TIER 2 RISK ASSESSMENT

HISTORIC LANDFILL AT KILLYCRONAGHAN LANDFILL, CO. MONAGHAN

SEPTEMBER 2019

Dúchraċt agus Díteall

FEHILY TIMONEY & COMPANY

TIER 2 RISK ASSESSMENT

HISTORIC LANDFILL AT KILLYCRONAGHAN LANDFILL, CO. MONAGHAN

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Abstract: This report represents the findings of a Tier 2 site investigation carried out at Killycronaghan Historic Landfill, Smithborough, Co. Monaghan, and conducted in accordance with the EPA Code of Practice for unregulated landfill sites. The site investigation was undertaken to determine the extent of the historic landfilling at the site.

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EXECUTIVE SUMMARY

Fehily Timoney & Company (FT) was appointed by Monaghan County Council (MCC) to complete a Tier 2 environmental risk assessment (ERA) of Killycronaghan 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 8km North-East of Clones town circa 1km off the N54 national road, close to the village of Smithborough. It was previously reported by MCC that the landfill accepted waste throughout the 1970s and early 1980s, ceasing in 1984.

A Tier 1 study conducted by FT in June 2018 determined the site to be a high-risk classification (Class A). The primary risks identified relate to the risk of leachate runoff entering the Kilgormly river and the risk of landfill gas migration on nearby human receptors. The completed Tier I study is included as an Appendix 1.

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

The following site investigation works were undertaken at the site:

- 16 No. Trial pit excavations
- Installation and monitoring of 3 No. groundwater boreholes
- Surface water, groundwater and landfill gas monitoring
- 1 No. Geophysical survey (2D resistivity and seismic refraction profiling)
- Topographical Survey
- Factual reporting

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 150m in length and 130m in width. The geophysical survey delineated the survey area into zones based on an interpretation of the ground conditions across the site. The following 4 No. zones were identified:

- Zone A: made ground/waste (predominantly organic) over Sand/Gravel with Leachate
- Zone B: southern site boundary where waste may be present.
- Zone C: possible leachate plume
- Zone D: possible leachate plume

Based on the interpretation of the intrusive works and geophysical findings, the maximum waste footprint including Zone A and Zone B is calculated to be approximately 2.28 hectares. A volume calculation 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 106,000 m^3 at the site.

Analysis of waste samples from the trial pits excavated, when assessed against the waste acceptance criteria indicated that much of the waste material within the site can be classified as typically inert. The waste classification is considered to reflect the level of degradation over time since landfilling ceased.

Analysis of groundwater samples recovered from all three monitoring wells GW01 to GW03 have reported ammonia concentrations which exceed guideline threshold values. Ammonia concentrations at both upgradient boreholes GW01 and GW02 are considered representative of background levels possibly due to agricultural land spreading. However, given the ammonia concentration of 33.2 mg/l recorded at GW03 is 100-times greater than upgradient levels, the landfill is impacting downgradient water quality due to the significant ammonia concentration differences between upgradient and downgradient monitoring locations.

The groundwater results presented elevated lead and barium concentrations which appear to be typical of localised background hydrochemistry due to the presence of historical lead mining sites across County Monaghan and the bedrock formations underlying the site.

Analysis of surface water samples recovered from the watercourses surrounding the site indicated 1 No. exceedances of the EQS (2009) guideline limit values for ammonia. The presence of ammonia at a concentration of 0.258 mg/l may be an indication of slurry spreading runoff from the surrounding agricultural fields in the area, rather than direct impact from the landfill.

Landfill gas monitoring from perimeter wells GW01 to GW03 at the site indicates gas concentrations detected are below threshold levels set by the EPA CoP. Despite the low gas concentrations measured at the perimeter wells, a high-risk score of 70% for SPR11 has been generated based on the presence of sands in the overburden strata between the landfill and identified agricultural buildings within 50m of the waste body and poultry sheds within 50m north-east of the site boundary. The pathway between the waste body and the onsite and offsite agricultural building receptors will require further investigation to verify the risk, if any, to these receptors.

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 posed to on-site and off-site users of the identified agricultural buildings from migration of landfill gas from the waste material encountered at the site, the shallow permeable landfill cap across the site and the risk to the groundwater aquifer from the migration of leachate from the waste body.

It is therefore recommended by FT that a Tier 3 DQRA be undertaken for the site in conjunction with an application for a Certificate of Registration for this site. As part of the Tier 3 assessment, further groundwater, surface water monitoring and landfill gas monitoring and analysis is being recommended at each monitoring location GW01 to GW03 and SW1 to SW4 inclusive. The results of this analysis should be used to confirm the conclusion of the Tier 3 report and inform future works.

1 INTRODUCTION

1.1 Background

Killycronaghan Landfill is in an area of open farmland approximately 8km north-east of Clones town circa 1km off the N54 national road, close to the village of Smithborough. Evidence provided by Monaghan County Council (MCC) suggests landfilling of the site commenced in the 1970s and early 1980s until operations ceased in 1984. Fehily Timoney (FT) understands that since its closure the site has reverted to private ownership, with the lands presently used for agriculture. The site has been capped with a soil cover, but no other remediation works have been carried out.

MCC is required to complete a tiered risk assessment of unregulated waste disposal sites in accordance with the Environmental Protection Agency (EPA) code of practice for unregulated waste disposal sites.

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

1.2 Scope of Works

FT's scope of work was to undertake a Tier 2 assessment of the site in accordance with the EPA Code of Practice (CoP) 2007: *Environmental Risk Assessment for Unregulated Waste Disposal Sites*. This approach required the completion of the following:

- Desk Study
- Site Walkover
- Intrusive Site Investigation
- Leachate Testing
- Environmental Risk Assessment (ERA)
- Geophysical and surveying to estimate extents and depths of waste
- Development of a conceptual site model (CSM)

As part of the initial desk study, a review of available information was undertaken. This was followed-up with a site walkover by FT personnel. The desk study and site walkover were used to determine the locations for the intrusive site investigation.

FT appointed Causeway Geotech Limited (CGL) to conduct the intrusive site investigation which included; excavation of trial pits and the installation of three onsite groundwater monitoring boreholes.

A full geotechnical report is included in Appendix 2 to this document.

APEX Geoservices were appointed by FT to undertake a geophysical survey of the site. Geophysical surveying including Electro Conductivity, Electro Resistivity and Seismic Refraction surveying methods.

The full geophysical survey report is included in Appendix 5 to this document.

The purpose of the geophysical study was to attempt to define the vertical and lateral extents of any waste body. Trial pits were excavated to provide a preliminary assessment of the volume, extent and type of waste infilled at the site. The groundwater monitoring boreholes were installed to assess the impact, if any, of the onsite groundwater.

Laboratory analysis of waste samples and groundwater were conducted to assess and quantify any potential or ongoing environmental impacts.

The information gathered from the desk study, intrusive site investigation and geophysical survey were used to inform the development of the CSM and the Environmental Risk Assessment (ERA). This report presents the findings of the assessment.

2 DESK STUDY

2.1 Introduction

The desk study included the review of the following literature sources and websites:

- Geological Survey of Ireland, Groundwater Web Mapping: www.gsi.ie
- Environmental Protection Agency Maps: http://gis.epa.ie/Envision
- National Parks and Wildlife Service Map Viewer: www.npws.ie
- Water Maps, http://watermaps.wfdireland.ie
- Monaghan County Council Site Plans and Drawings
- BS 5930: 1999, Code of Practice for Site Investigations
- BS 10175: 2000, Investigation of Potentially Contaminated Sites – Code of Practice
- EPA's Historic Mine Sites - Inventory and Risk Classification (2009)
- EPA - Assessing and Developing Natural Background Levels for Chemical Parameters in Irish Groundwater (2017)

A desktop review of available documentation for the site was conducted followed by a site walkover.

2.2 Desk Study

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

2.2.1 Site Description & On-Site Conditions

The site is approximately 9 hectares. The site is bounded to the southeast, east and north by the Kilgormly river. The Magheramey river bounds the site to the northwest. There are no dwelling houses located within 100m of the site although there are poultry house sites close to the north-eastern boundary of the site.

The site is surrounded by agricultural land with poultry buildings located to the northeast of the site. The land use in the area is primarily agricultural with the subject site currently used for pasture.

The location of the site is shown in Figure 2.1, overleaf.

2.2.2 Previous Studies

A Tier 1 Risk Assessment completed by FT on 25th June 2018 which comprised the following:

- Development of a conceptual site model (CSM);
- Identification of contaminant sources, pathways of contaminant migration and potential receptors which may be vulnerable if exposed to those contaminants; i.e. the identification of Source- Pathway-Receptor (SPR) linkages; and
- The prioritisation of sites and SPR linkages based on their perceived risk.

Based on the available information, the Tier 1 Assessment determined that the overall risk score for Killycronaghan Landfill was 70%, resulting in a risk classification of High (Class A).

A copy of this assessment is included in Appendix 1.

Map Path: R:\Map Production\2018\P1655\Workspace\Knockcronaghan 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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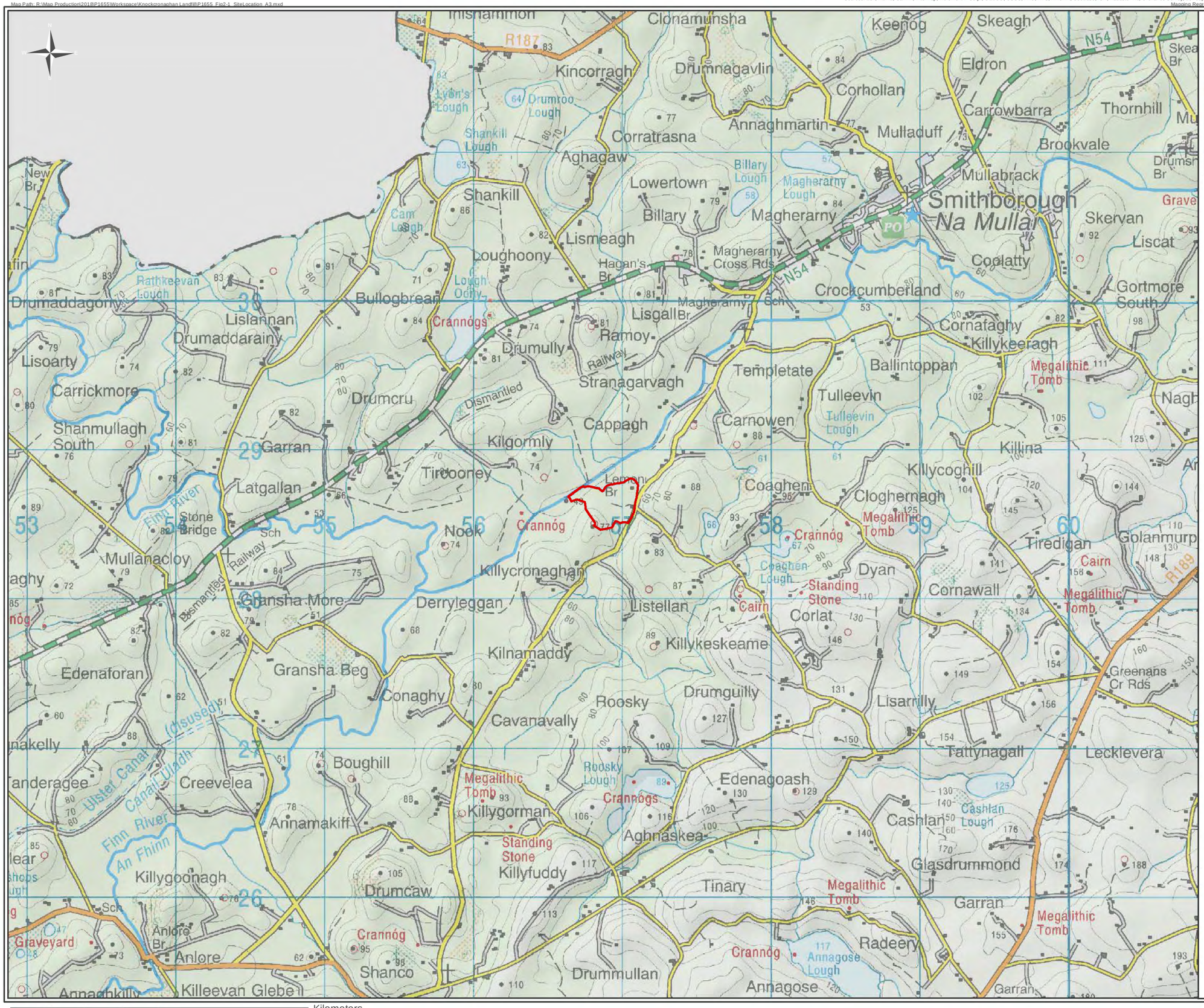

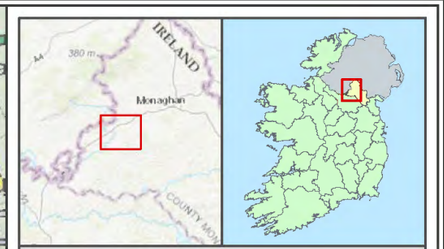

Legend

Site Boundary

Figure Title	Site Location Knockcronaghan
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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2.2.3 Topography

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, while more free-draining ground is found on the drumlins themselves. The site is generally described as flat with a hill rising on the southwestern portion of the site.

The site is at an elevation of between 50 m and 55 m above Ordnance Datum (OD).

2.2.4 Geology

Drift/Quaternary Geology

The Quaternary Map provided by GSI Online identifies the quaternary sediments at the site as tills derived from limestone, with the subsoils in the northern portion of the site mapped as sands and gravels derived from limestones. The GSI also identifies lenses of cut-over peat beyond the southern site boundary.

Localised deposits of alluvium are noted along the channel of the Kilgormly River to the east and north of the site and also to the west along the channel of the Magheramey River (see Figure 2.2).

During the installation of boreholes during the site investigation, the presence of peat and sand & gravel tills are described in the drillers logs to a depth of approximately 14.5m BGL at boreholes GW02 and GW03, as referenced in the CGL borehole logs, Appendix 2.

Solid or Bedrock Geology

The GSI online 1:100,000 scale bedrock geology map, shows the bedrock beneath to be found on two primary formations. The northern and western sections of the site and surrounding area are underlain by the Cooldaragh formation (CH) which is generally made up of Dinantian '*Pale brown-grey flaggy, silty mudstone'.* The southern and eastern sections of the site are underlain by the Feranaght formation (FT), which is generally made up of Dinantian '*Pale conglomerate & red sandstone'.*

A distinct bedding plane or anticline separates the Feranaght formation from the Coronea Formation located to the south of this stratigraphic line. The Coronea Formation consists of turbidite, red shale and minor volcanic properties.

The nearest bedrock outcrop to the site has been mapped approximately 1km from the western site boundary along the N54 roadway. The bedrock geology is presented in Figure 2.3.

Limestone bedrock was encountered at 4.5m BGL during the installation of borehole GW01 as referenced in the CGL borehole logs, Appendix 2.

Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig2-2_QuaternaryGeology_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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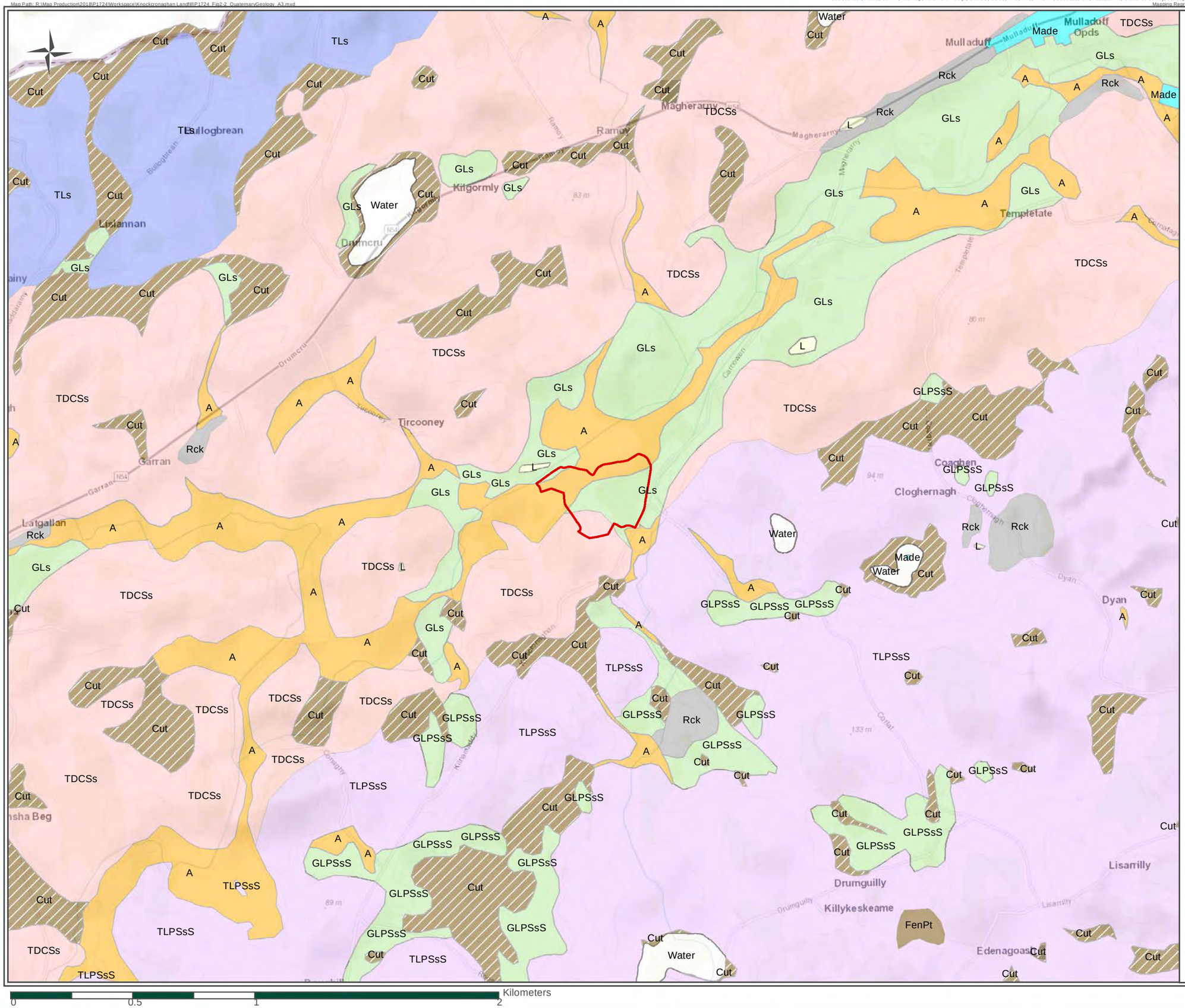

Legend

- Site Boundary

Subsoils Data

- A, alluvium
- Cut, cutover peat
- FenPt, fen peat
- GLPSsS, sandstone & shale sands and gravels
- GLs, limestone sands and gravels - Carboniferous
- L, lake sediment
- Made, made ground
- Rck, bedrock at surface
- TDCSs,
- TLPSsS, sanstone and shales till - Lower Paleozoic
- TLs, limestone till - Carboniferous
- Water, water

Figure Title
Quaternary Geology

Figure No. 2.2

Project
ERA of Historic Landfill at Knockcronaghan, Co. Monaghan

Client
Monaghan County Council

Scale 1:15,000 **Page Size** A3

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Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig2-3_BedrockGeology_A3.mxd

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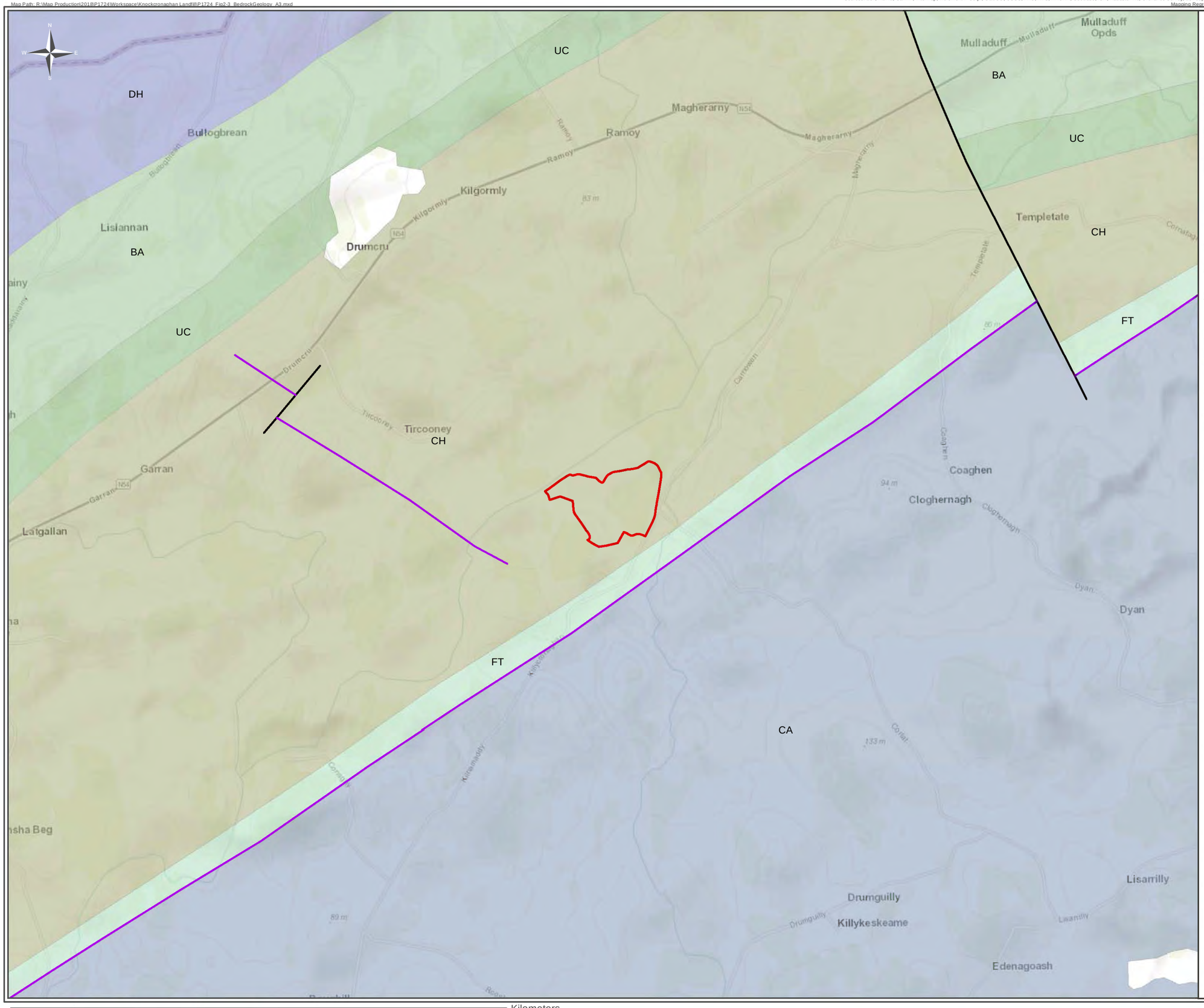

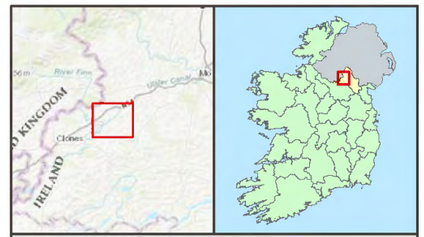

Legend

- Site Boundary
- Stratigraphical Linework
- Structural Linework

Bedrock Geology

- BA: Ballysteen Formation
- CA: Coronea Formation
- CH: Cooldaragh Formation
- DH: Drumgesh Shale Formation
- FT: Fearnaght Formation
- UC: Ulster Canal Formation

Figure Title
Bedrock Geology

Figure No. 2.3

Project
ERA of Historic Landfill at Knockcronaghan, Co. Monaghan

Client
Monaghan County Council

Scale 1:15,000 **Page Size** A3

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2.2.5 Hydrogeology

An examination of the national bedrock aquifer map on the GSI online mapping classifies the Cooldaragh formation as a Regionally Important Aquifer – Fissured Bedrock (Rf). The bedrock aquifer mapping is presented in Figure 2.4.

There are no karst landforms within the site boundary. The nearest karst landform is a spring named St. Maudain's Well, approximately 22.3km north of the site boundary. The spring lithology is muddy limestone.

Historical mapping for the area shows several springs in the surrounding area. A number of these springs are located at the base of the drumlins and may represent groundwater discharging from the drumlin sediments where these spread out at the base of the drumlins. There are a number of residences within 250m of the site where it is likely that unregistered private wells may be present.

Table 2.1 presents the details of the registered boreholes and springs within 2km of the site.

Table 2-1: Borehole and Spring Descriptions near the Project Site

BH / Spring	Yield class	Yield	Use	Depth (m)	Depth to Rock confidence (m)	Distance from site (km)	Date
2331NEW078	Poor	25.9	--	3.0	--	0.20	1899
2331NEW079	Poor	25.9	--	3.0	--	0.7	1899
2331NEW048	Poor	25.9	--	3.0	--	0.48	1899
2331NEW077	Poor	25.9	--	3.0	--	0.56	1899
2331NEW050	Moderate	51.8	--	40	21	0.46	1899
2331NEW159	Poor	32.7	--	2.4	--	<1	1973
2331NEW158	Poor	32.7	--	2.4	--	<1	1967
2331NEW154	Moderate	65.5	--	35.7	4.3	<1	1970

There are no Groundwater Drinking Water Protection Areas within the site boundaries according to GSI. The site sits between both the Clones and Monaghan Town public supply drinking water sources which are both located within 10km of the site. The outer protection area of the Clones and Monaghan groundwater source is 2.09km^2 and 3.76km^2 respectively.

The GSI shows that the groundwater body (GWB) is named Clones GWB and has a highly productive bedrock flow regime and is defined as being at *Good Status* under the Water Framework Directive.

There are no recorded public groundwater supplies and no recorded groundwater dependent ecosystems in the area.

The GSI national recharge map defined the annual recharge as 515mm/yr. The effective rainfall for the area is 606mm/yr, returning a recharge coefficient of 85%.

The GSI mapping showing approximate locations of known wells and springs is included in Figure 2.5.

Map Path: R:\Map Production\2018\P1655\Workspace\Knockcronaghan Landfill\P1655_Fig2-4_AquiferClassification_A3.mxd

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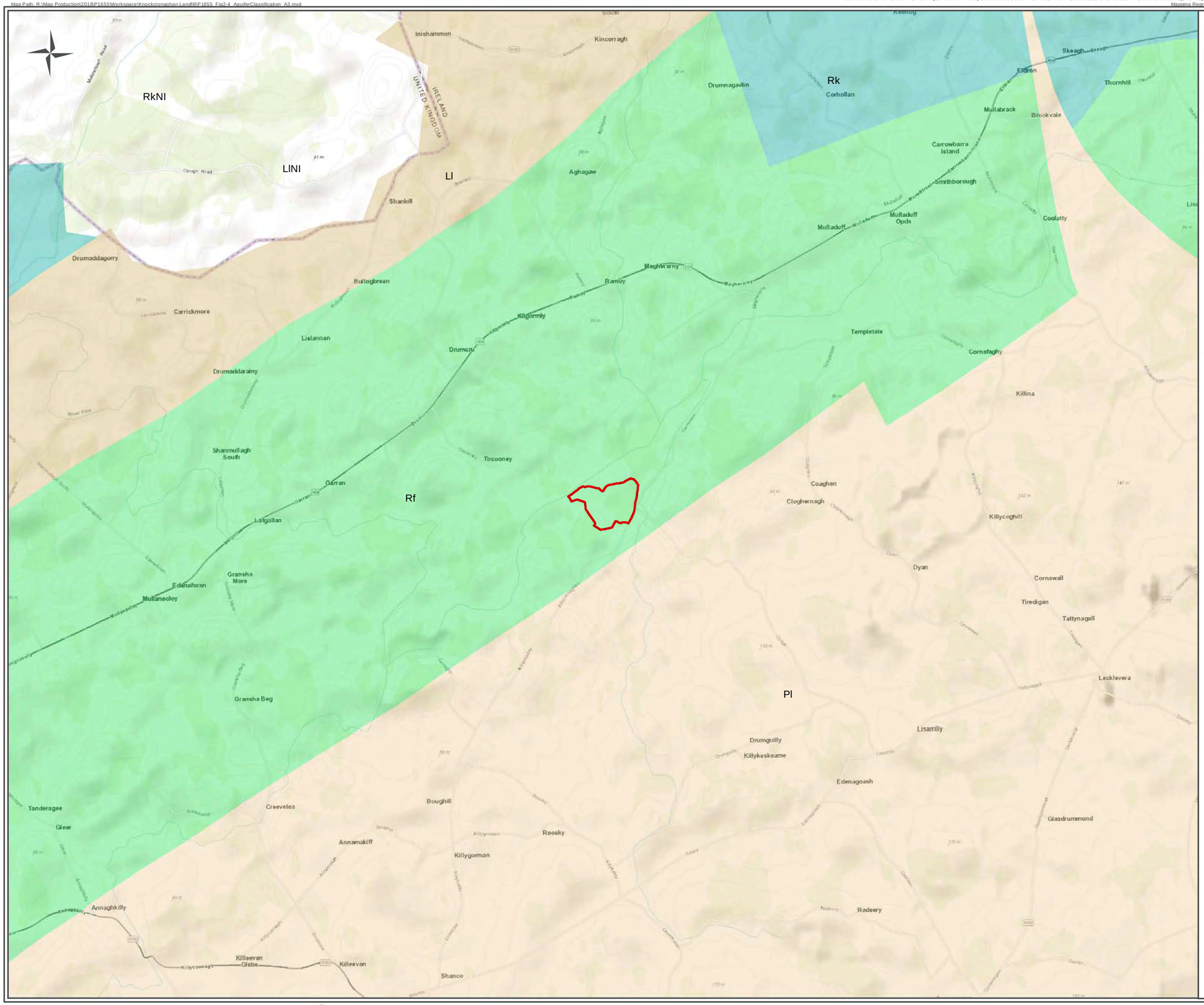

Legend

- Site Boundary
- LI: Locally Important Aquifer - Bedrock Mod Productive Locally
- Pl: Poor Aquifer Bedrock Generally Unproductive Except Locally
- Rf: Regionally Important Aquifer - Fissured Bedrock
- Rk: Regionally Important Aquifer - Karstified

Kilometers
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Figure Title
Aquifer Classification
Knockcronaghan

Figure No. 2.4

Project
Tier 1 Assessment of Historical Landfills in Monaghan

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Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig2-5_WellsAndSprings_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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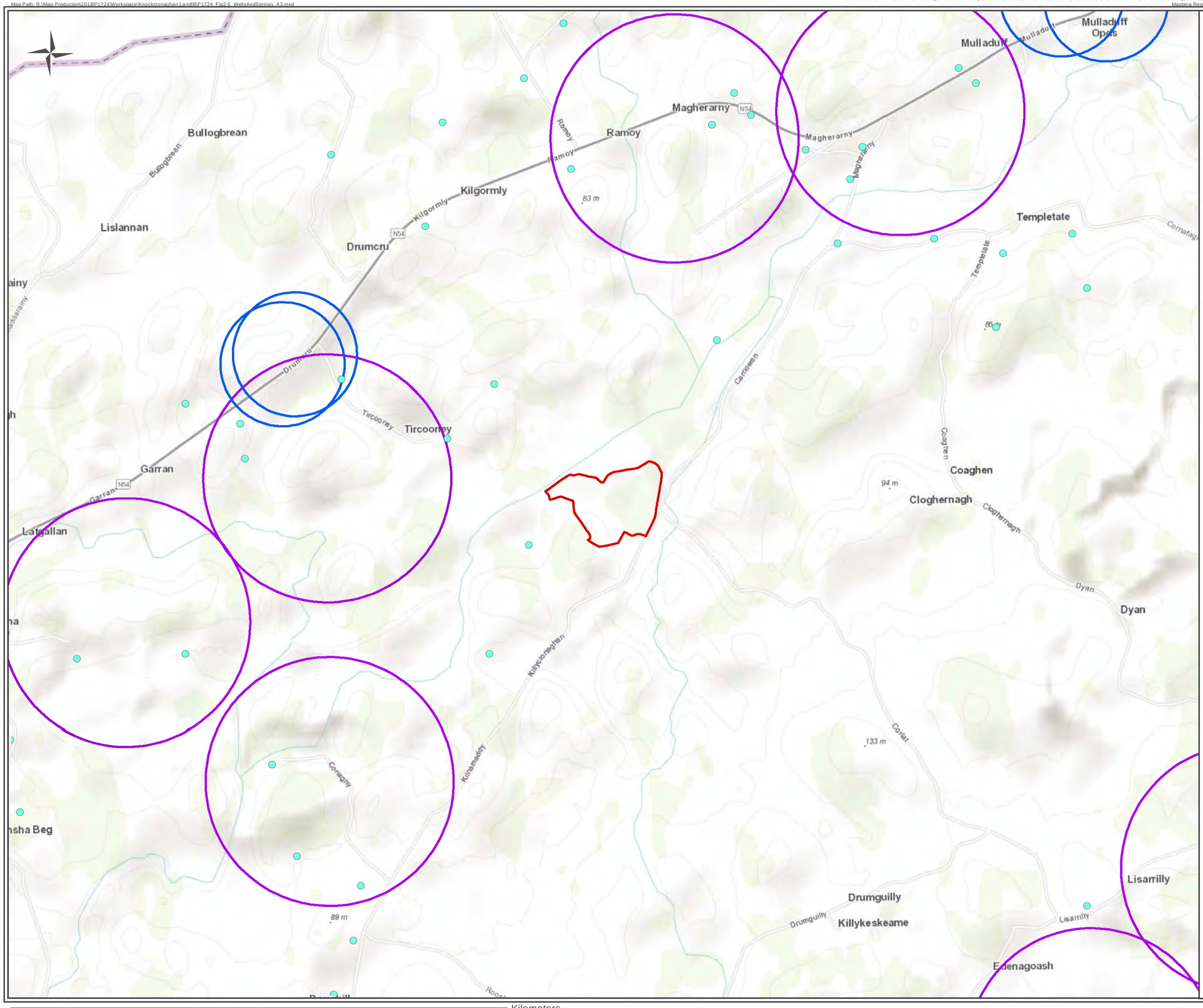

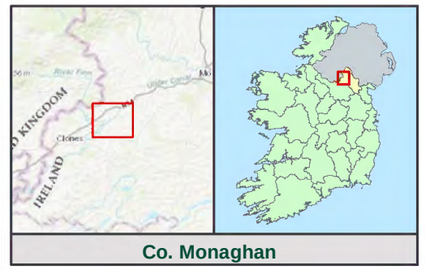

Legend

- Site Boundary
- Groundwater Well (10-50m Accuracy)
- Groundwater Well (200-500m Accuracy)
- Groundwater Well (500m-1km Accuracy)

Kilometers
0 0.5 1 2

Figure Title	Wells and Springs
Figure No.	2.5
Project	ERA of Historic Landfill at Knockcronaghan, Co. Monaghan
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2.2.6 Groundwater Vulnerability

Groundwater vulnerability, as defined by the GSI, is the term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

The factors used in assessing groundwater vulnerability include subsoil type and thickness and recharge type as indicated in Table 2.2. The GSI procedure whereby groundwater protection is assessed is outlined in the EPA-GSI publication *Groundwater Protection Schemes* (DELG/EPA/GSI, 1999).

The GSI Online mapping data set identifies the vulnerability of groundwater to contamination is classified as extreme to high, given the presence of bedrock outcrop at the site and thin overburden cover. The Groundwater Vulnerability mapping is presented in Figure 2.6.

The recharge coefficient associated with the western section of the site is 85% and the recharge rate is 200mm/year.

Table 2-2: GSI Guidelines – Aquifer Vulnerability Mapping

Vulnerability Rating	Hydrogeological Conditions *Subsoil Permeability (Type) and Thickness*		
	High Permeability (Shallow Bedrock)	Moderate Permeability (e.g. Sandy soil)	Low Permeability (e.g. Clayey subsoil, clay, peat)
Extreme (E)	0 - 3.0 m	0 - 3.0 m	0 - 3.0 m
High (H)	>3.0 m	3.0 -10.0 m	3.0 - 5.0 m
Moderate (M)	N/A	>10.0 m	5.0 - 10.0 m
Low (L)	N/A	N/A	>10 m

Notes:
N/A = Not Applicable
Precise permeability values cannot be given at present

Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig2-6_GroundwaterVulnerability_A3.mxd

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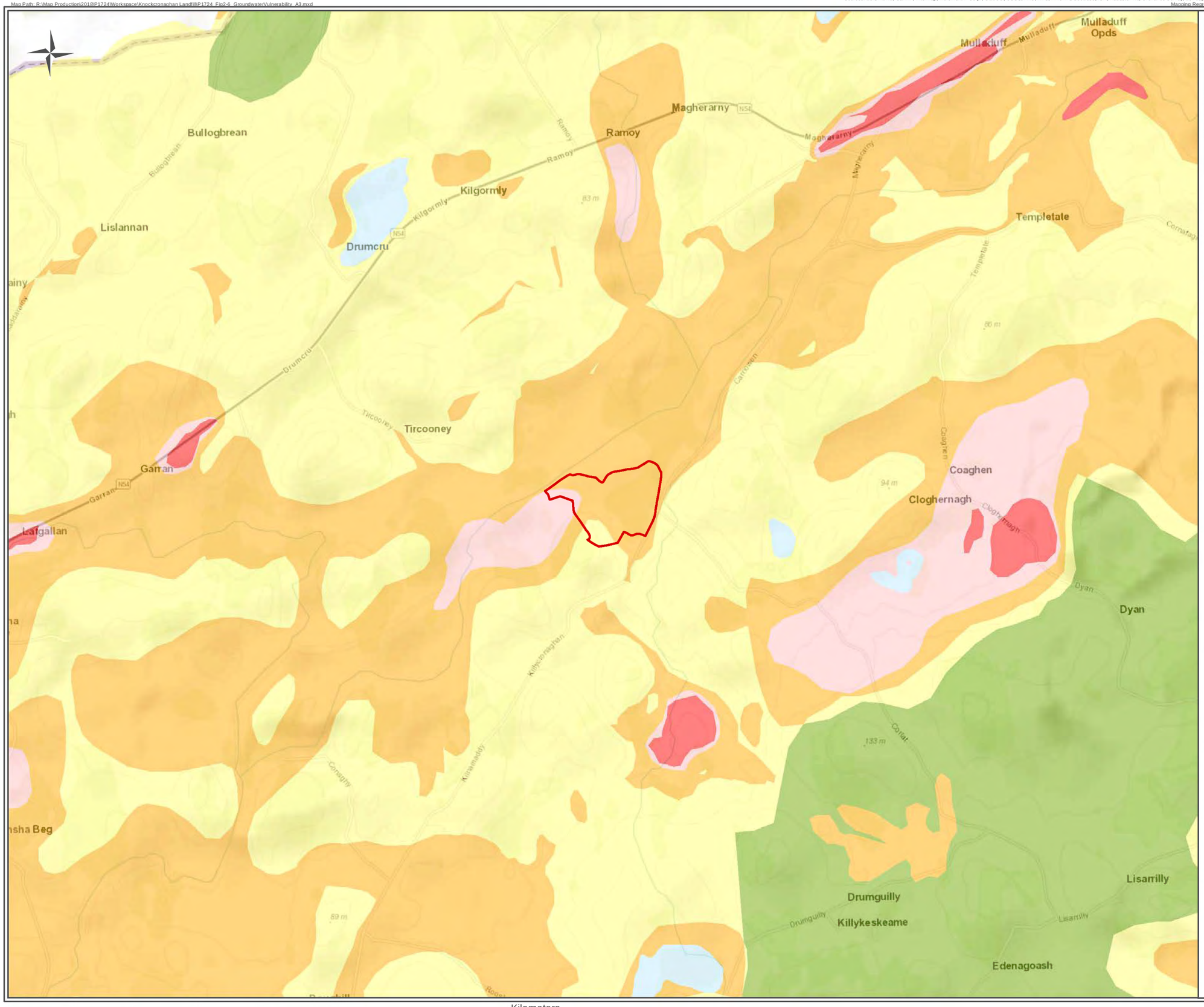

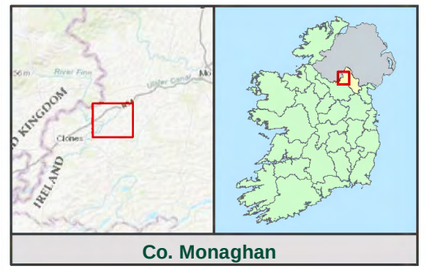

Legend

- Site Boundary

Groundwater Vulnerability

- E - Extreme
- H - High
- M - Moderate
- L - Low
- Water
- X (Rock Near Surface or Karst)

Figure Title	Groundwater Vulnerability
Figure No.	2.6
Project	ERA of Historic Landfill at Knockcronaghan, Co. Monaghan
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2.2.7 Hydrology

The site is located within the catchment of the River Erne which flows towards the west. The site is bounded to the southeast, east and north by the Kilgormly river. The Magherarny river bounds the site to the northwest. Surface water ditches bound the site to the southwest and south.

There are several small lakes located in the vicinity of the site. Coaghen Lough is located approximately 0.9km to the east of the site. Two smaller unnamed lakes are located approximately 0.5km and 0.7km east of the site, while Lough Oony is located approximately 1.2km northwest of the site.

The EPA has water quality stations on the Magherarny river and data from this station is as follows:

- Magherarny Bridge (RS36M010200) approximately 1km north-east of the site. Status at this point is listed as Poor (Q2-3) by the EPA, based on data collated in 2013.

2.2.8 Ecology

The site is not within or directly adjacent to any Natural Heritage Area (NHA), proposed NHA (pNHA), Special Area of Conservation (SAC) or Special Protection Area (SPA). Protected sites within the vicinity of the site include Lisarilly Bog proposed NHA (pNHA), approximately 1.8km southeast of the site. Lislallan Bog proposed NHA (pNHA) lies approximately 2.4km northwest of the site.

The ecology protected areas mapping is presented in Figure 2.7.

2.2.9 Site History

The earliest historical map available on the OSI website dates from 1837-1842. The OSI identifies the land within the site boundary was previously a gravel pit and arable land, with the surrounding area previously arable land.

The OSI Historical Mapping is presented in Figure 2.8.

2.2.10 Existing Geological Heritage

The GSI holds no records of areas of Geological Heritage within the site boundary or in the immediate vicinity of the site.

The nearest recorded of geological heritage held by the GSI is approximately 6km east of the site boundary at Calliagh. Calliagh is described as *"this site consists of a small 19th Century excavation or quarry on the summit of an unnamed hill"* and the geological feature of note is *"the first recorded location in Ireland and Britain of manganaxinite".*

The geological heritage mapping is presented in Figure 2.9.

2.2.11 Existing Geotechnical Stability

The GSI landslides database indicates that the nearest recorded geo-hazard was at Carrowmaculla, Lisnaskea Co. Fermanagh (ITM 643496 835192) in 1979, approximately 14.6 km northwest of the site boundary.

2.2.12 Archaeological Heritage

There are no Archaeological Heritage sites with the site boundary according to the Heritage Ireland GSI Geological Heritage map layer.

Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig2-7_EcologyProtectedSites_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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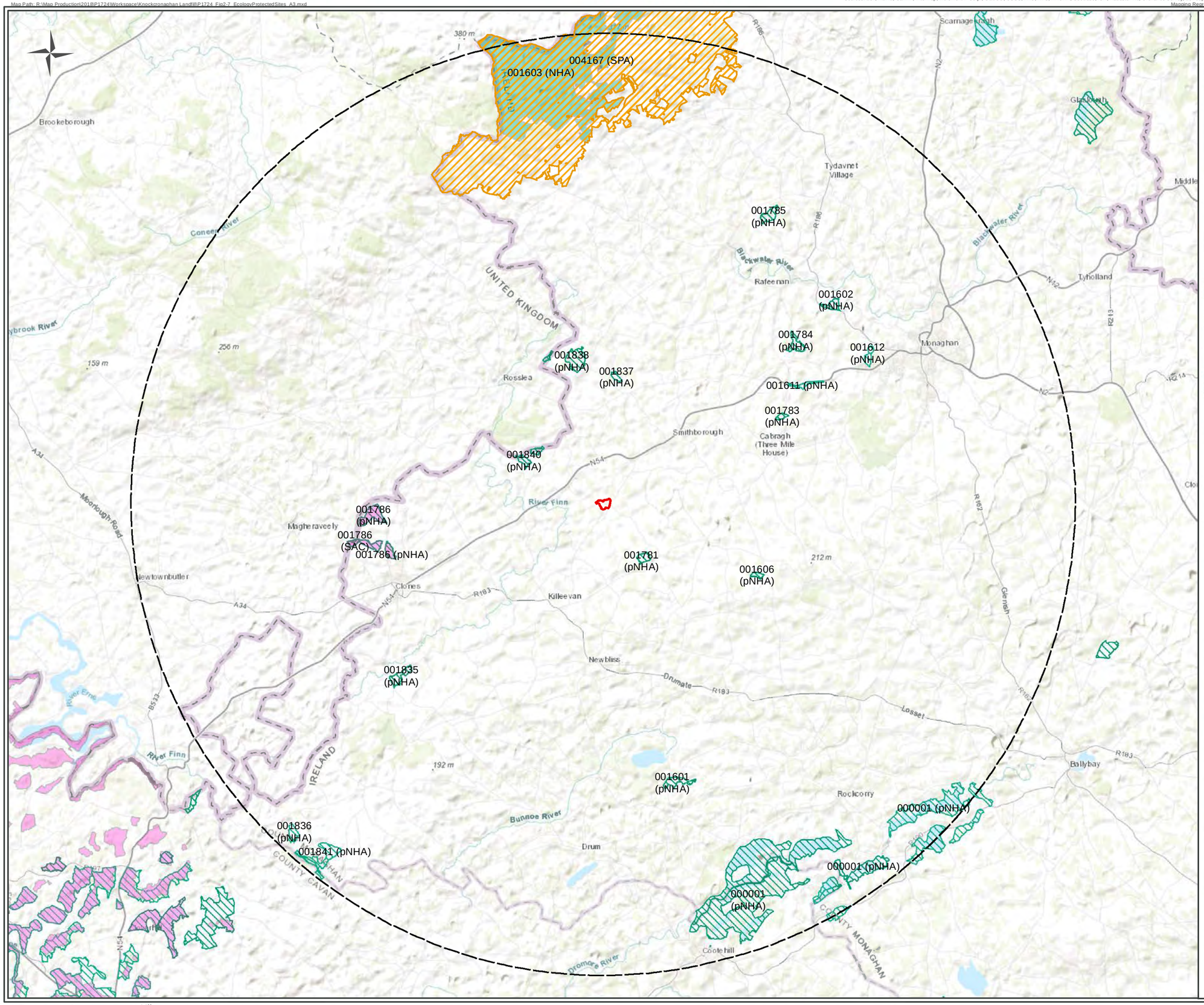

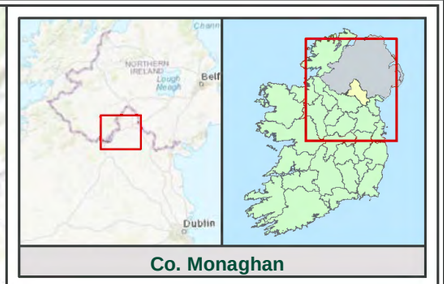

Legend

- Site Boundary
- 15km Distance from Site Boundary

Special Protection Area (SPA)
- Closest Site: 4.5km

Special Area of Conservation (SAC)
- Closest Site: 3.9km

Proposed Natural Heritage Area (pNHA)
- Closest Site: 1.8km

Natural Heritage Area (NHA)
- Closest Site: 4.4km

Kilometers
0 1 2 4

Figure Title
Ecology: Protected Sites

Figure No. 2.7

Project
ERA of Historic Landfill at Knockcronaghan, Co. Monaghan

Client
Monaghan County Council

Scale 1:120,000 **Page Size** A3

Revision A **Date** 14/11/2018

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Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig2-8_OSiHistoricalMapping_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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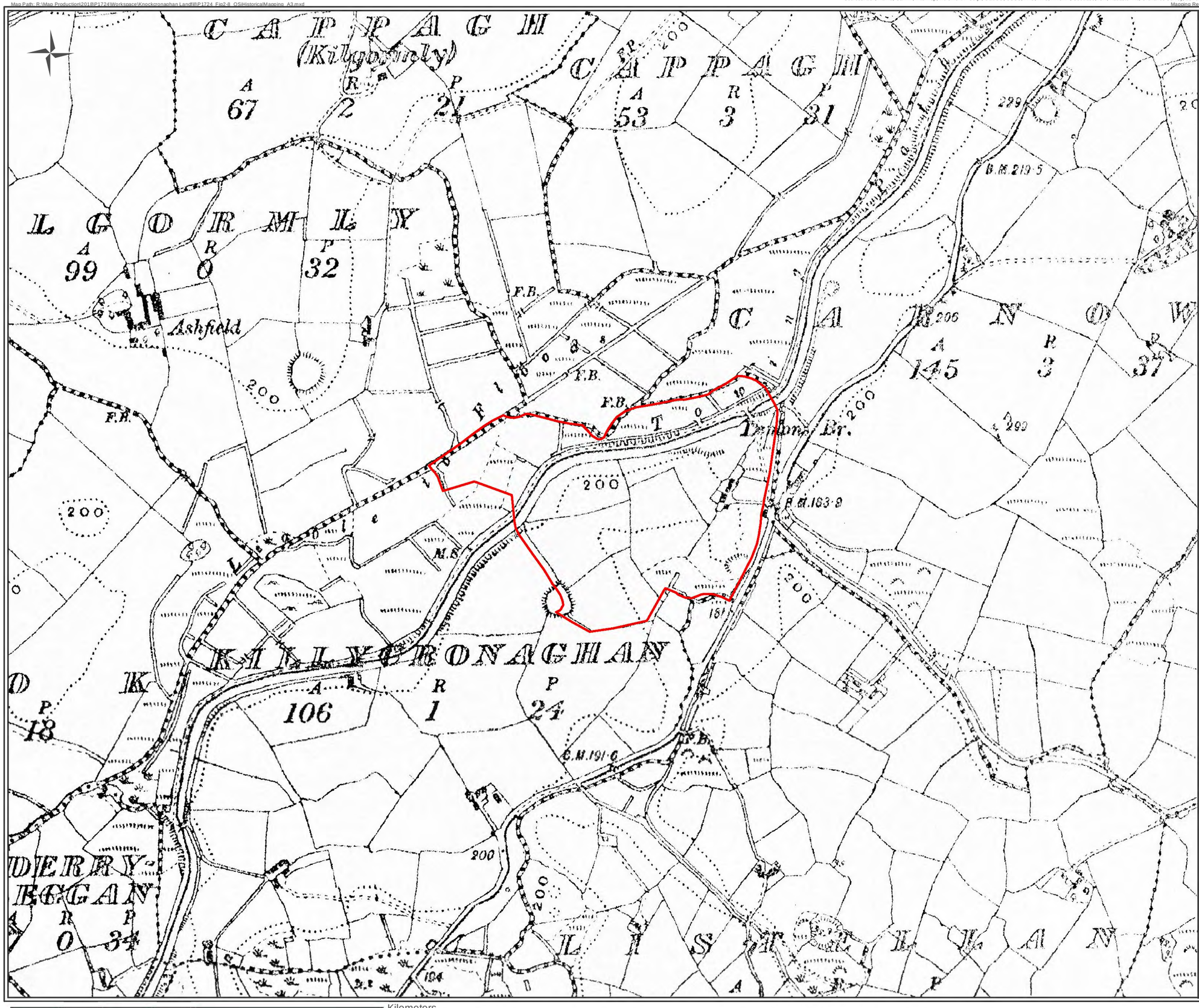

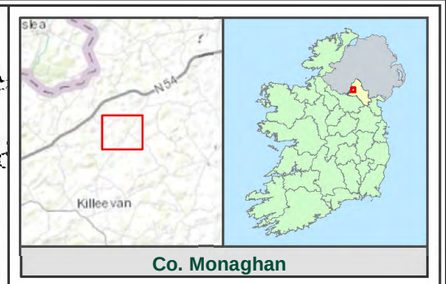

Legend

Site Boundary

Figure Title	OSi Historical Mapping
Figure No.	2.8
Project	ERA of Historic Landfill at Knockcronaghan, Co. Monaghan
Client	Monaghan County Council
Scale	1:5,000
Page Size	A3
Revision	A
Date	17/10/2018

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Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig2-9_GeologicalHeritage_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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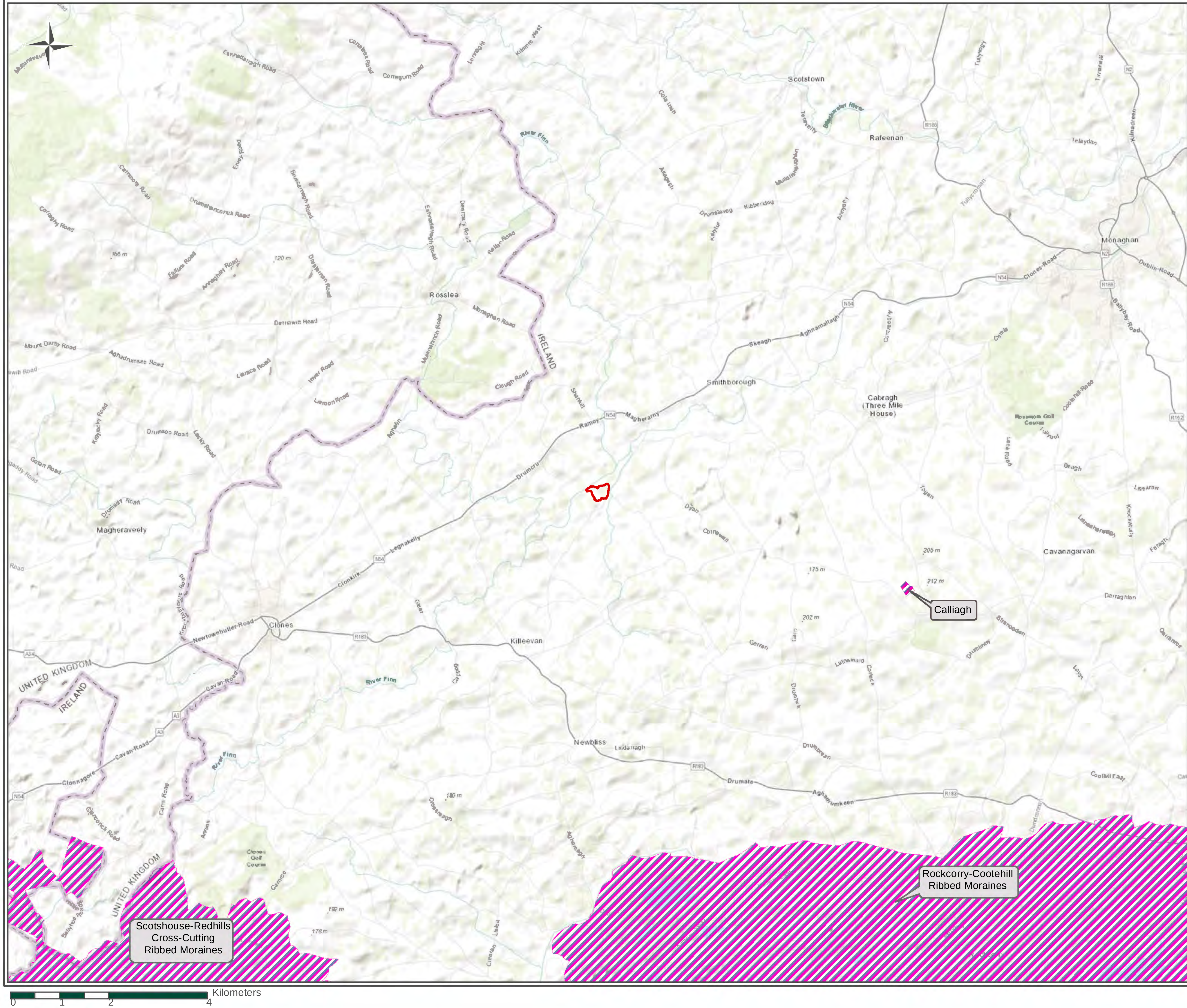

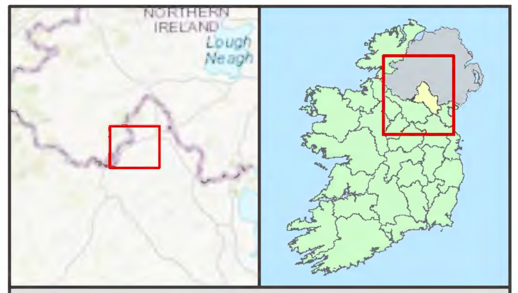

Co. Monaghan

Legend

- Site Boundary
- Geological Heritage Sites

Figure Title Geological Heritage

Figure No. 2.9

Project ERA of Historic Landfill at Knockcronaghan, Co. Monaghan

Client Monaghan County Council

Scale 1:75,000 **Page Size** A3

Revision A **Date** 17/10/2018

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3 TIER 2 SITE INVESTIGATION

3.1 Site Investigation Works

A site investigation rationale was devised based on findings of the Tier 1 assessment, site walkover, historical aerial photography and the preliminary risk assessment which formed part of that report.

The scope of site investigation works included:

- 16 No. Trial pit excavations
- Installation and monitoring of 3 No. groundwater boreholes
- 1 No. Geophysical survey (2D resistivity and seismic refraction profiling)
- Topographical Survey
- Factual reporting

The locations of the intrusive works at the site are presented in Figure 3.1.

The site investigation included the review of the following literature sources and websites:

- EPA 2003, Landfill Manuals: Landfill Monitoring (2nd Edition)
- EPA 1999, Landfill Manuals: Site Investigations
- BS 5930: 1999, Code of Practice for Site Investigations
- BS 6068 Water Quality: Sampling (parts 6.1-6.6 and 6.11-6.12, 6.14)
- BS 8855 Soil analysis (all parts)
- CLM: Ready Reference 2002, Section 3.1 Soil sampling strategies
- CLM: Ready Reference 2002, Section 3.2 Groundwater sampling/monitoring strategies
- CLM: Ready Reference 2002, Section 3.3 Gas sampling/monitoring strategies

3.1.1 Site Walkover

A site walkover was conducted prior to site investigation works by an FT Engineer and a CGL Engineer. During the site walkover the scope of the investigative works were evaluated based on the findings in the Tier I assessment.

The scope was agreed based on the site walkover assessment, historic aerial photography and other information received by MCC.

The site walkover checklist and photo log are included in Appendix 4.

Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig3-1_SiteInvestigationLocationPlan_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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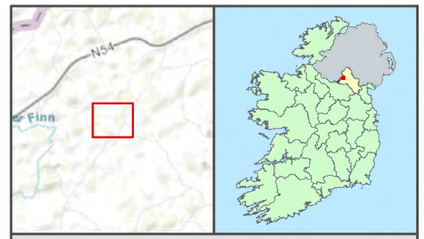

Co. Monaghan

Legend

- Groundwater Well Locations
- Trial Pit Locations
- Site Boundary

0 50 100 200 Meters

Figure Title
Site Investigation Location Plan

Figure No. 3.1

Project
ERA of Historic Landfill at Knockcronaghan, Co. Monaghan

Client
Monaghan County Council

Scale 1:2,500 **Page Size** A3

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

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3.1.2 Trial Pitting

A Causeway Geotech (CGL) Engineering Geologist supervised the advancement of 16 No. trial pits, shown in Figure 3.1, on the 24th September and 25th September 2018.

The trial pits (TP01 to TP16) were excavated to depths of 2.5m to 4.90m below existing ground level (bgl) using a JCB 3CX back-hoe excavator.

The geophysical survey used in conjunction with the profiles identified during trial pitting provided a picture of the underlying geology of the site and a general profile of the buried waste.

A summary of the ground conditions is presented in Table 3.1 below with photographs and exploratory hole logs provided in the CGL site investigation report, Appendix 2.

Table 3-1: Summary of Ground Conditions

Trial Pit ID	Depth of cover material (m BGL)	Depth to base of made ground / waste (m BGL)	Profile Description
TP01	0.10 (Topsoil) 0.10 – 0.90 (Clay / Silt) 0.9 – 2.5 (Sand)	2.5 (base of excavation - terminated due to pit walls collapsing)	Firm sandy slightly gravelly SILT / CLAY. Bluish grey fine to coarse SAND.
TP02	0.10 (Topsoil) 0.10 – 2.0 (Clay) 2.0 – 4.0 (Sand)	4.0 (base of excavation)	Firm brown / bluish grey slightly sandy slightly gravelly CLAY. Bluish grey fine to coarse SAND.
TP03	0.40 (Topsoil) 0.40 – 1.7 (Made Ground) 1.7 – 3.0 (Sand)	3.0 (base of excavation)	MADE GROUND: Black waste - 70% plastic, 5% glass bottles, 5% clothes, old pipes, string, measuring tape, bag of old meat. Bluish grey slightly gravelly fine to coarse SAND.
TP04	0.10 (Topsoil) 0.10 – 1.9 (Clay) 1.9 – 4.5 (Sand)	4.5 (base of excavation)	Firm brown / bluish grey slightly sandy slightly gravelly CLAY. Bluish grey fine to coarse SAND.
TP05	0.10 (Topsoil) 0.1 – 1.6 (Sand) 1.6 – 1.8 (Clay) 1.8 - 3.4 (Sand)	3.4 (base of excavation)	Light brown fine to coarse SAND Soft brown sandy silty CLAY. Light brown fine to coarse SAND
TP06	0.10 (Topsoil) 0.1 – 2.6 (Made Ground)	2.6 (base of excavation - terminated at possible bedrock)	MADE GROUND: Black waste with CLAY and boulders. 20% plastic, rubber, glass, foam, pipes, steel straps, planks of wood.
TP07	0.10 (Topsoil) 0.1 – 4.7 (Made Ground) 4.7 – 4.8 (Sand)	4.8 (base of excavation)	MADE GROUND: Black waste with sandy gravelly CLAY - 60% plastic, 5% glass bottles, old carpet, foam, clothes, old metal pipes, planks of wood, tin cans, straps of pallets and newspaper (The Irish Times Monday 19th July 1982). Bluish grey fine to coarse SAND.
TP08	0.20 (Topsoil) 0.2 – 4.5 (	4.5 (base of excavation)	MADE GROUND: Black waste - 60% plastic, 20% steel and metal pipes, glass

Trial Pit ID	Depth of cover material (m BGL)	Depth to base of made ground / waste (m BGL)	Profile Description
			bottles, old boxes of cardboard, planks of wood, clothes and newspaper from 1978.
TP09	0.10 (Topsoil) 0.1 – 0.5 (Silt) 0.5 – 4.5 (Sand)	4.5 (base of excavation)	Soft brown slightly sandy slightly gravelly SILT. Brown very gravelly slightly silty angular fine to coarse SAND.
TP10	0.10 (Topsoil) 0.1 – 0.6 (Silt) 0.6 – 3.0 (Sand)	3.0 (base of excavation)	Soft brown slightly sandy slightly gravelly SILT. Reddish brown slightly gravelly fine to coarse SAND.
TP11	0.10 (Topsoil) 0.1 – 4.5 (Made Ground)	4.5 (base of excavation)	MADE GROUND: Black waste with sandy gravelly CLAY - 60% plastic, 10% glass bottles, duct pipes, 10% clothes, fertiliser bags, foam, planks of wood, cartons from milk/ yoghurt factory.
TP12	0.30 (Topsoil) 0.3 – 4.8 (Made Ground) 4.8 – 4.9 (Gravel)	4.9 (base of excavation)	MADE GROUND: Black waste with sandy gravelly CLAY - 50% plastic, fertiliser bags, glass, 20% planks of wood, foam, shoes, clothes, coal bags. Bluish grey slightly sandy angular fine to coarse GRAVEL.
TP13	0.10 (Topsoil) 0.1 – 4.8 (Made Ground)	4.8 (base of excavation)	MADE GROUND: Black waste with high cobble and boulder content. 60% plastic, clothes, glass bottles, coal bags, fertiliser bags, planks of wood, net, 20% metal wires and newspapers (The Evening Heard Tuesday 4th May 1982, Woman's Way December 1982, Sunday Mirror October 1982, Irish Farmers Journal 1982).
TP14	0.10 (Topsoil) 0.1 – 0.5 (Clay) 0.5 – 2.5 (Sand)	2.5 (base of excavation - terminated due to pit walls collapsing)	Soft bluish grey slightly sandy slightly gravelly CLAY. Grey / brown slightly gravelly clayey fine to coarse SAND.
TP15	0.10 (Topsoil) 0.1 – 2.3 (Made Ground) 2.3 – 3.5 (Gravel)	3.5 (base of excavation - terminated due to pit walls collapsing)	MADE GROUND: Firm bluish grey slightly sandy slightly gravelly CLAY with fragments of plastic. Bluish grey slightly sandy clayey fine to coarse GRAVEL.
TP16	0.10 (Topsoil) 0.1 – 2.3 (Made Ground)	2.3 (base of excavation - terminated on obstruction.	MADE GROUND: Firm pinkish brown slightly sandy slightly gravelly CLAY with high cobble and boulder content.

Made ground comprising waste was encountered in 9 No. trial pits (TP03; TP06 - TP08; TP11 - TP13; TP15 and TP16). A shallow cover material was recorded at these trial pit locations and comprised 0.10m to 0.30m of topsoil. Possible bedrock was encountered in TP06 at 2.6m.

Waste material was encountered to the base of the excavation of between 3.0m – 4.8m in trial pits TP03, TP07, TP12 and TP15 where natural ground was confirmed. Groundwater was encountered in trial pits TP01, TP02, TP06, TP07, TP08 and TP12 at 2.0m, 2.1m, 1.6m, 3.7m, 2.1m and 4.2m respectively.

Natural ground comprising of quaternary glacial till was confirmed in the remaining trial pits TP01, TP02, TP04, TP05, TP09, TP10 and TP14.

3.1.3 Waste Sampling

A total of 2 No. samples of the made ground / waste at the site was collected from trial pits TP04 and TP07 advanced in the western portion of the site.

All samples were submitted for Waste Acceptance Criteria (WAC) testing to ALS Environmental Ltd, a UKAS/MCERTS approved laboratory. Samples were collected from site under Chain of Custody procedures.

The results are provided in Appendix G of the CGL Ground Investigation report, Appendix 2 of this report.

3.1.4 Evidence of Contamination

The trial pit excavation works identified waste material tending west-east near the southern site boundary with thicknesses ranging from 3.0 – 4.8m BGL. Evidence of waste material was identified in 9 No. trial pits locations (TP03; TP06 - TP08; TP11 - TP13; TP15 and TP16). The waste encountered was typically described as black waste with plastic, clothes, glass bottles, coal bags, fertiliser bags, planks of wood, nets, metal wires and newspapers dating back to 1978 and 1982. The waste material description as described by CGLs Engineering Geologist is very typical of MSW material.

Waste was not encountered in the perimeter trial pits TP01, TP02, TP04, TP05, TP09, TP10 and TP14 advanced in the west and north of the site.

The base of the waste material was not reached at the termination depth of 4.5 m BGL in four trial pits (TP06, TP08, TP11, TP13). The base of the waste was encountered between 3.0m – 4.8m in trial pits TP03, TP07, TP12 and TP15 where natural ground was confirmed.

As noted most of the Made Ground waste material encountered comprised sandy gravelly Clay mixed with MSW.

3.1.5 Geophysical Investigation

Apex Geoservices Ltd. (Apex) were instructed by FT to undertake a geophysical investigation of the site. The survey was carried out on the 30th and 31st October 2018.

The geophysical survey consisted of reconnaissance EM Ground Conductivity Mapping with follow-up Electrical Resistivity Tomography (ERT), Seismic Refraction profiling and the MASW method used to estimate shear-wave velocities (Vs) in the ground material. A total of 516m of electrical resistivity profiles were collected.

The geophysical survey, calibrated against the findings of the trial pitting and borehole installations was used to estimate a general profile of the buried waste above the in-situ bedrock.

The geophysical survey delineated the survey area into zones based on an interpretation of the ground conditions across the site. The following 4 No. zones were identified:

- Zone A: made ground/waste (predominantly organic) over Sand/Gravel with Leachate
- Zone B: southern site boundary where waste may be present.
- Zone C: possible leachate plume
- Zone D: possible leachate plume

A map showing a delineation of the identified zones is presented in Figure 3.2.

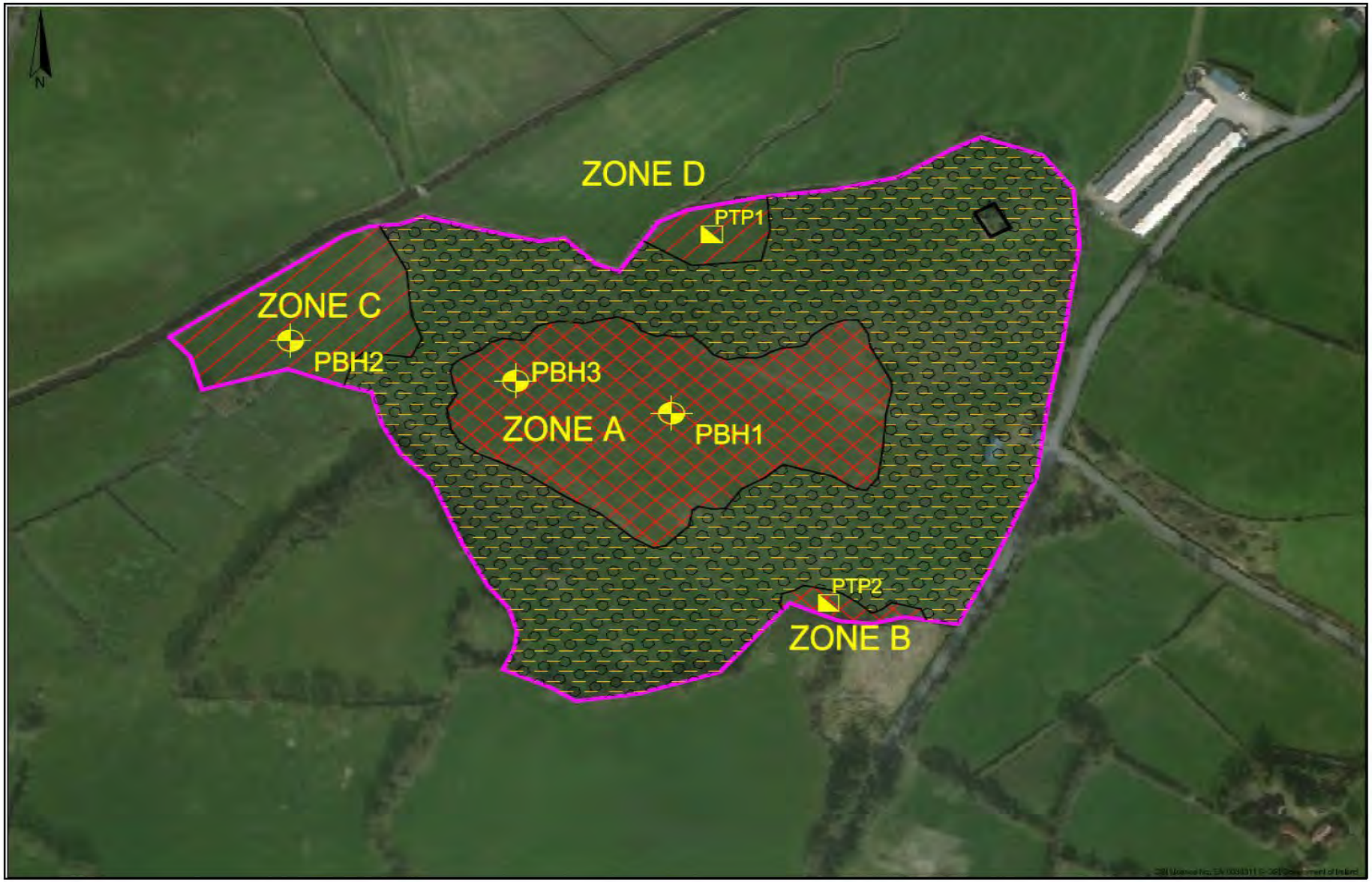

Figure 3-2: Maximum Anticipated Waste Footprint

Seismic Refraction Profiling & Electrical Resistivity Tomography (ERT)

Apex recorded 9 no. ERT profiles data along three designated profiles, see Figure 3.3. ERT profiles are named R1 through R9. The location of these profiles is given in Drawing No. AGL18165_01 and Drawing No. AGL18165_02 with interpreted cross sections compiled for these profiles on Drawings numbered AGL18165_R1 to AGL18165_R9.

Six seismic refraction profiles (S1-S6) were recorded across the site. The locations are shown on Drawing No. AGL18165_01 and the interpreted cross sections are presented in Drawings numbered AGL18165_R1-R9.

An interpretation of the results is included in the Apex geophysical survey report, Appendix 2.

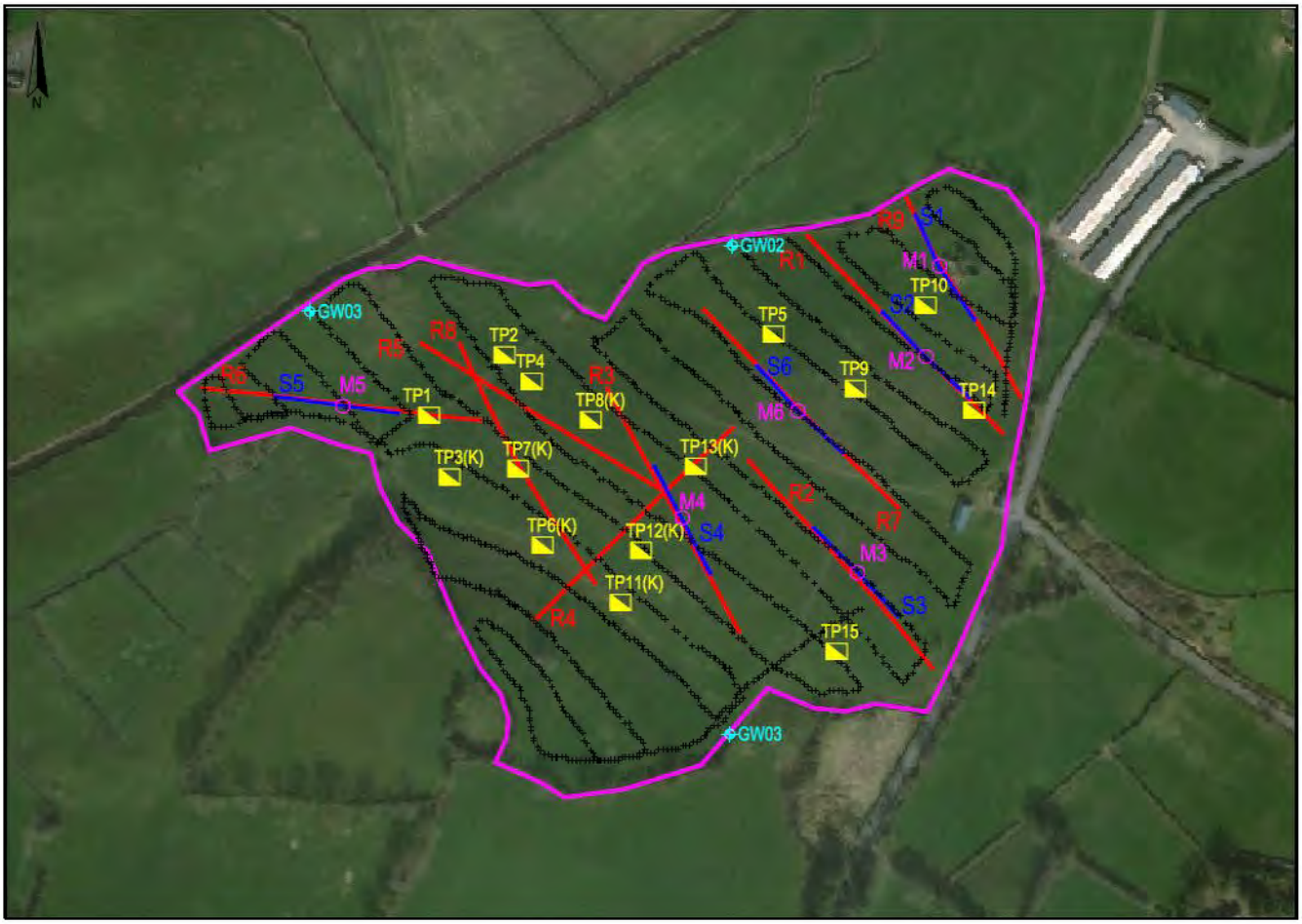

Figure 3-3: ERT Profile Transects R1 to R9

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 within one central location of the survey area.

The survey outlined an area of 2.2 ha in the centre of the survey area which has been interpreted as Topsoil over Made Ground/Waste (predominantly organic) over Sand/Gravel with Leachate (Zone A). This area corresponds well with the locations where trial pits encountered 'black bag type waste'. The survey also identified a small area (0.08 Ha) on the southern site boundary (Zone B), adjacent to TP15, where waste may be present.

Using the trial pit and MASW (multichannel analysis of surface waves) data, the average thickness of the Zone A waste is 5.0m. The thickness of the Zone B waste is unknown but nearby TP15 records 0.4m of waste.

The survey has interpreted an area of low resistivity on ERT profile R6 as a possible leachate plume (Zone C) in the direction of the river. A similar zone of low resistivity data occurs at the north-western end of R7 (Zone D) and has been indicated as a possible leachate plume on Drawing AGL18165_03 but may be due to increased alluvium content in area.

The remaining areas of the site surveyed outside of the zones identified is interpreted as Sandy Gravelly Clay overlying Bedrock.

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 Clay glacial till strata. The geophysical profiles indicate predominantly organic waste has been deposited in the centre of the site and leachate is more prevalent in this area of the site.

The modelled profiles and geophysical interpretations are presented in Figure 3.4 to Figure 3.12.

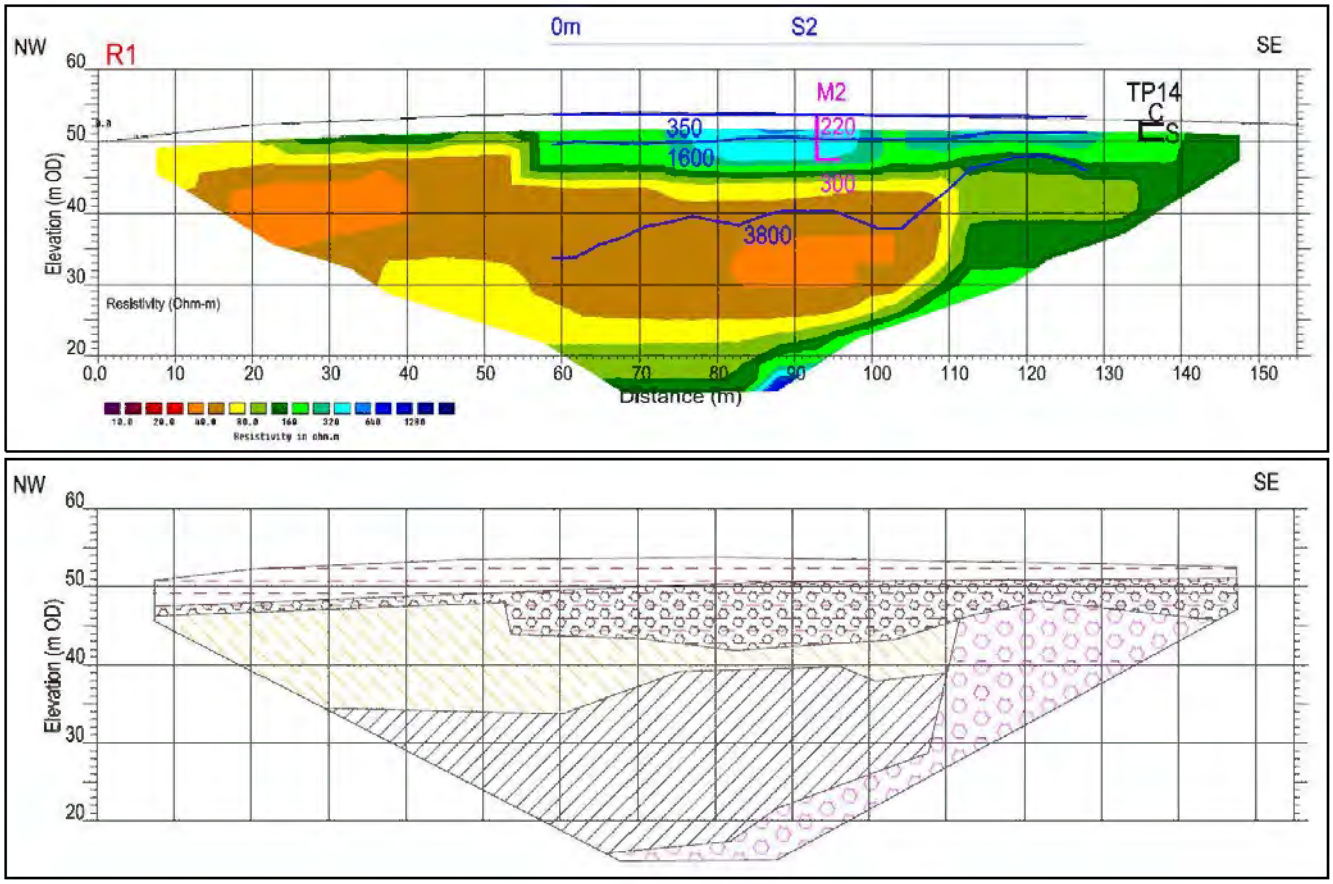

Figure 3-4: ERT Profile R1 Interpreted Cross Section

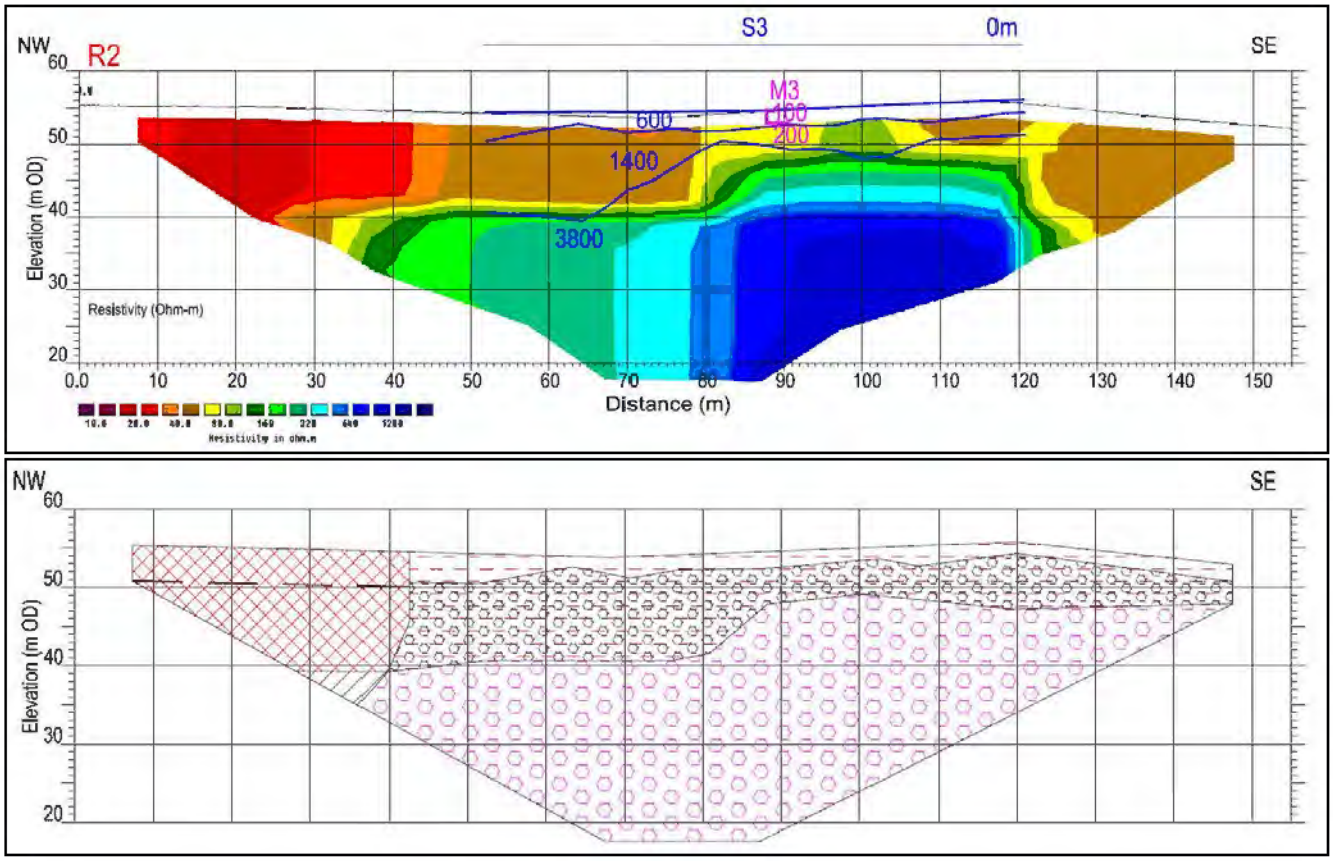

Figure 3-5: ERT Profile R2 Interpreted Cross Section

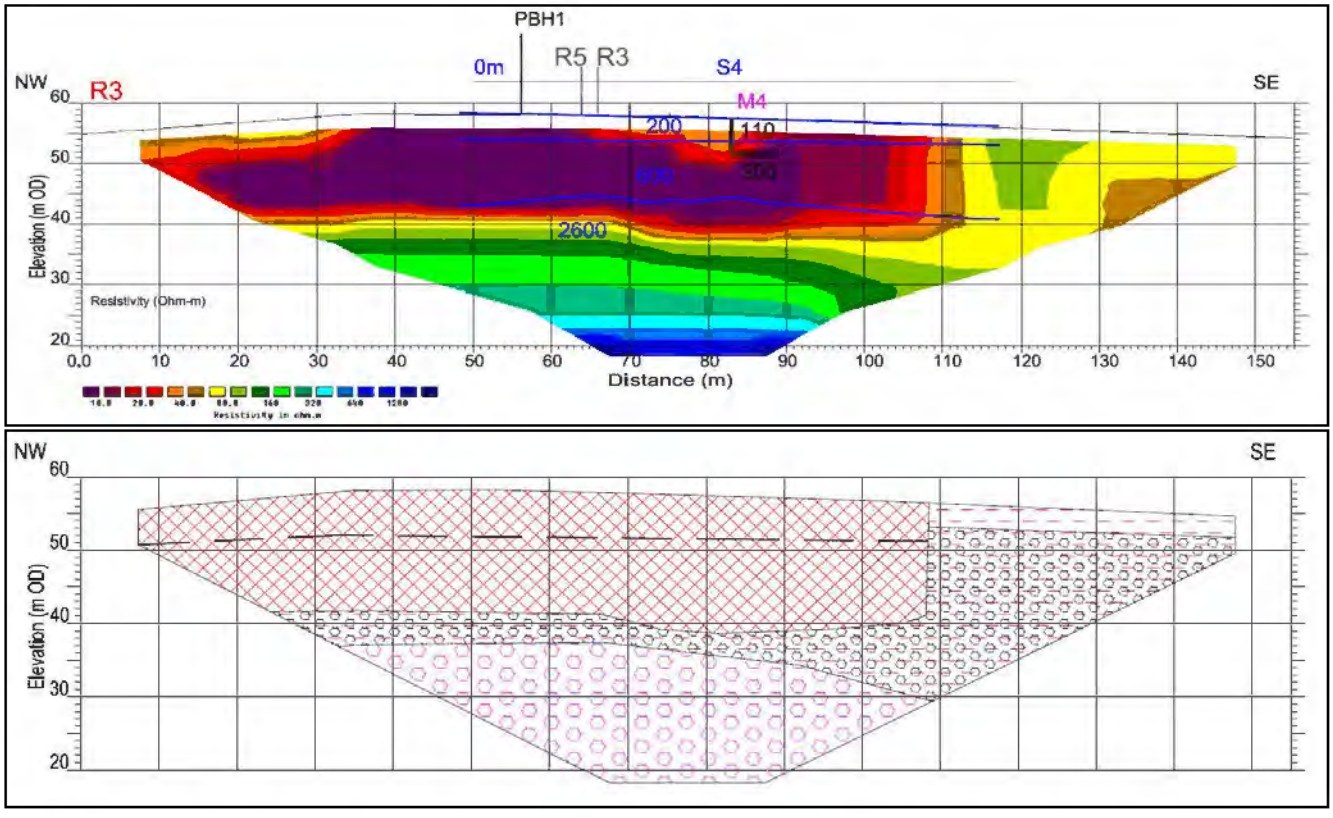

Figure 3-6: ERT Profile R3 Interpreted Cross Section

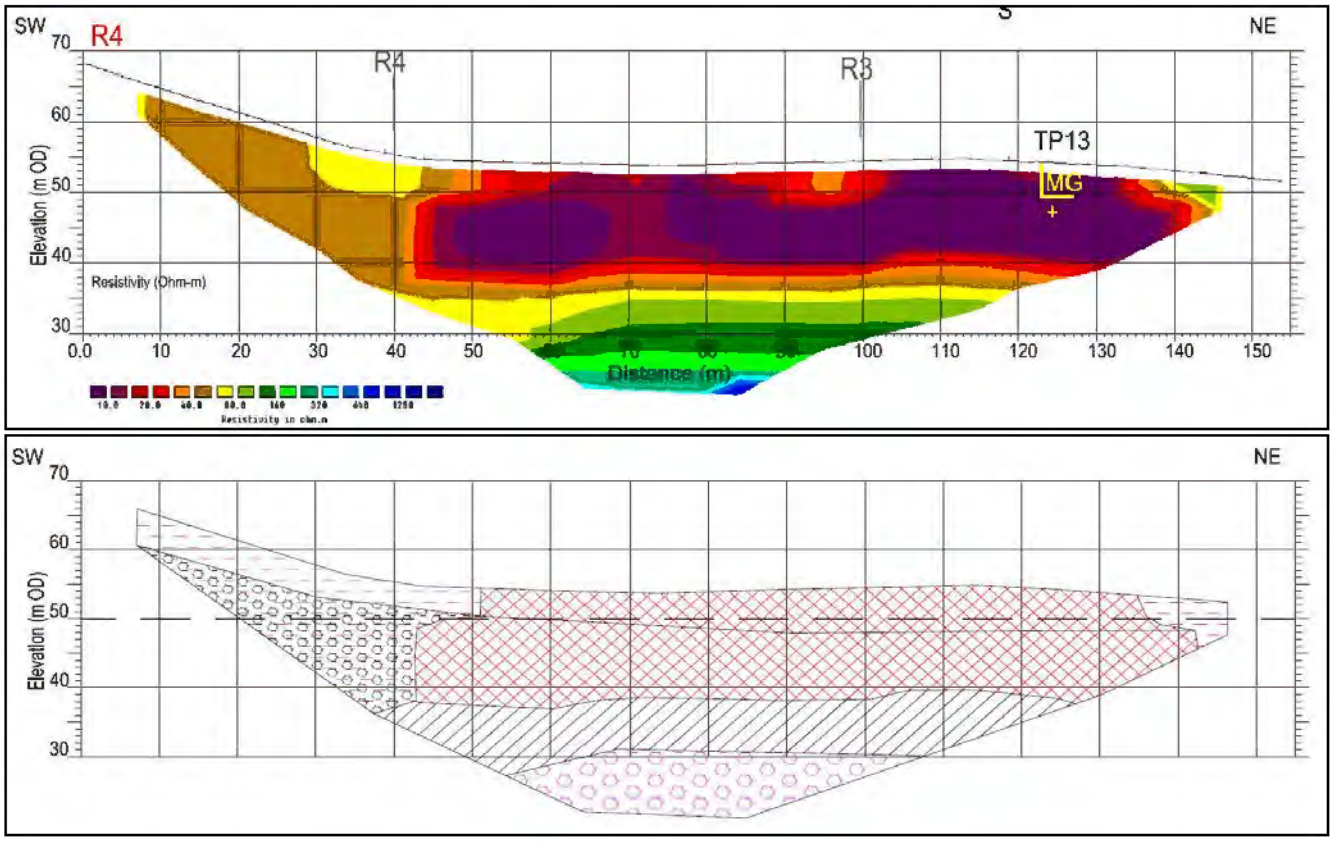

Figure 3-7: ERT Profile R4 Interpreted Cross Section

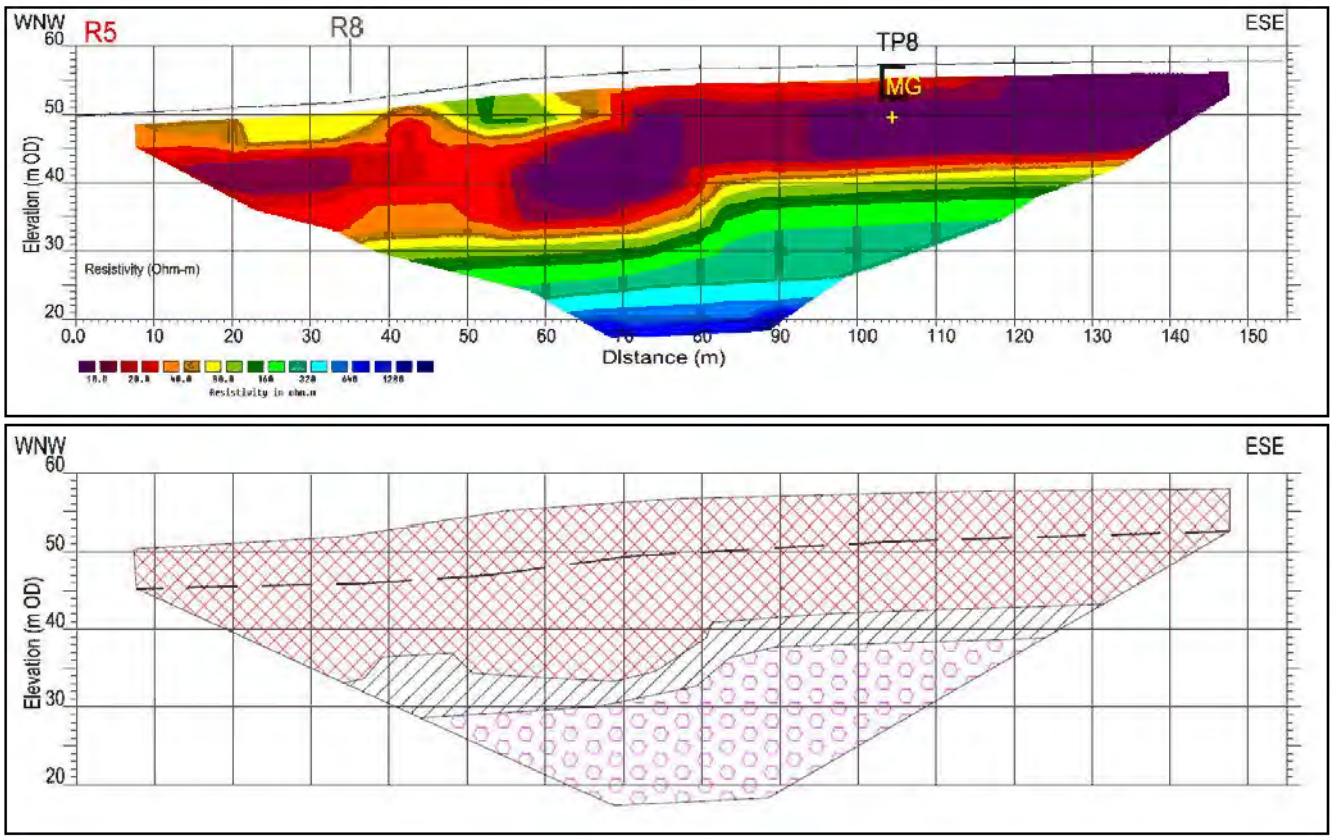

Figure 3-8: ERT Profile R5 Interpreted Cross Section

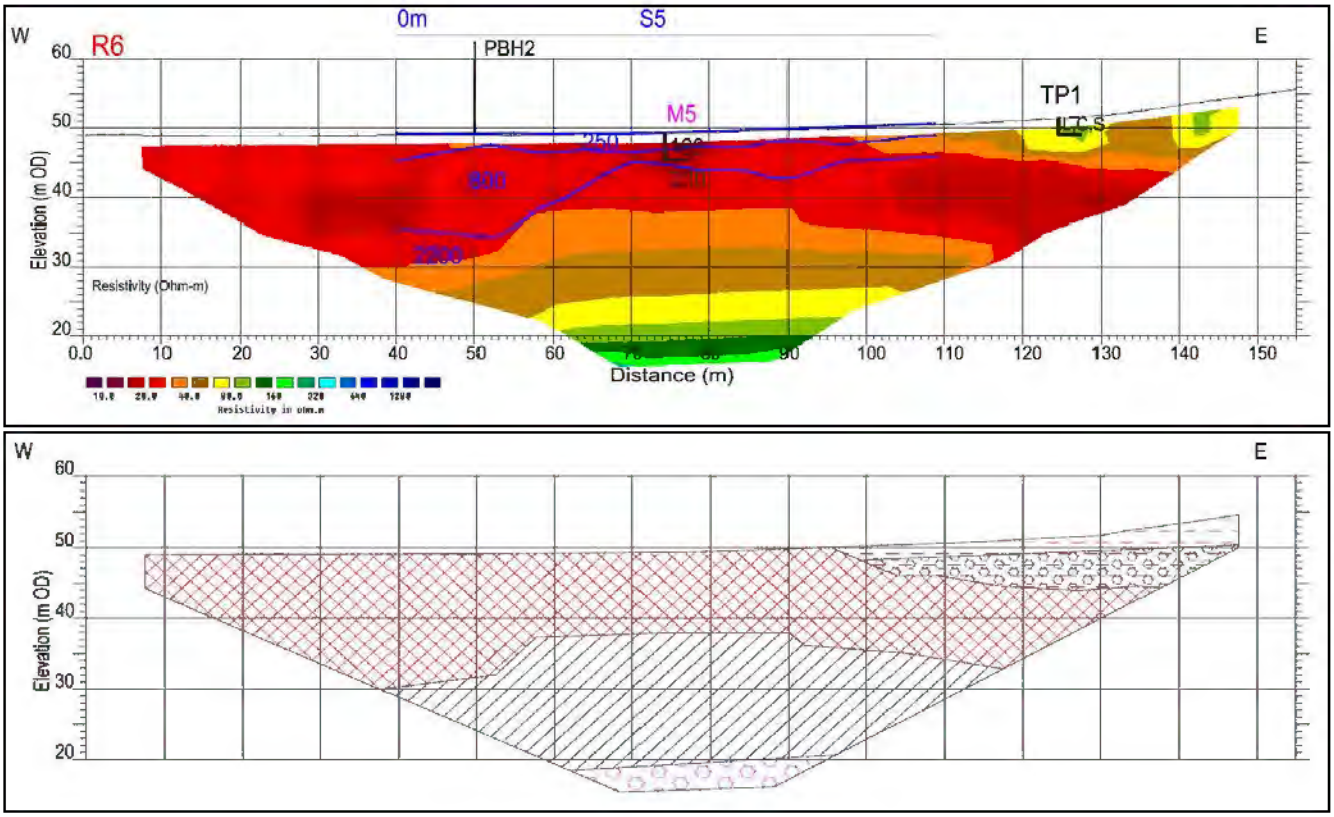

Figure 3-9: ERT Profile R6 Interpreted Cross Section

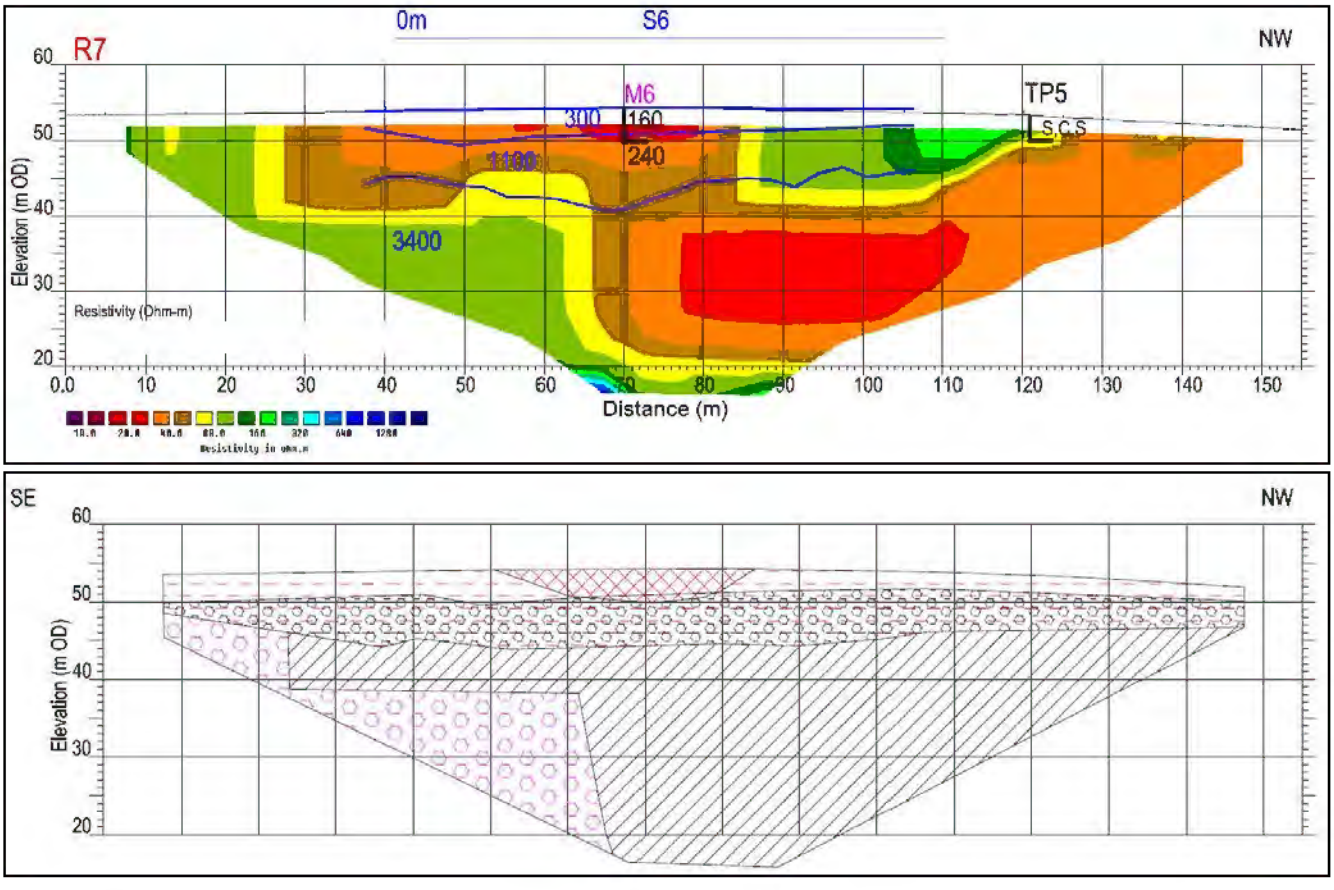

Figure 3-10: ERT Profile R7 Interpreted Cross Section

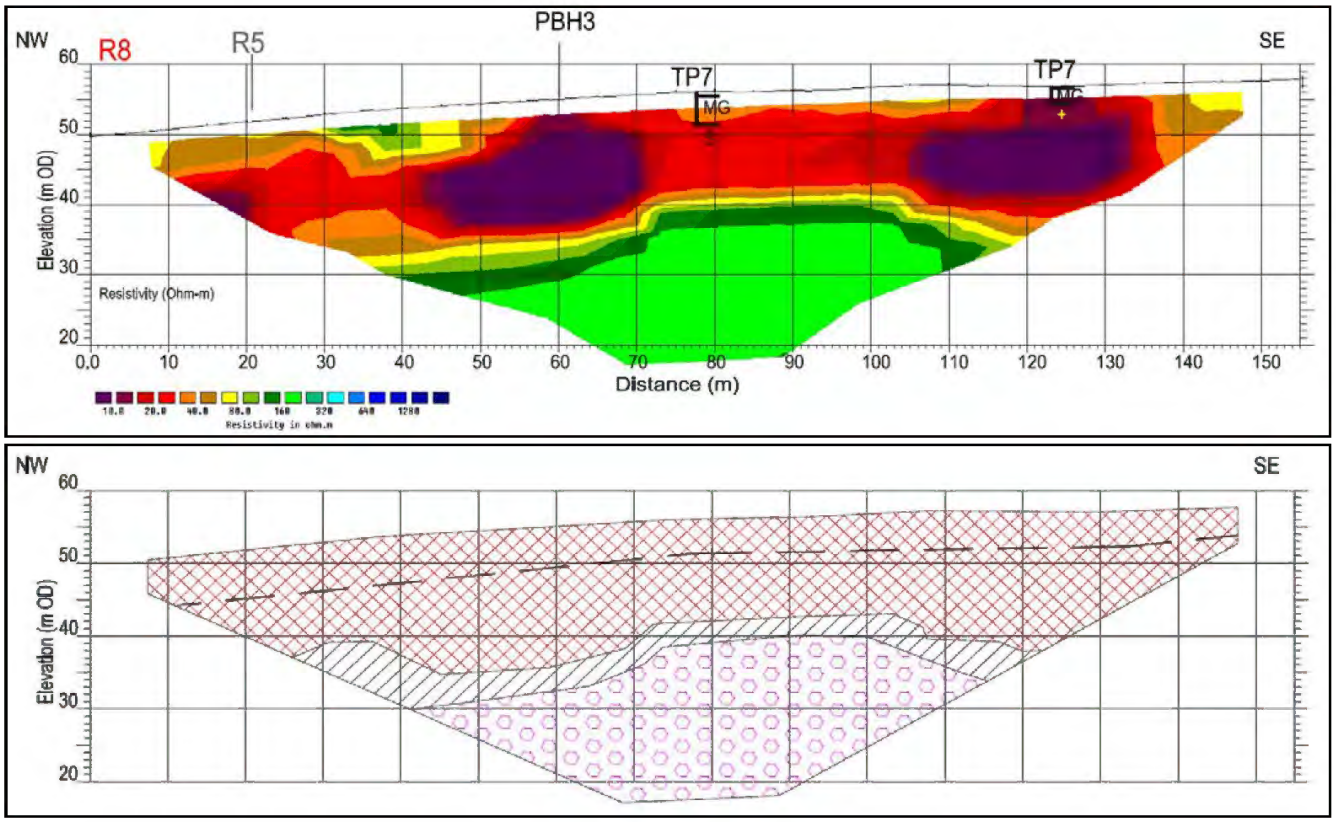

Figure 3-11: ERT Profile R8 Interpreted Cross Section

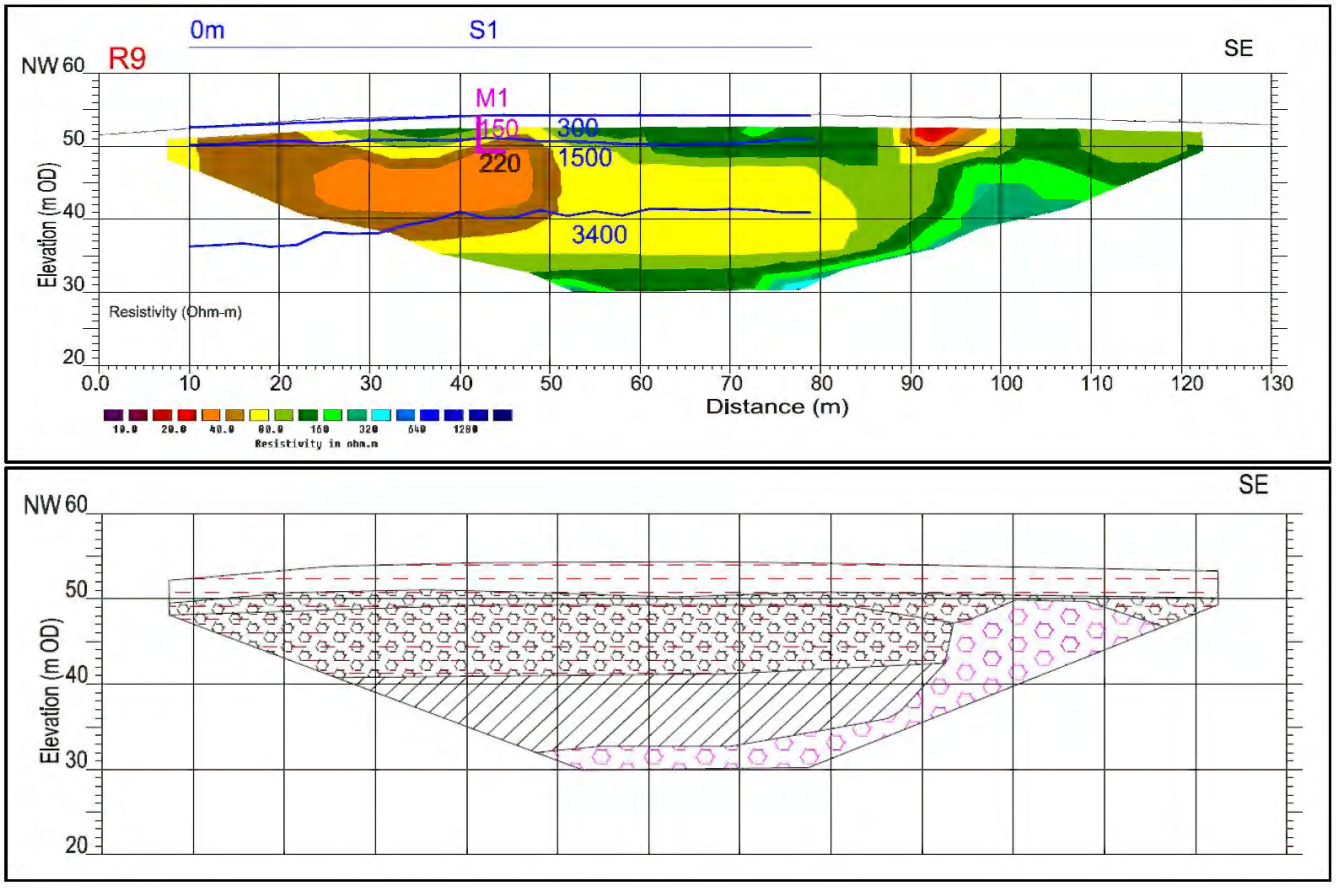

Figure 3-12: ERT Profile R9 Interpreted Cross Section

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 in the centre of the site and between approximately 150m in length and 130m in width.

Interpretation of the geophysical survey results indicate the presence of one waste composition type which have been designated as Zone A and Zone B. Both Zone A and Zone B are characterised as predominantly organic waste deposited in the centre of the site and a small pocket near the south-eastern site boundary.

The extent of the waste deposit has been interpreted by the findings of the geophysical survey and the presence of undisturbed ground encountered in 7 No. trial pits TP03, TP06, TP07, TP08, TP11, TP12 and TP13. Based on this interpretation, the maximum waste footprint of Zone A in the middle of the site is calculated to be approximately 2.2 hectares and the smaller waste mass at Zone B is estimated as 0.08 hectares.

An initial volume calculation was conducted 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 106,000m^3 at the site.

The maximum anticipated waste footprint is presented in
Figure 3-22.

3.1.7 Borehole Installation and Groundwater Sampling

Three boreholes (GW01, GW02 and GW03) were drilled to depths ranging between 14.5m bgl to 17.0m 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. The purpose of the boreholes was to intercept and define the groundwater flow direction upstream and downstream of the identified waste body.

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 26th September 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 TP03, TP07 and TP09 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 3.2 over.

Table 3-2: Soil Sample Classification

Sample Proportions	% Dry Mass		
	TP03	TP07	TP09
Cobbles	0	0	0
Gravel	38	15	26
Sand	45	37	71
Silt	15	39	3
Clay	3	10	--

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 3.3. The k value calculated for each of the samples classifies the existing capping material between a gravelly silty clay and a fine to coarse sand.

Table 3-3: Permeability by Hazen's Relationship

Sample ID	C	D_{10} (mm)	K (m/s)
TP03	0.01	0.0082	6.72×10^{-7}
TP07	0.01	0.00204	4.16×10^{-8}
TP09	0.01	0.131	1.72×10^{-4}

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, according to the EPA Landfill Site Design Manual. The permeability estimated for the three samples analysed at the Killycronaghan site are all greater than the EPA guidance and hence are not suitable as a capping material.

The shallow topsoil depth of 0.1 to 0.3m across the site coupled with 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.

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.

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

The results of the permeability testing including the horizontal permeability factor at boreholes GW01 to GW03 are presented in Table 3.4. The test data and associated infiltration graphs are presented in the Causeway site investigation report, Appendix 2.

Table 3-4: In-Situ Permeability Test Results

Test No.	Test Depth (m BGL)	Total Head (m)	Test Time (min)	Permeability Factor (k)
GW01	2.48 – 5.87	3.39	15	1.58×10^{-6} m/s
GW02	--	--	35	1.85×10^{-5} m/s
GW03	0.24 – 0.99	0.75	120	7.65×10^{-8} m/s

As can be seen in Table 3.3, the hydraulic conductivity (k) recorded at GW01, GW02 and GW03 was in the range of 7.65×10^{-8} m/s to 1.85×10^{-5} m/s across the site. According to the CGL borehole logs (Appendix 2), the permeability testing at borehole GW01 was carried out within gravelly Sands and weathered limestone bedrock, while permeability testing at borehole GW03 was carried out within brown gravelly Clay.

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 Killycronaghan Historic Landfill site are presented in the following sections.

4.2 Waste / Made Ground Assessment

The soil / 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 Samples

The soil samples analysed from the site investigations were assessed against the Waste Classification Assessment Criteria. A summary of the results for Killycronaghan 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 (0.2m)	TP07 (0.5m)
Asbestos in soil	--	**Detected**	**Detected**	**Detected**	ND	ND
Arsenic	$mg.kg^{-1}$	**0.5**	**2**	**25**	<0.050	<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**	<0.050	<0.050
Lead	$mg.kg^{-1}$	**0.5**	**10**	**50**	0.017	<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**	1.8	3.1
Sulphate	$mg.kg^{-1}$	**1000**	**20000**	**50000**	89	170
Total Dissolved Solids	$mg.kg^{-1}$	**4000**	**60000**	**100000**	410	1000
Total Monohydric Phenols	$mg.kg^{-1}$	**1**	**--**	**--**	<0.50	<0.50
Dissolved Organic Carbon	$mg.kg^{-1}$	**500**	**800**	**1000**	99	120
Sum of BTEX	$mg.kg^{-1}$	**6**	**--**	**--**	<0.010	<0.010
Total Organic Carbon *	%	**3**	**5**	**6**	<0.20	0.87
Moisture Content ratio	%	**--**	**--**	**--**	12	19
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 (0.2m)	TP07 (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**	**--**	8.5	8.3
Loss on ignition	%	**--**	**--**	**10**	1.8	4.1

* Hazardous Waste Landfill Criteria: >6% TOC
* Items shaded in green are in exceedance of the Inert WAC limit value

4.2.2 Waste Classification

As can be seen in Table 4.1, results of waste samples collected from 2 No. trial pits across the site demonstrate the interred waste to be typical of inert waste when assessed against the waste acceptance criteria (WAC). Due to the presence of MSW within the landfill, as confirmed during trial pitting, the results indicate that the waste material is likely highly stabilised due to the age of the waste.

4.3 Groundwater Analysis

Two rounds of groundwater quality monitoring were undertaken at the site on the 1st 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 9th October 2018 are calculated below.

Table 4-2: Groundwater Depth Analysis

Borehole ID	Location Gradient	Top of Casing (mAOD)	Dip (m) 09/10/18	Groundwater Level (mAOD)
GW01	Upgradient	53.730	1.87	51.86
GW02	Cross-gradient	51.48	0.85	50.63
GW03	Down gradient	50.94	0.71	50.22

*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 east to south-east. 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. A desktop analysis of the site in tandem with a site walkover estimated that the likely groundwater flow direction was West to North West based on the location of the Maheramy River.

The results of the first round of groundwater monitoring however indicate an east to south-easterly groundwater flow direction. GW01 and GW02 are therefore up-gradient of the waste mass identified. Borehole GW03 is the down-gradient monitoring location.

Map Path: R:\Map Production\2018\P1724\Workspace\Knockcronaghan Landfill\P1724_Fig4-1_GroundwaterFlowDirection_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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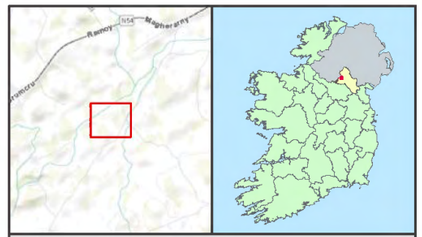

Co. Monaghan

Legend

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

Interpolated Dipped Water Level (mAOD)

- 50.00 - 50.25
- 50.26 - 50.5
- 50.51 - 50.75
- 50.76 - 51
- 51.01 - 51.25
- 51.26 - 51.5
- 51.51 - 51.75
- 51.76 - 52

0 50 100 200 Meters

Figure Title
Groundwater Flow Direction

Figure No. 4.1

Project
ERA of Historic Landfill at Knockcronaghan, Co. Monaghan

Client
Monaghan County Council

Scale 1:2,000 **Page Size** A3

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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 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
pH	pH units	**6.5 - 9.5**	--	8.34	7.66	7.91
Conductivity	mS/cm	**1**	**1.875**	0.549	0.793	0.702
Dissolved Oxygen	mg/l	**no abnormal change**	--	9.45	9.04	9.06
Alkalinity as CaCO3	mg/l	**200**	--	**291**	**421**	**333**
Ammoniacal Nitrogen as N	mg/l	**0.15**	**0.175**	**0.324**	**1.14**	**33.2**
Total Coliforms	cfu/100ml	**0**	--	**2420**	**1590**	**698**
Nitrite as N	mg/l	--	**0.375**	<0.0152	<0.0152	0.0797
BOD	mg/l	--	--	<1	<1	<1
COD	mg/l	--	--	7.21	<7	30.9
Sodium	mg/l	**150**	**150**	20.3	43	20.2
Sulphate as SO4	mg/l	**200**	**250**	7.17	9.93	6.47
Total Oxidised Nitrogen	mg/l	--	--	0.204	0.188	0.902
Total Organic Carbon	mg/l	--	--	<3	3.15	9.93
Arsenic	mg/l	**0.01**	**0.0075**	0.00081	0.00453	0.00115
Barium	mg/l	**0.1**	--	**0.133**	**0.780**	**0.352**
Boron	mg/l	**1.0**	**0.75**	0.0576	0.0182	0.0888
Cadmium	mg/l	**0.005**	**0.005**	<0.00008	<0.00008	0.0001
Calcium	mg/l	**200**	--	72.4	135	63.6
Chloride	mg/l	**30**	**187.5**	15.9	30.6	27.9
Chromium	mg/l	**0.03**	**0.05**	0.00102	<0.001	<0.001
Copper	mg/l	**0.2**	**2**	0.00446	0.00169	0.00386
Cyanide	mg/l	**0.01**	**0.0375**	<0.05	<0.05	<0.05
Fluoride	mg/l	**1.0**	**0.8**	<0.5	<0.5	<0.5
Iron	mg/l	**0.2**	--	**0.547**	**3.47**	0.0376
Lead	mg/l	**0.01**	**0.025**	**0.278**	**0.179**	**0.136**
Magnesium	mg/l	**50**	--	27.9	14.4	7.01
Manganese	mg/l	**0.05**	--	**0.0516**	**0.406**	**0.0771**
Mercury	mg/l	**0.001**	**0.001**	<0.00001	<0.00001	<0.00001
Nickel	mg/l	**0.02**	**0.02**	0.0038	0.0069	0.0041
Phosphorus	mg/l	**0.03**	**0.035**	**0.0312**	0.0137	**0.91**
Potassium	mg/l	**5**	--	2.38	2.4	**17.7**

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2016 Standards [2]	GW01	GW02	GW03
Uranium	mg/l	**0.009**	--	<0.0005	0.003	0.0019
Zinc	mg/l	**0.1**	--	0.0533	0.0153	0.0229
Mineral Oil	mg/l	--	**0.01**	<0.01	<0.01	<0.01
MTBE	mg/l	--	--	<0.01	<0.01	0.0013
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 (2010) – SI No. 9 of 2010
* 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 ammonia concentrations of 0.324 mg/l, 1.14 mg/l and 33.2 mg/l respectively, which exceed guideline threshold values. Ammonia concentrations at both upgradient boreholes GW01 and GW02 are considered representative of background levels possibly due to agricultural land spreading. Given the ammonia concentration of 33.2 mg/l recorded at GW03 is 100-times greater than upgradient levels, the landfill is impacting downgradient water quality due to the significant ammonia concentration differences between upgradient and downgradient monitoring locations.

All groundwater monitoring rounds have detected high levels of coliforms within samples collected from each sampling location GW01 – GW03. Concentrations of total coliforms are reported within a range between 698 cfu/ml to 2,420 cfu/ml with the highest concentrations recorded at upgradient borehole GW01.

The combined presence of elevated ammonia and coliform concentrations in all monitoring wells may also be evidence of localised contamination due to agricultural land spreading or poorly functioning septic tanks.

The detection of elevated lead concentrations ranging from 0.136 mg/l to 0.278 mg/l across all monitoring locations is considered to be evidence of the localised groundwater hydrochemistry based on the presence of historical lead mining in the north Monaghan region. Reference is made to a number of small metallic mineral deposits located in the County Monaghan area detailed in the EPA's Historic Mine Sites - Inventory and Risk Classification (2009).

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 gravels derived from those parent materials, which the Killycronaghan site is founded on. Similar to the naturally occurring lead levels in groundwater, the barium concentrations detected across all monitoring locations is considered to be evidence of the localised groundwater hydrochemistry.

The slightly elevated iron concentration of 0.547 mg/l at borehole GW01 and elevated manganese concentrations ranging from 0.0516 mg/l to 0.406 mg/l across all monitoring wells are considered to be typical of the local bedrock hydrochemistry. However, the iron concentration of 3.47 mg/l detected in upgradient borehole GW02 is 17-times the groundwater threshold value and is therefore considered to be a result of leachate migration from the waste body.

The elevated phosphorus and potassium concentrations of 0.91 mg/l and 17.7 mg/l detected in downgradient borehole GW03 exceeds guideline threshold values. The significant concentration difference between the upgradient and downgradient monitoring locations suggests that the waste body is contributing to the increased phosphorus and potassium concentrations in the downstream groundwater quality.

Elevated alkalinity (CaCO3) is consistent across all three sampling locations. The alkaline groundwater quality within the range 291 mg/l to 421 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.

Based on the presence of elevated ammonia and dissolved metal 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 therefore contributing to leachate migration from the landfill.

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 3.1. In accordance with the EPA CoP, methane, carbon dioxide, oxygen and atmospheric pressure were analysed at the 3 No. groundwater monitoring wells located outside 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 perimeter borehole are summarised in Table 4.4.

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

Date: 1-10-2018						
Sample Station	CH_4 (% v/v)	CO_2 (% v/v)	O_2 (% v/v)	Atmospheric Pressure (mbar)	Staff Member	Weather
GW01	0.1	0.2	21.6	1028	Daniel Hayden	Cloudy with light wind N-NE, 12°C - 14°C
GW02	0.2	0.7	21.1	1028		
GW03	0.2	0.1	23.8	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	0.1	0.2	22.6	1005	Daniel Hayden	Cloudy with light wind N - NE, 14°C - 16°C
GW02	0.1	0.5	22.4	1005		
GW03	0.1	0.3	21.9	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 below the threshold values set by the CoP during both monitoring rounds.

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 Magheramy river to the west of the landfill. Monitoring location SW2 is located along the western side of the landfill and samples the furthest downstream point of the Kilgormly river before it joins the Magheramy river. Locations SW3 and SW4 are located along the eastern side of the landfill and were selected to sample the Kilgormly river upstream of the landfill.

Two surface water monitoring rounds were carried out on the 1st October and 9th October 2018. The surface water sampling locations at the site are presented in Figure 4.2.

4.5.2 Monitoring Parameters

The results of surface water sampling analysed from the 4 No. sampling locations (SW1 – SW4) 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]	1st – 9th October 2018			
			SW1	SW2	SW3	SW4
pH (Laboratory)	pH Units	6.0<pH<9.0[2]	8.06	8.05	7.78	8.07
Dissolved Oxygen	mg/l	<9 – 6 [1]	9.9	9.88	9.64	9.88
Conductivity	µS/cm	1 [1]	0.466	0.456	0.290	0.281
BOD, unfiltered	mg/l	≤2.6 (95%ile)[2]	2.12	2.18	<1	<1
COD, unfiltered	mg/l	40 [1]	29.9	28.5	28.1	25.3
Sulphate	mg/l	200 [1]	6.47	6.4	3.07	2.7
Chloride	mg/l	250 [1]	21	19.9	19.6	19.7
Ammoniacal Nitrogen as N	mg/l	≤0.140(95%ile) [2]	**0.258**	<0.2	<0.2	<0.2
Potassium	mg/l	--	5.58	6.87	6.62	5.39
Sodium	mg/l	200 [1]	13.5	12.6	14.3	12.9

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 – SW4 show 1 No. exceedances of the EQS (2009) guideline limit values for ammonia. Results from sampling location SW1 detected an ammonia concentration of 0.258 mg/l. The presence of ammonia at these levels may be an indication of slurry spreading runoff from the surrounding agricultural fields in the area, rather than direct impact from the landfill.

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\Knockcronaghan Landfill\P1724_Fig4-2_SurfaceWaterSampling_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

- Surface Water Sampling Locations
- Rivers
- Site Boundary

Figure Title	Surface Water Sampling
Figure No.	4.2
Project	ERA of Historic Landfill at Knockcronaghan, Co. Monaghan
Client	Monaghan County Council
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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 Killycronaghan 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 Killycronaghan 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.