The 2002 Landfill Review and Audit

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Manatū Mō Te Taiao

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Executive Summary

Introduction

The objective of the Landfill Review and Audit Project is to build on the 1995 and 1998/99 National Landfill Census results to develop a clear picture of the risks associated with landfills in New Zealand. The risks have been assessed using the Landfill Rapid Screening System (LRSS).

The LRSS takes into account the following factors when assigning a risk score:

- landfill siting – the underlying material, proximity of groundwater users and surface water, rainfall and flood risk
- landfill design – engineered containment, stormwater diversion, leachate collection/ treatment, gas management and landfill cap
- landfill operation – types and volumes of waste accepted, site supervision, waste acceptance criteria, working cover/compaction, and monitoring (leachate, groundwater, surface water and gas).

The Landfill Review and Audit project involved:

- updating data from the 1998/99 National Landfill Census through an electronic survey form and telephone survey
- a programme of visits to operating landfills throughout New Zealand
- application of the Landfill Rapid Screening System.

Survey results

The survey results indicate that landfills in New Zealand have been moving towards improved siting, design and operation, with 'older style' operations improving their management practices and ultimately being replaced by modern facilities. Aspects of landfills where significant improvements have occurred include the use of landfill liners, stormwater management and landfill gas management.

The pace of this change is limited by the cost of closing or upgrading substandard landfill sites and the length of consent terms granted under the Resource Management Act 1991 (RMA).[1] This means that a site that received consent soon after the introduction of the RMA could have consent to operate until after 2020, regardless of the standard of siting, design or operation.

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1 Consent can be granted for up to 35 years under the RMA. While there may be review clauses in the consent conditions, these would generally focus on changing specific conditions (such as those covering monitoring parameters) rather than removing the right of the consent holder to carry out an activity.

Risk screening results

The results of the risk screening indicate that higher risk rankings are associated with a mixture of factors, including:

- landfill siting – distance to receptor, permeability of underlying material and depth to groundwater
- landfill design – leachate containment, engineered liner
- landfill operation – disposal controls, site operation.

Progress towards targets in the New Zealand Waste Strategy

Closure or upgrade of 'substandard' landfills by 2010

Most substandard landfills will be closed or upgraded by 2010. There is, however, no clear regulatory means to require the closure or upgrade of 'substandard' landfills. The proposed landfill classification and waste acceptance criteria system will provide a mechanism for controlling the disposal of hazardous waste at substandard landfills.

Full-cost charging at landfills by 2005

All local authority-controlled sites will be charging for waste disposal by 2005.

Organics waste diversion targets

The Ministry for the Environment's waste information project will provide information about the quantities of organic waste being disposed of to landfill in New Zealand. There are significant quantities of sewage sludge being disposed of to landfill.

Conclusions and recommendations

The results of the 1995 and 1998/99 Landfill Censuses and the 2002 Landfill Review and Audit indicate that landfill siting, design and operation are improving in New Zealand. Where new sites are being developed or existing sites are extending their resource consents, there is a general intention to comply as much as possible with generally accepted good practice.

Landfill operators and regional authorities have access to comprehensive guidance regarding the siting, design, operation and consenting of landfills in New Zealand. Barriers to improving practice in New Zealand include the cost of developing sites in accordance with best practice, the availability of appropriate sites, and reliance on a single containment strategy rather than several levels of containment as advocated in the *Landfill Guidelines* developed by the Centre for Advanced Engineering in 2000.

Based on the results of the survey and the rapid screening assessment, it is recommended that:

1 the Ministry continue to promote and support the existing guidance for landfill siting, design and operation

2 the Ministry work with the solid waste disposal industry to improve the quality of landfill operations, with a particular focus on operator training and stormwater management

3 the monitoring of landfill siting, design and operation in New Zealand be continued and integrated into the Waste Data Network framework. The next landfill survey should be undertaken in 2005.

1 Introduction

The Landfill Review and Audit is a screening-level assessment of landfill design and operation in New Zealand. The assessment has used information from site operators and regional authorities and a site visit programme to assemble information about all operating landfills sites in New Zealand.

This report:

- outlines the background of the Landfill Review and Audit Project, including the New Zealand Waste Strategy (Ministry for the Environment, 2002d) targets and a summary of the National Landfill Censuses (1995 and 1998/99)
- assesses progress towards good practice in the siting, design and operation of landfills in New Zealand
- assesses progress towards some of the targets set out in the New Zealand Waste Strategy
- presents the results of the screening-level risk assessment for operating landfills in New Zealand
- recommends further guidance and other initiatives.

2 The Landfill Review and Audit Project

Project outline

This project aimed to provide an indication of the 'state of play' of landfill operations in New Zealand using the results of a telephone/e-mail survey (2001/02), a site visit programme (2002) and a screening risk assessment methodology. The information collected has also been used for assessing progress towards New Zealand Waste Strategy targets, and has been included in a waste information database being developed for local authorities, the waste industry (disposal and diversion) and central government to help identify issues and design solutions.

The intention was to update the database of information on operating sites (from the 1998 National Landfill Census),[2] assess progress on the issues identified through the National Landfill Censuses, and apply a basic risk assessment to each site using the Landfill Rapid Screening System (LRSS). The details of the LRSS methodology are included in Appendix I.

The outputs from the project, reported here and elsewhere, are:

- a comparison between the 2001/02 survey information and that collected from the previous landfill censuses, giving a measure of progress made since 1998 on a regional and national basis (this report)
- a summary of the risks posed by operating landfills in New Zealand (this report)
- reports on individual landfills to landfill operators and regional authorities (confidential)

The project methodology for the Landfill Review and Audit project is presented in Appendix II.

Good practice in New Zealand

The Ministry for the Environment has endorsed the updated *Landfill Guidelines* (CAE, 2000) as a guide to good practice in landfill design, siting and operation in New Zealand. The guidelines advocate:

- siting landfills in areas with low-permeability underlying geology
- utilising an engineered liner system
- actively managing leachate, stormwater and landfill gas
- appropriate controls on the types of waste accepted for disposal
- monitoring the discharges from the site
- ensuring adequate separation from sensitive receptors (such as surface water and groundwater users) and confined spaces.

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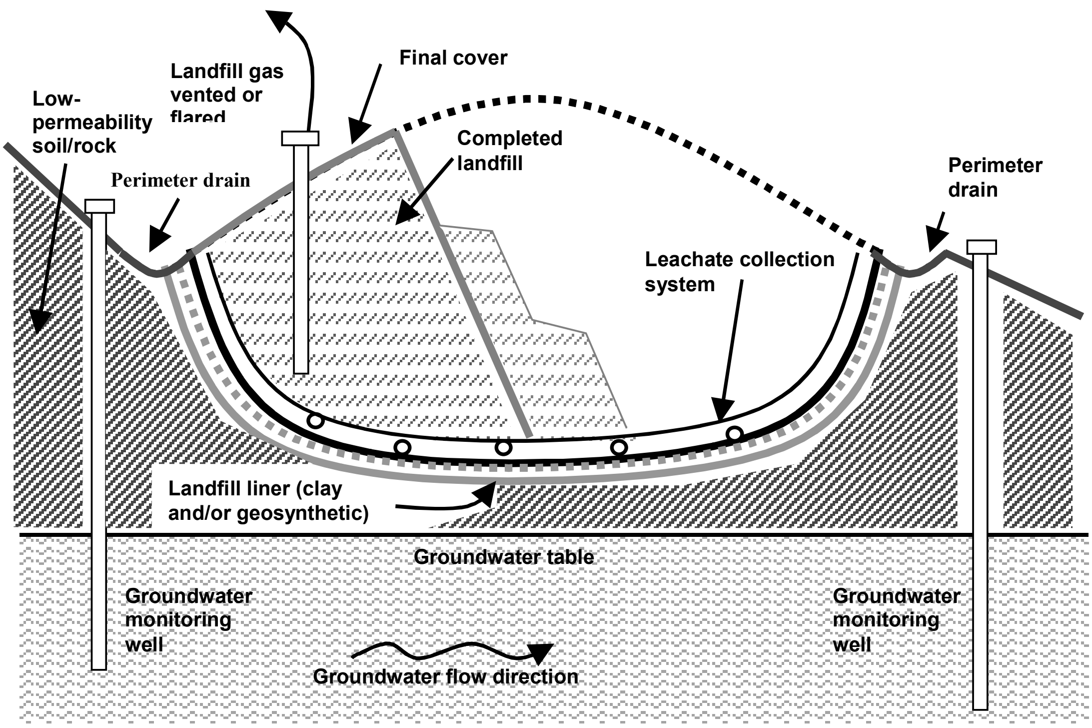
2 A questionnaire was sent to all landfill operators and regional authorities. It was based on questions from the 1998/99 National Landfill Census and used questions relating to resource consents, engineering issues, monitoring, after care and hazardous waste.

Inherent in this approach is a level of redundancy in that individual aspects of the approach outlined above could be relied on to prevent adverse effects alone. However, engineered containment, appropriate underlying geology *and* separation from receptors allows for the uncertainty in defining the nature of underlying geology and the risk of failure of the engineered containment system.

While the use of groundwater flow modelling to predict the fate and transport of specific indicator contaminants is a useful tool in assessing the potential effects of a landfill development, the uncertainty involved in defining underlying geology and the nature of the contaminants disposed of justifies the conservative nature of current good practice. In this context, relying purely on natural attenuation of indicator contaminants[3] to provide adequate containment rather than using the best practice approach combining good siting and engineered containment is not appropriate.

Figure 1: Landfill siting, design and operation



Leachate collection system – designed to minimise the hydrostatic pressure of leachate over the liner
Liner system – designed to contain the leachate and exclude groundwater
Landfill capping system – designed to minimise surface water infiltration and contain landfill gas
Perimeter drains – divert surface water around the landfill footprint (minimising surface water infiltration)
Underlying geology – low permeability (providing redundancy in the event of a liner failure)

3 Through mechanisms such as dilution, dispersion and absorption.

3 The New Zealand Waste Strategy

It is important to consider landfills in the context of overall waste policy for New Zealand, as outlined in the New Zealand Waste Strategy (NZWS). The Strategy has three core goals:

- to lower the social costs and risk of waste
- to reduce the damage to the environment from waste generation and disposal
- to increase economic benefit by the more efficient use of materials.

The NZWS also includes several specific targets relating to landfills:

- local authorities will have addressed their funding policies to ensure that full cost recovery can be achieved by December 2003
- full-cost charges will be calculated and a programme established to phase them in by 2005
- substandard landfills will be closed or upgraded by 2010
- cleanfills will comply with the *Guide to the Management of Cleanfills*[4] by 2005
- hazardous wastes will be appropriately treated before disposal by December 2004.

Other targets relate to the diversion of green waste, sewage sludge, commercial organic wastes, and construction and demolition wastes from landfills, and improved controls on the disposal of liquid wastes through improved wastewater treatment and trade waste controls.

The Landfill Review and Audit project aims to assess the potential for damage to the environment (the environmental risks) associated with current solid waste disposal practice in New Zealand. Section 5.5 discusses progress towards selected targets in the Strategy using the results of the Landfill Review and Audit.

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4 Ministry for the Environment, 2002a.

4 The National Landfill Census (1995 and 1998/99)

The Landfill Review and Audit project was developed to build on the results of the 1995 and 1998 Landfill Censuses. These used questionnaires filled in by landfill operators and regional authorities, and qualitatively assessed the following aspects of landfill performance in New Zealand:

- consent conditions
- after-care and closure plans
- waste acceptance criteria
- landfill siting
- landfill design
- leachate management
- landfill gas management.

4.1 1995 National Landfill Census

The first National Landfill Census was undertaken in 1995 and reported in 1997. At this time the Resource Management Act 1991 (RMA) had only been in place for four years and many sites had yet to transfer from previous legislation. The Ministry for the Environment produced the first *Landfill Guidelines* in 1992.

The 1995 National Landfill Census identified a need to:

- address RMA compliance and coverage issues
- develop definitions and acceptance criteria for hazardous and special wastes
- further develop the *Landfill Guidelines*
- prepare information on the effects of, and means to control, landfill burning
- facilitate the development and adoption of training programmes for landfill operators.

In response to the results of the 1995 Census, the Ministry for the Environment produced the *Landfill Full Cost Accounting Guide* (Ministry for the Environment, 1996) and *The Hazards of Burning at Landfills* (Ministry for the Environment, 1997b) as additions to the 1992 *Landfill Guidelines.*

4.2 1998/1999 National Landfill Census

The second National Landfill Census was undertaken in 1998/99 and reported in 2000. In brief, the Census results indicated:

- an improvement in the number of consented landfills
- a significant level of non-compliance
- poor performance by some landfill operators in managing hazardous wastes, particularly a lack of appropriate documentation for receipt of hazardous wastes and no consistent definition of what hazardous wastes are received
- a decrease in open burning at landfills
- a small improvement in landfill operator training
- a considerable variation in the quality of consent conditions
- evidence of inadequate management of closed landfills.

In response to the results of the 1998/99 Census the Ministry for the Environment produced *A Guide to the Management of Closing and Closed Landfills in New Zealand, A Guide to Landfill Consent Conditions, A Guide to the Management of Cleanfills* and an update to the *Landfill Full Cost Accounting Guide* (Ministry for the Environment, 2001a, 2001b, 2002a, 2002c). The *Landfill Guidelines* were also updated by Canterbury University's Centre for Advanced Engineering in 2000 (CAE, 2000).

5 The 2001/02 Landfill Review and Audit

5.1 Key questions

The key questions the Landfill Review and Audit project aimed to answer are:

- How have things changed since the 1998 Landfill Census (what progress has been made and where is there still work to do)?
- What are the risks posed by operating landfills in New Zealand (Landfill Risk Screening System results)?
- How well is the guidance currently available being used?
- Is there a need for further guidance or other initiatives?
- Are we likely to meet the targets set out in the New Zealand Waste Strategy?
- Are there any generalised comments that can be made regarding the state of solid waste disposal in New Zealand?

5.2 Survey results

Table 1 summarises the results of the 1995 and 1998 Landfill Censuses, the Landfill Review and Audit survey, and predicted survey results for 2010 (where it was considered possible to estimate the situation in eight years' time). In general the results indicate that landfills in New Zealand have been moving towards improved siting, design and operation, with 'older style' operations improving their management practices and ultimately being replaced by modern facilities. The pace of this change is limited by the cost of closing or upgrading substandard landfill sites and the length of consent terms granted under the RMA.[5] A site that received consent soon after the introduction of the RMA could have consent to operate until after 2020, regardless of the standard of siting, design or operation. This does not necessarily mean that a site is not complying with the conditions of consent, but rather that the consent does not require consistency with good practice in New Zealand.

[5] A consent can be granted for up to 35 years under the RMA. While there may be review clauses in the consent conditions, these would generally focus on changing specific conditions (such as those covering monitoring parameters) rather than removing the right of the consent holder to carry out an activity.

Table 1: National Landfill Census (1995 and 1998), LRA Survey Results (2002) and predictions for 2010

	1995	1998	2002	2010[b]
Total number of operating sites	327	209	115	43
Sites with consent to operate	–[a]	157	104	43
Low-permeability underlying material[c]	–	10%	15%	42%
Leachate management system:				
• engineered liner	–	4%	20%	67%
• leachate collection system	13%	35%	47%	88%
• leachate recirculation	–	7%	10%	Not known
Stormwater management system:				
• stormwater diversion	41%	67%	74%	100%
• stormwater monitoring	–	23%	50%	77%
• stormwater treatment	9%	27%	36%	67%
Landfill gas management system:				
• landfill gas monitoring	3%	11%	27%	77%
• landfill gas collection (flaring or beneficial use[d])	–	5% (10)	10% (12)	30% (13)
Working cover daily or more	–	25%	30%	93%
Landfill fires	52%	24%	17%[e]	Not known
Hazardous waste management:				
• hazardous waste accepted?	33%	20%	–[f]	Not known[g]
• definition				
– CAE guidelines	–	9%	20%	Not known
– HSNO definition	–	3%	6%	Not known
– standard list	–	5%	18%	Not known
– USEPA	–	2%	6%	Not known
– no definition	–	68%	18%	Not known
• documentation required	–	33%	53%	Not known
Measuring the quantity of waste	39%	63%	83%	100%
Charging for the disposal of waste	–	45%	82%	100%

a ‘–’ indicates that information is not available.

b The figures for 2010 are estimates based on discussions with operators and waste management organisations.

c Low permeability’ is defined as thick clays or < 10^{-9} m/s for this evaluation.

d 1998 – three electricity generation, six flare, one industrial use; 2002 – five electricity generation, six flare, one industrial use.

e The fires reported in 2002 were either at small rural sites where burning was not part of the formal management of the site, or minor incidents at larger landfills.

f While all sites state that they do not accept hazardous waste, the definition of hazardous waste varies. Some sites acknowledge that household waste will contain small quantities of hazardous waste.

g It is expected that all landfills will utilise the draft hazardous waste definition and landfill waste acceptance criteria developed by the Ministry for the Environment (www.mfe.govt.nz/wasteline).

Below we discuss these results in more detail.

5.2.1 Landfill siting

Fifteen percent of operating landfills (17 sites) are sited over low-permeability material. This is an improvement from 10% (21 sites) in 1998, although this is related to the closure of a significant number of sites overlying moderate- or high-permeability material rather than an increase in the number of sites with low-permeability underlying material. It is predicted that 43% (18 sites) of landfills in 2010 will overlie low-permeability material.

5.2.2 Landfill design

Engineered liner

Twenty percent of operating landfills (23 sites) have some form of engineered liner, an improvement from 4% (eight sites) in 1998. The nature of the 'liner' systems varies from state-of-the-art composite liners to simple base layers using 100–500 mm of re-compacted material from on site. It is predicted that 67% (29 sites) will have an engineered liner by 2010.

Leachate collection system

Forty-seven percent of operating landfills (54 sites) have some form of leachate collection system, an improvement from 13% (42 sites) in 1995 and 35% in 1998 (73 sites). It is predicted that 88% of landfills (37 sites) will have a leachate collection system in 2010.

Leachate recirculation

Ten percent of operating landfills (12 sites) are recirculating leachate, an increased percentage from 1998. Given the current debates about the recirculation of leachate and the development of the concept of bioreactor landfills, it is difficult (if not impossible) to predict the number of sites utilising recirculation in 2010.

Stormwater diversion

Fifty percent of operating landfills (58 sites) are diverting stormwater, a percentage increase from 1995 (41%) and 1998 (67%). It is predicted that all operating landfill sites in 2010 will have effective stormwater diversion in place.

Stormwater monitoring

Seventy-four percent of operating landfills (85 sites) monitor stormwater, an increase from 23% in 1998. It is predicted that 77% of landfills (33 sites) in 2010 will be monitoring stormwater quality.

Stormwater treatment

Thirty-six percent of operating landfills (41 sites) are treating stormwater prior to discharge, an increase from 1995 (9%) and 1998 (27%). It is predicted that 67% of landfills (29 sites) will be treating stormwater prior to discharge in 2010.

Landfill gas monitoring

Twenty-seven percent of operating landfills (31 sites) are monitoring for landfill gas, an improvement from 1995 (3%) and 1998 (11%). It is predicted that 77% of landfills (33 sites) will be monitoring for landfill gas in 2010.

Landfill gas collection

Twelve landfill sites are currently actively managing landfill gas (five for electricity generation, one reticulating for industrial use, six flaring), an improvement from 1998 (three for electricity generation, one reticulating for industrial use, six flaring). It is predicted that 30% of landfills (13 sites) will be actively managing landfill gas in 2010.

5.2.3 Landfill operation

Daily cover

Thirty percent of sites are covering waste on a daily or more frequent basis, similar to 1998 (25%). It is predicted that 93% of landfills (40 sites) will be covering waste on a daily basis by 2010.

Hazardous waste

The answers to the questions on hazardous wastes show that there are a variety of definitions in use. The definitions are variously based on the 2000 *Landfill Guidelines*, the Hazardous Substances and New Organisms Act (HSNO), the United States Environmental Protection Agency (USEPA) definition, and various lists of substances. The Ministry has recently released a draft hazardous waste definition based on the HSNO definition, and it is expected that this definition will be used by all landfill operators by 2005.

There are a variety of waste acceptance criteria systems in use throughout New Zealand. The Ministry is working on a Landfill Classification and Waste Acceptance Criteria system, which will be released as a module of the *Hazardous Waste Management Guidelines* in late 2002. It is expected that all landfills will adopt these waste acceptance criteria by 2010.

Waste quantity

Eighty-three percent of landfills (95 sites) are measuring the quantity of waste. This is an increase from 1995 (39%) and 1998 (63%). Of the sites currently measuring waste quantity, 28 (24% of the total number of operating sites) are using weighbridges. In general the remainder of sites estimate waste quantities based on volume. It is expected that all landfill sites will be measuring waste in 2010, with around 50% using a weighbridge.

Charging for waste disposal

Eighty-two percent of landfills (94 sites) are charging for waste disposal, an improvement from 45% in 1998. It is expected that all landfills will be charging for waste disposal in 2010.

5.3 Landfill rapid screening system results

5.3.1 Introduction

The Landfill Risk Screening System (LRSS) is a simple screening risk assessment tool based on the source-pathway-target model. The details of the LRSS methodology are included in Appendix I, and are outlined briefly below.

In the source-pathway-target model, for an adverse effect to occur it is assumed that there needs to be:

1. a source – leachate and landfill gas produced through decomposition of domestic refuse or industrial waste
2. a pathway – a way for the contaminant to be released to the environment and a way for the contaminant to come into contact with the target
3. a target – people and/or ecosystems that come into contact with the contaminant.

For an adverse effect to occur, there must be a source, a pathway *and* a target present. For landfills:

- the source is related to the nature and quantity of the waste disposed of at the site
- the pathway is related to engineered containment at the site (liner, leachate collection, etc) *and* the distance from the target
- the target is the nearest surface water body, groundwater user and/or potential receptor for landfill gas.

The application of the LRSS methodology relies on the judgement of the users, and is therefore subjective to a degree. As noted previously, the assessment for each site has been based on information provided by the site operator, regional authorities and a site visit. While every attempt has been made to verify and cross-check the information used in the LRSS, the assessment is ultimately based on a one- to two- hour site walkover and a desktop assessment.

5.3.2 Reference landfill

To provide a point of comparison, a theoretical 'reference landfill' based on the guidance in the 2000 *Landfill Guidelines* and typical siting in New Zealand was assessed using the LRSS screening system. The details of the reference landfill are presented in Table 2.

Table 2: Reference landfill details

Parameters	Comments
Waste source	Municipal solid waste, site fenced, staffed when open
Waste quantity	> 50,000 tonnes per annum
Leachate	Collection and treatment
Stormwater	Active management, including diversion, monitoring and treatment
Operation	Daily working cover, adequate compaction
Landfill liner	Liner consisting of 900 mm compacted clay with permeability less than 10^{-9} m/s on base and sides
Landfill gas	Landfill gas management system, including monitoring, collection and flare
Depth to groundwater	Groundwater > 15 m below base of refuse
Topography	Moderate slope from potential point of discharge to surface water
Surface water receptor	200 m to surface water body; surface water used for stock watering
Underlying material	> 15 m of low-permeability (10^{-7} m/s or less) underlying material
Annual rainfall	> 1000 mm
Groundwater receptor	> 300 m to nearest groundwater user; receptor is extraction for stock water or irrigation
Landfill cap	Cap equivalent to 600 mm, with permeability less than 10^{-9} m/s
Landfill gas receptor	200–300 m to nearest landfill gas receptor, recreational open space or agricultural

Reference landfill screening results:

- surface water risk = 0.18 or LOW risk ranking
- groundwater risk = 0.09 or LOW risk ranking
- landfill gas risk = 0.07 or LOW risk ranking.

5.3.3 Risk screening results

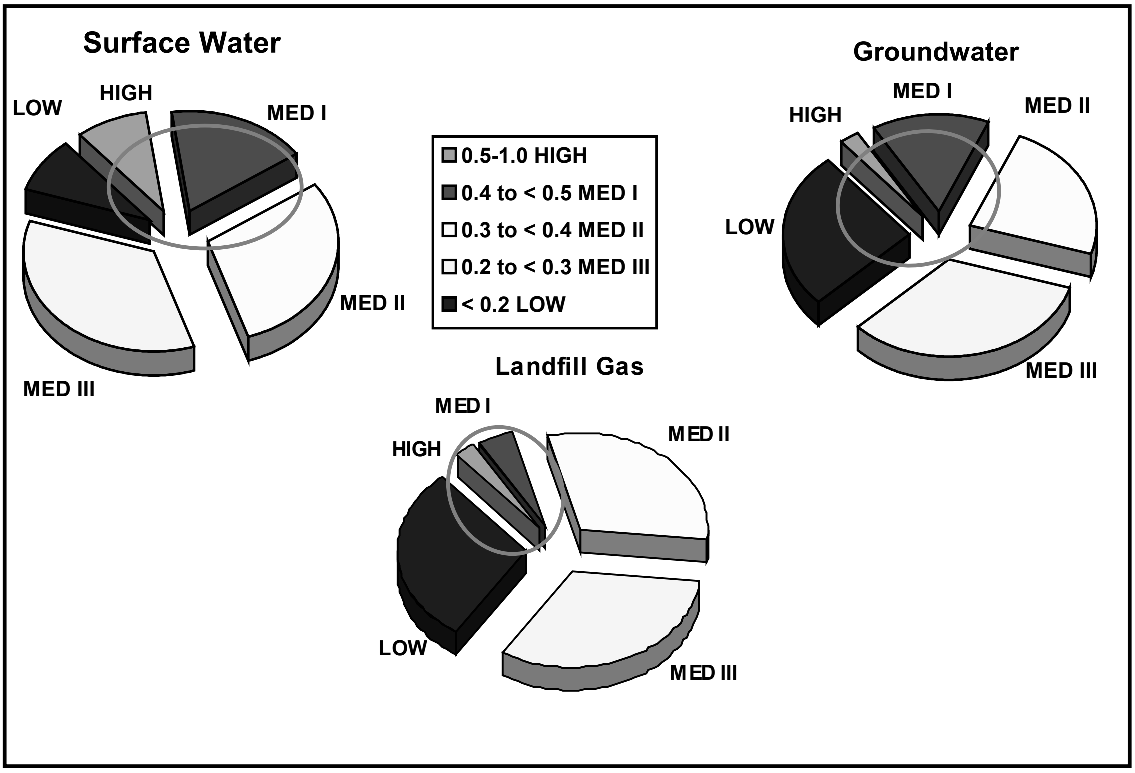
The LRSS uses a list of factors to calculate a risk ranking for three 'exposure scenarios' (via surface water, groundwater and landfill gas) for each site, as outlined in Appendix I. The results of this analysis are summarised in Table 3 and discussed in the following sections. For each scenario, scores have been separated into five bands to assist in identifying trends for each exposure scenario: high, med I, med II, med III and low.

Table 3: Landfill risk screening system results

Ranking	High	Med I	Med II	Med III	Low
Scoring range	0.5–1.0	0.5–0.4	0.3–0.4	0.2–0.3	0.0–0.2
Surface water risk	10	20	34	40	10
Groundwater risk	3	17	27	38	30
Landfill gas risk	3	5	35	37	34
Highest score for site (ie, highest from surface water, groundwater and landfill gas)	14	29	39	29	3

The number of sites with high risk ranking for each scenario is small, with surface water having the most sites with a high risk ranking (10 for surface water, three for both groundwater and landfill gas). Combining the high and med I rankings (circled on Figure 2) paints a similar picture, with groundwater having more sites with these two rankings than landfill gas (30 for surface water, 20 for groundwater, eight for landfill gas).

Figure 2: Landfill risk screening system results – pathways



5.3.4 Surface water risk

Results

Ten sites had a high risk ranking for the surface water scenario, 94 sites had a med risk ranking and 10 sites had a low risk ranking.

Source

For surface water the source parameter was assessed considering the quantity of waste and level of control over waste disposal. The results indicate that a site with a high ranking is more likely than sites with med or low ranking to have poor disposal controls.

Pathway

For surface water the pathway parameter was assessed considering surface water management, site operation, leachate containment (liner, leachate collection, leachate treatment), flood risk and distance to surface water, with the following results.

- None of the sites with a high risk ranking had effective surface water management (stormwater diversion, monitoring and treatment); 40–50% of med and low ranking sites had effective stormwater management.
- None of the sites with a high risk ranking were well operated (good compaction, effective working cover); 40–60% of med and low ranking sites were well operated.
- None of the sites with a high risk ranking had an engineered liner system; the percentage of sites with liners increased with decreasing risk ranking (ie, the presence of a liner decreased the risk ranking).
- Twenty percent of the sites with a high risk ranking had a leachate collection system; around 50% of med and low ranking sites had a leachate collection system.
- None of the sites with a high risk ranking had any form of leachate treatment (on-site treatment and/or reticulation off-site); 30–40% of med and low ranking sites had some form of leachate treatment in place.
- All of the sites with a high risk ranking were subject to high flood risk (> 1 in 100-year return period); the percentage of sites with high flood risk decreased with decreasing risk ranking (ie, the risk ranking increases with increasing flood risk).
- All of the sites with a high risk ranking were within 200 m of a sensitive surface water body; the percentage of sites within 200 m of a water body decreased with decreasing risk ranking (ie, the risk ranking decreases with increasing distance from surface water bodies).

Target

The receptors for surface water are generally of moderate concern for high, med and low risk rankings (stock watering rather than domestic water supply or contact recreation).

Comments

There is a fair amount of consistency in the nature of the receptor for surface water, although it is clear that differences in the source (quantity and nature of the waste) and the pathway (operation, engineered liner, flood risk and distance to surface water) are responsible for different risk rankings calculated using the LRSS.

A site with a high risk ranking for surface water is more likely than sites with med or low risk ranking to:

- have poor controls on disposal (be unattended while open, and have limited control over the types of waste disposed of at the site)
- be poorly operated with respect to stormwater management and compaction/cover
- have no liner or leachate collection
- be within 200 m of a surface water body (80% are within 100 m)
- have a relatively high risk of flooding.

5.3.5 Groundwater risk

Results

Three sites had a high risk ranking for the surface water scenario, 82 sites had a med risk ranking and 30 had a low risk ranking.

Source

For groundwater the source parameter was assessed by considering the quantity of waste and level of control over waste disposal. The results indicate that there is no clear difference in the waste source score between sites with high and med risk rankings.

Pathway

For groundwater the pathway parameter was assessed by considering site operation, leachate containment (liner, leachate collection, leachate treatment), groundwater monitoring, the depth to groundwater, permeability of underlying material, rainfall and distance to groundwater users, with the following results.

- Around 30% of the sites with a high risk ranking were well operated (good compaction, effective working cover); this increased to 40% for sites with a med ranking and 70% for low ranking sites.
- None of the sites with a high risk ranking had an engineered liner; around 10% of the med ranking sites and 50% of low ranking sites had some form of engineered liner (ie, the presence of a liner system decreased the risk ranking).
- None of the sites with a high risk ranking had a leachate collection system; 40% of med and 70% of low ranking sites had some form of collection system.

- None of the sites with a high risk ranking had appropriate groundwater monitoring programmes in place; this increased to over 30% for med ranking sites and 70% for low ranking sites.
- All of the sites with a high risk ranking had groundwater at or near the base of the refuse; the percentage of sites with groundwater at or near the base of the refuse decreased with decreasing risk ranking (ie, increasing separation of refuse from groundwater translates to a lower risk ranking).
- All of the sites with a high risk ranking had high-permeability underlying material; the percentage of sites with high-permeability underlying material decreased with decreasing risk ranking (ie, high-permeability underlying material translates to a higher risk ranking).
- Due to high rainfall throughout New Zealand, most sites were assessed as having high rainfall (> 1000 mm per year).
- All of the sites with a high risk ranking had a groundwater user (including discharge to a sensitive waterway) within 100 m; the percentage of sites within 100 m decreased with decreasing risk ranking (ie, increasing separation from groundwater users/discharge translates to a lower risk ranking).

Target

Seventy percent of the sites with a high risk ranking had a sensitive receptor. The percentage of sites with a sensitive receptor decreased with decreasing risk ranking (ie, decreasing sensitivity of the receptor translates to a lower risk ranking).

Comments

It is the differences in pathway (liner, leachate treatment, groundwater monitoring, underlying material, distance to groundwater user/discharge) and receptor for groundwater issues that are responsible for the different risk scores for groundwater. There are no significant differences in the standard of disposal control (source) for the different risk scores.

A site with a high risk ranking for groundwater is more likely than sites with med or low risk ranking to:

- have no liner or leachate collection
- have groundwater within 1–2 m of the base of the refuse at the site
- overlie high-permeability material (sands or gravels)
- have a groundwater user or discharge of groundwater to a significant waterway within 100 m.

5.3.6 Landfill gas risk

Results

Three sites had a high risk ranking for the surface water scenario, 77 sites had a med risk ranking and 34 sites a low risk ranking.

Source

For landfill gas the source parameter was assessed by considering the depth of waste and the level of control over waste disposal. The results indicate that a site with a high ranking is likely to be similar (in this respect) to those with med or low rankings.

Pathway

For landfill gas the pathway parameter was assessed considering site operation, liner (at base and sides), landfill gas monitoring, gas collection, final capping, permeability of adjacent material and distance to landfill gas receptor, with the following results.

- There was no apparent variation in the percentage of sites with poor site operation between sites with high, med and low risk rankings.
- None of the sites with a high risk ranking had a base or side liner; the percentage of sites with liners increased with decreased risk ranking (over 30% of sites with a low risk ranking).
- There was no apparent variation in the percentage of sites with a landfill gas monitoring programme between sites with high, med and low risk rankings.
- There was no apparent variation in the percentage of sites with a landfill gas collection system between sites with high, med and low risk rankings.
- There was no apparent relationship between the percentage of sites with adequate final capping and the risk ranking.
- All of the sites with a high risk ranking had high-permeability adjacent material; this decreased to 85% for sites with a low risk ranking.
- Around 70% of the sites with a high risk ranking were within 300 m of a gas receptor; this decreased to around 15% for sites with a low risk ranking.

Target

All of the sites with a high risk ranking had sensitive receptors for landfill gas nearby (enclosed spaces and/or residential properties). The percentage of sites with sensitive receptors nearby decreased to zero for sites with a low risk ranking.

Comments

The differences in the pathway (base liner, side liner, distance to gas receptor) and receptor are responsible for the different risk scores for landfill gas. There appears to be no significant differences in the source for landfill gas.

The lack of influence of factors such as landfill gas collection and final capping is due to the fact that most sites in New Zealand have not implemented best practice in this area (ie, most landfills could reduce their risk ranking by implementing improved gas management through active management and effective final capping).

A site with a high risk ranking for landfill gas is more likely than sites with med or low risk ranking to:

- have no liner (at the base or sides of the fill area)
- overlie and be surrounded by high-permeability material (sands or gravels)
- have a potential receptor within 300 m.

5.4 Issues identified through the risk-screening process

The results presented in the previous section indicate that the variations in risk rankings are attributable to a mix of factors for each of the exposure scenarios. These factors include:

- disposal controls (surface water)
- site operation (surface water)
- leachate containment (surface water and groundwater)
- engineered liner (surface water, groundwater, landfill gas)
- distance to receptors (surface water, groundwater and landfill gas)
- permeability of the underlying soil (groundwater and landfill gas)
- depth to groundwater (groundwater).

These factors can be related to landfill siting, design and operation as follows:

- landfill siting – distance to receptor, permeability of underlying material, depth to groundwater
- landfill design – leachate containment, engineered liner
- landfill operation – disposal controls, site operation.

5.4.1 Landfill siting

Issues identified for landfill siting are:

- high-permeability underlying material
- gas receptor close to landfill sites
- groundwater receptor close to landfill sites
- landfill sites close to surface water
- groundwater at or near the base of refuse
- high risk of flooding.

Barriers to addressing landfill siting issues include:

- existing consent terms and conditions – in some cases inappropriately sited landfills have consent to operate until past 2020
- remote locations – the cost of transport may mean that small landfills are sited at unsatisfactory sites to avoid high waste transfer/transport costs
- there are areas in New Zealand where finding suitable geology is problematic
- sometimes the best sites (on a technical basis) cannot be used due to political and community issues (not in my back yard, or NIMBY).

Work the Ministry is currently doing to address landfill siting issues includes:

- promotion of the 2000 *Landfill Guidelines*
- making submissions on consent applications for sub-standard landfills (improve landfill siting through opposing inappropriately sited landfills)
- guidance for site developers and regional authorities (*A Guide to Landfill Consent Conditions, A Guide to the Management of Cleanfills*, 2000 *Landfill Guidelines*)
- landfill standard (proposed).

An additional work area for the Ministry could involve outlining the potential for compromise on suitable sites (ie, use state-of-the-art engineered containment *and* rigorous disposal controls to compensate for lack of natural containment and/or sensitive receptors).

5.4.2 Landfill design

Issues identified for landfill design are:

- the liner
- leachate collection
- landfill gas management.

Barriers to addressing landfill design issues include:

- existing consent terms and conditions – in some cases sites without engineered containment have consent to operate until past 2020
- the cost of retrofitting leachate collection, landfill gas management and/or engineered liner systems – this cost is often high in areas where landfilling has already commenced. Where a site has an existing consent it may be hard to justify upgrades of this nature that are not required by the consent.

There is a common perception that there is no need or justification for constructing new cells consistent with best practice where there are older, unlined cells at the site. Why contain leachate now when there will always be leachate discharging from the old parts of the site? There is also the issue of the feasibility of leachate treatment for low volumes of leachate, because of the high unit cost for effectively treating leachate from smaller sites. This is related to the lack of economies of scale or transport distances (if diverting to a wastewater treatment plant). It can be hard to justify upgrade or closure based on measured effects, given the difficulty in establishing adverse effects from the discharge of leachate to surface and groundwater where the leachate discharge is subject to significant dilution. The containment philosophy found in the 2000 *Landfill Guidelines* is based on the premise that if contaminants are found in surface or groundwater, it is often harder and/or more expensive to mitigate effects rather than avoid the discharge in the first place.

Work the Ministry is currently doing to address landfill design issues includes:

- promotion of the 2000 *Landfill Guidelines*
- making submissions on consent applications for sub-standard landfills (raising the standard of design through the resource consent process)
- guidance for site developers and regional authorities (*A Guide to Landfill Consent Conditions*, *A Guide to the Management of Cleanfills*, 2000 *Landfill Guidelines*).

Additional work areas for the Ministry could include landfill standards for siting, design and/or operation.

5.4.3 Landfill operation

Issues identified for landfill operation are:

- poor controls on disposal (site unattended, inadequate hazardous waste controls)
- inadequate stormwater management
- inadequate compaction
- poor working cover
- lack of gas monitoring
- poor monitoring of groundwater and leachate chemistry.

Barriers to addressing landfill operation issues include:

- landfill operations contracts – these have been let based on cost only, although this is changing as regional authorities improve compliance monitoring
- poorly sited and designed landfills – landfill operators are often doing their with unsatisfactory sites (siting and design)
- lack of training of landfill operators – there is often no requirement for training in landfill consent conditions, landfill management plans or operations contracts
- unattended landfills and transfer stations – small, remote sites are often unmanned, leading to poor controls on disposal
- surface water control – the high rainfall in New Zealand means that effective management of stormwater is an important aspect of containing waste and decomposition products
- lack of knowledge regarding hazardous waste acceptance.

Work the Ministry is currently doing to address landfill operation issues includes:

- promotion of the 2000 *Landfill Guidelines*
- making submissions on consent applications for sub-standard landfills (raising the standard of operational controls through the resource consent process)
- guidance for site developers and regional authorities (*A Guide to Landfill Consent Conditions*, *A Guide to the Management of Cleanfills*)
- national guidelines for the management of hazardous waste, including Landfill Waste Acceptance Criteria.
- standards for landfill waste acceptance criteria (proposed).

Additional work areas for the Ministry could include:

- training guidance
- contracting guidance (in conjunction with WasteMINZ)
- web-based resources for issues such as stormwater control and waste acceptance criteria.

5.5 Progress towards the targets in the New Zealand Waste Strategy

The results from the Landfill Review and Audit survey have been used to assess progress towards meeting several of the targets set out in the NZWS.

5.5.1 Substandard landfills

Target 4: Targets for waste disposal

> *By December 2010, all substandard landfills will be upgraded or closed.*

The Ministry is currently working on developing a landfill classification system as part of the Landfill Waste Acceptance Criteria work programme. Under the proposed system there would be two classes of landfill: Class A landfills would be those consistent with the intent of the *2000 Landfill Guidelines*,[6] while Class B sites would be those that do not meet the intent of the guidelines. Sites could establish that they are consistent with the guidelines either by design standards and siting locations specified, or by using performance modelling to establish that the engineering and containment strategies employed are equivalent to the approach outlined in the guidelines. A site's getting a Class A classification is also likely to depend on the absence of certain fatal flaws, such as geotechnical instability, and the proximity of wetland, estuary, and culturally significant sites.[7]

For some Class B sites it may be possible to upgrade to Class A by improving the design (liner, leachate collection, stormwater management and/or gas management) and/or operational aspects of the landfill. This does, however, rely on having low-permeability underlying geology and adequate separation from sensitive receptors.

In considering sites likely to be operating in 2010, a list of simple criteria based on the 2000 *Landfill Guidelines* (see Table 4) has been used. In presenting this information it is important to note that the results are based on a screening-level assessment only. In a screening-level assessment of sites, 'substandard' could be defined as any site unable to meet the criteria. However, before defining a site as 'substandard' and prioritising any further action, site-specific issues should be considered in more detail. In Table 4, Landfill 1 is consistent with the 2000 *Landfill Guidelines* while Landfills 2 and 3 illustrate how sites may be consistent with different aspects of the guidelines.

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6 The 2000 *Landfill Guidelines* are used as a guide to best practice in New Zealand.

7 The details of the landfill classification and waste acceptance criteria work will be released as a module of the *Hazardous Waste Management Guidelines* (Ministry for the Environment, 2002b) by the end of 2002. The proposed landfill classification and waste acceptance criteria system will provide a mechanism for controlling hazardous waste disposal at Class A and Class B landfills.

Additional factors to be considered include:

- performance modelling may enable a shift to Class A
- in some cases adequate disposal controls mean that the nature of waste is of low concern[8]
- in some cases waste quantities are low
- practical alternative disposal options may not be available, or may be excessively expensive.

Table 4: Consistency with the 2000 Landfill Guidelines

	Landfill 1	Landfill 2	Landfill 3
Low-permeability underlying material	✓	✓	✗
Liner	✓	✗	✗
Leachate collection/treatment	✓	✓	✗
Gas management	✓	✓	✗
Stormwater management	✓	✓	✗
Appropriate landfill waste acceptance criteria	✓	✗	✗
Comprehensive monitoring programme	✓	✓	✗
Appropriately operated	✓	✗	✓
	All ticked	Most ticked	None or few ticked

Based on discussions with landfill operators and local authorities throughout New Zealand, it is estimated that there will be 43 landfills operating at the end of 2010. Of these, it is estimated that:

- 11 will be consistent with the approach advocated in the 2000 *Landfill Guidelines* (are likely to meet all of the criteria, be consistent with best practice and on this basis will be considered Class A)
- 32 will not meet at least one of the criteria noted above (will have no liner, will be sited over high-permeability soils and/or will not be appropriately managing waste acceptance, gas, leachate or stormwater; further assessment is required to determine whether these sites would fit into Class A or Class B in the proposed landfill classification system)
- six of the 32 sites will not meet the majority of the criteria noted above and are therefore likely to be considered 'substandard'.

The regional breakdown of numbers for these sites is presented in Table 5. The 'High std' sites are those that meet all the criteria. Further assessment may increase the number of sites considered high standard.

8 The disposal of hazardous wastes in landfills increases the likelihood of adverse effects from the discharge of leachate. In this context, the exclusion or tight control of hazardous waste disposal is an important tool in managing potential effects from a landfill operation.

Where a landfill is unable to meet the intent of the 2000 *Landfill Guidelines* but has consent to operate well past 2010, the Ministry for the Environment is considering the options to encourage early closure of the site. The Ministry advocates working towards closure or upgrade, with interim measures focusing on implementing best practice in managing stormwater, landfill waste acceptance[9] and monitoring. Review clauses for the consents may allow for changes to specific conditions (such as monitoring or waste acceptance), but are unlikely to allow the regional authority to remove the ability of the consent holder to undertake the activity allowed by the consent.

Where new sites are being developed or existing sites expanded beyond the terms of consent, it is expected that the design, siting and operation will be consistent with best practice in New Zealand and internationally (they will be Class A standard).

Table 5: Number of landfills, 2002 to 2010

Region	*2001/02*		*2005*	*2010*	
	No. Total	*Tonnes/yr*	*No.*	*No. Total*	*No. High standard*[a]
Auckland	6	930,000	3	3	1
Bay of Plenty	7	151,000	3	2[b]	1
Canterbury	9	340,000	2	3[b, c]	1
Hawke's Bay/Gisborne	4	140,000	3	5[c]	1
Manawatu/Wanganui	13	163,000	10	4	1
Northland	4	98,000	4	2[d]	1
Otago	13	162,000	11	6[e]	–
Southland	13	109,000	13	1[b, d]	1
Nelson/Tasman/Marlborough	4	106,000	4	3	–
Taranaki	6	60,000	2	1	1
Waikato	6	237,000	6	5[c]	2
West Coast	20	25,000	8	4[f]	–
Wellington	10	501,000	9	4	1
New Zealand	115	3,022,000	78	43	11

a = sites consistent with the approach advocated in the *Landfill Guidelines* (CAE, 2000); b = regional landfill planned; c = including site with consent but not yet developed; d = including site working through consent process; e = including two private landfills; f = may reduce to 2 sites depending on consolidation of disposal facilities.

It is evident from the results presented in Section 5.2 that landfill operators are working towards improved landfill siting, design and operation. There are a variety of reasons for the changes observed over the last eight years, including:

- landfill operators are making use of the guidance material that has been developed (1992 and 2000 *Landfill Guidelines*, Ministry for the Environment Landfill Management guidelines
- regional authorities are increasingly referring to guidelines and international best practice to establish the best practicable option for minimising the effects of discharges from landfills

9 The proposed Landfill Classification and Waste Acceptance Criteria system will provide guidance on appropriate waste acceptance criteria for each class of landfill.

- the cost of developing and operating small sites in accordance with consent requirements is increasing, so that many operators are seeking to take advantage of the economies of scale to develop larger sites that tend to be well sited, designed and operated.

> **Conclusions**
>
> - The number of landfills consistent with good practice in New Zealand is increasing.
> - The 2000 *Landfill Guidelines* provide clear guidance as to best practice in landfill siting, design and operation.
> - *Most* 'substandard' sites will be closed or upgraded by 2010.
> - The remaining substandard sites are likely to be well operated (operated to achieve the highest level of environmental protection given substandard siting and/or design).
> - There is no clear regulatory or legislative means currently available to require the upgrade or closure of 'substandard' sites. The 2000 *Landfill Guidelines* clearly outline what is best practice in landfill siting, design and operation in New Zealand. The Ministry has advocated the application of these guidelines to existing and proposed landfills through submissions on resource consent applications.

5.5.2 Full-cost charging

Targets for waste disposal: Target 2

> *By December 2005 operators of all landfills, cleanfills and wastewater treatment plants will have calculated user charges based on the full costs of providing and operating the facilities and established a programme to phase these charges in over a timeframe acceptable to the local community.*

Current disposal charges range from none to $100 per tonne, with most new disposal sites at the top of this range. Eighty-nine percent of sites (receiving 98.5% of total waste quantity) are currently charging for the disposal of waste, and most of the remaining site operators are considering phasing in user charges in some form. It is important to note that while all landfills will be charging for disposal within the next 10 years, there is some variation in how the charges are calculated and applied.

Historically, charges have been calculated to cover operational costs but have not necessarily reflected the costs associated with developing a site nor included any provision for after-care costs. The Ministry developed the *Landfill Full Cost Accounting Guide* in 1996 to address this issue, and recently updated the guide (Ministry for the Environment, 2002c) to reflect changes in accounting practice for local authorities.

In general the cost of disposal is likely to increase with decreasing quantities of waste due to the effects of economies of scale. In remote areas this effect may be offset by high transport costs; which is to say, it may be more cost effective to pay a high disposal cost for local disposal rather than the combination of low disposal cost and high transport costs for disposal to a regional landfill.

Conclusions

- All local authority-controlled landfill sites will be charging for waste disposal by 2005.
- There is some variation in the way charges are calculated. Promotion and support of the *Landfill Full Cost Accounting Guide* (Ministry for the Environment, 2002c) will address this issue.

5.5.3 Hazardous waste disposal

Targets for hazardous wastes: Target 2

By December 2004, hazardous wastes will be appropriately treated before disposal at licensed facilities, and current recovery and recycling rates will be established for a list of priority hazardous wastes.

There is significant variation in how hazardous wastes are defined in landfill management plans and resource consent conditions. Module I of the *Hazardous Waste Management Guidelines* (Ministry for the Environment, 2002b) starts to address this issue by providing a national definition for hazardous waste. Module II of the *Guidelines* will address landfill waste acceptance criteria and will be released in late 2002.

Where wastes that require special handling[10] are disposed of at a site, the availability of alternative treatment options is often a significant factor in determining waste acceptance. There are several examples of liquid wastes being disposed of to landfill due to the lack of any other options. This highlights the need for the concurrent development of disposal controls *and* alternative disposal options. There is potential for both central government and local authorities to work with the private sector to ensure that alternative disposal options are available for difficult wastes such as industrial sludges.

There are examples throughout New Zealand of private operators stepping in to provide a waste treatment service where specific wastes have been excluded from landfill disposal. The key lesson to be learnt from these examples is to allow an appropriate timeframe for phasing in disposal bans and/or disposal charges.

Barriers to improving hazardous waste disposal include:

- lack of disposal/treatment options
- cost of pre-treatment
- potential for illegal or inappropriate disposal of waste.

Opportunities include the potential for private industry to step in to provide services if there is a sufficient cost incentive.

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[10] Wastes that require special handling may include treated hazardous wastes, sewage sludges, asbestos, sensitive documents and dusts.

Conclusions

- There needs to be an integrated hazardous waste management framework to allow this target to be met (recognised through the other targets for hazardous wastes).
- The Ministry for the Environment should investigate ways to encourage the provision of treatment options for hazardous wastes throughout New Zealand.

5.5.4 Organics diversion

Targets for organic wastes: Target 2

> *By December 2005, 60 percent of garden wastes will be diverted from landfill and beneficially used, and by December 2010, the diversion of garden wastes from landfill to beneficial use will have exceeded 95 percent.*

There is access to composting and/or garden waste mulching in 44 districts, either by the territorial local authority or by the private sector. Based on the latest census data (2001 Census of Population and Dwellings) these services are estimated to cover 2.9 million people, or 78% of the population. Figures are not available for the percentage of green waste currently being diverted nationally. Garden waste makes up around 19% of the total waste stream (approximately 600,000 tonnes per year).[11]

The Ministry has instituted the SWAP Baseline Programme and the Waste Data programme to help local authorities measure the disposal and diversion of organic wastes.

Targets for organic wastes: Target 4

> *By December 2007, more than 95 percent of sewage sludge currently disposed of to landfill will be composted, beneficially used or appropriately treated to minimise the production of methane and leachate.*

Many sites accept sewage sludge and screenings from local wastewater treatment plants. Examples of diversion are limited, but include the Living Earth Joint Venture in Wellington, sludge drying in New Plymouth, in-vessel composting in Rodney District and Palmerston North City, and sludge digestion in Christchurch.

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11 The composition of waste disposed of to landfill varies significantly around New Zealand. This figure is based on several recent waste composition surveys.

Conclusions

- There is a need to measure the quantity of organic waste disposed of to landfill in New Zealand, and this is being addressed by the Waste Information project at the Ministry for the Environment.
- Many territorial local authorities provide composting facilities at landfills and transfer stations.
- In many cases the quantity of green waste being diverted is not measured.
- There is a significant quantity of sewage sludge disposed of to landfill.

5.6 Discussion

5.6.1 General comments

The issues identified through the risk-screening process and analysis of the survey responses relate to the siting, design and operation of landfills in New Zealand. While there are no statutory standards for landfills, operators, site developers and regional authorities have access to significant resources outlining the appropriate siting, design and operation for landfills. So why are there still substandard landfill sites in New Zealand? As outlined in the preceding sections, there are significant barriers, including:

- a dispersed population in many rural areas
- ongoing use of older landfills
- unavailability of appropriate locations with respect to geology and/or nearby receptors.
- decisions being made with an emphasis on development costs alone rather than integrating both financial and non-financial factors into the decision-making process
- the presumption that measured and/or modelled effects tell the full story about environmental impacts.
- the ‘lag time’ for improving landfill siting and design being up to 35 years (the maximum consent period under the RMA).

5.6.2 Remote locations

There are areas in New Zealand where transport distances and waste quantities mean that developing a small, appropriately sited, designed and operated landfill site may be comparable to transferring waste out of the area to appropriate disposal, in terms of both financial and environmental factors.

It has been possible to gain approval to develop or continue operating small, remote sites overlying unfavourable geology, without engineered containment and/or with inadequate management controls. While the *Landfill Guidelines* allow for taking site-specific factors into account when considering siting and design, the underlying philosophy is that landfills should provide for containment of wastes through both siting and design, rather than relying on one or the other.

Where the only locations available have permeable underlying geology, there is the potential to compensate for this through additional engineered containment and comprehensive management to control the nature of waste disposed of at the site. This is a grey area in the *Landfill Guidelines*, and both landfill operators and regional authorities would benefit from further clarification on this issue.

5.6.3 Integrating financial and non-financial factors

When deciding on the development/extension of a landfill, awarding operations contracts or developing overall solid waste management systems, decisions are often made on a financial basis. While this approach ensures best return for investment and minimal cost, the overall societal costs and environmental externalities are not included in the decision-making process.

5.6.4 The effects-based approach

For activities such as landfilling, there is an element of uncertainty about the actual environmental effects. Monitoring surface water, groundwater and air can give a very accurate indication of the level of contamination in the samples being analysed, but will always be subject to statistical uncertainty related to the sampling locations and times.

Some care therefore needs to be taken when interpreting the results of monitoring, especially if they are seen as giving unequivocal evidence of the presence or absence of contamination. In reality most monitoring programmes use indicator compounds to provide an indication to landfill operators and regional authorities of leachate or landfill gas discharges. Where the presence of leachate is suspected, further monitoring may be undertaken for specific contaminants.

In this context the adoption of an approach that includes several forms of containment is appropriate. For example, rather than assuming that the lack of leachate indicators in surface and groundwater samples indicates that no leachate is being discharged from a given landfill site, the landfill operator should continue to exercise appropriate control over the nature of wastes disposed of at the site to allow for the potential for leachate to discharge from the site and contaminate surface or groundwater.

In another context, the detection of low-level (below the limits set by the resource consent) contamination of groundwater should flag the need to assess the ability of the engineered containment at the site to contain and remove the leachate, rather than being taken to show that natural processes within the landfill and the underlying material are providing adequate mitigation of the discharge. The emphasis should be on reducing the possibility of higher concentrations of the contaminants in the groundwater or the release of contaminants not tested for.

5.6.5 Further investigations

The analysis of trends in landfill siting, design and operation through consideration of the survey results from 1995, 1998/99 and 2002 has enabled the identification of a series of key issues, as outlined in the preceding sections. While informed predictions have been made regarding the number and nature of landfills in 2005 and 2010, further surveys would serve to build the current data set and examine the effects of policy interventions.

While there are certainly sites that are not consistent with best practice in New Zealand currently operating, they are all (or will shortly be) subject to controls through the resource consent process. Sites identified as HIGH risk through the Landfill Rapid Screening System analysis are all working towards closure and/or are adequately managing the issues of concern. On this basis it is not considered necessary to undertake detailed investigations at these sites.

6 Conclusions and Recommendations

6.1 Progress towards good practice

The results of the 1995 and 1998/99 Landfill Censuses and the Landfill Review and Audit indicate that landfill siting, design and operation are improving in New Zealand. Where new sites are being developed or existing sites are extending their resource consents, there is a general intention to comply as much as possible with generally accepted good practice.

Many existing landfill sites are being progressively upgraded through improvements in engineered containment and operational practice. In some cases improvements are limited by inappropriate underlying geology.

6.2 Risk factors

Several factors contribute to an increased 'risk' for a high proportion of operating landfill sites in New Zealand. These are:

- lack of engineered containment (liner, leachate collection, landfill gas management)
- the siting of landfills in areas with high-permeability geology
- inadequate stormwater management.

Landfill operators and regional authorities have access to comprehensive guidance on siting, design, operation and consenting of landfills in New Zealand. Barriers to improving practice in New Zealand include the cost of developing sites in accordance with best practice, the availability of appropriate sites, and the reliance on a single containment strategy rather than multiple levels of containment as advocated in the 2000 *Landfill Guidelines*.

6.3 Recommendations

It is recommended that:

1. the Ministry continue to promote and support the existing guidance for landfill siting, design and operation
2. the Ministry work with the solid waste disposal industry to improve the quality of landfill operations, with a particular focus on operator training and stormwater management
3. the monitoring of landfill siting, design and operation in New Zealand be continued and integrated in the Waste Data Network framework. A follow-up landfill survey should be undertaken in 2005.

Appendix I: Landfill Risk Screening System Methodology

Introduction

The Landfill Review and Audit project aims to quantify the level of environmental risk associated with landfills around New Zealand. The Landfill Risk Screening System (LRSS) methodology outlined below is the first phase of the risk assessment process, and is designed to be a simple, effective, and relevant screening assessment of the comparative environmental risk posed by a given landfill site. A more comprehensive, site-specific risk assessment is required to adequately characterise the environmental risks posed by an individual landfill operation.

The LRSS methodology is based on source, pathway target scoring system used in the Risk Screening System for Contaminated Sites[12] (RSS) developed by Pattle Delamore Partners Limited (PDP) for the Ministry for the Environment / Regional Waste Officers Forum Contaminated Sites programme. The scoring guidance has been modified significantly to account for the differences between an operating landfill and a 'conventional' contaminated site. The direct contact pathway in the PDP system has been replaced by the landfill gas pathway, focusing on the potential for vertical and lateral migration of landfill gas and build-up in confined spaces. There is no consideration of potential 'greenhouse gas' effects, the risks associated with trace constituents of the landfill gas, or odour issues.

In addition, the containment parameter of the RSS has been modified to reflect the role of engineered and natural containment environmental monitoring and site operation in the management of risks associated with gas and leachate. This allows the containment parameter to reflect the contribution of a number of factors. A landfill with good containment (giving a smaller value) would be one that has a good liner, good cover and leachate and gas collection systems, with the performance of these measures regularly monitored. The total score for the containment parameter remains comparable with the Ministry for the Environment RSS scoring.

The risk parameter values are arrived at using information collected as part of the Landfill Census (1998/99) and updated in 2001/02 via a targeted telephone survey. Comments from regional authorities and site visits are considered, and a final risk score is arrived at giving a rank of high, med or low with respect to surface water, groundwater and landfill gas risks for each site. The overall risk ranking for the site is the highest of the individual risk scores.

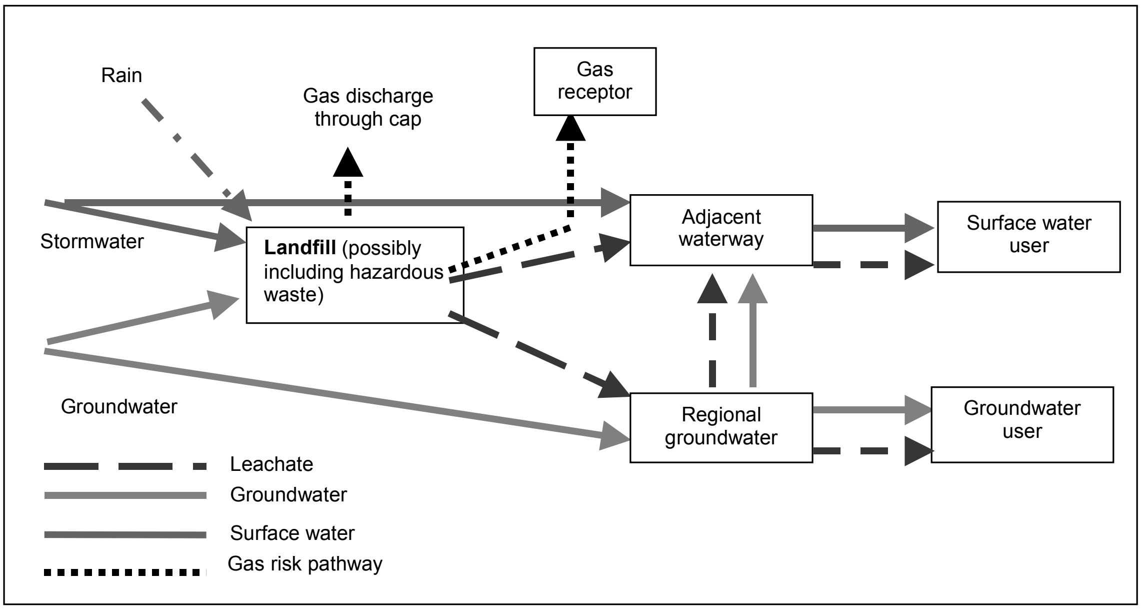
Reporting of the risk ranking for each site includes:

- the overall risk ranking (ie, the highest 'risk' for the site), including the pathway associated with the ranking
- the 'risk' associated with the remaining pathways for the site.

It is important to note that LRSS is a qualitative and comparative risk assessment tool only. The methodology is not intended to – and indeed is not able to – calculate a qualitative risk for an individual site.

12 Pattle Delamore Partners Limited, *Risk Screening System for Contaminated Site*, prepared for the Sustainable Management Fund, 2001 (http://www.mfe.govt.nz/issues/contamguide.htm).

Figure A1: LRSS conceptual model



Surface water, rain and groundwater enter the landfill through the cap and/or ‘liner’ and percolate through the refuse, enhancing the production of leachate and landfill gas. The composition and strength of the leachate is a function of the quantity of water moving through the site, the nature of the refuse, and conditions in the fill (temperature, Dissolved oxygen etc). The composition and strength of landfill gas will depend on the age of the fill, the volume of putrescible waste, the depth of fill and the moisture content.

Leachate discharges from the landfill through the ‘liner’ to groundwater and through the cap (and side liner) to surface water via overland flow and stormwater drains. Groundwater may ultimately discharge to surface water, or vice versa.

Landfill gas is generated within the landfill. This gas may discharge through the cap, or may migrate laterally through the subsurface and collect in low-lying areas or confined spaces.

The LRSS does not attempt to address issues such as odour, litter, or amenity values. Comments from regional authorities and site visits are considered for the final ranking for each site.

Input parameters

General comments

The risk for each scenario (surface water, groundwater, landfill gas) is dependant on the hazard associated with the leachate or landfill gas, potential exposure pathways, and the sensitivity of the receptors. The assessment ranking is based on the principle that the risk of harm will be dependant on these factors (ie, if any category has a zero characteristic, then the risk is zero), and that the multiplication (rather than summation) of each category score is appropriate.

Additional parameters have been introduced to better reflect issues relevant to landfill design, siting and operation. In order to maintain consistency with the scoring system from the contaminated sites RSS, the score for the exposure category is calculated by averaging the additional parameters with the product of the contaminated sites RSS parameters, as outlined below. This avoids assigning an undue weighting to the pathway category in determining the risk score for each scenario.

Where there are potential flaws or deficiencies in a site (eg, active faulting, potential 'short circuits' for groundwater flow, sited in an estuary or wetland), provision is made to introduce an adjustment factor to examine the potential score for the worst case scenario (such as an earthquake).

The risk score for each pathway (surface water, groundwater and landfill gas) is calculated as follows. The underlying calculations are presented in the following sections.

Risk score	**=**	**Hazard x Exposure x Receptor**

Hazard assessment

Hazard	**=**	**Toxicity x Quantity x Mobility**

Toxicity *– the potential toxicity of leachate/landfill gas produced at the site*

Consider the use of waste acceptance criteria at the site (site management plan, comments from regional authorities, site visit observations and consent conditions), the exclusion of hazardous and liquid wastes, hazardous waste definition, and the site operational procedures. When considering the potential toxicity of the contaminant (landfill gas or leachate), consideration needs to be given not only to documented site procedures, but also to reported and observed compliance with the documented procedures (ie, compliance reports from regional authorities, site staffing and security, etc).

Quantity *– likely volumes of leachate/gas produced*

Consider the quantity of refuse disposed of at the site, the likely maximum leachate volume, and the gas volume (related to the depth of fill, moisture content and nature of refuse disposed at the site). For the purposes of the LRSS, volumes of gas and leachate will be estimated on the basis of refuse volume and refuse depth, respectively; this parameter considers potential maximum volumes of leachate/gas produced within the landfill, while the containment and pathway assessments account for any subsequent containment or attenuation.

Mobility *– inherent mobility of the contaminant (leachate or gas)*

Assume high mobility of leachate and landfill gas. Issues relating to surrounding geology and designed containment are addressed in the exposure and containment assessment.

Exposure assessment

$$\textbf{Exposure} = \frac{\textbf{(Pathway + Containment)}}{\textbf{2}}$$

The exposure assessment considers containment of the leachate or landfill gas within the landfill, and potential migration pathways should the leachate/gas be discharged from within the landfill.

Containment assessment

Containment = Average of containment parameters

Surface water containment *– any systems or natural features that will prevent leachate from entering surface water*

Consider:

- stormwater diversion, monitoring and treatment
- surface water monitoring
- leachate treatment
- compaction
- working cover
- potential for leachate breakout and flow to surface water (intermediate cover and capping).

A site with a low score (good containment) would be expected to have a comprehensive stormwater management system (diversion, ensuring that water ingress is minimal, that water that comes into contact with refuse is treated as leachate and stormwater is monitored) and good site management (with respect to intermediate and final cover, and compaction and monitoring of the final cap).

Groundwater containment *– any systems or natural features that will prevent leachate from entering groundwater*

Consider:

- potential significant deficiencies in the site (fractured rock, gravels, active faults, instability)
- leachate collection
- monitoring (management)
- liner design (measured in thickness of earth liner material with permeability of 10^{-9} m/s, or equivalent geomembrane or composite)
- leachate management (recirculation, volumes, maximum leachate head, etc).
- depth to groundwater.

A site with a low score (good containment) would be expected to have a comprehensive leachate management system (including collection and monitoring), a well-designed liner, and be appropriately sited (no siting deficiencies that could compromise the integrity of the liner system).

Landfill gas containment *– any systems or natural features that will prevent leachate from entering surface water*

Consider:

- gas collection
- monitoring and management systems
- capping design
- landfill operational procedures (compaction, intermediate cover, etc.)
- liner (including side liner)
- surrounding and underlying geology.

A site with a low score (good containment) would be expected to have a comprehensive landfill gas management system (monitoring and, where appropriate, collection/treatment systems), good final cover design (low permeability), and a good lateral liner system.

Pathway assessment

SW pathway = Topography x Distance
or Flood risk

Topography *– topography from the point of potential leachate breakout to the closest surface water body*

Distance *– distance from surface water body*

Flood risk *– maximum flood risk within the landfill footprint or proposed footprint. The potential for surface waters to erode part of a landfill (eg, on a river bank or in a gully) should also be considered.*

GW pathway = Permeability x Rainfall x Distance

Permeability *– any low-permeability/confining layer (not including any engineered landfill liner) between the base of the landfill and the aquifer associated with the receptor/abstraction point. Include consideration of any potential preferential pathways (karst geology, etc).*

Annual rainfall *– maximum likely rainfall for the site.*

Distance *– distance from groundwater abstraction point (including discharge to surface water body.)*

Gas pathway	**=**	**Surface cover x Distance or Adjacent soil permeability**

Surface cover *– capping of the site in relation to containment of gas within the landfill footprint*

Distance *– distance from potential collection point for landfill gas*

Adjacent soil permeability *– permeability of soil surrounding the site (ability to limit lateral subsurface migration of landfill gas)*

Receptor assessment

Resource use *– the use of the surface/groundwater or the landuse/potential collection points for landfill gas. Other significant receptors could include ecologically sensitive areas.*

Scoring guideline

Refer to LRA Assessment Sheet.

Risk score

High	> 0.5
Med	0.3–0.5
Low	< 0.3

Hazard		**Scoring guidance**
Toxicity – nature of the refuse disposed of at the site	0.4 0.8 1	Controlled cleanfill only Municipal solid waste (fencing/controlled access, staffed during site opening times, random load inspections) Uncontrolled disposal of any waste types, or site accepts hazardous waste (limited or no waste acceptance criteria)
Quantity – leachate	0.8 0.9 1	Estimated refuse volume < 5,000 t/yr Estimated refuse volume 5,000 – 50,000 t/yr Estimated refuse volume > 50,000 t/yr
Quantity – gas	0.5 1	If refuse depth is < 5 m Refuse > 10 m
Mobility	1	Default value
Pathway		
Treatment – leachate	0.6 1	Treatment of leachate (removal to wastewater treatment plant, on-site treatment) No (or basic) treatment of leachate
Management – surface water (stormwater diversion, treatment and monitoring)	0.6 1	Active management including diversion and monitoring No stormwater management
Site operation (working cover, compaction)	0.8 1	Good working cover, adequate compaction (07–1.0 tonne/m^3) No or sparse working cover, inadequate compaction

Hazard		Scoring guidance
Breakout (leachate breakout to surface water)	0.7	No potential for breakout
	1	Uncontrolled seepage from base of landfill *or* potential for flood waters to erode landfill materials
Monitoring – groundwater	0.6	Active monitoring of leachate in liner
	1	No monitoring of liner
Constructed liner – base	0.6	Liner thickness at least 0.9 m of material with permeability of 10^{-9}m/s, or equivalent (such as geomembrane or composite)
	1	Liner less than 0.5 m of material with permeability of 10^{-9}m/s, or equivalent; breach of liner likely during landfill life
Leachate collection	0.7	Leachate collection system throughout the landfill
	1	No leachate collection system
Depth to groundwater	0.7	> 15 m below the base of refuse
	1	< 1 m below the base of the refuse
Landfill gas collection	0.5	Good collection/treatment system (incl. good impermeable cover)
	1	No or minimal collection
Monitoring – landfill gas	0.8	Monitoring of landfill gas carried out
	1	No landfill gas monitoring
Constructed liner – lateral	0.6	Liner (CAE specs) extends up the side of refuse
	1	No lateral liner, or liner below good standards
Topography (flow from breakout to surface water)	0.5	Flat ground (< 5^{o} slope)
	0.6	Moderate slope
	1	Steep slope (> 30^{o})
Distance – surface water	0.4	> 500 m to surface water body
	0.8	200 m to surface water body
	1	< 100 m to surface water body
Flood risk in landfill footprint	0.6	> 1 in 100 yr
	1	< 1 in 100 yr
Underlying low-permeability material	0.4	> 15 m of low-permeability (10^{-7} m/s or less) material overlying aquifer of interest
	0.7	5 m of low-permeability material overlying aquifer of interest
	1	Underlying material moderate or high permeability (> 10^{-7} m/s) overlying aquifer of interest
Average annual rainfall	0.8	< 400 mm average annual rainfall
	0.9	700 mm average annual rainfall
	1	> 1000 mm average annual rainfall
Distance – groundwater	0.6	> 300 m to nearest groundwater user (or discharge to surface water)
	0.8	100 m to nearest groundwater user
	1	< 50 m to nearest groundwater user
Cover – final (capping material, permeability)	0.3	Low permeability capping system (CAE – 600 mm 10^{-9})
	0.8	Non CAE cap
	1	No designed capping system
Distance – landfill gas	0.5	> 500 m to potential point of risk (explosive or asphyxiation)
	0.8	200–300 m from potential point of risk
	1	< 100 m from point of risk

Hazard		Scoring guidance
Adjacent low-permeability material	0.3 0.8 1	Low-permeability soils (clay, etc.) Medium-permeability soils (silt, silty sand) High-permeability strata (gravels, sand)
Receptor Receptor – surface water	0.2 0.7 1	Not used Irrigation, stock water, ecologically significant waterway Contact recreation, potable/domestic water, aquaculture
Receptor – groundwater	0.2 0.7 0.8 1	Not used Irrigation, stock water Groundwater discharge to significant (ecological, contact recreation, potable) waterway Potable/domestic water
Receptor – landfill gas	0.5 0.7 1	Recreational open space, agricultural Commercial industrial Residential, schools, etc.
Results		
SW Hazard		Tox x Quantity (leachate) x Mobility
SW Pathway – containment		Average (leachate treatment, stormwater management, site operation, potential for breakout)
SW Pathway – other		Topography x Distance to surface water Flood risk
SW Fatal Flaw Adjustment		eg, instability (leading to potential breakout), active faults, sited in estuary/wetland
SW Receptor		
SW Score		= SW Hazard x SW Pathway – containment x MAX (SW Pathway – Other, SW Fatal Flaw Adjustment) x SW Receptor
GW Hazard		Tox x Quantity (leachate) x Mobility
GW Pathway – containment		Average (site operation, groundwater monitoring, base liner, leachate collection, depth to groundwater)
GW Pathway – other		= Distance to GW user x Perm of underlying material x Rainfall
GW Fatal Flaw Adjustment		eg, active faults, karst geology, high permeability material (ie, potential for 'short circuit' of groundwater flow)
GW Receptor		
GW Score		= GW Hazard x GW Pathway – containment x MAX (GW Pathway – Other, GW Fatal Flaw Adjustment) x GW Receptor
Gas Hazard		Tox x Quantity (landfill gas) x Mobility
Gas Pathway – containment		Average (site operation, base liner, gas collection, gas monitoring, lateral liner, underlying low permeability material)
Gas Pathway – other		Distance to point of risk x permeability of adjacent material Landfill cap
Gas Receptor		
Gas Score		= Gas Hazard x Gas Pathway – containment x MAX (Gas Pathway – Other) x Gas Receptor
Overall Score		

Appendix II: Landfill Review and Audit Project Methodology

Project methodology

1 Review and update data from the 1998 Landfill Census. An electronic survey form was developed (MS Excel), filled in as much as possible using data from the 1998 Landfill Census, and sent to all landfill operators and regulatory agencies. Responses were clarified by telephone conversations where necessary.

2 Each operating site was visited and assessed, with the results recorded on a standard site assessment form. Any outstanding issues from the electronic survey form were also clarified during the site visit.

3 The LRSS was used to determine the comparative risk posed by each site. Information provided by the landfill operators, regional authorities and the site visit programme was used in determining the appropriate scores for each parameter in the LRSS.

4 Comments regarding the operation of the site were provided to each landfill operator and to regional authorities.

5 Analysis of the overall results of the LRSS, survey and site visit programme was compiled and included in this report.

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The Ministry for the Environment works with others to identify New Zealand's environmental problems and get action on solutions. Our focus is on the effects people's everyday activities have on the environment, so our work programmes cover both the natural world and the places where people live and work.

We advise the Government on New Zealand's environmental laws, policies, standards and guidelines, monitor how they are working in practice, and take any action needed to improve them. Through reporting on the state of our environment, we help raise community awareness and provide the information needed by decision makers. We also play our part in international action on global environmental issues.

On behalf of the Minister for the Environment, who has duties under various laws, we report on local government performance on environmental matters and on the work of the Environmental Risk Management Authority and the Energy Efficiency and Conservation Authority.

Besides the Environment Act 1986 under which it was set up, the Ministry is responsible for administering the Soil Conservation and Rivers Control Act 1941, the Resource Management Act 1991, the Ozone Layer Protection Act 1996, and the Hazardous Substances and New Organisms Act 1996.

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