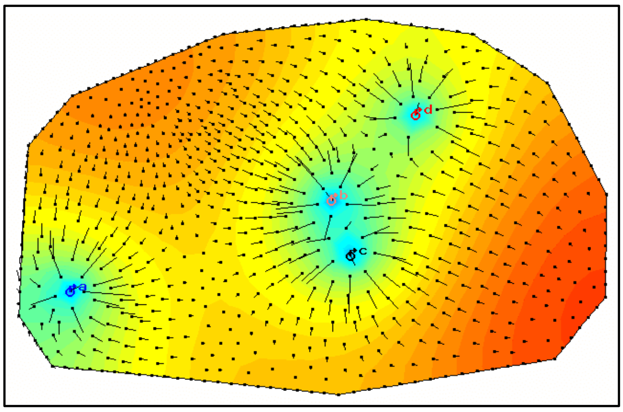
Numerical modelling of pollution transport through an aquifer is done on a routine basis by geohydrologists. Any of a variety of models may be used. *It is a requirement that modellers should demonstrate their competence in the modelling of groundwater systems, otherwise the DWA&F will not accept results from simulations.*

AQUAMOD is a mass transport model capable of simulating pollution transport through an aquifer. This software is available, free of charge from the following WEB site:

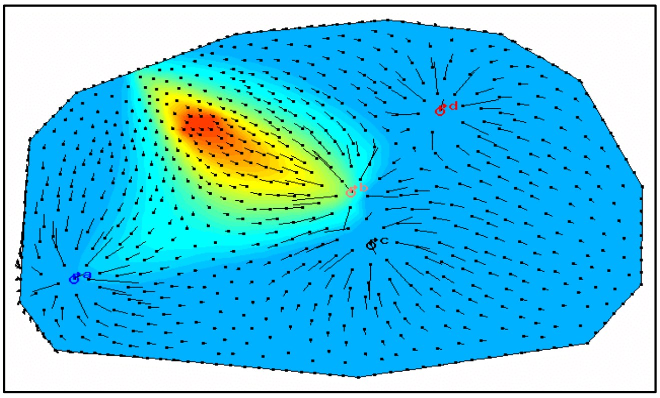
ftp://igs-nt.ouvs.ac.za/aquamod

Extensive field surveys are necessary to generate data of sufficient quality and magnitude for input into models of this kind. These models should therefore only be used in instances of extreme complexity and high risk.

Outputs from these models are usually in the form of particle tracking vectors or contours that show concentrations of various elements within the leachate plumes. Since these predictions are time dependent, simulations of the propagation of pollution plumes, many years in advance, may be done.



Groundwater contours, flow directions and velocities due to abstraction of groundwater from four boreholes.



Simulated pollution transport and dispersion from a waste facility during abstraction of groundwater.

Appendix B

BOREHOLE WATER SAMPLING

A summary of sampling techniques is presented below. For further information, the reader is referred to the manual on groundwater sampling by Weaver (1992).

Sampling of water from unequipped boreholes is a tedious and difficult task. Two methodologies may be considered, namely stratified sampling or composite sampling.

Stratified Borehole Water Sampling

Stratified sampling is done by removing a small volume of water from specific depths within a borehole. A prerequisite for stratified sampling is not to disturb the water column unduly while taking the sample. The intention of stratified sampling is to determine the vertical distribution of water quality within a borehole, thus identifying horizons where pollution enters into a borehole.

In cases which inorganic pollution is dominant, it may be possible to determine the need and detail of stratified sampling by first carrying out an electrical conductivity (EC) profile in the borehole.

Several models of stratified samplers are commercially available. The pneumatic sampler is recommended for South African conditions. It consists of a sampling cylinder with a non-return valve at the bottom. The cylinder is connected to two hydraulic tubes. One of the tubes leads t a pressurized gas bottle, while the other tube is used to obtain the water sample.

Procedures for sampling water are as follows:

1. Rinse the sampler and tubes on surface and make sure that everything works well.

2. Lower the pneumatic sampler to a predetermined depth in the borehole.

3. Pressurize the sampler and flush out any water within the sampler and tubes.

4. Release pressure on the sampler and wait 30 seconds for the sampler to refill with water.

5. Pressurize the sampler and collect the water sample from the exit tube.

6. Preserve sample according to suggestions in Appendix C and submit for analysis to a recognized analytical facility.

7. Repeat procedure from number 2 above fir samples from greater depths.

In more than 90% of instances, pollution in South African aquifers usually enters boreholes through fractures in the rock. Stratified sampling therefore constitutes an important component in the understanding of the distribution of contributing fractures in the aquifer below waste sites.

Composite Borehole Water Sampling

Composite water sampling is usually done by pumping water from a borehole. Procedures for composite sampling are as follows:

1. Activate the pump and remove (purge) at least three times the volume of water contained in the hole.

2. Collect a water sample.

3. Preserve sample according to suggestions in Appendix C and submit for analysis to a reputable analytical facility.

Various types of pumps may be used. Two types that may be considered, because of their ease of installation, are the submersible pump and the bladder pump.

Submersible pumps are available throughout South Africa. Even small submersible pumps are capable of delivering 1,0 litres per second.

Pumpage for 15-20 minutes, before taking a sample, should therefore be sufficient in most instances. Submersible pumps are recommended for the municipality or industry, doing their own sampling.

Bladder pumps are smaller and easier to install. Yield from these pumps is small and it usually takes more than 60 minutes before a representative composite sample may be obtained. Bladder pumps are not freely available is South Africa and need to be specially imported. Consulting companies, doing sampling of many different boreholes on a regular basis, may consider acquiring bladder pumps, because of their ease of use.

Where low-yielding monitoring boreholes are inevitable, removal of the dead volume by pumping could leave the borehole dry. In such instances, a sample should be taken of the newly accumulated groundwater after recovery or partial recovery of the water level in the borehole. In extreme cases, it may be necessary to revisit such a monitoring position a day or more after having purged the hole.

Recommendations

- Municipalities and industries performing their own sampling on a routine basis, should perform composite sampling.
- Groundwater consultants and others interested in the mechanism through which pollution may enter into a borehole should consider the need for performing stratified sampling.

Appendix C

SAMPLE FREQUENCY AND PRESERVATION

Sample bottles and filters

Bottles of plastic, with a plastic cap and no liner within the cap are required for most sampling exercises.

Glass bottles are required if organic constituents are to be tested for.

Such bottles and instructions for sample preservation should be obtained from the analytical laboratory.

Sample Frequency

Where waste management permits are issued, the minimum sampling frequency will be prescribed.

In other instances, the following guidelines may be adhered to:

Groundwater

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. The frequency, with which water samples are to be taken from groundwater access points, is therefore a function of the sampling objectives.

At any groundwater sampling facility, whether permitted or non-permitted, initial sampling should be done at a frequency high enough to obtain statistically valid background information. For any long-term monitoring facility, three initial sampling exercises, all within 90 days and not less than 14 days apart, are suggested.

Depending on the variation amongst these values, future sampling may be planned. A three-monthly sampling frequency will in most instances be sufficient.

Surface water

At the other end of the scale lies surface water chemistry. Surface water chemistry may change within minutes, depending on controlled or uncontrolled discharges. The frequency for surface water quality monitoring should therefore range from several times a day to weekly.

Continuous monitoring of the discharged flow volume and quality (be electrical conductivity method), is required in instances where polluted water is disposed of into a public stream.

Sample Preservation

Where indicated in the table below, samples must be preserved.

Sample preservation techniques for various tests vary significantly. The person responsible should check with the analytical laboratory to ensure that the preservation method meets their analytical requirements.

The samples should be sufficiently large to facilitate duplicate analyses.

It is a minimum requirement that samples be preserved according to specifications in this document.

Minimum requirements for water sample preservation

VARIABLE	ACTION
Carbon dioxide	Analyze immediately
Chloride – residual	
Dissolved oxygen	
pH	
Elect. Conductivity	No additives. Refrigerate. Analyze as soon as can reasonably be achieved
Acidity	
Alkalinity	
BOD	
Colour	
Chromium (VI)	
Nitrite	
Silica	
Sulphate	
Boron	Analyze when convenient
Bromide	
Chloride	
Fluoride	
Potassium	
Sodium	
Hardness	Filter in field. Add NHO_3 to pH<2
Metals (general)	
COD	Add H_2SO_4 to pH>2
Grease and oil	
Nitrogen – NH_4	
Nitrogen – NO_3	
Nitrogen – Organic	
Phenols	
TOC	
Cyanide	Add NaOH to pH>12
Sulphide	Add 4 drops 2N zinc acetate/100 ml

No preservatives are required if the sample is to be analyzed within 6 h.
Samples should always be stored or transported at temperatures around 4 degrees centigrade

Appendix D

ANALYTICAL PROCEDURES

This chapter is of a technical nature and the reader is referred to the references in the back of this document for more information on the exact analytical procedures.

Analytical procedures differ greatly from laboratory to laboratory. These range from well-documented so-called wet methods to the more sophisticated automated and computerized procedures.

Methods commonly used are:

- Titration against indicators, for pH and chloride.
- Specific ion electrode measurement for pH and fluoride.
- Spectrophotometric determination, for nitrate and COD.
- Turbidity measurement, for sulphate and turbidity.
- Conductivity measurement, for electrical conductivity.
- Ion chromatography (IC), for the anions.
- Atomic adsorption (AA) – flame and carbon furnace, for the cations.
- Inductively coupled plasma (ICP), for the cations.
- Gas chromatography (GC), for organic compounds.
- Mass spectrometer (MS), coupled with IC or ICP, for speciation of organic and inorganic substances.
- Other specialized and dedicated procedures, such as dissolved oxygen.

Each of the above analytical procedures represents different levels of sophistication. The following is a brief discussion of the various procedures that are generally available.

SABS

The SABS has drawn up a list of unsophisticated analytical procedures. The variables, which may be tested for, as well as the numbers for the analytical procedures, are listed below. Details on these procedures are available form the SABS, upon request. It is recommended that anyone interested in setting up small-scale analytical facilities for water should consider, first of all, the use of these well-proven methodologies.

SABS Method Reference List

1. PHYSICAL

DETERMINAND	METHOD REFERENCE
Colour	SABS 198
Conductivity	SABS 1057
Dissolved solids @ 180°C	SABS 213
Dissolved solids @ 550°C	SM 2540 (E)
Suspended solids @ 105°C	SABS 1049
Total solids @ 105°C	SM 2540 (B)
Total solids @ 550°C	SM 2540 (E)
Taste and odour	SABS 241 3.3
Turbidity	SABS 197

2. INORGANIC (NON-METALLIC)

DETERMINAND	METHOD REFERENCE
Acidity	SM 2310
Alkalinity	SM 2320
Boron	SABS 1053
Chloride	SABS 202
Chlorine (residual)	SABS 1052
Cyanide (qualitative)	SM 4500 – CN/K
Cyanide (total-quantitative)	SABS 204
Fluoride	SABS 205
Nitrogen:	
Ammonia – N	SABS 217
Kjeldahl – N	SM 4500 – N/B
Nitrate + nitrite – N	SABS 210
Nitrite – N	SM 4500 – NO_2
pH	
Phosphate:	
Ortho-phosphate	SABS 1055
Total phosphate	SM 4500 – P/B
Silica	SM 4500 – Si/D
Sulphate	SM 4500 – SO_4/E

Sulphide	SABS 1056

3. INORGANIC (METALLIC)

DETERMINAND	METHOD REFERENCE
Aluminium	SABS 1169
Antimony	ASTM D 3697
Arsenic	SABS 200
Cadmium	SABS 201
Calcium	SABS 216
Chromium	SABS 1054
Chromium (VI)	SABS 206
Cobalt	SABS 1170
Copper	SABS 203
Iron	SABS 207
Lead	SABS 208
Magnesium	SABS 1071
Manganese	SABS 209
Mercury	SABS 1059
Nickel	SABS 1171
Potassium	SM 3500 – K/D
Selenium	SABS 1058
Sodium	SABS 1050
Zinc	SABS 214

4. ORGANIC

DETERMINAND	METHOD REFERENCE
Chemical oxygen demand	SABS 1048
Oil and grease	SABS 1051
Oxygen absorbed	SABS 220
Phenolic compounds	SABS 211
Surfactants (anionic) – MBAS	SABS 199

5. SPECIFICATIONS

TITLE	METHOD REFERENCE
Water for domestic supplies	SABS 241-1984

Prepackaged analytical procedures

Also available commercially and based on principles similar to those of the SABS, are ready packed liquids, pellets and paper strips, containing exact amounts of reagent required for a measurement. These facilities are particularly useful for use in the field. The advantage of using these prepackaged facilities is that no standardization or calibration is usually required, thus eliminating human error.

Automated equipment

Many types of automated equipment for water analysis exist. Most of this equipment is computer controlled and operates efficiently. Typical such systems would include automated wet techniques, AA, ICP, IC, GC and MS.

All of this equipment is expensive and typically prices range from R100000 to R2000000 (1997).

Advantages of using these automated techniques are:

- High throughput of samples. Typical analytical times per determination are: IC (1 min); AA (<2 min.); ICP (<20 sec.).
- High repeatability.
- Detection limits for many of these automated techniques are orders lower than are those for wet techniques.

Several such automated laboratories presently exist in South Africa.

Disadvantages of using these automated techniques are:

- High cost of equipment.
- The specialized training required for handling the equipment.

Practical tips

pH

The pH measurement should preferably be done as the sample is taken. However, pH probes are sensitive pieces of equipment and high turbidity in water may soon clog the probe, thus rendering it useless. Because of this clogging, average life of a glass pH probe, used on an everyday basis in the field, is of the order of 3 months. Daily calibration is also required. In routine measurements, it is usually sufficient to distinguish between acid, neutral or alkaline water. For that purpose, the use of pH paper is recommended.

Electrical conductivity

Electrical conductivity is measured in milli-Siemens per metre. These measurements are fast, cheap and an easy way of determining the approximate salt concentration in water. By multiplying the electrical conductivity value by a factor of between 6–9, the total salt concentration may be estimated. The significant range for the multiplication factor is ascribed to the various conductance factors for different constituents in the water. Chloride typically has a high conductance (factor 6), while sulphate has a much lower conductance (factor 9).

Alkalinity and acidity

Alkalinity and acidity values may change rapidly after groundwater samples have been withdrawn from confined aquifers. For accurate measurements, these variables should therefore be measured in the field, immediately after the sample has been taken.

Alkalinity and acidity determinations involve titration of the water, using sulphuric acid, to pH end points of 8,3 and 4,5 respectively. Adding pH indicators to the water could assist detection of these end points. However, handling of strong acids in the field could be cumbersome and it is recommended that, for general applications, these determinations should rather be done within 6 hours, in a laboratory. Samples should be stored at 4 degrees centigrade.

Macro cations

Ca, Mg, Na and K usually occur in significant amounts in groundwater. Although wet techniques are available for their determination, AA or ICP are preferable. Wet determination of particularly Ca and Mg is based on the indirect EDTA method, through which calcium and magnesium hardness is measured. From this, the concentration of elemental Ca and Mg is then calculated. This method is not advisable.

Heavy metals

The term heavy metal refers to the metals and metalloids in the periodic table, with the exception of the macro cations, listed above. Since these elements usually occur in trace quantities, accurate and sophisticated analytical equipment is required. AA (carbon furnace) or ICP procedures are recommended. Modern carbon furnace equipment allows pre-concentration of elements through multiple injection, and extremely low concentrations can be detected. A sequential ICP, coupled with a hydride generator, can also detect heavy metals at satisfactorily low levels.

Anions

A complete scan of the anions present in water (F, Cl, NO_2, Br, NO_3, PO_4 and SO_4) can be obtained within 10 minutes or less, by using IC equipment. Detection limits range from less than 1ug/1 to more than 1 000 mg/l.

Only two limitations may apply – organic compounds in the water may interfere with the peak reading for fluoride and a multipoint calibration is necessary for accurate work over a wide range of concentrations.

Organic compounds

Analysis for unknown organic compounds is very difficult, because of the vast range of constituents that may be present. The use of GC equipment for routine analysis of waste of unknown composition is therefor not feasible. At best, certain probable compounds, which may be present within the waste, can routinely be tested for.

MS enables specification of the compounds and intensive effort usually results in recognition and quantification of the compound involved.

Both GC and MS work are highly specialized and expensive procedures.

Analytical costs

It is expensive to have water analyzed. Typically, a single determination may range from R 5 to R 10000, depending on the complexity of the determination. Below is a listing of variables commonly measured, and their relative costs (1997):

Electrical conductivity	R 5 – R 10
pH	R 6 – R 12
Macro cations per ion	R 10 – R 28
Anions per ion	R 10 – R 30
Oxygen absorbed	R 10 – R 20
Fluoride	R 15 – R 20
Chemical oxygen demand	R 15 – R 30
Ammonia (N)	R 15 – R 25
Heavy metals per ion	R 15 – R 40
Phenol	R 150 – R 200
Cyanide (quantitative)	R 300 – R 400
GC and MS work	R 1000 – R 10000

It is often even more expensive to collect samples for the field. The number of samples and the variables to be tested for, should therefore be selected carefully. The scope of an investigation should therefore be spelt out, before sampling commences. This will dictate:

- The samples to be taken
- The elements to be analyzed
- The sampling frequency.

A well-planned monitoring and sampling programme will save money in the long run.

Appendix E

DATA INTERPRETATION WITH WASTEMANAGER

Detailed account of the usage of statistical methods is given in a document on compliance monitoring published by the Department. Other facilities for the interpretation of water quality data exist within Waste Manger. These include line and bar charts, or plots of borehole and water level information. Some of these methodologies are less well known. These are, for instance, the specialized chemical diagrams, such as the Piper and Expanded Durov Diagrams.

Piper and

Expanded Durov Diagrams

The Piper and Expanded Durov Diagrams allow for the plotting of eight chemical variables for a single water sample. Either surface or groundwater chemistries may be plotted.

The procedure is as follows:

- Calculate concentrations for Ca, Mg, Na, K, Cl, SO_4, NO_3, T. Alk. In units of milli-equivalents per litre.
- Calculate relative percentages for the cations and anions.
- Plot the percentages cations in the bottom left triangle.
- Plot the percentages anions in the bottom right triangle.
- Project the two points to the central block on the Piper or Durov Diagrams and make a mark where the two projections cross.

Interpretation is as follows:

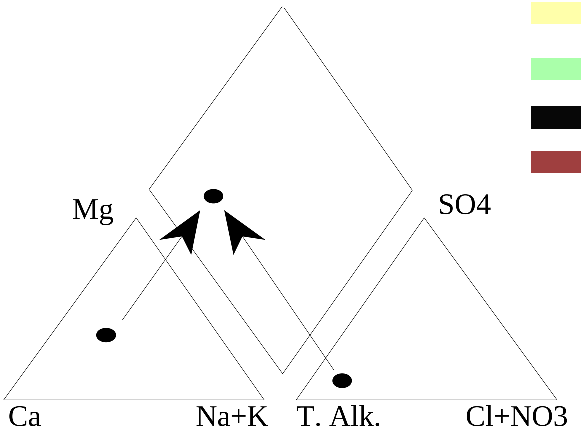
- It is a matter of personal preference whether the Piper of Durov Diagrams are used.
- Both diagrams should primarily be used as visual displays, summarizing the chemistry of all samples taken at a single site or at many sites.
- Of particular value is the identification of pollution trends, through the aid of these diagrams. A comparison between plots of successive sampling exercises will show whether or not trends in the chemistry of the water are developing. Trends to observe are:

    1) Sodium enrichment – typical of processes such as waste water discharge, chemical extraction of elements from ore, dewatering of deep mines, return flow from irrigation or natural deterioration of the groundwater quality by ion exchange within the aquifer.
    2) Sulphate enrichment – typical of most mining environments.
    3) Calcium enrichment – typical of lime dosing to neutralize acid water.
    4) Chloride enrichment – typical of leachate from domestic waste and dewatering of deep mines.

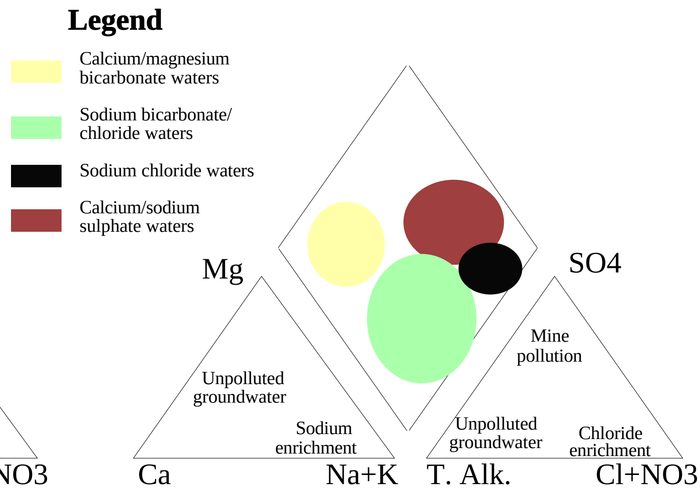
A word of caution though: groundwater chemistry is one of the most complex natural systems to predict, because of the many processes/variables that could affect it. The following are but a few examples of chemical changes that could occur within an aquifer:

- Dissolution of soluble elements, such as Na, K, Cl and HCO_3.
- Precipitation of oversaturated species.
- Ion exchange and adsorption onto clays, such as Ca-adsorption and Na-release.
- Chemical reaction between two waters mixing.
- Natural decay of substances, such as modern pesticides.
- Bacterial oxidation/reduction, such as pyrite oxidation and sulphate reduction.

The specialized diagrams and other techniques for the interpretation of the data, included within Waste Manager, may be used to identify trends. If undesirable pollution trends become obvious, it should be left to the geohydrologist for detailed interpretation.

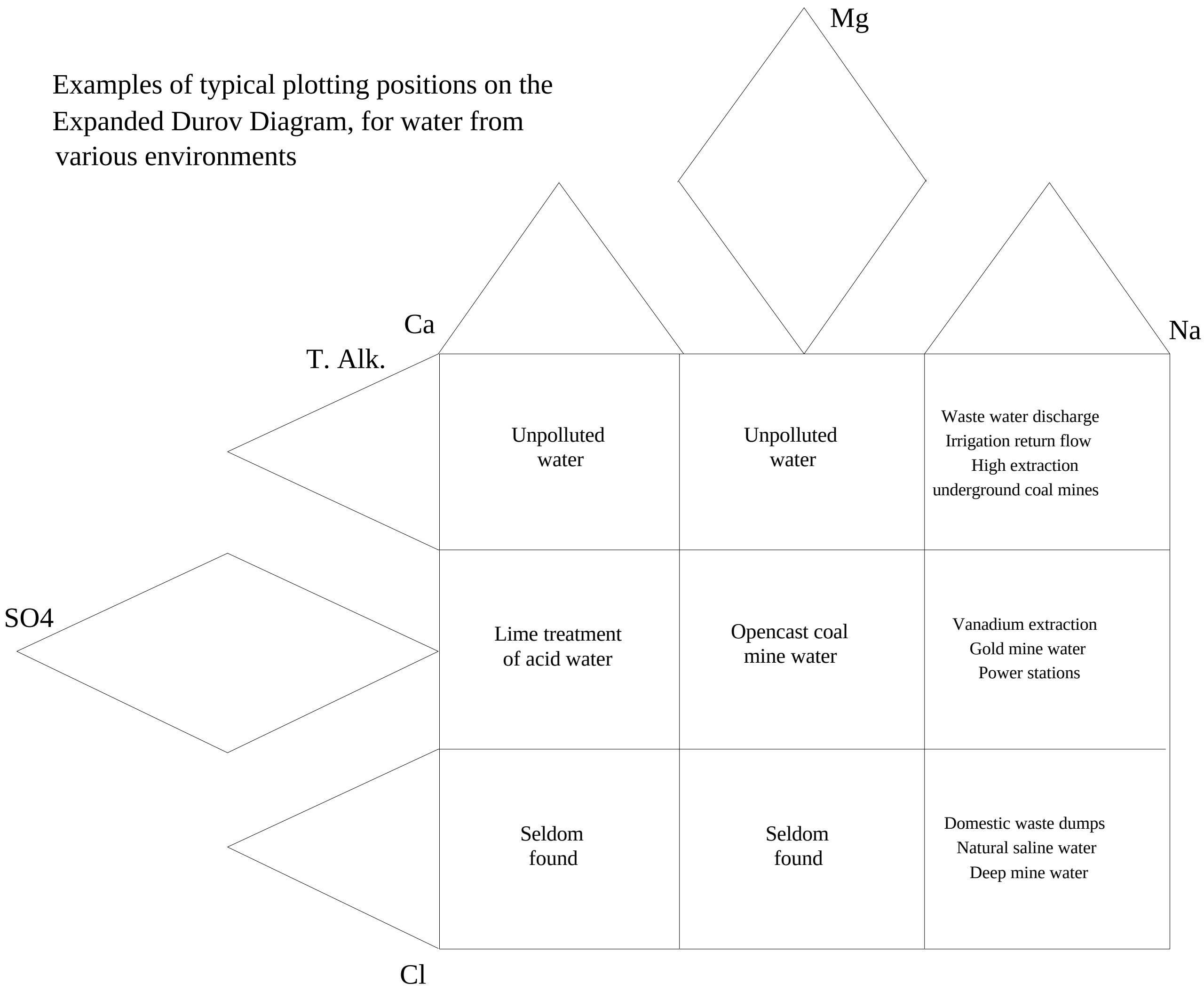


Plotting procedure on the Piper Diagram
Plot of water containing: 50% Ca, 35%Mg, 15% Na+K
80% T.Alk. 10% Cl and 10% SO4



Examples of typical plotting positions on the Piper Diagram, for water from various environments

Examples of typical plotting positions on the Expanded Durov Diagram, for water from various environments



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Appendix F

SUMMARY OF REQUIREMENTS

Minimum requirement

- *The lower limit which must be complied with. The right to appeal against compliance with the prescribed minimum requirements, based upon sufficient motivation, exists.*

Monitoring

- *The meaningful measurement of a variable(s) on a once-off basis during initial impact assessments, or on a routine basis.*
- *Table 6.1 lists requirements against various waste management activities. Also indicated on this table is a frequency for monitoring. Table 6.2 provides details on monitoring networks.*

Waste Management Facility

- *All wastes or products stored on a temporary or permanent basis, that could impact on surface or groundwater quality, by leaching into or coming in contact with water. See also Waste Management Documents, "Minimum requirements for waste disposal sites" and "Minimum requirements for the handling and disposal of hazardous waste"*

Expertise required

- *The installation of groundwater monitoring systems requires specialized knowledge, and consultation with an appropriately qualified geohydrologist is a requirement.*

Monitoring Network

- *Monitoring networks must extend beyond zones of impact.*

Aquifer Classification

- *It is a requirement that all future waste facilities be sited on Poor Aquifer Regions. In the event that this is not possible, a risk assessment and extensive motivation should be submitted to the Department for consideration.*

Risk Assessment

- *A risk assessment, to determine the risk of water being polluted, must be performed at all waste sites before the installation of a monitoring system. This is to ensure that the design of the monitoring system is adequate. The prescribed methodology for risk assessment is included in Appendix A.*
- *It is a requirement that modellers should demonstrate their competence in the modelling of groundwater systems, otherwise the DWA & F will not accept results from simulations.*

Rainfall

- *Rainfall for the past 24 hours must be recorded at 8h00 every morning.*

Evaporation potential

- *The measurement of pan evaporation is only a requirement at hazardous disposal sites.*

Run-off

- Run-off quantities and qualities must be recorded continuously, when specified in the permit. Leachate Collection/Toe Seepage.

- *Samples must be collected, preserved and analyzed according to specifications in this manual.*

Rehabilitation

- *Rehabilitation on top of waste must be done as soon as is reasonably possible.*

Borehole data

Data required from boreholes are:

- *Geological log.*
- *Water intersections (depth and quantity).*
- *Construction information (depth of hole and casing, borehole diameter, method drilled, date drilled).*
- *Use of borehole water, if not solely for monitoring; frequency of abstraction; abstraction rate and whether other water sources are readily available.*
- *Water quality (see chapter on chemical analyses).*

Borehole type

- *Borehole must be drilled by a drilling technique that will not introduce pollution into the aquifer.*

Hole diameter

- *Monitoring boreholes must be of a diameter that will allow easy access to the aquifer, for the purpose of water sampling and for lowering other test instruments.*

Hole depth

- *A monitoring hole must be such that the section of the groundwater most likely to be polluted first is suitably penetrated, to ensure the most realistic monitoring results.*

Casing, screens and filters

- *The materials used for casing, screens and filters in contact with water must be compatible with, and resistant to chemical attack by, the water being monitored.*
- *Casing, screens and filters must allow easy access for monitoring purposes and may in no way block the flow of water through the borehole.*
- *A security cap must be fitted to prevent accidental or willful interference with a monitoring borehole.*
- *Required minimum dimensions for the concrete block are 750 mm x 750 mm x 150 mm.*

Piezometer tubes

- *Piezometer tubes must allow easy access for water sampling over the whole of the aquifer.*

Borehole protection

- *Monitoring boreholes must be adequately protected to prevent accidental damage of the holes.*

Groundwater levels

- *Groundwater levels must be recorded within an accuracy of 10 cm using an electrical contact tape, float mechanism or pressure transducer.*

Pumping and/or packer tests

- *Where considered necessary by the geohydrologist or design engineer, pumping and/or tests must be carried out on boreholes to obtain additional data on the geohydrological conditions at that particular position.*

Fountains, wells, dams, pans, streams and rivers

- *Water sources around a waste management facility, within a radius as suggested by the risk assessment, must be sampled and preserved for chemical analysis.*
- *Flow from fountains and in streams must be estimated. If pollution occurs as a result of waste managing, then the Department may request continuous recording of flow and water quality.*

Water/salt balances

- *Water/salt balances: In instances where excess water is present and this water may have to be discharged into public streams, water and salt balances are required. At larger complexes such as mines, power stations or large industries, this usually implies water and salt balances for each of the contributing components, such as for raw water intake; for materials brought onto,* *removed from or disposed of on site; and for rainwater contribution and run-off.*

Monitoring Networks

- *Monitoring networks at waste management facilities must allow monitoring of the system on a representative basis (see Table 6.2).*
- *Local monitoring networks should extend beyond pollution plumes to allow for the delineation of plumes and investigations into the pollution migration rate.*

Water sampling

- *Water from monitoring positions must be sampled according to procedures prescribed in Appendices B and C.*

Sample bottles and filters

- *Bottles of plastic, with a plastic cap and no liner within the cap are required for most sampling exercises.*
- *Glass bottles are required if organic constituents are to be tested for.*

Sample Preservation

- *It is a minimum requirement that samples be preserved according to specifications in this document.*

Sample Frequency

- *Where waste management permits are issued, the minimum sampling frequency will be prescribed.*
- *At any groundwater sampling facility, whether permitted or non-permitted, initial sampling should be done at a frequency high enough to obtain statistically valid background information. For any long-term monitoring facility, three initial sampling exercises, all within 90 days and not less than 14 days apart, are suggested. Depending on the variation amongst these values, future sampling may be planned. A three-monthly sampling frequency will in most instances be sufficient.*

Surface water

- *Continuous monitoring of the discharged flow volume and quality (by electrical conductivity method) is required in instances where polluted water is disposed of into a public stream.*

Analytical variables

- *A recognized analytical laboratory that uses approved analytical procedures must analyze water samples.*
- *In instances where permits have been issued, permit conditions will specify the frequency of analyses and constituents to be tested for.*
- *For all new sites and first time monitoring at existing sites, a comprehensive analysis is required.*
- *Indicator analysis may be performed once comprehensive analyses have been completed. This process may continue until undesirable trends are uncovered.*

Reporting to the Department

- *Data must be stored in such a way as to be easily accessible for to the waste manager and to the Department.*
- *Data must be processed and interpreted after each sampling exercise.*
- *Reporting frequency to the Department will be specific in the waste management permit conditions. Otherwise, the reporting frequency is six-monthly.*

The following actions are recommended

Public participation

Public participation has for many years been ignored as input. This has now changed and without their participation, success with a venture of this magnitude cannot be achieved.

Company level

Monitoring programmes, on a company level, at each of the waste types described in Chapter 5, should be the first initiative. Individual sites for waste management within municipal boundaries, with a nominated responsible party, are also classified under this category.

Essential issues are:

- Environmental awareness on company management level.
- Acquisition of qualified people to manage waste facilities and liaise with the Department.
- Installation of suitable monitoring systems.
- Compliance monitoring, i.e. routine monitoring by the company, within permit stipulations.
- Remedial action, which is often almost impossible, is the responsibility of the waste Management Company.

Local authority level

Within municipal boundaries, one or more waste management facilities usually exist. These are municipal or private dumps, sewage treatment facilities and urban water run-off.

The following responsibilities lie with local authorities:

- Performing an annual survey of all waste management facilities within their boundaries.
- Ensuring that waste management companies comply with waste management permit conditions.
- Co-ordination of waste management activities.
- Receiving and evaluation of monitoring reports.
- Planning and co-ordination of future waste disposal, providing adequate waste disposal facilities, well in time for the application of waste management permits from the Department.

Departmental level

The responsibilities of the Department are:

- To receive and process waste management permit applications. To issue waste management permits.
- To perform routine field checks.
- To receive and process monitoring reports. Possible responses will be: issuing of acceptance letters; requesting additional information; requesting re-evaluation of monitoring systems; requesting contaminant clean-up; requesting a financial bond to guarantee successful clean-up and closure of the site.
- To maintain a national computerized data base on waste management facilities, which may be used for the co-ordination of waste management in South Africa and water quality management on a local and catchment level.
- To initiate training, guidance, public relations programmes and to provide support for the waste management community to ensure co-operative and successful management of the waste stream.