SKM ENVIROS

Environmental Protection Agency

EVALUATION OF ENVIRONMENTAL LIABILITIES AT KERDIFFSTOWN LANDFILL

- Final Report
- 20 October 2010

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SKM Enviros
Enviros House
Shrewsbury Business Park
Sitka Drive
Shrewsbury
Shropshire SY2 6LG
Tel: +44 (0)1743 284 800
Fax: +44 (0) 1743 245 558
Web: www.skmenviros.com

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Prepared under the Management of:	**Gary Grantham, Project Manager**
Reviewed and Approved By:	**Peter Young Project Director**
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1. Introduction, Objectives Scope and Method

The Environmental Protection Agency (EPA) has commissioned SKM Enviros to conduct an evaluation of potential environmental liabilities and related remedial costs associated with various closure scenarios of the existing landfill at Kerdiffstown, operated by Neiphin Trading Limited (herein after referred to as Neiphin). The need for this commission has arisen from continuing alleged breaches in licence conditions by the site operator, and associated nuisance complaints. The project objectives are to:

1) Assess technical environmental issues and then quantify financial environmental liabilities associated with both site operation and closure;
2) Suggest and comment upon possible financial mechanisms to act as financial guarantees;
3) Prepare sworn Statements of Evidence regarding costs to address financial liabilities.

The following specific tasks were identified;

- Estimate the volume of material currently deposited on site through review of aerial photographs, contour plots and other information;
- Assess the potential for deposited materials to degrade and produce leachate and landfill gas;
- Identify and comment upon receptors in the vicinity of the site which would be sensitive to potential leachate and landfill gas migration;
- Estimate a water balance for the site in order to enable leachate generation to be estimated;
- Estimate the potential impacts which migrating leachate may have on identified receptors;
- Assess options to mitigate potential impacts of leachate migration;
- Provide options and costs for management of future leachate produced at the site under various planned and unplanned closure scenarios;
- Estimate potential for future landfill gas production and provide details of future options for adequate gas migration control measures;
- Outline materials balance information for site restoration to ensure safety and stability and provide capping and restoration, including costs ranges associated with different scenarios (e.g. re-profiling and capping existing wastes, excavation and deposition in new containment cells on site (with any surplus taken off-site), or removal off-site;
- Provide cost estimates for at least two remediation scenarios based on risk assessment for potential migration risk mitigation.

The methodology adopted comprised the following activities;

- Orientation visit to site on 1st March 2010 for Peter Young and Gary Grantham of SKM Enviros, accompanied by Donal Howley (site inspector) and Kevin Motherway of the EPA, and follow up visit by Peter Young on 27th September 2010;
- Visit to EPA offices to view and select relevant information from the evidence EPA had compiled for Court proceedings;
- Obtaining additional information from published sources;
- Evaluation of geophysical investigation of site perimeter commissioned by EPA from APEX Geosciences, and report on surface emissions of gas conducted by Odour Monitoring Ireland.
- Limited site investigation in areas adjacent to the north-western and eastern boundaries of the site. The purpose of the investigation was to establish off-site ground conditions and test for evidence of landfill gas and leachate migration.

Sources of information used in this report are discussed further in Chapter 4.

Information has been assessed against the following;

- Use of guidance in EPA published document "Guidance on Environmental Liability Risk Assessment, Residuals Management Plans and Financial Provision", EPA 2006 as a basis to establish environmental risks associated with operation and requirements for closure and aftercare of the site. This guidance should be followed for all landfill and licensed waste sites in Ireland.
- Use of SKM Enviros experience in assessing environmental risks, closure and aftercare requirements for landfills and waste sites, including that obtained during a recent project conducted for the EPA, "Review of Environmental Liability Risk assessment(ELRA), Closure, Restoration, Aftercare Management Plans (CRAMP) and Financial Provisions(FP), draft report released to the EPA in April 2010.

Subsequent to our commission, the site operator, Neiphin Trading Limited, and their parent company Dean Waste have filed for bankruptcy. Neiphin Trading abandoned the site in June 2010.

2. Chronology of Site Development

The history of development of the site has been assessed from available information (see Chapter 3 for data sources). SKM Enviros has accepted this information as being a true and accurate representation of conditions at the site.

2.1. Site Setting

The site is located approximately 3.5km northeast of Naas and approximately 0.5km north west of the N7 road and Johnstown village. The site is bordered to the north east by parkland associated with Kerdiffstown House, to the north by a golf course, to the west and south by mixed land use comprising residential, agriculture and worked-out quarries. The PI 175A County Road from Sallins to Johnstown runs adjacent to the western and southern boundaries, other than where residential properties are present between the site and the road. The nearest residence is approximately 10m from the boundary. A plan showing details of the site and surroundings in 2010 is presented in Figure 1.

2.2. History of Development

A. Pre-Neiphin occupying the site

Prior to landfilling, the site was worked for sand and gravel. Few details are available concerning the nature of the quarrying operation. It is understood that sand and gravel had been extracted at the Kerdiffstown site over the past 50 to 60 years. We understand that quarrying operations generally did not extend into the water table, and ceased at a level around 83m above Ordnance Datum (mAOD). However, we cannot rule out that operations in some locations did penetrate to the water table. The aerial photograph of 1995 suggests water in the base of some pits, although whether this is perched water or in continuity with groundwater cannot be ascertained.

We understand that voids created were partially backfilled by different operators over the order of 40 years or so. We understand that records of backfilling during the period up to the 1990s do not exist. The nature of backfill cannot be confirmed, although information we have reviewed indicates that backfill was with predominantly inert materials (re. E&RM "Risk assessment report," Sept 2003).

The E&RM report states that excavation of deposited wastes was conducted by Neiphin from autumn 1999 to early 2000, as part of the Environmental impact Statement (EIS) required by the EPA. We understand that approximately 150,000 m^3 of previously placed wastes were excavated and subjected to screening on site using mobile plant. Based on visual observations, it was estimated that the wastes were predominantly stone, brick, broken concrete and subsoil. The screening trial produced three categories of materials as described in Table 2.1:

Table 2.1 Categorisation of excavated and sorted materials, 2000

Category	Description
FINES	Mainly inert topsoil/subsoil (<20mm size)
MEDIUM	Particle sizes 20 to 100mm, including some “litter”, glass, wood, hard plastic and metal
COARSE	Particle sizes greater than 100mm, containing steel, large pieces of concrete, wood and light plastic

We understand that the quantities of each category of material were not measured, but that based on visual assessments the operators determined that “a very large percentage of the materials comprised the inert fines and medium graded material”. The report compares the composition of wastes with typical construction and demolition (C&D) wastes in Ireland and other European countries and concludes that the material deposited is representative of C&D wastes.

The E&RM report estimates that at August 2000 a volume of 900,000m^3 of wastes were present in the area of the site which was not being operated by Neiphin, implying that this volume approximates to the amount of wastes deposited prior to Neiphin occupying the site.

An aerial photograph dated 23 June 1995 shows the sand quarry with a number of tracks across its base. The north-western zone of the floor of the quarry contains hummocks and depressions. We understand that at this time this area of the site was used for motocross or bike racing. The far north-western segment appears to be vegetated ground .Voids are also present in the south-eastern zone, although the majority of this area seems to be generally flat.

It is not apparent from the aerial photograph where waste materials may have been deposited. There is no evidence of waste stockpiles or on-going waste emplacement. The aerial photograph does show trucks in the quarry, although it cannot be ascertained whether vehicles are removing minerals or bringing in materials for infilling, or parked in the quarry. There is no obvious in indication of quarrying or landfilling plant (such as excavators, dozers, conveyors).

We understand that ownership of the quarry was split among a number of parties, and a number of parties were responsible for waste deposition. We understand that the bulk of the site is owned by Cement Roadstone Holdings, and the site is on a long term lease to Jenzsoph.

B. Occupation by Neiphin Trading Limited (Neiphin)

We understand that Neiphin first occupied the site and commenced receiving wastes during 1995, although it is not clear whether or not other operators were continuing waste disposal activities during this time. Neiphin commenced deposition of C&D wastes in 1996. From 2000, almost all of

the C&D wastes brought to the site originated from the Dean Waste Company's licensed facilities at Sheriff Street Upper (licence reference WL 42-1) and Greenhills Road (licence reference WL45-1).

The site holds planning permission reference 97/871 from Kildare County Council for restoration of the quarry to a maximum height of 108mAOD, which is likely to have been based on pre-excavation natural contours. However, a waste licence had not been issued by the EPA until 2003, as described below.

In May 1998 Neiphin applied to the EPA for a waste licence to restore the sand and gravel pit to its "original ground surface levels" using C&D wastes. The applicant subsequently updated their application in September 2000 to include for the development of a waste recovery facility and a lined landfill. The applicant submitted further modifications to their application in a submission dated October 2001, which was submitted in response to an Article 16 (Waste Management Licensing Regulations) Notice served by the EPA. The original application was for a facility of 16 hectares, whereas the updated application includes for approximately 28 hectares.

An Environmental Impact Statement (EIS) was prepared to accompany the licence application. An original EIS was prepared by K T Cullen and Company Limited in 1997 Chapter 4 of the EIS has been reviewed by SKM Enviros

On July 16th 2003 the EPA issued waste Licence Register Number W0047-01 to Neiphin. The licence is for an Integrated Waste Management Facility including a landfill for non-hazardous wastes. The licence provides for the following:

- Excavation and processing/recovery of waste previously illegally deposited at the facility (up to 330,000t/annum);
- Acceptance of commercial and industrial waste for processing/recovery, up to 100,000 tonnes per annum;
- Acceptance of C&D wastes for processing/recovery, up to 200,000 tonnes per annum;
- Provision for up to 183,000t/annum of residual material arising from waste recovery to be deposited in purpose built lined landfill cells (for non-hazardous and inert wastes).

Historically deposited wastes in Zone 2 comprised mixed C&D wastes and previously processed C&D wastes.

In July 2004 Neiphin submitted an application to the EPA for a review of the waste licence to take account of the following;

- Minor amendment to the boundary of the facility to regularise new ownership, limit facilitating removal of historically placed waste in the area, and extending the zone of lined engineered landfill cells;
- Regularisation of the final approved contours for the completed landfill between the planning permission limit (108mAOD) and Condition 4.2 of waste licence W0047-01, which specifies 100mAOD. The applicant requested a consistent limit of 108mAOD to be applied;
- Inclusion of composting in authorised processes (in-vessel with bio-filters) including disposal of residues;
- Addition of household recyclables to approved waste streams.

The review would also provide an opportunity to redraft certain elements of the existing licence with a view to accurately reflecting the development of the site since grant of the first licence and to assist in the regulation of the activity. There was no request to alter the total amount of waste permitted to be processed under waste licence W0047-01 of 630,000t/annum.

Following a period of waste deposit and processing, the EPA issued a revised waste licence W0047-02to replace the existing licence W0047-01. Licence W0047-02allows up to 630,000 tonnes per annum of waste to be processed at the site, provided that adequate processing capacity is available. Waste types permitted are C&D, household dry recyclables, commercial/industrial waste, compostable waste and waste which was previously landfilled at the site. The licence requires a lined landfill to be constructed in the void created by extracting previously deposited waste for processing. Only pre-treated residual waste and inert waste is permitted to be landfilled. The licensed area of the facility is approximately 30.6 hectares.

Over the time of operation of the site, Neiphin has progressively installed a range of waste processing facilities. By 2010, these comprised:

- Stone and concrete crushing and screening plants;
- Wood chipper;
- Hand picking processing lines (two number, but only one was operational during the SKM Enviros site visit);
- Composting plant, fully enclosed;
- Automated materials recovery plant, including metals separation and wet separation of fines;
- Substantial water and slurry settlement tanks of above ground concrete construction.

The operation of the facility has given rise to numerous complaints from local residents and land-owners, relating predominantly to odours and also to noise. A number of improvement and enforcement notices have been issued to the operator, but nuisance complaints have continued

Table 2.2 Summary of Site Chronology

Date	Activity
1950s to 1990s	Excavation of above water table sand and gravel by various operators. Details not known. Different parts of the site are owned by different entities. Details not known.
1950s to 1990s	Partial backfill of voids with materials unknown, by various operators. No records available.
1995	Neiphin occupy the site, and commence rationalisation of ownership. Area of site is 28.3ha.
1996	Neiphin commence receiving and treating wastes and depositing materials on site.
1997	Planning Permission reference 97/871 issued by Kildare County council to restore the quarry workings to landform of maximum height 108m AOD.
1997	Original EIS prepared on behalf of Neiphin by Kevin Cullen and Company Limited.
2000	Original EIS revised and submitted.
16th July 2003	Licence W0047-01 issued to Neiphin for an integrated waste management facility, including a landfill for non-hazardous wastes.
July 2004	Neiphin submit application for revision of licence W0047-01, to reflect changes in operation, site boundary ownership and to rationalise restoration levels permitted by the planning permission and the waste licence.
11 February 2010	Licence W0047-02amendment issued to Neiphin.

2.3. SKM Enviros View on Site Conditions at Time of Site Walk-Over, 1st March 2010

Peter Young and Gary Grantham of SKM Enviros attended site on 1st March 2010 accompanied by Kevin Motherway and Donal Howley of EPA. The purpose of the site visit was to provide an orientation visit to allow SKM Enviros personnel to view the site and current operations. Photographs were taken during the site visit. Our key observations and views are as follows;

A North-western zone

- No materials were being placed in this area, following a "Stop" order issued by the EPA. Existing material had been formed into a series of terraces, with steep slopes towards the eastern boundary and parts of the northern and extreme western boundaries;
- Material at surface comprised of processed wastes, including a high proportion of finely chipped wood, plastic and fines (presumed to be derived from on-site waste processing activities);
- A screening bund of fine, silty, material had been constructed along the south western boundary of the northern half of the site. SKM Enviros assumed that the bulk of this material compromised residue from the composting operation;
- Along the western boundary of the north of the site, boulders and rubble were deposited;
- Areas of the material were highly odourous, with odours dominated by sulphides and mercaptans (indicative of landfill gas generation);
- Water vapour was emanating from some points in the material along the north-western boundary, and strong odours were associated with these emissions;
- The operator had buried perforated pipes under the materials to act as gas collection zones, with the pipes terminating in piles of woodchip to act as odour attenuation. During the site visit, odours were noted to be emanating from the wood piles.
- The far north-western zone had not been subject to placement of waste/materials for storage. The original quarry face was exposed in this location, revealing uneven bands of sand and gravel interspersed with silty and clayey material.
- The far north-eastern boundary of the existing quarry was also exposed, and signs of material slippage were observed during the visit (stones were rolling down the slope of the quarry face).

B South-Eastern Zone

- The south-eastern zone is used for waste and materials storage; waste processing; composting; offices; vehicle parking. The area also contains a steep embankment of waste materials along its northern boundary, with a litter fence along part of the boundary. This area of the site also contains two lined waste cells and associated leachate collection infrastructure, including a below ground concrete leachate holding tank. The cells had received waste, which had been

covered with plastic sheeting to reduce rainwater infiltration. No wastes were being deposited during our visit. The following activities were taking place during our visit;

- Hand picking of wastes;
- Wood chipping with sheeted vehicle collection of the wood chips;
- Loose baling of wastes and storage inside a building;
- Processing of wastes, including wet separation of fines.

The following observations were made;

- The waste cells appear to be constructed to an appropriate standard to act as containment cells;
- There was no evidence of leachate or landfill gas within the cells;
- The leachate storage tank was dry;
- The composting operation is enclosed and no odours could be detected arising from it;
- The waste processing is a sophisticated operation with automated mechanical separation of metals and stones and settling of fines into above ground concrete settlement tanks;
- The hand-picking exercise is rudimentary and not efficient, and seemed to focus on recovery of higher value materials such as metals;
- Some wastes/materials were present on areas of soft-standing, with no containment of water draining through them;
- Most of the site area was used or occupied, and there were limited redundant areas of the site;
- Large piles of plastic contaminated with other materials were placed behind buildings in the central west of the site;
- In building processing and stacking of wastes was taking place with limited ventilation;
- A large amount of mobile plant was standing idle.

2.4. Visit on Monday 27th September 2010

Peter Young conducted a further unaccompanied cursory visit to the site on 27th September. The following were observed;

- A ditch and large concrete blocks were present across the entrance of the site, making vehicular access on to the site difficult;
- No people or activities were noted although and there was audio evidence of activity within the composting building;
- Mobile plant, equipment and portacabins were no longer present on the site;
- The composting building was intact
- Baled waste was still present within buildings;

- Material sorting lines were still present within buildings;
- The perimeter litter fence was still present;
- The two lined cells in the south-eastern area of the site contained leachate which was over-topping the cell wall and flowing across the surface of the site and infiltrating into the ground;
- There was a noticeable and persistent odour associated with this leachate;
- A leaking water supply pipe was running freely and draining to the site near the weighbridge;
- The area of wastes within the north-west portion of the site appeared to be similar state to that observed during the March 2010 walk-over.

3. Key Data Sources

Data has been procured from existing sources provided to us by the EPA and published information. The following sources of information were used in this report;

Table 3.1 Key sources of information

Information Source	Information use
Waste licences WO047-01 and WO047-02.	Legal framework and compliance criteria. General information about the site.
Chapter 4 of Environmental Impact Statement	Environmental setting and sensitivity. Information on geology, hydrogeology and hydrology.
Reports prepared by Environment and Resource Management Limited (ERML) in support of licence applications	History of site development; proposed environmental controls; volume and nature of wastes deposited/stored on site.
EPA responses connected with licence applications	History of site; environmental setting and sensitivities; volumes and nature of wastes deposited/stored on site.
Quarterly and Annual environmental monitoring reports	Potential off-site impacts of site operations.
Various correspondence from EPA	Potential off-site impacts and nuisance complaints. Technical evaluation of operator's objections to proposed licence amendments. Quantities and nature of wastes deposited/stored on site.
Aerial surveys of site and surroundings	Changes in volume of material deposited/stored at the site over time, and site infrastructure.
Report by WRC	Volume of material at the site. Waste composition. Potential for generation of landfill gas and leachate. Compositional data for GASSIM model.
Survey by APEX GEOSCIENCES	Geo-physical survey to provide information on off-site geology and ground conditions, and identifying zones of potential leachate

Information Source	Information use
	migration.
2010 site investigation	Nature of ground conditions off-site. Groundwater occurrence. Soil gas and groundwater quality off-site.
2010 site walkover by SKM Enviros	Overview of site conditions and level of environmental controls. Identification of receptors and potential migration pathways for landfill gas and leachate.
2010 surface emissions survey conducted by Odour Monitoring, Ireland	Measurement of volatiles emitting through surface of the site

A full list of references is presented in Appendix 1.

Preliminary assessment of the data indicated there was uncertainty in measurement of potential off-site impacts of gas and leachate. During the course of site operation, some off-site monitoring boreholes had become lost, unavailable or unreliable in terms of the information being obtained. Both the EPA and SKM Enviros considered it necessary to obtain up to date reliable data to evaluate the level of off-site impacts arising from migration of leachate and landfill gas (if any).Therefore further investigative work was procured by the EPA.

3.1. Geophysical Investigation

EPA commissioned a geophysical survey by APEX Geosciences. The survey was conducted on land adjacent to the perimeter of the site, where access could be obtained. No investigation was conducted within the site. The survey comprised electrical conductivity (EM-31),electrical resistivity (2-D)of the sub-surface, a seismic survey and use of ground Penetrating Radar (GPR) to eliminate interference from below ground services. These are established, non-intrusive geophysical techniques which enable soil profiles to be mapped according to their geological make up. Different soils and rock typeswill behave in different ways to electric currents and shock waves. Therefore it is possible to differentiate different soil horizons (for example clays can be differentiated from gravels, and hard rock from superficial deposits). The resistivity survey would also detect differences in conductivity which could be attributable to differences in groundwater quality. Therefore it is a useful technique to give vertical sections of geology and pore fluid and to inform a more targeted intrusive borehole investigation.

Findings from the survey are summarised in Appendix 2. The survey shows ground around the site of different resistivity, and suggests presence of underground services along the road by the north-

western boundary. An area of relatively high conductivity is present in a localised zone close to the north eastern boundary of the site particularly between the churchyard and Kerdiffstown House. APEX Geosciences interprets this as a higher permeability layer of ground (possibly gravels) with associated potential presence of leachate.

The findings from the geo-physical survey were used to assist in design of the intrusive borehole investigation.

3.2 Borehole Investigation

A focussed site investigation was conducted on 10th and 11th of May 2010. SKM Enviros assisted the EPA in specification of borehole construction, completion and visited locations before drilling commenced. The investigation was procured and managed by the EPA. 2 boreholes were constructed along the road which is present along the north-west boundary of the site. 8 boreholes were drilled in land to the east of the site in ownership of Kerdiffstown House . Each borehole was completed to facilitate monitoring of soil gas and sampling of groundwater (in boreholes where groundwater was encountered). For Health and Safety reasons related to its location on a pathway used by elderly persons EMW01 was backfilled immediately after drilling and was not completed as a monitoring well.

3.2.1 Ground Conditions

Borehole logs are presented in Appendix 3. Ground conditions encountered are summarised in the discussion of impacts on sensitive receptors presented in the following Chapter 4

3.2.2 Monitoring

Following completion, boreholes containing groundwater were purged and groundwater samples obtained on 14th May 2010. Samples were submitted to the EPA laboratory in Cork for analysis of major ions and parameters indicative of leachate presence. Follow up monitoring was conducted by the EPA on 22 July 2010, with sample analysis being conducted by EPA laboratory in Dublin.

Analytical results are presented in Appendix 3. Results are discussed in the following Chapter 4.

Odour Monitoring Ireland conducted a survey of emissions of volatile gases (methane and trace organics) from the surface of the site on 14th June 2010. The objective was to measure the concentrations of volatile gases emitting to atmosphere, and to update an earlier study conducted in 2009. Results are presented in Appendix 4.

4 Receptors, Impacts and Remediation Options

As a starting point to assess risks associated with the infilled areas, SKM Enviros used the existing EPA methodology to prepare an ELRA and CRAMP evaluation of the site in its current status (April 2010). This basic ELRA risk assessment is presented in Appendix 5. The concepts used in the basic ELRA are refined in this section using more detailed information obtained from our study.

4.2 Basis of Risk Assessment

The basic risk assessment concept involves identifying potential sources of contamination, potential receptors and potential pathways which link contamination from the source to the receptor. Each component of the risk assessment is now discussed in detail.

4.2.1 A Source Term of Contamination

Contaminants associated with the landfill at the Neiphin site arise as follows;

Landfill Gas

Landfill gas is generated from breakdown of degradable fractions of wastes. Under typical landfill conditions, wastes degrade anaerobically, producing a mixture of methane, carbon dioxide and trace components (which can number two to three hundred different compounds). In some situations, wastes may degrade in the presence of oxygen. Aerobic degradation produces carbon dioxide and trace components. Aerobic break-down usually occurs for a short period immediately following waste emplacement and for a longer period when the wastes are near the end of their degradation potential, and air is able to diffuse into wastes. Aerobic degradation may also occur at sites with active gas extraction, where over-extraction results in significant air ingress to the waste body.

Landfill gas constitutes a hazard as follows;

Methane is flammable within the range of concentrations 5% to 15% in air. Ignition of a gas mixture within the flammable range in a confined space can result in an explosion. Methane concentrations in air greater than 15% still represent a hazard, since the gas mixture will at some point become diluted within the flammable range. Mixtures of methane in air below 5% by volume cannot ignite. Methane has a Global Warming Potential (GWP) estimated to be approximately 22 to 26 times higher than carbon dioxide. Therefore conversion of methane to carbon dioxide will reduce GWP of emitted gas.

Carbon Dioxide is an odourless, asphyxiant gas. Industrial occupational health levels for carbon dioxide are set at 0.5% for 8 hour exposure and 1.5% for 10 minute exposure for workers.

Trace Components are variable across landfills, depending on the nature of waste materials deposited and the age of waste degradation. Trace components give rise to odours, and some have carcinogenic properties. During the SKM Enviros site visit in February 2010, odours were noted at several points on the site. Based on experience of the SKM Enviros staff of visits to many landfills, odours were tentatively identified a arising from sulphides and mercaptans, which are typical constituents of trace gases in landfill gas.

Odour thresholds for many trace components above are low, and a large dilution with air (for some compounds of the order of a million times) is required to render the gases odourless (although odour detection is subject to the sensitivity of individuals).

Some trace components have GWPs orders of magnitudes higher than methane and carbon dioxide.

Gas generation

The future volume of landfill gas which the site is likely to generate depends on the composition of materials deposited. The time for which gas will be produced depends on the rate of gas generation. Generation rate is influenced by a number of factors, key of which are the nature of the waste, the physical size on waste components, temperature within the waste body and moisture content of the waste.

Table 4.1 Factors influencing landfill gas production

Influencing factor	Effect of gas production
Nature of wastes	Degradable materials can be categorised by their relative contents of cellulose, hemi-cellulose and lignin (woody component). Materials with relatively high proportions of cellulose to lignin (such as food) degrade more rapidly than materials with a higher proportion of lignin (such as cloth) .
Physical Form of Wastes	Notwithstanding the above,, small particles of material will generally degrade faster than larger particles of the same material, since smaller particles have a much higher surface area to volume ratio, allowing microbes to be more effective in the degradation process. Therefore shredded paper will degrade faster than whole newspaper, and finely chipped wood will degrade faster than large chunks of wood (which may take thousands of years to achieve complete degradation).
Temperature	The effectiveness of the micro-organisms facilitating breakdown of waste increases with temperature, with maximum effectiveness occurring at approximately 65^{0}C. Above this temperature, the rate of breakdown falls rapidly. If the temperature is too high (approaching 75^{0}C) microbes will die. During the site investigation by WRC and site walk-over of SKM Enviros, water vapour was observed to be rising from points in the site, implying higher temperatures are present within the materials compared with ambient temperature.
Moisture content	Increasing moisture content increases the rate of degradation, with maximum rate achieved when wastes are approaching 100% moisture content, provided they remain free draining. Moisture content of waste samples was measured by WRC. Results ranged from 3.8% to 20% w/w dry residue.

4.2.2 Prediction of Future Gas Production at Kerdiffstown

In order to estimate the volume of gas which a site is likely to produce, the Environment Agency in England and Wales has developed a model, GasSim, which is also adopted by the EPA.

4.2.3 GasSim

The principal drivers behind the development of the HELGA model and subsequently GasSim were the concerns of the potential health effects of living near and working on landfills, and the need to substantiate these, as well as the need for a management tool to help meet international agreements to reduce the emissions of greenhouse gases to the environment. GasSim uses the modelling principals that were developed under the HELGA framework collating them in a MS Windows driven software package.

GasSim has been designed to:

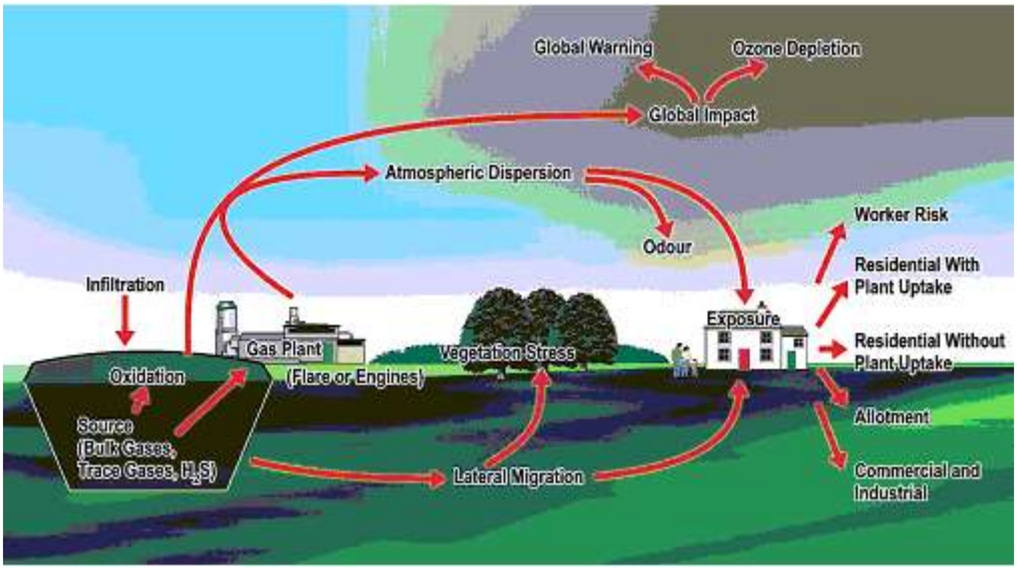
- Assess the risks from current and planned landfill gas emissions;
- Provide a framework that will contribute to the assessment and validation of the inventory of burdens associated with the landfilling of wastes;
- Help regulators and other relevant organisations compare the relative risks associated with different landfill gas management techniques.

GasSim consists of the following modules to aid in risk assessment:

- source term;
- emissions model;
- environmental transport; and
- exposure/impact.

GasSim is a probabilistic model based on Monte Carlo Simulation using probability distribution functions for the majority of model inputs. However, as the data supplied for landfill gas yield calculation for Kerdiffstown was simplistic only single probability distribution functions were used for model inputs and hence only a single (50^{th} percentile) result is expressed.

The interaction of the different modules of GasSim is expressed in the conceptual model for a particular landfill:



The GasSim model is recommended by the UK EA and subsequently by the Irish EPA and its method of calculation and output has been verified by UK based research conducted on UK landfills.

The GasSim source term module has been utilised for calculation of landfill gas yield from the landfill sites associated with the assets. In order to run the source term module for bulk landfill gas estimation only simple model inputs are required as discussed below.

GasSim Source Term

The GasSim source term module determines the generation of landfill gas for an individual landfill site based on the mass of waste deposited and the waste composition of the waste stream or streams. The model calculates the gas generation from the wastes based on a multi-phase first order decay model further details of which can be obtained from the user manual. The calculation adopts the following equation:

$$C_t=C_o-(C_{0,1}e^{(-k_1t)}+C_{o,2}e^{(-k_2t)}+C_{0,3}e^{(-k_3t)})$$

and $C_x=C_t - C_{t-1}$

where;

C_t = mass of degradable carbon degraded up to time t (Mg)

C_0 = mass of degradable carbon at time t = (Mg)

$C_{o,I}$ = mass of degradable carbon at time t = 0 in each fraction (1, 2, 3 rapidly, moderately and slowly degradable fractions respectively) (Mg)

C_x = mass of carbon degraded in year t (Mg)

t = time between waste emplacement and LFG generation (yrs)

k_i = degradation rate constant for each fraction of degradable carbon (per yr)

Waste input data is entered in tonnes input per year filled at a landfill. The types of wastes filled can then be chosen from default waste types such as domestic or industrial that has composition analyses based on HELGA (Gregory et al., 1999). If the composition of the waste is know then user defined waste types can be generated based on its constituent parts such as paper, card, inerts etc. The waste type can also be entered based on site specific data using its fraction of cellulose, hemi-cellulose, water content and an estimation of its decomposition potential to allow the model to calculate available carbon for degradation.

Utilising the waste data and other model inputs such as waste moisture content the model is able to calculate the gas generation from a landfill in m^3/ hr of landfill gas.

The composition of wastes at Neiphin is not typical of a “standard” landfill, and therefore assumptions were made on composition and proportion of materials on site. The report by WRC provides actual analysis of waste compositions from 12 locations across the north-western area of the site. We have used results from the waste analysis combined with our observations whilst on site to produce source term composition of wastes for input to GasSim as follows:

- *Minimum Degradable Composition*;

Non –degradables; 71%;

Fines 26%;

“Other” paper (i.e. not newspapers); 3%

Everything else (e.g. textiles, plastics, etc) less than 1%.

- *Maximum Degradable Composition; Scenario* 1

Non-degradable 7%

“Other” paper 40%;

Textiles 6%

Fines 47%;

Everything else less than 1%.

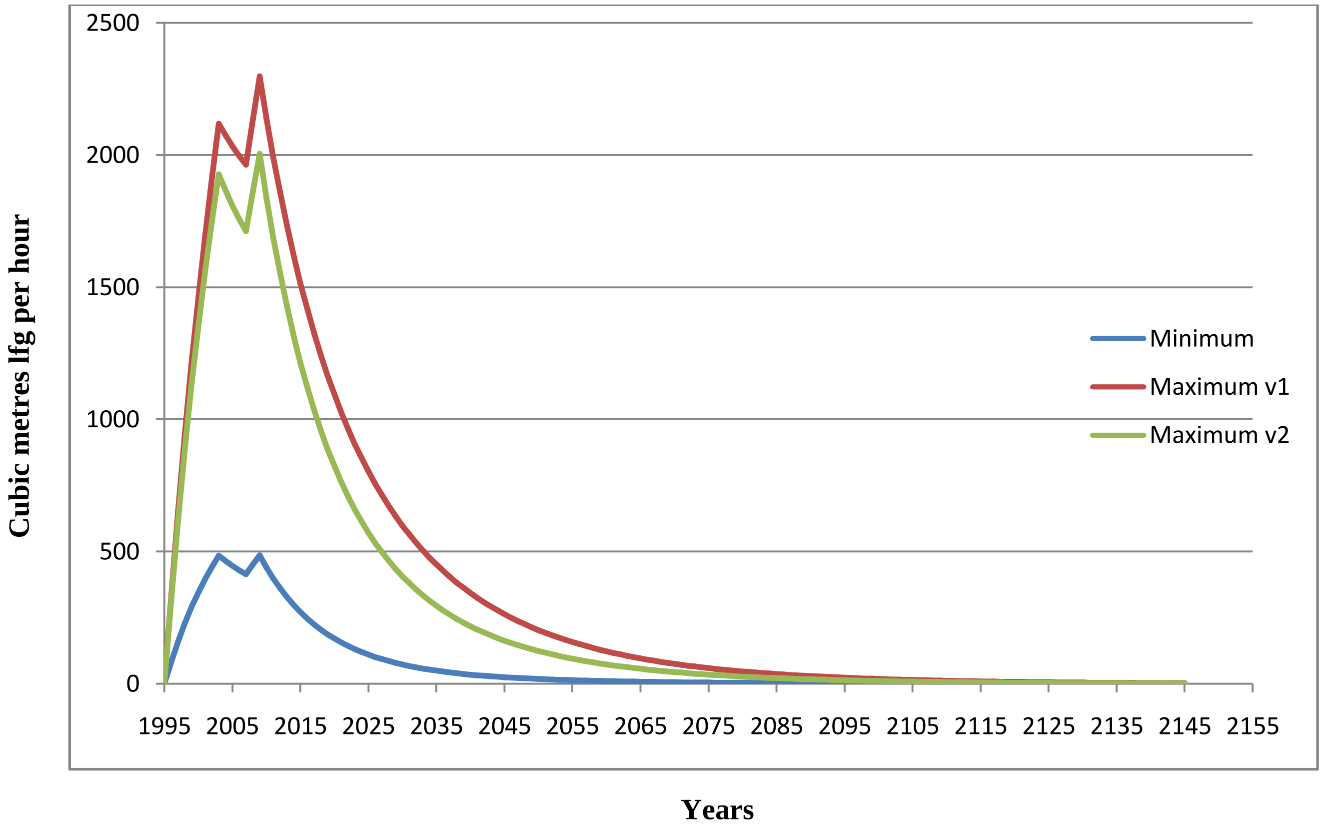
Maximum Degradable Composition, Scenario 2;
Fines 76%;

“other “paper 24%

Everything else less than 1%.

Results are presented in Appendix 6 and summarised below.

Allowing for uncertainties which exist in waste composition at Kerdiffstown, GasSim models show that even for conservative estimates, landfill gas will continue to be produced for many years in quantities that will require active management. The maximum rate of gas generation of the order of 2000 cubic metres per hour is indicated as occurring in the next few years.



As part of their licence application, ERML on behalf of the operator conducted GasSim models for wastes anticipated to be deposited at the site as follows, although details of the models and assumptions are not presented.;

- *Model 1*, 9% bio-degradable component: Peak rate of gas production 265m3lfg/hr (equating to 120m3 CH4/hr);
- *Model 2;* 20% bio-degradable; peak rate of gas production 590m3lfg/hr, (equates to 290m3CH4/hr).

Although a direct comparison between the ERML and SKM Enviros models cannot be made, all models indicate active generation of landfill gas at the site, and results imply that gas control will be required.. We consider that SKM Enviros figures are more likely to represent actual gas yields, since models are based on use of actual waste compositions at the site as analysed by WRC.

A rule of thumb for gas utilisation (electricity generation) is that 1000 m3/hr of landfill gas equates to 1MW of electricity generation. Although gas predictions will need to be refined when the actual remediation and restoration scheme for the site is agreed, this preliminary assessment indicates that gas utilisation may be viable at Kerdiffstown, provided a gas extraction system is installed within the next 1 to 2 years.

4.2.4 Leachate

Leachate is generated when water (usually rainwater) percolates into the wastes and dissolves components of degradation. Leachate is typically characterised by occurrence of ammoniacal nitrogen, organic material (usually dominated by organic acids) chloride and varying concentrations of metals. The composition, and hence strength of leachate, varies with the state of degradation of the wastes within the site. Leachate from recently emplaced wastes typically has a higher chemical and bio-chemical oxygen demand (COD and BOD) than that from older wastes, where methanogenesis has become established, where much of the organic material is converted to landfill gas rather than leachate. The composition of leachate generated at a particular site will be influenced by the following factors:

Table 4 2 Factors influencing leachate production

Factor influencing leachate production and composition	Observed effect
Nature of the wastes	As for gas production, leachate production will be influenced by the capability of wastes to degrade. Wastes with a high component of bio-degradable matter (such as food wastes) will tend to produce stronger leachate than wastes

Factor influencing leachate production and composition	Observed effect
	containing a higher proportion of inert waste. However, there is potential for contaminants adsorbed on inert materials to leach out (e.g. from contaminated soils). Wastes with relatively small particle size will produce leachate at higher strength than coarse material where water ingress comes into less intimate contact with the degrading wastes.
Rainwater infiltration to wastes. **Groundwater ingress**	The volume of leachate produced will depend on the volume of water entering the waste body. Uncapped sites (such as the current situation at Kerdiffstown) will be subject to substantially higher infiltration than sites which have a temporary or permanent low permeability cap. Groundwater flowing into unlined sites will also contribute to leachate production (although there is no indication that waste at Kerdiffstown are subject to groundwater inflow). Sites with high water ingress will tend to produce larger volumes of lower strength leachate than sites which have restricted water ingress. Also, unlined sites will experience leachate diluted but increased in volume by underlying groundwater flow. It is likely that the older wastes at Kerdiffstown will have reached field capacity and be generating leachate, whilst absorptive capacity has yet to be achieved for more recently deposited materials. WRC waste analysis results show moisture content ranges from 3% to 20% w/w dry residue for near surface (and hence assumed recently deposited) materials.
Stage of waste degradation	The stage of waste decomposition will influence the proportion of organic material which forms

Factor influencing leachate production and composition	Observed effect
	landfill gas, and the proportion which forms leachate. Where methanogenesis is established, much of the organic material is converted to gas rather than leachate. However, other components of degradation such as ammoniacal nitrogen, and soluble metals and salts remain in leachate.
Rate of Waste Degradation	The same factors of moisture content and temperature apply as presented for landfill gas production.

The materials currently in place at Kerdiffstown have never been capped, and therefore there has been no inhibition of rainwater entering the wastes. Rainwater entering deposited materials will at first be absorbed by the waste mass until the absorptive capacity has been reached, after which infiltrating water will form leachate. The actual absorptive capacity will vary with the composition, surface area and moisture content of the waste materials at the time of deposition. For example, plastics have a low absorptive capacity, whereas shredded paper can be highly absorbent. The actual process of leachate production can be complicated by short circuiting of rainwater through channels in the waste body, or localised lenses of low permeability material preventing water infiltrating downwards to underlying wastes.

The situation at Kerdiffstown is complicated by the fact that materials have been deposited, excavated, subject to processing and residuals re-deposited, so conducting a detailed water balance is difficult. Recent groundwater analysis (see later sections of this Chapter) demonstrate leachate contamination, confirming a portion of wastes within the site are at field capacity and generating leachate.

It is logical to assume that the older wastes have reached field capacity and are already contributing to leachate production. The rate at which more recently deposited materials reach field capacity depends on the rate and of deposition.

For a broad estimate, the following assumptions have been made for Kerdiffstown:

- “Recent” wastes 10m thick deposited uniformly across an area of 10ha;
- Average absorptive capacity of wastes is 20% (maximum value recorded by WRC)
- Average annual effective rainfall at the site 500mm.

The annual infiltration is 50,000m3, which implies wastes will be at absorptive capacity after 4 years.

If the wastes were capped, reducing infiltration to a nominal 50mm per year, wastes would take 40 years to achieve field capacity.

The visit to the site in September 2010 revealed that the wastes in the two containment cells are now likely to be at field capacity, and dilute leachate is now over-topping the cell wall and infiltrating into the ground. Given the approaching autumn and winter season where rainfall is typically high, we consider leachate will continue to be generated, migrate overland from the cells and continue to infiltrate into ground unless preventative measures are implemented.

However, the build up of leachate does indicate that the existing cell liner is effective in providing containment.

Impact of Leachate

Leachate has potential to cause the following impacts;

Table 4 3 Potential environmental impacts of leachate

Receptor	Potential Impact
Groundwater	Derogation of groundwater quality. Increase in salinity, nitrogen content (ammoniacal nitrogen, nitrate and nitrite), organic content (total organic compounds (TOC) and specific organics depending on the wastes and chemical oxygen demand (COD). Reduction in dissolved oxygen content. Rendering of groundwater unfit for drinking or irrigation. For industrial supplies, quality may become unsuitable for process use.
Surface Water	Derogation in quality. Reduction in dissolved oxygen, increase in ammonia and salts, and trace organic compounds can impact aquatic life, for example increased ammonia will cause fish mortality. Water may not be suitable for abstraction for irrigation, drinking and process applications.
Aquatic ecology	Impacted as a consequence of quality derogation. Reduction in bio-diversity, change to more pollution tolerant species.

Humans	Standing leachate is potentially odourous, which can result in odour nuisance.

4.2.5 Sensitive Receptors Identified at Kerdiffstown and Potential Migration Pathways

The following receptors and potential contaminant migration pathways are identified at Kerdiffstown landfill:

- Groundwater and surface water, particularly the Morell River are identified as receptors which potentially could be impacted by leachate.
- Buildings, underground services, site workers, nearby residents and utility workers are identified as receptors which could potentially be impacted by landfill gas.

Each is discussed below.

Groundwater

Groundwater is present in the superficial sand and gravel bands at the base of the quarry, and within the limestone bedrock (the Ballysteen Formation). The Ballysteen Formation is categorised by the Geological Survey of Ireland as a poor aquifer, which is generally unproductive except for local zones. We are not aware of any current groundwater abstractions in the vicinity. Groundwater was sampled during the 2010 investigation.

Protection of groundwater is enacted through the Groundwater Regulations, 2010.
The Regulations have been developed for the purposes of responding further to the requirements of the Water Framework Directive (2000/60/EC) and the Groundwater Directive (2006/118/EC). They establish a new strengthened regime for the protection of groundwater in line with the requirements of the Water Framework Directive (2000/60/EC) and by the Groundwater Directive (20006/118/EC). This will be achieved by establishing clear Environmental Objectives, Groundwater Quality Standards and Threshold Values for the classification of groundwater and the protection against pollution and deterioration The regulations also introduce the legal basis for a more flexible, proportionate and risk based approach to implementing the legal obligation to prevent or limit inputs of pollutants into groundwater which already exists under the old Groundwater Directive (80/69/EE).

The groundwater is considered to be at risk from leachate impact, since;

- The vast majority of the landfill is not lined, so there is no engineered barrier to prevent leachate migration from the site;

- The underlying unsaturated zone is thin and therefore there is limited potential for natural attenuation of components in leachate which does migrate from the site before it enters underlying groundwater;
- The landfill is not capped, so rainwater infiltration to waste will continue, leading to further leachate production.

Surface water

The Morell River is present north-east of the site and flows in a north-westerly direction. The Morell River is approximately 40m from the site boundary (50m from wastes) at its closest point.

Results from the 2010 site investigation show that groundwater is present in superficial deposits along the north-eastern boundary, with a component of flow towards the river. Therefore the Morell River is considered to be at risk from leachate contamination, since shallow groundwater, known to be contaminated by leachate, flows towards the river and is considered to contribute to base flow of the river. There is also the possibility that leachate could break out when wastes become fully saturated along the steep infill embankment forming the eastern boundary of the site and flow over land directly into the river.

As far as we are aware routine monitoring of surface water quality has not detected any impact from the landfill which can be ascribed to leachate contamination of the surface water. However, the river is fast flowing with substantial dilution capacity, and impact of a diffuse source of contamination on quality will not be easy to detect. Therefore there is potential that long term low level impact of contaminated groundwater on surface water may result in subtle changes in local quality which could disrupt local ecology in the river. Any impacts can only be assessed through a period of long-term biological monitoring.

Buildings

The risk to buildings from landfill gas ingress is associated with the flammability and potential explosion risk of methane.

There are a number of buildings and structures (enclosed spaces) on site and houses and outbuildings close to the north-western, western and southern boundaries of the site which could be vulnerable to landfill gas entry. Gas present in soils can enter buildings through cracks or holes in the floor slab, or via services which enter buildings below ground if no protection measures have been incorporated into building design.

The nearest off-site house is located approximately 10m from the site boundary. Another ten or so buildings plus outbuildings are present within 50m of the site boundary.

There are a number of buildings on site. During the SKM Enviros site visit, we observed one building located near to the underground leachate holding tank to be constructed directly on the ground, without any obvious evidence of gas protection measures (such as venting grilles and gas proof membranes). The building was thought to contain electrical transformers/switchgear and related equipment. Assessment of building construction and potential gas protection measures was not conducted during the site visit, since this was not a focus for the visit.

Residents and occupiers of off-site properties, site workers

The risks to people within buildings from landfill gas is associated with flammability and potential explosion risk of methane, and asphyxiation arising from accumulation of carbon dioxide and/or reductions in oxygen. Odours can make houses uninhabitable before gas concentrations reach dangerous levels.

Underground services

Underground services on-site (if present) and off-site are potentially at risk from landfill gas entry and accumulation, unless the services have been designed to prevent gas ingress. The risk to underground services from landfill gas ingress is associated with the flammability and potential explosion risk of methane.

In addition, services can act as pathways for gas to migrate into buildings via service entries.

Utility workers

The risks to utility workers from landfill gas are associated with flammability and potential explosion risk of methane, and asphyxiation arising from accumulation of carbon dioxide and/or reductions in oxygen. It is likely that practices for working below ground will take account of potential risks arising from accumulation of potentially asphyxiant and explosive atmospheres before work commences, although this may not be recognised by individuals working on their own premises.

Vegetation

Landfill gas which migrates into soils will tend to displace oxygen from the root zone, and in extreme cases can lead to anaerobic conditions in the soil. This can result in vegetation stress or die off.

4.3 Findings from the 2010 Site Investigation

Ground conditions encountered in the boreholes are summarised as follows, together with our view on potential for ground to transmit landfill gas and groundwater/leachate.

Table 4.4 2010 site investigation; summary of ground conditions

Borehole	Ground Conditions	Comments on Potential Influence on Gas and Leachate Migration
EMW01	Clay to 7.30 metres.	Low permeability, will inhibit gas and groundwater/leachate movement.
EMW02	Clay to 4.00 metres, sand from 4.00 to 5.50 metres, clay to end of borehole at 6.00 metres.	Confined sand layer will allow gas migration and groundwater/leachate movement.
EMW03	Sand and gravel to 4.00metres, clay to 14.00 metres, gravel from 14.00 to 16.50 metres, clay from 16.50metres to end of borehole at 17.50 metres.	Sand and gravel layers will allow migration of gas and groundwater/leachate. Gas migrating through the upper layer has ability to dissipate to atmosphere, and migrating leachate will be further diluted by rainwater infiltration. The lower sand layer is confined, so there is greater potential for horizontal movement of gas, and reduced potential for leachate dilution with rainwater.
EMW04	Sand and gravel to 3.40metres, clay to base of borehole at 7.00 metres.	Sand and gravel layers will allow migration of gas and groundwater/leachate. Gas migrating through the upper layer has ability to dissipate to atmosphere, and migrating leachate will be further diluted by rainwater infiltration.
EMW05	Clay to 2.00 metres, sand and gravel from 2.00 metres to 3.50metres, clay from 3.50 metres to base of borehole at 6.00 metres.	The sand and gravel layer will allow movement of gas and groundwater/leachate. The sand layer is confined, so there is greater potential for horizontal movement of gas, and reduced potential for leachate dilution with rainwater.
EMW06	Sand and gravel to 5.90 metres, clay from 5.90 metres to base of	Sand and gravel layers will allow migration of gas and

Borehole	Ground Conditions	Comments on Potential Influence on Gas and Leachate Migration
	borehole at 7.30 metres.	groundwater/leachate. Gas migrating through the upper layer has ability to dissipate to atmosphere, and migrating leachate will be further diluted by rainwater infiltration.
EMW07	Clay to 3.00 metres, sand and gravel from 3.00 to base of borehole at 6.00 metres.	The sand and gravel layer will allow movement of gas and groundwater/leachate. The sand layer is confined, so there is greater potential for horizontal movement of gas, and reduced potential for leachate dilution with rainwater.
EMW08	Sand to 1.00 metres, clay from 1.00 to 2.00 metres, sand and gravel from 2.00 metres to base of borehole at 5.00 metres.	Sand and gravel layers will allow migration of gas and groundwater/leachate. Gas migrating through the upper layer has ability to dissipate to atmosphere, and migrating leachate will be further diluted by rainwater infiltration. The lower sand layer is confined, so there is greater potential for horizontal movement of gas, and reduced potential for leachate dilution with rainwater.
EMW09	Sand and gravel to 19 metres. Boulders or weathered bedrock from 19.00 metres to base of borehole at 20.50 metres.	A large thickness of sand and gravel will allow migration of landfill gas through a wide cross-sectional area. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers. Groundwater/leachate will move through the sand and gravel , although the borehole as drilled was dry at 20.50 metres depth.
EMW10	Gravel to 2.30 metres, sand and	A large thickness of sand and gravel will

Borehole	Ground Conditions	Comments on Potential Influence on Gas and Leachate Migration
	gravel from 2.30 metres to base of borehole at 20.50 metres.	allow migration of landfill gas. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers, although the top clay layer will impede dissipation to atmosphere and encourage further lateral migration of gas. Groundwater/leachate will move through the sand and gravel, although the borehole as drilled was dry at 20.50 metres depth.

4.3.1 Groundwater impact

Groundwater, monitoring results are presented in Appendix 3. Ammoniacal nitrogen, chloride, Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) together are considered good indicators of the presence of leachate. Although other potential sources may contribute (for example, carbon and COD from animal wastes, chloride from road salt and ammoniacal nitrogen from fertiliser), considered together the parameters indicate leachate contamination.

Leachate is proven to be migrating from the along the north-eastern boundary of the site in groundwater flowing under the site. Two rounds of monitoring have been conducted, with preliminary results showing concentrations of indicator contaminants as follows;

Table 4 5 Groundwater quality 2010; leachate indicator species

Borehole	Contaminant	Concentration (mg/l) 14 May 2010	Concentration (mg/l) 22 July 2010
EW02	Ammoniacal nitrogen	0.429	2.34
	Chloride	30.2	38.2
	COD	18	10
	BOD	2.3	2
EW03	Ammoniacal Nitrogen	80.1	110.9
	Chloride	178	231.3

Borehole	Contaminant	Concentration (mg/l) 14 May 2010	Concentration (mg/l) 22 July 2010
	COD	167	340
	BOD	11.0	6
EW04	Ammoniacal Nitrogen	19.9	21.85
	Chloride	65.5	113
	COD	48	80
	BOD	3.0	19
EW05	Ammoniacal nitrogen	0.073	0.3
	Chloride	15.0	41.5
	COD	<10	<10
	BOD	1.4	2
EW06	Ammoniacal Nitrogen	0.061	Not sampled
	Chloride	271	Not sampled
	COD	<10	Not sampled
	BOD	4.2	Not sampled
EW07	Ammoniacal Nitrogen	1.82	3.43
	Chloride	125	64.5
	COD	35	22
	BOD	1.4	<2
EW08	Ammoniacal Nitrogen	0.146	0.17
	Chloride	5.7	7.3
	COD	<10	<10
	BOD	1.1	<2

Results indicate a general increase in contaminant concentrations from 14 May to 22 July sample results. Current impact appears to be restricted to boreholes close to the landfill boundary, with the highest concentration of ammoniacal nitrogen of 80 mg/l occurring in groundwater sampled from

borehole EM03, with substantially lower concentrations present in boreholes close to the River Morell.

The results suggest that the leachate contamination is relatively recent and is continuing.

Groundwater spot levels are shown in Figure 1.Groundwater flow appears to be influenced by the variable geology, although the inferred groundwater gradient has a component towards the River Morell, and further monitoring of groundwater levels is needed to accurately define groundwater gradient.

Although no measurements of hydraulic conductivity (k)have yet been conducted on site materials, published values for hydraulic conductivity (see Freeze and Cherry, 1979)) range from 10-1 ms-1 for gravel to 10-7ms-1 for silty sand. Applying these ranges of k to the Kerdiffstown site together with estimated groundwater gradients towards the River Morrell gives a range of estimated travel times derived using Darcy's Law (v=ki) as follows in Table 4.6:

Table 4.6 Estimated groundwater velocities

Borehole	G/W mAOD	Borehole	G/W (mAOD)	Estimated Distance between BHs (m)	Estimated gradient, i	Assumed hydraulic conductivity, k (m/sec)	Velocity v, m/sec (m/day)
EW04	80.47	EW05	78.43	60	0.033	0.1	0.0033 (285)
EW04	80.47	EW05	78.43	60	0.033	0.0000001	0.0000000033 (0.00029)
EW03	78.51	EW05	78.43	80	0.001	0.1	0.0001 (8.64)
EW03	78.51	EW05	78.43	80	0.001	0.0000001	0.0000000001 (0.0000086)

The assumptions in the calculations give rise to a large variation in calculated travel time of groundwater from the site to the Morell River. Travel time through the high permeability gravels is in the order of days to weeks, whereas travel through the lower permeability silty sands is of the order of tens to hundreds of years.

The rate and volume of groundwater flow through gravels will be substantially higher than through silts, and there is much less opportunity for natural attenuation of leachate species to occur in gravels given rapid travel time and lack of suitable substrate for adsorption and cation exchange of leachate species. However dilution of leachate will be larger in groundwater transmitted through gravels.

Further monitoring of groundwater levels and quality and testing of aquifer materials is necessary before a more accurate and refined estimation of long-term leachate impact can be derived, although current results confirm that groundwater is impacted by leachate.

4.3.2 Landfill Gas

Migration of Landfill gas

There are three main processes which cause gases to migrate;

- Differences in gas pressure;
- Differences in gas concentration;
- By dissolving in water or leachate which subsequently migrates from the landfill, with the dissolved gas coming out of solution.

Of these three mechanisms, ***pressure differential*** is usually the dominant mechanism. Within a landfill, continuing degradation of wastes replenishes landfill gas, which results in a positive gas pressure inside the site. Gas will move from zones of high pressure (e.g. within the wastes) to zones of lower pressure (e.g. soil surrounding the site or the atmosphere) until the pressure differential is equalised. Thus within an actively degrading landfill, there is a continuous production of landfill gas and potential for gas migration out of the wastes.

Currently there is no capping on the site, so gas has ability to vent to atmosphere. Following capping, the potential for horizontal gas migration will increase substantively if no gas control measures are installed at the site

A second mechanism of pressure induced migration is created by changes in atmospheric pressure. Low pressure and falling atmospheric pressure encourages migration of gas, whereas high atmospheric pressure has the opposite tendency.

Gas will also migrate by ***diffusion*** between areas of different gas concentration. For a landfill site, this means there is potential for high concentrations of methane and carbon dioxide to move from the wastes to atmosphere and surrounding soils, and for oxygen and nitrogen in the air and surrounding soils to migrate into the landfill. This mechanism for gas migration becomes significant where there is no pressure difference.

Both carbon dioxide and methane are soluble, with carbon dioxide being approximately 90 times more soluble than methane. Landfill gas can ***dissolve*** in leachate in the site, and as leachate migrates away the gases can come out of solution.

Other factors can affect the ability of gas to migrate. Wind blowing across a site or venting standpipe will lower the pressure and encourage gas migration to atmosphere. Heavy rain or ice may seal the surface of a landfill, inhibiting dissipation of gas to air and encouraging lateral movement. Rising leachate or groundwater in a landfill will create a piston effect, forcing gas to move from saturated areas on the site (this is unlikely to occur at Kerdiffstown since most of the site is not lined and leachate is unlikely to accumulate within the site).

During migration, reactions can occur which change the composition of landfill gas. Methane can be subject to microbial oxidation. This reaction causes methane and oxygen to be consumed and generates carbon dioxide and water vapour. Carbon dioxide can be removed from soil gas by dissolving in water contained in the soil. The result of these mechanisms occurring is that the composition of gas which has migrated from a landfill site can be substantially different from the composition of gas within wastes.

The geology surrounding much of the site is composed of a mix of sand, gravels, silts and clays. Recently constructed boreholes adjacent to the north-western boundary of the site prove sand and gravel beds are present between infilled areas of the site and adjacent properties. Given lack of practical gas control measures at the site, there is risk of uncontrolled migration of landfill gas off site and towards the properties and underground services in the road and to land within the ownership of Kerdiffstown House.

Monitoring Results

Monitoring was conducted using a portable gas meter. The following results were obtained.

Table 4 7 Gas monitoring results from boreholes installed in 2010

Location	Methane %		Carbon Dioxide %		Oxygen %	
	08/06/10	09 /09/10	08/06/10	09/09/10	08/06/10	09/09/10
EMWO2	Nd	Nd	**4.0**	**3.1**	17.8	17.1
EMWO3	**2.8**	Nd	**17.7**	**12.6**	3.8	7.8
EMWO4	Nd	Nd	3.**0**	**2.6**	17.5	17.7
EMW05	Nd	Nd	0.1	0.8	19.2	18.9
EMW06	Nd	Nd	**3.0**	**2.6**	17.4	17.4
EMW07	Nd	Nd	1.4	1.1	18.6	19.2
EMW08	Nd	Nd	0.4	Nd	19.4	19.9
EMW09	Nd	Nd	0.6	**4.2**	18.2	14.5
EMW10	Nd	Nd	**5.3**	**4.0**	15.3	16.1

R*esults in* ***bold*** *indicate exceedences of waste licence trigger levels of 1% methane and1.5% carbon dioxide. Nd= not detected at time of sampling)*

Comment on Results and Current off-site Risk Associated with Landfill Gas

The initial monitoring results show evidence of elevated methane at EMW03, and carbon dioxide at locations EMW02,03, 04 06 and 10. EMW 03 and 06 are adjacent to the north-eastern boundary and EMW10 adjacent to the north-western boundary. Other than EMW03, results do not show evidence of significant landfill gas, and even at this location the methane level is marginally below the lower flammable limit.

Oxygen results indicate presence of air, and other than EMW03 show air continues to be able to diffuse into the soil around the boreholes. Under conditions of substantive gas movement, air is displaced from soils by migrating gas, and sustained and severe oxygen depletion is usually an early indication of sustained and substantive gas migration. These conditions were not encountered around Kerdiffstown in this monitoring visit.

Atmospheric pressure was 989mbar during the July visit, and 999 mbar during September visit, which are relatively low pressures.(the mean Irish atmospheric pressure is around 1013 mbars)

Although migration pathways for landfill gas are present, we consider the current situation represents a low risk to identified receptors, including buildings and occupants at Kerdiffstown house and houses close to the north-western boundary of the site, and off-site vegetation.

A period of gas monitoring is necessary to establish trends of gas occurrence beyond the site boundary, particularly in response to changing atmospheric and weather conditions. Provided the site remains free venting and materials are not disturbed and surface venting is not impeded, we consider no further action is required, other than to review monitoring data regularly.

Prior to any significant changes on site (such as moving materials, demolition or capping areas) a revised risk assessment should be conducted. Gas migration controls will be needed as part of the site capping and restoration

Risk of off-site migration will increase substantially if the site is capped, and no gas migration controls are in place.

4.4 Summary of Proven and Potential Impacts

Actual and potential environmental impacts arising from the activities at Kerdiffstown are summarised as follows:

Table 4 8 Proven environmental impacts, 2010

Contaminant Source	Receptor	Impact likelihood and Severity
Leachate	Groundwater	The established impact would render the groundwater unfit for potable or agricultural use without treatment There is potential for more widespread contamination of groundwater, given that contamination levels have generally increased between the May and July monitoring visits.
Groundwater contaminated with leachate	Morell River	Groundwater exiting along the eastern boundary of the landfill flows towards the river. Although no specific impact has been detected on surface water quality, groundwater quality has deteriorated over a three month monitoring period.
Leachate seepage from embankment	Morell River	Up to September 2010 there was no evidence of leachate break-out along the embankment.

Contaminant Source	Receptor	Impact likelihood and Severity
along eastern boundary of the site with direct flow overland		Any such break out will flow across the ground surface and seep into the ground (and potentially into underlying groundwater) or flow into the Morell River. A continuing, substantive break-out is likely to be required in order to impact surface water quality.
Groundwater contaminated with leachate	Canal Feeder water channel to west of site, which accepts drainage flowing northwards and flows in a westerly to north-westerly direction to join the Grand Canal at Sallins	Previous monitoring results show this water course to be of poor quality, including comments that the channel was blocked with refuse. It is not known if the canal feeder is of artificial or natural construction. If natural, there is a low risk that leachate contaminated groundwater flowing in a westerly to north-westerly direction from the site could impact the surface water. If artificial, water will flow in a lined channel and therefore will be isolated from groundwater in-flow, and therefore not at risk from contamination.
Landfill gas migrating from the site through high permeability sands and gravels	Off-site buildings and occupants. Underground services and utility workers	There is evidence of migration of landfill gas from the north-western and north-eastern boundaries, with trigger levels for carbon dioxide and methane (one location) being exceeded Currently, there is no evidence of a significant and sustained plume of migrating gas, since the relatively high permeability wastes and uncapped site allows venting of gas to atmosphere within the site boundary. SKM Enviros considers there is currently a low risk of gas migrating into utilities/buildings. However this risk will increase to high if the site is capped or the existing free venting of the site is impeded (for example by storage of low permeability materials arising from decommissioning of existing plant on the

Contaminant Source	Receptor	Impact likelihood and Severity
		surface). Appropriate gas migration control measures will be required in the above circumstances to control off-site migration.
Landfill gas migrating from the site through high permeability sands and gravels	Vegetation off-site	There is evidence of migration of landfill gas from the north-western and north-eastern boundaries, with trigger levels for carbon dioxide and methane being exceeded Currently, there is no evidence of a significant and sustained plume of migrating gas, since the relatively high permeability wastes and uncapped site allows venting of gas to atmosphere within the site boundary. Currently, there is no apparent impact on off-sire vegetation. This risk will increase to high if the site is capped or the existing free venting of the site is impeded (for example by storage of low permeability materials arising from decommissioning of existing plant on the surface). Appropriate gas migration control measures will be required in the above circumstances to control off-site migration.
Landfill gas on site	On-site buildings and site workers	Currently we are not aware of the level of gas migration control (if any) which is incorporated into buildings on site. In the absence of any information, and dedicated gas migration controls on site, we consider there is a moderate risk of gas entering buildings and structures on site. If the wastes are capped, or venting to atmosphere is impeded, the risk will increase to high. No buildings or confined spaces should be entered until a risk assessment has been conducted, including gas monitoring within the building prior to entry and periodically during

Contaminant Source	Receptor	Impact likelihood and Severity
		occupation.

4.4.1 Established Impacts from the site

Information to date has established;

- there is a confirmed and worsening impact of leachate on groundwater along the north-eastern boundary of the site
- there is confirmed landfill gas migration from the north-western boundary and north-eastern boundaries of the site, with methane and carbon dioxide in exceedence of site licence trigger levels;
- landfill gas (and associated odours) emissions are continuing from the surface of emplaced wastes, including those wastes in the lined cells.

4.4.2 Existing environmental control measures at the site

Currently, the only environmental control measures in place at the site are as follows;

Wastes in Containment cells

A shallow thickness of waste has been deposited in the cells 1 and 2. The cells are lined with low permeability synthetic liner, designed to prevent leachate and gas migration. However, there is no evidence of maintenance of protection of the exposed liner or adequate protection before and during waste emplacement, so the integrity of the existing liner cannot be guaranteed. Leachate is designed to be collected and pumped to an existing below ground leachate tank for storage and subsequent off-site disposal. This is considered to be an appropriate method for leachate management.

However, given that there is no management or removal of leachate, rainwater infiltration has resulted in leachate filling the contained cells and over-topping the cell wall, flowing over the site surface and infiltrating into the ground. This will be contributing to leachate contamination of groundwater underlying the southern area of the site. Measures should be implemented to reduce or minimise future leachate impact in this area (for example by covering the wastes with low permeability sheeting and to intercept rainwater and divert run-off from the lined cells.

Landfill gas is intended to be collected by a network of perforated pipes, which passively vent through stockpiles of wood chip as an odour control mechanism.

This is not in accordance with good landfill practice which requires gas to be actively collected and flared or utilised from lined sites. There is little evidence that the wood chips are effective in removing odourous compounds from landfill gas. There is no longer management of this system.

Other areas of the Site

This system of passive gas venting is also in place in some areas of the north-western zone of the site. The same comments apply, and with the larger volumes of waste present in the north are even more important.

Along the north-western boundary during our site visit water vapour was noted to be rising from points along the boundary. These areas were also emitting odours. It is possible that the points from where water vapour was rising correspond to previous vent pits, which have subsequently been covered by waste. Similar observations of “steaming wastes” were reported by WRC during excavation of trenches into wastes to obtain samples for waste analysis.

Along the north-eastern boundary, there is evidence of rubble infill (stones, boulders, concrete slabs and bricks) which may have been applied to assist gas in venting from the site. It was not clear if this venting provision extends along the whole of the eastern boundary, since other waste materials are placed up to the boundary fence along most of the boundary, and it is now likely to be less effective in intercepting laterally migrating gas.

There is no control of leachate generation in the remainder of the site.

No area of the site has a low permeability temporary or permanent cap, with very little evidence of even daily cover of wastes.

4.5 Need for Remedial Works

Given that leachate and gas migration is proven, and we consider there to a moderate to high potential for future impacts, we consider remedial works are needed to control environmental and nuisance impacts arising from leachate and gas.

Currently, we consider that leachate impact is minor but will steadily increase in future as absorptive capacity of wastes becomes exhausted and proportionally more leachate is generated. Indications from GasSim modelling are that the wastes are nearing their peak of gas production. Thus the current potential impact from gas is greater than currently from leachate and unless specific gas migration control measures are installed off-site impacts are likely to increase markedly should the current open areas of waste become covered with low permeability materials.

5 Remediation Scenarios

Future environmental management of the site will need to consider a number of inter-related factors and objectives, which gives rise to a number of remediation scenarios. Currently, the site has limited effective environmental controls. Leachate migration is occurring from along the north-eastern boundary, gas migration is occurring along at least the north-western and north-eastern boundaries and gas venting to atmosphere from within the site continues to create potential odour nuisance.

Remediation is required to meet the following objectives:

a) Reduce future impact of leachate on groundwater (and potentially surface waters);

b) Ensure future leachate production is reduced, controlled and managed;

c) Ensure landfill gas is managed and controlled such that it does not constitute a risk to people, property and vegetation off-site and on-site;

d) Reduce the GWP of emitted gas (by conversion to carbon dioxide);

e) Eliminate odour nuisance if feasible, and reduce to an acceptable level during any re-excavation and placement of wastes within the site (or during disposal off-site);

f) Provide a safe landform which fits within planning and waste licence conditions for restoration.

(The current licence specifies;

Final profile to be domed and not to exceed 108mPoolbeg;

Top soil 150 to 300mm;

Subsoils, such that the topsoil and subsoils are at least 1m;

Drainage layer of 0.5m thickness having a minimum hydraulic conductivity of 0.0001 m/s;

Compacted mineral layer of a minimum 0.6m thickness with permeability of less than 0.00001m/s or a geosynthetic material or similar that provides equivalent protection;

Gas collection layer of natural material (0.3M) or geosynthetic layer;

Where tree planting is to be carried out above wastes, a synthetic barrier shall be used to augment the clay.)

g) Returns land to a long-term safe and beneficial afteruse.

A number of scenarios have been developed which could be implemented to achieve appropriate closure of the site with adequate environmental protection. These are not the only scenarios, and others may be possible.

The situation at the site has changed since our original commission in that Neiphin Trading Limited and Dean Waste have filed for bankruptcy, the site has been vacated and no further activities are occurring. This enforced lull in activity creates an opportunity to conduct further focussed investigations at the site to determine actual conditions within the existing wastes and refine existing impacts (e.g. quality of groundwater underlying the site) which will help to predict the impacts from the site in its current condition and to inform the most appropriate remedial strategy. In addition an up to date aerial survey of the site is required to establish levels and volumes of materials on site at point at which site was abandoned by the operator. The amount and condition of wastes stored within buildings also needs to be confirmed.

5.2 Scenario A

No more materials to be accepted at the site. Existing wastes (including those within the south-eastern area, including the lined cells) to be profiled in north-western area of the site to acceptable landform and completed with low permeability cap. Profile height not to exceed 108mPoolbeg. Active gas collection and flaring system to be installed. Existing waste processing plant to be removed from site.

5.2.1 Features of Scenario A

Reprofiling of the wastes will inevitably generate odour nuisance for a limited period until the wastes are capped. Capping of wastes will significantly reduce the potential for landfill gas to vent to atmosphere, but will inevitably cause lateral migration of gas through the unlined, permeable walls of the former quarry. Therefore an active gas abstraction system is essential. This will control both lateral migration and fugitive emissions to atmosphere.

An active gas extraction system will involve pumping from gas extraction wells installed within the wastes and around the boundary, removal of condensate (option for condensate to drain under gravity back into waste, or to be collected in a sump and pumped out to the existing leachate holding tank for subsequent tankering off-site) and flaring of gas. We have used spacing of gas wells at 40m centres, in accordance with current guidance. GasSim modelling suggests there may be sufficient yields of gas for utilisation, which would provide an income to the site. Our current costings do not take into account any revenue from gas utilisation. A utilisation feasibility study should be conducted over the next six months, to establish potential local users of the gas and feasibility of grid connections and related infrastructure development.

To accord with EPA guidance, the system will comprise a network of gas extraction wells installed on a 40m grid basis, and perimeter wells. Perimeter wells will be placed at 25 metres intervals along the most sensitive western and north-western boundary, where houses are located within 50m of the landfill boundary, and at 40m spacing along remaining boreholes. Wells will be connected to a pump and gas within removed to a high temperature flare stack located on site. Monitoring boreholes will be constructed around the perimeter of the site.

As an alternative to flaring, utilisation may be feasible by burning gas in engines to generate electricity. A feasibility study is needed to assess the practicality of utilisation.

Provided a high quality capping is installed, subject to independent quality control and verification, the gas extraction system will control lateral migration and prevent future odour nuisance from the site. Capping will require a synthetic membrane or acquisition of good quality clay, topsoil and sub-soil. The availability and costs of these materials is dependent on local “supply and demand” for materials, and therefore there is high degree of uncertainty in costing for these materials.

Capping will reduce future leachate production. Leachate within the wastes will continue to migrate through the base of the site and into groundwater. The River Morell is considered to be at risk from future leachate migration. This Scenario relies on natural attenuation of leachate in the soils. At present, it is not clear whether or not this will be sufficient to attenuate leachate to a level acceptable for discharge to the Morell. A long-term period of groundwater monitoring will be necessary to establish the effectiveness of natural attenuation mechanisms at Kerdiffstown.

Based on 2008 aerial survey contours, it should be possible to achieve an acceptable landform which meets the planning criteria of final landform not to exceed 108mPoolbeg. We have not conducted a detailed evaluation of settlement potential or slope stability, both of which will require evaluation before design can be finalised and any work proceeds.

This Scenario will have the least impact from odour and other nuisance (such as traffic) during landfill configuration, and will take least time of the Scenarios to complete. However, a residual impact on groundwater quality will remain. A period of further monitoring and assessment will enable the effectiveness of natural attenuation of leachate in groundwater to be assessed and future impact on surface water quality to be estimated.

A variation to this scenario would be to utilise the existing lined cells for disposal of some of the wastes, completion to final levels and restoration. This variation will require long term control of leachate, by pumping to the existing underground tank and tanker off-site for disposal. This will require long term management and additional costs for maintenance of the system and disposal of leachate.

The landfill gas system would also need to be extended to include wastes within the lined cells.

5.3 Scenario B

As for Scenario A, but including installation of shallow groundwater cut-off wall up hydraulic gradient to divert groundwater around the site and minimise potential for on-going contamination of groundwater, down gradient cut-off barrier to protect River Morell from proven and anticipated potential leachate contamination discharging from north eastern boundary and construction of groundwater scavenging boreholes through the base of the landfill. Groundwater to be pumped and treated on-site. Treated groundwater could be discharged to sewer (via the existing leachate holding tank on site),directly to the river Morell or back into groundwater via new re-injection boreholes. The quality of treated groundwater will need to be higher for direct discharge to surface water and groundwater than for tankering to sewer. A variation would be to tanker directly to sewer, without any on-site pre-treatment

5.3.1 Features of Scenario B

The Scenario has similar features to those associated with Scenario A, but with leachate impacts being actively managed by pumping and treating contaminated groundwater, and reducing future leachate generation by a combination of landfill capping and groundwater diversion. The practicality of installing groundwater diversion barriers around parts of the site (for example negotiating land access with Kerdiffstown House) have not been tested. Further exploratory boreholes will be needed to confirm ground conditions and depth of cut-off which will be required to achieve practical interception of groundwater. We have assumed a depth of 6 metres in the costs, and that a simple slurry wall barrier is installed.

There is uncertainty as to how long pump and treat would be required to operate, and further work would be required on quality and hydraulic properties of the underlying groundwater, and how easy it is to extract. Currently, costs assume 20 groundwater extraction boreholes will be required.

There are other variations to this Scenario such as installation of a down-hydraulic gradient reactive groundwater barrier (which controls groundwater movement through it and achieves in-situ treatment of contaminants).

Requirements for landfill gas control remain as for Scenario A.

5.4 Scenario C1

Remove all waste processing plant from the site. Existing lined cells to be filled. Construct new lined cells at the base of the area resulting from plant removal. Place remaining materials into lined cells. Install leachate removal and gas collection infrastructure in new lined area and extend active gas collection system into existing lined cells. Pump leachate to leachate tank and

tanker off-site or discharge to sewer, or construct an on-site treatment facility with discharge of treated leachate to sewer or surface water. Restore landfill with low permeability capping .

5.4.1 Features of Scenario C1

This differs from Scenarios A and B in that large scale excavation and movement of existing wastes is required, which has potential to generate significant odour nuisance over a period of many months, and possibly years. To minimise nuisance, waste movement and placement should be conducted as quickly as possible.

Preparation of the area to receive wastes will require the existing waste processing equipment to be removed from the site, which again is likely to take several months. Existing structures such as concrete tanks and buildings will also need to be demolished, which will generate additional (inert) wastes. It is likely that much of the concrete can be recycled and some can be used on site. A detailed materials balance will be needed to establish actual amounts of materials which will be generated during demolition.

Prior to constructing lined cells, the existing waste processing plant and equipment needs to be removed from the south-eastern area of the site and demolition waste also removed. There is likely to be a significant quantity of demolition waste (particularly concrete) generated, some of which could be used to construct access roads. There may be merit in retaining some processing on site, and to continue re-processing materials prior to final emplacement. This could generate revenue.

The phasing of the whole operation will need careful assessment to ensure wastes are exposed for a minimum of time to reduce nuisance impact from odour.

Since the site will be lined, leachate will be contained within the cells. Each cell should have a leachate pump and leachate will be removed for treatment. Costs in Appendix 7 assume that leachate will be treated on-site, prior to discharge to sewer. The feasibility of a sewer connection needs to be confirmed. The alternative option is to store leachate in the existing below ground leachate tank, and tanker off-site.

This scenario will ensure that future leachate migration will be prevented, and groundwater quality under the site will not continue to deteriorate once wastes have been removed. However, although leachate will be contained in the newly constructed cells, residual contamination associated with the current unlined area will remain. Therefore, contaminated groundwater underlying the site may also require pumping out and treating.

Requirements for gas control are effectively similar to Scenario A and B, again with option for potential utilisation to be considered.

5.5 Scenario C2

As for Scenario C1, but also line and utilise the void created in the north-western area of the site following waste removal to import and deposit new wastes in full containment landfill with active gas control and flaring or utilisation if feasible), leachate extraction with or without on-site treatment followed by off-site disposal by tanker or sewer connection, or discharge of treated leachate directly to surface water

5.5.1 Features of Scenario C2

Features are similar to Scenario C1, but includes the vacated north-western area of the site being available for deposit of new wastes in engineered containment cells. The main advantage of this scenario is to generate revenue from existing waste disposal. Capacity is estimated to be in excess of 1million cubic metres, which potentially is a substantial asset and may well interest commercial operators.

Retention of some of the existing waste processing plant on site may enable additional value to be realised from processing wastes and selling reclaimed materials.

However, there may major opposition to suggestion of further processing and waste disposal at the site which could last for many years, even if the operations were to be conducted to the highest standards.

5.6 Mixtures of Scenarios A to C

Other possibilities exist for the site, which currently have not been considered in detail. For example, Scenario A (or B) could be combined with creation of a new engineered and contained facility in the current south-eastern area of the site, following decommission and removal of the existing waste processing equipment. Aspects of the waste processing equipment could be retained for use in the new operation.

This hybrid option could generate revenue from the new operation to fund restoration and remediation of the existing wastes and could be conducted in a phased manner. This could be attractive to a potential operator, but there may be fierce local opposition to any further waste processing and landfilling at the site.

5.7 Scenarios A to C: Compliance with Landfill Directive and Groundwater Regulations

Both Scenarios A and B retain the existing wastes in-situ. Since some of the wastes deposited do not appear to have been placed in a manner compliant with the existing site licence, or, for the types of waste observed in the north west zone, with the current requirements of the Landfill

Directive, they are likely to represent an illegal deposit of materials. Under such circumstances to ensure compliance with licence conditions the existing wastes will need to be relocated to a contained environment (lined cells) such that the wastes comply with licence conditions and become compliant with the Landfill Directive.

Unlike scenarios A and B, Scenario C will create a fully contained landfill such that all wastes can be deposited in compliance with the requirements of the Landfill Directive, and Scenario C is more likely to be compliant with the Groundwater Regulations over the long term, due to early removal of waste currently in the unlined part of the Site.

5.8 Scenario D

Remove all processing plant, wastes and other materials from the site. Deposit all wastes off-site into another appropriately lined landfill.

5.8.1 Features of Scenario D

This Scenario would remove future sources of gas and leachate from the site, although as with Scenario C residual groundwater contamination will remain below the north-western area of the site.

Removing the large volume of materials which remain at the site (estimated to be of the order 1.7 million cubic metres) would be a major undertaking. As far as we are aware, an operation on this scale has never been conducted in UK or Ireland. The operation would likely give rise to significant nuisance impacts arising from odours as wastes are re-excavated and loaded to trucks, noise from site vehicles and trucks, increased road traffic and potentially dust and mud. Wet wastes would need to be transported in sealed trucks to ensure leachate does not seep out during transport. Facilities need to be in place on site to retain, collect and dispose of (tanker) free leachate which may be encountered within the wastes.

A further constraint is identifying sites with capacity and which are prepared to accept the wastes excavated from Kerdiffstown. A preliminary survey of local landfills indicated that they would require pre-treatment of wastes prior to acceptance, and no one site has capacity to accept the wastes. Wastes will need to be transported beyond the local area, and potentially to disposal sites in Northern Ireland or great Britain. There is no guarantee that all wastes can be accommodated. Such an exercise is unlikely to be considered to be a sustainable undertaking.

5.9 Cost Estimates

Three cost estimates has been compiled for each scenario and are presented in Appendix 7.Costs are based on updates of those originally provided for landfill control measures and restoration by UK Government in Waste Management paper 26, “Landfilling Wastes”, recent estimates obtained

for similar activities at other sites in Ireland and on recent wider UK experience. It must be recognised that costs for some elements (e.g. provision of clays and soil for restoration) are sensitive to availability of local supplies of materials and thus can vary widely. Local engineering rates can also vary considerably. There will be less variation in costs of infrastructure and capital items, such as membrane liners and gas extraction wells.

Estimates have been developed for each Scenario for “Base Cost”, “Upper Rate” and “Best Estimate”. The “Best Case” estimates the likely cheapest costs for the work, and the “Upper Rate” costs which are unlikely to be exceeded.

6 Conclusions

The following conclusions have been established;

Site Development

Kerdiffstown landfill is a former sand and gravel quarry, excavated to above the water table, which has been progressively backfilled with wastes by a variety of operators since the 1950s.Neiphin Waste Trading Limited (Neiphin) has occupied the site since 1995, and has conducted a variety of waste processing activities at the site as well as landfilling. Activities included excavation and processing of former wastes.

The site has planning permission reference 97/871issued by Kildare County Council. A condition of planning requires the site to be restored , with final restoration level not to exceed 108m Poolbeg. Neiphin operated the site under waste Licence W0047-01 (issued 16 July 2003) and modified by Waste Licence W0047-02(issued in 11 February 2010). The waste licences permit operation of an integrated waste management facility, including inert landfill operation.

Neiphin has progressively developed the site, such that in early 2010 activities comprised: processing of new and existing wastes using a variety of mobile and permanent plant, including hand picking lines; timber chipping; stone crushing; waste processing using automated lines; waste composting and; storage of baled waste in buildings. Neiphin had also constructed two lined landfill cells in the southern area of the site, into which a shallow thickness of waste had been deposited.

Since Neiphin occupied the site, there have been numerous complaints associated with site activities, dominated by odour complaints. The EPA and Neiphin have been in communication about the complaints for many years.

In June 2010 Neiphin vacated the site, leaving plant and materials on site.

Landfill gas and leachate production and management

The majority of wastes which are present at Kerdiffstown landfill are present in the north-western unlined area of the site. This area has limited measures to control migration of landfill gas, these being limited to passive venting via wood chip piles (the original main objective of which was odour control. No specific lateral gas migration controls are in place, although there is evidence that previously constructed rubble filled zones may be present along parts of the boundary which would have been constructed to encourage gas venting at the edge of the site.

SKM Enviros has modelled likely future gas production using GasSim, a recognised landfill industry standard model, and waste compositional data derived from previous waste analysis studies conducted at the site. The maximum rate of gas generation of the order of 2000 cubic metres per hour is predicted as occurring in the next few years, and the model indicated gas production occurring for decades.

Wastes are not covered or capped with low permeability material therefore there is no control on rainwater infiltration and leachate production. The situation at Kerdiffstown is complicated by the fact that materials have been deposited, excavated, subject to processing and residuals re-deposited, so conducting a detailed water balance is difficult.

A broad estimate shows that with no capping or other means to divert rainwater from the wastes, absorptive capacity will be achieved within 4 years, although leachate production is already occurring. The site is not lined, and there is no barrier for leachate which is generated to migrate into underlying strata and groundwater.

The most recent walkover visit by SKM Enviros (September 2010) also revealed that leachate was over-topping the two lined cells in the south of the site, flowing across the ground surface and infiltrating into the ground.

Impacts of landfill gas and leachate

The borehole investigation conducted by the EPA around the site in 2010 and follow up gas monitoring and groundwater sampling reveals the following key findings:

- Strata around the site include sands and gravels, which are conducive to gas and leachate migration;
- Carbon dioxide levels above site licence trigger levels are present around the site (highest concentration recorded 17.7%). Currently we consider that gas migration does not constitute an immediate risk to developments around the site since lack of capping is allowing gas to vent to atmosphere. Should low permeability material (capping or otherwise) be placed on the surface, the risk of migration will increase and gas migration controls should be installed. Such measures are should also control odour emissions.
- Groundwater contamination by leachate is proven in groundwater flowing from under the eastern boundary of the landfill towards the River Morrell. The most recent data set (July 2010) indicates a trend of worsening contamination in boreholes. Since there are no controls on leachate genetration, leachate will continue to migrate from the site for many years.
- Gas and leachate continue to give rise to odours on site, but since wastes are not being disturbed and new wastes are coming in to site, odour nuisance is less than when the site was operation.

Potential Remediation

Scenarios for remediation of the site together with cost estimates have been evaluated. Scenarios range from reprofiling and capping existing materials, and installation of gas collection and flaring system with reliance on monitored natural attenuation of groundwater to reduce leachate impact, to excavation of wastes and placement into lined landfill cells, leachate removal and treatment, capping and installation of active gas control system. A fully lined site is likely to be compliant with the Groundwater Directive and SKM Enviros has derived a broad cost estimate for this scenario as 30 million euros.

Costs of restoration materials can vary widely depending on availability of suitable restoration materials and economic factors pertaining at the time restoration is proposed. A firm quotation is recommended for each element of the landfill preparation, environmental controls and restoration and much of the work would benefit from carrying out a competitive tendering exercise.

- Given the existing financial situation in Ireland, temporary, pragmatic measures may need to be considered implemented which will have some effect in reducing environmental impacts.

  Without any action, environmental impacts will continue for decades.

Figures

Figure 1 Site Location Details and Groundwater Levels May 2010

Figure 2 Ammoniacal Nitrogen and Chloride Values in Groundwater Samples 22 July 2010

Figure 3 Carbon Dioxide Levels (%) 9 July 2010

Appendices

Appendix 1 List of References

1) Waste Licences W0047-01 and W0047-02 issued by EPA to Neiphin Trading Limited for "Integrated Waste Management Facility including a Landfill for Non-Hazardous Waste".

2) Golder Associates Ireland – annual and quarterly environmental reports for 2003 to 2007. Reports for Neiphin Trading Limited.

3) WRC reference UC 7939.3 "Investigation at Kerdiffstown Integrated Waste Management Facility, Naas, County Kildare" 27 April 2009. Report to EPA.

4) Environment & Resource Management Limited. Letter to EPA on EPER Register and GASSIM modelling of methane emissions. 23 December 2004.

5) Environment & Resource Management Limited. Gas Monitoring Borehole Logs. Letter and attachments to EPA, 21 December 2004.

6) Environment & Resource Management Limited. "Consolidated Report on Leachate Management", 27 April 2004. Report prepared for Neiphin Trading Limited.

7) Environment & Resource Management Limited. Letter to EPA "Re Neiphin Trading Ltd, - Waste Licence W0047-01. Condition 12.2 – Proposals regarding Environmental Liabilities, Risk Assessment (ELRA) and Financial Provisions". 13 October 2003.

8) Environment & Resource Management Limited. Letter to EPA Re Waste Licence Register No W0047-01 – "New Monitoring Location". 2 September 2003.

9) Environment and Resource Management Limited. "Risk Assessment Report Condition 3.13.5 and 3.13.6, Waste Licence Register W0047-01", September 2003. Report to EPA.

10) Environment & Resource Management Limited. "Report on Proposed Trigger Levels, Condition 6.4.2". October 2003.

11) Environment & Resource Management Limited. "Facility Infrastructure, Condition 3". August 2003.

12) Environment & Resource Management Limited. "Environmental Liabilities Risk Assessment, Condition 12.2.1". July 2000.

13) KT Cullen & Company Limited, adapted sections from an Environmental Impact Statement prepared in 1997; "The Receiving Environment, Mitigation Measures and Likely Significant Effects". September 2000.

14) Site Inspection reports and various correspondence provided by EPA.

15) Aerial photographs and volumetric analysis reports, provided by EPA.

Appendix 2 APEX GEOSCIENCES Geo-Physical Survey

Appendix 3 Results of 2010 Site Investigation

Appendix 4 Survey of Surface Emissions, Odour Monitoring Ireland

Appendix 5 Basic ELRA Assessments

Appendix 6 Results from Initial GasSim Model

Appendix 7 Cost Scenarios