Sub (70) office

Nevitt Lusk Action Group

Submission in objection to the application of Fingal County Council for Planning permission and a waste licence in Nevitt Lusk.
EPA Waste Licence Application W 0231-01

By John Shortt for Nevitt Lusk Action Group - 2nd January 2007

We hereby object to the above subject application on the following grounds and call on An Bord Pleanala/EPA to reject Fingal County Council application.

Environmental Protection Agency
-5 JAN 2007

Dear Sirs

Further to letter of December 14, 2006 from An Bord Pleanala requesting further submissions, since the completion of the oral hearing significant information has come to our attention and as you have accepted a subsequent submission from Fingal County Council/Department of the Environment Heritage and Local Government, in the interest of justice we know wish to make the following submissions for consideration in your review process.

As many of the issues we wish to have considered relate to both planning and environmental matters and due to the inter-relationship of these topics we deem it necessary that both the EPA and An Bord Pleanala be jointly addressed.

We hereby object to the above subject application on the following grounds and call on An Bord Pleanala/EPA to reject Fingal County Council application.

<u>Inadequate EIS.</u>

As part of the EPA prescribed guidelines Fingal County Council must carry out an EIA and publish the results in an EIS. One of the principal's of this process is to allow those opposed to the application to review the analysis and data contained in the EIS and make their objections to the EPA and An Bord Pleanala during the statutory reviews. Fingal County Council were not time constrained in the preparation of the EIS.

They have a statutory obligation to present an assessment of the likely impacts of the proposed development (as outlined under section 3.2.5 of the EPA guidelines on the information to be contained in Environmental Impact Statements dated March 2002). This guideline is to ensure that the data and comprehension of the investigation is such that 'ALL POTENTIAL' risks to the environment from their proposed development is adequately investigated, assessed and reported on in their application. **Provision for the prevention and control of abnormal operations (accidents) must be regarded as reasonable and prudent.**

It is clearly not meant to be an iterative process of the public having to engage 'Expert' Consultants to interrogate the EIS or indeed carry out their own investigations and for Fingal County Council to produce 'New Data' during the course of an oral hearing when if they had correctly carried out their investigations and honestly reported the data in the EIS an informed debate could have taken place during the Bord Pleanala oral hearing.

The introduction of 'New Data', Maladministration and witnesses for Fingal County Council misleading the inquiry clearly put the public at a distinct disadvantage during the hearing and completely undermined the principal that the EIS contained a fair and accurate representation of the facts. The EIS as issued prior to the Oral hearing has been found to be based on factual errors, negligent in failing to comply with the statutory obligations of an EIS and significant omissions on matters highly relevant to the competence and adequacy of the EIS as demonstrated later in this document. The fundamental of an EIS is that it is comprehensive in its treatment of the subject matter, objective in its approach and meets the requirement that it alerts the decision maker and members of the public to the effect of the activity on the environment and the consequences to the community inherent in the carrying out of the activity. It must meet the standards imposed by the regulations. The new evidence we are presenting clearly shows that significant adverse environmental effects would result if decisions were based on the EIS as reviewed in the oral hearing.

On this basis we call on An Bord Pleanala/EPA to reject the Fingal County Council application and restore credibility to the process of which An Bord Pleanala/EPA is the custodian.

<u>Failure to Identify and Assess All Likely Significant Impacts</u>.

<u>Background</u>

The EPA document "Guidelines on the Information to be contained in Environmental Impact Statements", sets out in section 3.2.5 the **statutory requirement for the applicant to present an assessment of the likely impacts of the proposed development**.

Whilst probable or likely impacts must be addressed, **risk assessments** of abnormal operations and accidents must be carried out "**where the worst case impacts pose significant threats to the environment and/or human health**", based on the likelihood of their occurrence.

The UK Environment Agency " Guidance on Assessment of Risks from Landfill Sites" (GARLS)(External Consultation, Version 1, May 2004) is presented in appendix 1 as a reference document that represents Best

Practice and Best Available Technology specifically related to landfill sites, and will be quoted frequently in this submission.

A Brief Summary of the GARLS Methodology

Risk assessment subjects relating to landfill sites are identified by GARLS

- Landfill Gas
- Hydrogeological
- Stability
- Dust
- Accidents

This section of the submission will therefore confine itself to these landfill related subjects.

GARLS proposes the following approach to risk assessment, i.e. "the use of a tiered approach, source-pathway- receptor methodology, and the use of environmental benchmarks to define what may represent an acceptable impact". The tiered approach is structured as follows

- Tier 1 – Risk Screening
- Tier 2 – Simple Risk Assessment
- Tier 3 – Complex Risk Assessment

Risk Screening

- Identifies complete source pathway receptor linkages
- Screens out insignificant risks
- Prioritises the risks and receptors
- Provides an initial assessment of the impacts at a receptor

Simple Risk Assessments are recommended when

- the risk screening is insufficient to make an informed decision on the risks posed by the site

"In reality most landfill sites will require a Simple Risk Assessment for further investigation of priority risks identified during the Risk Screening process".

Complex Risk Assessments should be carried out when

- A Simple Risk Assessment indicates an unacceptable level of risk, or
- There is sufficient uncertainty regarding the source -pathway-receptor linkages and the use of conservative assumptions does not provide a basis for a decision, or
- The site setting is sufficiently sensitive to warrant detailed assessment and a high level of confidence is required to ensure that the site does not pose any significant pollution risk.

In it's recommended methodology the GARLS document does not differ, except in terminology, with the EPA Guidelines document, however it is specifically designed to be applied to landfills.

GARLS – Sources, Pathways, and Receptors

GARLS has identified the potential sources of landfill pollution as

- Landfill gas
- **Accidents**
- Hydrogeological risks /Leachate
- Dust or particulate matter
- **Stability**

And the receptors as

- Humans
- Flora
- Fauna
- Air
- Water
- Land
- Buildings

"A number of subdivisions should be considered ---"

- **Domestic dwellings**
- Hospitals
- **Schools**
- Sensitive habitat
- **Commercial and industrial premises**
- **Public footpaths**
- **Major highways and minor roads**
- **Playing fields**
- Open spaces, parks and **farmland**
- Allotments
- On site vegetation
- Air quality management areas
- Groundwater (**including potential use of currently unused resources)**
- Groundwater fed discharges, springs, and river baseflow
- Surface water
- Public water sources and other licensed water abstractions (including source protection zones)
- **Licence exempt private water supplies**

Pathways can be airborne, surface, or subsurface.

Potential Sources and Receptors of pollution which have not been adequately addressed or not addressed at all in the EIS are highlighted in the above lists.

<u>A Simple Risk Assessment of Slope Stability</u>

Slope failure of landfills, even those constructed using the latest engineering techniques, are catastrophic events with potentially fatal consequences. (See examples in Appendix 2).

GARLS 3.14 Assessment of Stability Risk states that
"The level of complexity of the stability assessment will depend mainly upon the complexity of the natural geology and the design structures within the site, rather than the sensitivity of the setting. It is necessary for the operator to provide sufficient confidence that stability and integrity of the structures are assured. For simple slopes without a complex geology there may be little need for detailed assessment whereas steep slopes will require much more consideration. **For example Risk Screening with the provision of evidence of an unsaturated zone beneath the site may be sufficient to screen out the need to assess basal heave.**_The principle is that the assessment must provide sufficient confidence that stability is assured and the integrity of the structures within the site will be maintained."

- **The soil beneath the Nevitt site is within the saturated zone.**
- The subsoil is characterized by a top layer of saturated clay underlain by gavels to a depth of ten meters.
- Some trial boreholes indicate artesian conditions.
- Recirculaton of leachate is envisaged.

There is a risk of basal heave / excessive pore pressures, giving rise to loss of shear strength, most probably along the base liner interfaces, and seepage / piping, through underlying and perched gravels, giving rise to loss of toe pressure (see article and example in appendix 3). Adequate ground water control measures would need to be constructed. This may not be possible due to complex hydrogeological conditions, or practical, due to excessive cost.

Sources

- Slippage of a large quantity of waste, (the total facility is for approx. 10 million tons). A large slippage could reasonably be expected to be in the region of one million tons based on international examples of such events. (See Appendix 3 - Bogata).
- Destruction of cell bottom liner resulting in escape of large quantities of leachate to the surrounding environment.
- Destruction of leachate extraction and collection system leading to elevated heads of leachate in unaffected cells with consequential further slippages occurring and/or overflow of leachate in these cells i.e. a cascade effect.
- Destruction of gas collection system leading to escaping toxic gases and risk of explosion.

Pathways

Waste

- Down gradient southwards to the reception area <100metres.
- Down gradient eastwards to the MI (250metres), domestic dwellings (400) metres), primary school playing field

(400metres). NI (700metres), Hedgestown Primary School (800)metres)

Leachate

- Into the local streams and Cordoff River system flowing into Rogerstown Estuary.
- Into the groundwater downgradient to the northeast, east, southeast, south and southwest of the site.

Landfill gas

- Horizontally and vertically through affected waste cells and surrounding soils.
- Airbourne depending on climatic conditions, wind speed and direction.

Receptors

Human

- Site staff and members of the public using the reception area.
- Vehicles using the MI motorway.
- Residents east of the MI.
- Teachers and children using the school playing field
- Pedestrians, cyclists and motor vehicles using the NI.
- Teachers and children at Hedgestown Primary School.
- The MI Business Park at Walshestown Interchange

Environmental

- The Locally Important Moderately Productive Aquifer water resource.
- Horticultural wells down gradient of the landfill.
- The Corduff river.
- Rogerstown Estuary Widlife Reserve
- Horticultural fields and crops

Archaeological

- The extensive and nationally important archaeological feature discovered by geophysics within the southeast segment of the landfill enclosure.

This feature is the only known "Neimeadh" ever to be discovered in Ireland, and appears to be a Very Early Christian Eccesiastical enclosure. The placename Nevitt however has led Irelands foremost experts to the conclusion that the site is probably of Pre-Christian origin and has been described to an Bord Pleanala by Prof. Barry Raftery, UCD, Dr. Richard Warner, Ulster Museum, Dr. Andy Halpin, National Museum of Ireland, Mr. Donal MacGiolla Easpaig, Placenames Branch, and others as important and unique.

(See Appendix 4,4a, copy of communication to all objectors to the development from An Bord Pleanala dated 14 December 2006, with attached letter to Fingal County Council from the Dept. of the Environment, Heritage and Local Government, dated 27 November 2006)

Infrastructural
- The M1 Motorway
- The major natural gas pipeline which runs alongside the M1

Unacceptable risk to Humans

It is clear from this Simple Risk Assessment that the potential fatal consequences of Slope Failure during the construction, operation or aftercare of the proposed landfill at this site, warranted a Complex Risk Assessment of Slope Stability in the EIS, which could have been the subject of discussion and debate at the An Bord Pleanala Oral Hearing, and the subject of submissions to the EPA. This has not been done to a degree, which could be deemed Best Practice or Best Available Technology.

Consequently the public have been deprived of their statutory rights, and could be placed at risk if this facility were to proceed. Therefore in the interests of justice to the public, and public safety, we call on the EPA and An Bord Pleanala to reject this application on the grounds of this omission.

Unacceptable risk to the Environment

The breakdown of the leachate and landfill gas protection systems could lead to catastrophic environmental damage some such as horticultural wells would have to be closed down indefinitely. This application fails to address the environmental consequences of slope failure and should therefore be rejected on these grounds.

Unacceptable risk to Important Archaeology

It is also clear that a slope failure (or other form of accident such as leachate escape or gas explosion) in the vicinity of the archaeological site could result in its destruction or damage. On the basis of the sensitivity of the archaeology to such accidental destruction or damage we call on the EPA and An Bord Pleanala to reject this application.

Unacceptable risk to nationally important infrastructure

International experience has shown that slope failure even in modern engineered landfill facilities can result in waste travelling in excess of one kilometre from the landfill. The M1 motorway and main gas line are only 250 metres from the landfill boundary and are within the predicted pathway of a waste collapse. Damage and consequential closure of one or both of these nationally important facilities is an unacceptable risk. The failure of the EIS to address this eventuality is a justifiable ground for refusal of this application.

Risk Assessment of Accidents

The GARLS document makes the following statement at page23,

3.2.3 Planning Applications

"Where the planning application and the PPC permit application are being conducted in parallel then the **accidents, hydrogeological, landfill gas, particulate matter, and stability risk assessments** produced for the permit application can be used by the Agency to consider its response to the planning application"

We have already discussed the absence of any attempt at a comprehensive **Stability Risk Assessment** in the EIS. **Similarly no Accident Risk Assessment has been presented.**

GARLS page 62, " 7.4.2. PPC Permits", states that

"The sensitivity of the location will be particularly crucial when considering the consequences of failures that may occur at a landfill. The main use of the **accident scenarios** will be in determining whether the proposed site is so sensitive that a permit should not be issued, and for determining the acceptability of risk management measures, monitoring, and contingency planning. Where the consequences of an accident are serious then the risk management measures to prevent its occurrence must be correspondingly more robust. **In some cases, the consequences of an accident may be so significant that a serious risk is posed notwithstanding the proposed risk management measures, and this would make the location unsuitable for a landfill."**

The potential sources of accidents to the environment at a landfill are identified in the GARLS document at 4.1.4 "Source Term – Accidents", and are listed as **release of leachate, release of landfill gas, fire and explosion, and escape of waste**. (See attached Appendix 5 "Landfill Fires Guidance Document").

Any of the above accident scenarios at the proposed landfill have potentially lethal consequences. For example, a risk assessment of fire and explosion would reveal the possibility of lethal traffic accidents and /or long term closure of the M1. Yet no risk assessment for accidents is attempted in the EIS. **Fingal County Council by failing to adequately address or by**

omitting these important issues have failed in their statutory duty. Consequently we request the EPA and An Bord Pleanala to reject this application, and, on the basis of the above Slope Stability Risk Assessment to declare this site unsuitable for a landfill.

Illegal Landfill Site within site.

The farm holding original owned by Mr Jim Monks (Which is now in the ownership of Fingal County Council, acquired in 2006) lies within the proposed land take for the Landfill site.

It is an integral part of the proposed site and the EIS should have contained the comprehensive results of an Environmental Risk Assessment (Following an internationally recognised code of practice for site investigations e.g. British Standard) for this unregulated Waste Disposal Site.

As this Assessment was not carried out Fingal County Council are clearly in breach of ministerial Direction (WIR04/05).

EPA 'Code Of Practice' Environmental Risk assessment for Unregulated waste Disposal Sites (Oct 2006, page 10) states the following.

In relation to illegal sites that came into existence since a waste licensing regime was put in place, the policy direction states that certain sites should at all times be remediated such as

"Lands proximate to existing or planned residential development or educational facilities, in which case remediation shall require the removal, in the shortest practicable time, of all waste except where it is shown that an alternative solution provides greater protection to the environment and the health of the local population".

As the unregulated waste site is within 250 metres of the local school playground and six homes, it is imperative that all waste illegally disposed of on the site is removed prior to embarking on the risk assessment process.

As Fingal County Council failed to meet their statutory obligation of keeping a register of all wells with an extraction rate greater than 25 cubic metres (See attached letter exhibit 6) the EIS failed to identify all wells south and east of the proposed landfill site and no Source-Pathway-Receptor (S-P-R) conceptual model for environment management was presented. To have an illegal landfill site sitting within Europe's largest dump would create another variable that would make it impossible to identify the sources of pollution or implement mitigation measures in such an event. The EIS review of the unregulated site is totally inadequate and on this basis alone we call on the

EPA and An Bord Pleanala to reject the Fingal County Council application and instruct them to immediately remediate this site.

Health Impact assessment.

The EIS health impact assessment was proven to be totally unreliable and the credibility of Dr Hogan's research methodologies and presentation was proven to consist of plagiarism. The selective representation of literature reviews failed to give an accurate review of the health risks to the local community. No survey was taken of the health status; age profile of the local community and taking national demographics is insufficient. The local community actually has a high number of aged, infants and highly vulnerable people who would be severely impacted by the compulsory purchase order, consequences or living in close proximity to a landfill. As no health impact assessment was carried out on this basis alone we call on the EPA to reject the Fingal County Council application. (See attached letter exhibit 7 from Dr Anthony Staines)

Air Pollutants/Noise Pollution

As the traffic survey failed to carry out a detailed "TRIP SURVEY" of proposed movements of waste that would be coming to the site it is impossible to identify the number of trucks, haulage time or trip distances required. Therefore we cannot calculate the pollutant output or noise output resulting from the transport of waste from south, west, east and north county Dublin. In fact no comprehensive plan was presented as to how waste would be brought to the Dump. It is totally unclear whether raw waste would be brought directly to the dump or if waste would be processed at bailing stations etc. It is evident that Fingal County Council have not considered or investigated what the most suitable option is from a logistics, cost or environmental impact perspective, The EIS only identifies mitigation measures and without a detailed analysis of the volume of pollutants which will be introduced as a consequence of the dump how can you ascertain that the mitigation measures will be adequate. As no plan was presented in the EIS we cannot evaluate the risks posed by the proposed dump and on this basis alone we call on the An Bord Pleanala/EPA to reject the Fingal County Council application.

Need for site

Base upon the evidence presented (by CEWEP) at the Bord Pleanala hearing on existing/approved landfill capacity in the greater Dublin region and the national waste management policy of not developing new large scale sites we maintain there is no need for an additional dump in the greater Dublin region. Landfill has been eliminated in many countries and it is a non sustainable model which only deals with the effects of waste, our emphasis must be on avoidance and by granting a license to Fingal County Council we are making life easy for the local authorities in the short term and failing to deal with the root cause. It is imperative that we focus on sustainable models of managing waste and any decision, which goes against this principal, is fundamentally flawed and on this basis alone we call on the An Bord Pleanala/EPA to reject the Fingal County Council application.

Methane gas generated by site.

The EIS did not contain a detailed prediction of gas output, treatment process or volume of pollutants that would be emitted to the atmosphere as a result of the flaring or conversion of gas to energy. This proposed landfill is the largest in Europe and if the scale factors are not incorporated into the EIS we are unable to assess the risks posed to human health or the environment. There was no source-pathway-receptor assessment carried out on the risk from landfill gas migration This is a fundamental flaw and without the correct data or conceptual risk modelling being carried out it is impossible to make an informed decision. On this basis alone we call on the An Bord Pleanala/EPA to reject the Fingal County Council application.

Landfill site design

As no detailed site design was presented to show footprint, how they intended to maintain the 10 metres of clay cover, how they intended to reroute streams, identify portions of site that would be below the water table level and how they intended to deal with surface water or detailed capacity analysis for attenuation ponds, location or processing capability. The policy of Fingal County Council appears to be "Trust Me", it is our belief that it is their responsibility to prove that the proposed dump will not propose a threat to human health or the environment. Without a detailed plan and correct data this is a fundamental flaw of the EIS or without conceptual risk modelling being carried out it is impossible to make an informed decision. On this basis alone we call on the An Bord Pleanala/EPA to reject the Fingal County Council application.

Leachate migration.

There was no source-pathway-receptor assessment carried out on the risk from leachate migration. This is yet another fundamental flaw in the EIS. In fact the manner in which the topic was presented in the oral hearing would lead one to believe that the leachate would be totally contained in the 10-metre clay overburden. This is clearly not the fact and in our opinion was a misrepresentation of the truth. As no detailed drilling/ sampling took place in the majority of the landfill site cell footprint it is not possible to ascertain the vulnerability of the aquifer under the site.

Leachate treatment & disposal.

No detailed plan was provided showing the anticipated volume of leachate to be treated over the years of the site development or the size of treatment works required. The plan to pipe leachate over a significant distance to the local foul sewer in Lusk takes no cognisance of the fact that this pipe will have to pass over local rivers and no risk assessment or monitoring plans were presented. In fact the proposal is to transport the leachate to the Portrane waste treatment works (this is not in place and no timing for completion of this project was advised). It is therefore impossible to gauge if the correct infrastructure will be implemented and the function of the EIS is to ascertain that the correct infrastructure is being put in place to handle the leachate produced. This is a critical area and by omitting this critical data and analysis it is impossible to make an informed decision. On this basis alone we call on the An Bord Pleanala/EPA to reject the Fingal County Council application.

Hydrogeology

The GSI have designated the aquifer beneath the proposed landfill as "locally important moderately productive" and as such a potential resource for groundwater.

The EPA has identified this particular aquifer as being of exceptional potable quality.

The GSI have identified the fault line immediately to the east of the proposed landfill as being the area most likely suited in terms of sustainability and yield for the location of future Public Water Supply abstraction wells in the locality.

The IFA have stated that the aquifer is used locally as a source of water for the production and processing of more than half of Ireland's vegetable production, with an estimated annual value to the local economy of 500 million euros.

Accidental escape of large quantities of leachate from the landfill site could Have the effect of permanently polluting the groundwater down gradient of the landfill where the majority of the estimated 150 horticultural wells are located.

Please refer to the attached reports prepared subsequent to the An Bord Pleanala oral hearing by 4 eminent hydrogeological experts in which all consistently highlight the inadequacy of the hydrogeological section of the EIS and do not support the building of a Landfill site in the Nevitt.

Mott McDonald report 15th November 2006 Appendix 8
White Young Green report 23RD November 2006 Appendix 9
Kevin Cullen report 7th November 2006 Appendix 10
GSI letter of October 24th 2006 to EA Appendix 11

On this basis alone we call on An Bord Pleanala/EPA to reject the Fingal County Council application.

Archaeology

We have addressed above the importance of the Archaeology on site and its vulnerability to accidental damage. The map of the Odour Plumes predicted for at least the next 30 years extend across the main archaeology and would render it sterile for development as a tourist attraction. This is unacceptable and unprecedented and we call on the EPA to reject the application on this basis alone.

Community consultation

Consultation should be on a reasonably informed basis on both sides and not some courtly charade concerned more with the appearance of discussion and interplay than with real dialogue. I attach correspondence with Mr Gilbert Power Appendix 12 in which you can follow the trail of correspondence inadvertently addressed to our group member, which demonstrates the internal attitude of the most senior person with responsibility for Environment within Fingal County Council to the local community. Our group don't "Enjoy" spending their own personal time and finances to see our requests being treated with such frivolity and their attitude is representative of the reckless consideration we have been receiving from Fingal County Council throughout this entire process.

The unwillingness of Fingal County Council to propose any relocation plan to the families faced with CPO and eviction clearly reflects the lack of consultation.

On this basis alone we call on An Bord Pleanala/EPA to reject the Fingal County Council application.

Yours truly,

John Shortt

Composed with Nevitt-Lusk-Action group

APPENDIX 1

"Guidance on Assessment of Risks from Landfill Sites"

UK Environment Agency

ENVIRONMENT AGENCY

ENVIRONMENT AGENCY
GUIDANCE ON
ASSESSMENT OF RISKS FROM LANDFILL SITES

EXTERNAL CONSULTATION
VERSION 1.0
May 2004

Consultation Questions

Background

This guidance sets out what is required with respect to risk assessment for landfills. It is intended to provide the framework to enable landfill operators to produce a structured risk assessment that relates to the regulatory decisions that the Environment Agency must make. It does not provide all the necessary detail to undertake individual risk assessments.

The following is a summary of the main issues raised in the guidance and upon which the Agency would particularly welcome responses:

1. Scope of the document (Section 1)

The guidance covers risk assessments in respect of landfill gas, hydrogeological, stability, dust and accidents. The main emphasis of the guidance is on decision-making with respect to PPC permit applications.

Views are invited on the appropriateness of the scope of the guidance.

2. Risk Assessment Approach (Section 2)

The guidance describes the proposed approach to risk assessment. This includes the use of a tiered approach; the source pathway receptor methodology and the use of environmental benchmarks to define what may represent an acceptable impact. The Risk Screening approach adopted by the guidance involves basic scoring or ranking techniques to prioritise potential risks in relation to each other. This approach would place simple modelling and calculations primarily into the Simple Risk Assessment tier.

Views are invited on the approach to risk assessment in the guidance, in particular the approach to Risk Screening.

3. Expert Interpretation (sections 2 and 7)

The guidance stresses the need for expert interpretation. This is to ensure that any assumptions and uncertainties are clearly identified and addressed. The guidance also warns against undue reliance being placed on quantitative model results. This is to ensure that modelling is only used where the understanding of the site can support that use.

Views are invited as to the appropriateness of this emphasis and approach.

4. The Source, Pathways and Receptors (section 4)

The guidance describes the source of the risk, the pathways and the receptors with respect to each of the risk assessment subjects.

Views are invited as to how the guidance deals with the source, pathways and receptors.

5. Risk Assessment Scenarios (section 5)

The guidance considers three categories of events to describe the operations of a landfill: normal, abnormal and accidents. The guidance identifies example scenarios that can be considered in each of the risk assessment subjects.

Views are invited on this approach to categorising the potential impact of landfills through normal and abnormal occurrences and on how accidents are dealt with in the guidance. Views are invited on the example scenarios provided.

6. Reporting of Human Health Impacts (section 6)

Pollution is defined as emissions that may be harmful to human health or the quality of the environment, and the risk assessment must therefore consider the potential impact on people and the environment. The guidance gives recommendations as to how a risk assessment should be reported including the potential impact on human health

Views are invited on the reporting requirements in particular how the risk to individual receptors should be reported and how the potential human health impact should be set out.

*7. **Decision-Making (section 7)***

The guidance requires that the potential impact of the landfill is predicted for a variety of circumstances. The predicted impact is then considered together with any proposed regulatory measures and best practice operating techniques, in order to make a regulatory decision. The guidance stresses the need for expert interpretation; simple numerical pass and fail criteria cannot be used in isolation to make a decision. The Agency will make a decision based on professional judgement informed by the understanding of the landfill, the results from all the risk assessments and any consultation responses.

Views are invited on how normal, abnormal and accidents are used in the decision-making process. Views are also invited on whether the guidance provides a framework for a proportionate, consistent and transparent decision based on evidence.

Who should read this consultation?

This document will be of interest to landfill operators. It will be of particular interest to operators and consultants involved in preparing a landfill PPC permit application. It will also be of interest to those bodies who are consultees to the PPC application process or who may wish to contribute to the decision-making process.

How to respond to the consultation

Responses, requests for further copies, or queries regarding the scope or content of this paper should be made to: Jill Rooksby (Landfill Sector Coordinator), Environment Agency, Olton Court, 10 Warwick Road, Olton, Solihull, B92 7HX. email: jill.rooksby@environment-agency.gov.uk. The closing date for responses is **Friday 30th July 2004**.

Where representative groups respond to the proposals in this paper it would assist the Agency if they provided a summary of the people and the organisations that they represent. Please order your comments under the same headings as the consultation document. Responses may be made public unless confidentiality is specifically requested. All Reponses will be included in any statistical or other summary of results.

Code of Practice on written consultation

This consultation document has been produced in accordance with the Cabinet Office Code of Practice on written consultation.

The consultation criteria are:

1. Consult widely throughout the process, allowing a minimum of 12 weeks for written consultation at least once during the development of the policy.
2. Be clear about what your proposals are, who may be affected, what questions are being asked and the timescale for responses.
3. Ensure that your consultation is clear, concise and widely accessible.
4. Give feedback regarding the responses received and how the consultation process influenced the policy.
5. Monitor your department's effectiveness at consultation, including through the use of a designated consultation co-ordinator.
6. Ensure your consultation follows better regulation best practice, including carrying out a Regulatory Impact Assessment if appropriate.

Should consultees have any complaint or comment about how this consultation process is conducted they may direct them to the following person, who is outside the Agency team responsible for the document:

Mr Jack Bradley, Environment Agency Corporate Affairs, 2430 The Quadrant, Aztec West, Almondsbury, Bristol, BS32 4AQ. Telephone 01454 878786 or Email: jack.bradley@environment-agency.gov.uk

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Tel: 01454 624400 Fax: 01454 624409
Website: www.environment-agency.gov.uk

Dissemination Status
Internal: Available
External: Released for Consultation

Statement of Use
This guidance is intended for use by Agency staff in assessing submitted risk assessments. It will also be of use to landfill operators in assessing the risks from their landfill facilities and when preparing risk assessments in support of a PPC landfill permit application. It is intended to highlight the key issues to be addressed by risk assessments, and to direct readers to other detailed risk assessment guidance where that already exists.

List of Figures Tables and Boxes

1 INTRODUCTION

1.1 Background to the Guidance

Risk assessment is used in many areas of life as an aid to decision-making. It is particularly relevant to areas of environmental decision-making such as the operation of landfill sites. Landfill developments are almost always controversial and regulatory bodies such as the Environment Agency and the planning authorities have to make decisions as to whether the development is acceptable and what constraints should be imposed on the operator to manage the risks from the landfill. These decisions will be closely scrutinised by all interested parties.

In order to build and maintain public trust in the regulatory process, the Environment Agency's decision-making process should arrive at decisions that are:

- legal
- rational
- transparent
- justified
- understandable

These attributes are consistent with the "Principles of Managing Risks to the Public" established by the Government's risk improvement programme (http://www.hm-treasury.gov.uk/media//8B2AE/risk_principles_220903.pdf). This initiative was set up following a detailed review of risk management across government (Strategy Unit, 2002).

For landfill sites, risk assessment forms an essential part of the decision-making process, but it is only one part. The risk assessment does not itself provide an answer but it informs the process so that a rational and justified decision can be reached. The method of reporting is important – a structured and well documented risk assessment, where assumptions, limitations and areas of uncertainty are clearly presented provides the basis for transparent decision-making. This guidance relates to risk assessments to support decision-making in the regulation of landfill sites.

1.2 Purpose and Scope of the Guidance

This guidance document has been produced to promote the consistent application of risk assessment techniques in relation to decision-making at landfill sites. It is intended to provide the overall structure for undertaking and reporting a risk assessment for a landfill site. It should allow Agency staff to understand what is required from a submitted risk assessment. The guidance should also allow operators to understand what the required objectives and outcomes of the risk assessment process should be. This guidance does not provide all the detail needed to conduct a risk assessment for a landfill and reference must be made to other guidance on risk assessment.

Risk assessment must be used by operators to develop their design and risk management procedures for landfills. However the main emphasis of this guidance is on the production of risk assessments submitted in support of applications made to the Agency. In particular to provide guidance to operators as to the Agency's requirements for risk assessments produced in support of Pollution Prevention and Control Permit applications. Section 3 addresses PPC requirements and Section 7 provides an overview of relevant legislation.

The guidance can also be used to determine the risk assessment requirements to support the Agency's decision-making in the following areas:

- consultations on planning applications
- variation applications
- surrender applications

The main scope of the guidance is limited to five areas of risk assessment:

- Accidents and their Consequences
- Hydrogeology
- Landfill Gas
- Particulate Matter
- Stability

This guidance concentrates on the above key areas of concern specific to landfill sites. The scope of the guidance does not include a detailed consideration of "nuisance" such as litter, although the "amenity" risk assessments are dealt with briefly in section 3.1.5. For issues such as noise, reference should be made to the PPC cross-sectoral guidance (see Section 3.1.5).

The guidance indicates how impacts on human health and on habitats should be addressed. The guidance also covers how these impacts should be reported and how they guide the decision-making process.

The guidance does not deal directly with determining Best Available Techniques (BAT) for leachate and landfill gas treatment. The Agency is producing separate BAT guidance for leachate treatment. The Agency guidance on the management of landfill gas forms the basis for setting conditions in PPC permits that provide all appropriate measures to be taken against pollution, to limit emissions and impact on the environment including human health.

1.3 Additional Guidance

The main guidance that should be read in conjunction with this document is as follows:

Guidelines for Environmental Risk Assessment and Management (DETR et al., 2000);

IPPC H1 Horizontal Guidance: Environmental Assessment and Appraisal of BAT (Environment Agency 2003);

Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control and Trigger Levels (Environment Agency 2003);

Guidance on the management of landfill gas (Environment Agency, 2004);

The Stability of Landfill Lining Systems Report No 1 Literature Review (Environment Agency, 2002);

The Stability of Landfill Lining Systems Report No 2 Recommendations (Environment Agency, 2002);

Guidance on monitoring of landfill leachate, groundwater and surface water (Environment Agency, 2003);

Monitoring of Particulate Matter in Ambient Air around Waste Facilities, M17 (Environment Agency, 2003);

Guidance on Landfill Completion (Environment Agency, 2004);

Guidance on applying the Habitats Regulations to waste management facilities (Appendix 6 of the Habitats Directive Handbook (Environment Agency, 2003).

1.4 Structure of the Guidance

Section 2 introduces some of the key concepts of risk assessment including a tiered approach and discusses the different levels (tiers) of risk assessment that may be required at a landfill (Sections 2.4 to 2.7). The use of models and the iterative nature of risk assessment is discussed (Sections 2.8 to 2.9).

Sections 3.1 and 3.2 consider the risk assessment requirements for PPC permitting and planning respectively.

Section 4 considers the sources, pathways and receptors. A distinction is made between the source term for existing and new sites (Sections 4.1.1 and 4.1.2). Inert sites are considered in Section 4.1.9. Section 4.2 considers the main pathways for emissions and the issue of how much detail is needed in understanding the processes involved (section 4.2.3). Section 4.3 deals with the receptors. Section 4.4 considers the setting of environmental benchmarks against which to compare the impact of emissions. The issue of background quality is dealt with in Section 4.5.

Section 5 sets out the different categories of operations that need to be considered (Section 5.1), then looks at the scenarios that need to be addressed in the risk assessments (Sections 5.4 to 5.10).

Section 6 deals with the methods of reporting.

Section 7 considers decision-making, setting out the legislation background (Section 7.1), the assessment of impacts (Section 7.2) and regulatory decision-making (Section 7.3). This includes decisions on landfill location (Section 7.4) and the risk management measures (Section 7.5).

2 OVERVIEW OF RISK ASSESSMENT FOR LANDFILLS

2.1 Background

Risk assessment is used widely within regulation, business and finance as a management tool to aid decision-making. It involves the separate consideration of the likelihood and the consequences of an event, for the purposes of making decisions about the nature and significance of any risks, and how best to manage any unacceptable risks. It is an activity which is familiar to and performed by us all, albeit intuitively.

Risk assessment requires an understanding of the source of a hazard, the characteristics of a receptor that may be at risk from that hazard, and the means, or pathway, by which the receptor may be affected by that hazard. Risk management typically involves answers being sought to the following questions.

- What hazards are present and what are their properties?
- How might the receptors become exposed to the hazards and what is the probability and scale of exposure?
- Given exposure occurs at the above probability and magnitude, what is the probability and scale of harm?
- How significant is the risk and what are the uncertainties?
- What needs to be done to prevent, control or minimise the risks?

The Agency adopts a tiered approach to answering these questions, in accordance with good practice, which is described in its general guidance on environmental risk assessment and management (DETR et al, 2000). The tiered approach is outlined in Figure 2.1. By adopting a tiered approach, resources can be targeted where risks or uncertainties are high thus ensuring that the level of effort is proportionate and risk reduction is maximised.

Clear definition of the problem allows screening and prioritisation of risks, which allows the level of risk assessment to be matched to the needs of the problem. If the risk management decision cannot be made based on an initial Risk Screening assessment, then more detailed approaches are used, focusing on the key risks identified. The emphasis is on:

- understanding the environmental setting;
- employing simple, qualitative tools to identify and prioritise risks; and
- applying greater levels of quantified risk assessment according to need.

It is important that all risk assessments, are carried out in a robust, systematic and transparent manner.

It is important to distinguish between the terms risk and hazard. They are often used interchangeably but have distinct and separate meanings. These are defined in DETR et al., (2000) and are reproduced in Box 1 along with additional key terminology.

Box 1 – Definitions relevant to risk assessment

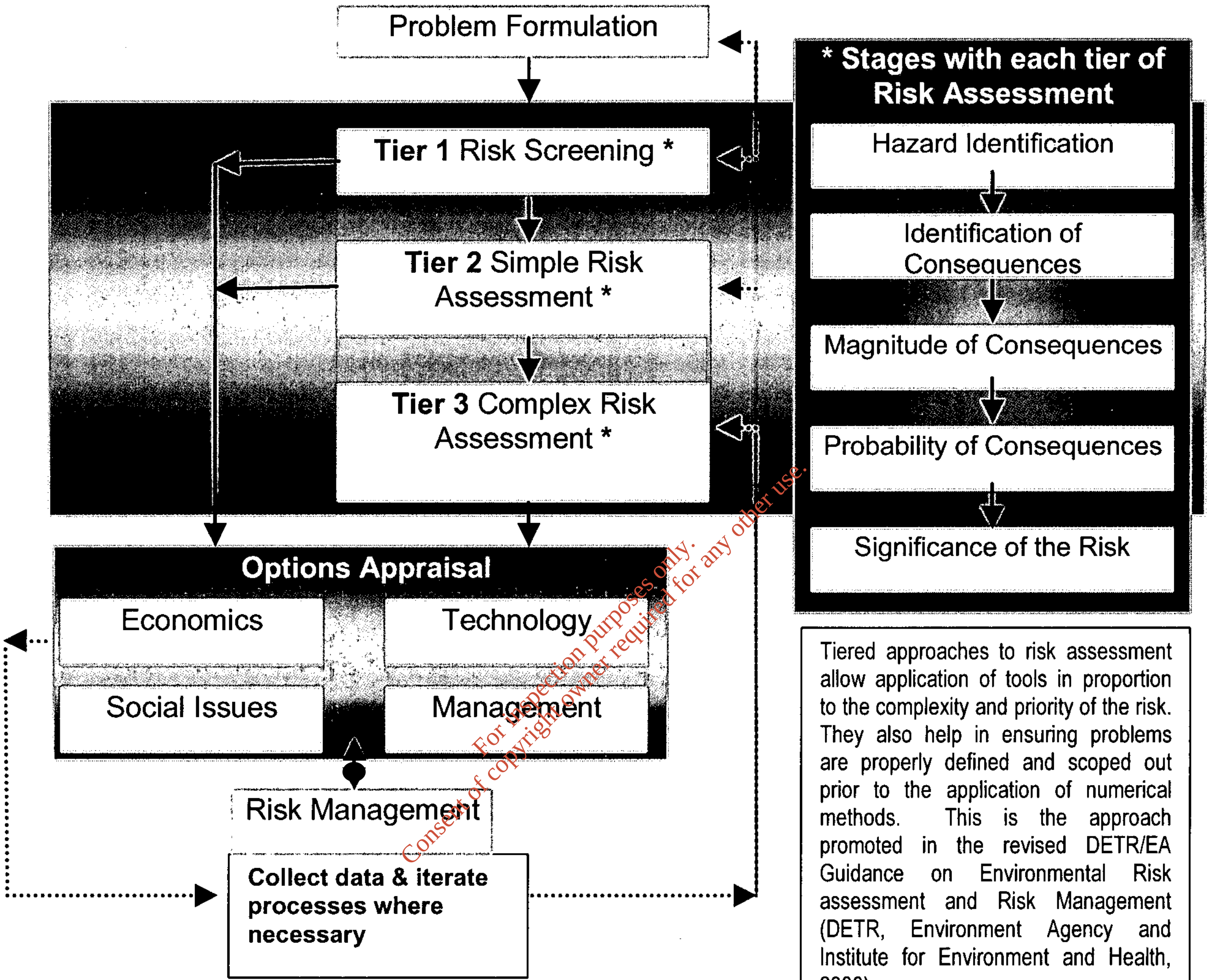
Consequences – the effects (or impacts) of a particular, situation or event. Impacts may be positive (benefits) or negative (costs or harm). Risk assessments usually focus on assessing the potential negative consequences (the harm) that may result from the realisation of the identified hazards.
Harm - the damage to a receptor that results when a hazard is realised.
Hazard - a property or situation that in particular circumstances could lead to harm .
Risk - a combination of the probability, or frequency, of occurrence of a defined hazard, and the magnitude of the consequences of the occurrence.
Risk assessment - the qualitative/quantitative estimation and characterisation of risks.
Risk management - the process of making and implementing decisions about accepting or altering risks.
Pollution - emissions as a result of human activity which may be harmful to human health or the quality of the environment, cause offence to any human senses, result in damage to material property, or impair or interfere with amenities and other legitimate uses of the environment.

Any risk assessment should be carried out at a level of complexity that is proportional to the potential environmental hazard that the site poses, the level of uncertainty, and the likelihood of risks being realised. This important principle means that the appropriate level of risk assessment should be that which is sufficient to provide confidence in the predicted impacts, in order to allow decision-making. The more sensitive the setting, the greater the level of confidence required.

The purpose of carrying out an environmental risk assessment is to inform a risk management decision; that is, to determine what risk management measures need to be taken to prevent and control the identified risks. There may be more than one way of managing the identified risks, and the decision as to which is the best option may need to be informed by a detailed options appraisal taking into account relevant factors of technology, economics, social issues and management. The Agency's H1 guidance on Environmental Assessment and Appraisal of Best Available Techniques (BAT) provides guidance on comparing different risk management methods (Environment Agency 2003a). Within this guidance, sections 7.4 and 7.5 describe the decision-making process with respect to PPC permitting.

The risk management measures, both for any particular site and for the operations taking place there, should be regarded as an integrated whole. A change to one part or element of the system, such as the design standards, or the quality and content of record keeping, or the training and competence of staff, will potentially change the effectiveness or performance of the risk management system as a whole. This means that any proposed changes to any part of a risk management system should be assessed for their effect on the overall performance of the risk management measures, to ensure that the necessary standards of environmental protection are maintained for that system and for the overall site operations.

Figure 2.1: Tiered Approach to Environmental Risk Assessment and Management (after DETR, et al 2000)



Tiered approaches to risk assessment allow application of tools in proportion to the complexity and priority of the risk. They also help in ensuring problems are properly defined and scoped out prior to the application of numerical methods. This is the approach promoted in the revised DETR/EA Guidance on Environmental Risk assessment and Risk Management (DETR, Environment Agency and Institute for Environment and Health, 2000).

2.2 The 'Source-Pathway-Receptor' Concept as the Basis for Risk Assessments

Fundamental to the good practice framework for risk assessment shown in Figure 2.1 is the source-pathway-receptor approach. For a risk to exist there must be an identified or plausible relationship between the three individual components of:

- source – i.e. the hazardous substance or material
- pathway – i.e. the mechanism by which the receptor and source can come into contact (e.g. by a hazardous event or action on site giving rise to a release of the hazardous substance or material to atmosphere or to ground)
- receptor – i.e. the entity (e.g. human, water body, ecosystem, building, etc.) that is vulnerable to the adverse effects of the hazardous substance or material

These are discussed in detail in Section 4 but an overview is provided below.

The 'source' for waste management facilities is defined by the hazardous properties of the waste types and operations to which they will be subjected on an existing or proposed site.

'Pathways' are the means by which the identified hazards are transferred from the source into the environment and from there to any defined 'receptors'. These include, but not necessarily restricted to:

- releases to atmosphere such as landfill gas and particulate matter (atmospheric pathway)
- releases to the sub-surface environment such as leachate and landfill gas (sub-surface pathway)
- releases to surface water such as a leachate breakout (surface water pathway)

If humans (or animals) are exposed to hazardous substances or emissions via one or more of the above pathways, harm to their health may occur through a number of "exposure pathways". For example, in the case of releases to atmosphere, exposure may be via inhalation or ingestion (see section 5.9).

Receptors are those entities that are liable to be adversely affected by the identified hazards. These include, but are not necessarily restricted to:

- people outside the site boundary
- properties outside the site boundary
- ecosystems, especially sites (but not exclusively) designated in accordance with the Habitats and Birds Directives
- surface water in the vicinity of the site
- groundwater in the vicinity of the site
- atmosphere, which is a receptor in regard to the risk of climate change.

If it can be shown that there is no plausible connection or pathway between potential releases from a specified hazardous source and environmental receptors, which are known or expected to exist in the vicinity of the site, then the situation cannot be considered to present a risk. In this case, there is no plausible source-pathway-receptor relationship.

Box 2 - Examples of potential human health source- pathway-receptor linkages

There is potential for wide exposure to dust/particulate matter from landfills and there is likely to be a complete source-pathway-receptor linkage at all landfills.

Deposits of dust, combustion products and/or raw gas constituents in areas of food production such as allotments or market gardens or irrigation of crops with contaminated water can occur and could impact on receptors including people. Accidental or deliberate consumption of soil may be an appropriate consideration, for example, where there are domestic dwellings with gardens.

Some of the trace constituents of landfill gas have known hazardous properties. Landfill gas, if not collected and treated, can be dispersed over a wide area with varying levels of dilution depending upon the meteorological and topographical conditions. At all landfills producing gas, where there are relevant receptors, there will be the potential for a complete source-pathway-receptor linkage.

The emissions from landfill gas flares and engines have different characteristics because of the different nature of the combustion but both have the potential to produce compounds harmful to human health. Where there are relevant receptors, there will be the potential for a complete source-pathway-receptor linkage from aerial combustion product emissions.

Where there is a drinking water supply down gradient of the landfill there will be the potential for a complete source-pathway-receptor linkage. Public water supplies from groundwater are carefully monitored and controlled and there is often some form of water treatment prior to use. The impact of leachate contamination on a public drinking water borehole would be a major environmental and water resource incident. Provided the problem is identified and the source-pathway –receptor linkage is broken, the impact would be the loss of the resource rather than an impact on public health. For a landfill situated on or in a non aquifer, with no private drinking water supplies and no surface water receptors, there would be no need to consider the human health impact of drinking contaminated water as for this scenario there would be no potential complete source-pathway-receptor linkages. In this case, other environmental pathways and receptors might require more attention.

A decision that a plausible source-pathway-receptor relationship exists does not always mean that there must be firm evidence of the presence of all three components. However, it must be evident that the source has hazardous properties that have the potential to adversely affect the receptors in question. Furthermore, the presence of the receptors must be proven or be a realistic possibility. It may not always be possible to prove the presence of a pathway linking the two, but again this should be a realistic likelihood rather than a purely theoretical possibility.

In making decisions about source-pathway-receptor relationships for waste management facilities, it is important to give consideration to taking a precautionary approach in the light of expected changes and events over the lifetime of the facility. These may result in the nature of the relationship changing with time. For example, changes to the physical and/or chemical structure and composition of waste materials will influence the nature of the associated hazard(s). Decisions should be made on a site-specific basis, bearing in mind the need to take both a proportionate and precautionary view.

If a plausible source-pathway-receptor relationship is identified for a particular site, this will normally be taken by the Agency to demonstrate the need for appropriate risk management measures to prevent the anticipated risks being realised. In many cases, robust decisions about the presence of a plausible source-pathway-receptor relationship will be sufficient for decision-making about the need for risk management measures. The resources applied to risk assessment should be proportional to the risk and this means that it may not always be necessary to undertake a detailed quantitative risk assessment. An exception is where detailed quantitative assessment of the probability and scale of risks involved may be necessary to enable detailed design of the risk management measures, for example, design of landfill liner systems. In other cases, simple assessments of probabilities and consequences may be sufficient to inform decision-making.

The basis of the tiered approach to risk assessment (see Figure 2.1) is that the level of effort put into assessing risk reflects the nature and complexity of the risk. For many waste management facilities, it will be more appropriate to put most effort into design and management of the facility, provided that robust initial decisions are made about source-pathway-receptor relationships, and the location of the site is potentially acceptable. Identification of such relationships requires a good understanding of the environmental setting and the processes that could result in receptors being exposed to the particular hazards.

2.3 Problem Formulation (Including Conceptual Model Development)

Understanding the problem to which the risk assessment is to be applied is a critical precursor to any risk assessment process. This involves formally defining what the risk assessment is actually for. This ensures a clear understanding as to the intentions and boundaries of the risk assessment. The main method of understanding the problem that the risk assessment must address is through the development of the conceptual model of the landfill.

In this guidance the term conceptual model means an understanding of the landfill (including the design and operational fundamentals) in its environmental setting. This understanding is then used as the basis for conducting the risk assessment.

It is important to recognise that the conceptual model is not just an understanding of the site setting alone. Without the understanding of the basic design and operational principles of the landfill (for example elements such as waste types, schematic containment design, cell sizing, gas management provisions etc) it is not possible to fully consider the relationship between the site and its environment. The development of the conceptual model is important since, if there is a misunderstanding of the basic concepts of the site's design or environmental setting, then any consideration of the risk will be flawed. The conceptual model is likely to change, with time. For example, monitoring is likely to provide an increased knowledge of the site illustrating the need to continually review and update the conceptual model (section 2.8) as more data are gathered and interpreted.

The conceptual model must identify possible sources, pathways and receptors and the processes that are likely to occur along each of those pollutant linkages. The conceptual model should incorporate a broad range of information into a single coherent model, for example, information on:

- geology
- hydrogeology and hydrogeochemistry
- hydrology
- topography
- landfill development
- local ecology
- human populations
- chemical analysis e.g. leachate and landfill gas

A conceptual model may use some or all of this information depending on the nature and complexity of the risks and the sensitivity of the site. A conceptual model may be presented in a visual form, that is, in diagrams indicating the various source-pathway-receptor linkages and in writing, possibly in tables giving the same information.

There should be only one conceptual model for the landfill site submitted as part of a PPC permit application. There must not be separate accident, hydrogeological, landfill gas, particulate and stability conceptual models.

General guidance on the development of conceptual site models for sub-surface contaminant transport has been published by the Agency (Environment Agency, 2001).

It is important to recognise that the conceptual model will not always be at the same level of detail. The level of detail will vary depending upon the complexity of the risk assessment to be undertaken. For instance a complex hydrogeological assessment may require a detailed understanding of the attenuation properties of the unsaturated zone in order to predict the behaviour of contaminants in that pathway. The level of uncertainty in the understanding of the site's setting is also an important consideration in determining the level of detail required in the conceptual model.

The information requirements that form part of the overall conceptual model are often related to the information needed for modelling tools at different levels of assessment. The overall principle is that the understanding of the site and its environmental setting must provide the Agency with sufficient confidence that the risk assessment is considering the correct issues i.e. the problem formulation is correct. For more sensitive locations, it is likely to be important to understand the landfill and its setting in greater site-specific detail.

2.3.1 Best Practice and Best Available Techniques (BAT)

Best practice landfill management techniques must be incorporated into the conceptual model. There are many examples of past risk assessments for biodegradable landfills where the risk of lateral migration of gas is considered and the suggested risk management measures are a barrier and active gas extraction. These risk management measures should be considered at the start of the assessment. The conceptual model and Risk Screening are the most important stages in determining the best practice requirements. The risk assessment process should be used to refine, where necessary, the best practice requirements. The requirements for risk management measures at a landfill will always be a mixture of best practice and the site-specific requirements determined through a risk assessment. At the PPC application stage the proposed design must form part of the conceptual model.

Meeting the technical requirements in the Landfill Regulations should be taken to fulfil the relevant requirements of the IPPC Directive (96/61/EC). The Landfill Regulations provide some specific technical requirements for each of the three different classes of landfill (landfills for inert, non-hazardous or hazardous wastes). The conceptual model must include the relevant requirements for that landfill type. Box 3 gives some examples of these technical requirements.

Where the Landfill Regulations do not provide any specific technical requirements, for example leachate treatment, the guidance produced by the Agency in respect to BAT should be applied in order to prevent or otherwise control emissions such that no significant pollution is caused. In order to comply with BAT requirements, landfill gas combustion should be carried out according to Agency guidance on the Management of Landfill Gas (Environment Agency 2004g) and associated guidance. Where landfill gas is being generated it must be collected and appropriately treated and it is essential to understand that best practice and/or Best Available Techniques are used to determine the majority of risk management measures for landfill gas. For such directly associated activities the H1 methodology (Environment Agency 2003a) can be used to assess the significance of the emissions and prioritise areas for control.

Box 3 - Examples of Landfill Regulation Requirements

Landfills must have a geological barrier (Paragraph 2 of Schedule 2).

A landfill for non-hazardous waste must have a leachate collection (including an artificial sealing liner) and extraction system (with few exceptions) as well as a geological barrier (Paragraph 3 of Schedule 2).

Where leachate collection is necessary, leachate accumulation at the base of the site shall be kept to a minimum (Paragraph 3 of Schedule 2).

Landfill gas must be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and, to the extent possible, used. Landfill gas which cannot be used to produce energy must be flared (Paragraph 4 of Schedule 2).

Landfill gas management must be carried on in manner which minimises damage to or deterioration of the environment and risk to human health (Paragraph 4 of Schedule 2).

2.4 Tiered Approach to Risk Assessment

The tiered approach allows the level of detail in a risk assessment to be proportionate to the nature and complexity of the risk being addressed. There are three tiers of risk assessment - Risk Screening, Simple Risk Assessment and Complex Risk Assessment. The level of detail required increases at each tier with the risk assessment focussing more closely on high priority risks identified in the previous stage as requiring further investigation. Each tier of risk assessment is described in the subsequent sections.

The necessary level of a risk assessment will always be a site-specific determination. Many factors such as uncertainty in data and site understanding will affect the level of risk assessment but Risk Screening will guide prioritisation of risks to be taken forward for more detailed assessment. Other factors that affect the level of risk assessment are sensitivity of the environment including the presence of relevant receptors and the confidence in how the models used represent the site-specific circumstances. The selected level(s) of assessment for each risk assessment topic, identified in Section 1.2, should be explicitly justified in the risk assessment report. The relevant reporting criteria are given in Section 6.1.4.

2.5 Tier 1- Risk Screening

Risk Screening is the first tier of risk assessment and involves the initial consideration of the risks associated with a landfill. Risk Screening is used to determine whether the landfill represents, or potentially represents, a risk to receptors. This process typically involves identification of possible source-pathway-receptor linkages from the conceptual model, and an initial assessment of the likelihood and magnitude of any effects that could be associated with each pollutant linkage. Where there are no complete potential source-pathway-receptor linkages then the risk need not be considered further. Based on the assessment of the likelihood and the consequences of effects, the Risk Screening stage should also prioritise the risks such that the efforts in any subsequent, more detailed, risk assessment stage can be focused on those risks identified as important.

Risk Screening should:

- identify complete source-pathway-receptor linkages
- screen out insignificant risks
- prioritise the risks and receptors
- provide an initial assessment of the impacts at a receptor

It is recommended that the Agency should be consulted on the Risk Screening assessment prior to making a PPC application. This will facilitate discussion between the operator and the Agency on the understanding of the site and the priorities for the subsequent risk assessment work.

Various approaches to Risk Screening have been developed, common criteria used are:

- **Identification and magnitude of consequences** – Risk Screening can be based on an initial evaluation of the likely pathways between the source and any potential receptors.

  Characterising the nature of the hazard requires a consistent measure to be used and usually reflects the importance of the hazard in relation to others. For example, one measure might be the relative toxicity to likely receptors of the chemical components of leachate.

- **Probability of consequences** – The likelihood of exposure to the hazard being realised can be roughly estimated using coarse indicators at the Risk Screening stage.

- **Significance of the risk** – This reflects the harm that may result if exposure to the hazard actually occurs. The screening of impacts or consequences should take account of their nature, geographical extent, timing and duration, and their likely importance.

This level of assessment involves basic scoring or ranking techniques to prioritise potential risks in relation to each other. Risk Screening may be based on numerical scoring scales such as low (1) to high (5) to score both probability and consequence, or qualitative scales where probability and consequences are ranked on a scale of, say, low to high. Examples of basic risk matrices are provided in Figure 2.2a and 2.2b; these are only intended to be illustrative and are not a prescriptive approach. Whatever scoring or ranking method is used, the key to effective Risk Screening is consistency and transparency of approach.

Figure 2.2a Illustrative example of basic risk matrices

		Consequences (C)		
		Low	Moderate	High
Probability (P)	Low	**Low**	Moderate	Moderate
	Moderate	Moderate	Moderate	High
	High	Moderate	High	High
		Risk (combination of P and C)		

Figure 2.2 b Illustrative example of basic risk matrices

		Consequences (C)				
		1	2	3	4	5
Probability (P)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25
		Risk (combination of P and C)				

The use of calculations is not usually necessary at the Risk Screening stage as these would normally be undertaken at Tier 2, or Simple Risk Assessment stage (section 2.6).

However, at some sites it may be useful to include scoping calculations in the Risk Screening process as an aid to conceptual model development. This may include use of gas generation models such as GasSim (Environment Agency 2002a). The use of models at the Risk Screening stage can be helpful when, say, updating an existing risk assessment. When using scoping calculations, risks may be prioritised by, for example, comparing chemical concentrations in the leachate and gas to appropriate standards/criteria to establish which may be the important substances to consider. In this guidance these criteria are called environmental benchmarks. Guidance on the selection and use of environmental benchmarks is provided in Section 4.4.

2.6 Tier 2 - Simple Risk Assessment

Simple Risk Assessments (Figure 2.1) should be carried out for landfills when the Risk Screening is insufficient to make an informed decision on the risks posed by the site. Simple risk assessments will be appropriate where there is confidence that the source-pathway-receptor linkages described in the conceptual model are well understood, the site is of low sensitivity and where the Risk Screening has not identified any receptors that would be particularly susceptible to the consequences of emissions. In reality, most landfills will require a Simple Risk Assessment for further investigation of priority risks identified during the Risk Screening process. Many of the source-pathway-receptor linkages are well understood and will require further consideration (see Section 4 for further information on the sources, pathways and receptors).

The level of detail will differ from that required at the Risk Screening tier mainly through a more detailed understanding of the source and particularly the pathways. More site-specific data will need to be collected for a Simple Risk Assessment. This data might be the site-specific concentrations of components in leachate and landfill gas; ambient dust concentrations etc. The criteria against which to compare this data must be appropriate for the receptor(s) of concern and might include site-specific environmental benchmarks (see section 4.4). Criteria used in the Simple Risk Assessment must be conservative in order that non-significant risks can be identified and "screened out". It is the use of conservative assumptions that may allow a Simple Risk Assessment to provide sufficient confidence that the impacts would be acceptable.

Typically, quantitative calculations should be used in Simple risk assessments. These are often based on generic information and data with conservative input parameters, assumptions and methods. A simple assessment may sometimes use probabilistic models such as LandSim 2.5 (Environment Agency 2003d) though often single values will be used rather than probability distributions.

Where conservative assumptions in a Simple Risk Assessment result in unacceptable predicted impacts, then it is not sufficient to conclude that if less conservative assumptions were to be used the situation would be acceptable. It would be more appropriate to complete a further iteration of the Simple Risk Assessment with less conservative inputs providing these are robust and can be justified. Alternatively, high priority risks may require more detailed investigation in a Complex Risk Assessment.

2.7 Tier 3 - Complex Risk Assessment

Complex Risk Assessments should be carried out when:

- A Simple Risk Assessment indicates an unacceptable level of risk, or
- There is sufficient uncertainty regarding the source-pathway-receptor linkages and the use of conservative assumptions does not provide the basis for a decision, or
- The site setting is sufficiently sensitive to warrant detailed assessment and a high level of confidence is required to ensure that the site does not pose any significant pollution risk.

A Complex Risk Assessment should focus on those source-pathway-receptor linkages where risks have not been "screened out". This means that different areas of risk assessment (accidents, hydrogeological, landfill gas, particulate and stability risk assessments – see Section 1.2) may require different levels of complexity – the examples in Box 4 illustrate this point.

Box 4 - Examples of different levels of complexity within landfill risk assessment

A landfill in a former clay pit with a significant natural geological barrier overlying a minor aquifer may not need a Complex hydrogeological assessment. It may however require a Complex landfill gas assessment depending upon the source-pathway-receptor linkages.

Within the landfill gas risk assessment, a site with receptors for aerial pathways may require a Complex Risk Assessment of the emissions from flares and engines. If a weak source-pathway-receptor linkage is present for subsurface emissions then a Simple Risk Assessment may be appropriate for the same site.

Complex Risk Assessments are detailed quantitative assessments and require more detailed site-specific information. The conceptual model for a Complex Risk Assessment would typically require a high level of detail. For instance, more site investigation may be required to understand the local hydrogeological pathways and to gather site-specific information on geochemical properties such as cation exchange capacity. Site-specific topographical data (terrain and buildings) would usually be needed to understand the pathways for aerial dispersion.

Complex risk assessments often use probabilistic techniques. Probabilistic modelling techniques can take account of the inherent variability of a heterogeneous waste body and the environmental setting. Complex Risk Assessments will often use sophisticated modelling tools such as new generation air dispersion models. A Complex stability assessment will often use models based on, for example, finite element analysis techniques.

2.8 Iteration in Risk Assessments

Risk assessment is an iterative process. This means that information gathered through undertaking the risk assessment (or through monitoring) is fed back into earlier stages and the process begins again. The understanding of the site will be refined (and may change) throughout the life of the site as more information is gathered and interpreted. The conceptual model must be continually updated to ensure that the fundamental understanding of the landfill site is correct. For example, monitoring or site investigations may provide information on groundwater levels that may necessitate a change in a number of assumptions in the conceptual model; this could then require a new iteration of the risk assessment

When operators are designing their site they will commonly go through a number of risk assessment iterations before arriving at their preferred option. The Agency will rarely see these iterations. In practice, the operator will submit the version of the risk assessment that reflects the specific proposals in the application. For regulatory decision-making, unless the Agency requires further risk assessment work, the decision will be based on the final iteration of the risk assessment submitted with an application.

It is important to understand that the risk assessment process does not end at the application stage. The risk assessment and conceptual model must be reviewed throughout the life of the site. Reviews should be undertaken at the annual review of the monitoring plan and data required by the PPC permit, at any point of relevant change in operation, at the four yearly review required by the Groundwater Regulations, and for surrender. The risk assessment process is only really complete when the Agency has accepted the surrender of the permit or waste management licence.

2.9 The Use of Models in Risk Assessment

There are a large number of models that can be used for each of the different risk assessment topics and at different stages of a risk assessment. It is essential to recognise that models are tools to be used in a risk assessment and that they are not the whole risk assessment. It has not been uncommon in the past for a LandSim model to be submitted on its own with the intention of satisfying the hydrogeological risk assessment requirement. GasSim models have been submitted as a landfill gas risk assessment. A model is not a risk assessment. It has often been argued that if the Agency has “agreed” (or not objected) to the input parameters then when the result shows an “acceptable discharge” (e.g. where a LandSim model predictions are below the environmental benchmark) then the assessment has definitively demonstrated that the impact is acceptable. This misses the important point that the limitations and assumptions in the model and the conceptual model all have to be considered in the decision-making process.

There are a large number of models that could be used for different aspects and levels of risk assessment. There are, however, some general points that should be considered for all models.

- Is the model applicable for the site (the conceptual model) and the scenarios to be considered i.e. is it fit for purpose?
- Is the model appropriate for the level of risk assessment considered?
- Are the limitations of the model clearly understood and reported?
- Has the model been validated?
- Are all the assumptions clearly stated?
- Are the key assumptions clearly identified?
- Are all input parameters justified and appropriate for the level of risk assessment i.e. site-specific for a complex assessment?
- Has a sensitivity analysis been carried out? i.e. is the significance of changes in the parameters clear?
- Have all relevant uncertainties been identified and appropriately addressed?

2.9.1 Model Headroom

A paper produced by the Agency's Air Quality Modelling and Assessment Unit a "Risk based pragmatic approach to address model uncertainty" (Environment Agency, 2002b) considers "model headroom". This is a measure of how close the predicted contribution and background levels are to the environmental benchmark (Environmental Assessment Level (EAL) or Air Quality Standard) – see section 4.4. Where the contribution of the emission and the existing background is close to the benchmark there is low model headroom. Where the combination of background and the impact of the emission are far from the benchmark then model headroom is high.

Model Headroom = (EAL – (background levels + predicted impact))/EAL (1)

This approach is directly applicable to landfill gas and particulate risk assessments. For the hydrogeological risk assessment, it may be possible to use the "model headroom" approach for List II substances, however it is not appropriate for List I substances since these must be prevented from entering groundwater. The Agency's guidance on Hydrogeological Risk Assessments should be referred to for more information (Environment Agency, 2003b). Model headroom can be generated by providing a predicted impact which can be added to the known baseline concentrations and compared to a relevant environmental quality standard as in equation (1) above. This approach may be particularly relevant where there is a quality objective for a surface water or other water body receptor. For air quality the predicted impact would be the maximum ground level concentration. Where probabilistic models have been used for the hydrogeological assessment then the 95% confidence limit value would normally be used.

2.9.2 Model Confidence

Model confidence is an indication of the complexity of the modelled scenario (i.e. terrain and buildings) and the quality of the input data (i.e. meteorological data). Where there is high confidence in the model and high model headroom then there may be no need for further modelling. Conversely low confidence and low model headroom clearly requires more detailed modelling work.

Model confidence can be considered on the basis of how exactly the site fits into the scenarios for which the model was developed (i.e. the complexity of the geology and hydrogeological systems, for instance faulting) and how much confidence there is in the input parameters. Confidence in input parameters may depend on the quality and quantity of monitoring and on site investigation data providing an understanding of site-specific material properties and hydrogeological behaviour.

2.9.3 Model Reporting

It is important that the limitations and applicability of all models used are understood by the operator and that this understanding is reflected in the risk assessment report. With respect to the reporting requirements the following should be considered.

- The limitations and applicability should be recorded
- Enough information to run commercially available models should be provided
- Electronic versions of input data should be provided
- Copies of in-house models should be supplied along with the technical specifications, user documentation, model validation documents and appropriate benchmarking studies
- An interpretation of results and comparison of predicted impacts to environmental benchmarks by an appropriate person should be provided
- All input parameters and assumptions recorded and justified
- Evidence of senior QA/QC review
- A sensitivity analysis should be provided

Appendix E of H1 (Environment Agency 2003a) summarises the reporting requirements for air dispersion modelling and the Hydrogeological risk assessment guidance (Environment Agency 2003b) provides reporting requirements for modelling risks to groundwater.

It is always important to remember that the use of any model forms only part of the risk assessment and the reporting must place it in the overall context of the site.

3 RISK ASSESSMENT FOR POLLUTION PREVENTION AND CONTROL (PPC) AND PLANNING

3.1 Pollution Prevention and Control

The application for a Pollution Prevention and Control (PPC) permit requires the production of a risk assessment covering accidents and their consequences, hydrogeological risk, landfill gas, particulate matter, stability and a Habitats Directive assessment. No part of the assessment should be considered in isolation. If the landfill gas assessment is passed to the operator's gas experts, the hydrogeological assessment to the hydrogeologists and the stability assessment to the engineers, who all separately work on their own section then this will not adequately reflect the interactions between these areas. It is crucial that the overall risk assessment process is based on a single conceptual model and all the interactions between risk assessment topics are considered. Examples of the interactions between the risk assessment topics are provided in Box 5. Section 5.2 considers further the interactions between the different risk assessment topics identified in Section 1.2.

Box 5 – Examples of interactions between the components of the risk assessments

For cell and phase design, the aim is likely to be minimising leachate generation, but it should also produce sufficient depths of waste to allow active gas extraction to be established as soon as possible and must produce waste slopes that are stable. Gas fluxes are likely to be highest through waste slopes so the design should aim to minimise the period these temporary slopes should exist.

Leachate recirculation is often briefly mentioned only in a leachate management section. However, it has implications for gas management, as it can substantially increase gas generation rates. Leachate recirculation also has implications for stability as it can increase the moisture content in sections of the waste mass.

Although experts will be required to consider each topic, it is vital that the individual risk assessment topics are considered together by the operator to produce a coherent risk assessment for the landfill as a whole. The Agency's guidance on the design and operation of landfill sites (Environment Agency 2004a) considers these interactions in landfill design. Agency staff must also ensure that the separate risk assessments submitted in support of an application are not considered separately when determining the application.

3.1.1 Assessment of Hydrogeological Risk

The Agency's guidance on assessing hydrogeological risk (Environment Agency, 2003b) gives an indication of the likely level of such an assessment based on the waste types and environmental setting and reference should be made to that guidance. The level of the assessment will depend on the sensitivity of the site. In practice, most landfills for hazardous and non-hazardous waste will require complex risk assessments unless they are located in low sensitivity environments, due to the need to reduce uncertainty, and the difficulties in obtaining adequate site-specific data. Source-pathway-receptor linkages to water supplies identified during Risk Screening would be likely to require a complex assessment with respect to human health. Similarly, linkages to receptors identified within the Habitats Directive (Section 5.10) may also require a Complex Risk Assessment. Before proceeding with a Complex Risk Assessment, a robust examination of the probability of the hazard being realised and the potential consequences should have been carried out during Risk Screening (Tier 1). Where appropriate, a Simple Risk Assessment (Tier 2) should have been undertaken to identify the most significant risks and provide a focus for the Complex Risk Assessment.

3.1.2 Assessment of Landfill Gas Risk

People are the primary receptors of concern with respect to the hazards associated with landfill gas. In general, a Complex Risk Assessment employing air dispersion modelling using appropriate models (such as AERMOD or ADMS) is likely to be required at the PPC permitting stage for all landfills taking biodegradable waste. The Agency has produced general guidance on air dispersion modelling (Environment Agency 2002c). A Complex Risk Assessment for landfill gas is likely to be required for landfills for hazardous wastes. In both cases, it is important that Risk Screening (Tier 1) and Simple Risk Assessment are undertaken first to ensure that the Complex Risk Assessment is robust and correctly focussed.

3.1.3 Assessment of the Risk from Particulate Matter

For the assessment of risk from particulate matter, at Risk Screening, there should be a consideration of whether there are waste streams possessing a hazardous property, where the physical characteristics of the waste will allow particulate generation and the presence of human receptors. Generation from area sources as well as the waste deposit should be considered so the phasing and restoration plans will be critical.

Risk Screening should be used to identify when a quantitative assessment is required. The procedure for identifying risks from landfills (Environment Agency 2003e) provides guidance on making this determination. The level of risk assessment will be dependent on the waste types and operations proposed at the landfill. For landfills for non-hazardous wastes, it is likely that a Simple Risk Assessment would be justified but a Complex Risk Assessment may not be necessary. More detailed quantitative assessment would usually be justified for particulate matter for a landfill for hazardous wastes.

The impact of the landfill on sites covered by the Habitats Directive must be assessed (Section 7.1.7) and the particulate matter assessment must consider receptors identified within the Habitats Directive. Risk Screening should take account of the proximity of the landfill to a European Site, as designated under the Habitat Regulations 1994. If the landfill site is within 2km/5km of a European Site (Special Area of Conservation (SAC) or Special Protection Area (SPA)) then further consideration of waste type, site controls, likely pathways and the sensitivity of the Interest features identified within the SAC or SPA is required. It will be necessary for the operator to provide sufficient information for the Agency to conclude that the landfill will have no adverse effect on the integrity of any relevant European sites and this may entail a Complex Risk Assessment.

3.1.4 Assessment of the Stability Risk

The level of complexity of the stability assessment will depend mainly upon the complexity of the natural geology and the design of the structures within the site, rather than the sensitivity of the setting. It is necessary for the operator to provide sufficient confidence that stability and integrity of the structures are assured. For simple slopes without a complex geology there may be little need for detailed assessment whereas steep slopes will require much more consideration. For example, Risk Screening with the provision of evidence of an unsaturated zone beneath the base of a site may be sufficient to screen out the need to assess basal heave. The principle is that the assessment must provide sufficient confidence that stability is assured and the integrity of the structures within the site will be maintained.

3.1.5 Risk Assessment of Amenity Topics

As well as the key landfill risk assessments identified above, there are a number of other aspects that need to be dealt with in the overall consideration of risk:

- noise and vibration
- odour
- litter
- birds, vermin and insects
- mud on road

This guidance does not deal in detail with all these aspects of the overall risk assessment. However it is worth highlighting that:

- the overall principles of risk assessment given in this guidance apply
- the same single conceptual model should be used for these assessments
- the same receptors and any relevant additional receptors should be considered

It is recommended that the proposed level of risk assessment for each amenity topic should be discussed at the pre-application stage.

There is cross-sectoral PPC guidance and guidance produced for waste management licensing on many of these topics and reference should be made to these. In addition to the H1 guidance (Environment Agency, 2003a*)* the following documents will be of use in assessing the risks for noise and odours.

Noise Guidance - Internal Guidance for the Regulation of Noise at Waste Management Facilities, Environment Agency, (2002d)

IPPC H3 – Horizontal Noise Guidance Part 1 'Regulation and Permitting', Environment Agency (2002e),

IPPC H3 – Horizontal Noise Guidance Part 2 'Noise assessment and Control', Environment Agency (2002f).

Odour Guidance - Guidance for the Regulation of Odour at Waste Management Facilities, Environment Agency, (2002g)

IPPC H4 - Horizontal Guidance for odour Part 1: Regulation and Permitting ,Environment Agency, (2002h)

IPPC H4 Horizontal Guidance for odour Part 2: Assessment and Control, Environment Agency, (2002i)

The Agency has produced a screening methodology for considering amenity risk assessments - Procedure for identifying risks from landfills (Environment Agency 2003e). This considers where a more detailed level of risk assessment is required. In the past, amenity risk assessments have often been qualitative but it is important to consider when a quantitative assessment should be undertaken. It is not possible to be prescriptive about when a more detailed risk assessment will be required. The key question is whether Risk Screening provides the Agency with sufficient confidence for decision-making.

For existing sites the current performance of the risk management measures can be used to help determine if a more detailed assessment is required. Noise or odour complaints or incidents can indicate that a quantitative assessment (e.g. a noise survey) is required. The absence of such complaints should not preclude a quantitative assessment. Where there are no high sensitivity receptors, a quantitative assessment may not be required.

Release of particulate matter has been considered separately in this guidance because this often requires more detailed quantitative assessment.

3.1.5.1 Human Health

Human health can be impacted by the amenity topics listed above. Odour experienced off site represents a completed source-pathway-receptor linkage that can have physiological and psychological (stress related) health effects. Odour is included within the definition of pollution as an off site emission that "causes offence to human senses". The impacts identified in the amenity assessments must be considered alongside those from the key risk assessments covered in this document. With respect to odour this is particularly relevant to the landfill gas risk assessment.

3.2 Planning

There are a number of different stages within the planning system that may require different levels of risk assessment. The important stages with respect to the landfill development are:

- strategic planning
- scoping for Environmental Impact Assessments
- planning applications, including environmental statements

3.2.1 Strategic Planning

Waste plans produced for strategic planning can take a number of forms, which are beyond the scope of this guidance. Risk Screening would normally be the appropriate level of assessment although more detailed assessment may be required where specific sites are to be identified in a strategic plan. This will depend upon the location of the landfill with respect to the Agency's Policy and Practice for the Protection of Groundwater (Environment Agency 1998) and Landfill Directive Regulatory Guidance Note 3

(Environment Agency 2002j), and the presence of receptors. It is possible that a Complex Risk Assessment might be necessary prior to the inclusion of a site in the waste local plan.

If a landraise is proposed the capacity of the site will depend on the footprint but also on the proposed slopes. A simple or complex assessment of the stability risk may therefore be required at the strategic planning stage.

3.2.2 Environmental Impact Assessments

Applications for new landfills will almost always require an Environmental Impact Assessment (EIA). It is important that the Agency replies to scoping opinions on EIAs to ensure that all the relevant issues are covered in the environmental statement which provides the risk assessment at the planning stage. Risk Screening or, sometimes, more detailed quantitative assessment (e.g. Simple Risk Assessments) should be used to guide development of environmental statements.

3.2.3 Planning Applications

There are some elements of a risk assessment that may require a more detailed consideration at the planning stage to avoid compromising the regulatory position at the permitting stage. Key issues include the location of gas flares and engines and the stack heights. To correctly size stack heights at a particular location and ensure acceptable ground level concentrations, a detailed air dispersion assessment may be needed. If planning permission has set the location and stack heights on the basis of visual amenity alone, this may compromise emission control.

The planning authority is also a competent authority under the Conservation (Natural Habitats, & c) Regulations 1994 (referred to in this document as the Habitats Regulations), and will therefore be required to conduct an Appropriate Assessment under Regulation 48 (1), for the landfill site planning application. As another relevant competent authority the Agency may be required to assist in the completion of this assessment. Therefore information for the Habitats assessment may be required to be submitted at the planning application stage.

Where the planning application and the PPC permit application are being conducted in parallel then the accidents, hydrogeological, landfill gas, particulate matter and stability risk assessments produced for the permit application can be used by the Agency to consider its response to the planning application.

4 SOURCES, PATHWAYS AND RECEPTORS

4.1 Source Term

The conceptual model must provide an understanding of the source term. The basic source term for landfills is the deposited waste, the properties of which may result in a hazard by the emission of liquid, gaseous and solid substances. There are a number of potential release points for emissions, for example the flux of gas through a waste flank, which are often referred to as sources. This guidance considers release points as part of the pathways not as the source (Section 4.2.1).

There is an important distinction between considering the source term for new landfills and existing landfills and this is discussed in detail below.

4.1.1 New Sites

For a new landfill there will be no site-specific information and the source term can only be based on:

- literature values
- information from "similar" landfills
- models (e.g. gas generation models)

This provides a key area of uncertainty. Before the site construction and operation, conservative literature values should be used for the source term at the Risk Screening and Simple Risk Assessment tiers to ensure that only truly insignificant risks are screened out and not considered further. When the site is operational, the monitoring programme and review process must address this uncertainty and provide an understanding of the implications of any deviations from the assumed values.

4.1.1.1 Landfill Gas

New sites will have no landfill gas composition data. The waste types must be considered carefully to determine from the literature the potential range of trace components in the gas stream. Data from landfills which have accepted "similar" waste types can be used with caution to provide predictions of composition. It is not possible to accurately predict the trace gas composition for landfills taking a wide range of waste types and this major uncertainty must be recognised and reflected in the substances and concentrations selected for consideration. Indicator (or surrogate) substances can be used but the selection of substances and levels must be clearly justified (Section 4.1.6).

4.1.1.2 Leachate

For a new site, the leachate source term will be based on a number of indicator determinands and not on actual leachate analysis. The leachate source term will have been estimated on basis of the expected wastes, experience at similar sites and the results from waste characterisation tests (see guidance on Hydrogeological Risk

Assessments for Landfills and the Derivation of Groundwater Control and Trigger Levels, Environment Agency, 2003b). The Agency is conducting research on the potential future source term with respect to leachate composition (Environment Agency 2004b).

4.1.1.3 Future Waste Types

The requirement in Regulation 10 of the Landfill Regulations to only accept treated waste has implications for the source term both for landfill gas and leachate. These changes in future waste streams make predictions of gas generation and leachate quality more uncertain. This emphasises the importance of appropriate monitoring of the source term (Environment Agency 2003h).

4.1.2 Existing sites

4.1.2.1 Monitoring

For existing sites the source term must be quantified through representative and reliable monitoring of the waste types accepted, the leachate quality and quantity, the landfill gas composition and rate of generation and other associated factors such as the moisture regime within the site. If this data does not exist then in order to support an application further monitoring to characterise the source term will be required. As with all monitoring, the methodologies must ensure representative results. Depending upon the age of the site, future predictions may still be need to be based on literature values to reflect the changes in the source term over time.

4.1.2.2 Landfill Gas

An important precursor for conducting a landfill gas risk assessment will be an understanding of the trace gas composition (Environment Agency 2002k). It is important that this is sampled at points within the site that will give representative results, since different areas of the site which have been landfilled at different times and with different waste streams may have a different gas composition. Pumping trials and monitoring within the waste body will also provide information on the source term. Records of volumes of gas extracted and treated are also important in understanding the source term. There are other site-specific indicators that must be considered including leachate recirculation, meteorological data (e.g. rainfall and recent history of atmospheric pressure) and waste types accepted.

4.1.2.3 Use of Monitoring Data in Risk Assessment

There will normally be a body of data relating to existing sites that can be used in a variety of ways to describe the source term in the different risk assessment tiers. For instance, in the Risk Screening or Simple Risk Assessment tiers, maximum recorded values could be used as conservative assumptions to determine the level of risk. In a Complex Risk Assessment, the same data could be used in a more statistical way to develop a more detailed understanding of the characteristics of the source term. With respect to the trace gas composition, Simple Risk Assessment might use maximum values from limited data, whereas a Complex Risk Assessment is likely to need a better statistical basis

(Environment Agency 2002m) and therefore more data (the issue of correctly collecting trace gas data is a vitally important one, Environment Agency 2004c).

Where indicator substances are selected for the risk assessment they should reflect the actual leachate or gas composition (and their hazardous properties) at the site.

4.1.3 Waste Types

Whatever the level of the risk assessment, the landfilled waste must be well understood, as this is the basis for the hazard from the landfill. The mix of waste types (and the site-specifics of the landfill) will determine the quality and quantity of the leachate and landfill gas source term and as such are a vital consideration in identifying the landfill hazards. For a new site, a detailed consideration of each waste type proposed will be required. For an existing site, consideration of records of the wastes accepted will be required.

Each individual waste stream should be considered in the assessment. It may be possible to group these into categories of wastes that present similar hazards so long as this is fully justified. Where there may be particular contaminant concentrations in a waste stream this should be identified. This will be of relevance to non-hazardous wastes with concentrations of substances below the levels necessary to make the waste hazardous as well as to hazardous wastes. All potentially incompatible wastes must be identified. Changes in waste types will require a review of the risk assessments and the relevant areas for this should be highlighted. Section 6.1.2 considers the risk assessment reporting requirements for waste types. However it should be recognised that accurate prediction of contaminant concentrations in leachate based on the wastes deposited is not possible (Knox et al, 2000).

4.1.3.1 Waste Acceptance Ratios

Waste acceptance ratios will be used in most landfills for non-hazardous wastes to ensure that the mix of waste types will produce a leachate within the normal range of predicted constituents. Limiting the ratios of different waste types has been a commonly used method of preventing an unacceptable concentration of contaminants within the leachate. Waste acceptance ratios are therefore an important risk management measure relevant across a number of risk assessments.

Box 6 - An example of a change in waste acceptance ratios

A review of the stability risk assessment would be required where an operator wishes to vary the waste acceptance ratio for sludges in the PPC permit. At most landfills the range of particle sizes in the waste is very large however future pre-treated wastes may have a narrower range of particle sizes. Any such changes in the nature of the wastes to be accepted must be reflected in a revised assessment which must feed into operational plans such as phasing plans.

4.1.4 Source Term - Accidents

The assessment should identify the hazards to the environment posed by the landfill installation. The following are examples of hazards that should be considered:

- release of leachate:
  - overfilling of tanks / lagoons;
  - failure of plant and/or equipment (e.g. pipework failures, blocked drains);
  - failure of engineered containment;
  - failure to contain firewater;
  - making the wrong connections in drains or other systems;
  - failure of valves or couplings;
  - failure of leachate extraction systems leading to elevated heads;
  - discharge of an effluent before adequate checking of its composition has taken place;
  - waste slippage;
  - vandalism of liners, pumps and equipment etc.;
- release of landfill gas:
  - failure of gas collection system;
  - failure of flares or engines;
  - waste slippage;
  - vandalism;
- fire and explosion:
  - failure of waste acceptance procedures i.e. incompatible substances coming into contact;
  - failure of landfill gas extraction systems/controls;
  - vandalism:
- escape of waste.

The hazard identification stage (Figure 2.1) is the key stage in the consideration of accidents and their consequences. The consideration has to be detailed and site-specific.

The consideration of hazards should be on the basis of the proposed risk management measures. What is not wanted is an assessment that, for example, identifies overfilling a leachate tank as a hazard and then proposes a filling procedure and monitoring to reduce the likelihood of occurrence. A landfill operator may have conducted a number of iterations of the risk assessment to arrive at the proposed risk management measures but the Agency will base its regulatory decisions on what is actually proposed. The risk assessment should consider the failure of the proposed or existing safeguards.

4.1.5 Source Term - Hydrogeological Risk

The hazard from leachate is primarily based on the contaminant concentrations. There has been a substantial amount of research on leachate composition (Department of the Environment 1995, Environment Agency 1997) as well as routine leachate monitoring at licensed sites and the hazard from landfill leachate is generally well understood. Future changes to the waste types may change this current understanding of the hydrogeological source term. Leaching limit values are a key waste acceptance criteria for landfills for hazardous and inert wastes. It may be possible to make assumptions on the source term based on the leaching limit values for inert sites (Section 4.1.9) and for landfills for hazardous wastes.

4.1.5.1 Decline in Leachate Contaminant Concentration

For most biodegradable landfills the application will consider the decline over time of the concentration of contaminants in the leachate. This is commonly described as a "declining source term" and is considered in models such as LandSim (Environment Agency, 2003d). The improvement in leachate quality with time is an important consideration in understanding the long-term risk. At the application stage, all that can be produced is a prediction of the decline in contaminant concentration. The risk assessment can provide an estimate of how long the management systems would need to be sustained in order to prevent the risk of pollution. The value of the declining source term is an initial prediction of the time that the landfill is likely to pose a pollution risk. This should be refined throughout the lifetime of the site.

4.1.6 Source term - Landfill Gas

Landfill gas should be taken to mean any gas produced by a landfill. For sites taking biodegradable wastes, this will be the familiar bulk constituents of methane and carbon dioxide and a wide range of trace constituents. Landfills taking only inorganic wastes will not produce the same type of landfill gas. This is of particular relevance to landfills for hazardous waste and landfills for non-hazardous wastes (or separate cells within those sites) taking non-biodegradable wastes.

4.1.6.1 Landfill Gas Hazards

The basic hazards that may exist from landfill gas are:

- odour;
- toxicity (including carcinogenic, mutagenic and toxic to reproduction) acute and chronic;
- explosion;
- asphyxiation;
- global warming.

It is the trace components of landfill gas that pose an odour and toxicity risk and the bulk gases that pose a risk due to explosion and asphyxiation (although carbon dioxide is also toxic). Trace concentrations and composition vary widely from site to site. The gas from some landfills possesses a greater hazard than that from others. Explosion and asphyxiation hazards are generally related to sub surface migration and accumulations of gas in enclosed spaces.

4.1.6.2 Gas Generation Rates

Landfill gas generation will alter with time. The rate of landfill gas generation will change as will the composition of the constituent gases. Gas combustion will peak after a number of years and utilisation will often not begin until a few years after waste deposit commences. Different areas of the site will be producing different compositions and volumes of gas depending on when and how the waste was deposited.

Consideration of the source term (for example, at the application stage for a PPC permit) will provide estimates of the gas generation potential and a time profile developed. At Risk Screening, an initial gas generation profile for the site should be produced. There are a number of factors that influence the gas generation and collection efficiencies and there are a variety of models that can be employed for predicting rates of gas production, for example GasSim (Environment Agency, 2002a). Gas generation models are likely to be used for all biodegradable landfills as part of the conceptual model development and to inform Simple and Complex Risk Assessments. As with all models the uncertainties in these predictions must be recognised. These models are generally indicative of the order of magnitude of the gas production and it is vital that during the operational and aftercare phases information is gathered on the actual gas produced. This will mean keeping records on, for example, gas volumes collected and any fluxes from the site. As well as the actual volumes generated, it is vital to ensure that the assumptions made in any gas generation predictions are critically evaluated through the monitoring and review process.

When looking at variations in emission rates of landfill gas for different areas of the site, it will be important to link this to the presence of pathways (i.e. for subsurface migration) and receptors. In addition to the concentration of landfill gas that is being produced by the biodegrading waste, the rate of gas flowing through the surrounding ground is important. However, it should be noted that very low gas flow rates over a prolonged period of time can result in the same build up of an explosive or asphyxiating mixture of landfill gas in confined spaces as that for higher flux rates. Therefore, gas flow rate figures have to be viewed in the light of the pathway-receptor linkages.

4.1.6.3 Trace Gases

Comparison of trace gas composition against environmental benchmarks (see Section 4.4) can indicate which substances are likely to pose the greatest risk. This prioritisation process should be used to determine which substances to consider in a quantified assessment and at what level of complexity this quantification should take place i.e. what level of risk assessment is required (Section 2.4). Additional information on important landfill gas trace components for consideration is provided in Agency guidance (Environment Agency 2004c). In the hydrogeological risk assessment, indicator substances are used to consider the impact. It is considered less appropriate to do this for trace gasses since additive impacts may need to be considered. All substances which are not screened out should be considered in the assessment and assessed against an environmental benchmark (or other suitable criteria). One possible alternative approach is to consider a conservative situation where all non-methane volatile organic compounds are taken to be one of the most harmful substances for example benzene.

4.1.6.4 Combustion Products

The substances that are emitted following combustion will depend upon the composition of the gas and the operating conditions under which the gas is burnt. For instance, where the gas contains hydrogen sulphide the emissions would include sulphur dioxide. Substances are converted during combustion; they cannot be lost. If the emission standards given in Agency guidance (Environment Agency 2004d and 2004e) cannot be met using best combustion practice, then generally gas clean up will be required pre or post combustion (Environment Agency 2004f).

4.1.7 Source Term – Particulate Matter

Particulate matter can contain hazardous substances and possess hazardous physical properties. Landfills are comparable to major earthworks or quarrying developments in that there are heavy plant and other traffic movements, areas of exposed soils, unsurfaced site roads and so on (Section 4.2.1). An additional concern with landfills is any dust that may be generated either directly from the waste or via processes within the waste i.e. bioaerosols.

The hazardous substances present are likely to be related to the waste types accepted at the landfill. The selection in the risk assessment of particulate substances with hazardous properties will therefore depend primarily upon the waste streams accepted or proposed for acceptance at the landfill. Each waste stream should be considered on the basis of the composition and characteristics (i.e. particle size, moisture content etc.). A list should be produced for the possible substances that should be considered in the quantitative particulate risk assessment. Comparison of maximum concentrations in the waste with environmental benchmarks will help prioritise the substances for consideration and provide a link to quantitative monitoring.

Determining the source term for particulate matter such as bioaerosols will be a challenge for the operator. In the absence of site-specific data literature values for emissions should be sought.

4.1.8 Source Term - Stability

Stability is slightly different from the other areas of risk assessment in that the risk assessment process for stability will largely concentrate on the source term and the risk management measures that are to be put into place. When assessing the stability and integrity of structures, consideration must also be given to the source-pathway-receptor linkages to determine the impact at the receptors at risk from any potential failures.

4.1.9 Inert Sites

Landfills which have only accepted - or will only accept - inert waste as defined by the Landfill Regulations (Regulation 7(4)) cannot produce polluting leachate and landfill gas. For the majority of the risk assessments considered here, these inert landfills would not present a hazard (though stability and nuisance dust must be addressed). An assessment of the impact of a landfill for inert waste under normal operations will therefore almost inevitably result in an acceptable impact. However, one of the principal environmental risks from inert waste landfills arises from inadvertent deposit of wastes that are not in fact inert.

Landfills for inert waste are often proposed in more environmentally sensitive locations and hence the acceptance of waste contaminated with potentially polluting substances can pose a significant environmental risk. Additionally, inert waste landfill proposals often involve minimal levels of engineering. In many cases reliance is placed on waste acceptance procedures as the principal risk management measure. In some instances, it is possible that the risk assessment may indicate a need for a higher degree of site engineering.

The likelihood of acceptance of non-inert wastes at a particular site will depend on a number of factors including:

- how well characterised the waste is
- the degree of heterogeneity of the waste
- whether the site is to accept waste from a single, pre-identified source or from numerous sources
- the waste acceptance procedures

The significance of the risk will depend upon:

- the environmental sensitivity of the landfill's setting
- the engineering measures i.e. an artificially established geological barrier

Requiring an assessment of the possible risk posed by inadvertent deposit of non-inert wastes does not imply that landfill operators will deliberately breach permit conditions. Instead, the need to consider this eventuality should be seen as essential to carrying out a comprehensive and realistic risk assessment.

4.1.9.1 Stability

Due to the nature of the waste in an inert landfill, settlement and consolidation will be considerably less than in a biodegradable landfill. Stability is still an important issue and the final landform and phase slopes must be designed to be stable over the short, medium and long term. One important change that has been made by the Landfill Regulations is the absolute requirement for a geological barrier to provide attenuation capacity (Schedule 2 paragraph 3 (4)). There is no requirement to collect leachate at an inert landfill and the design and stability assessment must consider any potential build up of water within the waste body.

4.1.9.2 Hydrogeological Assessment

The Landfill Regulations require that an inert landfill site has a geological barrier along its base and sides. Paragraph 3 (4) of Schedule 2 to the Landfill Regulations effectively sets a default standard for such a geological barrier. This standard is for a mineral layer that provides a degree of protection of groundwater, soil and surface water that is at least equivalent to that resulting from a mineral layer with a permeability of less than or equal to

10^{-7}m/s and a thickness of greater than or equal to one metre. The barrier must also provide sufficient attenuation capacity to prevent potential risk to soil and groundwater. Additionally, the Regulations allow for artificial completion or reinforcement of the geological barrier but require that in such cases the barrier is al least 0.5 metres thick. Consideration can be given to the use of suitable waste streams entering the site to enhance or establish a geological barrier if the natural materials around the site are not suitable. When artificially establishing a geological barrier using suitable waste inputs, the design of the attenuation layer can take into account different combinations of thickness and permeability in order to provide the necessary attenuation capacity.

The Regulations allow a reduction in the above standard if a hydrogeological risk assessment indicates that the landfill poses no potential hazard to groundwater, soil or surface water. Any risk assessment seeking to justify such a reduction should concentrate on the potential consequences of emissions i.e. it should reflect the sensitivity of the environmental setting.

The first step in determining the risk from an inert landfill should be a consideration of the sensitivity of the location; this should initially comprise a Risk Screening assessment that should consider all relevant pathways and receptors (Environment Agency 2003b). Consideration of pathways should take account of, for instance, likely unsaturated zone travel times; the potential for attenuation including the natural and/or artificially established geological barrier; travel times in the saturated zone; and levels of dilution to receptors and monitoring boreholes. The sensitivity of the receptors to contamination, including the consequences of contamination, should also be considered. If consideration of the receptors and the pathways, in particular the travel times, indicates a low sensitivity setting then further risk assessment effort may not be needed.

Where consideration of the setting indicates a sensitive location then further, more detailed assessment should be undertaken, initially a Simple Risk Assessment. The potential source term for an inert landfill can be assessed in a number of ways. This could include back calculating using the methodology for the derivation of remedial targets for soil and groundwater to protect water resources (Environment Agency 1999). This would give an indication of the leachable contaminant levels that would potentially be of concern. The leachate source term could be based on literature leaching values for contaminated soils. It would also be possible to initially consider the leachate quality at the levels of the waste acceptance leaching criteria for inert waste landfills then run further scenarios with increasingly greater levels of leachate contamination. This could provide an understanding of the source term that would have to be present to cause pollution. Where the site is operated in phases/cells the assessment could potentially consider a contaminated leachate in just one area of the landfill.

4.1.9.3 Landfill Gas Assessment

A qualitative Risk Screening approach to the source term for landfill gas at an inert landfill would normally be appropriate. This should be a similar approach to that described above for the hydrogeological risk. The assessment would normally be limited to a Risk Screening involving the consideration of the consequences of a risk being realised including the sensitivity of receptors. This is intended to ensure that the source term is evaluated at a level reflecting the sensitivity of the site. Further more detailed risk assessment might then be required, although the extent of any further assessment should be proportional to the risk identified. If there are receptors of sufficient sensitivity to justify it, migration monitoring along the pathway would be required, in addition to the monitoring within the waste, to ensure that a pollutant linkage does not arise undetected.

4.2 Pathways

Having identified the sources, the conceptual model must identify all the site-specific pathways along which any emissions may potentially travel. There are two basic pathways considered in this guidance for substances emitted from a landfill.

- Airborne
- Subsurface

There are other important pathways such as surface outbreaks or spillages of leachate and for mud on the road but the two basic pathways above represent the majority of the concerns for the risk assessments considered in detail here. Surface run-off should be dealt with mainly through the consideration of accidents (see Section 4.1.4).

4.2.1 Release Points

The pathway includes the release point that represents the start of the pathway. Even though a subsurface release may subsequently become an aerial release (e.g. landfill gas) the initial release point from the landfill needs to be considered. A list of potential release points is given in Box 7. This list is not exhaustive and other site-specific examples will exist.

Box 7 - Potential Release Points

Airborne	**Subsurface**
Leakage from landfill gas extraction system e.g. pipework, well heads, valves	Leachate leakage through the basal and side wall containment engineering
Emissions from gas combustion stacks e.g. gas engines and flare stacks	Side wall liner leakage of gas
Gas emissions from capped areas, intermediate capped areas, waste surfaces, flanks, tipping faces	Gas dissolution from the leachate following leakage
Particulate matter emissions from landfill surfaces, tipping faces, roads	

4.2.2 Processes within the Pathway

Movement through a pathway often changes the concentration of a substance from that emitted. This will be true where attenuation and dilution processes occur as leachate moves through the unsaturated and saturated zones and for aerial dispersion of landfill gas. The movement of gas through the ground or following dissolution from leachate can change the composition and concentration of the emitted substances. Describing and understanding these processes in the pathways will form an important part of a risk assessment.

Historically, most attention has been focussed on the subsurface pathways and these are most important for leachate movement and the subsurface movement of landfill gas that can lead to explosion or asphyxiation. Dispersion in ambient air also requires an equal emphasis; stack heights, meteorological data and topography are important elements of this pathway.

4.2.3 Level of Detail in Understanding the Pathways

The level of detail required in understanding the pathways will depend on the level of the risk assessment. In Risk Screening and Simple Assessments, it may be sufficient to have a basic understanding of the pathways since conservative assumptions are likely to be made. In a Simple Risk Assessment, it may be sufficient to assume that there is a direct source-pathway-receptor linkage without having a detailed understanding of the actual pathway. For instance, it might be assumed that there is no geological faulting and a direct hydrogeological pathway exists to a receptor. If such an assessment were to indicate that the impacts were not acceptable then the understanding of the pathway would need to be refined to assess whether the initial assumption was over conservative. The site investigation requirements for a Simple Risk Assessment must be sufficient to establish the basic geology and hydrogeology. If justifiable, conservative assumptions lead to an assessment that the risk is acceptable, more detailed assessment would not be required.

With respect to air dispersion, a Complex Risk Assessment is likely to require greater detail for topography than that required for a Simple Risk Assessment. For example, consideration of terrain may not be needed to conduct a Simple Risk Assessment whereas a more detailed modelling study is likely to consider the influence of buildings and terrain.

As well as the pathways through the environment the release points for the landfill will be an important part of understanding the landfill. For Risk Screening a general understanding of release points would be sufficient. Simple Risk Assessments using conservative parameters might select a plausible worst case set of release points. For a Complex Risk Assessment the site-specific release points would need to be identified and understood. Releases from area sources, such as gas releases from an uncapped phase or flank may need to be dealt with in more site-specific detail in a Complex Risk Assessment.

4.2.4 Monitoring

One key outcome from the consideration of the pathways should be the identification of monitoring locations. This should relate to the release points that represent the start of the pathway (e.g. monitoring of gas collection pipework) and to key points along the remainder of the pathways towards the receptors. It should be noted that the location of monitoring points will normally be based on a mixture of risk assessment and best practice. For instance, best practice requires boreholes for monitoring subsurface gas migration at intervals around the site even if there is no apparent source-pathway-receptor linkage (Environment Agency 2004g). Similarly for groundwater, two downstream monitoring boreholes are required as a minimum however the majority of landfills will require more than this due to the complexity of sub-surface flow. It is the understanding of the pathways that will dictate the number and location of boreholes for the downstream monitoring regime (see Environment Agency 2003h for more information).

4.3 Receptors

All the site-specific receptors must be identified in the conceptual model. There are a number of potential receptors that need to be considered with respect to landfill sites. The generic categories are listed below:

- humans
- flora
- fauna
- air
- water
- land
- buildings/structures

A number of subdivisions within these basic categories should be considered in the risk assessment and examples of these are listed below. It is worth noting that groundwater can be considered as both a receptor and a pathway. Although humans are the basic receptor at a house, hospital or footpath, for the purpose of the site-specific risk assessment the following list represents the types of receptor that should be considered:

- domestic dwellings (human occupation closer than 50m, between 50 and 250m, between 250 and 500m and beyond 500m)
- hospitals
- schools and colleges
- sensitive habitats and environmental areas e.g. SSSIs within 2 km, European sites (Special Area of Conservation (SAC) / Special Protection Area (SPA)) within 2km/5km
- offices, industrial units and commercial premises
- public footpaths or bridleways
- major highways and minor roads
- playing fields
- open spaces, parks and farmland
- allotments
- on site vegetation
- Air Quality Management Areas

- groundwater (including potential use of currently unused resources)
- groundwater fed discharges, springs, and river baseflow
- surface water
- public water supplies and other licensed abstractions (including source protection zones)
- licence exempt private water supplies

4.3.1 Exposure routes

Many of the listed receptors reflect different exposure routes to the same basic receptor i.e. people. Health risk assessments can include very detailed considerations of exposure routes and dosages. When considering the overall impact from the landfill these different potential exposure routes must be considered (Section 7.2.2).

It will be necessary to consider the nature of the risk at each receptor. There may be some instances when the same people are receptors for more than one source via more than one pathway. For instance a person living in one of the houses may walk regularly on a footpath next to the site and eat produce from an allotment.

4.3.2 Short and Long Term Exposure

One key consideration is whether the exposure at a receptor is long or short term. The site-specific receptors should be considered to determine over what time periods people may potentially be present to be exposed to an emission. Guidance to Local Authorities on air quality management (DEFRA, 2003) considers the locations with respect to Air Quality Strategy (AQS) Objectives. The objectives apply where members of the public are likely to be exposed over the averaging period of the objective. This principle can reasonably be applied to substances not covered by the objectives to provide a basis for the selection of appropriate environmental benchmarks. Section 4.4 considers the short and long term environmental benchmarks against which an emission may be compared.

4.3.3 Future Changes in Receptors

There may be a potential change in land use around the landfill that is known at time of a PPC application. For instance, where there is a planning permission in place, or where an area has been designated for a particular use. In these circumstances although the land may not yet contain the receptor in question it may be appropriate to consider the potential receptor in the risk assessment.

4.3.4 Grouping Receptors

It may be useful to group receptors together where the risks are likely to be similar e.g. a particular street or small group of houses. Section 6.1.3 considers the reporting requirements with respect to receptors.

4.3.5 Distance to Receptors

There should be no automatic cut off distance outside which a receptor should not be considered. It is possible that a receptor at 550m may be subject to higher concentrations of substances than a receptor at 450m. An airborne emission could have an impact a long way from the landfill depending on the pathways (i.e. topography and meteorological conditions). Similarly a leachate plume could have an impact a considerable distance from the landfill depending upon the pathways and receptors. Risk Screening can be used to exclude receptors where it can be demonstrated that the impact is not significant.

4.3.6 Habitat Receptors

Risk Screening should take account of the proximity of the landfill to a relevant receptor. If the landfill site is within 2km/5km of a European Site - (SAC) or (SPA) - then further consideration of waste type, site controls, likely pathways and the sensitivity of the Interest features identified within the SAC or SPA is required. It will be necessary for the operator to provide sufficient information for the Agency to conclude that the landfill will have no adverse effect on the integrity of any relevant European sites. Further assistance identifying relevant receptors is provided within Appendix 6 of the Habitats Directive Handbook. The sensitivity of specific types of Flora and Fauna protected within the European sites to landfill hazards is provided within Table 1 of that document (Environment Agency 2003i).

4.4 Environmental Benchmarks

It is important to determine the level of an emission from a landfill that would constitute pollution. All landfills have the potential to emit substances (even an inert landfill will emit some particulate matter), but what level can be considered not to be harmful? This is essentially defining what constitutes pollution e.g. what may constitute an unacceptable impact. Environmental benchmarks need to be selected to allow a comparison of the level of an emitted substance at a receptor (or compliance point) against relevant standards/criteria. For a quantified risk assessment the potential impact of an emission is evaluated through comparison against these appropriate standards in order to assess the significance of the impact and allow a decision to be made on whether the impact of the landfill on air or water quality may be acceptable.

The Agency guidance on Environmental Assessment and Appraisal of BAT H1 (Environment Agency 2003a) is essentially intended as a screening tool which indicates where an emission requires further assessment such as modelling the impacts of emissions to air. The basic principle being that if an impact is insignificant in comparison to the environmental benchmark then no further quantification is required.

The H1 guidance suggests screening out insignificant emissions to air where the predicted impact of an emission is:

- less than 1% of the long term environmental benchmarks; and/or
- less than 10% of the short term environmental benchmarks.

Where the emission is very low in comparison to the environmental benchmark then this can also be used to screen out insignificant emissions. For instance, if the concentration of a particular contaminant in the leachate is much less than the relevant environmental benchmark at the receptors, then after taking into account the uncertainty associated with the contaminant concentration it may be concluded that there is unlikely to be a significant risk associated with that contaminant.

Comparison against environmental benchmarks can also be used to prioritise the risks that need further consideration. For example substances are considered as percentages of their environmental benchmarks then the percentages can be compared to help prioritise the risks and concentrate the risk assessment effort. Similarly the comparison of predicted impacts against environmental benchmarks at the receptors could give a prioritisation of receptors. Further more detailed assessment may refine or change this prioritisation of the receptors. For instance, the output from a new generation air dispersion model may indicate which receptors are likely to be most at risk (exposed to the maximum ground level concentrations) from aerial emissions.

It is necessary to identify the most appropriate air and water quality standards for each site-specific receptor and compliance point. It should be noted that the national air quality objectives apply to any outdoor locations where the public is regularly present. Environmental benchmarks can be developed by considering existing environmental quality standards and other potential sources of relevant criteria. To set environmental benchmarks it will be necessary to consider:

- which emitted substances should be allocated an environmental benchmark for assessment
- what concentrations/criteria are appropriate
- what is the appropriate time period e.g. short or long-term, 8 hour or 15 minute average, hourly or annual means etc.
- The location at which the environmental benchmark will be assessed (this will be linked to monitoring locations and receptors)

Each point above should be explicitly addressed and justified.

4.4.1 Selection of Substances

Not every possible constituent of an emission need have an environmental benchmark selected. For existing sites knowledge of leachate, gas and dust composition can inform the choice of substances for which an environmental benchmark should be set. A limited number of indicator substances can be used in the risk assessment and it is these that should normally be assigned environmental benchmarks. The guidance on hydrogeological risk assessment (Environment Agency, 2003b) gives examples of the types of substances that could be used as indicator substances to limit the amount of modelling required. It is important that the choice of indicator substances represents the range of substances potentially emitted from the site (Section 4.1.6). As monitoring and analysis takes place through the life of the site the appropriate substances to consider may change and this would form part of the review process.

4.4.2 Selection of Values

The IPPC H1 Horizontal Guidance Note (2003a) uses environmental benchmarks as an indicator of a degree of environmental impact that can be considered acceptable for a particular substance to a receptor or environmental medium. Environmental Quality Standards (EQS) are prescribed for certain substances and are used to define the upper bound of a concentration of substance in the environment that is considered tolerable.

At present, statutory EQS exist only for a limited number of substances. However, the Agency has derived provisional benchmarks for substances released to each environmental medium from a variety of published UK and international sources. These are known as "Environmental Assessment Levels" (EALs).

For some substances with persistent, bioaccumulative or highly toxic effects, it is difficult to establish thresholds below which it could be considered "no harm" takes place. In these cases, the landfill operator should take a more precautionary approach to the prevention and control of the substance, and the substances should be given greater priority when considering the relative environmental risk between options. Further advice should be sought from the Agency regarding the scope and detail of risk assessment for these substances.

4.4.3 Values at Different Tiers of Risk Assessment

There may be differences in environmental benchmark selection and use depending on the level of risk assessment. For Simple Risk Assessment, selection of the most stringent value for environmental benchmarks for each media should be made without too much consideration as to specific receptors. Complex Risk Assessments considering the potential impact on human receptors may have to consider the sensitivity of the receptor in greater detail to develop environmental benchmarks using methods such as tolerable daily intake or other methods of developing health criteria values.

4.4.4 Hydrogeological Risk Assessment

The guidance on hydrogeological risk assessment (Environment Agency 2003a) provides environmental quality standards from which groundwater EALs can be derived. Unlike the air quality EALs, the hydrogeological risk assessment guidance includes consideration of baseline conditions in the selection of EALs

4.4.5 Landfill Gas

For toxicity risks both from landfill gas and its combustion products, the air quality EALs given in H1 (Environment Agency 2003a) should be used although for a Complex Risk Assessment of human health impact, further consideration of appropriate standards may be required. For odour, H4 (Environment Agency 2002h) provides guidance on odour thresholds.

Explosion and asphyxiation EALs are not considered in H1. The Guidance on the Management of Landfill Gas (Environment Agency 2004g) gives guidance on setting levels in external gas monitoring boreholes for assessment and compliance purposes. For explosion and asphyxiation these are based on 1% v/v Methane and 1.5% v/v Carbon Dioxide and a consideration of the site-specific background. These levels should be used as benchmarks for comparison against predicted impacts.

4.4.6 Particulate Matter

The particulate matter criteria appropriate for use at waste management facilities, including landfills, is considered in guidance on the monitoring of particulate matter in ambient air around waste facilities, M17 (Environment Agency, 2003f). M17 considers the categories of particulate matter to be taken into account in any assessment, the air quality criteria that exist for different types of suspended particulate matter around waste facilities and how to choose the most appropriate air quality criterion for a waste facility.

"Nuisance" dust is not dealt with in detail here, landfills can reasonably be expected to meet the same "nuisance " dust standards as other developments. M17 provides guidance for assessing nuisance dust around waste facilities. EQS for PM_{10} particles are available from Air Quality standards which are reproduced in the H1 guidance (Environment Agency 2003a). Where EALs are not found in H1 or M17 for the substances selected then methods such as using the tolerable daily intake should be used to determine an environmental benchmark. Operators should discuss any proposed approach with the Agency before proceeding.

4.5 Background Environmental Quality

Background information is required to determine the sensitivity of the receptors, for example, through issues such as model headroom (Section 2.9.1). This background data requirement will generally be the same for all levels of risk assessment though the level of interpretation of the data may vary.

For groundwater and surface water receptors, at both new and existing sites monitoring of the potential receptors must have been undertaken, so this background data must be available. Background monitoring for groundwater, surface water and soil gas is accepted practice at landfills. Routine aerial monitoring is not yet standard practice and such monitoring programmes will need to be developed using a risk based approach. Background information on air quality is available from a variety of sources (Department for Environment, Food and Rural Affairs 2003).

4.5.1 Characterisation of the Background

One of the often asked questions for new landfills is how long a background monitoring period is required. This is not the correct question to ask. The background monitoring must provide an understanding of the landfill's environmental setting whether this is for groundwater or ground gas levels. The question that operators should be asking is, can the background monitoring provide confidence that the environmental setting is understood to a sufficient level?

4.5.2 Groundwater

Groundwater monitoring over a period of twelve months is often mentioned since this will at least give a chance of observing seasonal trends. One year is insufficient to understand how the hydrogeology reacts to differing patterns of rainfall over the period of time that a landfill will pose a potential risk. In some circumstances such detailed long-term understanding may not be necessary. For example a landfill for non-hazardous waste where the groundwater is 100m below the base of the landfill with a substantial geological barrier will not need the same level of confidence as a landfill for non-hazardous wastes where the base of the landfill is 2m above the groundwater level. In the first case, only a limited amount of monitoring would be required to provide sufficient confidence in understanding of the groundwater. The second case would require a much greater understanding of the hydrogeological regime, which may require monitoring over a prolonged period.

4.5.3 Stability

The flow regime within the unsaturated zone and the rock units surrounding the site needs to be established to enable the stability of the slopes to be accurately assessed. This should consider the location of any seepage and the quantity of head build up that is likely to occur following those slopes being confined. This assessment should be carried out during conditions of high rainfall, to enable worst case conditions to be identified.

4.5.4 Soil Gas

It is essential to have an understanding of the background gas conditions. Monitoring of subsurface gas at the landfill must be sufficient to understand the levels and importantly the composition of the background gas. Trace gas analysis must be undertaken, sufficient to characterise the gas. The level of analysis required would be site-specific, but for all sites that have the potential to produce methane and carbon dioxide, the baseline gas composition should be sufficiently well understood to allow a comparison with future gas analysis. This must ensure that a distinction can always be made between gas originating from the landfill and the baseline gas.

5 RISK ASSESSMENT SCENARIOS

5.1 Planned and unplanned occurrences

Operations within landfill sites can be broadly characterised in three categories.

- Normal - including the inevitable degradation of engineering controls and management systems and planned maintenance, for example periodic shut downs of gas treatment plant for routine maintenance etc
- Abnormal - unplanned but foreseeable. Including for example unplanned shut downs of gas treatment plant and breakdowns of equipment such as leachate pumps
- Accidents

It is important to recognise that normal operations includes the predictable degradation of management and engineering systems such as leachate management measures including the artificial sealing liner and capping systems. LandSim 2.5 (Environment Agency 2003d) considers the degradation of management systems with respect to the hydrogeological risk assessment. The assessment of normal operations must therefore deal with the inevitable degradation over time of both management and engineering structures.

5.2 Risk Assessment Interactions

There are important inter-relationships between the different risk assessments and this must be reflected in the scenarios selected. For instance, the stability assessment of a waste slope would need to include leachate recirculation proposals. Leachate heads are also an important issue for stability and for landfill gas. It is important that these inter-relationships, illustrated in Table 5.1 be recognised and recorded as assumptions in the risk assessment. When circumstances deviate from the agreed risk assessment assumptions, for instance a leachate management problem (e.g. elevated heads above a permitted 1 metre) this must trigger a review of the stability and landfill gas assessment.

Whereas for the landfill gas and hydrogeological risk assessments there will be emissions that do not constitute pollution, in general for stability the structure either fails or it does not. An appropriate factor of safety must be selected that reflects the consequences of the failure. For instance where the consequences of a side wall liner failure would be to remove a barrier to a subsurface pathway to a sensitive receptor such as gas migration to a cellar, then the design should include a higher factor of safety. It is worth noting that without active extraction, engineered barriers cannot entirely break the pathway for gas migration.

Table 5.1 An illustration of risk assessment interactions.

Interactions	Hydrogeological	Landfill Gas	Particulate	Stability
Change in waste types	✓	✓	✓	✓
Waste acceptance ratios	✓	✓	✓	✓
Leachate recirculation	✓	✓		✓
Leachate heads	✓	✓		✓
Capping system	✓	✓		✓
Lining within the waste body	✓	✓		✓
Surface and groundwater management	✓	✓		✓
Phasing and cell design	✓	✓	✓	✓
Timing of capping and restoration	✓	✓	✓	✓
Basal and side wall liner designs	✓	✓		✓

5.3 General Requirements for Risk Assessment Scenarios

Landfills change significantly over time. These changes are associated with the progressive landfilling of waste, the physical, chemical and biological processes within the waste and degradation of risk management systems. It is important that the different stages of the landfill are reflected in the conceptual model and the risk assessment scenarios. For instance in the past, some waste management licence applications have not considered the impact of flare emissions because at the point of application the applicants were not sure when or how much gas they would be flaring. It would not be possible to permit a new landfill without evaluating the impact of flaring and future gas utilisation. The risk assessment scenarios must satisfy the following.

- The assessment must consider the risk over the whole life cycle of the landfill
- Different time scenarios must be considered in the risk assessment e.g. including the phasing and development plan, the operational phase as a whole; short term post closure and long term post closure etc
- The risk assessment must be conducted for the whole installation
- The interactions with other areas of risk must be considered
- The three categories of operations (normal, abnormal and accidents) must be reflected

The assessment of the risks posed by a landfill site should be conducted to cover the entire life cycle of the landfill. Landfill sites can present a hazard for very long periods of time and the assessment cannot be restricted to the short term operational life of the site. The risk assessment must cover the time until the landfill no longer poses an unacceptable risk to the environment. This means looking at the stabilisation processes within the waste and the degradation of any artificial engineering or other structures/processes which are used to manage the environmental risk.

Determining the scenarios that should be considered in the risk assessment is an important stage in the process and one that should be undertaken at the Problem Formulation stage (Section 2.3). Guidance on selecting scenarios is given in the following sections.

5.4 Accident Scenarios

There are some accident hazards which should be dealt with under the hydrogeological, landfill gas, particulate and stability assessments. This is highlighted in Table 5.2. Only where the accident scenarios cannot be covered in the individual risk assessments is a separate consideration required.

5.4.1 Fires

One key accident hazard is fire. Although related to landfill gas and hydrogeological risk assessments, it falls outside the usual scope of both. A separate fire and explosion assessment should be conducted. This should consider the airborne releases (gaseous and particulate) and water contamination issues such as contaminated firewater. Fire or explosion damage to engineered containment would normally be dealt with in the hydrogeological and/or landfill gas risk assessments. The principles given elsewhere in this guidance should be applied to the assessment e.g. the level of the assessment should be proportionate to the seriousness of the risk. Where there are near receptors for air borne emissions then modelling of emissions from fires would normally be required. The modelling should be repeated for a number of different meteorological conditions in order to feed into contingency plans that can be related to the conditions i.e. atmospheric stability and wind speed at the time of the incident.

5.4.2 Surface Water

Leachate spillages that do not enter groundwater will need to be considered separately to reflect the risk to surface water. Similarly the impact of flooding on surface water following overtopping will need an assessment outside the hydrogeological risk assessment. The risk to surface water (other than that fed by groundwater) will primarily be assessed through the consideration of accidents.

5.4.3 Waste Slippage

Any significant waste slippage would be considered as an accident. A movement of the waste that led to a slip into an unlined area of the site would have implications for leachate and landfill gas risk. The management of the risk of slippage (i.e. the movement of the waste mass) should be dealt with as part of the stability risk assessment. Consideration of the associated consequences of such an event i.e. landfill gas and leachate releases should be considered in the landfill gas and hydrogeological risk assessments respectively. The consideration of the accident hazards should inform the selection of scenarios for the landfill gas and hydrogeological risk assessments.

5.4.4 Example Accident Scenarios

The following table is a list of example accident scenarios that should be considered for quantification in the relevant risk assessment topics. The level of risk assessment employed for the scenarios would normally be the same as that conducted for normal operations. The risk assessments would usually cover specific accident scenarios using the same modelling techniques used for assessing the impact on receptors of normal (and abnormal) operations. Not all of these will be appropriate for each site and there may be other site-specific scenarios that require consideration.

Table 5.2 Example Accident Scenarios

Accident	Hydrogeological	Landfill Gas	Particulate	Stability
Flooding	✓	✓		✓
Catastrophic failure of the basal artificial sealing liner in one (or more) cell(s)	✓			✓
Catastrophic failure of the basal artificial sealing liner and artificially enhanced geological barrier in one (or more) cell(s)	✓			✓
Catastrophic failure of the side wall liner in one (or more) cell(s) no active landfill gas extraction	✓	✓		✓
Catastrophic failure of the side wall liner in one (or more) cell(s) with active landfill gas extraction		✓		
Elevated leachate heads in one (or more) cell(s)	✓	✓		✓
Catastrophic failure of the side wall liner in one (or more) cell(s) and elevated leachate heads with active landfill gas extraction	✓	✓		✓
Catastrophic failure of the side wall liner in one (or more) cell(s) and elevated leachate heads no active landfill gas extraction		✓		
Catastrophic failure of gas collection infrastructure		✓		
Waste slippages	✓	✓	✓	✓
Deep seated landfill fires		✓		✓
Leachate spillage	✓			

It is important that the accident scenarios used in different risk assessment topics are consistent. For instance the consideration of the failure of a side wall liner system should use the same assumptions in the stability, landfill gas and hydrogeological risk assessments.

5.5 Hydrogeological Risk Assessment Scenarios

For hydrogeological risk assessment, the time scenarios are discussed in Agency guidance (Environment Agency, 2003b) and basically reflect the operational phase (pre capping), the post closure period when management systems are still functioning and the long term situation where management systems are degrading and leachate quality is improving. LandSim 2.5 reflects this understanding of the change of the landfill with time.

The risk assessment must be conducted for the whole of the installation. Where areas that no longer receive waste ('closed' parts of the landfill) are included in the installation the risk assessment must address those areas. (Landfill Directive Regulatory Guidance Note 6 Environment Agency 2003g). The risk assessment must be able to differentiate between different areas of the landfill and predict the individual and cumulative impacts from separate sections of the site. The scenarios for operational periods and capped periods must be carefully developed. It is also necessary to be able to predict the impact of waste overlying existing deposits. Where a proposal involves the lining/deposit above existing waste deposits the hydrogeological risk assessment must quantify the impact of leachate release from the existing waste as a result of the placement of further waste above it.

5.6 Landfill Gas Scenarios

5.6.1 Scenarios for subsurface migration, surface and fugitive emissions

Landfill gas risk is managed through the effective collection of landfill gas (and subsequent proper treatment). The scenarios that should be considered in the risk assessment have to reflect the range of normal operations and also abnormal conditions. The scenarios that should be considered are summarised in Table 5.3 below:

Table 5.3 Gas Emission Scenarios

Scenarios assuming maximum gas generation rate	Subsurface migration assuming capped landfill	Surface and fugitive emissions
Proposed/predicted collection efficiency	Normal	Normal
Planned down times of gas extraction (based on proposed maintenance periods) and worst case meteorological conditions	Normal	Normal
Predicted degradation of artificial side wall liners, and other management systems e.g. silting/blockage of side wall aggregate layers	Normal	
Selected uncapped areas, waste flanks from phasing and capping plans		Normal
No active gas extraction due to unplanned failure based on proposed response/repair times	Abnormal	Abnormal
Longer term failure of active gas extraction	Abnormal	Abnormal
Fugitive emissions from collection infrastructure (based on times between monitoring of pipework etc.)		Abnormal
Fugitive emissions from a degraded cap (based on times between monitoring of surface emissions)		Abnormal

The abnormal scenarios will help determine the sensitivity of the site. It is important to consider the potential impact of no gas collection, even though this should not occur, as this will help inform the Agency's decisions on the appropriateness of the proposed risk management measures such as containment engineering, factors of safety, monitoring programmes, telemetry and response times for failures. Understanding what may happen if collection is not taking place will help determine how quickly the systems need to be repaired and whether back up secondary systems are needed, which spare parts are needed on site etc. This is linked to the contingency planning required (Section 6.1.1).

Any landfill is likely to contain a variety of potential point source emissions and fugitive emissions related to landfill gas. The release points will change with time, for example temporary waste slopes and the scenarios listed above must be examined with a range of release points that reflects the risks at different stages of the site's development. The times at which the above scenarios should be considered will depend upon the site-specific phasing and development plan but should include the aftercare phase as well as situations which may represent the plausible worst case. For example when there is exposed/sacrificial collection infrastructure and where a large waste surface/flank will be left exposed for the longest time. The proposed phasing plan should be considered together with the proximity and the pathway to receptors to develop a plausible worst case scenario. For subsurface gas migration, consideration should be given to the time where the area of the landfill against the pathway is full of waste with a cap in place.

The level of detail required for the quantification of the scenarios will depend upon the level of risk assessment required (Section 2.4).

5.6.2 Scenarios for point source emissions from combustion

When a new landfill site is proposed, the rate of gas production will not be known (and the limitations of models should be recognised - Section 2.9) and the timing of utilisation (i.e. electricity generation) can only be estimated. The risk assessment must reflect the likely long term combustion at the site i.e. the stage that should be modelled is the maximum predicted number of flares and engines. The scenarios that should be modelled are shown in Table 5.4 below. The table gives a matrix of combustion combinations and emission limit compliance.

Table 5.4 Gas Combustion Scenarios

	Emission Limits	
Operations	**Met**	**Exceeded**
Maximum predicted gas engines running at optimum capacity	Normal	Abnormal
No operational engines, all gas being flared	Normal	Abnormal
All gas engines and flares running at optimum capacity	Normal	Abnormal

The flares will often be in place as back-up to the engines but it is not unusual for the predictions of gas production to be under estimates and for the engines and flares to be running concurrently. The above situations should reflect the anticipated normal operations of the engines and flares and also the situation where all the combustion equipment is running at full capacity. Note that full capacity may not be identical to good operational practice as the need to reduce emissions may require that combustion is carried out at less than full capacity.

Each of the combustion combinations should be considered where emission limits are met and where emission limits are exceeded. Emission standards will be set in a PPC permit for both flares and engines (Environment Agency 2004d and 2004e). These will be compliance limits enforced by the Agency. Where an EQS may be breached or where the predicted site-specific impacts require it, more stringent emission limits than those given in the Agency guidance may be required. In order to determine the appropriateness of the risk management measures and the potential risk posed by the site it is necessary to understand the impact on the receptors of emissions above those proposed. This must include substances produced as a result of incomplete combustion and substances formed post combustion. The situations that may give rise to the exceedence of emission limits could include failure to operate the flares or engines according to best practice.

5.7 Particulate Risk Assessment Scenarios

An assessment of normal operations of the landfill should consider:

- deposit of identified waste streams within the proposed operational restrictions
- surface releases from waste and other surfaces based on the proposed phasing and restoration programme

- releases from vehicle movements based on proposed operational restrictions and dust suppression proposals

An assessment of abnormal operations should consider:

- failure of dust suppression procedures (e.g. bowser not on site within proposed response times etc.)
- deposit of identified waste streams with a failure of operational restrictions
- exceptional meteorological conditions

The key time period for particulate risk is when the site is operational. Effective restoration of the site should ensure that there is minimal particulate risk in the post closure period.

5.8 Stability Risk Assessment Scenarios

The stability risk assessment should consider each slope and structure that will exist throughout the landfill's life. This means a number of different temporary slopes need to be considered through the operational life of the site as well as the final pre and post settlement contours. The stress history of those slopes and the potential effect of pore water pressures should be considered

There are a number of elements that need to be considered in a stability risk assessment.

- The final landform
- Side wall liners
- Sub grade
- Temporary waste slopes
- Other structures i.e. leachate extraction and monitoring wells

The phasing plan for the site will indicate which waste slopes will exist and for how long each will exist. All the temporary waste slopes proposed in the phasing plan for the landfill must be assessed. A change to any one slope could have knock on effects for the whole phasing plan and the scheme for the site must be considered as a whole.

Associated structures can mean almost any landfill structures not otherwise covered but will primarily mean leachate management structures (wells and up slope risers) and structures such as cell separation bunds.

5.9 Human Health

Harm to human health is potentially the most emotive issue a site will have to deal with and a rigorous assessment of health risks will be essential to a smooth application process. When considering the risk assessment scenarios it is necessary to consider the possible source-pathway-receptor linkages that may have an impact on human health. The following is a list of some of the main exposure routes. There are other potential routes that may need to be considered at some landfill sites.

- Drinking contaminated water
- Inhalation/Ingestion of particulate matter
- Eating contaminated food/soil
- Inhalation of landfill gas
- Inhalation of combustion by-products

5.9.1 Risk Assessment Topics

The main potential risk to human health from most landfills is likely to come from airborne emissions. It is important that the risk assessment scenarios explicitly address human health impact. This will be predominantly within the landfill gas assessment but should also involve consideration of dust impact and possible other pathways. For example the contamination of food from allotments or market gardens may need to be considered depending on source-pathway-receptor linkages and Risk Screening. Health impacts will also need to be included when considering accidents and their consequences, for instance in the event of a fire. It is important that all the potential health effects are brought together in a summary. Some of the site-specific receptors will be potentially exposed to particulate matter, raw landfill gas and combustion by-products. Section 6.1.3 considers reporting requirements and where applicable, the impacts on a receptor should be brought together and the cumulative effect considered.

Table 5.5 presents an indicative summary of the main exposure routes and where these exposures should be considered in the risk assessment process. These should be adapted where necessary to address the site-specific risks.

Table 5.5 Examples of the risk assessment topics with respect to human health

Exposure route	Accidents	Hydrogeological	Landfill Gas	Particulate	Stability
Inhalation of landfill gas	✓		✓		
Inhalation of combustion by-products			✓		
Inhalation/Ingestion of dust	✓		✓	✓	
Eating contaminated food	✓	✓	✓	✓	
Drinking contaminated water	✓	✓			

Potential source-pathway-receptor linkage ✓

5.10 Habitats

The requirements of the Habitats Regulations should be integrated within the risk assessments ensuring all potential hazards from the landfill and their potential pathway to the European site are assessed. A worst case scenario will need to be considered for each hazard. This will then need to be linked into the specific sensitivities of each interest feature that the European site has been identified for, to ensure that the Agency has sufficient information to determine no / likely adverse effect on the integrity of the European site.

Table 5.6 indicates where the Habitats Directive assessment may need to be conducted in the risk assessment topics covered by this document. There may be other site-specific exposure routes that need to be considered. This will need to be combined with the amenity assessments that are beyond the scope of this document (Sections 1.2 and 3.1.5).

Table 5.6 Examples of the risk assessment topics with respect to Habitats

Exposure route to Habitat	Accidents	Hydrogeological	Landfill Gas	Particulate	Stability
Toxic Contamination (via water)	✓	✓			
Toxic Contamination (via air)	✓		✓	✓	
Nutrient Enrichment	✓	✓			
Habitat Loss	✓	✓	✓	✓	✓
Potential source-pathway-receptor linkage ✓					

6 REPORTING

Since the decision on a landfill application must be transparent, justifiable and understandable the reporting of a risk assessment is very important. The following sections outline the required outputs from the assessments and the recommended reporting requirements.

6.1 Risk Assessment Outputs

There are a number of outputs from the risk assessment process that must be recorded. These are summarised in Table 6.1. The key assumptions and their significance should be reported in a consistent format across the separate risk assessment topics. This will allow a ready check to be made as to whether the assumptions made are consistent. Any common assumptions used in the separate risk assessment topics must be recorded. Within each risk assessment topic the inter-relationships with other topics should be recorded and cross-references made to ensure a consistency of understanding on the part of the operator. This could be achieved through the production of a summary for each risk assessment using the relevant outputs in Table 6.1 as headings.

Review and update of key assumptions should be linked to the requirement for risk assessment reviews either annually or as part of a variation to working practices; or triggered by monitoring results (i.e. assessment levels). For example a proposed new waste type, such as a treatment sludge, may influence the stability assessment, the landfill gas generation profile and the absorptive capacity of the waste and thus may require a review of all of the risk assessments. It is important that the sensitivity analysis provides a detailed understanding of the significance of changes in key parameters. This is critical in understanding how important the detected changes are and enables a risk-based approach to regulation.

6.1.1 Accidents Outputs

Contingency plans are an important output from the assessment of accidents. It is important that contingency plans are site-specific rather than generic. This means that the on-site actions must be specific to identified hazards and that off-site requirements relate to actual receptors and consider existing pathways. For instance where modelling of fire scenarios has been undertaken, it should be clear where under different meteorological conditions the likely maximum ground level concentrations would arise and information or actions can then be focussed on the relevant receptors. Contingency plans must not consist of vague statements such as “appropriate steps will be taken where necessary following consultation with the Agency”.

Contingency Plans should cover the following areas:

- remedial actions
- mitigation measures
- monitoring measures
- liaison with other relevant bodies
- information provision to the public
- personnel responsibilities
- personnel training and guidance on specific accident scenarios

Following an incident a review of risk management measures and contingency plans should be triggered. This could involve undertaking an updated risk assessment based on knowledge gained as a result of the incident.

6.1.2 Waste Types

The consideration of the waste types for the risk assessment should follow a format similar to the example shown in Table 6.2 below. The European Waste Catalogue (EWC) should be used to identify either individual waste streams or, where this can be justified, to group together waste types where the hazard is sufficiently similar. It is likely that tables similar to Table 6.2 will contain a combination of qualitative and quantitative information. The limiting values should be specific maximum limits on the total concentrations and the leaching potential should provide limits on the leachable composition (this information may not be available for all waste types, for instance solid municipal waste).

Table 6.2 Example format for considering the hazard from waste types

EWC (or groups of codes)	Description	Physical form	Primary contaminants	Limiting values	Leaching potential	Gas generation potential	Odour generation potential	Particulate generation potential

Table 6.1 Recording of the risk assessment outputs

Outputs	Hydrogeological	Landfill Gas	Particulate	Stability
Assumptions	✓	✓	✓	✓
Areas of uncertainty	✓	✓	✓	✓
Sensitivity analysis	✓	✓	✓	✓
A review programme to test key assumptions i.e. a validation plan	✓	✓	✓	✓
Triggers for review of risk assessment	✓	✓	✓	✓
Selection of environmental benchmarks	✓	✓	✓	
Risks screened out as insignificant	✓	✓	✓	✓
Trigger (compliance) levels and control (assessment) levels	✓	✓	✓	✓
Emission limits		✓	✓	
Risk based monitoring programmes – locations, frequencies, determinands	✓	✓ e.g. migration monitoring locations and frequency	✓	✓
Operational parameters	✓ e.g. maximum leachate head and action levels (for example 1 metre maximum and 0.75m action level)	✓ e.g. justification for the timing of active extraction;	✓e.g. waste handling/ deposit; dust suppression; site road construction; speed limits.	✓ e.g. restrictions on areas for leachate recirculation; waste placement against phase separation bunds.
Design parameters	✓ e.g. permeability and thickness of enhanced geological barrier	✓ e.g. side wall liner and cap; extraction system design; gas treatment pre or post combustion; number and capacity of flares; utilisation capacity; stack heights	✓ e.g. phasing; capping and restoration.	✓ e.g. material properties for lining or subgrade materials; maximum slope angles and lengths; designs for associated structures; factors of safety
Maximum response times to specified failures of equipment	✓	✓	✓	
Programmed down times for equipment	✓	✓		
Telemetry requirements	✓	✓		
Indicative completion criteria	✓	✓		✓
Time period for active management	✓	✓		
Impact on receptors quantified and assessed against environmental benchmarks	✓	✓	✓	
Contingency plans	✓	✓	✓	✓

6.1.3 Receptors

The predicted impact at each receptor (or group of receptors) must be reported. The reporting should be centred on the receptors and the assessment of risk to each receptor clearly identified. Reporting the impact for each receptor enables the predicted impact from each risk assessment topics to be considered together. The most usual examples will be the impact of airborne emissions which will commonly impact upon the same receptors.

A single list of receptors should be provided with a reference to the site plan showing the locations. This can be reported in the form of a table which also provides reference to where in the risk assessment documentation an assessment of the risks to that receptor are presented. An example format is presented in table 6.3 below.

Table 6.3 Example format for reporting the risks to receptors

Receptor	Plan	Accidents	Hydrogeological	Landfill Gas	Particulate	Stability
Carnation Street	🗁	✓ 🗁		✓ 🗁	✓ 🗁	
Boundary Burn	🗁	✓ 🗁	✓ 🗁			✓ 🗁
Potential source-pathway-receptor linkage ✓				Document/Section/Page Reference(s) 🗁		

Human health impacts must be explicitly addressed for all the relevant human receptors identified. For many sites the landfill gas and particulate assessments will be the most appropriate place to deal with a summary of the health effects. There must be a single summary of the potential health effects bringing together all the risk assessment topics. Exposure of the same people at different locations (e.g. local residents who use footpaths and eat food from allotments) must be reported.

Reference should be made to the stability, hydrogeological and landfill gas risk assessment guidance for more precise information requirements in the risk assessment process.

6.1.4 Level of Risk Assessment

The level of risk assessment undertaken must be justified in the report. A possible format is shown below in Table 6.4.

Table 6.4 Example format for reporting the level (tier) of risk assessment undertaken

Risk Assessment Topic	Level of Risk Assessment	Justification reference	Risk Management Measures references
Accidents			
Hydrogeological			
Landfill Gas			
Sub surface migration			
Landfill gas releases			
Combustion point source releases			
Particulate Matter			
Stability			

6.1.5 PPC Statutory Consultees

6.1.5.1 Human Health

For a PPC permit application, the Primary Care Trust or the Local Health Boards (in England and Wales respectively) and the Food Standards Agency are two of the statutory consultees. This is an important part of the application process. The consultees have the public confidence and can provide knowledge or expertise the Agency may lack. If the consultees are satisfied with the risk assessment (assumptions, justifications, outputs and statements) the Agency is more likely to be satisfied and the application process should proceed more smoothly.

In order for the consultees to make an informed input into the permitting process the risk assessment must address their specific areas of concern. The reporting of the risk assessment should allow the consultees to make an informed response to the PPC application. A good PPC application will be one that provides sufficient information to enable the statutory consultees to provide a view to support the Agency's decision-making.

As stated above in section 6.1.3 there should be a single health impact assessment summary that directs the reader to the relevant sections of the individual risk assessment topics and, where relevant, considers any combinations of impacts on human receptors.

6.1.5.2 Nature Conservation

English Nature or the Countryside Council for Wales are the relevant statutory consultees in England and Wales respectively. If the landfill is within 2km/5km of a European site, they will be consulted on the application and will receive a summary of the Agency's Habitats assessment.

CROW Act assessments for Sites of Special Scientific Interest (SSSI's) may also require consultation with English Nature or the Countryside Council for Wales, if the application has the potential to damage a SSSI.

7 DECISION-MAKING

7.1 Legislation and Background

The basis for regulatory decision-making is the legislation. The following sections briefly outline the relevant legislation and regulatory background in England and Wales.

7.1.1 Overall Objective of the Landfill Directive

The overall objective (Article 1) of the Landfill Directive (1999/31/EC) is to prevent or reduce as far as possible negative effects on the environment (including harm to human health). This is to be achieved by way of stringent operational and technical requirements on the waste and landfills. The risk management measures adopted at the landfill must minimise the impact on the environment and human health.

7.1.2 Accidents

The Landfill Regulations require that a permit include appropriate conditions ensuring that the landfill is operated in such a manner that the necessary measures are taken to prevent accidents and to limit their consequences (Regulation 8 (2) (c)). Many landfill assessments have in the past been conducted assuming that all the risk management measures function perfectly for the entire life of the site. The Agency's experience of regulating landfill sites indicates that this is not the case. It is important to appreciate that an accident such as a major fire or leachate spillage could potentially have consequences beyond that expected during the lifetime of normal operations.

Box 8 - Example comparing accidental emissions to those of normal operations

A leachate pumping failure resulting in spillage into an unlined area of the site could equate to many years of leakage through the engineered containment. There is little point in collecting leachate from well engineered basal leachate sealing and collection systems and then subsequently handling it in poorly designed and managed pipework and storage facilities.

PPC permitting introduces a step change in the manner in which landfill operators must plan for and handle accidents. The consideration of accidents and their consequences is a crucial part of the landfill risk assessment.

7.1.3 Hydrogeological Risk Assessment

The basis for providing groundwater protection is currently the Groundwater Directive (80/68/EEC) which is implemented for PPC permits by the Groundwater Regulations 1998. The Directive will be replaced by a daughter directive under the Water Framework Directive in the future. The Groundwater Regulations have to be considered both at the PPC application stage and also for any variation which may impact on the risk to groundwater, as the PPC permit will be a groundwater authorisation. Paragraphs 2 and 3 of Schedule 2 of the Landfill Regulations set out additional specific requirements with respect to groundwater protection in particular the requirements for a geological barrier and the collection and extraction of leachate (Environment Agency 2003g).

Compliance with the Groundwater Regulations should be considered for the whole life of the landfill. Where the landfill represents a serious environmental risk at any stage of its lifecycle it should not be permitted. The hydrogeological risk assessment should be conducted in accordance with the Agency's guidance on Hydrogeological risk assessments for landfills and the derivation of groundwater control and trigger levels (Environment Agency 2003b). This guidance must be read in conjunction with that document.

7.1.4 Landfill Gas Risk Assessment

Paragraph 4(2) and (3) of Schedule 2 of the Landfill Regulations require that landfill gas be collected and that the collection, treatment and use of landfill gas must be carried on in a manner which minimises damage to or deterioration of the environment and risk to human health. For new sites Paragraph 1 of Schedule 2 requires that a landfill (PPC) permit *should only be issued where the locational characteristics or the corrective measures to be* taken indicate that the landfill does not pose a serious environmental risk. Reference should be made to the Guidance on the Management of Landfill Gas (Environment Agency 2004g) for more detailed guidance on how to conduct a landfill gas risk assessment.

7.1.5 Particulate Risk Assessment

Paragraph 5 of Schedule 2 of the Landfill Regulations require that measures must be taken to minimise the nuisances arising from the landfill in relation to odours and dust. Paragraph 1(1) of Schedule 2 of the Landfill Regulations requires the location of a site to take account of various potential receptors including residential, recreational, agricultural, urban sites and nature protection zones (see Section 7.4). In addition there are requirements for assessment when a European site (as defined by the Habitats Regulations) has been identified as a receptor and relevant hazards have been identified (Environment Agency 2003i).

7.1.6 Stability Assessment

The Landfill Regulations require in Schedule 2 paragraph 6 (1) that the placement of waste must ensure stability of all the waste on the site and associated structures and in particular must avoid slippages. Paragraph 6 (2) requires that where an artificial barrier is used, the geological substratum must be sufficiently stable, taking into account the morphology of the landfill, to prevent settlement that may cause damage to the barrier.

Although the requirement to consider stability is explicit in the Landfill Regulations this is not a new requirement and the stability of the waste mass should always have been an essential design feature for landfill sites. When undertaking the stability risk assessment reference must be made to the Agency's guidance on Stability of landfill lining systems (Environment Agency, 2002l). There are also many engineering documents providing guidance on stability issues, for instance on angles of repose.

7.1.7 Habitats Assessments

Regulation 48 (1) of the Habitats Regulations requires the Agency, as a competent authority, before issuing a landfill permit, to conduct an appropriate assessment of the application and its potential implications for any relevant European sites. Regulation 48 (2) requires the applicant to provide such information that the Agency may reasonably require for the purposes of this assessment. The request for this information is presented within the Habitats Assessment in Part B of the Landfill PPC application form.

Prior to the Landfill Permit being issued the Agency must determine, from information submitted, that the landfill will not have an adverse effect on the integrity of the European site (Regulation 48 (5)). A permit may only be granted if this is not determined, if there are no other alternatives solutions, and that the operation must go ahead for reasons of overriding public interest (Regulation 49).

7.2 Assessment of Impacts

The impact assessment is a key area in the decision-making process. It involves the prediction of the level of an emitted substance at a receptor and the comparison of the predicted levels, that may arise, against relevant criteria i.e. environmental benchmarks. This must provide an assessment of the potential environmental effects (including on human health) of emissions that have not been screened out as insignificant. The following points must have been addressed in a quantitative risk assessment in order to inform the decision-making process.

- a quantification of the impact of emissions
- a comparison of the predict impact must be made against the appropriate environmental benchmark (section 4.4)
- an evaluation of the potential human health impact must be made of the total cumulative exposure (e.g. additive) for each relevant receptor
- an interpretation must be made by an appropriately qualified person

Simple and Complex Risk Assessments must quantify the predicted level of substances, at each relevant receptor, for normal and abnormal operations and for accidents (see Section 5). Normal operations will occur, and the impact assessment is a consideration of the consequences of these operations. For abnormal operations and accidents the likelihood/frequency of occurrence must also be considered alongside the consequences of the predicted impact (see Section 7.4.2). Any decision will never be determined simply on whether the predicted impact is below the environmental benchmark. Predicted impacts near or approaching the criteria may, given the uncertainties, indicate that the proposed development may not be acceptable. Section 7.6 discusses decision-making in the face of uncertainty.

7.2.1 Accidents

H1 (Environment Agency 2003a) includes a methodology for considering the probability of occurrence and producing matrices of risk for accidents. The recommended approach here is to place a greater emphasis on the consequences of an occurrence (the impact) and using this to feed into the risk management procedures and contingency plans. Estimates of the probability of occurrence are just that, a qualitative consideration of the likelihood. The processes within a landfill are less well understood than, for example, a chemical manufacturing plant and methods of predicting occurrences such as fault tree analysis will be correspondingly less useful.

For each identified hazard an assessment of the impact at all relevant receptors should be made. As in all areas of risk assessment the effort must not be disproportionate to the risk and an appropriate level of detail should be achieved by employing a tiered approach as described in Section 2. The depth and type of assessment will depend on the characteristics of the installation and its location. The main factors which should be taken into account are:

- the scale and nature of the accident hazard presented by the landfill
- the potential impact on the receptors

Section 5.4 details where the individual risk assessment topics should consider the impact of accidents.

7.2.2 Human Health

Much of the required impact assessment falls under the landfill gas risk assessment. The impacts from landfill gas emissions and from any combustion point sources must be considered together for each human health receptor. Both short and long term exposure must be considered separately by comparing the predicted concentrations against appropriate criteria.

The health impact of accidental releases in addition to normal exposure should be considered. This will help in evaluating the appropriateness of the risk management measures and contingency plans.

7.2.3 Landfill Gas

Clearly a scenario representing no collection of gas cannot exist at the same time as one representing full capacity combustion. The proposed operations of the site should be considered including timings for flaring and utilisation, planned and unplanned down times taking into account the proposed response times and spare part storage etc. As part of the interpretation of the impacts, a plausible worst case combination of predicted impacts should be considered as well as the impact of the proposed normal operations. It is likely to be appropriate to compare exposure to elevated emissions and some other abnormal events or accidents (for example, the initial release of gas from a waste slippage) to the short term environmental benchmarks.

7.2.4 Global Warming

Global warming is not a site-specific risk issue and will not require a specific assessment of impact on local receptors.

Landfill gas is an important contributor to greenhouse gas emissions in the UK and biodegradable landfills must be designed and operated in a manner that ensures the maximum practicable collection and treatment of the gas. This maximum extraction and treatment (normally oxidation of methane to carbon dioxide through combustion) is consistent with the best practice requirement for managing landfill gas.

7.2.5 Personnel

It may seem self-evident that suitably qualified persons should conduct the risk assessment but this cannot be stressed too strongly. Any risk assessment will have made assumptions in the conceptual model and in any quantitative modelling undertaken; such assumptions require expert judgement. The interpretation of the impact must be made in full awareness of the significance of the assumptions and the uncertainties.

It is important that care is taken when comparing predicted concentrations against environmental benchmarks. The comparison is not a pass or fail scenario. For example for an environmental benchmark (or percentage thereof) of 100µg/l a predicted level of 95µg/l is not a pass and 105µg/l a failure. Given uncertainties in the assessment, there may be no real difference between the two predicted concentrations. A suitably qualified person who fully understands the limitations of the process and any implications arising from the predicted levels of emissions should conduct the comparison with the environmental benchmark.

7.3 Regulatory Decision-making

The objective of a risk assessment with respect to decision-making is to:

- provide the Agency with sufficient confidence to make the relevant regulatory decision

In order to support a decision, the risk assessment must:

- provide a sufficient understanding of the landfill site and its setting
- identify all the site-specific receptors and pathways
- define pollution for the site through environmental benchmarks
- provide an understanding of the critical assumptions/parameters
- evaluate the impact at the receptors
- report on the predicted impact at each individual (or groups of) receptor(s)

One key factor in this is a good understanding of the condition of the landfill through the conceptual model.

The two main areas where the Agency must make decisions are:

- location for new landfill facilities
- risk management measures

As is discussed below the two are closely linked for new sites since the risk assessment is conducted on the basis of the site setting *and* the proposed landfill design and operation.

The decision on landfill location can be made at the planning or PPC permitting stage. A decision on the acceptability of the corrective measures can only be finally made at the PPC permitting stage.

7.4 Decisions on Landfill Location

A decision as to whether a landfill location is acceptable is one of the most important decisions to be supported by a risk assessment. For new sites, the Landfill Regulations contain provisions as to landfill location which are outlined below. These provisions do not apply to existing sites (i.e. areas already in operation on 15 June 2002 or not already in operation but the relevant authorisation for its operation was granted before 15 June 2002) however they do apply to any extensions to existing sites.

Paragraph 1(1) of Schedule 2 of the Landfill Regulations relates to the location of a site with respect to various potential receptors including groundwater, waterways, water bodies and coastal waters. These receptors will largely be covered in the hydrogeological risk assessment. The impact on residential, recreational, agricultural and urban sites will largely be dealt with in the landfill gas and particulate risk assessments.

Paragraph 1(2) of Schedule 2 requires that a landfill (PPC) permit may be issued only if the locational requirements or the corrective measures to be taken indicate that the landfill does not pose a serious environmental risk. Paragraph 1(2) does not apply to existing sites.

Regulation 5 of the Landfill Regulations requires that a planning permission may only be granted for a landfill if the locational issues in paragraph 1(1) of Schedule 2 have been taken into consideration.

Landfill location with respect to groundwater is considered in Landfill Directive Regulatory Guidance Note 3 (Environment Agency 2002j).

7.4.1 Planning Permission

The basic decisions that the Agency can make with respect to a planning consultation are:

- to object to the application;
- to object on the basis of insufficient information;
- not to object to the application.

Since the locational requirements only apply to new sites it can be assumed that in most cases the decision will be supported by an Environmental Impact Assessment (EIA) at the planning stage. The EIA should provide at least a Risk Screening Assessment (particularly where the Agency has made a full response on the scoping of the EIA) and should have identified all the site-specific pathways and receptors. The Risk Screening with its consideration of the source-pathway-receptor linkages may be sufficient for the Agency to take the view that the proposed landfill poses a serious environmental risk and would justify the Agency objecting to the application. It may be that without further quantification of the impacts or details of the risk management measures that the Agency does not have the basis for making a decision. In these circumstances the Agency may choose to object to the application on the basis of insufficient information. If the pollutant linkages indicate that the sensitivity of the site's location may not be high and the concern is centred on the appropriateness of the risk management measures then the Agency is likely to not object to the planning permission. The determination of the acceptability of the risk management measures for the landfill can be made at the PPC permit stage.

The Agency will object to the planning application where the criteria in the landfill location position statement are met (Environment Agency 2002j). Where the Agency does not object to the planning application this does not mean that it will necessarily issue the PPC permit.

Where applications for planning permission and a PPC permit are being conducted in parallel then the risk assessments submitted in support of the PPC application can be used to inform the Agency's decision on what response to make to the planning authority.

The following section describes in more detail the decision-making process as it relates to a PPC application.

7.4.2 PPC Permits

The Landfill Regulations require that for a new landfill, a permit may be issued only if the locational characteristics or corrective measures to be taken indicate that the proposed landfill does not pose a serious environmental risk. This is a consideration of the sensitivity of the location and the proposed risk management measures. The risk assessment for a PPC permit application must provide the basis for this decision. With respect to groundwater, Landfill Directive Regulatory Guidance Note 3 (Environment Agency 2002j) provides the criteria for determining when a PPC permit should not be issued.

The risk assessment should have considered three basic scenarios:

- normal operations
- abnormal conditions
- accidents

Normal operations means that the proposed corrective measures are functioning as designed. It should be noted that normal operations should include the predicted degradation of management systems. Where the Agency believes that under normal operations the proposed new landfill poses a serious environmental risk then the permit should not be issued on those grounds. Environmental risk must be taken to include human health.

In order to determine if a serious environmental risk is posed it is necessary to consider failures of corrective measures, accidents and their consequences i.e. abnormal conditions and accidents. Section 5 outlines the scenarios that should be considered and should give a good understanding of the impacts of various occurrences. If the consideration of failures gives the Agency sufficient confidence that the landfill does not pose a serious environmental risk then the Agency can issue the permit. Where the predicted impact of an accident or failure would be unacceptable – and in many cases it would be surprising if they were not – this does not mean that the Agency must necessarily reject the application. What needs to be considered are:

- the magnitude of the consequences including the sensitivity of the location
- the likelihood of occurrence given the proposed risk management measures
- the risk management measures to prevent accidents/failures
- the contingency plans to mitigate the consequences

The sensitivity of the location will be particularly crucial when considering the consequences of failures that may occur at a landfill. The main use of the accident scenarios will be in determining whether the proposed site is so sensitive that a permit should not be issued and for determining the acceptability of risk management measures, monitoring and contingency planning. Where the consequences of an accident are serious then the risk management measures to prevent its occurrence must be correspondingly more robust. In some cases, the consequences of an accident may be so significant that a serious risk is posed notwithstanding the proposed risk management measures and this would make the location unsuitable for a landfill.

Having considered all the above issues, the professional judgement of the Agency officers will be used to determine if the proposed landfill would pose a serious environmental risk and whether the permit can be granted or should be refused.

7.5 Decisions on Risk Management Measures

For existing sites (i.e. areas already in operation on 15 June 2002 or not already in operation but the relevant authorisation for its operation was granted before 15 June 2002) the locational requirements do not apply (Paragraph 1(13) of Schedule 4 of the Landfill Regulations).

For all landfill applications, the decision that the Agency must make relates to the acceptability of the risk management measures in complying with the requirements of the Landfill, Groundwater, Habitats and PPC Regulations. This includes the requirements of Regulation 8 (2)(c) and paragraphs 3, 4 and 6 of Schedule 2 of the Landfill Regulations (accidents and their consequences, hydrogeological risk, landfill gas, particulate matter and stability respectively).

Not all risk management measures will be determined through the risk assessment. Regulations, best practice and where applicable Best Available Techniques will determine many of the design, operational and management measures required at the landfill. Some examples of the key requirements are illustrated in section 2.3.1 in Box 3. The operation and design of the landfill in accordance with best practice is an essential part of the decision-making process. The risk management measures must minimise the impact on the environment and this means that although an assessment may produce an "acceptable" impact a more stringent operational standard may still be required. One key example of this is where a hydrogeological risk assessment model may suggest that an acceptable concentration of List II substances would result from a leachate head, for example, of 5 metres. In such a case a compliance limit for the leachate level should still be set (for example, at a maximum 1 metre) to minimise the emissions to groundwater.

The key decision to be made by the Agency for all landfill applications is the acceptability of the risk management measures proposed. The assessment of the impact of normal operations will provide the basic support for the decision as to whether a permit can be granted, taking into account all the uncertainties and assumptions. For a quantified risk assessment, the comparison of the predicted impact of emissions against the relevant environmental benchmarks will form the basis of the assessment of the impact.

The assessment of accidents and abnormal operations will support the decision on the robustness of the engineering and management systems required, in particular issues such as contingency planning, monitoring of operations, telemetry, redundancy and back up equipment and procedures (see Section 7.4.2).

Where the risk assessment does not satisfy the professional judgement of the Agency officers that the risk management measures meet the necessary requirements then the Agency can consider:

- rejecting the permit
- requiring additional information on the risk management measures
- issuing the permit but include prescriptive or improvement conditions

Improvement conditions should not be an option for new sites, which can reasonably be expected to meet the necessary standards at the point of issue of the permit. For existing sites the risk assessments should clearly show where the priorities for improvements lie.

The operator may choose to withdraw the application for a new site and consider a more detailed risk assessment and a revision of the proposed risk management measures.

7.6 Decision-making in the Face of Uncertainty

There will always be uncertainty associated with a risk assessment. The areas of uncertainty for a landfill risk assessment include:

- proportions of waste types accepted
- leachate composition and quantity
- gas composition and generation rates
- particulate matter composition and generation
- monitoring data
- point source emission rates and composition
- fugitive/area emission rates and composition
- hydrogeological setting
- meteorological regime
- models and input parameters
- receptor presence and sensitivity
- short and long term performance of risk management measures

It is important that the areas of uncertainty are considered, understood and recorded. That there will always be uncertainty has to be accepted and there are a number of ways of potentially addressing this. These can include:

- further site investigation
- additional monitoring
- probabilistic models and probability density functions
- conservative "worst case" assumptions
- confidence levels
- concepts such as model head room and model confidence (section 2.9)
- more complex assessments
- factors of safety
- over engineering/redundancy

The above examples are ways of either addressing uncertainty by gathering more information, using modelling techniques to reflect the uncertainty or using the design to try and compensate for uncertainty.

It has to be remembered that a risk assessment does not provide the "answer". All risk assessments must be interpreted by appropriately qualified people who can understand the uncertainties, the assumptions made and their significance for an individual site. In particular, care must be taken that undue reliance is not placed on the "numbers" that are generated by quantitative modelling. It is tempting to generate a number from a model, to compare it against a numerical environmental benchmark and then to declare that the risk assessment has demonstrated acceptability. Modelling must not be relied on beyond the point that the understanding of the landfill can support.

There will be circumstances where uncertainty is of greater significance than in others. For landfill sites this will largely be related to the sensitivity of the environmental setting and hence the potential impact. This means that it will not always be necessary to fully address the uncertainties. It is the understanding of the site in its environmental setting i.e. the conceptual model and risk screening stages that are the most important elements of the decision-making process. A decision can be made provided that the significance of the uncertainty is understood. There will always be a residual level of uncertainty. The Agency's inclination is to require that uncertainty be addressed through the provision of additional information. Although this can be fully justified in many cases it will not always be justifiable. The question is whether a decision (rational and justifiable) can be made using the professional judgement of the officers involved. The uncertainties must be recognised and recorded to ensure the transparency of the decision-making. What the risk assessment must provide is confidence that the risks are understood to a sufficient level. A risk assessment, or any other process, can never provide certainty.

KEY POINTS

Risk Assessment

The level of risk assessment effort must be proportionate to the risk (Section 2.1)

The development of a robust conceptual model of the site is a vital precursor to the risk assessment process (Section 2.3)

Risk Screening is essential and needs to consider all the relevant source-pathway-receptor linkages to ensure that risk assessment effort is focussed on the significant risks (Section 2.5)

Interpretation of the risk assessment must be made by an appropriately qualified person who understands the assumptions and limitations of the conducted assessment and who can therefore place any quantitative results into the correct context (Section 2.9)

Risk Management Measures

Best practice/Best Available Techniques will determine many of the risk management measures required at the landfill (Section 2.3.1)

The risk management measures must prevent or minimise the impact on the environment and human health (Sections 7.1 and 7.5)

Decision-Making

The risk assessment must be considered in the overall context of the site, reflecting the assumptions and uncertainties (Sections 7.2.5 and 7.6)

The regulatory decision should never be based simply on whether quantitative assessment has produced a number lower than the relevant environmental benchmark to which it is being compared (Section 7.2.5)

The understanding of the landfill site in its environmental setting is the single most important element in the regulatory decision-making process (Sections 7.3 and 7.5)

The regulatory decision must be proportionate, consistent, transparent and it must be based on the evidence including that from consultees (Sections 6.1.5 and 7.3)

GLOSSARY

Best Available Techniques (BAT)	The most effective and advanced stage of development of activities and their methods of operation which indicates the practical suitability of particular techniques to prevent and where that is not practicable to reduce emissions and the impact on the environment as a whole. For these purposes: "available techniques" means "those techniques which have been developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the cost and advantages, whether or not the techniques are used or produced inside the United Kingdom, as long as they are reasonably accessible to the operator"; "best" means "in relation to techniques, the most effective in achieving a high general level of protection of the environment as a whole" and "techniques" "includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.
Best Practice	Best practice should be taken to mean all appropriate measures, in accordance with Agency guidance, to be taken against pollution, to limit emissions and the impact on the environment.
Conceptual Model	An understanding of the landfill (including the design and operational fundamentals) in its environmental setting. The conceptual model must identify the sources, pathways and receptors at a landfill. A conceptual model represents the understanding of the problem and is used as the basis on which to develop a site specific risk assessment. The level of detail required of the model will depend upon the complexity of the risk assessment.
Corrective Measures	The term used in Paragraph 1 of Schedule 2 of the Landfill Regulations. It should be taken to mean the risk management measures to be taken.
CROW Act	Countryside and Rights of Way Act 2000
Emission	The direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in an installation into the air, water or land.
Environmental Benchmark	A standard or criterion against which the level of an emitted substance can be compared at a receptor. For a quantified risk assessment the potential impact of an emission is evaluated through comparison against these appropriate standards in order to assess the significance of the impact and allow a decision to be made on whether the impact of the landfill on air or water quality may be acceptable.
European Site	Defined by Regulation 10 of the Habitats Regulations. This definition includes SACs and SPAs. It is also government policy to include RAMSAR sites within this definition.
Groundwater	All water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.

Groundwater Regulations	The Groundwater Regulations SI 1998 No. 2746
Habitats Regulations	Conservation (Natural Habitats, & c.) Regulations 1994 SI 1994 No. 2716
Harm	The damage to a receptor that results when a hazard is realised. Harm to the health of living organisms or other interference with the ecological systems of which they form a part and in the case of man includes offence to any of his senses or harm to his property.
Hazard	A property or situation that particular circumstances could lead to harm.
Landfill	A waste disposal site for the deposit of the waste onto or into land.
Landfill Gas	Any gas generated from landfilled waste.
Landfill Regulations	The Landfill (England and Wales) Regulations SI 2002 No. 1559
Leachate	Any liquid percolating through deposited waste and emitted from or contained within a landfill.
Pathways	The mechanism by which the receptor and source can come into contact (e.g. by a hazardous event or action on site giving rise to a release of the hazardous substance or material to atmosphere or to ground).
Pollution	Emissions as a result of human activity which may be harmful to human health or the quality of the environment, cause offence to any human senses, result in damage to material property, or impair or interfere with amenities and other legitimate uses of the environment.
PPC Regulations	The Pollution, Prevention and Control (England and Wales) Regulations SI 2000 No.1973 (as amended)
Ramsar sites	Ramsar sites are designated under the Convention on Wetlands of International Importance ('The Ramsar Convention').
Receptors	The entity (e.g. human, water body, ecosystem, building, etc.) that is sensitive or vulnerable to the adverse effects of the hazardous substance or material
Risk	A combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.
Risk assessment	The qualitative/quantitative estimation and characterisation of risks.
Risk management	The process of making and implementing decisions about accepting or altering risks
SAC	Special Area of Conservation as defined by the Directive 92/43/EEC, on the Conservation of Natural Habitats and of wild fauna and flora.

SPA	Special Protection Area as defined by the Directive 79/409/EEC on the Conservation of Wild Birds
Source	The hazardous substance or material. The 'source' for waste management facilities is defined by the hazardous properties of the waste types and operations to which they will be subjected on the proposed site.

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APPENDIX 2

Landfill Slope Failures

1. KETTLEMAN HILLS
2. LEUWIJAGAH
3. PAYATAS
4. RUMPKE

Civil Engineering Database

Kettleman Hills Waste Landfill Slope Failure. I: Liner-System Properties

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Journal of Geotechnical Engineering, Vol. 116, No. 4, April 1990, pp. 647-668
Purchase Information

Document type: Journal Paper

Discussion: by **M. K. Yegian** and et al. (See full record)

Closure: (See full record)

Abstract:

A slope-stability failure occurred in a 15 acre hazardous-waste landfill (90 ft high) in which lateral displacements of up to 35 ft and vertical settlements of up to 14 ft were measured. Failure developed by sliding along interfaces within the composite, multilayered geosynthetic-compacted clay liner system beneath the waste fill. The testing, analyses, and related studies made to determine the cause of the failure are the subject of this and a companion paper. The present paper presents details of a direct shear and pullout testing program undertaken to determine liner-system-interface shear-strength characteristics. The interfaces between the various geosynthetics, and between these materials and the compacted clay in the liner system, are characterized by low frictional resistance, with values of interface-friction angle as low as 8° for some combinations. The most critical interfaces were determined to be those between high-density polyethylene (HDPE) geomembrane and geotextile, HDPE geomembrane and geonet, and HDPE geomembrane and saturated compacted clay. Representative values of interface shear-strength parameters were obtained for use in the stability analyses described in the companion paper. The variations in measured strength parameters for the different interfaces in the liner system indicate the desirability of conducting similar test programs for proposed new facilities to establish design parameters.

dr. kölsch

Geo- und Umwelttechnik
Bandung (GB)

The Leuwigajah dumpsite disaster

The Leuwigajah dumpsite is located close to Bandung, the capital of Indonesian Western Java Province, 180 km South-East of Jakarta. 4500 t waste from Metropolitan area Bandung is delivered to the site. The landfill has been established in a narrow valley. The location offers a favourable hydrogeological situation with a bedrock covered by a thin layer of 1m clay. Precipitation is high in the region between 1500-2000 m per year and significantly non-uniform. Waste disposal procedure was carried out on a basic level. Dumping started from the top of the valley dropping the waste just over the edge.

After 3 days of heavy rainfall, the landslide happened on February 21st, 2005, when 2.7 mio cbm waste started sliding down the valley. The waste covered an area of 900 x 300 m. 147 people died in the ruins of two settlements. The satellite image, assembled by Institut Teknologi Bandung, shows the scenery. the yellow line indicates the former boundary of the dumpsite. Just a winding waste cliff was left from the former 70 m high dumpsite.

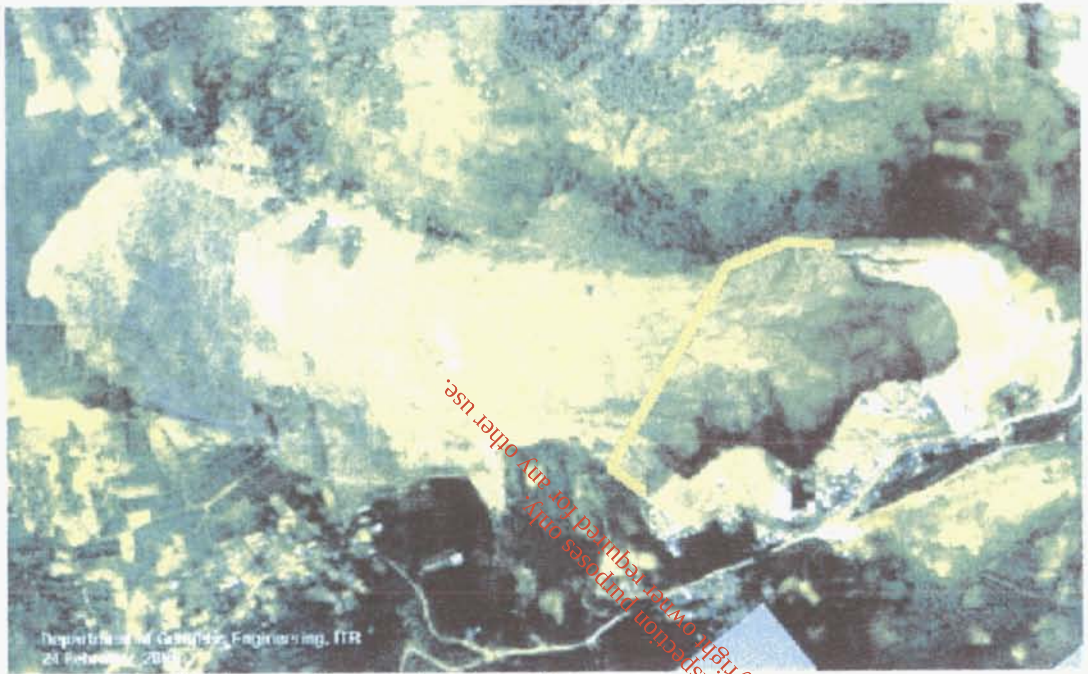

Figure 1: Satellite image - Leuwigajah dumpsite

Figure 2: View from the slope crest down to the valley.

Figure 3: Uphill view from the valley

Figure 4: Devasted valley area

Figure 5: Slope crest

The forensic analysis obtained some interesting results. The stability was affected by two major causes: Pore water pressure was generated in the surface between clay and waste due two ground water and surface run-off. Simultanously, smouldering fires in the upper part of the landfill had combusted plastic and paper particles, which acted as reinforcement.

The fornesic back calculations considered this effect by means of reducing fibre cohesion and cohesion to zero. Finally, the sliding body shown in figure 7 came out as the most unfavourable one while still matching the oberserved failure geometry.

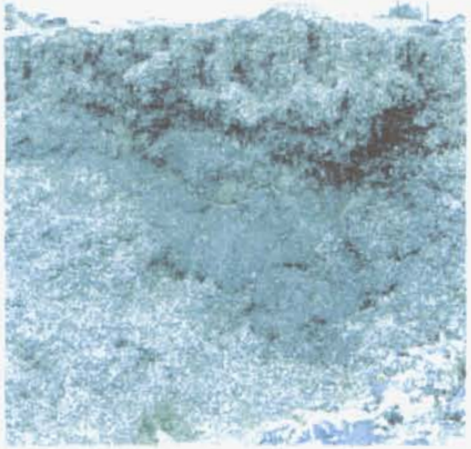

Figure 6: Combusted dumping sectors

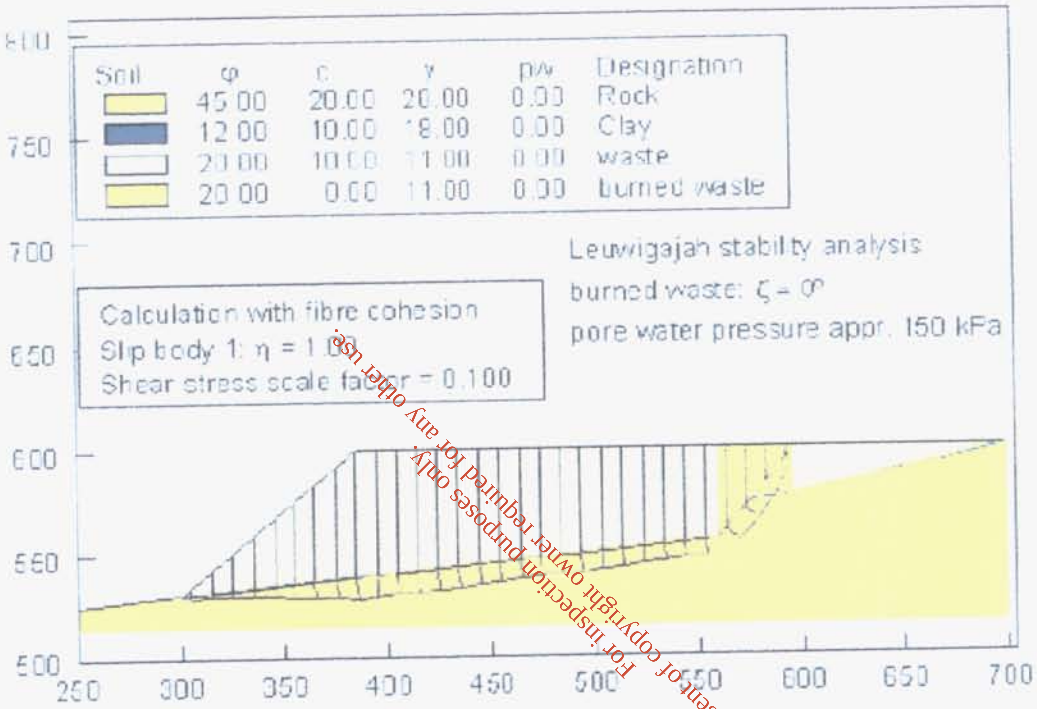

Abbildung 7: Stability calculation - most unfavourable section, yielding equilibrium

The result confirmed for the first time, what had been found in advanced calculations before. In case, the waste shows a high inner shear strength, the failure of the entire landfill turns into the most critical loading situation.

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3

dr. kölsch

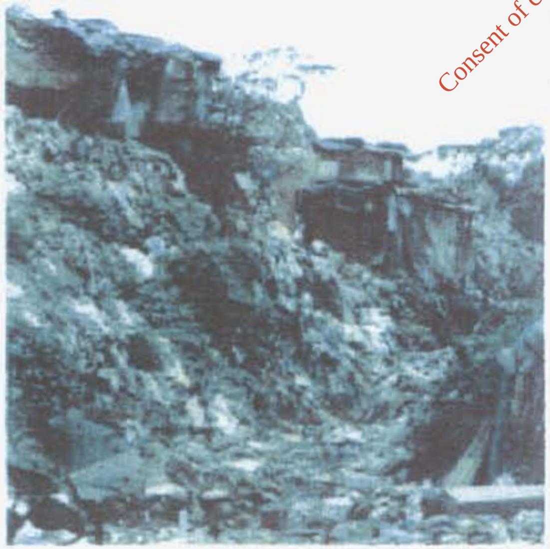
Geo- und Umwelttechnik
Payatas (GB)

Payatas landslide

Payatas dumpsite is located in Quezon City in the North-East of Manila, capital of the Philippines. Around the landfill the township Payatas B is placed, home of about 80.000 citizens.

The picture shows the housing area in front and the dumpsite in the background, about in March 2000, monthes before the landslide. As often in devolping countries, people are not only living around, but also at the daumpsite.

The image above shows slum huts at the dumpsite before the katastrophy, the picture on the left side shows abandoned huts after the landsilde, which had not been destructed.



On July 10,2000, early in the morning, the waste slope moved down like a garvalanche, burying dozens of these slum huts under meters of waste.

In the background the part of the slope, which remained unbroken, can be seen. In the foreground, the waste garvalanche of 1,2 Mio cbm came in from the left, burying the slum huts as well as a part of the township (right side).

The pictures of the rescue action indicates what really happended at that deadly place. The emergency teams found 230 people dead, but still up to 800 people ar missed.

The picture above shoes the situation in August 2000 about 4 weeks after the failure, when we arrived at the place to conduct a first forensic analysis. The rescue works were suspended close before. The view falls from the crest of the remaining slope over the shell-shaped failure area.

Same location, uphill view.

In order to protect the township from leachate water percolating out of the downslided waste, a trench has been constructed around the covered area.

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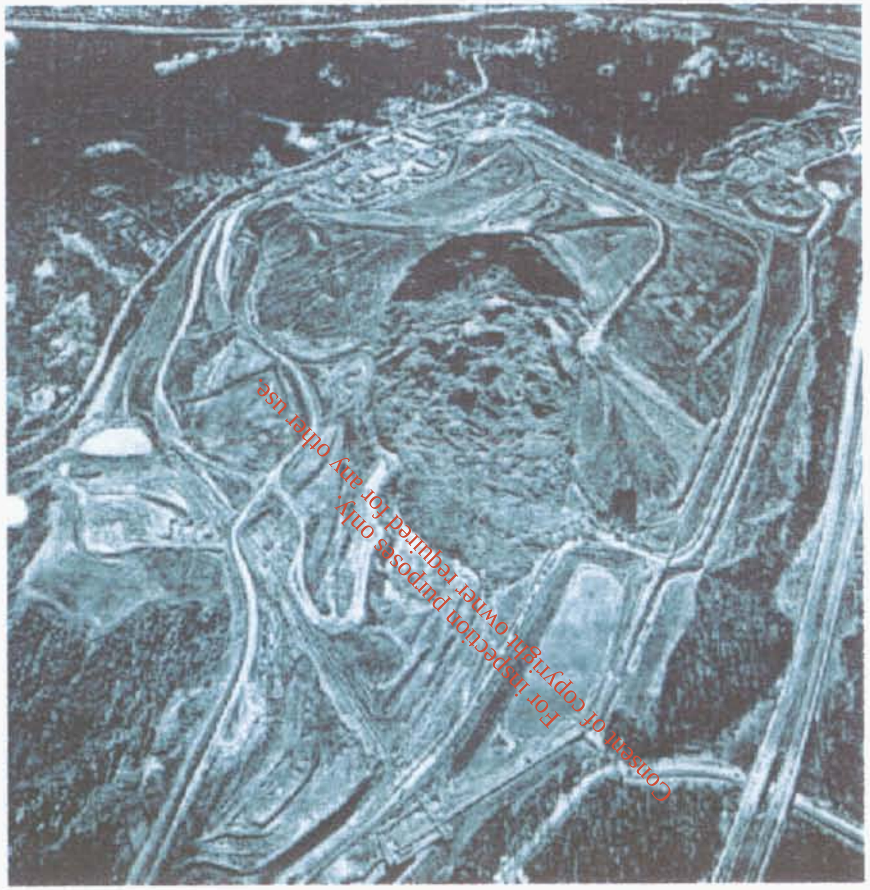
dr. kölsch

Geo- und Umwelttechnik
Rumpke (GB)

Rumpke landslide

Rumpke Consolidated Companies is the largest private waste company in the USA and the No. 4 in the nation. In Colerain, a township close to Cincinnatti (Ohio) the enterprise operates Rumpke Sanitary Landfill, one of the so-called Mega-landfills in the Midwest. Established in 1945, 1,6 Mio. t of municipal solid waste are disposed every year. Currently an dumping area of about 39 ha (120 acre) is in use, located north-west to an grandfathered area of about 54 ha. The grandfathered area has been destroyed by a slope failure on March 9,1996, when 1,2 Mio. m^3 waste were sliding down.



The grandfathered part of the landfill elevates 75 m high above the original ground. The North-west slope, where the landslide occurred, had an average slope ratio of 1:2,6. The landfill had no gas extraction. For leachate drainage not more than surrounding ditch at the toe of the slope has been constructed. 18 monthes before the failure, the original ground along the North-west slope has been excavated 42 m deep to prepare an expansion area. The slope down to the hole was 1:2,3. Additionally in October 1995, the toe of the slope was cut vertically 2,5 m high in order to get space for an access road. . On March 4,1996 local staff

recognized small cracks through the covering Earth material at the crest of the slope. Initially, the crack were identified as a result of common landfill settlements and were stuffed. But the following days the cracks showed up again and again. Till the morning of March, 9 the cracks had been expanded up to the toe of the slope.

Horizontal movements of the toe of the slope indicated the the entire slope was going to move. Around 11 A.M. the to of the slope had moved 3-5 m away, the cracks meanwhile opened up to 1 m. Close to noon, more cracks opened and black leachate was spurting out under high pressure. At noon, the entire slope started to move and within 5 minutes 1.2 Mio m^3 waste were sliding out of an landfill area of 5 ha 360 m downhill. A shell-shaped vertical wall, up to 60 m high with an extent of 300 m was the left-over.

shell-shaped failure area

waste covered expansion area after the slide

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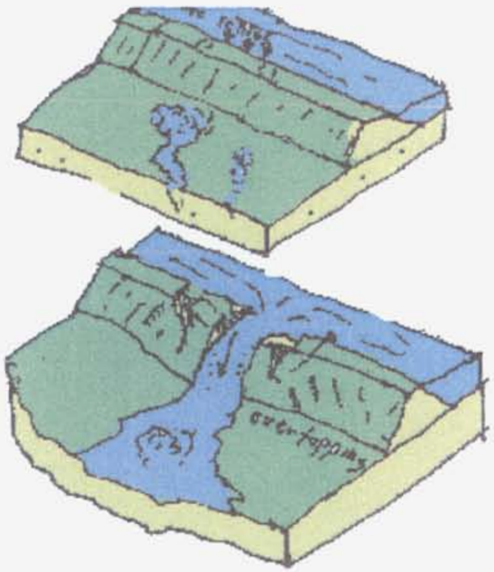
APPENDIX 3

Piping failure in gravel
– Richard Meehan, Stanford University

Pore pressure induced slide
- Bogata, Columbia

Large Landslide Risks in Solid Waste Facilities ...
- David H. Hendron

What do witnesses see when a failure occurs? Most often it has been the occurrence of sand boils near the toe of the levee, followed by overtopping. In most recent cases the river did not rise above the top of the levee; rather, the levee failed, sinking below the river level.



mech:1:boils.gif:98

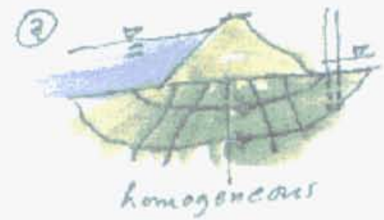
One traditional model of piping failure is based on the analysis of Terzaghi and predecessors who studied several catastrophic failures of concrete dams built on river alluvium. The model seepage was based most usually on the assumption of a uniform isotropic medium within which a coherent field of seepage pressure developed

following principles of heat or electric flow developed in the nineteenth century. Interestingly these methods arose at the same time as Lyell was promulgating his doctrine of uniformitarianism, a Victorian era governed by paternalistic, Protestant ideas about the world or if the world was not actually that way, how the world should be described. This image of the world continues to appeal, and among those groups to whom it appealed most powerfully was engineers, Northern European paternalists with a strong hand for command and control.

mech:3:1f22.gif:154

We have seen how this analytical technique realized in the form of a flow net from led the Corps of Engineersto reach the comforting conclusion that the upward gradient was a mere XX, well below what would be required to cause significant sand boils.

mech:5:1f23.gif:155

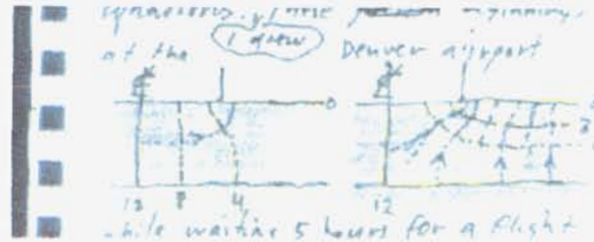


Levee designers are schooled in soil mechanics, which features theoretical models which assume homogeneous characteristics to the ground. Analysis based on homogeneity (encouraged by borings that are too shallow) suggests that flood pressures at the levee toe will be innocuous as in A. What, if as is more often the case, there is a ravel layer at a depthless than about 50 feet? Pressures can substantially exceed the "homogeneous" assumption. Suppose, further, that the gravel bed is truncated on the land side of the levee, and accessible to flood water via a pit on the river side of the levee? A potential for doubling the pressures exist, resulting in very large uplift and erosive potential at the toe. Analysis, untempered by experience in field geology, often leads to unsafe conclusions.

mech:5.5:1f42.gif:149

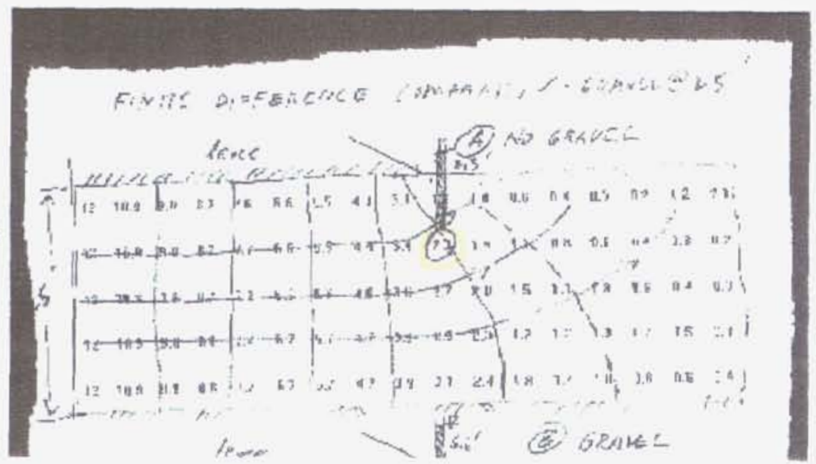
The permeability of the gravel layer is the main determinant of how seepage occurs, including the type and size of concentrated seepage from boils (equivalent to yield of a small well) and the rate of movement of a pressure have horizontally through the layer. Test results show that the gravel layer consists of about 70 percent gravel to 2 inch size with some coarse sand, soil "C" above, with behavior as indicated. Soil classification (by standard techniques) serves as a basis for estimating permeability, K, steady sand boil discharge, and erosive capacity.
Continue...

mech:9:1f32.gif:163



The pressures beneath the toe can be determined by drawing a *flow net*. Equipotentials and lines of flow must then approach square shapes to meet the equations of filed. I drew these beginnings of a flow net at the Denver airport while waitn 5 hours for a flight to SanFrancisco. They are pretty crude but I think that you can see that the case on the right, where seepage has insinuated a 12 ft head under the model in a presumed gravel layer is a lot worse than the case on the left.

mech1:9.5:1f48.gif:183



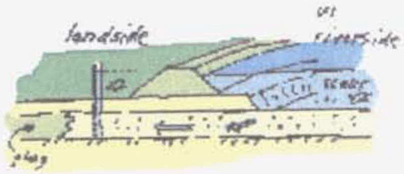
Clearly the precision of a flow net has its limitations; refininement can be achieved by setting up a small cross section as a finite difference equation on a spreadsheet. In the example I've shown here it is quite clear that the "gravel layer" has a greta influnece on the pressures beneath the toe of the levee, resulting of a factor of safety approaching 1 for development of a quicksand condition at the tow. Clearly under such conditions a head of 12 or so beneath the central part of the levee results in failure of the levee foundation and slippage of the toe.

mech1:9.8:flownets.gif:184

The mathematically ideal underseepage flow creates toe pressures equal to one half the river level.

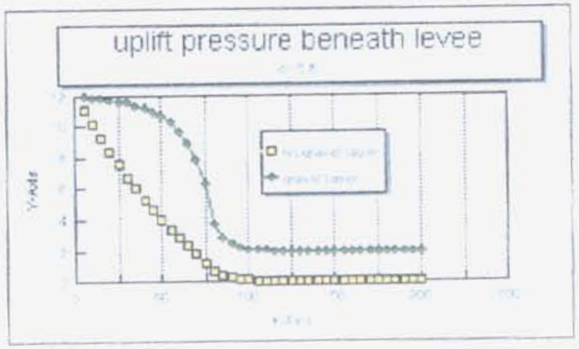
mech1:10:u2.gif:74

The real underseepage flow may create toe pressures equal to the river level.



mech1:11:u1.gif:75

The difference in pressure beneath the downstream section of the leveee is shown in the foundation pressure profile at a depth of 5 ft into the foundation. Obviously the sand layer makes a big difference so it is an important boundary condition to the problem.



mech1:15:1f49.gif:165

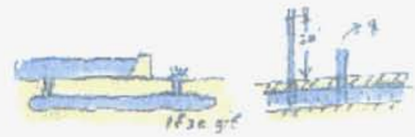
In effect we have a 6 million cubic foot leaky bladder (200 x 30 x 1000) of very loose sand. In the early stages the pressure will be confined by the overlying strata (except for D'Arcy flow). At a gradient of 0.5 to 0.7 sand boils will develop with flow constrained by the ability of the gravel to supply water to a single well. If this amount does not exceed a few gallons a minute, the

ability to create a large boil in several hours will be limited. If however the gravel delivers flows of several hundred gallons a minute -- and we know from local irrigation well experience that this is the case -- then the potential for a large boil, a rough pipe several miles in diameter, exists with potential for discharge of liquefied sand limited only by the fluid dynamics of liquefied material.
Continue...

mech1:16:1f27.gif:159

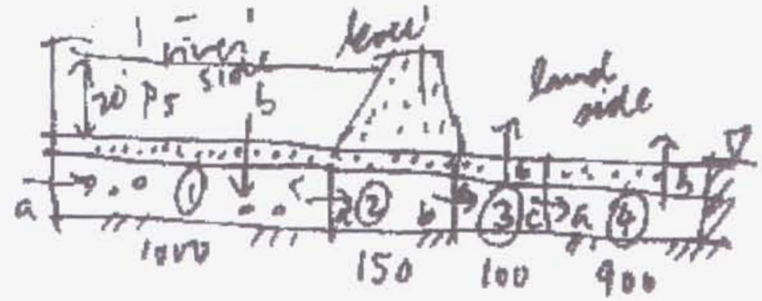
Why levees may fail *after* the flood peak

mech2:0.1::205



Why is there a lag time? Before sand boils develop it is necessary to "inflate" the sand boil breaks out. For each foot of levee as much as 100,000 gallons of water must enter the aquifer, a process that takes many hours. Similarly, as the flood recedes, the inflated aquifer remains pressurized, perhaps dangerously so, for hours after high water. Continue...

mech2:1:1f30.gif:161



Engineers use mathematical "models" to evaluate, predict, and manage physical processes. On January 27, I sketched out a model of the flow process beneath a typical Feather River levee that was underlain by an old river channel. To make it simple, I broke down the physical system into several cells; for example, cell (1) is the channel on the river side of the levee. It gets water from the river and feeds it into the levee foundation, cell (2).

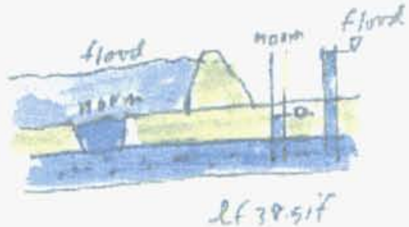
Each cell needs to be told something about itself; how permeable are its walls, how quickly does water flow through it, how much does it swell when pressurized. These define how fast a pressure wave will migrate through the foundation from the water to the land side of the levee.

These factors can be combined into a set of differential equations, or, as I've done here, into a step-by-step finite difference model.

$$\Delta p = \frac{K(p'-p)}{C \cdot l} \cdot \frac{w}{wh} \cdot t \qquad K_a \; K_b \; C$$

mech2:2:scalc1.gif:79

TIME LAG: Artesian pressures of about 15 feet are sufficient to cause uplift of the toe. These pressures take time to develop; it is necessary to pump water into the gravel to raise the pressure. Alternatively, each 100 foot cell requires 10 cubic feet of water to raise the pressure a foot. This results in a wave of pressure moving from the river to the landside. This process can be modeled on a spreadsheet. Principal variables are permeability of gravel and access of water to it.



mech2:3:1f38.gif:178

The increase in water pressure causes buoyancy to develop in the sand, with changes in pressure at 30 feet depth reducing from 30 psi to perhaps a third of that value. This carries ground heave of several inches (estimate 6 inches). Flood survivors describe a scene of zoological panic: snakes appear and the orchards fill with panic stricken badgers, skunks, and deer, like the famous fire scene from "Bambi."

mech2:4:1f29.gif:160

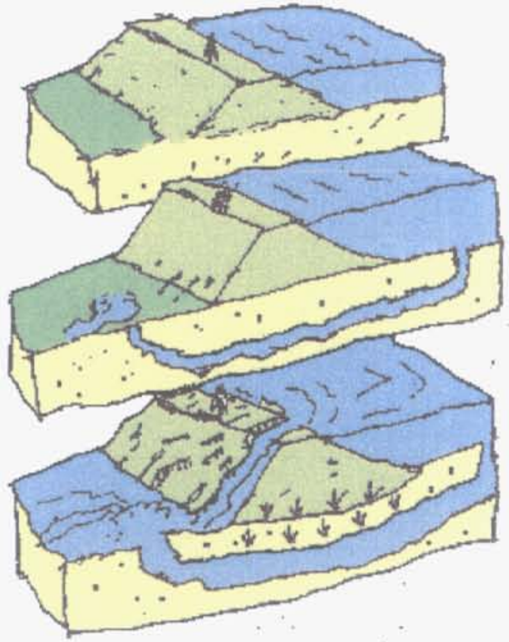
The model indicates that a pressure wave passes beneath the levee.

mech2:5:1f36.gif:176

Mechanics of a levee failure: what happens at failure?

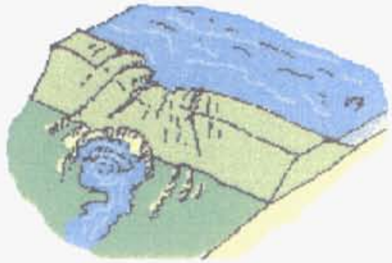
mech3:0.1::217

Here is one depiction of the failure mechanism.



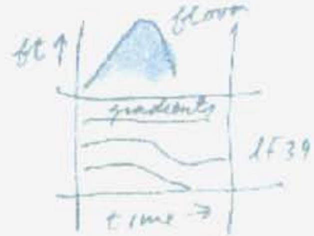
mech3:0.5:boilsb.gif:99

What is the process of final failure? No one knows for sure. But this illustration suggests a general likelihood, without providing all of the details. Continue...



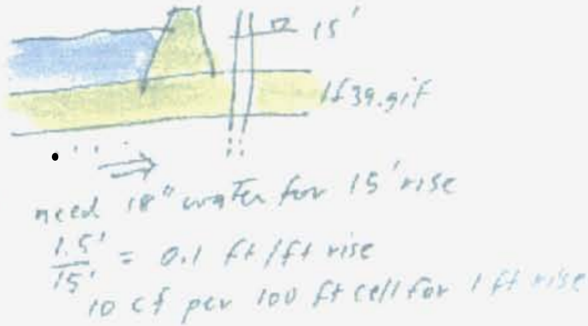
mech3:1:u3.gif:109

According to the model the history of the upward seepage gradient is as shown. By the time the actual failure, the gradient is predicted to be 0.5? Which is sufficient to cause heavy sand boils and also weaken the toe to the point of sliding of the levee toe.



mech3:2:1f34.gif:174

Typically, a rise of artesian toe pressure of 15 feet would assure failure. It would be sufficient to create near uplift of a 30 ft thick topstratum with unit weight of 100 lbs/cu ft.. Considering the saturation and swelling of the top stratum in the affected area, inflow of about 18 inches of water, or 0.1 ft water per foot of head change, would accompany this pressure rise.



mech3:3:1f39.gif:179

Mechanics of a levee failure: How pits make matters worse

mech4:0.1::216

Breaches in the top stratum by pits on the river side results in faster and larger buildup of pressures beneath the toe.

mech4:1:1f35.gif:175

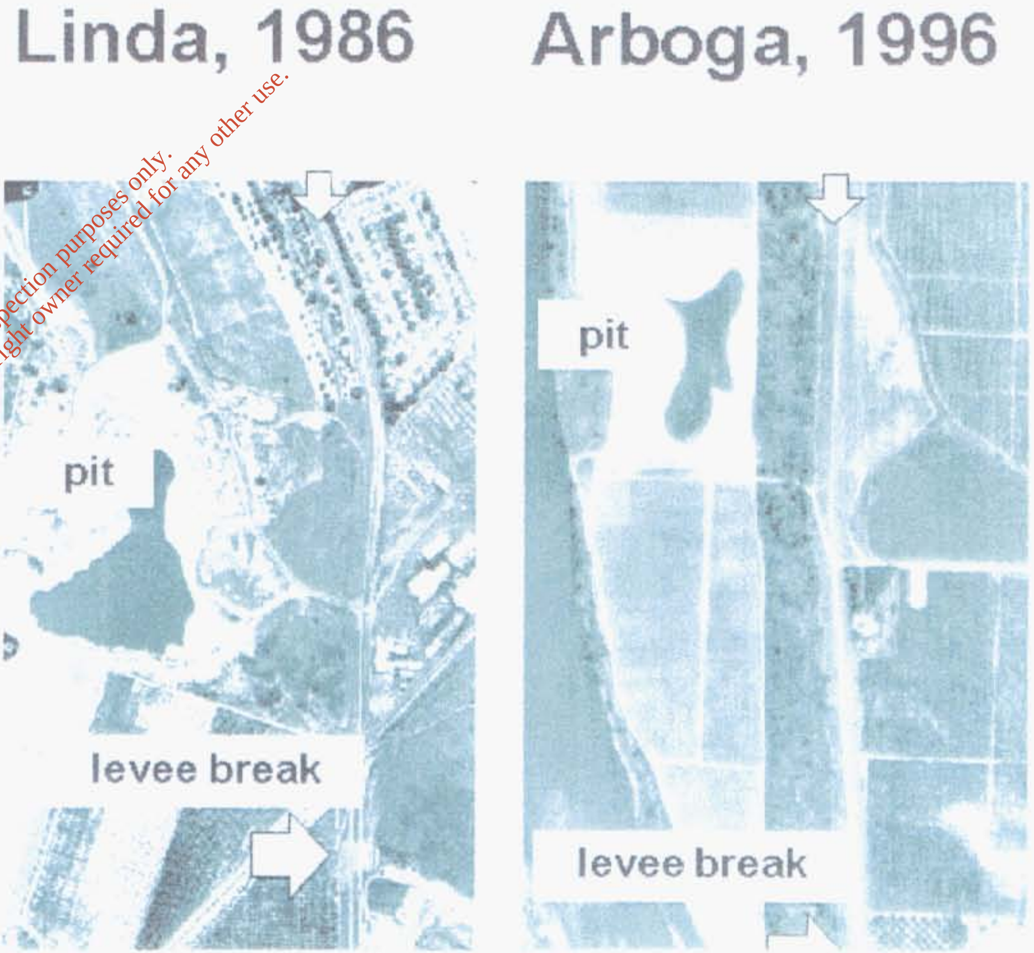
We see here a case in which a pit may exist 1000 feet

away from a levee. Using simple D'Arcy flow theory we can examine separately the relative influence of a pit with seepage through a natural 20 ft. floodplain blanket. Results indicate that each could contribute about 0.6 cfs or 250 gallons per minute; the pit even 1000 feet away significantly influences boil discharge. (Separate calculation of these two cases is not rigorously correct, but it is an informative approximate start on the problem.)

mech4:2:1f33.gif:164

Here is visual comparison between the 1986 and 1997 levee failures and the location of pits dug in the floodplain near the levees. Both photographs are the same scale.

Artificial pits were present at both failure sites as shown in the photographs (same scale). Pits are 1000 to 2000 ft. away from the failure points, in line with old channels that pass beneath the levees.



mech4:2:linda.gif:123

Questions or Comments?

meehan@blume.stanford.edu

Index

Pore Pressure Induced Slide in Solid Municipal Waste
Doña Juana Landfill -- Bogota -- Colombia

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A sudden and catastrophic slide involving approximately 1.5 million metric tons of solid waste took place on September 27, 1997 at the Doña Juana Landfill in Bogota, Colombia. The sliding mass moved approximately 1500 meters into the adjacent Tunjuelito River, which was temporarily dammed. Results from a forensic investigation carried out by the authors are presented in this report.

The Doña Juana landfill site encloses an area of 250 hectares (635 acres) where solid waste was placed in consecutive stages in several landfill cells. Two large solid waste cells, identified as Zone I and La Mansion were built prior to the construction of the Zone II cell, where the accident described in this report took place. Leachate was collected, injected and recirculated within the solid waste in the Zone II for about three months prior to failure. Short-term, gravity induced leachate recirculation was implemented in the older cells (Zone I and La Mansion) which remained stable.

The Zone II cell has a rectangular footprint area of about 25 Hectares (63 acres) which rests on a gently sloping terrain (about 7E) which dips in the direction of the long axis of the rectangle. The waste in the Zone II cell was placed in layers 2.5 meters thick interbedded with an intermediate soil cover 0.25 m to 0.3 m thick. An approximately 10 m-wide berm was installed every four waste layers and the face of the landfill slope between berms was built to a 3H:1V inclination. The overall slope of the waste cell in Zone II had an inclination of 4.7H:1V. The maximum thickness of the waste deposit was about 40 meters (131 ft) and due to the inclination of the ground surface, the difference in elevation between the toe and the crest of the waste landfill was about 100 m (328 ft).

Field measurements and stability analysis indicate that the excessive pore pressure generated within the waste in the Zone II mass was the principal cause of the slide. Pore pressures initially developed during landfill construction as a result of the high water content of the waste, and the inadequate drainage system of the landfill mass. Additional pore pressures were induced by three-months of leachate recirculation carried out in an attempt to reduce contamination prior to discharge. Leachate injection pressures, which are considered to be representative of the landfill pore pressures, increased gradually from about 10 psi to 15 psi at the initial time of injection to a range of 20 psi to 25 psi towards the latter part of the injection period and occasionally to 40 to 50 psi immediately prior to failure.

The original design criterion was based on a zero pore pressure condition within the solid waste mass. Stability analyses carried out in this study indicate a factor of safety of 2.0 under the design conditions. However, a marginally stable condition, with a factor of safety of about 1.2, was estimated for the initial pore pressures measured at the end of landfill construction. The marginal stability anticipated in the analyses corresponds well with the considerable bulging and cracking of the waste materials observed in the landfill prior to recirculation. Finally, unstable conditions, and successive failure, with a factor of safety of 1.0 or slightly lower was calculated with pore pressures corresponding to those measured in the injection lines during recirculation. The geometry of the critical failure surface corresponded well with the actual location of the sliding surface observed in the field.

Mechanical properties of the landfill materials used in the analysis were obtained from in-situ tests carried out in the landfill area. Their magnitudes are within the range of values reported in the literature, although the high water and organic content resolved in relatively low strength values.

This case history is considered to be significant because it documents a pore-pressure induced stability failure in a solid wastefill with a high initial water content and under leachate recirculation, and provides field measurements of the critical pore pressures required to induce failure.

Large Landslide Risks in Solid Waste Facilities... Geotechnical Fundamentals Count

By David M. Hendron, P.E.

Until recently, large landslides had not occurred in solid waste facilities. However, in 1992, a large landslide occurred in a hazardous waste facility in California. In 1996, an even larger landslide, about 1.5 million tons, occurred in Ohio. And in 1997, a still larger landslide, about 1.8 million tons, occurred in Bogata, Colombia. I was involved with the forensic evaluation of the cause of all three of these landslides and have a few insights into the lessons that can be learned from their occurrence.

The landslide that occurred at the Dona Juana Landfill in Colombia provides the best insight into the geotechnical aspects of these facilities that are the most important for designers. If these important aspects are not accounted for properly, designers risk the distinct possibility of repeating history and creating an opportunity for other geotechnical engineers to write about the lessons learned from the next large landslide in solid waste.

Dona Juana Background and History

Dona Juana Landfill was the central solid waste disposal facility for Bogata. The landfill handled about 8,000 tons of solid waste per day that contained a very high percentage of putrescible organic solids (compared to the waste streams in the United States). The newest part of the facility—about 35 acres in area—was the cell that failed. The facility design included membrane and soil liners, a very large and sophisticated base leachate collection system, and vertical gas collection piping on a grid throughout the landfill area. The gas collection piping fully penetrated the solid waste profile.

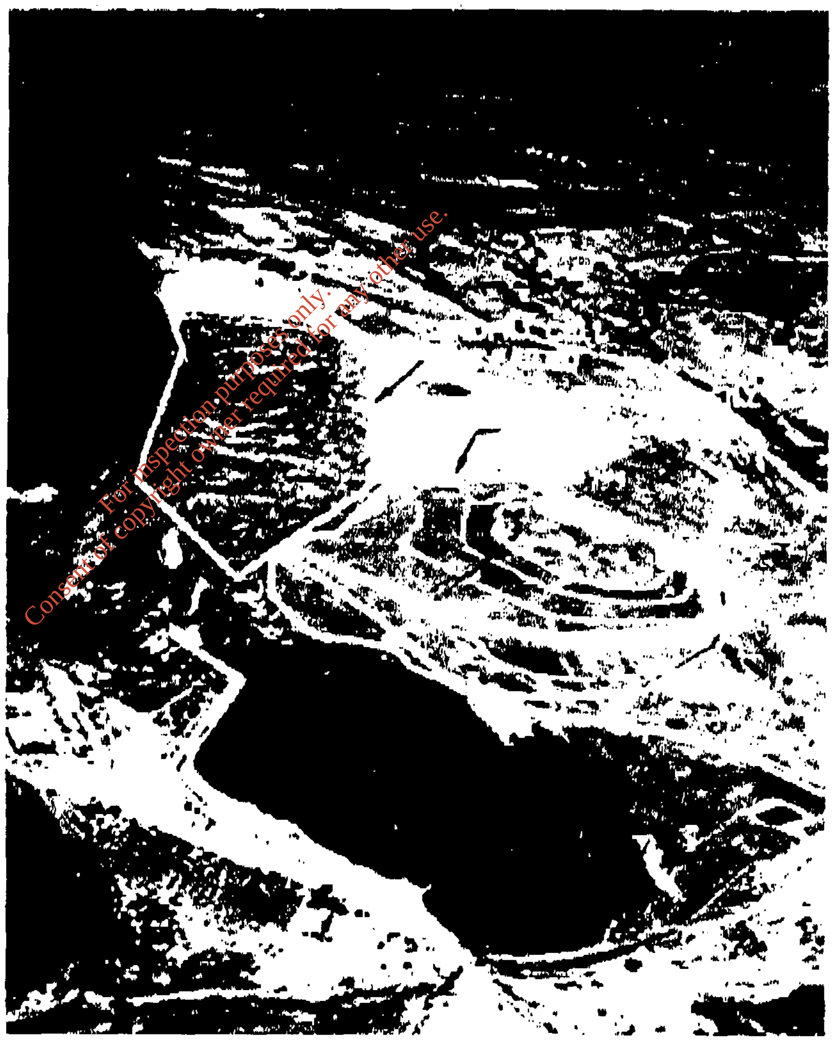

Figure 1. Dona Juana Landfill Site After Failure.

There were several prior landfill cells at the facility. These cells collected leachate and disposed of it in relatively untreated form by discharge to the river, located about 1-1/2 km away. The elevation of the river was about 200 m below the base elevation of the landfill. For the newest cell of the facility, the cell that failed, the City of Bogata decided to treat the leachate prior to disposal in the river. After due consideration of several alternate technologies, the City chose to treat the leachate using recirculation of the leachate into the landfill. A system of pumps and 300-m long horizontal pipes was designed to handle the reinjection of leachate at a maximum rate in the range of about 600 to 900 l/min to treat leachate.

After correcting some problems with the original piping design, the operator began reinjection in June 1997. Initially, the solid waste in the landfill accepted leachate at the rate it was being generated. However, approximately one month after the pumping started, the operator observed that the rate of leachate generation began to significantly increase and the rate at which the solid waste would accept the recirculation of leachate significantly decreased. The trends indicated by these two observations were 180 degrees out of phase with each other.

Almost immediately after it became apparent that rate of reinjection was much less than the rate of leachate generation, the landfill operator attempted to discuss the situation with the design engineer. The operator was told that the matter had to be resolved with the new engineering firm on the project which was responsible for inspection and certification of the work. The operator was told, in effect, that the original designer had no on-going responsibility for the system. The operator also was told to reinject all of the leachate or face consequences that included financial penalties for discharge of leachate to the river.

The operator continued his attempt to discuss the situation with the City of Bogata and at the same time tried to make improvements to the system to achieve the goal of no discharge to the river. On September 26, 1997, the operator observed a system of cracks developing on the face of the partially-completed landfill, and, within 24 hours, the landfill had failed in a catastrophic manner. Figure 1 is a photograph of the failure, which resulted in about 1.8 million tons of solid waste flowing 1 1/2 km to the river. The flow slide intersected and filled the river.

What Happened?

First and foremost, all of the engineering decisions made about use of recirculation at this facility were based solely on the analysis of the leachate chemical characteristics. The only geotechnical analysis made in the original design of the facility was that the excess pore pressure in the system was going to be "zero" because the leachate drainage and gas collection systems would remove all fluids and gasses from the facility, even those generated during the unprecedented rate of recirculation of leachate for treatment prior to disposal. Consequently, the slope stability analysis done for the design did not include any excess pore pressure in the solid waste.

As part of my analysis of the failure, I analyzed pore pressures measured in piezometers installed in the cell adjacent to the failed landfill cell immediately after the failure. The design of the adjacent landfill cell was identical to the failed cell with the exception that no recirculation was attempted in the adjacent cell. These piezometers showed that excess pore pressures of almost 35 meters of water existed in the center of the adjacent landfill. My visual observations in early October 1997 indicated that the adjacent landfill cell had significant evidence of open cracks on the exterior slope and was only marginally stable. I performed a simple stability analysis using the excess pore pressures described above and added the injection pressure data measured at the new cell that failed, showing that the failure of the new cell occurred by the application of the injection pressures. Had geotechnical engineers for the designers used this experience in the design of the new cell, they could not have assumed zero pore pressures for the new c

So how did this happen? This q tion leads us to the lessons that c learned from a case history like this I believe there are several answers t question that are generally interrel

First, the designers chose a l ate treatment technology that the nor understand very well. The re lation technology had not been in the intended manner for this si project. Moreover, there were nc studies made to determine wh the technology would even ac plish leachate treatment to the d needed to meet project objectives situation like this, one should al proceed cautiously, evaluate "wh scenarios that differ from antici conditions, and monitor perform

Second, the designers made easy (but incorrect) assumption excess pore pressures would be " because the internal drainage sys would perform on a long-term to achieve their assumed condi They had no analytical basis fo design assumption and undertoo monitoring to verify that excess pressures were not developed. without the application of the re tion pressures, there were signif pore pressures in an adjacent la cell, but no measurements were to document these conditions be the adjacent landfill was declared "stable" with a factor of safety as nally designed of about 1.5. In post failure observations of signif cracks on the exterior of this la cell and analyses by the forensic showed that the adjacent landfil a factor of safety of about 1.1 or l

Third, the entire design ignored the effect on pore pressu the solid waste mass that would be erated by basic physical and che phenomena of solid waste degrad especially degradation when enha by leachate recirculation. In ess unlike soils, the volume of soli a solid waste environment act decreases with decomposition, spaces are filled with landfill gas pressures above atmospheric, and peratures of the phases are signifi above the ambient conditions. All three differences are significantly exacerbated when recirculation is part of the facility design. Additionally, all three differences can result in much higher pore pressures in solid waste facilities than comparable soil situations.

Suggestions for the Future

Leachate recirculation (bioreactor technology) is being used more and more in solid waste facilities and will likely become a more important technology for the future. Nothing in this article is intended to detract from the use of this type of technology, as it can be used successfully. On the other hand, I hope that individuals working on present and future projects where recirculation is being considered will better recognize the geotechnical effect of the recirculation procedures on all elements of the solid waste facility and ensure that the operation is properly sized for the situation.

From the geotechnical engineering perspective of future projects, geotechnical engineers should fully realize what they do and do not know about the long-term performance of internal leachate and landfill gas collection systems. Specifically, they should recognize how these systems will actually reduce pore pressures in the solid waste to levels compatible with safe operations and with the assumptions used in the design of the facility. This is true for the occurrence of large sized mass landslides that occurred at Dona Juana, in California, and in Ohio, as well as for stability of surface cover elements of solid waste projects. ( )

David M. Hendron, P.E., is a geotechnical engineer with almost 40 years of experience consulting on geotechnical and environmental aspects of projects. He continues to be a very active practitioner of geo-environmental engineering on projects across the country and abroad. He is currently a senior consulting principal with GeoSyntec Consultants in Chicago, Illinois. Mr. Hendron can be reached at dhendron@geosyntec.com.

For the Att

John Short.

From

Gemma Larkin.

APPENDIX 4, 4a.

Our Ref: 06F.CH2269

Your Ref: John & Marion Shortt

An Bord Pleanála

O' Connell & Clarke Solicitors
Suite 142,
The Capel Building,
Mary's Abbey,
Capel Street, Dublin 7.

RECEIVED 15 DEC 2006

14th December 2006

Re: Fingal County Council Compulsory Purchase (Fingal Landfill) Order 2006.

Dear Sirs,

The Board is of opinion that in the particular circumstances of this case it is appropriate in the interests of justice to request you to make submissions or observations in relation to the enclosed submission dated the 27th of November, 2006 received from the Department of Environment, Heritage and Local Government.

Accordingly, you are requested to make, within **three weeks** beginning on the date of this letter, any submissions or observations that you may have in relation to this enclosure. Any submission in response to this letter should be received by the Board not later than **5.30 p.m. on 4th of January, 2007**. If no submission or observation is received before the end of the period, the Board will proceed to determine the case without further notice to you.

Please quote the above case reference number in any further correspondence.

Yours faithfully,

Siobhan White
Executive Officer

Encl:

64 Sráid Maoilbhríde.
Baile Átha Cliath 1.

Tel: (01) 858 8100
LoCall: 1890 275 175
Fax: (01) 872 2684
Web.http//www.pleanala.ie
email:bord@pleanala.ie

64 Marlborough Street.
Dublin 1.

4 a

1442

27th November 2006

Our Ref: **DAU-DU-DF-G2006/328**

AN ROINN COMHSHAOIL, OIDHREACHTA AGUS RIALTAIS ÁITIÚIL
DEPARTMENT OF THE ENVIRONMENT, HERITAGE AND LOCAL GOVERNMENT

County Secretary,
Fingal County Council,
County Hall,
Swords,
Co. Dublin.

FINGAL COUNTY COUNCIL
28 NOV 2006
CORPORATE SERVICES

AN ROINN COMHSHAOIL, OIDHREACHTA AGUS RIALTAIS ÁITIÚIL
DEPARTMENT OF THE ENVIRONMENT, HERITAGE AND LOCAL GOVERNMENT
DÚN SCÉINE
LÁNA FHEARCAIR
BAILE ÁTHA CLIATH 2
DÚN SCÉINE
HARCOURT LANE
D 2
Tel: +353 1 888 3109
Fax: +353 1 478 0721

Re: Ref. No. G2006/328 by Fingal County Council for proposed landfill site at Tooman/Nevitt, Co. Dublin.

A Chara,

We refer to the Council's notification in relation to the above-proposed development. Outlined below are the archaeological recommendations of the Department of the Environment, Heritage and Local Government.

This Department has examined the archaeological component of the Environmental Impact Assessment by Margaret Gowen and Co. Ltd., submitted in connection the above proposed development. We concur with the mitigation proposals forwarded in the EIS.

Given the significance and potential significance of the sites to be avoided by the development we make the following additional recommendation:

Should planning permission be granted for the development it is recommended that conservation and management plans be completed for each of the sites that are to be avoided by the development. Such plans should be submitted to this department for agreement in advance of the commencement of construction work for the landfill site.

Reason: To ensure the continued preservation (either *in situ* or by record) of places, caves, sites, features or other objects of archaeological interest.

Kindly forward a copy of your decision to the following address as soon as it issues:

The Manager,
Development Application Unit,
The Department of the Environment, Heritage and Local Government,
Dún Scéine, Harcourt Lane, Dublin 2.

In addition, please acknowledge receipt of this letter and forward the relevant receipt to the address above.

Mise le meas,

Proinsias De Bátúin
Development Applications Unit

AN BORD PLEANÁLA
TIME ________ BY ________
13 DEC 2006
LTR-DATED ________ FROM ________
PL ________

APPENDIX 5

1. Landfill Fires Guidance Documents
2. Landfill Fire Burning for a year
3. Vancouver Landfill Case History

See page 3

Landfill Fires Guidance Document

Note

Landfill fires, both surface and subsurface, are more common than one might expect. Although no one agency in the United States tracks the number of landfill fires a local search of web engines will indicate landfill fires have occurred from California to Minnesota and throughout the northern hemisphere. In California alone more than 25 subsurface landfill fires have been reported during the past 15 years. Most of the incidents are small fires or rapid oxidation events and are usually handled by the operating facility and the local or state regulatory agency. Seldom do the subsurface events become large-scale environmental responses.

Types of Landfill Fires

The most common types of fires occur at the surface, where fuel and oxygen are abundant. These fires can burn between the surface and one foot below ground. The other type smolders below ground and can extend down to 40 feet.

Surface Landfill Fires

A surface fire can start if the facility accepts hot objects (for example, barbeque coals or other ashes) or overdraws the landfill gas collection system. Also arson, spontaneous combustion, or a discarded cigarette can start fires. To keep fires small and manageable, immediate action is necessary. Actions may include using heavy equipment to remove the burning material to a safe area, the application of soil to suffocate the fire, or the use of suppression agent and firefighting activities. If no action is taken, significant amounts of rancid and toxic smoke will be generated from burning surface trash. Toxicity of this smoke depends on the composition of the waste stream.

Subsurface Landfill Fires

A subsurface fire typically starts from overdrawing a gas collection system or spontaneous combustion. These fires are more likely to burn slowly without visible flame or large quantities of smoke and are characterized by rapid oxidation of an organic waste. The waste mass tends to oxidize around the extraction well, in the influence zone of the extraction well, or near a surface feature that allows oxygen to enter the waste mass. Subsurface fires in gas collection systems are detected by elevated temperature at the well head or by the detection of soot in the gas collection system. At times, underground combustion/oxidation will go undetected until a sinkhole or smoke appears. Normally you will never see an actual flame during this type of fire unless the subsurface fire is excavated and exposed to the atmosphere.

How Spontaneous Combustion Occurs

In spontaneous combustion, waste material is heated by chemical oxidation and biological decomposition. The resulting heat causes the material to reach the point of ignition. This type of rapid oxidation in a municipal or construction/wood waste facility is directly related to the amount of moisture present in the fill. The bacteria--both aerobic and anaerobic--present in organic matter require water to biologically breakdown organic matter. As shown in the equation below, as organic material is biodegraded, heat is produced along with other constituents.

$$\begin{array}{c}\text{Organic Matter}\\ \text{(solid waste)}\end{array} + H_20 \xrightarrow{\text{Bacteria}} \begin{array}{c}\text{Biodegraded}\\ \text{organic matter}\end{array} + CH_4 + CO_2 + \text{Other gases}$$

Equation Text Description: In the presence of bacteria, organic matter (solid waste) and water react to produce increased heat (delta t), methane (CH4) gas and carbon dioxide (CO2) gas as well as other gases and degraded organic material.

With the correct conditions present, spontaneous combustion can occur in household trash or at construction debris facilities. This type of combustion will produce excessive amounts of carbon monoxide (CO) and other trace toxic gases due to incomplete oxidation.

Detecting Subsurface Fires

To determine if a subsurface fire exists, one must have visual confirmation or other conditions present. Generally a subsurface fire can be confirmed by:

- Substantial settlement over a short period of time
- Smoke or smoldering odor emanating from the gas extraction system or landfill
- Levels of CO in excess of 1000 parts per million (ppm)
- Combustion residue in extraction wells and/or headers
- Increase in gas temperature in the extraction system (above 140° Fahrenheit) or
- Temperatures in excess of 170° Fahrenheit.

To confirm a subsurface fire by using CO, the results must be acquired through quantitative laboratory analysis. Most field portable equipment only have qualitative abilities and are susceptible to cross-sensitivity with high temperatures, humidity, and other constituents of landfill gas (for example, volatile organic compounds, hydrogen sulfide, etc.). As a result, landfill gas containing these conditions and constituents may produce artificially high carbon monoxide readings when using portable monitors.

The CIWMB staff considers levels of CO in excess of 1,000 ppm to be a positive indication of an active underground landfill fire. Levels of CO between 100 and 1,000 ppm are viewed as suspicious and require further air and temperature monitoring. Levels between 10 and 100 ppm may be an indication of a fire but active combustion is not present.

Employee Health and Safety Risks

> EPA and An Bord Pleanala please note

Subsurface landfill fire can create many types of life threatening conditions. These conditions must be communicated to all site personnel and anyone who is involved in the project. Site hazards may include slips, trips, and falls; confined space issues; carbon monoxide and toxic gas exposures; possible cave-ins due to the void spaces; and burn issues from the elevated temperatures. Safety protocols and considerations related to subsurface landfill fires should be implemented for site workers.

For example, CIWMB air monitoring data from subsurface landfill fires detected CO levels in the range of 2,500 to 28,000 parts per million (ppm) at ground surface. Given that the immediate danger to life and health (IDLH) level is 1,200 ppm, personnel and site air quality monitoring for CO and other chemical exposures may be necessary. CIWMB staff has also recorded temperatures in excess of 300 degrees Fahrenheit within 1 to 3 feet below ground surface. Although not typical, sinkholes in excess of 8 feet in diameter and 5 feet in depth have occurred during underground fires. For additional information on employee protection, contact Cal/OSHA at 1-800-963-9424 or via e-mail at: InfoCons@dir.ca.gov.

Suppression Methods

As with any fire, once one side of the fire tetrahedron collapses the chemical reaction will stop. Landfill fires can be extinguished by smothering with soil, using heavy equipment and a suppressant agent, or simply temporarily shutting down the gas extraction system. No one method will work for all conditions. Each suppression plan will be unique due to site-specific conditions. At times, only an interim cap will prevent the extension of the fire, while other times the use of heavy equipment and foam is preferable.

Interim Cap Recommendations

Based on past experiences with other landfill fires and the thermal properties of plastics (e.g. geomembrane, geotextile, or geosynthetic anything), it is not recommended that a geomembrane or geosynthetic clay liner (GCL) be used to cover the landfill unit until the subsurface fire is extinguished. Although some GCLs do have a large clay component, the potential for rapid settlement from subsurface fires can make the repair and maintenance very difficult. It is recommended that the cap be constructed of a soil with the following properties:

a. A clean, low permeability soil capable of obtaining a permeability of $1x10^{-5}$ cm/sec with a maximum particle size of three inches or less
b. The soil should be classified as SC, ML, CL, or CH according to the unified soil classification system

c. The soil should be compacted to a minimum of 89 percent of the maximum dry density as determined by ASTM D-1557
d. The cover should extend a minimum of 10 feet beyond the landfill area if feasible
e. The clay cover should be a minimum of 18 inches, but recommended the clay cover be 24 inches and placed over a graded foundation layer
f. Each lift of clay should not exceed 9 inches before compaction.

Once the fire is confirmed extinguished, other layers including geotextile, geomembrane, GCL, and/or vegetative could be installed.

Suppression Agents

Although there are many types of foam and wetting agents, it is best to use a class A foam or wetting agent. These chemicals include a surfactant that reduces surface tension and improves penetration depth. Class B foams are ineffective because it is impossible to separate the oxygen from the fuel as it is done with flammable liquids. Class B foams are a two dimensional product, while class A and wetting agents work on three dimensional fires such as landfill and tire fires.

Water

The application of large amounts of water without a suppression agent is not recommend. Large amounts of water may actually acerbate the fire potential by increasing the amount of biodegraded matter and heat. The excess water will also increase contaminated runoff and leachate.

Who Needs to Be Notified?

Typically, if the landfill fire is localized and contained in a small area, the LEA, appropriate CIWMB staff, and the local fire department should be notified. Site specific factors, permit conditions, or other mandates may require that the landfill operator or site owner notify other entities including the local air quality management district, the United States Environmental Protection Agency, the California Office of Emergency Services, local hazardous materials program, and neighbors.

Conclusion

The recommendations presented in this document are based on practical working knowledge of past surface and subsurface fires at waste facilities. Each debris or landfill fire will have site-specific issues that must be addressed. For more information on monitoring requirements or other protocols, please contact Todd Thalhamer, P.E., at the CIWMB.

Todd Thalhamer has worked at CIWMB as a waste management engineer since 1992. He has worked on several major waste fires, including the Tracy tire fire and the Fresno debris fire. He is a registered civil engineer and also a

Lieutenant with the El Dorado Hills Fire Department.

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Landfill fire burning for a year

An underground fire has been smouldering under a Guernsey landfill site for a year, it has emerged.

The blaze, at Mont Cuet was first discovered last April when boreholes were dug and abnormally high temperatures recorded inside the waste.

Public Services bosses said it started when oxygen seeped into the landfill.

There has been one unsuccessful attempt to douse the fire with water. Now a team from the UK is to come over to use nitrogen to snuff it out.

Environmental services project manager for Public Services, Rob Roussel, said the fire was small and constant checks were being made on the site.

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Vancouver Landfill Case History

Smoke was observed at the Vancouver Landfill on Wednesday October 18th, 2000. It was quickly established that an 8m (24ft) thick layer of construction demolition waste was on fire in an 80 by 700m cell. Within hours Porschner Construction, the landfill earthmoving contractor mobilized three off-road Mac dump trucks to deliver water to the site. Each truck delivered a fire fighting payload of 20,000 litres (5,000 U.S. gallons). The trucks were operated around the clock.

With smoke and steam continuing to emanate from several vents on the landfill surface, the fire investigation team from LandfillFire Control Inc. was contacted on Friday morning. Within one hour an emergency assessment team was on the way to the fire site. A bar hole punch grid was quickly established to monitor temperature and landfill gas composition including carbon monoxide, oxygen, methane and hydrogen sulphide. All steam and smoke vents on the landfill surface were also flagged and surveyed to establish exact locations. As elevated CO levels and high O2 levels were detected, a water line capable of delivering up to 1,000 gpm was established to the fire site and a high capacity fire monitor was mobilized.

To cut off the oxygen supply to the fire, additional clay intermediate cover was placed on the side slopes of the burning cell over the weekend. Water application continued around the clock. Within a week the monitoring results conclusively demonstrated that carbon monoxide, temperature and oxygen levels were dropping. The fire was declared extinguished on Friday, October 27th. Total extinguishments costs were approximately $80,000 Cdn.

A forensic review established that the fire was triggered by spontaneous combustion of the demolition, land clearing and construction (DLC) materials. Gaps in the intermediate cover soil allowed entry of oxygen into the waste, promoting high temperature aerobic decomposition, exothermic pyrolysis, and

Mack truck delivering 5,000 gallons of water.

Skid mounted monitor delivers 200 gpm.

LandfillFire Control Inc. technician installing gas probe.

eventually a full scale fire.

Enquiries

Rapid response by the City of Vancouver, Porschner Construction and the LandfillFire Control Inc. team resulted in quick control of the fire and full extinguishment in less than two weeks.

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Smoke from major landfill fires threaten health of fire fighters as well as workers and residents in the area. Monitoring of air quality is vital to ensure that all parties will be properly protected. We provide a full range of air quality sensors for CO_2, CO, methane and H_2S. A trailer based air quality monitoring laboratory is available to test for a wider range of environmental parameters. Our team maintains a data base of qualified occupational hygienists across North America who can be rapidly mobilized to address health and safety issues.

Leachate generated by fire fighting water often presents another major environmental challenge, especially if the landfill is located near aquatic habitat, be it a stream, river, lake or wetland. Our team adopts fire fighting methods that do not apply excessive amounts of water to fires. When practical, we strive to recycle water and foam agents to minimize impacts.

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