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NATIONAL RIVERS AUTHORITY
ANGLIAN REGION

REFUSE FILL FOR THE CONSTRUCTION OF SEAWALLS

PROJECT IR 21601

National Rivers Authority
Anglian Region

JUNE 1990

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National Rivers Authority - - Anglian Region	- New Works Department - Legal Department - Water Quality Department - South Essex District Office Planning Department
Essex County Council	- Chief Executive and Clerk - Highways Department - Planning Department - Consumer and Public Protection Department

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SUMMARY

The National Rivers Authority (Anglian Region) and Essex County Council have, over the last 10 years, co-operated in four seawall improvement schemes which use controlled refuse as an infill material. The objective of this report is to amalgamate information pertaining to the legal, environmental, engineering and monitoring requirements of this type of scheme and to provide guidance for the future use of the technique.

PROJECT CO-ORDINATION

A pre-requisite of any proposed joint refuse disposal and seawall improvement scheme is a formal agreement between the parties involved detailing their respective responsibilities. One project manager will be required and, and as the construction works constitute a significant civil engineering project, suitably qualified site staff will need to be appointed to take overall responsibility for all site works.

LEGAL CONSIDERATIONS

Although there are a number of statutory considerations which might relate to a proposal for a refuse seawall, three requirements are of particular importance. Any proposal will require a **waste disposal licence** under the 1974 Control of Pollution Act. It is recommended that **planning permission** should be applied for on refuse seawall projects. If the development is deemed likely to have a significant impact on the environment, an **Environmental Statement** should also be prepared.

ENVIRONMENTAL CONSIDERATIONS

The use of refuse fill for seawall improvement raises a number of environmental concerns. Potential pollution is a major issue as both leachate and landfill gas are extremely hazardous. The design, construction, and monitoring of these structures must, therefore, be undertaken to keep the risk of pollution and possible explosions to an absolute minimum. Good site management is also essential in order to control litter, odour and noise problems.

Any proposal for a refuse seawall should also demonstrate full understanding and consideration of the following more general environmental issues:-

- Landscape and nature conservation.
- Health and safety
- Public relations
- Site restoration; agricultural or amenity after use
- Traffic and access; roads and footpaths

ENGINEERING CONSIDERATIONS

A potential site for a refuse seawall must meet a number of basic requirements before it can be considered in detail. These include:-

- Location relative to an adequate supply of suitable refuse.
- Arrangement of the existing sea defences.
- Potential for abandonment.
- Suitable ground conditions.
- Physical dimensions of the available site.

The design of a joint scheme, besides fulfilling the normal requirements of any sea defence (height, stability, overlapping, etc.) must contain and isolate the refuse fill element from all ground and surface waters, and prevent infiltration. This will reduce the rate of refuse decomposition, thereby reducing both the rate of production of harmful breakdown products, and overall settlement.

Construction of the refuse seawall scheme must be given an appropriate level of site supervision

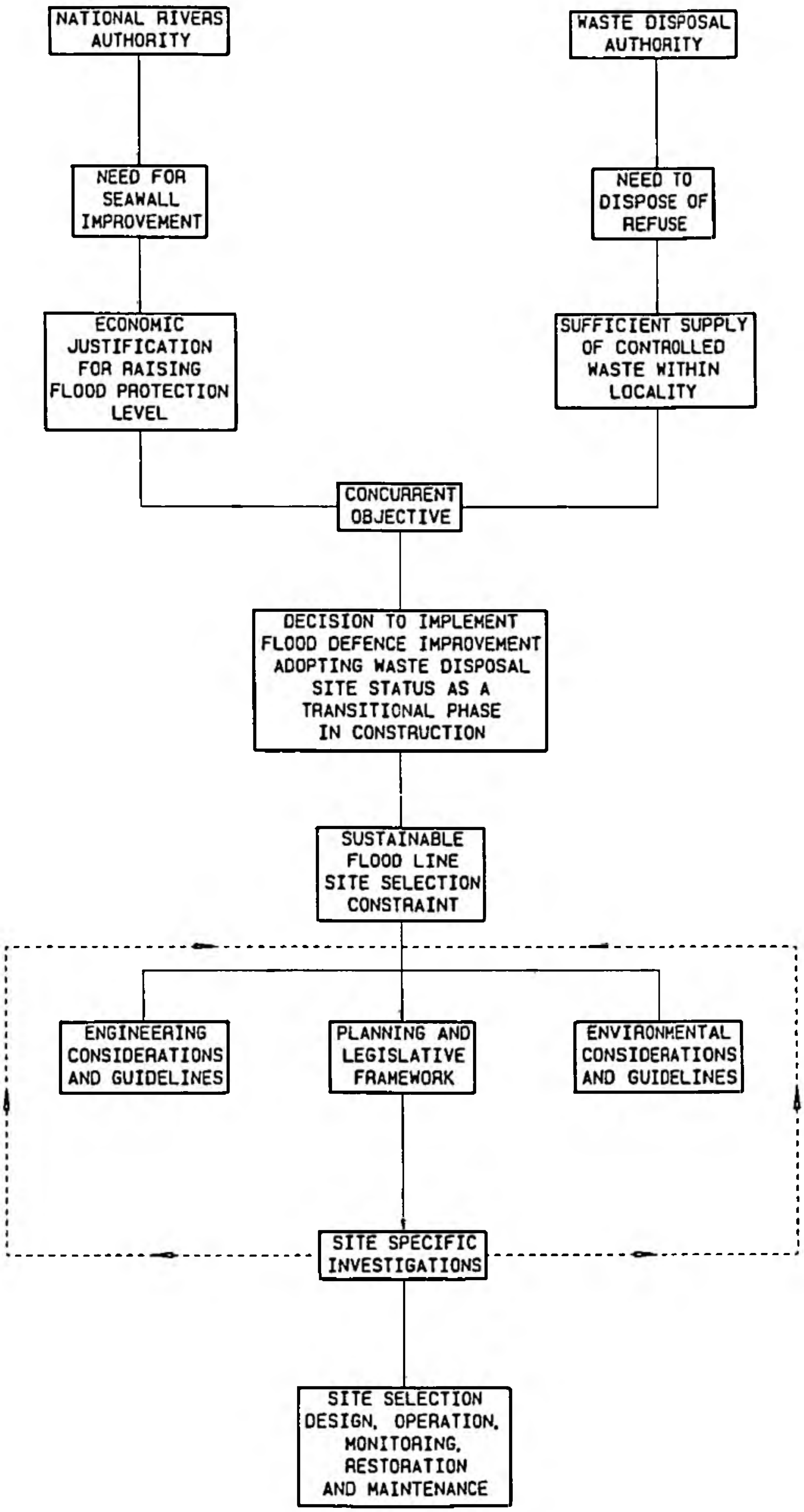
MONITORING REQUIREMENTS

Monitoring is an essential requirement of any refuse seawall scheme. Chemical and biological monitoring should commence before any works take place on the site to establish a baseline data set and should continue for a number of years after completion as leachates and other possible contaminants will continue to be produced for a considerable time. Long term engineering monitoring and maintenance will also be required to ensure that land movement or settlement does not threaten the integrity of the defence.

BENEFITS AND COSTS

Refuse seawalls represent one of a number of options available for seawall improvements, and their benefits and costs will therefore be similar to those attributed to conventional seawalls.

A flow diagram outlining the approach to project implementation is shown overleaf.


NATIONAL RIVERS AUTHORITY
WASTE DISPOSAL AUTHORITY
NEED FOR SEAWALL IMPROVEMENT
NEED TO DISPOSE OF REFUSE
ECONOMIC JUSTIFICATION FOR RAISING FLOOD PROTECTION LEVEL
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SITE SPECIFIC INVESTIGATIONS
SITE SELECTION DESIGN, OPERATION, MONITORING, RESTORATION AND MAINTENANCE

SECTION 1 : INTRODUCTION

1.1 BACKGROUND

The National Rivers Authority (Anglian Region) and Essex County Council have previously undertaken four seawall improvement schemes using controlled refuse as an infill material. These schemes, at Newlands, Deal Hall, Hadleigh Marsh and, most recently, at South Fambridge have been undertaken with varying degrees of success. At Deal Hall, localised leachate pollution of surface water necessitated remedial action. At Hadleigh Marsh a long-term monitoring programme has, to date, offered no evidence of any pollution problems. Works at South Fambridge are ongoing and the site is being progressively restored.

The objective of this report is to amalgamate information pertaining to the legal, environmental and engineering aspects of the use of domestic refuse as an infill material for seawall improvement. The report is intended to clarify the appropriate legal and environmental considerations and to provide guidance for future schemes of this type.

1.2 APPROACH

Existing data on legal and planning requirements, environmental issues, engineering design and construction constraints and the need for monitoring has been collated and reviewed. The likely impact of any sea level rise on refuse seawall structures has been appraised, and the benefit: cost implications of such joint initiatives for Waste Disposal Authorities and the NRA has been briefly assessed. Recommendations relate to the future use of refuse fill for the improvement of sea walls and incorporate site selection criteria, means of maximising cost-effectiveness and long-term monitoring requirements.

Refuse seawalls are an example of a type of landform rather than a conventional landfill. In many cases, however, there is no precedent differentiating between the respective environmental and legal requirements of landfilling, landforming and refuse seawall operations. Wherever possible, however, the report concentrates on those issues appropriate to joint refuse disposal and sea defence schemes. For further technical information on conventional landfilling sites, the reader is referred to the Department of the Environment's Waste Management Paper, Number 26 'Landfilling Wastes'.

1.3 REPORT STRUCTURE

The report is presented in discrete sections dealing with the legal, environmental, engineering and monitoring aspects of joint sea defence and refuse disposal schemes. There is inevitably some overlap, however, and the reader is therefore referred, as appropriate, to other sections elsewhere in the text. The contents of each section of the report are briefly described below.

1.4 LEGAL CONSIDERATIONS

Three key Acts of Parliament are of particular importance in any proposal to use refuse as an infill material for seawall improvement. The Town and County Planning Act 1971 provides the planning and development control, the Control of Pollution Act 1974 is concerned with waste collection and disposal licencing and the Water Act 1989 imposes pollution control duties on the National Rivers Authority.

The implications of all three Acts for joint initiatives of this type are assessed and the requirements are discussed. A number of other statutory enactments which may impose control on landfilling or sea defence activities are also reviewed.

1.5 ENVIRONMENTAL CONSIDERATIONS

The part of the report dealing with the environmental factors appropriate to the use of refuse fill for seawall improvement is divided into two sections. The first deals specifically with pollution and includes refuse breakdown processes, potential contaminants, landfill gas, leachates and litter. The second section reviews the more general environmental issues of access, health and safety, public relations, site restoration and after use, amenity and nature conservation. In both sections, the processes involved are described, the nature of the potential problem is discussed and its environmental significance assessed, and some appropriate ameliorative treatments are highlighted.

1.6 ENGINEERING CONSIDERATIONS

The engineering considerations of the use of refuse seawalls are appraised in terms of the planning, design, construction and maintenance requirements. The need for an agreement between the NRA and the County Council defining their respective responsibilities is demonstrated and site selection criteria are discussed. Design criteria are assessed in terms of meeting environmental needs and the need for careful site management and supervision throughout the construction operation is highlighted. The results of discussions relating to the abandonment issue and the implications of any sea level rise are also reported and breach repair is described.

1.7 MONITORING REQUIREMENTS

A comprehensive monitoring programme is an essential component of any scheme using refuse fill for sea wall improvement. The section of the report dealing with monitoring, reviews environmental concerns, in particular, the protection of ground and surface water, and details both biological and chemical monitoring programmes. Landfill gas monitoring is also discussed. Site aftercare requirements are examined and the special implications of works on sites of special scientific interest are appraised.

1.8 BENEFITS AND COSTS

The overall worthwhileness of refuse-seawall schemes is briefly assessed, and considerations for minimising scheme costs are discussed.

SECTION 2 : LEGAL CONSIDERATIONS

2.1 INTRODUCTION

Improvement of land drainage works and the operation and restoration of landfill sites in England and Wales are principally subject to control under three Acts of Parliament. First, the Town and County Planning Act 1971 (the TCPA 1971) as subsequently amended, provides the planning background and control to which all development of land is subject. The second is the Control of Pollution Act 1974 (COPA), Part 1 of which is concerned with waste collection and disposal and in particular requires all disposal sites to be licenced. The third is the Water Act 1989 which imposes certain duties on the National Rivers Authority (NRA) and specifies the main offences relating to pollution of water, amended from COPA.

It should be noted that significant changes in legislation to be brought in by the Environmental Protection Bill will affect waste disposal law in the future. The relevant changes are highlighted in Section 2.4.4.

2.2 THE REQUIREMENT FOR PLANNING PERMISSION FOR SEAWALL IMPROVEMENT USING REFUSE INFILL

Seawall improvement and seawall construction, the latter being undertaken in an area with no existing defence, both constitute development. Section 22 of the TCPA 1971 defines development as "the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in use of the land", and Section 23 of the TCPA 1971 requires that planning permission be obtained for the carrying out of any development of land.

Certain developments, however, are exempt from planning permission under the General Development Order 1988 (GDO). Part 15, Clause A stipulates that "development in connection with the improvement or maintenance or repair of land drainage works" is permitted development thereby being exempt from planning permission.

In proposals where traditional materials are used as infill for seawalls, a development involving improvement works would not require planning permission under the GDO but seawall construction, which is not covered under the GDO, would require planning permission.

The situation is different when refuse is being used as an infill material for seawall improvements. In this case the dumping of refuse is seen as a separate development albeit in order to improve a seawall defence.

The dumping of refuse comes under the definition of development as detailed under Section 22 of the TCPA 1971. Section 23 clarifies the requirement for planning permission by stipulating that "for the avoidance of doubt", "the disposal of refuse or waste materials on land involves a material change of use".

As a matter of fact and degree the deposit of controlled waste is a material part of this type of proposal and is "of substance", such that one development, the dumping of refuse, is being undertaken to complete another development, the seawall improvement. Although the latter development does not require planning permission under the GDO, the former is not exempt. The proposal for using refuse as infill for seawall improvement could therefore be seen as a dual development for which planning permission is required.

2.2.1 Test Cases

This problem of dual development and a requirement for planning permission requirement was highlighted in the Court of Appeal case of West Bowers Farm Products v Essex County Council (Property and Compensation Reports, June 5 and 17, 1985).

The appellants were a partnership of farmers who wished to construct a large reservoir of some 18 acres on part of their farm for the purpose of irrigating their crops. It was agreed that the construction viewed in isolation would fall within the general permission for engineering operations for agricultural purposes which was granted by the GDO, Article 3, 1977.

However, the construction of the reservoir necessitated the extraction of large quantities of gravel which was to be removed and sold. Broadly stated, the question at issue was whether the extraction of the gravel would constitute a use of the land for the winning or working of minerals for which a further permission was required. In the same way does improvement of seawalls using waste materials constitute a use of the land for a site of refuse disposal for which financial benefit is being accrued?

Pursuant to the powers conferred upon them by Article 4 of the GDO, the respondent local planning authority, the Essex County Council, directed that the general permission granted by Article 3 should not apply. It was agreed this meant that the appellants would have to apply for planning permission. The appellants did not apply for planning permission because the Council maintained that the application would not be entertained unless it had been advertised and a fee paid pursuant to Section 26 of the TCPA 1971 which stipulates the winning of mineral as a designated development, under GDO Article 8. The partnership appealed to the Court of Appeal.

The liabilities to advertise and to pay a fee rested on the answer to a single question. Would the construction of the reservoir be (1) solely for the carrying out of engineering operations requisite for the use of land for the purposes of agriculture or (2) a hybrid consisting partly of that activity and partly of the use of the land for the winning or working of materials?

Three court of appeal judges dismissed the appeal. Judge Norse concluded that "The planning legislation was not impressed by the indivisibility of single processes. It cared only for their effects. A single process might for planning purposes amount to two activities. Whether it did so or not was a question of fact and degree. If it involved two activities, each of substance, so that one was not merely ancillary to the other, then both required planning permission" (Journal of Planning Law 1985 857).

Applying the above test to the facts of the proposal to use controlled waste as infill for seawall improvement, it would appear that improvement of the seawall would involve two activities, each of substance. The essential character of the development can properly be regarded as a dual development comprising both the GDO Class A development and refuse disposal, thus constituting a "hybrid" which consists partly of seawall improvement and partly of the use of the land for the dumping refuse.

The introduction onto land of waste material, is either to get rid of that material, which could constitute a change of use requiring planning permission, or to alter the character of the land which can constitute an operation also requiring planning permission. The proposal might therefore constitute both an operation and a change, and one planning permission would be required.

In the case between Northaven District Council v Secretary of State for the Environment and Another, a farmer wished to improve drainage of land by removing 18 inches of topsoil, raising the land using non toxic refuse and replacing topsoil. In this case it was held that the purpose of the proposal was to improve drainage and not to make money out of providing a last resting place for refuse, and that therefore the main objective of improving drainage was covered under the GDO as permitted development. No planning permission was required.

These two cases highlight the problems involved in interpreting the facts of proposals by the planning authority and courts alike.

However, if a general permission is to be relied on, the developer must be able to show that the development is, **and only is**, an engineering operation as described in the GDO.

2.2.2 Planning Applications

Planning applications relating to the use of land for waste disposal are made to the County Council or Waste Disposal Authority. Plans and drawings and supporting statements necessary to describe the development must be included.

It is important to note that outline planning permission cannot be granted for landfill operations. "In the case of proposals for landfill development it is suggested that the applicant has informal discussions with the planning authority, together with the NRA and MAFF, if agricultural land is involved. The application should, as far as possible, be supported by the results of site investigation and an assessment of impacts on the environment, amenity and when relevant agriculture". (DOE 1988).

Under Section 11 of the GDO 1988, waste disposal is a designated as "bad neighbour development", and under Section 26 of the TCPA 1971 evidence is required of the application being advertised both in the local newspaper and by means of a site notice.

When the development of a landfill site is to be undertaken by a local authority within its own area, it resolves to seek permission for the carrying out of development. This is treated in the same way as a planning application. If, in due course the local authority proposes to proceed with the development, it passes a second resolution to carry out that development, and on passing that resolution, planning permission is deemed to be granted by the Secretary of State. The current regulations for developments by a local authority are contained within the Town and County Planning General Regulations 1976.

2.2.3 Consultations

Planning authorities or County Councils, in the case of resolutions, are required by the GDO to carry out consultations, the object of which is to establish whether the basic presumption in favour of development should be set aside and, if not, what conditions it may be necessary to attach to the granting of planning permission. Consultees will include the NRA, highways authority, Nature Conservancy Council (NCC) (for Sites of Special Scientific Interest (SSSI)), the Countryside Commission, district and parish councils. Very often Section 52 agreements will be entered into for the purpose of restricting or regulating development. Such agreements may contain incidental and consequential provisions, for example specifying site traffic routes.

2.2.4 Conditions in Planning Permissions for use of Land for Refuse Disposal

In giving consent, a planning authority (or the Secretary of State) may, and nearly always does, impose conditions concerning the following:

(a) amenity and public health, including screening, chimney height etc.;
(b) access;
(c) restoration and after use, including monitoring;
(d) protection of surface and/or underground water from pollution.

The various aspects are not necessarily confined to this list and the peculiarities of each particular case may warrant reference to other matters.

2.3 LICENCE REQUIREMENTS

Part 1 of the 1974 COPA requires that all waste disposal operations taking controlled wastes are licenced or covered by resolution. The basic aim of licencing is to ensure that landfilling operations entail no unacceptable risk to the environment and to public health, safety and amenity.

Once planning permission has been received, an application for a waste disposal licence can be rejected only on the grounds of danger to public health or risk of water pollution.

Consequently, licences will almost certainly be issued with conditions attached, these conditions being intended to ensure that health and environment quality, and in particular water quality, are safeguarded. Drawing up of a disposal licence is primarily a technical task in which many factors have to be considered.

2.3.1 Disposal Licence Conditions

In determining licence conditions, statutory consultees will include the NRA and waste collection authorities. Indeed it is an objective of the NRA to advise on the implications for water quality and the aquatic environment of applications for planning permission and other developments including flood defence work. The conditions imposed will reflect local circumstances as well as common landfill standards which the Disposal Authority expect to be achieved. Each landfill site calls for individual treatment and differing conditions are likely to be set for each licence. However, considerations may include:-

(a) timing and phasing of operations
(b) working hours
(c) progressive restoration
(d) measures to deal with water pollution and leachate
(e) fencing and gates
(f) cover material, both intermediate and final
(g) dealing with gas emissions and/or migration
(h) monitoring and the keeping of records

These conditions, however, only apply during the life of the site and do not give control over post-closure management. Planning permission will thus be improved in order to impose conditions necessary to implement aftercare, monitoring and restoration.

Disposal licences thus provide landfill operators with clear directions on operating standards. They also provide a mechanism by which the responsibility for the conditions to be imposed at a landfill site is placed at a suitable local level, so that proper account can be taken of local circumstances.

2.3.2 Sites Operated by a Local Authority

If a disposal authority itself proposes to undertake landfill operations, the relevant County Council of which it is part must pass a resolution under Section 11 of COPA 1974 which outlines special provisions for land occupied by disposal authorities. The provisions stipulate that the resolution must include a specification of the conditions under which the operation is to be conducted. This statement and the proposal must be referred to the local Water Authority (now NRA).

If the NRA disagrees with either the proposals or conditions then the disposal authority will not be able to proceed. The matter can then be referred to the Secretary of State.

It is the duty of the disposal authority to regulate its own operations as it would those of the private sector, and thereby maintain consistent standards.

2.3.3 Enforcement Action

A disposal authority is required to supervise all sites it licences to ensure that licence conditions are being observed and continue to be appropriate. Supervision is carried out by visits to the site by Disposal Authority Inspectors. Where an operation is considered to be a threat to water health or amenity, enforcement powers are available under COPA 1974. These include, prosecution, revocation of the licence, notice served to remedy the situation, and licence modification.

Under Section 107 of the Water Act 1989, a person shall be guilty of an offence if he/she causes or knowingly permits inter alia:-

(a) any poisonous, noxious, or polluting matter or any solid waste matter to enter any controlled waters; or

(b) any matter,........to enter controlled waters by being discharged from a drain or sewer in contravention of a relevant prohibition; or

(c) any trade effluent or sewage effluent to be discharged:-
   (i) into any controlled waters or
   (ii) through a pipe into the sea outside the seaward limits of controlled waters.

Section 108 provides various defences and they largely repeat those previously available under Part II of COPA with the exception that the defence of "good agricultural practice" is no longer available. Some notable examples of statutory defences include a discharge consent or consent under a Waste Disposal licence.

A power is conferred on the NRA under Section 110 of the Water Act 1989 to impose a requirement to take precautions against pollution, and to specify or describe the works, precautions or other steps which must be carried out.

Under the conditions of the licence it is the operator of the tip who is responsible. The operator will only be not guilty of an offence if they have been given authorisation by the NRA or the disposal licence to allow substances to enter a watercourse.

After surrender of the licence and/or ceasation of the licence, responsibility of the site rests on the side of the landowner.

2.3.4 Relationship between Planning and Disposal Licencing

Planning control and disposal licencing are intended to work side by side. In making planning permission a pre-requisite to issuing a disposal licence, the Control of Pollution Act 1974 assumes that appropriate conditions and other planning matters relevant to the suitability of a site for waste disposal will have been considered and conditions imposed. Thus the primary consideration in issuing a disposal licence should be to control operations in order to prevent water pollution and danger to public health. The enforcement powers of COPA 1974 apply mainly to the licence holder, not the landowner. Therefore, continued access to boreholes for monitoring purposes or maintenance of leachate control systems, which may need attention for several decades afterwards cannot be provided for in disposal licencing conditions.

One of the main distinguishing features between planning legislation and disposal licencing provisions is that planning permission conditions are designed to ensure benefit of the land. Disposal licence conditions apply only for the duration of a licence. Some planning authorities have attached conditions to ensure restoration and aftercare controls will apply after licence expiry. There are some difficulties in this approach, particulary in regard to enforcement of conditions for continued monitoring of sites after restoration. Some authorities are adopting alternative approaches such as asking applicants to include post-restoration pollution control measures in their planning applications, or by entering into Section 52 agreements.

2.4 OTHER LEGISLATION

As detailed above, the TCPA 1971, COPA 1974 and the Water Act 1989 provide the main legislative detail. The Acts and regulations discussed so far provide the main legislative control over waste disposal. There are, however, a number of other statutory enactments which may impose general controls on landfilling or its associated activities, or more specific controls dependent upon the nature, scale and location of the activity. Some Acts are discussed below and others are listed in Appendix 1.

2.4.1 The Public Health Act 1936

The disposal of waste to land, unless carried out expeditiously, can cause nuisance which could be covered by "Statutory Nuisance" legislation. Section 92 1(c) may describe the nuisance experienced in some cases as "any accumulation .... which is prejudicial to health or a nuisance". Section 92 1(d) may also apply; "only dust or effluvia or stream caused by any trade, business, manufacture or process and being injurious or likely to be injurious to public health or a nuisance".

If the nuisance experienced is covered by either of these definitions legal proceedings may ensue. When such proceedings are brought, a company may defend its action by providing that "best practicable means" have been taken to prevent the nuisance or counteract its effect.

2.4.2 Health and Safety at Work Act 1974

This Act places a general duty on employers to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all their employees. In the case of landfill operations, the requirements might be regarded as placing duties on site operators in relation to safeguarding from dangers arising from activities at the site, not only their employees, but also members of the public in the vicinity of the site and others who are not the direct employees of the operator, but who are required to have access to the site.

2.4.3 EEC Groundwater Directive 1980

The Groundwater Directive obliges Member States to "prevent" the introduction into groundwater of all substances in List I. This absolute prohibition is qualified only where the discharge concerned is to groundwater which is "permanently unsuitable for other uses" or where the discharge is found by other authorities to contain a List I substance "in a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater". The control requirements for List II substances are much less stringent. However, it is the duty of both the waste disposal authority and NRA to ensure that landfill operations do not adversely affect water quality. To meet the obligations, NRA should have developed aquifer protection practices or policies.

2.4.4 Future Legislation - The Environmental Protection Bill

Much tougher controls on polluting activities are to be brought in by the Government under the Environmental Protection Bill, including wide-ranging new powers to tackle waste management. Stricter, extended powers will be introduced to strengthen the existing licencing system of waste control. The onus under the Bill will be put on the waste producer and every one who handles waste, right through to final disposal and the reclamation of the site. Only fit and proper persons will be allowed to run waste sites. In addition owners of the sites will be held responsible for them until all risks of gas emissions or other pollution are past.

There will be a new duty of care which will apply to all producers, importers, holders and carriers who dispose of or treat waste. This duty means that reasonable measures must in future be taken to prevent anyone else illegally dumping wastes; to prevent the unauthorised release of waste to the environment and to hand over an adequate description of the waste. Breach of the duty will be an offence. A code of practice gives practical guidance on the discharge of this duty of care.

Waste management licences, previously waste disposal licences, will have amended and extended provisions particularly involving licence conditions. These conditions may relate to the activities which the licence authorises and particularly to the precautions to be taken and works to be carried out in connection with or as a consequence of those activities. It is made clear that these requirements may need to be complied with before activities have begun or after the activities have ceased.

This puts a greater responsibility onto the waste regulation authority to improve aftercare and monitoring conditions. There are also new procedures for the surrender of licences. Only after it has been determined that no pollution to the environment or harm to human health is likely to result will licence surrender be entertained. Referral should also be made to the National River Authority and any representations considered.

The Bill also imposes new duties on waste regulation authorities to inspect closed landfill sites from time to time and to detect whether any land is in such a condition, by reason of the relevant matters affecting the land, that it may cause pollution of the environment or harm to human health. The matters affecting land are named as the "concentration or accumulation in, and emission or discharge from the land of noxious gases or noxious liquids" caused by deposits of waste.

When it appears to the Waste Regulation Authority that the condition of the land is as specified above, then it is the responsibility of that Authority to undertake works to avoid pollution or harm. The "period of responsibility" extends from the time at which the condition first appeared to the time the authority is satisfied that no more pollution or harm will result.

Any costs incurred can be recovered from the person who is, for the time being, the owner of the land, except where the authority accepted the surrender of the former waste management licence.

Under the Environmental Protection Bill there will be no provision for COPA Section 11 resolutions which provide a power for the local authorities to carry out development on their own land. Rather, the County Council will become the Waste Regulator and will no longer own or operate any landfill sites. Operations will be under agreement or run on an arms-length basis by competitive companies. This will split up the council's dual role as both regulating and operating authority, ending the present "poacher and gamekeeper" relationship.

2.4.5 Environmental Protection

The legal protection of the natural environment is covered via conditions imposed and enforcement action taken under COPA and the 1971 Act, but the Water Act 1989 also makes it an offence to allow any discharge to enter a watercourse unless prior consent is given by the NRA. It also places a duty on the NRA to "further the conservation and enhancement of natural beauty and the conservation of flora, fauna, geological or physiographical features of special interest" and "to take into account any effect which proposals would have on the beauty and amenity of any rural or urban area or on any such flora, fauna, features, buildings, sites or objects".

Where the NRA have received a notification that the proposed site for seawall improvement is an SSSI, they must consult the Nature Conservancy Council (NCC) before carrying out operations which are likely to damage or destroy flora and fauna, geological or physiographical features or to significantly prejudice anything the importance of which is one of the reasons why the site was designated, (e.g. a rare or locally important wildlife species).

2.4.6 Requirement for an Environmental Statement

Land drainage operations and waste disposal activities are both bound by regulations which implement the European Community Directive on the Assessment of the Effects of Projects on the Environment.

The Land Drainage Improvement Works (Assessment of Environmental Effects) Regulations 1988 stipulate that "no drainage body shall carry out improvement works unless they have first considered whether by reason, inter alia, of their nature, size or location, the proposed works are likely to have significant effects on the environment and might therefore be made the subject of an environmental statement".

Notice must then be made in at least two local newspapers and to statutory consultees stating whether or not the body proposes to prepare an environmental statement. If they do not propose to prepare one, then any representations must be considered. The drainage body must then either proceed to prepare a statement or decide not to, and to apply the appropriate Minister for his/her direction.

Environmental Statements must be publicised, and all objections withdrawn before an operation can go ahead.

If a drainage body carries out improvement works without first observing the requirements of the regulations, or without the consent of the Minister where appropriate, enforcement action will be taken.

Similar procedures and regulations apply to projects which require planning permission, but under the Town and Country Planning (Assessment of Environmental Effects) Regulations 1988. Waste disposal is described under Schedule 2 as projects which require environmental assessment if they are likely to have significant impact on the environment.

The DOE Circular on Environmental Assessment defines waste disposal as "Installations including landfill sites, for the transfer, treatment or disposal of household, industrial and commercial wastes, with a capacity of more than 75,000 tonnes a year". Planning permission for these projects should not be granted unless environmental information has first been taken into consideration.

2.4.7 Local Authority's Own Developments

The Environmental Assessment regulations make provision for applying the requirements of the EC Directive to developments proposed by local authorities. Authorities are placed under a duty to prepare and publish an environmental statement for any development in Schedule 1 which they propose and, in the case of Schedule 2 projects, those likely to have significant environmental effects, and to take this information into consideration before passing a resolution.

This provision is of particular relevance to proposals for waste disposal installations. Authorities are under broadly the same obligations as other developers with respect to preparation of environmental statements and publicity for them, and are required to consult on their own statements and to place them on the planning register in the normal way.

2.4.8 Projects in Sensitive Locations

The relationship between a project and its location can be a crucial consideration. It follows that the more sensitive the location, the more likely it is that the environmental effects will be significant and warrant assessment.

Consideration should be given to Schedule 2 projects which are to take place in protected areas. Waste disposal and flood defence works may have a significant effect on the special character of a National Park, SSSI, Area of Outstanding Natural Beauty, National or Local Nature Reserve or an area or monument of major archeological importance.

Any views expressed by the NCC, the Countryside Commission or the Historic Buildings and Monuments Commission should be taken into account. Authorities should consult these bodies if they are in doubt about the significance of a project's likely effects on the natural or built heritage.

Special considerations apply to SSSI's which have been further classified as Special Protection Areas (SPA's) under the EC Birds Directive (EEC/79/409) and/or as wetlands of international importance under the Ramsar Convention (1971). In such areas there is a particular obligation to avoid developments which could have a damaging effect on the nature conservation interests of the site. Therefore, it is important that the effects of projects close to or in such sites should be subjected to rigorous examination.

The best environmental policy prevents the creation of pollution or nuisances at source rather than subsequently trying to counteract their effects. It is therefore imperative that environmental effects are taken into account at the earliest possible stage to save money, time and resources.

SECTION 3 : ENVIRONMENTAL CONSIDERATIONS : POLLUTION

3.1 WASTE TYPES AND DEFINITIONS

The wastes suitable for use in the improvement of seawalls are strictly limited to those within controlled categories, that is domestic, commercial, and trade wastes only. These must exclude any materials defined as Special Wastes under the Control of Pollution (Special Waste) Regulations (SI 1980:1709), or any subsequent listing of Special substances (DoE 1988). No liquid refuse should be dumped within these sites, and co-disposal of liquid and dry wastes must also be prohibited.

3.2 SOURCES AND NATURE OF CONTAMINANTS

Controlled wastes deposited in landfills degrade chemically and biologically to produce solid, liquid, and gaseous products. Ferrous metals are oxidised; organic and inorganic wastes are changed (by chemo-lithotrophic and chemo-organotrophic micro-organisms) through aerobic and anaerobic attack. Liquid waste products of microbial degradation, such as organic acids, also contribute to chemical activity within the fill.

Of all these, liquid and gaseous components pose the greatest potential environmental threat as they may escape the confines of the disposal site and contaminate the surrounding environment. The technical effort and attendant costs of ensuring the containment of these substances are therefore a major consideration in environmental management requirements for landforming with refuse.

3.3 THE CONTAINMENT APPROACH TO POLLUTION CONTROL

Over the last 10 years there has been a reversal in approaches to pollution control, from dilution and dispersal to containment, treatment and reduction. In response to stricter legislation on polluting emissions into the environment, the dictum "prevention is better than cure" is increasingly followed as a guideline for site selection, design, site operation, and environmental protection (Street and Dumble 1989; ENDS 1990). The minimisation of contaminants should therefore be a central priority in this type of project, to be achieved by isolating the refuse from exogenous water sources.

The pollution minimisation approach also has engineering advantages. For structural stability, reductions in settlement, and resistance to wave action, refuse banks have greater integrity when sealed by a resistant and impermeable membrane (Baum and Parker 1989).

3.4 REFUSE BREAKDOWN

Once refuse has been deposited, its breakdown depends on a range of factors. Breakdown generally results, however, in the internal generation of a cocktail of gases and liquids which has the potential to pollute.

3.4.1 Water Content

If waste has a water content below 40 per cent, decomposition will be slow. With a higher content of 40-80 per cent, however, faster aerobic decomposition takes place, with detrital microbes producing CO_2 and extra water. With an even higher water content, microbes capable of surviving anaerobic conditions dominate, producing rather more polluting effects. Methane and hydrogen sulphide are typical by-products of decomposition under anaerobic conditions.

3.4.2 Air Content

The abundance of oxygen influences the nature of refuse decomposition, the biological communities responsible, and the breakdown contamination products.

Aerobic microbes initially decompose the organic components of the waste, producing carbon dioxide, water, nitrate, and nitrite. As the oxygen is exhausted, facultative anaerobic micro-organisms take over and generate methane, carbon dioxide, water, organic acids, nitrogen, ammonia, ferrous and manganous salts, and hydrogen sulphide.

3.4.3 Refuse Density

In-place density affects decomposition by influencing the air and moisture content of the refuse. At densities above 500Kg/m^3 the dominant decomposition processes are anaerobic, with the resultant generation of methane and the appearance of carboxylic acids in leachate if necessary water is available.

3.4.4 Refuse Composition

Controlled waste contains a wide variety of materials, listed below:-

(a) Garbage; organic, putrescible, and can form acids; very wet; will compact to some extent but will continue to settle for years because of decomposition.

(b) Fibrous organics (wood, paper, fibrous wastes): will compact, can burn, will decay and continue to settle.

(c) Plastics: lightweight and easily blown causing a litter problem. Non-degradable materials which are difficult to compact.

(d) Metal (cans, bedsprings, etc.): will rust and settle, but can be compacted.

(e) Old tyres: inflammable, rubbery, resilient; compressible; will not compact and will not decay readily.

(f) Large organic (stumps, wood): slow to rot but will burn, difficult to compact and will prevent compaction of surrounding material.

(g) Large metal (auto bodies, refrigerators, etc.): loose, somewhat compressible, and will rust; difficult to compact and will prevent densification of other adjoining materials.

(h) Demolition wastes (brick, earth, stone, etc.): somewhat compressible; can be compacted if particles are smaller than 0.3 to 0.6m; larger pieces prevent densification and where nested together present hard spots in fill.

(i) Ashes: fluffy and will settle; may become cemented; can provoke corrosion of other materials.

A considerable change in the character of domestic refuse over recent years means that 65 per cent is biodegradable today as opposed to less than 30 per cent 30 years ago (Castle 1986). This means that the polluting potential of the waste has increased. Its considerable carbohydrate fraction degrades to form hydrogen, methane and carbon dioxide gases, as well as acetic, propionic, butyric, valeric and carboxylic acids. All form major components in leachate.

The other significant change in refuse composition which affects pollution is the appearance of plastics. They now constitute between two and four per cent of refuse, but are inert and consequently non-biodegradable and persistent (Castle 1986; Hagerty, Pavoni, and Heer 1973). Certain organic materials added to the base resins of some plastics may be susceptible to attack by certain microbes, or may be leached out over time, but the derivatives are not significantly different from those produced by the breakdown of other organic products.

3.4.5 Temperature

Landfill temperature is determined by the rate of energy production within the landform and the rate of heat loss to the surrounding environment. Refuse decomposition and methane generation takes place most quickly when refuse temperature reaches about 40°C. As temperatures of this order are unlikely to be achieved in the shallow depths of refuse used for seawall improvement, however, decomposition rates should not become unacceptably high. Temperature requirements are further discussed in Section 3.6.

Heat loss from landforming disposal sites, particularly refuse seawalls, is likely to be greater than landfills, since they have larger surfaces exposed to convect, conduct and radiate energy. However, the effect of a south-facing aspect for refuse seawalls could be to raise temperatures significantly. As this is undesirable, aspects needs consideration at an early stage in site selection and design.

3.5 THE MOVEMENT OF CONTAMINANTS

With a philosophy of containment, site management is orientated towards preventing the escape of any potential pollutant, in anything other than a minimal, controlled manner where treatment can be applied. The mechanisms by which such containment might be achieved are discussed in Section 5.3.

3.6 METHANE AND OTHER DECOMPOSITION GASES

The generation of landfill gas is enhanced by the presence of water and air in the waste, a high organic content of refuse, and a warm microclimate. Biological and bio-chemical processes then generate gases, whose nature and quantity vary widely over the years of breakdown. A typical pattern of gas production overtime is summarised in Figure 3.1.

The production of hydrogen normally occurs during the first few months of refuse breakdown and may reach 20 per cent by volume of the total gas evolved. Typically, some six to twelve months after deposition, substantial amounts of methane will also start to be produced. The concentration of methane will increase until it reaches about 65 per cent of the total gas exuded.

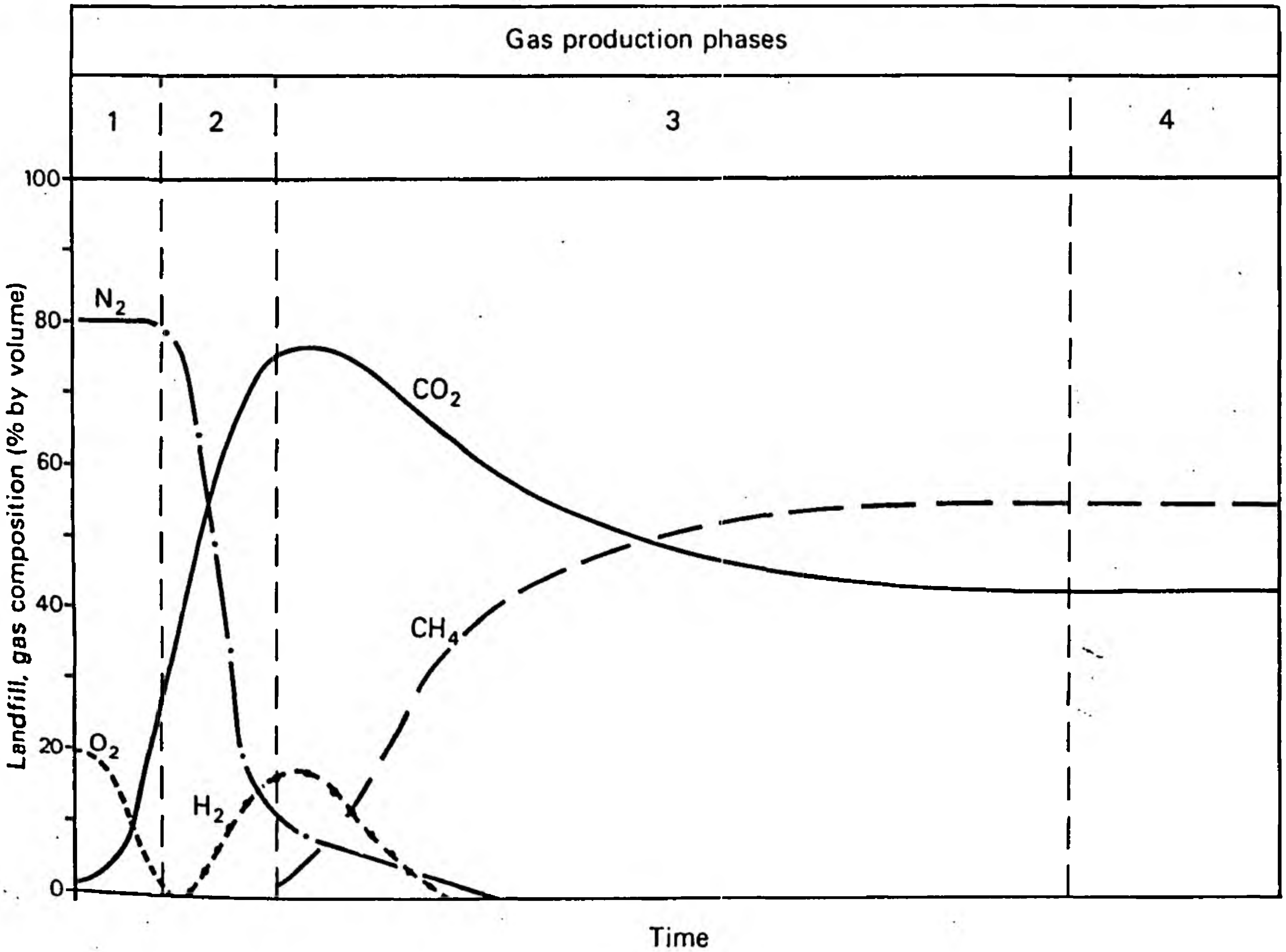


Fig 3.1

(Source : DoE 1988)

Methane is produced by anaerobes prospering in unsaturated wastes with a moisture content of greater than 40 per cent. These microbes can only survive a narrow pH range, between ph 6.4 to 7.4, and will be most active in refuse at 29°C to 37°C. These conditions should therefore be avoided where possible.

Problems caused by gas generation fall into the following five categories (adapted from DoE 1988):

(a) explosions or fires due to gas collecting in confined spaces (such as buildings, culverts, manholes, and ducts) or leaking through fissures to the surface on or near the disposal site;

(b) asphyxiation of people entering culverts, trenches, or manholes on landfill sites; other risks to human health from exposure to gas emissions;

(c) detrimental effects on crops or vegetation cover on or adjacent to landfill sites;

(d) nuisance problems, especially odour;

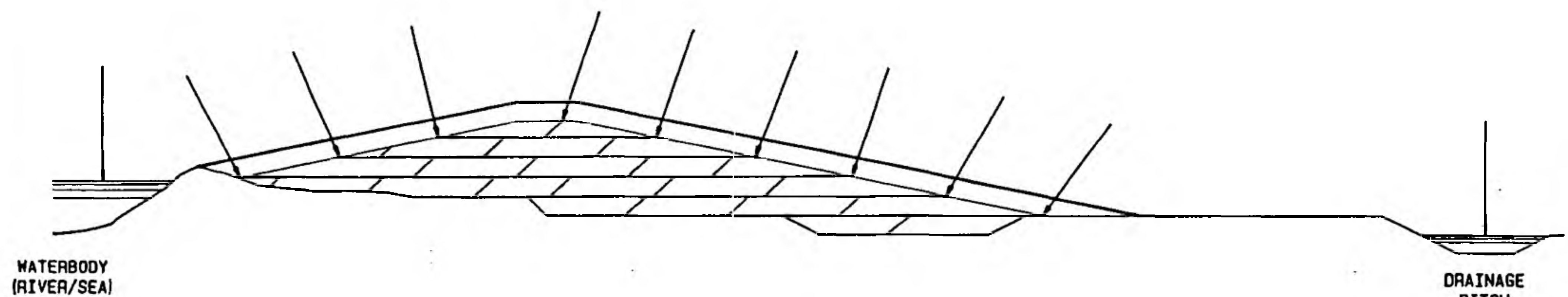
(e) contribution to the 'Greenhouse' effect.

3.6.1 The Methane Hazard

Methane creates an explosive hazard, specifically when present in certain concentrations. In broad terms, below 5 per cent, it is too dilute to combust, and above 15 per cent, the lack of oxygen prevents ignition. Between the two however, the 'methane in air' combination is extremely volatile.

To prevent explosions, two main approaches have been adopted; the containment of gases in small volumes, within internal landfill cells; and the venting of gas and its collection via various drainage mechanisms incorporated into the landfill's internal structure. Neither has been specially designed for use in landforming disposal works such as refuse seawalls, but both approaches might undergo modification on an ad hoc basis to meet this new mode of operation. There has, as yet, been no tailor-made treatment developed to deal with gas build-up in refuse seawall disposal sites and particular care should therefore be taken with any electrical switch gear enclosures (e.g. for penstocks or floodgates) as there is a risk of igniting methane by an electrical spark.

Certain characteristics of refuse seawalls as opposed to landfill sites will, however, affect gas generation and control, reducing the potential volume of gas that can be generated. Firstly, higher densities of refuse compaction will predominate in refuse banks, since these structures, built for flood protection, need to have the necessary strength. Secondly, their sloping sides will reduce infiltration of rainfall. The absence of water slows down refuse decomposition which produces the gas in the first place. Thirdly, the ratio of inert fill to refuse is greater in landforming structures such as refuse seawalls than for landfill sites. Finally, the total volumes of refuse to be accommodated in landform sites are generally smaller than for landfill ones. Other characteristics of landforming sites, however, might generate gas problems. A concentration of gases under the peaks of structures is possible, and layers of intermediate inert cover will abut the sides of the structure near its surface, where there is the potential for gas to escape. (See Figure 3.2). These problems can be treated by traditional collection and venting methods using either passive venting or gas pumping. The potential areas for gas accumulation would then be used as collection lines along which to drain gases.



POTENTIAL AREAS OF GAS BUILD UP AND ESCAPE

FIG 3.2

3.6.2 Gas Accumulation

To deal with the asphyxiation risk, the potential for gas build-up behind culverts and sluices must be recognised, and provision made for safe venting and dispersal. Given the heavier nature of some of the gases produced, and cooler air temperatures over water bodies, attention should also be paid to potential gas accumulation in ditches and over waterways. Provision for monitoring and treatment in these environments should be made.

Above certain concentrations, decomposition gases become toxic to vegetation cover and to soil organisms. Methane for instance, displaces the normal soil atmosphere and prevents diffusion of oxygen into the soil. If gases permeate into soil pores or escape to ground level, organisms may be poisoned. This has been demonstrated on Moulton Marsh landfill site in Lincolnshire, where around 170 square metres of vegetation have been damaged by gas escape (K. Heath, personal communication). Sub-lethal doses also reduce plant vigour, and this in turn reduces their effectiveness as protective ground cover (See Figure 3.3 and 3.4). Gas permeation will also affect agricultural productivity, should this be the final land use.

Vegetation damage provides a useful bio-indication of a gas problem. Plant recovery can then be used to gauge the success of remedial measures.

3.6.3 Odours from Gas Generation

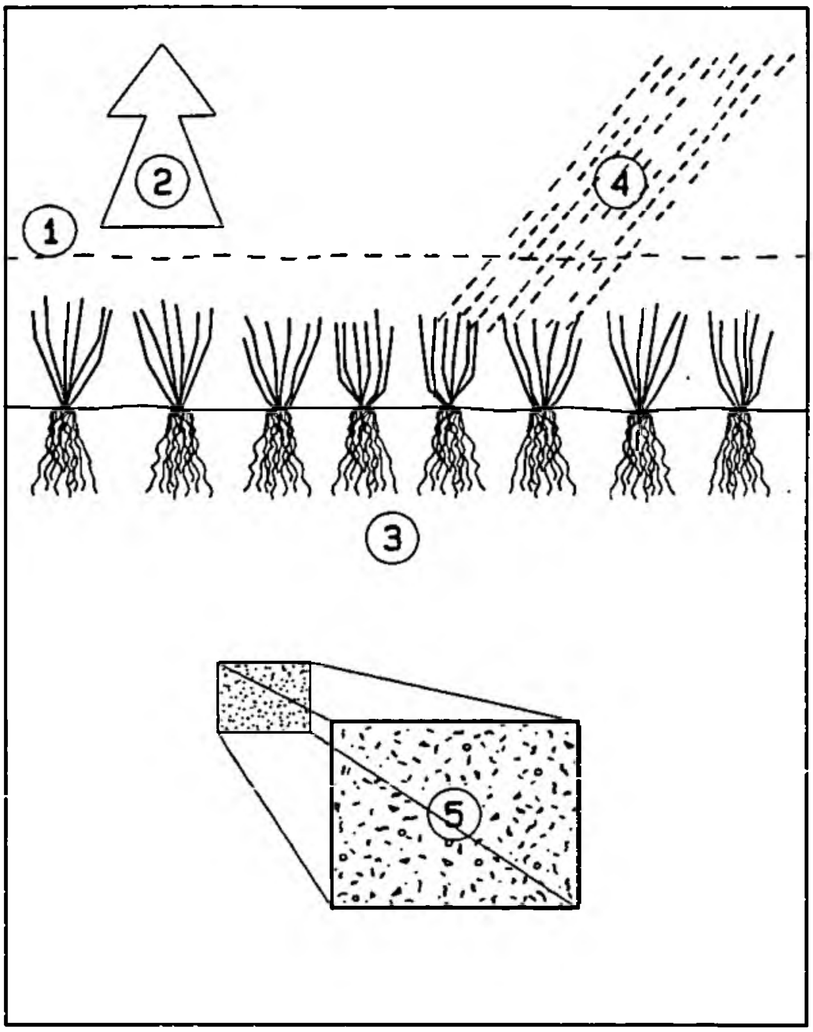
Research has indicated that odour is likely to be a nuisance rather than a health hazard, provided there is sufficient dilution of gases (DoE 1988). Objectional smells can, however, be significantly reduced by good site management, in the same way odour control is instituted for ordinary landfill sites (Ibid.).

With the use of refuse for seawall improvement, extra attention should be paid to odour nuisances that occur across any river banks, or along adjacent water corridors. In particular, the wind patterns characteristic of land/water interfaces should be investigated, and assessed within the context of prevailing weather conditions. Warm stable weather may lead to the generation of 'sea breezes' which will tend to blow inland during the day, and seaward during the night (Barry and Chorley 1978). Any odours will circulate accordingly.

Although all possible steps should be taken to prevent odour nuisance, any subsequent complaints from the public, landowners, or site workforce need to be dealt with through established and responsive lines of communication involving both the site operator and the Waste Disposal Authority. Remedial measures should be implemented where possible, for example completing daily cover of refuse, increasing depth of cover, and making provision for gas minimisation, collection, and treatment.

The acceptable degree of an odour nuisance does depend on the site's predicted after-use, and remedial measures should be designed accordingly.

ENVIRONMENTAL AND ENGINEERING BENEFITS PROVIDED BY VIGOROUS PLANT COVER



(1) BOUNDARY LAYER CLIMATE HELPS TO MAINTAIN STABLE BIOPHYSICAL ENVIRONMENT ENABLING SOIL FAUNA TO SURVIVE AND REDUCING THE LIKELIHOOD OF FISSURING

(2) EVAPOTRANSPIATION REDUCES NET INFILTRATION

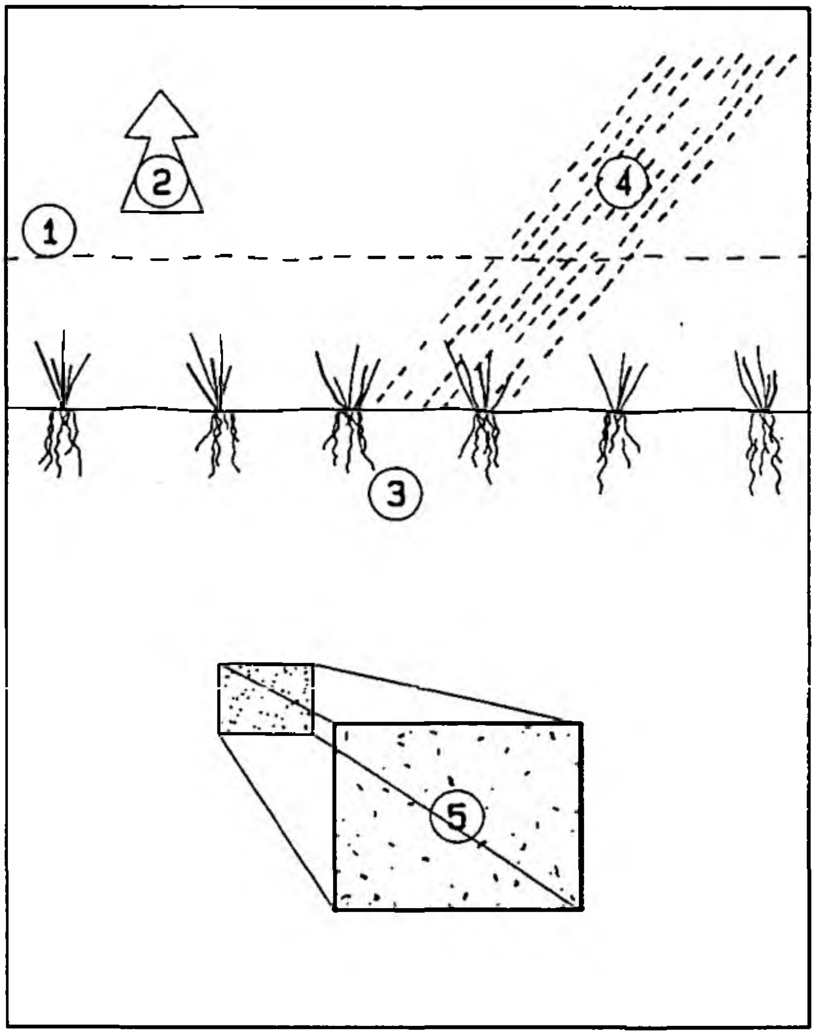
(3) ROOTS BIND AD STABILISE TOPSOIL. HELPING TO REDUCE EROSION

(4) LEAVES INTERCEPT AND DISSIPATE RAINFALL IMPACT AND SLOW SURFACE WATER RUN OFF. THIS SIGNIFICANTLY REDUCES THE POTENTIAL FOR EROSION

(5) SOIL FAUNA BREAKDOWN DEAD PLANT MATERIAL MAINTAINING THE FERTILITY WHICH ENABLES CONTINUED GROWTH

FIG 3.3

ENVIRONMENTAL AND ENGINEERING PROBLEMS FROM DYING PLANT COVER



1. LESS STABLE BOUNDARY LAYER CLIMATE LEADING TO FISSURING AND IMPOVERISHED SOIL FAUNA.

2. REDUCED EVAPOTRANSPIATION LEADING TO HIGHER RATES OF INFILTRATION AND FASTER RUN OFF.

3. THINNER ROOT NETWORK WITH LOWER ABILITY TO BIND SOIL AND RESIST EROSION.

4. GRASS INTERCEPTS AND DISSIPATES LESS RAINFALL IMPACT LEADING TO AN ACCELERATOIN OF EROSION.

5. IMPOVERISHED SOIL FAUNA INCAPABLE OF SOIL BUILDING OR ENRICHMENT..

3.6.4 Greenhouse Gases Produced by Refuse Decomposition

Methane and carbon dioxide are both powerful 'Greenhouse' gases, contributing to the build up of heat-trapping elements in the atmosphere. Although production of these gases makes only a minute contribution to the overall problem, there is a relatively straightforward way to balance their small impact. As trees grow they take up carbon dioxide from the atmosphere and bind it into their tissue. Planting in spare corners of landfill sites, where roots will not interfere with the capping material, is therefore an appropriate ameliorative measure. Since conifers are quick to grow, and are relatively shallow rooting (see Section 4.3.2), species such as larch (**Larix decidua**) and Scots pine (**Pinus sylvestris**) should be grown, with willow (**Salix** spp.) in wetter areas. Specialist advice should, however, be sought (from the Farming and Wildlife Advisory Group and ADAS for agricultural areas) so that species are matched to site conditions. To ensure tree survival, maintenance must be provided, notably mulching and weeding around tree trunks.

3.7 LEACHATE CONTAMINATION OF SURFACE AND GROUNDWATER DRAINAGE

If water resources are to be protected and legislative requirements on polluting emissions met, it is essential that leachate escape is prevented through the containment approach. This involves appropriate site design and management based on an assessment of water budgets and the hydrogeology of the site, and the engineering of an impermeable layer around the refuse body. Design requirements are outlined in Section 5.3.

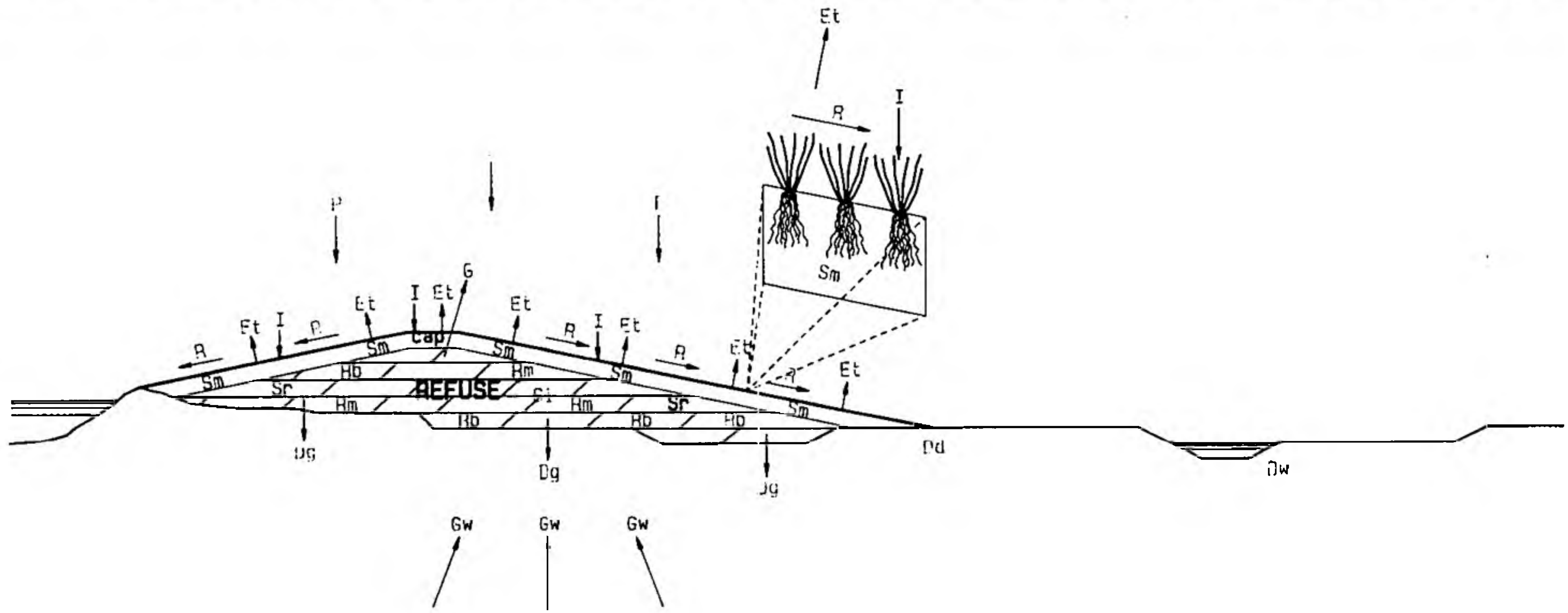
3.7.1 Leachate Generation

Leachate is produced by physio-chemical and biological processes which function according to the type and age of waste, its microbiology and the prevailing waterbalance. The latter consideration is a primary influence on leachate, from two aspects. Firstly, the presence of water is an essential ingredient in the bio-chemical reactions that produce contaminants. Secondly, passage of water through decomposing refuse leaches out suspendable and soluble constituents, and will introduce these pollutants into surface water or groundwater systems should the resulting liquid escape. The water budget of the refuse landform is therefore the critical factor in determining the rate and quantity of leachate generation (See Figure 3.5).

3.7.2 Leachate Contents

Leachates are derived primarily from the organic fraction of the refuse and are produced by the microbial breakdown of the large organic molecules present in food, paper and similar wastes. Breakdown results in the production of simpler compounds including hydrogen, ammonia, water, CO_2 and organic acids. Other water soluble refuse components will also be present in leachate. Leachate constituents therefore fall into four classes:

(a) major elements and ions such as calcium, magnesium, iron, sodium, ammonia, carbonate, sulphate, and chloride:
(b) trace elements such as manganese, chromium, nickel, lead, and cadmium:
(c) a wide variety of organic compounds, which are usually measured as Total Organic Carbon (TOC). Individual organic species including phenol can also be of concern;
(d) microbial components.



P - PRECIPITATION
Rm - REFUSE MOISTURE
Gw - GROUND WATER
Dw - DRAIN WATER
Rb - MOISTURE FROM REFUSE BREAKDOWN
I - INFILTRATION
Dd - DRAINAGE OUT THROUGH DRAINS AND PERMIABLE VEINS
Dg - DRAINAGE OUT INTO GROUND WATER
Ds - SEEPAGE

R - RUN OFF
G - WATER LOSS WITH GAS RELEASE
Sm - SOIL MOISTURE
Sr - MOISTURE ABSORBED BY SPAY REFUSE
Si - MOISTURE ABSORBED BY INERT FILL

KEY

MOISTURE INPUTS
MOISTURE OUTPUTS
MOISTURE STORES

WATER BUDGET OF SEAWALL WITH REFUSE INFILL

FIG 3.5

FIGURE 3.5

To minimise the breakdown of refuse, which produces contaminants and creates settlement problems, water entering into refuse cells must be minimised.

Inputs

Inputs from Gw must be prevented by a secure impermeably base to the fill. Dw entering the site must be prevented from coming into contact with refuse, by secure drainage or preferably by diverting drainage. Rm should be minimised by the rapid deposition and cover of fill. Rb is dependent on the organic fraction of the refuse.

Stores

Refuse itself has a capacity to store moisture (Sr) although this will change as it decomposed. Inert internal cover may have some absorption capacity (SI) depending on its composition. The topsoil material will hold soil moisture (Sm), especially if it has a high organic fraction.

Outputs

With the philosophy of containment, Dd, and Dg must be prevented, and this is the role of the secure impermeable membrane surrounding the refuse. The escape of gas, and G should only take place through controlled venting. R should be encouraged by ensuring free-draining slopes are reinstated over refuse.

This concoction is highly pollutive, up to 200 times stronger than raw sewage, and has all the characteristics of a strong industrial waste water (Anon. 1986; Pavori, Heer, and Hagerty 1975).

3.7.3 Surface Water Pollution by Leachate

The escape of strong organic leachate promotes eutrophication (excessive nutrient enrichment) of surface water. As refuse seawalls will often be constructed in close association with borrow ditches draining into streams, rivers or sea, this hazard is especially important. The prolific algal growth encouraged by eutrophic conditions seriously depletes dissolved oxygen levels, and consequently, endangers other aquatic life.

Leachate is also likely to contain non-biodegradable compounds, such as heavy metals. This creates a risk of toxic build-up in the sediments. If these compounds are taken up by organisms, there is a significant risk that they will be concentrated along food chains and acrete beyond toxic thresholds. This risk is high within aquatic communities since they contain a high proportion of detrivores, the initiators of the bio-accumulation process.

It should also be noted that, although the effect on aquatic organisms of individual compounds can be assessed or predicted with some confidence, the combined effects of several compounds cannot, especially as watercourses may already contain pollutants. Actual levels of toxicity also depend on other environmental parameters, including temperature, pH, and dissolved oxygen concentrations. Cause and effect relationships for leachate cannot be universally applied for all aquatic environments and monitoring should therefore remain flexible.

3.7.4 Groundwater Pollution by Leachate

The effects of leachate on groundwater can be serious because of low rates of dispersal and long persistence. Dissolved oxygen levels are naturally low, so the pollutive effects of leachate are exaggerated (DoE 1988).

The nature of the strata and groundwater flow rates will control the extent of any pollution plume and its movement along the groundwater gradient. Saline intrusion and the movement of groundwater encouraged by tidal movements should also be considered.

If groundwater becomes polluted it is likely to be unsuitable as a source of drinking water for many years, depending on the attenuation capacity of the hydrogeology. Alternatively, leachate pollution adds to the cost of cleansing operations before water can be used.

There is a widespread belief that groundwater contamination associated with waste disposal is not a significant problem. Since little monitoring of groundwater pollution has been undertaken, however, this view is not well substantiated.

3.7.5 Leachate Control and Mitigation

To control leachate, surface drainage must be prevented from coming into contact with refuse, refuse must be prevented from coming into contact with groundwater; and infiltration must be minimised by draining the refuse seawall surface.

A survey of the drainage system of the site is a critical prerequisite of refuse tipping. Any drainage flowing into the site must be intercepted and any remaining drainage out must be terminated. Stream and ditch diversions may be required to bypass the site. Further, as the steeper slopes of completed landforms will increase the volume and rates of runoff, higher peak flows may require the enlargement of drainage channels.

For groundwater protection, one orthodox solution has been to lower the watertable below landfills to provide isolation from potentially polluting refuse. This is not, however, likely to be an option in the coastal or riverine setting of seawalls. The use of impermeable membranes to isolate refuse is an acceptable option. Several types of impermeable barriers have been used in this type of situation and these are summarised in Table 3.1

Table 3.1

Type of Barrier	Advantages	Disadvantages
Asphaltic/Bituminious Liners	Impermeable	Settlement may lead to cracking. Expensive.
Synthetic	Polyvinyl chloride is impervious to gas as well as liquids.	Care is needed in laying liner to prevent puncturing.
Clay	Cheap and resistant to trafficing.	Subject to variations in quality. Fissures.
Chemical Foam	Easy application.	Easily damaged. Expensive.

To date, clay has been by far the most widely used containment material, since requirements for its local abundance, quality, impermeability, uniformity, and bearing capacity have all frequently been met.

Clay is, however, susceptible to fissuring when subject to alternate drying and wetting, and also as a result of soil movement. In sensitive locations, the additional cost associated with other techniques may be justified for instance in protecting aquifers or nature conservation or recreation resources. Increasingly stringent environmental legislation, and the development of new techniques in environmental engineering may increase the frequency with which these alternative materials need to be used. In addition, the construction of impervious peripheral bunds around refuse deposits to prevent contaminant escape into neighbouring watercourses is seen as a potentially relevant protective measure.

The collection of any leachate from refuse landforms is discussed in Section 5.3.2.

To minimise surface infiltration, certain steps can be taken both during and after construction. Efforts should be made to minimise the timespan between the start of tipping in any one area, and the completion of the final capping over it. Where reliable weather forecasts are available, additional inert daily cover should be put in place in advance of heavy precipitation, to help absorb water. Once in place, the quick establishment of vegetation cover is the next critical measure. The nature of the soil is also important, since coarsely textured soils and those with low organic fractions will not absorb and retain moisture. Topsoil should therefore be suitably selected. Finally, the grading and surface drainage of the seawall surface should encourage runoff and prevent surface ponding. These features must be monitored, and maintained in the event of any settlement.

3.8 LITTER

Wind blown litter has proved to be a problem at previous refuse fill seawall sites. The nature of these locations is such that they are generally open and exposed, and therefore frequently windy. In order to contain litter, a working practice needs to be established whereby freshly tipped refuse is compacted and covered as quickly as possible. Even then, there will still be litter that escapes and temporary fencing will need to be deployed to catch this before it is blown off site. The fencing will need to be substantial as, when choked by refuse, it will attract considerable wind loading. Fencing will therefore need to be regularly cleaned of refuse and redeployed around the site as the works progress.

Plastics create a particular problem. They are light and get blown around easily, but unlike other windblown materials their breakdown is very slow. Consequently, they persist as potential blockages for inlet/outfall pipes or filters of motor equipment for example. In estuarine and coastal environments, plastic debris is also a serious hazard to wildlife. Mudflats, saltings, the water and the tideline are critical feeding areas for large concentrations of waders, ducks, and geese. For all these reasons, in addition to the fencing to trap wind-blown material, regular collection must also be carried out around the circumference of the tipping site. Waste managers will be aware that effective litter control is an important component in maintaining good public relations.

SECTION 4 : ENVIRONMENTAL CONSIDERATIONS : HUMAN, LANDSCAPE AND CONSERVATION FACTORS

4.1 HEALTH AND SAFETY

4.1.1 Road Access

Access requires consideration, both at the site itself and through the rural roads in the immediate vicinity. Existing roads may prove to be inadequate to take the traffic to and from a new site since the minimum viable quantity of 50,000 tonnes of refuse annually would generate between 4000 and 8000 lorry round trips per year.

If a proposed site is sufficiently large to warrant expenditure, new access roads may be required. Significant contributions may also have to be made towards the cost of improvements to other local roads along the major access routes to the site.

Since sites are likely to be away from established road networks, liaison and agreement with local landowners may also be required to enable private roads and farm tracks to be used improved, maintained, and reinstated by the Waste Disposal Authority in return for use during tipping. If new roads are needed, appropriate arrangements will have to be made with landowners. The physical and social impact of new and/or improved roads must be given full consideration, including their landscape, amenity, historic, drainage, and nature conservation implications. Any improved access to the site will, however, be a continuing advantage after completion of filling in permitting easier access for maintenance works.

In addition to road maintenance, vehicles should be well serviced to minimise the pollutive emissions they produce. Vehicle emissions damage the environment and represent a health hazard for site workers. Noise from machinery should also be monitored, reduced where possible and kept within required standards. Traffic considerations are especially important for seawall tip sites because of restricted manoeuvering space.

4.1.2 Road Safety

Road safety arrangements for tipping at seawalls should follow the guidelines already established for normal landfill sites. (DoE 1988).

The main additional aspect of road safety relating to any operation on seawalls is the movement of vehicles over slopes. Care should be taken therefore that safety margins for vehicles on slopes are established, monitored, and enforced, and that vehicles are suitably modified with roll bars and other protective features where necessary. Vehicles also need to be kept away from the edges of watercourses unless adequate bearing capacities can be guaranteed.

4.1.3 Site Security

The restriction of unauthorised access to seawall refuse sites is different from normal landfill operations for several reasons. Seawall tips are likely to be smaller and to have smaller working faces, but because they are long and thin, they will have a larger perimeter to area ratio. Fencing costs will be relatively high and patrolling difficult. Seawalls may also be traversed by established rights of way, in which case, diversions need to be arranged with the landowners and highways authorities. Provision should also be made for controlling unauthorised access from waterways.

Unrestricted access presents significant health and safety problems not only for trespassers but also to authorised site users and occupants of adjacent properties (DoE 1988).

4.1.4 Site Safety

Seawall tipping sites are likely to be isolated and provision for first aid, hazard treatment, and other emergencies should therefore be stringent. The proximity of watercourses necessitates that training in these areas should cover aquatic and marine environments; for example, the use of life-jackets and safety boats should be arranged.

4.1.5 Site Management

Site management for tipping at seawalls should follow the guidelines already established for normal landfill sites (DoE 1988). However, additional attention must be paid to the special concerns highlighted in this report. Appropriate modified management practices will therefore be needed if high standards of site operation, restoration, and maintenance are to be continued.

4.2 PUBLIC RELATIONS

First and foremost, in any planning process involving the proposed use of domestic refuse as an infill material for sea wall improvement at a particular site, the landowner must be consulted and must be in agreement with the proposals. Contact should then be made with representatives of the local community, notably Parish Councils, Residents Associations, and Community Councils. The would-be site operator should liaise with local people, both to assess their opinions and to keep the community informed of developments at the site. If the site's proposed location gives particular cause for concern, regular meetings should be arranged between representatives of the operator, the Local Authority, and the community to prevent issues developing into conflicts (DoE 1988).

Because of possible problems of public perception, there is a need for sensitive and responsive consultation with the public. Such consultation may be mutually beneficial for the local population and the disposal authority: a public reassured by sound safety and strict operations control is less likely to object to the location of a new site. Similarly, if the public are aware that a complaints procedures is in place to deal with any problems as quickly as possible, they are less likely to object. The corollary of consideration for the public is a better case for the Disposal Authority at the planning application stage.

To minimise disturbance during the operational stage, and to make clear that tipping will be undertaken in an organised and controlled manner, it is necessary to ensure that restoration is progressed as quickly as possible in the completed sections of seawall. The advantages of restoration need to be clearly expressed, and re-inforced with information on comparable sites already completed. The benefits of flood prevention from refuse banking should also be highlighted.

4.3 SITE RESTORATION AND AFTER-USE

4.3.1 Restoration Requirements and Procedures

A key requirement when seeking planning permission for refuse disposal will be the appearance and after-use of the finished bank. It is therefore essential that the restoration process is well conceived and fully implemented.

The procedure for restoration and after use should include:

(a) determination of appropriate after-uses in advance of restoration;

(b) attempts to maximise the final benefit to be gained from the land, either by a single land-use or combination of uses;

(c) the identification of any special restoration requirements, whether relating to flood defence, ecology and nature conservation, agriculture, or recreation.

(d) deciding completed levels and gradients which are visually acceptable and which conform to the requirements of after-use;

(e) phasing of landscape planting and modelling to enable screening to take place in advance of tipping operations whenever possible but in preparation for the final landscaping scheme and after-use drainage plans;

(f) assessment of the scope for landscape, landuse, and conservation enhancement, in line with statutory and planning requirements.

Whilst the over-riding objective is maintaining a viable flood defence, the requirement for restoration means that topsoil will need to be re-instated, vegetation encouraged, topography created, and the drainage lines laid.

4.3.2 The Role of Plant Cover

Establishing vegetation cover is a cost-effective means of making a landfill cap resistant to the physical forces that might otherwise endanger its integrity. The presence of plant cover and root networks minimises erosion by reducing rainfall impact, decreasing water run-off velocities, and minimising soil capping (Johnson and Urie 1985). It also produces a thin boundary layer microclimate within which climatic extremes are reduced. The materials near the surface are therefore exposed to reduced physical stress, and suffer lower wind velocities and lower soil freezing depths. This also helps prevent damage to the capping material. Evapotranspiration from plants also benefits bank protection, exporting soil moisture and thereby reducing rates of infiltration into the bank, which in turn cuts down on the leachate generated. (See Figure 3.3).

Vegetation cover also provides a more acceptable visual quality for the site, as well as opportunities for enhancing the landscape's amenity and conservation features.

The establishment of vegetation on refuse banks can also cause problems since grass, trees, and crops increase infiltration by providing passages for water along root channels. If roots come into contact with contaminated zones, plants may take up toxic elements and bring them to the surface. Small mammals, encouraged by the presence of plant food may have the same effect by burrowing. The risk of roots penetrating the cap material is also frequently cited, but the heavy compaction of both fill and capping soils actually result in small pore spaces and retarded root penetration. Roots that do develop, grow primarily along cleavage planes within the soil and/or refuse since moisture, aeration, and pore spaces are available. Lateral roots rather than tap roots therefore dominate in heavily compacted soils. Certain plants do, however, have a propensity to develop tap roots and these should be avoided in any landscaping or habitat creation initiated over refuse landforms. Regular mowing or grazing can be used to check natural succession and thus to prevent such species becoming established.

Although the sloping banks of refuse seawalls should prevent the development of perched water tables, poor drainage can still present a potential problem. During wet periods especially, lack of oxygen in saturated zones may limit root growth or even kill existing roots. The deliberate use of saturated zones to limit root penetration may provide a further 'insurance' measure to protect the refuse cap against root penetration.

To maintain plants in a healthy condition, roots must also be isolated from any toxic products of refuse decomposition. For both this reason and to protect the refuse cap from root penetration, appropriate depths of 'soil over cap' and cap thickness should be established.

4.3.3 Topsoil Requirements

To enable any vegetation cover to develop, topsoil must be provided as a bedding medium for plant growth. This applies for both recreation/amenity and proposed agricultural after-uses. The provision of a substantial topsoil cover also protects the clay cap from damage by burrowing animals.

Normal procedures of topsoil removal before tipping, followed by replacement after completion may have to be slightly modified because the surface area of the final refuse bank will be larger than that which it replaced. Consequently the original soil may either need to be topped-up or spread more thinly over the surface. A decision to import additional topsoil may have to be made, balancing the soil depth requirements of the proposed after-use and the cost of importing sufficient new material. As little as 75mm can suffice to provide a grass sward on good filling providing the spreading and grass sowing are completed before any erosion can occur.

Where cultivation and agricultural uses are proposed, however, certain minimum depths are recommended. The Ministry of Agriculture, Fisheries, and Food specify at least 300mm of good soil over the fill cap, and under adverse conditions it may be necessary to provide an even greater depth before satisfactory conditions can be achieved (DoE 1971). The exact depth and arrangement of both topsoil and subsoil will, however, ultimately depend upon the grade of agricultural land being created.

Rooting depths of selected agricultural crops are also given in Table 3.2.

Table 3.2 Root Zone Depth for Selected Agricultural Crops

Crop	Potential Root Depth (mm)	(in)
Wheat	>1830	>60
Sugar-beet	1520	50
Potatoes	1520	50
Pasture	910	30

Source Johnson and Urie (1985).

4.3.4 Seed Mixture Considerations

To protect the cap from root penetration and the vegetation from poisoning, shallow rooting plants are undoubtedly the most suitable for restoring vegetation cover to refuse sea walls. Grasses are tolerant of a wide range of environmental conditions and they have highly developed root systems which extract the maximum nutrient from the soil enabling them to survive where other species would not (DoE 1971). They therefore appear to be the best solution to re-vegetating refuse seawall banks, particularly where arable agriculture is inappropriate because of slope or other limitations.

To ensure good grass germination, the seed mixture should be sown when a period of moisture and warmth can be reasonably expected, say from late March to early May or August to mid-October. Capping and top-soiling should be carefully timed so that bare soil is not exposed in periods when excessive erosion is likely.

Seed mixtures may need to meet particular requirements in terms of amenity (eg resistance to trampling for footpaths), maintenance (minimising the need for mowing), farming (preventing the spread of weed seeds), or nature conservation (encouraging flower and herb rich swards). The scope for combining all such objectives should be investigated and implemented wherever possible.

The resistance of vegetation to salt spray may also need to be considered at exposed sites.

4.3.5 Agricultural Afteruse

The potential for returning the land on which the refuse seawall is constructed to agricultural use must be considered at an early stage in the planning process. Agricultural use, either arable or grazing, will impose limitations on both topsoil and subsoil characteristics including depth, and on slope. There may also be implications for the viability of using synthetic membranes for sealing purposes. Finally, if grazing is proposed, consideration should be given to possible soil structural damage due to poaching (overgrazing during wet conditions).

4.3.6 Tree Planting Considerations

Where tree planting can be accommodated within a seawall site, efforts should be made to plant and maintain trees both to take up carbon dioxide as discussed in Section 3.6.2 and for landscape, amenity, and conservation benefits. The choice of suitable species is essential however, and tree after-care must be provided by arrangement between the operator and land owner.

4.3.7 Restoration of Aquatic Habitats

Seawalls frequently occur in association with borrow ditches, which in some cases contain biological communities of significant ecological and nature conservation value. Restoration work undertaken at Hadley Marsh has led to the development of procedures for encouraging re-colonisation and these should be followed in new schemes where relevant. Retrospective studies did, however, conclude that the colonisation rates achieved were relatively slow (Berridges 1988).

Certain enhancement techniques were suggested and these, along with other colonisation guidelines, are reiterated below:

(a) The provision of artificial substrates on dyke banks improves soil stability and therefore the establishment and stability of macrophyte communities.

(b) Less steep slopes provide greater littoral area which plants can colonise, improving the richness of the biological communities that may develop.

(c) Subject to land availability, the creation of a series of shallow ponds will enhance the site's nature conservation value. If these can be isolated from the main seawall drainage network they also provide a source of unaffected flora and fauna which may recolonise a stretch of waterway if it is damaged by pollution.

(d) From landscape and conservation viewpoints, linear alignment of waterways should be avoided where possible, since winding watercourses provide more attractive features and better wildfowl habitat.

(e) Reduction of turbidity by flocculation and the increased presence of macrophyte populations will increase the productivity and diversity of the biological community that evolves.

(f) Old and new drainage ditches should be interconnected along their whole length to aid cross-colonisation before work commences.

(g) Re-colonisation can be encouraged by the transfer of aquatic vegetation, by seeding of banks, and by the careful transfer (by hand where appropriate) of plant and animal-rich substrate.

For further information on habitat restoration, reference should be made to Newbold, Honnor and Buckley (1989).

4.4 AMENITY AND NATURE CONSERVATION

4.4.1 Amenity

Seawalls and other flood defences are widely used for passive recreation, providing access to attractive coastal areas or stretches of recreational green space. Footpaths, walking the dog, getting "outdoors", and watching wildlife are all common uses. These should be seen in a positive light and encouraged, with all possible efforts made to arrange for their accommodation when the seawall is complete. Further, any interference to formal or informal recreation during tipping operations should be kept to an absolute minimum, alternative provision made, and temporary diversions of existing rights of way included as part of the initial planning application.

Potential problems associated with recreation use of the site relate to ponding and the erosion of cover along footpaths. These must be rectified through regular path maintenance. Problems with litter and leachate escape and gas emissions must also be dealt with and rendered harmless.

Access for walkers is also, however, access for vandals, so siting of monitoring equipment and sluice gates should be discreet (Hagerty, Pavoni, and Heer 1973).

4.4.2 Landscape Considerations

It is important to recognise that landforming operations such as seawall improvement using refuse fill may visually affect a wide area, especially in the flat riverine and coastal landscapes of Essex and the wider Anglian NRA Region. Attention must therefore be given to restoration and landscape quality. The visual impact can be an important consideration when planning permission is being sought. To assist in its assessment, as well as in engineering design, computer modelling systems such as MOSS and Arc/Info may prove useful to replicate in three dimension the finished seawall structure and its setting in the landscape.

Some potential landforming sites may be in areas designated as Heritage Coast or Areas of Outstanding Natural Beauty. A refuse seawall should therefore intrude as little as possible, and should not result in the loss of features of landscape interest. Such features might include woodland, ancient monuments, and sites of archaeological interest.

Before commencing disposal operations, plans should have been approved to avoid adverse visual impacts. Floodwalls may be flat-topped, angular and straight, but these are all characteristics which detract from landscape quality. Screening with trees should therefore be as comprehensive as possible. The presence of trees and shrubs adjacent to the refuse seawalls, at locations where root penetration will not threaten to interfere with the structure (as discussed in Section 3.6.4), will break up the visual monotony of the structures and create new habitats for wildlife. Where public recreation is an appropriate after-use, tree planting also creates a more attractive countryside.

4.4.3 Nature Conservation

For planning purposes, a complete assessment of the impact of the proposed seawall modification on nature conservation will be necessary. A process of consultation with statutory and local conservation organisations will enable the initial identification of any ecological interests on the site or in its vicinity, with detailed ground surveying as a follow-up to identify and locate any rare or protected species (Street and Dumble 1989). Species and habitats should be protected wherever possible. Careful consideration should be given to developing appropriate and progressive restoration proposals which are sensitive to the surrounding ecological conditions, and which will enable NRA and the County Council to fulfil their statutory landscape and conservation enhancement responsibilities.

Damage to Sites of Special Scientific Interest (SSSI) must not take place, and provision for habitat restoration on sensitive and/or important sites will need to be shown during planning applications. Successful procedures for liaison with the NCC over SSSI re-instatement have already been established at Hadleigh Marsh, and these should be followed if the need for such cooperation arises again. However, the cost associated with such remedial work can be avoided by selecting sea wall sites away from sensitive conservation areas.

SECTION 5 : ENGINEERING CONSIDERATIONS

5.1 INTRODUCTION

The use of refuse to provide a source of fill for improving flood defences is a significant departure from conventional techniques and the engineering aspects of any scheme therefore require careful consideration throughout the planning, design, construction and monitoring phases.

5.2 PLANNING

5.2.1 Agreement

A refuse floodwall scheme will most commonly be a jointly funded project by the authorities responsible for flood defence and refuse disposal, i.e. the National Rivers Authority and County Council respectively. The scheme must fulfil two primary functions; the improvement of the flood defence and the disposal of refuse. Before any joint scheme is considered, it is necessary for the relationship between the two Authorities to be carefully defined in an agreement, setting out the individual responsibilities and duties of both parties. The agreement must be clear from the outset in apportioning responsibility for the planning, design, construction, monitoring, maintenance and cost of the scheme.

Any significant engineering scheme should be under the overall direction of a Project Manager, and it is particularly important with a joint scheme that agreement should be reached regarding the appointment of one such individual. The role of the Project Manager will be to ensure the co-ordination of effort by both parties at all stages of the scheme.

5.2.2 Identification of suitable Joint Schemes

Assuming an existing sea defence, the basic conditions required for a refuse fill site will usually dictate the suitability of a potential refuse floodwall scheme at any particular location. The following assessment of the basic requirements for floodwalls and refuse disposal sites only address those factors peculiar to a joint scheme.

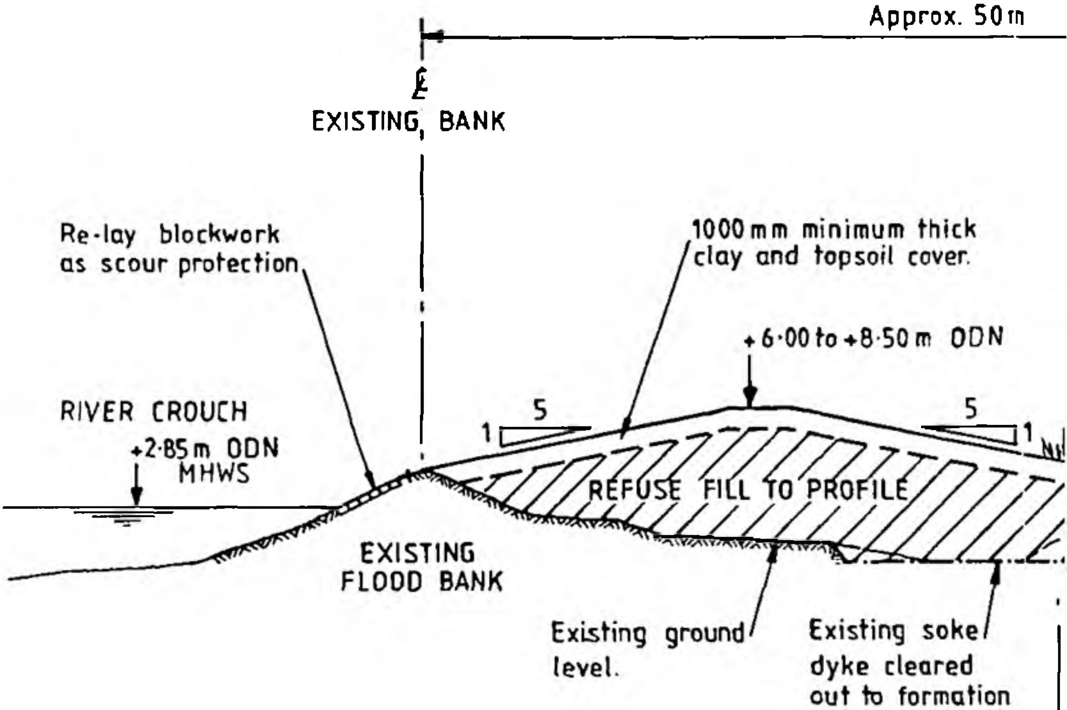
5.2.3 Requirements for a Flood Defence

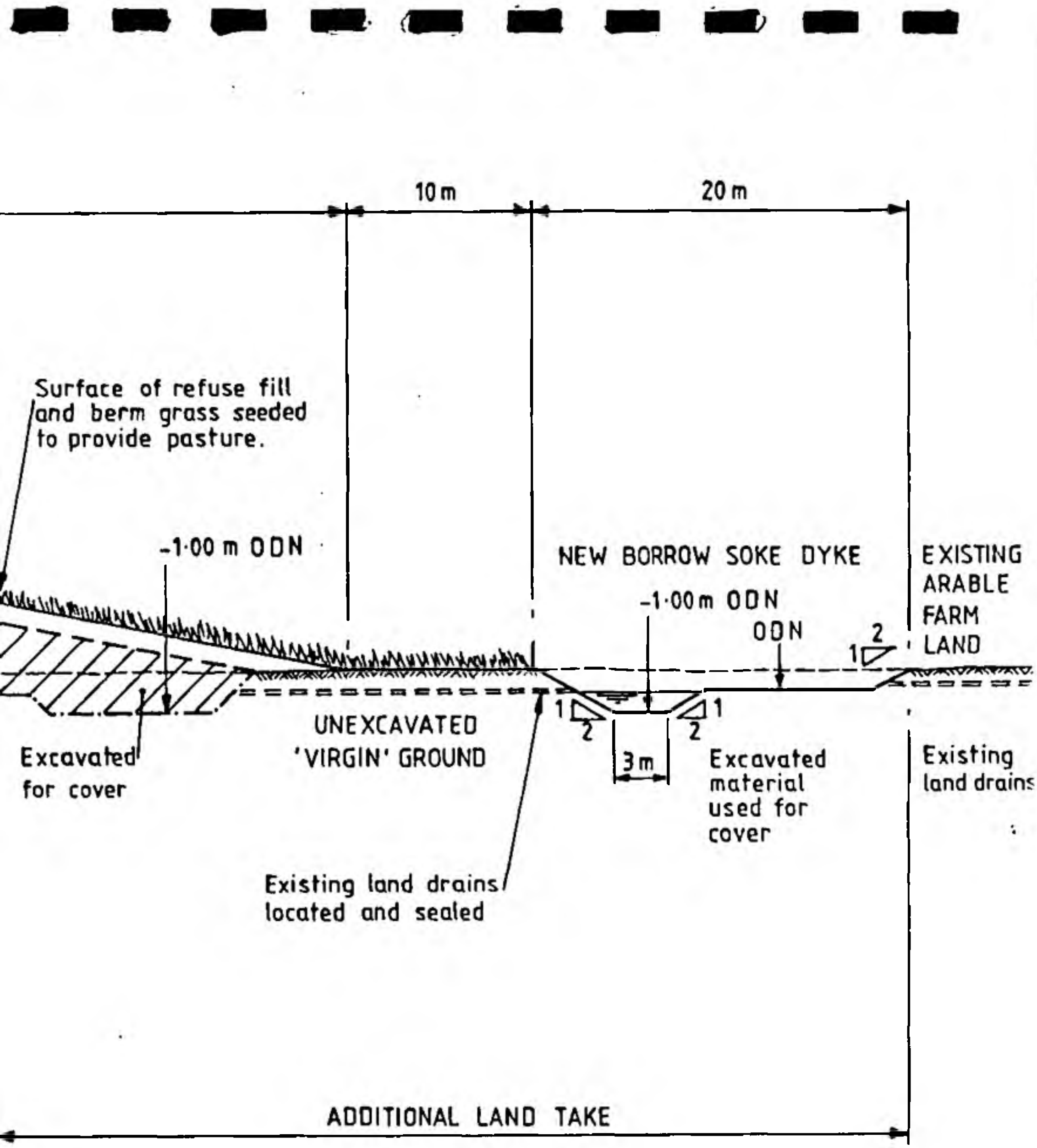
Location

It is likely that a joint refuse wall scheme would only be considered for areas where the existing flood defence comprises an earth bank protecting a relatively isolated rural flood compartment.

Type of Defence

The flood defence element of the structure must provide the required impermeable barrier to the passage of water into the flood compartment, as refuse is relatively permeable. Ideally, the existing earth bank should be retained in an undisturbed state at the front face of the combined embankment so that it can continue to provide the main defence (See Figure 5.1). The refuse fill will be used to augment both the overall stability of the bank and any raising. Any existing defence being considered for a joint scheme must, therefore, be suitable for retention.


Approx. 50m
℄
EXISTING BANK
Re-lay blockwork
as scour protection
1000mm minimum thick
clay and topsoil cover.
+6·00 to +8·50m ODN
RIVER CROUCH
+2·85m ODN
MHWS
5
1
5
1
REFUSE FILL TO PROFILE
EXISTING
FLOOD BANK
Existing ground
level.
Existing soke
dyke cleared
out to formation



REFUSE WALL STUDY

TYPICAL CROSS SECTION AT FAMBRIDGE

FIGURE 5.1

5.2.4 Potential Abandonment

Rising sea levels, together with receding or eroding foreshores, will ultimately combine to force retreat from the current flood defences in some areas where the existing alignment becomes untenable. To date there has been no such abandonment, so the potential problems involved have not yet been fully identified. A refuse wall would add the problem of potential pollution if the abandoned defence were to be eroded by wave action. This would allow the refuse to be washed into the sea and dispersed over the foreshore.

The severity of such pollution is difficult to predict. It is unlikely that a joint refuse wall would be considered for a sea defence which might be abandoned within the next 40 years. Any subsequent erosion by the sea may not occur for some time after abandonment. By this time, the refuse should only present a major pollution nuisance in the form of non-degraded materials such as plastics and metals, but this pollution would be difficult to contain and expensive to clean up. Any refuse wall scheme should therefore be planned to minimise this future risk by rejecting sites where there is a possibility of future abandonment. Factors to be considered in assessing this would be the likely need to strengthen and raise all the defences within the flood compartment under consideration, and the long term stability of the foreshore or saltings seaward of the defence line. It is then important to recognise that refuse walls, by virtue of their size, height and width, are unlikely to be overtopped or breached. Subject to the stability of the foreshore area, they would only be abandoned if they were out flanked by shortcomings in the defences either side. This eventuality can be prevented either by improving all the primary defences within a flood compartment, or by providing short secondary closure banks into high ground on either side.

5.2.5 Requirements for Refuse Disposal

Ground Conditions

It is essential that any proposed site for a joint sea defence/refuse disposal initiative has a good thickness of clay material present below the intended formation level of the refuse filling. The exact thickness would depend upon the type of clay itself, but it is unlikely that a thickness of less than 500mm would be adequate. A greater depth of clay is preferable because of the improved scope of excavation in the formation of the tip site, not only increasing the potential tip volume, but also winning clay material for use in forming, sealing and capping layers. The clay must be sound and unfissured to provide an impermeable seal to the base of the refuse and must also be sufficiently firm to permit trafficking by the road going refuse freighters during construction.

It is unlikely that continuous uniform conditions will be present throughout a proposed site. In particular, former creek beds with significant amounts of sandy material may be present in an otherwise ideal bed stratum. This was the case at both the Hadleigh and Fambridge site in Essex and such areas were left unfilled by refuse.

Refuse Quality

To supplement the controlled refuse, there must be an adequate supply of inert fill. The required proportion will be a function of the proposed filling arrangement, but is likely to be of the order of 20-25 per cent by compacted volume. This material will comprise topsoil or subsoil arising from local building or construction work and will be used to form a seal to each days refuse filling. Some inert material should be available on the site from the preparatory earthworks carried out prior to tipping. Experience has shown, however, that this is seldom sufficient and that local material, which is invariably of better quality than the incoming inert material, is better saved for final reinstatement.

Refuse Quantity and Availability

If the quantity of refuse likely to be available within a catchment extending 12-20 miles (20-32km) from with site is below 50,000 tonnes per year, then it is unlikely that the site would be viable. A supply of less than 50,000 tonnes per year would be insufficient to enable the continuous working of the earth moving and compaction plant needed on site. Not only would this result in an unacceptably high unit cost for the refuse disposal, but the consequent intermittent nature of such work has been shown to result in poor placement and compaction.

The range of potential catchment area sizes is wide because the viability of a specific site would depend upon the availability of other, cheaper, means of refuse disposal locally. However, it is unlikely that haul distances greater than 20 miles would be economic. A supply of refuse which is available for less than two years might also lead to doubts about the economic viabilities of a particular site.

Capacity and size of site

It is difficult to define a minimum acceptable capacity for a potential site, as this will be governed by the acceptable maximum unit cost for refuse disposal in the immediate area and this is a highly variable figure. The economic viability of a proposed site will also depend on its total potential capacity and the initial site set up costs.

The depth of filling will be controlled by stability, planning restrictions and minimum defence standards among others. There is, however, a minimum acceptable width of fill which must be greater than 40-50m at base level in order to ensure that the refuse freighters have room to turn. Local width restrictions may be acceptable at culverts for example, but a general width less than this figure would eventually result in congestion of the working area because the working width narrows as fill height increases.

5.2.6 Other Planning Matters

The legal considerations in the planning process, including the requirement for planning permission, are dealt with in Section 2. Public relations during the planning process are discussed in Sections 4.2 and 4.4.1. Monitoring requirements are appraised in Section 6.1.

5.3 DESIGN

5.3.1 Introduction

The basic requirements for the design of a joint scheme are similar in may respects to those of normal floodwall improvements and include crest level, protection against wave action, and resistance to overtopping. It is not intended to cover these aspects in detail, but to concentrate on the peculiarities of joint refuse wall schemes.

5.3.2 General Site Arrangement

Figure 5.1 shows the site arrangement used at Fambridge and demonstrates most of the essential features of laying out the overall defence. The existing earth bank sea wall has been retained, and is the major element in keeping out floodwaters. Existing earth banks have typically been raised many times, as part of routine maintenance programmes, to counteract the settlement of the bank under its own weight into the underlying, generally soft strata. The bank material therefore probably penetrates some depth into the stratum, forming an effective cut-off. This should be left undisturbed.

The refuse fill itself is used to raise the embankment beyond the required defence level. The top level has been chosen to accommodate as large a volume of refuse as possible within planning or stability constraints. The refuse fill acts as the primary flood defence barrier above the level of the existing bank and, as refuse is very permeable, it is necessary to provide a capping layer of impermeable clay material to control seepage. This capping layer extends over the complete upper surface of the fill as it serves another important function in reducing the rate of rainwater infiltration. As discussed in Section 3.4 the rate at which the refuse breaks down is governed by the presence or otherwise of ground water. By controlling the infiltration, breakdown is slowed, and there are attendant benefits in reducing the rate of settlement and the rate of production of undesirable breakdown products. With a philosophy of containment, site management is orientated towards preventing the escape of any pollutant, in anything other than a minimal controlled manner where treatment can be applied, if required.

The most practicable way of isolating the refuse is to contain it with an impermeable clay layer. At Fambridge this comprised virgin clay at the base and a minimum one metre depth of clay capping; the latter won from the refuse fill formation excavation.

The design of the clay capping layer requires particular care in order to control the formation of cracks, and the moisture content of the material at the time of placing must be optimised to reduce shrinkage.

If it is felt that the existing ground conditions make the complete containment of leachate difficult, provision can be made to pump out any leachate which has accumulated in the refuse fill. At Rainham, a series of herring bone pattern underdrains were installed in the refuse formation. These are pumped out periodically and the leachate is taken away in tankers for treatment.

As discussed in Section 5.2.5, the width of the refuse fill bank is governed by access requirements during tipping. It is probable that the excavation of a new soke dyke at the landward toe of the fill slope will be required and, in order to control the movement of leachate into this dyke, an unexcavated berm of virgin clay ground should be left between the dyke and the refuse fill. There is also considerable scope in the formation of this new soke dyke to accommodate environmental improvements in terms of habitat creation and aesthetic considerations.

5.3.3 Leachate Containment

The gross movement of liquid and gas contaminants will be minimised by the clay membrane constructed around the refuse. Any movement within the bank, however, is determined by barriers and avenues within the refuse structure. A saturated layer provides an effective barrier against movement. Bands of unsaturated coarser material conversely will be exploited by gases and liquids as lines of weakness. Any sand or gravel veins running under the site must therefore be sealed. Other potential escape routes for either gases or liquids, including culverts, service lines, ducts, sluices and drains should also be assessed.

Overall, any barrier engineered to control movement needs to be continuous around the cell. It should also be of sufficient thickness to prevent breaching due to fissuring, drying, and shrinkage during and after construction, and be capable of providing long-term containment of contaminants for at least 50 years.

Any concrete or steel structures in contact with the refuse fill will be potentially at risk of sulphate or acid attack. Both organic acids and hydrogen sulphide produced by decomposition of the refuse can be particularly troublesome in this respect. Care must be taken to provide adequate concrete cover with the correct specification of concrete. Alternatively, barrier methods should be considered to isolate the structure at risk from the refuse fill.

5.3.4 Geotechnical Properties

Uncompacted refuse has a density in the range 500 to 650kg/m^3; lightly compacted, this can be increased to about 1,000kg/m^3 or with heavier compaction, and the incorporation of clay in layers to act as a binder, to 1200kg/m^3. The moisture content of refuse (weight ratio of free water contained in the refuse to that of dry material) varies from 10 to 35 per cent. This variation reflects fills of differing composition, those of higher moisture content containing a larger proportion of organic material.

Site investigations, undertaken for the purposes of building development on old domestic refuse tips, have yielded variable Standard Penetration Test (SPT) 'N' values, ranging from 1 to 10, with most results in the range of 2 to 5 (very loose to loose). These figures would apply to uncompacted or very lightly compacted refuse which had consolidated under self-weight. Although details of individual tests are not published in the literature, these low values are thought to represent, in part, voids in the refuse through which the penetration tool passed during the test thus markedly reducing the overall blow count.

The angle of shearing resistance for such low N values is thus less than 28 degrees, though this relationship was developed for sands, not heterogeneous materials like refuse and is therefore not reliable.

The literature reports ultimate bearing capacity between $25kN/m^2$ and $40kN/m^2$, though structures would reach their serviceability limit at stress levels well below these values due to settlement. Using Skempton's bearing capacity equation this gives an undrained strength of 4 to $7kN/m^2$ (very soft).

An undrained elastic modulus of 1140kN/m2 is reported in the literature for refuse consolidated under its own weight; there is no value for a well compacted fill.

A single permeability of 3×10^{-4} m/d is reported for refuse, a value similar to a medium sand. Conversation with staff from Binnie and Partners, Consulting Engineers, who undertook hydraulic field testing of a trial flood defence embankment constructed of refuse (on the Thames Estuary) tended to confirm this result. This embankment leaked water at some considerable rate.

To summarise, domestic refuse, even when compacted has extremely low strength and is moderately permeable. It does have the advantage of being lighter than conventional fill, and bearing pressures are therefore relatively low, making the material an attractive option on weak foundations.

The geotechnical properties could be markedly improved by the incorporation into the refuse of compacted clay, in layers. Clearly some improvement on the above figures would be achieved due to the reinforcing effect derived from the clay. Permeability would also be reduced. Modern refuse, being composed of plastics, paper and organic material, is an especially poor material to use alone.

5.3.5 Earthworks

Current refuse tip practice is to spread material with a bulldozer in layers 1m to 2m thick and to compact it with a 'Trashmaster' steel grid roller with protruding lugs (similar to a sheep's foot roller, but larger). At the end of each working day, 200mm of firm clay is placed on top of the refuse and rolled in to form a seal.

There would seem to be little point in reducing the uncompacted thickness of refuse below 1.0m in seawall improvement works, but greater soil structural strength would be achieved by increasing the clay layer thickness and by working the refuse into discrete "cells", interlocked with one another. Each cell would thus comprise a bund of refuse encapsulated in a clay membrane, providing environmental benefits in terms of containment.

The earthworks in refuse sea walls are best capped by a minimum of 1.0m impermeable clay forming a seal. The majority of existing flood banks are grassed and mown regularly to create a dense sward providing resistance to erosion by flood waters. Top soil depth should therefore be sufficient to sustain grass growth. (See Section 4.3).

The settlement of domestic refuse fill continues for long periods after placement and although it is largely complete inside 10 years, could continue for up to 30 years. An overall settlement of 20% of the vertical thickness seems to be typical for a poorly compacted refuse, reducing to 10% for a well compacted one (say to $1200 kg/m^3$).

The specific settlement characteristics of refuse are similar to that of peat. This process involves a large initial elastic (or immediate) settlement, very little primary consolidation settlement (due to the free-draining nature of the material allowing immediate dissipation of poor water pressures), and large secondary consolidation (creep) due to decomposition.

The elastic settlement is normally complete within one month of placing the refuse. This settlement is largely due to the expulsion of air from the refuse mass, and to elastic strain in the refuse particles. The magnitude of elastic compression can be estimated from the expression:-

$$\Delta e = - Cc \log \frac{\sigma'_o + \Delta\sigma}{o}$$

where Δe = change in void ratio

Cc = compression index

σ'_o = initial effective stress in the fill

$\Delta\sigma$ = change in effective stress in the fill

The compression index, Cc, is typically 0.15 e_o (where e_o = initial void ratio of refuse) for a refuse of low organic content, to 0.55 e_o for a refuse of high organic content.

Creep (secondary consolidation settlement) decreases gradually, giving a straight line when plotted graphically against time. The magnitude of the creep settlement may be estimated over any time period from the expression:-

$$\Delta e = -\alpha \log \frac{t_2}{t_1}$$

where Δe = change in void ratio

t_1, t_2 = times from start of consolidation

α = creep coefficient

α is typically 0.03 e_o (e_o as defined above) for anaerobic decomposition, and 0.09 e_o for aerobic decomposition. It can therefore be seen that aerobic decomposition of the refuse continues at three times the rate of decomposition under unaerobic conditions, i.e. below the water table.

To conclude, good compaction will reduce the magnitude of the final settlement of the fill and decomposing refuse will settle faster above the water table than below.

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To conclude, good compaction will reduce the magnitude of the final settlement of the fill and decomposing refuse will settle faster above the water table than below.

5.3.7 Slope Stability

Both the nature of domestic refuse and the degree of compaction that can be achieved are so variable that it is considered wise to form slopes which are as flat as is practical. Local failures are likely in areas where the variable fill quality is poor and the design of slopes should therefore use the lower bounds of the relevant properties when considering stability. Failure of slopes formed from compacted refuse is fairly common, generally by shear.

At Hadleigh Marsh in Essex, a refuse fill landward slope of 15° (1 in 3.7) was used successfully. At Fambridge, the slopes were slightly flatter at 13° (1 in 4.3). Settlement of the refuse will cause changes in the side slopes but this will not be a problem from the point of view of stability as settlement will tend to flatten bank slopes, the thicker layers of fill in the centre of the embankment settling more than the comparatively thin layers at the toe of the side slope. However, settlement may affect the top slopes which have been provided to ensure the run off of surface water. Such slopes should be designed to allow for settlement without the risk of undesirable ponding occurring.

5.3.8 Drainage

The existing land drainage regime must be accommodated within any proposals and must be permitted to function continuously throughout the construction. If the scheme requires the excavation of a new soke dyke there may be advantages in constructing this first and diverting drainage to it in advance of the main filling operations. From an engineering point of view the new dyke will provide drainage to the preliminary excavation works and will significantly reduce or eliminate the need for temporary diversions or overpumping during construction. From an ecological standpoint, such a course of action will permit the transfer or migration of flora and fauna from the existing soke dyke prior to infilling.

Surface water run off from the sealed refuse fill bank must be encouraged in order to minimise ingress into the refuse. Bearing in mind the probability of differential settlement of the refuse fill and its underlying strata as discussed above, adequate top and side slopes should be provided. Where flatter slopes are required, for example if the filled bank is to be returned to agriculture, consideration should be given to the provision of land drainage.

If an underdrainage system is to be provided for removal of leachate from the refuse fill, care is needed in the design and detailing of this to prevent any subsequent accidental interconnection between this system and the surface water drainage system.

5.3.9 **Existing Services**

It is possible that the site for any refuse fill scheme will be crossed by existing outfalls, drains or other services. These will require specific measures to deal with them where they pass beneath the new embankment. The requirements for the many different types of service likely to be encountered are various, and each should be dealt with on its own merits. However, potential courses of action will include strengthening works, ducting, an area of no refuse filling local to the service, or complete diversion of the service elsewhere.

5.3.10 **Methane**

Methane should not be a problem providing adequate steps are taken to prevent its accumulation in any enclosed structures, e.g. drains or culverts. If ingress cannot be prevented, then such enclosed spaces should be adequately ventilated. Particular care should be taken with any electrical switch gear for penstocks or floodgates, however, as there is a real risk of explosion of unvented methane ignited by an electrical spark.

5.3.11 **Other Environmental Concerns**

Many other environmental concerns, together with their implications for engineering design and site operation have been discussed elsewhere in this report. The reader is therefore referred to the following sections dealing with:-

(a)	Landfill gas control	:	3.6.1 3.6.2 3.6.4 6.6
(b)	Leachate Control	:	3.7.5
(c)	Temperature Requirements	:	3.4.5 3.6
(d)	Odour	:	3.6.3
(e)	Access	:	4.1.1
(f)	Litter	:	3.8
(g)	Role of Vegetation	:	4.3
(h)	Afteruse (including agricultural use)	:	4.3.3 3.6.2

5.4 CONSTRUCTION

5.4.1 Division of Construction

The division of the responsibility for construction of the various scheme elements should take account of the skills and abilities of the participating Authorities. The formation of access roads and the placing, compacting and covering of refuse fill would best be carried out by the County Council. Alterations to existing drainage patterns and improvements to the front line defence should be the responsibility of the NRA. Arrangements will, however, need to be made on a scheme specific basis and ongoing liaison between the two Authorities will be essential in order to ensure that the works are properly co-ordinated.

5.4.2 Access to the Site

An early requirement of any scheme will be the establishment of adequate access to the site. The majority of schemes will require road access to enable the rubbish freighters to drive to the fill site and discharge directly into the bank formation. It is unlikely that a scheme involving the importing of rubbish to the site by barge could be economically justified as such a procedure would require facilities at the site whereby the refuse could be off-loaded from barges onto tipper trucks for distribution around the site. This exercise would be very expensive and may only be justified if the site was both sufficiently large to warrant the cost of such temporary facilities, and within an economically viable distance of an existing transfer station where refuse could be loaded onto the barges.

5.4.3 Supervision of Construction

Refuse sea wall construction represents significant civil engineering work and as such should be adequately supervised. Previous sections have highlighted the engineering and environmental requirements for any future refuse seawall scheme. In order to be certain that these requirements are met, and that day-to-day site problems can be satisfactorily dealt with, a suitably qualified site engineer must have overall authority for site works. His duties should include the following supervisory and regulatory functions:-

(a) Directing and monitoring preparatory earthworks to ensure that topsoil and impermeable clay materials are separately identified and stockpiled for later re-use.

(b) Monitoring the nature and condition of the formation material to ensure that the strata is impermeable and free of uncharted drains or former creek beds.

(c) Regulating the placing and compaction of refuse material.

(d) Ensuring the daily sealing of refuse is adequate to control wind blown litter nuisance, and ensuring litter fencing is adequately deployed.

(e) Monitoring the balance of refuse and inert material, including the regulation of stockpiling or the transfer around the site if necessary to regain the correct balance.

(f) Controlling the depth and quality of impermeable capping material ensuring its freedom from refuse contamination.

(g) Supervising the topsoiling, seeding and landscaping works.

(h) Monitoring the performance of completed parts of the works, including the measurement of movement or settlement and the detection of slips or signs of leachate pollution.

(j) Supervision and measurement of any associated civil engineering works including the provision of culverts, drains, service diversions and scour protection works.

(k) Liaising with local landowners and residents to minimise disruption and forestall possible complaints.

5.5 MONITORING AND MAINTENANCE

5.5.1 The monitoring required to detect potential pollution is covered in detail in the next section of this report. Additional monitoring would be required to detect any settlement or movement of the refuse fill which could consequently endanger the defence integrity or encourage the infiltration of surface water.

Failure of embankments constructed on soft clay ground is most likely to occur immediately after construction, before the increased pore water pressure in the underlying strata caused by the surcharge of the embankment weight has had time to dissipate. As this pressure dissipates, so the potential risk of slip abates. Monitoring of the embankment for failure should be carried out at relatively frequent intervals during the first year after filling, with the frequency decreasing after this if there are no signs of movement.

Inspection of the bank for the ponding of rainwater as a result of differential settlement would need to be carried out as part of the normal periodic inspection of the flood defence.

5.5.2 Breach Repair

The height and width of the type of refuse seawall discussed combine to reduce the risk of breaching to a very low level. If, however, a breach were to occur then the techniques for repair would differ little from normal practice. For emergency sealing, the immediately available plant and materials would be pressed into service.

For a permanent repair, it would not be practicable to use refuse as the fill material, and conventional materials would need to be imported to the breach site. One problem not present in normal breach repair, however, is the cleaning up of the dispersed refuse material.

SECTION 6 : MONITORING REQUIREMENTS

6.1 ENVIRONMENTAL CONCERNS

Refuse disposal is an emotive subject, and any proposed scheme could, therefore, attract adverse public feeling. In almost all cases refuse is seen as a nuisance rather than a resource. If refuse disposal as infill in seawalls is to become an acceptable practice, it is therefore essential that comprehensive monitoring is used to assess potential environmental damage.

Leachate from domestic refuse has a highly polluting nature which, if allowed to enter the surrounding environment, would have a deleterious effect on both aquatic and terrestrial resources.

The proposed use of refuse as infill material for seawall improvement will depend on containing leachate within the landfill for some appreciable time, so that attenuation processes have time to act. Monitoring is imperative to confirm the integrity of the site, and to ensure that the measures taken for environmental protection remain effective. Pollution can continue for many years and monitoring should therefore continue beyond cessation of filling operations. Proper planning of the total landfill operation, including aftercare, should overcome this problem.

The monitoring of a refuse seawall and its environs is not the sole responsibility of the operator, although he must bear the major share. The disposal authority, if different, will also wish to undertake some monitoring to ensure that licence conditions are being adhered to and that these conditions remain appropriate. Similarly, in exercising its water pollution prevention duties, the NRA should undertake some monitoring. With three parties potentially involved, there is a need to ensure that duplication of effort does not take place. All parties should therefore agree an appropriate monitoring scheme, including who is responsible for what, at an early stage in the programme. All biological and chemical monitoring should be undertaken by suitably qualified and independent bodies. The contractor, for example, should not have responsibility for any site monitoring. Subsequent analysis must be on a regular and consistent basis to facilitate the comparison of results.

Any monitoring scheme must provide detailed information on the development of leachate within and beyond the refuse seawall. The monitoring scheme will be site specific. It should be drawn up at the site investigation stage and implemented as far as practicable in the first stage of site preparation. It is vital that background readings (i.e. ambient levels) are obtained before any landfilling operations begin, so that the results of later monitoring can be compared to pre-landfilling conditions. Without such background data it is very difficult to determine what effect, if any, a refuse seawall has had on the environment. A baseline survey should therefore be a requirement of planning consent.

6.2 PROTECTION OF SURFACE AND GROUNDWATER

In a landfill structure which is raised above the level of the surrounding land, leachate may either flow through the base of the fill material into the underlying deposits or emerge onto low-lying surrounding land.

Unless the NRA's consent has been given, the discharge of leachate to surface waters must be prevented. Surface water can usually be protected by careful engineering design. Leachate can, however, escape by various routes and hydrogeological investigations are therefore needed to ensure that all significant routes are detected and dealt with.

The protection of groundwater is more difficult and calls for a thorough investigation of the hydrogeological characteristics of the site to establish the possible fate of any leachate. There is a legal requirement to protect groundwater as the EEC groundwater directive obliges member states to "prevent" the introduction into groundwater of all substances in List 1. As discussed in Section 2.4.3, this absolute prohibition is qualified only where the discharge concerned is to groundwater which is "permanently unsuitable for other uses" or where a discharge is found by authorities to contain a List 1 substance "in a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater". Household, commercial and inert industrial wastes do not usually pose a pollution hazard to groundwater from the presence of trace quantities of hazardous substances. However, investigations by the Water Research Centre have shown that chlorinated solvents which would certainly qualify for List 1 can occur at significant levels in leachate from such landfills. (Ends Report 180, January 1980). The proper containment of sites should prevent constituents of dangerous wastes reaching groundwater. Movement of leachate in a contained site should be severely restricted but nevertheless some migration must be expected to occur in time.

The effects of high strength organic leachates on groundwater will persist for a long time due to both the limited amount of dissolved oxygen available and the low rates of dispersion. The identification and quantification of a pollution plume is difficult to achieve unless a large number of boreholes are constructed and groundwater samples abstracted and analysed at regular intervals. These boreholes must be sunk during operation not only within the seawall, but also on land adjacent to the site to ascertain the extent of any leachate seepage into the groundwater. Care must be taken to ensure that the boreholes do not provide an escape route for either leachate or landfill gas through, for example, shrinkage of the clay capping. In such cases remedial action should be taken.

6.3 BIOLOGICAL MONITORING

An environmental monitoring programme will involve biological surveillance and chemical analysis from a number of sampling points. The objectives of the biological surveillance are as follows (Hadleigh Seawall Project, Berridge Laboratories Ltd. 1988):-

(a) To identify the existing flora and fauna in a length of undisturbed borrow ditch, to form a baseline data guide.

(b) To measure the return of flora and fauna to new borrow ditches, and to compare this with the baseline guide.

(c) To ensure that no pollution attributable to domestic refuse leachate is present and, should evidence of such pollution be found, to identify the source of the pollution and recommend remedial work as necessary.

(d) To monitor the presence of the rarer terrestrial flora and fauna.

Biological surveillance should include studies of benthic macro invertebrates and macrophytes, and phytoplankton counts. Biological monitoring requires a full appreciation of the background conditions and the typical natural seasonal variation which is appropriate for that system. Different ecological systems will require different approaches, depending on whether sedimentary or free swimming animals, algae or higher plants, or combinations of these are present. The methods of sampling used may alter during any exercise due to physical changes in the environment.

6.4 CHEMICAL MONITORING

Biological monitoring provides an integrated response over a period of time which reflects physical, chemical and biological change. However, there may be problems in obtaining objective data and difficulties of interpretation. In order to gain a comprehensive and accurate picture of events, chemical analysis will also be necessary. Changes observed may not necessarily be due to leachate pollution but to a change in water quality characteristics e.g. nutrient supply and salinity, or in substratum characteristics.

Chemical analysis must include all the major parameters:- pH, BOD, Conductivity; Ammoniacal Nitrogen, Salinity, Chloride, Total Organic Carbon, Potassium, Iron, Manganese, Dissolved Oxygen, Total Oxidised Nitrogen and Phosphate. This will facilitate monitoring of the salinity regime, organic and nutrient parameters, general trophic pollution status, and trace elements and toxins. Because the nature of refuse is highly volatile, a large range of analyses is needed to cover these requirements. Routine chemical analysis of water samples from both old and new borrow systems is more likely to detect leaks of tip leachate or the undue ingress of seawater before these would be demonstrated by the biological monitoring programme, thereby also providing an early opportunity to carry out remedial works.

The sampling and analytical methods will largely be standard but they may have to be adapted due to varying site characteristics. It is appropriate to consider chemical and biological data simultaneously, to directly assess the impact of any activity on the environment and identify the cause of change.

6.5 BIOLOGICAL AND CHEMICAL MONITORING PROGRAMMES

Monitoring of the dyke system should be continued on a regular basis, particularly in view of the ongoing pollution potential and the need to assess the establishment and recovery of biological indicators. During the landfilling operation, sampling should take place every month with frequency reducing, as operations cease, to an annual (summer) biological survey and a chemical analysis at two monthly intervals.

A comprehensive monitoring programme must include sampling points at:-

(a) A control site
(b) The old and new borrow ditch systems
(c) Areas of completed seawall, including boreholes, in and adjacent to the structure.

The stages of operation and maturity represented by the different sampling sites, supported by the undisturbed control area, will give a broad representation of the conditions which might be encountered as the project progresses.

The main justification for undertaking a comprehensive site monitoring programme is to obtain early information on any changes to the local environment, particularly chemical quality, which might have influences on the long term recolonisation and recovery of the disturbed area.

Liaison between the various bodies is imperative to ensure sampling is not restricted or disrupted by ongoing operations. It is important that sampling sites are always accessible so that regular monitoring can take place. In this way pollution events will be identified early and sampling results will be more accurate and objective. It is also important to stress that processes acting within or close to a landfill site can continue for many years after the last deposit of waste. In view of the consequent potential for pollution it is imperative that a long-term monitoring programme is undertaken.

6.6 LANDFILL GAS MONITORING

Various gases, collectively known as landfill gases and including methane, carbon dioxide, nitrogen and hydrogen, are produced as a result of the biological decomposition of the waste organic materials, enhanced by an anaerobic high moisture content environment. The gas can pose both a hazard, through the risk of fire or explosions, and a public nuisance. Precautions must be taken in the design and operation of landfill sites to minimise these risks. At a shallow, contained site as proposed, the quantities of landfill gas escaping into the environment should be minimal. However, monitoring must be undertaken to confirm the integrity of the site and to ensure that the production of landfill gases does not place the site or its surroundings at risk.

There is a legal requirement to monitor landfill sites under the Control of Substances Hazardous to Health Regulations 1988. These impose a duty to demonstrate that gases evolved from decaying refuse do not pose a significant health risk to the site workers.

An initial site assessment is recommended, to establish the likely occurrence of a gas hazard after the completion of the seawall. Unless the assessment can guarantee that no risk exists, it will be necessary to introduce and operate a monitoring programme for as long as landfill gas could be produced. Various courses of action may be required, depending on the problems' likely severity, including the installation of a permanent gas control scheme. At shallow sites of up to about 5m, this can take the form of passive venting. Under no circumstances should methane or other landfill gases be allowed to build up within the refuse seawall site, because of the risk of explosion.

At any landfill scheme involving progressive restoration, it is desirable to install gas control wells or boreholes before significant gas production commences. This method of operation allows for the control of water input to the waste, an important parameter in gas production. The site should be operated in such a way as to minimise the possibility of accidental damage to wells by the vehicles working on the site. Drilling of monitoring boreholes will locally accelerate any escape of gas. Careful consideration should be given to the possibility of release of a noxious toxic and/or flammable gas during drilling. There can be a temptation to combine landfill gas and leachate monitoring at the same borehole. Care must be taken therefore to ensure that any equipment used to monitor leachate is compatible.

If high gas concentrations are discovered as a result of routine monitoring, a detailed survey must be undertaken by competent persons to establish the gas source. Boreholes maybe required at some distance from the site to assess whether a migration problem exists or to confirm that the gas control measures are efficient.

6.7 REQUIREMENT FOR MONITORING AT SITES OF SPECIAL SCIENTIFIC INTEREST

Areas designated as SSSI warrant protection by virtue of the important fauna, flora, geological or physiographical feature they contain. The sites are designated by the Nature Conservancy Council (NCC) who must notify the landowners and the local authority. When considering planning applications in an area, the local planning authority must take account of this designation and stringent conditions may consequently be imposed. Such conditions might include activities to minimise the overall environmental impact, and a requirement to reinstate the dyke system to its former condition in accordance with NCC consultation and advice. Both biological and chemical monitoring will be required to assess the environmental impact and to establish whether re-colonisation is taking place. In many cases water quality will be permanently altered, preventing the re-colonisation of some former species. Chemical monitoring must be continuous to ensure that pollution events are identified sufficiently quickly for any appropriate remedial measures to be taken. An accurate and comprehensive monitoring programme is particularly important at SSSIs where rare or locally important species must be preserved.

In an SSSI it is important that a sustainable ecology on the site is maintained not only in terms of species diversity but also as a habitat and food supply for the site's valuable wildlife population. The monitoring of re-colonisation will thus highlight areas requiring artificial re-vegetation in order to prevent erosion and maintain a good vegetation cover.

6.8 AFTERCARE REQUIREMENTS

As part of the aftercare plans, monitoring should also be undertaken to provide data on the soil/plant system of the seawall, with particular regard to nutrition and restoration success.

At Hadleigh Marsh, work was undertaken by the Environment and Industrial Research Unit (1988). Four permanent transects were established across the seawall in areas identified as having been restored in different years, and thus representing a range of maturity states. Three replicate 0-30cm cores were taken at random from each of the following zones of the transect: seaward slope, ridge, landward slope and plane between seawall and borrow ditch.

The cores were analysed for, inter alia, moisture content, microbial activity, nitrogen mineralisation and a series of chemical parameters. A vegetation survey was also undertaken across the four transects. Results showed that re-colonisation with many maritime species had taken place. This exemplifies natural succession in action, with the changing salinity being reflected in the species composition.

The main objective of monitoring, that of providing an assessment of the impact of the seawall development overall, must be fulfilled by assessing a combination of effects (e.g. physical changes, leachate contamination etc.) in an attempt to establish how closely the system is being restored to its original status.

6.9 CONCLUSION

Refuse decomposes, leachate will be produced, and leachate generation will continue for 15 years or more. Although past projects appear to have been successful, the full time period for leachate generation has not yet finished and potential problems may not have surfaced. A long-term monitoring programme is therefore essential. Containment sites must have a facility for off-site disposal or leachate. These may include drains to concentrate the liquor and inspection manholes. On no account should the wall be abandoned and the degree of settlement must be monitored.

No attempt has been made to define or describe the monitoring techniques available as a detailed appraisal can be found in the Hadleigh Seawall Project Report by Berridge Environmental Laboratories Limited (1988).

SECTION 7 : BENEFITS AND COSTS

7.1 SCHEME WORTHWHILENESS

7.1.1 In assessing the overall worthwhileness of a scheme, the costs and benefits that accrue to both flood defence and refuse disposal elements must be taken into account. The benefits to be gained by the flood defence element will be the flood damage which is avoided as a result of the defence improvement. The benefit accruing from the refuse disposal element will be the net cost saving relative to the method of disposal which would otherwise be employed.

7.1.2 Each of the two participants in this type of joint scheme will make a saving relative to a non-joint scheme. In the case of flood defence, this reduction in cost may well make viable a non grant-aided scheme to improve defences in areas not otherwise warranted. In the case of refuse disposal, the saving will be represented by a net reduction in unit disposal costs, and/or a deferral of the costs of acquisition and development of alternative disposal sites.

7.1.3 As with conventional seawalls, refuse seawalls may qualify for grant aid if they can be shown to be economically worthwhile.

7.2 THE DIVISION OF COSTS

7.2.1 The division of costs between the two participants has to date been the subject of individual agreements and it is recommended that this practice be continued. At Fambridge, in addition to a detailed division of responsibility for costs of access roads, loss of land, loss of crops and construction costs, NRA paid an additional sum of about £6 per linear metre of floodwall. This figure had been calculated to represent the additional cost of working the refuse tip due to the constraints imposed by it also being a flood defence. However, this sum may not be relevant in future cases and its applicability will require detailed review at the time any agreement is in preparation.

7.3 MINIMISING SCHEME COSTS

7.3.1 The improvement of seawalls using refuse fill at environmentally sensitive site could potentially increase the total cost of a scheme. Environmental factors should therefore be assessed at the earliest possible stage to ascertain the likely cost of surveying and of the preventative or ameliorative measures which might be required.

7.3.2 A number of other factors could reasonably be expected to increase scheme costs. Existing services crossing the site will need to be accommodated, any new roads required to improve access could add a major element to the scheme cost and, at less isolated sites, a consideration is also required of the possible cost of any measures required to minimise disturbance to residents. An ideal site will therefore be away from environmentally sensitive areas, having existing road access, no services crossing the site and be some distance from existing or planned residential developments.

7.3.3 In general terms, economies of scale apply to refuse seawall schemes. Scheme set-up costs are high, so maximum benefits will be obtained at a site with a long seawall length and a large available land area.

7.3.4 Scheme costs will also increase if leachate has to be pumped out or collected and transported off site. Designing to minimise or prevent the production of leachate is therefore essential.

7.3.5 Long-term monitoring costs will be incurred at all sites but this is unavoidable. The careful management of monitoring should, however, keep these costs to a minimum.

SECTION 8 : CONCLUSIONS AND RECOMMENDATIONS

8.1 LEGAL CONSIDERATIONS

8.1.1 Compliance

The legislative requirements associated with the proposed use of domestic refuse as infill material for seawall improvement have been fully discussed in the report. It is essential that all the legislative implications of any proposal are fully established before the operation is commenced.

8.1.2 Waste Disposal Licence

Part I of the 1974 COPA requires that all waste disposal operations taking controlled wastes are licenced, or covered by resolution if the works are to be carried out by the local authority. The aim of licencing is to ensure that landfilling operations entail no unacceptable risk to the environment and to public health, safety and amenity.

8.1.3 Planning Permission

It is strongly recommended that planning permission is applied for if it is proposed to use refuse as an infill material for seawall improvement. Failure to do so could result in enforcement action being taken.

The conditions attached to any planning permission are designed to protect the environment and should ensure the implementation of a long-term monitoring and aftercare programme.

8.1.4 Environmental Assessment

Land drainage operations and waste disposal activities are both bound by Regulations which require that environmental assessment be carried out if operations are likely to have a significant environmental effect. It is imperative that environmental considerations are taken into account at the earliest stage and this is particularly important at sensitive locations such as SSSIs and heritage coasts.

8.2 ENVIRONMENTAL CONSIDERATIONS

8.2.1 Pollution of Ground and Surface Waters

It is imperative that adequate measures be taken to adhere to the containment philosophy of pollution control at landfill sites. The leachate produced by refuse breakdown is potentially highly toxic and the refuse must therefore be isolated, using clay or artificial membranes, from all exogenous water sources. Run off should be encouraged, surface ponding eliminated and infiltration potential minimised by drainage. Although the seawall should be designed to minimise their production, it will sometimes be necessary to make arrangements for the collection and subsequent disposal of the leachates produced during decomposition.

8.2.2 Landfill Gases

Provision must be made during the design and construction of refuse seawalls for the safe venting and dispersal of landfill gases in order to minimise the building of noxious, toxic and flammable gases and hence reduce the risk of explosion. In particular, attention should be paid to the siting and operation of electrical equipment.

8.2.3 Site Management Procedures

Good site management is essential to meet statutory requirements, and to reduce potential environmental problems. Site management procedures should include odour control, the elimination of litter and the implementation of certain monitoring procedures (discussed below). The importance of public relations should not be overlooked as maintaining the confidence of the local community is critical to both on-going schemes and any proposed future use of domestic refuse as an infill material for seawall improvement.

8.2.4 Access and Traffic

Any proposal for refuse seawalls will require a consideration of the implications for local roads, farm tracks and private roads and footpaths. The impact of the transportation of large quantities of refuse to the disposal site should include, for example, an evaluation of the provision of temporary rights of way, the need for access across private land, and the environmental effects of the construction of new roads or increased use of existing ones. The transporting of refuse to the study site by barge should also be considered, although in many instances this may not prove to be an economically viable option.

Vehicles to be used in the landfilling operation may require modification for work on seawalls to take account of the slope angles and the proximity of water bodies.

8.2.5 Site Afteruse

The angle of the rear face of the bank, the required depths of topsoil and subsoil, and vegetation cover are among the engineering design criteria which will depend upon the proposed site afteruse. The requirements for agriculture will, for example, be markedly different from those of recreation and amenity use and the proposed afteruse of the site should therefore be determined at an early stage in the planning process.

8.2.6 Vegetation, Landscape and Nature Conservation

The potential impact of refuse seawalls on both landscape and nature conservation requires careful consideration, particularly in open riverine environments such as the Essex Marshes where such structures are especially noticeable.

Developments in or affecting designated sites of landscape, archeological or nature conservation interest should generally be avoided. The careful selection of vegetation species for planting can, however, lead to environmental benefits in terms of both habitat creation and a reduction in visual intrusion. Establishing vegetation cover is also of critical importance for engineering reasons as plant roots bind and stabilise the soil and leaf cover provides further protection against erosion.

8.3 ENGINEERING CONSIDERATIONS

8.3.1 Scheme Responsibilities

Responsibility for both overall project management and individual scheme components such as improvements to the front line defence should be clearly defined and agreed at the outset of any proposed refuse seawall.

8.3.2 Site Selection Criteria

The following criteria should apply to the selection of potential sites for refuse seawalls.

(a) To ensure economic viability, a refuse seawall requires a minimum annual supply of 50,000 tonnes of domestic, commercial or trade waste (defined in Section 3.4). This supply will usually need to be available both within a 20 mile (32km) maximum radius of the site and for a minimum of two years. Furthermore, an adequate proportion of this refuse must be inert material for use as interlayer sealing.

(b) From the NRA viewpoint, refuse seawalls may be considered as an opportunity to improve a seawall for which conventional improvements cannot be justified in economic terms.

(c) Any proposed refuse seawall site will require a waste disposal licence. It is recommended that planning permission should also be applied for, and an Environmental Assessment undertaken for each proposed scheme.

(d) The agreement and co-operation of the appropriate landowner(s) is an essential pre-requisite of any proposed refuse seawall works. Such co-operation will ensure not only the availability of land but also the provision of access to the site. Access requirements are likely to be long-term because of the lengthy post-completion monitoring period.

(e) The existing drainage pattern at a proposed site should be amenable to modification should this be required as the refuse fill must be isolated from all exogenous water sources.

(f) The preferred location for a refuse seawall scheme is away from both residential area and environmentally sensitive sites. Even a well managed site is likely to experience occasional problems with litter, odour, noise, traffic and possibly hazard. An isolated location should generate fewer complaints, and potential damage to ecologically important sites is also likely to decrease with increasing distance from the refuse seawall.

(g) The design of North/South orientated refuse seawalls should recognise the additional problem of accelerated rates of refuse breakdown brought about by increased thermal gain.

(h) Any seawall site selected for improvement using refuse fill should ultimately be capable of being returned to its original land-use. In many cases this will involve agricultural production and, in others, provision for nature conservation, recreation and amenity use. Each will have different implications for scheme design so early consideration is essential.

(i) Existing services crossing the site will need to be investigated as their accommodation will be a requirement of the design process.

(j) The existing strata at the site must be suitable to contain leachate.

(k) The width of the proposed site must be sufficient to allow manoeuvering of the rubbish freighters.

(l) Liaising with local landowners and residents to minimise disruption and forestall possible complaints.

8.3.3 Design Considerations

The essential design philosophy of a refuse fill seawall is to isolate and contain the refuse fill, thereby reducing the rate of production of potentially harmful breakdown products. Where total isolation is seen as either impracticable, or unachievable, then specific measures are to be taken to safety deal with leachate or gaseous products.

8.3.4 Site Supervision

The construction of the refuse seawall scheme must be supervised in the same way as any other comparable civil engineering work. The level of supervision must be set to ensure that engineering design objectives are actually achieved, and that the sensitive environmental factors are given full consideration.

8.4 MONITORING REQUIREMENTS

8.4.1 Chemical and Biological Monitoring Programme

It is essential that the landfill operator, the Waste Disposal Authority (if different) and the NRA agree upon a comprehensive biological and chemical monitoring programme at the site investigation phase of the project. Monitoring should commence as the first stage of site preparation and, as leachate production will continue for 15 or more years after landfilling has been completed, will continue as a long-term operation.

8.4.2 Monitoring at Sites of Nature Conservation Interest

Long-term monitoring should also be undertaken as part of the aftercare programme to provide data on the success of restoration provisions. This is especially important in sites of designated nature conservation interest where rare or locally important species may need to be protected.

8.4.3 Responsibility for Monitoring

All biological and chemical monitoring should be undertaken by suitably qualified and independent bodies. The contractor, for example, should not have responsibility for any site monitoring.

8.4.4 Engineering Monitoring and Maintenance

In addition to biological and chemical monitoring, regular monitoring is required to detect any settlement or movement of the refuse fill which could consequently endanger the integrity of the sea defence.

GLOSSARY

A

AFTERCARE - The maintenance work needed to ensure that a restored landfill site does not produce environmental problems.

AFTERUSE - The use to which a landfill site is put following its restoration.

ATTENUATION - The decrease in concentration of chemical species present in a liquid, e.g. the decrease in concentration of pollutants in liquid seeping from the foot of a landfill as a result of its passage through the soil.

B

BACTERIA - Single-cell micro-organisms which multiply by fission. Aerobic bacteria need oxygen for growth. Anaerobic bacteria grow in an oxygen deficient environment. Other bacteria are typified according to the predominant reaction involved e.g. acetogenic bacteria which break down organic matter to produce acetic acid, methanogenic bacteria form methane from the fatty acids produced by acetogenic and other bacteria.

BEARING CAPACITY- The maximum safe load which the surface of a landfill can support.

BIOACCUMULATION- Accumulation of (usually) toxic materials within the tissues of living organisms and not readily excreted by them; thus affording their concentration in for example, food chains.

BIODEGRADATION - The breakdown of material by the action of micro-organisms.

BOD (BIOCHEMICAL OXYGEN DEMAND) _ A measure of the amount of material present in water which can be readily oxidised by micro-organisms and is thus a measure of the power of that material to take up the oxygen in water supplies.

BULK DENSITY - The density of a material expressed as the ratio of unit mass to unit volume, including voids.

C

CAPPING - The covering of a landfill with impervious material to inhibit penetration by liquids.

CARBOXYLIC ACID - An organic compound containing one or more units of the acid group - COOH.

CELLULOSE - Organic material present in wood, cotton and other fibrous materials.

COD (CHEMICAL OXYGEN DEMAND) - A measure of the total amount of chemically oxidisable material present in liquid.

COMPACTING - Increasing the density of solid waste in landfills by the repeated passage of heavy machinery over its surface. Also refers to baling machines and stationary compactors for use in compacting solid waste into containers.

CONTAINMENT-SITE Landfill site where the rate of release of leachate into the environment is extremely low. Polluting components in wastes are retained within such landfills for sufficient time to allow biodegradation and attenuation processes to have occurred; thus preventing the escape of polluting species at unacceptable concentration.

CONTAMINATION - Contamination is the addition, or the result of the addition, or presence of a material or materials to, or in, another substance to such a degree as to render it unfit for its intended purpose, or unacceptably polluted.

CONTAMINATION PLUME - The area of contaminated ground water below (and usually down gradient of) a landfill.

CONTROLLED WASTE - This includes household, industrial and commercial wastes.

D

DECOMPOSITION - Breakdown of matter into more simple molecules. Decomposition may be caused by physical, chemical or micro-biological action

E.

EVAPOTRANSPIRATION The total water transferred to the atmosphere by evaporation from the soil surface and transpiration by plants.

EXOGENOUS - From outside, i.e. the penetration of precipitation, groundwater or surface runoff into the refuse bank.

G

GENERAL DEVELOPMENT ORDER 1988 - This order specifies 30 classes of development which may be undertaken upon land without the permission of the local authority or Secretary of State. This type of permission is called a general planning permission

GENERAL PERMISSION		A general planning permission is provided through the GDO for developments which can go ahead without the permission of the local planning authority or Secretary of State.
GROUND COVER	-	Plants grown to prevent or reduce soil erosion.

L

LANDFORMING	-	The building up of land into new hills, mounds or banks.
LANDFILL	-	The subsurface deposit of waste in such a way that pollution or harm to the environment is prevented and, through restoration, to provide land which may be used for another purpose. "Controlled landfill" - is a disposal practice where wastes are deposited in an orderly planned manner at a site licensed under the Control of Pollution Act 1974.
LANDFILL GAS	-	A by-product from the digestion by anaerobic bacteria of putrescible matter present in waste deposited on landfill sites. The gas is predominantly methane (65%) together with carbon dioxide (35%) and trace concentrations of a range of vapours and gases.
LEACHATE	-	Liquid which seeps through a landfill, and by so doing extracts substances from the deposited waste. Leachate recirculation - the practice of returning leachate to the upper layers of a landfill, from which it has been abstracted, usually by direct spraying on to its surface.
LEACHING	-	The process of extracting substances from a material by contacting it with a liquid.
LITTER	-	The haphazard distribution of waste on land. At landfill sites this is usually the light, windblown, fraction in household waste such as paper and plastic which escapes before the waste is compacted and covered.
LITTER SCREEN	-	A moveable screen used on landfill sites to catch litter and prevent its escape from the site.

M

MACROPHYTE	-	A large plant, especially of aquatic forms.
METHANE	-	CH_4, a colourless, odourless, flammable gas, formed during the anaerobic decomposition of putrescible matter. It forms explosive mixture in the range 5-15% methane in air.

MICROBE MICRO-ORGANSIM - Small organisms, usually single cells which normally are only visible under a microscope. They include algae, bacteria and fungi. See also BACTERIA.

MOISTURE CONTENT Weight of moisture (usually water) contained in a sample of waste or soil. Usually determined by drying the sample at 105°C to constant weight.

MONITORING - A continuous or regular periodic check to determine the environmental impact of landfill operations to ensure compliance with disposal licence conditions and other statutory environmental safety requirements (see Section 9(a) and (b of the Control of Pollution Act 1974).

O

OUTLINE PLANNING PERMISSION - The purpose in allowing such an application to be made is that it gives a prospective developer the opportunity to find out at an early stage, and before he has incurred substantial cost, whether or not a proposal is likely to be approved by the local planning authority. In the case of landfill proposal and other large developments, outline planning permission is not permitted because the small amount of detail required by an outline application would be too insufficient to make a decision.

P

PHYTOPLANKTON - Planktonic plant life; typically comprising suspended microscopic algal cells .

POLLUTION, POLLUTANT - The addition of materials or energy to an existing environmental system to the extent that undesirable changes are produced directly or indirectly in that system. A pollutant is a material or type of energy whose introduction into an environmental system leads to pollution.

PUTRESCIBLE - Readily able to be decomposed by bacterial action. Offensive odours usually occur as by-products of a decomposition.

R

RESOLUTIONS - A formal expression of proposal given by a legislative body, usually an authority who wants to carry out development on its own land.

S

SECTION 52 AGREEMENT - Section 52 of the TCPA provides a power for the local planning authority to enter into an agreement with any person interested in land in their area. Its purpose is to restrict or regulating the development or use of the land, either permanently or during such a period as may be prescribed by the agreement. The agreement may contain such incidental and consequential provisions (including provisions of a financial character) as appear to the local planning authority to be necessary or expedient for the purposes of the agreement.

T

TOC - Total Organic Carbon (TOC) is a measure of the amount of elemental and/or combined carbon present in the 'organic chemical' fraction of that material.

TOPSOIL - The biologically active surface layer of soil which provides a medium for the cultivation of plants

TOXIC(TOXICITY) - A substance or material which when taken in produces a detrimental effect on human, animal or plant life.

W

WATERBALANCE - The net volume of water leaving or entering a landform dependant on inputs, outputs, and stores associated with it.

N.B. Some definitions are abstracted from DoE (1988)

APPENDIX 1

Local Government Act 1985
Food and Environment Protection Act 1985
Energy Act 1983
Litter Act 1983
Local Government (Miscellaneous Provisions)Act 1982
Oil and Gas Enterprise Act 1982
Town and Country Planning (Minerals)Act 1981
Wildlife and Countryside Act 1981-1985)
Local Government Planning and Land Act 1980
Highways Act 1980
Water (Scotland) Act 1980
Refuse Disposal (Amenity) Act 1970
Reservoir Act 1975
Road Traffic Act 1974
Housing Act 1974
Dumping at Sea Act 1974
Heavy Commercial Vehicles (Controls and Regulations) Act 1973
Supply of Goods (Implied Terms) Act 1973
Water Act 1973
Weeds Act 1973
Gas Act 1972
Gas Safety Regulations 1972
Defective Premises Act 1972
Road Traffic Act 1972
Dangerous Litter Act 1971
Oil in Navigable Waters Act 1971
Public Health (Recurring Nuisances) Act 1969
Mines and Quarries (Tips) Act 1969
Clean Air Act 1968
Countryside Act 1968 (1981 and 1985)
Trade Descriptions Act 1968
Farm and Gardens Chemicals Act 1967
Road Traffic Regulations Act 1967
Rivers (Prevention of Pollution (Scotland) Act 1965
Airport Authorities Act 1965
Scrap Metal Dealers Act 1964
Water Resources Act 1963
London Government Act 1963
Pipelines Act 1962
Public Health Act 1961
Rivers (Prevention of Pollution)Act 1961
Factories Act 1961
Noise Abatement Act 1960
Clean Rivers (Estuaries and Tidal Waters)Act 1960
Radioactive Substances Act 1960
Occupiers Liability Act 1957
Clean Air Act 1956 (1968)
Mines and Quarries Act 1954
Agriculture (Poisonous Substances) Act 1952
Public Health (Drainage of Trade Premises) Act 1937
Petroleum (Consolidation) Act 1928
Alkali etc Works Regulation Act 1906

In addition there are a number of Local Acts whose provisions may impinge on landfills in the areas to which they apply.

REFUSE REFERENCES

Anon.	Landfill Sites - What Goes in Must Come Out. The Surveyor 10.7.86
Anon.	Building on Marginal and Derelict Land ICE Conference, Glasgow (1986)
Anglian Water	Biological Surveillance of the Effect of Seawall Reconstruction with Domestic Refuse on the Naturalised Flora and Fauna Contained in the Associated Borrow Ditches. Essex Rivers Division Progress Reports 1-8 (1979-81)
Bailey G. and Hawkins R.	The Future for Rubbish : Waste Management Options for the Environment Reviewed (1983)
Bing C. Yen and Scanlon B.	Sanitary Landfill Settlement Rates. Journal of the Geotechnical Engineering Division pp.475.87 May (1975)
Berridge Environmental Laboratories Ltd.	Hadleigh Seawall Project, Report No. 6674, Section I,II and III Appendices 1-8 (1988)
Castle K.	The Recyclers Guide to Greater London (1986)
DoE	Refuse Disposal : Report of the Working Party on Refuse Disposal (1971)
DoE	Pollution of Water by Tipped Refuse : Report of the Technical Committee on the Experimental Disposal of House Refuse in Wet and Dry Pits : HMSO (1970)
DoE	Landfilling Wastes : A Technical Memorandum for the Disposal of Wastes in Landfill Sites. DoE Waste Management Paper No. 26 (1988)
Dumble J. and Street A.	Above Ground Landfill : The Engineered Approach Paper to IWEM Conference on Waste Management, September (1989)
Environmental Data Services Limited	Report 180 (January 1990)
Environmental & Industry Research Unit (EIRU)	Chemical, Microbiological and Vegetation Survey of the Seawall, Hadleigh Marsh 1987-1988. A Rpeort to Essex County Council Project No. 204.34
Fleming G.	Recycling Marginal and Derelict Land, Institute of Civil Engineers (1990)
Guswa J., Lyman W., Donigan A., Lo T., Shanahan E.	Groundwater Contamination and Emergency Response Guide (1984)

Harrison R.M. — Pollution : Causes, Effects, Control. The Royal Society of Chemistry Special Publication No. 44 (1983)

Hunter Blair A. — Hydrogeological Factors in Groundwater Pollution pp. 30-45 From Groundwater Pollution In Europe. Proceedings of a Conference Organised by the Water Research Association, September (1972)

Johnson D. and Urie D. — Landfill Caps : Long Term Investments in Need of Attention. Waste Management and Research, Volume 3 pp. 143-148 (1985)

Mann P. — Report on the Use of Domestic Refuse in the Raising of Sea Walls at Deal Hall and Hadleigh Marsh, Essex and the Biological and Chemical Surveillance of the Associated Borrow Ditches. (December 1984)

Merz R. and — Landfill Settlement Rates. Public Works pp. 103-107, Volume 93, No. 9 September (1962)

Newbold C., Honnor J. and Buckley K. — Nature Conservation and the Management of Drainage Channels. NCC (1989)

Pavoni J., Heer J. and Hagerty D. — Handbook of Solid Waste Disposal. Materials and Energy Recovery (1975)

Reeds J. — EC Move Forces Landfill Pollution Check. The Surveyor 30.11.89

Robinson H. and Maris P. — Leachate from Domestic Wastes : Generation Composition and Treatment - A Review. Water Research Centre Technical Report TR108 March (1979)

Sargunan A. and Rajamanik K. — Foundation Problems of Waste Disposal Fills in Madras. In Building on Marginal and Derelict Land. (Authors unknown) (1986)

Schoon N. — Hill of Rubbish Could Solve Waste Problem, Independent 20.1.89

Sowers G. — Settlement of Waste Disposal Fills, pp. 207-210 (1973)

Sowers G. — Foundation Problems in Sanitary Landfills. Journal of Sanitary Engineering Division. Proceedings of the American Society of Civil Engineers pp. 103-117. February (1968)

Welsh J.P. — Dynamic Deep Compaction of Sanitary Landfill to Support Superhighways. Proceedings of 8th International Conference on Soil Mechanics and Foundation Engineering, Helsinki (1983)

Wilson D. — Long-Term Planning for Solid Waste Management. Waste Management and Research, Volume 3 pp. 203-316 (1985)

LEGAL REFERENCES

The Control of Pollution Act 1974 : Journal of General Acts 1974

DOE Circular 27/87 "Nature Conservation"

DOE Circular 15/88 "Environmental Assessment"

Environmental Protection Bill 1989 : HMSO

The General Development Order 1988 : SI No. 1813

The Land Drainage Improvement Works (Assessment of Environmental Effects) Regulations 1988 : SI No. 1217

Property and Compensation Reports, June 5 and 17 1985

Town and County Planning Act 1971 : Butterworths Planning Law Handbook

The Town and County Planning (Assessment of Environmental Effects) Regulations 1988 : SI No. 1199

Water Act 1989 : HMSO