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Fassaroe Historic Landfills

Environmental Risk Assessment

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1 INTRODUCTION

In 2017, RPS was appointed by Wicklow County Council to carry out an Environmental Risk Assessment (ERA) for the historic landfills located at Fassaroe, Co. Wicklow. The site, hereinafter referred to as the Fassaroe Site is show in **Figure 1**. An ERA is required in support of the application for a Certificate of Authorisation from the Environment Protection Agency (EPA) in relation to the historic landfill sites, as descried in the Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulations 2008 (S.I. No. 524 of 2008). The ERA and this report has been completed in accordance with the EPA Code of Practice for Unregulated Waste Disposal Sites, 2007, hereinafter referred to as the EPA Code of Practice. A detailed site investigation and associated programme of environmental monitoring was undertaken on the Site between November 2015 and March 2018, following the completion of desk based risk assessment as outlined in the EPA Code of Practice.

1.1 BACKGROUND

Five historic unregulated landfills (Site 1, Site 2, Site 3B, Site 3A and Site 3C) are located on the Fassaroe Site, which is currently allocated for future development as a mixed development area. Before the Fassaroe site can be developed a Certificate of Authorisation is required from the EPA that addresses the legacy contamination issues associated with the five historical landfill sites. The landfill sites on the Fassaroe site are currently in the ownership of Cosgrave Developments at Fassaroe, Co. Wicklow.

From a review of the register compiled in accordance with Section 22 of the Waste Management Act 1996 as amended (the Act) and presented in the Eastern Midlands Region Waste Management Plan 2015 – 2021, Wicklow County Council (WCC) have registered four Historic Unregulated Local Authority Landfills located within lands on the Fassaroe Site as shown in **Table 1.1**.

Table 1.1 - Section 22 Register

Site ID	Local Authority	Site Name	Risk Rating
S22-02639	Wicklow County Council	Fassaroe No.2	B (Moderate Risk)
S22-02633	Wicklow County Council	Fassaroe No. 3A	A (High Risk)
S22-02635	Wicklow County Council	Fassaroe No. 3B	C (Low Risk)
S22-02637	Wicklow County Council	Fassaroe No. 3C	A (High Risk)

Source: Eastern Midlands Region Waste Management Plan 2015-2021

An additional historic landfill (Site 1) is also located within Cosgrave Development's ownership (see **Figure 1** below) with reference made to such in WCC's report entitled 'Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)' which states:

Between the early-1970s and the mid-1990s, Wicklow County Council operated a number of municipal landfills in the Fassaroe area, to the west of Bray, in north County Wicklow. Four landfills were sited on the northern side of Berrysfield Lane with a fifth small landfill located to the south of the road.

Tier 1 Risk Assessments have been completed by WCC for four Local Authority sites in accordance with the requirements as set out under S.I. No. 524/2008 Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulations, 2008 (the Regulations) with the following risk rankings being applied:

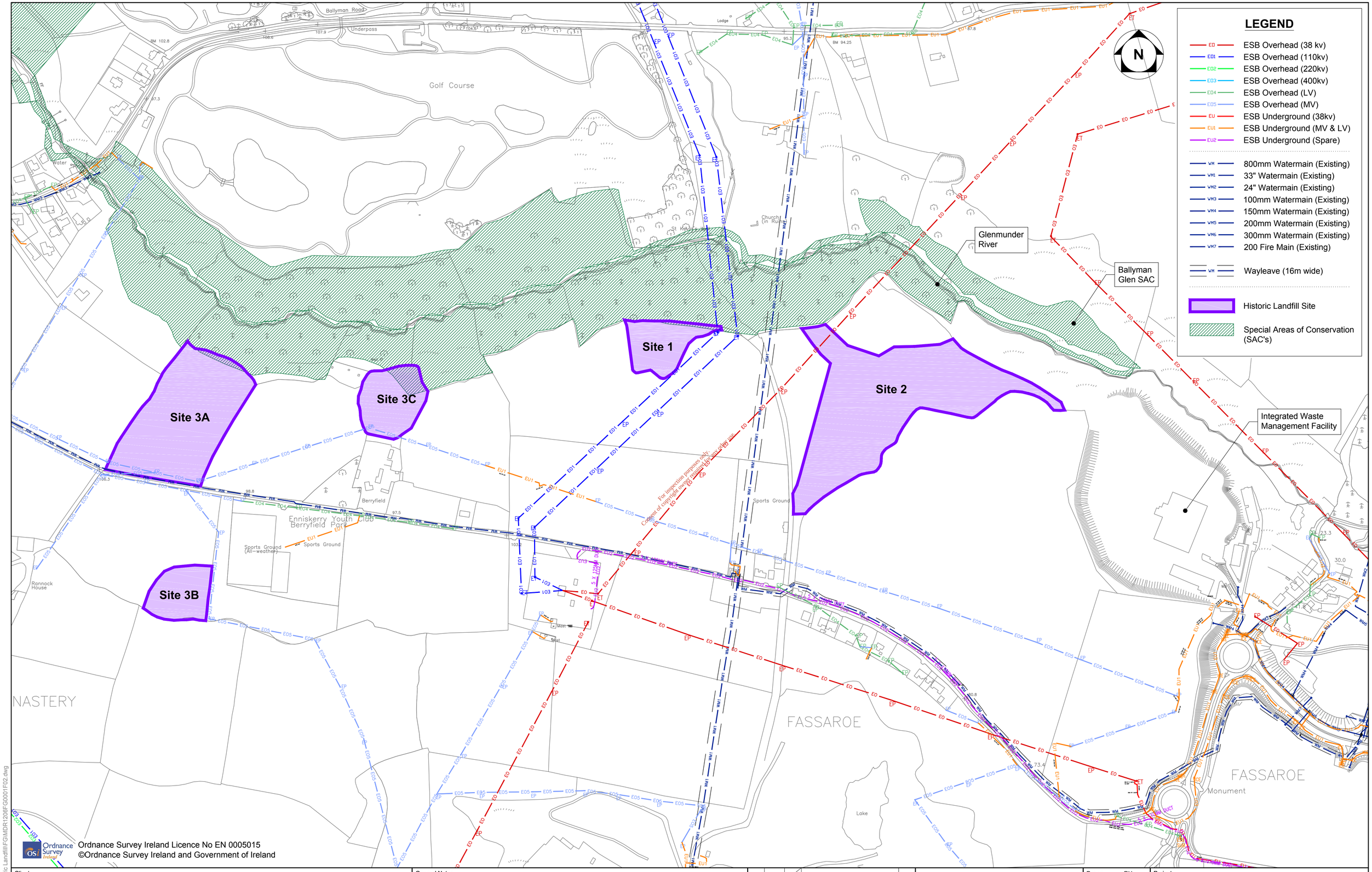
- Site 2 – Moderate Risk (B)
- Site 3A – High Risk (A)
- Site 3B – Low Risk (C)
- Site3C – High Risk (A)

Sites 3A and 3C have been investigated further (to Tier 2-3) by WCC and applications for Certification of Authorisation (COA) have been submitted to the EPA in accordance with the requirements as set out in the Regulations.

At the time of compiling this report, RPS is unaware of any investigations of Site 1 by WCC.

The following risk assessment has been carried out to examine the extent of the waste bodies and also to determine if they are causing a likely significant risk to the environment and human health.

The aim of the risk assessment is to provide an understanding of the potential risks associated with the waste detected at the sites and also provide recommendations and options for any remediation if required, having consideration of the proposed development.



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Client

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General Notes

(i) This drawing is the property of RPS Consulting Engineers, it is a confidential document and must not be copied, used, or its content divulged without prior written consent.

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No.	Date	Drn./Chk.	Amendment / Issue	App
F02	03.05.18	DM/LG	COA APPLICATION	CC
F01	May '16	RH/LD	FINAL ISSUE	CC

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Job No.	MDR1206

Project
FASSAROE HISTORIC LANDFILL

Title
PLAN SHOWING HISTORIC LANDFILL LOCATIONS, EXISTING SERVICES, WAYLEAVES & SAC's

File Ref. MDR1206FG0001F02.dwg | Drg. No. Figure 1 | Rev. F02

1.2 OBJECTIVES

The principal objective of the ERA is to assess the potential risk that waste deposited at the five landfill sites currently poses to human or environmental receptors. On the basis of this assessment a Remediation Options Appraisal (ROA) that conforms to the EPA Code of Practice shall be provided. The document provides a Generic and Detailed Quantitative Risk Assessment (GQRA & DQRA) which integrates relevant data obtained from the recent site investigations and associated programme of environmental. The objectives ERA include the following:

- Determination of the nature and extent of the waste mass at each landfill site;
- Provision of information to assess the significance of active pollutant (Source-Pathway-Receptor) linkages present at each landfill site;
- Provision of an initial GQRA, followed by a DQRA using best practice modelling techniques in respect to contaminant transport and human health if required;
- Provision of a final, detailed Conceptual Site Model (CSM) for each landfill site;
- An evaluation of the contamination status of the site and immediate environs that can be used to inform the requirements of Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulations 2008 (Statutory Instrument No. 524 of 2008) and the EPA Code of Practice; and
- Provide an outline assessment of Remediation Options for managing risks identified with respect to the five landfill sites in advance of any future development.

1.3 OVERALL METHODOLOGY

In order to achieve the above objectives the following scope of work was undertaken:

- Desk based survey and site walkover including collation of information from Wicklow County Council (WCC), Atkins and Muir Associates;
- Development and subsequent refinement of a CSM based on available information;
- Design and implementation of an exploratory soil and water site investigation in accordance with BS 10175:2011+A1:2013 and BS 5930:2015;
- Design and delivery of programme of environmental monitoring between November 2015 and March 2018 to provide a time series dataset to inform the CSM and baseline characterisation of the hydrogeological system;
- Assessment of risks to human and environmental receptors in accordance with the EPA Code of Practice;
- Production of a Remediation Options Appraisal (ROA); and
- Preparation of a report in accordance with Chapter 8 “Reporting Requirements” in the EPA Code of Practice.

1.4 RISK ASSESSMENT APPROACH

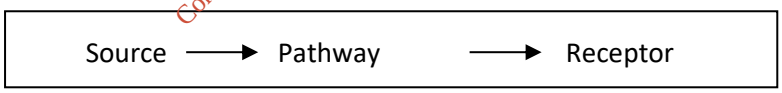
This assessment has been carried out in accordance with the EPA Code of Practice (EPA, 2007). The consideration of the impact of the historical landfill sites may have on the environment and human health is based on a risk assessment of active pollutant 'Source–Pathway–Receptor (SPR)' linkages defined from the CSM for each landfill site, where the probability of impact by the landfill sites is considered in the context of the severity of consequence of that event actually happening. The pollutant (SPR) linkage approach underpins the EPA Code of Practice.

The assessment looks at the relationship of possible contamination of the environment (*i.e.* the surroundings and habitats) and of a range of receptors (such as humans, flora, fauna, groundwater and ecological systems) to develop a conceptual understanding of what is occurring. Aspects of the source material and impacts on the receptors are identified and measured as part of a characterisation process. This in turn facilitates the development of environmental engineering design controls to manage, mitigate, protect, and/or remediate the site.

The principal sources of contamination from landfilled waste are liquid leachate and landfill gas generated through the decomposition of the waste mass. The type of waste is characterised in order to determine the potential magnitude of risk posed to surface water and groundwater receptors.

An assessment of the potential for landfill gas generation as a contaminant source is also a requirement and its rate of gas generation and potential for migration needs to be considered. This assessment is undertaken in accordance with the Code of Practice.

The relationship between the discrete **source** of the contamination (*i.e.* waste material) and the receiving environment known as the **receptor** (*e.g.* surface water or groundwater) is considered. The connecting route, known as the **pathway** (groundwater flow, drainage systems and soil systems) and the driving force in the form of a fluid (*i.e.* liquid in the form of rainfall and leachate) can induce contamination to move through the system. Thus the system can be summarised by the following:



Source: Substance or material that has the potential to cause harm to the environment or human health by virtue of its physical or chemical characteristics.

Pathway: Historical, current or possible future mechanism by which the receptor can be exposed to the source.

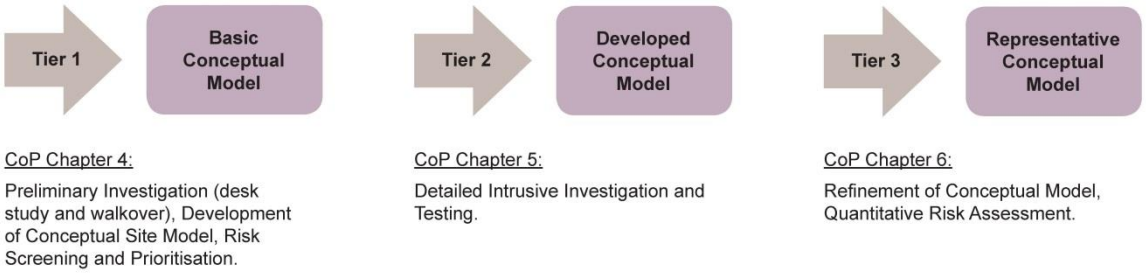
Receptor: A human or environmental entity which has the potential to be harmed through direct or indirect exposure to the source.

In the EPA Code of Practice pollutant (SPR) linkage approach to risk assessment, all three elements have to be present and linked in order for a risk to be present. If any of these components is absent there is, by definition, no risk.

The EPA Code of Practice utilises a structured phased approach to identify the SPR components and conduct a risk assessment of the linkages between the elements. The process involves preliminary

site investigations and initial screening to indicate the range of high to low risk factors. Areas requiring further investigation are identified, and finally the model is refined. At each stage the information and risks are reviewed and assessed before progressing to the next phase.

The Code of Practice tiered methodology is as follows:



Assumptions and uncertainties in the development of a conceptual model must be identified and clearly expressed to ensure that the degree of representation is understood before evaluation can meaningfully take place. The tiered technique of risk assessment within the Code of Practice seeks to minimise gaps in characterising each of the components within the SPR framework, so that at each stage the conceptual model is refined and uncertainties are reduced. Accordingly, the extent of information and data available at each stage of the model development is incorporated within each individual section of the assessment for individual tiers.

1.5 REPORT LIMITATIONS AND CONDITIONS

The findings and opinions provided in this document are given in good faith and are subject to the limitations and constraints imposed by the information sources described in this report.

Where comments and opinions have been provided based on ground investigation works and reports carried out by a third party, RPS can accept no liability for the accuracy or reliability of such information.

Any figure or opinion on the possible configuration of strata, contamination or other spatially variable features between or beyond investigation positions is conjectural and given for guidance only.

Evaluation of groundwater is based on observations made at the time of the investigation, or subsequently. It should be noted that groundwater levels and quality may however vary because of seasonal and other effects.

All new monitoring borehole locations were installed on lands within the ownership of Cosgrave Developments which combined with access/slope stability constraints restricted the siting and availability of down gradient groundwater monitoring locations. The constraints on the installation of down gradient monitoring boreholes, have however been mitigated through the monitoring of springs within the river valley.

Historic boreholes are in existence across Sites 1 and 2 however borehole logs were not available therefore the integrity of existing monitoring infrastructure could not be established and were not utilised during the monitoring regime.

It is understood that specialist ecological surveys and associated assessments are to be collated under separate contract and are excluded from the scope of this report.

The duration of gas monitoring was limited due to restrictions in contract timeline.

1.6 REPORT FORMAT

The environmental risk assessment report is presented in accordance with the following format:

- Section 2: Previous Site Investigations
- Section 3: Tier 1 - Preliminary Investigation and Risk Screening
- Section 4: Tier 2 - Site Investigation and Testing
- Section 5: Tier 3 - Refinement of CSM and Quantitative Risk Assessment
  - Section 5.1 - Refinement of CSM
  - Section 5.3 - Refinement of Risk Screening & Prioritisation
- Section 6: Tier 3 Quantitative Risk Assessment
  - Section 6.1 - Generic Quantified Risk Assessment (Landfill Gas, Human Health and Water Environment)
  - Section 6.2 - Detailed Quantified Water Environment Risk Assessment
- Section 7 - Remediation Options Appraisal
- Section 8 - Conclusions

2 PREVIOUS SITE INVESTIGATION

The following historic investigative reports were provided by the current land owner of the Fassaroe Site (Cosgrave Developments) and were reviewed as part of the Tier 1 desk study and associated risk screening and prioritisation. Relevant summary information has been provided on a site by site basis.

- Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013);
- Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services, April 2013;
- Fassaroe Business Park Geotechnical Interpretative Report – Atkins McCarthy, July 2001;
- Fassaroe Historic Landfill Environmental Risk Assessment – Atkins, June 2010;
- Fassaroe AGS and Excel ground investigation data (IGSL and Glovers logs) received from Atkins on the 19th of October 2015;
- Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998;

2.1 SITE 1

The following information was provided by Atkins with respect to ground investigations within the vicinity of Site 1;

- Fassaroe Business Park Geotechnical Interpretative Report – Atkins McCarthy, July 2001;
- Fassaroe Historic Landfill Environmental Risk Assessment – Atkins, June 2010;
- Fassaroe AGS and Excel ground investigation data (IGSL and Glovers logs) received from Atkins on the 19th of October 2015.

A total of 5 No. trial pits were excavated within Site 1, ranging in depth from 1.80 metres below ground level (mbgl) to 4.00mbgl with base of waste encountered (1.20mbgl) in TP094 only. The general description of the waste encountered appears to correspond with anecdotal evidence that this was a construction and demolition (C&D) waste disposal facility, however it should be noted that TPB36 documented the presence of domestic waste. The European Commission defines C&D waste as consisting of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil.
(http://ec.europa.eu/environment/waste/construction_demolition.htm).

Table 2.1 - Site 1: Historic Site Investigation Data

ID	Depth (m)	Base of waste (m)	Waste Type
TPB36	1.80	>1.80	**Domestic** waste in clay matrix
TP092	4.00	>4.00	Plastic, glass, metal, concrete blocks, tyres, brick, wood
TP093	2.90	>2.90	Metal, plastic piping, concrete blocks, reinforced concrete, glass
TP094	3.60	1.20	Plastic, glass, ceramics, metal,

Source: Atkins, 2010

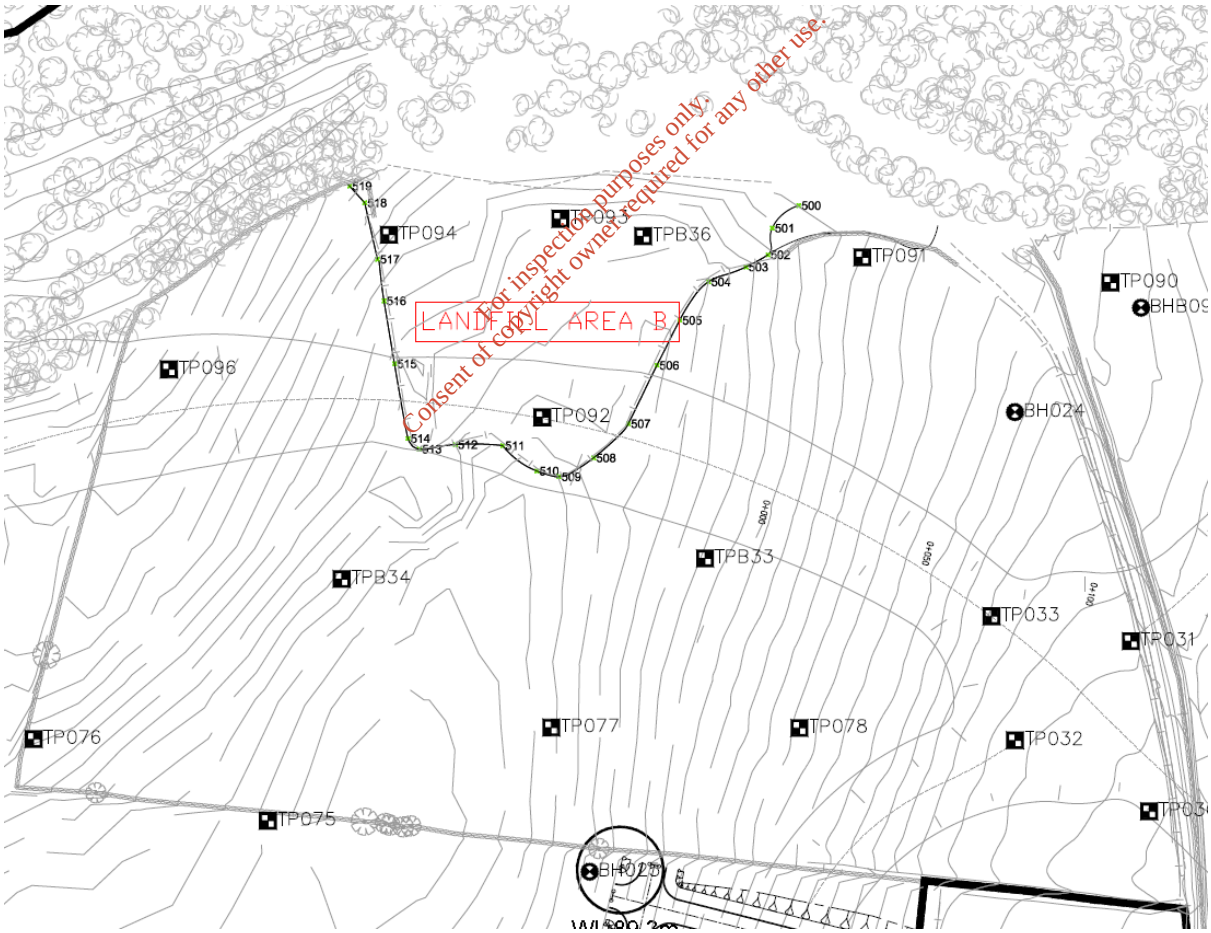
Paragraph 6 of the Atkins Report '*Fassaroe Historic Landfill Environmental Risk Assessment, June 2010*' confirms that no sampling was conducted on Site 1.

Available intrusive data suggests the site comprises C&D waste however reference to the presence of domestic waste in TPB36 and the lack of available data to confirm the vertical and lateral extent of the waste body would raise some uncertainty on the overall classification/characterisation of the waste body.

It should also be noted that to RPS's knowledge no environmental monitoring (i.e. gas, leachate, groundwater or surface water) has been completed within Site 1, which leads to uncertainty in determining the intrinsic risk posed to receptors (i.e. human health or environmental).

Site 1 is located adjacent to the Ballyman Glen Special Area of Conservation (SAC) (Site Code: 000713). Due to the lack of environmental monitoring data and the fact that an Appropriate Assessment Screening (Stage 1) has not been completed, the potential risk posed to the SAC cannot be adequately determined at this time.

Figure 2 Site 1: Historic SI Locations (Atkins)



Source: Extract from Atkins Drawing 1739GE001 Site Investigation Borehole and Trial Pit Locations.
Note Site 1 equates to 'Landfill Area B'

2.2 SITE 2

The following information was compiled by Muir Associates and provided by Cosgrave Developments:

- Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998.

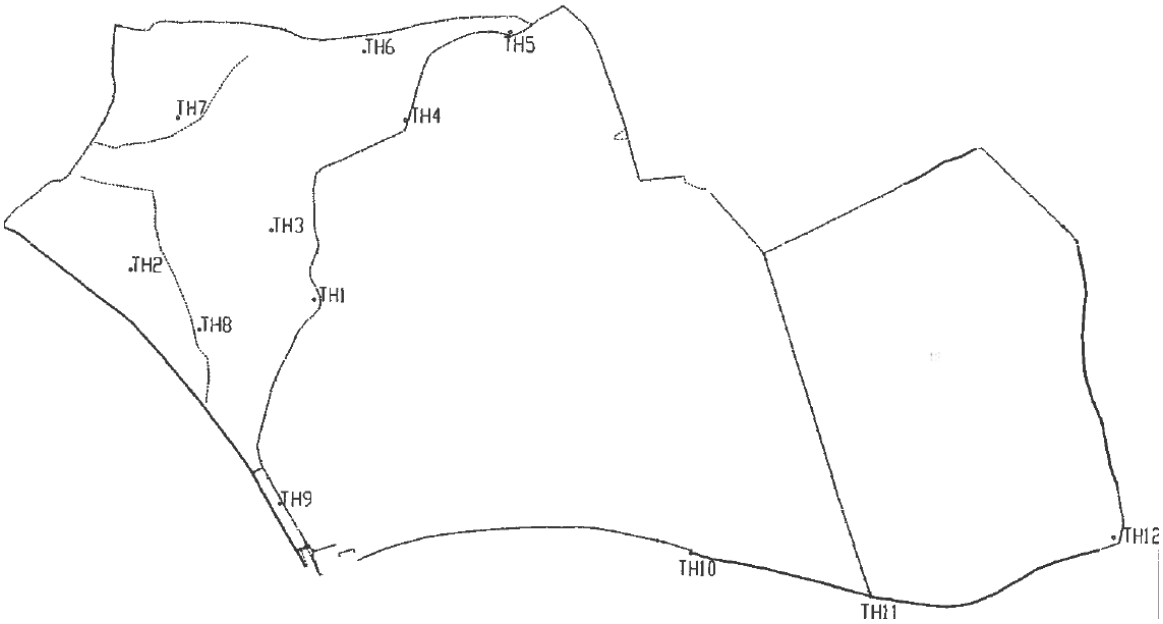
As part of the environmental evaluation of Site 2, Muir Associates supervised the excavation of 9 No. trial pits within the vicinity of Site 2 and 3 no. within the surrounding environs. The trial pits varied in depth from 2.70mbgl to 4.80mbgl.

Table 2.2 - Site 2: Historic Site Investigation Data

ID	Depth (m)	Base of waste (m)	Waste Type
TH1	2.90	1.30	Domestic waste including plastic bags and bottles
TH2*	2.70	-	No waste encountered
TH3	3.60	>3.60	Domestic waste including plastic bags, bottles, concrete, fabric, timber, waving piping and newspaper
TH4	4.30	1.50	Domestic waste including plastic bags
TH5	4.80	1.30	Domestic waste including plastic bags, bottles, concrete
TH6	3.10	>3.10	Domestic waste including plastic bags and bottles
TH7*	3.40	-	No waste encountered
TH8	3.40	>3.40	Domestic waste including plastic bags, bottles and tins
TH9	3.30	-	No waste encountered (MADEGROUND hardcore fill noted)
TH10*	3.30	-	No waste encountered (MADEGROUND hardcore fill noted)
TH11*	3.50	-	No waste encountered
TH12*	3.60	-	No waste encountered

Source: Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998; * Outside landfill boundary

Figure 3 Site 2: Historic SI Locations (Muir Associates, 1998)



Source: Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998

The report also noted the presence of waste outside the area delineated as landfill which raised some doubt regarding the lateral extent of the waste body.

A total of 8 No samples were taken from the trial pits (Samples were taken from trial pits 2, 3, 4, 6, 7, 9, 10 and 12) and analysed for the Interdepartmental Committee of the Redevelopment of Contaminated Land (ICRCL Guidance Note 59/83, Second Edition, 1987) suite. Elevated levels (above threshold vales) of copper, nickel, lead, arsenic, cadmium, zinc and phenols were recorded in samples taken from within waste. Elevated levels of arsenic (above target value for action) were noted outside the waste body (TH10).

Gas monitoring (for methane only) was completed at trial pits 1-8 inclusive and recorded elevated methane concentrations across the site however it should be noted that no gas pressure or flow analysis was conducted. These results are indicative of the presence of methane only and should not be interrogated further as they were atmospheric concentrations recorded at open pits and are therefore not considered to be representative of the potential gas characteristics of the site.

Two surface water samples were also taken (at “upstream” and “downstream” locations) which indicated that there was no discernible impact associated with the waste body at the time of monitoring.

The report recommended further investigations to determine the depth of waste, type of subsoil, depth to groundwater, groundwater quality, groundwater flow and gas levels (flow and migration).

The following information was provided by Atkins with respect to ground investigations within the vicinity of Site 2:

- Fassaroe Business Park Geotechnical Interpretative Report – Atkins McCarthy, July 2001;
- Fassaroe Historic Landfill Environmental Risk Assessment – Atkins, June 2010; and
- Fassaroe AGS and Excel ground investigation data (IGSL and Glovers logs) received from Atkins on the 19th of October 2015.

A total of 16 No. trial pits and 8 No. boreholes were completed within Site 2. The trial pits varied in depth from 2.90mbgl to 5.00mbgl with base of waste encountered within five of the trial pits for which records are available. Base of waste, at a depth which averaged c.1.3m, was determined in those trial pits located along the lateral extent of the waste body.

Available records suggest the waste type is municipal, which corresponds with information provided by WCC.

It should be noted that no waste characterisation has been conducted therefore the presence/absence of hazardous material has not been determined.

A total of 20 No. samples were recovered from the Atkins McCarthy ground investigation and analysed for the suite as set out in the ICRCL guidance. The principal contaminants noted were heavy metals, sulphides and phenols.

It should be noted that no analysis for Asbestos Containing Material (ACM) was completed at the site.

Atkins and City Analysts also completed environmental monitoring at the site in May 2010. It should be noted that no groundwater monitoring was completed during this monitoring event. The presence of leachate was confirmed within three boreholes (located to the south of the site) however the results should be considered with caution as the integrity of the boreholes cannot be determined due to the lack of information regarding installation details. The leachate samples were analysed for a range of contaminants based on the EPA Leachate Characterisation Suite 2003 however it should be noted that no analysis for trace organic substances was completed.

Results indicated that the leachate is of moderate strength. Parameters of typical note are ammonia, iron, boron, manganese and lead.

Table 2.3 - Site 2: Historic Site Investigation Data (Atkins, 2001)

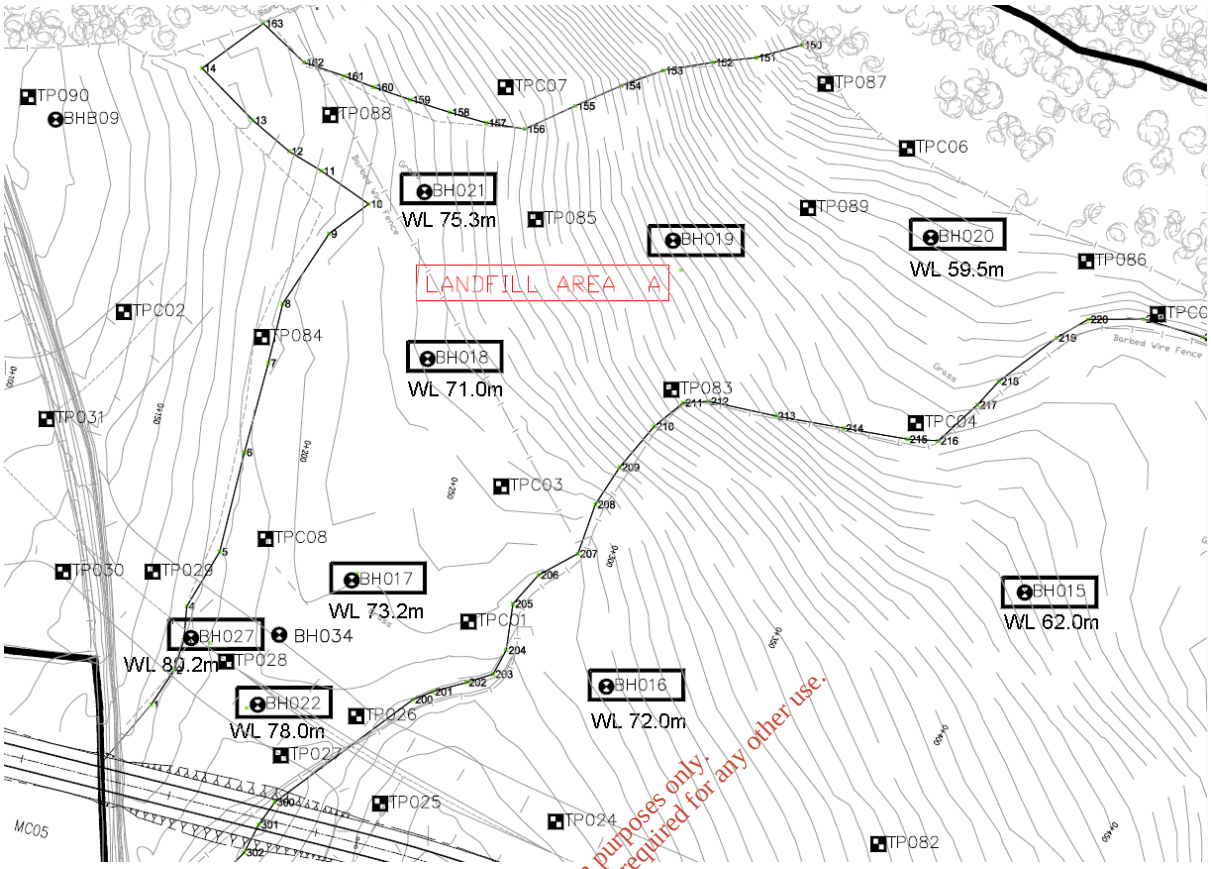
ID	Depth (m)	Base of waste (m)	Waste Type
TPC01	2.90	1.10	Domestic waste
TPC03	3.60	>3.60	Plastic, wood, concrete, domestic waste
TPC04	4.30	1.50	MADE GROUND – some plastic found at 1.50m
TPC05	5.00	1.30	Concrete, paper
TPC06	3.10	>3.10	Domestic waste
TPC08	3.40	1.20	Plastic, domestic waste
TP026	No Data Available		
TP027	No Data Available		
TP028	3.30	>3.30	Plastic, material, glass, paper, concrete
TP083	3.30	>3.30	Plastic, glass, paper, wood
TP084	3.50	-	CLAY – no waste encountered
TP085	3.60	>3.60	Plastic, wood, newspaper, metal, glass, brick, concrete blocks
TP086	3.20	>3.20	Plastic, metal, wood, concrete blocks, textiles, glass
TP087	3.60	-	MADE GROUND – no waste encountered
TP088	3.60	>3.60	Plastic, metal, glass, rubble
TP089	3.20	>3.20	Plastic, material, paper, glass, wood, metal
BH017	Gas Monitoring Borehole (323878.6 : 218469.2) – No Data Available		
BH018	Gas Monitoring Borehole (323819.8 : 218476.9) – No Data Available		
BH019	Gas Monitoring Borehole (323656.1 : 218386.3)– No Data Available		
BH020	Gas Monitoring Borehole (323529.7 : 218249.6)– No Data Available		
BH021	Gas Monitoring Borehole (323541.9 : 217759.7) – No Data Available		
BH022	Gas Monitoring Borehole – No Data Available		
BH027	Gas Monitoring Borehole – No Data Available		
BH034	No Data Available		

Source: Atkins

Gas monitoring was also completed by Atkins and City Analysts in May 2010 with elevated concentrations of methane (max. 74% v/v) and carbon dioxide (max. 27% v/v) being recorded across the site. Vegetation die back was also noted across the site which is suggestive of the presence of vertical fugitive gas emissions.

The gas monitoring results should also be interpreted with caution due to the lack of information regarding the integrity of the monitoring boreholes, coupled with the lack of gas valves at monitoring locations (with boreholes passively venting prior to monitoring).

Figure 4 Site 2: Historic SI Locations



Source: Extract from Atkins Drawing 1739GE001 Site Investigation Borehole and Trial Pit Locations.
Note Landfill Area A equates to Site 2

2.3 SITE 3A

The following information was provided by WCC with respect to ground investigations and environmental monitoring within the vicinity of Site 3A:

- Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013); and
- Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services, April 2013.

WCC completed a Tier 2 investigation of Site 3A in 2012 which comprised 12 No. trial pits and 2 No. boreholes (MW3 and MW4). Municipal waste was encountered in all trial pits excavated at Site 3A and base of waste was not encountered.

Table 2.4 - Site 3A: Historic Site Investigation Data – Trial Pits (WCC, 2013)

Trial Pit	Topsoil Depth (m)	Clay/Capping Depth (m)	Waste Depth (m)	Waste Thickness (m)	Waste Type	% by volume waste (visual)
A1	0.70	0.70-3.10	3.10-6.00	>2.90	Domestic	30-40
A2	0.30	0.30-0.60	0.60-6.00	>5.40	Domestic	65-85
A3	0.20	0.20-0.80	0.80-3.00	>2.20	Domestic	70-80
A4	0.30	0.30-2.50	2.50-6.00	>3.50	Domestic	40
A5	0.30	0.30-0.70	0.70-6.00	>5.30	Domestic	50
A6	0.25	0.25-0.55	0.55-5.00	>4.45	Domestic	30
A7	0.30	0.30-1.50	1.50-6.00	>4.50	Domestic	60-70
A8	0.30	0.30-3.00	3.00-6.00	>3.00	Domestic	30-40
A9	0.30	0.30-1.30	1.30-5.50	>4.20	Domestic	70-80
A10	0.20	0.20-0.45	0.45-5.50	>5.05	Domestic	70-80
A11	0.40	0.40-2.50	2.50-5.00	>2.50	Domestic	60-70
A12	0.35	0.35-3.80	3.80-6.00	>2.20	Domestic	30-40

Source: Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

Boreholes MW3 and MW4 included the installation of gas monitoring standpipes within the waste body. MW3 also included a groundwater monitoring standpipe installed within the gravels beneath the waste body.

No up-gradient or down-gradient groundwater monitoring boreholes are known to have been installed at the site.

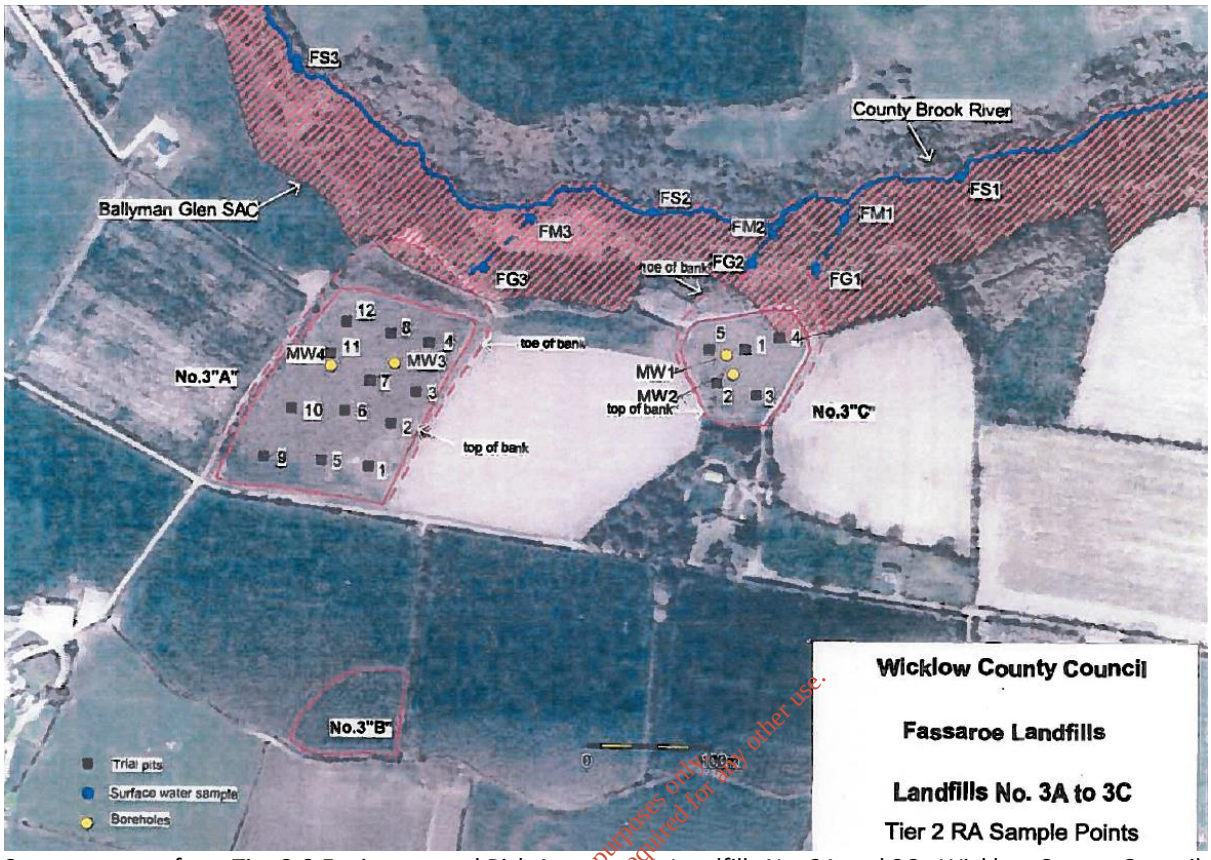
Table 2.5 - Site 3A: Historic Site Investigation Data – Boreholes (WCC, 2013)

Borehole	Topsoil Depth (m)	Clay/Capping Depth (m)	Waste Depth (m)	Borehole Total Depth (m)	Waste Thickness (m)	Waste Type
MW3	0.10	0.10-2.50	2.50-11.90	17.70	9.40	MSW
MW4	0.10	0.10-1.85	1.85-10.50	13.30	8.65	MSW

Source: Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

A number of springs and drains were identified within the vicinity of Site 3A. The springs/drains were sampled by WCC along with upstream and downstream monitoring locations on the County Brook River. The WCC report concluded that Site 3A was contributing elevated levels of ammonia and manganese to the surface water drainage network, however due to the assimilative capacity of the County Brook River it was considered that there is no adverse impact on the water quality within the river.

Figure 5 Site 3A & 3C: Historic SI locations



Source: extract from Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

Gas monitoring was completed at the 2 No. boreholes installed on the site in September and November 2012. Elevated concentrations of methane, ranging from 46.7%v/v to 67.4%v/v, and carbon dioxide, ranging from 17.2%v/v to 35.3% v/v were recorded. Vegetation die back was noted across the site which is suggestive of vertical fugitive gas emissions.

No perimeter and/or off site gas monitoring boreholes have been installed at the site therefore the potential for lateral gas migration has not been assessed.

2.4 SITE 3B

The following information was provided by WCC with respect to ground investigations and environmental monitoring within the vicinity of Site 3B:

- Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013); and
- Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services, April 2013.

As part of the Tier 2 investigation of Sites 3A and 3C, WCC excavated 2 No. trial pits within Site 3B which confirmed the presence of municipal waste in excess of 4.00m.

Table 2.6 - Site 3B: Historic Site Investigation Data (WCC, 2013)

Trial Pit	Topsoil Depth (m)	Clay/Capping Depth (m)	Waste Depth (m)	Waste Thickness (m)	Waste Type	% by volume waste (visual)
B1	0.40	0.40-1.00	1.00-5.00	>4.00	Domestic	50-60
B2	0.35	0.35-0.75	0.75-5.00	>4.25	Domestic	70-80

Source: Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

2.5 SITE 3C

The following information was provided by WCC with respect to ground investigations and environmental monitoring within the vicinity of Site 3C:

- Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013); and
- Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services, April 2013.

WCC completed a Tier 2 investigation of Site 3C in 2012 which comprised 5 No. trial pits and 2 No. boreholes (MW1 and MW2). Municipal waste was encountered in all trial pits excavated at Site 3C and base of waste was not encountered.

Table 2.7 - Site 3C: Historic Site Investigation Data – Trial Pits (WCC, 2013)

Trial Pit	Topsoil Depth (m)	Clay/Capping Depth (m)	Waste Depth (m)	Waste Thickness (m)	Waste Type	% by volume waste (visual)
C1	0.20	0.20-1.50	1.50-5.50	>4.00	Domestic	50
C2	0.40	0.40-1.20	1.20-5.50	>4.30	Domestic	70
C3	0.30	0.30-0.80	0.80-5.50	>4.70	Domestic	70-80
C4	0.40	0.40-1.50	1.50-5.50	>4.00	Domestic	60-70
C5	0.35	0.35-2.00	2.00-5.50	>3.50	Domestic	40

Source: Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

Boreholes MW1 and MW2 included the installation of gas/leachate monitoring standpipes within the waste body. No up-gradient or down-gradient groundwater monitoring boreholes have been installed at the site.

Table 2.8 - Site 3C: Historic Site Investigation Data – Boreholes (WCC, 2013)

Borehole	Topsoil Depth (m)	Clay/Capping Depth (m)	Waste Depth (m)	Borehole Total Depth (m)	Waste Thickness (m)	Waste Type
MW1	0.20	0.20-1.00	1.00-4.00	4.00	>4.00	MSW
MW2	0.10	0.10-1.25	1.25-5.40	8.10	4.15	MSW

Source: Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

Gas monitoring was completed at the 2 No. boreholes installed on the site in September and November 2012. Elevated concentrations of methane, ranging from 32.4%v/v to 67.7%v/v, and carbon dioxide, ranging from 17.8%v/v to 33.3% v/v were recorded. RPS is unaware of the availability of any flow data for Site 3C.

No perimeter and/or off site gas monitoring boreholes have been installed at the site therefore the potential for lateral gas migration has not been assessed.

3 TIER 1 – PRELIMINARY INVESTIGATION & RISK SCREENING

3.1 INFORMATION SOURCES

In accordance with the EPA Code of Practice a comprehensive desk study of existing data available for the sites and the surrounding area was conducted in completion of the Tier 1 Assessment. The Tier 1 Assessment also benefitted from previous site investigation data supplied by Atkins, Muir Associates and WCC. A comprehensive review of this information was completed as part of the Tier 1 Assessment.

The following sources of information were consulted as part of the desk study:

- Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013);
- Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services, April 2013;
- Fassaroe Business Park Geotechnical Interpretative Report – Atkins McCarthy, July 2001;
- Fassaroe Historic Landfill Environmental Risk Assessment – Atkins, June 2010;
- Fassaroe AGS and Excel ground investigation data (IGSL and Glovers logs) received from Atkins on the 19th of October 2015;
- Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998;
- Eastern Midlands Region Waste Management Plan 2015-2021;
- EPA Code of Practice – Environmental Risk Assessment for Unregulated Waste Disposal Sites (EPA, 2007);
- Geological Survey of Ireland online datasets;
- OSI Aerial Photography;
- National Parks and Wildlife Service (NPWS) online maps and data. Database of Special Areas of Conservation, National Heritage Areas, National Parks, Special Protection Areas including site synopsis reports;
- Ordnance Survey of Ireland (OSI) Discovery Series, Sheet 32:20/ 32:22; and
- Geology of Wicklow, Geological Survey of Ireland (GSI) datasets.

3.2 SITE DESCRIPTION

3.2.1 Site Location & Land-use

The five historical landfill sites are located in Fassaroe, Bray, Co. Wicklow immediately to the south of the Dublin/Wicklow county boundary. The sites are located to the west of the M11 motorway and are accessed from Berryfield Lane. A summary of the site location is provided in **Figure 1**.

The landfill sites are situated between Berryfield Lane and the County Brook River (Fassaroe Stream). The valley which is known as Ballyman Glen is designated a SAC (Site Code: 000713) designated on the basis of the following habitats and/or species listed on Annex I/II of the EU Habitats Directive: petrifying springs with tufa formation; and alkaline fens.

Berryfield Lane is characterised by one off housing developments in a predominantly agricultural setting. As shown in **Figure 1** a sports ground and associated facilities are located in lands immediately to the east of Site 3B.

An integrated waste management facility (EPA Ref. W0053-03) is located immediately to the east of Site 2. The licence is for the following operations: bulking of municipal solid waste prior to transfer off site for disposal, composting, wood shredding, processing/storage of dry recyclables, recovery of construction and demolition waste, acceptance of waste at a civic waste facility including acceptance of hazardous waste such as bonded asbestos waste, WEEE and chlorofluorocarbons.

A sand and gravel quarry is located to the south of Berryfield Lane which is operated by Roadstone Limited. The site also holds an EPA licence (W0269-01) for operation as a soil recovery facility comprising the following activities:

(i) the restoration of the sand and gravel quarry using soil and stones; and
(ii) the operation of a construction and demolition waste recycling operation.

A number of utilities/services are located within the vicinity of the existing landfills:

- An ESB 38kV overhead traverses the north west margin of Site 1;
- A twin 110kV overhead ESB pylon traverses the western margin of Site 1;
- A water main runs in a north south direction between Sites 1 and 2;
- A MV ESB overhead traverses the southern margins of Sites 3A and 3C; and
- A MV ESB overhead traverses the western margin of Site 3B.

3.2.2 Site Inspection

RPS carried out an initial site inspection on the on the 12th of October 2015. An understanding of the delineation of and the location of imported material was obtained and an opinion on the composition of the surface material was established.

Olfactory evidence of landfill gas was noted at Sites 3A and 3C. Vegetative die back was notable in Sites 2 and 3B with Sites 1, 3A and 3C showing notable signs of ground disturbance

Visible evidence of waste was noted in the northern margins of Site 2 where erosion has taken place on the slopes leading to the river valley.

In total 9 discrete springs were noted along the southern river bank of the County Brook River (Fassaroe Stream) between Site 1 and Site 3a. Spring 1 (see Plate 1) is located at the base of a steep embankment adjacent the river. The ground was soft underfoot, with clear signs of ochre staining and hydrocarbon sheening at surface. Plate 2 shows Spring 3, which is more typical of the springs within the SAC that emerge as diffuse flow from the wet embankments and coalesce into a small channel with distance downstream.

Emerging groundwater spring flows feed the tufa deposits and alkaline fen and therefore constitute a Groundwater Dependant Terrestrial Ecosystems (GWDTE) receptor as identified in the EPA Code of Practice and protected through the Water Framework Directive (WFD). An example of tufa deposits observed on the southern bank of the river is shown below in Plate 3.

Plate 1. Photograph of Spring 1 in October 2015 (SP1)

Plate 2.Photograph of Spring 3

Plate 3. Photograph of Tufa Deposit near river bank (off-white deposit in the centre of the picture)

3.2.3 Aerial Photographs

Aerial photography indicates that the Site 2 and 3A – 3C are grassed with evidence of vegetation die back. Site 1 consists of scrub and Gorse with some surface debris.

Figure 6 Aerial Photography

Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/ Airbus DS, USDA, USGS, AEX, Geomapping, Aerogrid, IGN, IGP, swisstopo and the GIS User Community

3.2.4 Historical Land Use

It is understood that Sites 1, 3A and 3C were previously operated as sand and gravel pits. Wicklow County Council's report entitled 'Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council', December 2012 (amended April 2013) states:

Between the early-1970s and the mid-1990s, Wicklow County Council operated a number of municipal landfills in the Fassaroe area, to the west of Bray, in north County Wicklow. Four landfills were sited on the northern side of Berrysfield Lane with a fifth small landfill located to the south of the road.

Available information regarding the volumes and types of waste deposited as well as the duration of filling have been taken from the EPA's Section 22 register and presented in **Table 3.1** below. Information has been provided for Sites 2, 3B and 3C only.

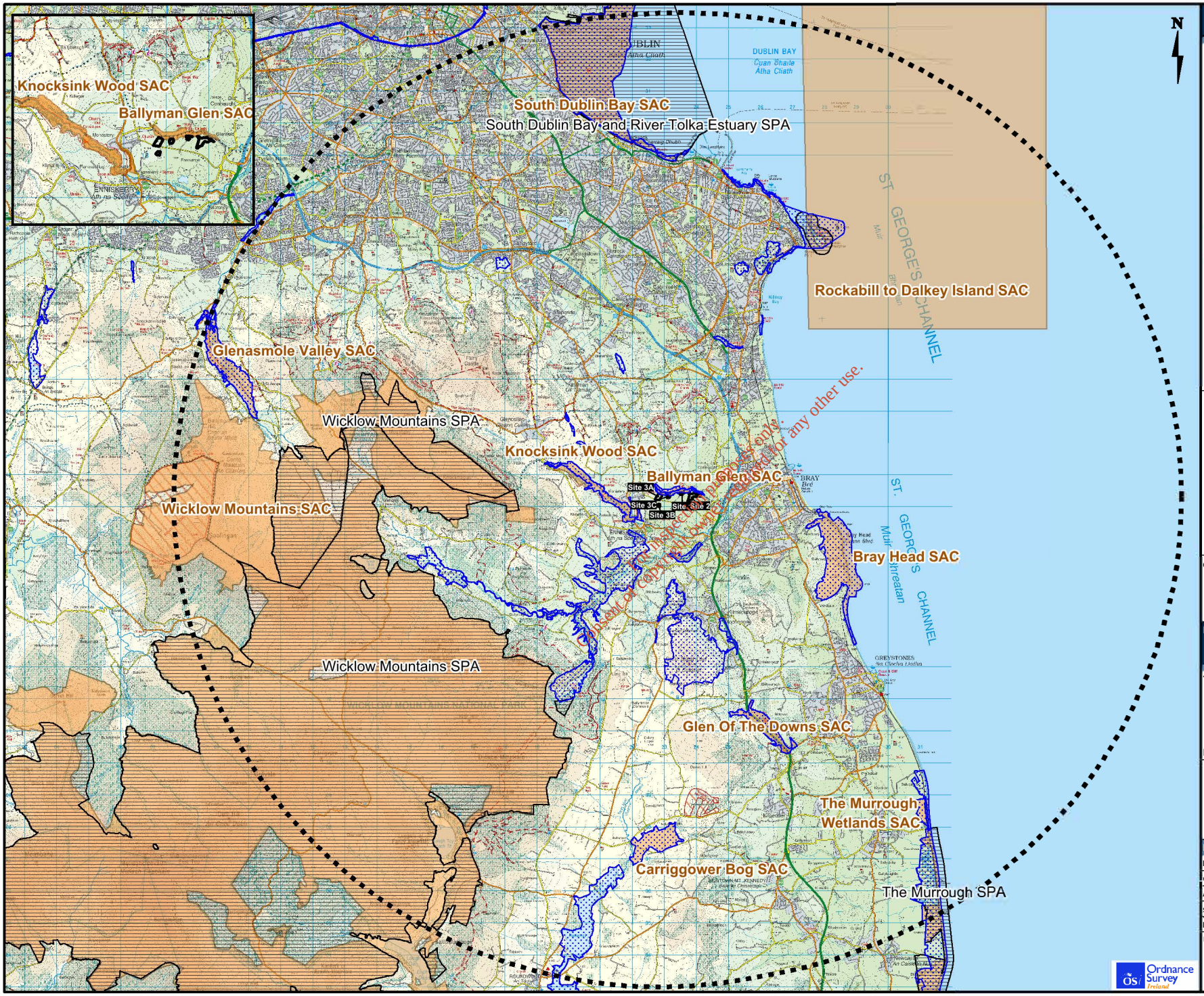
3.2.5 Local Sensitive Sites

Sites 1, 2, 3A and C are located adjacent to the Ballyman Glen SAC (Site Code: 000713) designated on the basis of petrifying springs with tufa formation and alkaline fens (see Appendix A for the site synopsis and **Figure 1** for site locations). The tufa deposits are not explicitly mapped within the SAC area, however numerous isolated instances of tufa deposits were noted along the southern banks of the County Brook River (Fassaroe Stream), typically associated with seepages from the bank.

Table 3.1 - Data from EPA Section 22 Register

Site Name	Waste Type	Hazardous Waste	Waste Quantity	Verification	Start Date	End Date	Holder of Waste	Site Owner
Fassaroe 2	Municipal	-	150,000	Local Knowledge	01/01/1979	31/12/1991	Wicklow Co Co	Cosgrave Bros
Fassaroe 3B	Municipal	-	9,000	Local Knowledge	01/01/1994	31/12/1995	Wicklow Co Co	Borg Developments
Fassaroe 3C	Municipal	-	30,000	Walk Over Survey	01/01/1992	31/12/1995	Wicklow Co Co	Borg Developments

Source: EPA



Legend

- Sites
- 15km Buffer
- Natural Heritage Areas (NHA/pNHA)
- Special Protection Areas (SPA)
- Special Areas of Conservation (SAC)

DATA SOURCE:
National Parks and Wildlife Service (NPWS).

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Project

Fassaroe Historic Landfill

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Designations within 15 km

Figure 7

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3.3 HYDROLOGY

3.3.1 Regional Hydrology

The northern site boundary is bordered along the County Brook River (Fassaroe Stream) (EPA Name: County Brook). County Brook River (Fassaroe Stream) flows eastwards into the Dargle River and flows into St. Georges Channel and into the Irish Sea. The Dargle River is a registered salmonid river under the Salmonid Regulations (S.I. 293). The Dargle River catchment forms part of the Eastern River Basin District.

Outside of the river valley, the Fassaroe site is underlain by thick permeable subsoil and as a result the surface water drainage density is low, with very few field drains in the area and no ponds or tributaries to the County Brook River (Fassaroe Stream). As such there is no formal drainage system connecting the land around the historical landfill sites and the County Brook River (Fassaroe Stream) or its associated drainage system within the valley.

Groundwater fed springs and seepages are evident in the riparian zone along the County Brook River. These springs feed the alkaline fen and tufa deposits. The spring flows are relatively small coalesce downstream to form a more defined channel.

3.3.2 Surface Water Quality

The Water Framework Directive (WFD) status of the County Brook River has been assigned as 'Good' in periods between 2007-2009 and 2010-2012. The EPA has previously completed river water quality monitoring both upstream and downstream of the site on the County Brook River (Fassaroe Stream) at Ballyman Road Bridge (Site No. RS10C060200) and Thornhill Road Bridge (No. RS10C060300) respectively.

3.4 GEOLOGY

3.4.1 Regional Bedrock Geology

The geology of the site is presented in **Figure 8** Bedrock Geology.

The site is underlain by bedrock of the Ordovician Maulin Formation which consists of dark blue-grey slate, phyllite & schist (Deep marine). The Glencullen River formation, consisting of namely tuff & greywacke bedrock is found to the south site of the site. These units are predominantly striking NE-SW with minor deviations in strike.

The metasediments of the Maulin and Glencullen River bedrock formations are thrust faulted against Cambrian metasediments (consisting of dominantly greywacke & quartzite rock) to the east and southeast of the site towards Bray. The rocks are highly folded and faulted as a result of several phases of deformation. The predominant structures in the region are primarily NE / SW trending normal faults with minor thrust faults and associated folding. These structures influence the overall hydrology and topography of the region in the area with river valleys following the structural features.

3.4.2 Regional Superficial Geology

The Fassaroe site is underlain by shallow, well drained mineral (mainly basic) soils (BminSW, (Teagasc, 2004).

The subsoils (Quaternary Geology units above the rock) at the site consist of glaciofluvial sands and gravels. According to the GSI, these sand and gravel deposits derived dominantly from Limestones make up the Fassaroe Delta. The site forms part of the Enniskerry delta, listed as an Irish Geological Heritage Site (WW020).

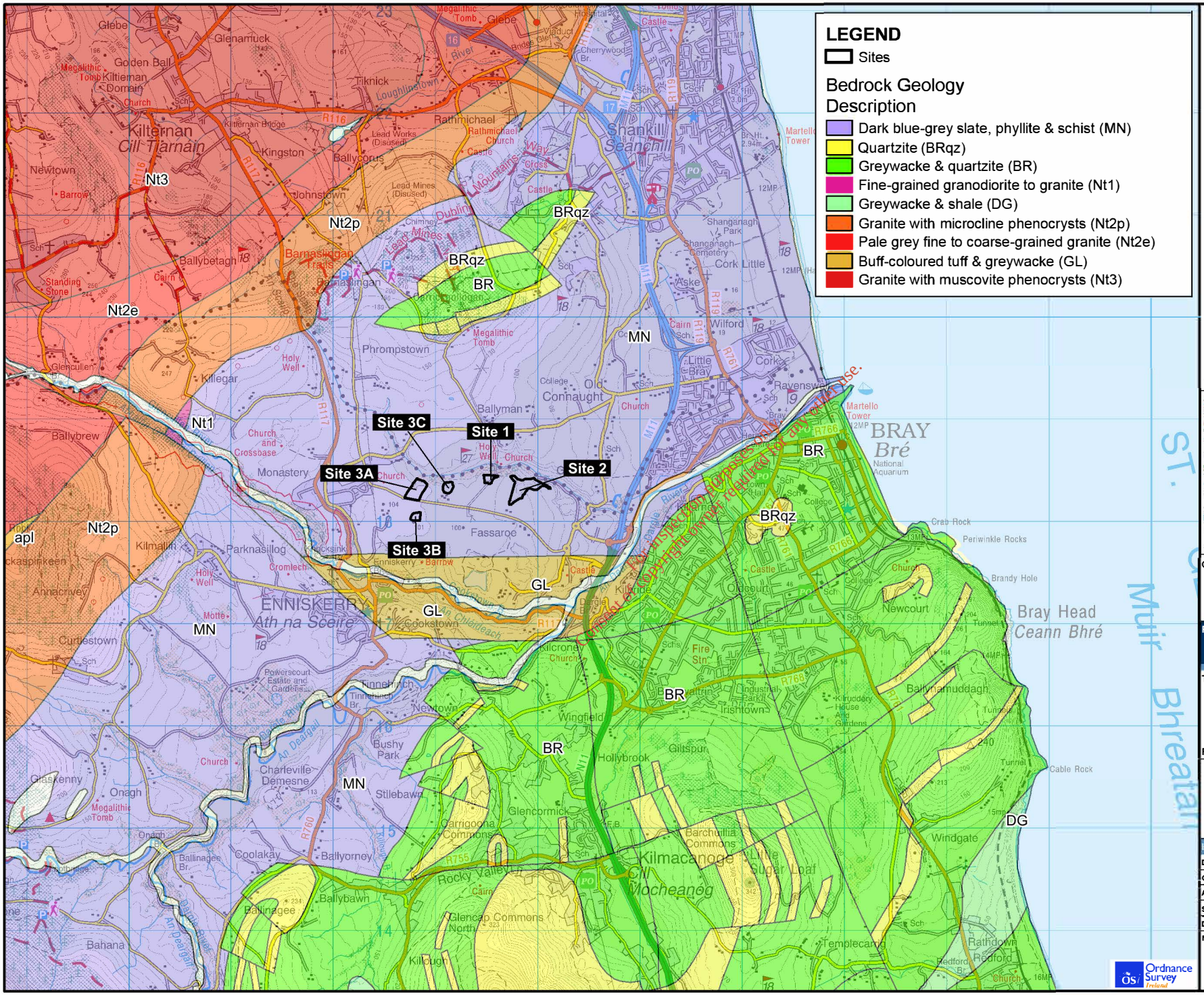
Depth to bedrock has not been proven at the site to date, albeit occurrences of shale/ schist outcrops were observed along the adjacent river at a small number of locations. In particular outcrop was noted directly north of Site 1 at approximately 55m above Ordnance Datum (aOD), see Plate 4 below.

Plate 4 Bedrock outcrop within the river north of Site 1

3.4.3 Local Geological Conditions

Topsoil has an average thickness of 0.2 m and normally overlies consolidated or lightly over consolidated alluvial clays consisting soft to firm sandy, gravely silts and clays with an approximate thickness of 3.4-4.0 metres. The alluvium is considered by GSI to be largely cohesive in nature and is underlain by granular glacio-fluvial deposits of sands and gravels. These sand and gravel deposits are of variable thickness but increases to approx. 18 m towards the river. The granular deposits can be underlain by glacial till (boulder clay) deposits consisting of stiff to very stiff grey sandy gravelly clay containing numerous cobbles and occasional boulders.

Historic boreholes did not intersect the bedrock or boulder clay units.



DATA SOURCE:
Geological Survey Ireland (GSI)

Client

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Project

Fassaroe Historic Landfill

Title

Bedrock Geology

Figure 8

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3.5 HYDROGEOLOGY

3.5.1 Aquifer Classification

The Enniskerry groundwater body (IE_EA_G_038) is designated a locally important gravel aquifer (Lg). Although the aquifer is permeable, the groundwater flow velocity is will be comparatively low due to a high storativity and subdued water-table elevations expected. As a result the discharge to rivers will not be flashy and will be sustained through drier periods of the year (GSI, 2016).

The bedrock beneath the gravel aquifer, i.e. the Maulin Formation, is classified by the GSI as a locally important, moderately productive bedrock aquifer in local zones (Ll) (See **Figure 9**). Fracture flow is the dominant pathway for groundwater movement in the bedrock aquifer however the permeability is expected to be moderately low with most groundwater flow in within the top 20m of rock head.

3.5.2 Aquifer Vulnerability

Groundwater vulnerability maps are based on the type and thicknesses of subsoils and the presence of certain karst features. Groundwater is most at risk of contamination where the subsoils are absent or thin and, in areas of karstic limestone, where surface streams sink underground at swallow holes.

The aquifer vulnerability at the Fassaroe site is classified as High due to the presence of greater than 3m thick unsaturated zone overlying a gravel aquifer (DoELG & GSI 1999). (See **Figure 10**) and **Table 3.2** below.

Table 3.2 – GSI Vulnerability Categories

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness			Unsaturated Zone	Karst Features
	High permeability (sand/gravel)	Moderate permeability (e.g. Sandy subsoil)	Low permeability (e.g. Clayey subsoil, clay, peat)	(Sand/gravel aquifers only)	(<30 m radius)
Extreme (E)	0 - 3.0m	0 - 3.0m	0 - 3.0m	0 - 3.0m	-
High (H)	>3.0m	3.0 - 10.0m	3.0 - 5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0 - 10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

Notes: (1) N/A = not applicable.
(2) Precise permeability values cannot be given at present.
(3) Release point of contaminants is assumed to be 1-2 m below ground surface.

3.5.3 Groundwater Flow and Recharge

The Enniskerry groundwater body is recharged by rainwater that percolates through the topsoil and the unsaturated sand and gravel deposits. Surface runoff is estimated at approximately 20% of effective rainfall (GSI, 2016). The GSI recharge map (www.gsi.ie) for the area presents an annual

recharge value of 575mm/year, due to the presence of the relatively permeable gravels at the surface.

Groundwater flow within the granular aquifer is expected to be towards the local river, where groundwater discharges emerge as springs and seeps along the lowest boundary of the groundwater body and regionally towards the Irish Sea. Previous reports have shown the local groundwater regime over the site is dominated by the County Brook River (Fassaroe Stream) valley to the north, and the valley of the River Dargle to the east.

3.5.4 Groundwater Quality

According to the EPA (Envision Maps) the Water Framework Directive (WFD) status for the Enniskerry Gravel water body has been assigned as 'Good' between 2007 and 2012.

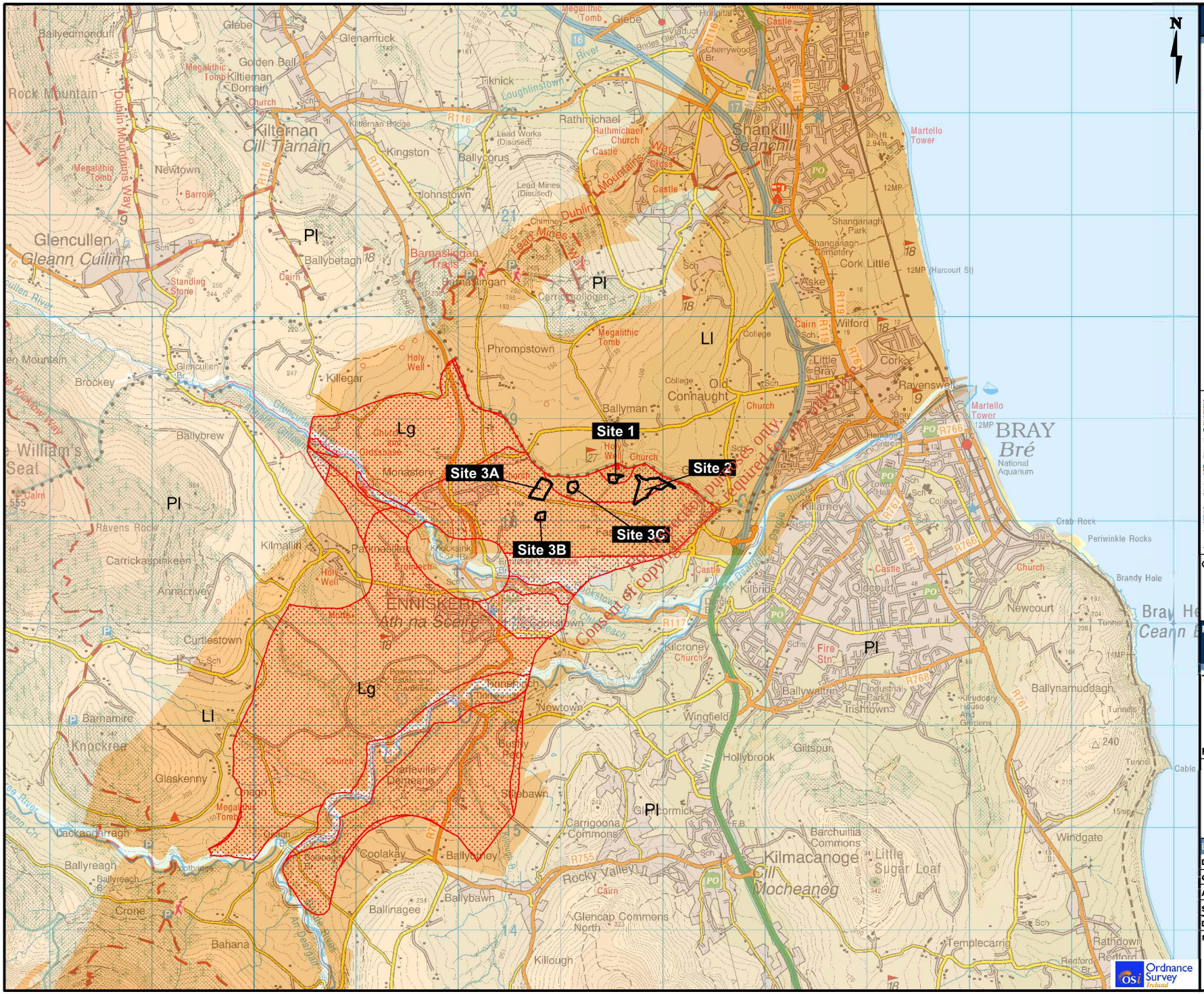
The Ballyman Glen SAC which runs along the County Brook River (Fassaroe Stream) adjacent to the Fassaroe landfill sites comprises riparian wet woodland and contains a small strip of fen. The fen is very alkaline and is associated with petrifying springs and seepage areas, which have given rise to thick deposits of marl. The nature of the springs suggests they are discharging from the gravel unit, which is mainly derived from limestone. The earth of the banks around the landfill is unstable, and as a result, silt is being released into the County Brook River (Fassaroe Stream).

3.5.5 Groundwater Users/ Private Wells

Groundwater users are identified in Figure 11. The GSI well database lists a number of springs and old boreholes (from 1965) in the surrounding areas of Enniskerry and Bray, of which only a small number of have been assigned as domestic use.

The nearest spring, St Kevin's Well (GSI code 3224SWW137) is located immediately north of the site, noted on the original six inch (c. 1830) maps. The GSI well data-base is not a fully comprehensive list and additional groundwater using wells may be present in the area.

There are no recorded large abstractions from the Enniskerry groundwater body.



Legend

- Sites
- Lg — Gravel
- LI — Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
- PI — Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones

DATA SOURCE:
Geological Survey Ireland (GSI)

Client

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Fassaroe Historic Landfill

Title

Aquifer Bedrock

Figure **9**

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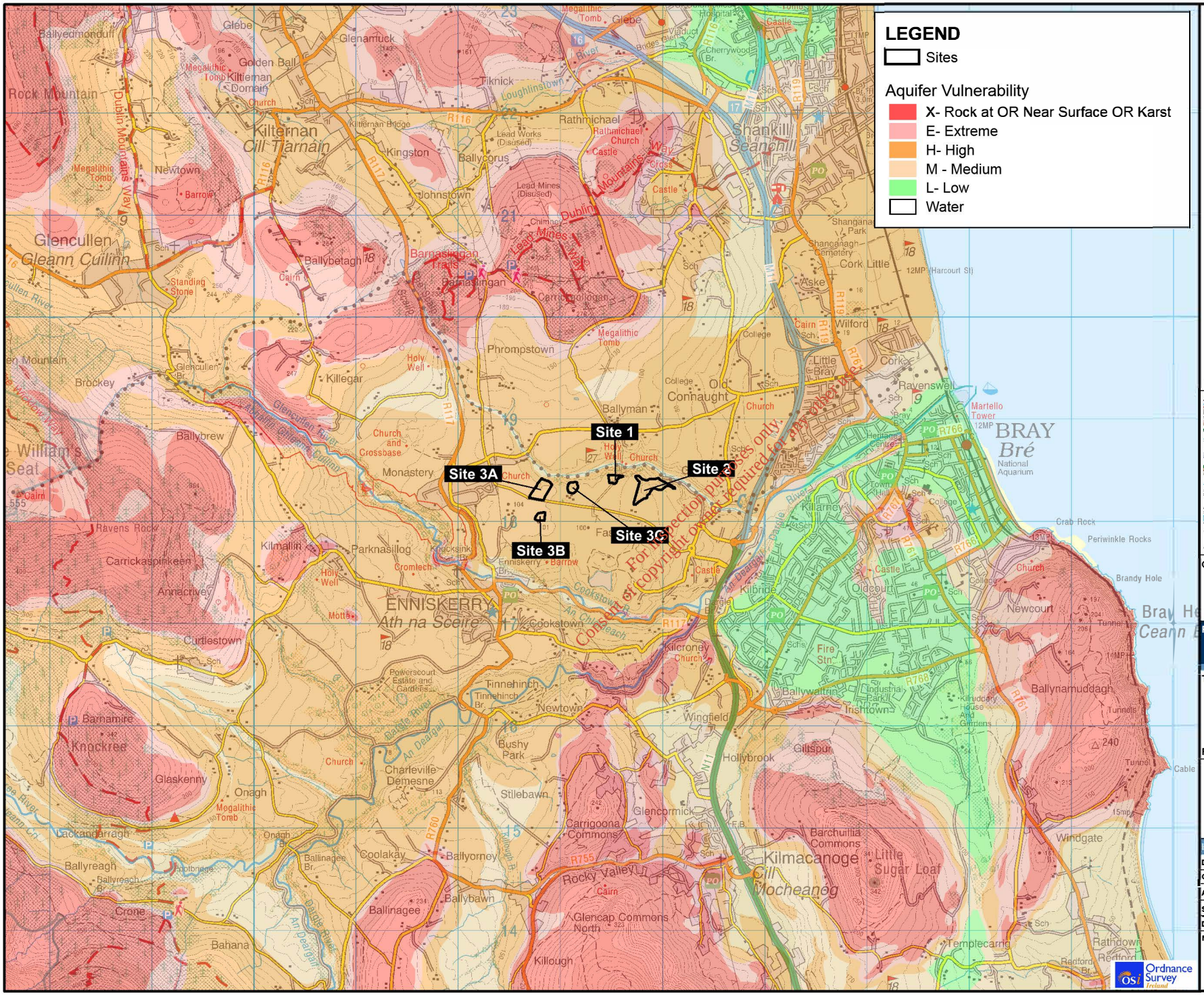

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DATA SOURCE:
Geological Survey Ireland (GSI)

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Project
Fassaroe Historic Landfill

Title
Groundwater Vulnerability

Figure 10

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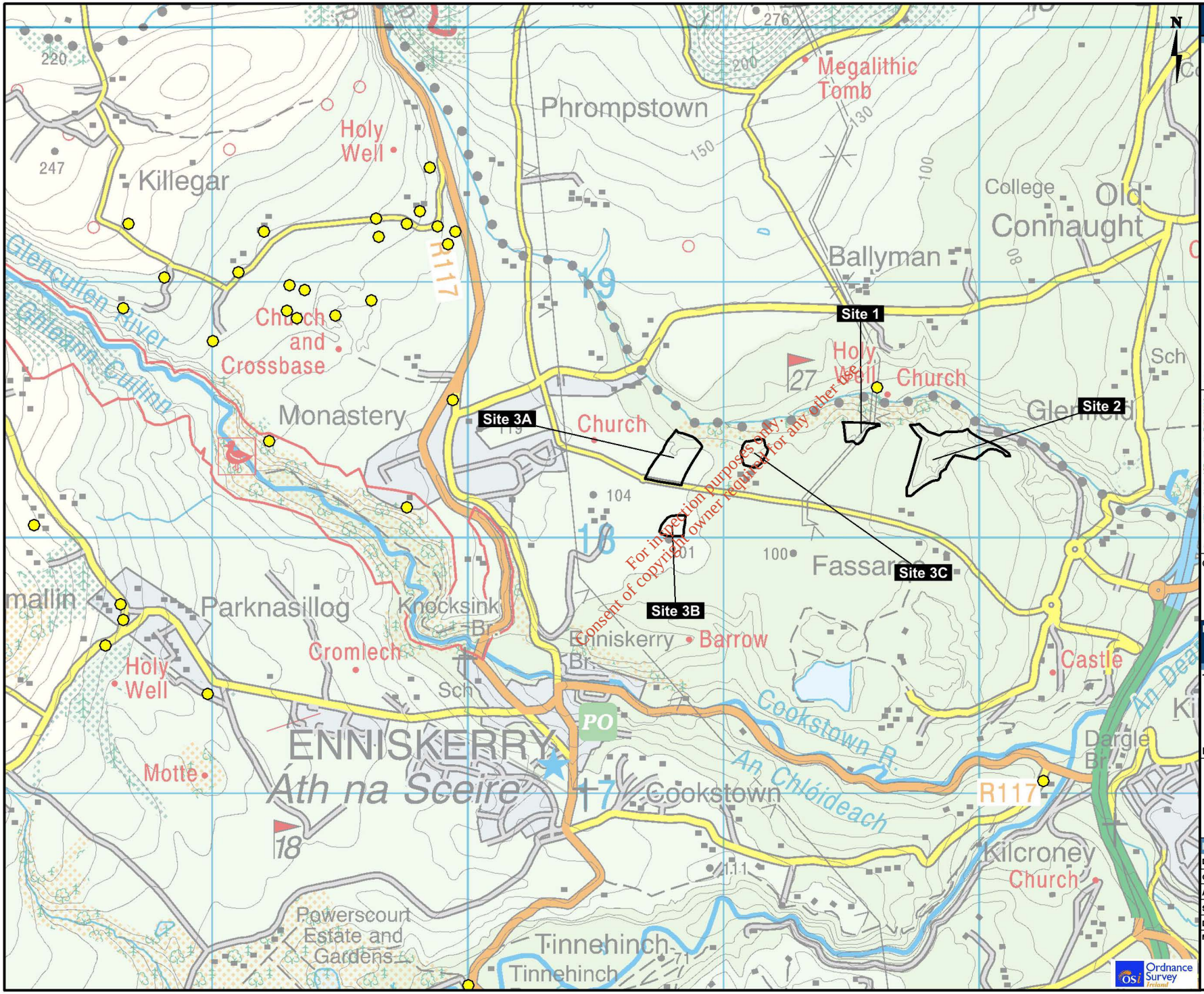
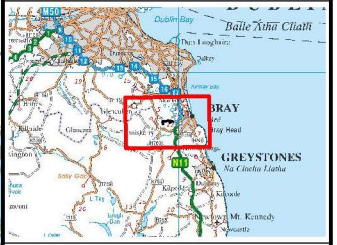


Legend

- Sites
- Groundwater Well

DATA SOURCE:
Geological Survey Ireland (GSI)



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Fassaroe Historic Landfill

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GSI Groundwater Wells

Figure 11

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Date:	27/05/2016	ITM	

Notes
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3.6 TIER 1 RISK ASSESSMENT

3.6.1 Initial Conceptual Site Model and Tier 1 Risk Screening

A review was undertaken of historic site investigations and previous reports at the sites in order to develop an initial Conceptual Site Model (CSM) and identify any gaps for which further data was required. The initial CSM is based on the concept of pollutant (source-pathway-receptor) linkages defined by the Tier 1 preliminary investigation described above. The Tier 1 risk prioritisation and classification approach outlined by the Code of Practice (EPA, 2007) is also base on the concept of pollutant linkages, herein after referred to as SPR linkages.

3.6.1.1 Sources

Four principal contamination sources have been identified for the purpose of the initial CSM:

- Leachate (S1)
- Waste (S2)
- Asbestos Containing Material (S3)
- Landfill Gas (S4)

3.6.1.2 Receptors

A variety of receptors have been identified with respect to the site environmental setting and site users (currently and following future development). Environmental and water receptors potentially relevant to the local site setting include the following:

- WFD Surface Water Body – County Brook River (R1)
- Surface Water Protected Area - Ballyman Glen SAC (R2)
- Private Wells – Groundwater abstraction sources (R3)
- Groundwater Dependent Terrestrial Ecosystem (GWDTE) - Ballyman Glen SAC (Site Code: 000713) (R4)
- Aquifer – Locally important gravel aquifer (Lg) - Enniskerry groundwater body (R5)
- Public Supply Well (R6)

Human health receptors potentially relevant to the landfill sites include the following:

- Current and Future Site Users (R7)
- Construction Workers (R8)
- Adjacent Buildings and Structures (R9)
- Non-designated land (R10)

3.6.1.3 Pathways

A number of pathways have been identified that potentially connect the sources of contamination associated with the five landfill sites and receptors. These include:

- Vertical migration to groundwater then horizontal flow through Surface Water (SW) drainage channels into the river (County Brook river) (P1);
- Vertical migration to groundwater and horizontal (lateral) flow through saturated groundwater / aquifer (P2);
- Surface Water drainage system (P3);
- Direct dermal contact, ingestion of dust and soil or inhalation of dust (P4);
- Lateral migration of landfill gas through subsoils, resulting in inhalation and/ or explosion (P5);
- Lateral migration of dissolved phase landfill gas through groundwater (P6);
- Vertical migration of landfill gas through subsoil (P7); and
- Migration of landfill gas through existing &/or proposed services routes (P8).

Tables 3.3, 3.4 and 3.5 detail the classification of probability, classification of consequence and risk matrix taken from CIRIA C552 (Contaminated Land Risk Assessment) (CIRIA, 2001) that was used in the development of the initial CSM.

The initial CSM developed from this review is presented in **Table 3.6** and addresses the Source, Pathway and Receptor elements across the five landfill sites. In order to complete **Table 3.6** the worst case scenario for each element from all five landfill sites was chosen.

Table 3.3 – Classification of Probability (from CIRIA C552, 2001)

Probability/ Classification	Definition
High Likelihood	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage and all the elements are present and in the right place, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low Likelihood	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such event would take place, and is less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.

Table 3.4 – Classification of Consequence (from CIRIA C552, 2001)

Classification	Definition	Examples
Severe	Short-term (acute) risk to human health likely to result in "significant harm" as defined by the Environment Protection Act 1990, Part IIA. Short-term risk of pollution (note: Water Resources Act contains no scope for considering significance of pollution) of sensitive water resource. Catastrophic damage to buildings/ property. A short-term risk to a particular ecosystem or organisation forming part of such ecosystem (note: the definitions of ecological systems within the Draft Circular on Contaminated Land, DETR, 2000)	High concentrations of cyanide on the surface of an informal recreation area. Major spillage of contaminants from site into the water environment. **Explosion, causing building collapse (can also equate to a short-term human health risk if buildings are occupied).**
Medium	Chronic damage to Human Health ("significant harm" as defined by DETR, 2000). Pollution of sensitive water resources (note: Water Resources Act contains no scope for considering significance of pollution). A significant change in a particular ecosystem or organism forming part of such ecosystem (note: the definitions of ecological systems within Draft Circular on Contaminated Land, DETR, 2000).	Concentration of a contaminant from site exceeds the generic or site-specific assessment criteria. Leaching of contaminants from a site to a major or minor aquifer. Death of a species within a designated mature reserve. **Lesser toxic and asphyxiate effects of carbon dioxide**
Mild	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services ("significant harm" as defined in the Draft Circular on Contaminated Land, DETR, 2000). Damage to sensitive buildings/ structures/ services or the environment.	Pollution of non-classified groundwater. Damage to building rendering t unsafe to occupy (e.g. foundation damage resulting in instability).
Minor	Harm, although not necessarily significant harm, which may result in a financial loss or expenditure to resolve. Non-permanent health effects to human health (easily prevented by means such as personal protective clothing, etc). Easily, repairable effects of damage to buildings, structures and services.	The presence of contaminants at such concentrations that protective equipment is required during site works. The loss of plants in a landscaping scheme. Discolouration of concrete

Table 3.5 – Risk Matrix – Comparison of Consequence and Probability (from CIRIA C552, 2001)

Risk = Probability x Consequences		Consequence			
		Severe	Medium	Mild	Minor
Probability	High likelihood	Very high risk	High risk	Moderate risk	Moderate/ low risk
	Likely	High risk	Moderate risk	Moderate/ low risk	Low risk
	Low likelihood	Moderate risk	Moderate/ low risk	Low risk	Very low risk
	Unlikely	Moderate/ low risk	Low risk	Very low risk	Very low risk

Table 3.6 – Initial Conceptual Site Model

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
Water Environment									
S1	Leachate	P1	Vertical to groundwater then horizontally through possible surface water drainage channels into the river	R1	WFD Surface Water Body	Unlikely	Medium	Low Risk	The Tier 1 preliminary investigation including site walkover investigations did not identify any surface water drainage system connecting the landfill sites to the SAC and/or County Brook River and hence no discharge to surface land drains.
				R2	Surface Water Protected Area	Unlikely	Medium	Low Risk	
		P2	Vertical & Horizontal via Groundwater	R3	Private Wells	None	Medium	No Risk	There are no residential properties or private wells situated down gradient of the landfill sites (water main connection in the area)
				R4	Groundwater Dependent Terrestrial Ecosystem (GWDTE)	Likely	Medium	Moderate Risk	GWDTE understood to be present within the SAC boundary.
				R5	Aquifer	Likely	Medium	Moderate Risk	The underlying bedrock and gravel aquifers are at risk by direct connection
				R6	Public Supply Well	None	Mild	No Risk	There are no public water supply wells in the area.
				R1	WFD Surface Water Body	Likely	Medium	Moderate Risk	The County Brook River (Fassaroe Stream) is at risk
		P3	Surface Water Drainage	R1	WFD Surface Water Body	Unlikely	Medium	Low Risk	The Tier 1 preliminary investigation including site walkover investigations have not identify any surface water drainage system connecting the landfill sites to the SAC and/or County Brook River and hence no discharge to surface land drains.
				R2	Surface Water Protected Area	Unlikely	Medium	Low Risk	
Human Health									
S2	Waste	P4	Direct dermal contact. Ingestion dust	R7	Current and Future Site Users	Unlikely	Mild	Very Low Risk	No previous waste characterisation completed. Currently minimal clay cap in place.

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
			and soil. Inhalation of dust	R8	Construction Workers	Low Likelihood	Minor	Very Low Risk	No previous waste characterisation completed. Currently minimal clay cap in place.
S3	ACM	P4	Direct dermal contact. Ingestion dust and soil. Inhalation of dust.	R7	Current and Future Site Users	Unlikely	Severe	Moderate/ Low Risk	No analysis for ACM completed.
				R8	Construction Workers	Likely	Severe	High Risk	No analysis for ACM completed. Presence of C&D waste in Site 1 presents risk of presence of ACM. Currently minimal clay cap in place
S4	Landfill Gas	P5	Lateral Migration Subsoil Inhalation and/ or explosion	R7	Current and Future Site Users	Low Likelihood	Mild	Low Risk	Landfill gas known to be present onsite however no dataset available. No offsite gas monitoring completed. Age, extent, volume and composition of waste unknown. Potential for exposure to construction workers during excavations. Potential for ingress to existing buildings and structures. Potentially, landfill gas migration could occur into existing adjacent buildings through cracks within the floor slab construction and/or around service/utility routes. Risks associated with gas migration into existing buildings should be considered further by the Local Authority.
				R8	Construction Workers	Likely	Severe	High Risk	
				R9	Adjacent Buildings and Structures	Low Likelihood / Likely	Severe	Moderate/High Risk	
				R10	Non-designated land	Low Likelihood / Likely	Minor	Very Low/Low Risk	
S4	Landfill Gas	P6	Lateral Migration Groundwater	R7	Current and Future Site Users	Unlikely	Mild	Very Low Risk	Landfill gas known to be present onsite however no dataset available. No offsite gas monitoring completed. Age, extent, volume and composition of waste unknown. Groundwater and leachate levels to be established
				R8	Construction Workers	Unlikely/Low Likelihood	Severe	Low/Moderate Risk	
				R9	Adjacent Buildings and Structures	Unlikely/Low Likelihood	Severe	Low / Moderate Risk	

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
S4	Landfill Gas	P7	Vertical Migration Subsoil	R7	Current and Future Site Users	Low Likelihood	Mild	Low Risk	Existing clay cap c.1-2m – information regarding composition and thickness lacking. The lack of an engineered cap will enable vertical migration of gas and atmospheric dispersion and dilution at surface. Landfill gas known to be present onsite however no credible dataset available. No offsite monitoring completed. Age, extent, volume and composition of waste unknown. Water level and effect on gassing regime unknown. Potential for exposure to construction workers during excavations. Potential for ingress to existing and proposed buildings and structures. Vegetation die back noted.
				R8	Construction Workers	Likely	Severe	High Risk	
				R9	Adjacent Buildings and Structures	Low Likelihood / Likely	Severe	Moderate / High Risk	
				R10	Non-designated Land	Likely	Minor	Low Risk	
S4	Landfill Gas	P8	Existing & Proposed Services Routes	R9	Adjacent Buildings and Structures	Low Likelihood / Likely	Severe	Low / Moderate Risk	No offsite gas monitoring known to have been completed.

3.6.2 Tier 1 – Risk Prioritisation & Classification

The EPA Code of Practice identifies eleven specific pollutant Source-Pathway-Receptor (SPR) linkages that should be considered within the CSM and assessed as part of the Tier 1 Risk Prioritisation process. Each of these linkages is scored using the scheme provided in the Code of Practice (EPA, 2007) in order to provide an overall risk categorisation for each landfill site.

An initial model was developed based on the information given above with consideration given to the eleven SPR linkages identified in the Code of Practice (EPA, 2007). During Tier 1 each aspect of each SPR linkage can be assessed according to particular criteria as defined within the Code of Practice (EPA, 2007). The Code of Practice uses a separate scoring matrix for each aspect of an SPR linkage, which are defined within Tables 1a to 3f of the Code of Practice. Where an individual aspect is not present or not relevant within the context of the conceptual model it is given a score of 0.

The score of each linkage is normalised with respect to 100 by dividing the score for each linkage by the maximum available points for that linkage to express as a percentage. The overall score for the site is taken as the maximum of the individual normalised scores. The site can then be placed in a prioritisation category depending upon the potential level of risk identified. Sites with a higher score represent those with either a higher level of risk, which may require remediation, or a high level of uncertainty, which requires further intrusive investigation. If a high score is due to a high level of uncertainty then the assessment should proceed to Tier 2 (Site Investigation and Testing) to refine the risk assessment.

The risk prioritisation and classification for each site is summarised in **Table 3.5** below. The full assessment, including relevant calculations, is presented in **Appendix B**. The risk category bands relating to site scores as defined in the EPA Code of Practice are presented in **Table 3.4**.

Table 3.7 - Risk Category and Prioritisation Class

Score	Priority Class	Risk Category	Definition
> 70%	A	High	High risk/high uncertainty sites. Further investigation required to confirm status. Presents potentially high risk to environment in current condition. Remediation / mitigation will be necessary. Highest priority with Regulating Authority.
40% to 70%	B	Moderate	Moderate risk/moderate uncertainty sites. Further investigation required to confirm status. Presents potentially moderate risk to environment in current condition. Remediation / mitigation may be required.
< 40%	C	Low	Low risk sites. Not considered to present risk to environment in current condition however further investigation may be required in case of change of land use.

Table 3.8 - Summary of Risk Category and Prioritisation

Site	Risk Classification	Priority Class	Highest SPR Score	SPR*	Comment
1	Low	C	5	SPR9	The Tier 1 Risk Ranking and Prioritisation suggests that Site 1 is a Low Risk based on the assumption that the waste type is C&D. The highest SPR linkage relates to the potential for leachate migration through the surface water network to surface water dependant terrestrial ecosystems.
2	High	A	70	SPR8 SPR9 SPR10	The SPR linkages of primary concern relate to the potential for leachate to impact surface water bodies and the SAC through surface water migration as well as the potential risk of lateral migration of landfill gas to a human presence.
3A	High	A	70	SPR9	The SPR linkage of primary concern relates to the potential for leachate migration through the surface water network to the Ballyman Glen SAC.
3B	Low	C	30	SPR10	The primary risk relates to the potential for lateral gas migration which should be investigated further due to the presence of buildings within c.100m of the site boundary.
3C	Moderate	B	50	SPR9 SPR10	The SPR linkages of primary concern relate to the potential for leachate to impact surface water bodies and the SAC through surface water migration as well as the potential risk of lateral migration of landfill gas to a human presence.

*SPR Linkage Number from EPA Code of Practice (2007)

3.7 SUMMARY OF TIER 1 ASSESSMENT

3.7.1 Site 1

The Tier 1 Risk Ranking and Prioritisation suggests that Site 1 is a Low Risk site (Class C) based on the assumption that the waste type is C&D.

Available intrusive data suggests the site comprises C&D waste however reference to the presence of domestic waste in TPB36 and the lack of available data to confirm the vertical and lateral extent of the waste body would raise some uncertainty on the overall classification/characterisation of the waste body.

Should the waste be classified as Municipal the risk classification would be upgraded to Moderate (Class B) due to the potential for leachate and gas generation and migration to relevant receptors.

It should also be noted that to RPS's knowledge no environmental monitoring (i.e. gas, leachate, groundwater or surface water) has been completed within Site 1, which leads to uncertainty in determining the intrinsic risk posed to receptors (i.e. human health or environmental).

3.7.2 Site 2

The Tier 1 Risk Ranking and Prioritisation suggests that Site 2 is a High Risk site (Class A) based on the nature and extent of the waste and proximity of receptors.

The SPR linkages of primary concern relate to the potential for leachate to impact surface water bodies and the SAC through surface water migration as well as the potential risk of lateral migration of landfill gas to a human presence.

Due to the lack of available information regarding the integrity of the leachate/gas monitoring boreholes sampled in 2010, coupled with the absence of landfill gas flow rates, groundwater monitoring boreholes, surface water monitoring data and off site landfill gas monitoring boreholes, uncertainty exists regarding the intrinsic risk posed to receptors.

Site 2 is located adjacent to the Ballyman Glen SAC (Site Code: 000713). The report entitled '*Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services, April 2013'* makes reference to Site 2 and concluded that an AA (Stage 2) would be required for Site 2 as the northern margins abutting the SAC had eroded with waste falling directly into the SAC and stream valley.

3.7.3 Site 3A

The Tier 1 Risk Ranking and Prioritisation suggests that Site 3A is a High Risk site (Class A). The SPR linkage of primary concern relates to the potential for leachate migration through the surface water network to the Ballyman Glen SAC.

Due to the absence of landfill gas flow rates, up-gradient/down-gradient groundwater monitoring boreholes and off site/perimeter landfill gas monitoring boreholes, uncertainty remains regarding the intrinsic risk posed to receptors.

3.7.4 Site 3B

The Tier 1 Risk Ranking and Prioritisation suggests that Site 3B is a Low Risk site (Class C) based on the extent of the waste body and proximity to receptors.

The primary risk relates to the potential for lateral gas migration which should be investigated further due to the presence of buildings within c.100m of the site boundary.

It should also be noted that no environmental monitoring (i.e. gas, leachate, groundwater or surface water) has been completed within Site 3B therefore uncertainty remains regarding the intrinsic risk posed to receptors.

3.7.5 Site 3C

The Tier 1 Risk Ranking and Prioritisation suggests that Site 3C is a Moderate Risk site (Class B).

The SPR linkages of primary concern relate to the potential for leachate to impact surface water bodies and the SAC through surface water migration as well as the potential risk of lateral migration of landfill gas to a human presence.

Due to the absence of landfill gas flow rates, up-gradient/down-gradient groundwater monitoring boreholes and off site/perimeter landfill gas monitoring boreholes, uncertainty remains regarding the intrinsic risk posed to receptors.

3.8 CONCLUSIONS

Sites 2 and 3A are classified as High Risk sites with Site 3C classified as a Moderate Risk site therefore all three require a sufficiently detailed site investigation programme to confirm (or otherwise) the relevant risk classifications and inform the Tier 3 quantitative risk assessment and subsequent recommendations for remediation as required.

Sites 1 and 3B are classified as Low Risk sites. It is recommended that additional investigations are required to assess the potential for lateral gas migration from Site 3B and to confirm the nature of waste within Site 1. The additional site investigation should provide sufficient information to verify the characterisation of the sites and inform any subsequent recommendations. The proposed site investigations aimed at addressing the data gaps identified in Table 3.9.

Table 3.9 – Identified Data Gaps

	Identified Gaps
1	Waste characterisation unknown. Chemical analysis and leachability testing of waste material not completed
2	The presence of ACM unknown as no sampling and analysis completed
3	Limited SI completed in the vicinity of the waste bodies to determine vertical and lateral extent of waste bodies
4	Limited or no monitoring locations available within the relevant waste bodies. Where boreholes are present, logs are unavailable therefore borehole construction and integrity are unknown.
5	No offsite gas monitoring locations have been installed to investigate potential lateral migration
6	Gas monitoring is limited, no reference to methodology utilised during monitoring, no flow measurements, atmospheric conditions not recorded.
7	Limited or no leachate monitoring locations, sampling and analysis. Lack of information regarding leachate quality and quantity
8	Limited information available regarding the thickness of the existing clay cap and no analysis completed to determine composition.
9	Limited or no groundwater quality data available. Groundwater monitoring to be completed following establishment of potential contaminants of concern.
10	Limited information available on location of springs within the SAC and therefore mapping and sampling of these is required to determine potential impacts on spring water quality and flow.
11	Limited dataset available for surface water quality.

4 TIER 2 – SITE INVESTIGATION & TESTING

4.1 INTRODUCTION & OBJECTIVES

The Tier 1 assessment recommended the completion of a Tier 2 site investigation and testing programme at all sites to further develop the initial CSM, confirm the relevant risk classifications for each landfill and inform the Tier 3 quantitative risk assessment and subsequent recommendations for remediation as required for Sites 2 and 3A.

The Tier 2 investigation and testing programme was designed to address gaps identified during the Tier 1 assessment and to provide further information on the following:

- The nature of the waste material;
- The lateral and vertical extent of the waste material;
- The volume and quality of leachate within the waste;
- The relationship between leachate and groundwater and the identification of leachate plumes beneath or outside of the waste bodies;
- The potential for landfill gas generation and migration;
- The ground conditions in the vicinity of the site, in particular the absence/presence of low permeability subsoil deposits between the waste and the aquifer;
- Determine time-series water quality within the aquifer, springs and surface waters to inform Tier 3 risk assessments determine potential risk to the environment and to human health.

The Tier 2 intrusive investigation included the following;

- Additional trial pitting within each site to inform the extent, composition and characterisation of the waste;
- Installation of leachate monitoring boreholes within the waste body of each site;
- Installation of additional groundwater monitoring boreholes;
- Installation of additional landfill gas monitoring boreholes to determine the presence and concentrations of landfill gas;
- Additional groundwater, surface water, spring, leachate and gas sampling to determine potential impact to human and environmental receptors;
- Additional soil sampling above and below the waste body to determine potential impact to human health and environmental receptors; and
- Pumping of existing boreholes (MW2, MW3 and MW4) remove silting and increase borehole performance.

4.2 TIER 2 METHODOLOGY

The Tier 2 investigation was conducted in two phases as follows:

Non Targeted Investigation

- **Geophysical Investigation:** This investigation was completed in December 2015 and further supplemented in March 2016 in order to assist in the delineation of the waste material, identify the presence of anomalous features and determine the extent of gravels below the

waste body. The survey was carried out using EM31 conductivity, Electrical Resistivity Tomography (ERT) and seismic refraction methods.

- **Non Targeted Ground Investigation:** This investigation was also completed in December 2015 and involved the excavation of twenty eight (28) trial pits and the collection of soil samples using 50m (Sites 1, 3b and 3C) and 75m (Sites 2 and 3A) sampling grids. Samples were taken from the waste body and the underlying undisturbed subsoil when encountered.

Targeted Investigation

- **Targeted Ground Investigation:** The intrusive targeted investigation involved the installation of twenty one (21) combined gas/leachate monitoring boreholes, twenty five (25) gas monitoring boreholes and eleven (11) groundwater monitoring boreholes between January and March 2016. The targeted investigation comprised cable and rotary percussive drilling, leachate, groundwater, surface water and soil sampling and landfill gas monitoring.

The investigations were carried out in accordance with;

- BS 10175:2011+A1:2013, Investigation of potentially contaminated sites - Code of practice;
- BS 5930:2015, Code of practice for ground investigation;
- Applicable CEN and ISO Standards for Analysis and Sampling;
- Environment Agency (EA) Guidance on Assessment of Risks from Landfill Sites;
- CIRIA C665, Assessing Risks Posed by Hazardous Ground Gases (2007)
- All relevant Health and Safety Regulations and Guidance ((including the Health, Safety and Welfare at Work Act 2005, and Safety, Health and Welfare at Work (Construction) Regulations 2006 as amended); and
- EPA Code of Practice Environmental Risk Assessment for Unregulated Waste Disposal Sites, 2007

4.3 INVESTIGATIVE FIELDWORKS

4.3.1 Geophysical Investigation

The objectives of the geophysical survey were to:

- Identify the lateral extent of the waste body;
- Identify the thickness of the waste body and presence of any anomalous features;
- Identify trace metals that could potentially be leaching from the site; and
- Identify any leachate plumes outside of or below the waste body.

The survey was carried out using electromagnetic EM131 ground conductivity, electrical resistivity tomography (ERT) and seismic refraction methods. EM31 ground conductivity mapping was completed over the filled area in order to map the extent of the fill, to map variations in the fill and to investigate the presence of any leachate plume and obtain background values for the soils and rock.

Fifteen (15) ERT profiles were completed across the five sites to investigate variations in the thickness and extent of the fill material and leachate, as well as to investigate the subsoil type and bedrock geology.

Five seismic refraction spreads were recorded on selected ERT profiles across all five sites to assist in determining the base of the landfill material which may be masked in the ERT results by the migration of leachate. Data quality was poor as signal transmission was limited due to the significant thickness and heterogeneous nature of the unconsolidated waste material.

The results of the geophysical survey were used in the development of the conceptual site model sections for the landfills. For instance the geophysical survey results suggest that the leachate plume (S1) has reached as far as 40 metres below the depth of waste, particularly to the northeast at Site 2. The surveys identified the potential migration of leachate from the landfills and the direction and depth of leachate migration. The surveys also provided information on the stratification of the subsoil and depth to waste.

The full report is presented in **Appendix C**.

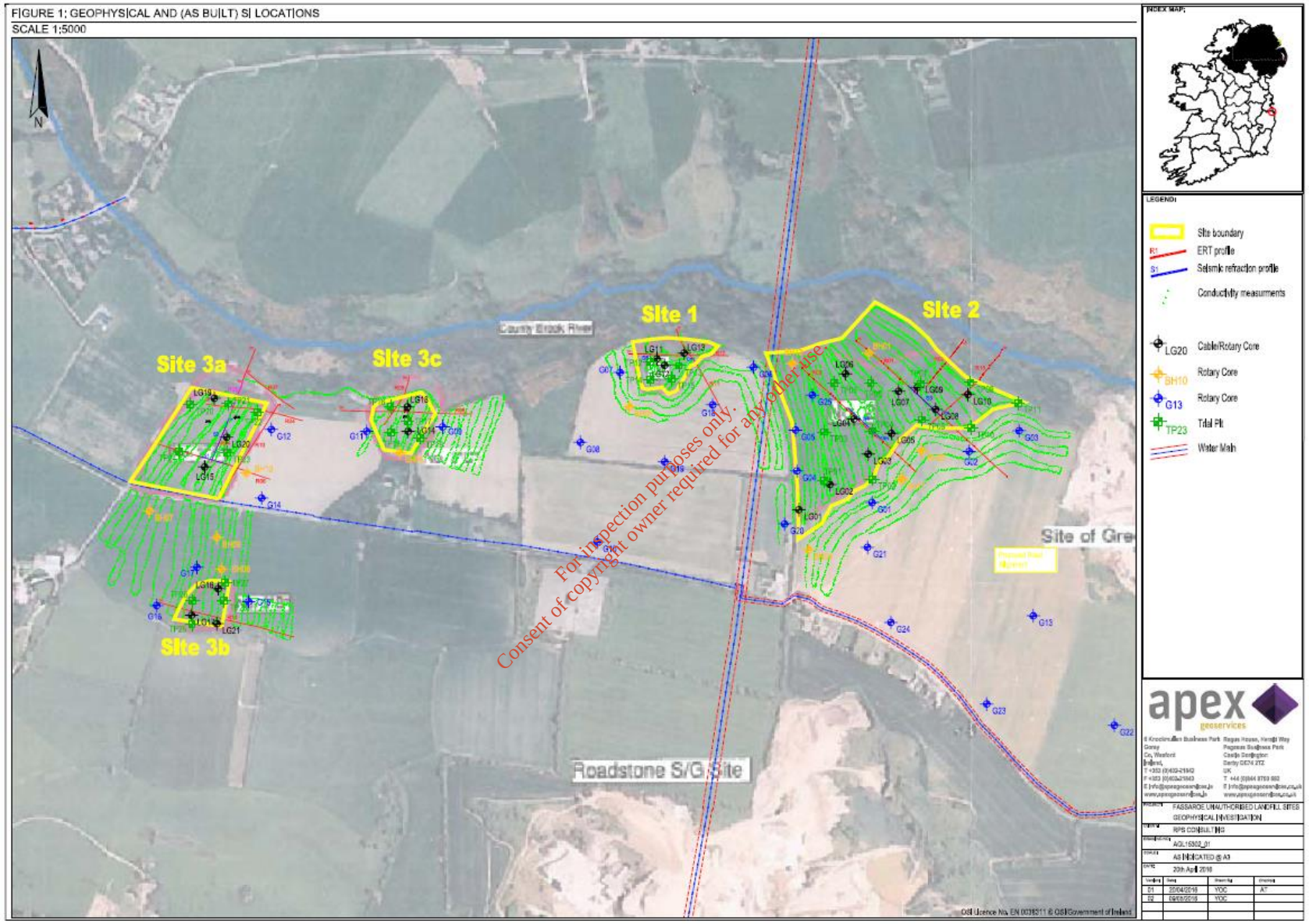

Figure 12 Geophysical Survey Locations (Apex Geoservices 2016)

4.3.2 Trial Pits

Given the size of the sites and the level of historic ground investigations a total of twenty eight (28) trial pits (TP1 – TP28) were excavated across the five sites to depths ranging between 3.5 to 4.6mbgl in December 2015. The proposed number of trial pits for each site is outlined in **Table 4.1.**

Table 4.1 – Proposed Number of Trial Pits

Site	No. of Trial Pits	Comments
Site 1	4	4 No. trial pits were excavated within a c.50m grid to characterise the waste, ascertain base of waste and identify natural ground.
Site 2	11	11 No. trial pits were excavated within a c. 75m grid to characterise the waste, ascertain base of waste and identify natural ground.
Site 3A	5	Site 3A – In light of the extensive ground investigations previously completed by WCC and the fact that depth of waste was established in boreholes MW3 and MW4 at 11.9mbgl and 10.5mbgl respectively, 5 No. trial pits were excavated to characterise the waste.
Site3B	4	Site 3B – In light of the size of the site (0.9ha) 4 No. trail pits were excavated to characterise the waste, ascertain base of waste and identify natural ground.
Site3C	4	Site 3C – Due to the extensive ground investigations previously completed by WCC and the fact that depth of waste was established in boreholes MW2 at 5.4mbgl, 4 No. additional trial pits were excavated to characterise the waste.

Detailed trail pit logs and photographs are presented in Appendix D with a summary of findings presented in **Table 4.2** below.

All trial pits were excavated using a mechanical excavator. The trial pits were excavated, under the supervision of Priority Geotechnical Limited, between 7th and 10th December 2015 and were back-filled on completion by replacing material in the order in which it was excavated. The locations of the trail pits are presented in **Figure 13**.

LEGEND

- ESB Overhead (38 kv)
- ESB Overhead (110kv)
- ESB Overhead (220kv)
- ESB Overhead (400kv)
- ESB Overhead (LV)
- ESB Overhead (MV)
- ESB Underground (38kv)
- ESB Underground (MV & LV)
- ESB Underground (Spare)
- Extent of Waste

Landownership

- Cosgraves
- Borg Developments
- Special Areas of Conservation (SAC's)

Site Investigation

- TP1 Proposed Trial Pit Locations

SITE INVESTIGATION CO-ORDINATES

ID	X Co-ordinate	Y Co-ordinate
As-Built Trial Pits		
TP1	723682.65	718266.99
TP2	723757.63	718269.22
TP3	723683.29	718342.00
TP4	723757.61	718343.86
TP5	723698.18	718417.17
TP6	723755.25	718417.29
TP7	723831.84	718416.68
TP8	723833.74	718361.20
TP9	723908.99	718418.51
TP10	723909.82	718348.09
TP11	723982.10	718386.82
TP12	723414.49	718450.11
TP13	723458.97	718444.41
TP14	723414.97	718423.27
TP15	723447.72	718424.38
TP16	723014.00	718380.99
TP17	723040.13	718358.27
TP18	723014.33	718340.98
TP19	723059.40	718333.16
TP20	722705.01	718384.46
TP21	722764.01	718385.63
TP22	722808.05	718372.09
TP23	722761.86	718310.22
TP24	722687.96	718312.14
TP25	722707.43	718045.32
TP26	722708.27	718080.97
TP27	722758.68	718109.21
TP28	722757.06	718081.29

Client: Comhairle Contae Chill Mhantáin

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No.	Date	Dn/Ck	Amendment / Issue	App
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F01	May '16	RH/LD	FINAL ISSUE	CC

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Project: **FASSAROE HISTORIC LANDFILL**

Title: PLAN SHOWING TRIAL PIT LOCATIONS

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Table 4.2 - Summary of 2015 Trial Pit Investigations

TP ID	Site ID	Total Depth (m)	Depth of Waste (m)	Description of Waste	Notes
TP01	Site 2	4.4	0.8 - >4.4	Plastic, concrete, textiles, metals, timber, glass and plastic bottles. Household waste	Strong unidentified odour
TP02	Site 2	4.5	0.8 - >4.5	Plastic bags and bottles, bricks, textile, aerosol cans, household waste, car tyres	Strong unidentified odour
TP03	Site 2	4.6	0.9 - 3.7	Household waste described as plastic, glass, metals and rubber	Strong unidentified odour
TP04	Site 2	4.5	0.6 - >4.5	Plastic bags, paper, timber, glass bottles, metal, rubber	Strong unidentified odour
TP05	Site 2	4.5		No waste encountered	
TP06	Site 2	4	0.6 - >4	Plastic refuse, glass bottles, metals, timber, general household waste and a car door	Strong unidentified odour
TP07	Site 2	4.5	0.6 - >4.5	Rubber tyres, plastic refuse, paper, glass, tin cans, toys, wire and other metals and textiles	
TP08	Site 2	4.5	0.6 - >4.5	Black refuse bags, metals, paper, timber, tin cans, glass bottles, plastic and textiles (waste increases from 1.5mbgl)	
TP09	Site 2	4.5	0.5 - >4.5	Plastics, timber, textiles, glass bottles, paper, metals and general household waste	Strong unidentified odour
TP10	Site 2	4.5	0.7 - 3.5	Plastics, cardboard, timber, glass, textiles, tin cans	Strong unidentified odour
TP11	Site 2	4.5	0.8 - 1.3 2 - >4.5	Plastics, metals, glass, timber, paper, cardboard, styrofoam, general household waste and car wheel - waste dated from 1985	Strong unidentified odour
TP12	Site 1	4.5	0 - 1 1.5 - >4.5	Concrete, red bricks, steel parts, concrete posts, re-bar and concrete, tarmac, timber and slings	
TP13	Site 1	4.5	0 - >4.5	Some large blocks of concrete up to 1m in size and some red brick, plastics, paper, glass, medical waste (e.g. syringes), textiles and polystyrene	Slight hydrocarbon odour
TP14	Site 1	4.5	0 - >4.5	Large concrete slabs (approximately 1m in size), polystryene, red bricks, rebar, plastics, glass, metals, tin cans and paper. Waste dated back to 1976	
TP15	Site 1	4.5	1.5 - 3	Plastics, metals, textiles and polystyrene	Assume natural ground from 3-4.5mbgl, difficult to determine as walls of pit collapsing
TP16	Site 3C	4.5	0 - >4.5	Plastics, glass, textiles, household waste, timber, rubber tyres, small amount of steel shavings and tarmacadam	Strong unidentified odour
TP17	Site 3C	4.5	0.9 ->4.5	Household waste, plastics, glass, metals and timber	Strong unidentified odour
TP18	Site 3C	4.5	1.1 - >4.5	Plastics, rope, mattress, glass, paper, timber, textiles, household waste, shoes, coins and bones. Waste dated from 1992	Strong unidentified odour

TP ID	Site ID	Total Depth (m)	Depth of Waste (m)	Description of Waste	Notes
TP19	Site 3C	4.5	0.9 - >4.5	Plastics, household waste, glass, timber, textiles including rugs, rubber tyres and pipes	Strong unidentified odour
TP20	Site 3A	4.5	0.1 - 1.2 2.1 - >4.5	Occasional plastic fragments Household waste	Strong unidentified odour
TP21	Site 3A	4.5	1 - 2.2 2.2 - >4.5	Occasional plastic fragments Rubber, glass, paper and household waste	Strong unidentified odour
TP22	Site 3A	4.5	1.1	Thin layer of plastics at 1.1mbgl	
TP23	Site 3A	4.5	0.5 - 1 1.7 - >4.5	Plastics, paper, metal, textiles, footwear and general household waste	Strong unidentified odour
TP24	Site 3A	4.5	0.6 - >4.5	Car tyre, plastics, perspex, metals, wire, paper and household waste	Strong unidentified odour
TP25	Site 3B	4.5	0.8 - >4.5	Household waste, plastics, glass, timber, textiles and footwear. Waste dates to 1992.	Strong unidentified odour
TP26	Site 3B	4.5	1.2 - >4.5	Plastics, household refuse, paper, metals, timber and textiles	
TP27	Site 3B	4.5		No waste encountered	
TP28	Site 3B	3.5	0.7 - >3.5	Plastics, paper, household waste, copper, glass and textiles	Strong unidentified odour

No waste or base of waste encountered

4.3.3 Borehole Drilling

A targeted approach, based on the geophysical survey report, was completed for the installation of gas, combined gas/leachate and groundwater monitoring boreholes between the 15th January 2016 and 1st March 2016 with a total of fifty seven (57) monitoring boreholes installed across the five sites.

The objective of the installation of the groundwater monitoring boreholes was to demonstrate the local geological sequence; demonstrate the presence of a contamination plume where present; and confirm groundwater levels / flow directions.

Previously installed boreholes within Site 3A (MW3 & MW4) and Site 3C (MW2) have been included within this assessment as they provide useful monitoring locations situated within the waste body. The historic boreholes used within the risk assessment are as follows;

- MW2 - leachate monitoring borehole located within Site 3C – screened within the waste and will confirm quantity and quality of leachate
- MW3 and MW4 – leachate monitoring boreholes located within Site 3A – screened within the waste and will confirm quantity and quality of leachate

Combined gas/leachate monitoring boreholes were installed within the relevant waste bodies to enable monitoring of the worst case situation with respect to gas generation and to ascertain the quantity and quality of leachate.

The geophysical survey was utilised to identify the expected worst case gas monitoring locations within each of the waste bodies. The geophysical survey was also utilised in conjunction with the historic SI to site combined gas/leachate monitoring boreholes at peripheral locations within the waste masses to confirm the lateral extent of waste infill.

Gas monitoring boreholes were also sited and installed outside the fill areas to assess potential lateral migration. Offsite gas monitoring boreholes were installed to the maximum depth of the source i.e. the relevant waste body.

The EPA Landfill Monitoring Manual 2nd Edition recommends that locations for gas monitoring within the waste body should be at a density of at least one monitoring point per hectare of filled area in unlined landfills.

CIRIA report *Assessing risks posed by hazardous ground gases to buildings* (CIRIA C665) recommends that for 'even the smallest of sites a minimum of three wells is installed'. CIRIA C665 indicated that the spacing of gas monitoring wells will largely be dependent on the location and number of gas source as well as the sensitivity of the proposed end use and permeability of ground. In accordance with best practice, offsite gas monitoring boreholes were located a minimum of 20m from the perimeter of the waste body where practicable and installed to at least the maximum depth of the waste body in question.

All monitoring borehole installations were completed with 50mm diameter standpipes. Clean pea gravel was used as a gravel pack around the monitoring wells with bentonite seals above the slotted

screen sections to minimise the potential for surface water entering the monitoring boreholes. All monitoring boreholes were fitted with upright steel covers.

See **Figure 14** for borehole locations and Appendix D for Priority Geotechnical factual report containing borehole logs. A summary of the borehole installation details at each of the five sites are presented below in **Tables 4.3 – 4.7**.

SITE INVESTIGATION CO-ORDINATES

Drill Rig	ID	X Co-ordinate	Y Co-ordinate
Existing Boreholes			
	MW2	723021.66	718380.78
	MW3	722762.91	718368.44
	MW4	722696.61	718368.44
Gas Monitoring Boreholes			
Rotary	G01	723757.16	718233.48
Rotary	G02	723906.63	718311.72
Rotary	G03	723983.99	718344.07
Rotary	G04	723640.81	718281.92
Rotary	G05	723638.54	718344.71
Rotary	G06	723574.12	718441.70
Rotary	G07	723368.29	718433.97
Rotary	G08	723306.94	718326.45
Rotary	G09	723094.22	718349.85
Rotary	G10	723333.19	718171.75
Rotary	G11	722977.05	718343.28
Rotary	G12	722830.39	718345.89
Rotary	G13	724005.86	718058.15
Rotary	G14	722815.16	718240.44
Rotary	G15	722795.09	718080.09
Rotary	G16	722652.69	718073.96
Rotary	G17	722714.71	718133.46
Rotary	G18	723510.87	718384.05
Rotary	G19	723436.56	718295.62
Rotary	G20	723622.36	718199.82
Rotary	G21	723750.29	718164.27
Rotary	G22	724131.18	717889.25
Rotary	G23	723934.27	717921.64
Rotary	G24	723786.25	718048.22
Rotary	G25	723664.69	718398.81

SITE INVESTIGATION CO-ORDINATES

Drill Rig	ID	X Co-ordinate	Y Co-ordinate
Combined Gas/Leachate Monitoring Boreholes			
Rotary	LG01	723643.770	718221.920
Cable Percussive/Rotary	LG02	723692.440	718261.440
Rotary	LG03	723751.300	718307.500
Cable Percussive/Rotary	LG04	723728.580	718362.080
Rotary	LG05	723787.000	718340.400
Rotary	LG06	723716.450	718432.320
Cable Percussive/Rotary	LG07	723798.300	718404.520
Rotary	LG08	723854.760	718376.730
Rotary	LG09	723827.260	718410.840
Cable Percussive/Rotary	LG10	723905.210	718400.280
Cable Percussive/Rotary	LG11	723425.300	718455.260
Rotary	LG12	723436.860	718445.090
Rotary	LG13	723466.520	718463.670
Cable Percussive/Rotary	LG14	723040.800	718343.190
Cable Percussive/Rotary	LG15	722726.870	718288.020
Rotary	LG16	722747.850	718100.420
Cable Percussive/Rotary	LG17	722707.076	718059.122
Rotary	LG18	723040.160	718381.470
Cable Percussive/Rotary	LG19	722742.400	718394.040
Rotary	LG20	722760.540	718333.710
Cable Percussive/Rotary	LG21	722746.330	718045.610
Combined Groundwater/Gas Monitoring Boreholes			
Rotary	BH01	723751.990	718464.300
Rotary	BH03	723833.940	718313.090
Rotary	BH04	723658.950	718159.830
Rotary	BH05	723381.970	718381.360
Rotary	BH06	723028.340	718310.420
Rotary	BH07	722641.500	718220.000
Rotary	BH08	722752.550	718129.880
Rotary	BH09	722746.090	718179.230
Rotary	BH10	722791.600	718279.040
Rotary	BH11	723802.550	718268.990
Rotary	BH13	723633.990	718448.250

LEGEND

- ESB Overhead (38 kv)
- ESB Overhead (110kv)
- ESB Overhead (220kv)
- ESB Overhead (400kv)
- ESB Overhead (LV)
- ESB Overhead (MV)
- ESB Underground (38kv)
- ESB Underground (MV & LV)
- ESB Underground (Spare)
- Extent of Waste

Landownership

- Cosgraves
- Borg Developments
- Special Areas of Conservation (SAC's)

Site Investigation

- MW1 Existing Boreholes
- G01 Gas Monitoring Borehole
- LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)
- LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)
- Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)
- BH01 Combined Groundwater/Gas Monitoring Boreholes

Client

Comhairle Contae Chill Mhantáin

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(ii) All Levels refer to Ordnance Survey Datum, Malin Head.

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FASSAROE HISTORIC LANDFILL

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Table 4.3 - Site 1: Borehole Installation Details

BH ID	BH type	Northing	Easting	BH Ground level (mAOD)	Standpipe level (mAOD)	Casing Height (cm)	Static Water Level *)	Water Elevation (mAOD)	Drilling Method	Drill Date (2016)	Total drilled depth (mbgl)	Blank pipe Interval (mbgl)	Slotted Pipe Interval (mbgl)	Screened Lithology
ONSITE														
LG11	Combined gas/leachate	723425.5	718455.0	95.371	95.638	31	11.30	84.3	Rotary	22/02	17.0	0-1	1 - 13	Waste
LG12	Combined gas/leachate	723437.1	718445.2	95.955	96.182	44	Dry	84.2	Rotary	27/01	24.0	0-1	1-12	Waste
LG13	Combined gas/leachate	723466.3	718463.4	96.048	96.476	53	9.12	87.4	Rotary	23/02	20.0	0-1	1-9	Waste
OFFSITE														
BH05	Groundwater	723382.0	718381.3	96.06	96.321	48	20.00	76.3	Rotary	28/01	29	0-19	19-29	Sand
G06	Offsite gas	723574.4	718441.7	90.99	91.303	41	Dry (wet sand)	80.3	Rotary	26/01	12	0-1	1-11	Sandy gravel
G07	Offsite gas	723368.3	718433.8	93.033	93.236	40	Dry	79.2	Rotary	28/01	14	0-1	1-14	Gravel/ sandy gravel/ sand
G08	Offsite gas	723307.1	718326.1	94.286	94.602	45	Dry	80.6	Rotary	01/02	14	0-1	1-14	Gravel
G10	Offsite gas	723333.0	718171.6	98.856	98.947	37	9.26	89.7	Rotary	04/02	20	0-1	1-18	Sand/ clay/ gravel/ silty sand
G18	Offsite gas	723510.3	718383.7	93.73	93.834	30	Dry	79.8	Rotary	01/02	14	0-1	1-14	Sandy clay/ gravel/ gravelly sand
G19	Offsite gas	723436.3	718295.9	98.244	98.393	40	7.92	90.5	Rotary	02/02	14	0-1	1-14	Sandy clay/ gravel/ gravelly sand

* Static water level is taken as metres below top of standpipe as measured following construction on 26/.04.2016. All groundwater level data provided in Table 4.15.