LANDFILL MANUALS

LANDFILL OPERATIONAL PRACTICES

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PREFACE

The Environmental Protection Agency was established in 1993. The functions of the Agency are set down in the Environmental Protection Agency Act 1992. They include the licensing and regulation of significant industrial activities, the monitoring of the quality of the environment, the provision of support to local authorities in respect of environmental protection activities and the promotion of environmental research. These powers were supplemented in 1996 with the passing of the Waste Management Act. The latter makes the Agency responsible for the licensing and control of the majority of Ireland's waste management infrastructure.

Under Section 62 of the 1992 Act the Agency is required to specify and publish criteria and procedures for the selection, management, operation and termination of use of landfill sites. These criteria and procedures are being published in a number of manuals under the general heading of "Landfill Manuals". Two manuals have already been published: *Investigations for Landfills* and *Landfill Monitoring*.

The purpose of this manual is to provide guidance on operational practices on landfill sites. It is aimed at operators of new and existing landfills involved in the acceptance of biodegradable wastes. The guidance is intended to ensure that site operations will, in the future, be conducted to a satisfactory standard, with an associated minimisation of the impacts of such sites on human health and the environment. The Waste Management Act 1996 will have a significant impact on the manner by which landfills will be developed, managed, monitored and subjected to aftercare procedures. This manual also is intended to assist operators meet the standard required by waste licences. Improvements are needed for environmental and public health reasons, but also to provide reassurance that waste management can be undertaken in a competent and professional manner.

It is envisaged that further manuals will be available in due course and, at the time of writing, manuals on landfill site selection and waste acceptance are in preparation. Given that this Operational Practices Manual is one of a series, it is important that this manual is read in conjunction with the other published documents.

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1. INTRODUCTION

1.1 EU AND NATIONAL POLICY

A comprehensive waste management framework for Ireland is being developed by the Department of the Environment, in conjunction with the Agency and local authorities. This framework includes policy, legislation, infrastructure and other management measures. The Waste Management Section (Section 9) of the Operational Programme for Environmental Services 1994-1999 states that particular emphasis will be placed on waste management planning, arrangements for waste disposal and recovery facilities and associated services.

These developments parallel initiatives at EU level. The objectives of EU policy on waste management can be summarised by programmes aimed at:

- the prevention of waste;
- reducing the quantity of non-recoverable waste;
- recycling and re-using waste to the maximum extent for raw material and energy; and
- disposing safely of any remaining wastes which cannot be recovered.

The means by which these objectives are to be pursued are set out in the EU Fifth Environmental Action Programme “Towards Sustainability”. Under the Programme, particular attention is to be given to the prevention of waste, the use of clean technologies, the encouragement of re-use and recycling, the provision of facilities for recycling and the development of infrastructure for the safe disposal of waste. In recent years the EU has adopted a Waste Strategy and a revised Directive on Waste. A Directive on Packaging and Packaging of Waste (94/62/EEC) also has been adopted. The standards and requirements set out in the national regulations implementing these Directives will have a direct bearing on the approaches taken to waste prevention, reduction and secure ultimate disposal.

A proposal for a Directive on the Landfilling of Waste is at present under negotiation, although an earlier version was rejected by the European Parliament. That version of the Directive had passed through a considerable number of drafts, each containing varying degrees of detail required to be imposed by the Directive on Member States. If agreed by Member States and implemented, the Directive’s primary purpose will be to upgrade EU landfills to a satisfactory standard by setting down requirements aimed at the reduction of adverse environmental impacts of landfill and risks to human health.

The Waste Management Act 1996 designates the Agency as the licensing authority for significant waste management facilities. This will include all landfills taking significant quantities of biodegradable wastes. The Act sets down criteria which must be adhered to for a waste licence to be issued and retained. Overall, it is expected that these requirements will stimulate an already observable trend towards large engineered sites. Many existing landfills in Ireland will require upgrading to meet higher standards.

1.2 THE ROLE OF LANDFILL

In Ireland, landfill is the primary method for the disposal of household, commercial and industrial wastes, accepting a total of at least two million tonnes of waste per year. The extensive use of landfill is likely to continue in the future, despite considerable efforts in the direction of recycling and waste minimisation. Currently, approximately 92% of household and commercial waste in Ireland is disposed of to landfill sites. Even when the current target of 20% recycling of household and commercial waste is achieved, it is likely that much of the remaining 80% will pass to landfill. Within this context, it should also be noted that, in the past decade, the quantity of waste delivered to local authority landfills has increased on an annual basis.

Whilst there are other non-landfill disposal options available, it is unlikely that their adoption over the next ten years will displace landfill as the major disposal route for Ireland’s wastes. Although incineration remains a possibility, this technology is subject to significant constraints. Other options, such as composting and waste derived fuel manufacture, may have a role at diverting wastes away from landfill sites. But in the short to medium term landfill will continue to contribute significantly towards the disposal of waste.

In the past, landfill sites were rarely engineered to containment status. The absence of environmental monitoring programmes at many older sites meant that the impact of the landfill on the surrounding environment could not be assessed in advance of problems developing. When badly managed, the landfilling of waste can have significant environmental impacts. Often problems associated with poor standards may have long term, inter-generational effects. They include possible contamination of the groundwater and surface water regimes and the uncontrolled migration of landfill gas. Shorter term impacts include the generation of odour, noise, litter and visual nuisance.

Over the past decade, standards and practices at landfills have been subject to a slow, but steady, improvement. An example is the role of lining technology. In addition, it is now generally acknowledged that landfill construction and operation is a significant and demanding sub-discipline of civil engineering. The use of landfill as a source of energy also has been actively pursued at a number of existing sites.

It is important therefore that landfills are located, designed, operated and monitored to ensure that they do not, to any significant extent:

- harm the environment;
- endanger human health;
- create an unacceptable risk to water, soil, atmosphere, plants or animals;
- create unacceptable nuisances through noise or odours; and
- adversely affect the countryside or places of special interest.

Experience with the more modern landfills in the country, and also elsewhere in Europe, indicates that well managed and adequately resourced landfill sites can attain these criteria on a long term basis.

1.3 THE OPERATIONAL PRACTICES MANUAL

The objective of this manual is to contribute to the improved management of existing biodegradable landfill sites, whilst providing guidance on how new sites are to be operated. The manual should thus be seen as contributing to the process of improving national landfill standards which will accelerate with the implementation of the Waste Management Act. It sets down the basic requirements for effective day-to-day operations, covering such matters as waste emplacement, cover, cell design, site management, leachate and gas control. However, effective site management cannot be based solely on how operations on a landfill site are conducted. It is equally important that the interface between the site and its neighbours is considered carefully. As important as it is to improve the physical operations on a site, it is equally important to address the context within which a landfill operates, especially the negative public perception of landfill as a waste disposal concept. This is crucial both to those persons living or working in proximity to a site and also to site users. Hence there are sections within this manual on such matters as site appearance, nuisance and liaison with the general public.

The manual is, as noted, one of a series and hence should be read in conjunction with the two published manuals and with future manuals when they are available. Whilst landfill gas and leachate production are considered, the monitoring requirements for such substances are set out in the manual *Landfill Monitoring*. Similarly, the design of new sites, and those existing sites undergoing significant extensions, will be addressed in a forthcoming manual entitled *Landfill Site Design*.

The statutory basis of this manual is s62 of the 1992 Environmental Protection Agency Act. That section requires the Agency to specify and publish criteria and procedures for landfills. These criteria relate not only to domestic wastes but also apply to the disposal of other wastes in landfills. This Operational Practices Manual is addressed to operators of landfill sites accepting biodegradable waste, be they local authorities or from the private sector. Under s62(5) of the 1992 Act, local authorities are required to take steps as soon as practicable to ensure that any landfill site managed or operated by them complies with any specified criteria or procedures published by the Agency.

Landfill science and practices are dynamic by their nature, in the sense that the whole discipline of landfill management is evolving on a continuous basis. Accordingly, the Agency intends to periodically update the Landfill Manual series to reflect advances in landfill management.

2. SITE RECORD KEEPING AND MANAGEMENT

2.1 INTRODUCTION

Daily operations on a landfill site involve the application of manpower, plant and materials, with increased demands being placed on all of these. Site management is required to have a much better understanding and control of the site and, particularly, over its biodegradation process and associated impacts. This is a consequence of the increased sophistication of the technology used in landfill operations and the highly biodegradable nature of many of the wastes being accepted. These developments indicate a need for comprehensive forward planning, so that the remaining life of the site is managed in an organised, structured manner. Such forward planning will also go hand-in-hand with the requirements for compliance with waste licences under the Waste Management Act 1996.

2.2 THE ENVIRONMENTAL MANAGEMENT PLAN

All sites should be subject to a detailed Environmental Management Plan. Operators of landfills which do not have the benefit of such a document should have one developed as a matter of priority. The Plan is not only necessary for competent site management, but will provide essential information for any application for a waste licence under the Waste Management Act.

The Environmental Management Plan can be broken down into a number of sections and associated drawings. Table 1 shows the basic details which need to be included within such a document, and further detailed guidance will be given by the Agency in conjunction with the waste licence application form. In certain cases, information on older, and already filled, parts of the site may not be readily available to the operator. However, as much information as possible should be given, even where estimates have to be made.

It is essential that a detailed topographical survey of each landfill site is undertaken. This should be based upon identified fixed datum points located in areas of the site which are not likely to be disturbed and which relate to ordnance datum. These will provide a benchmark for subsequent site surveys, so that surveys are comparable and the resultant plans can be used to overlay each other.

The site survey and associated voidspace calculation should be repeated annually, so that the rate of fill can be assessed. The up-to-date survey can be used as the basis for other plans and for developments on the site. The survey should include filled areas so that the effects of settlement can be assessed. All leachate pumping chambers and other leachate and landfill gas monitoring points should be surveyed and accurately recorded. Benchmarks on all leachate level monitoring points should be accurately surveyed so that leachate levels can be assessed in respect of the fixed reference monitoring points at the landfill periphery. The accuracy of these benchmarks should be checked during the annual survey to ensure that factors such as settlement and lateral movement within the fill are taken into account.

2.3 OTHER SITE RECORDS

A comprehensive series of site records should be maintained for all landfills. A full set of drawings of the site and structures on the site should be retained. As-built drawings of all lining, leachate drainage and collection systems should be included, along with drawings of all capping works. Plans should be accompanied by written descriptions of development works undertaken, as well as photographs of the site at various stages and details of particular capital projects. Site input records should be maintained for all wastes entering the site, including inert materials for restoration and cover.

The results and an interpretation of the results of environmental monitoring should always be included in the site records. Good record keeping is an essential component of the effective management of a landfill. Monitoring records are needed in order to assess and manage the biodegradation process.

The necessity for an organised system of record keeping should be borne in mind and introduced at the earliest possible stage in the development of a landfill facility. Although older sites may have scant data, the introduction of a record keeping system is still necessary and should be considered a high priority for the operator.

Records should be retained throughout the life of the facility, and for the closure and aftercare periods. Documents should be organised, legible, dated and signed by the appropriate personnel. At least one complete duplicate set of records should be held at a location other than the site itself.

TABLE 1: LANDFILL SITE ENVIRONMENTAL MANAGEMENT PLAN

Details of Operator

Name and Address of Operator and Site. Included should be contact names in respect of person with managerial responsibility for site operations, including the site manager, site engineer. Relevant telephone numbers should also be given.

Site Description

A description of the site should be provided which covers the following:

- boundaries and topography
- geological and hydrological characteristics of the area
- local meteorology

Types of Waste Accepted

A detailed description of the procedures for acceptance and the types of waste that can be accepted on the site should be given. This should clearly state whether household, commercial and industrial wastes are to be accepted. Hazardous wastes and other difficult wastes should be listed separately and a clear indication given, where appropriate, of the maximum permissible concentration or loading thresholds for particular substances. Consideration should be given to the procedures to be employed for the acceptance of other difficult wastes such as tyres, empty drums, sewage sludge, asbestos and so on.

Quantity of Wastes Accepted

Details should be given on the annual quantity of waste taken into the site. This should be sub-divided into major types (examples would be household waste, commercial waste, industrial waste – specified by type, source etc).

Site Capacity

An estimate should be provided of the original site capacity and remaining capacity. The latter should be derived from the annual survey.

Engineering Details

Details of all significant site engineering works should be included. Where applicable the information should cover:

- site preparation and provision of services
- containment details
- leachate drainage, collection and treatment
- landfill gas abatement methods (e.g. passive trenches, active extraction) collection and flaring
- monitoring points for landfill gas, leachate, surface water, groundwater etc.
- fencing, gates and other security
- site access roads and secondary site roads
- offices, fuel stores etc
- current landscaping and tree planting
- wheel cleaning infrastructure, site weighbridge etc
- surface water control measures, ditches, road drains, wheelwash water, etc.

TABLE 1 (CONTINUED)

Operational Matters

These should include:

- description of the operations
- phasing of filling
- water, leachate and gas control measures
- measures for the control of environmental nuisances
- site opening and operating times
- access control and waste acceptance procedures
- equipment to be utilised
- waste placement procedures
- cover requirements
- site personnel, including qualifications, duties and responsibilities
- monitoring and maintenance procedures
- operational and safety rules (including safety statement) and emergency procedures
- litter abatement methods and procedures
- noise and dust abatement
- wheel cleaning procedures
- measures to deal with vermin and other pests
- assessment of settlement in filled areas
- assessment of compacted waste density

Closure and Aftercare

Closure and aftercare procedures should include:

- final capacity and expected operational period of the facility
- final contours and topography of the site
- the restoration plan
- phases for closure and restoration of completed areas
- aftercare monitoring and other control measures
- maintenance programme for aftercare phase.

Site records should include:

- copies of all site appraisal and investigation documents, borehole logs etc;
- information and plans on the landfill design and the design of other structures on the site;
- copies of site rules for staff, visitors, contractors etc;
- waste acceptance procedures;
- documentation of inspection records, training and notification procedures;
- a detailed scheme for restoration and aftercare;
- site surveys and void space calculations;
- locations of all landfill gas, ground and surface water and leachate monitoring points, along with sampling protocols;
- environmental monitoring programmes;
- results and interpretation of the results of all environment monitoring;
- names, positions and qualifications of all staff involved in site design, management, engineering and environmental monitoring;
- records kept of quantity, nature and origin of the waste accepted into the facility;
- site inspection records;
- in the case of a hazardous or difficult wastes, details of the types and quantities accepted along with a site plan indicating their location;
- details of complaints and remedial actions;
- procedures and records as required regarding safety and health, accidents and fires;
- a copy of the site's planning permission (where required), environmental impact statement and Ministerial Certificate (if issued);
- a copy of the application for a waste licence (when required), including information submitted in support of the application;
- a copy of the waste licence (when issued) and any amendments; and
- copies of all other official documents relating to the landfill including consents and other certificates.

2.4 ANNUAL ENVIRONMENTAL REPORT

All operators should audit their landfills at least once a year. The results of that audit, along with other site records, should be used to prepare an Annual Report for the site. Table 11 of the Agency's *Landfill Monitoring Manual* sets down the minimum requirements for the Annual Report. The report should describe the inputs of waste accepted over the previous year, indicating such matters as the location of cells and the phasing system used in that period. Any deposits of difficult waste should be clearly identified. A comprehensive account of the environmental monitoring should be included, with a clear assessment of the implications of the results obtained and of the impact of the site on the environment. All complaints received should be summarised, along with the remedial actions taken. A programme of work should be included which highlights areas of priority work for the forthcoming year. In annual reports for subsequent years, an account should be included of how these priorities have been addressed in the year.

2.5 SITE MANAGEMENT AND STAFFING

All landfill sites should be supervised by a suitably qualified person who is designated as the site manager. Other persons should be designated as having responsibility for the site in the absence of that person. Whilst the site manager may not need to be on site all the time, a significant proportion of the site manager's working week should be spent on the landfill site supervising its operations.

All landfill sites should have a named engineer assigned to the site. The engineer should be educated to degree standard or equivalent and have appropriate experience. The duties of the engineer will include the carrying out of routine site visits, inspections/certifications and overall supervision of developments at the site.

In certain circumstances, the site manager and the site engineer may be the same person. However, the operator should be able to demonstrate that such a person has adequate qualifications and experience in both facets of the job.

The construction of earthworks, such as lining systems, and the installation of key environmental protection measures, such as landfill gas trenches, must be supervised by the engineer. Where necessary, third parties may be employed to undertake the quality assurance of significant site engineering works, particularly lining and capping systems. Increasingly, Quality Assurance/Quality Control (QA/QC) or Construction Quality Assurance (CQA) techniques will need to be implemented.

QA/QC techniques cover the requirements for planning and verification which ensure that engineering works are subject to both high quality design and that these designs are fully implemented when the works are carried out. CQA should be seen as an essential tool in the development of key structures on landfill sites, using a system of certification by way of the employment of an independent engineer. The latter has the duty of assessing matters such as the design, materials and workmanship and whether these meet the required criteria. Usually, the whole process is based on an agreed construction quality assurance method statement, which sets out in detail the manner by which the works are to be approved, along with record keeping procedures, test methods and frequencies and mechanisms for addressing non-compliance. Many of the testing methods to be undertaken are set down as recognised international standards (for example, British Standards (BS) or International Standards Organisation (ISO)), but others may need to be developed and agreed between the site designer, operators and, if required, the Agency.

Other specialist tasks such as the design and installation of leachate treatment plants, gas collection systems (especially gas flares), lining systems etc should be undertaken by persons with significant practical experience in these matters. They should not be undertaken by the site operator directly, unless that person can demonstrate the requisite practical experience and technical competence.

It is vital that all sites should have personnel capable of undertaking key tasks and acting responsibly on behalf of the operator. Of particular importance is the need for personnel assigned responsibility for waste acceptance to be full time employees of the licence holder/operator. Given the fact that many wastes can only be checked at the time of deposit – in other words on the working face – it is crucial that plant operators are aware of the relevant procedures and in a position to effectively implement them. The operation of the working face should be supervised at all times by members of the site's permanent staff. Supervision of the working face and responsibilities for checking materials being deposited should never be delegated to temporarily employed operatives. Hired-in staff cannot be expected to have the experience and the personal responsibility/interest required for load checking at the face.

Adequate back-up staff should be available to manage and operate a site in the event of sickness, holidays and so on.

It is not desirable that one individual, working alone should be left in charge of a landfill which is open for the acceptance of waste. It is not possible to adequately check loads in these circumstances, and this arrangement may be undesirable for health and safety reasons.

Professional development and training should be provided so that staff are familiar with the required standards of operation, statutory requirements and, in particular, the need to verify the appropriateness of incoming wastes. All operatives should be trained to a standard which will satisfy the requirements of national health and safety legislation, particularly in the safe operation of equipment. They should be aware of the contents of the Environmental Management Plan for the site, the conditions of any waste licence and the standards of operation required. The nature and types of wastes being handled, and the difficulties involved in ensuring continuous supervision make it essential that staff receive a high standard of training.

2.6 SITE INSPECTION

During the operational phase, the landfill should receive thorough and regular inspections by the site manager. A written record of each inspection should be kept. This inspection should be carried out at least weekly and should cover the area of current operations, as well as completed areas. This inspection should also include the site perimeter and site security arrangements.

An example of a site inspection report form is shown in Table 2.

TABLE 2: SITE INSPECTION REPORT FORM

SITE INSPECTION REPORT

Site Name .... Ref No ....

Date of Inspection .... Time in .... Inspector's Name ....

Reason for Inspection .... Time out .... Weather .... Site: Open/Closed

Status at Time of Inspection	Unsatisfactory	Satisfactory	Not Checked	Inapplicable	Comments
Environ. Man. Plan Compliance					
Types of Waste					
Layering/Compaction of Waste					
Covering of Waste					
Crushing Large Objects					
Litter Screens & Litter Control					
Liner/Protective Layer					
Condition of Site Roads					
Condition of Site Entrance					
Highway/Wheel Cleaning					
Site Tidiness					
Fires					
Insects/Vermin/Birds					
Surface Water Drainage					
Leachate Control (on-site)					
Landfill Gas					
Odour					
Noise					
Dust					
Gate/Fencing/Security					
Office/Site Notice Board					
Manning & Supervision					
Site Record Keeping					
Fuel & Equipment Storage					
Cover Stockpile					
Site Environs – Litter					
Site Environs – Leachate					

Other Observations/Action Required:

IMMEDIATE ACTION IS REQUIRED ON:

Site Operator's Comments:

Samples Taken: Yes/No Photographs Taken: Yes/No	Inspector's Signature:	Received by: ....

3. SITE APPEARANCE AND INFRASTRUCTURE

3.1 INTRODUCTION

The negative public image of landfills is very much a result of past experience with untidiness, litter problems and poor or non-existent landscaping. These factors do not engender public confidence that a site is well managed. Accordingly, an essential pre-requisite to establishing a degree of community acceptance is attention to a site's physical appearance. It is important that a positive impression is gained by

- the general public;
- neighbouring residents; and
- users of the landfill.

To develop a positive image it is necessary for the operator to address certain key elements. The most important are that:

- site management is in compliance with the Environmental Management Plan, published guidelines and waste licence conditions;
- sympathetic design and landscaping is arranged, which blends the development in with surroundings and topography; and
- environmental protection policies and practices are effectively implemented.

In order to demonstrate to the public that the landfill is being operated effectively, the development must work and look well. The design should take account of the characteristic topography and details of the surrounding landscape. By definition, the new topography created as the landfilling activity progresses should merge with the existing landscape at the common boundaries. Although existing landfills will face constraints in this respect, attention should be given to improving site appearance. For example, at many existing sites it may be possible to greatly improve visual appearance by paying attention to the final landform to be created at the restoration stage. This may involve re-profiling and revisions to older areas of the site, where poor quality restoration has occurred sometime in the past.

It is important to pay attention to the visual impact of the perimeter zone of the landfill. The primary function of this zone is to provide a screening barrier around the site to minimise potential visual, noise and odour impacts. Existing vegetation in the perimeter zone should be disturbed as little as possible as it provides an immediate visual barrier. Existing planting should be supplemented by landscaping works as appropriate. Again, it may be possible to greatly improve the appearance of existing sites in these respects.

For a new landfill, it is essential that a holistic approach is taken, in the sense that the development, filling and after-care stages of the site are all considered at the design stage. Whilst this objective is clearly much more difficult to achieve at existing sites, it may nevertheless be necessary to make changes and improvements which build upon this principle. In particular, the restoration of the site should be arranged progressively as areas of the site are filled, and these should blend in with the initial screening works undertaken prior to the commencement of landfilling activities. Consideration of the eventual landform and after-use of the site is necessary at the design stage. For existing sites, consideration of the final topography and restoration of the landfill should be a priority, with appropriate improvements being enacted as soon as feasible.

The following sections set down a number of matters which must be evaluated in the light of the need to diminish the impact of both new and existing landfill sites on the local environment. The major elements are shown in Figure 1.

3.2 SCREENING AND LANDSCAPING

Screening in the perimeter zone and at divisions between different phases in a landfill can be provided by hard landscaping in the form of earth bunds. Earth bunds provide visual barriers and assist in the restriction of unauthorised access to the site. They can also considerably dampen noise impact. Both permanent and temporary bunds can have a role. Temporary bunds can provide screening and are a useful way of storing large quantities of materials that can be used for later restoration. Permanent bunds may be desirable to provide a maturing, long term screen. In either case, it is important that they are constructed, where possible, in a manner which complements existing topography. Sudden changes of gradient and obviously artificial slopes should be avoided.

Planting, either in conjunction with bunds or separate to them, can prevent undesirable views, restrict litter, dust and noise problems and generally “soften” any hard landscaping. All planting needs maintenance, particularly in the early stages of growth. Weed removal is desirable as it considerably reduces competition for water and nutrients at plant roots and

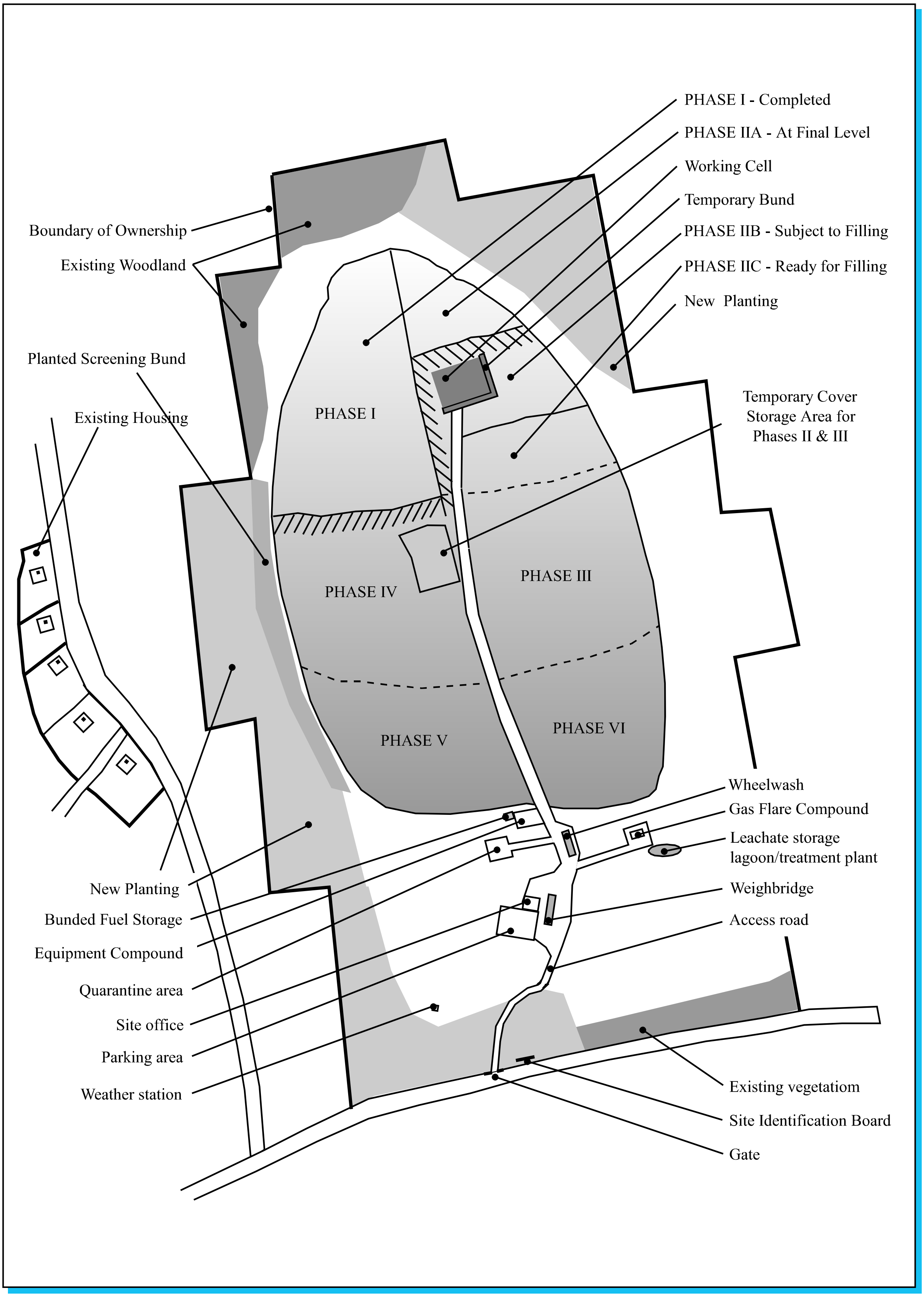

FIGURE 1: TYPICAL LANDFILL

hence encourages strong growth and associated rooting systems. Ideally, planting should use native species and should be designed to blend in with the site's surroundings. It should be noted that the use of quick growing conifers around a landfill may increase the degree of visual intrusion rather than reduce it. Accordingly, unless already existent in the environs of the site, the use of this type of screening should be avoided.

Priority attention should be paid to areas which have the greatest impact upon members of the public. This applies particularly to the site entrance, boundaries adjacent to the public highway and at locations in proximity to residential dwellings. A well laid out site entrance and access road gives a positive impression to both users of the site and passers by. A curving access road is preferable to one that is dead straight, both for reasons of visual affect and also to keep vehicle speeds low. It may be possible to arrange the siting of the access road so that, in conjunction with planting and landscaping, the site office and active cells are screened from the public highway. Well laid out site offices and waste reception area also provide a positive impression.

As noted, the final contours of the filled site should be considered at an early stage. This will assist early establishment of the screening scheme and results in the planting being in a mature state when landfill completion is near. It is important that the final surface of the landfill is designed with a view for environmental enhancement, taking into account settlement and the needs of capping. In all these respects, the construction of flat horizontal surfaces are highly undesirable. These rapidly become concave due to settlement. This attracts rather than repels water ingress into the site, negatively affecting leachate management. In addition, a flat surface is often visually unattractive and does little to improve the image of landfill.

3.3 SITE INFRASTRUCTURE

3.3.1 ACCESS

The access road between the public highway and the site should be of substantial construction, preferably being surfaced with concrete or tarmac. Unpaved roads at this key location should be avoided. They deteriorate quickly, generate dust in the summer and cannot be cleaned mechanically. Bitumen macadam or concrete roads, conversely, can be swept regularly and hence serve to prevent mud tracking out of the site onto the public highway. Maintenance is an essential pre-requisite of any of the options chosen, as a badly potholed, patched surface may cause inordinate vehicle wear, contribute to the noise effect of vehicles leaving the site and project a negative image.

It is important that excessive vehicle speeds on the access roads are prevented. It is preferable that roads are designed to ensure speed reduction. For example, a curving road will reduce speeds, whilst a dead straight road will encourage fast driving. Whilst speed control ramps can be used, these are generally undesirable when other options are available. They may significantly add to noise effects from empty vehicles leaving the site. In many cases, clearly marked road signs, coupled with the vigorous application of site rules, should preclude excessive speeding by site users.

Secondary roads can be constructed to a lower specification, where they are temporary by nature and due for replacement as filling proceeds. Hence quarry stone, construction waste or similar materials can be used in these locations. However, should such a road be intended for use over a period of some years, a more substantial surfacing should be installed. This will allow for road sweeping and improved general maintenance.

Figure 2 shows a typical cross section of both an access road and a temporary site road.

For all roads constructed on a landfill, care should be taken to ensure that adequate drainage is provided. All roads should be constructed in a manner which allows the unrestricted discharge of surface water.

Roads should be laid out so that vehicles can pass easily, using passing places where applicable. At larger sites it may be possible to introduce a one way system, with the way out being sited in conjunction with wheel cleaning facilities.

Careful layout of the entrance is also necessary. A badly designed entrance can attract nocturnal or weekend flytipping. In many cases, the realignment of the entrance of an existing site can be a way of addressing this problem. For example, improved sight lines at the entrance mean that it is much more open and hence flytipping activities are visible from the public highway. Such measures can be supplemented by large gates which close flush to the public highway, being either hinged or run laterally across the entrance on rollers. Finally, the use of a video camera at the entrance may be necessary where flytipping has become a major problem.

In the case where a landfill shares an entrance and site road with a civic amenity facility, it is important that private cars and heavy goods vehicles are segregated for safety reasons. In addition, the civic

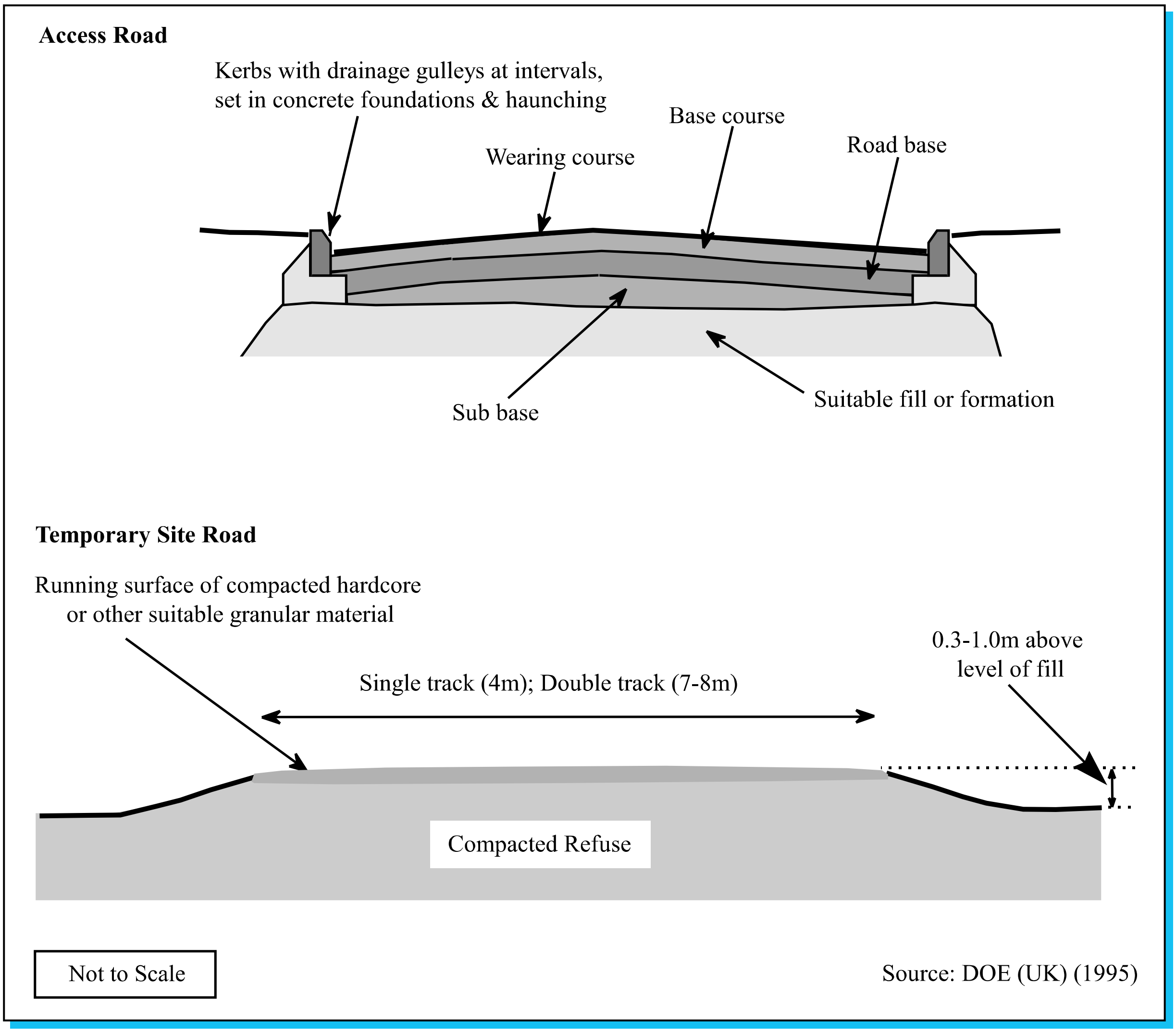

FIGURE 2: CROSS SECTION OF SITE ROADS

3.3.2 SITE IDENTIFICATION AND INFORMATION BOARD

A site identification board of durable material and finish should be displayed near the site entrance providing the following information:

- the site name;
- the name, address and telephone number of the operator and/or owner;
- the licence identification number;
- the site opening hours; and
- the contact and emergency telephone numbers.

The site notice board must be maintained and updated as required.

3.3.3 SECURITY

It is imperative that landfill sites are secure from unauthorised access. This should be a priority at all landfills.

The security provided should be based on an assessment of potential risks, taking into account location (particularly proximity to the public highway) and target populations. In areas where unauthorised access is deemed likely, the site should be enclosed by unclimbable palisade, chainlink or equivalent fencing. Alternatively at less sensitive locations, stock-proof fencing may be adequate.

It may be desirable for reasons of cost and on the assessment of likelihood of trespassing to have more than one type of fencing. For example, high specification security fencing may be restricted to the entrance and areas containing weighbridge, employees' amenity building, garage, stores, garage and fuel supplies.

Access to the landfill should be restricted to those times when the site staff are on duty and the gates should be locked at other times.

3.3.4 PLANT AND BUILDINGS

Buildings and structures for administration of the site and for the checking of incoming loads should be in a convenient location adjacent to the entrance. They should provide adequate accommodation for the site workforce. All landfill sites should have, at a minimum, a water supply and associated cleaning facilities, toilet, telephone and electricity. Shower facilities may need to be provided.

All site buildings should be well maintained. A neat, clean and well maintained site office gives a positive impression to both the public and site users.

3.3.5 WASTE INSPECTION AREAS

All sites should be provided with a place where wastes can be inspected prior to deposit. Often it will be appropriate to locate this area in proximity to the site offices so that wastes can be checked when a vehicle driver checks in. At sites equipped with weighing facilities, inspection can be done whilst the vehicle is stationary on the weighbridge.

In order to assist inspections, it is desirable that the inspection area is lit for the receipt of wastes late in a winter's day.

Whilst it is desirable that all wastes are checked at the inspection area, it is acknowledged that this may not be always possible. Wastes are often delivered in closed containers. It is therefore essential that materials delivered in this fashion, along with other wastes already subjected to inspection on arrival, are checked on deposition at the landfill face.

3.3.6 WHEELCLEANERS

All sites must have some provision for the cleaning of vehicles, particularly with a view of the prevention of mud being deposited on a public highway. Figure 3 shows three types of wheel cleaner. All of these can be supplemented by built-in water sprays which are operated by the contact of vehicles to a pressure pad. A further configuration is a combination of a wheelwash/shaker bar system, whereby two sets of shaker bars are separated by a wheelwash.

In general, a wheelwash is preferable to a wheel cleaning arrangement based on shaker bars. The latter tends to deteriorate quickly, is often difficult to clean out and may be noisy in use. Similarly, wheel spinners are high maintenance items, as are systems using water sprays. Spinners have the significant disadvantage that they only clean the driving wheels of a vehicle. Many require the driver to dismount to operate the spinning mechanism and hence encourage users of the site to avoid using the cleaning infrastructure for that reason.

Clear instructions must be provided to ensure that all heavy goods vehicles use the wheel cleaning infrastructure. This requirement can be supplemented by a one way system for vehicles entering and leaving the site.

Contaminated water will emanate from any wheel cleaning equipment, either due to its operation or when it is cleaned out. This should not be allowed to discharge directly to watercourses or local ditches. An oil trap should be provided along with settlement ponds to retain suspended solids. These ponds should be inspected regularly and cleaned out as necessary. Monitoring for contaminants such as oil and diesel should be undertaken.

3.3.7 WEIGHBRIDGES

It is becoming increasingly important that incoming wastes are recorded prior to deposition at landfills. There is a need to assess accurately the rate of fill at any site. Weighbridges retrofitted at existing sites have resulted in the discovery of significant errors in input estimation methods.

There is also the wider national requirement to provide suitable statistics to inform the local authority and Agency waste planning process. Accordingly, all of the larger existing landfills should be equipped with weighbridges. As an indication of the appropriate threshold, weighbridges should be installed at all sites with annual inputs of greater than 10,000 tonnes per year and should be considered at other sites where the life expectancy is in excess of five years.

A weighbridge should be located so that traffic does not back up through the site gates and onto the public highway. A number of different types of weighbridge exist, but platform weighbridges are more desirable than axle weighers. The raised type of platform weighbridge may be the preferred option as it is relatively easy to move it to another location (for example when the landfill site is finished). Whichever configuration of weighbridge is selected, care should be taken to ensure that landfill gas does not collect in the void under the weighing unit. All weighbridges should be subject to regular calibration in accordance with the manufacturer/installer's instructions.

3.3.8 QUARANTINE AREAS

Provision should be made for an area for the temporary storage of rejected loads or other materials which are deemed unsuitable. This storage area should be secure, bunded and surfaced to deal with spillages of liquids (an example might be a damaged drum). This area should be located so that it can be supervised by the occupants of the site office, but should not, for obvious reasons, be located immediately adjacent to the office.

3.3.9 FUEL STORAGE

Other than that contained in the tanks of plant and equipment, all fuel should be stored only in tanks located in bunded areas. The bunds should be constructed to be of a capacity of 110% of the contained tank (or 110% of the combined volumes in the case where more than one tank is present) and no taps, gauges etc should project beyond the internal side of the bund. All bunds should be waterproof. No drainage taps should be permitted in the bund and any retained water should be pumped out for disposal. Inevitably, when drainage taps are provided, they are often left open, completely negating the purpose of the bund itself. As a properly constructed bund will quickly fill with rainwater, it may be desirable that the bunded area is roofed.

All tank outlets should be adequately secured by locking mechanisms with a view to the prevention of vandalism.

Mobile re-fuelling equipment such as fuel bowsers should generally not be left out on the landfill at night. Instead, they should be locked away in a surfaced and bunded area in either a site building or storage compound.

Tank bunds and bowser storage areas are easily damaged in the landfill environment. Hence they should be subject to regular inspection by the site manager and repaired as necessary.

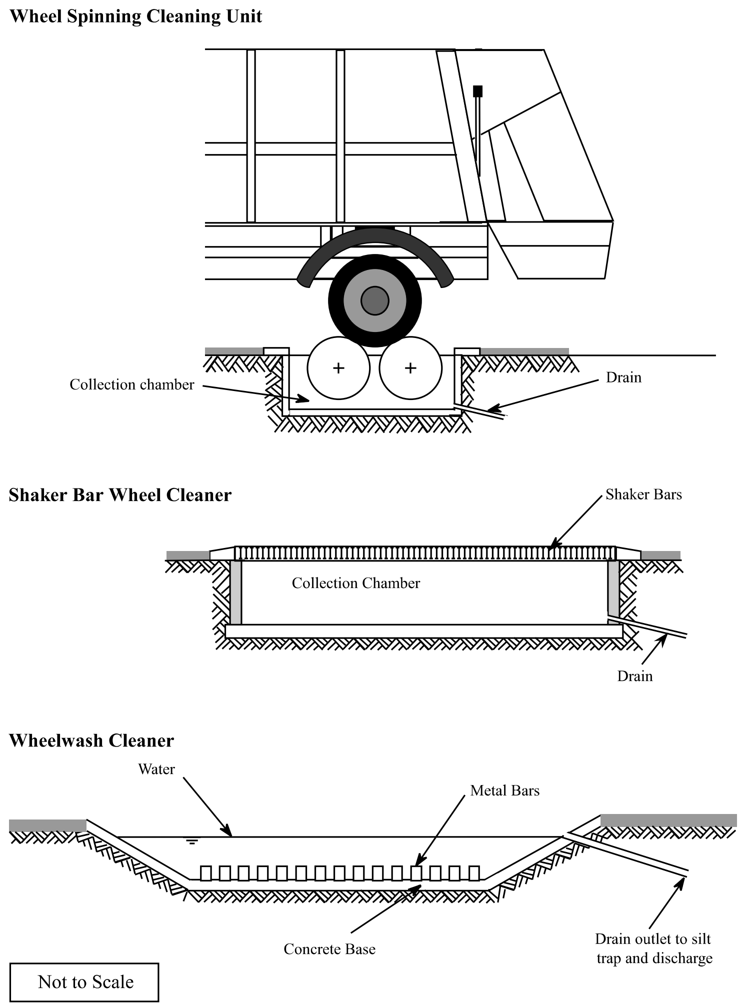

FIGURE 3: WHEEL CLEANERS

4. WASTE EMPLACEMENT

4.1 INTRODUCTION

This chapter addresses waste emplacement processes and sets out the basis by which areas of a landfill site should be delineated into cells and phases. Cover materials and the installation of capping works are also considered.

The site's Environmental Management Plan should, in conjunction with the conditions of the waste licence, determine the nature of day-to-day and year-to-year operation so that landfill volume is efficiently utilised, a safe working environment is created and environmental nuisances are minimised. For new sites, this plan should be developed during the design of the landfill. For existing sites, an important element of the Plan is sections which address the filling process, along with the completion, capping and restoration of existing areas.

4.2 METHOD OF FILLING

Prior to landfilling activities starting at untipped areas of the site, such areas should be cleared of standing surface water, vegetation and other materials. All standing surface water should, after environmental monitoring to ensure that it is free of contamination, be pumped out prior to the commencement of landfill activities at new areas of the site. The disposal of biodegradable wastes directly into water should not occur.

Where it is not proposed to construct new phases of the site by the use of artificial liner systems, the site should be engineered to ensure effective drainage to one or more selected leachate pumping or gravity drainage points. A basal drainage system will also need to be included. Landfill lining and drainage works are covered separately on the Agency's *Landfill Site Design Manual*.

Deposited waste should generally be compacted into shallow layers of up to two metres. The working face should be maintained at a slope no greater than 1 in 3 to ensure the effectiveness of the compaction equipment.

Unless permeable cover is available, consideration should be given to scraping off any soil-based daily cover materials, prior to the commencing of each day's filling activities. Whilst it is difficult to guarantee effective removal of all of the cover, partial scraping off will facilitate the subsequent movement of leachate and landfill gas within the deposited wastes. The removal of cover material allows for its subsequent re-use and prevents it significantly consuming void space. However, scraping off cover material may, in certain circumstances, cause the emission of undesirable odour. Where this occurs a decision may need to be taken to leave cover in situ.

A number of landfilling techniques can be distinguished. However in practice, operating conditions may cause the distinctions between them to become blurred. The two main techniques are portrayed diagramatically as Figure 4 and can be summarised as follows:

a) Face Tipping. In this method the wastes are tipped out and then compacted into a bench. The bench continues level across the cell or phase for a period of days or weeks until the other side is reached. Generally the height of the bench will be about two metres, with the compactor working down the face, as well as along the surface of the bench. This method tends to find favour with machine drivers, but supervision is needed to ensure that they run the compactor down the face. Otherwise, compaction may be poor in areas other than on the horizontal surface of the bench itself. Bulky objects which are difficult to bury can be placed at the base of the face and then covered from above. The disadvantages of this method are that waste can become windblown when tipped over the edge and that the landfill surface becomes heavily compacted by the passage of vehicles. This can lead to the possibility of zones of perched leachate.

b) Onion skin method. This has similarities to face tipping, but with the toe of the face extending at a much shallower gradient. The compactor operates solely on the gradient of the more shallow face, pushing thin layers of wastes and applying compaction pressure to them. Whilst it is more difficult to bury bulky objects or other difficult waste, this method has the advantage of having a lower probability of windborne litter. Perching may be lessened by the lack of compacted flat surface. Higher lifts of refuse can occur with this method.

A hybrid of these two methods would involve working the compactor up the slope. Here the wastes are deposited on the lower surface and compacted in an upward direction.

4.3 WASTE COMPACTION EQUIPMENT

Wastes other than cover materials should not be allowed to remain in loose piles on a landfill. There has been a trend towards the use of steel wheeled

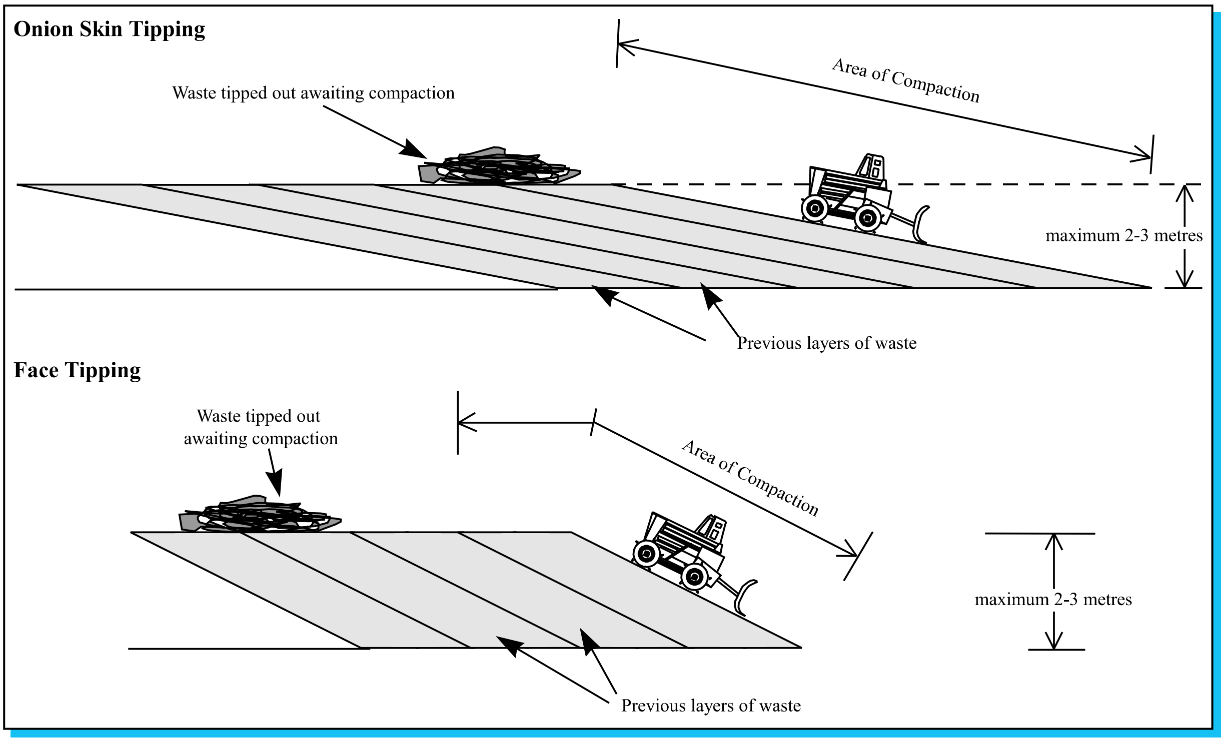

FIGURE 4: TIPPING METHODS

refuse compactors on many of the larger landfill sites. Whilst these are high capital cost items, they enable the maximum quantity of waste to be placed in available space. This is particularly the case where cells have been made up of pre-determined dimensions. Up to 1.0 tonnes per cubic metre waste density can be obtained from the efficient use of compaction equipment. Compaction also causes the deposited waste to be pinned down and hence it is less likely to become windblown, whilst being less attractive to vermin.

Except at sites taking only baled wastes, mobile wheeled compactors should be used on all landfills accepting significant quantities of household and other similar wastes.

The main parameters affecting compaction are:

- the nature of the waste material;
- the weight of the compactor;
- the number of passes by the compactor; and
- the depth of each layer of waste subject to compaction.

The operation of a refuse compactor is a skilled job that should be effectively supervised. If not undertaken correctly, poor compaction can occur. Hence no more that 0.5m in height of uncompacted waste should be compacted at any one time, with the compactor working down to the "toe" of the working face. Thinner layers will allow greater compaction densities. Besides poor compaction, inefficient operation may result in fuel being wasted, as well as causing the sub-optimal usage of a high capital cost machine.

A range of different pattern compactor wheels are available. These will dictate the number of passes needed over the waste to achieve the required refuse density. For a small site, it may be possible to utilise a compactor for spreading material such as cover. However, compactors are not specifically designed for that purpose and hence it would be usual for a separate machine to be available for this purpose.

In the minority of cases where tracked machines are used for waste emplacement, the operator should identify measures to deal with uncompacted refuse, particularly in respect of cover, litter, vermin protection and so on. The design of many tracked excavators is such as to be almost a mirror image of a landfill compactor, in the sense that many types of tracks are specifically designed to minimise ground pressure. Consequently, compaction by way of a tracked machine may be less than desirable. If this option is to be used, the machine should work uphill on a sloping working face as this arrangement maximises the ground pressure. It is also possible to purchase track plates which will assist in the process of shredding the waste. However, waste is an aggressive material on vehicle tracks and hence their life may be significantly reduced.

In all cases, workforce health and safety must be considered. It is desirable that the cabs of machines used on landfills are air conditioned and protected by dust filters. They must be fitted with roll-over protected cabs, which should also have protection against falling objects. Audible reversing signals are also essential. A final pre-requisite is that staff are adequately trained and supervised.

4.4 THE DISPOSAL OF DIFFICULT WASTES

Certain wastes may not fall within the criteria of a hazardous waste under the Waste Management Act 1996. However, they may fall into the category of being a "difficult waste" for the reason that their properties require special arrangements for disposal to landfill. Usually, this means that they cannot be placed with other materials on the working face and compacted alongside other refuse. Wastes consisting wholly or mainly of animal or fish waste, condemned food, sewage sludge and other obnoxious materials all fall within this category. Other examples of difficult waste include light materials such as polystyrene and dusty wastes. Liquid wastes may arise which can be disposed of to landfill, provided that the quantities deposited are small and that they are of a low hazard. Where necessary water balance calculations can be used to determine the effect of additional liquid inputs on leachate generation. Examples of low hazard liquids include cement bearing liquids from concrete production facilities and out of specification foodstuffs such as fruit juice.

Whether a site should take difficult wastes is mainly a matter for the operator, but will need to take in account the suitability of both the waste and the site and also be in compliance with any conditions of the waste licence. Whilst certain landfills may be suitable for the deposit of difficult wastes, this does not mean that the disposal of such materials is acceptable at all landfills.

Difficult wastes should not normally be deposited directly with other wastes in the working area. Instead they should be placed in front of the working face and immediately covered with other waste. Any obnoxious material should not be located within one metre of the surface or two metres from the flanks or face. Alternatively, disposal in an area of already filled material may need to be considered. In this case, a disposal trench is dug into deposited waste with the deposited difficult wastes being immediately covered over. However, care must be taken to ensure that the sides are stable and that the trench is clearly marked and cordoned off. Open trenches are most suited to the disposal of materials which do not have an inherent smell. Figure 5 shows two types of difficult waste trench.

In the case of the disposal of smelly, pumpable liquid wastes, a trench excavated in old refuse can be back-filled with coarse rubble and covered (see Figure 5).

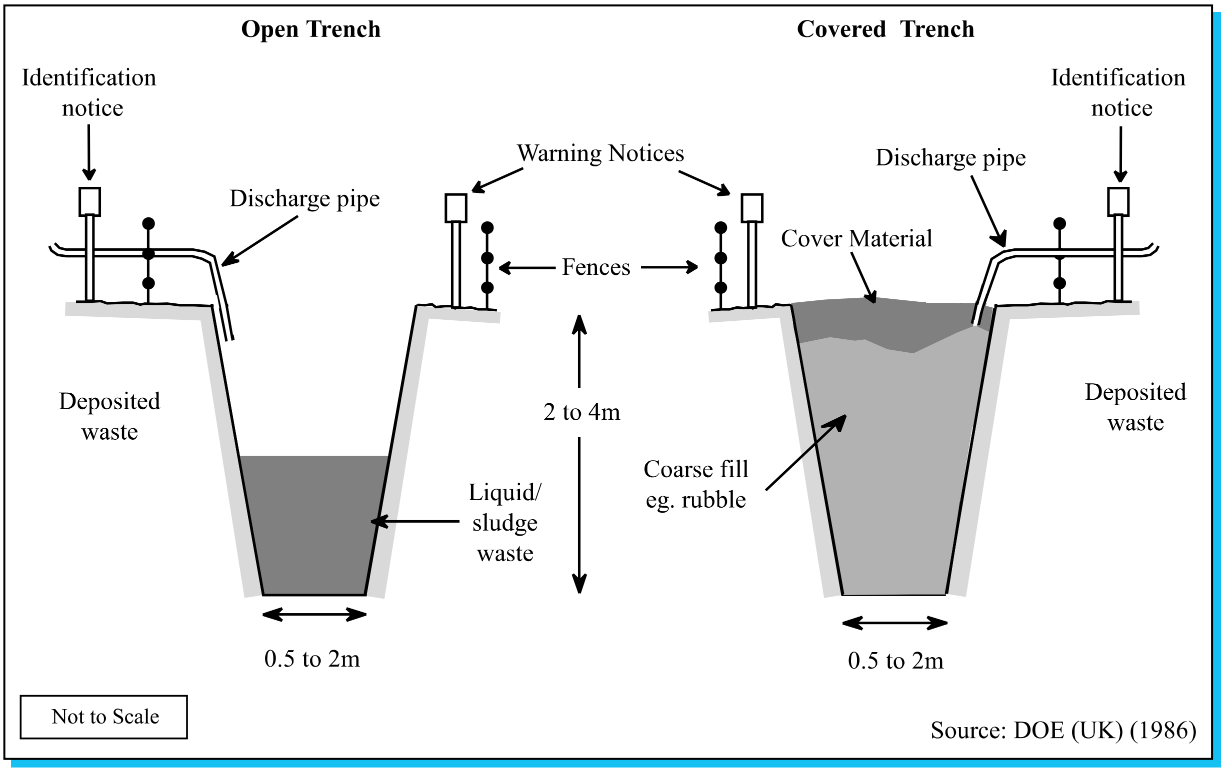

FIGURE 5: DIFFICULT WASTE DISPOSAL TRENCHES

A length of pipe should be buried at one end, with the other end of the pipe being served by a tanker coupling. This arrangement ensures that any discharge of waste is made beneath the landfill surface

Whilst the deposit of empty drums may, depending upon their contents, be acceptable, it is increasingly desirable that such materials are recycled. If drums are to be disposed of at a landfill, they should be thoroughly crushed and compacted. They should be thoroughly inspected prior to deposition to ensure that they do not contain any hazardous residues. Sampling and analysis of residues or vapours in the drums may be necessary.

Dusty waste may need to be delivered in sealed bags. Alternatively, this waste should be sprayed with water.

4.5 WATER BALANCE AND WASTE EMPLACEMENT

As will be expanded upon in the Agency's *Landfill Site Design Manual*, one of the principal considerations in relation to the design of any new landfill is a comprehensive approach to leachate management. In order to design an effective leachate management system it is necessary to first understand and predict the liquid inputs and outputs from a facility. This is the role of an assessment involving water balance calculations. For new facilities, water balance calculations are relatively straightforward. However, at existing sites such calculations are an approximation and a larger margin of error must be assumed, given that certain variables at existing sites cannot often be accurately assessed. Nevertheless, consideration must also be given to water balance calculations at existing sites as some useful information still can be obtained. This information can be used to significantly improve existing operational practices.

As is explained further in the next chapter, the key parameters of leachate management are:

- the control over the manner by which water (rainfall, runoff, groundwater, etc) is allowed to come into contact with deposited wastes; and
- the way in which the resultant leachate is to be removed from the site.

Very extensive groundwater and rainfall infiltration over large areas of unlined, uncovered or uncapped waste will create copious amounts of often dilute leachate. This material will require disposal. For example, one metre of annual rainfall falling on open waste will rapidly saturate the deposited wastes. Once saturation occurs, leachate will be emitted. If any evaporation from the surface is ignored for the purposes of this illustrative example, a one hectare expanse of open saturated waste subject to one metre of rainfall infiltration might create as much as 10,000 cubic metres of leachate per year. This material will require disposal and/or treatment.

The above example is a very simple illustration of the effects of rainfall and the need to consider a site's "water balance". A more detailed discussion of this topic will be found in the *Landfill Site Design Manual*. But the example clearly illustrates the crucial influence of rainfall infiltration and explains the need to reduce open surfaces of refuse to a minimum area wherever possible. Additional benefits will also accrue at older unlined sites where there is likely to be loss of leachate to groundwater. Any efforts to reduce leachate production by the control of infiltration will have a beneficial effect on local groundwater quality.

Rainfall infiltration can be controlled by temporary capping, by contouring the surface of completed areas and by the restriction of operational area to minimum dimensions. Leachate management techniques, including leachate abstraction and drainage, along with such matters as the diversion away from the site of uncontaminated run-off and the interception of shallow groundwater inflows, are considered in the next chapter.

4.5.1 PHASING PLAN

A landfill site should be divided into a series of phases and filled to final levels in succession. Hence a cycle of progressive filling across the site should occur, with one phase being restored, a second filled and a third prepared for filling. Figure 6 illustrates this process, with Figure 7 showing a cross section through Figure 6's phases I-III.

The nature of the phases should be set down in the site's Environmental Management Plan. The benefits of phasing are that it:

- allows site disposal operations to become tightly organised;
- will diminish leachate generation;
- may reduce noise and litter; and
- provides a positive visual impression and hence encourages public confidence that the site is well controlled and will be subject to adequate restoration.

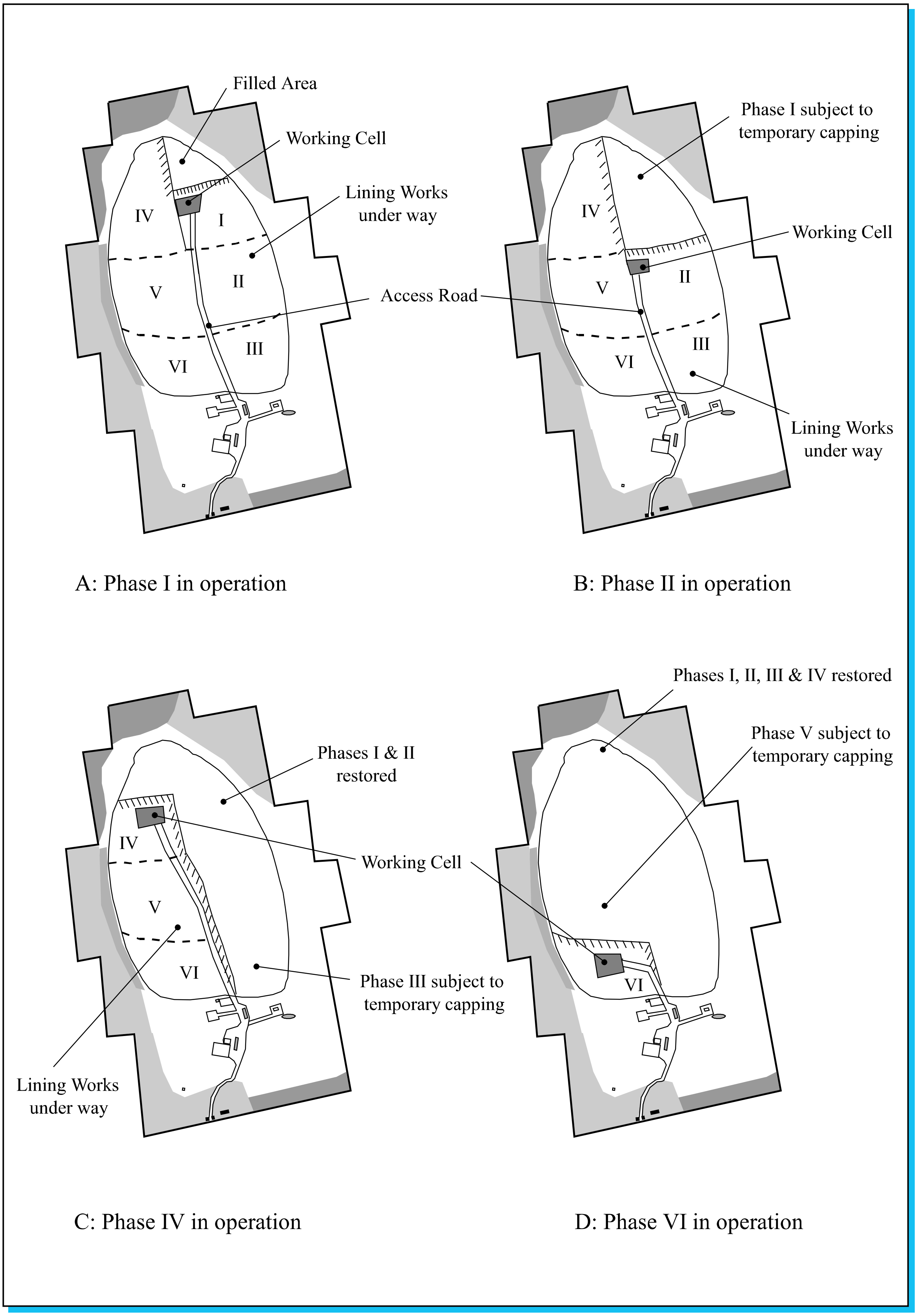

FIGURE 6: PHASING PLAN

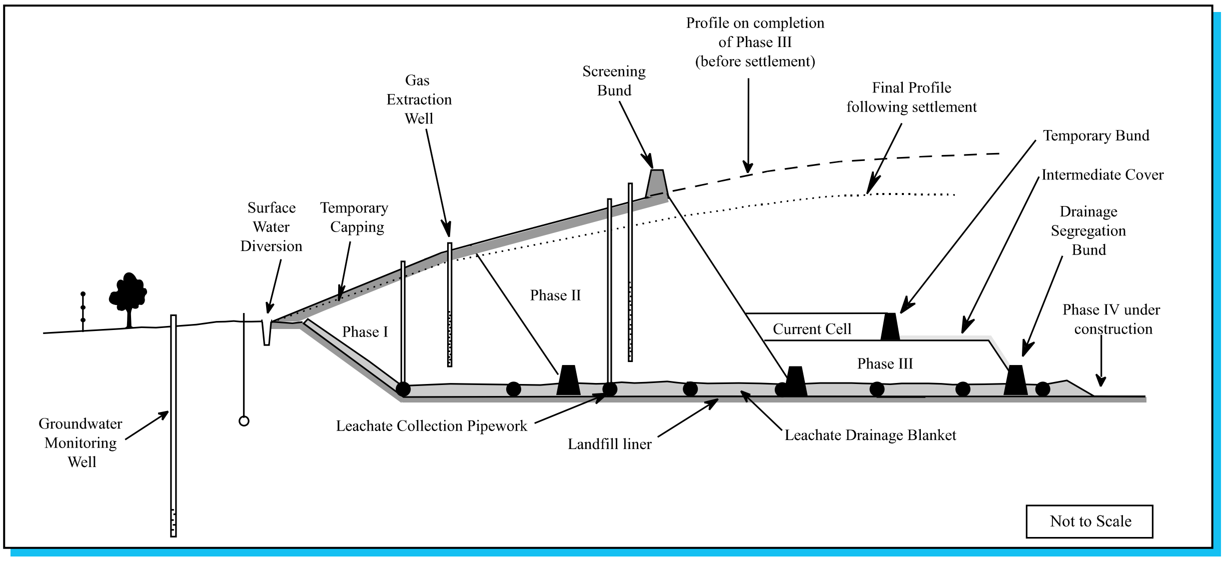

FIGURE 7: TYPICAL LANDFILL FILLING SEQUENCE

The phasing plan shown in Figure 6 may have a limited practical application in certain contexts. It is best utilised at shallow sites, as it is undesirable to have high and steep banks between the filled and unfilled parts of the site. These may develop stability problems, could cause unacceptable risks to site users and are likely to result in a very small cell size when near final levels. Accordingly, a series of phases overlaying each other would be normal for deeper sites. This is shown schematically in Figure 8. Intermediate cover or temporary capping should be used over parts of the landfill surface which will be awaiting further filling activities. New phases are started on top of the lower phases after scraping off as much of the cover as is possible.

Settlement is another reason why landfills may need to be filled in a series of overlapping phases. Settlement can account for up to 30% reduction of the height of the infilled material at deep sites. At shallower sites, settlement may be typically up to 20%. Accordingly, it may be desirable to allow a completed phase to settle and to place additional waste material on top immediately prior to final restoration and capping. The results of settlement will reduce this to the intended level of the landform. However, neither the prediction of settlement nor the degree of over-filling is easy to establish. Significant over-tipping may be unsightly in certain circumstances as it may temporarily exaggerate the height of the site. All these reasons suggest that final levels will need some, greater or lesser, adjustment with time.

4.5.2 CELLS AND WORKING AREAS

It is desirable that waste is deposited into cells which are delineated by pre-constructed bund walls. These sub-divide the area of the site delineated as a phase. Operating a cellular method of filling enables waste to be deposited in a tidy manner since the bunds serve to both conceal the tipping operation and to act as a windbreak.

One potential disadvantage of the cell method, particularly where space is limited, is the amount of void space which may be lost due to building the cell walls. In addition, the delineation of the cell by this method may present barriers to leachate and gas circulation. These drawbacks may be overcome by subsequently excavating the wall and using as much of the reclaimed material for purposes such as cover.

Where it is not possible to excavate away the cell walls, they should normally be cut through in places when landfilling activities move into the neighbouring cell. This action facilitates leachate and gas movement throughout the fill. If there is doubt that a free flow of leachate will occur between cells, additional leachate drainage infrastructure may need to be installed as filling progresses.

For larger sites, there is no reason why the structure of cell walls cannot be made up mainly of deposited waste, with the external faces coated in cover

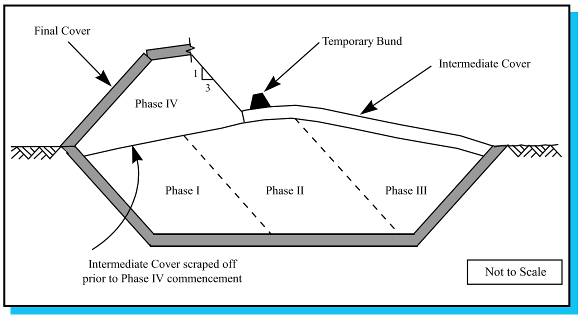

FIGURE 8: OVERLAYING PHASES

material. The latter may have the advantage as it is more economical on the use of the void space, avoiding the use of large amounts of inert wastes. In addition, it may allow leachate to move more readily between areas on the site and hence prevent leachate perching.

4.5.3 CELL SIZES

A key area to be addressed is the size of the cell. In this respect, it is crucial that cell size should be maintained to the minimum practical dimensions. Minimising the cell sizes will:

- provide the smallest surface area of exposed waste;
- assist in controlling windblown litter;
- reduce the requirements for cover material; and
- will lower contact with rainfall and hence minimise leachate generation.

The major constraint on cell size is, however, created by safety and operational considerations. Incoming vehicles will need room to manoeuvre and to unload. They must kept be well away from uncompacted waste and from any compaction equipment.

Overall, the site operator must balance these competing objectives. Hence a busy site would have more emphasis placed upon allowing adequate space for vehicle unloading and for turning. A small rural site, conversely, could have a much smaller cell size.

4.5.4 EMERGENCY CELLS

It is a desirable that part of a cell is reserved for the disposal of wastes with high paper content at times of high winds. Often this can be located at a sheltered location at the landfill, for example at the base of the site in close proximity to filled phases.

4.6 COVER MATERIALS

4.6.1 “TRADITIONAL” COVER

These materials are typically composed of subsoils and other excavation wastes or construction industry wastes such as bricks and crushed broken concrete.

The material selected for cover purposes ideally should be free draining and, preferably, of low clay content. Highly impermeable cover materials may encourage the perching of leachate. In addition, the remnants of cover material may adversely affect vehicle traction on wet days and may generate mud which will then track out onto site access roads.

In the past, subsoils and other construction industry wastes have been used as cover, with a target of 150 mm depth being applied towards the end of the working day. However, the use of soil-based cover materials has been recognised as leading to low permeability horizons in the filled materials and, consequently, leachate perching. In addition, this type of cover material utilises valuable void space. For example, it has been estimated that the “traditional” forms of daily cover may occupy approximately 7% by volume of the total available void, when bunds are included within this calculation. Increased recycling of these materials will mean that this type of cover not always available on a daily basis. Hence alternative cover systems will need to be considered. However, soil-based cover should be stockpiled as it has an essential function as intermediate cover.

If soil-based cover materials are to be used, the feasibility of their extraction from the site itself should be considered. This means that the size of the void is not affected by the emplacement of cover materials and that transport costs and associated impacts are limited. However, the increasing trend for landfills to be located in clay type geological strata means that the resultant excavated materials may suffer from permeability problems. All these reasons suggest that some of the more recent developments in alternative cover systems should be given serious consideration.

Where cover is to be brought in, the quantities of cover material should be calculated and suitable sources located well in advance of the material actually being needed. To ensure that a supply of material is available to meet the requirements of daily cover, a stockpile of cover material should be maintained on site for use. It is generally recommended that a stockpile of between 1-3 months’ supply is maintained.

4.6.2 ALTERNATIVES TO “TRADITIONAL” COVER

Given the difficulties inherent in obtaining “traditional” cover and the problems it may create at the landfill, other types of cover should be considered. Many of these alternatives are still undergoing trials and experience will be necessary to determine the operational effectiveness of the various available products. Hence operators will need to undertake their own verification. Only where sufficient evidence of practical effectiveness is available at the particular landfill should a long term commitment be made to move away from soil-based cover materials. Accordingly, substitute cover materials should be utilised when a comprehensive demonstration has been made of their ability to prevent vermin, odours, blowing litter and other similar problems. If these criteria can be satisfied, the use of such forms of cover should be seriously considered.

It should be made clear that the materials falling within this category are mostly for daily cover purposes. It seems doubtful that such materials can be expected to provide effective cover on completed areas which are left for periods of several weeks or months, awaiting further filling. Many types will not act as a barrier to rainfall infiltration, and may be susceptible to wind damage. For medium and long term purposes, the more “traditional” methods of covering should be utilised.

Non-traditional cover materials include:

- the use of heavy duty, reusable plastic sheets;
- non-reusable plastic films;
- geotextiles;
- fibre matting;
- foams;
- shredded wood/green waste; and
- composted wastes.

4.6.3 DAILY AND INTERMEDIATE COVER

Daily cover serves an essential function on all landfills accepting municipal and other biodegradable wastes. In particular, daily cover improves the appearance of working areas and decreases the possibility of windblown debris (eg paper, plastics). It also significantly reduces access to the waste by birds, insects and vermin and diminishes odours and fire risk.

Intermediate cover is used when filled surfaces are likely to be left for a period of weeks or months before additional lifts of waste are to be added. This type of cover significantly reduces rainfall infiltration, whilst it binds the deposited wastes down and hence reduces litter. Intermediate cover materials will be subsoils or similar wastes. Most of the alternatives to traditional daily cover detailed above are not robust enough for long term protection purposes of the landfill surface.

Intermediate cover is usually spread to a greater thickness than would be the norm with daily cover. Hence a reasonable target should be about 300 mm in depth. The area should be regularly inspected by site staff and any cover materials eroded by rainfall action should be replenished.

When the area subject to intermediate cover is to be used for further tipping, the cover should be extensively scraped off. Whilst there are practical limitations on the degree to which all the material can be removed, the removal process should ensure that intermediate cover does not impede the flow of landfill gas and leachate.

4.7 CAPPING

4.7.1 TEMPORARY CAPPING

In the early years of biodegradation, settlement will be quite rapid. This will be a function of the weight of the material deposited, along with the biodegradation process. The latter will have the most significant long term effect, with the decomposition of a proportion of the landfilled materials into landfill gas and leachate. This rapid rate of settlement is likely to affect the structural integrity of any permanent cap. Hence the installation of permanent capping works should be delayed for this reason.

Instead of installing a permanent cap early on, it is preferable to place a temporary cap of low permeability material over the filled area. This should be laid to a fall in order to shed water. Once the initial settlement rate has slowed, usually within the first five years after completion of filling, the temporary cap can be removed. Low spots resultant from settlement should be rectified and the permanent capping system can be installed. To allow for erosion and to provide a consistent depth over other wastes, it is recommended that temporary capping is laid to a minimum depth of about 0.5m.

Unless areas are to be left awaiting final capping for many years, there is no necessity to engineer the installation of the temporary cap. Its main function is to prevent infiltration and to shed rainfall.

The result of the effects of settlement is that a permanent capping system should not be installed until significant settlement has ceased. Accordingly, phased restoration may be desirable in many cases in the interim. This is because it is undesirable to leave large expanses of filled and capped areas open and unseeded. Undesirable rainwater ingress may occur adding to the leachate management burden. In addition, unseeded areas will rapidly degenerate into an unsightly mass of weeds and rough scrub, whilst unvegetated areas may suffer from erosion and cause surface waters elsewhere on the site and its environs to be polluted with suspended solids. Hence filled areas should be subject to intermediate capping and seeding in order to stabilise the bare surface and provide a visually acceptable green sward.

Temporary capping should be undertaken on all of the phases of the site which are at final levels or where landfill activities will not return to a partially filled area of the site for a number of years. The utilisation of temporary capping reduces exposed landfill area and thus diminishes negative visual impacts and reduces leachate generation. A thin layer of topsoil or soil conditioner should be applied to any area that it likely to await final capping for a number of years. Coupled with appropriate seeding, this stabilises the area and reduces negative visual impact. Seeding permits water to be lost by transpiration and hence contributes to the reduction of rainfall infiltration.

4.7.2 FINAL CAPPING

The final landform created by the infilling process should be designed. It should not have slopes sufficient to cause heavy and rapid run-off. Whilst run-off in these circumstances can be mitigated by step profiling and the provision of longitudinal open drains, there remains a danger that it may cause erosion and hence affect the integrity of the cap in the long term. Although steep gradients should be avoided, slopes should not be of such a shallow gradient as to result in water-logging and ponding. Hence the minimum gradient should be 1:20 and the maximum gradient should not exceed 1:3.

Drainage channels constructed in an area of the restored site should be monitored for the effects of subsidence and be designed in the knowledge that subsidence is inevitable. They should also be able to cope with storm water conditions and should be constructed in such a way that they do not cause any gradual leakage into the filled material.

The type of capping and restoration materials and their depth of emplacement will be a function of the design requirements of the cap and the intended after use of the site. The restoration layer above the cap should be at least one metre thickness of soil/sub-soil. Otherwise the cap will not receive adequate protection from after uses of the site. Further details will be set out in the Agency's Manual on *Termination of Use and Aftercare*.

The installation of a cap should be viewed as an engineering operation and treated as such. Source testing of the capping material should always be undertaken. Post-constructional testing of the cap should also be carried out to confirm the design objectives. Both field and laboratory testing should be undertaken. These evaluations will ensure that the material is both suitable for use and has been put in place in a manner which guarantees the requisite permeability standard. Like the installation of liners (see the Agency's *Landfill Site Design Manual*), QA/QC procedures should be followed. Furthermore, independent verification of the quality of the cap may need to be undertaken.

5. LEACHATE

5.1 THE NATURE OF LEACHATE

The term "leachate" describes any liquid percolating through the deposited wastes and emitted from or contained within a landfill. The composition and characteristics of leachate depends on factors such as:

- the type of the wastes deposited;
- rainfall and other climatic factors;
- the degree of surface and groundwater ingress;
- the age of deposited waste;
- degree of compaction; and
- cover, capping and restoration.

Leachate generated in landfills is a potential threat to both surface and groundwaters. An uncontrolled discharge to surface waters may have a significant effect on fish stocks and on the aquatic ecosystem in general. Table 3 shows a range of typical analyses for leachates, whilst Figure 9 shows a simplified flow chart of the various stages in the decomposition of household waste. Figure 10 shows how these changes affect the composition of leachate being generated.

It is essential to landfill operation that leachate management is given due consideration throughout the life of the landfill. Factors of relevance relate principally to the generation, composition, control, treatment/disposal, and monitoring of leachate. They pertain as much to day-to-day site operations as to the initial site selection, landfill design and development or site aftercare phases. The key to the understanding of these factors and their effects is the comprehensive monitoring of the biodegradation processes in the landfill and interpretation of the results.

The requirements for the monitoring of landfills are set down in the Agency's *Landfill Monitoring Manual*. It should be emphasised that these are minimum requirements. Accordingly, the frequency and scope of monitoring may need to be increased:

a) where further information is needed on the biodegradation processes; and/or

b) where site specific factors suggest that additional monitoring is required.

5.2 LEACHATE GENERATION

The quantity of leachate is dependant on the quantity of liquids entering the deposited wastes. Sources of liquid include:

- liquids within the wastes deposited;
- rainfall;
- surface water inflow; and
- groundwater intrusion.

All these factors influence the production of leachate from the site. Reductions in leachate generation may also have a favourable economic payback where leachate is discharged to sewer or is tankered away for treatment at a sewage treatment plant.

5.2.1 LIQUIDS IN WASTES DEPOSITED

The amount of liquid contained within the waste deposited may not be readily controllable by the operator. For example, domestic refuse will always have a significant moisture content. However, other waste sources can be controlled by way of waste acceptance procedures. Sewage sludge and certain industrial wastes can be significant sources of liquids. The desirability of additional liquid loadings should be assessed on a site specific basis, particularly in relation to the effect on the biodegradation process and upon leachate generation. Where possible, industrial wastes should be significantly dewatered, but even then many filter cakes can contain an aqueous phase in excess of 50% by weight. Sewage sludge will be usually much wetter with a typical dewatered sludge solids content of 10% to 20% by weight. A cautious view should be taken of the continued disposal of liquids at existing sites which are not containments and where the effects of leachate on the groundwater regime are not well understood.

5.2.2 RAINFALL

Rainfall on a landfill site is the single most significant source of leachate generation. This source is highly variable, ranging from 900mm per annum on the east coast of Ireland to 2000 mm in the west. The quantity of liquid remaining after evapotranspiration is known as effective rainfall. Effective rainfall averages about 700 mm per annum in Ireland. This figure means that, out of an average rainfall figure of about 1 150 mm, 700mm contributes towards leachate generation at a typical landfill site. The latter figure is very much an average and the quantity of annual rainfall across the

TABLE 3: TYPICAL LEACHATE COMPOSITION OF 30 SAMPLES FROM UK/IRISH LANDFILLS ACCEPTING MAINLY DOMESTIC WASTE (1992 FIGURES)

	Overall Values		**Overall Range**	
Determinand	Median	Mean	Minimum	Maximum
pH-value	7.1	7.2	6.4	8.0
conductivity (µS/cm)	7180	7789	503	19200
alkalinity (as $CaCO_3$)	3580	3438	176	8840
COD	954	3078	<10	33700
BOD_{20}	360	>834	4.5	>4800
BOD_5	270	>798	<0.5	>4800
TOC	306	717	2.8	<5690
fatty acids (as C)	5	248	<5	3025
Kjeldahl-N	510	518	1.0	1820
ammmoniacal-N	453	491	<0.2	1700
nitrate-N	0.7	2.4	<0.2	32.8
nitrite-N	<0.1	0.2	<0.1	1.4
cyanide	<0.05	<0.05	<0.05	0.16
sulphate	70	136	<5	739
phosphate	1.1	3.0	<0.1	15.8
chloride	1140	1256	27	3410
boron	2.80	7.0	<0.02	116
sodium	688	904	12	3000
magnesium	125	151	18	470
potassium	492	491	2.7	1480
calcium	155	250	43	1440
vanadium	0.5	0.73	<0.1	2.9
chromium	0.05	0.07	<0.04	0.56
manganese	0.5	1.99	0.10	23.2
iron	12.1	54.5	0.4	664
nickel	0.07	0.10	<0.03	0.33
copper	0.04	0.04	<0.02	0.16
zinc	0.16	0.58	<0.01	6.7
arsenic	0.007	0.008	<0.001	0.049
cadmium	<0.01	<0.01	<0.01	0.03
tin	1.8	5.4	0.4	46.9
mercury (µg/l)	<0.1	0.1	<0.1	1.0
lead	0.09	0.10	<0.04	0.28
aluminium	<0.1	<0.1	<0.1	<0.1
silicon	11.53	11.90	3.42	22.85

Notes:
Results in mg/l except pH-value, conductivity (µS/cm) and mercury (µg/l).

Source: Department of the Environment (1995b)

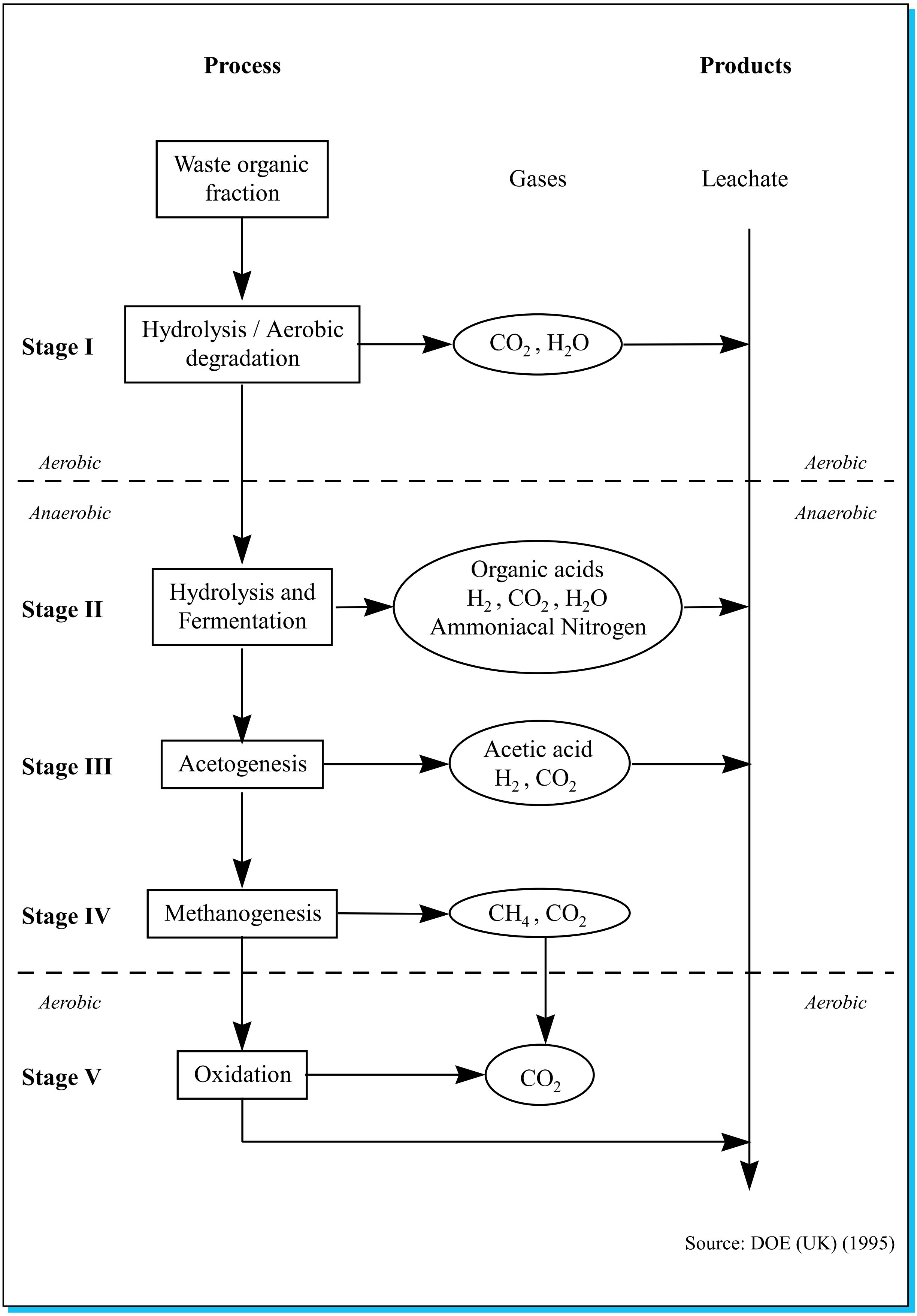

FIGURE 9: MAJOR STAGES OF WASTE DEGRADATION

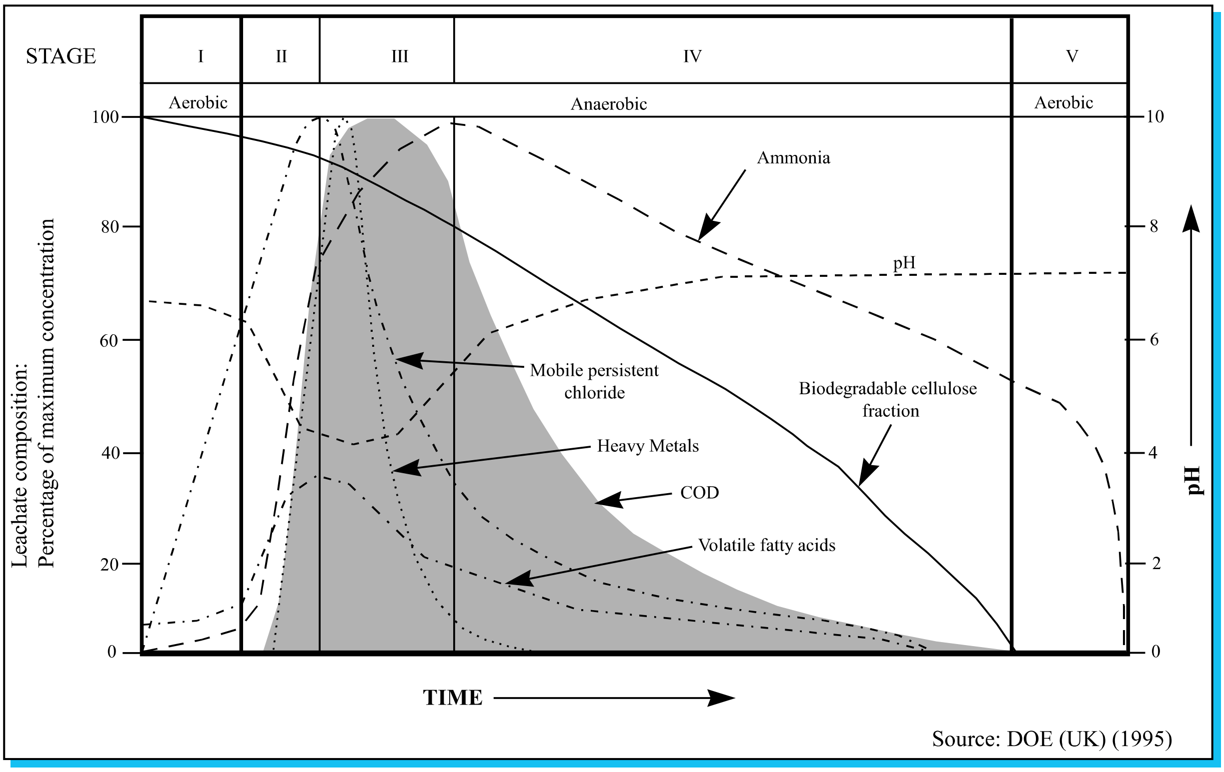

FIGURE 10: CHANGES IN LEACHATE COMPOSITION

country varies with geographical location and other factors such as altitude.

Given the significance of rainfall in the generation of leachate, it is important that uncontrolled rainfall ingress into the deposited materials is minimised. The most obvious control methods are the capping of completed areas of a landfill and the use of intermediate cover at areas where waste deposition ceases for a number of months. Besides capping works, the selection of the minimum appropriate cell size has a significant effect on leachate generation.

5.2.3 SURFACE WATER INFLOW

The uncontrolled inflow of surface water from land surrounding a landfill can greatly contribute to the generation of leachate. This can be further supplemented by the discharge from surface water ditches into the landfill or from areas of the site which are currently unfilled. Inflows from all of these sources should be prevented and operators of existing sites should address these matters as a priority.

In many cases, simple ditching and drainage diversion works on existing unfilled areas can intercept run off from neighbouring land, whilst the diversion of ditches can mitigate direct discharges. Should pooled surface water in unfilled areas be known to be uncontaminated, it can be pumped away for discharge. However, monitoring for contaminants is an essential pre-requisite of such pumping operations.

Areas of standing clean water should also be subject to protection measures so that they do not become contaminated by leachate. This can be done by the construction of temporary bunds and other structures.

5.2.4 GROUNDWATER INTRUSION

Groundwater may add to the leachate burden, particularly at old sites where there was no sub-surface engineering or natural liner to prevent such an intrusion. It is difficult to remedy this problem at older sites, unless the groundwater ingress is from near-surface sources. In the latter case, it may be possible to intercept it and drain it around the landfill. New sites should be specifically designed to prevent groundwater intrusion.

However, where significant sources are diverted, care should be taken to ensure that other users are not affected.

5.3 THE NEED FOR LEACHATE CONTROL

Modern landfill site design requires that leachate is collected and treated. New phases of existing sites which are located on unfilled sub-strata should be designed on this basis. Filled areas of older sites may have more ad-hoc arrangements and these may need to be substantiated in order to decrease the likelihood of leachate contamination. Much will depend on the assessment of the location of the wastes accepted and any requirements of the waste licence.

Appropriate measures should be taken with respect to landfill characteristics and meteorological conditions to:

- control water from precipitation entering the landfill body;
- prevent surface and/or groundwater from entering into the landfilled waste;
- collect contaminated water and leachate; and
- treat contaminated water and leachate collected from the landfill to the appropriate standard required for their discharge.

One of the most significant environmental impacts of an uncontrolled discharge of leachate through the base of an unlined landfill is upon groundwater. Groundwater is protected by way of the EU Groundwater Directive (80/68/EEC), the Local Government (Water Pollution) Act 1977 and regulations made thereunder.

The Directive contains two catalogues of substances, Lists I and II, and sets down a series of environmental protection requirements in respect of substances present on these Lists. It also differentiates in its requirements between direct and indirect groundwater discharges. Table 4 shows the range of substances on the two Lists.

In summary, the Directive requires Member States to prevent the introduction of List I substances into groundwater and to limit List II discharges so that groundwater pollution is prevented. The need for control applies irrespective of whether the groundwater is currently being used, thereby safeguarding any future groundwater abstraction uses. However, exclusions are set down, which relate to discharges which are of such a small concentration as not to effect groundwater quality and where groundwater is permanently unusable.

Of fundamental importance to the requirements of the Directive are two principles. The first is a design involving containment at new landfills, along with the lining of new phases or capping works at existing sites. The second is groundwater monitoring as set out in the Agency's *Landfill Monitoring Manual*.

5.4 LEACHATE COLLECTION

An effective leachate collection and removal system is a pre-requisite of new sites. For existing sites, the installation of an improved collection and removal system should be considered in the light of data obtained by way of the environmental monitoring. Of particular importance is evidence of leachate migration and/or high leachate levels within the filled areas. Unless controlled, the latter may continue to rise with infiltration and eventually escape at the lowest point of weakness. An uncontrolled outflow of leachate may have a significant effect on the local environment, particularly on the aquatic systems.

Typically, leachate collection involves two stages. These are the installation of a system which directs leachate to a small number of collection points and the abstraction of leachate from the collection points themselves. Figure 11 illustrates a typical leachate collection system.

Whilst it is possible only to retrofit abstraction and pumping systems in completed areas, for new phases or cells constructed in unfilled areas, the collection system should be installed alongside comprehensive basal leachate drainage blankets. These are also essential at new containment landfills. Basal leachate drainage blankets are composed of a series of pipes across the base of the site, which meet at one or more leachate collection points. The collection pipework should be surrounded by at least 0.5m depth of granular, low fines aggregate. This granular layer assists the migration of leachate towards the collection system. This arrangement means that localised blockages in the collection pipes are less likely to cause a problem to the operation of the drainage system. The use of vehicle tyres as a drainage medium is not recommended. The base of site should be constructed so that at least a 1:50 gradient is attained in the direction of the leachate collection points.

The drainage media selected should:

- be structurally robust to withstand loading;
- be sufficiently coarse to preclude blockage;
- have a minimum permeability of 1 x 10-3 m/s; and
- should not be susceptible to chemical attack by the leachate.

Where the sides of a landfill are at a gradual slope, the blanket can be extended up the sides. This allows for the installation of a rodding point at the surface so that the pipework can be cleared of blockages and facilitates access for CCTV inspection.

In the selection of collection pipes, an assessment should be made of their compressibility under load from the filled materials above.

As filling progresses, leachate collection pipework should be extended upwards through the deposited wastes. This can be done by way of a continuous

TABLE 4 GROUNDWATER DIRECTIVE (80/68/EEC): LIST I AND II SUBSTANCES

List I	List II
1. Organohalogen compounds and substances which may form such compounds in the aquatic environment	The following metalloids and metals and their compounds: 1. Zinc, 2. Copper, 3. Nickel, 4. Chrome, 5. Lead, 6. Selenium, 7. Arsenic, 8. Antimony, 9. Molybdenum, 10. Titanium, 11. Tin, 12. Barium, 13. Beryllium, 14. Boron, 15. Uranium, 16. Vanadium, 17. Cobalt, 18. Thallium, 19. Tellurium, 20. Silver.
2. Organophosphorus compounds	2. Biocides and their derivatives not appearing in List I
3. Organotin compounds	3. Substances which have a deleterious effect on the taste and / or odour of groundwater, and compounds liable to cause the formation of such substances in such water and to render it unfit for human consumption
4. Substances which possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment* ** Where certain substances in list II are carcinogenic, mutagenic or teratogenic, they are included in category 4 of List I*	4. Toxic or persistent organic compounds of silicon, and substances which may cause the formation of such compounds in water, excluding those which are biologically harmless or are rapidly converted in water into harmless substances
5. Mercury and its compounds	5. Inorganic compounds of phosphorus and elemental phosphorus
6. Cadmium and its compounds	6. Fluorides
7. Mineral oils and hydrocarbons	7. Ammonia and Nitrites
8. Cyanides	

"wall" of leachate drainage material extending vertically though the site to the surface. Alternatively, leachate drains can be installed horizontally at different levels, intersecting with the vertical leachate collection points. Either of these options will assist the migration of leachate to the collection pipework and will mean that blockages at lower levels will not cause the system as a whole to malfunction.

In deep sites where leachate pumping is required, leachate collection has traditionally been undertaken by the construction of a leachate collection chamber out of manhole rings. The rings are usually cast of sulphate resistant concrete and should be drilled (or otherwise contain holes) in the sides to assist percolation. They should not normally have access ladders within them, as this may encourage unauthorised entry. Care should be taken to ensure that the chambers have suitable foundations which will not subside when a succession of rings are placed on top of each other and that the weight of the rings will not damage any liner system. This may lead to the substitution of the concrete rings by artificial materials such as plastics.

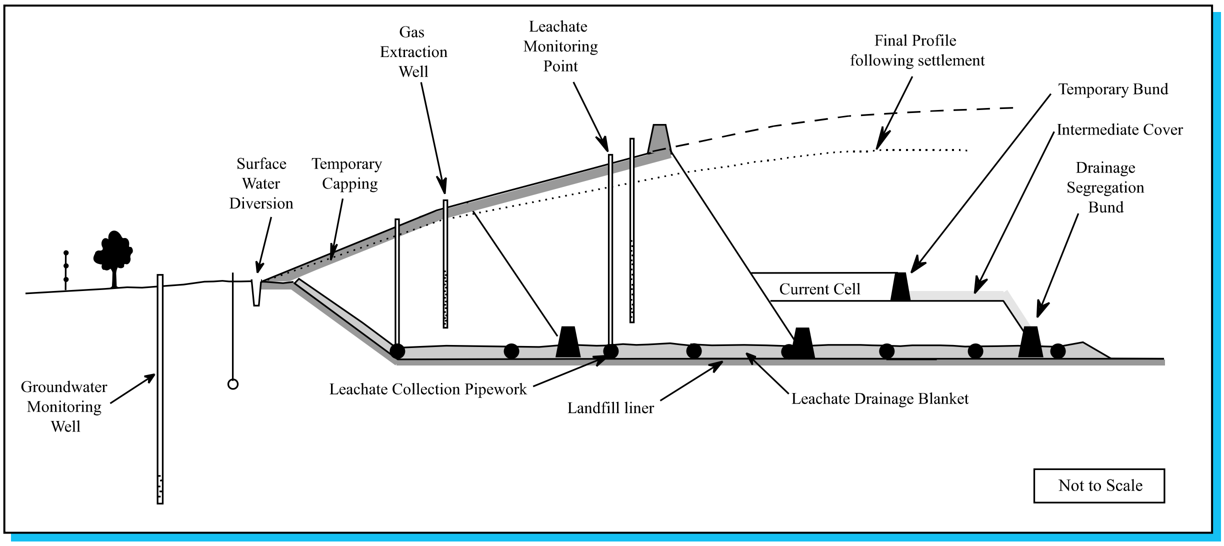

FIGURE 11: LEACHATE COLLECTION AND CONTROL MEASURES

Vertical leachate collection chambers should be surrounded by a permeable drainage media – not deposited wastes – to assist in vertical percolation of leachate to the chamber. Figure 12 shows the general arrangement for a leachate pumping chamber for illustrative purposes.

A number of configurations of leachate collection point are possible. The use of low angled leachate risers which are laid parallel to the side of the site should be considered. These act as alternatives to the traditional leachate chambers illustrated earlier. Although not suitable for sites with steep sides, the system exerts much lower pressures on the liner system. A second advantage is that vertical chimneys often suffer from sideways movement due to settlement. The low angle riser system is less prone to damage from the filling process as they are located at the perimeter of the phase. Pumps can be introduced by way of a skid system. When a site is suitable, gravity drainage systems should be considered.

Besides leachate extraction using submersible pumps, a number of leachate dewatering techniques have been developed, including some which utilise eductor pumps. These have the advantage of being suitable for installation in small diameter boreholes (150mm). In addition, the eductors do not contain moveable parts. The only maintenance necessary is the cleaning of slimes from the spray head. Figure 13 shows an eductor pump leachate removal system.

A primary objective of leachate removal is that significant leachate heads should not be allowed to build up in any landfill in an uncontrolled fashion. Unless the surrounding land is equally saturated, leachate may escape from the site through the base or the sides. It could also cause significant pressures to occur on the inside of temporary structures. Bunds used to separate the filled and unfilled phases of the site are particularly vulnerable. Accordingly, it is desirable that a leachate head of no more than one metre should occur, and gravity drained sites can achieve a significantly lower leachate level.

All landfills should be monitored for leachate levels at least at the frequency set down in the Agency's *Landfill Monitoring Manual*. Such monitoring points should be at locations which are independent of any leachate pumping chambers, with the locations and number of monitoring points being selected to give a representative picture of the leachate levels within the filled material.

Open chambers on the surface of the site are undesirable for health and safety reasons. Hence all leachate collection chambers should have lockable lids, which should be only left open when the pumping system is under maintenance.

As is expanded upon in Chapter 6, methane levels in pumping chambers and collection pipes must be monitored and venting should be provided where necessary. All pumps should be intrinsically safe, whilst any monitoring equipment should not be able to cause sparks within any closed spaces. For example, it is undesirable that steel balers are used to sample in leachate chimneys.

5.5 LEACHATE TREATMENT/DISPOSAL

Once leachate has been removed from the deposited waste, its storage and disposal are necessary. In many cases, leachate treatment is required to reduce the leachate strength.

A variety of leachate treatment methods are available, with the choice of technology being a function of cost and the intended disposal method. They include :

- recirculating the leachate through the landfill;
- treatment at a sewage works; and
- treatment on site.

5.5.1 RECIRCULATION

Recirculation of leachate through landfilled waste provides some reduction in leachate strength by anaerobic treatment within the landfill. The organic fraction of leachate can be reduced by the recirculation process but other constituents are not significantly removed (ammonia, chloride and metals in particular). Leachate recirculation may assist the biodegradation process and hence shorten the period required for stabilisation of a landfill in the short to medium term. However, eventually the chemical composition of the leachate will become affected, with a rising proportion of substances which do not respond to the action of bacteria in the fill. The result will be an imbalance between these substances and the other, more treatable, components of leachate. This may cause biodegradation to slow and hence extend the time over which landfill gas and leachate is produced.

Recirculation on existing sites which were not designed with basal lining and leachate drainage is not recommended. The recirculation of leachate without the monitoring of leachate levels in the site is also undesirable and should not occur.

Where recirculation is practised, the recycled leachate should as far as possible be evenly distributed throughout the body of the landfill. This can be done by way of an irrigation system placed under the cap of any completed phases. Optimum operating conditions for leachate recirculation are site specific. The rate of application of the recirculated leachate is dictated by the amount of leachate available. Recirculation should be practised without causing hydraulic, surface or groundwater problems. Care should be taken to

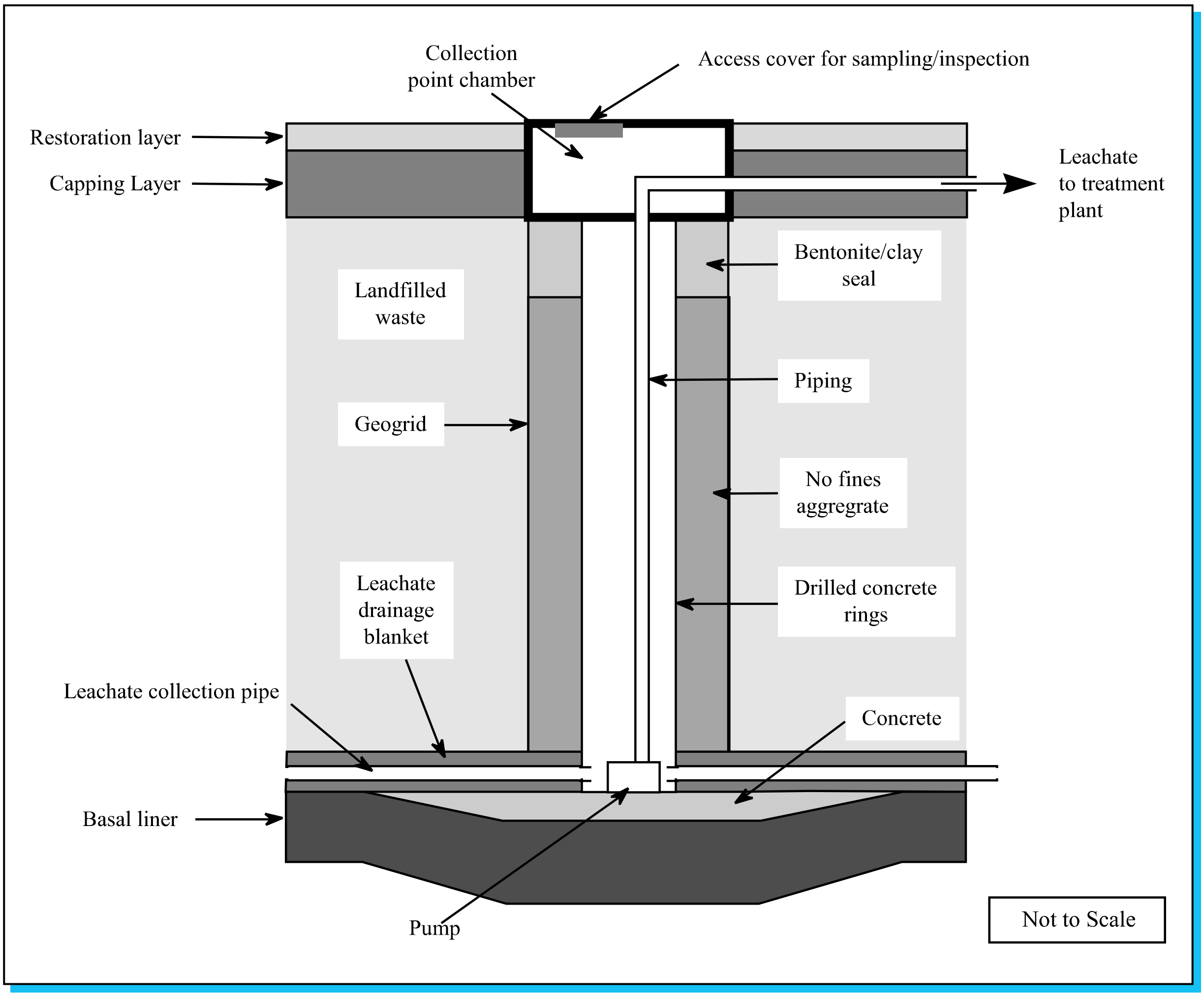

FIGURE 12: LEACHATE COLLECTION CHAMBER – GENERAL ARRANGEMENT

ensure that leachate is not becoming perched in the site and that the recirculated leachate is reaching the leachate collection system.

It should be recognised that recirculation is a leachate management method, not a disposal solution. It has the short term attraction of making the leachate disposal problem less acute for the early years of the site's life. However, unless infiltration of rain water is prevented, leachate levels in a containment site will build up as the wastes become increasingly saturated. This phenomenon demonstrates the need for monitoring and confirms that leachate disposal will still require a solution in the long term.

5.5.2 TANKERING AND SEWER DISCHARGE

Where leachate generation is low, transport to a sewage works may be a possibility. This is essentially dependent upon cost and whether the operator of the sewage works wishes to accept the material.

Sewer discharge is an option, but it is dependent on the ability of a sewage works to treat the leachate. The capacity of the sewerage network to receive the additional flows may also be a criteria at certain locations.

In all cases where sewer discharge occurs, leachate should be tested for dissolved methane. Methane is an explosive gas which may pass out of solution by processes such as aeration. The build up of methane is not desirable and may result in unacceptable risks to other sewer users. For this reason, methane levels in leachate discharges to sewer must be sampled regularly. If necessary, the leachate must be pre-treated and degassed. Methane degassing is generally undertaken as part of leachate treatment as it involves the aeration of the leachate.

All sites involved in off-site leachate disposal will need some form of leachate storage. This is necessary to ensure that levels do not rise above the maximum acceptable level within deposited waste. Storage also provides essential back-up where problems arise with transport or at the final disposal outlet. Accordingly, storage capacity of at least seven days leachate production will be necessary at most sites where leachate is pumped directly to a sewer. However, larger capacity may be needed where reliance is placed upon tankerage or gravity drainage.

5.5.3 ON-SITE TREATMENT

On-site treatment may be economical at larger sites or where sewer disposal is not possible and tankering to a sewage works prohibitively expensive. A number of the more common treatment technologies include:

- Air Stripping/Aeration;
- Reed Beds;
- Rotating Biological Contactors;
- Reverse Osmosis; and
- Oxidation and other Chemical Treatment.

It should be appreciated that the treatment methods listed above are possible responses aimed at addressing problems that may arise in the practical context. Indeed, certain techniques may need to be used in tandem or otherwise in combination to produce the desired result. In the end, the choice will be a function of the nature of the leachate to be treated, which in itself is dependent on the composition and volume of the leachate and the selected discharge medium and its location.

One of the older methods of leachate treatment is the spray irrigation of leachate. This was done either on the filled areas of the landfill site or off-site on neighbouring land. This techniques relies upon evaporation and aeration of the leachate, whilst evapotranspiration and some biodegradation could occur where off-site land treatment was practised. In the context of modern landfill operation, spray irrigation has considerable disadvantages. Off-site leachate irrigation may pollute local groundwater and/or may be a contravention of the provisions on groundwater protection, principally the Local Government (Water Pollution) Regulations 1992 and the EU Groundwater Directive. A particular problem results from leachates containing an elevated heavy metal content. A second disadvantage is that the effectiveness of the method is dependent upon the ability of the recipient soil structure to accommodate the additional liquid load. Often the soil structure begins to break down or the iron content of the leachate causes the creation of a hard pan. In addition, aerial spraying may result in a significant odour nuisance. All these factors greatly diminish the desirability of continuing this practice so that it is only used in exceptional circumstances.

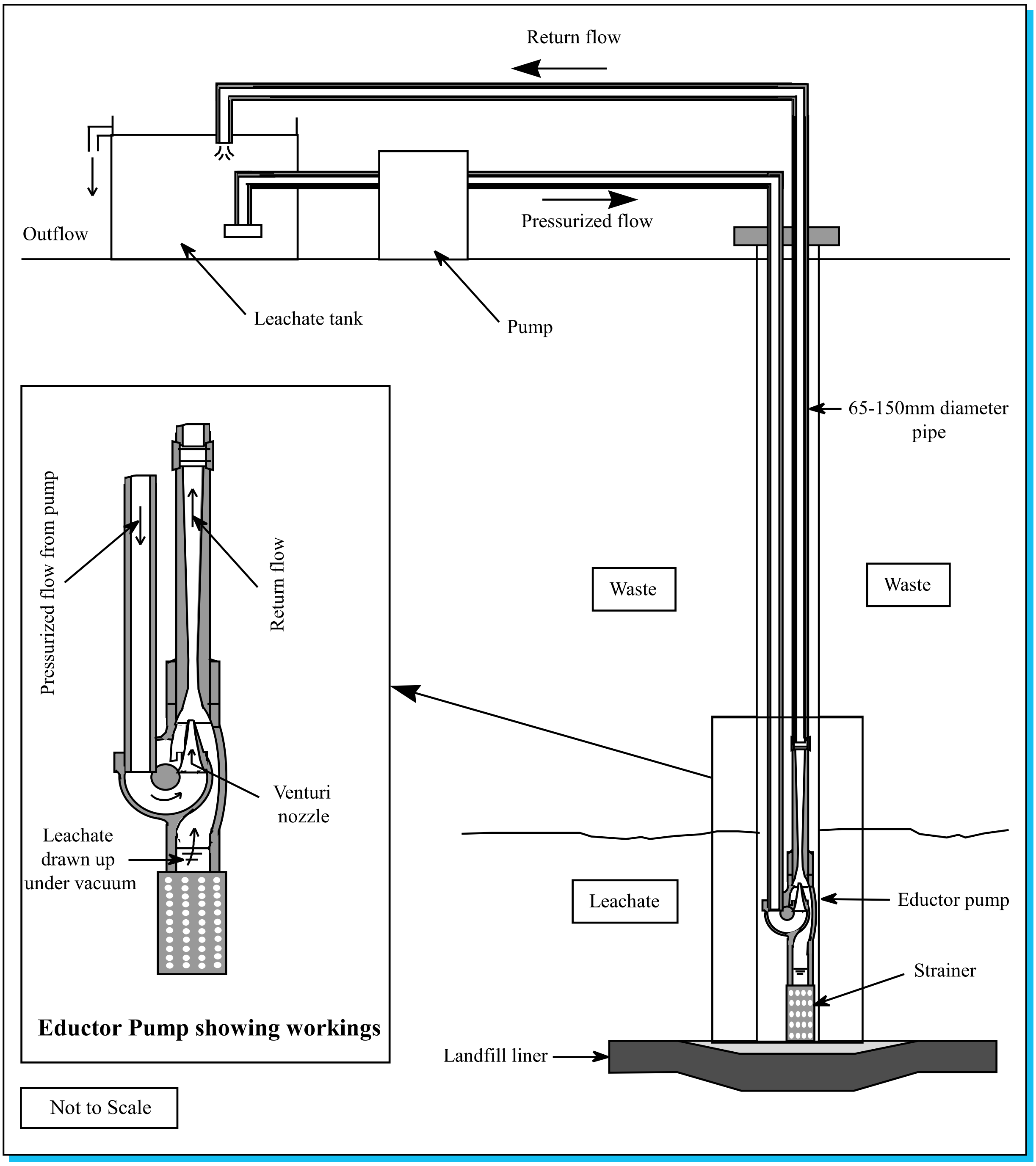

FIGURE 13: EDUCTOR PUMP LEACHATE REMOVAL SYSTEM

6. LANDFILL GAS CONTROL

6.1 THE NATURE OF LANDFILL GAS

The biodegradation process in a landfill produces both leachate and landfill gas. The latter is primarily composed of methane, carbon dioxide and water vapour and evolves on the commencement of the anaerobic decomposition of the filled material. Trace components provide landfill gas's characteristic vinegary smell. In certain circumstances, other gaseous compounds may be present in significant quantities, where large quantities of industrial waste of particular types have been accepted for disposal. For example, a very large proportion of plasterboard in a site may cause the evolution of hydrogen sulphide. The latter circumstance would be unusual and, normally, methane and carbon dioxide are the primary constituents of environmental importance in landfill gas.

Methane is flammable and explosive at concentrations of 5-15% v/v in air. The gas is usually saturated with moisture and is corrosive. If not properly monitored and controlled, landfill gas can give rise to flammability, toxicity, asphyxiation and other hazards as well as vegetation dieback. In addition to its explosive properties, landfill gas is also an asphyxiant when found in a closed space in significant quantities.

Landfill gas is produced in significant quantities in the landfill environment, with a typical annual emission figure being about $10m^3$ of gas per tonne of deposited wastes. The rate of landfill gas production is a function of a number of factors including:

- the physical dimensions of the landfill site;
- the types of waste deposited and the associated input rate;
- the age of the waste;
- moisture content, pH, temperature and density of wastes deposited; and
- the application of cover, compaction and capping.

Leachate can also contain dissolved methane. As methane can emanate from solution, care should be taken to ensure that this does not occur either from an off-site leachate plume at sub-surface level or from leachate discharged to the sewerage network.

It should be appreciated that methane emissions will occur naturally from some soils and that other industrial activity, such as the proximity of gas mains, coal workings etc, may also cause gas production. Although non-landfill gas emissions are beyond the scope of this document, it is important that any public health risks from those other sources are addressed when they are discovered.

6.2 GAS PRODUCTION AND MIGRATION

The nature of operation of landfill sites makes it difficult to predict the onset of landfill gas production and also its cessation. These depend on both the rate of biodegradation and the by-products of the biodegradation process. These are themselves related to such factors as moisture levels and types of wastes deposited. It is usual for aerobic decomposition to cease within a few days of wastes being put in place, being followed by anaerobic processes which result in gas generation. Figures 9 (see Chapter 5) and 14 schematically show how landfill gas composition changes with the different stages of waste decomposition. As can be seen, enhanced carbon dioxide levels from aerobic decomposition are a precursor to the production of methane-bearing landfill gas in the anaerobic phase. Hence a steady rise in carbon dioxide is a good indicator that gas production is commencing. Once anaerobic biodegradation has started, the quantities of landfill gas will steadily increase over the following 12 months.

Gas production will then continue for a number of decades, eventually declining due to the decrease in microbiological activity in the site. In certain circumstances, gas evolution may step up again if the site is disturbed, particularly in a manner which affects the moisture content of the filled material. Hence changes in the water table or in the efficiency of capping may have a significant effect on gas generation. Accordingly, extreme care should be taken in making a decision to cease or significantly reduce landfill gas monitoring when gas generation rates appear to be slowing or to have ceased.

Landfill gas has approximately the same density as air, but some variations in density will occur due to variabilities in the proportion of methane to carbon dioxide in the gas. Natural convection from the raised temperatures within the filled material will cause gas to migrate to the surface. Changes in atmospheric pressure may result in significant alterations in the pattern of gas migration and its rate of emission from the site. In particular, a sudden drop in pressure may result in a differential pressure gradient occurring between the filled material and the atmosphere above, tending to cause gas to be drawn from the ground.

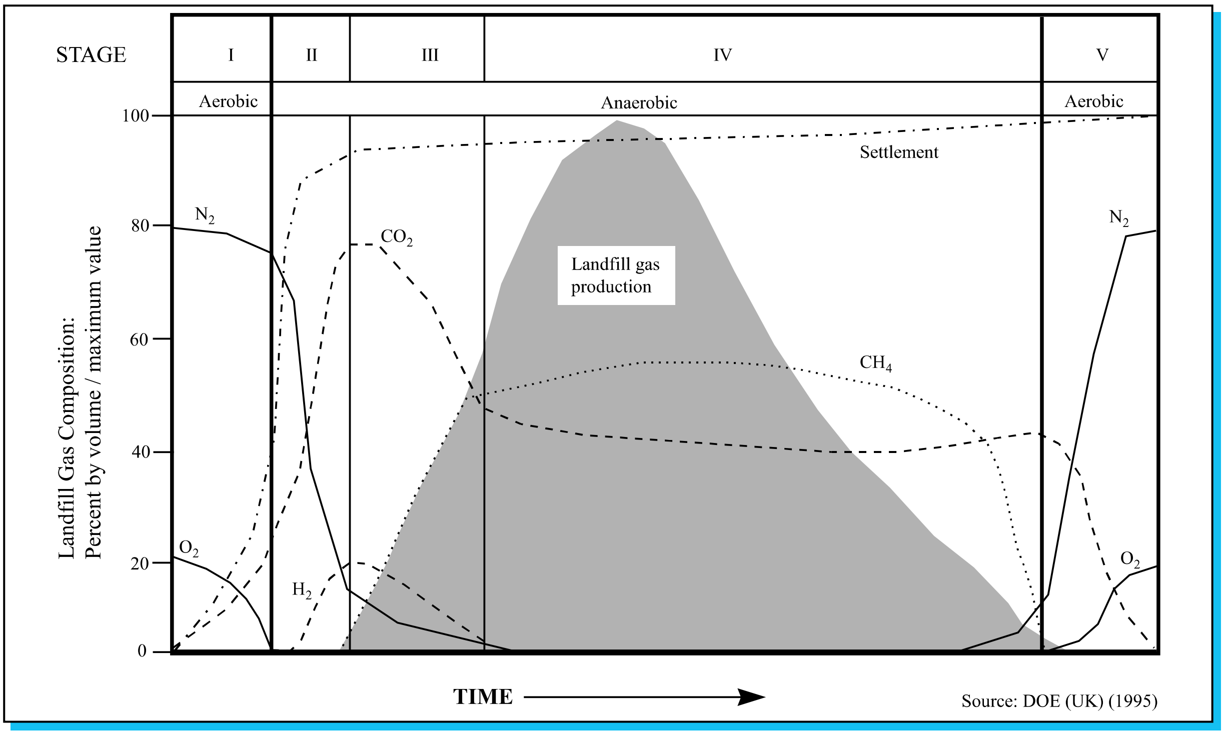

FIGURE 14: CHANGES IN LANDFILL GAS COMPOSITION

As it rises, landfill gas will follow the path of least resistance. It may therefore be emitted laterally when upward movement is fully or partially obstructed, for example by layers of low permeability materials. Besides convection, pressure build up of gas within the waste mass may cause migration at landfill sites. Figure 15 shows a variety of possible migration pathways from a completed site.

The settlement process of the filled materials may affect migration pathways in the long term and hence cause changes in patterns of emission. The installation of an impermeable cap on the completed areas of a landfill can have a significant impact on the pattern of landfill gas migration. It is important that the need for the gas to pass through the cap is addressed. Otherwise uncontrolled lateral migration is likely to be an inevitable consequence of the presence of an impermeable cap. The design and installation of a cap which, on the one hand, prevents significant water ingress and, on the other, permits landfill gas emissions is a challenging matter which may require specialist expertise, particularly at the design stage.

Other factors which may cause changes in migration patterns include temporary sealing of open gas venting trenches by washed out materials or by snow or ice.

Besides the on-site factors mentioned above, the immediate geological and hydrogeological environment of the landfill will have a significant effect on off-site migration. Of importance is the structure of the adjoining geological materials and their potential permeability. The existence of drains and service ducts nearer the surface must also be taken into account, as must the presence of adits and other sub-surface structures.

Uncontrolled off-site migration should not occur. Localised vegetation die-back may be the first sign of environmental stress. Of greater significance is the possibility that landfill gas will migrate into closed spaces and consequently build up. Basements and cellars, service ducts, under-floor spaces, cupboards, wall cavities, lighting columns and drains can all act as migration pathways. Precautions must be taken to ensure that landfill gas does not present a threat to properties in close proximity to a landfill site or to buildings or other enclosed spaces within the site perimeter.

6.3 GAS CONTROL MEASURES

All sites accepting biodegradable waste should undertake landfill gas monitoring. The nature of that monitoring is set out in the Agency's *Landfill Monitoring Manual*. The monitoring frequencies set out in that document are minima and it would be usual for frequencies significantly in excess of these requirements to be implemented at sites in close proximity to other built development.

Besides environmental monitoring, all landfill operators should take appropriate measures to assess landfill gas production and to control its

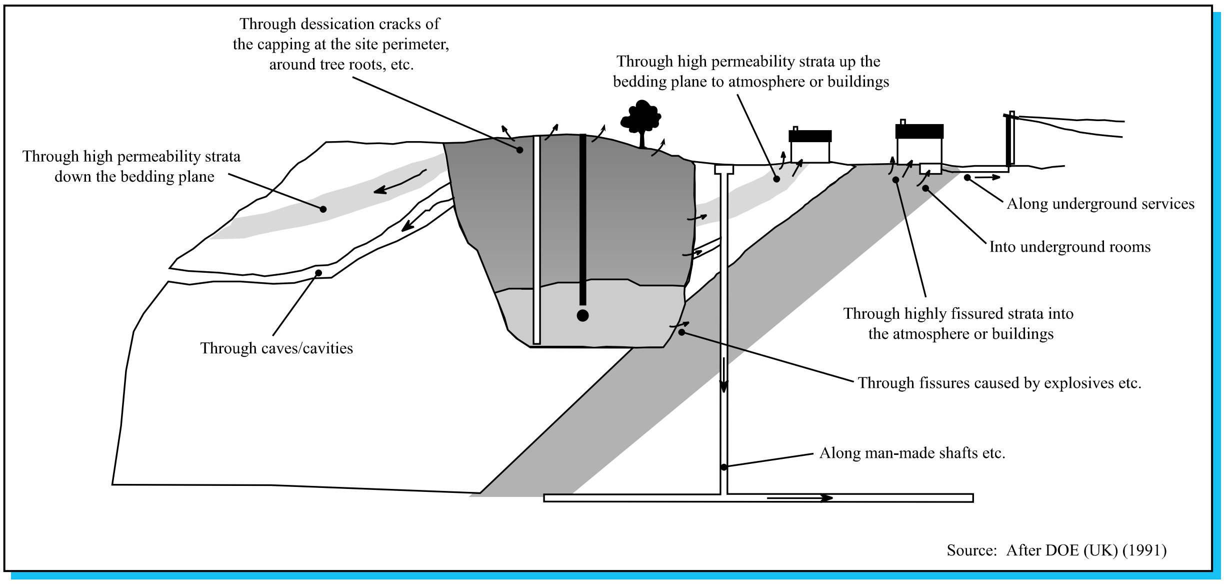

FIGURE 15: POSSIBLE GAS MIGRATION PATHWAYS FROM A COMPLETED/RESTORED SITE

accumulation and migration. In general, all significant sites should have gas collection systems. Landfill gas generated at such sites should not be allowed to vent to atmosphere in an uncontrolled, ad-hoc fashion. Rather it should be contained within the site boundary and collected.

When collected in sufficient quantities to support combustion, landfill gas should be flared, rather than passively vented to the atmosphere. Methane is aggressive in the upper atmosphere and hence is a significant contributor to the greenhouse effect. Ideally, landfill gas should be utilised for the production of energy or for space heating purposes.

On all landfill sites where landfill gas is present in significant quantities, the collection and treatment of landfill gas should be carried out in a manner which minimises damage to or deterioration of the environment and risk to human health. As has been noted, methane concentrations of between 5% (the lower explosive limit: LEL) and 15% (the upper explosive limit) are explosive. Whilst it is not possible to establish hard-and-fast rules which apply in all cases, in general site operators should ensure that the concentration of methane generated by the facility does not exceed:

- 20% of the LEL (1% v/v) in structures on the site (excluding the gas control or recovery system) or
- 20% of the LEL in unfilled land around the site or outside the area of influence of the gas control system.

Applicable thresholds for carbon dioxide are 1.5% by volume.

If these trigger levels of methane or carbon dioxide are exceeded, the operator should take immediate steps to mitigate the migration of landfill gas.

Figure 16 shows a typical landfill layout where gas collection and monitoring have been installed, and where landfill gas is being extracted.

6.4 GAS CONTROL SYSTEMS.

The exact nature of the infrastructure used to control landfill gas is site specific. The over-riding objective is to prevent landfill gas passing beyond the perimeter of the site, whilst safeguarding the workforce and users of the landfill. Generally, effective landfill gas control requires specialist expertise, particularly where the landfill operator has had only limited experience in gas management.

Gas control systems fall into two types: active systems and passive systems. Often a combination of these is used. In either case, it is vital that the systems selected are designed and protected against failure and damage. The landfill environment requires rugged equipment and such equipment may well become damaged at some time either by the site operations or by the settlement process itself. It must also function 24 hours a day for every day of the year. The possibility of failures occurring should be addressed at the design stage, as should the provision of back-up alarm systems. Regular inspection by site personnel is essential. Otherwise passive systems can become inadvertently blocked or pumping systems may fail with potentially serious consequences.

No single control mechanism will provide a panacea to the challenges resultant from gas emissions from

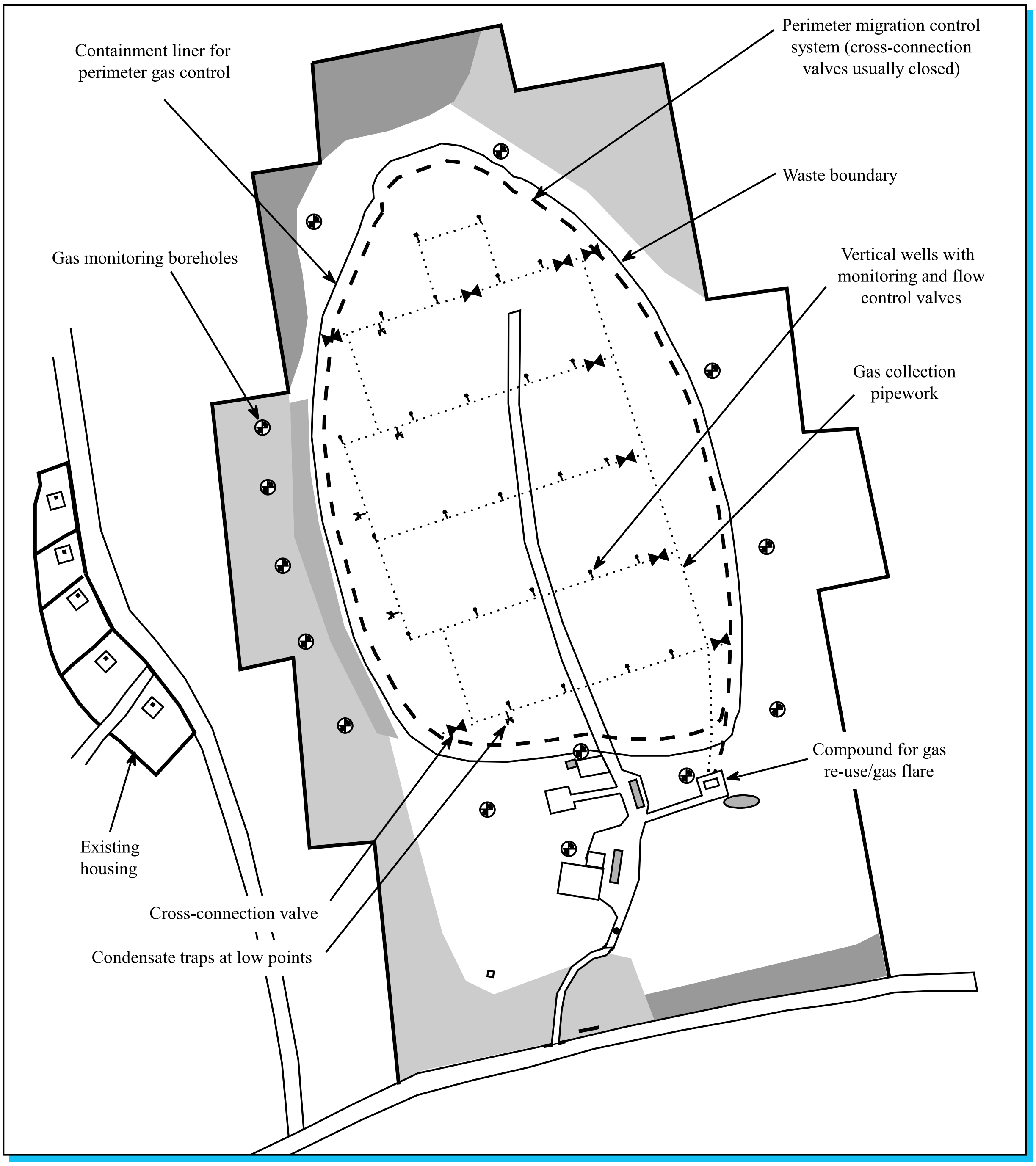

FIGURE 16: LANDFILL GAS ABSTRACTION SYSTEM

landfills. Usually, a number of systems will need to be used in tandem. Only where a site is in a highly rural location, well away from any residential or other development, will a single control measure be adequate. In this respect, it should be noted that the demands on a gas management infrastructure will change over the site's life. For example, at the early stages of biodegradation, gas management solely by passive venting may be appropriate as gas production levels will be low. As gas production increases, a more sophisticated, active system may be required. When gas quality reaches a sufficient standard to support combustion, flaring or other energy recovery methods may be required.

Active Systems

Active gas control systems usually abstract landfill gas by way of applying a negative pressure to the fill from selected boreholes or gas wells. This is achieved by pumping, with the gas being collected for flaring or utilisation.

It should be appreciated that the installation of a gas abstraction system can speed up the biodegradation process and hence will often stimulate enhanced rates of settlement. This factor will need to be considered in the design and maintenance of abstraction systems. The operation of the system will have particularly noticeable effects in the year after it has been installed.

Care must be taken to balance the pumping carried out in various gas wells on the site. Otherwise certain areas may become over-pumped, with the result that air is drawn through the refuse and into the gas extraction system. It may also increase the likelihood of fires occurring. This may affect the combustion of the gas at the flaring stage and may diminish the biodegradation process. Conversely, under-pumping at other locations may result in only partial gas extraction and possible migration. Hence each well should have its own sampling point and control valve.

The concentration of landfill gas being transmitted via the wells to the abstraction system should be monitored. In particular, transmission within the explosive range for methane of 5-15% by volume should be avoided.

Abstraction wells will vary between 0.25 to 1.0 metre in diameter. A typical cross section of a gas well is shown in Figure 17. The bulk of the well is composed of a drilled or slotted pipe, surrounded by an annulus of clean permeable stone of low fines content. The head of the well must be sealed so that no air can be drawn in by the gas abstraction process. Otherwise gas yields for energy use and flaring purposes will diminish and the aerobic conditions may create additional risks of fire. Usually low permeability clay or other equivalent materials should be used to seal around the top of the vent or abstraction pipes. The pipe should be composed of a suitable composition plastic, such as high density polyethylene (HDPE). It is not appropriate to use metal pipes for the reason that trace constituents of landfill gas are corrosive.

Generally, gas wells should not extend to the base of the site. This is particularly the case where wells are retrofitted to filled areas of existing sites. In the latter case, a margin of about 25% of the total depth should be allowed between the bottom of the well and the base of the site. Otherwise, the vagaries of the drilling process and settlement may cause the well to come into contact with any liner.

As an alternative to drilling, gas wells can be constructed after wastes have been deposited by way of excavation using an hydraulic excavator. This technique may have a possible advantage over drilling as there is less likelihood of compaction in the waste surrounding the well. Hence gas flow to the well will be assisted. This technique is not suitable for the construction of wells in deep sites.

The location and spacing of the wells will be site specific and dependent on whether there is any intention to use the landfill gas for energy generation and whether migration is already causing a problem. Again, it should be emphasised that assessments of this kind should only be done by suitably experienced organisations.

Where landfill gas is detected in perimeter monitoring points around the site, monitoring point density may need to be increased to pin-point the extent of the migration. Increased numbers of monitoring points may also be needed where very high concentrations of gas are being produced. Abstraction wells may need to be installed in parallel to the sides of the site.

Each gas well should be connected to a grid of pipes. Pipe diameters are dependent on gas flow rates but generally diameters of between 100mm to 200mm should be utilised. Plastic pipework should be utilised and these should be selected for integrity against frost damage and sunlight. It is preferable that pipes are buried, but this may prove difficult in sites which have yet to reach final levels or the capping stage.

The interconnections between the collection pipes themselves, and between the collection pipes and the wellhead, will require careful design and monitoring. They may be subject to considerable pressures and lateral stresses resultant from the movement and settlement of the filled material. It is important that pipework is laid to a designed fall and that condensate traps are fitted at any low points. This prevents the pipework becoming blocked. Given that condensate is inevitable in landfill gas extraction, it is important that effects of settlement on pipework are regularly monitored. Otherwise, low spots may develop and attract condensate to them.

The heart of an active gas management system is one or more extractor pumps. These should be protected by a moisture removal trap and, where a flare is installed, a flame arrestor. A wide variety of pumps are available which are suitable for landfill gas abstraction. The selection of such pumps is a matter for those with specialist experience in landfill gas monitoring and control. However, they must be suitably rugged and able to operate reliably for long periods in a corrosive environment. All pumps must be subject to planned maintenance

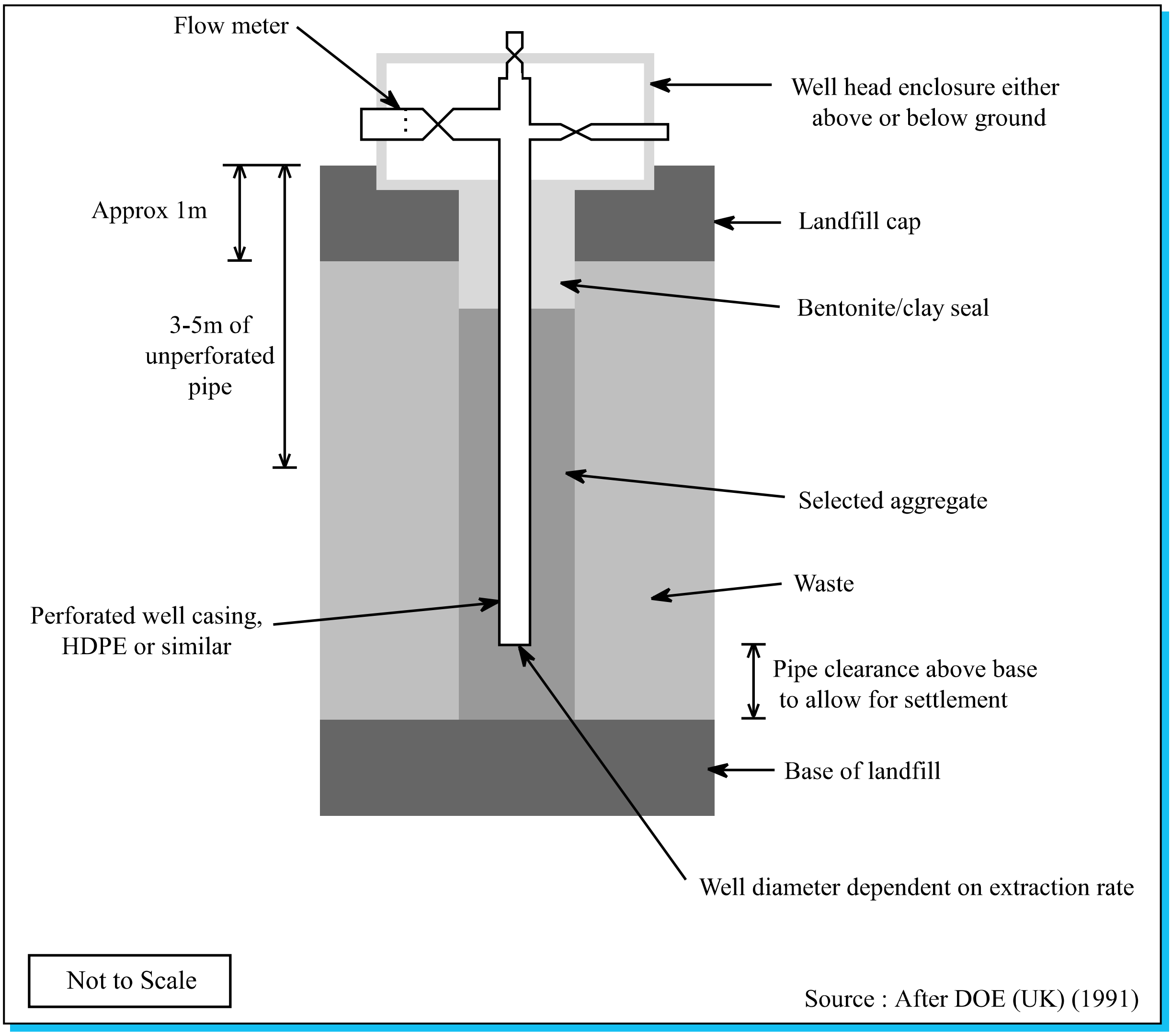

FIGURE 17: TYPICAL LANDFILL GAS EXTRACTION WELL

The selection and design of flare stacks should be a matter for specialist advice. They should be sited in a raised area, with appropriate security. Care should be taken that the grounding of the flare does not provide a hazard to site personnel on windy days. Alarm systems must be included to indicate instances when combustion is no longer occurring.

All electrical equipment must be intrinsically safe, sparkproof and suitable for use in a potentially explosive environment.

In conclusion, gas abstraction and management is a highly specialised area where expert advice is usually required. In particular, the utilisation on landfills of makeshift equipment for gas collection and flaring is unacceptable.

Passive Systems

Passive systems are generally made up of gas venting systems or gas barriers, albeit that these can be used in combination. Such control systems rely on natural pressure and convection mechanisms to vent landfill gas to the atmosphere. They are less efficient than active systems, but are cheaper and have lower maintenance requirements.

The choice between a passive system or an active system will be dependent on a number of factors. A key decision criterion will be the results of environmental monitoring carried out and whether gas migration may be presenting a problem. Notwithstanding these factors, odour nuisances from passive systems may increase the desirability of establishing an active gas management system and associated flaring.

Minimum landfill gas monitoring requirements are set out in the *Landfill Monitoring Manual*. More detailed monitoring should be undertaken where passive landfill gas barriers are used to protect sensitive targets. In particular, monitoring should be undertaken on both sides of any passive gas barrier in order to show, firstly, whether gas is reaching the barrier and, secondly, to test the effectiveness (or otherwise) of the barrier. It should be emphasised that it is not sufficient to rely on a gas barrier without undertaking the requisite environmental monitoring.

At the very minimum, some type of passive system should be installed to control landfill gas emissions at all sites accepting biodegradable wastes. Figure 18 illustrates a typical passive venting well installed within the filled material and Figure 19 shows a venting trench constructed at the edge of a landfill. It can be seen that a series of vertical pipes forms the heart of the venting system, being surrounded by granular, no fines material. The pipework and the granular material assist the migration of the landfill gas to the surface.

6.4.1 GAS BARRIERS

Artificial liner systems, such as clay, bentonite or HDPE, will give some degree of protection from landfill gas migration. However, the impermeability of these to gas migration has not been completely evaluated and hence care must be taken to ensure that an undue reliance is not placed upon them.

In many cases, operational sites will require that gas barriers are installed in waste already deposited. Trenches can be dug in shallow sites using appropriate equipment. In the case of deeper sites, or where the ground is difficult, barriers can be injected into the substrata surrounding the waste. The injection of grout and other types of barrier should be undertaken only by experienced contractors.

6.4.1.1 Barriers and Trenches

Gas barriers can be installed in trenches of a width as low as half a metre. They should be constructed on firm ground outside the filled material. Generally, gas barriers should be constructed to at least two metres below the deposited waste, unless keyed into very low permeability natural substrate.

A typical vent trench is illustrated in Figure 20. The side furthest away from the waste is lined with an artificial lining medium of low permeability. Perforated or slotted vent pipes should be utilised. As the trench is built up, further slotted collection pipes should be introduced. The spacing of the vertical vent pipes will depend upon an assessment of the potential migration of the landfill gas, taking account of the effects of later capping activities on the site. The trenches should be lined with geotextile at the surface and then capped with impermeable materials to prevent water and fines ingress. The vertical vent pipes should be proud of this surface and should not be slotted at the point where they pass through the capping materials.

In the past a series of horizontal pipes have been suggested which inter-connect with the vertical pipes just described. Whilst this may be acceptable in trenches constructed in natural ground (such as that illustrated in Figure 20), this practice is undesirable in the type of gas barrier sandwiched between waste and natural ground shown in Figure 19. Settlement will put considerable pressure on the matrix of pipework. The horizontal cross connections and the interconnections themselves will be areas of weakness which may cause the pipework to pull apart under load.

It is not acceptable to rely on convection through the aggregate alone to achieve venting. Vent pipes must be used in all cases. The trench should be capped in a manner which does not disrupt the permeability of the aggregate. A gas trench constructed without piping and capping may also create a path for rainwater infiltration.

The construction of the trench should be supervised to ensure that no short-cuts are taken. When in operation, care should also be taken to ensure that the trenches do not become blocked with fines or that bad weather – particularly snow – does not adversely affect the operation of the venting pipes.

6.4.1.2 Vertical Gas Drains

A series of gas drains can be installed in the active areas of the landfill as filling progresses. These assist the evolution of gas in the direction of the abstraction system and/or away from peripheral gas trenches.

These should be constructed of slotted pipes surrounded by clean and low fines aggregate. The pipe/aggregate construction should be collectively about 1 metre diameter. Gas drains can either be constructed in recently deposited refuse or can be built up proud of the deposited wastes and the deposited materials placed around them. Alternatively, gas drains can be drilled or excavated into wastes already in situ. The latter may be preferable, as the on-going construction of gas drains in parallel to waste disposal activities can interfere with filling operations. In addition, the infrastructure itself may suffer damage from machinery operating on the site.

Gas drains can be used in conjunction with leachate collection points as shown in Figure 21.

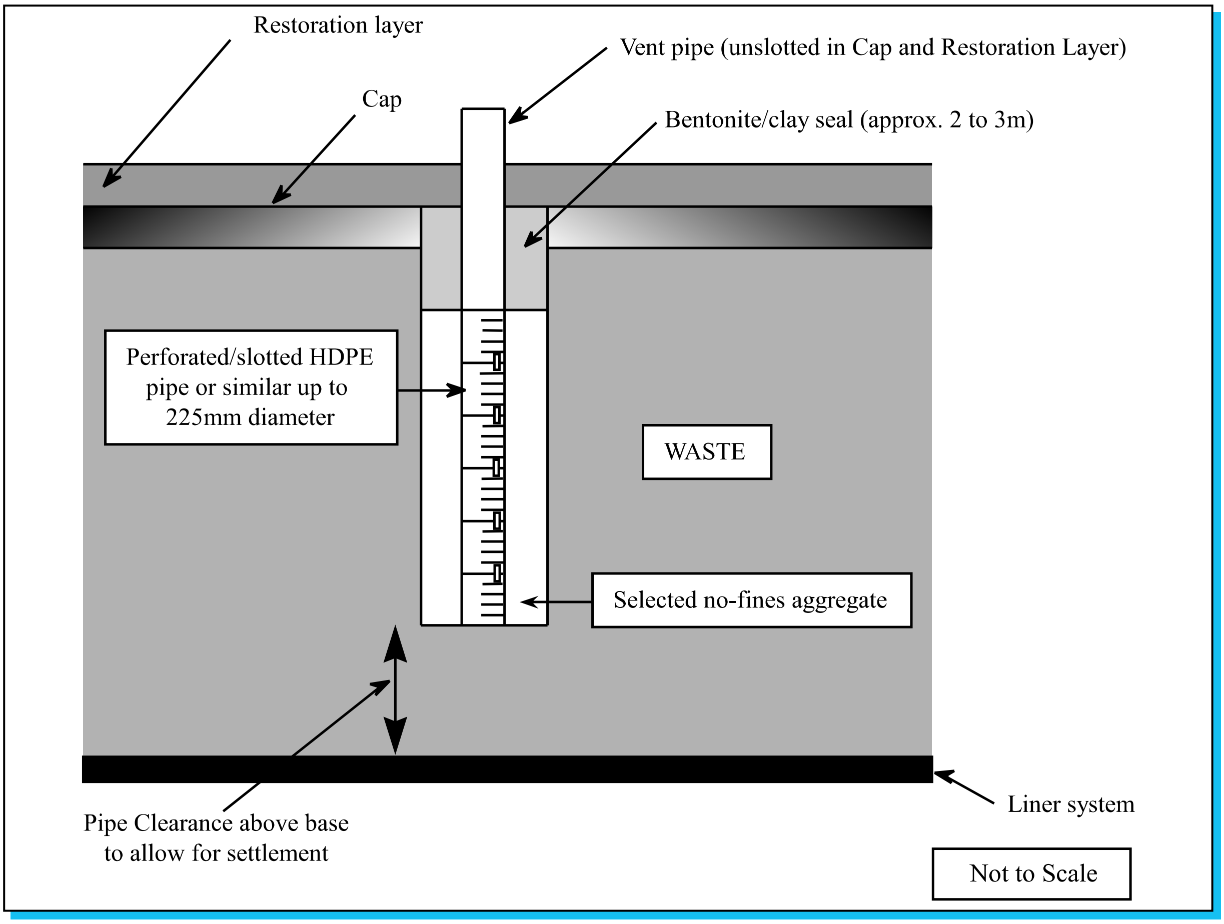

FIGURE 18: PASSIVE VENTING WELL

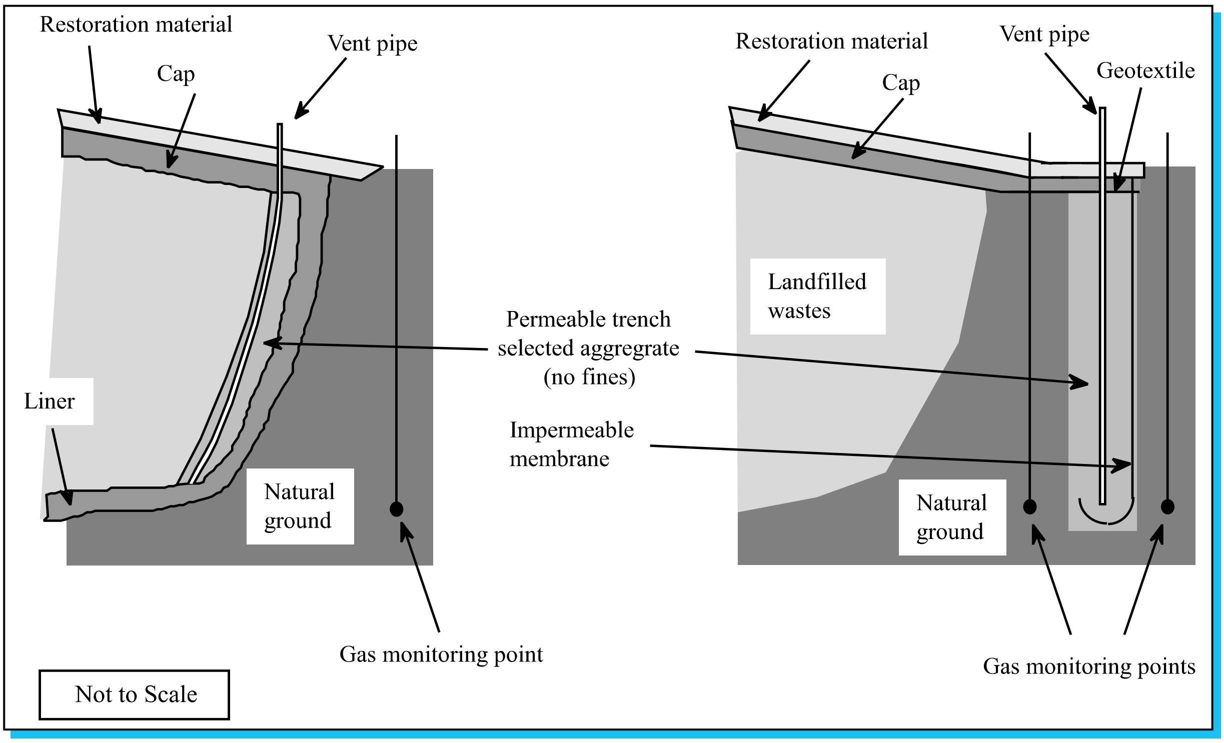

FIGURE 19: GAS VENT TRENCH AT EDGE OF CONTAINMENT (CROSS SECTION)

FIGURE 20: GAS VENT TRENCH – SET IN NATURAL GROUND (CROSS SECTION)

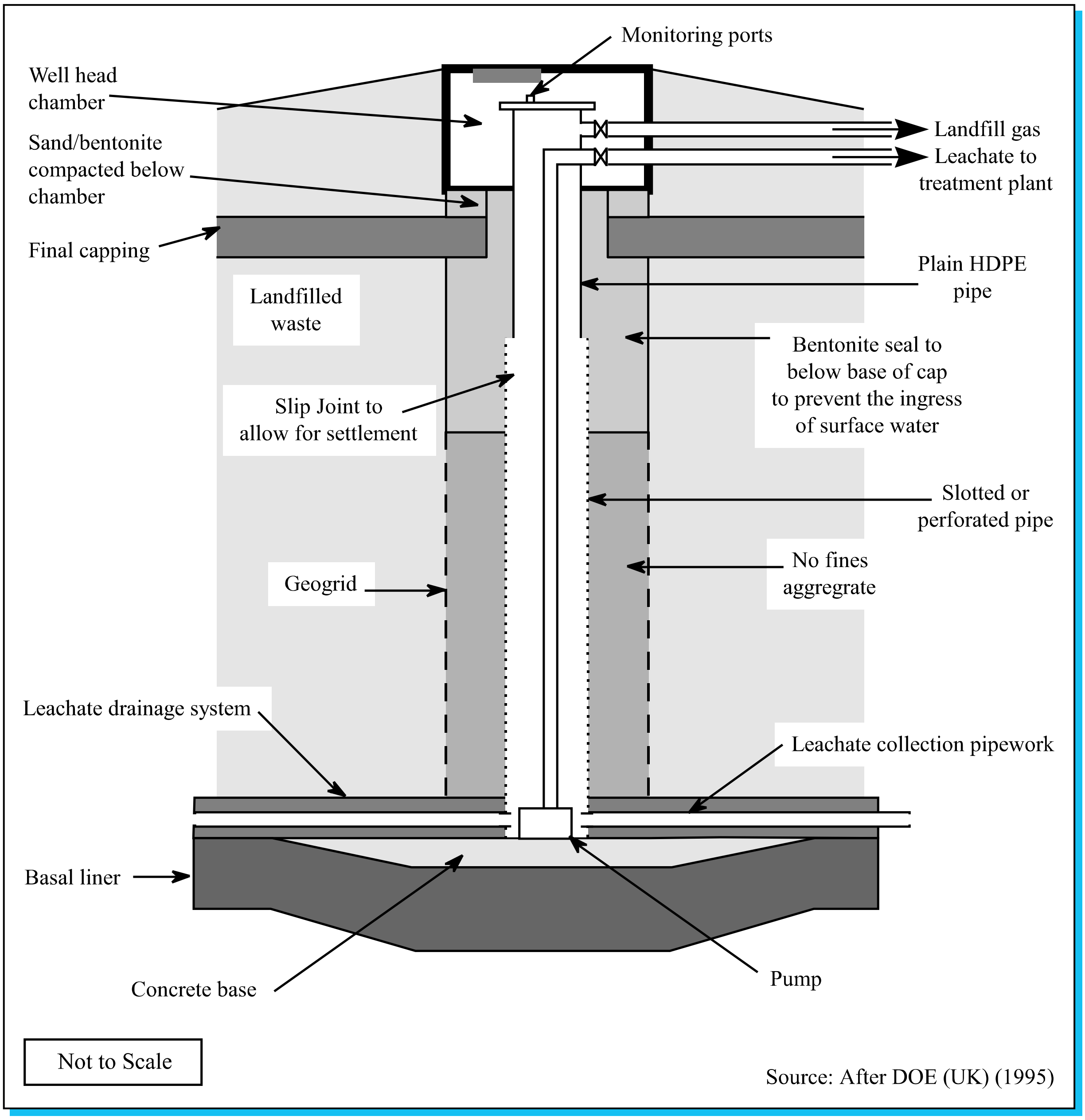

FIGURE 21: TYPICAL COMBINED LEACHATE AND LANDFILL GAS COLLECTION WELL

7. NUISANCE

7.1 NUISANCE CONTROL

A key item in the effective management and control of landfill operations is the control of nuisances. Unless an operator effectively addresses nuisance-related matters on a daily basis, a landfill may become detrimental to local amenity. Factors such as litter and odour have contributed to the poor reputation of landfill in the past.

The potential impacts of landfill operations on local amenities should be considered at the planning stage. In the operating phase all complaints should be logged and investigated. It is good practice to contact complainants to ascertain the nature and source of the problem so that corrective measures can be taken at the site.

Nuisances which may cause concerns include:

- vehicle traffic;
- litter;
- odours;
- noise;
- birds;
- vermin, insects and other pests;
- fires; and
- dust and mud.

These potential impacts should be addressed by clear operating procedures with a view to their minimisation. The following sections set out a range of actions available to mitigate the above nuisances.

7.1.1 TRAFFIC IMPACTS

Traffic is inevitable at all landfills and can become a significant problem at sites served by minor roads. This issue is best addressed at the site selection stage. At existing sites only minor changes may be possible to mitigate the impact; but in certain circumstances even small alterations will significantly reduce the impact.

Often sites may be served by alternative routes. If this is the case, it may be possible to route traffic away from the more sensitive areas, either permanently or at particular times (an example might be school opening and closing hours). The main method by which this can be achieved is by the operator issuing strict instructions to those delivering wastes to the site.

The queuing of vehicles on the public highway whilst awaiting access to the site is undesirable. Where this is a problem provision should be made for queuing lanes within the site.

7.1.2 LITTER CONTROL

The negative visual impact from inadequate litter control at landfills can be a major cause of complaints and a significant nuisance to site neighbours. Litter control should therefore be a high priority. A range of abatement techniques is available, with their use depending on site specific factors such as the degree of shelter of active tipping areas, proximity of other land users and types of waste being deposited.

7.1.2.1 Site Management

On windy days the direction of tipping and compaction should be influenced by the need to ensure protection from the prevailing wind direction. At larger sites, an emergency tipping area should be provided, sited in a protected location. If conditions are exceptionally bad, the site should be closed until the wind has abated.

A daily patrol of the site’s perimeter, access roadways and adjacent public roadways, should be undertaken. Larger sites may require full time litter pickers. If litter has escaped from a site, a priority should be the clearance of gardens of domestic properties, farmland where livestock are kept, and the public highway.

Strict enforcement of the requirement that all vehicles be properly enclosed or covered should prevent litter on access roadways. Vehicle drivers should be issued with warnings about inadequate covering and should be precluded from using the site if these are unheeded.

7.1.2.2 Site infrastructure

Movable screens or nets should be positioned near the working face to control wind blown litter. Screening bunds, fencing, and buffer zones enclosing the site’s perimeter will provide protection for adjacent properties.

Canopy nets or mobile nets attached to a framework on rails have been used to enclose the working area and prevent wind blown litter. Enclosed netting systems have been successful at some locations, but at others they have resulted in operational problems by obstructing the working area.

All types of litter screens and nets should regularly be cleaned of litter. Otherwise, effectiveness may be reduced and/or support structures may be damaged.

As noted earlier, cover material has a significant role in litter abatement. Accordingly, it is desirable that cover is stockpiled on the site. This can be done in the form of bunds around the working face or emergency tipping area, which themselves offer protection from the wind.

The use of steel wheeled compactors can reduce the potential sources of litter. However, other methods such as nets will usually be required.

7.2 ODOUR CONTROL

Offensive odours at landfills arise from:

- previously deposited waste disturbed by digging activities;
- malodorous wastes, such as industrial or agricultural wastes and sewage sludges;
- leachate treatment systems, particularly aerial spraying;
- stagnant leachate in lagoons or other holding containers; and
- landfill gas.

Odours from landfills can be reduced by good site management. The principal means of minimising landfill odours include:

- effective compaction;
- the provision of adequate cover;
- rapid deposition of malodorous wastes, using covered trenches where necessary;
- effective landfill gas collection and subsequent efficient combustion;
- rapid burial of excavated wastes and the closure of such excavations; and
- prevention of stored leachate becoming anaerobic.

7.3 NOISE CONTROL

Site personnel should be aware of the need to minimise noise and of the health hazards of exposure to excessive noise. Vehicles or equipment visiting or in use on the site should conform to EU standards in relation to noise performance. Special attention should be given to fitting sound reduction equipment to power tools, machines and fixed plant. Acoustic screens may be necessary in proximity to generators and pumps, particularly those used on a 24 hour basis.

Speed limits should reduce noise of vehicles accessing the site. High quality road surfacing will have similar effects.

Gas flares can be noise sources on occasion. Audible bird scarers may cause irritation to residents, when located in inappropriate locations or operated outside the hours of site working. Accordingly, they should not be used after the hours of darkness or in the late evening during summer months.

In certain cases, bunds, vegetative screens and other noise barriers can dampen the ability for noise to travel. These features should be provided to ensure that adjacent properties are shielded from active areas of the landfill development. However, they should be carefully sited, designed to fit in with the topography of the site and the surrounding landscape.

7.4 PEST CONTROL

When well run, the modern landfilling process will avoid many potentially adverse environmental impacts. The rigorous application of cover material, proper compaction of wastes, and general “good housekeeping” are the most effective means of pest control.

Where it is proposed to use alternative types of cover such as foam, increased vigilance should be taken to ensure the adequacy of pest control measures used. Where pests are a continual problem, a reversion back to the more traditional types of cover, such as sub-soils, may be the only option. If an insect control problem appears to develop in the summer months on sites using non-traditional cover materials, it may be appropriate to temporarily switch to soil based cover materials until the breeding season has finished. In addition, the prompt burial of difficult wastes containing meat and foodstuffs should reduce insect infestation.

Regular site inspection will indicate the prevalence of pests. When significant numbers are identified, an experienced pest control specialist should be employed to deal with the problem.

7.5 BIRD CONTROL

Scavenger birds such as starlings, crows, blackbirds, and gulls are most commonly associated with active landfills. They can be a nuisance, transfer pathogens, litter and scraps to neighbouring areas and also be a hazard to aircraft.

Landfill operations should all aim to reduce the attractiveness of the deposited wastes to birds.

Mainly this involves decreasing the potential supply of food by:

- frequent covering of wastes;
- baling or bagging waste containing food sources and/or trench disposal; and
- eliminating the acceptance of wastes that represent food sources for birds.

Many of the methods may have only a short term effect as the birds adapt to the environment in which they find the food. Varying the control techniques may prevent birds becoming accustomed to a single method. Examples include:

- gas cannons to discourage birds from food scavenging;
- visual deterrents including realistic models of the bird's natural predators;
- distress calls of scavenger birds and any sound of its natural predators;
- use of physical barriers such as nets around the working face;
- the utilisation of birds of prey such as falcons; and
- the flying of kites over the landfill.

Bird shooting should be a last resort and is generally undesirable. The activities of persons employed to shoot birds must be effectively supervised. Some birds resident on landfills are protected species and this protection must be respected at all times.

The most consistently effective measure is the proper covering of all exposed waste as quickly as possible.

7.6 FIRES

No material should be burnt on or close to the boundaries of a landfill. On no account should litter pickers burn collected wastes on the site. Fires in landfills should be regarded as emergencies and dealt with immediately. Site personnel should notify the appropriate agencies and other emergency response contacts should smoke emissions from the filled material be observed.

Measures for fire prevention and control include:

- training of employees in fire prevention and control;
- prominent posting of emergency response contact numbers (fire service, police, ambulance and other agencies);
- fire extinguishers and two-way radios on all mobile equipment;
- the provision of on-site water supply and, if necessary, water storage and portable water tanks; and
- the provision of fire fighting equipment in the site office.

Fires in landfills are difficult to extinguish. Proper landfill control methods and operational practices afford the best protection against the risk of fires. The most effective fire prevention programme combines "good housekeeping" with constant vigilance by site personnel. Fire prevention must start with advance identification of potentially hazardous areas and trouble spots. Careful handling of fuels and routine clearing of equipment tracks are examples of methods to prevent fires from starting. Site personnel must be alert for incoming loads that show evidence of burning. Loads that are suspect should be denied entry or immediately segregated and placed in a designated quarantine area.

Any waste containing hot ashes should be segregated and quenched or covering material should be immediately ploughed into it.

If a deep-seated fire is discovered or suspected, the extent of the fire can be verified by measuring temperatures in the area of the fire by means of a temperature probe inserted into pipes driven into the tipped material. Readings should start in the unaffected areas and progressively move towards the area of the fire. The affected area should be marked off by indicator boards.

Attempts at smothering fires by the use of impermeable materials are generally ineffectual and may cause the fire to become deep rooted. Accordingly, the recommended strategy is to dig out the deposited waste and quench it with water. The area containing the fire may also need to be segregated by trenching. The trench should then be back-filled with inert material, such as sub-soils. Fires close to leachate chambers or gas extraction wells may have serious consequences. These may provide access points for oxygen and hence it may be necessary that they are sealed.

Deep-seated fires can be dangerous to personnel and machines as the fire may cause the surface of the affected area to become unstable. Personnel or machines should not move over the affected area in these circumstances.

7.7 MUD AND DUST CONTROL

Mud and dust generated by a landfill may be a major local concern, particularly where such materials pass off-site. The deposition of significant quantities of mud on the public highway is unacceptable and should warrant immediate attention and rectification. Road sweeping equipment should be immediately dispatched to correct the situation if mud is tracking out onto the public highway. Mud control should be part of the routine site inspection program.

The problem of the tracking out of deposited materials can be addressed by effective design and site operation. Good quality temporary access roads to the working face, a well designed site access road, wheel cleaning equipment and, where necessary, mud collection and road sweeping all contribute to effective mud abatement. In general, a wheelwash should be sited a reasonable distance away from the public highway. Otherwise an undesirable skim of mud may extend from it and this may freeze in winter. In addition, it is insufficient to consider the installation of a wheelwash as a complete solution to a problem which may be a function of other factors, such as poor site road construction.

In certain cases, it may be appropriate to arrange for the cleaning of the public highway, footways, walls etc if traffic can be shown to have spattered these with mud. Often, other non-landfill traffic has created this problem. But it may be desirable to sweep the roads and footways for public relations reasons.

Dust may be a problem in summer months. In addition, localised difficulties may be created by the disposal of dusty wastes. The control of such difficult wastes has been addressed earlier in this Manual. The emission of dusts may be mitigated by the damping down of site access roads, using water sprays. The surfacing of access roads with materials such as concrete and tarmac allows mechanical sweeping, which in itself can be used to removed deposited materials prior to the creation of dust problems on drying.

8. SAFETY

8.1 INTRODUCTION

This section sets out the basic requirements of the effective control of health and safety at landfill sites. It constitutes general guidance which should be considered and enacted by all site operators. However, readers should note two important matters:

- site specific guidance relevant to an operator's own safety requirements should be available in the organisation's relevant health and safety statements and working procedures; and
- the operator of a site has an overlying legal duty to ensure that each landfill is operated in compliance with the Safety, Health and Welfare at Work Act 1989 and associated Regulations.

Accordingly, the following text should be viewed as general guidance and it should be appreciated that the fundamental requirement must be the compliance with the above documents, particularly the 1989 Act and the Regulations. All operators of landfill facilities should have read, understood and, where appropriate enacted, the requirements of the provisions mentioned above.

8.2 LANDFILL HAZARDS

Like all industrial activities, there are inherent hazards associated with the operation of a landfill. Historically accidents at landfills have in the main resulted from the temporary nature of much of the site infrastructure – eg site roads, sharp bends and steep gradients – and because vehicles and machinery are often operated in confined areas and in close proximity to each other. Reversing vehicles are a significant problem, particularly where staff are required to cross the working area on foot or direct vehicles at the landfill face.

Accidents can be minimized by the implementation of safety and training programmes and by effective site management. These programmes should include the following

- identification of potential sources of risk;
- assessment of the degree of risk from these sources;
- determination of procedures for addressing the risks;
- development of procedures to minimise accident/risks when they occur; and
- on-going monitoring to ensure proper implementation of safe working procedures.

8.3 SAFETY, HEALTH AND WELFARE AT WORK

The Safety, Health and Welfare at Work Act 1989 is composed of five principal elements. Firstly, the Act contains the over-riding duty on all employers to ensure "so far as is reasonably practicable" the safety, health and welfare of both employees and other affected persons. The criterion of "reasonably practicable" is satisfied by way of compliance with the relevant legislation and any available code of practice, as well as "good practice" within the particular industrial sector as a whole. Secondly, there is a duty on all employers to compile Safety Statements, with such statements being based on the comprehensive written identification of hazards and an assessment of relevant risks. The third element is the right of employees to be consulted on safety, health and welfare issues. Fourthly, all employees are also given a duty to take reasonable care in safeguarding their own safety. Finally, the Health and Safety Authority was to be established to promote and enforce safety issues.

The Act is supplemented by way of Regulations which fill out the Act's more general provisions. The Safety, Health Welfare at Work (Construction) Regulations 1995 (SI No 138 of 1995) have particular application to landfill sites. Under the Regulations a project supervisor must be appointed for the design and development stages of all construction works. A safety and health plan will be required. The purpose of the Plan is to co-ordinate health and safety requirements which may affect all persons present on the site. As construction is an on-going process at a landfill, the requirements of these Regulations need to be addressed throughout the life of the site.

In the light of these provisions, the operator should ensure the safety, health and welfare at work of all persons employed on the landfill. This duty should include the following priorities:

- the landfill should be constructed and maintained in a safe condition;
- a safe means of access to the site for staff and vehicles should be provided;
- plant and machinery should be maintained in a safe condition;
- risks should be appraised and safe systems of work planned, organised and performed;
- suitable safety information, instruction, training and supervision should be provided;

- suitable protective clothing and equipment should be provided and maintained;
- emergency plans should be prepared and revised as necessary;
- that the presence of any article or substance on the site must not present unacceptable risks to health; and
- adequate welfare facilities for staff must be provided and maintained.

A key requirement of the 1989 Act is preparation of the safety statement by all employers. This statement is fundamental in ensuring the safety, health and welfare at work of employees in the workplace. The safety statement should be based on an identification of the hazards at each landfill and an assessment of the risks posed by those hazards.

It is a statutory requirement that the safety statement is up-dated in the light of changing circumstances at the site, any new legal requirement and good practice within the industry. Risks to employees and others should be periodically re-assessed. Accordingly, the statement should be seen as an evolving, rather than static, document. The Health and Safety Authority published a revised version of their Guidelines on Safety Statements in 1993. All employees should have read the safety statement, with managers and supervisors being fully aware of the statement's implications.

8.3.1 PERSONNEL

One or more persons within any organisation must be formally designated in the Safety Statement with the responsibility for safety and for the implementation of the Act and Regulations. Precisely who should be so designated is left to the discretion of any organisation. Individuals so designated should understand the statutory requirements, be able to act as competent persons under the legislation and ensure the continued maintenance of a safe system of work. The latter tasks should include matters relating to training and supervision. They should be responsible for the identification of hazards and designated managers should transmit such information by verbal or written instructions to the workforce, contractors, site users and site visitors. Designated persons should also be responsible for ensuring that the safety statement is applied and compliance with all statutory requirement. An important task is ensuring that all accidents are reported to the Health and Safety Authority if they involve an employee being off work for more than three consecutive days (excluding the day of the accident itself).

Regular site safety inspections should be undertaken by a designated safety officer in accordance with the safety statement. Written reports of inspections should be maintained at the site or at the operator's principal offices.

8.4 LANDFILL HEALTH AND SAFETY

8.4.1 TRAINING

Operators should provide suitable training and instruction to site employees, both full time and part time. The operator should also ensure that any contractor working on site is also informed of the hazards and the necessary precautions. There is also a responsibility for persons employing contractors to ensure that the latter are able to act as competent project supervisors in relation to the safety aspects of the relevant design and construction elements of their work.

All site personnel should be familiar with contingency procedures in the event of accident, injury, fire etc. The locations of emergency equipment should be identified during routine employee training. Phone numbers for local police, fire and ambulance services should be prominently displayed for use in the event of an emergency. Table 5 sets out an example emergency contact sheet. Other information will need to be displayed on the site in accordance with the requirements of the Safety, Health and Welfare at Work (Construction) Regulations 1995.

8.4.2 STAFFING LEVELS

All staff and users of the site should be effectively supervised. No site open to receive waste should be manned by one member of staff working on their own. Similarly no unloading of vehicles should occur in the absence of site staff or out of their immediate view.

8.4.3 MEDICAL

Good personal hygiene is essential to workers on landfill sites and hence hot and cold washing facilities must be provided. All workers at landfill sites, including those employed temporarily by the operator or by contractors working on the site, should have adequate protection against tetanus. This protection must be kept up to date, with boosters given at 10 yearly intervals. The onus should be on the employer to ensure that these injections have been received by employees and to require appropriate assurances from contractors working on the site.

8.4.4 FIRST AID

A first aid box should be available on site in a clearly marked location. The contents of the box should be monitored for use, so that supplies are checked regularly by a named individual responsible for its upkeep. Eye wash facilities also should be available: these should either employ running water or involve non-reusable eye wash bottles. Any bottle with a broken seal must be disposed of immediately and replaced. The operator should arrange for recognised occupational first aid training, with a minimum of one person with a first aid qualification normally present on site. All staff should be familiar with the first aid facilities available on site. The Health and Safety Authority has published guidelines on first aid.

8.4.5 PERSONAL PROTECTION EQUIPMENT

High visibility clothing should be provided and worn by all site staff and visitors. Safety boots and/or wellingtons should be issued to all site workers. They should have steel toecaps and have a steel insert in the sole to resist injury from projections of glass, metal or other items in the deposited wastes. Gloves should be issued as required. The type of glove should be puncture resistant and should be suitable for the relevant task, eg litter collection, vehicle fuelling, cold weather conditions. Safety helmets and eye protection should be available as necessary. Ear defenders should be available for those driving site machinery or working in high noise areas. Operatives at landfill sites work in all weather conditions and will need to be provided with suitable windproof wet weather clothing.

8.4.6 LANDFILL GAS

All site staff should be made aware of the possible hazards from landfill gas. Smoking on site should be forbidden except in designated areas in the site cabins. Buildings and other enclosed structures located at the landfill should be designed to prevent the accumulation of flammable gas within them. Facilities to permit the free circulation of fresh air will generally be required, particularly under floors. It is imperative that all cabins, other store rooms and voids such as those below weighbridges and cabins should be regularly monitored for the presence of flammable gas. All service duct entries to buildings should be seen as possible gas pathways and hence appropriately monitored.

Where it has been established that concentrations of landfill gas are above 20% of the lower explosive limit (LEL), the relevant building should be evacuated. Where this level has been observed within site buildings, the installation of continuous landfill gas monitors and an audible alarm is essential. Extreme care should be taken when re-entering buildings which have been previously evacuated. Procedures for the evacuation and re-entry of buildings when significant amounts of landfill gas have been observed should be contained in the operator's safety statement.

The unnecessary creation of enclosed spaces on site, such as by inversion of a skip for maintenance, should be avoided on all landfills. Lighting columns may permit the accumulation of landfill gas. Hence they should be sealed at the base and should contain intrinsically safe electrical equipment.

Health and safety issues should have particular priority where any site works involves the disturbance of filled areas. In particular, drilling in deposited wastes may give rise to the evolution of noxious and/or combustible gases. Hence regular checks on gas build-up should be made as drilling proceeds. Similarly, any trenches constructed for the purposes of gas collection pipes will need to be physically stable and also monitored for landfill gas. On no account should persons enter trenches or other confined spaces without gas monitoring, rescue and other appropriate safety measures. All contractors should be aware of the hazards of working on landfill sites and be suitably experienced to address them.

Instructions should be issued to all employees that no-one should enter any confined space below ground level, such as culverts and manholes, unless an appropriately authorised person has certified that it is safe to do so. Safety precautions for areas where gas may accumulate require that:

- only persons with appropriate experience and training should be involved in entering confined spaces or providing back-up on the surface;
- smoking should not be allowed;
- persons entering a manhole should be equipped with self-contained breathing apparatus;
- persons entering a manhole should have a safety harness and appropriate line manned by at least two other employees;
- other employees at the surface should have spare breathing apparatus and the requisite training in its use; and
- lights or tools to be used in manholes should be intrinsically safe.

If there is any doubt as to safety of an enclosed space, it should not be entered. The Health and Safety

TABLE 5: HEALTH & SAFETY INFORMATION

NAME OF SITE: ....

LOCATION: .... **Grid Ref**.............................

OPERATOR: .... **Phone** ....

Fax ....

SAFETY OFFICER: .... **Phone** ....

Fax.....................................

LICENSING AUTHORITY:...................................... **Phone**..................................

Fax ....

DOCTOR:... **Phone**................................

Fax.....................................

AMBULANCE:... **Phone** ....

HOSPITAL:.. **Phone** ....

POLICE:... **Phone** ....

FIRE SERVICE:... **Phone** ....

LOCATION MAP

(showing site location and services as above)

OTHER INFORMATION

8.4.7 SITE INFRASTRUCTURE, SIGNS AND BARRIERS

Steep gradients and sharp curves on site access roads should be avoided. If this is not possible warning signs and crash barriers must be provided. Speed limits should be displayed and enforced by the site operator. Vehicles should not travel over unstable areas on a landfill surface. Neither should they travel with their vehicle bodies raised up or being lowered.

Sites should be provided with adequate lighting to allow for safe and efficient operation at the tipping area at dawn and dusk in the winter period.

Trenches and lagoons used for liquid or sludge disposal should be fenced or be clearly marked with poles and bunting and each trench should be labelled to indicate the type of wastes allowed to be deposited. When filled, trenches should be covered immediately. After filling, it may be desirable that the position of trenches remains clearly marked. Their soft nature, particularly when sludges have been deposited, may make them a hazard to site workforce, users and trespassers. Hazard notices should be utilised on the site in relation to deep water, leachate lagoons or steep faces.

Physical barriers should be in place to prevent unauthorised access to culverts and other confined spaces. Culverts on landfill sites may be attractive to children and must be subject to adequate security measures to prevent entry.

8.4.8 OTHER SITE OPERATIONS

It must be emphasised that the working area at a landfill site is dangerous with vehicles regularly manoeuvring in tight spaces. Totting or scavenging by site operatives should not be allowed. Any banksman directing vehicles at the face should be required to stand well clear of reversing vehicles and other machinery.

Site personnel should be instructed to prevent the access of obviously unsafe vehicles. However, it may be appropriate that these are unloaded and then are prevented from returning.

8.4.9 HAZARDOUS SUBSTANxCES

The operator should ensure that exposure of persons at a landfill to hazardous substances, is minimised or, where exposure cannot be avoided, adequately controlled. Employees should be trained regarding:

- potential risks;
- associated preventative measures and precautions;
- existence of occupational exposure limits;
- actions to be taken;
- hygiene requirements; and
- personal protective equipment.

Guidance to occupational exposure limits in relation to chemical agents is given in a Code of Practice for the Safety, Health and Welfare at Work (Chemical Agents) Regulations 1994. A schedule to the Code gives exposure limits for substances listed and reference should be made to the requirements of that schedule.

Landfills represent working environments where employees could be potentially exposed to a variety of different substances. Operators should assess the types of substances likely to be received at their sites and identify the risks they pose. Where known hazardous substances such as asbestos are deposited, clear procedures and supervision should be undertaken as part of the safety statement for the site.

8.4.10 ELECTRICAL HAZARDS

The electricity distribution system should be inspected annually by a qualified electrician. Residual current breakers should be fitted to all power outlets. External contractors undertaking works at the site must comply with the requirements of the National Rules for Electrical Installations and should preferably be members of the Register of Electrical Contractors of Ireland (RECI).

Electrical equipment located in areas where accumulations of flammable gas could occur should be selected, installed, and maintained in accordance with the requirements of BS 5345 Part 1. Portable equipment likely to be used in such areas should be similarly treated, e.g. telephones, monitoring equipment, radios etc.

Overhead power lines may cross the site. These should be either diverted or measures should be taken to ensure that the level of waste does not rise above a level agreed with the electricity supply authority. At no time should vehicles or equipment be able to get within arcing distance of any electrical cables. All power lines should be signposted by protective barriers which should have cross members to prevent raised vehicle bodies passing in proximity to them. Any damage to these barriers should be dealt with immediately. On no account should excavation equipment be operated in proximity to live power lines. The Health and Safety Authority and/or the Electricity Supply Board should be contacted for advice in respect of landfill sites in close proximity to overhead cables.

8.4.11 SCAVENGING

Scavenging is the separation and removal for re-use of items such as scrap metal. In the past, it provided a means by which materials were recovered and recycled.

The practice is dangerous and interferes with the efficient operation of a landfill. Scavenging is perhaps the greatest single cause of accidents and fatalities at landfill sites, due to the partially obstructed view of drivers of vehicles when they are reversing. For these reasons, scavengers should be prohibited on all sites.

9. PUBLIC LIAISON

A significant duty of any landfill operator is communication and liaison with the public. Most often this will be with neighbours of the site or site users, but this may also extend to the local or national media.

Contact with site neighbours will be made at some point, if only for the operator to explain to the nature of operations at a site. It is important that operators are pro-active in this respect and that the names of responsible persons have been passed to site neighbours. The telephone number of the site and the names of senior management should be communicated to persons in proximity to the site. This should include an out-of-hours emergency contact number where appropriate.

All sites should be effectively resourced and managed so that regular nuisances are avoided. The long term occurrence of litter inside or outside the site fence, for example, does nothing to suggest that the site is being operated in a competent manner. It also does not engender public confidence that the site is managed effectively in respect of other environmental risks. A similar comment would apply to mud tracking out on the public road, smells, vermin and so on.

9.1 COMMUNICATION AND DEALING WITH COMPLAINTS

It is important that complainants have access to the site's local management, so that problems are dealt with by the person directly responsible for the site. No complainant will feel that they are being taken seriously if they are passed from person to person around an organisation. Local site management should be able to deal with complainants effectively and in a civil manner, both on the telephone and where a person visits the site to raise a problem. Staff should be clearly aware of the procedures to be utilised when such a request is made.

Where complaints have been received, they should be logged, responded to rapidly and the details of the mitigating actions taken communicated to the complainant. In this way, neighbours of sites will be aware that their complaints are being addressed. All remedial actions in respect of complaints should be recorded .

Where significant site works in proximity to neighbours (such as those which affect matters such as screening) are due to be undertaken it may be beneficial to discuss the nature of these works with the affected parties in advance. This may allay fears about the extent of the operation and allow a cogent explanation to be given of the purpose and impact of what is intended.

9.2 LOCAL LIAISON GROUPS

The possibility of establishing a local liaison group between the landfill operator and neighbours of the site should be considered. These have the obvious benefits that information can be communicated quickly, efficiently and directly between parties, without the influence of third parties.

When liaison groups have been set up, it is important that dates are set for regular meetings. Provision should also be made for the calling of meetings when particular issues arise. An agenda should be circulated in advance and minutes taken at the meeting of the main points of discussion.

REFERENCES AND FURTHER READING

- Byrne R (1995) *A Guide to Safety, Health and Welfare at Work Regulations*, NIFAST Ltd, Dublin
- Department of the Environment (1986) *Waste Management Paper No. 26, Landfilling Wastes*, HMSO, London
- Department of the Environment (1991) *Waste Management Paper No. 27 Landfill Gas*, HMSO, London
- Department of the Environment (1995) *Waste Management Paper No. 26B, Landfill Design, Construction and Operational Practice*, HMSO, London
- Department of the Environment (1995b) *The Technical Aspects of Controlled Waste Management – A Review of the Composition of Leachates from Domestic Wastes in Landfill Sites*, Waste Technical Division, Department of the Environment, London
- Environmental Protection Agency (1995) *Landfill Manual: Landfill Monitoring*, EPA, Wexford
- Environmental Protection Agency (1995) *Landfill Manual: Investigations for Landfills*, EPA, Wexford
- Environmental Protection Agency (1996) *National Waste Database Report 1995*, EPA, Wexford
- EPA (1996) *Waste Catalogue and Hazardous Waste List*, EPA, Wexford
- *Health and Safety Authority Guidance on First Aid*
- *Health and Safety Authority Guidance on Working in Confined Spaces*
- Health and Safety Authority Code of Practice for the Safety, Health and Welfare at Work (Chemical Agents) Regulations 1994
- Environmental Protection Agency Act 1992
- Waste Management Act 1996
- EU Council Directive on Waste (75/442/EEC) (OJ L 194 p39), as amended by Directives 91/156 (OJ L78 p 32) and 91/692
- Council Directive on the Protection of Groundwater against Pollution Caused by Certain Dangerous Substances (80/68/EEC) (OJ L20 p43)
- Council Directive on Hazardous Waste (91/689/EEC) (OJ L 377 p20)
- Commission Decision on a List of Wastes (94/3/EEC) (OJ L 5 p 15)
- European Parliament and Council Directive on Packaging and Packaging Waste (94/62/EEC) (OJ L 365 p10)
- Council Decision on a List of Hazardous Waste (94/904/EEC) (OJ L 356 p14)
- Health Safety and Welfare at Work Act 1989.

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