Results

The geophysical survey succeeded in validating the general location of the waste material. Both the elevated EM conductivity readings in combination with the trial pit logs show the waste to be present across the entire survey area.

The survey outlined an area of 0.67 ha which has been interpreted as TOPSOIL over MADE GROUND/WASTE (predominantly organic) over very soft PEAT/CLAY with LEACHATE (Zone A). This area corresponds well with the locations where trial pits encountered 'black bag type waste'.

The survey has interpreted an area of 0.65 ha as TOPSOIL over MADE GROUND/WASTE (mixed with CLAY/SILT) over very soft PEAT/CLAY (Zone B). This area corresponds with the locations where trial pits encountered brown or grey-black waste mixed with clay or silt.

The survey estimated the average thickness of the Zone A waste as 2.1m and the average thickness of the Zone B waste as 2.4m.

The geophysical results confirm the findings of the desk study and anecdotal information gathered, indicating that the site was backfilled with municipal solid waste directly atop the underlying Peat or Clay glacial till strata. The geophysical profiles indicate predominantly organic waste has been deposited in the western portion of the site towards Corrinshigo Lough and leachate is more prevalent in this area of the site.

The modelled profiles and geophysical interpretations are presented in Figure 3.2 to Figure 3.6.

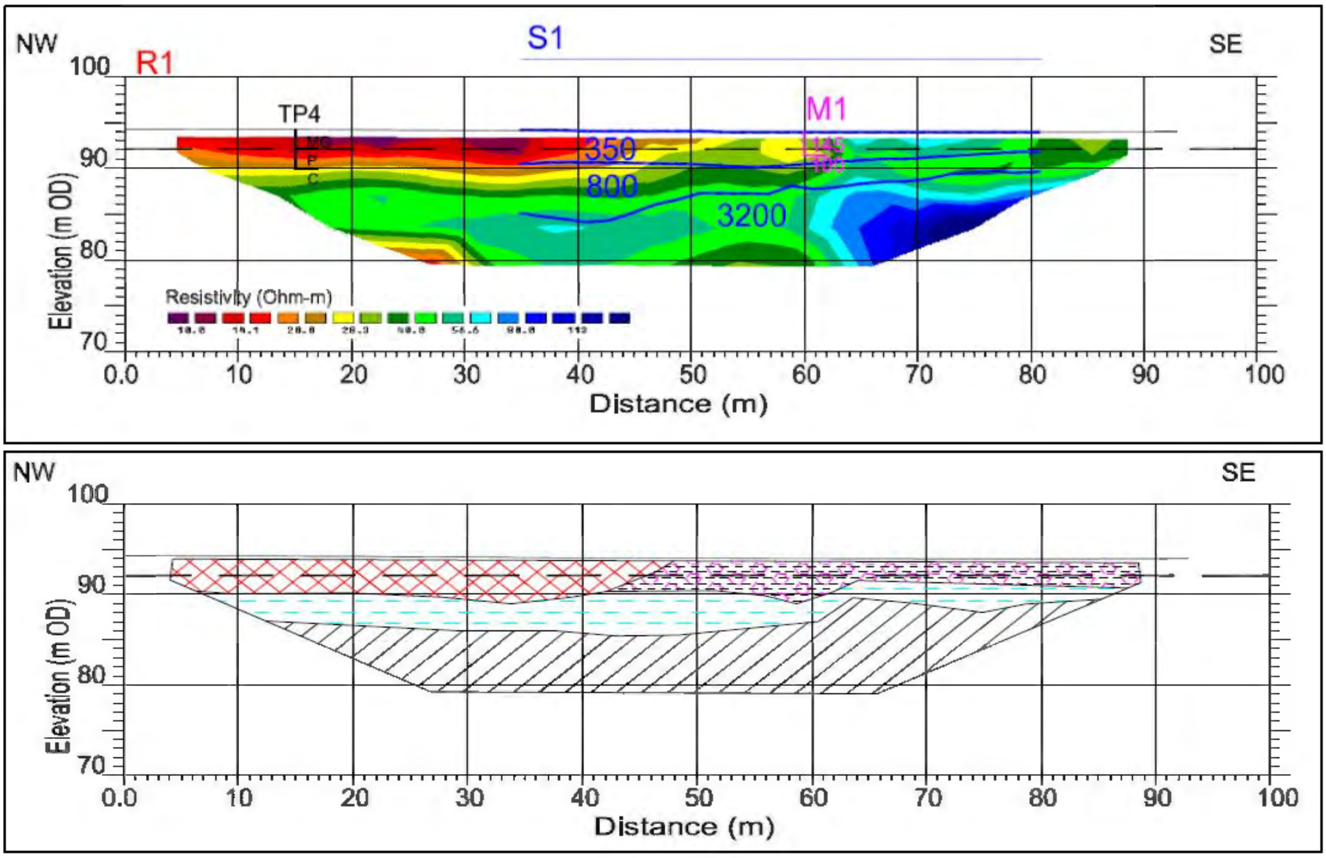


Figure 3-3: ERT Profile R1 Interpreted Cross Section

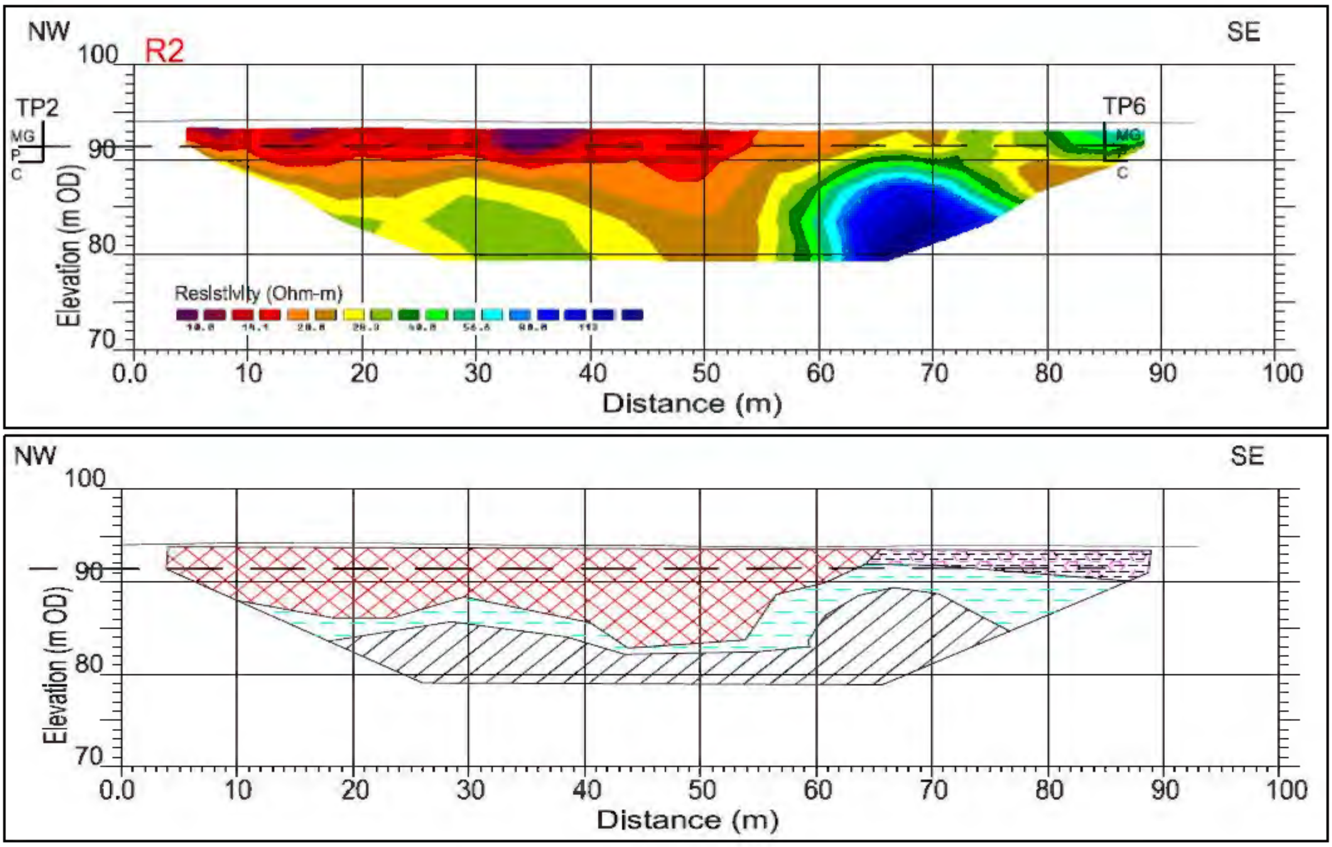


Figure 3-4: ERT Profile R2 Interpreted Cross Section

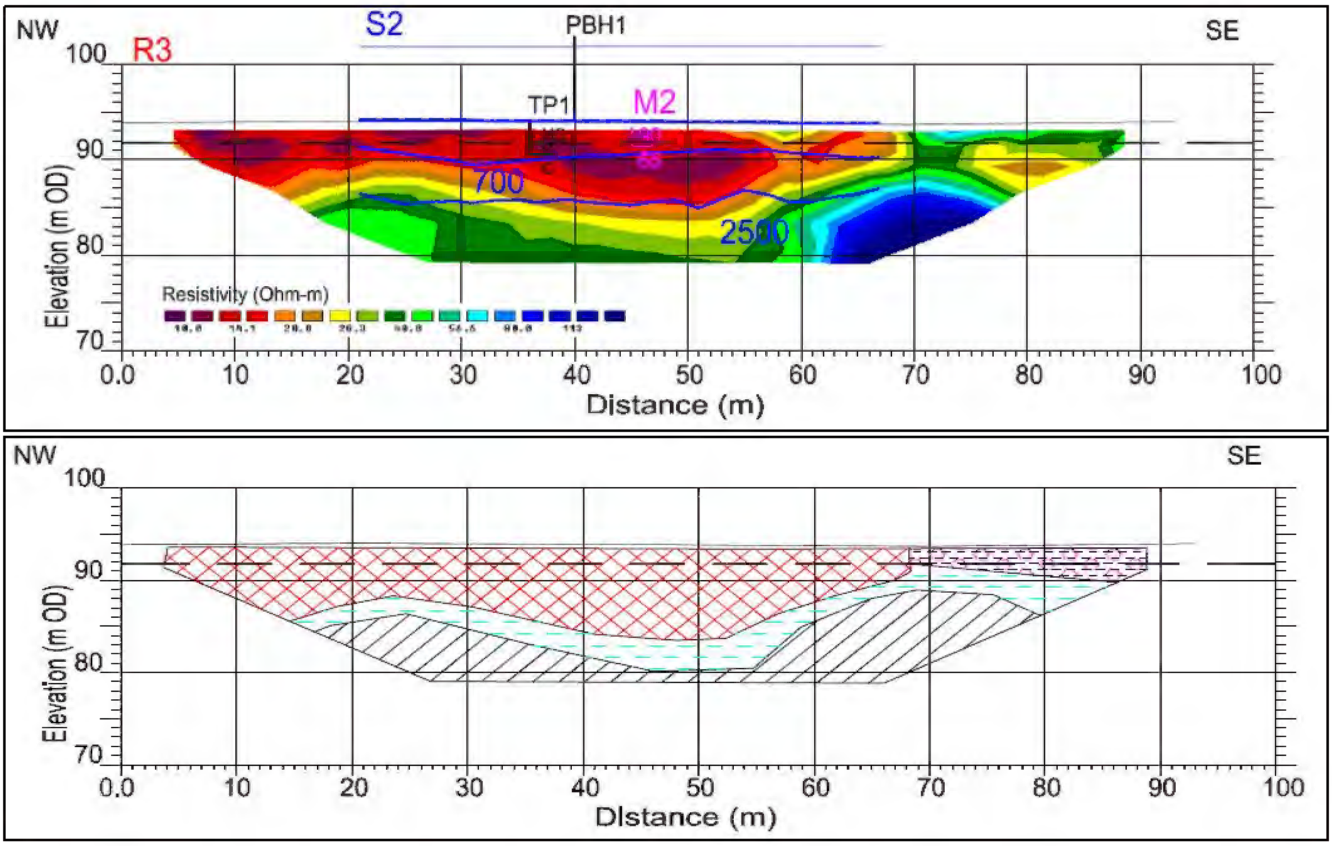


Figure 3-5: ERT Profile R3 Interpreted Cross Section

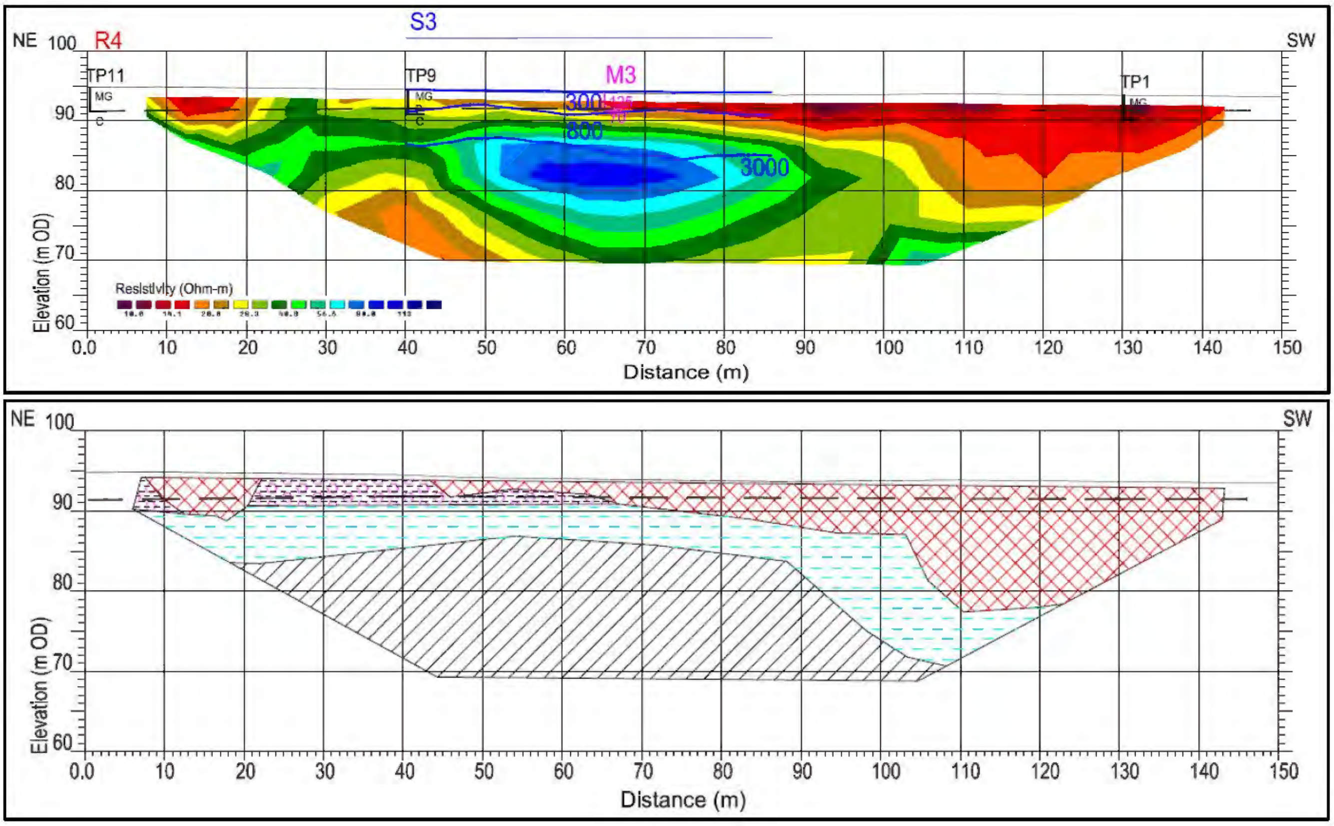


Figure 3-6: ERT Profile R4 Interpreted Cross Section

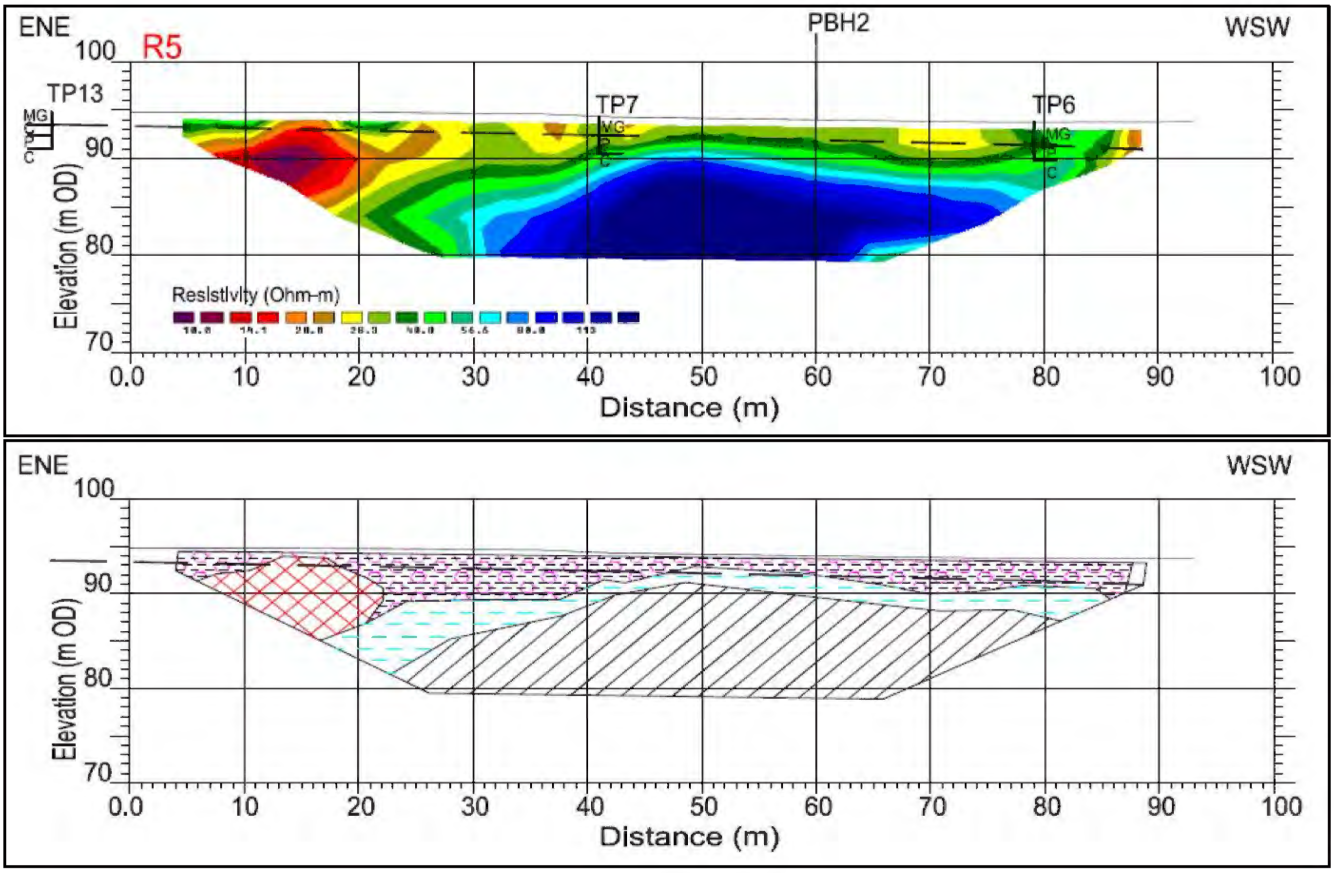


Figure 3-7: ERT Profile R5 Interpreted Cross Section

3.1.6 Waste Delineation

The combined findings of the geophysical survey and intrusive site investigation were used to interpret the aerial extent of the waste mass.

The findings of the site investigation work suggest the waste material is deposited in a single infill area tending west to east across the site and between approximately 140m in length and 120m in width.

Interpretation of the geophysical survey results indicate the presence of two waste composition types which have been designated as Zone A and Zone B. Zone A is characterised as predominantly organic waste deposited in the western portion of the site towards Corrinshigo Lough and a small pocket near the eastern site boundary. Zone B is dispersed over the remaining site footprint and is characterised as waste mixed with Clay/Silt glacial till.

The extent of the waste deposit has been interpreted by the presence of undisturbed ground encountered in 13 No. trial pits TP01 to TP13. Based on this interpretation, the maximum waste footprint is calculated to be approximately 1.15 hectares.

A volume calculation was conducted based on the surveyed surface profiles for the existing ground level and the base of waste as interpreted, estimates indicate an interred waste volume of approximately 29,700 m^3 at the site. This is in line with MCCs estimate which was in the region of 30,000 cubic meters.

The maximum anticipated waste footprint is presented in Figure 3-2. Eight trial pits record 'black bag type waste' on the logs have been designated with a 'K' after the trial pit number, also on Figure 3.2.

3.1.7 Borehole Installation and Groundwater Sampling

Three boreholes (GW01, GW02 and GW03) were drilled to a total depth of 10.0m bgl at the site. The boreholes were drilled for installing groundwater monitoring installations.

All exploratory holes were advanced near the boundary of the deposited waste as identified during the desk study and site walkover. Based on the findings of the geophysical survey and trial pitting, the boreholes are installed within the waste body and screened within the bedrock aquifer below the site. The purpose of the boreholes was to intercept and define the groundwater flow direction upstream and downstream of the identified waste body.

It is noted that the monitoring boreholes were installed within the waste body due to the restricted space available within the site.

Groundwater monitoring was undertaken in boreholes GW01 – GW03 on 2nd and 9th October 2018. Prior to sampling, the standpipe wells were purged and developed with Waterra groundwater sampling pipework/ foot valves and gas caps installed by CGL on the 1st October 2018 in preparation for groundwater monitoring to be undertaken by FT.

All samples were appropriately bottled (using prepared laboratory bottle ware) and packaged for submission to the laboratory. The samples were submitted for laboratory testing to ALS Environmental Ltd. The analysis results are contained in Appendix 3 and are further discussed in the proceeding sections.

3.2 Geotechnical Analysis

3.2.1 In-situ Capping Permeability Testing

Bulk disturbed soil samples from TP02, TP07 and TP13 were submitted for geotechnical analysis by Causeway Geotech Ltd for analysis of moisture content, Atterberg limits and particle size distribution (PSD). The results of the geotechnical analysis are included in the Intrusive Site Investigation Report prepared by Causeway Geotech in Appendix 2. This testing was undertaken to assess the suitability of the existing capping material at minimising rapid rainfall infiltration and preventing leachate generation within waste body.

The PSD analysis determined the soil samples comprised the following gravel, sand, silt and clay content, shown in Table 3.3.

Table 3-3: Soil Sample Classification

Sample Proportions	% Dry Mass		
	TP02	TP07	TP13
Cobbles	0	0	0
Gravel	42	38	34
Sand	30	42	35
Silt	25	17	26
Clay	3	4	5

Hazen's relationship[1] for sands in a loose condition was used to estimate the permeability of the soils sampled. Hazen's relationship is calculated as follows:

$$k = CD_{10}{}^{2}\ m/s$$

Where,

D_{10} is the effective size, mm

C is the coefficient 0.01 to 0.015.

The permeability of the three samples calculated using Hazen's relationship is shown in Table 3.4. The k value calculated for each of the samples classifies the existing capping material between a sandy gravelly SILT and a sandy gravelly silty CLAY.

Table 3-4: Permeability by Hazen's Relationship

Sample ID	C	D_{10} (mm)	K (m/s)
TP02	0.01	0.00461	2.13×10^{-7}
TP07	0.01	0.00692	4.78×10^{-7}
TP13	0.01	0.00369	1.36×10^{-7}

In accordance with the EPA Landfill Site Design Manual an engineered capping material -should have a permeability less than or equal to 1×10^{-9} m/s to minimise infiltration of rainwater into the waste body. The permeability estimated for the three samples analysed at the Killycard site are all greater than the EPA guidance and is not suitable as a low permeability capping material.

The shallow topsoil depth of 0.05 to 0.1m across the site and the high permeability values do not comply with the capping design specification set out in the Landfill Design Manual. The existing soil cover is not sufficient at preventing rainfall ingress which is contributing to leachate generation within the waste body or providing sufficient protection to site users from the interred waste.

[1] Graham Barnes 2010, Soil Mechanic Principles and Practice, 3rd Edition. Chapter 3: Permeability and Seepage.

3.2.2 Variable Head Permeability Testing

The permeability of the limestone bedrock aquifer was assessed by undertaking variable head permeability tests at three installed groundwater wells; GW01 to GW03. The permeability tests undertaken at the site were undertaken in accordance with B.S. 5930:1999.

The results of the permeability testing including the horizontal permeability factor at boreholes GW01 to GW03 are presented in Table 3.5. The test data and associated infiltration graphs are presented in the Causeway site investigation report, Appendix 2.

Table 3-5: In-Situ Permeability Test Results

Test No.	Test Depth (m BGL)	Total Head (m)	Test Time (min)	Permeability Factor (k)
GW01	0.74 – 1.48	1.82	60	3.36×10^{-7} m/s
GW02	0.90 – 2.17	2.38	90	2.54×10^{-7} m/s
GW03	0.35 – 0.96	1.21	90	5.11×10^{-8} m/s

The permeability recorded at GW01, GW02 and GW03 ranged from, 2.54×10^{-7} m/s to 5.11×10^{-8} m/s. According to the CGL borehole logs (Appendix 2), the permeability testing at each borehole GW01 to GW03 was carried out within the overburden which comprised of Made Ground / Waste material and Peat.

4 ENVIRONMENTAL ASSESSMENT

4.1 Chemical Assessment Criteria

- Council Decision 2003/33/EC – Waste Acceptance Criteria
- European Communities, Environmental Objectives (Groundwater)(Amendment) Regulations, 2016 (S.I. No. 366 of 2016)
- Interim Guideline Values (IGV) set out in the EPAs Groundwater *Towards Setting the Guideline Values for the Protection of Groundwater in Ireland*.
- European Communities Environmental Objectives (Surface Waters) (Amendment) Regulations, 2012 (S.I. No. 327 of 2012)
- European Communities Environmental Objectives (Surface Waters) Regulations, 2009 (S.I No. 272 of 2009)
- European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989 (S.I. No. 294/1989).

The results of the environmental assessment at the Killycard Historic Landfill site are presented in the following sections.

4.2 Waste / Made Ground Assessment

The waste / made ground samples analysed during this assessment have been compared against Waste Acceptance Criteria (WAC) to determine the appropriate waste classification rating associated with the interred waste. WAC screening is chosen for this assessment to suitably categorise the interred waste as inert, non-hazardous or hazardous material.

4.2.1 Chemical Results for waste / made ground Samples

The waste/ made ground samples analysed from the site investigations were assessed against the Waste Classification Assessment Criteria. A summary of the results for Killycard Landfill is outlined in Table 4.1 below, while the laboratory reports are presented in Appendix 3.

Table 4-1: Waste Sampling Results – Solid Waste Analysis

Parameter	Units	Inert Waste Acceptance Criteria	Non-Hazardous Waste Acceptance Criteria	Hazardous Waste Acceptance Criteria	Sampling Results - Sample ID	
					TP04 (0.5m)	TP08 (0.5m)
Asbestos in soil	--	**Detected**	**Detected**	**Detected**	ND	ND
Arsenic	$mg.kg^{-1}$	**0.5**	**2**	**25**	0.054	<0.050
Barium	$mg.kg^{-1}$	**20**	**100**	**300**	<0.50	<0.50
Cadmium	$mg.kg^{-1}$	**0.04**	**1**	**5**	<0.010	<0.010
Chromium	$mg.kg^{-1}$	**0.5**	**10**	**70**	<0.050	<0.050
Copper	$mg.kg^{-1}$	**2**	**50**	**100**	<0.050	<0.050
Mercury Dissolved	$mg.kg^{-1}$	**0.01**	**0.2**	**2**	<0.0050	<0.0050
Molybdenum	$mg.kg^{-1}$	**0.5**	**10**	**30**	<0.050	<0.050
Nickel	$mg.kg^{-1}$	**0.4**	**10**	**40**	0.051	<0.050
Lead	$mg.kg^{-1}$	**0.5**	**10**	**50**	0.14	<0.010
Antimony	$mg.kg^{-1}$	**0.06**	**0.7**	**5**	<0.010	<0.010
Selenium	$mg.kg^{-1}$	**0.1**	**0.5**	**7**	<0.010	<0.010
Zinc	$mg.kg^{-1}$	**4**	**50**	**200**	<0.50	<0.50
Chloride	$mg.kg^{-1}$	**800**	**15000**	**25000**	<10	<10
Fluoride	$mg.kg^{-1}$	**10**	**150**	**500**	1.3	1.3
Sulphate	$mg.kg^{-1}$	**1000**	**20000**	**50000**	49	65
Total Dissolved Solids	$mg.kg^{-1}$	**4000**	**60000**	**100000**	300	290
Total Monohydric Phenols	$mg.kg^{-1}$	**1**	**--**	**--**	<0.50	<0.50
Dissolved Organic Carbon	$mg.kg^{-1}$	**500**	**800**	**1000**	130	68
Sum of BTEX	$mg.kg^{-1}$	**6**	**--**	**--**	<0.010	<0.010
Total Organic Carbon *	%	**3**	**5**	**6**	3.0	0.92
Moisture Content ratio	%	**--**	**--**	**--**	16	14
Mineral Oil	$mg.kg^{-1}$	**500**	**--**	**--**	<10	<10

Parameter	Units	Inert Waste Acceptance Criteria	Non-Hazardous Waste Acceptance Criteria	Hazardous Waste Acceptance Criteria	Sampling Results - Sample ID	
					TP04 (0.5m)	TP08 (0.5m)
PCBs (Sum of 7)	$mg.kg^{-1}$	**1**	**--**	**--**	<0.10	<0.10
PAH (Sum of 17)	$mg.kg^{-1}$	**100**	**--**	**--**	<2.0	<2.0
pH	pH units	**>6 or <9**	**>6**	**--**	7.6	7.8
Loss on ignition	%	**--**	**--**	**10**	7.4	3.0

* Hazardous Waste Landfill Criteria: >6% TOC

4.2.2 Waste Laboratory Analysis Discussion

As can be seen in Table 4.1, based on the 2 No. samples submitted for laboratory analysis, waste material encountered within the site are typically inert in terms of their leachate production indicating a high level of degradation over time since landfilling activities ceased at the site.

4.3 Groundwater Analysis

Two rounds of groundwater quality monitoring were undertaken at the site on the 2nd October and 9th October 2018. The findings from the monitoring and an interpretation of the results are presented in the following sections.

4.3.1 Groundwater Depth Analysis

Groundwater depth analysis was undertaken on one occasion following the installation of the rotary core standpipes. Static groundwater levels from the 2nd October 2018 are calculated below.

Table 4-2: Groundwater Depth Analysis

Borehole ID	Location Gradient	Top of Casing (mAOD)	Dip (m) 2/10/18	Groundwater Level (mAOD)
GW01	Upgradient	95.39	1.77	93.61
GW02	Cross-gradient	95.84	2.42	93.43
GW03	Down gradient	94.22	1.11	93.03

*Note: Location gradient is in reference to the identified waste deposition area

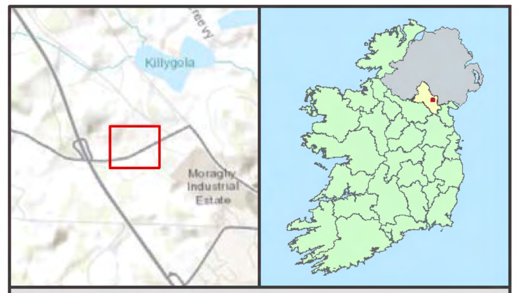
Based on the above field survey measurements, the groundwater flow direction is assumed to be west-south-west. A potentiometric map illustrating the hydraulic gradient and the direction of groundwater flow is presented in Figure 4.1.

4.3.2 Groundwater Borehole Position

The location of the groundwater boreholes installed at the site where based on the anticipated groundwater flow direction. The potentiometric mapping indicates the likely groundwater flow direction is west to south-west.

GW03 is located to the west of the waste mass i.e. downgradient.

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig4-1_GroundwaterFlowDirection_A3.mxd



Co. Monaghan

Legend

- Dipped Water Level (mAOD)
- Groundwater Flow Direction
- Site Boundary

Interpolated Dipped Water Level (mAOD)

- 93.03 - 93.09
- 93.1 - 93.19
- 93.2 - 93.29
- 93.3 - 93.39
- 93.4 - 93.49
- 93.5 - 93.6

Figure Title

Groundwater Flow Direction

Figure No. 4.1

Project ERA of Historic Landfill at Killycard, Co. Monaghan

Client Monaghan County Council

Scale 1:1,500 **Page Size** A3

Revision A **Date** 09/11/2018

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4.3.3 Groundwater Quality Monitoring

The results of groundwater samples analysed from the 3 No. boreholes (GW01 – GW03) at the site have been assessed against the EPAs Interim Guideline Values (IGVs) and the European Groundwater Regulations (2010) assessment criteria. A summary of the maximum results reported for each parameter over two monitoring rounds undertaken on the 2nd and 9th October is outlined in Table 4.3, while the laboratory reports are presented in Appendix 3.

Table 4-3: Groundwater Sampling Results

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2016 Standards [2]	GW01	GW02	GW03
				US	CG	DS
pH	pH units	**6.5 - 9.5**	--	7.66	7.68	7.59
Conductivity	mS/cm	**1**	**1.875**	0.736	0.473	0.708
Dissolved Oxygen	mg/l	**no abnormal change**	--	7.76	6.01	8.34
Alkalinity as CaCO3	mg/l	**200**	--	**377**	**305**	**405**
Ammoniacal Nitrogen as N	mg/l	**0.15**	**0.175**	**19.2**	**1.13**	**4.1**
Total Coliforms	cfu/100ml	**0**	--	**1990**	**549**	**2420**
Nitrite as N	mg/l	--	**0.375**	<0.0152	<0.0152	<0.0152
BOD	mg/l	--	--	2.7	2.04	<1
COD	mg/l	--	--	48.7	115	9.93
Sodium	mg/l	**150**	**150**	59.4	17.1	64.8
Sulphate as SO4	mg/l	**200**	**250**	49.7	4.4	15.3
Total Oxidised Nitrogen	mg/l	--	--	0.119	0.203	0.111
Total Organic Carbon	mg/l	--	--	12.3	4.66	3.15
Arsenic	mg/l	**0.01**	**0.0075**	**0.0147**	0.00367	0.00215
Barium	mg/l	**0.1**	--	**0.294**	0.0761	**0.119**
Boron	mg/l	**1.0**	**0.75**	0.106	0.0283	0.0161
Cadmium	mg/l	**0.005**	**0.005**	<0.0008	<0.0008	<0.0008
Calcium	mg/l	**200**	--	115	71.2	105
Chloride	mg/l	**30**	**187.5**	42.3	15.2	15.5
Chromium	mg/l	**0.03**	**0.05**	<0.001	<0.001	<0.001
Copper	mg/l	**0.2**	**2**	0.00077	0.00148	0.00236
Cyanide	mg/l	**0.01**	**0.0375**	<0.01	<0.01	<0.01
Fluoride	mg/l	**1.0**	**0.8**	<0.5	1.04	<0.5
Iron	mg/l	**0.2**	--	**6.22**	0.0546	0.0936
Lead	mg/l	**0.01**	**0.025**	0.00052	**0.168**	**0.0743**
Magnesium	mg/l	**50**	--	20.2	21.5	21
Manganese	mg/l	**0.05**	--	**1.92**	**0.172**	**0.36**
Mercury	mg/l	**0.001**	**0.001**	<0.00001	<0.00001	<0.00001
Nickel	mg/l	**0.02**	**0.02**	**0.0228**	0.00452	0.00579
Phosphorus (ortho as PO4)	mg/l	**0.03**	**0.035**	<0.05	<0.05	<0.05

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2016 Standards [2]	GW01	GW02	GW03
				US	CG	DS
Potassium	mg/l	**5**	--	**15.6**	3.49	3.59
Uranium	mg/l	**0.009**	--	0.0017	<0.001	0.0053
Zinc	mg/l	**0.1**	--	0.0387	0.0683	0.025
Mineral Oil	mg/l	--	**0.01**	<0.1	**0.181**	<0.1
MTBE	mg/l	--	--	<0.001	<0.001	<0.001
Semi-Volatile Organic Compounds (SVOCs)						
1,2,4-Trichlorobenzene	µg/l	**0.40**	--	<0.01	<0.01	<0.01
2,4,6-Trichlorophenol	µg/l	**200**	--	<10	<10	<10
2-Chlorophenol	µg/l	**200**	--	<10	<10	<10
Benzo(k)fluoranthene	µg/l	**0.05**	--	<0.01	<0.01	<0.01
Hexachlorobenzene	µg/l	**0.03**	--	<0.01	<0.01	<0.01
Hexachlorobutadiene	µg/l	**0.1**	--	<0.01	<0.01	<0.01
Nitrobenzene	µg/l	**10**	--	<1	<1	<1
n-Nitroso-n-dipropylamine	µg/l	--	--	<1	<1	<1
Pentachlorophenol	µg/l	**2**	--	<0.01	<0.01	<0.01
Phenol	µg/l	**0.5**	--	<0.01	<0.01	<0.01
Combined Pesticides / Herbicides						
Aldrin	µg/l	**0.01**	--	<0.01	<0.01	<0.01
Atrazine	µg/l	--	**0.075**	<0.01	<0.01	<0.01
Chlorfenvinphos	µg/l	**5**	--	<1	<1	<1
Dichlorvos	µg/l	**0.001**	--	<0.01	<0.01	<0.01
Dieldrin	µg/l	--	**0.075**	<0.01	<0.01	<0.01
Permethrin I	µg/l	**20**	--	<1	<1	<1
Permethrin II	µg/l	**20**	--	<1	<1	<1
Simazine	µg/l	--	**0.075**	<0.01	<0.01	<0.01
4,4 – DDT	µg/l	--	**0.075**	<0.01	<0.01	<0.01
Organics						
Benzo(alpha)pyrene	µg/l	--	**7.5**	<1	<1	<1
Vinyl Chloride	µg/l	--	**0.375**	<0.01	<0.01	<0.01
Benzene	µg/l	--	**0.75**	<0.01	<0.01	<0.01
Total Trichloroethane	µg/l	--	**7.5**	<1	<1	<1
Total Tetrachloroethene	µg/l	--	**7.5**	<1	<1	<1
1,2-Dichloroethane	µg/l	--	**2.25**	<1	<1	<1

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

4.3.4 Groundwater Analysis Discussion

The results of the groundwater monitoring from GW01 – GW03 have reported several exceedances of the IGVs and European Groundwater limit values.

Samples recovered monitoring wells GW01, GW02 and GW03 reported elevated ammonia concentrations of 19.2 mg/l, 1.13 mg/l and 4.1 mg/l respectively, which exceed guideline threshold values. Given that all monitoring wells were installed within the waste body and screened in bedrock, it is considered that the landfill is contributing to a deterioration in groundwater quality locally.

The presence of peat underlying the waste body across the site may also be contributing to the elevated ammonia concentrations detected in the groundwater locally. The combined presence of elevated ammonia and coliform concentrations in all monitoring wells GW01 to GW03 may also be evidence of localised contamination due to agricultural land spreading or poorly functioning septic tanks in the area.

Based on the presence of elevated ammonia concentrations typical of landfill leachate, the shallow soil cap is not considered suitable at preventing rainfall infiltration into the waste body. The groundwater table also appears to be intersecting the waste body and contributing to leachate migration from the landfill.

The detection of elevated lead concentrations of 0.168 mg/l and 0.0743 mg/l at monitoring locations GW02 and GW03 and slightly elevated nickel concentration at GW01 are considered to be evidence of the localised groundwater hydrochemistry based on the presence of historical lead mining north of Castleblayney. Reference is made to several small metallic mineral deposits, most notably lead and zinc, located near Castleblayney as detailed in the EPA's Historic Mine Sites - Inventory and Risk Classification (2009). Despite the detection of lead in the localised groundwater, the elevated lead concentrations at GW02 and GW03 may also be attributable to the landfill.

According to the EPA publication *'Assessing and Developing Natural Background Levels for Chemical Parameters in Irish Groundwater'*, barium concentrations have been recorded throughout Ireland over four orders of magnitude and appears to be controlled by both lithology and location. The study shows that high concentrations tend to be associated with the Dinantian Sandstones and shales derived from those parent materials, which the Killycard site is founded on. Similar to the naturally occurring lead levels in groundwater, the barium concentration detected at monitoring locations GW01 and GW03 are considered to be evidence of the localised groundwater hydrochemistry.

The slightly elevated manganese concentrations ranging from 0.172 mg/l to 1.92 mg/l across all monitoring wells are considered to be typical of the local bedrock hydrochemistry.

The iron concentration of 6.22 mg/l detected in upgradient borehole GW01 is 30-times the groundwater threshold value and is likely a result of leachate from the waste body. The elevated arsenic concentration of 0.0147 mg/l at GW01 is twice the GTV and may also be an indication of leachate migration from the waste body to this location.

The elevated potassium concentrations of 15.6 mg/l detected in upgradient borehole GW01 exceeds the guideline threshold value. The significant concentration difference between the upgradient and downgradient monitoring locations suggests that the waste body is contributing to the increased potassium concentrations in groundwater quality at this location.

The results of groundwater monitoring have returned one slight exceedance of the groundwater threshold value for mineral oil at monitoring location GW02. Mineral oil was detected at a concentration of 0.181 mg/l which exceeds the guideline threshold value of 0.01 mg/l.

Elevated alkalinity ($CaCO_3$) is consistent across all three sampling locations. The alkaline groundwater quality within the range 305 mg/l to 405 mg/l is considered to be a factor of local bedrock hydrochemistry.

The results of groundwater monitoring when assessed against typical leachate constituents (List 1 and List 2 substances – SVOCs, pesticides, herbicides, organics) shows all results are below the laboratory limit of detection in all assessments across all three sampling locations.

4.4 Landfill Gas Monitoring

FT carried out monitoring of landfill gas (LFG) parameters at each monitoring borehole location (GW01 – GW03) as indicated on Figure 4.1. In accordance with the EPA CoP, methane, carbon dioxide, oxygen and atmospheric pressure were analysed at the 3 No. groundwater monitoring wells located within the waste body using a geotechnical instrument GEM5000 Landfill Gas analyser.

4.4.1 Monitoring Results

In accordance with the CoP, the trigger level for methane outside the waste body is 1% v/v and for carbon dioxide is 1.5% v/v. The monitoring results for methane, carbon dioxide and oxygen levels for the monitoring boreholes are summarised in Table 4.4.

Table 4-4: Perimeter Well Monitoring Results September & October 2018

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

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

As can be seen in Table 4.5, concentrations of both CO_2 and CH_4 at all monitoring boreholes GW01 to GW03 were generally recorded below the threshold values set by the CoP during both monitoring rounds. However, one exception is the detection of a slightly elevated methane concentration of 1.5% v/v at upgradient sampling location GW01. Gas concentrations at these levels are an indication of the stabilised nature of the interred MSW at the site.

It is noted that the monitoring boreholes have been installed within the identified waste body due to the restricted space available within the site.

4.5 Surface Water Monitoring

4.5.1 Monitoring Locations

The surface water monitoring locations were selected upstream and downstream of the landfill footprint, as shown on Figure 4-2. Monitoring location SW1 was selected as the furthest downstream location and samples the Corrinshigo Lough to the west of the landfill. Monitoring location SW2 is located along the northern boundary of the landfill and samples from a drainage channel upstream of the landfill.

Two surface water monitoring rounds were carried out on the 2nd October and 9th October 2018.

4.5.2 Monitoring Parameters

The results of surface water sampling analysed from the 2 No. sampling locations (SW1 and SW2) at the site have been assessed against the Maximum Admissible Concentration (MAC) Regulations (1989) and the Environmental Quality Standard (EQS) for Surface Waters Regulations (2009) assessment criteria.

A summary of the maximum values reported for each parameter from the two monitoring rounds is outlined in Table 4.5, while the laboratory reports are presented in Appendix 3.

Table 4-5: Surface Water Sampling Results

Parameter	Units	MAC [1] / EQS [2]	2nd – 9th October 2018	
			SW1 Downstream	SW2 Upstream
pH (Laboratory)	pH Units	6.0<pH<9.0[2]	7.84	7.43
Dissolved Oxygen	mg/l	<9 – 6 [1]	9.9	9.04
Conductivity	µS/cm	1 [1]	0.421	0.434
BOD, unfiltered	mg/l	≤2.6 (95%ile)[2]	**3.73**	<1
COD, unfiltered	mg/l	40 [1]	35.5	20.8
Sulphate	mg/l	200 [1]	7.63	7.40
Chloride	mg/l	250 [1]	46.9	46.6
Ammoniacal Nitrogen as N	mg/l	≤0.140(95%ile) [2]	**0.318**	<0.140
Potassium	mg/l	--	5.02	5.07
Sodium	mg/l	200 [1]	33.4	30.4

Notes:

1 Maximum Admissible Concentration (MAC), as classified by European Communities (Quality of Surface Water intended for abstraction of drinking water) Regulations 1989 (S.I No. 294 of 1989)

2 Environmental Quality Standard (EQS), European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I No. 272 of 2009)

* Items shaded in **orange** are in exceedance of the 2009 EQS Regulations

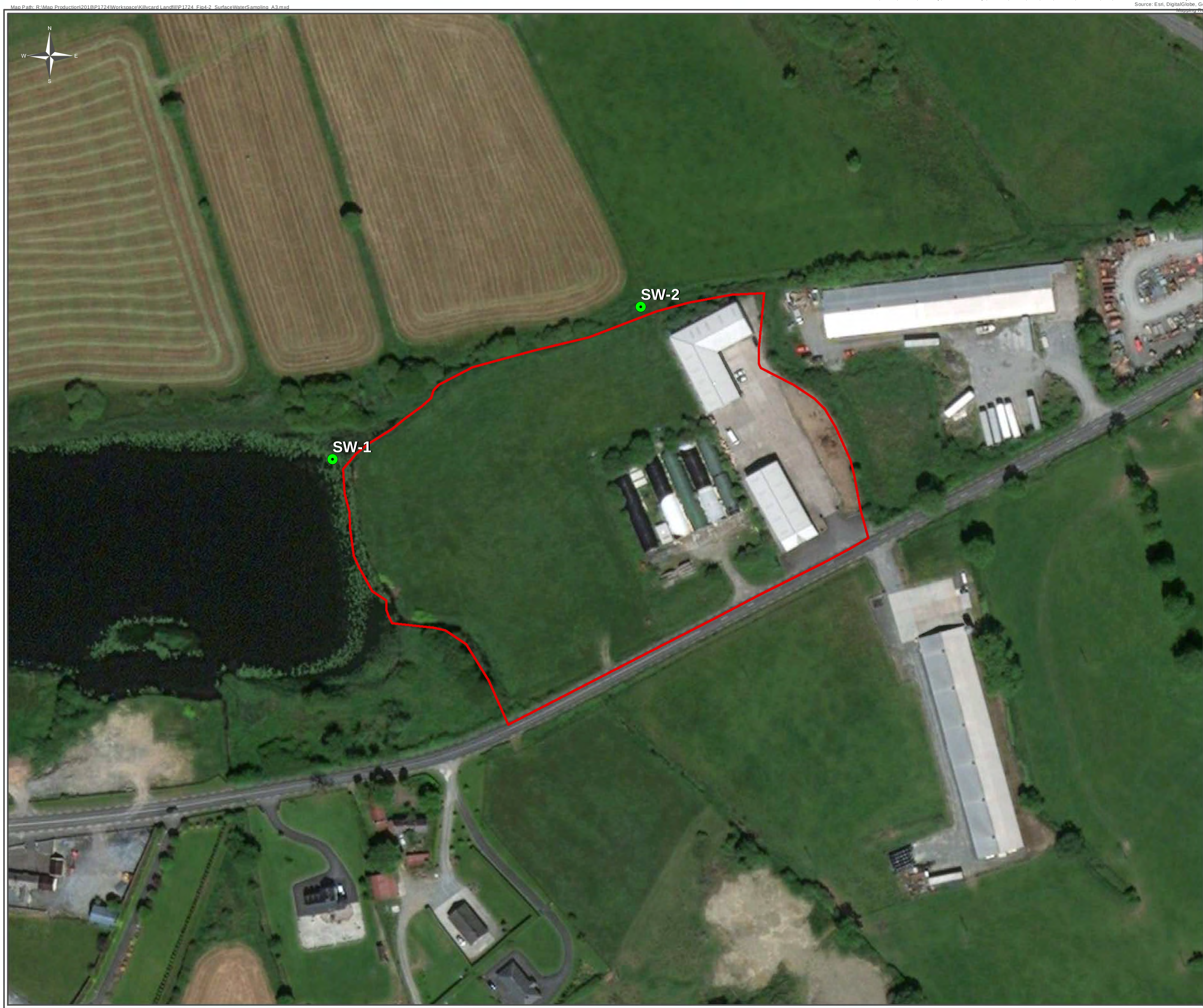
4.5.3 Surface Water Analysis Discussion

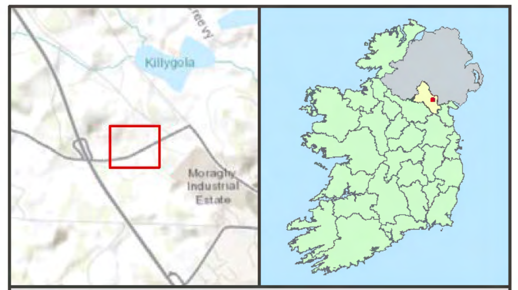
The results of the surface water monitoring from SW1 and SW2 show 2 No. exceedances of the EQS (2009) guideline limit values for ammonia and BOD. Results from sampling location SW2 detected an ammonia and BOD concentrations of 0.318 mg/l and 3.73 mg/l respectively. Given that he determined groundwater flow direction is west-south-west from the waste body, the detected ammonia and BOD at these levels may be evidence of impact from the landfill.

The presence of ammonia and BOD at these levels may also be an indication of slurry spreading runoff from the surrounding agricultural fields in the area, rather than direct impact from the landfill. Surface water runoff from the steep agricultural fields north of the landfill feed into Corrinshigo Lough and may be deteriorating water quality in the lake.

The remaining results of the surface water laboratory analysis as presented in Table 4.5, when assessed against the MAC (1989) and EQS (2009) quality standards were found to be below the guideline values in all assessments.

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig4-2_SurfaceWaterSampling_A3.mxd





Co. Monaghan

Legend

- Surface Water Sampling Locations
- Site Boundary

0 25 50 100 Meters

Figure Title	Surface Water Sampling
Figure No.	4.2
Project	ERA of Historic Landfill at Killycard, Co. Monaghan
Client	Monaghan County Council
Scale	1:1,500
Page Size	A3
Revision	A
Date	09/11/2018

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5 RISK ASSESSMENT

5.1 Introduction

Risk assessment considers the likelihood of occurrence and the consequence of occurrence of an event (Royal Society, 1992[2]). ERA (Environmental Risk Assessment) is based on the development of a Conceptual Site Model (CSM) which is used to determine the potential exposure of a vulnerable receptor to a contaminant. The CSM is used as the basis for the risk assessment. It is used to identify all possible sources (S), pathways (P) and receptors (R) as well as the processes that are likely to occur along each of the source-pathway-receptor (S-P-R) linkages and uncertainties.

Based on the desktop investigation and completed site investigation, this CSM assumes the source to be the made ground containing waste deposit, the pathway to involve the migration of landfill gas, surface water and groundwater and the ultimate receptors to be the surface water features, groundwater, groundwater abstraction well and all human presence near the waste material.

5.2 Potential Pathways and Receptors

A pathway is a mechanism or route by which a contaminant encounters, or otherwise affects, a receptor. Contaminants associated with deposited waste may include leachate generated from groundwater/rainwater infiltration into the waste material and/or the generation of landfill gas from the degradation of the biodegradable fraction of deposited waste.

The potential pathways associated with the Killycard site are:

- Groundwater migration; and
- Surface water infiltration;

5.2.1 Groundwater/Leachate Migration

According to the EPA CoP, there are three main pathways for leachate migration. These are:

- Vertically to the water table or top of an aquifer, where groundwater is the receptor
- Vertically to an aquifer and then horizontally in the aquifer to a receptor such as a well, spring, stream or in this case, the adjacent coastline
- Horizontally at the ground surface or at shallow depth to a surface receptor

The migration and attenuation of leachate from the site depends on the permeability and thickness of subsoil and on both the bedrock permeability value and type. These elements are encompassed in groundwater vulnerability, groundwater flow regime and surface water drainage. The main receptors to leachate migration from this site are:

- Aquifer;
- Surface water features; and
- Human presence nearby the site

5.2.2 Landfill Gas Migration

According to the EPA CoP, there are two main pathways for landfill gas migration. These are:

- Lateral migration via subsoil
- Vertical migration via subsoil

[2] Royal Society 1992, Risk: Analysis, Perception and Management. The Royal Society, London (ISBN 0-85403-467-6).

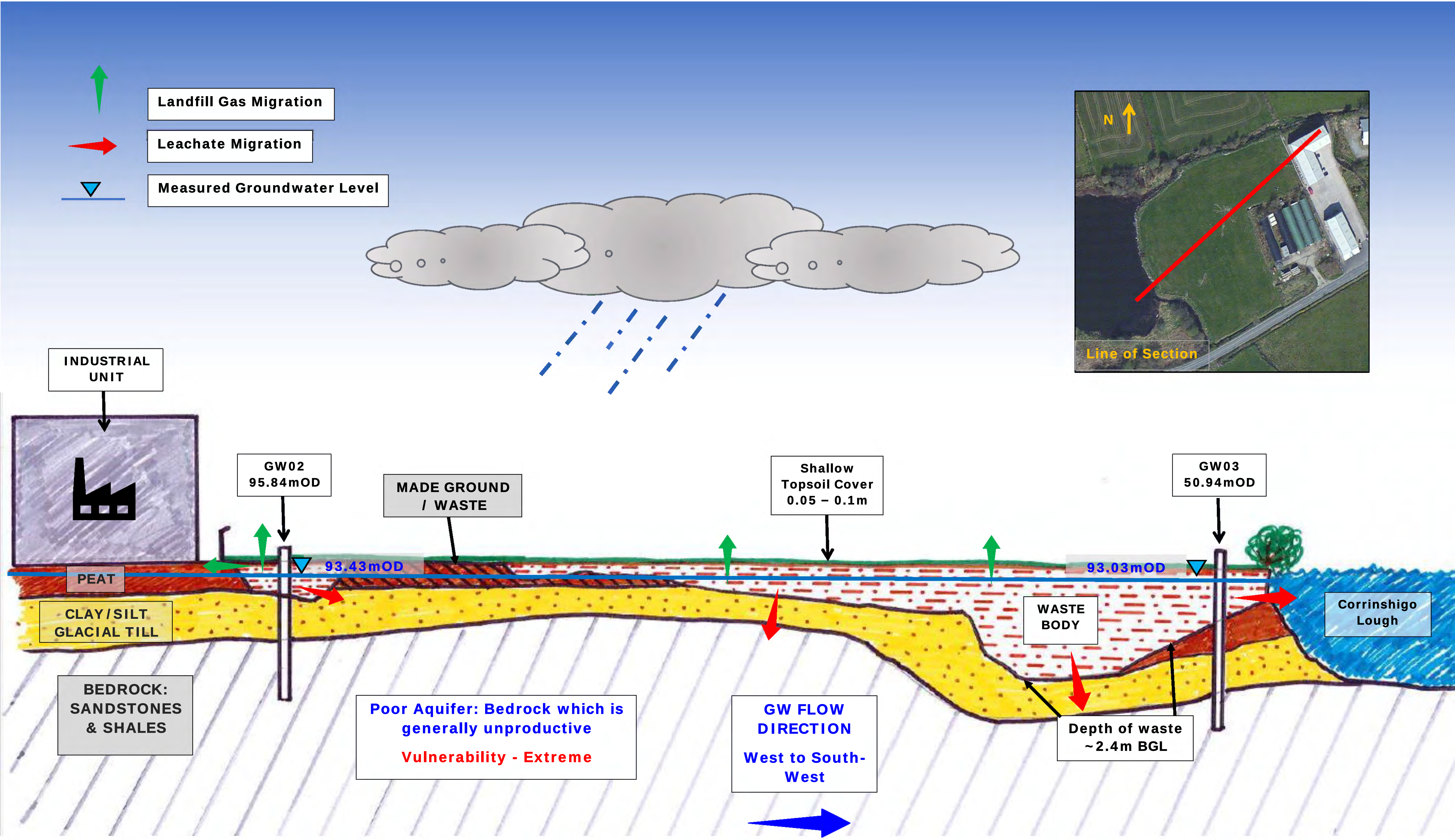
The migration of landfill gas from the site depends on the nature of the material deposited and the nature, permeability and thickness of the surrounding subsoil or bedrock.

The main receptors to potential landfill gas migration from this site are:

- Human Presence/Buildings nearby the waste body

5.3 Conceptual Site Model

Based on the review of the Tier 1 assessment and site investigation works undertaken for Killycard Historic Landfill, an assessment of the risk is made to confirm the source – pathway – receptor (S-P-R) linkages identified in the preliminary investigation. The results and analysis of the investigation has enabled a revised conceptual model to be produced for the site, which is presented in Figure 5.1, overleaf.



CROSS SECTION NORTH-EAST / SOUTH-WEST

FIGURE 5.1 KILLYCARD HISTORIC LANDFILL CONCEPTUAL SITE MODEL

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5.4 Risk Prioritisation

Risk prioritisation enables resources to be prioritised on the highest risk facilities and on the highest source – pathway – receptor linkage potential.

The risk prioritisation process assigns a score to each linkage and the overall score is the maximum of the individual linkages for the site. The higher the score a site/linkage receives the higher the risk.

To classify the risk, scores will be applied to the information obtained during the site investigation of Killycard Historic Landfill. Where there is insufficient information available (i.e. where there is a high degree of uncertainty) the highest score is assumed.

In accordance with the EPA CoP (2007) the scoring matrices are as follows:

- Leachate: Source/hazard scoring matrix, based on waste footprint
- Landfill gas: Source/hazard scoring matrix based on waste footprint
- Leachate migration: Pathway (Vertical)
- Leachate migration: Pathway (Horizontal)
- Leachate migration: Pathway (Surface water drainage)
- Landfill gas: Pathway (Lateral migration potential)
- Landfill gas: Pathway (Upwards migration potential)
- Leachate migration: Receptor (Surface water drainage)
- Leachate migration: Receptor (Human presence)
- Leachate migration: Receptor (Protected areas – SWDTE or GWDTE) (Surface water/groundwater dependent terrestrial ecosystems)
- Leachate migration: Receptor (Aquifer category – Resource potential)
- Leachate migration: Receptor (Public water supplies – other than private wells)
- Leachate migration: Receptor (Surface water bodies)
- Landfill gas: Receptor (Human presence)

Table 5.1 calculates the points awarded to each of the headings listed above.

Table 5-1: Risk Classification Calculation – Killycard Landfill

EPA Ref	Risk	Points	Rationale
1a	Leachate; source/hazard scoring matrix, based on waste footprint.	7	Based on a waste footprint of >1 & <5ha, the shallow permeable soil cap across the site, the presence of elevated ammonia in the groundwater samples and the waste is Municipal Waste a score of 7 is being maintained.
1b	Landfill gas; source/hazard scoring matrix, based on waste footprint.	7	Based on a waste footprint of >1 & <5ha, the discovery of peat below the waste body and the detection of one gas concentration exceedance at GW01 the score is being maintained at 7 due to the proximity of the industrial buildings to the eastern boundary of the waste body.
2a	Leachate migration: Pathway (Vertical)	3	GSI describes the groundwater vulnerability as Extreme and the presence of a shallow permeable soil cap across the site.
2b	Leachate migration: Pathway (Horizontal)	1	The bedrock is classified by the GSI as a Poor Aquifer (PI) - Bedrock which is unproductive except for local zones.

EPA Ref	Risk	Points	Rationale
2c	Leachate migration: Pathway (Surface water drainage)	2	There is a direct connection between the waste body and the adjacent Corrinshigo Lough as verified during the site walkover.
2d	Landfill gas: Pathway (Lateral migration potential)	3	The landfill is surrounded by Made Ground.
2e	Landfill gas: Pathway (Upwards migration potential)	1	The landfill is underlain by peat and there are no building structures present above the waste body.
3a	Leachate migration: Receptor (Human presence)	3	Based on the presence of residential housing and industrial units within 50m of the waste body onsite the score is being maintained at 3.
3b	Leachate migration: Receptor (Protected areas – SWDTE or GWDTE) (Surface water/ groundwater dependent terrestrial ecosystems)	1	Greater than 250m but less than 1km from the waste body/Undesignated sites within 50m of site of the waste body.
3c	Leachate migration: Receptor (Aquifer category – Resource potential)	1	The bedrock is classified by the GSI as a Poorly Productive Aquifer (PI) – bedrock which is unproductive except in Local Zones.
3d	Leachate migration: Receptor (Public water supplies – other than private wells)	0	Greater than 1km (no karst aquifer).
3e	Leachate migration: Receptor (Surface water bodies)	3	Surface water within 50m of site boundary. Corrinshigo Lough adjacent to waste body.
3f	Landfill Gas: Receptor (Human presence)	5	Based on the detection of one gas concentration exceedance at GW01 the score is being maintained at 5 due to the proximity of the industrial buildings to the eastern boundary of the waste body.

Table 5-2: Normalised Score of S-P-R Linkage

Calculator		S-P-R Values	Maximum Score	Linkage	Normalised Score
Leachate migration through combined groundwater and surface water pathways					
SPR1	1a x (2a + 2b + 2c) x 3e	7 x (3+1+2) x 3 = **126**	300	Leachate => surface water	42%
SPR2	1a x (2a + 2b + 2c) x 3b	7 x (3+1+2) x 1 = **42**	300	Leachate => SWDTE	14%
Leachate migration through groundwater pathway					
SPR3	1a x (2a + 2b) x 3a	7 x (3+1) x 3 = **84**	240	Leachate => human presence	35%
SPR4	1a x (2a + 2b) x 3b	7 x (3+1) x 1 = **28**	240	Leachate => GWDTE	11.6%

Calculator		S-P-R Values	Maximum Score	Linkage	Normalised Score
SPR5	1a x (2a + 2b) x 3c	7 x (3+1) x 1 = **28**	400	Leachate => Aquifer	7%
SPR6	1a x (2a + 2b) x 3d	7 x (3+1) x 0 = **0**	560	Leachate => Surface Water	0%
SPR7	1a x (2a + 2b) x 3e	7 x (3+1) x 3 = **84**	240	Leachate => SWDTE	35%
Calculator	**S-P-R Values**		**Maximum Score**	**Linkage**	**Normalised Score**
Leachate migration through surface water pathway					
SPR8	1a x 2c x 3e	7 x 2 x 3 = **42**	60	Leachate => Surface Water	**70%**
SPR9	1a x 2c x 3b	7 x 2 x 1 = **14**	60	Leachate => SWDTE	23%
Landfill gas migration pathway (lateral & vertical)					
SPR10	1b x 2d x 3f	7 x 3 x 5 = **105**	150	Landfill Gas => Human Presence	**70%**
SPR11	1b x 2e x 3f	7 x 1 x 5 = **35**	250	Landfill Gas => Human Presence	14%
Site maximum S-P-R Score					**70%**
Risk Classification					**A – High**

Table 5.2 shows the maximum S-P-R scoring for the site is **70%.**

The following are the risk classifications applied:

- Highest Risk (Class A) Greater than 70 for any individual SPR linkage
- Moderate Risk (Class B)41-69 for any individual SPR linkage
- Lowest Risk (Class C) Less than 40 for any individual SPR linkage

Based on this, the site can be classified as a **High Risk Classification (Class A)**. The principal risks identified on the site are the risk to Corrinshigo Lough from the migration of leachate from the landfill into the surface water receptor, the shallow permeable soil cap across the site contributing to leachate generation and the risk to the adjacent industrial building receptor from the migration of landfill gas from the waste material encountered at the site.

6 CONCLUSIONS & RECOMMENDATIONS

A Tier 2 study was conducted by FT in accordance with the EPA CoP for Killycard Historic Landfill. The study consisted of a desktop study, geophysical survey and intrusive site investigation works. These works informed the development of the CSM and risk screening model.

The findings of the site investigation work and geophysical surveying suggest the waste material is deposited in a single infill area tending west to east in the centre of the site and between approximately 140m in length and 120m in width. The maximum waste footprint including Zone A and Zone B is calculated to be approximately 1.15 hectares.

A volume calculation based on the surveyed surface profiles for the existing ground level and the base of waste as interpreted, preliminary estimates indicate an interred waste volume of approximately 29,700 m^3 at the site.

Analysis of waste samples from the trial pits excavated, when assessed against the inert waste acceptance criteria indicated that much of the waste material meet the inert waste classification. This is likely due to the level of degradation over time since landfilling ceased.

Analysis of groundwater samples recovered from the three monitoring wells GW01 to GW03 have reported ammonia concentrations which exceed guideline threshold values. Given that all monitoring wells were installed within the waste body, as confirmed by the trial pit and geophysical findings, the landfill is contributing to a deterioration in groundwater quality locally. The monitoring boreholes were installed within the waste body due to the restricted space available within the site.

The presence of peat underlying the waste body across the site may also be contributing to the elevated ammonia concentrations detected in the groundwater locally. The combined presence of elevated ammonia and coliform concentrations in all monitoring wells GW01 to GW03 may also be evidence of localised contamination due to agricultural land spreading or poorly functioning septic tanks in the area.

Based on the presence of elevated ammonia concentrations typical of landfill leachate, the shallow soil cap is not considered suitable at preventing rainfall infiltration into the waste body. The groundwater table also appears to be intersecting the waste body and contributing to leachate migration from the landfill.

The detection of elevated lead concentrations of 0.168 mg/l and 0.0743 mg/l at monitoring locations GW02 and GW03 and slightly elevated nickel concentration at GW01 are considered to be evidence of the localised groundwater hydrochemistry based on the presence of historical lead mining north of Castleblayney. Reference is made to several small metallic mineral deposits, most notably lead and zinc, located near Castleblayney as detailed in the EPA's Historic Mine Sites - Inventory and Risk Classification (2009).

Landfill gas monitoring from perimeter wells GW01 to GW03 at the site indicates gas concentrations detected are within the range typical of inert waste with the exception of a slightly elevated methane concentration detected at upgradient sampling location GW01. Based on the detection of slightly elevated gas concentrations and the proximity of the industrial buildings to the eastern boundary of the waste body, additional gas monitoring should be considered as part of future works.

Analysis of surface water samples recovered from the watercourses surrounding the site indicated 2 No. exceedances of the EQS (2009) guideline limit values for ammonia and BOD. Given that he determined groundwater flow direction is west-south-west from the waste body, the detected ammonia and BOD at these levels may be evidence of impact from the landfill. However, the presence of ammonia and BOD at these levels may also be an indication of slurry spreading runoff from the surrounding agricultural fields in the area, rather than direct impact from the landfill.

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

6.1 Recommendations

Based on the results of this Tier 2 assessment the site is classified as High Risk. The site is therefore: "considered to pose a significant risk to the environment or human health." For a high-risk site, the CoP indicates that a Tier 3 environmental risk analysis be undertaken including a Detailed Quantitative Risk Assessment. Further the site be regularised/authorised in accordance with current waste management legislation.

It is recommended by FTC that a Tier 3 DQRA be undertaken for the site in conjunction with an application for a Certificate of Registration for this site.

FT further recommended that further groundwater, surface water monitoring and landfill gas monitoring and analysis be undertaken at each monitoring location GW01 to GW03, SW1 and SW2 inclusive. The results of this analysis should be used to confirm the conclusion of the Tier 3 report and inform future works.

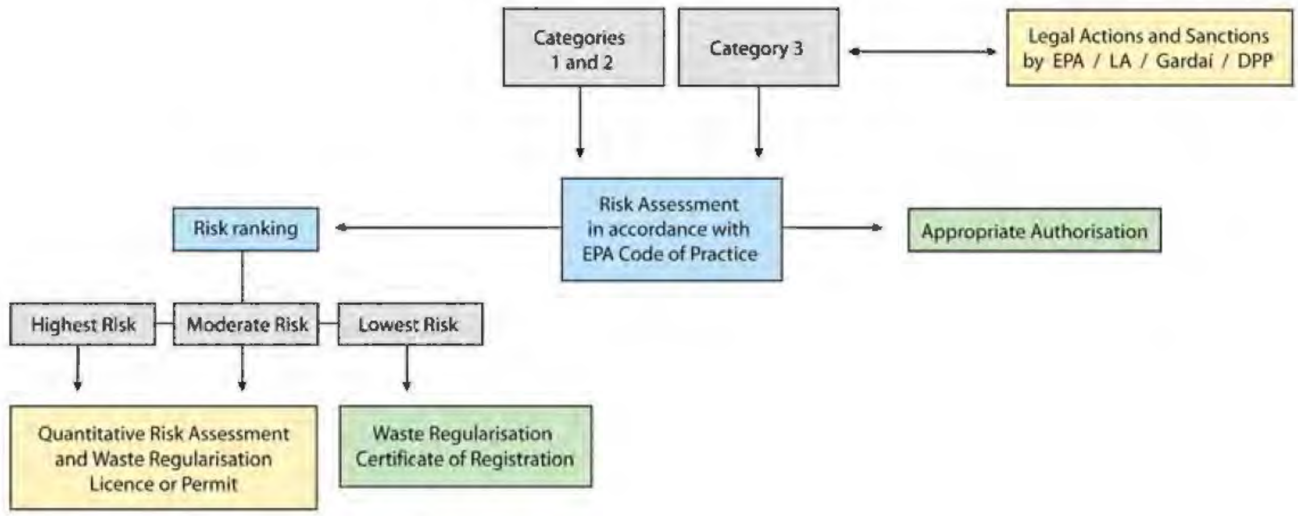

Figure 6-1: Extract from Section 1.3 of the EPA Code of Practice

Appendix I

Tier 1 Study




TIER 1 ENVIRONMENTAL RISK ASSESSMENT

HISTORIC LANDFILL AT KILLYCARD LANDFILL CO. MONAGHAN

JUNE 2018

Dúthracht agus Dícheall

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TIER 1 ENVIRONMENTAL RISK ASSESSMENT

HISTORIC LANDFILL AT KILLYCARD LANDFILL CO. MONAGHAN

User is Responsible for Checking the Revision Status of This Document

Rev. Nr.	Description of Changes	Prepared by:	Checked by:	Approved by:	Date:
0	Issue for Client Review	SM/MG	JON	BG	22.06.2018

Client: Monaghan County Council

Keywords: Site Investigation, environmental risk assessment, waste, landfill, historic

Abstract: This report represents the findings of a Tier 1 risk assessment conducted at the historic landfill at Killycard Landfill, Co. Monaghan in accordance with the EPA Code of Practice on Environmental Risk Assessment for Unregulated Waste Disposal Sites.

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PREAMBLE

Fehily Timoney & Co. (FT) was appointed by Monaghan County Council (MCC) to complete a Tier 1 environmental risk assessment (ERA) of the existing environment in the historical landfill located in Killycard, Co. Monaghan. This ERA was carried out in accordance with the EPA Code of Practice (CoP) on ERA for Unregulated Waste Disposal Sites (2007).

The historic landfill is located approximately 1.7km to the North-West of Castleblayney Town on the R-183 Castleblayney to Ballybay Regional Road. The historic site covers approximately 2.0 hectares.

A Tier 1 assessment was conducted by FT which included a detailed desk study and site walkover. The ERA concluded that a **high-risk classification (Class A) can be assigned to the site**.

A Tier 2 quantitative risk assessment is required for a site which is classified as high risk. FT recommend further intrusive site investigations and sampling as part of the Tier 2 assessment.

For a high-risk site, the CoP directs that the site will have to apply for a waste regularisation licence or permit through an administrative system, which will be established for the purpose in the context of Section 22 of the Waste Management Acts, 1996 to 2005.

1. INTRODUCTION

1.1. Background

Killycard historic landfill is located approximately 1.7km to the North-West of Castleblayney town on the R183 Castleblayney to Ballybay Regional Road. The landfill ceased operations in 1987.

The site is approximately 2.0 hectares in size. There are dwelling houses within 50 metres of the site boundary. Commercial developments have been constructed on site including mushroom houses (now derelict) and a number of warehouses. The western portion of the site shares a boundary with Corrinshigo lake. Since its closure the site has been covered with a soil cap, no other remediation works have been carried out. The exact quantity of waste deposited on site is unknown however MCC have estimated the quantity to be in the region of 30,000 cubic metres.

MCC requested that an ERA be carried out for the site in accordance with the EPA CoP on ERA for Unregulated Waste Disposal Sites.

1.2. Scope of Works and Project Objectives

The scope of work was to undertake a Tier 1 assessment of the site based on the risk assessment methodology approach, in accordance with the EPA CoP. This approach requires the carrying out of a:

- Desktop Study
- Detailed Site Walkover
- Environmental Risk Assessment (ERA)
- Development of Conceptual Site Model (CSM)

1.2.1. Project Objectives

As part of the initial desk study a preliminary assessment of available information was undertaken. This was followed-up with a site walkover. The desk study and site walk-over were used to inform the development of both the preliminary conceptual site model (CSM) and the ERA.

This report presents the findings of the assessment.

2. METHODOLOGY

2.1. Introduction

A desktop review of available documentation for the site was conducted and a visit was undertaken to carry out a detailed site walkover on 12th June 2018.

The documentation made available to FT for the desktop review included:

- Ordnance Survey of Ireland (OSI), www.osi.ie
- Geological Survey of Ireland (GSI), www.gsi.ie
- EPA http://gis.epa.ie/Envision
- Office of Public Works (OPW), http://www.opw.ie/hydro/index.asp?mpg=main.asp
- Water Maps, http://watermaps.wfdireland.ie
- Monaghan County Council Site Plans and Drawings

2.2. Desk Study

This section of the report presents the findings of the desk study.

2.2.1. Site Description and On-Site Conditions

The landfill is located within a primarily rural setting in an area of rolling topography dominated by drumlins. Areas between the drumlins are often boggy at lower elevations while more free-draining ground is found on the drumlins themselves. The land use in the area is primarily agricultural with the site currently used for pasture and poultry production. The site is bounded to the north by agricultural land, to the west by Corrinshigo lake and to the east and south by farmland and farm buildings.

2.2.2 Existing Bedrock Geology

According to the GSI the site and surrounding area is underlain by the Silurian Oghill formation (OL) which is generally made up of

> '*grey to grey-green massive sandstone (greywacke), microconglomerate and amalgamated beds with subordinate thin to thick-bedded greywacke and locally, at least partly, infaulted dark grey or black pyritic, occasionally graptolitic shale-mudstone*'.

The GSI bedrock geology map shows a fault travelling north-south across the eastern area of the site.

2.2.3 Existing Overburden Geology

The landfill site is underlain by cut over raised peat overlying a poorly productive bedrock aquifer. The subsoils are typically of cutover/cutaway peat. According to the GSI, the glacial overburden is mapped as 'Cut over raised peat', as shown in Figure 2.3.

Map Path: R:\Map Production\2018\P1655\Workspace\Killycard Landfill\P1655_Fig2-1_SiteLocation_A3.mxd

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
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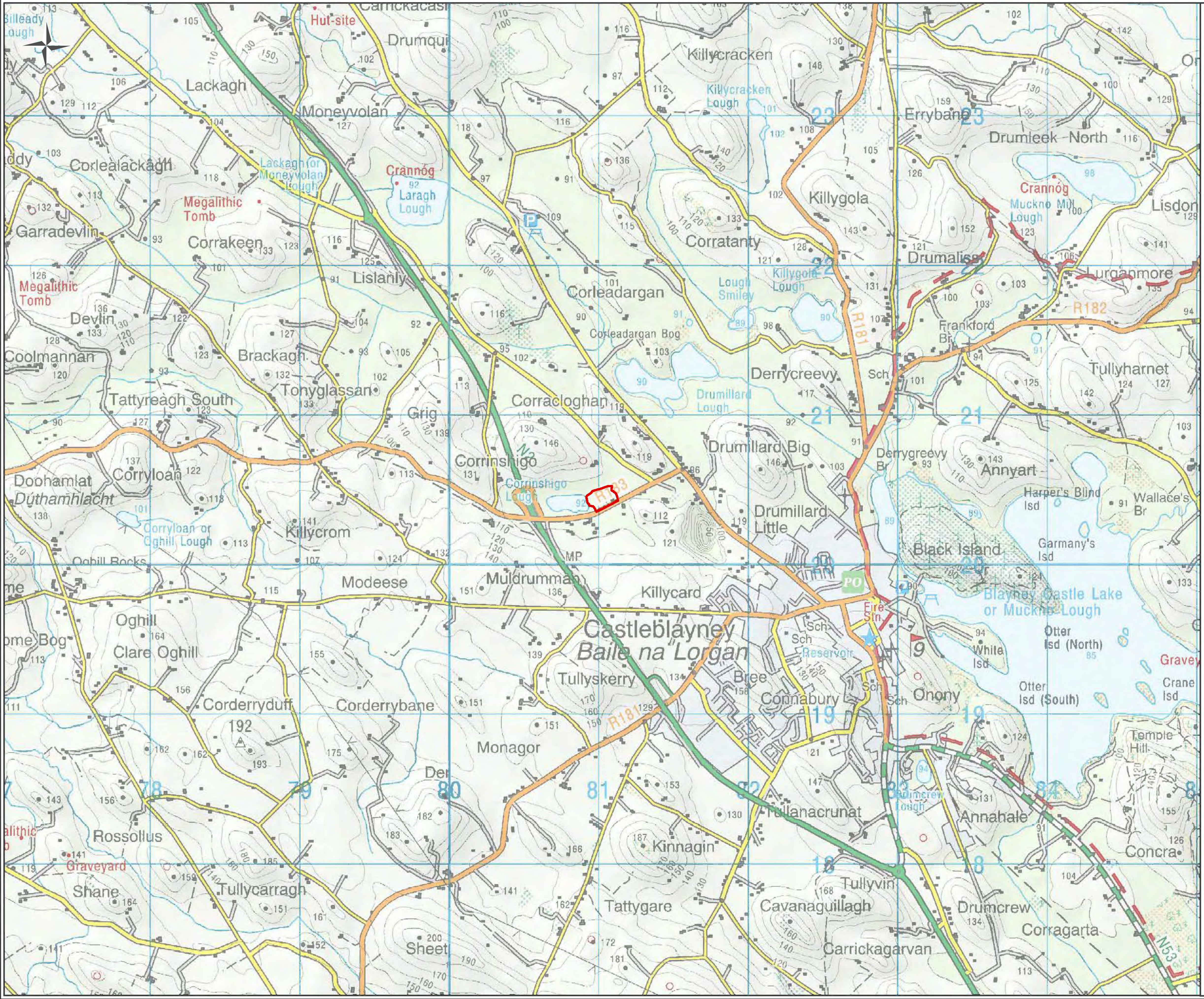

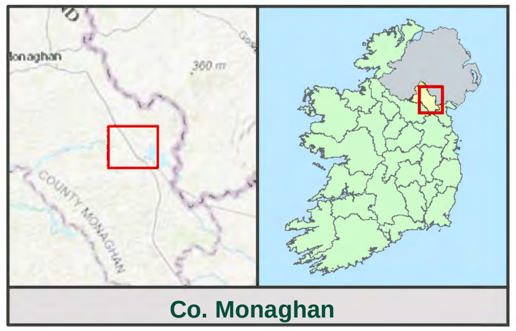

Legend

Site Boundary

Figure Title	Site Location Killycard
Figure No.	2.1
Project	Tier 1 Assessment of Historical Landfills in Monaghan
Client	Monaghan County Council
Scale 1:25,000	**Page Size** A3
Revision A	**Date** 15/06/2018

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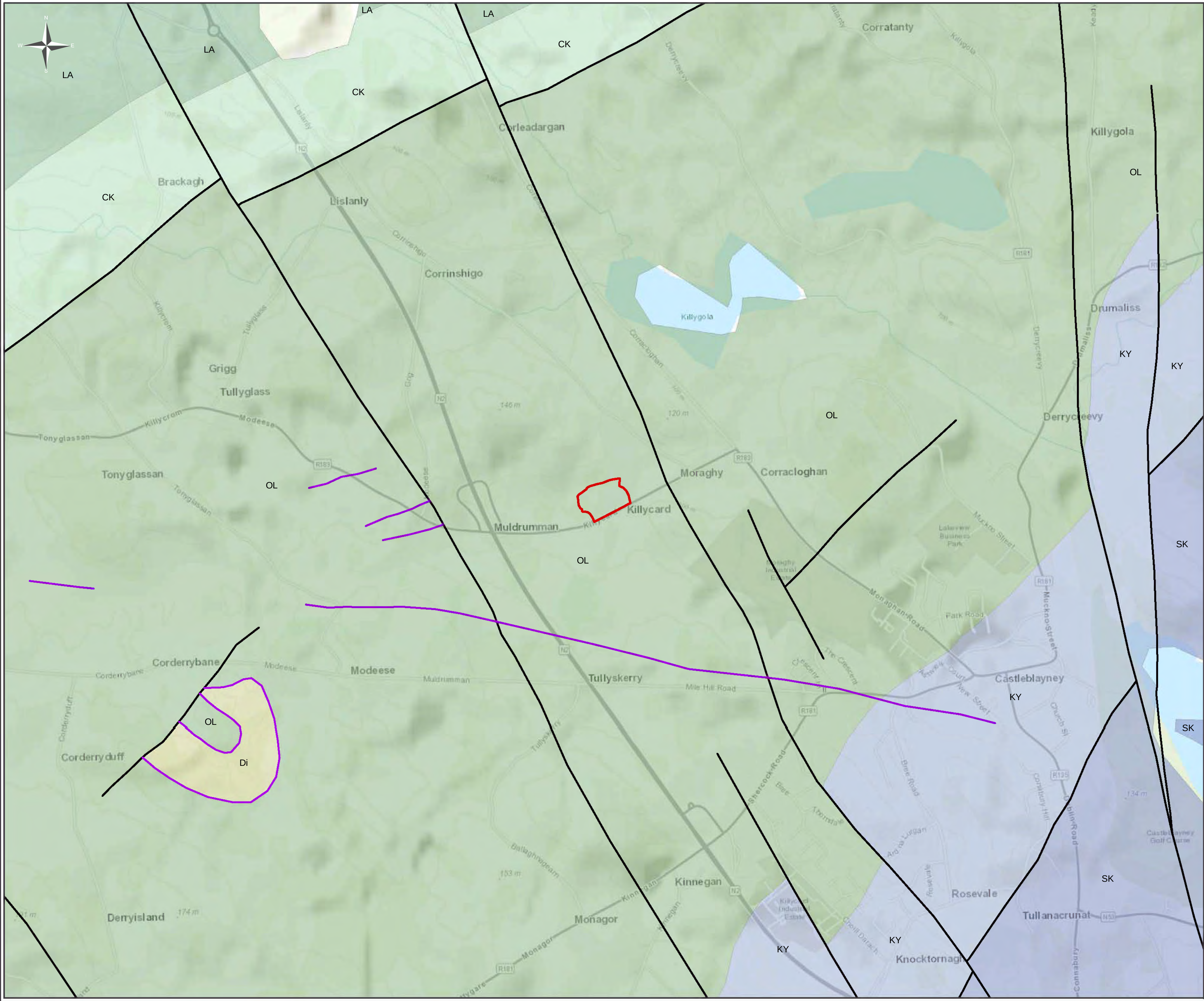
0 0.5 1 2 Kilometers

Map Path: R:\Map Production\2018\P1655\Workspace\Killycard Landfill\P1655_Fig2-2_BedrockGeology_A3.mxd



Legend

- Site Boundary
- Dip of Bedding in Degrees
- Stratigraphical Linework
- Structural Linework

Bedrock Geology

- CK: Carrickatee Formation
- Di: Diorite
- KY: Kehernaghkilly Formation
- LA: Lough Avaghon
- OL: Oghill Formation
- SK: Shercock Formation

0 0.5 1 2 Kilometers

Figure Title	Bedrock Geology Killycard
Figure No.	2.2
Project	Tier 1 Assessment of Historical Landfills in Monaghan
Client	Monaghan County Council
Scale	1:15,000 — **Page Size** A3
Revision	A — **Date** 15/06/2018

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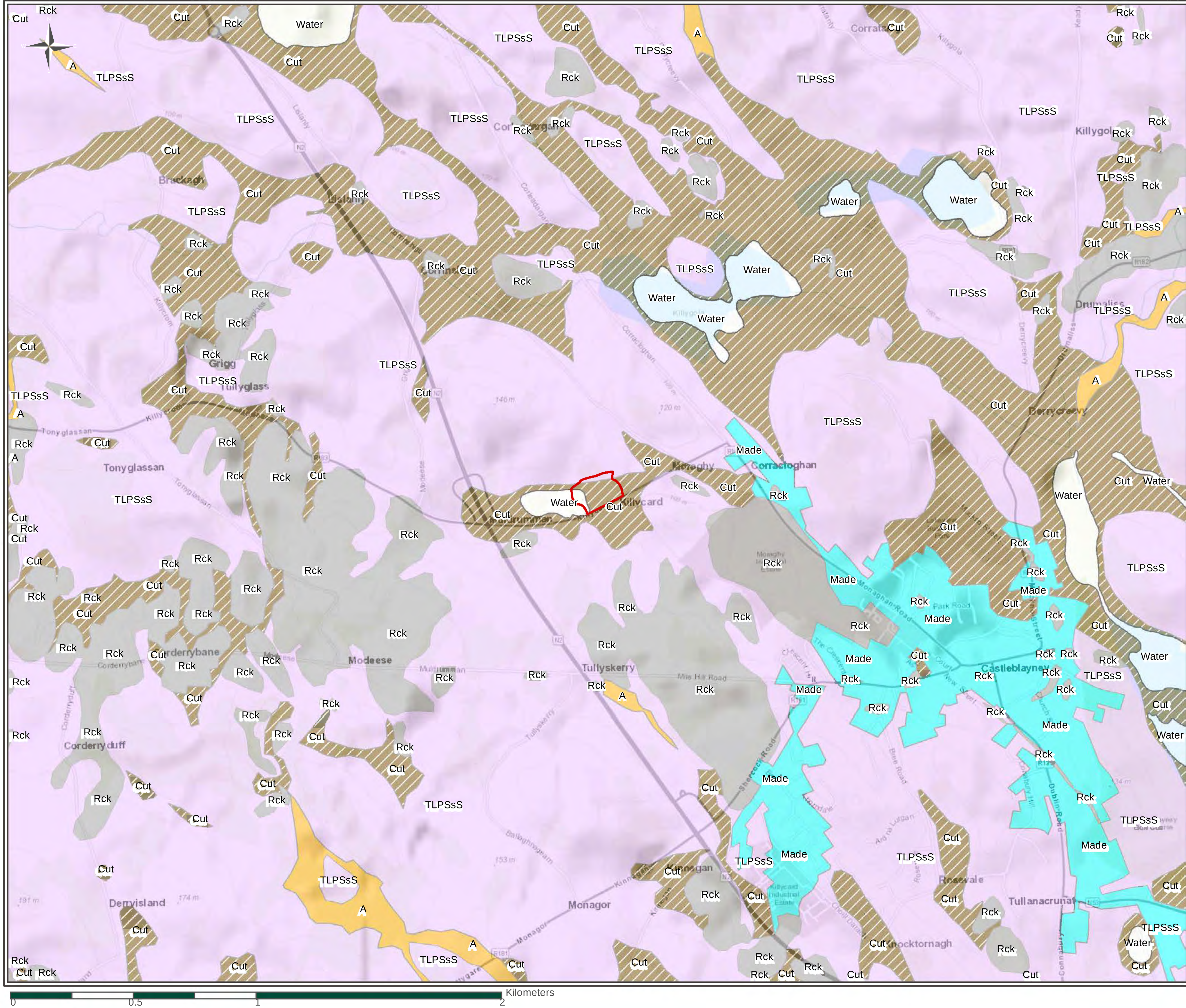

Legend

- Site Boundary

Subsoils Data

- A, alluvium
- Cut, cutover peat
- Made, made ground
- Rck, bedrock at surface
- TLPSsS, sanstone and shales till - Lower Paleozoic
- Water, water

Figure Title	Quaternary Geology Killycard
Figure No.	2.3
Project	Tier 1 Assessment of Historical Landfills in Monaghan
Client	Monaghan County Council
Scale	1:15,000
Page Size	A3
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