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SOUTH AND WEST KERRY LANDFILLS

TIER 3 RISK ASSESSMENT
HISTORIC LANDFILL AT DINGLE, CO. KERRY

Prepared for: Kerry County Council

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Date: April 2021

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User is responsible for Checking the Revision Status of This Document

Rev. No.	Description of Changes	Prepared by:	Checked by:	Approved by:	Date:
00	DRAFT	EOC/CF	CJC	CJC	07.04.2020
01	Draft for review	EOC/CF	CJC	CJC	23.04.2020
02	Final Submission	EOC/MG	CJC	CJC	04.08.2020
03	Final for Submission	EOC/AM	CJC	CJC	07.04.2021

Client: Kerry County Council

Keywords: Environmental Risk Assessment, site investigation, waste, leachate, remediation.

Abstract: This report presents the findings of a Tier 3 risk assessment carried out on the Dingle Historic Landfill site, Co. Kerry, and conducted in accordance with the EPA Code of Practice for unregulated landfill sites. The Tier 3 risk assessment was conducted following recommendations made in an earlier Tier 2 risk assessment.

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1. INTRODUCTION

1.1 Overview

Fehily Timoney and Company (FT) was appointed by Kerry County Council to carry out and prepare a Tier 3 risk assessment for Dingle Historical landfill located at Dingle, Co. Kerry. This Tier 3 makes reference to the:

- Tier 1 risk assessment findings and classifications (2007 and 2011).
- Tier 2 Site investigation and testing and risk assessment (2020).

All FT risk assessments were carried out in accordance with the Environmental Protection Agency (EPA) Code of practice (CoP) - Environmental Risk Assessment for Unregulated Waste Disposal Sites guidance document.

1.2 Tier 1 Risk Classification

Kerry County Council initially prepared a Tier 1 risk assessment in 2007. This risk assessment determined that the site was a high (Class A) risk to the receiving environment. Applying the EPA risk assessment tool as per the EPA CoP for Unregulated Waste Disposal Sites, yielded risk scores of 70% for source-pathway-receptors (SPR) linkage SPR8. A summary of the risks is presented below in Table 1.1.

The Tier 1 risk assessment was reviewed in 2011. A comparison between the 2007 and 2011 Tier 1 assessment showed relatively minor changes to risk scores calculated between the two Tier 1 assessments. SPR10 (lateral landfill gas migration was increased 7% which raised this potential risk from low to moderate. Although there were some changes to scoring between 2007 and 2011 all other SPR risks were classified as low, moderate or high as per the 2007 assessment, with the highest score remaining at 70%. The site therefore remained classified as a high-risk site, requiring further investigation. All other SPR linkages were calculated to be of low risk.

Table 1-1 normalised scores for 2007 and 2011 Tier 1 assessments have been provided for reference purposes to reflect records as per the current (2020) EPA Section 22 register.

Table 1-1: Tier 1 SPR Linkages (2007 and 2011)

SPR No.	Linkage	Normalised Score	Justification[1]
Leachate migration through combined groundwater and surface water pathways			
SPR1	Leachate => surface water	35% (2007) 35% (2011)	
SPR2	Leachate => SWDTE	0% (2007) 0% (2011)	There are no groundwater dependent terrestrial ecosystems (GWDTEs) or surface water dependent terrestrial systems (SWDTEs) located within 1km of the historical landfill.
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence	26.25% (2007) 18% (2011)	Groundwater vulnerability is moderate and aquifer is only locally important while potential human receptors are located 50m of the site.
SPR4	Leachate => GWDTE	0% (2007) 0% (2011)	There are no GWDTEs located within 1 km of the waste body.
SPR5	Leachate => Aquifer	15.75% (2007) 16% (2011)	
SPR6	Leachate => Public Supply	0% (2007) 0% (2011)	Nearest public water supply is located over 1 km from the site.
SPR7	Leachate => SWDTE	26.25& (2007) 26% (2011)	
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	70% (2007) 70% (2011)	There is a direct connection between the waste body and the adjacent Kilfountan River as verified during the site walkover. Leachate was also observed to be present within surface drains adjacent to the site.
SPR9	Leachate => SWDTE	0% (2007) 0% (2011)	There are no SWDTEs located within 1 km of the historical landfill.
Landfill gas migration pathway (lateral & vertical)			
SPR10	Landfill Gas => Human Presence	35% (2007) 42% (2011)	
SPR11	Landfill Gas => Human Presence	28% (2007) 0% (2011)	There are no receptors located immediately above the waste body.

Note 1: Justification refers to 2011 risk scoring

1.3 Tier 2 Site investigation

Fehily Timoney and Company (FT) was appointed by Kerry County Council to

- Carry out site investigations and testing;
- Prepare a Tier 2 environmental risk assessment report on the Dingle historical landfill, located at Dingle, Co. Kerry.

Dingle's site investigation included the following elements:

- Site walkover.
- 1 No. geophysical survey (2D resistivity and seismic refraction profiling).
- 5 No. trial pit excavations.
- Installation and monitoring of 2 No. groundwater boreholes.
- Topographical survey.

The Tier 2 site investigations confirmed that the historic landfill typically contained mixed municipal solid waste deposited within a single infill area which covers an area approximately 23,600 m^2. The depth of waste was estimated from the seismic refraction and 2D-resistivity to have an average thickness of 3.2 m. An initial volume calculation estimates an interred waste volume of approximately 75,500 m^3 at the site.

1.4 Tier 2 Risk Classification and Tier 2 SPRs

The Tier 2 site investigation risk assessment concluded that the risk rating of the site was High (Class A). The highest single risk rating for the site was calculated to be 70% for source-pathway-receptor (SPR) Linkage 8, which referred to leachate migration through a surface water pathway to a surface water receptor. The SPR linkages examined in the Tier 2 are highlighted and discussed in further details below.

Table 1-2: Tier 2 Selected SPR Linkages

SPR No.	Linkage	Normalised Score	Justification
Leachate migration through combined groundwater and surface water pathways			
SPR1	Leachate => surface water	28%	Groundwater aquifer is classified as being a locally important aquifer with a moderate vulnerability and there is a direct connection from the waste body to the adjacent Kilfountan River. Site Investigation suggests that groundwater present in the underlying sand/gravel beneath the waste is hydraulically linked to the adjacent river.
SPR2	Leachate => SWDTE	0%	There are no groundwater dependent terrestrial ecosystems (GWDTEs) or surface water dependent terrestrial systems (SWDTEs) located within 1km of the historical landfill.

SPR No.	Linkage	Normalised Score	Justification
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence	18%	Groundwater vulnerability is moderate and aquifer is only locally important while potential human receptors are located 50m of the site.
SPR4	Leachate => GWDTE	0%	There are no GWDTEs located within 1 km of the waste body.
SPR5	Leachate => Aquifer	11%	Aquifer vulnerability is moderate and is classified as being a locally important aquifer.
SPR6	Leachate => Public Supply	0%	Nearest public water supply is located over 1 km from the site.
SPR7	Leachate => Surface water body	18%	Surface water within 50 m of site boundary. Kilfountan River adjacent to waste body.
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	**70%**	There is a direct connection between the waste body and the adjacent Kilfountan River as verified during the site walkover. Leachate was also observed to be present within surface drains adjacent to the site.
SPR9	Leachate => SWDTE	0%	There are no SWDTEs located within 1 km of the historical landfill.
Landfill gas migration pathway (lateral & vertical)			
SPR10	Landfill Gas => Human Presence	14%	No gas exceedances recorded but residential dwellings are present within 50 m of the site boundary.
SPR11	Landfill Gas => Human Presence	17%	No gas exceedances recorded but residential dwellings are present within 50 m of the site boundary.

1.4.1 Leachate migration through combined groundwater and surface water pathways (SPR1)

As part of the Tier 2 site investigation and assessment, two groundwater monitoring boreholes were installed to the north and south of the waste body (upgradient and downgradient). Groundwater sampling was conducted on two occasions in July 2019 and September 2019. Groundwater monitoring showed elevated concentrations of manganese above the EPA IGV[1] threshold of 50 µg/l within three samples obtained from BH01 and BH02. Borehole BH01 yielded manganese concentrations of 506 µg/l and 166.4 µg/l, while BH02 yielded concentrations of 3,690 µg/l and 3,620 µg/l.

[1] Towards Setting guideline Values for the protection of Groundwater in Ireland - Interim Report (EPA, 2003)

Analysis of results with respect to exceedances of groundwater quality thresholds concluded:

- The natural hydrochemistry within the area in general was for the most part responsible, albeit that elevated concentrations of iron and manganese may arise from the landfill, (iron was detected above the EPA IGV of 0.2mg/l on one occasion at BH01 at a concentration of 4.94 mg/l).
- Elevated concentrations of mineral oil in BH01 may arise from leachate in the waste body.

Leachate was observed to be present in adjacent surface water drains indicating a linkage between groundwater, rainfall infiltration, leachate generation and the subsequent migration of this leachate to nearby surface water. Although leachate was not observed to be present within the adjacent river this is likely caused by dilution of surface drainage flows.

1.4.2 Leachate migration through surface water pathways (SPR8)

Leachate was visually observed at the surface and in adjacent surface water features. Surface water monitoring was conducted on two occasions in July 2019 and September 2019 at locations on the Kilfountan River upstream and downstream of the historic landfill. The monitoring results did not present concentrations above the relevant surface water quality thresholds nor did they suggest any deterioration in water quality downstream of the waste body.

Although leachate wasn't observed within the Kilfountan River directly and the outcome of surface water monitoring doesn't suggest the site is actively causing a deterioration in water quality downstream of the site there is still a potential pathway for leachate to migrate to the river.

2. TIER 3 QUANTITATIVE RISK ASSESSMENT SCOPE OF WORKS

2.1 Tier 3 Overview

A Tier 3 assessment includes some form of quantitative risk assessment for **Moderate or High-risk sites**, either as a Generic Quantitative Risk Assessment (GQRA) or as a Detailed Quantitative Risk Assessment (DQRA).

This Tier 3 report further examines the Tier 2 (see Table 1-2) linkages in relation to the following:

- SPR1 Leachate migration through combined groundwater and surface water pathways 28%.
- SPR8 Leachate migration through surface water pathway resulting in a risk rating score of 70%.
- SPR10 Lateral Landfill gas migration to human receptors resulting in a risk rating score of 14%

Based on the outcomes of the GQRA/DQRA, suitable remediation measures and associated costs are determined if required.

Additionally, as part of the Tier 3 assessment, a further review of the Tier 2 site investigations and environment risk assessments was conducted. As shown in Section 1 of this report, both the Tier 1 and the Tier 2 investigations concluded that the site presented a **high risk** to the environment

The 2019 site investigation findings and the subsequent 2020 Tier 2 assessment concluded that the Dingle site presents a **high risk** therefore, (as per the EPA CoP), a GQRA or a DQRA are required as part of this Tier 3 assessment.

This Tier 3 assessment report uses the following DQRAs to further assess the risks to surface waters, groundwater and gas migration:

- An assimilative capacity assessment and a mass balance calculation were carried out to predict the potential impact on surface water quality from a leachate discharge to the adjacent river.
- Groundwater contaminant dispersion modelling (EA Remedial Targets Worksheet) was undertaken to quantitatively assess the risks posed to the aquifer.
- Predictive landfill gas modelling (LandGEM) was used to assess gas migration risks.

Based on the outcomes of the DQRAs, suitable remediation measures and associated costs are presented in Section 5 of this report.

3. DETAILED QUANTITATIVE RISK ASSESSMENT (DQRA)

3.1 Detailed Quantitative Risk Assessment

The detailed quantitative risk assessment addressed the following primary risks:

- Leachate migration through surface water pathway to surface water receptors (SPR1).
- SPR8 Leachate migration through surface water pathway to surface water receptors (SPR8).
- SPR10 Lateral Landfill gas migration to human receptors (SPR11).

The DQRAs rely on information gathered as part of the Tier 2 investigations. Relevant environmental characteristics considered in evaluating the site and carrying out this Tier 3 investigation are discussed below.

3.2 Existing Geological, Hydrogeological and Hydrological Environment

As discussed in Section 1, the risk to adjacent surface waters was identified as the primary environmental risk associated with the site. The application of the EPA risk calculation and scoring methodology, as outlined in the EPA CoP, is reliant on understanding the geological and hydrogeological characteristics of the site and the surrounding environment. An accurate understanding and rating of the geological, hydrogeological and hydrological characteristics of the site and environment are directly linked to determining the primary source-pathway-receptor linkages and potential impacts/risks associated with the site. The Tier 2 site investigation and risk assessment provided a better understanding of the site and surrounding environs. Summary findings of the relevant environmental characteristics considered when evaluating the site and carrying out this Tier 3 investigation are discussed below.

The site is approximately 2.6 ha in size, on an area of open land located in a rural, primarily agricultural area in north Kerry. The site is located 2 km from Dingle town. Lands within 1 km of the site are used primarily for residential, commercial and industrial purposes. The quaternary map provided by GSI Online identifies the quaternary sediments at the site as 'Till derived from Devonian sandstones' (TDSs). During the installation of boreholes during the site investigation, the presence of Sand and Gravel Till is described in the driller's logs to a depth of approximately 7 m BGL at borehole BH01 and 10m BGL at BH02. These Sand and Gravel Till layers are underlying the waste and Made Ground Capping Layer.

The bedrock beneath the site is founded on two different formations and geology types. The northern portion of the site is underlain by the Coumeenoole Sandstone Formation comprising cross-bedded sandstone. This formation consists of grey, medium grained sandstones commonly cross-bedded. The site is also underlain by the Slea Head Formation, which comprises pebbly sandstone and conglomerate. This formation consists of brown-grey pebbly, coarse to very coarse sandstones and subordinate pebble conglomerates. The boundary between these two formations transects the site in an approximate west to east direction. Bedrock was not encountered during the installation of the boreholes.

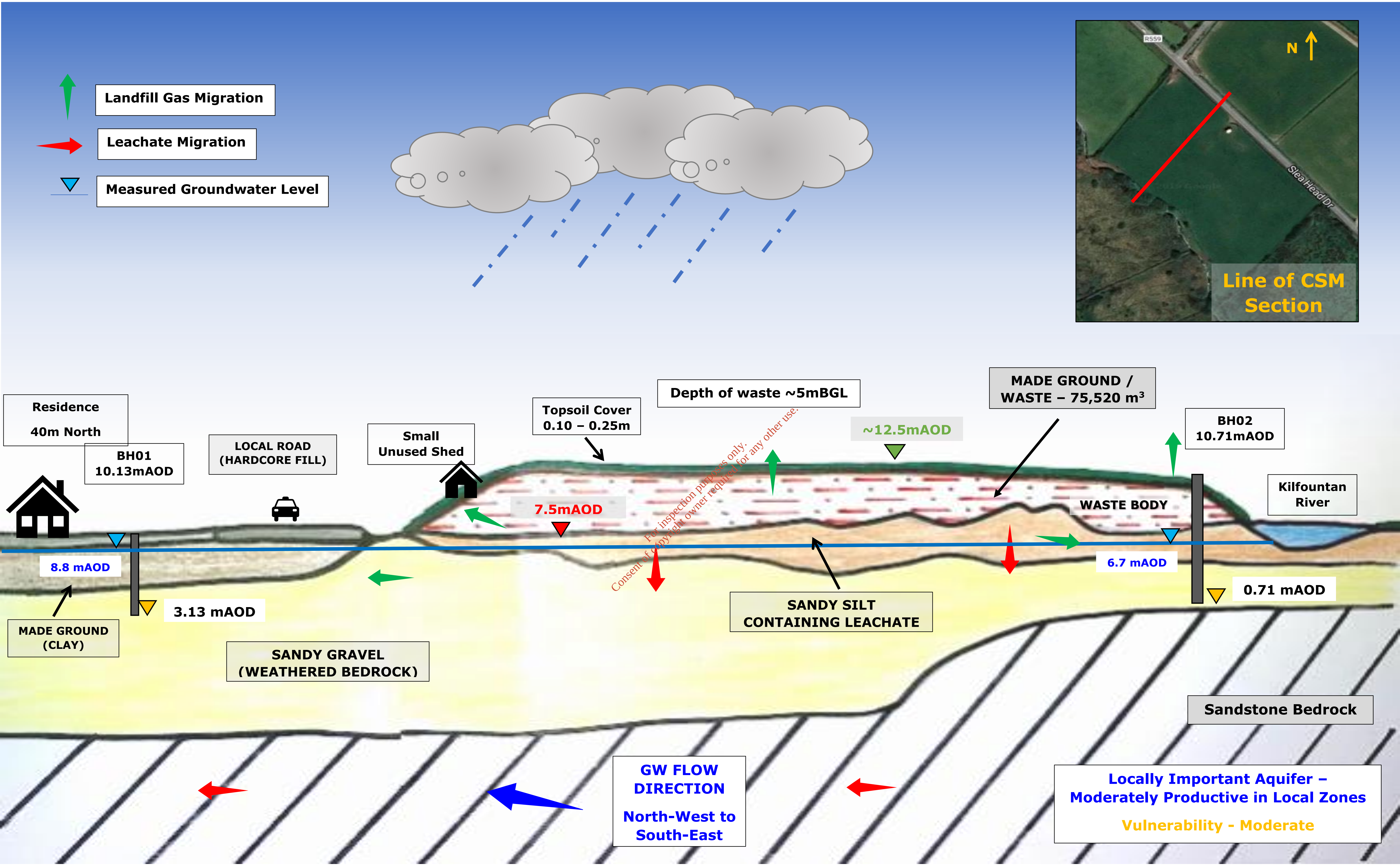
The underlying bedrock aquifer is a 'Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones'. There are no Groundwater Drinking Water Protection Areas within the site boundaries according to GSI. The closest one, Ardfert PWS, is located approximately 40 km from site.

The vulnerability of groundwater to contamination is classified as Moderate. This vulnerability is consistent with site investigation results indicating that the depth to the top of competent bedrock beneath the waste body is up to approximately 15 m below ground level.

The site is located within the: Laune-Main-Dingle Bay catchment (Hydrometric Area 22), Ballynahow Commons sub-catchment and Milltown (Kerry) river sub-basin. The nearest surface water feature to the site is a river (EPA Name: Kilfountan River) which bounds the site immediately to the west and flows in a southerly direction eventually meeting the Milltown River c.0.55 km downstream of the site. The Milltown River is located approximately 0.2 km east of the site at its closest point. The Milltown discharges to Dingle Harbour c. 0.9 km south-east of the site and c.0.5 km from the Milltown River- Kilfountan River confluence. Land drains are located along the northern and southern boundaries of the site and surface water runoff entering these drains likely flows towards this river.

3.2.1 Conceptual Site Model (CSM)

A revised conceptual site model has been prepared as part of the Tier 2 assessment and is included below for reference. The revised CSM illustrates the identified potential groundwater and landfill gas pathway from the site to nearby residential areas.



CROSS SECTION NORTH-EAST TO SOUTH-WEST

FIGURE 5.1 DINGLE HISTORIC LANDFILL

CONCEPTUAL SITE MODEL

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3.3 Impact of Leachate on Groundwater

The site location is underlain by a 'Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones'. The aquifer vulnerability is classified as being moderate at the site, indicating that the aquifer at this location is moderately vulnerable to and moderately influenced by rainwater infiltration at the site, and by any pollutants migrating vertically to the bedrock aquifer. Although the underlying bedrock aquifer may not be at a significant risk directly, as discussed above, the generation of leachate via infiltration of rainwater through the shallow soil cap and underlying waste, and migration of that leachate to surrounding surface water drainage and the adjacent stream is a risk.

3.3.1 Potential Leachate Generation

In quantifying the potential impact that the leachate generated at the historical landfill may have on the groundwater or surface water receptors, it is important to estimate the quantity of leachate or contaminated groundwater produced at the site. As part of the Tier 2 site investigation static groundwater levels within groundwater monitoring wells BH01 and BH02 were measured on two separate occasions in July and September, yielding average static water levels of 8.807 mAOD and 6.746 mAOD at BH01 and BH02 respectively. These measurements indicated that the static groundwater level is below the waste body. This suggests that the generation and subsequent vertical migration of leachate is driven predominantly by rainfall percolation inputs through the waste body, as opposed to the lateral movement of groundwater through the waste body.

The vertical infiltration of rainfall above the site to the underlying groundwater aquifer is determined by the groundwater recharge rate at this site. The recharge coefficient applied by GSI to the entire historical landfill area is 22.5%. Applying an effective rainfall rate 1,120 mm/year this equates to a recharge rate of 252 mm/year. GSI do apply a recharge cap of 200 mm/year based on the classification of the aquifer as being only a 'locally important aquifer', for the purpose of this exercise a conservative value of 252 mm/year is applied.

22.5% x 1,120 mm/year = 252 mm/year or 0.252 m/year (available rainfall for recharge over the landfill area

Aquifer Recharge Volume = Recharge x area of landfill

Aquifer Recharge Volume = 0.252 m/year x 26,000 m^2

Aquifer Recharge Volume over landfill area = 6,552 m^3/year ***[17.95 m^3/day]***

3.3.2 Leachate Dispersion Modelling and Assessment

To further determine the potential downstream concentration of leachate/contaminated groundwater generated at the site and the potential risks it may pose to groundwater downstream and subsequently surface water the Hydrogeological Risk Assessment for Land Contamination - Remedial Targets Worksheet developed by the UK Environment Agency's Science Group was utilised.

This model is generally used to develop remediation targets in soil or groundwater to ensure a desired downstream concentration at a point e.g. a well or other receptor downstream. The model allows the user to predict at what point in time and distance that the desired groundwater concentration will be met.

This assessment tool was used to predict the potential groundwater concentration for select parameters downstream of the site. The model relies on the following (simplified) inputs:

- Source characteristics (i.e. leachate species concentration, retardation, half-life).
- Aquifer characteristics (permeability, porosity, hydraulic gradient).

The UK EA worksheet relies on the input of single values therefore it was necessary to make several assumptions based on available site-specific data, and typical values obtained from literature and understanding of the site.

The input parameters used in this model are outlined in Table 3-1 below:

Table 3-1: UK EA Remedial Targets Worksheet Model Inputs

Input Parameter	Unit	Manganese	Source
Target Concentration	*mg/l*	0.05	S.I No. 9 of 2016 and EPA IGV
Initial contaminant concentration in groundwater at plume core	*mg/l*	3.69	Manganese: groundwater concentration at BH02 (in waste/edge of waste body)
Half-life for degradation of contaminant in water	*days*	$1x10^9$	Assumed high value (no degradation)
Width of plume in aquifer at source (perpendicular to flow)	*m*	110	Approximate width of site/waste extent based on site investigation
Plume thickness at source	*m*	7	Assumed thickness, S>I did not confirm depth to bedrock. Site is underlain by sands and gravels
Saturated aquifer thickness	*m*	14	Assumed aquifer thickness, depth to bedrock unknown. Modelling groundwater movement in underlying sands and gravels
Bulk density of aquifer materials	*g/cm3*	2	Assumed sands and gravels
Effective porosity of aquifer	*fraction*	0.385	Assumed porosity based on range of values for sands and gravels referenced in Environmental Agency Landsim manual
Hydraulic gradient	*fraction*	0.008	Estimate based on elevations gradient between BH01 and BH02 (2019 S.I)

Input Parameter	Unit	Manganese	Source
Hydraulic conductivity of aquifer	*m/d*	0.01728	Assumed - within range of typical values for sands and gravels
Distance to compliance point	*m*	300	Hypothetical compliance point distance
Time Since Pollutant entered groundwater	*days*	25, 50, 100, 500 and 1000 years [9,125, 18,250,36,500, 182,500, 365,000 days]	Time intervals selected
Soil Water Partition Co-efficient	*l/kg*	0	Value of 0 applied as a conservative approach

Note 1: BH01 manganese concentration is comparable to UK leachate inventory 'most likely' value of 0.78 mg/l.

3.3.3 Results – EA UK Remedial Targets Worksheet

This model was used to estimate the dispersion of manganese. Manganese was shown to exceed the EPA Interim Guideline Value (IGV) for groundwater quality in samples obtained from groundwater monitoring well BH02. Although elevated concentrations of manganese above the groundwater quality threshold value can be attributed to the natural geological characteristics of the area, the significant difference in concentrations between upstream well BH01 and downstream well BH02 indicated that the historical landfill may be influencing manganese concentrations in groundwater beneath the site. The groundwater concentrations at a range of distances from the source at different time intervals are presented in Table 3-2 below.

The range of distances are automatically generated by the model based on the percentages of the compliance point distance (300 m) i.e. 15 m [5%], 75 m [25%], 150 m [50%] and 300 m [100%].

Table 3-2: Modelled Downstream Concentrations (UK EA Remedial Targets Worksheet)

Manganese (mg/l)			*Groundwater threshold Value (GTV) = 0.05 mg/l*		
Years of Dispersion	Initial Plume Concentration (mg/l)	*Conc.at 15m (mg/l)*	*Conc. at 75 m (mg/l)*	*Conc. at 150m (mg/l)*	*Conc. at 300 m (mg/l)*
25	3.69	**0.729**	0	0	0
50	3.69	**1.212**	0.001	0	0
100	3.69	**1.711**	0.035	0	0
500	3.69	**2.857**	**1.131**	**0.165**	0.0001
1000	3.69	**3.273**	**1.893**	**0.772**	0.0336

Note 1: Soil-water partition co-efficient of 0 l/kg was applied for this modelling scenario.

3.3.4 Discussion of Results

The model was used to predict downgradient concentrations of manganese at 15 m, 75 m, 150 m and 300 m downstream of the site after the stated number of years of dispersion (25, 50, 100, 500 and 1000 years) at the defined permanent source concentrations.

The model assumed a worst-case scenario of a **non-depleting** source concentration. This is very conservative estimate and assumes that there will be no ongoing dilution and dispersion of contaminants, reducing the source concentration over time.

Modelling, following a review of concentrations in BH02, assumed a manganese source concentration of 3.69 mg/l based on groundwater monitoring results at groundwater monitoring well BH02. The EA UK Leachate Inventory advises typical leachate concentrations range between 0.78 mg/l and 324 mg/l.

The model predicted some dispersion of manganese beyond the site with concentrations exceeding the groundwater quality threshold value at 15 m from the source at all time intervals. The model also predicted exceedances at 75 m and 150 m from the source after 500 years of dispersion. Whilst the model assumed a non-depleting source potential pollutant within the waste body and leachate will most likely deplete over time and the plume will most likely deplete after 100 or more.

Overall, the model suggests that:

- Pollutant dispersion is likely to be a local issue and that the historic landfill is unlikely to influence groundwater quality regionally.
- Elevated concentrations of manganese in groundwater may arise from naturally occurring manganese in both bedrock and leachate.
- Contamination of groundwater locally may potentially impact surface water quality.

Given the risk of local contamination to both ground and surface waters remedial works are required.

3.4 Impact of Leachate on Receiving Surface Waters

The potential impact of leachate emissions to the adjacent river along the western boundary of the site was identified as being a primary risk associated with the site. Although surface monitoring did not show a significant difference water quality between upstream and downstream samples, concentrations of manganese and chloride (in particular) and ammoniacal nitrogen detected in groundwater monitoring boreholes installed at the site were elevated and shown to exceed the relevant groundwater quality threshold. Ammonia is a commonly occurring pollutant associated with landfills as well as agricultural activity, which can pose a risk to surface waters.

The evidence of residual leachate and contamination of groundwater, as indicated by groundwater monitoring shows that a potential source of contamination to surface water remains at the site.

Although surface water monitoring did not indicate contamination, it was limited to two monitoring rounds. The potential impact of the site on the Kilofountain River was further assessed by conducting an assimilative capacity assessment and a mass balance calculation with ammonia chosen as a representative potential pollutant. A copy of the assimilative capacity and mass balance calculations are included in Appendix 3.

3.4.1 Assimilative Capacity Assessment

Table 3-3 shows the assimilative capacity of receiving waters in relation to Ammonia to be **0.17 kg/day**:

Table 3-3: Assimilative Capacity

Assimilative capacity = (C_{max} – C_{back}) x F95 x 86.4 kg/day		
Where:	Value	Source
C_{max} = maximum permissible concentration (EQS – 95%ile value) (mg/l)	0.14	95%-ile 'good' status threshold as per S.I No. 77 of 2019 - European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019
C_{back} = background upstream concentration (mg/l mean value)	0.035	Assumed background concentration as per 2014 baseline concentration from EPA monitoring Station RS22M030300 on Milltown River (c. 450 m north-east).
F95 = the 95%ile flow in the river (m^3/s)	0.019	Obtained from online EPA Hydrotool for river segment adjacent to site.
Assimilative Capacity kg/day	**0.17**	AC (kg/day) = (0.14 - 0.035) x 0.019 x 86 .4

3.4.2 Potential Impacts of Leachate Breakouts on Receiving Surface Waters

To determine potential impacts that leachate surface breakouts from the landfill may have on the assimilative capacity of the receiving water body, the mass of ammonia discharging from the site is calculated applying the equation below.

Mass Emission (kg/day) = Discharge Flow (m^3/day) x Concentration (mg/l) /1000

Assumed criteria:

- *Flow range of assumed leachate breakouts:* 1-5 l/s
- *Concentration of ammonia in leachate:* 0.4 mg/l NH_4 based on BH02 observations
- *Significant pollution threshold if:* > S.I. No. 77 of 2019 ('Good' status mean 0.065 mg/l) or > S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l)

A range of assumed discharge flows (1 - 5 litres/second) was applied and the percentage of the assimilative capacity removed following discharge to the receiving water was also calculated (Daily Mass Emission ÷ Assimilative Capacity). A discharge ammonia concentration of 0.4 mg/l (highest ammonia observation from groundwater BH02) was assumed for this calculation. The calculated mass emissions and the impacts on the assimilative capacity, for a range of assumed discharge rates, of the receiving water are shown in Table 3-5.

3.4.3 Mass Balance Assessment

A mass balance calculation was used to determine the potential change in ammonia concentration within the receiving water downstream of the discharge. The following calculation as shown in Table 3-4 was applied.

Table 3-4: Mass Balance Calculation

T = (FC + fc)/(F + f)		
Where:		*Source*
F is the river flow upstream of the discharge (95%ile flow m^3/sec);	0.019	Obtained from online EPA Hydrotool for river segment adjacent to site.
C is the concentration of pollutant in the river upstream of the discharge (mean concentration in mg/l);	0.035	Assumed background concentration as per 2014 baseline concentration from EPA monitoring Station RS22M030300 on Milltown River (c. 450 m north-east).
f is the flow of the discharge (m^3/sec);	0.001 to 0.005	Assumed discharge rate
c is the maximum concentration of pollutant in the discharge (mg/l);	0.40	Maximum concentration of ammonia (NH_4) detected in BH02
T is the concentration of pollutant downstream of the discharge.	Varies 1-5 l/s	Predicted ammonia concentration in receiving water downstream of discharge
Water Quality Standard (mg/l)	0.140	'Good' Status 95%-ile as per S.I No. 77 of 2019
	0.065	'Good' Status Mean as per S.I No. 77 of 2019

Table 3-5: Potential Impacts of Leachate Breakouts on Assimilative Capacity of Receiving Downstream Waters

Assumed Leachate Breakout Flow (l/s)	Assumed Leachate Breakout Flow (m^3/day)	Daily Mass Emission (kg/day) assuming NH_4 concentration 0.4 mg/l	% Impact Breakout has on of Assimilative Capacity (see Note 3)	Estimated Downstream Concentration NH_4 (mg/l)
1	86	0.035	20%	0.053
2	173	0.069	40%	0.070
3	259	0.104	60%	0.085
4	346	0.138	80%	0.098
5	432	0.173	100%	0.111

Note 1: Water quality standard as per S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l).

Note 2: Water quality standard as per S.I. No. 77 of 2019 ('Good' status mean 0.065 mg/l).

Note 3: Assimilative capacity assumed to be 0.17 kg/day ammonia (Table 3-3).

Table 3-5 results show that leachate discharge flow rates of 3, 4 and 5 litres/s (259, 346 and 432 m^3/day) will be compliant with S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l).

However downstream concentrations exceed the S.I. No. 77 of 2019 'Good' status mean concentration of 0.065 mg/l NH_4 and have potential to moderately impact the assimilative capacity of the river with reference to mean flows.

At discharge rates of 1, 2 and 3 litres/s (86, 173 and 259 m^3/day) the discharges to surface waters will consume 20%, 40% and 60% respectively, of the assimilative capacity of the river, with respect to ammonia. Under these flow rates estimated downstream ammonia concentrations comply with both "Good" status mean and "Good" status 95%-ile flows.

Tables 3-4 and 3-5 mass balance calculation predicts that leachate breakouts containing of 0.40 mg/l NH_4 will cause downstream concentrations of ammonia 0.053 mg/l to 0.111 mg/l for flow rates between 1 and 5 l/s.

3.4.4 Discussion of Results

Overall the above assessment shows that:

- For low leachate breakout flow rates (1 to 3 l/s) the downstream surface water assimilative capacity will be able to accommodate leachate breakouts containing up to 0.40 mg/l NH_4. Under these flow rates the risk of ammonia contaminating receiving surface waters is low for both mean and 95%-ile flows.
- For higher leachate breakout flows (4 to 5 l/s) the downstream surface water assimilative capacity will be unable to accommodate leachate breakouts containing up to 0.40 mg/l NH_4 for 'Good' status mean flows. Under these flow rates the risk of ammonia contaminating receiving surface waters will be significant for 'Good' status mean flows albeit that receiving waters will be compliant with 95%-ile flows low.

On the basis of visual site observations, the leachate breakout flow rates were estimated to be between 1 and 5 l/s. In the absence of detailed breakout flow rate information being available, the CoP requires a conservative approach to be adopted. Accordingly, remedial measures will be required to mitigate the risk of leachate breakout contaminating receiving surface waters.

3.5 Landfill Gas Assessment - LandGEM

LandGEM is an excel based screening model developed by the US EPA for estimating the quantity of landfill gases generated during both the operational phase of a landfill and post-closure of the landfill. The model applies a first-order decomposition rate equation to estimate the quantity of landfill gases being produced from decomposing waste present in a landfill.

The model relies on a limited number of inputs, some of which are supplied within the model as a variety of default values and site-specific information provided by the user. A summary of the model inputs used for this Tier 3 assessment are presented in Table 3-7 below.

Site remediation including the installation of an engineered cap at the historical landfill can alter the current landfill gas migration regime and as such may present a potential risk associated with landfill gas migration from the site. The results of this model will aid in informing what, if any, remedial measures or control measures should be put in place to mitigate or monitor that risk.

Monitoring for landfill gases emitted from offsite wells BH01 and BH02, was conducted in October 2019 as part of the Tier 2 site investigation. Monitoring wells BH01 and BH02 yielded methane concentrations of 0.4% v/v and 0.6% and carbon dioxide concentrations of 0.6% v/v and 0.9%v/v respectively. In accordance with the EPA CoP the trigger level for methane outside the waste body is 1.0% v/v for methane and 1.5% v/v for carbon dioxide. As evident these results are below each threshold.

Table 3-6: Landfill Gas Monitoring Results October 2019

Date: 23/10/2019						
Sample Station	CH_4 (% v/v)	CO_2 (% v/v)	O_2 (% v/v)	Atmospheric Pressure (mbar)	Staff Member	Weather
BH01	0.4	0.6	22.3	1005	Emily Archer	Scattered cloud with light showers, 8-12°C
BH02	0.6	0.9	21.9			

Although the concentrations are shown to be below the EPA trigger levels for offsite locations the relative proximity of existing commercial property to the site presents a potential risk.

Table 3-7: LandGEM Model Inputs

Landfill Characteristics	Input	Source
Landfill Open Year	1980	Exact timeframe of landfill operation is unknown. Assumed site to be operational through the 1970s. Start of filling operations assumed.
Landfill Closure Year	1996	Anecdotal evidence suggests landfilling activities ceased c.1996
Have Model Closure Calculate Closure Year	Yes	
Waste Design Capacity (megagrams/tonnes)	105,728	Mass based on estimated waste volume determined as part of Tier 2 assessment and site investigation.

Determining Model Parameters		
Methane Generation Rate, k (year^{-1})	CAA Conventional – 0.05	Default value – maximum values applied as a conservative worst-case scenario approach
Potential Methane Generation Capacity, L_0 (m^3/Mg)	CAA Conventional – 1070	
NMOC Concentration (ppmv as hexane)	CAA – 4,000	
Methane Content (% by volume)	CAA – 50% by volume	
Select Gases/pollutants		
Gas/Pollutant #1	Total Landfill Gas	Standard – No other specific gases of concern
Gas/Pollutant #2	Methane	
Gas/Pollutant #3	Carbon Dioxide	
Gas/Pollutant #4	NMOC	
Enter Waste Acceptance Rates (Mg/year)		
1980 - 1996	6,608	Exact waste acceptance quantities per year are unknown. Worst case assumed waste design capacity was filled equally over 1980 to 1996 (16 year) period

3.5.1 Results - LandGEM

As an output, LandGEM produces a report on the model inputs and outputs. This report is included in Appendix 2 of this report. LandGEM estimates the mass and volume of landfill gases generated both during the operational/filling phase of the landfill and beyond. The estimated quantity of gas generated for the current year (2019) and after 10 years of further +degradation (2029) are presented in Table 3-8. The model predicted that the site is currently generating 22 m^3/hr of methane across the entire site area. This will reduce to 14 m^3/hr by 2029.

Table 3-8: Estimated landfill Gases Generated (2019 and 2029)

Gas/Pollutant	Tonnes/year		m^3/year		tonnes/hour		m^3/hour	
	2019	2029	2019	2029	2019	2029	2019	2029
Total Landfill Gas	490	297	392,724	238,199	0.06	0.03	45	27
Methane	131	79	196,362	119,100	0.01	0.01	22	14
Carbon dioxide	359	218	196,362	119,100	0.04	0.02	22	14
NMOC	6	3	1,571	953	0.00	0.00	0.18	0.11

The approximate maximum waste deposition footprint was estimated to be approximately 26,600 m^2. The estimated volume and mass of landfill gas generated and potentially released per m^2 of the total landfill area are presented in Table 3-9.

Table 3-9: Estimated gases generated/released per m^2 (2019)

Gas/Pollutant	Tonnes/year/m^2	m^3/year/m^2	tonnes/hour/m^2	m^3/hour/m^2
Total Landfill Gas	0.019	15	0.000	0.002
Methane	0.005	8	0.000	0.001
Carbon dioxide	0.014	8	0.000	0.001
NMOC	0.000	0.060	0.000	0.000

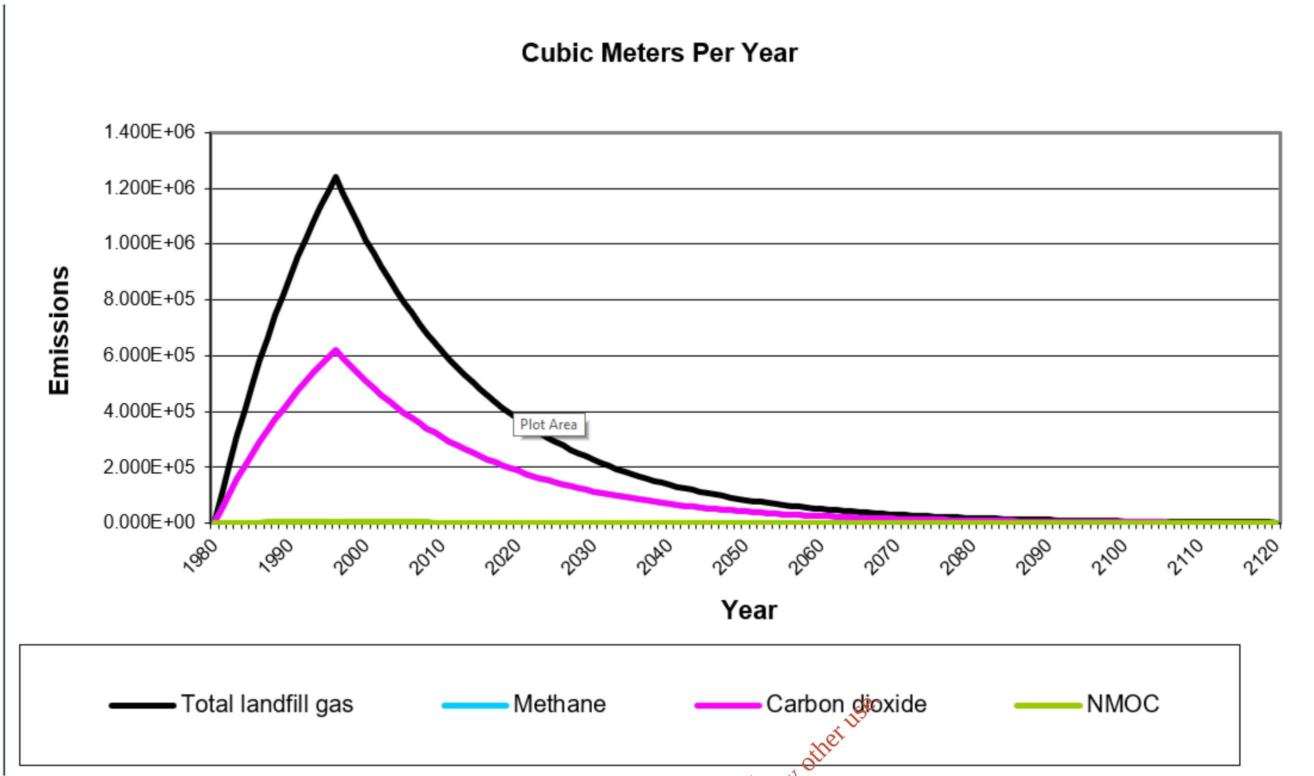
3.5.2 Discussion of Results

The outcome of the LandGEM model predicts a low rate of landfill gas generation in 2019 (45 m^3/hr).

The EPA guidance document, 'Management of Low Levels of Landfill Gas' prepared by Golder Associates Ireland Ltd outlines readily available flaring technologies that meet EPA requirements on temperature and retention specifications. These technologies generally require gas flow rates ranging from 40-2,500+ m^3/hr. with methane contents ranging from 10 to 50+ percent. The lowest methane content referring to Low-CV (Calorific value) flare technology.

As shown in Table 3-8 LandGEM estimated that in the current year (2019) a relatively moderate quantity, of 45m^3/hour of landfill gas across the whole site is generated and assuming 50% percent of that volume being methane (22m^3). Landfill gas monitoring of groundwater wells conducted in 2019 yielded only trace amounts of methane present, at 0.4% v/v and 0.6%v/v. The LandGEM model suggests that at the estimated quantity of waste deposited at the site that methane production is still occurring in low quantities and will continue for a number of years.

Figure 3-2 below shows the estimated landfill gas generation rates per year during the assumed operational phase (c.1980 to 1996) and predicted generation rates from 1996 onwards following closure of the site. It is noted that the model assumes equal production rates for both methane and carbon dioxide and are represented by the pink trendline.



Note 1: LandGEM assumes methane and carbon dioxide production volumes are equal and the magenta line shown represents both methane and carbon dioxide.

Figure 3-2: LandGEM Landfill Gas Volume Generation Rate

The complete summary report on model inputs and outputs/results generated by LandGEM is included in Appendix 2 of this report.

4. SUMMARY FINDINGS AND RECOMMENDATIONS

4.1 Summary Findings

This Tier 3 assessment:

- Reviewed the findings of the Tier 1 risk assessment.
- Reviewed the findings of the Tier 2 site investigation and risk assessment.
- Assessed and determined the overall risk the site may pose to the receiving environment.
- Determined appropriate measures to mitigate or eliminate that risk.

Subsequent reviews in this Tier 3 assessment determined:

- The site to be a High Risk (Class A), with the main risk being the direct connection between the waste body and the adjacent stream and its connection to downstream surface water bodies, albeit predictive modelling showed that an impact would only occur at very high leachate discharge rates being discharged under low flow conditions, i.e. resulting in low dilution of pollutants.
- The site presents high risks to surface water and potential human receptors.
- The risk of landfill gas to nearby human receptors

Intrusive site investigations showed that the site only comprises a shallow soil cap (min: 0.1 m, max: 0.6 m, average: 0.29 m) and determined:

- The shallow cap may facilitate deep percolation inputs following rainfall which may result in increased leachate generation.
- Potential landfill gas emissions from the waste body were present.

Quantitative risk assessments of potential leachate generation from the site, determined:

- On a regional scale, the site does not pose a risk to the groundwater quality of the underlying groundwater body, and
- The site occupies only 0.007% of the groundwater body area.

However, the presence of waste which and the migration of leachate to the underlying groundwater and the proximity of the site to a river means that:

- There is an inherent risk to surface water quality.
- The presence of waste may pose a risk to groundwater quality at a local level.
- The presence of waste may pose a landfill gas migration risk

4.1.1 Surface Water

The assimilative capacity assessment and mass balance calculations indicated that:

- Potential breakout of leachate and discharge to the adjacent river is unlikely to have a significant impact on water quality downstream of the site.
- The receiving river is likely to have sufficient assimilative capacity to accommodate a potential leachate emission at the site.

A mass balance calculation was carried out to predict the potential concentration of ammonia within the river downstream of the site, assuming discharge rates of 1l/s to 5l/s of leachate to the river. The calculation predicted:

- The background concentration of 0.035 mg/l would increase to downstream concentrations ranging from 0.053 mg/l to at 0.111 mg/l.
- At all assumed flow rates the predicted downstream concentrations remains below the 95%-ile threshold value (0.140 mg/l) while the mean threshold value (0.065 mg/l) is only exceeded at (high) flow rates of 3 l/s , 4 l/s and 5 l/s as per the *European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019 - S.I No. 77/2019.*

4.1.2 Groundwater

The groundwater contamination assessment used the UK EA Remedial Targets Worksheet model to examine the potential impacts on groundwater quality beneath the waste body. The model indicated that the potential impact on groundwater quality may be localised with the EPA IGV limit for groundwater quality limit only being exceeded at 150 m from the source after 500 years of dispersion. The model assumed a non-depleting source and therefore, it is more likely that after this period, pollutants would not be continuing to leach from the waste body at high concentrations or continue to cause a deterioration in groundwater quality. The presence of a stream immediately adjacent to the site presents an inherent risk, whereby any impact on groundwater locally or directly beneath the site could impact this stream and downstream receiving surface waters.

4.1.3 Landfill gas

The landfill gas assessment using LandGEM showed that landfill gas will continue to be generated for several years at relatively low flow rates. Gas monitoring did not indicate elevated gas concentrations and applying the EPA risk scoring tool, the risk of landfill gas migration was deemed to be low.

In the absence of an engineered cap the preferential pathway historically would have been diffuse, vertical migration through the existing shallow cap.

The EPA Landfill Site Design Manual Guidance for Non-hazardous Landfills EA recommends a minimum 1.0 m cap over waste. Once constructed this may cause a consequential side effect that may increase the risk of lateral gas migration. Accordingly, landfill gas management measures will be required in the site remediation plan to minimise the risk of lateral landfill gas migration in accordance with the EPA Guidance document: *Management of Low Levels of Landfill Gas. Appropriate measures are* are discussed in Section 5.0 of this report.

4.2 Recommendations

In summary, because the site has a shallow soil cover on the *insitu* cap, the Tier 3 environmental risk assessment:

- Confirmed the risk rating of the site to be High risk (Class A).
- Determined the need for remedial works.

The primary objectives of the proposed remedial capping works will be to mitigate:

- The risk to animals and human receptors.
- The risk of leachate contaminating ground and surface waters.
- Mitigate the risk of landfill gas impacting nearby receptors via lateral migration.

Further details regarding the proposed landfill cap are discussed in Section 5.

5. REMEDIAL ACTION PLAN

5.1 Overview of the Risks

5.1.1 Tier 3 Summary Findings

The existing site has an established grass cover used by cattle for grazing. Site walkovers and Tier 2 and 3 risk assessments showed:

- An in-situ landfill cap that is not compliant with either the Landfill Directive or Environmental Protection Agency (EPA) publication landfill manual - Landfill Site Design.
- Evidence of:
  - In-situ mixed and primarily municipal solid wastes.
  - Low-level landfill gas emissions.
- Potential for leachate to contaminate receiving surface and groundwaters.
- Proximity to buildings and adjacent permeable road formation.

5.1.2 Overview of the Primary Risks

The primary issue of concern associated with the Dingle site is its shallow cap (average thickness 0.29 m). The EPA Landfill Site Design Manual Guidance for Non-hazardous Landfills requires a minimum thickness of 1.0 m.

The existing shallow cap has potential, albeit low, to:

- Expose animals to waste and negatively impact both animal welfare, and because the animals are used as a feed source, human welfare.
- Allow rainfall ingress to potentially produce leachate that may subsequently contaminate receiving surface and groundwaters.

5.1.3 Objectives of the Proposed Remediation Plan

The proposed remediation plan objectives will be to:

- Mitigate the risk of animals coming into contact with waste by increasing the cap thickness to 1.0 m.
- Isolate the waste body from rainfall inputs to:
  - Mitigate the risk rainfall percolation inputs producing of leachate that might otherwise contaminate adjacent surface and ground waters.
  - Reduce groundwater flows below the waste body and so mitigate the risk of elevated groundwater flushing contaminants from the base of the landfill into adjacent ground and surface waters.
- Facilitate passive venting of landfill gas as may be present via a controlled outlet in the engineered cap to mitigate the risk of lateral gas migration.

5.2 Remediation Plan

5.2.1 Proposed Engineering Solution

The proposed remediation plan to address these issues shall:

- Require an engineered cap over the in-situ cap using guidance presented in the EPA Landfill Site Design Manual Guidance for Non-hazardous Landfills.
- Be cognisant of the future site use and proposed adjacent developments.

The preliminary remediation design footprint with a typical indicative cross section is presented in Appendix 4 on drawing:

- P1788-0101-0001

The engineered cap solution will need to make provision for a 1.0 m thick cap comprising:

- A topsoil layer to support a grass cover.
- A subsoil layer to facilitate, in combination with topsoil, cap thickness not less than 1.0 m
- A surface drainage system manage surface water runoff.
- A subsurface drainage system to manage rainfall percolation inputs above the proposed barrier layer.
- A barrier system to isolate the waste body from rainfall inputs with vertical cut-offs on all boundaries.
- A gas management system to facilitate safe passive venting, and/or oxidation of methane if required, of landfill gas emissions.

5.3 Engineered Cap

5.3.1 Engineered Cap

The engineered cap shall comprise:

- 200 mm topsoil, on
- 800 mm subsoil, on
- Subsurface drainage geocomposite and collection pipework or similar, on
- Barrier (LLDPE) including vertical cut-offs, on
- Gas collection system, on waste with provision to manage below liner leachate that may be released in the short term following secondary consolidation.
- Provision for future ground and surface water monitoring

Construction details for respective elements of the proposed cap will be subject to prior Agency approval.

Key design recommendations for respective elements are listed below under respective section headings.

5.3.2 Topsoil

Topsoil 200 mm shall be placed on top of the subsoil. Topsoil shall be seeded with a robust pasture or similar durable grassland mix.

Topsoil shall be compliant to BS3882:2015 or equal approved and graded to ensure no localised surface depressions are present.

5.3.3 Subsoil

Infill subsoil materials will be required to re-profile the landfill to fill in localised depressions.

Subsoil, minimum thickness 800 mm, shall be provided using a uniformly graded material with stone sizes not greater that 50 mm or equal approved.

5.3.4 Surface drainage

Surface drainage layouts using grassed waterways or similar shall collect and direct surface water runoff including subsurface drainage outfall flows to one or more dedicated surface drainage outfalls into existing surface water perimeter drain(s).

Surface drainage shall be designed to mitigate the risk of rill or gully erosion giving rise to suspended solid loadings from the cap entering receiving waters.

5.3.5 Subsurface drainage on cap

A subsurface drainage layer on the cap barrier (hydraulic conductivity should be equal to or greater than $1x10^{-4}$ m/s for a thickness of 500 mm) or equal approved geocomposite shall be placed between the subsoil and barrier layer.

The drainage layer shall discharge to a subsurface pipe work collection system and thence to the surface drainage system.

5.3.6 Barrier System

The barrier system shall use 1.0 mm LLDPE or similar approved.

This barrier will require vertical cut-offs on all boundaries to mitigate the risk of lateral landfill gas migration.

Vertical cut-offs shall be installed using LLDPE cap liner, shall be welded to the LLDPE liner and shall terminate a minimum of 3.0 m below existing ground level. The primary objective of the cut-off on the eastern boundary will be to mitigate the risk of lateral groundwater migration into adjacent stream. Its secondary function will be to prevent lateral gas migration.

Vertical cut-offs on the western boundary adjacent to the railway line shall be immediately adjacent to the existing surface water drains and shall be located to the east of the existing drains. The primary function of the vertical cut-off on the western boundary will be to mitigate the risk of lateral gas migration. The barrier to lateral gas migration will be the vertical cut-off and saturated water conditions below the drain.

Similar vertical cut-offs on the northern and southern boundaries shall be installed to mitigate the risk of lateral gas migration.

5.3.7 Landfill Gas Collection System

The landfill gas collection system shall comprise an under-liner gas collection geocomposite or similar approved stone drainage layer. The Landfill Directive does not define a thickness or permeability. The EPA Landfill Site Design manual advises equivalence should not be less than a 150 mm stone layer with a hydraulic permeability of $1x10^{-4}$m/s.

The gas collection layer shall make provision for:

- Passive venting of landfill above the liner with methane oxidation if required.
- Management of below liner leachate breakouts following secondary consolidation or condensate using gravel soakaways or similar approved.

The landfill gas collection system design will require:

- A gas pump test to define gas flow rate and gas quality.
- A gas management risk assessment to mitigate environmental pollution in accordance with best practice.
- Measures to mitigate risks of asphyxiation and explosion.
- An updated gas prediction model, with reference to the gas prediction model presented in this report to facilitate selection of the most appropriate landfill gas management solutions be they venting and/or oxidation as may be required.

Gas vent stacks (150 mm diameter pipe) if required shall terminate at least 3.0 m above adjacent ground surfaces and be detailed to prevent rainfall ingress and insertion of ignition sources (cigarettes or other).

Biological methane oxidation filters if used shall be excavated into the cap, fenced and isolated from pedestrian, vehicular or animal activities.

Existing wells on site shall be capped and retained for future monitoring as may be required.

Vertical wells used for the gas pump test shall be used for future landfill gas monitoring and or extraction as may be required.

5.3.1 Proposed Groundwater and Surface Water Monitoring Regime

The EPA Landfill Monitoring landfill manual outlines recommended, minimum monitoring requirements for ground and surface waters. These parameters are shown in Table 5-1 below and are as presented in Table C.2 of the EPA's *Landfill Manuals - Landfill Monitoring, 2nd Edition (2003).*

Groundwater monitoring shall be carried out at existing perimeter wells BH1 and BH2 and surface water monitoring shall be carried out at the proposed surface water discharge outfall in the north west corner of the site annually in accordance parameters listed in Table 5-1.

Surface water monitoring shall be measured at proposed SW1 downstream location.

Table 5-1: Parameters for Monitoring of Groundwater and Surface Water

Monitoring Parameter[2]	Frequency	Surface Water	Groundwater
Fluid Level	Annual	-	-
Flow Rate		-	-
Temperature		✓	✓
Dissolved Oxygen		✓	-
pH		✓	✓
Electrical Conductivity[3]		✓	✓
Total suspended solids		✓	-
Total dissolved solids		-	✓
Ammonia (as N)		✓	✓
Total oxidized nitrogen (as N)		✓	✓
Total organic carbon		-	✓
Biochemical Oxygen Demand		✓	-
Chemical Oxygen Demand		✓	-
Metals[4]		✓	✓
Total Alkalinity (as $CaCO_3$)		✓	✓
Sulphate		✓	✓
Chloride		✓	✓

[2] Tables D.1 and D.2 of the EPA Landfill Monitoring manual recommend guideline minimum reporting values for parameters.

[3] Where saline influences are suspected, a salinity measurement should also be taken.

[4] Metals for analysis should include: calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium (total), copper, nickel, lead, zinc, arsenic, boron and mercury.

Monitoring Parameter[2]	Frequency	Surface Water	Groundwater
Molybdate Reactive Phosphorous[5]		✓	✓
Cyanide (Total)		✓	✓
Fluoride		✓	✓

5.3.2 Proposed Gas Monitoring Regime

Gas monitoring shall be carried out at existing site boreholes (2 No), proposed new gas bore holes (4 No) and at any future oxidation or venting outlet and at the 3 No proposed perimeter monitoring wells LG 01 through LG03.

Subject to agency approval it is recommended that:

- Gas monitoring be carried out annually.
- Vertical gas monitoring wells be allowed to vent passively throughout the year.
- Prior to annual monitoring, well vents should be closed for a period of 24 hours to allow representative sampling.

Gas sampling should be carried out using a calibrated gas analyser for the following parameters:

- Methane
- Carbon dioxide
- Oxygen
- Carbon monoxide
- Temperature.

5.4 Remediation Cost Estimates

The following section outlines the potential costs associated with the remediation of the site. The costs estimate is limited to "once-off" civil and mechanical and electrical works.

Long term costs associated with maintenance, license compliance and environmental liabilities are not considered.

Table 5.2 outlines the remediation costs associated with capping the site.

[5] Total Phosphorus should be measured in leachate samples where colorimetric interference is likely.

Table 5-2: Remediation Cost Estimate Dingle Historic Landfill

Item	Quantity	Unit	Rate, €	Cost
Design				
Allowance for Additional Site Investigation works	1	Rate	€25,000	€25,000
Detailed Design and Supervision	1	Rate	€75,000	€75,000
Land Rental Costs	1	Rate	€5,000	€5,000
General Site Clearance and Demolition Works	***2.36***	***ha***	-	
General Site Clearance	2.36	ha	€20,000	€47,200
Excavation Works	23600	m^2		
Excavation of Existing Cover/Capping for Reuse/Filling	11800	m^3	€15	€177,000
Landfill Capping Works	23600			
Preparation of Excavated Surfaces	23600	m^2	€1	€17,700
Supply and Installation of 50mm Protection Layer	23600	m^2	€2	€41,300
Supply and Installation of Landfill Gas Collection Layer	23600	m^2	€6	€129,803
Installation of 1mm LLDPE Cap	23600	m^2	€7	€153,400
Installation of Sub Surface drainage collection Layer	23600	m^2	€6	€129,800
Surface drainage	23600	m^2	€1	€23,600
Importation of 800mm Subsoil Capping Layer	23600	m^2	€9	€200,600
Importation of 200mm Topsoil Capping Layer	23600	m^2	€3	€70,800
Seeding	23600	m^2	€2	€47,200
Fencing	614	m2	€100	€61,449
Allowance Landfill Gas Migration Network Infrastructure	4	No	€1,000	€4,000
Allowance Surface Water Drainage Infrastructure	23600	m^2	€4	€94,400
Biological filter	1	Item	€10,000	€10,000
Independent CQA	1	Sum	€15,000	€15,000
Landfill Gas Pumping Trial				
Mobilisation	1	Sum	€3,500	€3,500
Landfill Gas Well ex. M&E, inc. piping and backfill	4	No.	€4,000	€16,000
Landfill Gas Well Heads	4	No.	€500	€2,000
Supporting Infrastructure	1	Sum	€5,000	€5,000
Design, Supervision and Interpretation	1	Sum	€10,000	€10,000
Sub-Total 1				**€1,364,752**
Add 10% Contractor Prelims	10.0%			€136,475
Sub-Total 2				**€1,501,227**
Add 7.5% Contingency	7.5%			€112,592
Grand Total (excl VAT)				**€1,613,819**

FT in making this Engineers Estimate advises the following:

- FT used rates over the period 2018 to 2019 for similar tendered works items where possible and has used engineering judgement to estimate rates & sums where similar rates were not available.
- Management of hazardous materials was not allowed for.
- Pricing was based on a concept design, no detailed designs were prepared.
- The cost estimate assumes that materials to be imported are readily available from local sources.
- The cost estimate excludes VAT.
- The cost estimate excludes in/deflation.
- The estimate includes for a level of contingency as indicated.

Prices may change subject to prevailing market conditions.

FEHILY TIMONEY

CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 1

EA UK Remedial Targets Worksheet

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Manganese		from Level 1
Target Concentration	C_T	5.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Domenico - Time Variant — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to pollutants in all phases (e.g. field derived valu**

	Variable	Value	Unit	Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	3.69E+00	mg/l	*Groundwater concentration a BH01, edge of waste body*
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+09	days	*assumed no degradation*
Calculated decay rate	λ	6.93E-10	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.10E+02	m	*estimated width of waste body*
Plume thickness at source	Sy	7.00E+00	m	*assumed*
Saturated aquifer thickness	da	1.40E+01	m	*assumed double plume thickness, depth to*
Bulk density of aquifer materials	ρ	2.00E+00	g/cm^3	*assumed bulk density for gravels and sand (literature*
Effective porosity of aquifer	n	3.85E-01	fraction	*assumed based on literature values for sands and gravels*
Hydraulic gradient	i	8.00E-03	fraction	*estimated basd on static water level measurements between BH01 and BH02*
Hydraulic conductivity of aquifer	K	1.73E-02	m/d	*assumed - with range of typical hydraulic c*
Distance to compliance point	x	3.00E+02	m	*hypothetical compliance point*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.13E+03	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	0.00E+00	l/kg	*see options*
Longitudinal dispersivity	ax	3.00E+01	m	*see options*
Transverse dispersivity	az	3.00E+00	m	*see options*
Vertical dispersivity	ay	3.00E-01	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.59E-04	m/d
Retardation factor	Rf	1.00E+00	fraction
Decay rate used	λ	6.93E-10	d^{-1}
Rate of contaminant flow due to retardation	u	3.59E-04	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Domenico - Time Variant				
Distance to compliance point		**300**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**0.00E+00**	**mg/l**	Domenico - Time Variant
after		**9.1E+03**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	0.00E+00	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		l/kg
Sorption coefficient for ionised species	$K_{oc.i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	0.00E+00	l/kg

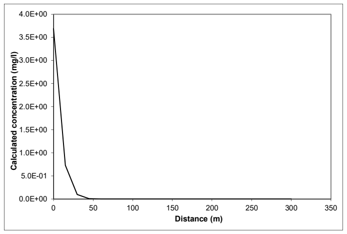
Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	3.00E+01	7.41E+00	m
Transverse dispersivity	**az**	0.00E+00	3.00E+00	7.41E-01	m
Vertical dispersivity	**ay**	0.00E+00	3.00E-01	7.41E-0[illegible]	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Environment Agency



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared
with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Dingle
Completed by:	EOC
Date:	########
Version:	1.01

Calculated concentrations for distance-concentration graph

Domenico - Time Variant
From calculation sheet

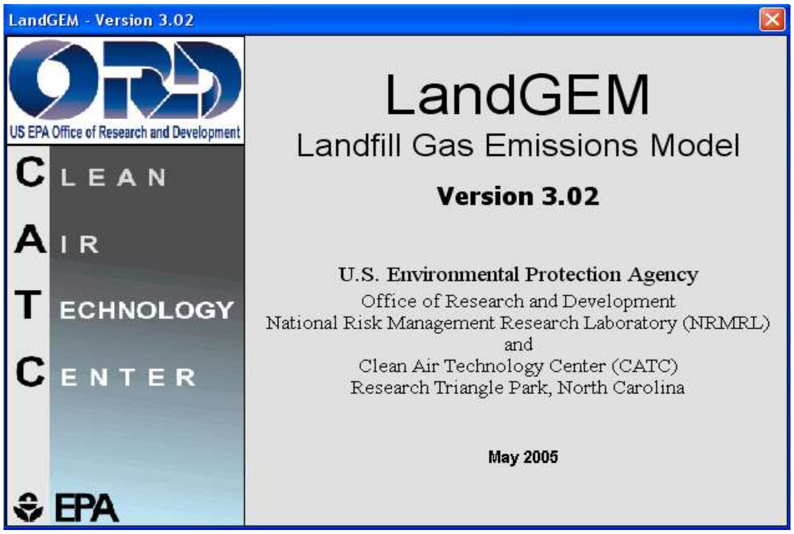
Distance	Concentration
	mg/l
0	3.7E+00
15.0	7.29E-01
30.0	9.42E-02
45.0	4.43E-03
60.0	7.26E-05
75.0	4.02E-07
90.0	0.00E+00
105.0	0.00E+00
120.0	0.00E+00
135.0	0.00E+00
150.0	0.00E+00
165.0	0.00E+00
180.0	0.00E+00
195.0	0.00E+00
210.0	0.00E+00
225.0	0.00E+00
240.0	0.00E+00
255.0	0.00E+00
270.0	0.00E+00
285.0	0.00E+00
300.0	0.00E+00

FEHILY TIMONEY

CONSULTANTS IN ENGINEERING,
ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 2

LandGem Model Summary Report



Summary Report

Landfill Name or Identifier: Dingle Historical Landfill - Co.Kerry

Date: Friday 13 March 2020

Description/Comments:

About LandGEM:

First-Order Decomposition Rate Equation:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10} \right) e^{-kt_{ij}}$$

Where,

Q_{CH4} = annual methane generation in the year of the calculation *(m^3/year)*
i = 1-year time increment
n = (year of the calculation) - (initial year of waste acceptance)
j = 0.1-year time increment
k = methane generation rate (*$year^{-1}$*)
L_o = potential methane generation capacity (*m^3/Mg*)

M_i = mass of waste accepted in the i^{th} year (*Mg*)
t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (*decimal years*, e.g., 3.2 years)

LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in municipal solid waste (MSW) landfills. The software provides a relatively simple approach to estimating landfill gas emissions. Model defaults are based on empirical data from U.S. landfills. Field test data can also be used in place of model defaults when available. Further guidance on EPA test methods, Clean Air Act (CAA) regulations, and other guidance regarding landfill gas emissions and control technology requirements can be found at http://www.epa.gov/ttnatw01/landfill/landflpg.html.

LandGEM is considered a screening tool — the better the input data, the better the estimates. Often, there are limitations with the available data regarding waste quantity and composition, variation in design and operating practices over time, and changes occurring over time that impact the emissions potential. Changes to landfill operation, such as operating under wet conditions through leachate recirculation or other liquid additions, will result in generating more gas at a faster rate. Defaults for estimating emissions for this type of operation are being developed to include in LandGEM along with defaults for convential landfills (no leachate or liquid additions) for developing emission inventories and determining CAA applicability. Refer to the Web site identified above for future updates.

Input Review

LANDFILL CHARACTERISTICS

Landfill Open Year	**1980**	
Landfill Closure Year (with 80-year limit)	**1995**	
Actual Closure Year (without limit)	***1995***	
Have Model Calculate Closure Year?	**Yes**	
Waste Design Capacity	**105,728**	*megagrams*

MODEL PARAMETERS

Methane Generation Rate, k	**0.050**	*$year^{-1}$*
Potential Methane Generation Capacity, L_o	**170**	*m^3/Mg*
NMOC Concentration	**4,000**	*ppmv as hexane*
Methane Content	**50**	*% by volume*

GASES / POLLUTANTS SELECTED

Gas / Pollutant #1:	**Total landfill gas**
Gas / Pollutant #2:	**Methane**
Gas / Pollutant #3:	**Carbon dioxide**
Gas / Pollutant #4:	**NMOC**

WASTE ACCEPTANCE RATES

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	*(short tons/year)*	*(Mg)*	*(short tons)*
1980	6,608	7,269	0	0
1981	6,608	7,269	6,608	7,269
1982	6,608	7,269	13,216	14,538
1983	6,608	7,269	19,824	21,806
1984	6,608	7,269	26,432	29,075
1985	6,608	7,269	33,040	36,344
1986	6,608	7,269	39,648	43,613
1987	6,608	7,269	46,256	50,882
1988	6,608	7,269	52,864	58,150
1989	6,608	7,269	59,472	65,419
1990	6,608	7,269	66,080	72,688
1991	6,608	7,269	72,688	79,957
1992	6,608	7,269	79,296	87,226
1993	6,608	7,269	85,904	94,494
1994	6,608	7,269	92,512	101,763
1995	6,608	7,269	99,120	109,032
1996	0	0	105,728	116,301
1997	0	0	105,728	116,301
1998	0	0	105,728	116,301
1999	0	0	105,728	116,301
2000	0	0	105,728	116,301
2001	0	0	105,728	116,301
2002	0	0	105,728	116,301
2003	0	0	105,728	116,301
2004	0	0	105,728	116,301
2005	0	0	105,728	116,301
2006	0	0	105,728	116,301
2007	0	0	105,728	116,301
2008	0	0	105,728	116,301
2009	0	0	105,728	116,301
2010	0	0	105,728	116,301
2011	0	0	105,728	116,301
2012	0	0	105,728	116,301
2013	0	0	105,728	116,301
2014	0	0	105,728	116,301
2015	0	0	105,728	116,301
2016	0	0	105,728	116,301
2017	0	0	105,728	116,301
2018	0	0	105,728	116,301
2019	0	0	105,728	116,301

WASTE ACCEPTANCE RATES (Continued)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	(short tons/year)	(Mg)	(short tons)
2020	0	0	105,728	116,301
2021	0	0	105,728	116,301
2022	0	0	105,728	116,301
2023	0	0	105,728	116,301
2024	0	0	105,728	116,301
2025	0	0	105,728	116,301
2026	0	0	105,728	116,301
2027	0	0	105,728	116,301
2028	0	0	105,728	116,301
2029	0	0	105,728	116,301
2030	0	0	105,728	116,301
2031	0	0	105,728	116,301
2032	0	0	105,728	116,301
2033	0	0	105,728	116,301
2034	0	0	105,728	116,301
2035	0	0	105,728	116,301
2036	0	0	105,728	116,301
2037	0	0	105,728	116,301
2038	0	0	105,728	116,301
2039	0	0	105,728	116,301
2040	0	0	105,728	116,301
2041	0	0	105,728	116,301
2042	0	0	105,728	116,301
2043	0	0	105,728	116,301
2044	0	0	105,728	116,301
2045	0	0	105,728	116,301
2046	0	0	105,728	116,301
2047	0	0	105,728	116,301
2048	0	0	105,728	116,301
2049	0	0	105,728	116,301
2050	0	0	105,728	116,301
2051	0	0	105,728	116,301
2052	0	0	105,728	116,301
2053	0	0	105,728	116,301
2054	0	0	105,728	116,301
2055	0	0	105,728	116,301
2056	0	0	105,728	116,301
2057	0	0	105,728	116,301
2058	0	0	105,728	116,301
2059	0	0	105,728	116,301

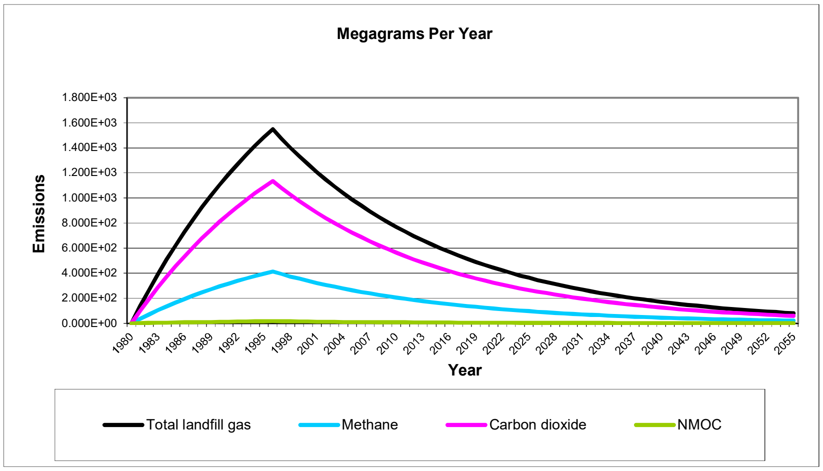
Pollutant Parameters

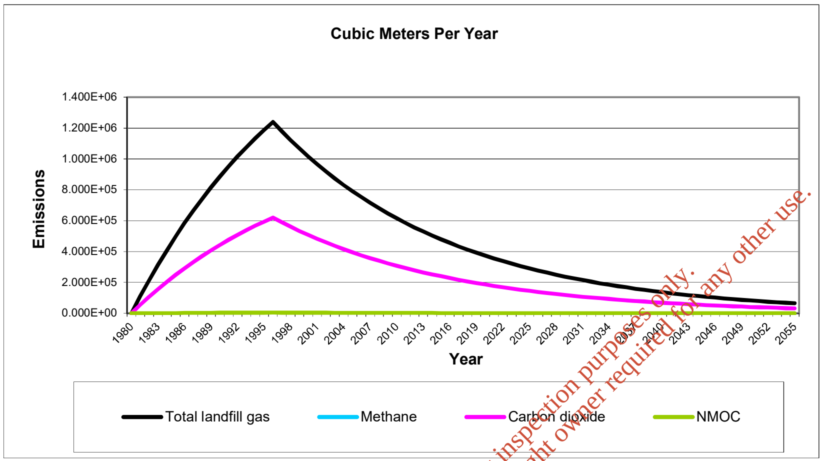
	Compound	Gas / Pollutant Default Parameters: Concentration (*ppmv*)	Molecular Weight	User-specified Pollutant Parameters: Concentration (*ppmv*)	Molecular Weight
Gases	Total landfill gas		0.00		
	Methane		16.04		
	Carbon dioxide		44.01		
	NMOC	4,000	86.18		
Pollutants	1,1,1-Trichloroethane (methyl chloroform) - HAP	0.48	133.41		
	1,1,2,2-Tetrachloroethane - HAP/VOC	1.1	167.85		
	1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC	2.4	98.97		
	1,1-Dichloroethene (vinylidene chloride) - HAP/VOC	0.20	96.94		
	1,2-Dichloroethane (ethylene dichloride) - HAP/VOC	0.41	98.96		
	1,2-Dichloropropane (propylene dichloride) - HAP/VOC	0.18	112.99		
	2-Propanol (isopropyl alcohol) - VOC	50	60.11		
	Acetone	7.0	58.08		
	Acrylonitrile - HAP/VOC	6.3	53.06		
	Benzene - No or Unknown Co-disposal - HAP/VOC	1.9	78.11		
	Benzene - Co-disposal - HAP/VOC	11	78.11		
	Bromodichloromethane - VOC	3.1	163.83		
	Butane - VOC	5.0	58.12		
	Carbon disulfide - HAP/VOC	0.58	76.13		
	Carbon monoxide	140	28.01		
	Carbon tetrachloride - HAP/VOC	4.0E-03	153.84		
	Carbonyl sulfide - HAP/VOC	0.49	60.07		
	Chlorobenzene - HAP/VOC	0.25	112.56		
	Chlorodifluoromethane	1.3	86.47		
	Chloroethane (ethyl chloride) - HAP/VOC	1.3	64.52		
	Chloroform - HAP/VOC	0.03	119.39		
	Chloromethane - VOC	1.2	50.49		
	Dichlorobenzene - (HAP for para isomer/VOC)	0.21	147		
	Dichlorodifluoromethane	16	120.91		
	Dichlorofluoromethane - VOC	2.6	102.92		
	Dichloromethane (methylene chloride) - HAP	14	84.94		
	Dimethyl sulfide (methyl sulfide) - VOC	7.8	62.13		
	Ethane	890	30.07		
	Ethanol - VOC	27	46.08		

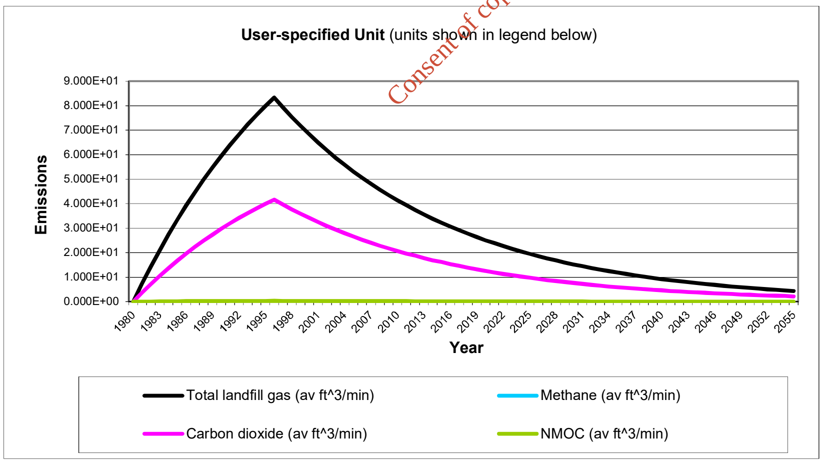
Pollutant Parameters (Continued)

	Compound	Gas / Pollutant Default Parameters: Concentration (*ppmv*)	Molecular Weight	User-specified Pollutant Parameters: Concentration (*ppmv*)	Molecular Weight
Pollutants	Ethyl mercaptan (ethanethiol) - VOC	2.3	62.13		
	Ethylbenzene - HAP/VOC	4.6	106.16		
	Ethylene dibromide - HAP/VOC	1.0E-03	187.88		
	Fluorotrichloromethane - VOC	0.76	137.38		
	Hexane - HAP/VOC	6.6	86.18		
	Hydrogen sulfide	36	34.08		
	Mercury (total) - HAP	2.9E-04	200.61		
	Methyl ethyl ketone - HAP/VOC	7.1	72.11		
	Methyl isobutyl ketone - HAP/VOC	1.9	100.16		
	Methyl mercaptan - VOC	2.5	48.11		
	Pentane - VOC	3.3	72.15		
	Perchloroethylene (tetrachloroethylene) - HAP	3.7	165.83		
	Propane - VOC	11	44.09		
	t-1,2-Dichloroethene - VOC	2.8	96.94		
	Toluene - No or Unknown Co-disposal - HAP/VOC	39	92.13		
	Toluene - Co-disposal - HAP/VOC	170	92.13		
	Trichloroethylene (trichloroethene) - HAP/VOC	2.8	131.40		
	Vinyl chloride - HAP/VOC	7.3	62.50		
	Xylenes - HAP/VOC	12	106.16		

Graphs


Megagrams Per Year
Emissions
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


Cubic Meters Per Year
Emissions
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


User-specified Unit (units shown in legend below)
Emissions
Year
Total landfill gas (av ft^3/min)
Methane (av ft^3/min)
Carbon dioxide (av ft^3/min)
NMOC (av ft^3/min)

Results

Year	Total landfill gas (Mg/year)	Total landfill gas (m^3/year)	Total landfill gas (av ft^3/min)	Methane (Mg/year)	Methane (m^3/year)	Methane (av ft^3/min)
1980	0	0	0	0	0	0
1981	1.372E+02	1.098E+05	7.381E+00	3.664E+01	5.492E+04	3.690E+00
1982	2.677E+02	2.143E+05	1.440E+01	7.150E+01	1.072E+05	7.201E+00
1983	3.918E+02	3.137E+05	2.108E+01	1.047E+02	1.569E+05	1.054E+01
1984	5.099E+02	4.083E+05	2.743E+01	1.362E+02	2.041E+05	1.372E+01
1985	6.222E+02	4.982E+05	3.348E+01	1.662E+02	2.491E+05	1.674E+01
1986	7.290E+02	5.838E+05	3.922E+01	1.947E+02	2.919E+05	1.961E+01
1987	8.306E+02	6.651E+05	4.469E+01	2.219E+02	3.326E+05	2.235E+01
1988	9.273E+02	7.426E+05	4.989E+01	2.477E+02	3.713E+05	2.495E+01
1989	1.019E+03	8.162E+05	5.484E+01	2.723E+02	4.081E+05	2.742E+01
1990	1.107E+03	8.862E+05	5.955E+01	2.956E+02	4.431E+05	2.977E+01
1991	1.190E+03	9.529E+05	6.402E+01	3.178E+02	4.764E+05	3.201E+01
1992	1.269E+03	1.016E+06	6.828E+01	3.390E+02	5.081E+05	3.414E+01
1993	1.344E+03	1.077E+06	7.233E+01	3.591E+02	5.383E+05	3.617E+01
1994	1.416E+03	1.134E+06	7.618E+01	3.782E+02	5.669E+05	3.809E+01
1995	1.484E+03	1.188E+06	7.985E+01	3.964E+02	5.942E+05	3.992E+01
1996	1.549E+03	1.240E+06	8.334E+01	4.137E+02	6.201E+05	4.167E+01
1997	1.473E+03	1.180E+06	7.927E+01	3.936E+02	5.899E+05	3.964E+01
1998	1.402E+03	1.122E+06	7.541E+01	3.744E+02	5.611E+05	3.770E+01
1999	1.333E+03	1.068E+06	7.173E+01	3.561E+02	5.338E+05	3.586E+01
2000	1.268E+03	1.015E+06	6.823E+01	3.387E+02	5.077E+05	3.411E+01
2001	1.206E+03	9.659E+05	6.490E+01	3.222E+02	4.830E+05	3.245E+01
2002	1.147E+03	9.188E+05	6.174E+01	3.065E+02	4.594E+05	3.087E+01
2003	1.092E+03	8.740E+05	5.873E+01	2.916E+02	4.370E+05	2.936E+01
2004	1.038E+03	8.314E+05	5.586E+01	2.773E+02	4.157E+05	2.793E+01
2005	9.876E+02	7.908E+05	5.314E+01	2.638E+02	3.954E+05	2.657E+01
2006	9.395E+02	7.523E+05	5.055E+01	2.509E+02	3.761E+05	2.527E+01
2007	8.936E+02	7.156E+05	4.808E+01	2.387E+02	3.578E+05	2.404E+01
2008	8.501E+02	6.807E+05	4.574E+01	2.271E+02	3.403E+05	2.287E+01
2009	8.086E+02	6.475E+05	4.350E+01	2.160E+02	3.237E+05	2.175E+01
2010	7.692E+02	6.159E+05	4.138E+01	2.055E+02	3.080E+05	2.069E+01
2011	7.317E+02	5.859E+05	3.936E+01	1.954E+02	2.929E+05	1.968E+01
2012	6.960E+02	5.573E+05	3.745E+01	1.859E+02	2.787E+05	1.872E+01
2013	6.620E+02	5.301E+05	3.562E+01	1.768E+02	2.651E+05	1.781E+01
2014	6.297E+02	5.043E+05	3.388E+01	1.682E+02	2.521E+05	1.694E+01
2015	5.990E+02	4.797E+05	3.223E+01	1.600E+02	2.398E+05	1.611E+01
2016	5.698E+02	4.563E+05	3.066E+01	1.522E+02	2.281E+05	1.533E+01
2017	5.420E+02	4.340E+05	2.916E+01	1.448E+02	2.170E+05	1.458E+01
2018	5.156E+02	4.129E+05	2.774E+01	1.377E+02	2.064E+05	1.387E+01
2019	4.904E+02	3.927E+05	2.639E+01	1.310E+02	1.964E+05	1.319E+01
2020	4.665E+02	3.736E+05	2.510E+01	1.246E+02	1.868E+05	1.255E+01
2021	4.438E+02	3.554E+05	2.388E+01	1.185E+02	1.777E+05	1.194E+01
2022	4.221E+02	3.380E+05	2.271E+01	1.128E+02	1.690E+05	1.136E+01
2023	4.015E+02	3.215E+05	2.160E+01	1.073E+02	1.608E+05	1.080E+01
2024	3.820E+02	3.059E+05	2.055E+01	1.020E+02	1.529E+05	1.028E+01
2025	3.633E+02	2.909E+05	1.955E+01	9.705E+01	1.455E+05	9.774E+00
2026	3.456E+02	2.767E+05	1.859E+01	9.232E+01	1.384E+05	9.297E+00
2027	3.288E+02	2.633E+05	1.769E+01	8.781E+01	1.316E+05	8.844E+00
2028	3.127E+02	2.504E+05	1.683E+01	8.353E+01	1.252E+05	8.413E+00
2029	2.975E+02	2.382E+05	1.600E+01	7.946E+01	1.191E+05	8.002E+00

Results (Continued)

Year	Total landfill gas			Methane		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2030	2.830E+02	2.266E+05	1.522E+01	7.558E+01	1.133E+05	7.612E+00
2031	2.692E+02	2.155E+05	1.448E+01	7.190E+01	1.078E+05	7.241E+00
2032	2.560E+02	2.050E+05	1.378E+01	6.839E+01	1.025E+05	6.888E+00
2033	2.435E+02	1.950E+05	1.310E+01	6.505E+01	9.751E+04	6.552E+00
2034	2.317E+02	1.855E+05	1.246E+01	6.188E+01	9.275E+04	6.232E+00
2035	2.204E+02	1.765E+05	1.186E+01	5.886E+01	8.823E+04	5.928E+00
2036	2.096E+02	1.679E+05	1.128E+01	5.599E+01	8.393E+04	5.639E+00
2037	1.994E+02	1.597E+05	1.073E+01	5.326E+01	7.983E+04	5.364E+00
2038	1.897E+02	1.519E+05	1.020E+01	5.066E+01	7.594E+04	5.102E+00
2039	1.804E+02	1.445E+05	9.707E+00	4.819E+01	7.224E+04	4.854E+00
2040	1.716E+02	1.374E+05	9.234E+00	4.584E+01	6.871E+04	4.617E+00
2041	1.633E+02	1.307E+05	8.784E+00	4.361E+01	6.536E+04	4.392E+00
2042	1.553E+02	1.244E+05	8.355E+00	4.148E+01	6.218E+04	4.178E+00
2043	1.477E+02	1.183E+05	7.948E+00	3.946E+01	5.914E+04	3.974E+00
2044	1.405E+02	1.125E+05	7.560E+00	3.753E+01	5.626E+04	3.780E+00
2045	1.337E+02	1.070E+05	7.191E+00	3.570E+01	5.351E+04	3.596E+00
2046	1.271E+02	1.018E+05	6.841E+00	3.396E+01	5.090E+04	3.420E+00
2047	1.209E+02	9.684E+04	6.507E+00	3.230E+01	4.842E+04	3.253E+00
2048	1.150E+02	9.212E+04	6.190E+00	3.073E+01	4.606E+04	3.095E+00
2049	1.094E+02	8.763E+04	5.888E+00	2.923E+01	4.381E+04	2.944E+00
2050	1.041E+02	8.335E+04	5.601E+00	2.781E+01	4.168E+04	2.800E+00
2051	9.902E+01	7.929E+04	5.327E+00	2.645E+01	3.964E+04	2.664E+00
2052	9.419E+01	7.542E+04	5.068E+00	2.516E+01	3.771E+04	2.534E+00
2053	8.960E+01	7.174E+04	4.820E+00	2.393E+01	3.587E+04	2.410E+00
2054	8.523E+01	6.825E+04	4.585E+00	2.276E+01	3.412E+04	2.293E+00
2055	8.107E+01	6.492E+04	4.362E+00	2.165E+01	3.246E+04	2.181E+00
2056	7.712E+01	6.175E+04	4.149E+00	2.060E+01	3.088E+04	2.075E+00
2057	7.335E+01	5.874E+04	3.947E+00	1.959E+01	2.937E+04	1.973E+00
2058	6.978E+01	5.587E+04	3.754E+00	1.864E+01	2.794E+04	1.877E+00
2059	6.637E+01	5.315E+04	3.571E+00	1.773E+01	2.657E+04	1.786E+00
2060	6.314E+01	5.056E+04	3.397E+00	1.686E+01	2.528E+04	1.698E+00
2061	6.006E+01	4.809E+04	3.231E+00	1.604E+01	2.405E+04	1.616E+00
2062	5.713E+01	4.575E+04	3.074E+00	1.526E+01	2.287E+04	1.537E+00
2063	5.434E+01	4.352E+04	2.924E+00	1.452E+01	2.176E+04	1.462E+00
2064	5.169E+01	4.139E+04	2.781E+00	1.381E+01	2.070E+04	1.391E+00
2065	4.917E+01	3.937E+04	2.646E+00	1.313E+01	1.969E+04	1.323E+00
2066	4.677E+01	3.745E+04	2.517E+00	1.249E+01	1.873E+04	1.258E+00
2067	4.449E+01	3.563E+04	2.394E+00	1.188E+01	1.781E+04	1.197E+00
2068	4.232E+01	3.389E+04	2.277E+00	1.130E+01	1.694E+04	1.139E+00
2069	4.026E+01	3.224E+04	2.166E+00	1.075E+01	1.612E+04	1.083E+00
2070	3.829E+01	3.066E+04	2.060E+00	1.023E+01	1.533E+04	1.030E+00
2071	3.643E+01	2.917E+04	1.960E+00	9.730E+00	1.458E+04	9.799E-01
2072	3.465E+01	2.775E+04	1.864E+00	9.255E+00	1.387E+04	9.321E-01
2073	3.296E+01	2.639E+04	1.773E+00	8.804E+00	1.320E+04	8.867E-01
2074	3.135E+01	2.511E+04	1.687E+00	8.375E+00	1.255E+04	8.434E-01
2075	2.982E+01	2.388E+04	1.605E+00	7.966E+00	1.194E+04	8.023E-01
2076	2.837E+01	2.272E+04	1.526E+00	7.578E+00	1.136E+04	7.632E-01
2077	2.699E+01	2.161E+04	1.452E+00	7.208E+00	1.080E+04	7.260E-01
2078	2.567E+01	2.056E+04	1.381E+00	6.857E+00	1.028E+04	6.905E-01
2079	2.442E+01	1.955E+04	1.314E+00	6.522E+00	9.776E+03	6.569E-01
2080	2.323E+01	1.860E+04	1.250E+00	6.204E+00	9.300E+03	6.248E-01

Results (Continued)

Year	Total landfill gas			Methane		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2081	2.209E+01	1.769E+04	1.189E+00	5.902E+00	8.846E+03	5.944E-01
2082	2.102E+01	1.683E+04	1.131E+00	5.614E+00	8.415E+03	5.654E-01
2083	1.999E+01	1.601E+04	1.076E+00	5.340E+00	8.004E+03	5.378E-01
2084	1.902E+01	1.523E+04	1.023E+00	5.080E+00	7.614E+03	5.116E-01
2085	1.809E+01	1.448E+04	9.732E-01	4.832E+00	7.242E+03	4.866E-01
2086	1.721E+01	1.378E+04	9.258E-01	4.596E+00	6.889E+03	4.629E-01
2087	1.637E+01	1.311E+04	8.806E-01	4.372E+00	6.553E+03	4.403E-01
2088	1.557E+01	1.247E+04	8.377E-01	4.159E+00	6.234E+03	4.188E-01
2089	1.481E+01	1.186E+04	7.968E-01	3.956E+00	5.930E+03	3.984E-01
2090	1.409E+01	1.128E+04	7.580E-01	3.763E+00	5.640E+03	3.790E-01
2091	1.340E+01	1.073E+04	7.210E-01	3.579E+00	5.365E+03	3.605E-01
2092	1.275E+01	1.021E+04	6.858E-01	3.405E+00	5.104E+03	3.429E-01
2093	1.213E+01	9.710E+03	6.524E-01	3.239E+00	4.855E+03	3.262E-01
2094	1.153E+01	9.236E+03	6.206E-01	3.081E+00	4.618E+03	3.103E-01
2095	1.097E+01	8.786E+03	5.903E-01	2.931E+00	4.393E+03	2.951E-01
2096	1.044E+01	8.357E+03	5.615E-01	2.788E+00	4.179E+03	2.808E-01
2097	9.928E+00	7.949E+03	5.341E-01	2.652E+00	3.975E+03	2.671E-01
2098	9.443E+00	7.562E+03	5.081E-01	2.522E+00	3.781E+03	2.540E-01
2099	8.983E+00	7.193E+03	4.833E-01	2.399E+00	3.596E+03	2.416E-01
2100	8.545E+00	6.842E+03	4.597E-01	2.282E+00	3.421E+03	2.299E-01
2101	8.128E+00	6.508E+03	4.373E-01	2.171E+00	3.254E+03	2.187E-01
2102	7.732E+00	6.191E+03	4.160E-01	2.065E+00	3.096E+03	2.080E-01
2103	7.354E+00	5.889E+03	3.957E-01	1.964E+00	2.945E+03	1.978E-01
2104	6.996E+00	5.602E+03	3.764E-01	1.869E+00	2.801E+03	1.882E-01
2105	6.655E+00	5.329E+03	3.580E-01	1.778E+00	2.664E+03	1.790E-01
2106	6.330E+00	5.069E+03	3.406E-01	1.691E+00	2.534E+03	1.703E-01
2107	6.021E+00	4.822E+03	3.240E-01	1.608E+00	2.411E+03	1.620E-01
2108	5.728E+00	4.586E+03	3.082E-01	1.530E+00	2.293E+03	1.541E-01
2109	5.448E+00	4.363E+03	2.931E-01	1.455E+00	2.181E+03	1.466E-01
2110	5.183E+00	4.150E+03	2.788E-01	1.384E+00	2.075E+03	1.394E-01
2111	4.930E+00	3.948E+03	2.652E-01	1.317E+00	1.974E+03	1.326E-01
2112	4.689E+00	3.755E+03	2.523E-01	1.253E+00	1.878E+03	1.262E-01
2113	4.461E+00	3.572E+03	2.400E-01	1.192E+00	1.786E+03	1.200E-01
2114	4.243E+00	3.398E+03	2.283E-01	1.133E+00	1.699E+03	1.141E-01
2115	4.036E+00	3.232E+03	2.172E-01	1.078E+00	1.616E+03	1.086E-01
2116	3.839E+00	3.074E+03	2.066E-01	1.026E+00	1.537E+03	1.033E-01
2117	3.652E+00	2.924E+03	1.965E-01	9.755E-01	1.462E+03	9.825E-02
2118	3.474E+00	2.782E+03	1.869E-01	9.279E-01	1.391E+03	9.346E-02
2119	3.305E+00	2.646E+03	1.778E-01	8.827E-01	1.323E+03	8.890E-02
2120	3.143E+00	2.517E+03	1.691E-01	8.396E-01	1.259E+03	8.456E-02

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
1980	0	0	0	0	0	0
1981	1.005E+02	5.492E+04	3.690E+00	1.575E+00	4.394E+02	2.952E-02
1982	1.962E+02	1.072E+05	7.201E+00	3.073E+00	8.574E+02	5.761E-02
1983	2.871E+02	1.569E+05	1.054E+01	4.498E+00	1.255E+03	8.432E-02
1984	3.737E+02	2.041E+05	1.372E+01	5.854E+00	1.633E+03	1.097E-01
1985	4.560E+02	2.491E+05	1.674E+01	7.143E+00	1.993E+03	1.339E-01
1986	5.343E+02	2.919E+05	1.961E+01	8.370E+00	2.335E+03	1.569E-01
1987	6.088E+02	3.326E+05	2.235E+01	9.537E+00	2.661E+03	1.788E-01
1988	6.796E+02	3.713E+05	2.495E+01	1.065E+01	2.970E+03	1.996E-01
1989	7.470E+02	4.081E+05	2.742E+01	1.170E+01	3.265E+03	2.194E-01
1990	8.111E+02	4.431E+05	2.977E+01	1.271E+01	3.545E+03	2.382E-01
1991	8.721E+02	4.764E+05	3.201E+01	1.366E+01	3.811E+03	2.561E-01
1992	9.301E+02	5.081E+05	3.414E+01	1.457E+01	4.065E+03	2.731E-01
1993	9.853E+02	5.383E+05	3.617E+01	1.543E+01	4.306E+03	2.893E-01
1994	1.038E+03	5.669E+05	3.809E+01	1.626E+01	4.535E+03	3.047E-01
1995	1.088E+03	5.942E+05	3.992E+01	1.704E+01	4.754E+03	3.194E-01
1996	1.135E+03	6.201E+05	4.167E+01	1.778E+01	4.961E+03	3.333E-01
1997	1.080E+03	5.899E+05	3.964E+01	1.692E+01	4.719E+03	3.171E-01
1998	1.027E+03	5.611E+05	3.770E+01	1.609E+01	4.489E+03	3.016E-01
1999	9.771E+02	5.338E+05	3.586E+01	1.531E+01	4.270E+03	2.869E-01
2000	9.294E+02	5.077E+05	3.411E+01	1.456E+01	4.062E+03	2.729E-01
2001	8.841E+02	4.830E+05	3.245E+01	1.385E+01	3.864E+03	2.596E-01
2002	8.410E+02	4.594E+05	3.087E+01	1.317E+01	3.675E+03	2.469E-01
2003	8.000E+02	4.370E+05	2.936E+01	1.253E+01	3.496E+03	2.349E-01
2004	7.609E+02	4.157E+05	2.793E+01	1.192E+01	3.326E+03	2.234E-01
2005	7.238E+02	3.954E+05	2.657E+01	1.134E+01	3.163E+03	2.125E-01
2006	6.885E+02	3.761E+05	2.527E+01	1.079E+01	3.009E+03	2.022E-01
2007	6.549E+02	3.578E+05	2.404E+01	1.026E+01	2.862E+03	1.923E-01
2008	6.230E+02	3.403E+05	2.287E+01	9.760E+00	2.723E+03	1.829E-01
2009	5.926E+02	3.237E+05	2.175E+01	9.284E+00	2.590E+03	1.740E-01
2010	5.637E+02	3.080E+05	2.069E+01	8.831E+00	2.464E+03	1.655E-01
2011	5.362E+02	2.929E+05	1.968E+01	8.400E+00	2.344E+03	1.575E-01
2012	5.101E+02	2.787E+05	1.872E+01	7.991E+00	2.229E+03	1.498E-01
2013	4.852E+02	2.651E+05	1.781E+01	7.601E+00	2.120E+03	1.425E-01
2014	4.615E+02	2.521E+05	1.694E+01	7.230E+00	2.017E+03	1.355E-01
2015	4.390E+02	2.398E+05	1.611E+01	6.878E+00	1.919E+03	1.289E-01
2016	4.176E+02	2.281E+05	1.533E+01	6.542E+00	1.825E+03	1.226E-01
2017	3.972E+02	2.170E+05	1.458E+01	6.223E+00	1.736E+03	1.166E-01
2018	3.779E+02	2.064E+05	1.387E+01	5.920E+00	1.651E+03	1.110E-01
2019	3.594E+02	1.964E+05	1.319E+01	5.631E+00	1.571E+03	1.055E-01
2020	3.419E+02	1.868E+05	1.255E+01	5.356E+00	1.494E+03	1.004E-01
2021	3.252E+02	1.777E+05	1.194E+01	5.095E+00	1.421E+03	9.550E-02
2022	3.094E+02	1.690E+05	1.136E+01	4.846E+00	1.352E+03	9.085E-02
2023	2.943E+02	1.608E+05	1.080E+01	4.610E+00	1.286E+03	8.642E-02
2024	2.799E+02	1.529E+05	1.028E+01	4.385E+00	1.223E+03	8.220E-02
2025	2.663E+02	1.455E+05	9.774E+00	4.171E+00	1.164E+03	7.819E-02
2026	2.533E+02	1.384E+05	9.297E+00	3.968E+00	1.107E+03	7.438E-02
2027	2.409E+02	1.316E+05	8.844E+00	3.774E+00	1.053E+03	7.075E-02
2028	2.292E+02	1.252E+05	8.413E+00	3.590E+00	1.002E+03	6.730E-02
2029	2.180E+02	1.191E+05	8.002E+00	3.415E+00	9.528E+02	6.402E-02

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
2030	2.074E+02	1.133E+05	7.612E+00	3.249E+00	9.063E+02	6.090E-02
2031	1.973E+02	1.078E+05	7.241E+00	3.090E+00	8.621E+02	5.793E-02
2032	1.876E+02	1.025E+05	6.888E+00	2.940E+00	8.201E+02	5.510E-02
2033	1.785E+02	9.751E+04	6.552E+00	2.796E+00	7.801E+02	5.241E-02
2034	1.698E+02	9.275E+04	6.232E+00	2.660E+00	7.420E+02	4.986E-02
2035	1.615E+02	8.823E+04	5.928E+00	2.530E+00	7.058E+02	4.743E-02
2036	1.536E+02	8.393E+04	5.639E+00	2.407E+00	6.714E+02	4.511E-02
2037	1.461E+02	7.983E+04	5.364E+00	2.289E+00	6.387E+02	4.291E-02
2038	1.390E+02	7.594E+04	5.102E+00	2.178E+00	6.075E+02	4.082E-02
2039	1.322E+02	7.224E+04	4.854E+00	2.071E+00	5.779E+02	3.883E-02
2040	1.258E+02	6.871E+04	4.617E+00	1.970E+00	5.497E+02	3.694E-02
2041	1.196E+02	6.536E+04	4.392E+00	1.874E+00	5.229E+02	3.513E-02
2042	1.138E+02	6.218E+04	4.178E+00	1.783E+00	4.974E+02	3.342E-02
2043	1.083E+02	5.914E+04	3.974E+00	1.696E+00	4.731E+02	3.179E-02
2044	1.030E+02	5.626E+04	3.780E+00	1.613E+00	4.501E+02	3.024E-02
2045	9.796E+01	5.351E+04	3.596E+00	1.535E+00	4.281E+02	2.877E-02
2046	9.318E+01	5.090E+04	3.420E+00	1.460E+00	4.072E+02	2.736E-02
2047	8.864E+01	4.842E+04	3.253E+00	1.389E+00	3.874E+02	2.603E-02
2048	8.431E+01	4.606E+04	3.095E+00	1.321E+00	3.685E+02	2.476E-02
2049	8.020E+01	4.381E+04	2.944E+00	1.256E+00	3.505E+02	2.355E-02
2050	7.629E+01	4.168E+04	2.800E+00	1.195E+00	3.334E+02	2.240E-02
2051	7.257E+01	3.964E+04	2.664E+00	1.137E+00	3.172E+02	2.131E-02
2052	6.903E+01	3.771E+04	2.534E+00	1.081E+00	3.017E+02	2.027E-02
2053	6.566E+01	3.587E+04	2.410E+00	1.029E+00	2.870E+02	1.928E-02
2054	6.246E+01	3.412E+04	2.293E+00	9.785E-01	2.730E+02	1.834E-02
2055	5.942E+01	3.246E+04	2.181E+00	9.308E-01	2.597E+02	1.745E-02
2056	5.652E+01	3.088E+04	2.075E+00	8.854E-01	2.470E+02	1.660E-02
2057	5.376E+01	2.937E+04	1.973E+00	8.422E-01	2.350E+02	1.579E-02
2058	5.114E+01	2.794E+04	1.877E+00	8.011E-01	2.235E+02	1.502E-02
2059	4.865E+01	2.657E+04	1.786E+00	7.620E-01	2.126E+02	1.428E-02
2060	4.627E+01	2.528E+04	1.698E+00	7.249E-01	2.022E+02	1.359E-02
2061	4.402E+01	2.405E+04	1.616E+00	6.895E-01	1.924E+02	1.293E-02
2062	4.187E+01	2.287E+04	1.537E+00	6.559E-01	1.830E+02	1.229E-02
2063	3.983E+01	2.176E+04	1.462E+00	6.239E-01	1.741E+02	1.170E-02
2064	3.788E+01	2.070E+04	1.391E+00	5.935E-01	1.656E+02	1.112E-02
2065	3.604E+01	1.969E+04	1.323E+00	5.645E-01	1.575E+02	1.058E-02
2066	3.428E+01	1.873E+04	1.258E+00	5.370E-01	1.498E+02	1.007E-02
2067	3.261E+01	1.781E+04	1.197E+00	5.108E-01	1.425E+02	9.575E-03
2068	3.102E+01	1.694E+04	1.139E+00	4.859E-01	1.356E+02	9.108E-03
2069	2.950E+01	1.612E+04	1.083E+00	4.622E-01	1.289E+02	8.664E-03
2070	2.807E+01	1.533E+04	1.030E+00	4.397E-01	1.227E+02	8.241E-03
2071	2.670E+01	1.458E+04	9.799E-01	4.182E-01	1.167E+02	7.839E-03
2072	2.539E+01	1.387E+04	9.321E-01	3.978E-01	1.110E+02	7.457E-03
2073	2.416E+01	1.320E+04	8.867E-01	3.784E-01	1.056E+02	7.093E-03
2074	2.298E+01	1.255E+04	8.434E-01	3.600E-01	1.004E+02	6.747E-03
2075	2.186E+01	1.194E+04	8.023E-01	3.424E-01	9.553E+01	6.418E-03
2076	2.079E+01	1.136E+04	7.632E-01	3.257E-01	9.087E+01	6.105E-03
2077	1.978E+01	1.080E+04	7.260E-01	3.098E-01	8.644E+01	5.808E-03
2078	1.881E+01	1.028E+04	6.905E-01	2.947E-01	8.222E+01	5.524E-03
2079	1.790E+01	9.776E+03	6.569E-01	2.803E-01	7.821E+01	5.255E-03
2080	1.702E+01	9.300E+03	6.248E-01	2.667E-01	7.440E+01	4.999E-03

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2081	1.619E+01	8.846E+03	5.944E-01	2.537E-01	7.077E+01	4.755E-03
2082	1.540E+01	8.415E+03	5.654E-01	2.413E-01	6.732E+01	4.523E-03
2083	1.465E+01	8.004E+03	5.378E-01	2.295E-01	6.403E+01	4.302E-03
2084	1.394E+01	7.614E+03	5.116E-01	2.183E-01	6.091E+01	4.093E-03
2085	1.326E+01	7.242E+03	4.866E-01	2.077E-01	5.794E+01	3.893E-03
2086	1.261E+01	6.889E+03	4.629E-01	1.976E-01	5.511E+01	3.703E-03
2087	1.200E+01	6.553E+03	4.403E-01	1.879E-01	5.243E+01	3.522E-03
2088	1.141E+01	6.234E+03	4.188E-01	1.788E-01	4.987E+01	3.351E-03
2089	1.085E+01	5.930E+03	3.984E-01	1.700E-01	4.744E+01	3.187E-03
2090	1.032E+01	5.640E+03	3.790E-01	1.617E-01	4.512E+01	3.032E-03
2091	9.821E+00	5.365E+03	3.605E-01	1.539E-01	4.292E+01	2.884E-03
2092	9.342E+00	5.104E+03	3.429E-01	1.464E-01	4.083E+01	2.743E-03
2093	8.887E+00	4.855E+03	3.262E-01	1.392E-01	3.884E+01	2.610E-03
2094	8.453E+00	4.618E+03	3.103E-01	1.324E-01	3.694E+01	2.482E-03
2095	8.041E+00	4.393E+03	2.951E-01	1.260E-01	3.514E+01	2.361E-03
2096	7.649E+00	4.179E+03	2.808E-01	1.198E-01	3.343E+01	2.246E-03
2097	7.276E+00	3.975E+03	2.671E-01	1.140E-01	3.180E+01	2.137E-03
2098	6.921E+00	3.781E+03	2.540E-01	1.084E-01	3.025E+01	2.032E-03
2099	6.583E+00	3.596E+03	2.416E-01	1.031E-01	2.877E+01	1.933E-03
2100	6.262E+00	3.421E+03	2.299E-01	9.810E-02	2.737E+01	1.839E-03
2101	5.957E+00	3.254E+03	2.187E-01	9.332E-02	2.603E+01	1.749E-03
2102	5.666E+00	3.096E+03	2.080E-01	8.877E-02	2.476E+01	1.664E-03
2103	5.390E+00	2.945E+03	1.978E-01	8.444E-02	2.356E+01	1.583E-03
2104	5.127E+00	2.801E+03	1.882E-01	8.032E-02	2.241E+01	1.506E-03
2105	4.877E+00	2.664E+03	1.790E-01	7.640E-02	2.131E+01	1.432E-03
2106	4.639E+00	2.534E+03	1.703E-01	7.268E-02	2.028E+01	1.362E-03
2107	4.413E+00	2.411E+03	1.620E-01	6.913E-02	1.929E+01	1.296E-03
2108	4.198E+00	2.293E+03	1.541E-01	6.576E-02	1.835E+01	1.233E-03
2109	3.993E+00	2.181E+03	1.466E-01	6.255E-02	1.745E+01	1.173E-03
2110	3.798E+00	2.075E+03	1.394E-01	5.950E-02	1.660E+01	1.115E-03
2111	3.613E+00	1.974E+03	1.326E-01	5.660E-02	1.579E+01	1.061E-03
2112	3.437E+00	1.878E+03	1.262E-01	5.384E-02	1.502E+01	1.009E-03
2113	3.269E+00	1.786E+03	1.200E-01	5.121E-02	1.429E+01	9.600E-04
2114	3.110E+00	1.699E+03	1.141E-01	4.872E-02	1.359E+01	9.132E-04
2115	2.958E+00	1.616E+03	1.086E-01	4.634E-02	1.293E+01	8.686E-04
2116	2.814E+00	1.537E+03	1.033E-01	4.408E-02	1.230E+01	8.263E-04
2117	2.677E+00	1.462E+03	9.825E-02	4.193E-02	1.170E+01	7.860E-04
2118	2.546E+00	1.391E+03	9.346E-02	3.989E-02	1.113E+01	7.476E-04
2119	2.422E+00	1.323E+03	8.890E-02	3.794E-02	1.058E+01	7.112E-04
2120	2.304E+00	1.259E+03	8.456E-02	3.609E-02	1.007E+01	6.765E-04

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APPENDIX 3

Surface Water Assimilative Capacity Assessment

Dingle

Assimilative capacity = (Cmax – Cback) x F95 x 86.4 kg/day — **Ammonia**

Where:

C_{max} = maximum permissible concentration (EQS – 95%ile value) (mg/l)	0.14
C_{back} = background upstream concentration (mg/l mean value)	0.035
Q95 = the 95%ile flow in the river (m^3/s)	0.019

Note: (60x60x24)/1000 = 86.4

AC kg/d	=	**(Cmax**	**-**	**Cbak)**	**x**	**F95**	**x**	**86.4**
	=	0.14	-	0.035	x	0.019	x	86.4
	=		0.105		x	0.019	x	86.4
AC kg/d	=	**0.17**	**kg/day**					

Emission Concentration (mg/l)	0.4		
	Flow (m3/day)	Daily Mass Emission (kg/day)	%-age of AC
	86.4	0.035	20%
	172.8	0.069	40%
	259.2	0.104	60%
	345.6	0.138	80%
	432	0.173	100%

Mass balance Equation:

$$T = \frac{FC + fc}{F + f}$$

$$f(m^3/sec) = \frac{f\left(\frac{m^3}{day}\right) \div 24hours}{3600\ seconds}$$

F =	0.019	m^3/sec
C =	0.035	mg/l
f =	86.4	m^3/day
	0.005	m^3/sec
c =	0.400	mg/l

where:

- F is the river flow upstream of the discharge (95%ile flow m^3/sec);
- C is the concentration of pollutant in the river upstream of the discharge (mean concentration in mg/l);
- f is the flow of the discharge (m^3/sec);
- c is the maximum concentration of pollutant in the discharge (mg/l);
- T is the concentration of pollutant downstream of the discharge.

T = (F x C + *f* x c) / (F + *f*)

1. (0.019 x 0.035 + 0.005 x 0.400) / (0.019 + 0.005)
2. (0.000665 + 0.002) / 0.0240
3. 0.003 / 0.024
4. **T = 0.111 mg/l**

EQS (mg/l)	
0.14	*Good' Status 95%-ile EQS*
0.065	*Good' Status mean EQS*

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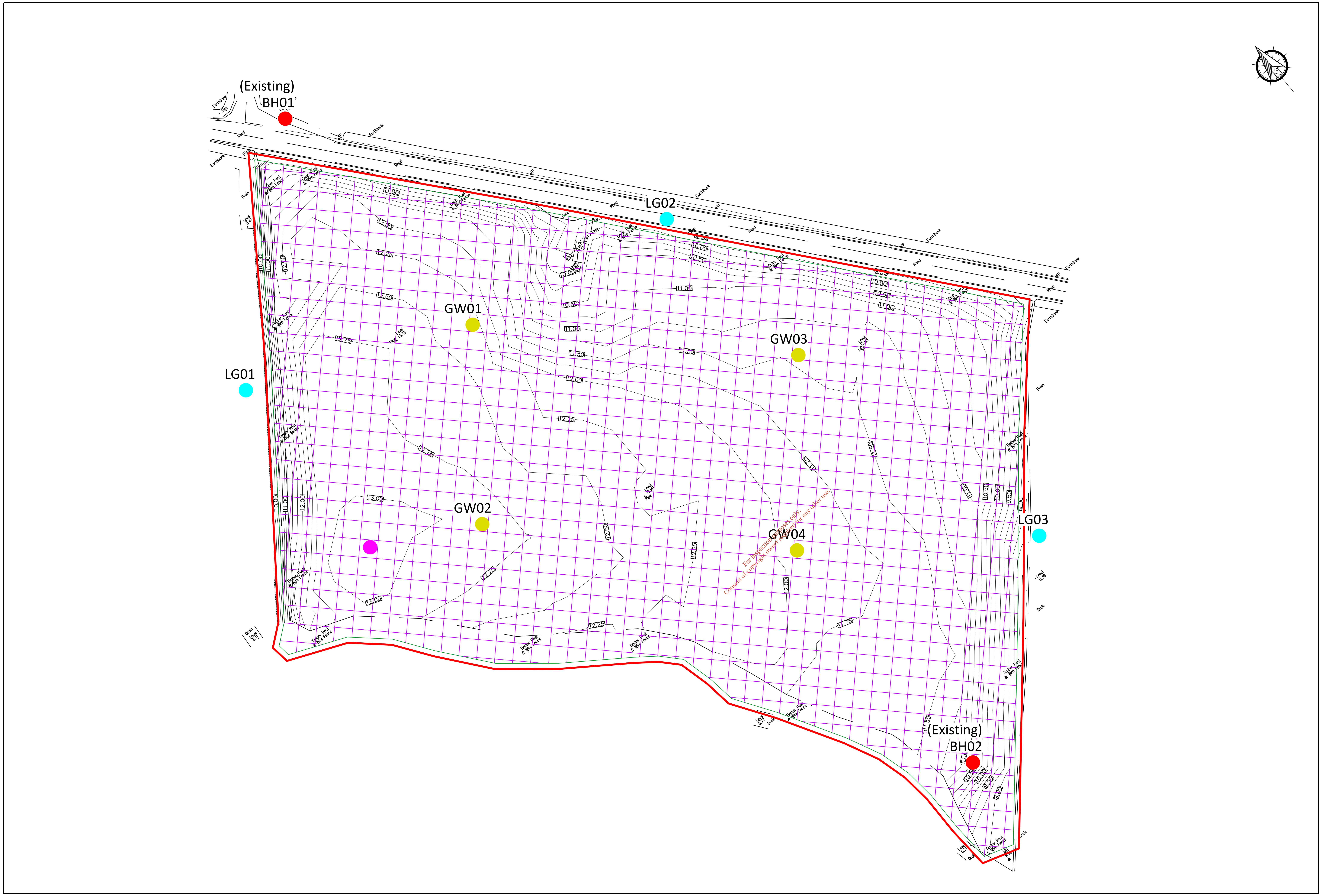
APPENDIX 4

Remediation Plan Drawings



Legend

- Site Boundary
- Capping Area
- Proposed Cap Footprint
- Ground Water Extraction Wells
- Permitted Gas Monitoring Well
- Proposed Gas Well
- Proposed Passive Vent/Excration Location

0m 5m 10m 15m 20m 25m 30m 35m 40m 45m 50m

Scale 1:500

If Applicable : Ordnance Survey Ireland Licence No. EN 0001220 © Ordnance Survey Ireland and Government of Ireland

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Rev.	Description	App By	Date
A	ISSUE FOR APPROVAL	CJC	13.03.20

PROJECT

SOUTH AND WEST KERRY LANDFILLS

CLIENT

KERRY COUNTY COUNCIL

SHEET

DINGLE HISTORIC LANDFILL PROPOSED REMEDIATION PLAN

Date	Project number	Scale (@ A1-)
13.03.20	P1788	1:500

Drawn by	Drawing Number	Rev
SOC	P1788-0101-0001	A

Checked by
EA

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13 March 2020

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