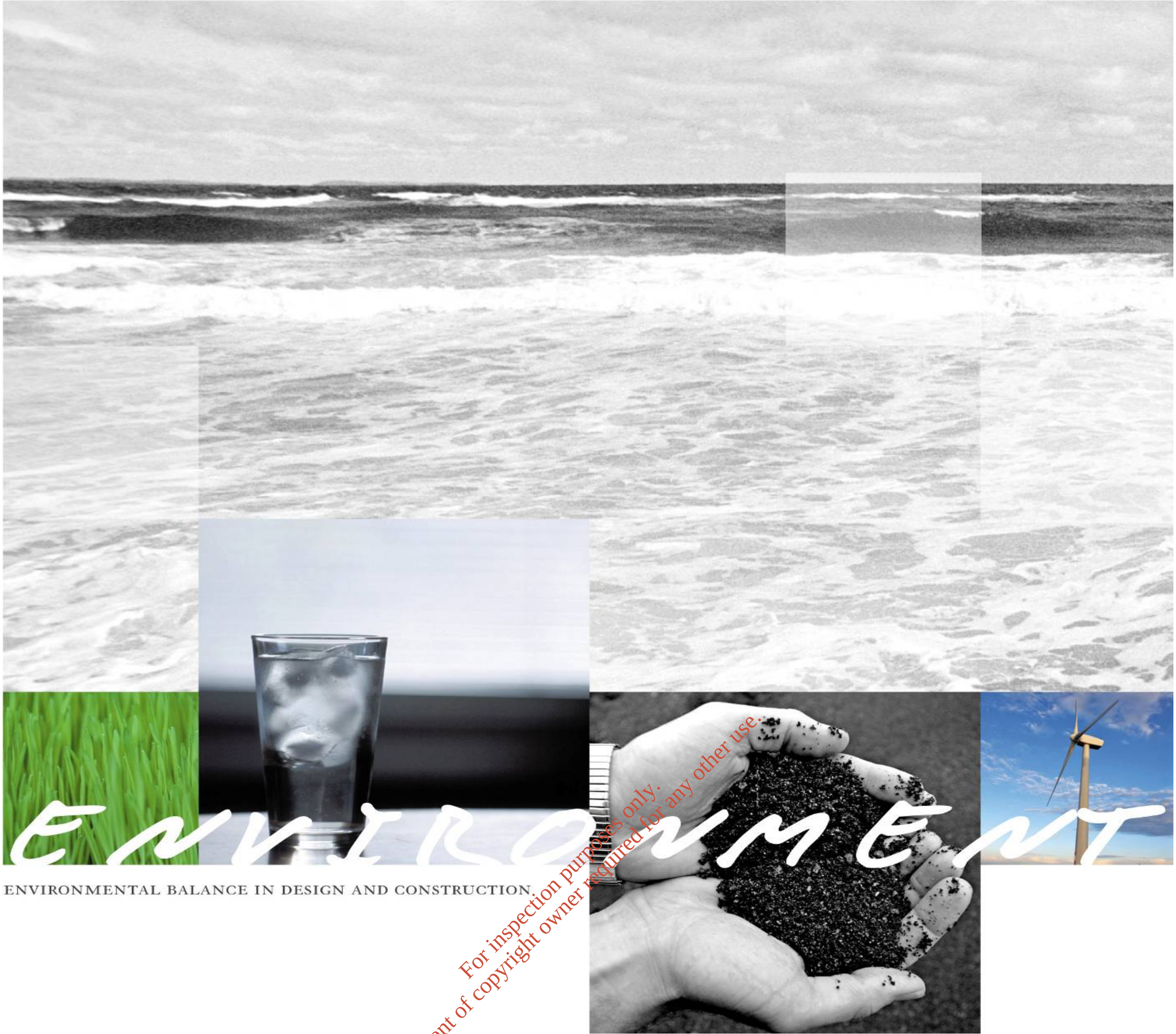

TIER 3 RISK ASSESSMENT

KILLYCARD HISTORIC LANDFILL SITE, CO. MONAGHAN

DECEMBER 2019

TIER 3 RISK ASSESSMENT

KILLYCARD HISTORIC LANDFILL, CO. MONAGHAN

User is Responsible for Checking the Revision Status of this Document

Rev. Nr.	Description of Changes	Prepared by:	Checked by:	Approved by:	Date:
0	Issue for Client Comment	EOC/MG	JON	BG	29.05.2019
1	Issue to Client	EOC/MG	JON	BG	05.12.2019

Client: Monaghan County Council

Keywords: Site Investigation, environmental risk assessment, waste, leachate,

Abstract: This report represents the findings of a Tier 3 risk assessment carried out on Killycard Historic Landfill site, Co. Monaghan, and conducted in accordance with the EPA Code of Practice for unregulated landfill sites. The Tier 3 risk assessment was conducted following on from the findings on the previously conducted Tier 2 risk assessment.

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NON-TECHNICAL SUMMARY

Fehily Timoney & Company (FT) was appointed by Monaghan County Council (LCC) to complete a Tier 3 environmental risk assessment (ERA) on Killycard Historic Landfill in accordance with the Environmental Protection Agency (EPA) Code of Practice (CoP) (2007): *Environmental Risk Assessment for Unregulated Waste Disposal Sites*.

Killycard historic landfill is located approximately 1.7km to the North-West of Castleblayney town on the R183 Castleblayney to Ballybay Regional Road. According to information provided by Monaghan County Council (MCC), the landfill ceased operations in 1984.

A Tier 1 Assessment completed by Fehily Timoney & Co. (FT) in June 2018 determined the site has a risk classification of High (Class A) based on risk of leachate runoff entering Corrinshigo Lough and the risk of landfill gas migration to nearby human receptors.

The Tier 2 study consisted of a desktop study, geophysical survey, intrusive site investigation works, environmental monitoring (soil, waste, surface water and groundwater sampling) and laboratory analysis. The results of these works informed the development of the conceptual site model (CSM) and risk screening model.

The results of the Tier 2 assessment and risk model confirmed that the site is a **High-Risk Classification (Class A)**. The principal risks identified on the site are the risk to Corrinshigo Lough from the migration of leachate from the landfill into the surface water receptor, the shallow permeable soil cap across the site is contributing to leachate generation and the risk to the adjacent industrial building receptor from the migration of landfill gas from the waste material encountered at the site.

The purpose of this Tier 3 assessment was to further examine and quantify those risks/impacts through generation of computer models allowing a prediction of both the current and future impact on groundwater quality, associated impacts to surface water quality and the current and future volumes of landfill gas being generated by the waste present on site. This information was used to inform appropriate remedial and mitigation measures to either eliminate or reduce those risks.

The predicted contaminant concentration results obtained from the LandSim model confirmed a risk to groundwater and the likely migration of pollutants further downgradient of the site. LandSim was used to determine the impact the installation of a permeable landfill cap on the waste material may have on the generation of leachate and the dispersion of pollutants within the aquifer.

LandGEM was utilised to estimate the quantity of landfill gas produced by the waste body.

The Tier 3 assessment concludes that to mitigate the impact of leachate on the underlying aquifer and receptors downgradient, a landfill cap layer should be placed across the site. It is recommended that the proposed landfill cap will be constructed in accordance with the EPA recommendations/requirements for landfill site design. This will mitigate the contribution of rainfall infiltration towards leachate generation on the site.

The landfill cap will include a vertical cut off and leachate interception trench along the northern land drain boundary and western lake edge boundary of the site. The leachate interception trench will be constructed to break the pathway linkage between the landfill waste and the boundary drain and lake. This trench will mitigate leachate migration to surface water.

The landfill capping will also include active and/or passive landfill gas controls. A final decision on landfill gas control measures will be made upon completion of a landfill gas pumping trial. The pumping trial will be used to determine the quantity and quality of landfill gas actively produced at the site. The most appropriate landfill gas control measures should be determined with reference to EPA Guidance: Management of Low Levels of Landfill Gas and EPA Landfill Manuals, Landfill Site Design.

Additional surface water and groundwater monitoring and landfill gas migration locations are recommended.

1 TIER 3 QUANTITATIVE RISK ASSESSMENT

1.1 Background

Following the completion of a site investigation and Tier 2 risk assessment at former landfill at Killycard, Co. Monaghan by Fehily Timoney & Co in 2018 it was concluded that a Tier 3 assessment should be conducted. The findings of the Tier 2 assessment produced a firmer understanding of the characterisation of the site and facilitated the production of a revised Conceptual Site Model (CSM).

A Tier 3 assessment includes a quantitative risk assessment either as a Generic Quantitative Risk Assessment (GQRA) or a Detailed Quantitative Risk Assessment (DQRA). This Tier 3 assessment report outlines the outcomes of a DQRA. Elevated concentrations of ammonia were detected in all groundwater monitoring wells (GW01 to GW03) within the site area, indicating that the landfill and leachate generated may be having a deleterious effect on groundwater quality. Surface water monitoring was conducted on the northern drainage channel upstream of Corrinshigo Lough (SW1) and which runs immediately adjacent to the landfill and further downstream on this channel where it enters the lough (SW2). SW1 showed elevated concentrations of ammoniacal nitrogen and biochemical oxygen demand (BOD) when compared to the upstream monitoring locations suggesting that the site may be impacting on surface water quality.

LandSim modelling software was utilised as part of this DQRA to examine, quantify and forecast the potential impact of leachate generation from the landfill on downstream receptors. The outcome of this modelling aids in the determining the of appropriate remedial measures, which is a vital aspect of the Tier 3 assessment.

LandSim was created by Golder Associates Ltd for the UK Environmental Agency to provide probabilistic quantitative risk assessments of specific landfill site performance in relation to groundwater protection. LandSim is a probabilistic model which uses the Monte Carlo simulation technique to select randomly from a pre-defined range of possible input values to create parameters for use in the model calculations.

Repeating the process many times gives a range of output values, the distribution of which reflects the uncertainty inherent in the input values and enables the likelihood of the estimated output levels being achieved to be ascertained.

The potential impact of gas generation was also considered as part of the Tier 3 assessment using LandGEM is a MS Excel operated model, developed by the US EPA, that estimates the quantity of landfill gases generated on site over a defined period. Again, as with LandSim this can be used to determine what, if any, remedial measures may be required to appropriately manage any emissions from the site and mitigate the potential risk to human or environmental health.

1.2 DQRA Model Setup - LandSim

LandSim setup involves several different stages which are described below. For many of the parameters and characteristics entered to the model, a degree of uncertainty is involved. This is modelled using a probability distribution function (PDF) i.e. the probability of the random numbers chosen by the model falling within a range of values. These PDFs have been determined based on the information available at the time of writing of this report, and statistical analysis of this information. Advice and default data provided in the LandSim documentation and guidance provided by the National Groundwater & Contaminated Land Centre (UK) have also been used, where appropriate.

1.2.1 Domain Area

The initial step involves the definition of the domain area. The domain area is the total area that will be modelled and contains the landfill phase and receptor.

The domain area is defined in terms of x and y. The x direction (left to right) is orientated in the direction of groundwater flow, and the y direction runs perpendicular to the direction of groundwater flow (i.e. the site is modelled with an alternative orientation to its actual orientation in terms of North, South, East and West).

Phase Definition

Within the domain, the landfill is broken into distinct areas or phases. Based on available information and the history of the site, no defined phases of waste acceptance and filling of the area could be defined, either spatially or chronologically. Therefore, for the purposes of defining the estimated waste disposal footprint area within the model, the Killycard site was defined as a single 'phase'.

Figure 1-1 shows the screen shot of the domain area for the Killycard model. The model can only simulate groundwater flow from left to right, so the orientation of the site is adjusted accordingly.

For each domain, the time offset from the start of filling (i.e. the opening year of the facility) is also defined.

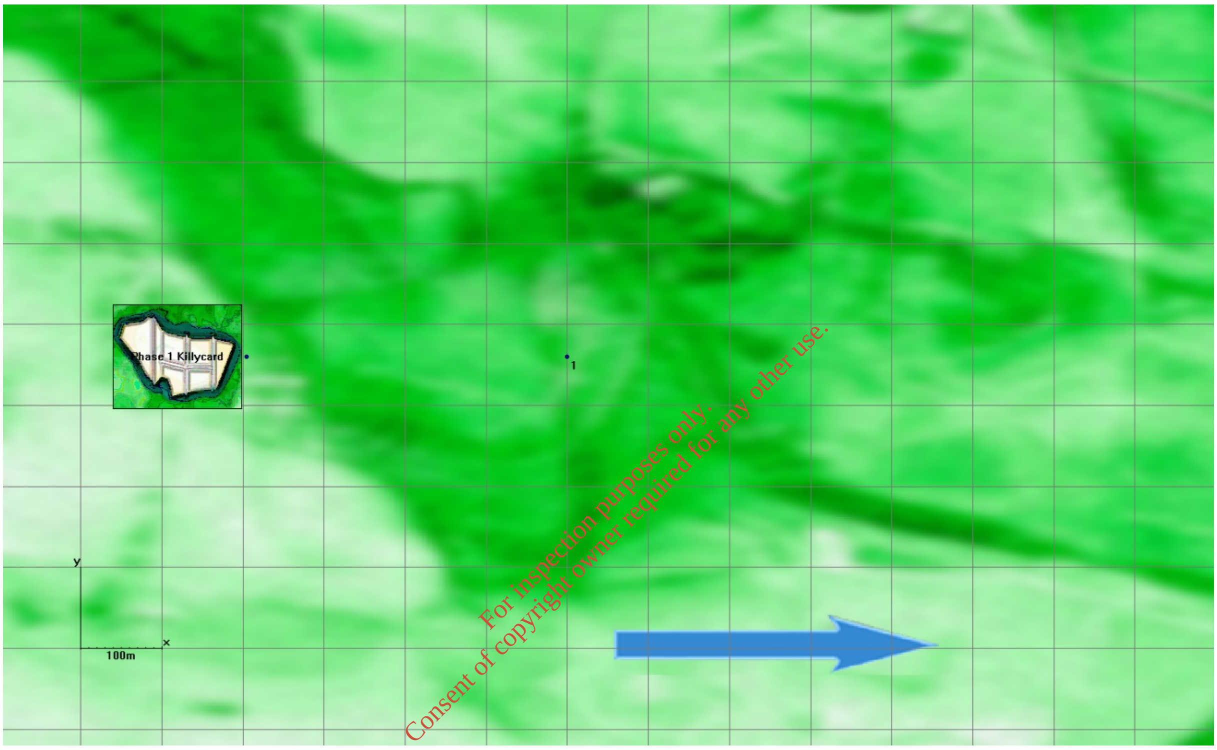


Figure 1-1: Domain Layout in LandSim

Aquifer Properties

Within the domain area, the aquifer properties are defined. LandSim automatically calculates the pathway length, which is dependent on the domain area and the geometry of the site, while the pathway width will vary for each phase, as it is the width of the phase across groundwater flow.

The remaining aquifer characteristics are aquifer thickness, vertical, longitudinal and transverse dispersivity, hydraulic conductivity, regional hydraulic grade, and pathway porosity.

The Tier 2 assessment site investigation determined that the groundwater table transects the waste body and is confined at its base only by the competent sandstone bedrock identified, underlying the site. It is understood that as a result the sandstone bedrock may also be confining the spread of leachate generated onsite. Groundwater and leachate are potentially confined to moving downgradient along the surface of the sandstone bedrock. It is this sandstone stratum that has been applied in the LandSim model as the aquifer pathway.

LandSim assumes that all layers i.e. the landfill cells, unsaturated pathway, vertical pathway and aquifer pathway etc. are clearly separate layers with defined boundaries, each with their own characteristics.

Intrusive site investigation did not confirm the thickness of the sandstone bedrock aquifer. Based on the estimated waste thickness and publicly available information on the general characteristics of the bedrock aquifer provided by Geological Survey Ireland (GSI) an aquifer thickness of between 13m to 18m was applied in the model. The variation in thickness was used to account for the variation in waste thickness across the site.

The vertical, longitudinal and transverse dispersivities were calculated using standard calculation methods:

- Longitudinal Dispersivity:
  $a_x = 0.1 * L$ (Pickens and Grisak, 1981)
- Transverse Dispersivity:
  $a_y = 0.1 * a_x \rightarrow a_x$ (Freeze & Cherry, 1979)
  or
  $a_y = 0.1 * a_x \rightarrow 0.33 * a_x$ (Gelhar, 1992)
- As a rule of thumb, vertical dispersivity may range between $1*10^{-99}$ to 0.1 times the longitudinal dispersivity.

The site-specific findings on groundwater levels within investigative wells across the sites yielded a hydraulic gradient for the aquifer underlaying the site, of approximately 0.0028 to 0.0055. This corresponds with observations and the topographical survey of the site.

Falling head permeability tests were conducted to the determine permeability of the sandstone bedrock. The falling head tests took account of the top 4m of the sandstone bedrock. These tests were conducted on three wells on site (GW01, GW02 & GW03) and yielded permeabilities of $3.36x10^{-7}$ m/s, $2.54x10^{-7}$ m/s and $5.11x10^{-8}$ m/s, respectively (mean = $2.14x10^{-7}$).

These results are within the expected range of hydraulic conductivity for the geology type identified onsite. The pathway porosity was inputted based on standard published data for the lithologies present[1].

1.2.2 Phase Details

The next step was to define the characteristics of each phase. For each phase, the characteristics listed below are defined.

Each input must be defined at the time of entry. Appendix 1 contains the output from LandSim, which details the inputs for each of the parameters for each phase.

Infiltration

The infiltration to open waste, the cap design infiltration rate in each phase were entered as single values. An effective rainfall of 654 mm/year, as published Geological Survey Ireland (GSI) spatial data, was applied as the infiltration rate to open waste. Grazed areas of the site are covered with a shallow soil cap. There are currently several derelict mushroom houses on site and a more recently developed commercial/industrial area on the eastern portion of the site. For simplification and as a conservative measure the entire site has been modelled as a single 'phase' and the same infiltration rates have been applied across the entirety of the site.

The GSI have applied a groundwater recharge co-efficient 22.5% for the area and a stated maximum recharge capacity of 100 mm/yr. Conservatively, a calculated recharge of 147 mm/yr (22.5% of 654 mm/yr.) was applied as the current cap design infiltration rate.

[1] Domenico, P.A. and Schwartz, F.W. (1990) Physical and Chemical Hydrogeology

The infiltration rate was adjusted for the remedial scenario model. This scenario assumes the installation of a more impermeable landfill cap reducing infiltration rates. The remedial scenarios modelled aims to represent a 'what if' scenario whereby an alternate landfill management and/or engineering design is applied to the site. A further reduction in infiltration (10% of the effective rainfall rate) was applied. The proposed remedial measures are discussed in greater detail in Section 3 below.

Cell Geometry

Site investigations did not identify any designed cells or cell structures within the overall the waste deposition area. It has been assumed (conservatively) that a single cell covers approximately the total area of the defined waste footprint.

The waste thickness applied to the model was determined as part of the Tier 2 assessment site investigation. Geophysical surveying of the site identified that the thickness of waste was quite variable throughout the site. An average waste thickness of 2.2m to 2.4m was determined. A uniform distribution, *Uniform (2.2,2.4)* metre thickness was applied in the model.

As no exact data on waste porosity is available, a review of available literature yielded an estimated waste porosity was included in the model as *Triangular (0.42,0.54,0.62).*

Density of waste assumed a range between 1.2 and 1.6 kg/l.

The waste field capacity used ranged between 0.2 and 0.4.

Leachate Inventory

Groundwater monitoring conducted as part of the Tier 2 assessment identified elevated concentrations of ammoniacal nitrogen and lead in downgradient well GW03. Only these parameters were considered in the model. Ammoniacal nitrogen was also noted to be elevated above the groundwater quality threshold values in wells GW01 and GW02.

It is unknown what the characteristics of leachate generated at the site may have been while the site was operational or in the immediate years post closure . It was therefore necessary to utilise published source concentrations to apply in the model. For ammoniacal nitrogen and lead the default concentrations available in LandSim were applied. These values included were derived based on data analysis and review presented in '*A review of the composition of leachate from waste in landfill sites'* (Robinson, 1995).

No wells upgradient of the site and waste footprint area are available and therefore site-specific background concentrations could not be determined for the model. The Tier 2 assessment reported that the presence of peat underlying the site and waste which could be contributing to the elevated ammonia in groundwater.

An EPA study report titled '*Assessing and Developing Natural Background Levels for Chemical Parameters in Irish Groundwater*' (2017) was reviewed to aid in determining suitable background concentrations. That study yielded a 95th percentile concentration for lead in groundwater of 0.0029 mg/l. This was the chosen background concentration applied in the model.

With respect to ammoniacal nitrogen or ammonium only, a limited number of appropriate monitoring points and data sets were available for study. The predicted background concentrations exceeded groundwater threshold values. As a conservative measure, the lower limit of 0.065 mg/l (65 ug/l) for ammonium as per the European Union Environmental Objectives (Groundwater) (Amendment) Regulations 2016 (S.I. No. 366 of 2016 was applied as a background concentration.

Leachate concentrations and baseline background concentrations applied in the model are shown in Table 1.1 over.

Table 1-1: Leachate and Background Concentrations

Parameter	Concentration in Leachate [1] (mg/l)	Background Concentration (mg/l)
Ammonia	Triangular (4.37, 723, 3640)	Single (0.065)
Lead	Triangular (0.00957,0.13, 1.02)	Single (0.0029)

† A triangular distribution is defined by a minimum, most likely and maximum, based on statistical analysis.
Note 1: Leachate concentrations as per LandSim UK Default Leachate Inventory values

Drainage System (at the base of the cell)

For this calculation it was only necessary to specify the head of leachate at the base of the landfill. There is no constructed drainage system underlying the landfill nor is there any form of leachate head control. As an estimation the leachate head was specified as being the range of thicknesses of overburden or waste material from the underlying sandstone bedrock to ground surface, that is an average thickness of between 2.2 to 2.4m.

Engineered Barrier

There is no known engineered barrier underlying the landfill therefore none was accounted for in the model.

1.2.3 Geosphere Details

The output from the engineered barrier systems module of the LandSim is a rate of leachate leakage through the base of each phase of the landfill. Along with the individual contaminant concentrations output from the source term, these rates are used as a starting point to examine the behaviour of the leachate within the geosphere.

The geosphere consists of three pathways – the unsaturated zone, the vertical pathway and the aquifer pathway, as shown in Figure 1-2 below. Each of these geosphere pathways is assumed homogeneous and isotropic.

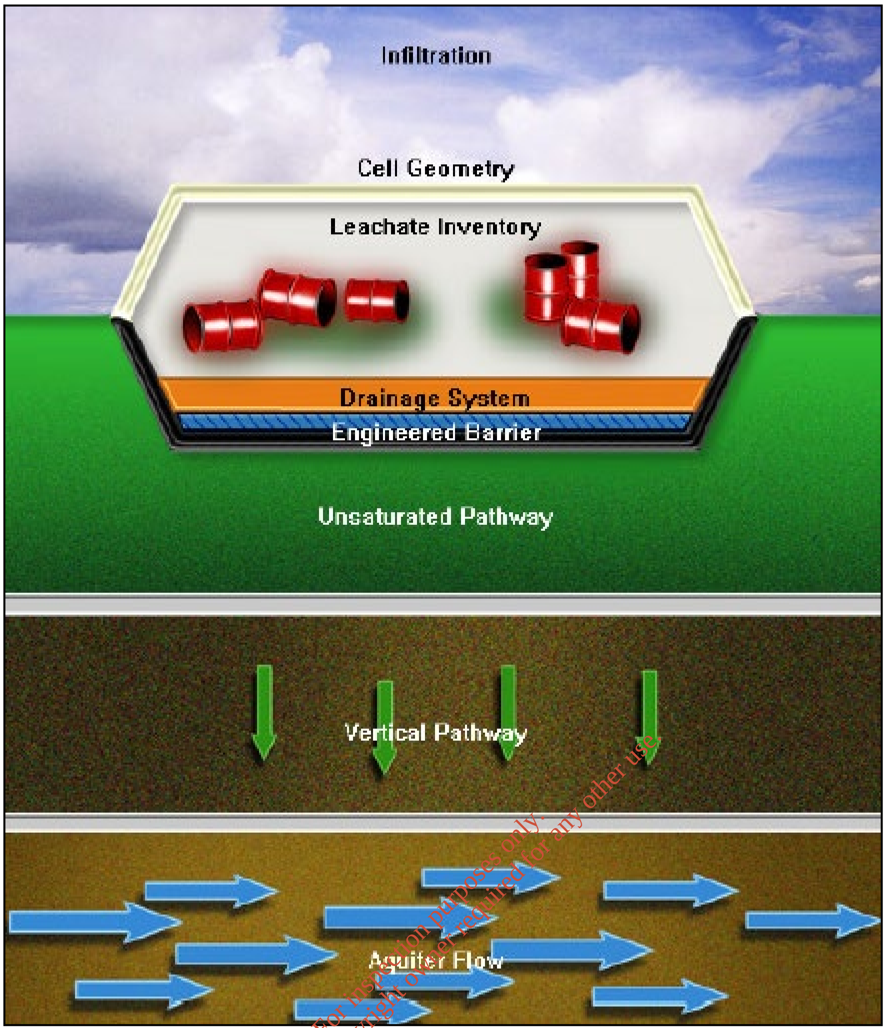


Figure 1-2: Geosphere Schematic

Unsaturated Pathway

It is known from site investigation that the groundwater table transects the waste material. One limitation of LandSim is that it is not possible to reflect this exactly. LandSim assumes that each aspect or layer of the geosphere as shown above is separate. As means to reflect the saturated nature of the waste body and the assumed direct contact between waste material and underlying aquifer, a minimal unsaturated pathway thickness was applied in the model.

Vertical Pathway

As per the comments regarding the unsaturated pathway aspect of the model, to mimic the direct contact much of the waste material is likely to have with the underlying aquifer no vertical pathway was modelled.

Aquifer

The aquifer details were input as described above.

1.2.4 Model Scenarios

LandSim is used as part of this Tier 3 assessment to aid in the determination of any engineering works or other remedial measures that may be required in to mitigate the identified risks to the environment associated with the historical landfill.

Two different model scenarios were developed to facilitate a comparison between mitigated and unmitigated landfill conditions.

Scenario 1 - a 'base' model was developed to reflect current conditions at the site and to predict present and future risks to groundwater should no remedial measures be implemented.

Scenario 2 - a 'remediation' scenario model was developed to predict the potential effects of the implementation of site remediation measures i.e. landfill cap would have on the generation and propagation of leachate from the landfill. As the site has been modelled as only one phase it is assumed that any hypothetical remedial measures are applied across the whole site. The installation of a landfill cap can be reflected through the adjustment of several model inputs, shown below:

- Cap design Infiltration (mm/yr.)
- PE Cap (yes/no)
- Infiltration to grassland (mm/yr.)
- Start of cap degradation (years from end of waste disposal)
- End of cap degradation (years from end of waste disposal)

This remediation scenario model examined the impact of the installation of a low permeability capping layer across the site. This was reflected in the model through the input of a reduced cap design infiltration rate. A single value of 65.4 mm/year (10% of effective rainfall rate) cap design infiltration rate was applied.

A list of model inputs, generated by LandSim, for both scenarios are presented in Appendix 1 of this report.

1.3 Results - LandSim

1.3.1 Leachate Concentration

A full calculation run of 1,001 iterations was carried out on each model to examine the relative changes in model outputs or potential impacts between each model scenario. The model outputs are shown in Table 1-2:

Table 1-2: Source Concentration at Year 0, 50 and 500 (Base Model)

Parameter	Year	5%ile	50%ile	95%ile	GW Monitoring Oct 2018	
					Min	Max
Ammoniacal Nitrogen (mg/l)	0	208.9	472.7	886.4		
	50	17.81	43.26	85.13	1.13	19.2
	500	0.00013	0.00049	0.0018		
Lead (mg/l)	0	0.083	0.16	0.28		
	50	0.035	0.06	0.095	0.00021	0.0743
	500	0.00036	0.00057	0.00086		

Table 1-3 presents species concentration values below which concentrations will remain for respective %-iles i.e. time intervals (95%, 50% and 5%).

For example, Ammoniacal Nitrogen will remain below:

- 886.4 mg/l for 95% of the time
- 472.7 mg/l for 50% of the time
- 208.9 mg/l for 5% of the time

LandSim results generated at the 50-year point are assumed to approximately reflect present day conditions. It is noted that the groundwater monitoring wells installed as part of the Tier 2 assessment site investigation are located within the waste footprint and leachate was encountered during the investigation. Although the presence of leachate did not appear to be distributed evenly throughout the site the groundwater monitoring results obtained could be regarded as representing leachate/source concentrations at present. Source concentrations for both ammoniacal nitrogen and lead at 50 years are within the range of those groundwater monitoring results obtained as part of the Tier 2 assessment.

1.3.2 Leachate Generation

The rate of leachate generation under the current condition scenario and remediation scenario were compared. The rate of leachate generation is directly dependent on the rainfall infiltration rate to the waste material. As stated above, the installation of a low impermeable landfill cap is reflected in the model through the application of a reduced cap design infiltration rate.

Table 1-3: Leachate Generation Rates

Site Scenario	Time slice (years)	95%-ile (l/day)	50%-ile (l/day)	5%-ile (l/day)
Current	10	37,243	37,243	3,724
	50	8,371	8,371	8,371
	100	8,371	8,371	8,371
Remediation (Cap only)	10	37,243	3,7243	3,724
	50	3,724	3,724	3,724
	100	3,724	3,724	3,724

At 10 years the site was still operational and waste material was still being deposited. As the site has been modelled as a single phase it is assumed that the entirety of the site area contains waste. To develop this model, it has been assumed and stated in the model that waste activities took place for 14 years. During this period the open waste infiltration rate is applied, after which it is assumed that the site was closed and capped. At this point the 'cap design infiltration rate' is applied. This corresponds with a c.77.5% reduction in leachate generation rate at the 50-year point as shown in Table 1.3. The remediation scenarios assume the installation of a more effective, lower permeability capping yielding a greater reduction in leachate generation (c.90%).

1.3.3 Monitor Well Concentrations

Another output from the LandSim model that was examined as part of this assessment was the concentration of each contaminant of concern at the perimeter of the waste body/phase as defined in the model. LandSim automatically places a monitor well at the downstream perimeter edge of each phase area included in the model. The 95%-ile and 50%-ile results were examined with the 95%-ile values representing an extreme worst-case scenario.

A summary of concentration results at the monitor well location for each of the selected parameters is provided in Table 1.4 over.

Table 1-4: Monitor Well Concentrations (Base Scenario)

Parameter	Time slice	Base Scenario 95%-ile (mg/l)	Base Scenario 50%-ile (mg/l)	Capping Scenario 95%-ile (mg/l)	Capping Scenario 50%-ile (mg/l)	GTV* (mg/l)
Ammoniacal N	10	0.0764	0.0650	0.0665	0.065	0.065 – 0.175
	50	803.88	174.761	911.671	6.38109	
	100	836.498	343.119	1409.99	81.2726	
	500	58.8335	12.8793	412.284	82.3231	
Lead	10	0.0029	0.0029	0.0029	0.0029	0.0075
	50	0.0029	0.0029	0.0029	0.0029	
	100	0.0029	0.0029	0.0029	0.0029	
	500	0.0029	0.0029	0.0029	0.0029	

*GTV: as per Groundwater quality threshold values - S.I. No. 366/2016

1.3.4 Discussion of Results

Table 1-3 summarises the predicted source concentrations generated by LandSim under the base scenario. Predicted source concentrations at the 50-year point (assumed to be present day) are within the range of concentrations observed in groundwater samples obtained and analysed in 2018. It is noted that monitoring results were shown to vary considerably between the two leachate wells/sampling locations, particularly with respect to ammoniacal nitrogen and lead. This is indicative of the likely heterogeneity of the waste and its composition throughout the site. Results for source concentrations at 500 years are also included showing the predicted decline in source concentration over a greater time-period. As discussed previously in the report, lateral infiltration of groundwater to the waste body is likely to be contributing to the removal and leaching of material from the landfill.

The results obtained from the LandSim model show that there is a likely ongoing risk to groundwater quality (and surface water as a consequence) beneath and downstream of the site. The model predicts aquifer concentrations greater than those observed from groundwater samples therefore limiting the application of the model to accurately determine/predict downstream aquifer concentrations in the future. However, for demonstrating the potential efficacy of remedial measures on leachate generation and dispersion the model was deemed to be suitable.

As shown in Table 1-3, there is a significant reduction in leachate generation/leakage when a lower permeability capping material is assumed resulting in a lower infiltration rate to the underlying waste material. One constraint of LandSim in its application to quantitatively assess the Killycard site is that it is assumed that all leachate generated relates directly to the volume of rainfall. As stated above it is known from site investigation that the groundwater table transects the waste body and it would be expected that a significant depth of waste is saturated with groundwater. As such, it is likely that the movement of groundwater through the waste body has historically and is currently a significant factor in the generation of leachate from the site.

Proposed remediation measures are discussed in Section 3 of this report.

1.4 Background DQRA Landfill Gas

The Tier 2 assessment identified lateral and vertical landfill gas migration as a high risk, (normalised risk scores of 70% and 14% respectively)

Monitoring for landfill gases emitted from onsite groundwater monitoring wells was conducted on two occasions as part of the Tier 2 site investigation.

All wells tested yielded positive results for methane during both monitoring rounds with methane concentrations being above the threshold at GW01 (1.0 v/v CH_4) on the 9th of October. This indicates the waste is still biologically active and continuing to produce methane.

The monitoring results from the two gas monitoring events are shown in Table 1-5 below.

Table 1-5: Combined Groundwater/Gas Well Monitoring Results September and October 2018

Date: 2-10-2018						
Sample Station	**CH_4 (% v/v)**	**CO_2 (% v/v)**	**O_2 (% v/v)**	**Atmospheric Pressure (mbar)**	**Staff Member**	**Weather**
GW01	0.8	1.2	21.8	1028	Daniel Hayden	Cloudy with light wind N-NE, 12°C - 14°C
GW02	0.2	0.1	22.3	1028		
GW03	0.4	0.6	22.0	1028		
Date: 9-10-2018						
Sample Station	**CH_4 (% v/v)**	**CO_2 (% v/v)**	**O_2 (% v/v)**	**Atmospheric Pressure (mbar)**	**Staff Member**	**Weather**
GW01	**1.5**	1.3	20.1	1005	Daniel Hayden	Cloudy with light wind N - NE, 14°C - 16°C
GW02	0.2	0.5	21.3	1005		
GW03	0.8	0.9	21.3	1005		

1.5 Model Setup - 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 1.6.

The results of this model will assist to identify any remedial or control measures to mitigate or monitor landfill gas risk.

Table 1-6: LandGEM Model Primary Inputs and Variables

Landfill Characteristics	Input	Source
Landfill Open Year	1970	Exact timeframe of landfill operation is unknown. Start of filling operations assumed.
Landfill Closure Year	1984	Anecdotal evidence suggests landfilling activities ceased c.1984.
Have Model Closure Calculate Closure Year	Yes	

Landfill Characteristics	Input	Source
Waste Design Capacity (megagrams/tonnes)	67,200	Estimated waste volume determined as part of Tier 2 assessment and site investigation, average waste thickness multiplied by site area at assumed waste bulk density (1.4 kg/l).
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)		
1970 - 1984	4800	Exact waste acceptance quantities per year are unknown. Worst case assumed waste design capacity was filled equally over 1970 to 1984 (14 year) period

1.6 Results – LandGEM

Modelling landfill gas generation in LandGEM generates a series of graphs illustrating the production rate of each specified pollutant.

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 1-7. The model predicts that the site is currently generating 8.17 m^3/hr of methane across the entire site area. This will reduce to 4.95 m^3/hr by 2029.

Table 1-7: 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	179	108	143125	86810	0.020	0.012	16.34	9.91
Methane	48	29	71563	43405	0.005	0.003	8.17	4.95
Carbon dioxide	131	79	71563	43405	0.015	0.009	8.17	4.95
NMOC	2	1	573	347	0.000	0.000	0.07	0.04

The approximate maximum waste deposition footprint was estimated to be approximately 2.2 Ha (22,000 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 1-8.

Table 1-8: 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	0.008	6.506	9.27×10^{-7}	7.43×10^{-4}
Methane	0.002	3.253	2.48×10^{-7}	3.71×10^{-4}
Carbon dioxide	0.006	3.253	6.80×10^{-7}	3.71×10^{-4}
NMOC	9.33×10^{-5}	0.026	1.06×10^{-8}	2.97×10^{-6}

1.6.1 Discussion of Results

The outcome of the LandGEM model predicts a very low rate of landfill gas generation in the current year (16.34 m^3/hr). As shown in Table 1-7 LandGEM estimated that in the current year (2019) a relatively low quantity of 16.34 m^3/hour of landfill gas across the whole site is generated and assuming 50% percent of that volume being methane (8.17 m^3).

Landfill gas migration monitoring of leachate wells conducted in 2018 yielded methane contents of 0.2 to 1.5% supporting the findings that only low quantities of landfill gas and methane are being produced.

Figure 1-3 below shows the estimated landfill gas generation rates per year during the operational phase (c.1970 to 1984) and predicted generation rates from 1984 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.

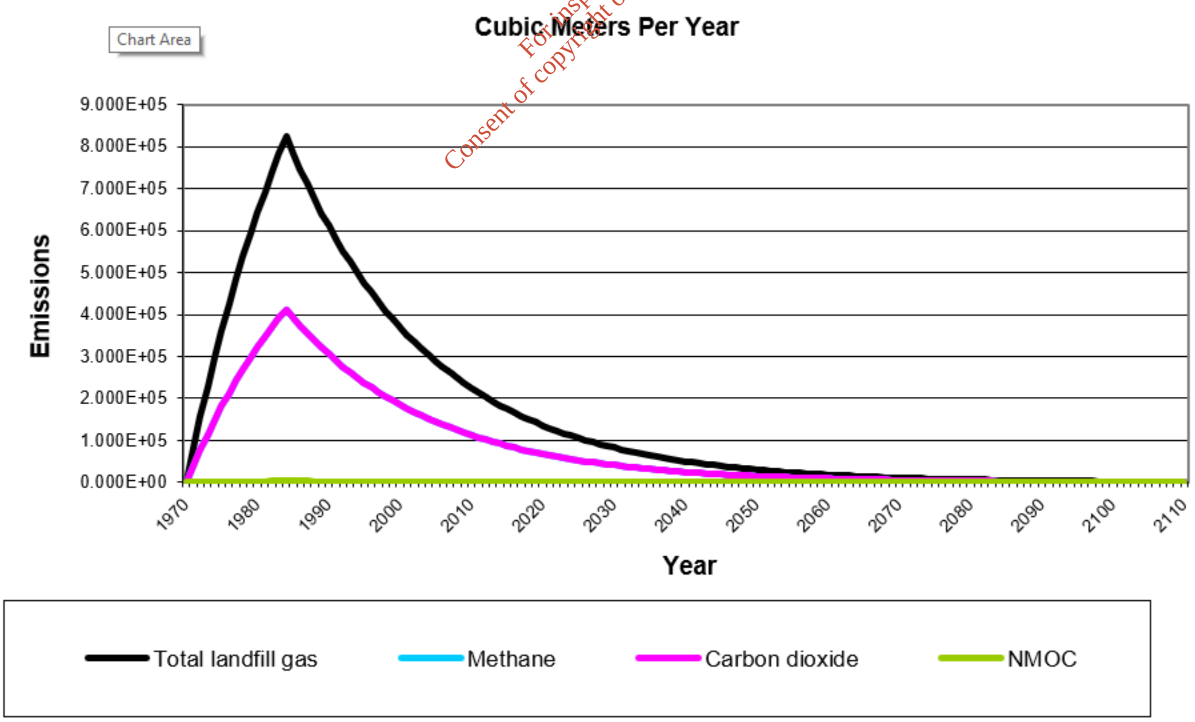


Figure 1-3: LandGEM Landfill Gas Volume Generation Rate

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

2 CONCLUSION AND RECCOMENDATIONS

The aim of this Tier 3 assessment was to examine (quantitatively) the potential impact the historical landfill site on the receiving environment.

Two computer models were used in this Tier 3 assessment. LandSim was used to examine the potential impacts on aquifer/groundwater quality and subsequently on the receiving surface water body (Corrinshigo Lough) and to compare the magnitude of the impact where potential remediation measures are applied.

Two different modelling scenarios (scenario 1 - current site conditions 'base' scenario and scenario 2- "remediation" – an improved cap scenario) were examined as part of this assessment. Scenario 1 - "base" model was prepared to represent the current site conditions with respect to existing site capping and any current site management methods. Scenario 2 included the adjustment of the cap design infiltration rate to representing the installation of an improved, low permeability cap layer.

The models conclude that the installation of a lower permeability cap yielded a significant predicted reduction in leachate generation and leakage from the base of the landfill. The landfill cap should be designed in accordance with the EPA Landfill design manual for non-inert, non-hazardous landfills. The capping should typically consist of the following

- 200mm Topsoil Layer
- 800mm Sub Soil
- Sub-Surface Drainage Geocomposite
- 1mm LLDPE Barrier Layer
- Sub-Surface Landfill Gas Collection Geocomposite

LandGEM outputs predict that relatively low quantities of landfill gas (16.34 m3/hr) will be generated at the site. It is recommended that landfill gas control measures should be installed at the site to minimise the risk of landfill gas migration to adjacent commercial building post capping.

Appropriate control measures shall be selected in accordance with the EPA Guidance document: *Management of Low Levels of Landfill Gas.* Passive ventilation to atmosphere combined with landfill gas migration cut off trenches will be utilised to minimise the risks associated with low levels of landfill gas.

The remedial action plan sets out the proposed remedial measures recommended.

3 REMEDIAL ACTION PLAN

Based on the findings of the modelling exercises and quantitative risk assessment the following measures are proposed to mitigate the identified risks to surface waters from leachate and identified risk arising from gas generation at the landfill.

3.1 S-P-R Linkages

Following comprehensive desktop review, a site investigation and a Tier 2 assessment identified the primary source-pathway-receptors (S-P-R) linkages for the site to be leachate migration through surface water pathways and vertical and lateral migration of landfill gases. Proposed remedial measures for each of these linkages are discussed below.

3.1.1 Leachate Migration through surface water pathway (SPR8)

Results of environmental monitoring and observation made onsite demonstrated that site is hydrologically linked to the Corronshigo Lough both immediately adjacent to the site to the west and via land drains located along the northern boundary of the site. The aquifer and groundwater underlying the landfill is likely to be also hydraulically connected with the lough.

It is expected that during the operational phase of the site that the Corrinshigo Lough was a primary receptor of any leachate or contaminated runoff from the waste deposited, particularly along the western boundary of the site and the northern boundary of the site along the land drain. Waste material was observed at the surface along this drain during a site walkover conducted as part of the Tier 1 assessment.

The following remediation measures are proposed to mitigate the effect of the landfill on the neighbouring Corrinshigo Lough.

Landfill Capping

A fully engineered landfill cap is proposed for the site. The landfill cap will be designed in accordance with the EPA Landfill design manual for non-inert, non-hazardous landfills. The capping will typically consist of the following

- 200mm Topsoil Layer
- 800mm Sub Soil
- Sub-Surface Drainage Geocomposite
- 1mm LLDPE Barrier Layer
- Sub-Surface Landfill GAS Collection Geocomposite

The proposed landfill cap will significantly reduce the generation of leachate via percolation of rainwater and subsequently the potential migration of leachate to surface water . The capping design should be consistent with the future uses of the site for agricultural grazing purposes. The sub soil layer will be therefore be adequately specified to ensure it is free draining to support grazing.

Leachate Interception Trench – Northern and Western Boundary

The landfill cap will also include vertical cut off and leachate interception trench along the land drain and lake shore boundary of the site (Northern and Western Boundary).

The leachate interception trench will be constructed to break/limit the pathway linkage between the landfilled waste and the boundary drain/lough. Localised hydraulic control/drainage of leachate will minimise leachate flows to the surface water receptor. The leachate interception trench will be drained to a controlled collection sump located to the western extent of the site

The leachate sump will be set to a control level (0.5m) below (or greater) that of the drain invert limiting hydraulic connectivity between the site and the surface water system. Localised hydraulic control/drainage of leachate will minimise leachate flows to the surface water receptor.

A vertical cut-off constructed using LLPDE liner will also be constructed to further limit the potential for leachate to enter the surface water bodies. The barrier will provide an impermeable pathway between the source (waste body) the lough and land drain receptor. The barrier will also ensure that leachate pumping from the interceptor trench does not inadvertently affect the base flow of the stream.

3.1.2 Vertical and Lateral Gas Generation (SPR10 & SPR11)

It is recommended that landfill gas control measures will be installed at the site. It is proposed that passive ventilation measures and vertical landfill gas interception trenches be used to mitigate the risk of landfill gas migration. The proposed measures are discussed in further detail below.

Passive Ventilation

The DQRA model indicates insufficient landfill gas volumes are present to warrant active abstraction and passive ventilation may be the most appropriate technique to mitigate landfill gas migration. It is proposed that capping will include a landfill gas drainage layer, the drainage layer will be directly connected to collection network and a series of vertical stand pipes venting to atmosphere at 2-3m above the final ground level.

The vertical stand pipes will provide a preferential pathway for LFG to escape to atmosphere mitigation risks associated with migration to offsite receptors.

Installed ventilation stand pipes will include a carbon filtration packs to "scrub" any odour and low concentrations of methane from the landfill gas prior to venting. Wind driven rotating cowls will also be used to induce a negative pressure within the stand pipe improving potential LFG flow.

3.1.3 Landfill Gas Interception Trench (SPR11)

A landfill gas interception trench is proposed along the Eastern site boundary of the site between the site and the existing development. The interception trench will comprise a deep vertical cut of barrier installed to prevent gas migration laterally to the adjoining building. The barrier will be installed to a depth of approximately 2.0 - 2.5m; subject to detailed design and further site investigation.

The installed LLDPE barrier will link to the landfill gas migration network to provide a preferential flow pathway via the installed landfill gas management system.

3.1.4 Environmental Monitoring: Existing Locations

It is recommended that groundwater and surface water monitoring continue at all existing monitoring locations at the site specifically

- Groundwater (Groundwater Quality and Landfill Gas Migration):
  - GW01
  - GW02
  - GW03
- Surface Water (Surface Water Quality):
  - SW1
  - SW2

Continued environmental monitoring should be undertaken on a quarterly basis up until the recommendations of the Certificate of Authorisation are known and remediation works are complete.

Monitoring data should be available prior to detailed remediation design to confirm the findings of this report and for use post remediation as baseline data for comparative analysis.

3.1.5 Environmental Monitoring: Proposed New Locations

It is proposed that an additional monitoring points be installed up and down gradient of the site.

The following additional surface water monitoring locations are recommended, final location should be agreed on site based on site conditions and access.

- SW3 – Downgradient of the site at a point on Corrinshigo Lough

The following additional landfill gas migration locations are recommended:

- LFG1 – Eastern Boundary
- LFG2 – Eastern Boundary
- LFG3 – Eastern Boundary

The following additional groundwater and landfill gas migration locations are recommended:

- GW04 –Baseline Upgradient (>25m<50m Upgradient of Waste Body)
- GW05 - Downgradient Receptor (>50m <100m Downgradient of Waste Body)

3.2 Remediation Design

The preliminary remediation design is presented in the following drawings:

- P1724-0100-0001
- P1724-0100-0002
- P1724-0500-0001
- P1724-0500-0002
- P1724-0700-0001
- P1724-0900-0001
- P1724-0900-0002
- P1724-0900-0003
- P1724-0900-0004

Drawings are included in Appendix 3 to this document.

3.2.1 Landfill Capping Works

The proposed capping works will be subject to Certificate of Authorisation, detailed design and agreement with existing site users and private landowner(s) and will be cognisant of the future site use.

A standard 1m capping layer is recommended across the site in line with the EPA Landfill Design Manual Guidance for non-inert, non-hazardous landfills.

Details are shown in drawing: P1724-0900-0001-4 inclusive.

The proposed sub-surface drainage system will comprise a herring bone drainage network across the site. The network will comprise sub-surface drains within the capping area connected with french drains external to the capping area.

Plan details are shown in drawing: P1724-0500-0001.

Inspection chambers will be located at all drain junctions for future maintenance and inspection.

A leachate interception trench will run along the northern land drain boundary and western boundary of the site, along Corrinshigo Lough.

The interception trench will be excavated vertically within the existing waste body to the required depth. The target depth of the trench will vary depending on location and gradients but will typically extend from 2.5-4.0 m below existing ground level.

Plan details are shown in drawing: P1724-0500-0002.

Section details for the proposed landfill gas interception trench along the Eastern site boundary are shown in drawing P1724-0900-0002.

Section details for the proposed leachate interception trench along the stream boundary are shown in drawing P1724-0900-0003.

Section details for the proposed leachate interception trench along the western site boundary is shown in drawing P1724-0900-0004.

3.2.2 Landfill Gas Management

Given the proximity of an industrial site to the site additional measures to mitigate lateral migration of landfill gases from site to this area an additional barrier is proposed to be installed along the western boundary of the industrial area. This type of barrier may comprise a typical anchor trench to include LLDPE barrier and gas collection geocomposite and backfilled with a compacted cohesive material.

The current estimated gas generation rate is relatively low and onsite monitoring has measured gas concentration nearing emissions limit values. Due to the presence of buildings immediately adjacent to the historic landfill and the risk that these buildings may also be underlain by waste and human activity on the site it is recommended that continuous gas monitors be installed onsite. It is recommended that CEMs be installed within all fully enclosed internal areas within buildings above the site.

This will ensure that in the extremely unlikely event of the build-up of landfill gas in occupied spaces above acceptable limits, these exceedances will be detected, and additional appropriate measures implemented if required.

A typical fixed gas monitor and control panel unit are shown below. Monitors such as these are regarded as being relatively low cost are simple to install and maintain. They are robust in terms of the variety of analytes that can be monitored for and probes that can be applied.

Figure 3-1: Typical Fixed Gas Monitor (Xgard fixed point gas detector)

Figure 3-2: Typical Gas Monitor Control Panel (Vortex Control Panel)

It is recommended a full internal survey of all buildings and spaces potentially at risk undertaken to identified all enclosed rooms and spaces, attention should be paid to smaller enclosed spaces such as maintenance cupboards/ server rooms and storage areas were no ventilation may exist.

3.3 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.

3.3.1 Landfill Capping

Table 3.1 over, outlines the costs associated with capping the site. The proposed capping is as per the EPA Landfill Design manual recommendations as presented previously.

Table 3-1: Landfill Capping: Remediation Cost Estimates

Item	Quantity	Unit	Rate, €	Cost	Note
Design and Supervision					
Allowance for Additional Site Investigation works	1	Rate	€25,000.00	€25,000.00	Allowance
Detailed Design and Supervision	1	Rate	€100,000.00	€100,000.00	Allowance
Land Rental Costs	1	Rate	€5,000.00	€5,000.00	Allowance
General Site Clearance and Demolition Works	***1.52***	***Ha***	-		
General Site Clearance	1.52	ha	€20,000.00	€30,400.00	Allowance for Clearance of Existing Site
Excavation Works	15200	m^2			Estimated area of Capping Area 15,200m^2
-					
Excavation of Existing Cover/Capping for Reuse/Filling	1520	m^3	€1.50	€2,280.00	Excavation of area to 100mm
Landfill Capping Works	15200				
Preparation of Excavated Surfaces	15200	m^2	€0.75	€11,400.00	Approximate Area, Local Rates 2018
Supply and Installation of 50mm Protection Layer	15200	m^2	€1.75	€26,600.00	Approximate Area, Local Rates 2018
Supply and Installation of Landfill Gas Collection Layer	15200	m^2	€5.50	€83,600.00	Approximate Area, Local Rates 2018
Installation of 1mm LLDPE Cap	15200	m^2	€6.50	€98,800.00	Approximate Area, Local Rates 2018
Installation of Surface Water Collection Layer	15200	m^2	€5.50	€83,600.00	Approximate Area, Local Rates 2018
Importation of 800mm Subsoil Capping Layer	15200	m^2	€8.50	€129,200.00	Approximate Area, Local Rates 2018

Item	Quantity	Unit	Rate, €	Cost	Note
Importation of 200mm Topsoil Capping Layer	15200	m^2	€3.00	€45,600.00	Approximate Area, Local Rates 2018
Allowance Landfill Gas Migration Network Infrastructure	15200	m^2	€3.00	€45,600.00	Allowance
Allowance Sub Surface Water Drainage Infrastructure	15200	m^2	€4.00	€60,800.00	Allowance
Independent CQA	1	Sum	€20,000.00	€20,000.00	Estimate Local Rates
Leachate Interception Trench (Northern Boundary)	137				Leachate Trench 137m
-					
Excavation of Existing Waste Materials	137	m^3	€4.00	€548.00	Assumed design, Local Rates 2018
Disposal of Waste Offsite	219.2	tonnes	€50.00	€10,960.00	Assumed design, Local Rates 2018
Lining of Interception Trench	479.5	m^2	€15.00	€7,192.50	Assumed design, Estimated Rate
Backfill with 16 23mm Rounded Washed Drainage Stone	137.0	m^3	€15.00	€2,055.00	Assumed design, Estimated Rate
225mm Slotted SDR 17 Drainage Pipe	137	m	€40.00	€5,480.00	Assumed design, Local Rates 2018
Leachate Collection Sump	1	Sum	€2,500.00	€2,500.00	Allowance
Intermediate Inspection Chambers	3	No.	€1,500.00	€4,110.00	Allowance
Mechanical and Electrical	1	Sum	€15,000.00	€15,000.00	Allowance
Leachate Interception Trench (Western Boundary)	132				Leachate Trench 132m
-					
Excavation of Existing Waste Materials	231	m3	€4.00	€924.00	Assumed design, Local Rates 2018
Disposal of Waste Offsite	370	tonnes	€75.00	€27,720.00	Assumed design, Local Rates 2018
Lining of Interception Trench	462	m2	€15.00	€6,930.00	Assumed design, Estimated Rate
Backfill with 16 23mm Rounded Washed Drainage Stone	231	m3	€15.00	€3,465.00	Assumed design, Estimated Rate
225mm Slotted SDR 17 Drainage Pipe	132	m	€40.00	€5,280.00	Assumed design, Local Rates 2018

Item	Quantity	Unit	Rate, €	Cost	Note
Leachate Collection Sump	1	Sum	€4,000.00	€4,000.00	Allowance
Intermediate Inspection Chambers	3	No.	€1,500.00	€3,960.00	Allowance
Mechanical and Electrical	1	Sum	€15,000.00	€15,000.00	Allowance
Landfill Gas Pumping Trial					
-					
Mobilisation	1	Sum	€3,500.00	€3,500.00	Local Rates 2018
Landfill Gas Well Ex. M&E, inc. piping and backfill	4	No.	€1,850.00	€7,400.00	Assumed design depth 6 8m and spacing, Local Rates 2018
Landfill Gas Well Heads	6	No.	€500.00	€3,000.00	Local Rates 20198
Supporting Infrastructure	1	Sum	€5,000.00	€5,000.00	Allowance
Design, Supervision and Interpretation	1	Sum	€10,000.00	€10,000.00	Allowance
Leachate Management Infrastructure					
Leachate Storage Tank	1	Sum	€50,000.00	€50,000.00	Estimate
Leachate Handling Yard	1	Sum	€75,000.00	€75,000.00	Estimate
Mechanical and Electrical					
Continuous Emissions Monitor Control Panel	2	No.	€2,200.00	€4,400.00	12 Channel Vortex Unit Budget Quotation CSL
Methane Detection Unit	16	No.	€230.00	€3,680.00	Budget Quotation, Estimated No. of Monitors
Carbon Dioxide Detection Unit	16	No.	€730.00	€11,680.00	Budget Quotation, Estimated No. of Monitors
Audio Visual Alarm Mounted	16	No.	€70.00	€1,120.00	Budget Quotation, Estimated No. of Monitors
Installation	1	Sum	€5,000.00	€5,000.00	Estimate
Commissioning and Testing	1	Sum	€1,500.00	€1,500.00	Budget Quotation, Estimated No. of Monitors

Item	Quantity	Unit	Rate, €	Cost	Note
Sub Total 1				€1,064,284.50	
Add 10% Contractor Prelims	10.0%			€106,428.45	
Sub Total 2				€1,170,712.95	
Add 7.5% Contingency	7.5%			€87,803.47	
Grand Total (excl VAT)				€1,258,516.42	

Notes

- This preliminary cost estimate does not purport to guess potential tender submissions in current and future market conditions.
- FTC has used approximations of rates for similar works items where possible and has used engineering judgement to estimate rates & sums where similar rates are not available
- Management of Hazardous Materials has not been allowed for.
- Pricing is based primarily on concept design provided for the site, no detailed designs have been completed
- This cost estimate assumes that materials to be imported are available from local sources
- This cost estimate excludes VAT
- This cost estimate excludes in/deflation
- This estimate includes for a level of contingency as indicated
- Costs are largely based on previously tendered rates for similar work or cited reference sources, Prices may have changed in the intervening period.

The estimated total remediation cost is **€1,258,516.42 (ex. VAT)** including the contingency as specified (7.5%).

Appendix 1

LandSim Model Inputs

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

Biodegradation

Saturated Vertical Pathway:

Retarded values used for simulation

Biodegradation

Aquifer Pathway:

Retarded values used for simulation

Biodegradation

Timeslices at: 10, 50, 100, 500

Decline in Contaminant Concentration in Leachate

Ammoniacal_N	Non-Volatile
c (kg/l): 0.59	m (kg/l): 0
Lead	Non-Volatile
c (kg/l): 0.0171	m (kg/l): 0.0443

Contaminant Half-lives (years)

Unsaturated Pathway:

Lead	SINGLE(1e+009)

Saturated Vertical Pathway:

Lead	SINGLE(1e+009)

Aquifer Pathway:

Lead	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Ammoniacal_N	SINGLE(0.065)
Lead	SINGLE(0.0029)

Phase: Phase 1 Killycard

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(147)
Infiltration to waste (mm/year):	SINGLE(654)
End of filling (years from start of waste deposit):	14

Justification for Specified Infiltration

Open Waste infiltration rate is GSI effective rainfall for area, cap design is based on application of GSI recharge co-efficient of 22.5%

Duration of management control (years from the start of waste disposal): 2000

Cell dimensions

Cell width (m):	130
Cell length (m):	159.231
Cell top area (ha):	2.08
Cell base area (ha):	2.07
Number of cells:	1
Total base area (ha):	2.07
Total top area (ha):	2.08
Head of Leachate when surface water breakout occurs (m)	SINGLE(2)
Waste porosity (fraction)	TRIANGULAR(0.42,0.54,0.62)
Final waste thickness (m):	UNIFORM(2.2,2.4)
Field capacity (fraction):	UNIFORM(0.2,0.4)
Waste dry density (kg/l)	UNIFORM(1.4,1.6)

Justification for Landfill Geometry

Single cell assumed for simplicity, assumed to be entire site area, finasl waste thickness based on geophyis and investigation, waste porosity assumed, density based on site investigation and material analysis, field capacity assumed, surface water breakout based on geophys sections

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(4.37,723,3640) *Data are spot measurements of Leachate Quality*
Lead	LOGTRIANGULAR(0.00957,0.13,1.02) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate

Contaminants of concern seleted based on groundwater monitoring. LandSim UK default concentrations applied. Background concentrations assumed. [CHANGED]

Drainage Information

Fixed Head.

Head on EBS is given as (m): UNIFORM(2.2,2.4)

Justification for Specified Head

Assumed as full thickness of input final waste thickness

Barrier Information

There is no barrier

Justification for Engineered Barrier Type

Unjustified value

pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(0.65,0.42)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.15,0.3)
Pathway Density (kg/l):	UNIFORM(0.8,2)

Justification for Unsat Zone Geometry
Estimated based on borehole logs and groundwater levels

Pathway hydraulic conductivity values (m/s): UNIFORM(1e-010,1e-006)

Justification for Unsat Zone Hydraulics Properties
Assumed based on literature values for peats and glacial tills

Pathway longitudinal dispersivity (m): NORMAL(0.065,0.042)

Justification for Unsat Zone Dispersion Properties
10% of pathway length values

Retardation parameters for pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,2)
Lead	LOGUNIFORM(27,270000)

Justification for Kd Values by Species
Kd assumed based on LandSim manual values

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(400,560)
Pathway width (m):	SINGLE(130)

Peat pathway parameters

Modelled as vertical pathway.

Pathway length (m):	UNIFORM(2.5,3.3)
Pathway porosity (fraction):	UNIFORM(0.2,0.8)

Justification for Vertical Path Geometry

Simplified geometry assumed based on borehole logs and CSM [CHANGED] [CHANGED]

Pathway dispersivity (m):	UNIFORM(0.25,0.33)

Justification for Vertical Path Dispersion Details

10% of pathway length

Retardation parameters for Peat pathway

Modelled as vertical pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,2)
Retardation parameters for Peat pathway	
Lead	LOGUNIFORM(27,270000)
Retardation parameters for Peat pathway	

Justification for Vertical Path Kd Values by Species

Assumed - values based on those provided in LandSim manual

Pathway Density (kg/l):	TRIANGULAR(0.8,1,2)

pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):

Calculated. Aquifer Thickness: UNIFORM(13,18)

Justification for Aquifer Geometry

Aquifer thicness based on GSI initial characterisation of Louth GWB and site inveistigation, groundwater levels etc.

Pathway regional gradient (-):	UNIFORM(0.0028,0.0055)
Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(3e-010,2.54e-007,3.36e-007)
Pathway porosity (fraction):	UNIFORM(0.05,0.3)

Justification for Aquifer Hydraulics Properties

Site specific falling head tests on LandSim manual data on sandstone K values.

Pathway longitudinal dispersivity (m):	UNIFORM(40,60)
Pathway transverse dispersivity (m):	UNIFORM(12,16.8)

Justification for Aquifer Dispersion Details

Longitudinal =10% of pathway length

Transverse = 3% of pathway length

Retardation parameters for pathway

Modelled as aquifer pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,2)
Lead	LOGUNIFORM(27,270000)

Justification for Aquifer Kd Values by Species

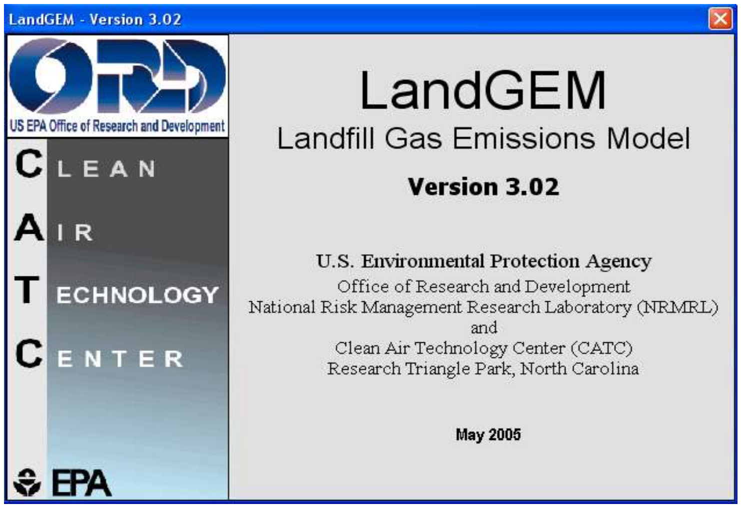
Assumed based on values provided in LandSim manual

Pathway Density (kg/l): UNIFORM(1.3,2)

Appendix 2

LandGEM Model Summary Report



Summary Report

Landfill Name or Identifier: Knockcronaghan Historical Landfill - Co.Monaghan

Date: Monday 13 May 2019

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	**1970**	
Landfill Closure Year (with 80-year limit)	**1983**	
Actual Closure Year (without limit)	***1983***	
Have Model Calculate Closure Year?	**Yes**	
Waste Design Capacity	**147,784**	*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)*
1970	10,556	11,612	0	0
1971	10,556	11,612	10,556	11,612
1972	10,556	11,612	21,112	23,223
1973	10,556	11,612	31,668	34,835
1974	10,556	11,612	42,224	46,446
1975	10,556	11,612	52,780	58,058
1976	10,556	11,612	63,336	69,670
1977	10,556	11,612	73,892	81,281
1978	10,556	11,612	84,448	92,893
1979	10,556	11,612	95,004	104,504
1980	10,556	11,612	105,560	116,116
1981	10,556	11,612	116,116	127,728
1982	10,556	11,612	126,672	139,339
1983	10,556	11,612	137,228	150,951
1984	0	0	147,784	162,562
1985	0	0	147,784	162,562
1986	0	0	147,784	162,562
1987	0	0	147,784	162,562
1988	0	0	147,784	162,562
1989	0	0	147,784	162,562
1990	0	0	147,784	162,562
1991	0	0	147,784	162,562
1992	0	0	147,784	162,562
1993	0	0	147,784	162,562
1994	0	0	147,784	162,562
1995	0	0	147,784	162,562
1996	0	0	147,784	162,562
1997	0	0	147,784	162,562
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2000	0	0	147,784	162,562
2001	0	0	147,784	162,562
2002	0	0	147,784	162,562
2003	0	0	147,784	162,562
2004	0	0	147,784	162,562
2005	0	0	147,784	162,562
2006	0	0	147,784	162,562
2007	0	0	147,784	162,562
2008	0	0	147,784	162,562
2009	0	0	147,784	162,562

WASTE ACCEPTANCE RATES (Continued)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	*(short tons/year)*	*(Mg)*	*(short tons)*
2010	0	0	147,784	162,562
2011	0	0	147,784	162,562
2012	0	0	147,784	162,562
2013	0	0	147,784	162,562
2014	0	0	147,784	162,562
2015	0	0	147,784	162,562
2016	0	0	147,784	162,562
2017	0	0	147,784	162,562
2018	0	0	147,784	162,562
2019	0	0	147,784	162,562
2020	0	0	147,784	162,562
2021	0	0	147,784	162,562
2022	0	0	147,784	162,562
2023	0	0	147,784	162,562
2024	0	0	147,784	162,562
2025	0	0	147,784	162,562
2026	0	0	147,784	162,562
2027	0	0	147,784	162,562
2028	0	0	147,784	162,562
2029	0	0	147,784	162,562
2030	0	0	147,784	162,562
2031	0	0	147,784	162,562
2032	0	0	147,784	162,562
2033	0	0	147,784	162,562
2034	0	0	147,784	162,562
2035	0	0	147,784	162,562
2036	0	0	147,784	162,562
2037	0	0	147,784	162,562
2038	0	0	147,784	162,562
2039	0	0	147,784	162,562
2040	0	0	147,784	162,562
2041	0	0	147,784	162,562
2042	0	0	147,784	162,562
2043	0	0	147,784	162,562
2044	0	0	147,784	162,562
2045	0	0	147,784	162,562
2046	0	0	147,784	162,562
2047	0	0	147,784	162,562
2048	0	0	147,784	162,562
2049	0	0	147,784	162,562

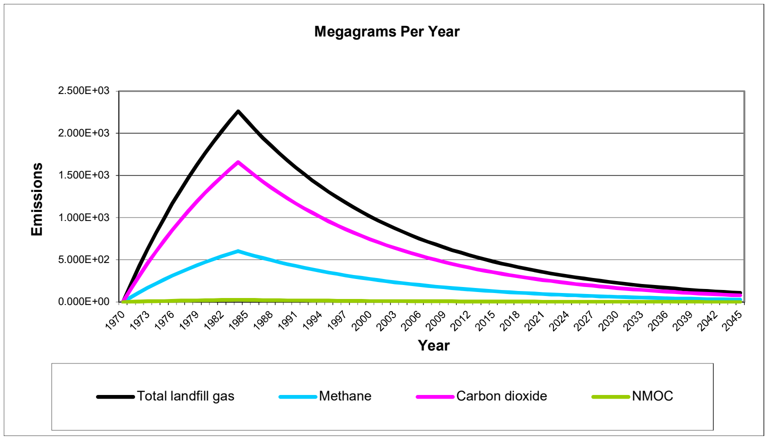
Pollutant Parameters

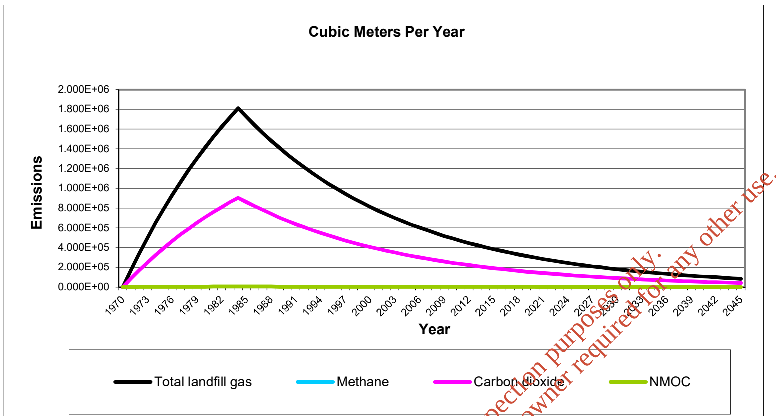
	Compound	Gas / Pollutant Default Parameters: Concentration (*ppmv*)	Molecular Weight	User-specified Pollutant Parameters: Concentration (*ppmv*)	Molecular Weight
Gases	Total landfill gas		0.00		
	Methane		16.04		
	Carbon dioxide		44.01		
	NMOC	4,000	86.18		
Pollutants	1,1,1-Trichloroethane (methyl chloroform) - 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		

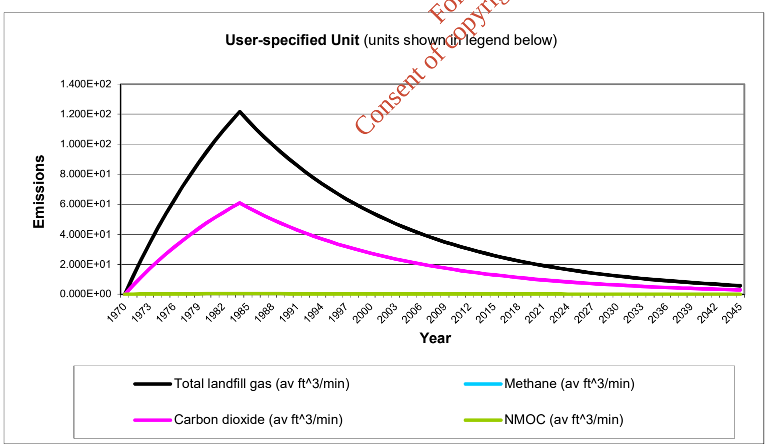
Pollutant Parameters (Continued)

	Gas / Pollutant Default Parameters:			User-specified Pollutant Parameters:	
	Compound	Concentration (*ppmv*)	Molecular Weight	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			Methane		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
1970	0	0	0	0	0	0
1971	2.191E+02	1.755E+05	1.179E+01	5.853E+01	8.774E+04	5.895E+00
1972	4.276E+02	3.424E+05	2.301E+01	1.142E+02	1.712E+05	1.150E+01
1973	6.259E+02	5.012E+05	3.367E+01	1.672E+02	2.506E+05	1.684E+01
1974	8.145E+02	6.522E+05	4.382E+01	2.176E+02	3.261E+05	2.191E+01
1975	9.939E+02	7.959E+05	5.348E+01	2.655E+02	3.979E+05	2.674E+01
1976	1.165E+03	9.325E+05	6.266E+01	3.111E+02	4.663E+05	3.133E+01
1977	1.327E+03	1.063E+06	7.139E+01	3.544E+02	5.313E+05	3.570E+01
1978	1.481E+03	1.186E+06	7.970E+01	3.957E+02	5.931E+05	3.985E+01
1979	1.628E+03	1.304E+06	8.760E+01	4.349E+02	6.519E+05	4.380E+01
1980	1.768E+03	1.416E+06	9.512E+01	4.722E+02	7.079E+05	4.756E+01
1981	1.901E+03	1.522E+06	1.023E+02	5.077E+02	7.611E+05	5.114E+01
1982	2.027E+03	1.623E+06	1.091E+02	5.415E+02	8.117E+05	5.454E+01
1983	2.148E+03	1.720E+06	1.155E+02	5.736E+02	8.598E+05	5.777E+01
1984	2.262E+03	1.811E+06	1.217E+02	6.042E+02	9.056E+05	6.085E+01
1985	2.152E+03	1.723E+06	1.158E+02	5.747E+02	8.615E+05	5.788E+01
1986	2.047E+03	1.639E+06	1.101E+02	5.467E+02	8.195E+05	5.506E+01
1987	1.947E+03	1.559E+06	1.047E+02	5.200E+02	7.795E+05	5.237E+01
1988	1.852E+03	1.483E+06	9.964E+01	4.947E+02	7.415E+05	4.982E+01
1989	1.762E+03	1.411E+06	9.478E+01	4.706E+02	7.053E+05	4.739E+01
1990	1.676E+03	1.342E+06	9.016E+01	4.476E+02	6.709E+05	4.508E+01
1991	1.594E+03	1.276E+06	8.576E+01	4.258E+02	6.382E+05	4.288E+01
1992	1.516E+03	1.214E+06	8.158E+01	4.050E+02	6.071E+05	4.079E+01
1993	1.442E+03	1.155E+06	7.760E+01	3.853E+02	5.775E+05	3.880E+01
1994	1.372E+03	1.099E+06	7.382E+01	3.665E+02	5.493E+05	3.691E+01
1995	1.305E+03	1.045E+06	7.022E+01	3.486E+02	5.225E+05	3.511E+01
1996	1.241E+03	9.941E+05	6.679E+01	3.316E+02	4.970E+05	3.340E+01
1997	1.181E+03	9.456E+05	6.353E+01	3.154E+02	4.728E+05	3.177E+01
1998	1.123E+03	8.995E+05	6.043E+01	3.000E+02	4.497E+05	3.022E+01
1999	1.068E+03	8.556E+05	5.749E+01	2.854E+02	4.278E+05	2.874E+01
2000	1.016E+03	8.139E+05	5.468E+01	2.715E+02	4.069E+05	2.734E+01
2001	9.668E+02	7.742E+05	5.202E+01	2.582E+02	3.871E+05	2.601E+01
2002	9.197E+02	7.364E+05	4.948E+01	2.457E+02	3.682E+05	2.474E+01
2003	8.748E+02	7.005E+05	4.707E+01	2.337E+02	3.503E+05	2.353E+01
2004	8.321E+02	6.663E+05	4.477E+01	2.223E+02	3.332E+05	2.239E+01
2005	7.916E+02	6.338E+05	4.259E+01	2.114E+02	3.169E+05	2.129E+01
2006	7.530E+02	6.029E+05	4.051E+01	2.011E+02	3.015E+05	2.026E+01
2007	7.162E+02	5.735E+05	3.853E+01	1.913E+02	2.868E+05	1.927E+01
2008	6.813E+02	5.456E+05	3.666E+01	1.820E+02	2.728E+05	1.833E+01
2009	6.481E+02	5.189E+05	3.487E+01	1.731E+02	2.595E+05	1.743E+01
2010	6.165E+02	4.936E+05	3.317E+01	1.647E+02	2.468E+05	1.658E+01
2011	5.864E+02	4.696E+05	3.155E+01	1.566E+02	2.348E+05	1.577E+01
2012	5.578E+02	4.467E+05	3.001E+01	1.490E+02	2.233E+05	1.501E+01
2013	5.306E+02	4.249E+05	2.855E+01	1.417E+02	2.124E+05	1.427E+01
2014	5.047E+02	4.042E+05	2.716E+01	1.348E+02	2.021E+05	1.358E+01
2015	4.801E+02	3.844E+05	2.583E+01	1.282E+02	1.922E+05	1.292E+01
2016	4.567E+02	3.657E+05	2.457E+01	1.220E+02	1.828E+05	1.229E+01
2017	4.344E+02	3.479E+05	2.337E+01	1.160E+02	1.739E+05	1.169E+01
2018	4.132E+02	3.309E+05	2.223E+01	1.104E+02	1.654E+05	1.112E+01
2019	3.931E+02	3.148E+05	2.115E+01	1.050E+02	1.574E+05	1.057E+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)*
2020	3.739E+02	2.994E+05	2.012E+01	9.987E+01	1.497E+05	1.006E+01
2021	3.557E+02	2.848E+05	1.914E+01	9.500E+01	1.424E+05	9.568E+00
2022	3.383E+02	2.709E+05	1.820E+01	9.037E+01	1.355E+05	9.101E+00
2023	3.218E+02	2.577E+05	1.731E+01	8.596E+01	1.289E+05	8.657E+00
2024	3.061E+02	2.451E+05	1.647E+01	8.177E+01	1.226E+05	8.235E+00
2025	2.912E+02	2.332E+05	1.567E+01	7.778E+01	1.166E+05	7.834E+00
2026	2.770E+02	2.218E+05	1.490E+01	7.399E+01	1.109E+05	7.452E+00
2027	2.635E+02	2.110E+05	1.418E+01	7.038E+01	1.055E+05	7.088E+00
2028	2.506E+02	2.007E+05	1.348E+01	6.695E+01	1.003E+05	6.742E+00
2029	2.384E+02	1.909E+05	1.283E+01	6.368E+01	9.545E+04	6.414E+00
2030	2.268E+02	1.816E+05	1.220E+01	6.058E+01	9.080E+04	6.101E+00
2031	2.157E+02	1.727E+05	1.161E+01	5.762E+01	8.637E+04	5.803E+00
2032	2.052E+02	1.643E+05	1.104E+01	5.481E+01	8.216E+04	5.520E+00
2033	1.952E+02	1.563E+05	1.050E+01	5.214E+01	7.815E+04	5.251E+00
2034	1.857E+02	1.487E+05	9.990E+00	4.960E+01	7.434E+04	4.995E+00
2035	1.766E+02	1.414E+05	9.503E+00	4.718E+01	7.071E+04	4.751E+00
2036	1.680E+02	1.345E+05	9.039E+00	4.488E+01	6.727E+04	4.520E+00
2037	1.598E+02	1.280E+05	8.598E+00	4.269E+01	6.399E+04	4.299E+00
2038	1.520E+02	1.217E+05	8.179E+00	4.061E+01	6.086E+04	4.089E+00
2039	1.446E+02	1.158E+05	7.780E+00	3.863E+01	5.790E+04	3.890E+00
2040	1.376E+02	1.101E+05	7.401E+00	3.674E+01	5.507E+04	3.700E+00
2041	1.308E+02	1.048E+05	7.040E+00	3.495E+01	5.239E+04	3.520E+00
2042	1.245E+02	9.966E+04	6.696E+00	3.325E+01	4.983E+04	3.348E+00
2043	1.184E+02	9.480E+04	6.370E+00	3.162E+01	4.740E+04	3.185E+00
2044	1.126E+02	9.018E+04	6.059E+00	3.008E+01	4.509E+04	3.030E+00
2045	1.071E+02	8.578E+04	5.764E+00	2.861E+01	4.289E+04	2.882E+00
2046	1.019E+02	8.160E+04	5.483E+00	2.722E+01	4.080E+04	2.741E+00
2047	9.693E+01	7.762E+04	5.215E+00	2.589E+01	3.881E+04	2.608E+00
2048	9.220E+01	7.383E+04	4.961E+00	2.463E+01	3.692E+04	2.480E+00
2049	8.771E+01	7.023E+04	4.719E+00	2.343E+01	3.512E+04	2.359E+00
2050	8.343E+01	6.681E+04	4.489E+00	2.228E+01	3.340E+04	2.244E+00
2051	7.936E+01	6.355E+04	4.270E+00	2.120E+01	3.177E+04	2.135E+00
2052	7.549E+01	6.045E+04	4.062E+00	2.016E+01	3.022E+04	2.031E+00
2053	7.181E+01	5.750E+04	3.863E+00	1.918E+01	2.875E+04	1.932E+00
2054	6.831E+01	5.470E+04	3.675E+00	1.825E+01	2.735E+04	1.838E+00
2055	6.497E+01	5.203E+04	3.496E+00	1.736E+01	2.601E+04	1.748E+00
2056	6.181E+01	4.949E+04	3.325E+00	1.651E+01	2.475E+04	1.663E+00
2057	5.879E+01	4.708E+04	3.163E+00	1.570E+01	2.354E+04	1.582E+00
2058	5.592E+01	4.478E+04	3.009E+00	1.494E+01	2.239E+04	1.504E+00
2059	5.320E+01	4.260E+04	2.862E+00	1.421E+01	2.130E+04	1.431E+00
2060	5.060E+01	4.052E+04	2.723E+00	1.352E+01	2.026E+04	1.361E+00
2061	4.813E+01	3.854E+04	2.590E+00	1.286E+01	1.927E+04	1.295E+00
2062	4.579E+01	3.666E+04	2.463E+00	1.223E+01	1.833E+04	1.232E+00
2063	4.355E+01	3.488E+04	2.343E+00	1.163E+01	1.744E+04	1.172E+00
2064	4.143E+01	3.318E+04	2.229E+00	1.107E+01	1.659E+04	1.115E+00
2065	3.941E+01	3.156E+04	2.120E+00	1.053E+01	1.578E+04	1.060E+00
2066	3.749E+01	3.002E+04	2.017E+00	1.001E+01	1.501E+04	1.008E+00
2067	3.566E+01	2.855E+04	1.919E+00	9.525E+00	1.428E+04	9.593E-01
2068	3.392E+01	2.716E+04	1.825E+00	9.060E+00	1.358E+04	9.125E-01
2069	3.227E+01	2.584E+04	1.736E+00	8.618E+00	1.292E+04	8.680E-01
2070	3.069E+01	2.458E+04	1.651E+00	8.198E+00	1.229E+04	8.257E-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)*
2071	2.920E+01	2.338E+04	1.571E+00	7.798E+00	1.169E+04	7.854E-01
2072	2.777E+01	2.224E+04	1.494E+00	7.418E+00	1.112E+04	7.471E-01
2073	2.642E+01	2.115E+04	1.421E+00	7.056E+00	1.058E+04	7.106E-01
2074	2.513E+01	2.012E+04	1.352E+00	6.712E+00	1.006E+04	6.760E-01
2075	2.390E+01	1.914E+04	1.286E+00	6.385E+00	9.570E+03	6.430E-01
2076	2.274E+01	1.821E+04	1.223E+00	6.073E+00	9.103E+03	6.117E-01
2077	2.163E+01	1.732E+04	1.164E+00	5.777E+00	8.659E+03	5.818E-01
2078	2.057E+01	1.647E+04	1.107E+00	5.495E+00	8.237E+03	5.535E-01
2079	1.957E+01	1.567E+04	1.053E+00	5.227E+00	7.835E+03	5.265E-01
2080	1.862E+01	1.491E+04	1.002E+00	4.972E+00	7.453E+03	5.008E-01
2081	1.771E+01	1.418E+04	9.527E-01	4.730E+00	7.090E+03	4.764E-01
2082	1.684E+01	1.349E+04	9.063E-01	4.499E+00	6.744E+03	4.531E-01
2083	1.602E+01	1.283E+04	8.621E-01	4.280E+00	6.415E+03	4.310E-01
2084	1.524E+01	1.220E+04	8.200E-01	4.071E+00	6.102E+03	4.100E-01
2085	1.450E+01	1.161E+04	7.800E-01	3.873E+00	5.805E+03	3.900E-01
2086	1.379E+01	1.104E+04	7.420E-01	3.684E+00	5.522E+03	3.710E-01
2087	1.312E+01	1.050E+04	7.058E-01	3.504E+00	5.252E+03	3.529E-01
2088	1.248E+01	9.992E+03	6.714E-01	3.333E+00	4.996E+03	3.357E-01
2089	1.187E+01	9.505E+03	6.386E-01	3.171E+00	4.752E+03	3.193E-01
2090	1.129E+01	9.041E+03	6.075E-01	3.016E+00	4.521E+03	3.037E-01
2091	1.074E+01	8.600E+03	5.779E-01	2.869E+00	4.300E+03	2.889E-01
2092	1.022E+01	8.181E+03	5.497E-01	2.729E+00	4.090E+03	2.748E-01
2093	9.718E+00	7.782E+03	5.229E-01	2.596E+00	3.891E+03	2.614E-01
2094	9.244E+00	7.402E+03	4.974E-01	2.469E+00	3.701E+03	2.487E-01
2095	8.793E+00	7.041E+03	4.731E-01	2.349E+00	3.521E+03	2.366E-01
2096	8.365E+00	6.698E+03	4.500E-01	2.234E+00	3.349E+03	2.250E-01
2097	7.957E+00	6.371E+03	4.281E-01	2.125E+00	3.186E+03	2.140E-01
2098	7.569E+00	6.061E+03	4.072E-01	2.022E+00	3.030E+03	2.036E-01
2099	7.199E+00	5.765E+03	3.873E-01	1.923E+00	2.882E+03	1.937E-01
2100	6.848E+00	5.484E+03	3.685E-01	1.829E+00	2.742E+03	1.842E-01
2101	6.514E+00	5.216E+03	3.505E-01	1.740E+00	2.608E+03	1.752E-01
2102	6.197E+00	4.962E+03	3.334E-01	1.655E+00	2.481E+03	1.667E-01
2103	5.894E+00	4.720E+03	3.171E-01	1.574E+00	2.360E+03	1.586E-01
2104	5.607E+00	4.490E+03	3.017E-01	1.498E+00	2.245E+03	1.508E-01
2105	5.333E+00	4.271E+03	2.870E-01	1.425E+00	2.135E+03	1.435E-01
2106	5.073E+00	4.062E+03	2.730E-01	1.355E+00	2.031E+03	1.365E-01
2107	4.826E+00	3.864E+03	2.596E-01	1.289E+00	1.932E+03	1.298E-01
2108	4.591E+00	3.676E+03	2.470E-01	1.226E+00	1.838E+03	1.235E-01
2109	4.367E+00	3.497E+03	2.349E-01	1.166E+00	1.748E+03	1.175E-01
2110	4.154E+00	3.326E+03	2.235E-01	1.109E+00	1.663E+03	1.117E-01

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
1970	0	0	0	0	0	0
1971	1.606E+02	8.774E+04	5.895E+00	2.516E+00	7.019E+02	4.716E-02
1972	3.134E+02	1.712E+05	1.150E+01	4.909E+00	1.370E+03	9.202E-02
1973	4.587E+02	2.506E+05	1.684E+01	7.186E+00	2.005E+03	1.347E-01
1974	5.969E+02	3.261E+05	2.191E+01	9.351E+00	2.609E+03	1.753E-01
1975	7.284E+02	3.979E+05	2.674E+01	1.141E+01	3.184E+03	2.139E-01
1976	8.535E+02	4.663E+05	3.133E+01	1.337E+01	3.730E+03	2.506E-01
1977	9.725E+02	5.313E+05	3.570E+01	1.523E+01	4.250E+03	2.856E-01
1978	1.086E+03	5.931E+05	3.985E+01	1.701E+01	4.745E+03	3.188E-01
1979	1.193E+03	6.519E+05	4.380E+01	1.869E+01	5.215E+03	3.504E-01
1980	1.296E+03	7.079E+05	4.756E+01	2.030E+01	5.663E+03	3.805E-01
1981	1.393E+03	7.611E+05	5.114E+01	2.182E+01	6.089E+03	4.091E-01
1982	1.486E+03	8.117E+05	5.454E+01	2.328E+01	6.494E+03	4.363E-01
1983	1.574E+03	8.598E+05	5.777E+01	2.466E+01	6.879E+03	4.622E-01
1984	1.658E+03	9.056E+05	6.085E+01	2.597E+01	7.245E+03	4.868E-01
1985	1.577E+03	8.615E+05	5.788E+01	2.470E+01	6.892E+03	4.631E-01
1986	1.500E+03	8.195E+05	5.506E+01	2.350E+01	6.556E+03	4.405E-01
1987	1.427E+03	7.795E+05	5.237E+01	2.235E+01	6.236E+03	4.190E-01
1988	1.357E+03	7.415E+05	4.982E+01	2.126E+01	5.932E+03	3.986E-01
1989	1.291E+03	7.053E+05	4.739E+01	2.023E+01	5.643E+03	3.791E-01
1990	1.228E+03	6.709E+05	4.508E+01	1.924E+01	5.367E+03	3.606E-01
1991	1.168E+03	6.382E+05	4.288E+01	1.830E+01	5.106E+03	3.430E-01
1992	1.111E+03	6.071E+05	4.079E+01	1.741E+01	4.857E+03	3.263E-01
1993	1.057E+03	5.775E+05	3.880E+01	1.656E+01	4.620E+03	3.104E-01
1994	1.005E+03	5.493E+05	3.691E+01	1.575E+01	4.394E+03	2.953E-01
1995	9.565E+02	5.225E+05	3.511E+01	1.498E+01	4.180E+03	2.809E-01
1996	9.098E+02	4.970E+05	3.340E+01	1.425E+01	3.976E+03	2.672E-01
1997	8.654E+02	4.728E+05	3.177E+01	1.356E+01	3.782E+03	2.541E-01
1998	8.232E+02	4.497E+05	3.022E+01	1.290E+01	3.598E+03	2.417E-01
1999	7.831E+02	4.278E+05	2.874E+01	1.227E+01	3.422E+03	2.299E-01
2000	7.449E+02	4.069E+05	2.734E+01	1.167E+01	3.255E+03	2.187E-01
2001	7.086E+02	3.871E+05	2.601E+01	1.110E+01	3.097E+03	2.081E-01
2002	6.740E+02	3.682E+05	2.474E+01	1.056E+01	2.946E+03	1.979E-01
2003	6.411E+02	3.503E+05	2.353E+01	1.004E+01	2.802E+03	1.883E-01
2004	6.099E+02	3.332E+05	2.239E+01	9.554E+00	2.665E+03	1.791E-01
2005	5.801E+02	3.169E+05	2.129E+01	9.088E+00	2.535E+03	1.704E-01
2006	5.518E+02	3.015E+05	2.026E+01	8.645E+00	2.412E+03	1.620E-01
2007	5.249E+02	2.868E+05	1.927E+01	8.223E+00	2.294E+03	1.541E-01
2008	4.993E+02	2.728E+05	1.833E+01	7.822E+00	2.182E+03	1.466E-01
2009	4.750E+02	2.595E+05	1.743E+01	7.441E+00	2.076E+03	1.395E-01
2010	4.518E+02	2.468E+05	1.658E+01	7.078E+00	1.975E+03	1.327E-01
2011	4.298E+02	2.348E+05	1.577E+01	6.733E+00	1.878E+03	1.262E-01
2012	4.088E+02	2.233E+05	1.501E+01	6.404E+00	1.787E+03	1.200E-01
2013	3.889E+02	2.124E+05	1.427E+01	6.092E+00	1.700E+03	1.142E-01
2014	3.699E+02	2.021E+05	1.358E+01	5.795E+00	1.617E+03	1.086E-01
2015	3.519E+02	1.922E+05	1.292E+01	5.512E+00	1.538E+03	1.033E-01
2016	3.347E+02	1.828E+05	1.229E+01	5.243E+00	1.463E+03	9.828E-02
2017	3.184E+02	1.739E+05	1.169E+01	4.988E+00	1.391E+03	9.349E-02
2018	3.029E+02	1.654E+05	1.112E+01	4.744E+00	1.324E+03	8.893E-02
2019	2.881E+02	1.574E+05	1.057E+01	4.513E+00	1.259E+03	8.459E-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)
2020	2.740E+02	1.497E+05	1.006E+01	4.293E+00	1.198E+03	8.047E-02
2021	2.607E+02	1.424E+05	9.568E+00	4.083E+00	1.139E+03	7.654E-02
2022	2.480E+02	1.355E+05	9.101E+00	3.884E+00	1.084E+03	7.281E-02
2023	2.359E+02	1.289E+05	8.657E+00	3.695E+00	1.031E+03	6.926E-02
2024	2.244E+02	1.226E+05	8.235E+00	3.515E+00	9.805E+02	6.588E-02
2025	2.134E+02	1.166E+05	7.834E+00	3.343E+00	9.327E+02	6.267E-02
2026	2.030E+02	1.109E+05	7.452E+00	3.180E+00	8.872E+02	5.961E-02
2027	1.931E+02	1.055E+05	7.088E+00	3.025E+00	8.439E+02	5.670E-02
2028	1.837E+02	1.003E+05	6.742E+00	2.878E+00	8.028E+02	5.394E-02
2029	1.747E+02	9.545E+04	6.414E+00	2.737E+00	7.636E+02	5.131E-02
2030	1.662E+02	9.080E+04	6.101E+00	2.604E+00	7.264E+02	4.881E-02
2031	1.581E+02	8.637E+04	5.803E+00	2.477E+00	6.910E+02	4.643E-02
2032	1.504E+02	8.216E+04	5.520E+00	2.356E+00	6.573E+02	4.416E-02
2033	1.431E+02	7.815E+04	5.251E+00	2.241E+00	6.252E+02	4.201E-02
2034	1.361E+02	7.434E+04	4.995E+00	2.132E+00	5.947E+02	3.996E-02
2035	1.294E+02	7.071E+04	4.751E+00	2.028E+00	5.657E+02	3.801E-02
2036	1.231E+02	6.727E+04	4.520E+00	1.929E+00	5.381E+02	3.616E-02
2037	1.171E+02	6.399E+04	4.299E+00	1.835E+00	5.119E+02	3.439E-02
2038	1.114E+02	6.086E+04	4.089E+00	1.745E+00	4.869E+02	3.272E-02
2039	1.060E+02	5.790E+04	3.890E+00	1.660E+00	4.632E+02	3.112E-02
2040	1.008E+02	5.507E+04	3.700E+00	1.579E+00	4.406E+02	2.960E-02
2041	9.589E+01	5.239E+04	3.520E+00	1.502E+00	4.191E+02	2.816E-02
2042	9.122E+01	4.983E+04	3.348E+00	1.429E+00	3.987E+02	2.679E-02
2043	8.677E+01	4.740E+04	3.185E+00	1.359E+00	3.792E+02	2.548E-02
2044	8.254E+01	4.509E+04	3.030E+00	1.293E+00	3.607E+02	2.424E-02
2045	7.851E+01	4.289E+04	2.882E+00	1.230E+00	3.431E+02	2.305E-02
2046	7.468E+01	4.080E+04	2.741E+00	1.170E+00	3.264E+02	2.193E-02
2047	7.104E+01	3.881E+04	2.608E+00	1.113E+00	3.105E+02	2.086E-02
2048	6.758E+01	3.692E+04	2.480E+00	1.059E+00	2.953E+02	1.984E-02
2049	6.428E+01	3.512E+04	2.359E+00	1.007E+00	2.809E+02	1.888E-02
2050	6.114E+01	3.340E+04	2.244E+00	9.579E-01	2.672E+02	1.795E-02
2051	5.816E+01	3.177E+04	2.135E+00	9.111E-01	2.542E+02	1.708E-02
2052	5.533E+01	3.022E+04	2.031E+00	8.667E-01	2.418E+02	1.625E-02
2053	5.263E+01	2.875E+04	1.932E+00	8.244E-01	2.300E+02	1.545E-02
2054	5.006E+01	2.735E+04	1.838E+00	7.842E-01	2.188E+02	1.470E-02
2055	4.762E+01	2.601E+04	1.748E+00	7.460E-01	2.081E+02	1.398E-02
2056	4.530E+01	2.475E+04	1.663E+00	7.096E-01	1.980E+02	1.330E-02
2057	4.309E+01	2.354E+04	1.582E+00	6.750E-01	1.883E+02	1.265E-02
2058	4.099E+01	2.239E+04	1.504E+00	6.421E-01	1.791E+02	1.204E-02
2059	3.899E+01	2.130E+04	1.431E+00	6.108E-01	1.704E+02	1.145E-02
2060	3.709E+01	2.026E+04	1.361E+00	5.810E-01	1.621E+02	1.089E-02
2061	3.528E+01	1.927E+04	1.295E+00	5.526E-01	1.542E+02	1.036E-02
2062	3.356E+01	1.833E+04	1.232E+00	5.257E-01	1.467E+02	9.854E-03
2063	3.192E+01	1.744E+04	1.172E+00	5.000E-01	1.395E+02	9.373E-03
2064	3.036E+01	1.659E+04	1.115E+00	4.757E-01	1.327E+02	8.916E-03
2065	2.888E+01	1.578E+04	1.060E+00	4.525E-01	1.262E+02	8.481E-03
2066	2.747E+01	1.501E+04	1.008E+00	4.304E-01	1.201E+02	8.068E-03
2067	2.613E+01	1.428E+04	9.593E-01	4.094E-01	1.142E+02	7.674E-03
2068	2.486E+01	1.358E+04	9.125E-01	3.894E-01	1.086E+02	7.300E-03
2069	2.365E+01	1.292E+04	8.680E-01	3.704E-01	1.033E+02	6.944E-03
2070	2.249E+01	1.229E+04	8.257E-01	3.524E-01	9.831E+01	6.605E-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)*
2071	2.140E+01	1.169E+04	7.854E-01	3.352E-01	9.351E+01	6.283E-03
2072	2.035E+01	1.112E+04	7.471E-01	3.188E-01	8.895E+01	5.977E-03
2073	1.936E+01	1.058E+04	7.106E-01	3.033E-01	8.461E+01	5.685E-03
2074	1.842E+01	1.006E+04	6.760E-01	2.885E-01	8.049E+01	5.408E-03
2075	1.752E+01	9.570E+03	6.430E-01	2.744E-01	7.656E+01	5.144E-03
2076	1.666E+01	9.103E+03	6.117E-01	2.610E-01	7.283E+01	4.893E-03
2077	1.585E+01	8.659E+03	5.818E-01	2.483E-01	6.928E+01	4.655E-03
2078	1.508E+01	8.237E+03	5.535E-01	2.362E-01	6.590E+01	4.428E-03
2079	1.434E+01	7.835E+03	5.265E-01	2.247E-01	6.268E+01	4.212E-03
2080	1.364E+01	7.453E+03	5.008E-01	2.137E-01	5.963E+01	4.006E-03
2081	1.298E+01	7.090E+03	4.764E-01	2.033E-01	5.672E+01	3.811E-03
2082	1.234E+01	6.744E+03	4.531E-01	1.934E-01	5.395E+01	3.625E-03
2083	1.174E+01	6.415E+03	4.310E-01	1.840E-01	5.132E+01	3.448E-03
2084	1.117E+01	6.102E+03	4.100E-01	1.750E-01	4.882E+01	3.280E-03
2085	1.063E+01	5.805E+03	3.900E-01	1.665E-01	4.644E+01	3.120E-03
2086	1.011E+01	5.522E+03	3.710E-01	1.583E-01	4.417E+01	2.968E-03
2087	9.614E+00	5.252E+03	3.529E-01	1.506E-01	4.202E+01	2.823E-03
2088	9.145E+00	4.996E+03	3.357E-01	1.433E-01	3.997E+01	2.685E-03
2089	8.699E+00	4.752E+03	3.193E-01	1.363E-01	3.802E+01	2.555E-03
2090	8.275E+00	4.521E+03	3.037E-01	1.296E-01	3.617E+01	2.430E-03
2091	7.871E+00	4.300E+03	2.889E-01	1.233E-01	3.440E+01	2.311E-03
2092	7.488E+00	4.090E+03	2.748E-01	1.173E-01	3.272E+01	2.199E-03
2093	7.122E+00	3.891E+03	2.614E-01	1.116E-01	3.113E+01	2.091E-03
2094	6.775E+00	3.701E+03	2.487E-01	1.061E-01	2.961E+01	1.989E-03
2095	6.445E+00	3.521E+03	2.366E-01	1.010E-01	2.817E+01	1.892E-03
2096	6.130E+00	3.349E+03	2.250E-01	9.603E-02	2.679E+01	1.800E-03
2097	5.831E+00	3.186E+03	2.140E-01	9.135E-02	2.549E+01	1.712E-03
2098	5.547E+00	3.030E+03	2.036E-01	8.690E-02	2.424E+01	1.629E-03
2099	5.276E+00	2.882E+03	1.937E-01	8.266E-02	2.306E+01	1.549E-03
2100	5.019E+00	2.742E+03	1.842E-01	7.863E-02	2.194E+01	1.474E-03
2101	4.774E+00	2.608E+03	1.752E-01	7.479E-02	2.087E+01	1.402E-03
2102	4.541E+00	2.481E+03	1.667E-01	7.114E-02	1.985E+01	1.334E-03
2103	4.320E+00	2.360E+03	1.586E-01	6.767E-02	1.888E+01	1.269E-03
2104	4.109E+00	2.245E+03	1.508E-01	6.437E-02	1.796E+01	1.207E-03
2105	3.909E+00	2.135E+03	1.435E-01	6.123E-02	1.708E+01	1.148E-03
2106	3.718E+00	2.031E+03	1.365E-01	5.825E-02	1.625E+01	1.092E-03
2107	3.537E+00	1.932E+03	1.298E-01	5.541E-02	1.546E+01	1.039E-03
2108	3.364E+00	1.838E+03	1.235E-01	5.270E-02	1.470E+01	9.879E-04
2109	3.200E+00	1.748E+03	1.175E-01	5.013E-02	1.399E+01	9.398E-04
2110	3.044E+00	1.663E+03	1.117E-01	4.769E-02	1.330E+01	8.939E-04

Appendix 3

Remediation Plan Drawings

Legend

- Site Boundary
- Area To Be Capped 15,146m²
- Existing Buildings To Be Surveyed For Installation Of CH4 And CO2 C.E.M.
- Existing Derelict Structures To Be Removed (Subject To Appropriate Consent)

0m 10m 20m 30m 40m 50m 60m 70m 80m 90m 100m

Scale 1:1000

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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT

ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET

SITE LOCATION MAP: KILLYCARD

CLIENT

MONAGHAN COUNTY COUNCIL

Date	Project number	Scale (@ A1-)
12.04.19	P1724	1:1000

Drawn by	Drawing Number	Rev
SOC	P1724-0100-0001	A
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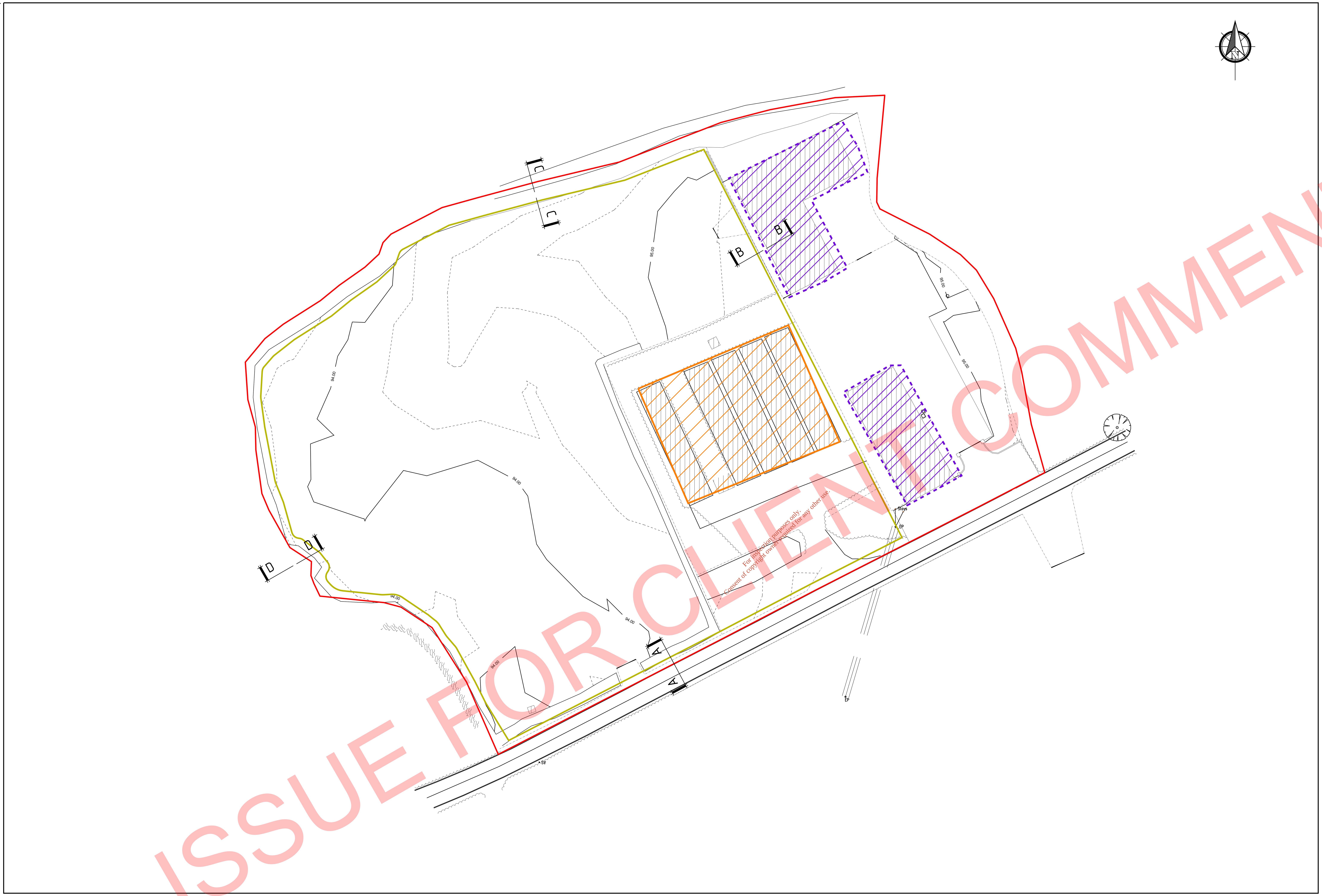

Legend

- Site Boundary
- Area To Be Capped 15,146m²
- Existing Buildings To Be Surveyed For Installation Of CH4 And CO2 C.E.M.
- Existing Derelict Structures To Be Removed (Subject To Appropriate Consent)

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

Scale 1:500

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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT

ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET

KILLYCARD WASTE BOUNDARY PLAN

CLIENT

MONAGHAN COUNTY COUNCIL

Date: 12.04.19	Project number: P1724	Scale (@ A1-): 1:500	
Drawn by: SOC	Drawing Number: P1724-0100-0002		Rev: A
Checked by: JON			

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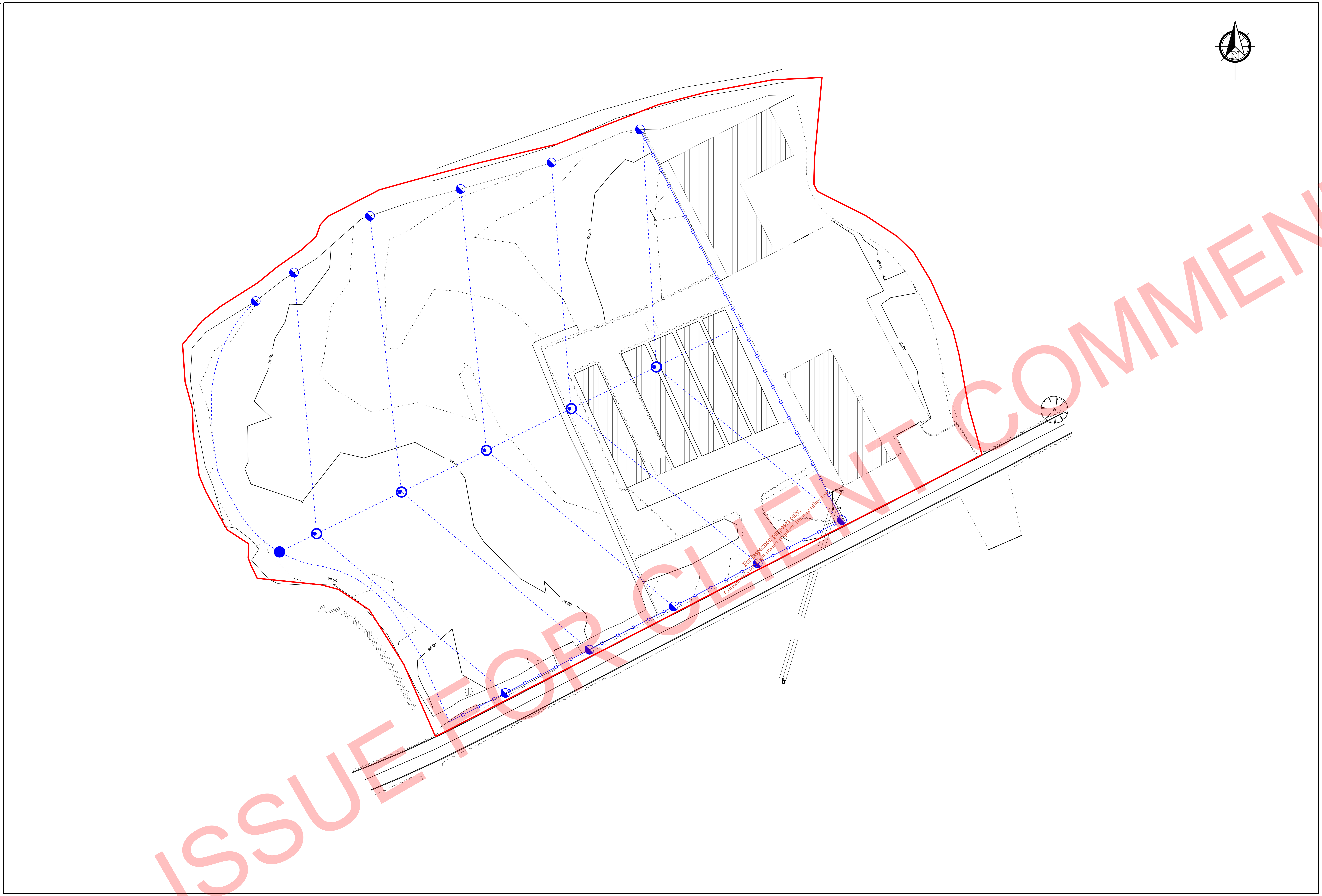
Tuesday 14 May 2019



Legend

- Site Boundary
- Sub Surface Drainage Network
- Combined Sub Surface/French Drain
- Intermediate Inspection Chamber
- Outfall Chamber
- Rodding/Jetting Access Point

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

Scale 1:500

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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT

ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET

SUB-SURFACE AND SURFACE DRAINAGE PLAN

CLIENT

MONAGHAN COUNTY COUNCIL

Date	Project number	Scale (@ A1-)
12.04.19	P1724	1:500

Drawn by	Drawing Number	Rev
SOC	P1724-0500-0001	A

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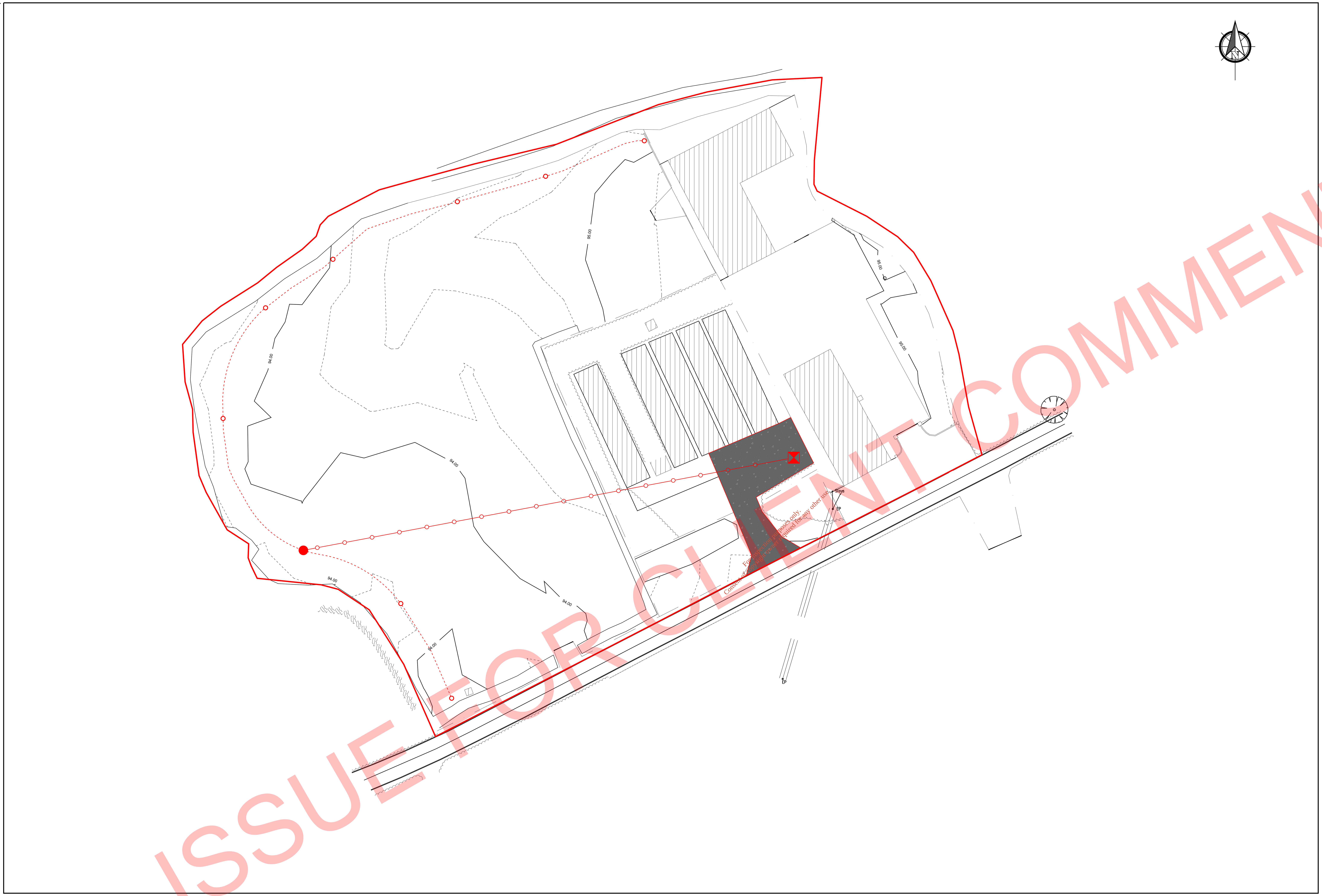

Legend

- Site Boundary
- Leachate Interception Drain
- Leachate Rising Main
- Intermediate Inspection Manhole
- Leachate Collection Sump
- Leachate Collection Tank
- Leachate Collection Yard

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

Scale 1:500

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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT

ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET

LEACHATE MANAGEMENT PLAN

CLIENT

MONAGHAN COUNTY COUNCIL

Date 12.04.19	Project number P1724	Scale (@ A1-) 1:500	
Drawn by SOC	Drawing Number		Rev
Checked by JON	P1724-0500-0002		A

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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT

ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET

LANDFILL GAS MANAGEMENT PLAN

CLIENT

MONAGHAN COUNTY COUNCIL

Date	Project number	Scale (@ A1-)
12.04.19	P1724	1:500

Drawn by	Drawing Number	Rev
SOC	P1724-0700-0001	A

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DETAIL A-A: ANCHOR TRENCH & FRENCH DRAIN

Scale 1:10

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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT
ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET
DETAILS SHEET 1 OF 4

CLIENT
MONAGHAN COUNTY COUNCIL

Date	Project number	Scale (@ A1-)
12.04.19	P1724	1:10

Drawn by SOC	Drawing Number	Rev
Checked by JON	P1724-0900-0001	A

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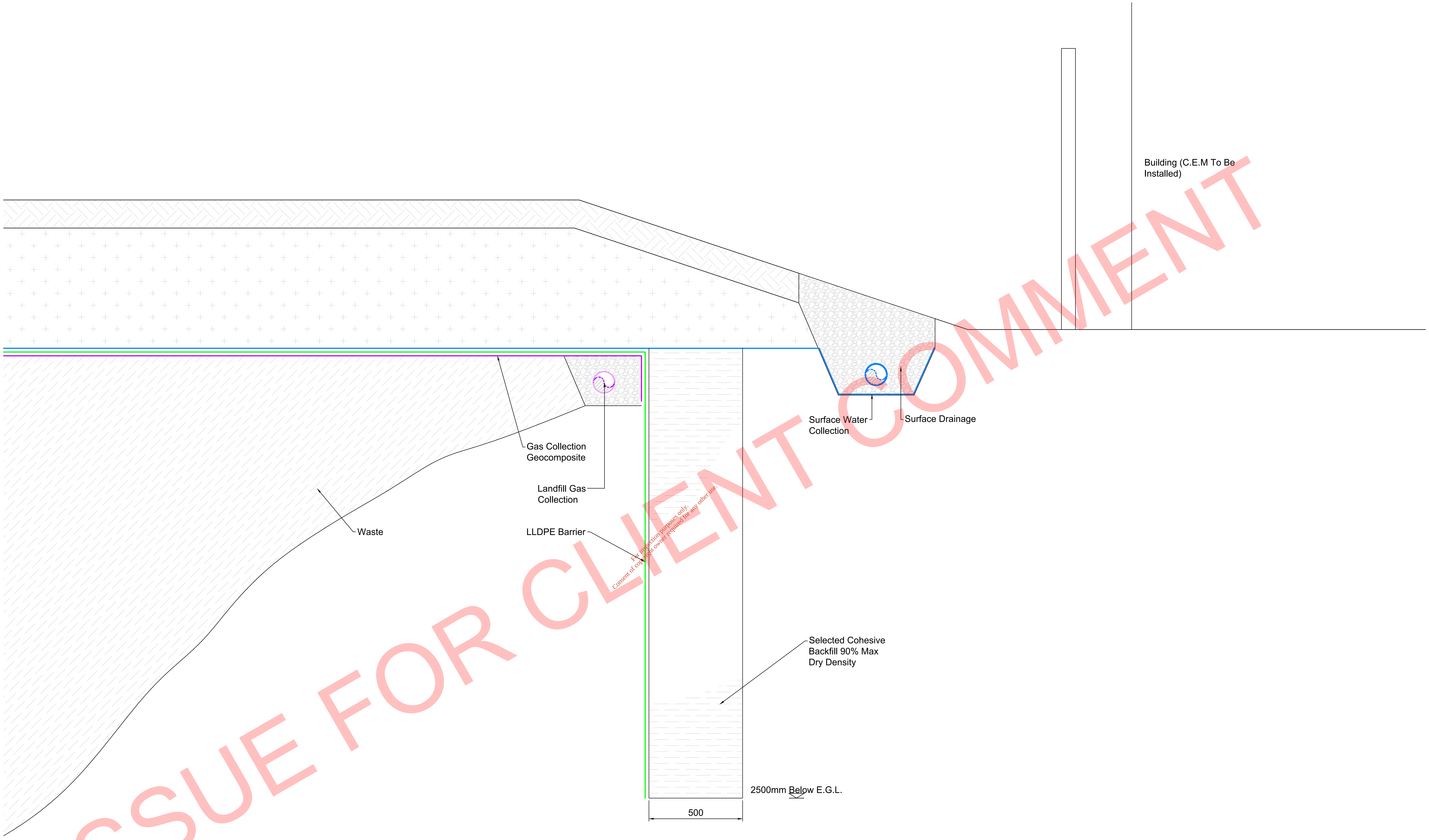

DETAIL B-B: LANDFILL GAS INTERCEPTOR TRENCH

Scale 1:10

0m 0.1m 0.2m 0.3m 0.4m 0.5m 0.6m 0.7m 0.8m 0.9m 1m
Scale 1:10

Rev.	Description	App By	Date
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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT
ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET
DETAILS SHEET 2 OF 4

CLIENT
MONAGHAN COUNTY COUNCIL

Date	Project number	Scale (@ A1-)
12.04.19	P1724	1:10

Drawn by	Drawing Number	Rev
SOC	P1724-0900-0002	A
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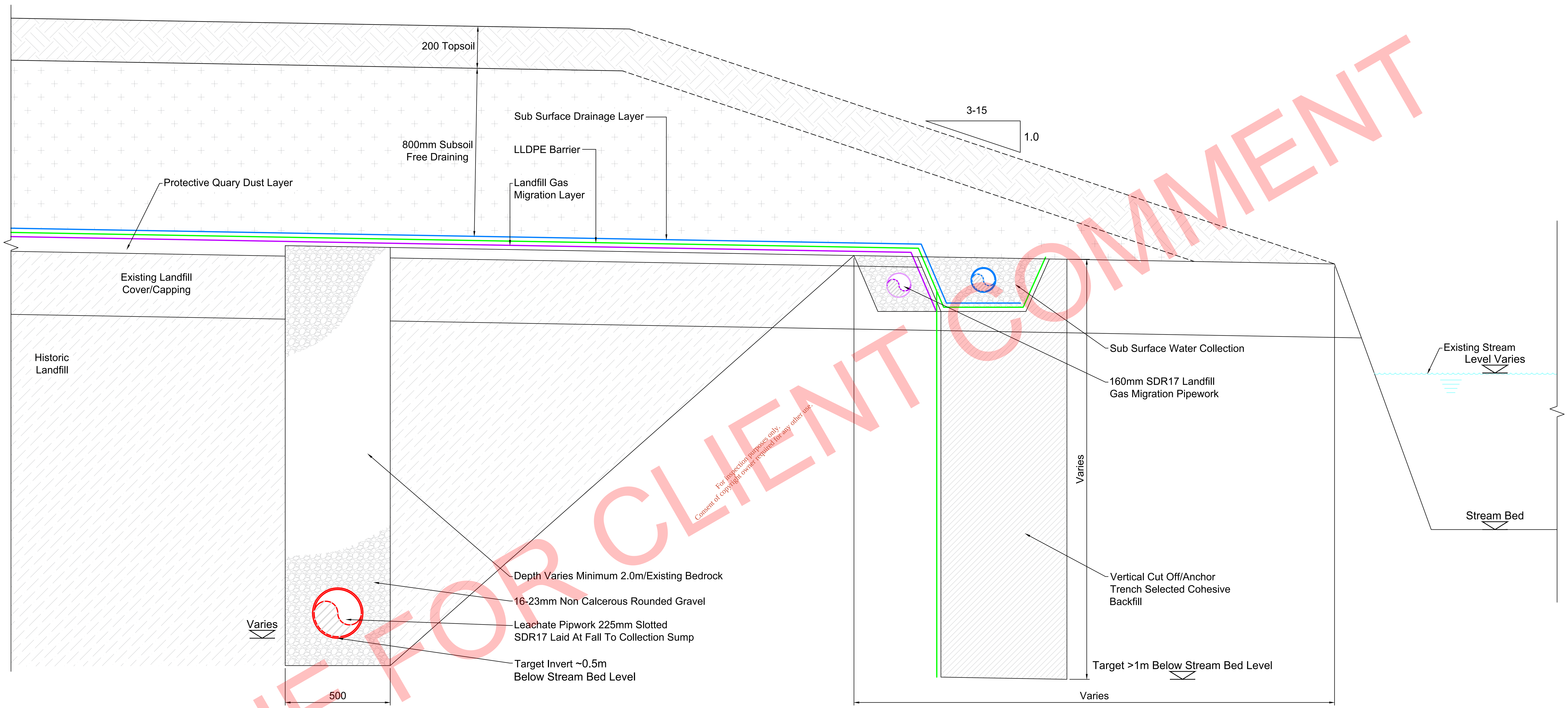

DETAIL C-C: LANDFILL ANCHOR TRENCH & LEACHATE INTERCEPTION DRAIN

Scale 1:10

0m 0.1m 0.2m 0.3m 0.4m 0.5m 0.6m 0.7m 0.8m 0.9m 1m

Scale 1:10

Rev.	Description	App By	Date
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PROJECT

ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET

DETAILS SHEET 3 OF 4

CLIENT

MONAGHAN COUNTY COUNCIL

Date 12.04.19	Project number P1724	Scale (@ A1-) 1:10	
Drawn by SOC	Drawing Number		Rev
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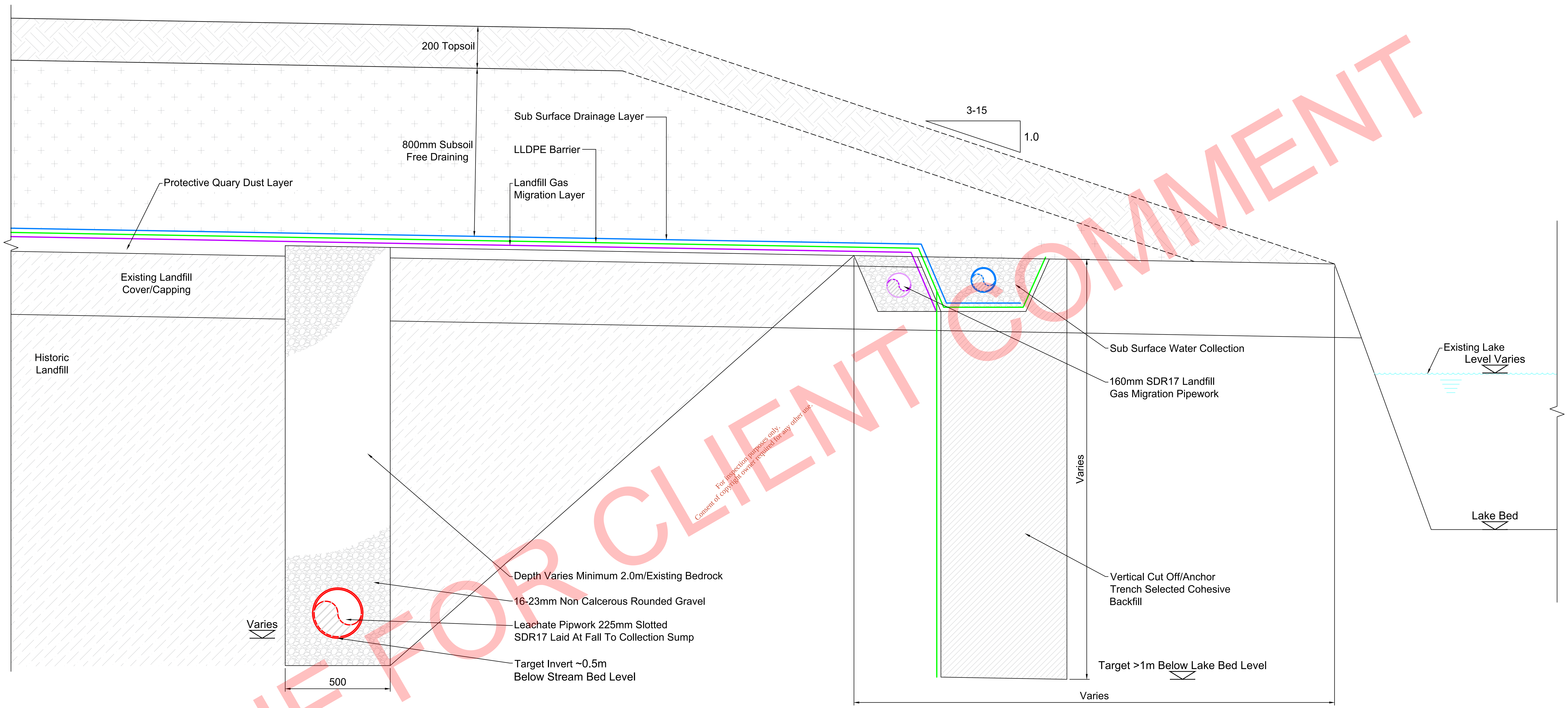
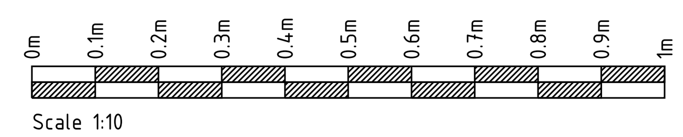


DETAIL D-D: LANDFILL ANCHOR TRENCH & LEACHATE INTERCEPTION DRAIN

Scale 1:10



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CODE	STATUS	SUITABILITY DESCRIPTION	PURPOSE OF ISSUE

PROJECT

ERA OF HISTORIC LANDFILLS AT KILLYCARD AND KNOCKCRONAGHAN

SHEET

DETAILS SHEET 4 OF 4

CLIENT

MONAGHAN COUNTY COUNCIL

Date 12.04.19	Project number P1724	Scale (@ A1-) 1:10	
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