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TIER 3 RISK ASSESSMENT
SCOTCH CORNER HISTORIC LANDFILL SITE

Prepared for: **Monaghan County Council**

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Date: November 2019

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User is responsible for Checking the Revision Status of This Document

Rev. No.	Description of Changes	Prepared by:	Checked by:	Approved by:	Date:
0	Issue for Client Review	EOC/CF	JON	BG	15.11.2019

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 Scotch Corner Historic Landfill site, Co. Monaghan, The risk assessment was 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 Scotch Corner Historic Landfill in accordance with the Environmental Protection Agency (EPA) Code of Practice (CoP) (2007): *Environmental Risk Assessment for Unregulated Waste Disposal Sites*.

The site is located approximately 4km south-west of Clontibret off the R184 in Co. Monaghan. The 4.5-hectare historic landfill is located to the south of the licenced Scotch Conor Landfill on the opposite side of the local access road. The historic landfill accepted municipal waste throughout the late 1970s and 1980s and is reported to have ceased operation in 1991.

A Tier 1 study was conducted by FT in June 2018 and determined the site to be a moderate-risk classification (Class B). The primary risks identified related to the risk of leachate runoff entering a tributary of the River Fane downstream of the waste body.

This Tier 2 study consisted of a desktop study, geophysical survey, intrusive site investigation works, environmental monitoring (soil, waste, leachate, 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.

Based on the results of the Tier 2 site assessment and risk model, the site was maintained as a **Moderate-Risk Classification (Class B)**. The principal risks identified on the site are the risk posed to surface waters from the migration of landfill leachate from the waste material encountered at the site via groundwater. Environmental monitoring had also indicated several instances of Generic Assessment Criteria (GAC) value exceedances across surface water, groundwater and landfill gas.

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 the landfill of the receiving environment a landfill cap 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. The leachate interception trench will be constructed to break/mitigate the pathway linkage between the landfill waste and licenced facility to the north. This trench will mitigate leachate migration to surface water downstream as well and further transport of contaminants via groundwater.

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.

It is proposed to extend the site capping around the site to include constructing a lined surface water channel. The lined channel will be provided physical separation of the waste body and the direct surface water pathway in the immediate vicinity of the site.

Groundwater monitoring is currently conducted at wells both upgradient and downgradient of the waste body as part of the adjacent licensed site's IElicence, continued IElicence compliance monitoring and additional monitoring is proposed as part of the remediation plan.

Additional surface water and landfill gas migration monitoring locations are also recommended. A proposed schedule of monitoring is provided. Annual surface VOC monitoring and continuous emissions monitoring within nearby buildings is also proposed.

1 TIER 3 QUANTITATIVE RISK ASSESSMENT

1.1 Background

In 2018, following the completion of a site investigation and Tier 2 risk assessment at the former landfill at Scotch Corner, Co. Monaghan by Fehily Timoney & Co it was concluded that a Tier 3 assessment should be conducted. Long-term monitoring at downgradient monitoring borehole B5a has consistently detected elevated ammonia above the GTV[1] since March 2015. The elevated ammonia results suggest leachate from the historic landfill is being detected in the groundwater at this location. Chloride concentrations have been generally below GTVs since March 2015 except for one exceedance recorded in March 2018.

The findings of the Tier 2 assessment produced a better understanding of the characterisation of the site and facilitated the production of a revised Conceptual Site Model (CSM). A Tier 3 assessment includes a Detailed Quantitative Risk Assessment (DQRA). This Tier 3 assessment report outlines the outcomes of a DQRA.

LandSim modelling software was utilised as part of this DQRA to examine, quantify and forecast the potential impact of leachate generation from the historic 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 calculations 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. 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] Groundwater Threshold Values: European Communities Environmental Objectives (Groundwater)(Amendment) Regulations (2016) – SI No. 366 of 2016

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 distinct 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 Scotch Corner site was defined as a single 'phase'.

Figure 1.1 shows the screen shot of the domain area for the Scotch Corner 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.

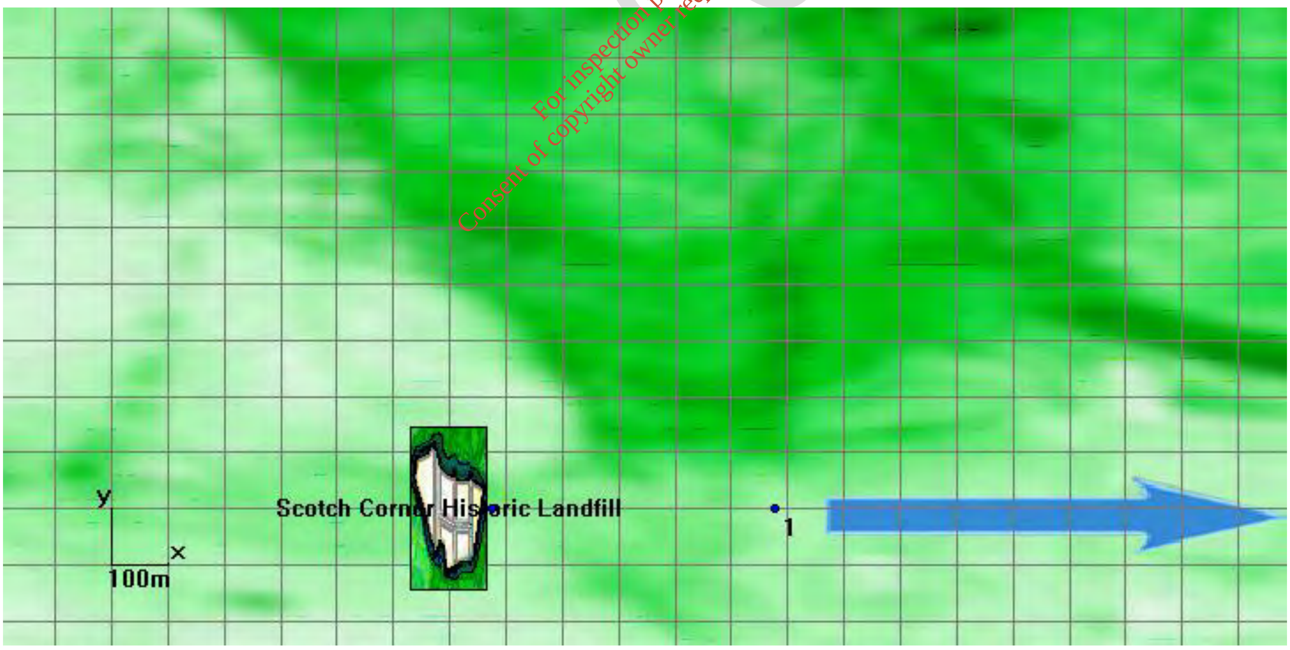

Figure 1.1: Domain Layout in LandSim

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. Waste material is either sitting directly on top of bedrock or is underlain by a relatively narrow band of subsoil (clay ,till).

It is understood that as a result, the sandstone bedrock may also be confining the spread of leachate generated onsite. Groundwater and leachate are likely confined to moving downgradient along the surface of the sandstone bedrock where it may continue to migrate via a groundwater pathway or eventually break to the surface at stream hydraulically connected with the groundwater table. 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 surrounding bedrock aquifers provided by Geological Survey Ireland (GSI) an aquifer thickness of between 3m to 15m was applied in the model, with the majority of lateral groundwater movement taking place in the top 3m of the aquifer. 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 0.0089. This corresponds with observations and the topographical survey of the site.

Hydraulic conductivity of the underlying bedrock aquifer applied in the model was assumed, based on typical values for sandstone included in the LandSim manual.

The pathway porosity was inputted based on standard published data for the lithologies present[2].

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

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 683 mm/year, as published Geological Survey Ireland (GSI) spatial data, was applied as the infiltration rate to open waste. The site is completely open with only a shallow soil cap above waste material as proven as part of the site investigation works.

The GSI have applied a groundwater recharge co-efficient ranging from 22.5% up to 85% at and adjacent to the site. This corresponds to infiltration rates of between 154 mm/year to 581 mm/year. A triangular distribution range of 154, 368, 581 mm/year (minimum, average, maximum) was therefore applied as the current cap design infiltration rate.

The infiltration rate was adjusted for the remedial scenario model. This scenario assumes the installation of an impermeable landfill cap in compliance with the EPA Landfill Design Manual 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 3.2.

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. For the purpose of simplifying the model and to match the estimated waste volume as determined by the Tier 2 investigation and assessment it was assumed that a single waste thickness of 4m 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

Historical monitoring conducted at the site and groundwater monitoring conducted as part of the Tier 2 assessment identified ammoniacal nitrogen as being the primary contaminant in wells downgradient of the site.

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).

One upgradient groundwater monitoring location/well (B1a) was utilised and examined to determine suitable background concentrations to apply in the model. Results of monitoring conducted by FT are presented in Table 1-1.

Table 1-1: Groundwater Sampling Results - June and September 2018

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2016 Standards [2]	B1a	
				June 2018	September 2018
pH	pH units	**6.5 - 9.5**	--	6.9	7.0
Conductivity	mS/cm	**1**	**1.875**	0.589	0.538
Ammoniacal Nitrogen as N	mg/l	**0.15**	**0.175**	**0.22**	**0.42**
Total Oxidised Nitrogen	mg/l	--	--	<0.50	<0.50
Total Organic Carbon	mg/l	--	--	5.2	5.4
Chloride	mg/l	**30**	**187.5**	12.54	11.03
Dissolved Oxygen	mg/l	**no abnormal change**	--	1.51	1.93

[1] EPA - Towards Setting Guideline Values for the Protection of Groundwater in Ireland (2003) – Interim Guideline Values

[2] European Communities Environmental Objectives (Groundwater)(Amendment) Regulations (2016) – SI No. 366 of 2016

* Items shaded in **bold** are in exceedance of both EPA IGV Standards

* Items shaded in **orange** are in exceedance of the Drinking Water Regulations

A review of historical groundwater monitoring carried out by MCC was also conducted for ammonia and chloride. This yielded average concentrations of 0.159 mg/l and 12.44 mg/l for ammoniacal nitrogen and chloride, respectively. These concentrations were then applied in setting up the model. It is noted that in calculating average concentrations, where recorded concentrations have been presented as being below the limit of detection (LOD) as a conservative measure that LOD value has been applied as the measured concentration. In order to account for the variation in concentrations recorded the background concentrations were input as a 'triangular' distribution in LandSim.

Leachate concentrations and baseline background concentrations applied in the model are shown in Table 1-2 over.

Table 1-2: Leachate and Background Concentrations

Parameter	Concentration in Leachate [1] (mg/l)	Background Concentration (mg/l)
Ammonia	Triangular (4.37, 723, 3640)	Triangular (0.01, 0.159, 1.25)
Lead	Triangular (0.00957,0.13, 1.02)	Triangular (5.29, 12.44, 28.05)

† 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 a limited leachate control system in place underlying a portion of the historical landfill site but this was not taken into account in this model. As an estimation the leachate head was specified as being the thicknesses of the waste material, that is 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 over. Each of these geosphere pathways is assumed homogeneous and isotropic.

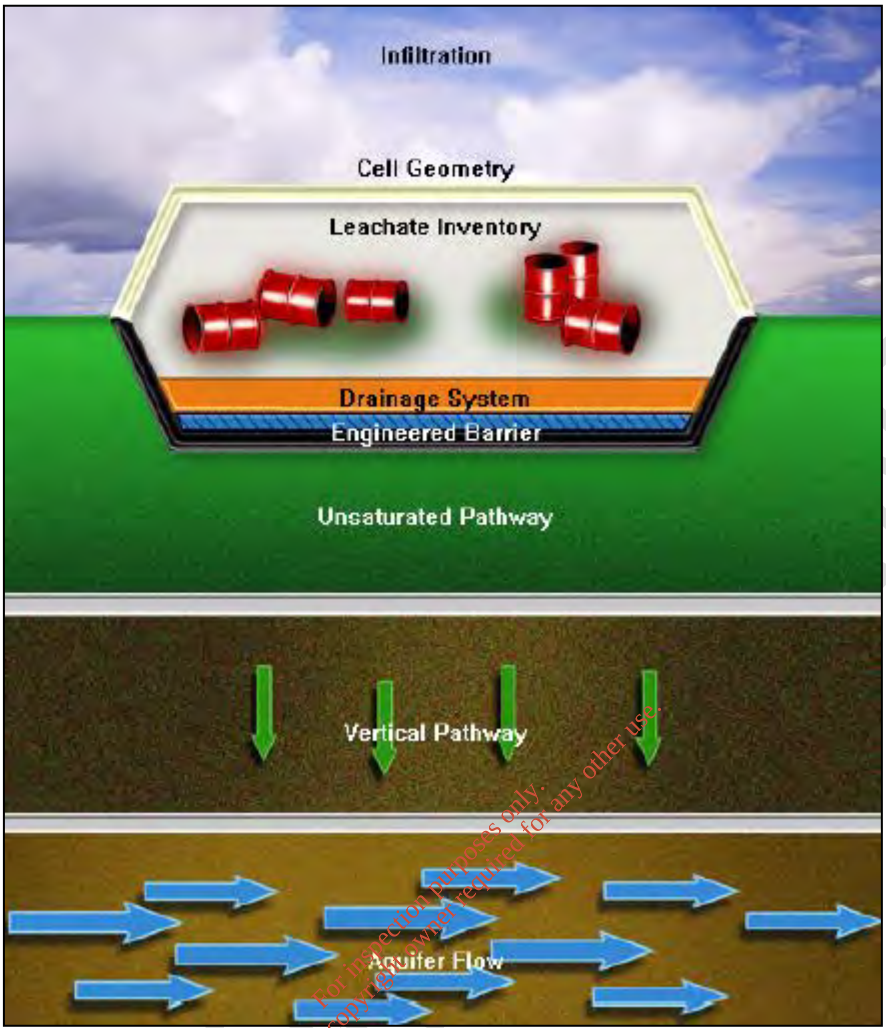

Figure 1.2: Geosphere Schematic

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

It is known from intrusive site investigation and geophysical surveying that the waste is likely underlain by a relatively narrow band of saturated clay material. Lateral movement of groundwater and subsequently contaminants is dictated primarily by the bedrock aquifer not subsoil groundwater.

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 68.3 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 1-3.

Table 1-3: Source Concentration at Year 0, 40 and 500 (Base Model)

Parameter	Year	5%ile	50%ile	95%ile	GW Monitoring Oct 2018 (SI6 – SI10)	
					Min	Max
Ammoniacal Nitrogen (mg/l)	0	205.92	467.44	893.74		
	40	24.62	62.09	137.81	6.54	268
	100	1.12	5.93	27.58		
	200	0.00	0.12	2.55		
	500	0.00	0.00	0.00		
Chloride (mg/l)	0	710.055	1429.96	2486.27		
	40	50.58	126.22	272.15	13.9	136
	100	1.15	7.18	40.93		
	200	0.00	0.06	2.42		
	500	0.00	0.00	0.00		

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:

- 893.74 mg/l in 95% of the scenarios generated (worst case scenario)
- 467.44 mg/l in 50% of the scenarios generated (most likely scenario)
  205.92 mg/l in 5% of the scenarios generated (best case scenario)

LandSim results generated at the 40-year point are assumed to approximately reflect present day conditions. These results are compared against minimum and maximum leachate ammoniacal nitrogen and chloride concentrations determined by monitoring conducted by FT. Source concentrations for both ammoniacal nitrogen and chloride at 40 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 1-4: Leachate Generation Rates

Site Scenario	Time slice (years)	95%-ile (l/day)	50%-ile (l/day)	5%-ile (l/day)
Current	7	154,458	154,458	154,458
	40	115,847	84,143	49,656
	100	115,847	84,143	49,656
Remediation (Engineered Capping Installed at 40 Years post commencement of deposition)	7	154,458	154,458	154,458
	40	15,445	15,445	15,445
	100	15,445	15,445	15,445

The model considers that at 7 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 does contain some quantity of 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 equates to a 25%(minimum) to 68%(maximum) reduction in leachate generation rate at the 40-year point as shown in Table 1-4.

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 1-5.

Table 1-5: Monitor Well Concentrations

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	7	3.91	0.65	1.102	0.464	0.065 – 0.175
	40	674.24	275.22	2693.46	1185.050	
	100	215.36	61.38	2373.37	1164.880	
	500	2.14	0.60	50.917	183.512	
Chloride	7	1472.49	824.21	874.49	470.496	187.5
	40	233.386	437.687	3170.21	1359.82	
	100	54.7771	128.709	472.346	254.897	
	500	14.6709	24.4032	83.584	48.554	

*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 40-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 leachate wells/sampling locations, particularly with respect to ammoniacal nitrogen.

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.

The results obtained from the LandSim model show that there is a likely ongoing risk to groundwater quality and surface water at 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 1-4, 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 Scotch Corner 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 3.2 of this report.

1.4 Background DQRA Landfill Gas

The Tier 2 assessment identified lateral and vertical landfill gas migration as a low risk, (normalised risk scores of 23% and 14% respectively)

Analysis of landfill gas from the leachate wells installed across the site as part of the Tier 2 investigation showed concentrations of both CO_2 and CH_4 within the waste body remain substantially high. This indicates that biodegradation of the interred municipal waste remains active, the landfill gas risk also remains high due to the proximity of Local Authority and Civic Amenity buildings within 50m north of the waste body. The elevated gas concentrations from perimeter borehole B8a are likely to be due to the borehole being screened within the waste body underlying the entrance forecourt to Scotch Corner licenced landfill.

The monitoring results from the four gas monitoring events are shown in Table 1-6 and Table 1-8.

Table 1-6: Onsite Leachate Well Monitoring Results October 2018

Date: 1-10-2018						
Sample Station	CH_4 (% v/v)	CO_s (% v/v)	0_2 (% v/v)	Atmospheric Pressure (mbar)	Staff Member	Weather
SI6	**68.1**	**31.4**	**0.5**	1028	Daniel Hayden	Sunny with light wind S-SE, 14°C - 16°C
SI7	0.2	**3.9**	18.9	1028		
SI8	0.7	0.6	22.1	1028		
SI9	**10.8**	**7.0**	**8.3**	1028		
SI10	**64.2**	**32.6**	**0.3**	1028		

Table 1-7 Onsite Leachate Well Monitoring Results October 2018

Date: 10-10-2018						
Sample Station	CH_4 (% v/v)	CO_s (% v/v)	0_2 (% v/v)	Atmospheric Pressure (mbar)	Staff Member	Weather
SI6	**66.8**	**28.6**	**1.3**	1002	Daniel Hayden	Sunny and wind SE-S, 15°C - 20°C
SI7	0.3	**2.8**	18.4	1002		
SI8	0.6	0.8	22.6	1002		
SI9	**12.8**	**8.7**	**6.5**	1002		
SI10	**67.6**	**35.6**	**0.2**	1002		

Table 1-8: Perimeter Well Monitoring Results August 2018

Date: 28-08-2018						
Sample Station	CH_4	CO_s	0_2	Atmospheric Pressure	Staff Member	Weather
	(% v/v)	(% v/v)	(% v/v)	(mbar)		
B1a	0.0	0.0	20.7	997	Daniel Hayden	Sunny with light wind S-SE, 16°C - 18°C
B5a	0.0	0.2	20.3	997		
B7a	0.0	0.0	20.5	997		
B8a	**65.3**	**34.2**	**0.4**	997		

Table 1-9 Perimeter Well Monitoring Results September 2018

Date: 27-09-2018						
Sample Station	CH_4	CO_2	0_2	Atmospheric Pressure	Staff Member	Weather
	(% v/v)	(% v/v)	(% v/v)	(mbar)		
B1a	0.0	0.0	20.5	1007	Daniel Hayden	Cloudy with light rain and wind NW-W, 13°C - 15°C
B5a	0.0	0.0	20.7	1007		
B7a	0.0	0.2	20.6	1007		
B8a	**58.1**	**31.3**	**1.7**	1007		

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 1-10

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

Table 1-10: LandGEM Model Primary Inputs and Variables

Landfill Characteristics	Input	Source
Landfill Open Year	1977	Exact timeframe of landfill beginning operation is unconfirmed but estimated to be late 1970s.
Landfill Closure Year	1991	Anecdotal evidence suggests landfilling activities ceased c.1991
Have Model Closure Calculate Closure Year	Yes	
Waste Design Capacity (megagrams/tonnes)	229,600	Estimated waste volume (164,000m^3) 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)		
1977 - 1991	16,400	Exact waste acceptance quantities per year are unknown. Worst case assumed waste design capacity was filled equally over 1977 to 1991 (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 1-11. The model predicts that the site is currently generating 39.61 m^3/hr of methane across the entire site area. This will reduce to 24.02 m^3/hr by 2029.

Table 1-11: 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	867	526	693940	420896	0.099	0.060	79.22	48.05
Methane	231	140	346970	210448	0.026	0.016	39.61	24.02
Carbon dioxide	635	385	346970	210448	0.073	0.044	39.61	24.02
NMOC	9.95	6	2776	1684	0.001	0.001	0.32	0.19

The approximate maximum waste deposition footprint was estimated to be approximately 4.1 Ha (41,000 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 1-12.

Table 1-12: 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	0.021	0.013	16.925	10.266
Methane	0.006	0.003	8.463	5.133
Carbon dioxide	0.015	0.009	8.463	5.133
NMOC	$2.43x10^{-4}$	$1.47x10^{-4}$	0.068	0.041

1.6.1 Discussion of Results

The outcome of the LandGEM model predicts a relatively high rate of landfill gas generation in the current year (79.22 m^3/hr). As shown in Table 1-11 LandGEM estimated that in the current year (2019) a relatively low quantity of 79.22 m^3/hour of landfill gas across the whole site is generated and assuming 50% percent of that volume being methane (39.61 m^3).

Landfill gas migration monitoring of leachate wells conducted in 2018 yielded methane contents of 0.7 up to a maximum of 68.1% supporting the findings that landfill gas is being produced at the site.

Figure 1-3 below shows the estimated landfill gas generation rates per year during the operational phase (c.1977 to 1991) and predicted generation rates from 1991 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.

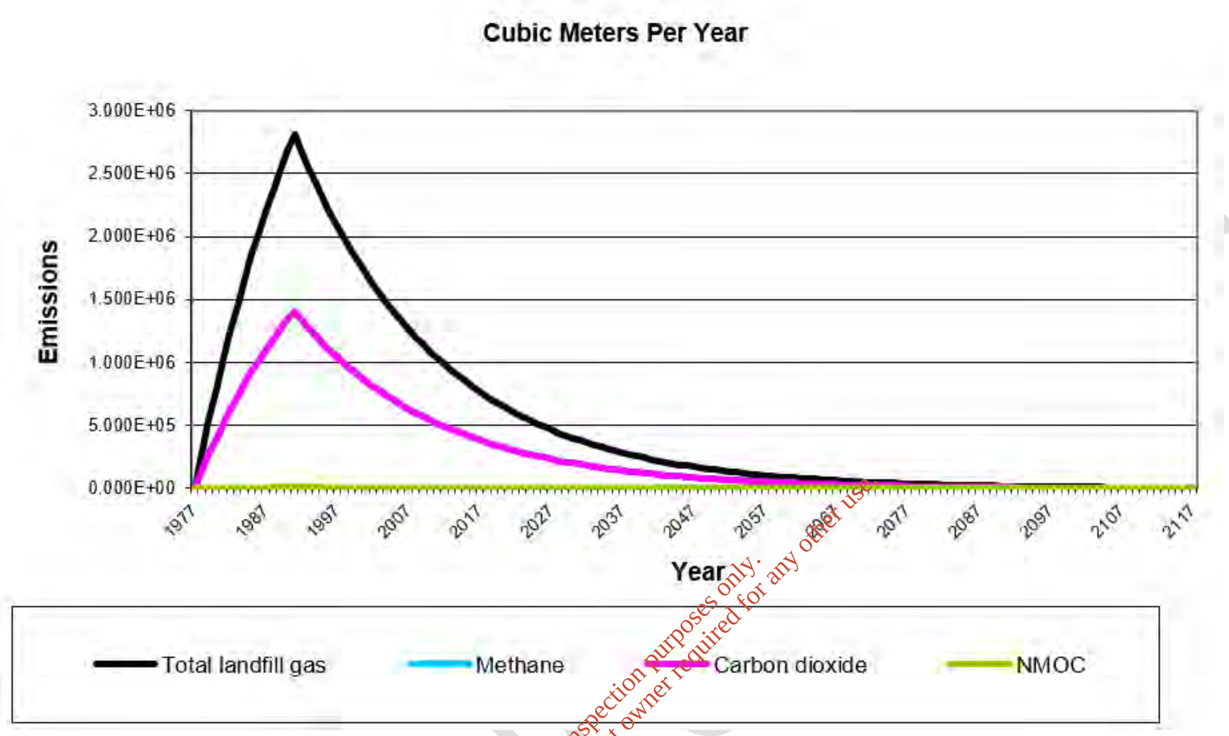

Figure 1-3: LandGEM Landfill Gas Volume Generation Rate

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

1.7 Risk to Surface Water Quality

At present a surface water drain surrounds a portion of the waste body at the historical landfill site. This perimeter drain is installed to direct all surface water runoff towards a sump, from here the collected surface water is pumped to a central location in the western portion of the site to percolate down through stockpiled material. The infiltrated surface water is then collected at sump 'G5 recirculated' at the foot of an embankment and directed north and ultimately the River Fane tributary stream within the licenced facility.

Fehily Timoney and Company conducted surface monitoring at 2 no. monitoring locations on this surface water drainage network as part of the Tier 2 assessment in October 2018, namely locations G8 (upstream) and G3 (upstream).

Other surface water monitoring locations G4, G5, G6, G5-recirculated, G9, G10, G11 and G13 were dry at time of sampling therefore it was not possible to obtain results for these. Surface water quality monitoring has also been historical conducted by Monaghan County Council. Monitoring data for locations G5 recirculated and G6 were reviewed for comparison, being downstream surface monitoring locations. This review identified elevated concentrations for ammonia at locations G3, G5 recirculated and G6. It is noted however that ammonia concentrations were shown to increase significantly between G5 recirculated and G6 for September 2018 results provided by MCC, suggesting that there may be ingress of contaminants from the surrounding waste body between these two sampling points. Additionally, review of data provided by MCC for surface water monitoring conducted between 2016 and 2018 has shown that ammonia concentrations are generally, consistently higher at G6 than G5 recirculated.

A review of MCC's 2018 annual environmental report (AER) states that the average ammonia concentration at G6 was 3.8 mg/l and suggests that this discharge was not having a negative impact on surface water quality at SW monitoring location S1, at the northern stream. S1 monitoring yielded an average 2018 ammonia concentration of 2.6 mg/l.

Discharge from G6 enters an open land drain which flows north through the licensed site to a pond located at the north boundary of the licensed site, which ultimately discharges to the adjacent stream. It is noted that this drain is frequently dry and flow from G6 is often relatively low thereby the limiting the potential risk to the receiving stream.

2 CONCLUSION AND RECOMMENDATIONS

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 groundwater rand potentially surface water 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 predicts that moderate quantities of landfill gas (79.22 m^3/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.* The final landfill management to be employed will be determined based on the findings of an onsite landfill gas pumping trial.

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.

SPR	Linkage	Max Score	Normalised Score	
SPR1	Leachate => surface water	300	28%	
SPR2	Leachate => SWDTE	300	0%	
SPR3	Leachate => human presence	240	11.6%	
SPR4	Leachate => GWDTE	240	0%	
SPR5	Leachate => Aquifer	400	7%	
SPR6	Leachate => Surface Water	560	0%	
SPR7	Leachate => SWDTE	240	23%	
SPR8	Leachate => Surface Water	60	**46%**	
SPR9	Leachate => SWDTE	60	0%	
SPR10	Landfill Gas => Human Presence	150	23%	
SPR11	Landfill Gas => Human Presence	250	14%	

3.1.1 Leachate Migration through surface water pathway (SPR8)

Results of environmental monitoring, previous environmental assessments and observation made onsite demonstrated that site is hydrologically linked to the downgradient surface water drainage features both naturally via groundwater connection and via a controlled discharge to a stream that flows in an easterly direction along the boundary of the northern licensed site. This stream is a tributary of the River Fane which is located further east of the site.

The following remediation measures are proposed to mitigate the effect of the landfill on the neighbouring licensed waste facility and downstream receptors. The measures are proposed based on the results of the DQRA modelling undertaken.

3.1.1.1 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 e.g. low intensity agricultural grazing purposes or the development of natural habitat area – wildflower/traditional meadow.

The sub soil layer will be therefore be adequately specified to ensure it is free draining to support grazing with the top soil layer adequately specified to support growth.

3.1.1.2 Leachate Interception Trench – Northern Boundary

The landfill cap will also include a leachate interception trench along the full extent of the northern boundary of the site, following the adjacent road.

The leachate interception trench will be constructed to limit the pathway linkage between the landfilled waste and the licensed waste facility to the north. 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 north western corner 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.

3.1.1.3 Lined Surface Water Drains

It is proposed to extend the site capping around the site to include constructing a lined surface water channel. The lined channel will be provided physical separation of the waste body and the direct surface water pathway in the immediate vicinity of the site.

The surrounding surface water drains will be lined using 1mm LLDPE. Adequate protection and lining of the surface water drains

3.1.1.4 *Removal of Existing Infrastructure*

It is proposed to remove all existing recirculation and direct discharge infrastructure from the site as part of the proposed works.

There is an existing surface water drainage network surrounding the historical landfill site. This perimeter drainage directs all surface water runoff towards a sump located along the northern boundary. Surface water is pumped from the G5 sump back to a central location in the western portion of the site to percolate down through stockpiled fill material.

The infiltrated surface water is then collected at sump 'G5 recirculated' at the foot of an embankment and directed north towards G6 and ultimately the River Fane tributary stream within the licenced facility.

3.1.2 Lateral Gas Generation (SPR10)

The proposed landfill cap will be the primary control measure to limit vertical landfill gas migration from the site. The capping system will be supplemented by landfill gas control measures.

It is recommended that landfill gas control measures shall be installed at the site. Suitable control measures should be selected following landfill gas pumping trials at the site. It is proposed that Landfill gas pumping trials be designed and conducted at the site to accurately quantify the nature and quality of landfill gas being produce at the site.

Landfill gas pumping trials should be designed and undertaken by an appropriately qualified person, the results of which should also be supported with a suitably calibrated landfill gas generation model.

It is recommended that dependant on the results of these trials an appropriate remediation design shall be adopted. Appropriate control measures shall be selected in accordance with the EPA Guidance document: *Management of Low Levels of Landfill Gas.*

Potential options are discussed in brief detail below.

3.1.2.1 *Active Gas Abstraction to Existing LFG Flare*

Active landfill gas abstraction to a flare would involve the installation of a network of landfill ages well across the site. The wells would be drilled into the waste body to 80-90% of the total waste depth and be connected via a network of gas collection pipework to the landfill gas flare.

The landfill gas flare would treat all abstracted landfill gas by oxidation (burning), it is assumed based on the age of the landfill that a Low Calorific landfill gas flare may utilised.

3.1.2.2 *Active Gas Abstraction to Bio Oxidation*

Active landfill gas abstraction to a bio-oxidation may be utilised if landfill gas with methane concentrations in the range of 0-15% are expected at the site following completion of pumping trials. This would also involve the installation of a network of landfill ages well across the site.

The wells would be drilled into the waste body to 80-90% of the total waste depth and be connected via a network of gas collection pipework to the bio oxidation unit.

The proposed bio-oxidation unit would treat abstracted landfill gas by bio-oxidation. Bio oxidation is the conversion of methane to carbon dioxide by bacteria typically grown or cultured within an organic (wood chip, mussels shells) or proprietary inorganic media.

3.1.2.3 Passive Ventilation

If pumping trial indicate insufficient landfill gas volumes are present to warrant active abstraction, passive ventilation may be utilised. Typically, landfill gas well will be installed within the waste body and directly connected to a series of vertical stand pipes venting to atmosphere at 2-3m above the final ground level. Alternatively stand pipes may be connected contiguously with the installed landfill gas migration layer in the absence of drilled wells.

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

Installed ventilation stand pipes may include a carbon filtration packs to "scrub" odour and methane from the landfill gas prior to venting. Rotating cowls may also be used to induce a negative pressure within the stand pipe improving the LFG flow.

3.1.3 Landfill Gas Interception Trench (SPR10)

The proposed leachate interception trench will also act as a landfill gas interception/venting trench along the northern site boundary of the site between the site and the existing development.

It should be noted that the most sensitive (i.e. nearest) receptors to the site are part of the wider Scotch Corner Landfill site and it is therefore assumed that all building including suitable detection and control measures in their design.

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):
    - B5a (downgradient)
    - B8a (downgradient)
    - B7a (cross-gradient)
    - B1a (upgradient)

- 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

The following section outlines the proposed schedule and locations of environmental monitoring to assess the efficacy of the remediation works. The schedule of environmental monitoring includes

- Leachate
- Groundwater
- Surface water
- Landfill Gas

3.1.5.1 Leachate

It is proposed that in waste leachate monitoring should be conducted as part of the ongoing maintenance and monitoring of the site. The following monitoring locations are proposed.

- Leachate (Leachate Quality and Landfill Gas):
  - SI6
  - SI8
  - SI10
- Leachate Sump

Leachate monitoring should be conducted annually at the four proposed locations (SI6, SI8, SI 10 AND Leachate Sump (as installed)), the monitoring schedule should be as per the Table 7.2 of the EPA Landfill Manual (2003) shown below.

Table 3-1: Proposed Leachate Monitoring Schedule

Leachate Monitoring: Table 7.2 of the EPA Landfill Manual (2003)	
Depth (mAOD)	Temperature
pH-value	Chloride
Conductivity (µS/cm)	Sodium
Alkalinity (as CaCO3)	Magnesium
COD	Potassium
BOD5	Calcium
Total Organic Carbon	Chromium
Fatty Acids (as C)	Manganese
Ammoniacal-N	Iron
Nitrite-N	Nickel
Sulphate (as SO4)	Copper
Phosphate (as P)	Chloride

3.1.5.2 Groundwater and Surface Water

The proposed schedule of ground water and surface water monitoring is set out in Table 3-2 below.

Table 3-2 Remediation Design Surface and Groundwater Monitoring Schedule

Schedule	Groundwater			Surface Water		
Parameter	Monthly	Quarterly	Annual	Monthly	Quarterly	Annual
Visual						
Colour	X			X		
Odour	X			X		
Turbidity	X			X		
Indicators						
pH	X			X		
Electrical Conductivity	X			X		
Temperature	X			X		
Alkalinity, Total as CaCO3	X			X		
Ammoniacal Nitrogen	X			X		

Schedule	Groundwater			Surface Water		
Parameter	Monthly	Quarterly	Annual	Monthly	Quarterly	Annual
BOD	X			X		
Chloride	X			X		
COD	X			X		
Dissolved oxygen	X			X		
Fluoride	X			X		
Nitrite as N	X			X		
Organic Carbon, Total	X			X		
Phosphate (ortho) as PO4	X			X		
Sulphate	X			X		
Total Organic Carbon	X			X		
Total Oxidised Nitrogen as N	X			X		
TSS	X			X		
Metals						
Antimony		X			X	
Arsenic		X			X	
Barium		X			X	
Beryllium		X			X	
Boron		X			X	
Cadmium		X			X	
Calcium		X			X	
Chromium		X			X	
Cobalt		X			X	
Copper		X			X	
Iron		X			X	
Lead		X			X	
Magnesium		X			X	
Manganese		X			X	
Mercury		X			X	
Molybdenum		X			X	
Nickel		X			X	
Phosphorus		X			X	
Potassium		X			X	
Selenium		X			X	
Silicon		X			X	
Silver		X			X	
Sodium		X			X	
Tellurium		X			X	
Thallium		X			X	
Tin		X			X	
Titanium		X			X	

Schedule	Groundwater			Surface Water		
Parameter	Monthly	Quarterly	Annual	Monthly	Quarterly	Annual
Uranium		X			X	
Vanadium		X			X	
Zinc		X			X	
Mineral Oils and Greases						
Mineral Oil / Oils & Greases			X			X
SVOC's						
Semi-Volatile Organic Compounds (SVOCs)			X			X
VOC's						
Volatile Organic Compounds (VOCs)			X			X
Pesticides and Herbicides						
Combined Pesticides / Herbicides			X			X

3.1.5.3 Landfill Gas

All proposed and existing dual landfill gas/groundwater monitoring points should be monitored monthly in accordance with the table below.

Table 3-3 Landfill Gas Monitoring Schedule

Location	Monthly
CH_4 (v/v %)	**x**
CO_2 (v/v %)	**x**
O_2 (v/v %)	**x**
Bal. (v/v %)	**x**

Internal building areas as identified i.e. landfill offices and external buildings should be continuously monitored as per best practice guidance.

3.2 Remediation Design

The preliminary remediation design is presented in the following drawings:

- P1679-0100-0001
- P1679-0100-0002
- P1679-0500-0001
- P1679-0500-0002
- P1679-0501-0001
- P1679-0501-0002

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: P1679-0501-0001-2 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 surface water drains external to the capping area.

Plan details are shown in drawing: P1679-0500-0001.

A leachate interception trench will run along the northern boundary of the site, along the R184 road.

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: P1724-0500-0003.

Section details for the proposed landfill gas interception trench along the northern site boundary are shown in drawing P1679-0501-0001-2 inclusive.

Section details for the proposed leachate interception trench along the northern boundary are shown in drawing P1679-0501-0001-2 inclusive.

3.2.2 Landfill Gas Management

Based on the proximity of an operational waste facility to the site and due to the presence of buildings immediately adjacent to EPA licensed lined and unlined landfills it is assumed that all building includes suitable GAS detection and control measures in their design and construction.

It is recommended that an audit of the existing gas detection measures be conducted at the site to ensure all areas are suitably monitored. A typical fixed gas monitor and control panel unit are shown below.

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 that the audit include 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 3-4 over, outlines the costs associated with capping the site. The proposed capping is as per the EPA Landfill Design manual recommendations as presented previously.

The estimated total remediation cost **€3,203,510.75** including the contingency as specified (10.0%).

Table 3-4: Landfill Capping: Remediation Cost Estimates

Item	Quantity	Unit	Rate, €	Cost	Note
Design					
Allowance for Additional Site Investigation works	1	Rate	€25,000.00	€25,000.00	Allowance
Detailed Design & Procurement	1	Rate	€100,000.00	€100,000.00	Allowance
Contract Supervision	1	Rate	€90,000.00	€90,000.00	Allowance
Land Rental Costs	1	Rate	€15,000.00	€15,000.00	Allowance
General Site Clearance and Demolition Works	5.4	ha			
General Site Clearance	5	ha	€5,000.00	€27,000.00	Allowance for Clearance of Existing Site
Excavation Works	54,000	m^2			Estimated area of Capping Area 54,000m^2
Reprofiling of Existing Cover/Capping for	10,800	m^3	€2.50	€27,000.00	Excavation of area to 100mm
Importation of Capping/Restoration Profiling Materials	13,500	m^3	€10.00	€135,000.00	
Landfill Capping Works	54,000				
Preparation of Excavated Surfaces	54,000	m^2	€0.75	€40,500.00	Approximate Area, Local Rates 2018

Item	Quantity	Unit	Rate, €	Cost	Note
Supply and Installation of 50mm Protection Layer	54,000	m^2	€1.75	€94,500.00	Approximate Area, Local Rates 2018
Supply and Installation of Landfill Gas Collection Layer	54,000	m^2	€5.50	€297,000.00	Approximate Area, Local Rates 2018
Installation of 1mm LLDPE Cap	54,000	m^2	€6.50	€351,000.00	Approximate Area, Local Rates 2018
Installation of Surface Water Collection Layer	54,000	m^2	€5.50	€297,000.00	Approximate Area, Local Rates 2018
Importation of 800mm Subsoil Capping Layer	54,000	m^2	€8.50	€459,000.00	Approximate Area, Local Rates 2018
Importation of 200mm Topsoil Capping Layer	54,000	m^2	€3.00	€162,000.00	Approximate Area, Local Rates 2018
Allowance Landfill Gas Migration Network Infrastructure	54,000	m^2	€3.00	€162,000.00	Allowance
Allowance Sub surface Water Drainage Infrastructure	54,000	m^2	€4.00	€216,000.00	Allowance
Independent CQA	1	Sum	€43,200.00	€43,200.00	Estimate Local Rates
Leachate Interception Trench (Northern Boundary)	350				Leachate Trench -275m
-					
Excavation of Existing Waste Materials	525	m^3	€4.00	€2,100.00	Assumed design, Local Rates 2018
Management of Excavated Waste	840	tonnes	€25.00	€21,000.00	Assumed design, Local Rates 2018
Backfill with 16-23mm Rounded Washed Drainage Stone	525	m^3	€15.00	€7,875.00	Assumed design, Estimated Rate
225mm Slotted SDR 17 Drainage Pipe	350	m	€40.00	€14,000.00	Assumed design, Local Rates 2018
Leachate Collection Sump	1	Sum	€10,000.00	€10,000.00	Allowance
Intermediate Inspection Chambers	7	No.	€3,500.00	€24,500.00	Allowance
Mechanical and Electrical	1	Sum	€15,000.00	€15,000.00	Allowance

Item	Quantity	Unit	Rate, €	Cost	Note
Lined Surface Water Channels	1,000				Surface Water Channels
-					
Excavation Anchor Trench	90	m^3	€15.00	€1,350.00	
Excavation of Surface Swale	1,500	m^3	€4.00	€6,000.00	Assumed design, Local Rates 2018
Lining of Swale	5,000	m^2	€10.00	€50,000.00	Assumed design, Estimated Rate
Protection to Swale	5,000	m^2	€2.50	€12,500.00	Assumed design, Local Rates 2018
Infill of Anchor Trench	90	m^3	€7.50	€675.00	Allowance
Allowance Crossings, Penetrations and Detailing	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	4	No.	€500.00	€2,000.00	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
Sub-Total 1				**€2,709,100.00**	
Add 7.5% Contractor Prelims	7.5%			€203,182.50	
Sub-Total 2				**€2,912,282.50**	
Add 10% Contingency	10%			€291,228.25	

Item	Quantity	Unit	Rate, €	Cost	Note
Grand Total (excl VAT)				**€3,203,510.75**	

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.

FEHILY TIMONEY
30 YEARS

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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: 7, 40, 100, 500

Decline in Contaminant Concentration in Leachate

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

Chloride Non-Volatile
c (kg/l): 0.2919 m (kg/l): 0.0298

Contaminant Half-lives (years)

Unsaturated Pathway:

Chloride	SINGLE(1e+009)

Saturated Vertical Pathway:

Chloride	SINGLE(1e+009)

Aquifer Pathway:

Chloride	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Ammoniacal_N	TRIANGULAR(0.01,0.159,1.36)
Chloride	TRIANGULAR(5.29,12.44,28.05)

Phase: Scotch Corner Historic Landfill

Infiltration Information

Cap design infiltration (mm/year):	TRIANGULAR(154,368,581)
Infiltration to waste (mm/year):	SINGLE(683)
End of filling (years from start of waste deposit):	14

Justification for Specified Infiltration

Open waste infiltration rate based on effective rainfall value provided by GSI mapping. Cap design infiltration rate based on applicaton of GSI range of recharge co-efficient of 22.5%. to 85%

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

Cell dimensions

Cell width (m):	140
Cell length (m):	294.286
Cell top area (ha):	4.13
Cell base area (ha):	4.12
Number of cells:	2
Total base area (ha):	8.24
Total top area (ha):	8.26
Head of Leachate when surface water breakout occurs (m)	SINGLE(4)
Waste porosity (fraction)	TRIANGULAR(0.42,0.54,0.62)
Final waste thickness (m):	SINGLE(4)
Field capacity (fraction):	UNIFORM(0.2,0.4)
Waste dry density (kg/l)	UNIFORM(1.2,1.6)

Justification for Landfill Geometry

Assumed single cell as no engineered cells in place. Assumed single waste thickness based on S.I, to simplify model and to match estimated waste volume as per S.I. Porosity, field capacity and density assumed [CHANGED]

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*
Chloride	LOGTRIANGULAR(36.6,2270,7760) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate

Inital leachate concentration based on UKLandSim values Background concentration based on upgradient well monitoring [CHANGED] [CHANGED] [CHANGED]

Drainage Information

Fixed Head.

Head on EBS is given as (m): SINGLE(4)

Justification for Specified Head

Head on EBS assumed to be maximum thickness of waste body

Barrier Information

There is no barrier

Justification for Engineered Barrier Type

Unjustified value

pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0.01)
Flow Model:	porous medium
Pathway moisture content (fraction):	SINGLE(0.5)
Pathway Density (kg/l):	UNIFORM(1.3,2.3)

Justification for Unsat Zone Geometry

Assumed minimul unsaturated zone as groundwater head transects waste. High moisture content based on soil samples

Pathway hydraulic conductivity values (m/s):	TRIANGULAR(1e-011,4.7e-009,2e-006)

Justification for Unsat Zone Hydraulics Properties

HIgh moisture content based on soil samples, hydraulic conductivity assumed based on LandSim manual values for clays and tills.

Pathway longitudinal dispersivity (m):	SINGLE(0.001)

Justification for Unsat Zone Dispersion Properties

10% of pathway length

Retardation parameters for pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,2)
Chloride	SINGLE(0)

Justification for Kd Values by Species

LandSim manual values

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(510,650)
Pathway width (m):	SINGLE(295)

glacial till, clay pathway parameters

Modelled as vertical pathway.

Pathway length (m):	SINGLE(2)
Pathway porosity (fraction):	UNIFORM(0.34,0.6)

Justification for Vertical Path Geometry
assumed uniform thickness of subsoil beneath waste to match assuemd uniform waste thickness. Porosity as per LandSIm manual values for clays.

Pathway dispersivity (m):	SINGLE(0.2)

Justification for Vertical Path Dispersion Details
10% of pathway length

Retardation parameters for glacial till, clay pathway
Modelled as vertical pathway.
Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0.5,2)
Retardation parameters for glacial till, clay pathway	
Chloride	SINGLE(0)
Retardation parameters for glacial till, clay pathway	

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

Pathway Density (kg/l):	UNIFORM(1.3,2.3)

Mudstone and Sandstone pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):

Calculated. Aquifer Thickness: UNIFORM(3,15)

Justification for Aquifer Geometry

pathway width considered same width as wastebody, aquifer thickness based on review of GSI characterisation for adjacent GWB, dispersivity = 1% of pathway length. [CHANGED]

Pathway regional gradient (-): SINGLE(0.0089)

Pathway hydraulic conductivity values (m/s): UNIFORM(3e-010,6e-006)

Pathway porosity (fraction): UNIFORM(0.05,0.3)

Justification for Aquifer Hydraulics Properties

assumed conductivty based on LandSim manual values for sandstone, regional gradient estiamted based on groundwater contour maps, pathway porosity assumed based on landsim manual values for sandstone.

Pathway longitudinal dispersivity (m): UNIFORM(51,65)

Pathway transverse dispersivity (m): UNIFORM(15.3,19.5)

Justification for Aquifer Dispersion Details

Longitudinal dispersivity is 10% of pathway length

Transverse dispersivity is 3% of pathway length

Retardation parameters for Mudstone and Sandstone pathway

Modelled as aquifer pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N UNIFORM(0.5,2)

Chloride SINGLE(0)

Justification for Aquifer Kd Values by Species

Kd for ammonia and chloride based on LandSim manual values.

Pathway density assumed based on literature values for sandstone densities.

Pathway Density (kg/l): UNIFORM(2,2.6)

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APPENDIX 2

LandGEM Model Summary Report

Summary Report

Landfill Name or Identifier: Scotch Corner Historical Landfill - Co.Monaghan

Date: Wednesday 14 August 2019

Description/Comments:

About LandGEM:

First-Order Decomposition Rate Equation:

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

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	**1977**	
Landfill Closure Year (with 80-year limit)	**1990**	
Actual Closure Year (without limit)	***1990***	
Have Model Calculate Closure Year?	**Yes**	
Waste Design Capacity	**229,600**	*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)*
1977	16,400	18,040	0	0
1978	16,400	18,040	16,400	18,040
1979	16,400	18,040	32,800	36,080
1980	16,400	18,040	49,200	54,120
1981	16,400	18,040	65,600	72,160
1982	16,400	18,040	82,000	90,200
1983	16,400	18,040	98,400	108,240
1984	16,400	18,040	114,800	126,280
1985	16,400	18,040	131,200	144,320
1986	16,400	18,040	147,600	162,360
1987	16,400	18,040	164,000	180,400
1988	16,400	18,040	180,400	198,440
1989	16,400	18,040	196,800	216,480
1990	16,400	18,040	213,200	234,520
1991	0	0	229,600	252,560
1992	0	0	229,600	252,560
1993	0	0	229,600	252,560
1994	0	0	229,600	252,560
1995	0	0	229,600	252,560
1996	0	0	229,600	252,560
1997	0	0	229,600	252,560
1998	0	0	229,600	252,560
1999	0	0	229,600	252,560
2000	0	0	229,600	252,560
2001	0	0	229,600	252,560
2002	0	0	229,600	252,560
2003	0	0	229,600	252,560
2004	0	0	229,600	252,560
2005	0	0	229,600	252,560
2006	0	0	229,600	252,560
2007	0	0	229,600	252,560
2008	0	0	229,600	252,560
2009	0	0	229,600	252,560
2010	0	0	229,600	252,560
2011	0	0	229,600	252,560
2012	0	0	229,600	252,560
2013	0	0	229,600	252,560
2014	0	0	229,600	252,560
2015	0	0	229,600	252,560
2016	0	0	229,600	252,560

WASTE ACCEPTANCE RATES (Continued)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	(short tons/year)	(Mg)	(short tons)
2017	0	0	229,600	252,560
2018	0	0	229,600	252,560
2019	0	0	229,600	252,560
2020	0	0	229,600	252,560
2021	0	0	229,600	252,560
2022	0	0	229,600	252,560
2023	0	0	229,600	252,560
2024	0	0	229,600	252,560
2025	0	0	229,600	252,560
2026	0	0	229,600	252,560
2027	0	0	229,600	252,560
2028	0	0	229,600	252,560
2029	0	0	229,600	252,560
2030	0	0	229,600	252,560
2031	0	0	229,600	252,560
2032	0	0	229,600	252,560
2033	0	0	229,600	252,560
2034	0	0	229,600	252,560
2035	0	0	229,600	252,560
2036	0	0	229,600	252,560
2037	0	0	229,600	252,560
2038	0	0	229,600	252,560
2039	0	0	229,600	252,560
2040	0	0	229,600	252,560
2041	0	0	229,600	252,560
2042	0	0	229,600	252,560
2043	0	0	229,600	252,560
2044	0	0	229,600	252,560
2045	0	0	229,600	252,560
2046	0	0	229,600	252,560
2047	0	0	229,600	252,560
2048	0	0	229,600	252,560
2049	0	0	229,600	252,560
2050	0	0	229,600	252,560
2051	0	0	229,600	252,560
2052	0	0	229,600	252,560
2053	0	0	229,600	252,560
2054	0	0	229,600	252,560
2055	0	0	229,600	252,560
2056	0	0	229,600	252,560

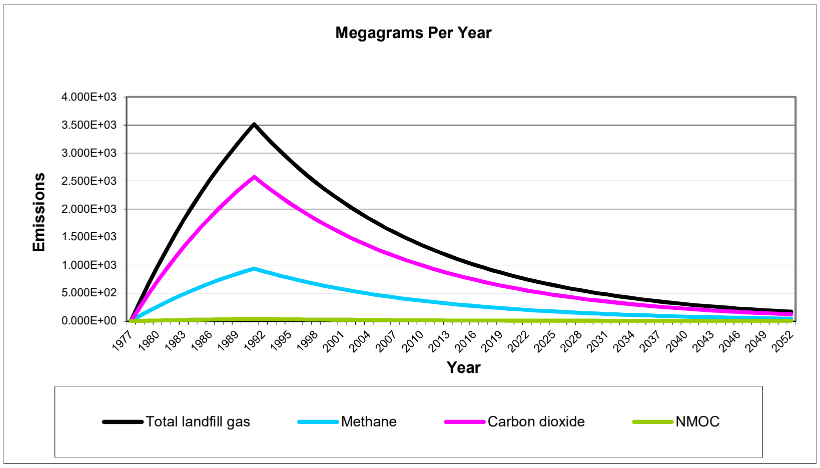
Pollutant Parameters

	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
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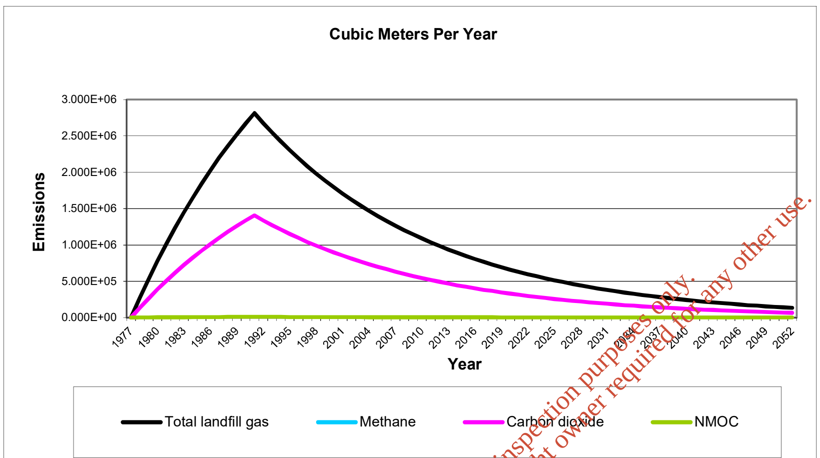
3.500E+03
3.000E+03
2.500E+03
2.000E+03
1.500E+03
1.000E+03
5.000E+02
0.000E+00
1977 1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049 2052
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


Cubic Meters Per Year
Emissions
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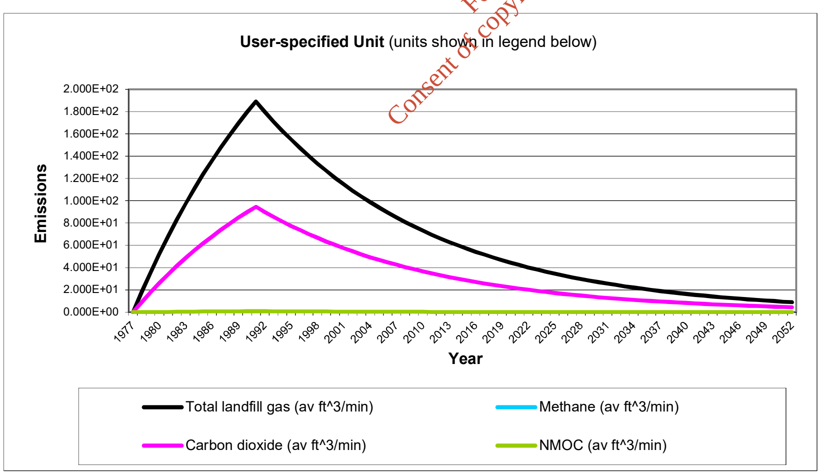
2.500E+06
2.000E+06
1.500E+06
1.000E+06
5.000E+05
0.000E+00
1977 1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049 2052
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


User-specified Unit (units shown in legend below)
Emissions
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1.600E+02
1.400E+02
1.200E+02
1.000E+02
8.000E+01
6.000E+01
4.000E+01
2.000E+01
0.000E+00
1977 1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049 2052
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)
1977	0	0	0	0	0	0
1978	3.405E+02	2.726E+05	1.832E+01	9.094E+01	1.363E+05	9.159E+00
1979	6.643E+02	5.320E+05	3.574E+01	1.774E+02	2.660E+05	1.787E+01
1980	9.724E+02	7.786E+05	5.232E+01	2.597E+02	3.893E+05	2.616E+01
1981	1.265E+03	1.013E+06	6.808E+01	3.380E+02	5.066E+05	3.404E+01
1982	1.544E+03	1.236E+06	8.308E+01	4.125E+02	6.182E+05	4.154E+01
1983	1.809E+03	1.449E+06	9.735E+01	4.833E+02	7.244E+05	4.867E+01
1984	2.062E+03	1.651E+06	1.109E+02	5.507E+02	8.254E+05	5.546E+01
1985	2.301E+03	1.843E+06	1.238E+02	6.147E+02	9.214E+05	6.191E+01
1986	2.530E+03	2.026E+06	1.361E+02	6.757E+02	1.013E+06	6.805E+01
1987	2.747E+03	2.199E+06	1.478E+02	7.337E+02	1.100E+06	7.389E+01
1988	2.953E+03	2.365E+06	1.589E+02	7.888E+02	1.182E+06	7.945E+01
1989	3.150E+03	2.522E+06	1.695E+02	8.413E+02	1.261E+06	8.473E+01
1990	3.337E+03	2.672E+06	1.795E+02	8.912E+02	1.336E+06	8.976E+01
1991	3.514E+03	2.814E+06	1.891E+02	9.387E+02	1.407E+06	9.454E+01
1992	3.343E+03	2.677E+06	1.799E+02	8.929E+02	1.338E+06	8.993E+01
1993	3.180E+03	2.546E+06	1.711E+02	8.494E+02	1.273E+06	8.554E+01
1994	3.025E+03	2.422E+06	1.627E+02	8.079E+02	1.211E+06	8.137E+01
1995	2.877E+03	2.304E+06	1.548E+02	7.685E+02	1.152E+06	7.740E+01
1996	2.737E+03	2.192E+06	1.473E+02	7.311E+02	1.096E+06	7.363E+01
1997	2.603E+03	2.085E+06	1.401E+02	6.954E+02	1.042E+06	7.004E+01
1998	2.476E+03	1.983E+06	1.332E+02	6.615E+02	9.915E+05	6.662E+01
1999	2.356E+03	1.886E+06	1.267E+02	6.292E+02	9.432E+05	6.337E+01
2000	2.241E+03	1.794E+06	1.206E+02	5.985E+02	8.972E+05	6.028E+01
2001	2.132E+03	1.707E+06	1.147E+02	5.693E+02	8.534E+05	5.734E+01
2002	2.028E+03	1.624E+06	1.091E+02	5.416E+02	8.118E+05	5.454E+01
2003	1.929E+03	1.544E+06	1.038E+02	5.152E+02	7.722E+05	5.188E+01
2004	1.835E+03	1.469E+06	9.871E+01	4.900E+02	7.345E+05	4.935E+01
2005	1.745E+03	1.397E+06	9.389E+01	4.661E+02	6.987E+05	4.695E+01
2006	1.660E+03	1.329E+06	8.931E+01	4.434E+02	6.646E+05	4.466E+01
2007	1.579E+03	1.264E+06	8.496E+01	4.218E+02	6.322E+05	4.248E+01
2008	1.502E+03	1.203E+06	8.081E+01	4.012E+02	6.014E+05	4.041E+01
2009	1.429E+03	1.144E+06	7.687E+01	3.816E+02	5.721E+05	3.844E+01
2010	1.359E+03	1.088E+06	7.312E+01	3.630E+02	5.442E+05	3.656E+01
2011	1.293E+03	1.035E+06	6.956E+01	3.453E+02	5.176E+05	3.478E+01
2012	1.230E+03	9.847E+05	6.617E+01	3.285E+02	4.924E+05	3.308E+01
2013	1.170E+03	9.367E+05	6.294E+01	3.125E+02	4.684E+05	3.147E+01
2014	1.113E+03	8.910E+05	5.987E+01	2.972E+02	4.455E+05	2.993E+01
2015	1.058E+03	8.476E+05	5.695E+01	2.827E+02	4.238E+05	2.847E+01
2016	1.007E+03	8.062E+05	5.417E+01	2.689E+02	4.031E+05	2.709E+01
2017	9.578E+02	7.669E+05	5.153E+01	2.558E+02	3.835E+05	2.576E+01
2018	9.110E+02	7.295E+05	4.902E+01	2.433E+02	3.648E+05	2.451E+01
2019	8.666E+02	6.939E+05	4.663E+01	2.315E+02	3.470E+05	2.331E+01
2020	8.243E+02	6.601E+05	4.435E+01	2.202E+02	3.300E+05	2.218E+01
2021	7.841E+02	6.279E+05	4.219E+01	2.095E+02	3.140E+05	2.109E+01
2022	7.459E+02	5.973E+05	4.013E+01	1.992E+02	2.986E+05	2.007E+01
2023	7.095E+02	5.681E+05	3.817E+01	1.895E+02	2.841E+05	1.909E+01
2024	6.749E+02	5.404E+05	3.631E+01	1.803E+02	2.702E+05	1.816E+01
2025	6.420E+02	5.141E+05	3.454E+01	1.715E+02	2.570E+05	1.727E+01
2026	6.107E+02	4.890E+05	3.286E+01	1.631E+02	2.445E+05	1.643E+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)
2027	5.809E+02	4.652E+05	3.125E+01	1.552E+02	2.326E+05	1.563E+01
2028	5.526E+02	4.425E+05	2.973E+01	1.476E+02	2.212E+05	1.486E+01
2029	5.256E+02	4.209E+05	2.828E+01	1.404E+02	2.104E+05	1.414E+01
2030	5.000E+02	4.004E+05	2.690E+01	1.336E+02	2.002E+05	1.345E+01
2031	4.756E+02	3.808E+05	2.559E+01	1.270E+02	1.904E+05	1.279E+01
2032	4.524E+02	3.623E+05	2.434E+01	1.208E+02	1.811E+05	1.217E+01
2033	4.303E+02	3.446E+05	2.315E+01	1.149E+02	1.723E+05	1.158E+01
2034	4.094E+02	3.278E+05	2.202E+01	1.093E+02	1.639E+05	1.101E+01
2035	3.894E+02	3.118E+05	2.095E+01	1.040E+02	1.559E+05	1.048E+01
2036	3.704E+02	2.966E+05	1.993E+01	9.894E+01	1.483E+05	9.964E+00
2037	3.523E+02	2.821E+05	1.896E+01	9.411E+01	1.411E+05	9.478E+00
2038	3.352E+02	2.684E+05	1.803E+01	8.952E+01	1.342E+05	9.016E+00
2039	3.188E+02	2.553E+05	1.715E+01	8.516E+01	1.276E+05	8.576E+00
2040	3.033E+02	2.428E+05	1.632E+01	8.100E+01	1.214E+05	8.158E+00
2041	2.885E+02	2.310E+05	1.552E+01	7.705E+01	1.155E+05	7.760E+00
2042	2.744E+02	2.197E+05	1.476E+01	7.330E+01	1.099E+05	7.382E+00
2043	2.610E+02	2.090E+05	1.404E+01	6.972E+01	1.045E+05	7.022E+00
2044	2.483E+02	1.988E+05	1.336E+01	6.632E+01	9.941E+04	6.679E+00
2045	2.362E+02	1.891E+05	1.271E+01	6.309E+01	9.456E+04	6.353E+00
2046	2.247E+02	1.799E+05	1.209E+01	6.001E+01	8.995E+04	6.044E+00
2047	2.137E+02	1.711E+05	1.150E+01	5.708E+01	8.556E+04	5.749E+00
2048	2.033E+02	1.628E+05	1.094E+01	5.430E+01	8.139E+04	5.469E+00
2049	1.934E+02	1.548E+05	1.040E+01	5.165E+01	7.742E+04	5.202E+00
2050	1.839E+02	1.473E+05	9.896E+00	4.913E+01	7.364E+04	4.948E+00
2051	1.750E+02	1.401E+05	9.414E+00	4.674E+01	7.005E+04	4.707E+00
2052	1.664E+02	1.333E+05	8.954E+00	4.446E+01	6.664E+04	4.477E+00
2053	1.583E+02	1.268E+05	8.518E+00	4.229E+01	6.339E+04	4.259E+00
2054	1.506E+02	1.206E+05	8.102E+00	4.023E+01	6.029E+04	4.051E+00
2055	1.432E+02	1.147E+05	7.707E+00	3.826E+01	5.735E+04	3.854E+00
2056	1.363E+02	1.091E+05	7.331E+00	3.640E+01	5.456E+04	3.666E+00
2057	1.296E+02	1.038E+05	6.974E+00	3.462E+01	5.190E+04	3.487E+00
2058	1.233E+02	9.873E+04	6.634E+00	3.293E+01	4.936E+04	3.317E+00
2059	1.173E+02	9.391E+04	6.310E+00	3.133E+01	4.696E+04	3.155E+00
2060	1.116E+02	8.933E+04	6.002E+00	2.980E+01	4.467E+04	3.001E+00
2061	1.061E+02	8.498E+04	5.710E+00	2.835E+01	4.249E+04	2.855E+00
2062	1.009E+02	8.083E+04	5.431E+00	2.696E+01	4.042E+04	2.716E+00
2063	9.602E+01	7.689E+04	5.166E+00	2.565E+01	3.845E+04	2.583E+00
2064	9.134E+01	7.314E+04	4.914E+00	2.440E+01	3.657E+04	2.457E+00
2065	8.689E+01	6.957E+04	4.675E+00	2.321E+01	3.479E+04	2.337E+00
2066	8.265E+01	6.618E+04	4.447E+00	2.208E+01	3.309E+04	2.223E+00
2067	7.862E+01	6.295E+04	4.230E+00	2.100E+01	3.148E+04	2.115E+00
2068	7.478E+01	5.988E+04	4.024E+00	1.998E+01	2.994E+04	2.012E+00
2069	7.114E+01	5.696E+04	3.827E+00	1.900E+01	2.848E+04	1.914E+00
2070	6.767E+01	5.418E+04	3.641E+00	1.807E+01	2.709E+04	1.820E+00
2071	6.437E+01	5.154E+04	3.463E+00	1.719E+01	2.577E+04	1.732E+00
2072	6.123E+01	4.903E+04	3.294E+00	1.635E+01	2.451E+04	1.647E+00
2073	5.824E+01	4.664E+04	3.134E+00	1.556E+01	2.332E+04	1.567E+00
2074	5.540E+01	4.436E+04	2.981E+00	1.480E+01	2.218E+04	1.490E+00
2075	5.270E+01	4.220E+04	2.835E+00	1.408E+01	2.110E+04	1.418E+00
2076	5.013E+01	4.014E+04	2.697E+00	1.339E+01	2.007E+04	1.349E+00
2077	4.768E+01	3.818E+04	2.565E+00	1.274E+01	1.909E+04	1.283E+00

Results (Continued)

Year	Total landfill gas			Methane		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
2078	4.536E+01	3.632E+04	2.440E+00	1.212E+01	1.816E+04	1.220E+00
2079	4.315E+01	3.455E+04	2.321E+00	1.152E+01	1.727E+04	1.161E+00
2080	4.104E+01	3.286E+04	2.208E+00	1.096E+01	1.643E+04	1.104E+00
2081	3.904E+01	3.126E+04	2.100E+00	1.043E+01	1.563E+04	1.050E+00
2082	3.714E+01	2.974E+04	1.998E+00	9.919E+00	1.487E+04	9.990E-01
2083	3.532E+01	2.829E+04	1.901E+00	9.436E+00	1.414E+04	9.503E-01
2084	3.360E+01	2.691E+04	1.808E+00	8.975E+00	1.345E+04	9.039E-01
2085	3.196E+01	2.559E+04	1.720E+00	8.538E+00	1.280E+04	8.599E-01
2086	3.040E+01	2.435E+04	1.636E+00	8.121E+00	1.217E+04	8.179E-01
2087	2.892E+01	2.316E+04	1.556E+00	7.725E+00	1.158E+04	7.780E-01
2088	2.751E+01	2.203E+04	1.480E+00	7.348E+00	1.101E+04	7.401E-01
2089	2.617E+01	2.096E+04	1.408E+00	6.990E+00	1.048E+04	7.040E-01
2090	2.489E+01	1.993E+04	1.339E+00	6.649E+00	9.967E+03	6.697E-01
2091	2.368E+01	1.896E+04	1.274E+00	6.325E+00	9.481E+03	6.370E-01
2092	2.252E+01	1.804E+04	1.212E+00	6.016E+00	9.018E+03	6.059E-01
2093	2.143E+01	1.716E+04	1.153E+00	5.723E+00	8.578E+03	5.764E-01
2094	2.038E+01	1.632E+04	1.097E+00	5.444E+00	8.160E+03	5.483E-01
2095	1.939E+01	1.552E+04	1.043E+00	5.178E+00	7.762E+03	5.215E-01
2096	1.844E+01	1.477E+04	9.922E-01	4.926E+00	7.383E+03	4.961E-01
2097	1.754E+01	1.405E+04	9.438E-01	4.686E+00	7.023E+03	4.719E-01
2098	1.669E+01	1.336E+04	8.978E-01	4.457E+00	6.681E+03	4.489E-01
2099	1.587E+01	1.271E+04	8.540E-01	4.240E+00	6.355E+03	4.270E-01
2100	1.510E+01	1.209E+04	8.123E-01	4.033E+00	6.045E+03	4.062E-01
2101	1.436E+01	1.150E+04	7.727E-01	3.836E+00	5.750E+03	3.864E-01
2102	1.366E+01	1.094E+04	7.350E-01	3.649E+00	5.470E+03	3.675E-01
2103	1.300E+01	1.041E+04	6.992E-01	3.471E+00	5.203E+03	3.496E-01
2104	1.236E+01	9.899E+03	6.651E-01	3.302E+00	4.949E+03	3.325E-01
2105	1.176E+01	9.416E+03	6.326E-01	3.141E+00	4.708E+03	3.163E-01
2106	1.119E+01	8.957E+03	6.018E-01	2.988E+00	4.478E+03	3.009E-01
2107	1.064E+01	8.520E+03	5.724E-01	2.842E+00	4.260E+03	2.862E-01
2108	1.012E+01	8.104E+03	5.445E-01	2.703E+00	4.052E+03	2.723E-01
2109	9.627E+00	7.709E+03	5.180E-01	2.572E+00	3.854E+03	2.590E-01
2110	9.158E+00	7.333E+03	4.927E-01	2.446E+00	3.667E+03	2.464E-01
2111	8.711E+00	6.975E+03	4.687E-01	2.327E+00	3.488E+03	2.343E-01
2112	8.286E+00	6.635E+03	4.458E-01	2.213E+00	3.318E+03	2.229E-01
2113	7.882E+00	6.312E+03	4.241E-01	2.105E+00	3.156E+03	2.120E-01
2114	7.498E+00	6.004E+03	4.034E-01	2.003E+00	3.002E+03	2.017E-01
2115	7.132E+00	5.711E+03	3.837E-01	1.905E+00	2.855E+03	1.919E-01
2116	6.784E+00	5.432E+03	3.650E-01	1.812E+00	2.716E+03	1.825E-01
2117	6.453E+00	5.167E+03	3.472E-01	1.724E+00	2.584E+03	1.736E-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)*
1977	0	0	0	0	0	0
1978	2.495E+02	1.363E+05	9.159E+00	3.909E+00	1.091E+03	7.327E-02
1979	4.869E+02	2.660E+05	1.787E+01	7.627E+00	2.128E+03	1.430E-01
1980	7.126E+02	3.893E+05	2.616E+01	1.116E+01	3.115E+03	2.093E-01
1981	9.274E+02	5.066E+05	3.404E+01	1.453E+01	4.053E+03	2.723E-01
1982	1.132E+03	6.182E+05	4.154E+01	1.773E+01	4.946E+03	3.323E-01
1983	1.326E+03	7.244E+05	4.867E+01	2.077E+01	5.795E+03	3.894E-01
1984	1.511E+03	8.254E+05	5.546E+01	2.367E+01	6.603E+03	4.437E-01
1985	1.687E+03	9.214E+05	6.191E+01	2.642E+01	7.372E+03	4.953E-01
1986	1.854E+03	1.013E+06	6.805E+01	2.904E+01	8.103E+03	5.444E-01
1987	2.013E+03	1.100E+06	7.389E+01	3.154E+01	8.798E+03	5.911E-01
1988	2.164E+03	1.182E+06	7.945E+01	3.391E+01	9.459E+03	6.356E-01
1989	2.308E+03	1.261E+06	8.473E+01	3.616E+01	1.009E+04	6.778E-01
1990	2.445E+03	1.336E+06	8.976E+01	3.831E+01	1.069E+04	7.181E-01
1991	2.576E+03	1.407E+06	9.454E+01	4.035E+01	1.126E+04	7.563E-01
1992	2.450E+03	1.338E+06	8.993E+01	3.838E+01	1.071E+04	7.194E-01
1993	2.330E+03	1.273E+06	8.554E+01	3.651E+01	1.019E+04	6.843E-01
1994	2.217E+03	1.211E+06	8.137E+01	3.473E+01	9.688E+03	6.510E-01
1995	2.109E+03	1.152E+06	7.740E+01	3.303E+01	9.216E+03	6.192E-01
1996	2.006E+03	1.096E+06	7.363E+01	3.142E+01	8.766E+03	5.890E-01
1997	1.908E+03	1.042E+06	7.004E+01	2.989E+01	8.339E+03	5.603E-01
1998	1.815E+03	9.915E+05	6.662E+01	2.843E+01	7.932E+03	5.330E-01
1999	1.726E+03	9.432E+05	6.337E+01	2.705E+01	7.545E+03	5.070E-01
2000	1.642E+03	8.972E+05	6.028E+01	2.573E+01	7.177E+03	4.822E-01
2001	1.562E+03	8.534E+05	5.734E+01	2.447E+01	6.827E+03	4.587E-01
2002	1.486E+03	8.118E+05	5.454E+01	2.328E+01	6.494E+03	4.364E-01
2003	1.414E+03	7.722E+05	5.188E+01	2.214E+01	6.178E+03	4.151E-01
2004	1.345E+03	7.345E+05	4.935E+01	2.106E+01	5.876E+03	3.948E-01
2005	1.279E+03	6.987E+05	4.695E+01	2.004E+01	5.590E+03	3.756E-01
2006	1.217E+03	6.646E+05	4.466E+01	1.906E+01	5.317E+03	3.573E-01
2007	1.157E+03	6.322E+05	4.248E+01	1.813E+01	5.058E+03	3.398E-01
2008	1.101E+03	6.014E+05	4.041E+01	1.725E+01	4.811E+03	3.233E-01
2009	1.047E+03	5.721E+05	3.844E+01	1.640E+01	4.576E+03	3.075E-01
2010	9.961E+02	5.442E+05	3.656E+01	1.560E+01	4.353E+03	2.925E-01
2011	9.475E+02	5.176E+05	3.478E+01	1.484E+01	4.141E+03	2.782E-01
2012	9.013E+02	4.924E+05	3.308E+01	1.412E+01	3.939E+03	2.647E-01
2013	8.573E+02	4.684E+05	3.147E+01	1.343E+01	3.747E+03	2.518E-01
2014	8.155E+02	4.455E+05	2.993E+01	1.278E+01	3.564E+03	2.395E-01
2015	7.757E+02	4.238E+05	2.847E+01	1.215E+01	3.390E+03	2.278E-01
2016	7.379E+02	4.031E+05	2.709E+01	1.156E+01	3.225E+03	2.167E-01
2017	7.019E+02	3.835E+05	2.576E+01	1.100E+01	3.068E+03	2.061E-01
2018	6.677E+02	3.648E+05	2.451E+01	1.046E+01	2.918E+03	1.961E-01
2019	6.351E+02	3.470E+05	2.331E+01	9.950E+00	2.776E+03	1.865E-01
2020	6.042E+02	3.300E+05	2.218E+01	9.464E+00	2.640E+03	1.774E-01
2021	5.747E+02	3.140E+05	2.109E+01	9.003E+00	2.512E+03	1.688E-01
2022	5.467E+02	2.986E+05	2.007E+01	8.564E+00	2.389E+03	1.605E-01
2023	5.200E+02	2.841E+05	1.909E+01	8.146E+00	2.273E+03	1.527E-01
2024	4.946E+02	2.702E+05	1.816E+01	7.749E+00	2.162E+03	1.452E-01
2025	4.705E+02	2.570E+05	1.727E+01	7.371E+00	2.056E+03	1.382E-01
2026	4.476E+02	2.445E+05	1.643E+01	7.011E+00	1.956E+03	1.314E-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)
2027	4.257E+02	2.326E+05	1.563E+01	6.669E+00	1.861E+03	1.250E-01
2028	4.050E+02	2.212E+05	1.486E+01	6.344E+00	1.770E+03	1.189E-01
2029	3.852E+02	2.104E+05	1.414E+01	6.035E+00	1.684E+03	1.131E-01
2030	3.664E+02	2.002E+05	1.345E+01	5.740E+00	1.601E+03	1.076E-01
2031	3.486E+02	1.904E+05	1.279E+01	5.460E+00	1.523E+03	1.024E-01
2032	3.316E+02	1.811E+05	1.217E+01	5.194E+00	1.449E+03	9.736E-02
2033	3.154E+02	1.723E+05	1.158E+01	4.941E+00	1.378E+03	9.261E-02
2034	3.000E+02	1.639E+05	1.101E+01	4.700E+00	1.311E+03	8.810E-02
2035	2.854E+02	1.559E+05	1.048E+01	4.471E+00	1.247E+03	8.380E-02
2036	2.715E+02	1.483E+05	9.964E+00	4.253E+00	1.186E+03	7.971E-02
2037	2.582E+02	1.411E+05	9.478E+00	4.045E+00	1.129E+03	7.583E-02
2038	2.456E+02	1.342E+05	9.016E+00	3.848E+00	1.073E+03	7.213E-02
2039	2.337E+02	1.276E+05	8.576E+00	3.660E+00	1.021E+03	6.861E-02
2040	2.223E+02	1.214E+05	8.158E+00	3.482E+00	9.713E+02	6.526E-02
2041	2.114E+02	1.155E+05	7.760E+00	3.312E+00	9.240E+02	6.208E-02
2042	2.011E+02	1.099E+05	7.382E+00	3.150E+00	8.789E+02	5.905E-02
2043	1.913E+02	1.045E+05	7.022E+00	2.997E+00	8.360E+02	5.617E-02
2044	1.820E+02	9.941E+04	6.679E+00	2.851E+00	7.953E+02	5.343E-02
2045	1.731E+02	9.456E+04	6.353E+00	2.712E+00	7.565E+02	5.083E-02
2046	1.647E+02	8.995E+04	6.044E+00	2.579E+00	7.196E+02	4.835E-02
2047	1.566E+02	8.556E+04	5.749E+00	2.454E+00	6.845E+02	4.599E-02
2048	1.490E+02	8.139E+04	5.469E+00	2.334E+00	6.511E+02	4.375E-02
2049	1.417E+02	7.742E+04	5.202E+00	2.220E+00	6.194E+02	4.161E-02
2050	1.348E+02	7.364E+04	4.948E+00	2.112E+00	5.891E+02	3.958E-02
2051	1.282E+02	7.005E+04	4.707E+00	2.009E+00	5.604E+02	3.765E-02
2052	1.220E+02	6.664E+04	4.477E+00	1.911E+00	5.331E+02	3.582E-02
2053	1.160E+02	6.339E+04	4.259E+00	1.818E+00	5.071E+02	3.407E-02
2054	1.104E+02	6.029E+04	4.051E+00	1.729E+00	4.824E+02	3.241E-02
2055	1.050E+02	5.735E+04	3.854E+00	1.645E+00	4.588E+02	3.083E-02
2056	9.987E+01	5.456E+04	3.666E+00	1.564E+00	4.365E+02	2.933E-02
2057	9.500E+01	5.190E+04	3.487E+00	1.488E+00	4.152E+02	2.789E-02
2058	9.036E+01	4.936E+04	3.317E+00	1.416E+00	3.949E+02	2.653E-02
2059	8.596E+01	4.696E+04	3.155E+00	1.347E+00	3.757E+02	2.524E-02
2060	8.176E+01	4.467E+04	3.001E+00	1.281E+00	3.573E+02	2.401E-02
2061	7.778E+01	4.249E+04	2.855E+00	1.218E+00	3.399E+02	2.284E-02
2062	7.398E+01	4.042E+04	2.716E+00	1.159E+00	3.233E+02	2.172E-02
2063	7.037E+01	3.845E+04	2.583E+00	1.102E+00	3.076E+02	2.067E-02
2064	6.694E+01	3.657E+04	2.457E+00	1.049E+00	2.926E+02	1.966E-02
2065	6.368E+01	3.479E+04	2.337E+00	9.975E-01	2.783E+02	1.870E-02
2066	6.057E+01	3.309E+04	2.223E+00	9.489E-01	2.647E+02	1.779E-02
2067	5.762E+01	3.148E+04	2.115E+00	9.026E-01	2.518E+02	1.692E-02
2068	5.481E+01	2.994E+04	2.012E+00	8.586E-01	2.395E+02	1.609E-02
2069	5.213E+01	2.848E+04	1.914E+00	8.167E-01	2.278E+02	1.531E-02
2070	4.959E+01	2.709E+04	1.820E+00	7.769E-01	2.167E+02	1.456E-02
2071	4.717E+01	2.577E+04	1.732E+00	7.390E-01	2.062E+02	1.385E-02
2072	4.487E+01	2.451E+04	1.647E+00	7.030E-01	1.961E+02	1.318E-02
2073	4.268E+01	2.332E+04	1.567E+00	6.687E-01	1.865E+02	1.253E-02
2074	4.060E+01	2.218E+04	1.490E+00	6.361E-01	1.774E+02	1.192E-02
2075	3.862E+01	2.110E+04	1.418E+00	6.050E-01	1.688E+02	1.134E-02
2076	3.674E+01	2.007E+04	1.349E+00	5.755E-01	1.606E+02	1.079E-02
2077	3.495E+01	1.909E+04	1.283E+00	5.475E-01	1.527E+02	1.026E-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)*
2078	3.324E+01	1.816E+04	1.220E+00	5.208E-01	1.453E+02	9.762E-03
2079	3.162E+01	1.727E+04	1.161E+00	4.954E-01	1.382E+02	9.285E-03
2080	3.008E+01	1.643E+04	1.104E+00	4.712E-01	1.315E+02	8.833E-03
2081	2.861E+01	1.563E+04	1.050E+00	4.482E-01	1.250E+02	8.402E-03
2082	2.722E+01	1.487E+04	9.990E-01	4.264E-01	1.189E+02	7.992E-03
2083	2.589E+01	1.414E+04	9.503E-01	4.056E-01	1.131E+02	7.602E-03
2084	2.463E+01	1.345E+04	9.039E-01	3.858E-01	1.076E+02	7.232E-03
2085	2.343E+01	1.280E+04	8.599E-01	3.670E-01	1.024E+02	6.879E-03
2086	2.228E+01	1.217E+04	8.179E-01	3.491E-01	9.739E+01	6.543E-03
2087	2.120E+01	1.158E+04	7.780E-01	3.321E-01	9.264E+01	6.224E-03
2088	2.016E+01	1.101E+04	7.401E-01	3.159E-01	8.812E+01	5.921E-03
2089	1.918E+01	1.048E+04	7.040E-01	3.005E-01	8.382E+01	5.632E-03
2090	1.824E+01	9.967E+03	6.697E-01	2.858E-01	7.973E+01	5.357E-03
2091	1.735E+01	9.481E+03	6.370E-01	2.719E-01	7.584E+01	5.096E-03
2092	1.651E+01	9.018E+03	6.059E-01	2.586E-01	7.215E+01	4.847E-03
2093	1.570E+01	8.578E+03	5.764E-01	2.460E-01	6.863E+01	4.611E-03
2094	1.494E+01	8.160E+03	5.483E-01	2.340E-01	6.528E+01	4.386E-03
2095	1.421E+01	7.762E+03	5.215E-01	2.226E-01	6.210E+01	4.172E-03
2096	1.352E+01	7.383E+03	4.961E-01	2.117E-01	5.907E+01	3.969E-03
2097	1.286E+01	7.023E+03	4.719E-01	2.014E-01	5.619E+01	3.775E-03
2098	1.223E+01	6.681E+03	4.489E-01	1.916E-01	5.345E+01	3.591E-03
2099	1.163E+01	6.355E+03	4.270E-01	1.822E-01	5.084E+01	3.416E-03
2100	1.107E+01	6.045E+03	4.062E-01	1.733E-01	4.836E+01	3.249E-03
2101	1.053E+01	5.750E+03	3.864E-01	1.649E-01	4.600E+01	3.091E-03
2102	1.001E+01	5.470E+03	3.675E-01	1.568E-01	4.376E+01	2.940E-03
2103	9.524E+00	5.203E+03	3.496E-01	1.492E-01	4.162E+01	2.797E-03
2104	9.060E+00	4.949E+03	3.325E-01	1.419E-01	3.959E+01	2.660E-03
2105	8.618E+00	4.708E+03	3.163E-01	1.350E-01	3.766E+01	2.531E-03
2106	8.197E+00	4.478E+03	3.009E-01	1.284E-01	3.583E+01	2.407E-03
2107	7.798E+00	4.260E+03	2.862E-01	1.222E-01	3.408E+01	2.290E-03
2108	7.417E+00	4.052E+03	2.723E-01	1.162E-01	3.242E+01	2.178E-03
2109	7.056E+00	3.854E+03	2.590E-01	1.105E-01	3.084E+01	2.072E-03
2110	6.712E+00	3.667E+03	2.464E-01	1.051E-01	2.933E+01	1.971E-03
2111	6.384E+00	3.488E+03	2.343E-01	1.000E-01	2.790E+01	1.875E-03
2112	6.073E+00	3.318E+03	2.229E-01	9.513E-02	2.654E+01	1.783E-03
2113	5.777E+00	3.156E+03	2.120E-01	9.049E-02	2.525E+01	1.696E-03
2114	5.495E+00	3.002E+03	2.017E-01	8.608E-02	2.402E+01	1.614E-03
2115	5.227E+00	2.855E+03	1.919E-01	8.188E-02	2.284E+01	1.535E-03
2116	4.972E+00	2.716E+03	1.825E-01	7.789E-02	2.173E+01	1.460E-03
2117	4.730E+00	2.584E+03	1.736E-01	7.409E-02	2.067E+01	1.389E-03

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APPENDIX 3

Remediation Plan Drawings

FEHILY TIMONEY Cork | Dublin | Carlow
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Rev.	Description	App By	Date
A	ISSUE FOR	BG	21.10.19

PROJECT
TIER 2 SCOTCH CORNER HISTORICAL LANDFILL

CLIENT
MONAGHAN COUNTY COUNCIL

SHEET
PROPOSED LANDFILL CAPPING AREA

Date	Project number	Scale (@ A1-)
21.10.19	P1679	1:1250

Drawn by	Drawing Number	Rev
CS	P1679-0100-0001	A
Checked by JON		

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21 October 2019

Legend

- Landfill capping area
- Slit Trench Location To Confirm Extent of Waste

0m 13m 25m 38m 50m 63m 75m 88m 100m 113m 125m

Scale 1:1250

FEHILY TIMONEY

Cork | Dublin | Carlow

www.fehilytimoney.ie

Rev.	Description	App By	Date
A	ISSUE FOR	BG	21.10.19

PROJECT	TIER 2 SCOTCH CORNER HISTORICAL LANDFILL
CLIENT	MONAGHAN COUNTY COUNCIL
SHEET	PROPOSED SLIT TRENCH LOCATIONS
Date	21.10.19
Project number	P1679
Scale (@ A1-)	1:1250
Drawn by	CS
Checked by	JON
Drawing Number	P1679-0100-0002
Rev	A

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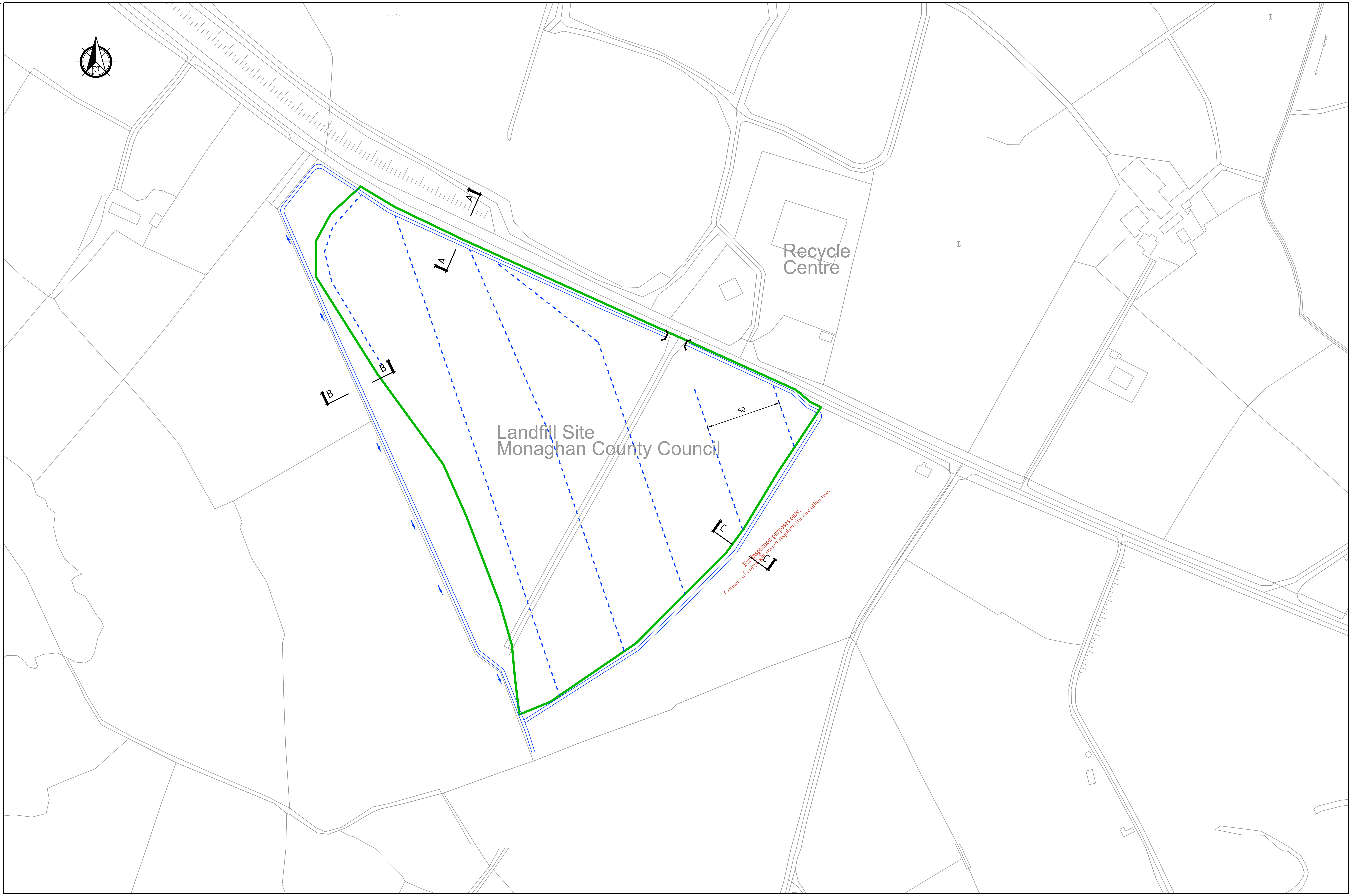
21 October 2019



Legend

- Landfill capping area
- Sub Surface Drainage
- Surface Water Drain
- Inspection Chamber

Note:
Refer to Drawings P1679-0501-0001 & 0002 For Sections

0m 13m 25m 38m 50m 63m 75m 88m 100m 113m 125m

Scale 1:1250

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Rev.	Description	App By	Date
A	ISSUE FOR	BG	21.10.19

PROJECT: TIER 2 SCOTCH CORNER HISTORICAL LANDFILL	CLIENT: MONAGHAN COUNTY COUNCIL
SHEET: PROPOSED DRAINAGE	Date: 21.10.19; Project number: P1679; Scale (@ A1-): 1:1250
	Drawn by: CS; Drawing Number: P1679-0500-0001; Rev: A
	Checked by: JON

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21 October 2019

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Rev.	Description	App By	Date
A	ISSUE FOR	BG	21.10.19

PROJECT

TIER 2 SCOTCH CORNER HISTORICAL LANDFILL

CLIENT

MONAGHAN COUNTY COUNCIL

SHEET

PROPOSED LANDFILL GAS COLLECTION

Date 21.10.19	Project number P1679	Scale (@ A1-) 1:1250	
Drawn by CS	Drawing Number P1679-0500-0002		Rev A
Checked by JON			

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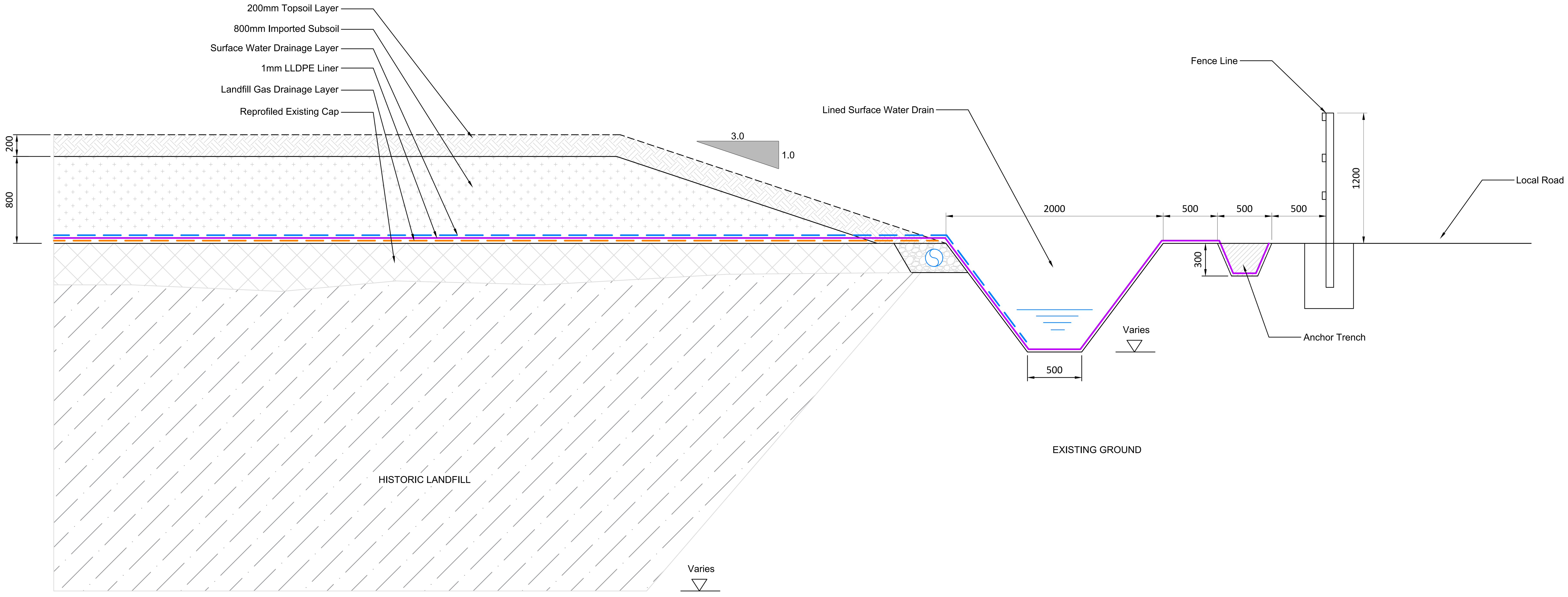
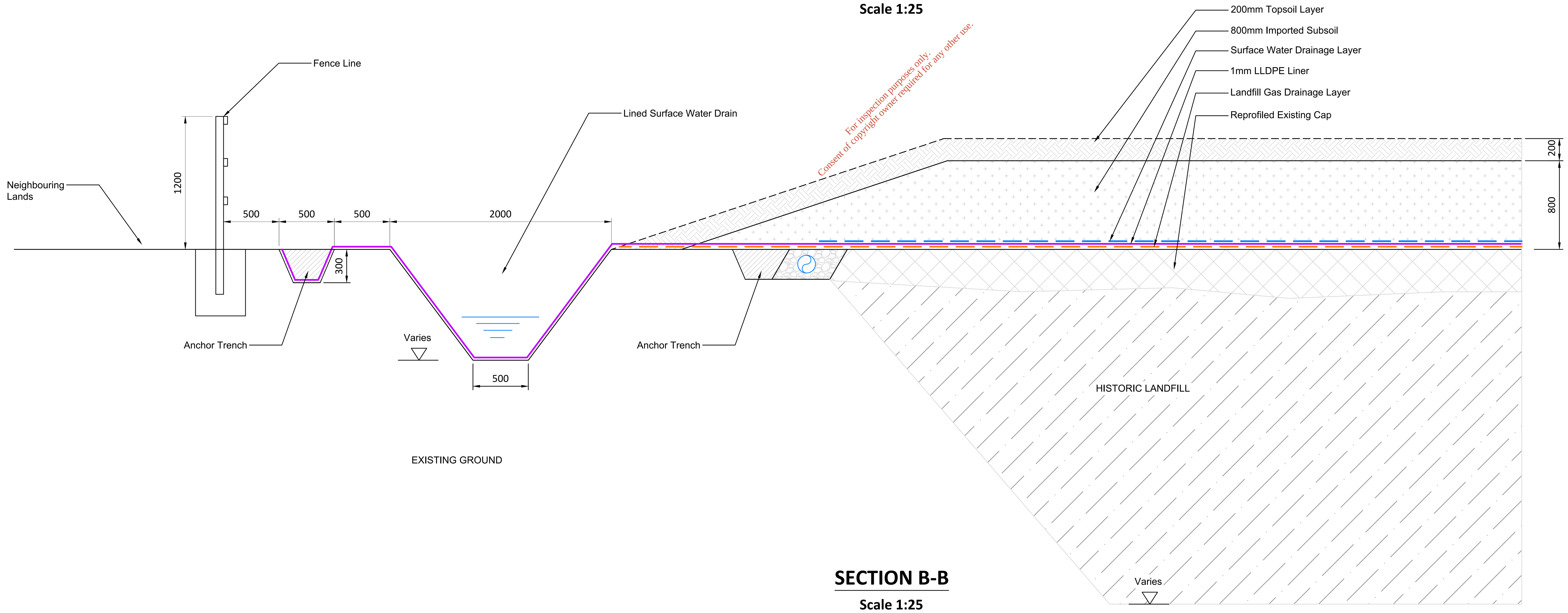
21 October 2019

Note:
Refer to Drawing P1679-0500-0001 For Section Locations



SECTION A-A

Scale 1:25



SECTION B-B

Scale 1:25

0m 0.25m 0.50m 0.75m 1.00m 1.25m 1.50m 1.75m 2.00m 2.25m 2.50m

Scale 1:25

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Rev.	Description	App By	Date
A	ISSUE FOR	BG	21.10.19

PROJECT: TIER 2 SCOTCH CORNER HISTORICAL LANDFILL	CLIENT: MONAGHAN COUNTY COUNCIL
SHEET: SITE SECTIONS SHEET 1 OF 2	Date: 21.10.19; Project number: P1679; Scale (@ A1-) 1:25; Drawn by: CS; Checked by: JON; Drawing Number: P1679-0501-0001; Rev: A

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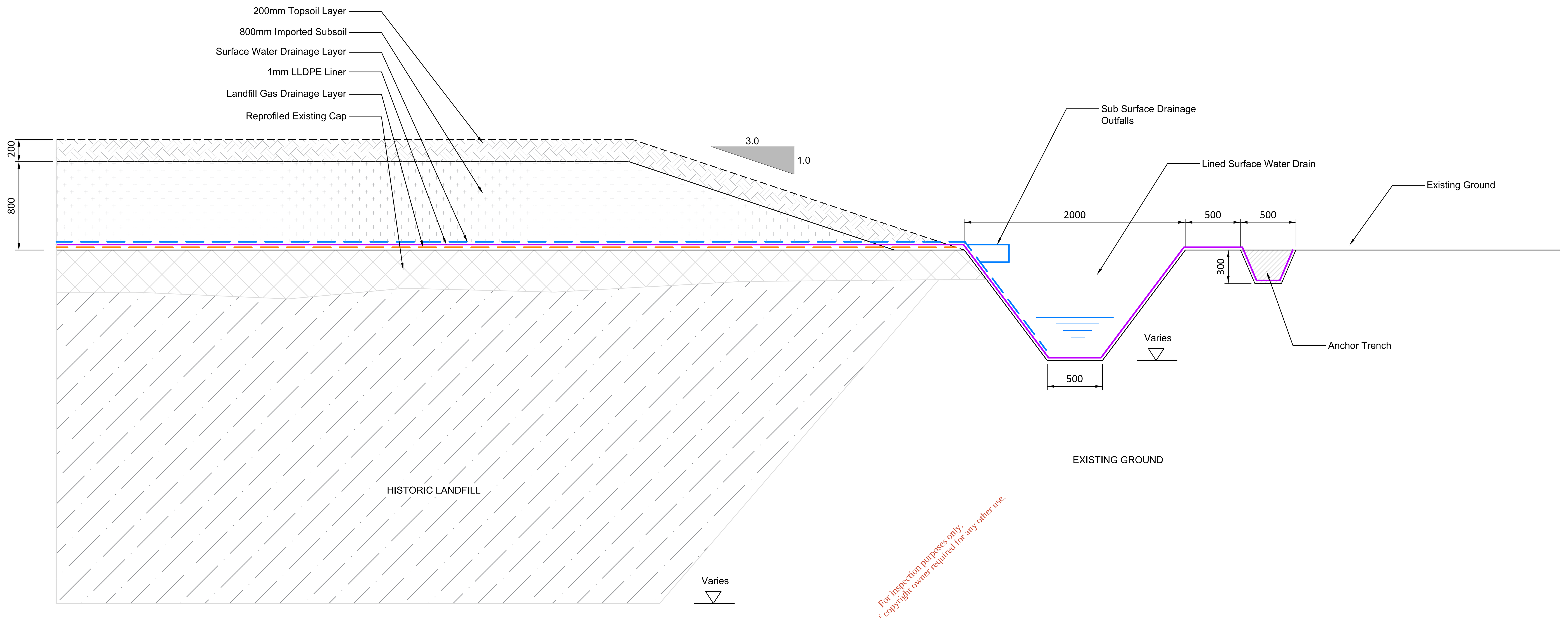
21 October 2019

Note:
Refer to Drawing P1679-0500-0001 For Section Locations



SECTION C-C

Scale 1:25

0m 0.25m 0.50m 0.75m 1.00m 1.25m 1.50m 1.75m 2.00m 2.25m 2.50m

Scale 1:25

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Rev.	Description	App By	Date
A	ISSUE FOR	BG	21.10.19

PROJECT

TIER 2 SCOTCH CORNER HISTORICAL LANDFILL

CLIENT

MONAGHAN COUNTY COUNCIL

SHEET

SITE SECTIONS
SHEET 2 OF 2

Date 21.10.19	Project number P1679	Scale (@ A1-) 1:25	
Drawn by CS	Drawing Number P1679-0501-0002		Rev A
Checked by JON			

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21 October 2019

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QUALITY ISO 9001:2015 NSAI Certified

ENVIRONMENT ISO 14001:2015 NSAI Certified

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APPENDIX 3

Environmental Monitoring Schedule

The schedule of environmental monitoring includes:

- Leachate
- Groundwater and Surface water
- Landfill Gas

Table 1: Leachate Monitoring Schedule

Leachate Monitoring: Table 7.2 of the EPA Landfill Manual (2003)	
Depth (mAOD)	Temperature
pH-value	Chloride
Conductivity (µS/cm)	Sodium
Alkalinity (as CaCO3)	Magnesium
COD	Potassium
BOD5	Calcium
Total Organic Carbon	Chromium
Fatty Acids (as C)	Manganese
Ammoniacal-N	Iron
Nitrite-N	Nickel
Sulphate (as SO4)	Copper
Phosphate (as P)	Chloride

Table2: Surface and Groundwater Monitoring Schedule

Schedule	Groundwater			Surface Water		
Parameter	Monthly	Quarterly	Annual	Monthly	Quarterly	Annual
Visual						
Colour	X			X		
Odour	X			X		
Turbidity	X			X		
Indicators						
pH	X			X		
Electrical Conductivity	X			X		
Temperature	X			X		
Alkalinity, Total as CaCO3	X			X		

Schedule	Groundwater			Surface Water		
Parameter	Monthly	Quarterly	Annual	Monthly	Quarterly	Annual
Ammoniacal Nitrogen	X			X		
BOD	X			X		
Chloride	X			X		
COD	X			X		
Dissolved oxygen	X			X		
Fluoride	X			X		
Nitrite as N	X			X		
Organic Carbon, Total	X			X		
Phosphate (ortho) as PO4	X			X		
Sulphate	X			X		
Total Organic Carbon	X			X		
Total Oxidised Nitrogen as N	X			X		
TSS	X			X		
Metals						
Antimony		X			X	
Arsenic		X			X	
Barium		X			X	
Beryllium		X			X	
Boron		X			X	
Cadmium		X			X	
Calcium		X			X	
Chromium		X			X	
Cobalt		X			X	
Copper		X			X	
Iron		X			X	
Lead		X			X	
Magnesium		X			X	
Manganese		X			X	
Mercury		X			X	
Molybdenum		X			X	
Nickel		X			X	
Phosphorus		X			X	
Potassium		X			X	
Selenium		X			X	
Silicon		X			X	
Silver		X			X	
Sodium		X			X	
Tellurium		X			X	
Thallium		X			X	
Tin		X			X	

Schedule	Groundwater			Surface Water		
Parameter	**Monthly**	**Quarterly**	**Annual**	**Monthly**	**Quarterly**	**Annual**
Titanium		X			X	
Uranium		X			X	
Vanadium		X			X	
Zinc		X			X	
Mineral Oils and Greases						
Mineral Oil / Oils & Greases			X			X
SVOC's						
Semi-Volatile Organic Compounds (SVOCs)			X			X
VOC's						
Volatile Organic Compounds (VOCs)			X			X
Pesticides and Herbicides						
Combined Pesticides / Herbicides			X			X

Table 5: Landfill Gas Monitoring Schedule

Location	Monthly
CH_4 (v/v %)	**x**
CO_2 (v/v %)	**x**
O_2 (v/v %)	**x**
Bal. (v/v %)	**x**

FEHILY TIMONEY
30 YEARS

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APPENDIX 4

Summary of European Sites

SITE SYNOPSIS

SITE NAME: SLIEVE BEAGH SPA

SITE CODE: 004167

The Slieve Beagh SPA comprises much of the eastern and south-eastern sectors of the Slieve Beagh upland area that extends from County Monaghan into Northern Ireland.

Mountain blanket bog is well developed at the higher altitudes and especially at Eshbrack (peak of 365 m). The vegetation is largely dominated by Deergrass (*Scirpus cespitosus*), Ling Heather (*Calluna vulgaris*), Cross-leaved Heath (*Erica tetralix*), Hare's-tail Cottongrass (*Eriophorum vaginatum*), Common Cottongrass (*E. angustifolium*), Crowberry (*Empetrum nigrum*) and a range of mosses such as *Sphagnum capillifolium*, *S. papillosum*, *S. tenellum* and *Hypnum cupressiforme*. Elsewhere the bog is mostly cutover and there are also wet and dry heaths present. In total, bog and heath occupies 43% of the site. The mid-slopes are afforested (40% of site), with plantations of various ages (open canopy, closed canopy, clear-fell). The remainder of the site is rough or marginal grassland (16%). Some of the old field systems support species-rich wet grassland vegetation dominated by Soft Rush (*Juncus effusus*). Several small dystrophic lakes are present within the site.

The site is a Special Protection Area (SPA) under the E.U. Birds Directive, of special conservation interest for Hen Harrier.

The site is one of the strongholds for Hen Harrier in the country. A survey in 2005 recorded four pairs, representing over 1.9% of the all-Ireland total. However, when the Northern Ireland sector of Slieve Beagh is considered, there was a total of 10 breeding pairs in 2005. The mix of forestry and open areas provides optimum habitat conditions for this rare bird, which is listed on Annex I of the E.U. Birds Directive. The early stages of new and second-rotation conifer plantations are the most frequently used nesting sites, though some pairs may still nest in tall heather of unplanted bogs and heath. Hen Harriers will forage up to *c.* 5 km from the nest site, utilising open bog and moorland, young conifer plantations and hill farmland that is not too rank. Birds will often forage in openings and gaps within forests. In Ireland, small birds and small mammals appear to be the most frequently taken prey.

The site also supports breeding Merlin, with two pairs recorded in 2002-03. Further survey is required to determine the exact status of this small falcon. Red Grouse is found in unplanted areas of bog and heath – this is a species that has declined in Ireland and is now Red-listed. Peregrine nest in the Northern Ireland sector of Slieve Beagh and can be seen over the site at times.

Slieve Beagh SPA is of ornithological importance because it provides excellent nesting and foraging habitat for breeding Hen Harrier and is one of the top sites in the country for the species. The presence of three species, Hen Harrier, Merlin and Peregrine, which are listed on Annex I of the E.U. Birds Directive is of note.

25.1.2012

Site Name: Dundalk Bay SAC

Site Code: 000455

Dundalk Bay, Co. Louth, is a very large open, shallow sea bay with extensive saltmarshes and intertidal sand/mudflats, extending some 16 km from Castletown River on the Cooley Peninsula in the north, to Annagassan/Salterstown in the south. The bay encompasses the mouths and estuaries of the Rivers Dee, Glyde, Fane, Castletown and Flurry.

The site is a Special Area of Conservation (SAC) selected for the following habitats and/or species listed on Annex I / II of the E.U. Habitats Directive (* = priority; numbers in brackets are Natura 2000 codes):

[1130] Estuaries
[1140] Tidal Mudflats and Sandflats
[1220] Perennial Vegetation of Stony Banks
[1310] *Salicornia* Mud
[1330] Atlantic Salt Meadows
[1410] Mediterranean Salt Meadows

Saltmarsh vegetation occurs in four main areas: at Lurgangreen, Marsh South, Dundalk Harbour and Bellurgan. Two types are represented – Atlantic and Mediterranean salt meadows. The Atlantic salt meadows are commonest and are characterised by Sea-purslane (*Halimione portulacoides*) (often as a dominant band), along with Common Saltmarsh-grass (*Puccinellia maritima*), Thrift (*Armeria maritima*), Red Fescue (*Festuca rubra*), Common Scurvygrass (*Cochlearia officinalis*), Sea Plantain (*Plantago maritima*) and Sea Rush (*Juncus gerardi*). Common Cord-grass (*Spartina anglica*) is frequent and often dominant over substantial areas. Glassworts (*Salicornia* spp.) occur on the lower zones of the saltmarshes, and in places extend out onto the sandflats. Mediterranean salt meadows are mostly confined to the upper levels of the saltmarshes or along stream sides where they merge with grassland habitats (though the transitional zone is now absent in many places). The habitat contains Sea Rush (*Juncus maritimus*), Sea Arrowgrass (*Triglochin maritima*) and Sea Aster (*Aster tripolium*). The saltmarshes at Lurgangreen and Marsh South are partially fenced and grazed by sheep.

Shingle beaches are particularly well represented in Dundalk Bay, occurring more or less continuously from Salterstown to Lurgan White House in the south bay, and from Jenkinstown to east of Giles Quay in the north bay. The shingle is mostly stable, occurring on post-glacial raised beaches. The shingle often occurs in association with intertidal shingle, saltmarsh and or shingle-based grassland. The shingle supports species such as Spear-leaved Orache (*Atriplex prostrata*), Sea Mayweed (*Matricaria maritima*), Sea Beet (*Beta vulgaris* subsp. *maritima*), Sea Rocket (*Cakile maritima*), Wild Carrot (*Daucus carota*), Sea-holly (*Eryngium maritimum*), Sea Sandwort (*Honkenya peploides*) and Sea Radish (*Raphanus raphanistrum* subsp. *maritimus*). Yellow Horned-poppy (*Glaucium flavum*) and Lyme-grass (*Leymus arenarius*) occur here at their most northern locality on the east coast, while the Red Data Book species Sea-kale (*Crambe maritima*) has recently been recorded.

The extensive sandflats and mudflats (over 4,000 ha) occur and are comprised of ecological communities such as muddy fine sand communities and fine sand community complexes. In the centre of Dundalk Bay there is a gravel community dominated by polychaetes. These habitats host a rich fauna of bivalves molluscs, marine worms and crustaceans and are the main food resource of the tens of thousands of waterfowl (including waders and gulls) which feed in the intertidal area of Dundalk Bay. The saltmarshes are used as high-tide roosts by all of these species, while the grazing birds (notably Brent Goose and Wigeon) feed on the saltmarsh grasses, areas of *Zostera* and other grassland vegetation. Brent Goose also feed on the mats of green algae on the mudflats. At night the wintering Greylag and Greenland White-fronted Goose, and Whooper Swans, from Stabannan/Braganstown (inland from Castlebellingham) roost in Dundalk Bay.

The site is internationally important for waterfowl (numbers in brackets refers to the average maximum over the period 1994/95 to 1997/98) because it regularly holds over 20,000 birds (up to 57,000 have been recorded) and supports over 1% of the North-West European/East Atlantic Flyway populations of Brent Goose (366), Bar-tailed Godwit (2,312) and Knot (11,948). Additionally, it is nationally important for Golden Plover (4,266), Great Crested Grebe (193), Greylag Goose (312), Shelduck (463), Mallard (657), Pintail (100), Red-breasted Merganser (148), Oystercatcher (6,940), Grey Plover (218), Ringed Plover (133), Wigeon (565), Dunlin (9,112), Black-tailed Godwit (754), Curlew (1,593), Lapwing (4,822), Greenshank (20) and Redshank (1,455). Both Golden Plover and Bar-tailed Godwit are Annex I species. The site has been designated a Special Protection Area (SPA) under the E.U. Birds Directive and it is also a designated Ramsar site.

This is a site of significant conservation value because it supports good examples of a range of coastal habitats listed on Annex I of the E.U. Habitats Directive, as well as large numbers of bird species, some of which are listed in the Birds Directive.

SITE SYNOPSIS

SITE NAME: DUNDALK BAY SPA

SITE CODE: 004026

Dundalk Bay is a large open shallow sea bay with extensive saltmarshes and intertidal sand/mudflats, extending some 16 km from Castletown River on the Cooley Peninsula, in the north, to Annagassan/Salterstown in the south.

The extensive sand flats and mud flats have a rich fauna of bivalves, molluscs, marine worms and crustaceans which provides the food resource for most of the wintering waterfowl. The outer part of the bay provides excellent shallow-water habitat for divers, grebes and sea duck. In summer, it is thought to be a major feeding area for auks from the Dublin breeding colonies. The bay is used at night for roosting by wintering flocks of Greylag Goose, Greenland White-fronted Goose and Whooper Swan from Stabannan/Braganstown (inland of Castlebelligham) and other inland sites.

The site is a Special Protection Area (SPA) under the E.U. Birds Directive, of special conservation interest for the following species: Great Crested Grebe, Greylag Goose, Light-bellied Brent Goose, Shelduck, Teal, Mallard, Pintail, Common Scoter, Red-breasted Merganser, Oystercatcher, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Knot, Dunlin, Black-tailed Godwit, Bar-tailed Godwit, Curlew, Redshank, Black-headed Gull, Common Gull and Herring Gull. The E.U. Birds Directive pays particular attention to wetlands and, as these form part of this SPA, the site and its associated waterbirds are of special conservation interest for Wetland & Waterbirds.

The site is of international importance because it regularly supports an assemblage of over 20,000 wintering waterbirds. It also qualifies as a site of international importance for supporting populations of Light-bellied Brent Goose (370), Knot (9,710), Black-tailed Godwit (1,100) and Bar-tailed Godwit (1,950) - all figures, unless stated otherwise, are five year mean peaks for the period 1995/96 to 1999/2000. A variety of other species occur in numbers of national importance, i.e. Great Crested Grebe (303), Greylag Goose (435), Shelduck (522), Teal (538), Mallard (765), Pintail (117), Common Scoter (581 - five year mean peak for the period 2000/01 to 2004/05), Red-breasted Merganser (121), Oystercatcher (8,746), Ringed Plover (151), Golden Plover (5,967), Grey Plover (204), Lapwing (4,892), Dunlin (11,518), Curlew (1,264) and Redshank (1,659). Other wintering species which occur include Red-throated Diver, Great Northern Diver, Cormorant, Grey Heron, Little Egret, Mute Swan, Wigeon, Goldeneye, Greenshank and Turnstone.

The site also supports nationally important populations of three wintering gull species - Black-headed Gull (6,643), Common Gull (551) and Herring Gull (754).

In spring and autumn the site attracts a range of passage migrants, including Little Stint, Curlew Sandpiper and Ruff.

Dundalk Bay SPA is one of the most important wintering waterfowl sites in the country and one of the few that regularly supports more than 20,000 waterbirds. Four species occur in numbers of international importance and a further 19 species in numbers of national importance. The regular occurrence of Golden Plover, Bar-tailed Godwit, Red-throated Diver, Great Northern Diver and Little Egret is of particular note as these species are listed on Annex I of the E.U. Birds Directive. Dundalk Bay is a Ramsar Convention site and parts of Dundalk Bay SPA are designated as Wildfowl Sanctuaries.

7.2.2014

Slieve Beagh-Mullaghfad-Lisnaskea SPA (UK9020091)

The Slieve Beagh – Mullaghfad - Lisnaskea SPA comprises a single land unit extending between Slatbeg in the north-east and Coolnasillagh in the south-west and incorporating the Slieve Beagh massif, Mullaghfad Forest and Lisnaskea Forest. Slightly more than half the eastern boundary is formed by the border with the Republic of Ireland.

The site is delimited principally by physical boundaries closest to merged radii extending 2.5km from nest sites used by hen harriers between 1997 and 2004. The site encompasses all lands within these boundaries, excluding wholly-improved pasture, arable land, buildings and associated lands.

It includes coniferous plantations, blanket bog, wet and dry heath, grass moor, scrub and limited semi-improved agricultural grassland. The principal interest is the breeding population of hen harrier. The site qualifies under Article 4.1 of the Directive (79/409/EEC) by supporting internationally important populations of hen harrier. It should be noted that the site adjoins a proposed SPA for hen harrier in the Republic of Ireland.

Slieve Beagh SAC (UK0016622)

Slieve Beagh SAC in Northern Ireland is an extensive area of undulating upland Blanket bogs and heathland that extends into County Monaghan in the Republic of Ireland. Within Northern Ireland, the peatland complex contains a number of natural dystrophic lakes and ponds that range in size from 5.5 ha to less than 0.5 ha. The site contains the largest concentration of medium- to large-sized dystrophic lakes in Northern Ireland. The smaller lakes and ponds are steep-sided with banks and bed formed by layers of deep peat. The larger lakes have shallow, shelving shores and hard, stony beds. Although the base-poor waters are low in plant nutrients and tend to have a characteristically impoverished flora and fauna, some important communities are present on the site.

The most common type is characterised by the aquatic mosses *Sphagnum cuspidatum*, *S. denticulatum*, *Drepanocladus* spp. and the liverwort *Jungermannia* sp. The floating and marginal vegetation tends to be sparse and restricted and consists of a scattered swamp and acid poor-fen fringe. The lakes are also important for a range of upland invertebrates.

Slieve Beagh is one of the most extensive areas of intact blanket bog in Northern Ireland. It contains a comparatively large area of a mixture of generally *Sphagnum*-rich mire vegetation with cross-leaved heath *Erica tetralix* and *Sphagnum papillosum*, together with deergrass *Trichophorum cespitosum* and hare's-tail cottongrass *Eriophorum vaginatum* with high dwarf-shrub cover. It is less markedly oceanic than other Northern Ireland sites but has some limited areas of surface patterning

Lough Neagh and Lough Beg SPA (UK9020091)

Situated in the centre of Northern Ireland, Lough Neagh is the largest lake in the British Isles. The Special Protection Area includes three eutrophic water bodies, Lough Neagh and two related loughs, Lough Beg and Portmore Lough, together with surrounding swamp, fen, wet grassland and swampy woodland.

he boundary of the proposed Special Protection Area follows the boundaries of the Lough Neagh ASSI, Lough Beg ASSI and Portmore Lough ASSI. The site also forms part of another site which is listed as a wetland of international importance under the Ramsar Convention.

Under Article 4.1 of EC Directive 79/409, it further qualifies by regularly supporting whooper swans and also under Article 4.1 by regularly supporting nationally important numbers of breeding common tern.

Finally, under Article 4.2 of the Directive, it qualifies as a wetland of international importance by regularly supporting over 20,000 of a variety of species of waterfowl in winter. Pochard, tufted duck, goldeneye, little grebe, great crested grebe, cormorant, mute swan, greylag goose, shelduck, wigeon, gadwall, teal, mallard, shoveler, scaup, and coot.

Lough Neagh is also notable for supporting an important assemblage of breeding birds, some species which occur in nationally important numbers - great-crested grebe, gadwall, pochard, tufted duck, snipe, redshank common gull, lesser black-backed gull and black-headed gull. Other important breeding wetland species include shelduck, teal, shoveler, lapwing and curlew.

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